DEVELOPMENT OF A MASTER DRAINAGE PLAN – FINAL SUBMISSION

City of Iqaluit

Prepared for:

City of Iqaluit
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Project No.:

144902610
May 3, 2019

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1 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by The City of Iqaluit (The City) to develop a master drainage plan (MDP) for the City. The following sections outline the background and work scope for this project.

1.1 Background

City of Iqaluit is currently experiencing drainage issues due to:

- Incomplete or lack of drainage system inventory or configuration data
- Incomplete or lack of drainage system component condition data
- Lack of framework for assessment of drainage system components
- Existing flooding issues within the City
- Concerns with channel erosions and impact on water quality
- Water quality concern from trash impacting aesthetic aspects
- Inadequate slope, flat and depressed areas resulting in poor drainage
- Off-site areas draining through watercourses within the City
- Saturated roadway impacting driving and roadway conditions
- Snow drift and piling impacting spring runoff blockage conditions
- Culvert blockages due to freeze thaw cycles during spring runoff
- Potential climate change impact concerns of unusual precipitation conditions and loss of permafrost on flooding, operation and maintenance and water quality
- Inadequate funding for asset management, system improvements and system expansion

1.2 Work Scope

The work scope for this project includes:

- Identifying all major drainage areas, routes and channels within the City,
- Characterizing the existing environmental conditions for all drainage areas within the City;
- Assessing the effectiveness of existing drainage management infrastructure at conveying the drainage and reducing the negative impacts of drainage on the environment;
- Assessing the impacts of climate change on the effectiveness of existing infrastructure;
- Identifying new drainage measures, retrofit opportunities or improvements to existing infrastructure that could improve the level of flow capacity;
- Determining the framework for an Asset Management model that incorporates costs of capital;
- Operations and maintenance, and replacement with a life-cycle approach;

- Recommending strategy and policies for drainage management in the City; and
- Recommending multi-year implementation plan.

2 DATA COLLECTION AND REVIEW

Data collection for this project consisted of searching for relevant information from the City and other governmental agencies, researching scientific literature, as well as a small field program intended to identify major culverts and record snow piling and snowmelt conditions along major roads in Iqaluit.

2.1 Data Collection Status

The following data was collected as part of this project:

Table 2-1: Iqaluit Master Drainage Plan - Data Request List

Data Requested	Requested From	Status
Applicable CAD/GIS Data		
Aerial Imagery (2013)	City of Iqaluit	Received
Contour Data (2013)	City of Iqaluit	Received
Roads (2013)	City of Iqaluit	On file
Building Outlines (2013)	City of Iqaluit	On file
Watercourses (2013)	City of Iqaluit	On file
Waterbodies (2013)	City of Iqaluit	On file
Culvert Data - Locations, Sizes, condition, etc.	City of Iqaluit	**No information on file.** Major culverts only collected in field by Stantec. Other culvert information collected anecdotally or by identifying suspects from windshield survey videos or aerial imagery
Topographical Data (DEM)	Natural Resources Canada	Received
Geographical Feature Data	Natural Resources Canada	Received
Previous Reports/Studies:		
Drainage	City of Iqaluit	**None Available**
Culverts	City of Iqaluit	**None Available**
Flooding	City of Iqaluit	**None Available**
Land Development Reports	City of Iqaluit	One received - Plateau
Creeks (esp. Airport/Carney and Apex)	City of Iqaluit	Previous Stantec brief on Apex River as part of Water Supplementation Study
Lake Geraldine Spillway (Dam Assessment)	City of Iqaluit	On file
Erosion Studies/Reports	City of Iqaluit / Government of Nunavut (GN)	**None Available**

Data Requested	Requested From	Status
Water Quality Reports	City of Iqaluit / GN	**None Available**
Other Electronic Records:		
Work Orders (drainage or flooding related)	City of Iqaluit	**None Available**
Maintenance Records (drainage or flooding related)	City of Iqaluit	**None Available**
Planning Data:		
Land Use/Zoning	City of Iqaluit	On file
Monitoring/Measurement Records		
Flooding Records	City of Iqaluit	**None Available**
Flow Monitoring Records	City of Iqaluit	**None Available**
Rainfall Records	City of Iqaluit	**None Available**
INAC Water Quality Reports	Indigenous and Northern Affairs Canada (INAC)	Received
Apex River Levels and Flow	Water Survey of Canada	Received
Inflow and level into Lake Geraldine	Water Survey of Canada	Received
Lake Geraldine Level	Water Survey of Canada	Received
Sylvia Grinnell River Flow and Level	Water Survey of Canada	Received
Iqaluit Rainfall Records	Environment Canada	Received
Iqaluit Climate Records	Environment Canada	Received

2.2 Data Gap Assessment

While there are several data gaps in the requested information list, there are two particular pieces of missing information which significantly impair the development of the master drainage plan. Crucially, no information was available on existing culvert locations, let alone culvert properties (length, size, slope, condition, etc.). Also absent were any monitoring or measurement records – particularly flood reports – meaning that it is not possible to validate calculated or modelled flooding with any observed results.

These two significant gaps mean that much of the work of the MDP development will need to be prepared using remote-sensed data (e.g. aerial photography, GIS data, etc.) which is generally less accurate. Attempts have been made within this project to compensate for this lack of data, for example via staff interviews to provide anecdotal information and field inspections of primary creek crossings, however a major recommendation of the implementation plan (discussed in section 8) is a topographical survey of all culverts within the City.

2.3 Previously Completed Storm Drainage Reports

Several previous studies were reviewed to identify the existing challenges and issues in the Iqaluit town.

- General Planning Documents available from the City of Iqaluit & the GN Water Board

- Previous Stantec Studies
- Studies by other consultants
- Academic literature and papers related to streamflow and water quality in Iqaluit streams and the vicinity

The following reports have specifically been selected as having helpful information and are briefly summarized below.

2.3.1 General Plan and Zoning Bylaw - (October 2015)

This study was conducted to assess the existing infrastructure condition in Iqaluit region. The report looked at the existing zoning bylaws and identified the need for updating bylaws. It concluded that the previous zoning bylaws are based on the historical climate data and needs to be updated to account for the recent climate changes and global warming.

Of particular concern for arctic infrastructure were changes in permafrost, the frequency and severity of extreme weather events, precipitation, the coastal environment and ultraviolet radiation levels.

Research and consultation identified a decrease in the permafrost layer and increased depth of the active layer as the most significant climate-related concerns for Iqaluit's infrastructure. The report noted that buildings with shallow foundation systems; buildings, roads and buried pipes located on steep south-facing slopes and/or in an area of high snow accumulation; any building or road in an area of poor drainage where water may pool; and the landfill and former waste disposal sites are particularly at risk. Coastal infrastructure was also identified to be susceptible to damage from flooding or storm surges.

All buildings in Iqaluit have water and sewer services by pipe (utilidor) or truck. Trucked services are currently provided in five main areas: Tundra Valley, Apex, the southern portion of Tundra Ridge, the West 40, the majority of the North 40 area, and three small sections of the Core Area. The City plans to convert one of these small sections, known as the Uivvaq Loop, to piped water service in the near future. Areas of piped municipal services are shown in Figure 2-1.

Infill development and redevelopment opportunities were encouraged to maximize use of the existing system.

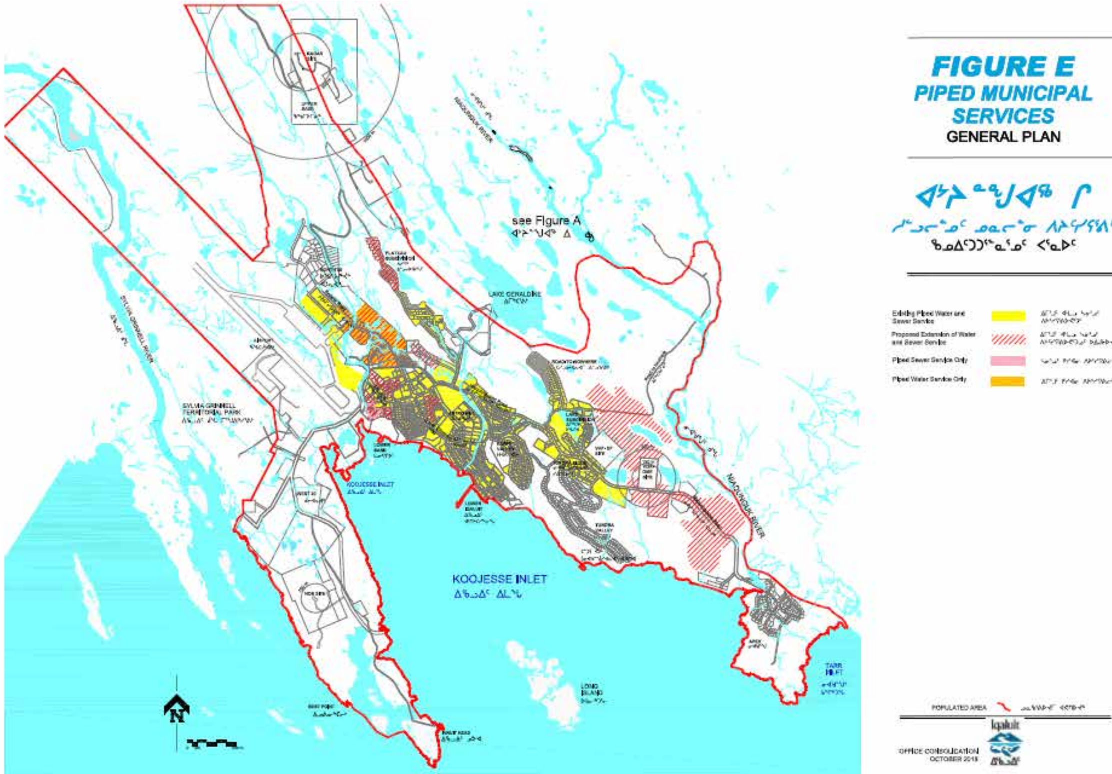


Figure 2-1: Piped Municipal Services, figure from General Plan and Zoning Bylaw (October 2015)

2.3.2 Plateau Subdivision (December 2004)

Due to tremendous population growth of 24% between 1996 and 2001 in Iqaluit, and with Iqaluit being named the territorial capital of Nunavut, the city retained several consultants to explore sustainable solutions for the existing infrastructure.

The report looked at the existing water services in the area and identified sustainable solutions. Based on the workshops and consultation with the key stakeholders, it was concluded that utilidor system for water conveyance is more efficient, sustainable and cost beneficial, when compared to the trucked system.

Traditionally, the trucked systems are thought to reduce the water conservation. However, with newer developments in the area, the homeowners are installing larger water tanks that provide a more dependable water supply, which in essence increase the water conservation to the same level as utilidor system. Furthermore, the trucked system has less capital cost in the beginning, but more operational costs. This when combined with lower level of service, makes trucked system less efficient.

The City of Iqaluit has a user pay system for water and sewer services. This means the users are charged for the services based on water consumption, however the City still subsidizes both systems. Although the utilidor system has a much higher capital cost, this cost is recovered through the leasing of the developed land. The capital costs for the trucked system, purchase of vehicles, is not a recovered cost, but is borne by the City as an operating cost. Therefore, the utilidor system is a much more cost effective system for the City to provide the services, among other benefits such as improved fire protection and reduced truck traffic in residential areas. The City of Iqaluit has recently decided that no new major development will proceed on the trucked system and is taking steps to remove areas of the city off the trucked system and on to the utilidor system due to the differential operating costs.

2.3.3 GN Water Board – Various Articles and Correspondence (Multiple Dates)

Several GN Water Board reports was reviewed to obtain any past information relevant to this project. Of all the information reviewed, the majority were related to administration. One such report looked at the dams present in the Iqaluit area and identified the condition and past concerns.

This study was conducted to identify dam history, condition and repair requirements in the Iqaluit area. The Canadian Dam Safety Guidelines (DSGs) require that all structures exceeding prescribed height and volume minimums be subject to Dam Safety Reviews (DSR's) and Dam Safety Inspections (DSIs) at regular intervals.

Lake Geraldine was identified to fall under the requirements of DSGs. The first DSR conducted on the dam was completed in 2002. The second DSR was completed in 2007. The report recommended a third DSR in 2017 unless significant alterations to the dam are undertaken.

In the late 1950s, the demand for a reliable year-round source of water in the City of Iqaluit (then Frobisher Bay) resulted in the construction of a cast-in-place concrete gravity dam, and a section of earth berm with a central cast-in-place concrete cut-off wall. The project was designed and built by the Department of National Defense. According to records, the original construction took place circa 1958. Since that time, as the City has grown, and water demands have risen, the dam has been raised four times to increase the storage capacity.

The first height increase of 0.3 m reportedly took place in 1979. This involved a concrete extension, which was dowelled into the existing structure.

The second construction took place in 1985 and increased the height of the spillway structure by approximately 1.15 m. The embankment portion was widened and heightened as well to accommodate the increased storage capacity. Again, the extension was constructed of concrete dowelled into the existing structure and incorporated a steel formwork frame over the spillway section.

The third extension was done in 1995 and increased the height of the gravity dam structure by a further 1.5 m of concrete, with a corresponding increase in berm geometry. Based on analysis done prior to the extension, it was determined that the gravity dam would not have an adequate factor of safety against overturning if the extension was simply "dowelled-in" as before. The 1995 alteration therefore included an extensive rock-anchoring program for the gravity dam portion to provide the required stability to the structure.

The latest extension was completed in two phases over 2005/06. Additional rock anchors were installed in 2005 in preparation for a further height extension of 2m in 2006. The existing embankments were enlarged, and the existing cut-of-walls were extended in height. A new embankment and cut off wall were installed to the south of the existing dam structures.

In the time span of the available historical data, which extends back to 1984, there have been only a few notable events relating to the safety and serviceability of the dam structures.

a) In November 1984 joint and patch repairs were made to localized areas on the upstream side of the spillway structure by diving contractors. Reporting was minimal.
b) In June 1990 an inspection report (3) of the structure by diving contractors was made following construction blasting. The 1984 repair areas were also assessed. The 1984 repairs were noted to have generally deteriorated. No conclusions were made. Reporting was minimal.
c) In June 1990 a visual inspection report (4) was prepared for the City by an engineering consultant, as a result of the construction blast. No significant damage was noted, and no recommendations were made for repair.
d) In July 1990 a dam inspection and stability report (5,6) was conducted for the City by an engineering consultant. Recommendations were made regarding repair of leaking joints, and provisions to increase stability should the dam be raised in the future.
e) In September 1990, a diving contractor performed crack repairs and prepared an inspection report (7). Repair material used was oakum. These repairs appeared to generally address areas observed in the June 1990 diving inspection. Reporting was minimal.
f) In October 1997 a visual inspection report (10) was prepared for the City by an engineering consultant. Leaking cracks were identified; however, these were not viewed as being structurally significant. It was recommended that leaking cracks be chemically grouted. This work was not done.
g) In June 1998, a study (11) was prepared for the Department Of Public Works by an engineering consultant to assess the hydrological impact of a dam failure on a proposed downstream hospital site.
h) A diving inspection was reportedly carried out in 1999. A report was not submitted. A video record was provided. The video provides images of the water intake, but no record of the condition of the dam.
i) A DSR (the first on record) was completed in 2002.
j) DSIs were conducted in 2002, 2003, 2005, and in 2006 (as part of the DSR)
k) Epoxy injection of cracks was completed in 2003, and again in 2005.

2.3.4 Exposure to Coastal Hazards in a Rapidly Expanding Northern Urban Centre (December 2015)

With recent expansion in the urban center, significant growth in population, climate changes and rise in sea water level, this study was conducted to investigate the exposure of infrastructure to coastal hazards and recommend an adaptation plan. The study objectives include identifying natural hazards that present a risk to coastal infrastructure in Iqaluit, quantifying the waterfront exposure in the context of observed trends and sea level projections and identifying coastal infrastructure at risk in Iqaluit.

This study has identified three coastal hazards relevant to infrastructure in Iqaluit.

1. **Exposure to ride-up or pile-up of sea ice:** This hazard involves variety of factors associated with climate-induced expansion of open water season. Ice also plays a protective role in the form of the winter ice floor, which shelters the shore and nearby infrastructure from direct impacts of mobile ice over the tidal flats.

2. **Exposure to flooding of coastal infrastructure:** The dominant risk factor identified is tidal dynamics, combined with relatively minor contributions from steric, barometric, and wind stress events.

3. **Wave run-up and associated setup:** These events have the potential to overtop the sewage retaining berms and damage other infrastructure along the urban waterfront. A more detailed analysis of this hazard is recommended as part of this study.

Using the upper limit of 0.7m above mean sea level, the change in flooding extent was also evaluated. Approximately 28% of the 30.5m coastal zone and 14% of coastal Sijjaanga District will be inundated due to this rise. This assumption of 0.7m rise is also in line with historical data, and global trends. Following conclusions were made from this study:

- Steepening of the coastal profile through revetment or armouring may protect against waves, but a steeper profile with a narrow ice foot allows higher ice pile-up, increasing exposure of infrastructure directly landward of the revetment to potential ice impact.
- Accurate surveys of coastal infrastructure have allowed the estimation of waterfront elevations and freeboard under various sea level rise, high water, and wave run-up scenarios. The maximum recorded water level is 6.04 m above mean sea level (1964), and the highest surveyed swash line is 6.51 m (date unknown). This study has shown that for an observed extreme high-water event added to a plausible upper limit of the most recent projections of sea level for 2100 (0.7 m above the 2010 mean sea level), 50% of the infrastructure within the coastal “open space” planning zone would be affected, and significant areas of land would be flooded in the developed backshore.
- Some shorefront infrastructure in Iqaluit is already at risk of flooding in extreme high-water events, as demonstrated by the tide gauge record for 21 November 1964 and the anecdotal and photographic evidence from October 2003. The expanded flood risk from potential sea level rise within the range of the latest projections warrants attention. This is particularly the case for the coastal subsistence infrastructure, which is an essential contributor to sustainability in Iqaluit, yet its position on the coast means that it is most exposed to any change in hazards arising from sea level rise or changing sea ice and wave regimes.

2.3.5 People at the Tidal Flats (Scott Hatcher, Thesis, 2014)

Recent rapid changes within the Arctic climate system have exacted heavy tolls on the infrastructure of some Arctic coastal communities (Arehart, 2012). Study reported that the parts of artic region is experiencing global warming at an increasing rate than the rest of the world (Serreze & Barry, 2011). Larsen et al. (2008) speculated an additional $5.6-$7.6 billion on the coastal infrastructure with this rate of global warming.

Thawing permafrost has been identified as big challenge for people living in City of Iqaluit. Most of the building infrastructure is already affected by the permafrost situation. This when added with global warming and population growth, poses big issues for the city. The report speculated sustainability issues in the future, explaining how choosing between expanding versus the ageing infrastructure would be an issue.

2.3.6 Other Documents

- Water source supplementation studies:
  - Water Supplementation Project – Field Assessment at the Sylvia Grinnell River (Stantec, 2017): The report looked at the desktop assessment of river morphology and pipeline route reconnaissance for Sylvia Grinnell River. In addition, fish use and habitat along with the environmental DNA (eDNA) sampling was conducted at Lake Geraldine Reservoir.
  - City of Iqaluit Supplementary Water Supply Study (exp., 2014): This study looked at the water quality in Iqaluit region and as such provided recommendation for improvements. The summary of findings for this report can be found in section 3.4.7.
- Iqaluit Airport design reports:
  - Iqaluit Airport Improvement Project, Drainage Review Report (Stantec, 2014)
  - Rapport de validation hydraulique … dans le ponceau arqué existant de Carney Creek, (Sintra-Iqaluit, 2016)
  - Carney Creek Concept Design of Fish Habitat Improvement Structures, (Sintra, 2016)
  - Iqaluit Airport - Approach Lighting Replacement, Project Proposal Information Requirement. (WSP, 2016)

Raw field data from Environment Canada, Water Survey of Canada, INAC, etc. were also reviewed for a better understanding of major creeks in the Iqaluit region.

2.4 Topographic Data

As part of this project, topographic and GIS data was obtained and reviewed from City of Iqaluit and Natural resources Canada as outlined in Table 2-2 below.

Table 2-2: Topographic Data received from City of Iqaluit and Natural Resources Canada

Data Requested	Requested From
Applicable CAD/GIS Data	
Aerial Imagery	City of Iqaluit
Contour Data	City of Iqaluit
Roads	City of Iqaluit
Building Outlines	City of Iqaluit
Watercourses	City of Iqaluit
Waterbodies	City of Iqaluit
Culvert Data - Locations, Sizes, condition, etc.	City of Iqaluit

Data Requested	Requested From
Topographical Data (DEM)	Natural Resources Canada
Geographical Feature Data	Natural Resources Canada

2.5 Field Inspection & Creek Survey

Although Inspections / Field surveys were conducted in June 2018 and September 2018. Critical culvert sizes, configuration along with the condition were captured for further analysis, the photographs of which are appended to this report in **Appendix A**.

The location of culverts can be seen on **Drawing 1**, attached at the end of this report. In addition, a database was created for all the existing crossings located along major creeks as outlined in Table 3-2**,** Table 3-3 and Table 3-4**.**

2.6 Windshield Survey Videos

Windshield surveys were conducted on three dates i.e. May 24, 2018, June 07, 2018 and June 12, 2018. The drive route for the three surveys are highlighted in Figure 2-2 below.

The surveys looked at all the ditches / swales present in the City of Iqaluit. Additionally, while developing the model for City, Stantec noticed some deficiencies in the drainage infrastructure. Those deficiencies were cross referenced with the windshield surveys. The windshield surveys are provided in digital format along with this report, the information for which can be found in **Appendix E**.

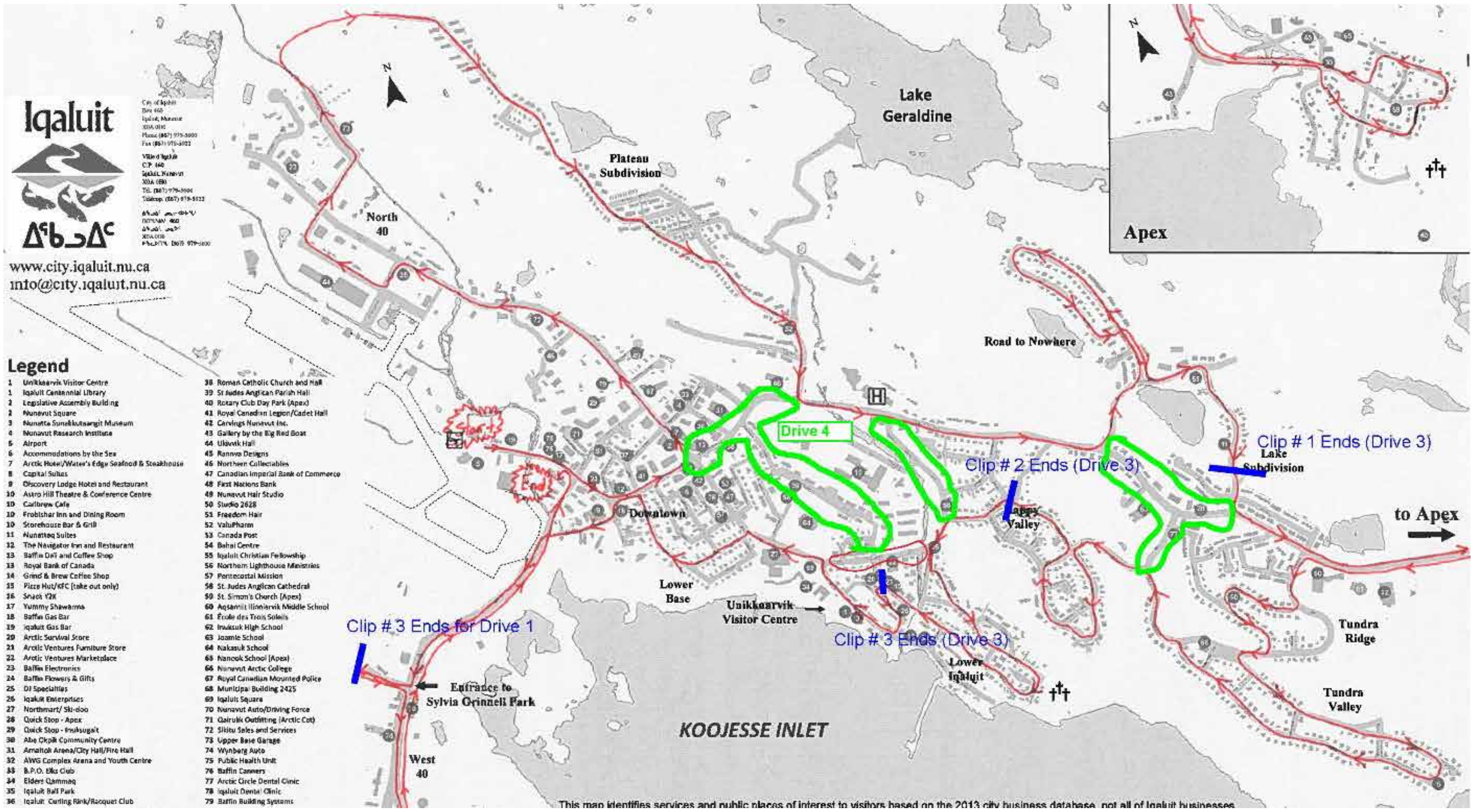


Figure 2-2: Drive route for Windshield Surveys (in red and green).

2.7 Technical Workshops

Two technical workshops were conducted as part of stakeholder consultation. The workshops discussed the existing infrastructure issues as seen in the media literature. In addition, the results from the weather station analysis, and the field inspection / surveys were discussed with the City to confirm the issues at hand. Both the workshops were conducted in Stantec office in Iqaluit in May and November of 2018.

The presentations from both workshops are appended to this report in **Appendix B.**

2.8 Historical Climate Data

Climate data was requested from Environment Canada to develop trends and IDF curves for City of Iqaluit. The complete list of all the data provided is appended to this report in **Appendix C.** Received data consisted of records from six different stations namely 2402590, 2402591, 2402592, 2402594 and 2402596. Two of the stations (2402590 and 2402591) are located at the airport, which is at the head of the inlet and near sea level. The others are from the climate station located on the road to Apex, which is above 100 m elevation.

Data used for development of IDF curves and precipitation trends mainly consisted of precipitation, rain and snow. The smallest available interval for precipitation data was found to be of 15 minutes between 2008 and 2018. For the precipitation amounts of 5 and 10 minutes, no new data can be obtained. Similarly, snow data was obtained for the period between 1955 and 2018. The summary of the data used for IDF and trend analysis can be seen in Table 2-3 below.

Table 2-3: Data used for IDF Curves and Trend Analysis

Element Name	Start Year	End Year
PRECIPITATION AMOUNT – 15 MINUTES	2008	2018
HOURLY PRECIPITATION AMOUNT	2004	2018
HOURLY PRECIPITATION	1982	2002
SIX HOURLY PRECIPITATION	1950	2018
DAILY TOTAL RAINFALL	1946	2018
DAILY TOTAL PRECIPITATION	1946	2018
DAILY TOTAL SNOWFALL	1946	2018
SNOW ON GROUND	1955	2018
GREATEST RAINFALL	1946	2002
GREATEST AMOUNT OF PRECIP IN 5 MIN	1982	2002
GREATEST AMOUNT OF PRECIP IN 10 MIN	1982	2002
GREATEST AMOUNT OF PRECIP IN 15 MIN	1982	2002
GREATEST AMOUNT OF PRECIP IN 30 MIN	1982	2002
GREATEST AMOUNT OF PRECIP IN 1 HOUR	1982	2002
GREATEST AMOUNT OF PRECIP IN 2 HOURS	1982	2002
GREATEST AMOUNT OF PRECIP IN 6 HOURS	1982	2002
GREATEST AMOUNT OF PRECIP IN 12 HOURS	1982	2002
GREATEST AMOUNT OF PRECIP IN 24 HOURS	1982	1990

3 CHARACTERIZATION OF STUDY AREA

The study area consists of three major watershed areas (as shown on Figure 3-1), namely:

3.1 Airport Creek

Airport Creek (also known as Carney Creek) drains a small basin of approximately 1600 ha, and its lower reaches are exposed to industrial, military (historic), and urban impacts.

3.2 Apex River

The Apex River, located on the eastern side of Iqaluit, flows into the community of Apex, a subdivision of the City of Iqaluit that is home to approximately 1500 people, many of whom hunt, fish, and trap. The Apex river catchment area has been estimated at approximately 60 km^2, and elevations within the watershed reach as high as 365 m above sea level at the headwaters. The river flows through two gorges, which cover 4 km of the creek's 8 km length.

3.3 Lake Geraldine

Lake Geraldine is located just north/northeast of the primary inhabited area of the City of Iqaluit. It is the reservoir for the City's potable water supply. While there is a spillway channel that runs from the lake through the City and discharges to Koojesse Inlet, the spillway structure has not overtopped in several years. The basin measures 660 ha, of which 393 ha feeds directly to Geraldine Lake.

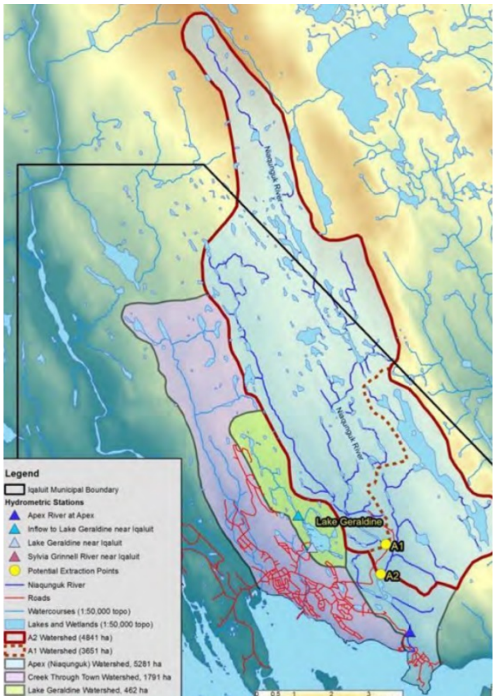


Figure 3-1: Watershed area for all three creeks in Iqaluit region. Excerpt from City of Iqaluit Supplementary Water Supply Study, Page 3.

3.3.1 Other Basins

1. Sylvia Grinnell – This river is located west of Iqaluit and its large basin extends far to the north. The Water Survey of Canada estimates the gross drainage area at 2,980 km^2. Because it is not
2. Downtown Iqaluit – Measuring about 80 ha, this includes the area east of Airport Creek and west of the Lake Geraldine Spillway. Drainage is primarily overland via sheet flow with some concentrated flow points along streets and swales.
3. East Iqaluit – This area lies east of the Lake Geraldine Spillway but west of Apex, measuring about 150 ha. Drainage is primarily overland via sheet flow and concentrated flow in some localized watercourses. Concentrated flow points along streets and swales in the Tundra Valley neighbourhood is the primary anthropogenic drainage contribution.

3.4 Climatic & Environmental Conditions

3.4.1 Precipitation

Annual maximum precipitation was calculated from 1946 to 2017. The results can be seen on Figure 3-2.

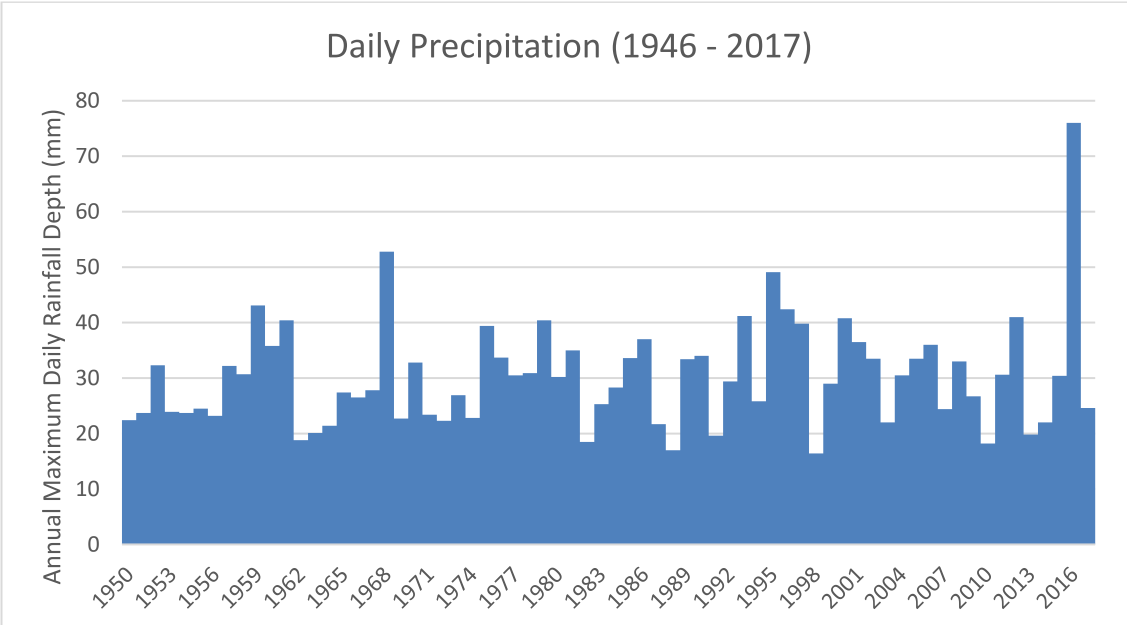


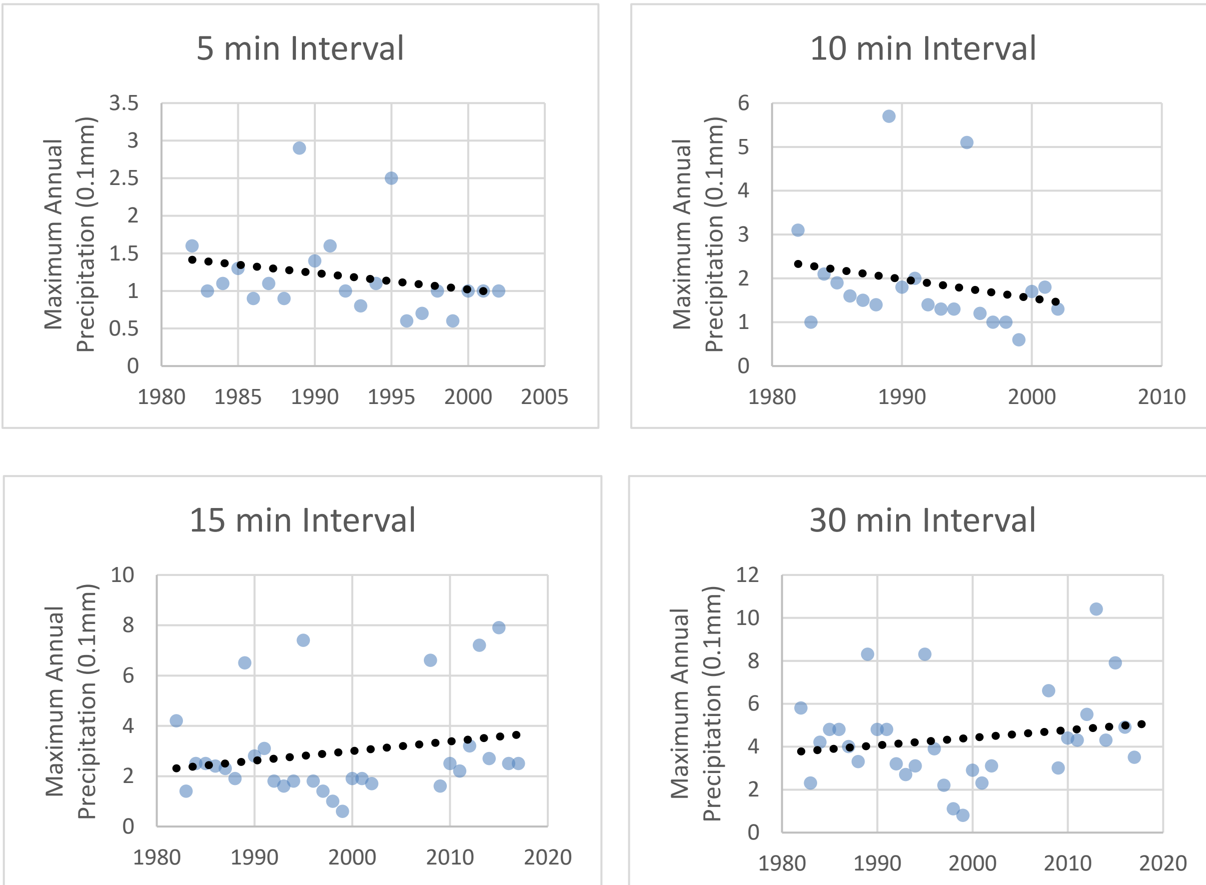
Figure 3-2: Annual Maximum Daily Precipitation (1946 – 2017)

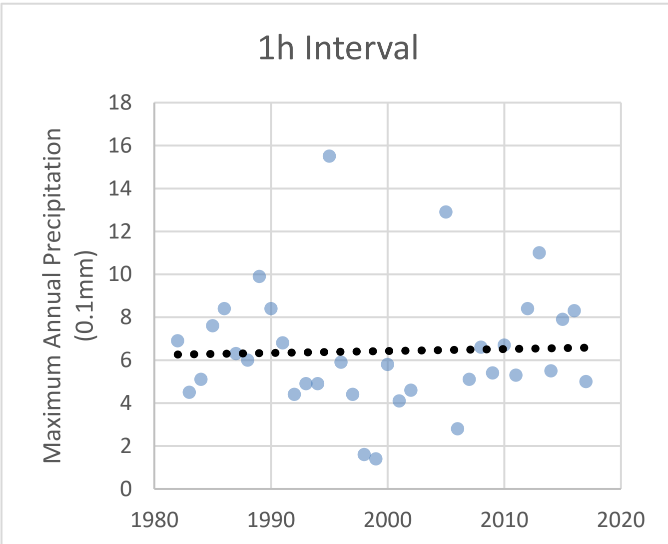
Data obtained from Environment Canada was analyzed for maximum annual precipitation. As can be seen in **Section 2.8**, the available data consisted of precipitation intervals ranging from 5 min to 24-hour intervals. However, each of these intervals had discontinuities and missing data for certain years. This missing data was built from smaller precipitation intervals. For example, 15 min precipitation intervals data were converted to 30 min, 30 to 60 and so on and so forth. All possible combinations of 15 min precipitation interval continuous data were analyzed to build 30 min annual maximum precipitation results.

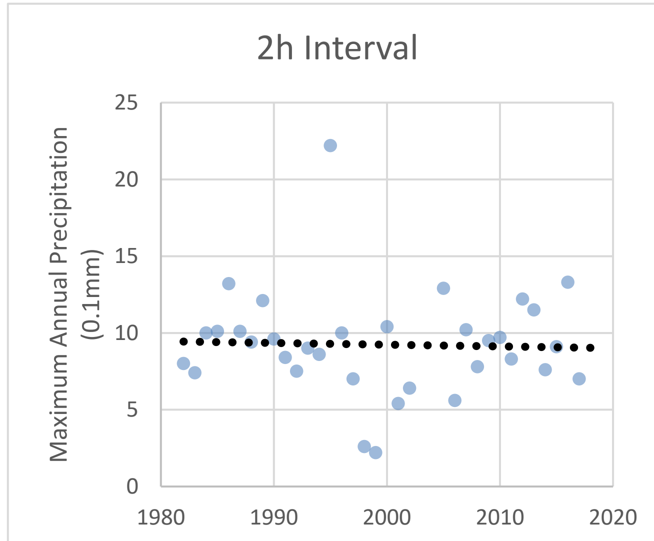
Although the data for precipitation interval of 5 min and 10 min was available, but they ranged only from 1982 to 2002. As such, the smallest precipitation interval of 15 min was used to build all the succeeding intervals. Once all the precipitation intervals were built, they were cross checked with the available data on hand.

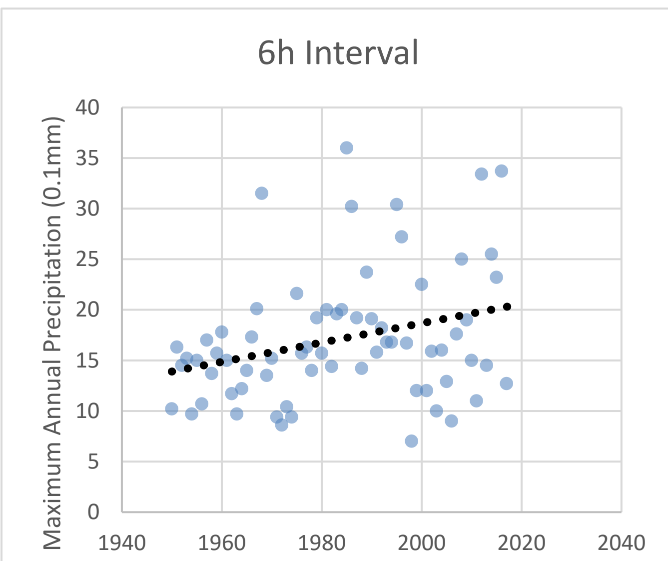
The 5-min and 10-min precipitation intervals could not be updated due to unavailability of the new data. 15-min, 20-min, 1-hr and 2-hr precipitation values were calculated for period ranging from 1982 to 2002. No data could be obtained for years preceding 1982. The 6-hr, 12-hr and 24-hr precipitation intervals were updated for the period ranging from 1946 to 2018.

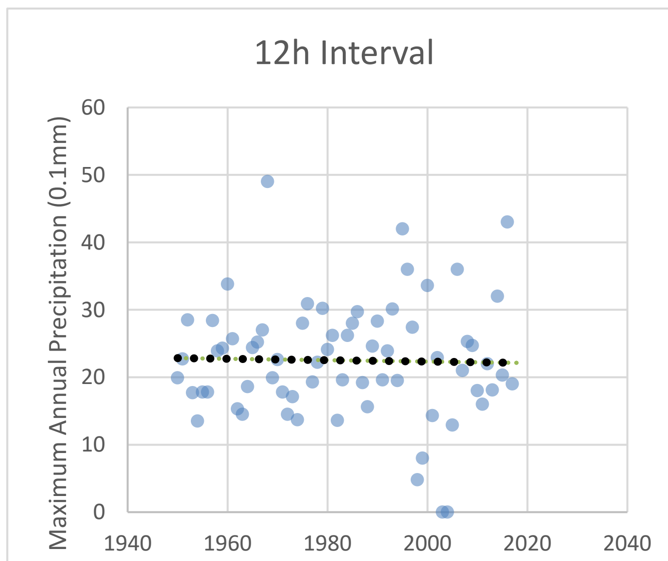
Results obtained were consistent with the reviewed media literature. As can be seen on the figure above, the maximum annual precipitation for the year 2016 was recorded to be approximately 77mm and suggests that the upward trends could be steeper in the future. Similarly, the rest of the data was analyzed to assess precipitation trends for various durations; presented below in Figure 3-3:




1h Interval
Maximum Annual Precipitation (0.1mm)
0
2
4
6
8
10
12
14
16
18
1980
1990
2000
2010
2020


2h Interval
Maximum Annual Precipitation (0.1mm)
0
5
10
15
20
25
1980
1990
2000
2010
2020


6h Interval
Maximum Annual Precipitation (0.1mm)
0
5
10
15
20
25
30
35
40
1940
1960
1980
2000
2020
2040


12h Interval
Maximum Annual Precipitation (0.1mm)
0
10
20
30
40
50
60
1940
1960
1980
2000
2020
2040

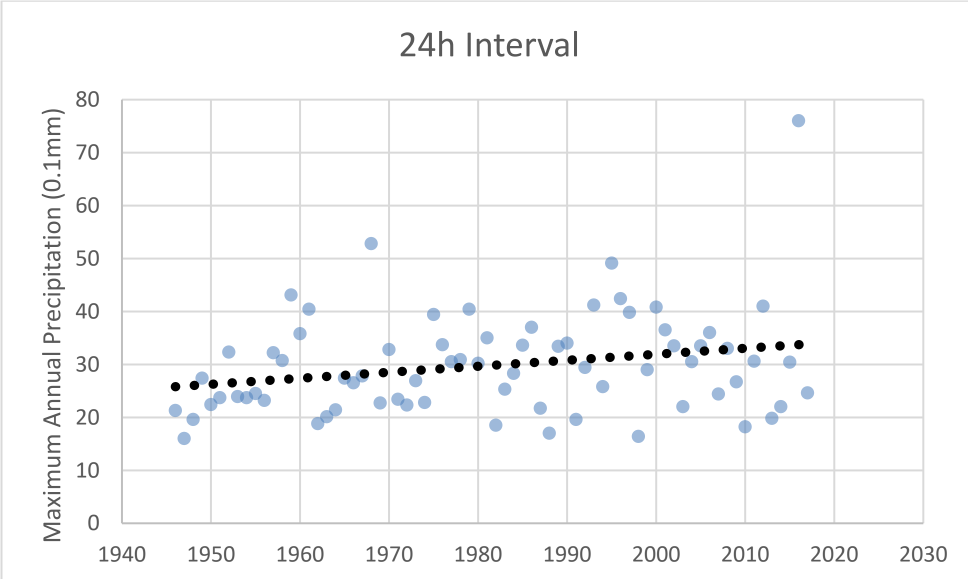


Figure 3-3: Figures representing maximum annual rainfall amounts for various durations: 5, 10, 15, and 30 minutes, as well as 1, 2, 6, 12, and 24 hours.

Generally, a trend of slightly increasing maximum precipitation values can be observed over time for most durations – with the exception of the 5 and 10 minute durations. It should be noted that 5 and 10 minute data was only recorded during the 1982-2001 period.

3.4.2 Snow-on-Ground Depths

Daily snow-on-ground data (measured as a depth in cm) from Environment Canada was reviewed and analyzed to obtain general trend. Available data covers the periods from 1955 to 2017. The histogram below (Figure 3-4) shows the frequency of snow depths recorded since 1955. The results for each year can be seen on Figure 3-5**.**

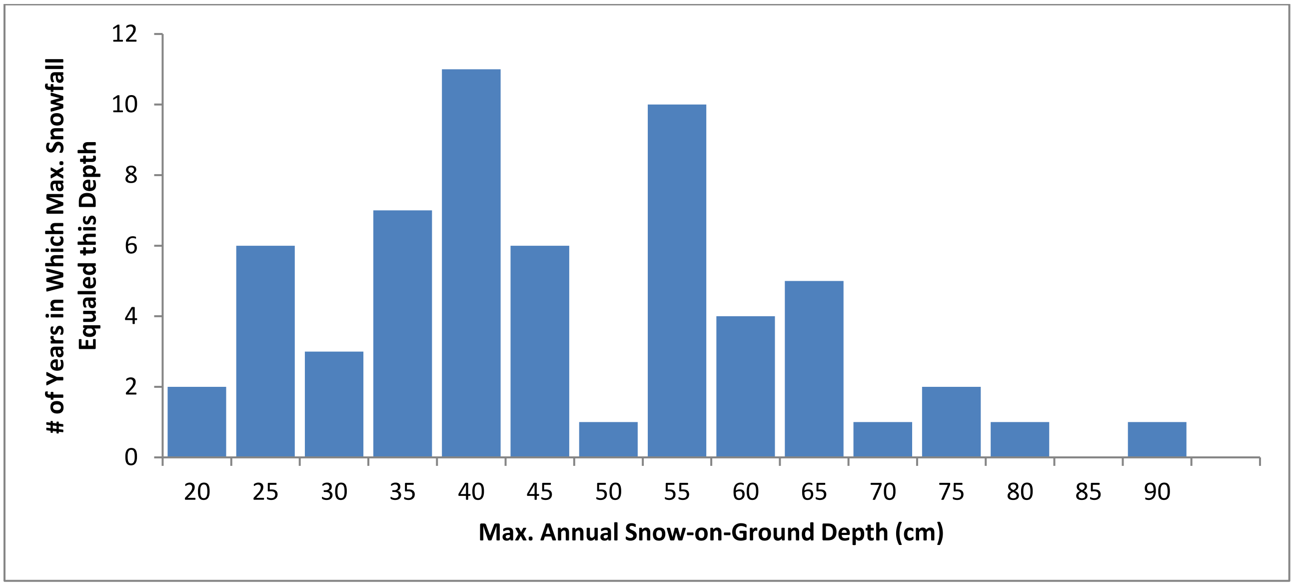


Figure 3-4: Frequency of maximum annual snow-on-ground depths for the period 1955-2017

On average, Iqaluit sees a snow depth between 40-45 cm per year. This is also consistent with the return period calculated for the snow depths as shown in Table 3-1.

Table 3-1 Return Period for Maximum Annual Snow-on-Ground Depths

Return Period	Snow-on-Ground Depth (cm)
2-yr	42.1
5-yr	55.7
10-yr	64.6
25-yr	76.0
50-yr	84.4
100-yr	92.8
200-yr	101.1

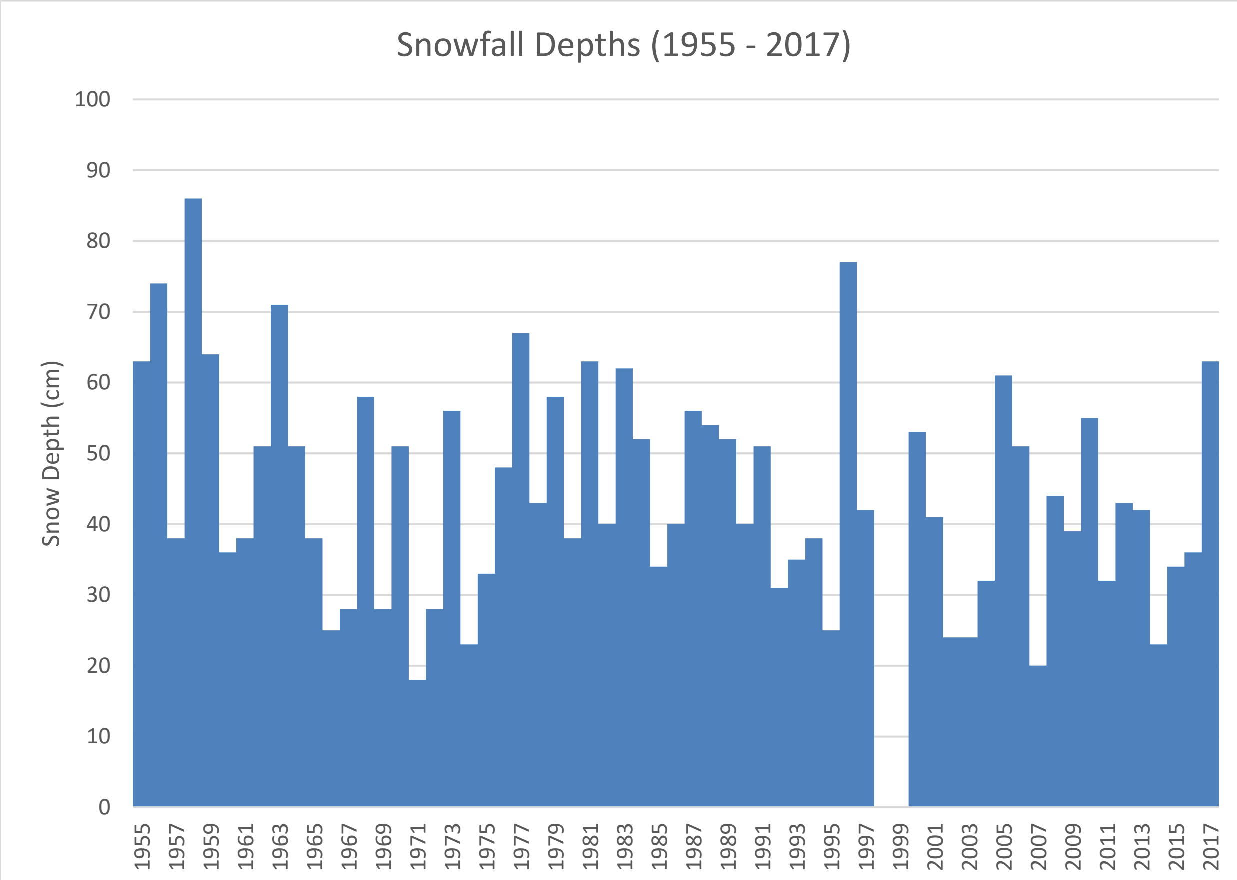


Figure 3-5: Snowfall Depth 1955 – 2017

Note: the unofficial peak snow depth in 2018 was 31 cm.

3.4.3 Tidal Levels

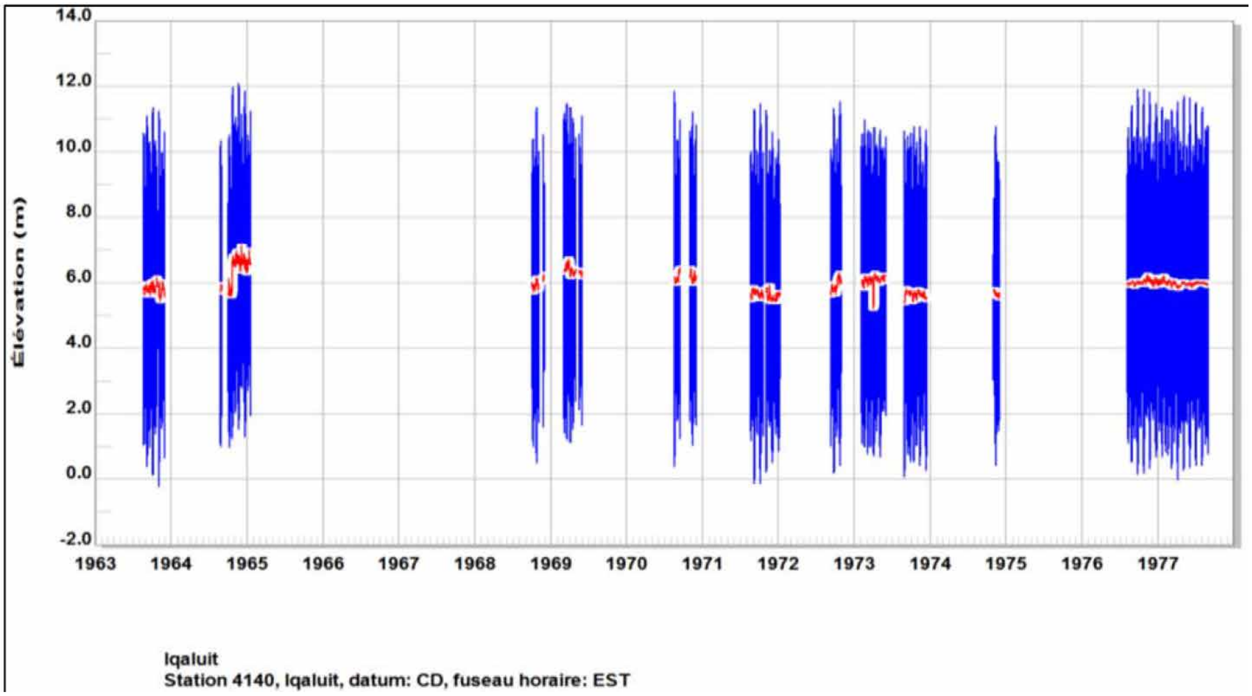


Figure 3-6: Tidal Levels 1963 – 1978 – Excerpt from Sea Level projection for five pilot communities of Nunavut

Figure 3-6 above indicates a tidal change of +/- 12m as recorded at station 4140. Highest water level rise of 12 m was noted in 1964.

Sea level projection for five pilot communities of the Nunavut

The report confirmed that the average rate of sea level rise in the last four decades (1961 to 2003) was 1.8 ± 0.5 mm/yr, but the rate appears to have accelerated in the last decade (1993 to 2003) to 3.1 ± 0.7 mm/yr. It was noted, however, that decadal variability in sea-level rise during the 20th century ranged from about -1.0 mm/yr to +3.7 mm/yr (Church and White, 2006); thus it was difficult to estimate how much of this sea rise can be attributed to change in trend.

At the lower end, the Intergovernmental Panel on Climate Change (IPCC) projections indicate an average rate of sea-level rise similar to that observed for the last half of the 20th century (1.8 ± 0.5 mm/yr). At the higher end, the IPCC projections indicate an average rate of sea-level rise that is nearly double the rate that was observed recently (3.1 ± 0.7 mm/yr).

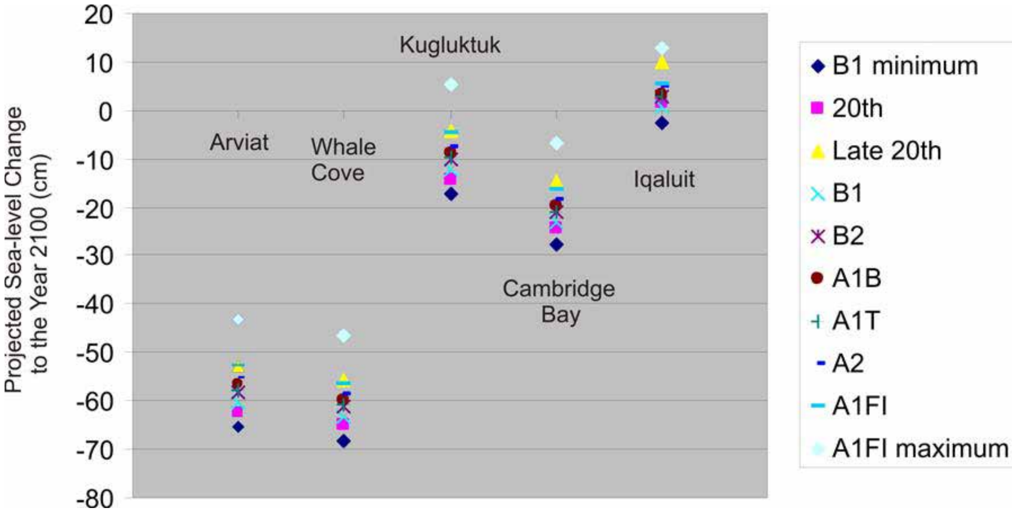


Figure 3-7: Sea Level projection for minimum, mid-points and maximum IPCC projections (Meehl et al., 2007) and for the Twentieth Century and Alte 20th Century Scenarios

<u>(James, Simon, Forbes, Dyke, & Mate, 2011) - Sea-level Projections for Five Pilot Communities of the Nunavut Climate Change Partnership</u>

This report looked at the vertical land motions in five communities in the Nunavut region. Of interest was the City of Iqaluit. Due the global warming and climate change impacts, a contribution of 1mm/yr to sea level rise was assumed due to ice thinning in Antarctica, arctic, Greenland, glacier and ice caps. Overall, the effects from each of these global sources were taken into consideration to estimate the sea level rise and vertical land motion in each of the above-mentioned communities.

Various scenarios were taken into consideration, from different literature available. The Figure 3-7 shows the results based on the scenarios provided by IPCC. The results confirmed that Arviat and Whale Cove are rising the fastest and feature more than 50 cm of sea level fall. Iqaluit although rising slowly, was reported to have a vertical land motion of 0.9 +/- 1 mm/yr (in the year 2010) and is speculated to rise to 8 +/- 9 mm/yr in the next 90 years by 2100. A range of 64 cm for the sea level change was predicted.

Figure 3-8: Flooding that occurred in October 2003. Photo courtesy of Rick Armstrong. The winds were light and offshore (northwest). The high-water level was not associated with a storm, so was likely the result of an anomalously high tide. This photo was taken roughly 50 m from the base of the main breakwater, facing east.

(Hatcher S. , 2014) - People at the tidal flats: coastal morphology and hazards in Iqaluit, Nunavut

With rapid environmental change observed in the Canadian Arctic, this thesis looked at the impacts of projected changes on the people living on tidal flats. GIS modelling and geoscientific data was collected over three field seasons, with the aim to provide coastal hazard mapping for Iqaluit, Nunavut. Nearshore current velocities were recorded to be between 0.1 - 0.3 m/s, with greater velocities at the top 3 m of the water column. Results showed limited freeboard of 0.3-0.8 m for most coastal infrastructure under an upper-limit projection of 0.7 m relative sea-level rise from 2010 to 2100. Key infrastructure, and especially the subsistence infrastructure focused on the coast, was confirmed to be below past recorded maximum water levels during high spring tides.

Figure 3-9 and Figure 3-10 below shows the hazard map for the City of Iqaluit. The historical high-water levels are taken from the tide-gauge record (Canadian Hydrograph Service). The 95th and 99th quantile water levels from the tide-gauge were recorded to be 4.00m and 4.87 m respectively. The maximum level of 6.04 was recorded by tide-gauge on November 21, 1964. A projected sea-level rise of 0.7m (upper limit IPCC) over 90 years was added to already recorded water levels. It was concluded that with the addition of 0.7m, usable land on the main coastline of Iqaluit will decrease by 24,458 m^2, accounting for 28% of the coastal "open space" and 14% of the coastal district land. Addition of projected sea level rise onto repeated highest recorded water level flooded 46 of 91 coastal structures and 5 of 61 municipal structures (8%).

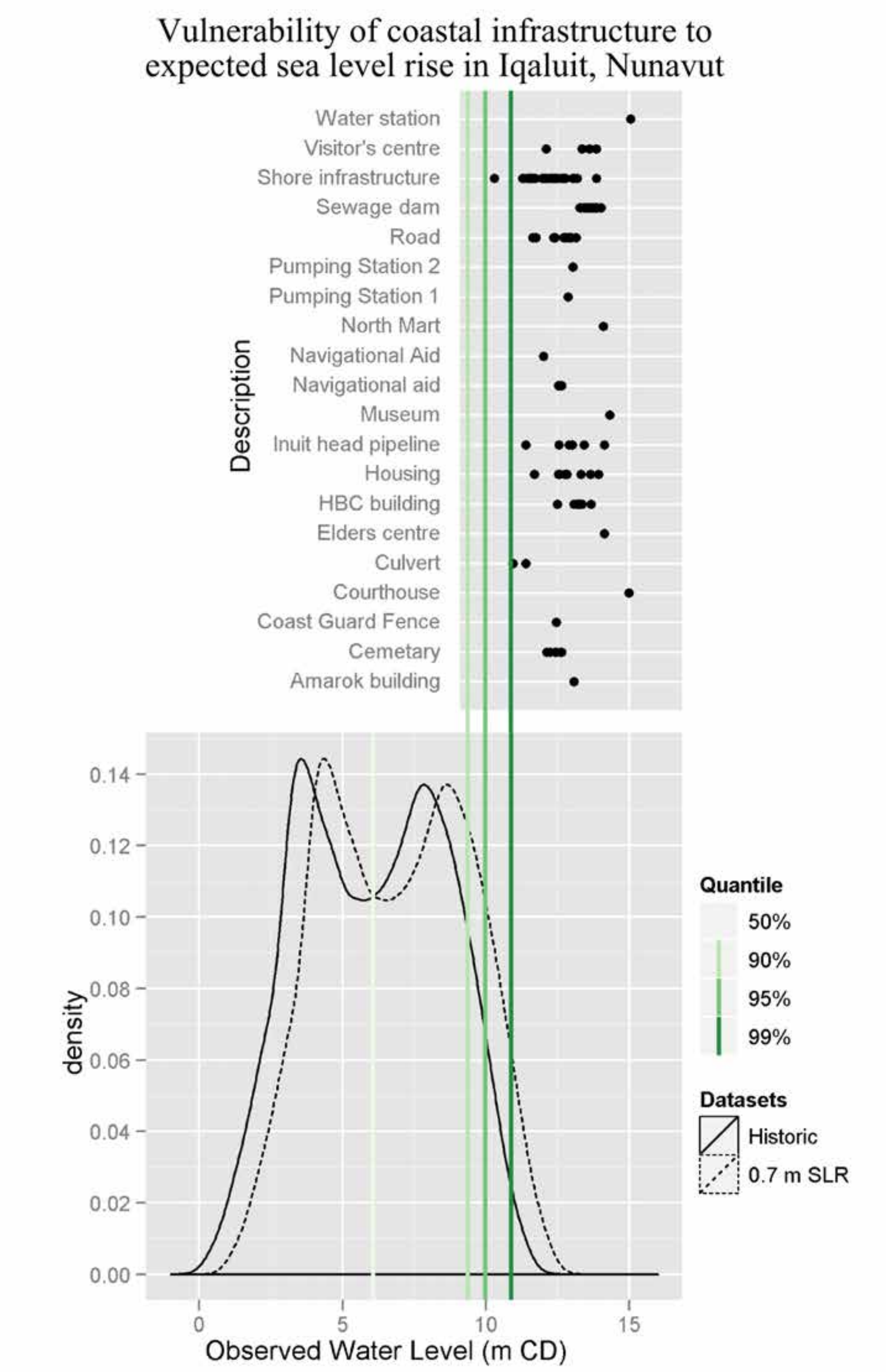


Figure 3-9: Elevation ranges for infrastructure groups with sea level descriptors plotted. Note the small buffer between high tide levels and the subsistence infrastructure. pg. 143.

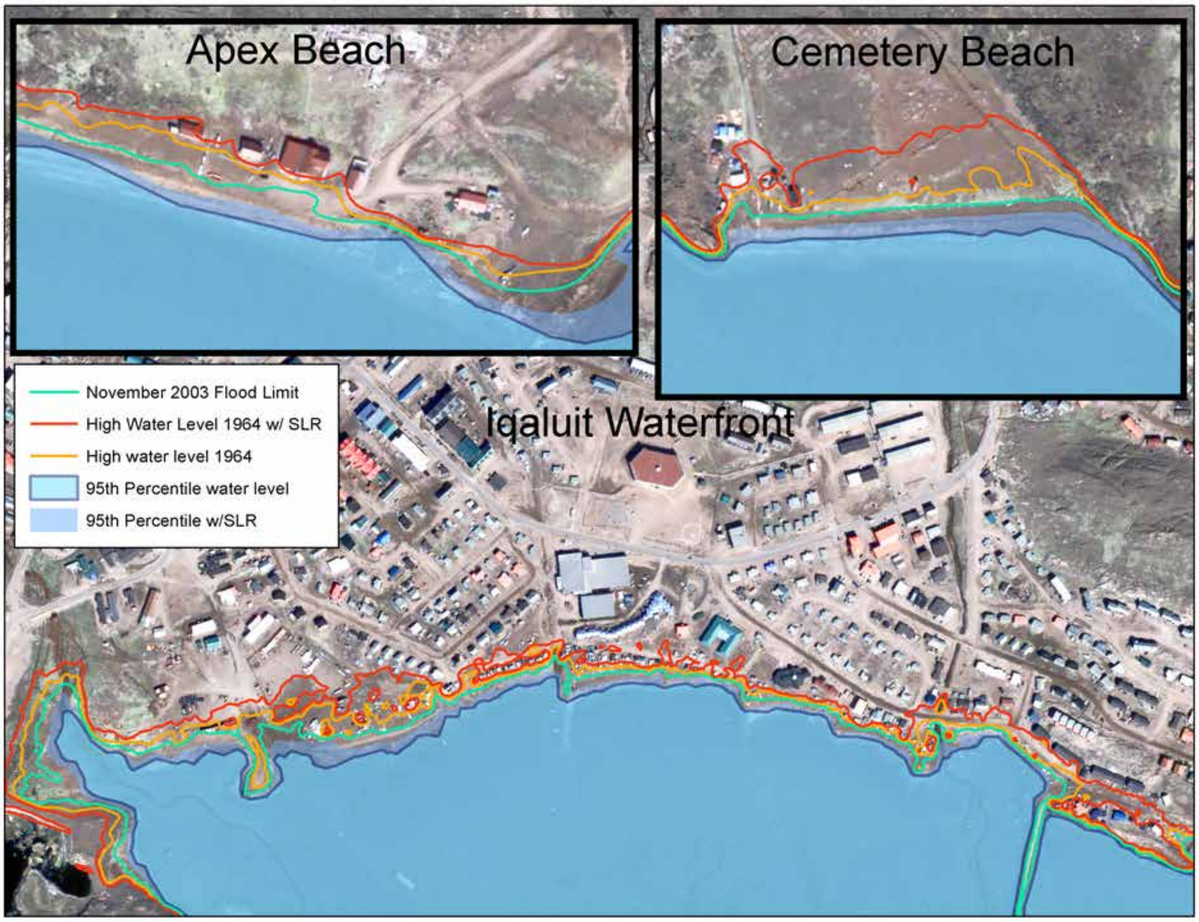


Figure 3-10: Flood hazard mapping along the main sections of the coast in Iqaluit and Apex. The three areas of the map follow the insets labeled in fig. 3.4 and fig. 3.7. The highest inundation line shows the addition of projected sea level to 2100 from James (2010) added on top of the highest recorded water level in November 1964 (6.04 m + 0.70 m).

3.4.4 Streamflow

Peak flows for the Apex River were analyzed to obtain trends. The data requested from Environment Canada spans the period from 1974 to 2018 and does not include period from 1996 to 2002. The analysis concluded the increasing stream flows over the period of last 44 years. As can be seen on the Figure 3-11 below, data from 1973 to 1995 follows a somewhat similar trend. However, since 2007 and onwards, Iqaluit has been seeing an increase in stream flows.

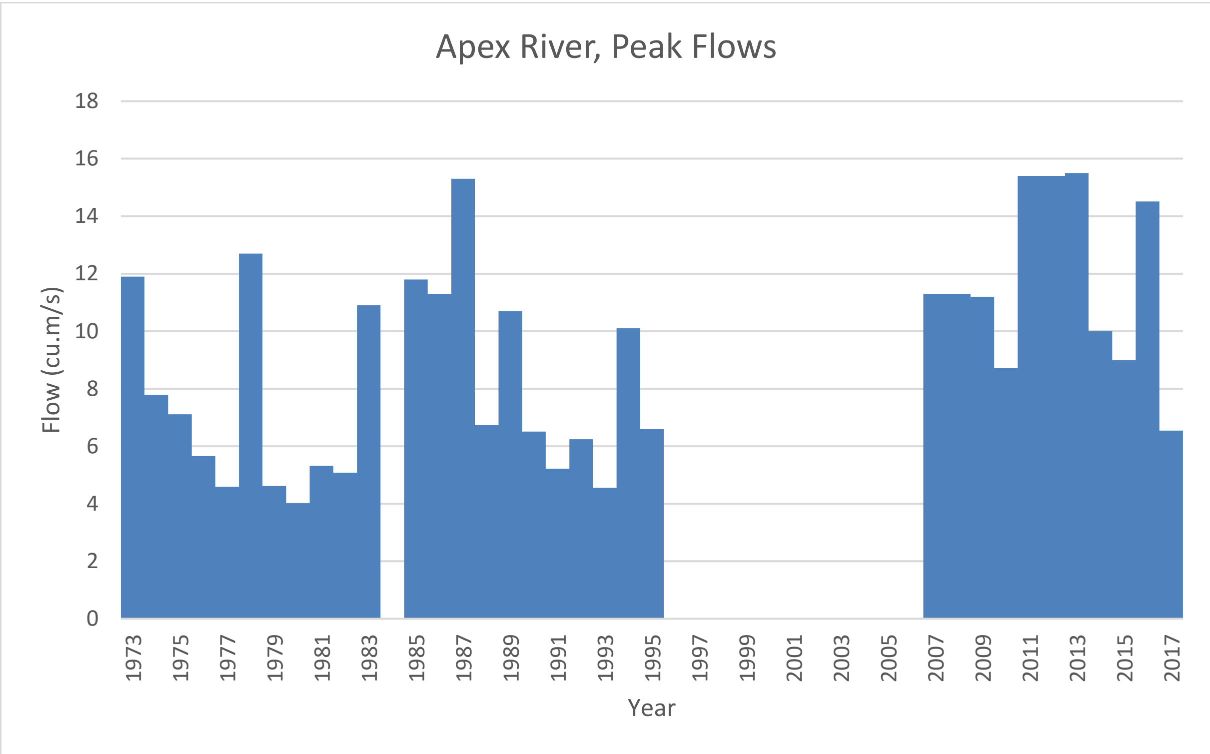


Figure 3-11: Apex River Stream flows 1973 – 2017

Data is available at three gauged locations in the Iqaluit area:

1. Apex River
2. Inflow to Lake Geraldine
3. Sylvia Grinnell River

3.4.5 Flooding & Media Reports

No formal flooding records are available from the City. Past reports and media literature were reviewed to identify areas of past flooding concerns. Very few media reports existed, with none indicating significant damage. Most reports indicated that flooding is considered a "nuisance", as it does not generally cause real or personal property damage, however it may impede access or cause erosion problems.

Media searched included:

- Internet News Search
- Social Media Search
- Historical Newspaper Search **(**Figure 3-13 and Figure 3-14**)**

In order to compensate for the lack of flooding data, workshop sessions with City staff and windshield surveys were conducted (see Figure 3-12, Figure 3-15, Figure 3-16, Figure 3-17, Figure 3-18 and Figure 3-19) to identify areas of potential flooding concern. In addition, hydrologic model was created, to examine overland flow routes in the city.

In general, the older areas in the city were built without any provisions for overland water flows such as ditches and swales, in particular the downtown area. The newer communities built in the suburbs mostly have ditches and swales for water conveyance to major creeks. The topographic model further confirms this concerns as the downtown area is relatively flat when compared to suburbs.

Figure 3-12: Example Spring Flooding in Iqaluit (Federal Road, just north of Mivvik Street intersection, south of Legislative Assembly.

The weather office told us last week that a new record for rainfall was set last August. These youngsters seem to be enjoying the mud created by all that water.

Figure 3-13: An excerpt from Nunatsiaq News, 12 Sep 1986 (Year 14, no.31).

6:30 Muppet Show
7:00 Upchat Line
7:30 The Rare Breed
8:00 CBC Film Festival: Second Wind

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SPRING IN FROBISHER BAY

It's springtime in Frobisher Bay and the bugs are sneaking from their long winter retreats. To the delight of children on Qulanni Street, the critters are lurking in the many puddles. These children found some after a concentrated poking and searching effort.

Figure 3-14: An excerpt from Nunatsiaq News, 7 June 1979 (Year 7, No.17).

Figure 3-15: Water rushing through Apex Creek, just upstream of the main Apex Road bridge on 21 July 2016. Source: Youtube.com, user Teirersias.

Figure 3-16: Water overflowing across the Apex Bypass Road (looking west) during July 2016 flooding. Source: CBC News, Taqialuk Peter.

Figure 3-17: Snowmelt during May 2018 on Apex Bypass Road, looking west.

Figure 3-18: Overland water flowing to the culvert in the far-right corner.

Figure 3-19: Flooding across Apex Bypass Road (looking eastward) on 21 July 2016. Source: Nunatsiaq News Online, Thomas Rohner.

3.4.6 Culverts

Culverts along the three major creeks (Airport, Geraldine and Apex) were identified during field inspections conducted on two different dates. The photographs for these field inspections are appended to this report in Appendix A. In addition, windshield surveys were conducted on three different dates, information on which can be found in section 2.6.

Culverts were evaluated for structural and operational defects. Also, a database outlining all the culvert crossings was created as shown in Table 3-2, Table 3-3 and Table 3-4. Culvert crossings were assigned names, and locations were confirmed with field inspections. Field inspections did NOT include topographical survey or measurement of slope, inverts or elevations. **Drawing 1** at the end of this report shows all the culvert locations along the major creek. A shapefile containing geospatial location of all the culverts along major creeks has also been provided in digital format (see Appendix E).

Table 3-2, Table 3-3 and Table 3-4 tabulate all the culvert crossings along the three major creeks in Iqaluit region. Each of these culverts has been assigned a name, which corresponds to the locations shown on **Drawing 1**. In addition, the condition, shape, downstream and upstream end locations were identified and listed in the tables below. Several culverts were identified to be in critical condition and are highlighted in the last column.

Table 3-2: Culvert Crossings along Airport Creek

Airport Creek

Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
X1a	N	S	1800	Corrugated Steel	Circular	Projected	N	Surface Corrosion on floor
X1b	N	S	1800	Corrugated Steel	Circular	Projected	N	Surface Corrosion on floor
X2	N	S	2100	Corrugated Steel	Circular	Projected	Y	Deformed Edges, surface corrosion on floor
X3a	NE	SW	1000	Corrugated Steel	Circular	Projected	N	Torn out edges, surface corrosion on floor
X3b	NE	SW	1000	Corrugated Steel	Circular	Projected	N	Torn out edges, surface corrosion on floor
X3c	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X3d	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor, multiple roof sags identified
X3e	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X3f	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X4	NE	SW	800	Corrugated Steel	Circular	Projected	N	
X5a	NE	SW	3000	Corrugated Steel	Circular	Projected	N	Deformed Edges, Fine deposits on the upstream end, Culvert inoperative due to deposits
X5b	NE	SW	3000	Corrugated Steel	Circular	Projected	N	Culvert end worn out, broken pieces
X5c	NE	SW	3000	Corrugated Steel	Circular	Projected	N	Deformed Edges, Garbage identified in the Culvert. Culvert floor significantly corroded at the upstream end.
X6	NW	SE	1200	Corrugated Steel	Circular	Projected	Y	
X6b	NW	SE	600	Corrugated Steel	Circular	Projected	N	
X7	NE	SW	600	Corrugated Steel	Circular	Projected	N	Deformed Edges. Significant amount of fine deposition in the Culvert.
X8a	NW	SE	1000	Corrugated Steel	Circular	Projected	N	
X8b	NW	SE	1600	Corrugated Steel	Circular	Projected	Y	Mud deposit at the downstream end
X8c	NW	SE	1000	Corrugated Steel	Circular	Projected	N	Surface Corrosion on the floor of Culvert

Airport Creek

Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
X9	NE	SW	2100	Corrugated Steel	Circular	Projected	N	Torn out edges, significant amount of debris deposited at the upstream end. A furniture was identified in the Culvert
X10a	NW	SE	3100	Corrugated Steel	Arch	Projected	N	Garbage deposits at the upstream end
X10b	NW	SE	1600	Corrugated Steel	Circular	Projected	N	
X12a	N	S	1000	Corrugated Steel	Circular	Projected	N	Deformed Culvert, elliptical in shape, surface corrosion on floor
X12b	N	S	1000	Corrugated Steel	Circular	Projected	N	Worn Out Edges, surface corrosion on floor
X12c	N	S	1000	Corrugated Steel	Circular	Projected	N	Surface corrosion on floor
X12d	N	S	2100	Corrugated Steel	Circular	Projected	N	Deformed Culvert, deflected sidewall at 2 O'clock, at the downstream end.
X13	NW	SE	1600	Corrugated Steel	Circular	Projected	N	Deteriorated Edges at the downstream end

Table 3-3: Culvert Crossings along Apex River

Apex River

Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
Ia				Corrugated Steel	Circular	Projected	N	Broken Culvert, Surface corrosion on the floor
C1a	N	S	900	Corrugated Steel	Circular	Projected	N	Deformed Edges, Surface corrosion on floor, minor roof sagging
C1b	N	S	900	Corrugated Steel	Circular	Projected	N	Deformed Culvert appears oval in shape, significant roof sagging observed in the middle. Surface corrosion on floor.
C1c	N	S	900	Corrugated Steel	Circular	Projected	N	Surface corrosion on floor, torn out edges
C1d	N	S	900	Corrugated Steel	Circular	Projected	N	Surface corrosion on floor, torn out edges
C2a	N	S	1100	Corrugated Steel	Circular	Projected	Y	Torn out edges, Surface corrosion on floor
C2b	N	S	1100	Corrugated Steel	Circular	Projected	Y	Torn out edges, Surface corrosion on floor, gravel deposits

Apex River

Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
C2c	N	S	1100	Corrugated Steel	Circular	Projected	Y	Torn out edges, Surface corrosion on floor and side walls
C3a	N	S		Corrugated Steel	Circular	Projected	N	Surface corrosion on floor, roof sagging in the middle
C3b	N	S		Corrugated Steel	Circular	Projected	Y	Surface corrosion on floor, worn out ends
C3c	N	S		Corrugated Steel	Circular	Projected	N	Deformed Culvert, Roof sags identified at multiple locations

Table 3-4: Culvert Crossings along Town Stream (from Lake Geraldine)

Lake Geraldine

Crossing#	Type	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
X1a		NE	SW	700	Corrugated Steel	Circular	Projected	Y	Torn out edges, boulder obstructing the flow. Fine and gravel deposits identified in the Culvert.
X1b		NE	SW	700	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X2a		NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Deformed edges, Surface corrosion on floor.
X2b		NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Significant fine deposits at the downstream end. Culvert not usable
X2c		NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, roof sag identified at downstream end. Fine and gravel deposits observed at the upstream end.
X3a		N	S	1500	Corrugated Steel	Circular	Projected	Y	Cardboard and barrel identified in stream, blocked Culvert due to fine and gravel deposits
X3b		N	S	1500	Corrugated Steel	Circular	Projected	Y	Surface corrosion on floor, Bicycle

Lake Geraldine

Crossing#	Type	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
									identified in stream at the downstream end, Fine and gravel deposits observed.
X3c		N	S	1500	Corrugated Steel	Circular	Projected	Y	Deformed Culvert, elliptical in shape
X3d		N	S	620	Corrugated Steel	Circular	Projected	N	Deformed Culvert, with multiple bulging along the length of Culvert
X3e		N	S	620	Corrugated Steel	Circular	Projected	N	Minor deformities at edges
X4a		N	S	1350	Corrugated Steel	Circular	Projected	Y	Culvert half buried in the substrate, significant roof sagging, deformed Culvert
X4b		N	S	1350	Corrugated Steel	Circular	Projected	Y	Culvert half buried in the substrate, significant roof sagging, multiple circumferential cracks, deformed Culvert
X5	Bridge	NW	SE						Unstable bank on downstream left
X6a		NW	SE	1300	Corrugated Steel	Circular	Projected	Y	
X6b		NW	SE	800	Corrugated Steel	Circular	Projected	N	Deformed Culvert, elliptical in shape
X6c		NW	SE	1300	Corrugated Steel	Circular	Projected	Y	Deformed at downstream end, multiple roof sags identified along the length of Culvert
X7	Footings	NW	SE	3200	Wooden Cribs	Arch	Projected	Y	Significant amount of fine and rock deposits in the Culvert. Culvert inoperable.
X8a		N	S	1950	Corrugated Steel	Circular	Projected	N	
X8b		N	S	1950	Corrugated Steel	Circular	Projected	Y	

Lake Geraldine

Crossing#	Type	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
X9	Dam	N	S						Concrete wingwall is broken, and not tied in long enough. Undermined structure. Further degradation of dam could result in possible collapse.
X10a		N	S	1350	Corrugated Steel	Arch	Beveled	N	Culvert significantly corroded at the floor, minor gravel deposits observed
X10b		N	S	1350	Corrugated Steel	Arch	Beveled	N	Culvert significantly corroded at the floor, minor gravel deposits observed

3.4.7 Water Quality Media Review

A study (Zerehi, 2015) on the local freshwater resources in the Iqaluit area included sampling of local streams for water quality parameters. The report documents several complaints made by residents of Iqaluit regarding an oil spill in the creek. The study concluded that the water quality in Airport Creek is impaired. Scientists observed that north of town there are 40 different types of benthic invertebrates that live in the water. However, only three types were found in the Creek south of the City.

Carney Creek runs from Iqaluit's industrial North 40 sector into Airport Creek. Scientists who have been sampling the waters of the area since 2005 says contaminated water is brought into close contact with a populated area. (Zarate, 2010)

Local concerns over water quality in the Iqaluit area prompted research in 1999. This research was conducted by a group of scientists who worked closely with the Nunavut Research Institute in developing the methodology, sampling technique, and sampling of several lakes and rivers in the area to examine those concerns. It was discovered that fish in Airport Creek were contaminated with high concentrations of short and medium chained polychlorinated biphenyl (PCB's, a persistent organic pollutant). Scientists believe that North 40 seepage of heavy metals, PCBs, and hydrocarbons is due to the military presence in 1950s-70s (Hamilton, 2015).

Carney Creek (Airport Creek) has a legacy issue that has caused degradation of water quality. It is primarily from North 40 seepage and other legacy contamination leftover from the military presence in Iqaluit. It is made worse by urban and industrial waste that is often dumped into the river.

Authors (Medeiros, Luszczek, Shirleys, & Quinlan, 2011) investigated benthic populations and water quality at several locations within Airport Creek and Apex River in July and August of each year in 2007 – 09. Sampling sites were set at different points on the two creeks as shown in the figure below.

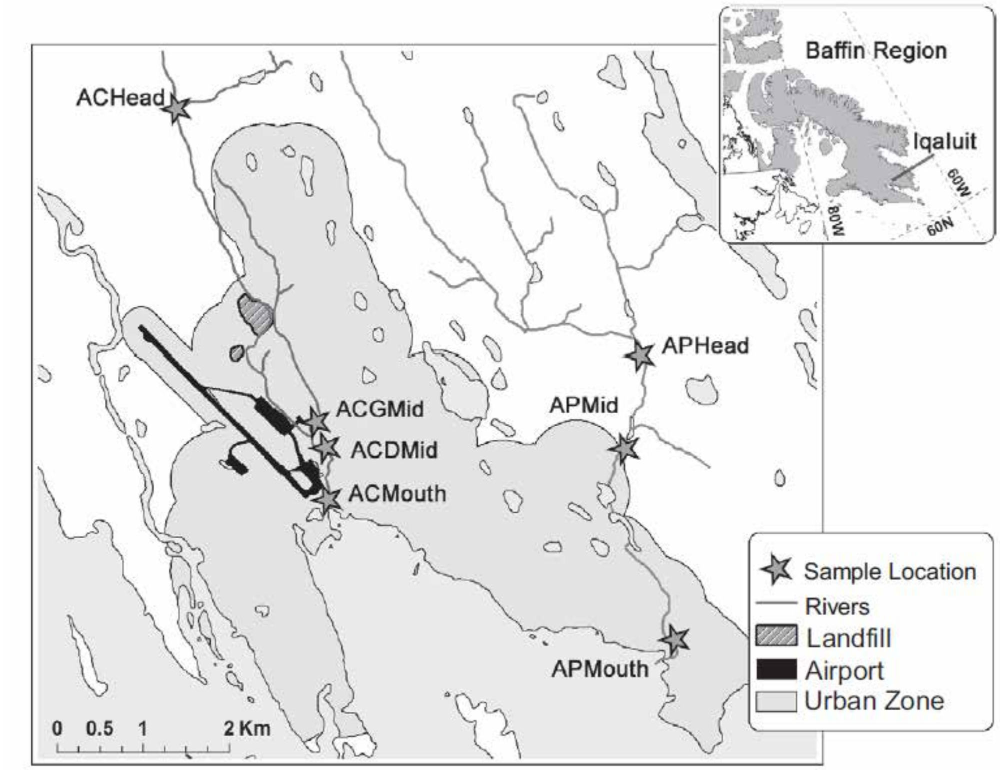

Figure 3-20: Excerpt from Benthic Biomonitoring in Arctic Tundra Streams (Medeiros et al., 2011), Pg. 61

The study looked at the influents along the both creeks. It was found that Airport creek (also known as Carney Creek) is exposed to industrial, military (historic), and urban impacts. Furthermore, it was observed that the municipality mines on both sides of the stream for gravel, which contributes considerable sediment to the stream. The city has also dug a trench approximately 200 m long to divert the river flow around industrial areas.

An abandoned military landfill and scrap yard located close to a gravel-hauling operation is thought to be affecting stream water quality during the melt season as water flows from the dumpsite into small ephemeral streams that discharge into the main channel. In addition, waste oil and chemicals have reportedly been dumped into the main channel, where the creek flows through the city's industrial park. The report confirmed that in 2007, approximately 170 L of crankcase oil were dumped into the creek over the course of 48 hours (Neary, 2006). The elevated concentrations of dissolved lead, aluminum, manganese, and iron that have been reported in water samples have been reported, the cause of which could be due to the numerous metal contamination points along the urbanized portion of the stream (Peramaki and Decker, 2000; INAC, 2008). High concentrations of short- and medium-chained chlorinated paraffins have also been reported in sediment and water from several locations along Airport Creek downstream of the military landfill and gravel haul operation (Dick et al., 2010).

Unlike Airport Creek, the Apex River does not have any known contamination points along its reaches. The main inputs to the river are limited to areas adjacent to gravel haul operations, approximately 2 km upstream from the river mouth, where the City of Iqaluit has excavated gravel for the last ~10 – 12 years to produce material for local development.

They found that the streams had suffered biological impairment in the benthic community at locations downstream of the urbanized portions of the streams. Additionally, they also found elevated levels of total nitrogen (TN), total phosphorus (TP) and several metals (Zn, Sr, Rb, Al, Co, Fe).

Scientists sampled the number of organisms along the creeks, the results of which are on Figure 3-21 below. It was found that the types of organisms in the creek decreased overtime as the water flew to the south of the town. The results concluded that the water quality downstream of the creek is heavily influenced by the urbanization in the city. Further to that, over the period of three years, the number of the organisms have decreased relatively, concluding that with time, the water quality getting worse.

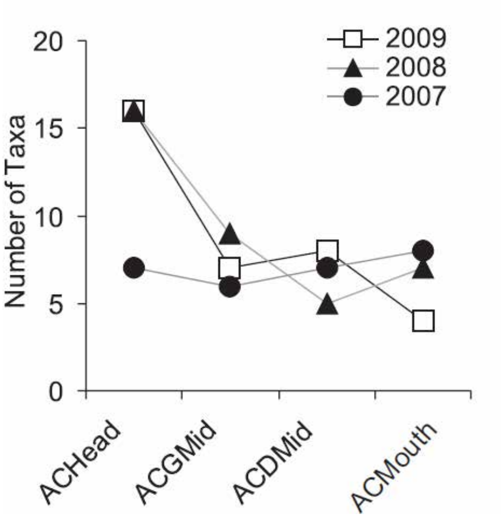

Figure 3-21: Excerpt from Benthic Biomonitoring in Arctic Tundra Streams, Pg. 64

Figure 3-22 below shows an excerpted table from the report presenting the concentration of various constituents, including heavy metals, measured during the study.

Sites	NO_2/NO_3 µg/L	TP µg/L	TN µg/L	DIC mg/L	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	Al µg/L	Cr µg/L	Co µg/L	Cu µg/L	Fe µg/L	Pb µg/L	Mn µg/L	Mo µg/L	Ni µg/L	Rb µg/L	Sr µg/L	Zn µg/L
AC9Head	71	1.9	175	9.1	14.8	1.82	0.16	0.86	13.2	0.05	0.02	1.69	45.3	0.31	1.5	0.24	0.33	0.29	22.2	2.83
AC9GMid	37	2.8	104	8.5	12.2	1.67	0.51	1.89	15.4	0.10	0.02	1.10	15.2	0.02	1.3	0.41	0.13	0.39	26.4	2.22
AC9DMid	38	18.8	118	7.7	9.9	1.25	0.30	1.16	52.9	0.18	0.08	3.09	110.0	0.13	8.7	0.25	0.23	0.38	17.9	4.40
AC9Mouth	43	7.4	184	11.9	17.2	2.13	0.56	2.51	29.1	0.16	0.12	1.21	161.0	0.07	41.9	0.46	0.22	0.54	32.5	7.77
AC8Head	120	5.0	120	0.5	31.0	3.10	0.20	1.40	4.7	0.01	0.20	0.50	5.0	0.01	0.3	0.20	0.10	0.30	28.5	2.30
AC8GMid	217	6.2	319	17.1	24.5	3.77	1.46	8.32	27.5	0.18	0.04	1.74	39.9	0.08	1.9	1.32	0.18	0.86	60.1	1.63
AC8DMid	140	20.0	290	3.3	20.6	1.80	0.20	1.30	25.0	0.01	0.20	0.90	428.0	0.20	26.4	0.30	0.60	0.50	31.0	3.60
AC8Mouth	310	5.0	360	2.0	38.9	5.10	1.00	6.40	19.7	0.20	0.30	1.50	425.0	0.01	132.0	0.60	0.50	0.80	70.8	16.3
AC7Head*	50	0.5	130	0.2	10.1	1.30	0.10	0.60	9.7	0.01	0.10	0.70	50.0	0.01	0.70	0.20	0.20	0.20	12.8	1.10
AC7DMid	17	1.4	107	3.6	5.7	0.71	0.21	0.71	26.4	0.20	0.05	1.80	44.0	0.01	1.8	0.25	0.20	0.77	27.6	1.99
AC7Mouth*	31	0.5	36	1.4	17.4	2.40	0.40	2.10	44.1	0.01	0.10	1.20	209.0	0.01	49.0	0.40	0.30	0.40	27.1	5.60
AP9Head	18	0.7	95	4.8	6.9	0.84	0.16	0.70	18.4	0.06	0.03	0.42	16.4	0.01	2.3	0.08	0.25	0.34	11.6	0.60
AP9Mid	15	1.2	103	4.1	6.0	0.77	0.13	0.52	8.5	0.02	0.01	0.52	13.7	0.01	2.6	0.12	0.15	0.30	10.5	0.47
AP9Mouth	14	1.2	84	4.2	6.0	0.75	0.14	0.54	12.6	0.05	0.01	0.49	19.4	0.01	1.1	0.09	0.17	0.31	10.4	0.29
AP8Head	58	3.6	191	5.5	8.6	1.10	0.20	0.82	19.4	0.08	0.08	0.93	65.2	0.03	4.9	0.13	0.24	0.45	15.1	1.90
AP8Mid	74	1.1	166	6.2	9.2	1.26	0.18	0.81	11.4	0.06	0.03	2.17	42.5	0.05	5.9	0.19	0.18	0.42	16.5	0.35
AP8Mouth	47	4.1	116	6.0	9.2	1.21	0.16	0.84	17.1	0.12	0.02	1.04	45.0	0.03	1.4	0.16	0.23	0.45	16.7	2.18
AP7Head	89	3.1	166	5.2	8.1	0.96	0.18	1.16	42.5	0.11	0.15	2.70	76.3	0.21	9.7	0.08	0.29	0.37	12.9	3.79
AP7Mid	59	2.4	134	5.3	7.9	0.92	0.17	0.98	29.5	0.01	0.07	3.33	68.4	0.09	7.3	0.09	0.20	0.38	13.0	1.46
AP7Mouth*	10	0.5	90	0.4	7.0	1.00	0.10	0.60	30.0	0.80	0.10	0.60	50.0	0.50	1.6	0.10	0.20	0.20	10.2	10.0

Figure 3-22: Excerpted Table from Benthic Biomonitoring in Arctic Tundra Streams, Pg 69

Lead in soil and sediment in Iqaluit, Nunavut, Canada, and links with human health (April 1999)

This study looked at the soil contamination in the Iqaluit region. Scientists performed lab analysis on the soil samples to determine the lead levels and compared against the environmental guidelines to assess the associated human health risk. Various known or potential point sources of lead samples such as the upper base, the Sylvia Grinnell dump and the metal dump, were collected. The research findings concluded the elevated levels of bioavailable lead present in the soil. Lead concentration in Sylvia Grinnell dump and apex river were confirmed to exceed health-based guidelines. The research at that time (1999) concluded that the soil poses no serious health hazards, however looking at the behavioural and environmental factors, the soil may create a risk of lead exposure in the future.

City of Iqaluit Supplementary Water Supply Study (exp., 2014)

This study was conducted in August 2014 to analyze the water supply in Iqaluit region. The report looked at two different locations A1 and A2 as potential source for water intake as shown on Figure 3-23 below.

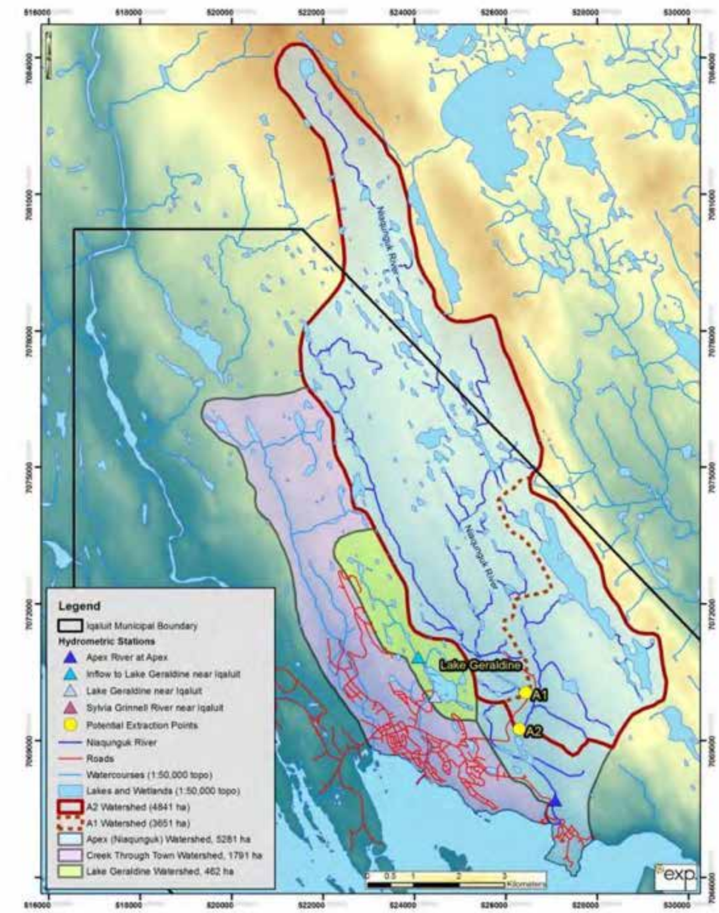

Figure 3-23: Excerpt from City of Iqaluit Supplementary Water Supply Study, Page 3

Samples from both the sites were collected and compared against Canadian drinking water quality guidelines (CDW QG). In general, pH and turbidity were found to be in excess of CDW QG, concluding that the water is acidic in nature and contains turbid materials. This lower pH was not deemed health risk at the moment, however it was noted that this could lead to increased concentration of metals in drinking water. Furthermore, an increased trend was identified in calcium, magnesium, silicon and Sulphur concentrations.

Iqaluit Baseline Water Quality Monitoring Program Data (INAC, 2008)

Indian and northern affairs Canada (INAC) was contacted for water quality studies conducted in Iqaluit region. One such report was received and is appended to **Appendix F – INAC Baseline Water Quality Monitoring Program Data**.

4 EXISTING INFRASTRUCTURE EVALUATION

As discussed in section 2.2, two particular pieces of missing information significantly impaired the development of the master drainage plan. Crucially, no information was available on existing culvert locations, let alone culvert properties (length, size, slope, condition, etc.). Also absent were any monitoring or measurement records – particularly flood reports – meaning that it is not possible to validate calculated or modelled flooding with any observed results.

These two significant gaps mean that much of the work of the MDP development has been prepared using remote-sensed data (e.g. aerial photography, GIS data, etc.) which is generally less accurate. Attempts have been made within this project to compensate for this lack of data, for example via staff interviews to provide anecdotal information and field inspections of primary creek crossings, however a major recommendation of the implementation plan (discussed in section 8) is a topographical survey of all culverts within the City.

Due to all of the missing data elements, it was determined that the model built during the MDP development would not yet be able to yield useful results; the outputs are too variable given the lack of information on culvert and ditch slopes. It is recommended that the model be updated once topographical field data has been collected. In the meantime, the model has been built to a detailed level in other regards and can still be used to understand drainage paths, subcatchments and tributary areas.

4.1 Hydrologic and Hydraulic Model

4.1.1 Model Selection

PCSWMM software was selected as the platform to be used or constructing the hydrologic and hydraulic model. The software has several advantages: it uses the industry-standard EPA-SWMM model file format which has wide acceptance, experience and support, the computational engine is open source and transparent, the engine is free (gratis) and model files can be used by any competent future consultants which the City wishes to engage.

4.1.2 Data Preparation

GIS data was collected to develop a hydrologic and hydraulic model for the City of Iqaluit. Prior to this study, the city did not have any past models and/or data present. Most of the information obtained during the course of this project on drainage infrastructure was in the form of photos, videos and anecdotal information from City staff.

Photographs captured through site inspection and surveys along with the windshield survey videos were used to digitize all the existing drainage infrastructure.

For the topography in the urban area, LIDAR data was used. However, no LIDAR data was available in more remote upstream areas. Instead, lower-quality data was used, namely Canadian Digital Elevation Data (CDED) and vector data on waterbodies and watercourses (both available online from Natural

Resources Canada). These data were assessed to determine flow paths entering and exiting the drainage infrastructure.

Once the drainage infrastructure was digitized in vector format, attributes were assigned based on the field inspections. Where no information was available, estimates were provided or default values used. Field inspection focused only on the three major creeks, i.e. Airport Creek, Lake Geraldine (aka Town Stream) and Apex River Creek. For all the other drainage infrastructure, such as culverts crossing roads or driveways, culverts were digitized based on topographic surface and aerial photograph inspection as well as the windshield survey videos. Crossings along the major creeks were inspected for size and condition, the results of which are discussed in **Section 3.4.6**. Culverts are divided in four major categories i.e.:

- **City-Marked Culverts**: Culverts delineated by City of Iqaluit staff during the two workshop sessions. However, sizes were not provided by the city, and as such a minimum diameter of 0.45m for each culvert is used. This number is based on the minimum specified diameter in the City of Iqaluit design standards.
- **Creek Culverts**: Culverts identified during field inspection along the three major creeks. These culverts were assessed for size and condition. Model contains the locations as well as the geometry and sizes of these culverts. Note that slope and inverts are only estimates, based on surrounding LiDAR surface – future topographical survey is still required.
- **Stantec Confirmed Culverts:** Culverts visible on windshield survey videos recorded by Stantec. These culverts mostly consist of driveway culverts in residential areas. These observations were cross referenced with mapping, surface and aerial imagery to identify locations. Culvert sizes were assumed to be of 0.45 m diameter, as per justification used for City-marked culverts.
- **Stantec Suspected Culverts:** Culverts which Stantec suspect exist based on inspection of surface topography, however windshield survey videos and aerial imagery are obscured or ambiguous.

Within the model, culvert crossing were supplemented with weirs to represent the overflow spill (usually over a driveway or roadway) on all the major creeks and roads.

Ditches and overland flows were also delineated using the windshield survey videos, aerial imagery and topographic data. The ditches are categorized as:

- **Stantec Confirmed Ditch:** Ditches identified during the windshield survey videos and further confirmed by looking at the available aerial imagery, topographic and mapping data. Once the locations were identified, further attributes such as cross-sectional profile were assigned using topographic data.
- **WDT (Watershed Delineation Tool):** Overland water flow paths calculated using GIS software and the created digital elevation models, supplemented by watercourse data provided by the Environment Canada.

All the major flow paths such as creeks and overland flow paths were assigned cross-sectional profiles from the available digital elevation model data.

Digital Elevation Models

Three digital elevation models were used to create the topography surface for water flow paths and creeks. These include:

- **LIDAR Data:** LiDAR was obtained from historical City of Iqaluit projects and repurposed for this project. LIDAR data was only available for some tiles of the City and upstream areas. Where LIDAR data was available, it was used to measure cross sectional profile for water flow paths.
- **Contours (1m):** This data mainly corresponded to the developed city area. For water flow paths within the city, the cross-sectional profiles were developed from this model. This model, however, did not have any elevations for building structure within the city. As such, where LIDAR data was not available, this model was used.
- **DEM – UTM 19:** Digital elevation model obtained from Environment Canada for UTM 19. This elevation model predicts the elevation in UTM 19 zone on a high level and is not very precise. For all the upstream contributing areas, where neither the LIDAR data nor the contours were present, this elevation model was used. In future, this should be replaced with LIDAR or any other digital elevation model, that predicts the topography with a more refined detail. This will allow the model to predict more accurate results.

Subcatchments

Subcatchments were delineated based on the surface data to represent the local watershed in the area. Due to the level of detail that would be required, these subcatchments did not account for building downspouts within the city, using just the general topography instead. Auto-generated subcatchments were manually modified to include the effect of road infrastructure as well as the water bodies.

Storages

Waterbody-related data was obtained from Environment Canada. Waterbodies are included in the model as storages. The attenuating effect on hydrograph peaks of these storages along conveyance paths were determined by the model.

Figure 4-1 through Figure 4-4 present example screenshots taken during model construction and of final model appearance, progressively. Large format PDF drawings have also been prepared which can be used to view the model in finer detail. The drawing descriptions are:

- Drawing 2 - Overall Model, with Catchments
- Drawing 3 - Overall Model, No Catchments
- Drawing 4 - City of Iqaluit View, Model with Catchments
- Drawing 5 - City of Iqaluit View, Model with No Catchments
- Drawing 6 - Downtown Model View, No Catchments

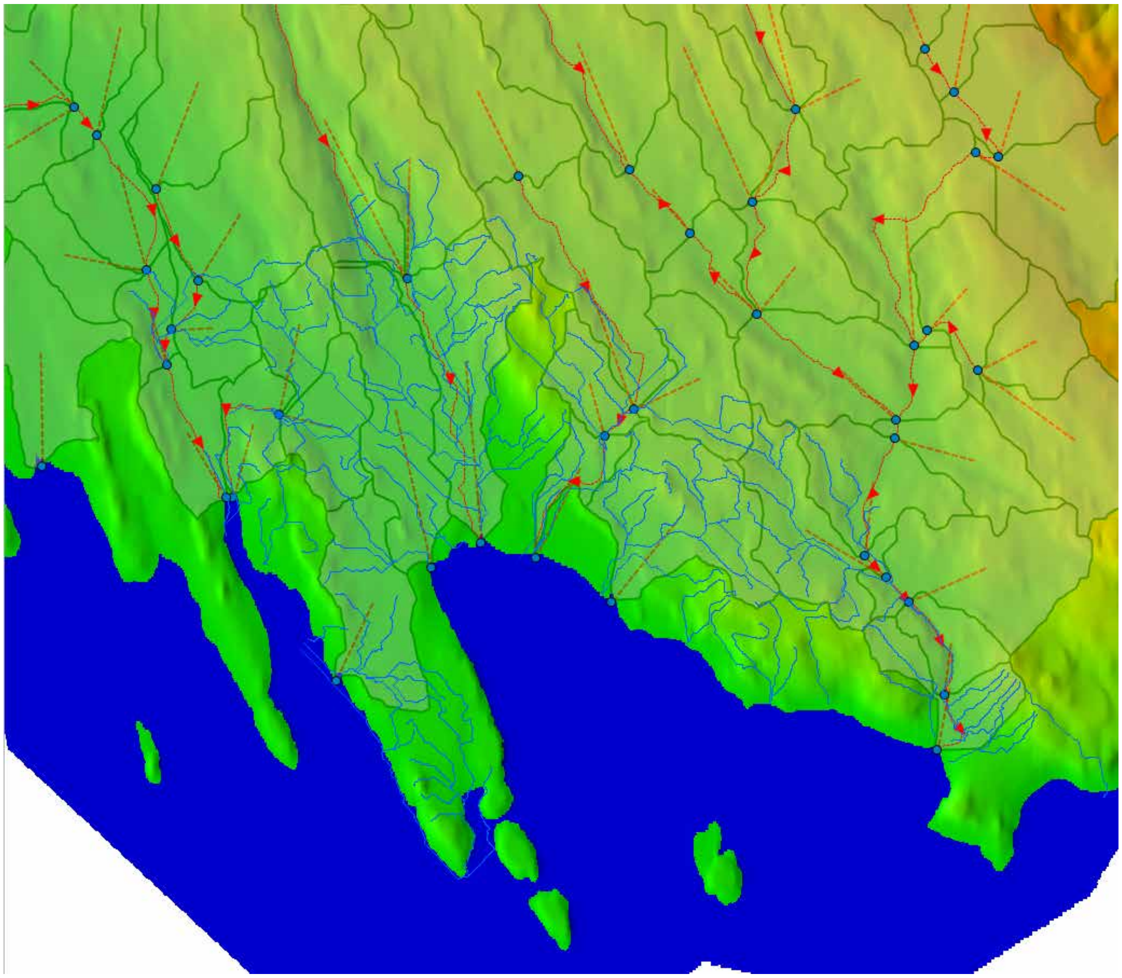

Figure 4-1: Zoom-out view showing coarse terrain model and main drainage courses as part of model build process.

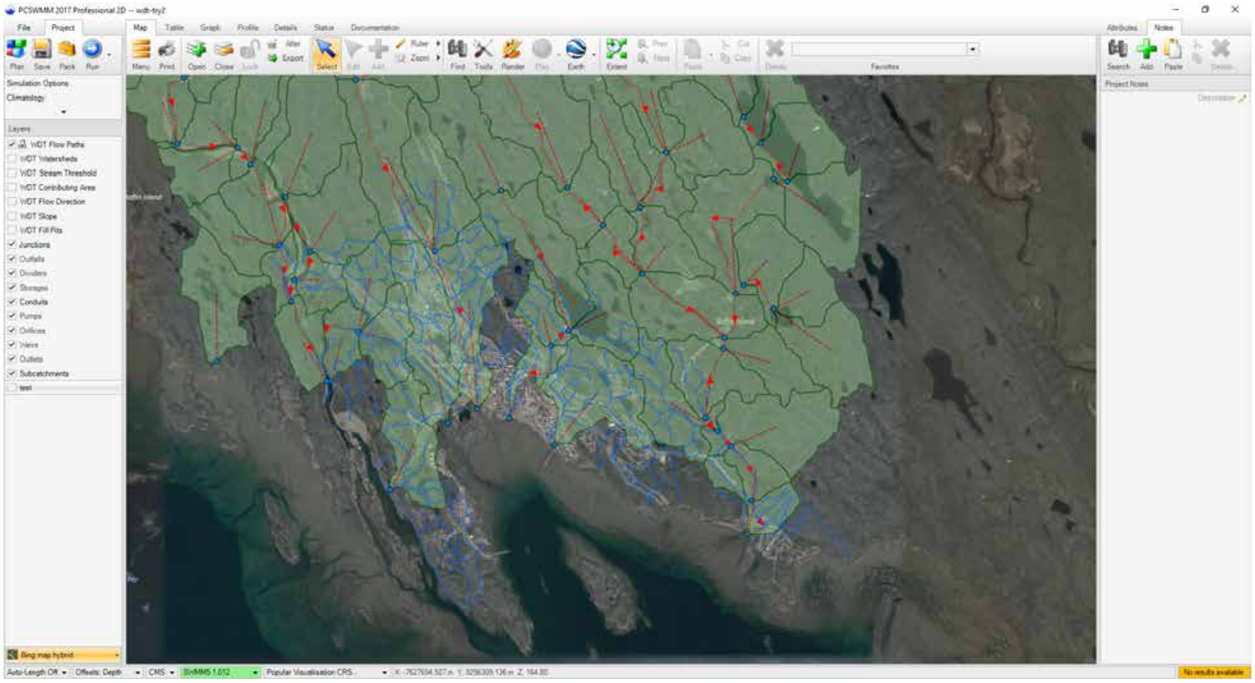

Figure 4-2: Screen shot of watershed model construction in PCSWMM software.

Figure 4-3: Detailed model elements in the vicinity of Lake Geraldine oulet to Koojesse Inlet

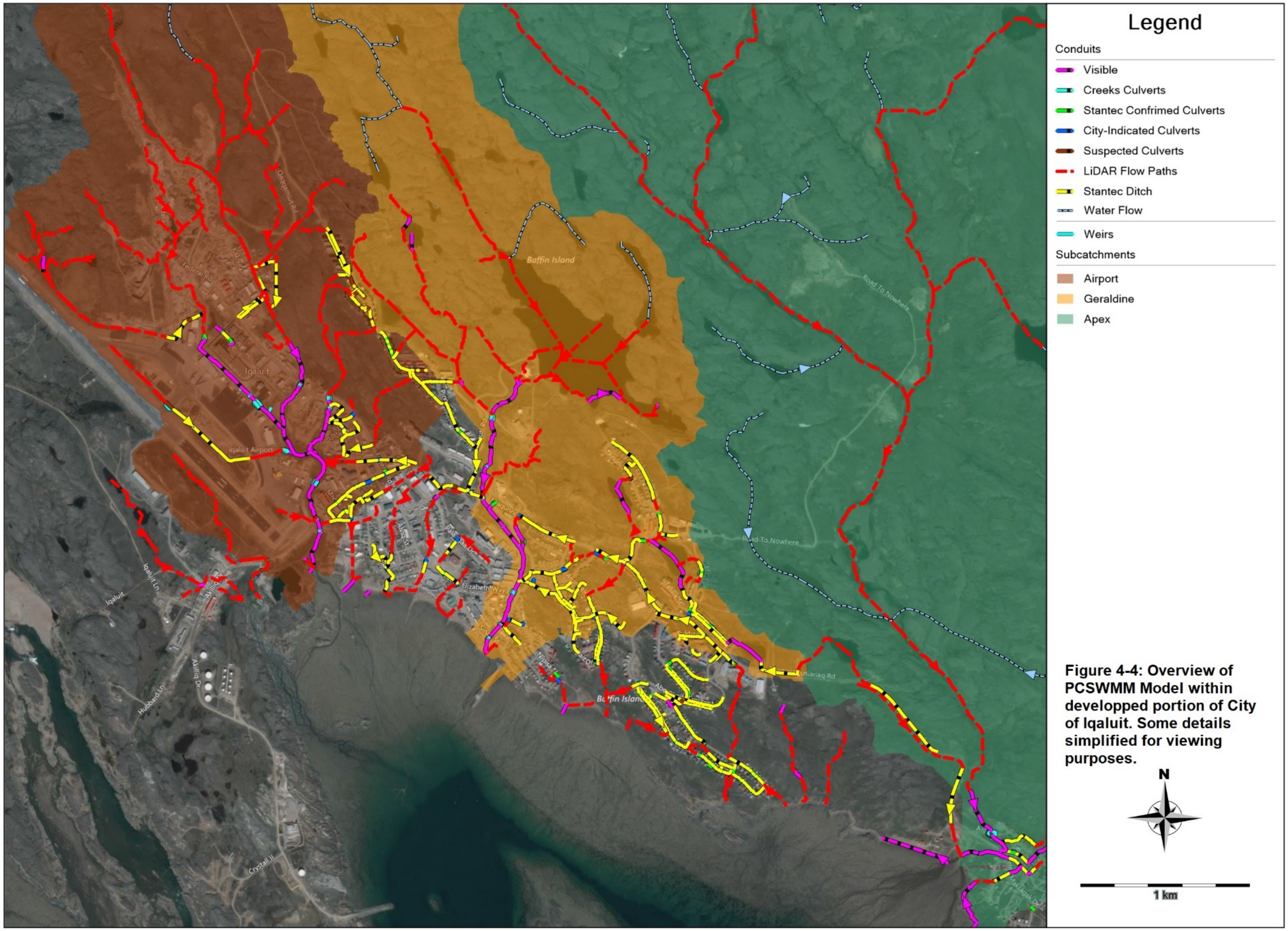

Figure 4-4: Overview of PCSWMM Model within developped portion of City of Iqaluit. Some details simplified for viewing purposes.

4.2 Culvert Capacities

As discussed in section 4.1, the hydrologic and hydraulic model was built using GIS and aerial data, as well as visual observations. However, information about elevations and culvert slopes was not available, meaning that culvert capacities cannot be properly assessed. As mentioned in other sections, a topographical survey of culvert locations, elevations, and slopes is strongly recommended. The information from this survey can then be input to the model to determine the level of service provided.

In the interim, we have prepared a table of calculated culvert capacities under 100 year flows, presented in Table 4-1. This information is very approximate given the number of assumptions that were required, however it does generally indicate whether a culvert has been sized properly relative to its tributary area. Again, actual culvert capacities could vary greatly if the slope data changes.

Table 4-1: Calculated Culvert Capacities, 100 Year Event

LOCATION	**DRAINAGE AREA**		**Culvert Data**					
Culvert ID	Area (ha)	Peak Flow (L/s)	Culvert Diameter (mm)	MATERIAL (-)	Slope (assumed) %	Max. Pipe Capacity (L/s)	% Full (-)	Velocity (m/s)
Airport Creek								
X1a	233	8,747	1800	CSP	1.00	6,496	135%	2.82
X1b	233	8,747	1800	CSP	1.00	6,496	135%	2.82
	466	**17,493**				**12,991**	**135%**	
X2	453	17,011	2100	CSP	1.00	9,798	174%	3.12
X3a	74	2,763	1000	CSP	1.00	1,266	218%	1.87
X3b	74	2,763	1000	CSP	1.00	1,266	218%	1.87
X3c	74	2,763	1200	CSP	1.00	2,203	125%	2.15
X3d	74	2,763	1200	CSP	1.00	2,203	125%	2.15
X3e	74	2,763	1200	CSP	1.00	2,203	125%	2.15
X3f	74	2,763	1200	CSP	1.00	2,203	125%	2.15
	442	**16,580**				**11,346**	**146%**	
X4	33	1,223	800	CSP	1.00	629	194%	1.57
X5a	34	1,265	3000	CSP	1.00	13,989	9%	1.74
X5b	34	1,265	3000	CSP	1.00	13,989	9%	1.74
X5c	34	1,265	3000	CSP	1.00	13,989	9%	1.74
	101	**3,796**				**41,968**	**9%**	
X6a	39	1,476	1200	CSP	1.00	2,203	67%	2.03
X6b	39	1,476	600	CSP	1.00	347	425%	1.36
	79	**2,951**				**2,550**	**116%**	

LOCATION	**DRAINAGE AREA**		**Culvert Data**					
Culvert ID	Area	Peak Flow	Culvert Diameter	MATERIAL	Slope (assumed)	Max. Pipe Capacity	% Full	Velocity
	(ha)	(L/s)	(mm)	(-)	%	(L/s)	(-)	(m/s)
X7	5	173	600	CSP	1.00	347	50%	1.18
X8a	135	5,074	1000	CSP	1.00	1,266	401%	1.87
X8b	135	5,074	1600	CSP	1.00	3,995	127%	2.50
X8c	135	5,074	1000	CSP	1.00	1,266	401%	1.87
	405	**15,223**				**6,528**	**233%**	
X9	2	75	2100	CSP	1.00	9,798	1%	0.00
X10a	135	5,074	3100	CSP	1.00	13,989	36%	2.73
X10b	135	5,074	1600	CSP	1.00	3,995	127%	2.50
	270	**10,148**				**17,984**	**56%**	
X12a	45	1,695	1000	CSP	1.00	1,266	134%	1.87
X12b	45	1,695	1000	CSP	1.00	1,266	134%	1.87
X12c	45	1,695	1000	CSP	1.00	1,266	134%	1.87
X12d	45	1,695	2100	CSP	1.00	9,798	17%	1.97
	181	**6,778**				**13,598**	**50%**	
X13	137	5,156	1600	CSP	1.00	3,995	129%	2.50
Lake Geraldine								
X1a	121	4,560	700	CSP	1.00	475	960%	1.47
X1b	121	4,560	700	CSP	1.00	475	960%	1.47
	243	**9,120**				**950**	**960%**	
X2a	80	3,016	1200	CSP	1.00	2,203	137%	2.15
X2b	80	3,016	1200	CSP	1.00	2,203	137%	2.15
X2c	80	3,016	1200	CSP	1.00	2,203	137%	2.15
	241	**9,048**				**6,610**	**137%**	
X3a	46	1,729	1500	CSP	1.00	3,995	43%	2.08
X3b	46	1,729	1500	CSP	1.00	3,995	43%	2.08
X3c	46	1,729	1500	CSP	1.00	3,995	43%	2.08
X3d	46	1,729	620	CSP	1.00	347	498%	1.36
X3e	46	1,729	620	CSP	1.00	347	498%	1.36
	230	**8,646**				**12,678**	**68%**	

LOCATION	DRAINAGE AREA		Culvert Data					
Culvert ID	Area	Peak Flow	Culvert Diameter	MATERIAL	Slope (assumed)	Max. Pipe Capacity	% Full	Velocity
	(ha)	(L/s)	(mm)	(-)	%	(L/s)	(-)	(m/s)
X4a	60	2,270	1350	CSP	1.00	3,016	75%	2.26
X4b	60	2,270	1350	CSP	1.00	3,016	75%	2.26
	121	**4,541**				**6,032**	**75%**	
X5	104	3,902	xx	CSP	1.00	#N/A	#N/A	#N/A
X6a	34	1,272	1300	CSP	1.00	2,203	58%	1.94
X6b	34	1,272	800	CSP	1.00	629	202%	1.57
X6c	34	1,272	1300	CSP	1.00	2,203	58%	1.94
	102	**3,815**				**5,036**	**76%**	
X7	99	3,732	3200	CSP	1.00	13,989	27%	2.46
X8a	49	1,849	1950	CSP	1.00	8,041	23%	2.03
X8b	49	1,849	1950	CSP	1.00	8,041	23%	2.03
	99	**3,699**				**16,083**	**23%**	
X9	57	2,130	xx	CSP	1.00	#N/A	#N/A	#N/A
X10a	26	961	1350	CSP	1.00	3,016	32%	1.78
X10b	26	961	1350	CSP	1.00	3,016	32%	1.78
	51	**1,922**				**6,032**	**32%**	
Apex River								
C1a	36	1,349	900	CSP	1.00	1,023	132%	1.78
C1b	36	1,349	900	CSP	1.00	1,023	132%	1.78
C1c	36	1,349	900	CSP	1.00	1,023	132%	1.78
C1d	36	1,349	900	CSP	1.00	1,023	132%	1.78
	144	**5,395**				**4,092**	**132%**	
C2a	36	1,349	1100	CSP	1.00	1,543	87%	1.96
C2b	36	1,349	1100	CSP	1.00	1,543	87%	1.96
C2c	36	1,349	1100	CSP	1.00	1,543	87%	1.96
	108	**4,046**				**4,629**	**87%**	
C3a	36	1,349	xx	CSP	1.00	#N/A	#N/A	#N/A
C3b	36	1,349	xx	CSP	1.00	#N/A	#N/A	#N/A
C3c	36	1,349	xx	CSP	1.00	#N/A	#N/A	#N/A

LOCATION	DRAINAGE AREA		Culvert Data					
Culvert ID	Area	Peak Flow	Culvert Diameter	MATERIAL	Slope (assumed)	Max. Pipe Capacity	% Full	Velocity
	(ha)	(L/s)	(mm)	(-)	%	(L/s)	(-)	(m/s)
	108	**4,046**				**#N/A**	**#N/A**	

Several of the assumptions that were required are: the data uses the tributary area to each crossing location, excluding area upstream of the nearest waterbody in order to account for lake attenuation effects. Peak flows were calculated using a 30 minute time of concentration for runoff coefficients of 0.5 with the new Iqaluit IDF curves for the 100 year event. Some culvert diameters were not available. Slope of 1% is assumed – actual slopes could vary greatly or even be negative, resulting in large changes in culvert capacity. Culvert capacity is calculated using the Manning's equation for gravity flow with a roughness of 0.024. When actual field data is finally collected, culvert capacity should be checked using more appropriate equations (e.g. using the model) and checked for inlet and outlet control. Culvert performance in spring conditions where ice is often obstructing flow is not represented in the above table; therefore the desirable "% Full" amount should likely be much lower than 100% - perhaps as low as 50%.

4.3 IDF Curves

At the time of this report, no IDF parameters are specified in the City of Iqaluit Design Guidelines, however it is presumed most practitioners would turn to the IDF curves published by Environment Canada for the Iqaluit Airport. These existing IDF curves were identified to have two issues of concern:

1. IDF curves are based on only 18 years of record, from 1982 to 2002 (2 years omitted), when in fact longer periods of data are available; and
2. A two-parameter curve fit equation was used by Environment Canada, however a three-parameter equation would provide a better fit to the data and this form of equation is much more commonly used among North American municipalities.

The existing IDF curves were updated using the precipitation data from 1946 to 2018. In addition, a three-parameter equation form was used to fit the calculated IDF data. Conventionally, this three-parameter fit is based on the shifted power model, however the statistical analysis showed wide error ranges in the residuals when using this equation form. As such, the curve fit equations for IDF curves were changed to use a Hoerl equation form which resulted in a closer fit to the measured data. The equations and parameters are provided in Table 4-2. These curves have also been recommended for inclusion in the revised design standards for the City of Iqaluit, which have been updated as part of this study. The revised IDF curves can be seen on Figure 4-5**.**

The recommended revisions to the design standards are appended to this report in **Appendix D**.

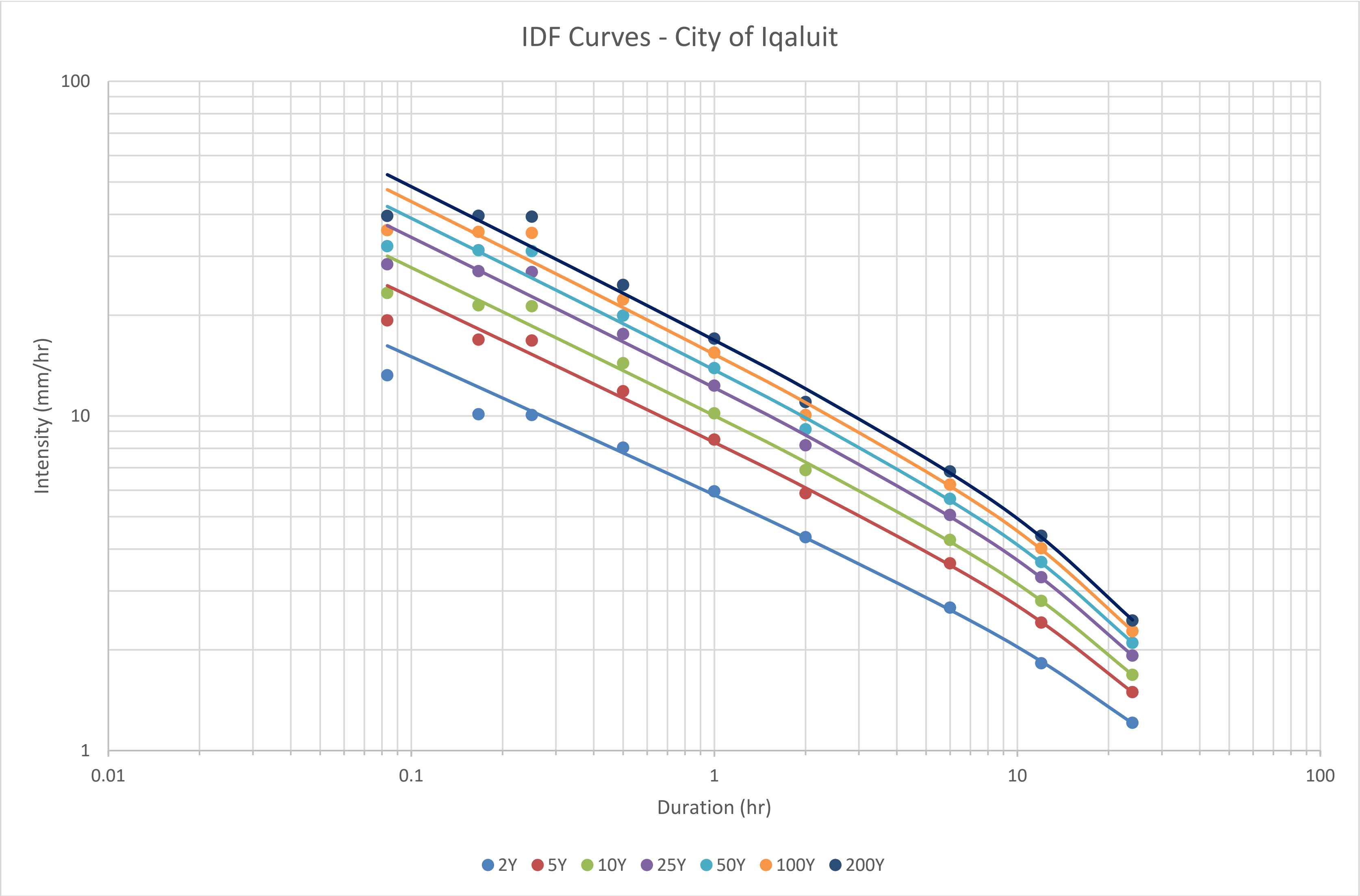

Figure 4-5: Proposed IDF Curves for Iqaluit

Additionally, the parameters for the curves are tabulated in Table 4-2**.**

Table 4-2: IDF Parameters for Iqaluit.

Rate = $* b^t * t^c$	Return Frequency						
Parameters	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
a	5.876	8.466	10.188	12.369	13.989	15.598	17.203
b	0.988	0.985	0.983	0.981	0.980	0.979	0.979
c	-0.409	-0.428	-0.436	-0.442	-0.446	-0.448	-0.450

Where t = duration in hours

Rainfall Rate (in mm/hr) = $\boldsymbol{a * b^t * t^c}$

4.4 Climate Change Impacts

Climate change impacts on the IDF equations were assessed using the IDF Climate Change Tool 3.0, developed by Dr. Slobodan Simonovic of the University of Western Ontario (Simonovic, Schardong, Sandink, & Srivastav, 2016). The tool uses global circulation models (GCMs) and downscales the impacts to the local level of a climate monitoring station. Scenarios can be assessed using various RCP values (representative concentration pathway) published by the IPCC (Intergovernmental Panel on Climate Change). Low, medium and high-risk are represented by RCP values of 4.5, 6.0 and 8.5.

Impacts to the existing Iqaluit Climate station IDF curves were assessed using the tool and the percentage increases were then applied to the newly-updated Iqaluit IDF equations.

For example, the percent increases for the 24-hour rainfall at Iqaluit under the climate change scenarios for various return periods are presented in Figure 4-6. At the low end, a minimum of approximately 15% increase is estimated under the low risk scenario while a 50% increase is estimated for the high-risk scenario.

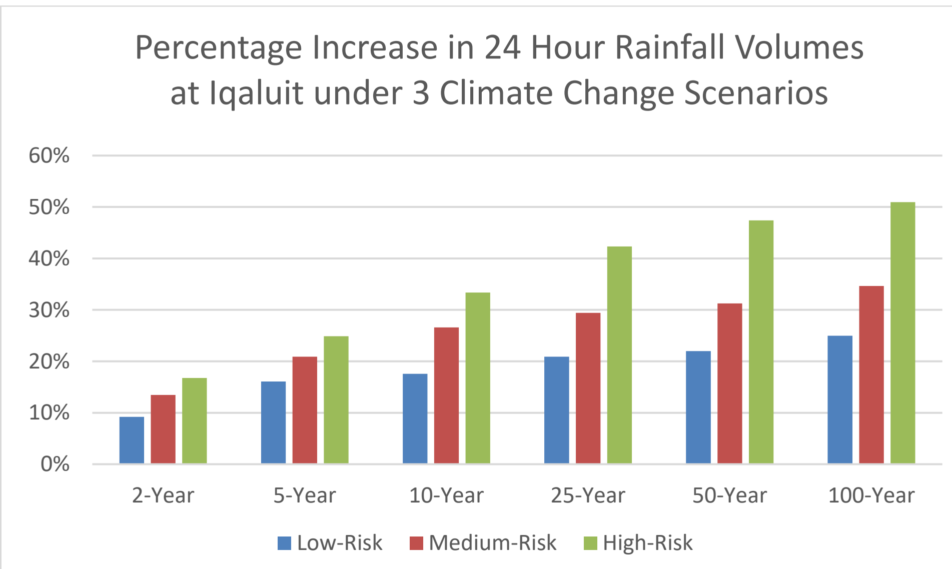

Figure 4-6: Potential increase in storm volume due to climate change, using values from

Results from the high-risk (RCP 8.5) scenario of the climate change tool were applied to the IDF curves generated from the weather station data. The results can be seen on Figure 4-7. For all future designs, Stantec recommends using the non-climate change IDF curves for design and that a “stress test” be performed using the IDF climate change equations to determine whether future climate change would impact infrastructure.

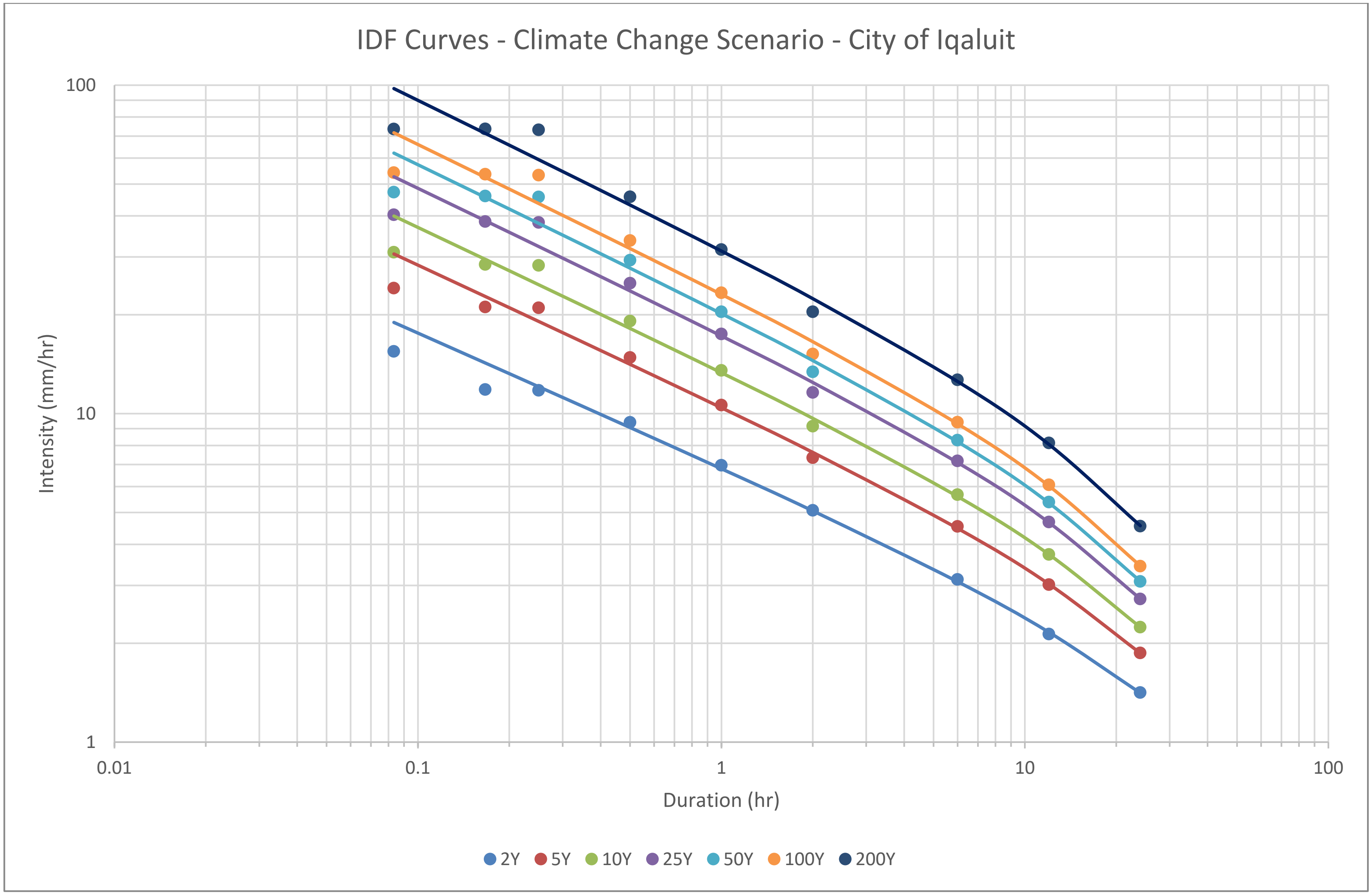

Figure 4-7: Proposed IDF Curves for Iqaluit - Climate Change Scenario

The updated IDF curves for the climate change were also curve fitted using the two-parameter equation. The parameters along with the equation are outlined in Table 4-3 below.

Table 4-3: IDF Parameters for Iqaluit Under Climate Change Scenario RCP 8.5.

Rate = $a * b^t * t^c$	Return Frequency						
Parameters	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
a	6.875	10.583	13.550	17.564	20.564	23.553	31.940
b	0.988	0.985	0.983	0.981	0.980	0.979	0.979
c	-0.409	-0.428	-0.436	-0.442	-0.446	-0.448	-0.450

Where t = duration in hours

Rainfall Rate (in mm/hr) = $a * b^t * t^c$

4.4.1 Assessment of Spring Snowmelt on Drainage System

Spring snowmelt has been a significant challenge in the City of Iqaluit. Major roadways are known to be susceptible to overflowing issues in the spring season. This is also confirmed by the field inspection / survey as well as the media literature.

Snow-on-ground depth data was previously obtained from Environment Canada; the data begins as early as 1955. Figure 4-8 presents the last date in each year on which there was still snow measured on the ground. A general downward trend can be seen, indicating that the date on which all snow has melted is moving earlier over time, as would be expected from climate change predictions.

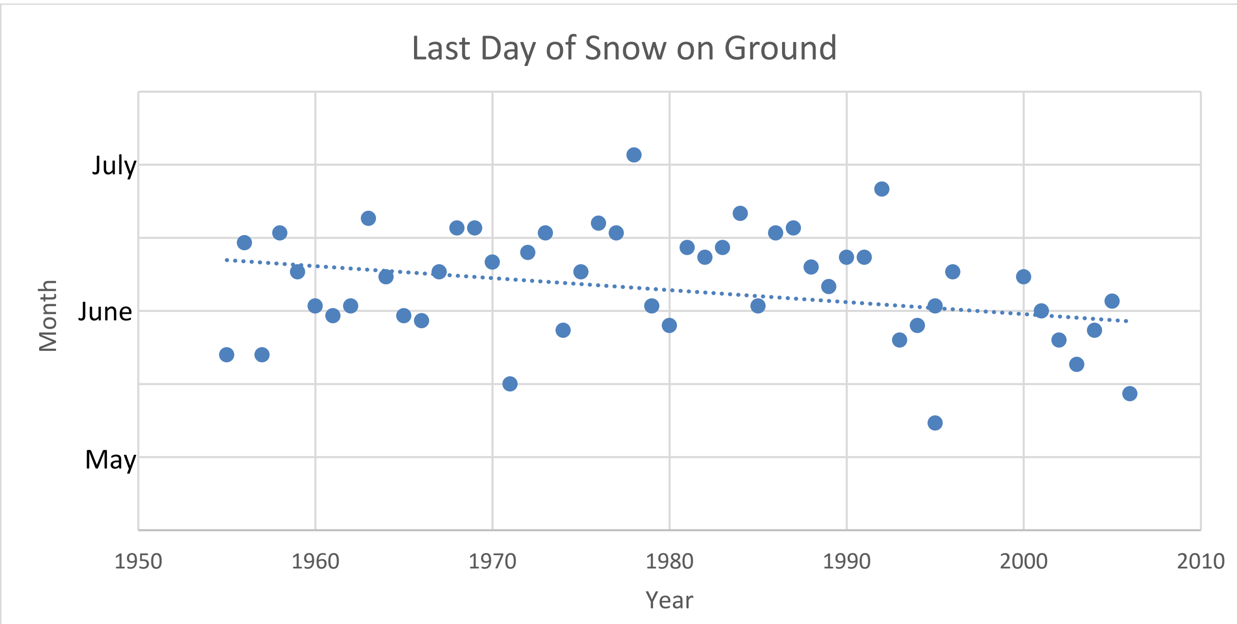

Figure 4-8: Last Spring Day of Snow-on-Ground, 1955-2006.

Stantec also calculated daily melt rates (in cm/day) and created an annual maximum series (Figure 4-9) over the period 1955-2006, then used this data to obtain the melt rate for different return periods; the results can be seen in Table 4-4.

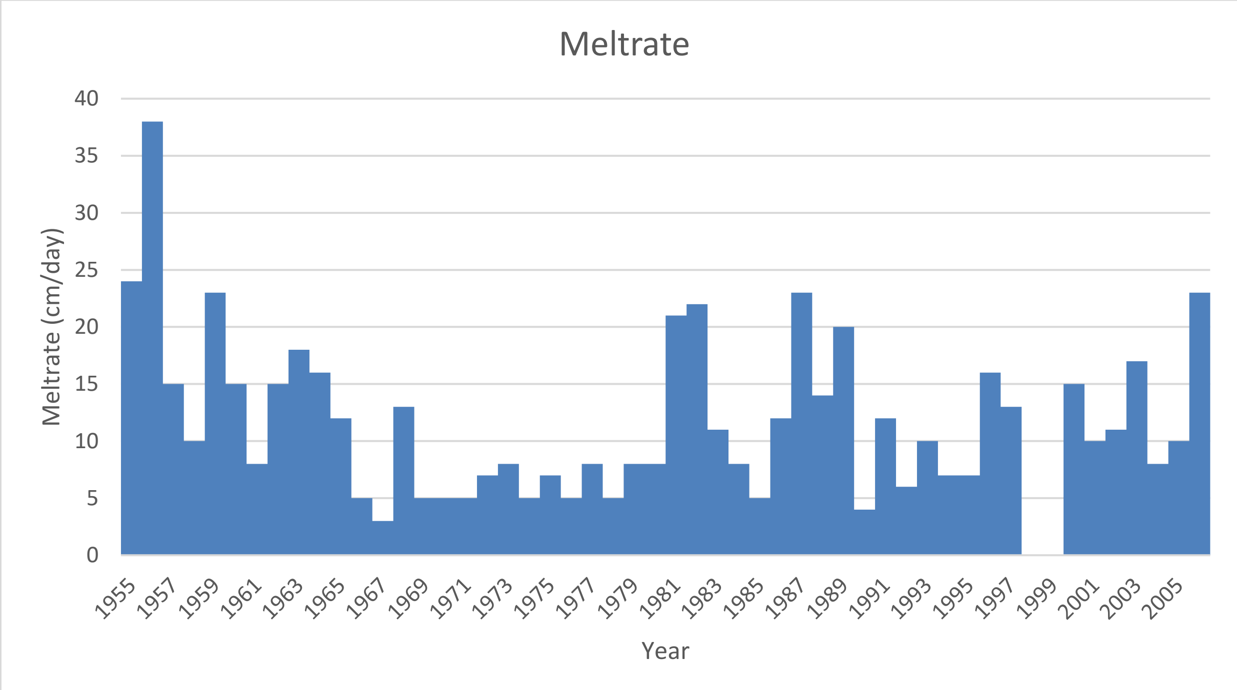

Figure 4-9: Annual Maximum Daily Snowmelt rate calculated from Snow-on-Ground Data, 1955-2006

Table 4-4: Return Period for spring snowmelt in Iqaluit

Return Period	Snowmelt (cm/day)
2	14.7
5	24.8
10	31.5
25	40.0
50	46.3
100	52.5
200	58.7

These results can be used to design future roadways or drainage infrastructure. For comparison purposes, the 100 year 24 hour rainfall depth is 54.7 mm, equivalent to about 55 cm of snow. Therefore a 100 year melt rate is roughly equivalent to a 100 year rainstorm. It is possible that a rain-on-snow event could cause a large amount of runoff – from both the storm event and the melting of the snowpack. The combined statistical likelihood of this event would be rare, certainly in excess of 100 years. However, as climate change occurs, trends based on historical data will shift and will make the event more likely.

If an area is being used for snow storage (not just at the officially-designated City snow dumps, but at other locations in the City used by contractors), the spring snowmelt will exceed the rain event. It is therefore recommended that these areas be assessed using the melt rates above (with 1 cm of snow = 1 mm of runoff) to determine the required drainage capacity of the downstream receiving infrastructure.

4.4.2 Spring Freshet

Streamflow data for the Apex River has also been collected as referenced in section 3.4.4. The date of first non-zero flow was noted for each year of record – meant to represent the beginning of the spring freshet, or the first day of melt sufficient to cause water in the river to move at the gauging station. As can be seen on the Figure 4-10 below, over the course of 44 years, the date of first flow has shifted from mid-June and early July to mid-May or early June.

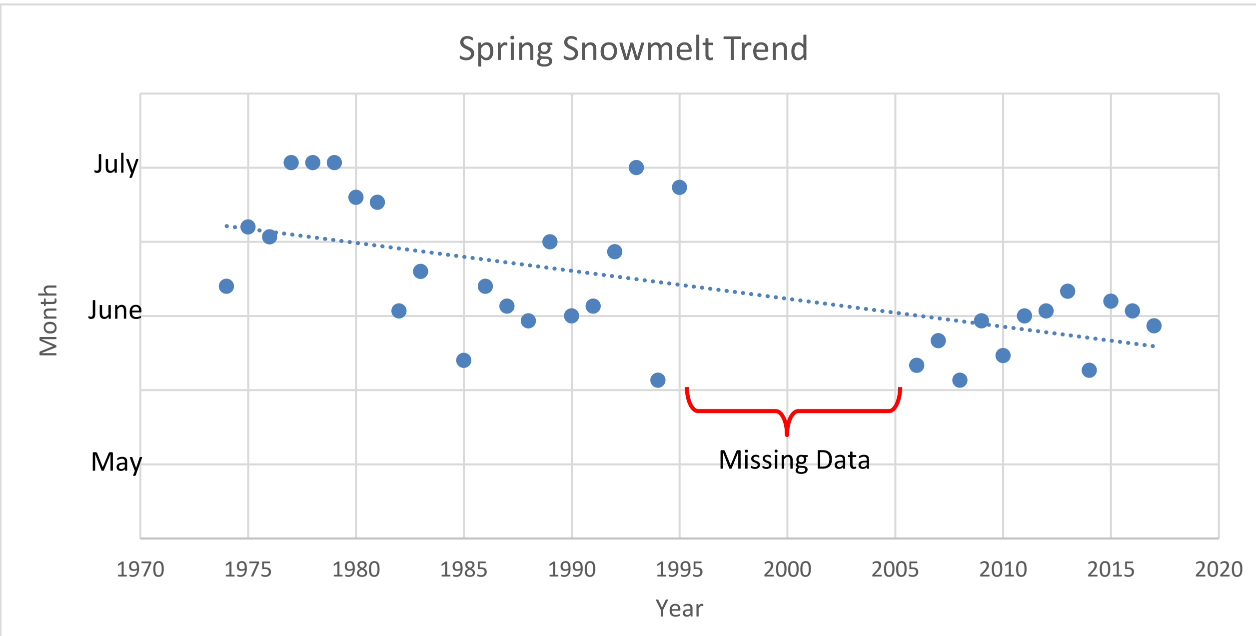

Figure 4-10: Annual Dates of First Flow in Apex River – 1974 to 2017

This trend would be expected given climate change and increasing arctic temperature trends. The trend toward earlier ice breakup on Iqaluit watercourses and waterbodies and later freeze-up is likely to continue, resulting in longer periods of the year where precipitation falls as rain. Breakup flooding is likely to be less severe. Increased runoff from major arctic rivers and increased precipitation over the Arctic Ocean are likely to decrease its salinity.

4.4.3 ClimateAtlas Predictions for Iqaluit

The Climate Atlas of Canada (ClimateAtlas.ca) is an online tool which presents and visualizes climate data in an interactive format. The website was created by the Prairie Climate Centre and displays not only historical data but also future predictions to the year 2100 using the BCSD climate model. We have excerpted some of the website's visualizations for Iqaluit to help illustrate future climate change impacts.

Figure 4-11 presents a summary table of future climate change impacts in comparison to the historical mean.

Figure 4-12 presents a climograph (representing temperatures and precipitation) for each month for historical and future values.

RCP 8.5: High Carbon climate future

GHG emissions continue to increase at current rates

Variable	Period	1976-2005 Mean	2021-2050 Low	2021-2050 Mean	2021-2050 High	2051-2080 Low	2051-2080 Mean	2051-2080 High
Precipitation (mm)	Annual	443	388	494	625	426	546	682
Precipitation (mm)	Spring	80	54	90	138	64	99	151
Precipitation (mm)	Summer	159	106	169	241	106	182	265
Precipitation (mm)	Fall	127	94	144	217	102	159	229
Precipitation (mm)	Winter	76	49	93	148	62	108	164
Mean Temperature (°C)	Annual	-8.9	-8.6	-6.2	-3.7	-6	-3.4	-0.2
Mean Temperature (°C)	Spring	-13.1	-14	-10.6	-7.2	-11.9	-8	-2.7
Mean Temperature (°C)	Summer	6.1	5.7	7.5	9.6	7.1	9.1	11.9
Mean Temperature (°C)	Fall	-4.6	-4.7	-2.1	0.4	-2.7	0	2.4
Mean Temperature (°C)	Winter	-24.1	-24.9	-19.7	-14	-20.2	-14.9	-9
Tropical Nights	Annual	0	0	0	0	0	0	0
Very hot days (+30°C)	Annual	0	0	0	0	0	0	0
Very cold days (-30°C)	Annual	48	5	21	53	0	4	29
Date of Last Spring Frost	Annual	June 24	May 31	June 12	July 2	May 22	June 4	June 20
Date of First Fall Frost	Annual	Sep. 4	Sep. 5	Sep. 18	Sep. 29	Sep. 13	Sep. 22	Oct. 3
Frost-Free Season (days)	Annual	72	70	98	118	87	110	132

Figure 4-11: ClimateAtlas.ca report on expected impacts to various climate parameters in Iqaluit and vicinity under the IPCC RCP 8.5 Scenario - i.e. GHG emissions continue to increase at current rates. https://climateatlas.ca/report/climate/city/246

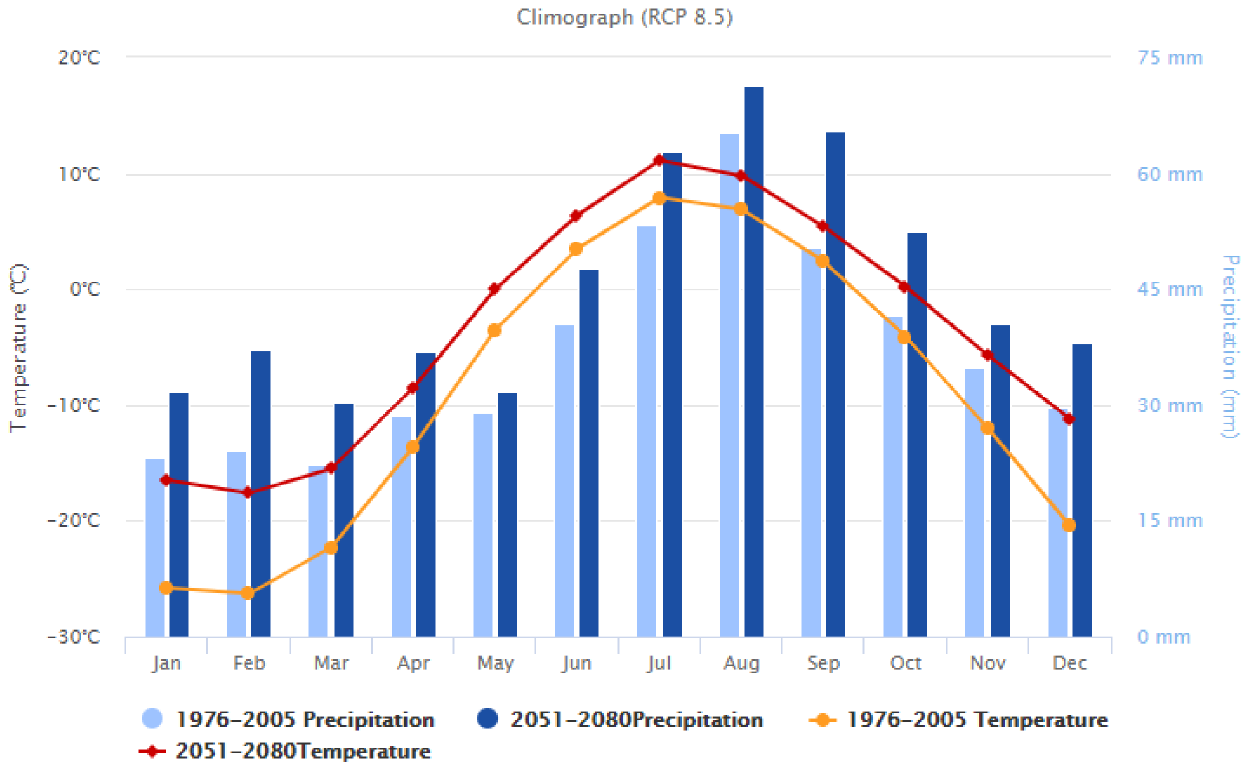

Figure 4-12: ClimateAtlas.ca Iqaluit projected climograph by month comparing climate normal from 1976-2005 with those predicted for 2051-2080 under IPCC RCP 8.5. (https://climateatlas.ca/data/city/246/annual_meantemp_2060_85)

Figure 4-13 through Figure 4-16 present graphed historical and predicted data (using IPCC RCP 8.5 scenario) from ClimateAtlas.ca for annual mean temperature, annual total precipitation, coldest minimum temperature, and warmest maximum temperature respectively. All four graphs anticipate an upward trend, meaning more rainfall and warmer temperatures.

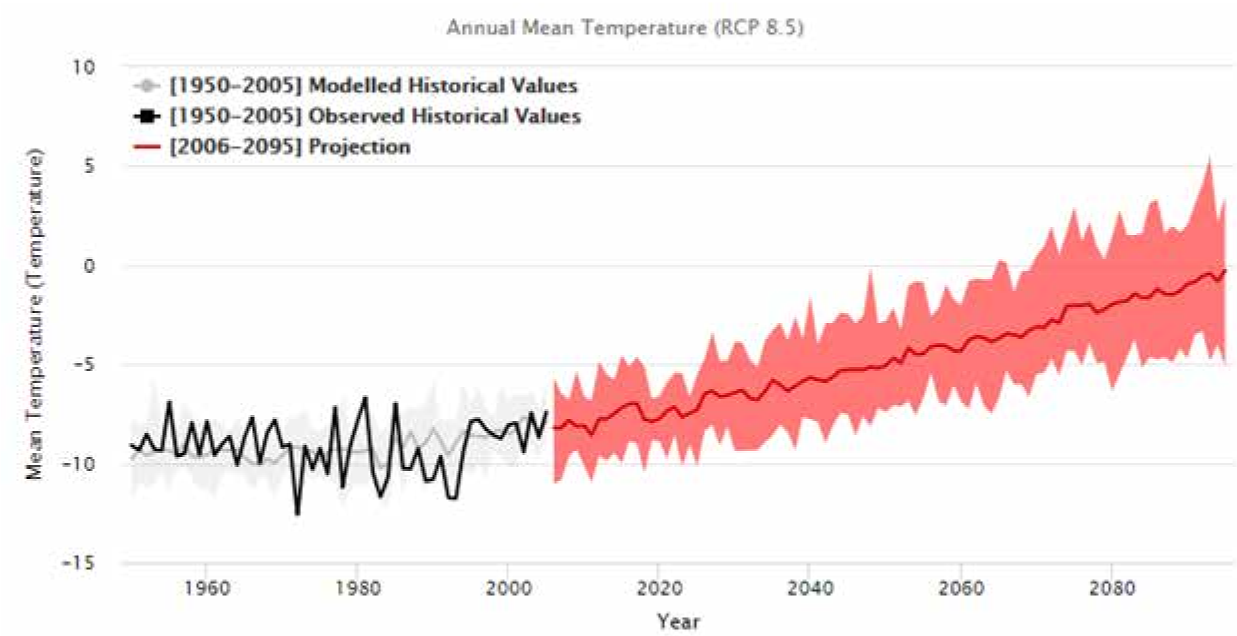

Figure 4-13: ClimateAtlas.ca Iqaluit projections for annual mean temperatures to 2100 under IPCC RCP 8.5. (https://climateatlas.ca/data/city/246/annual_meantemp_2060_85)

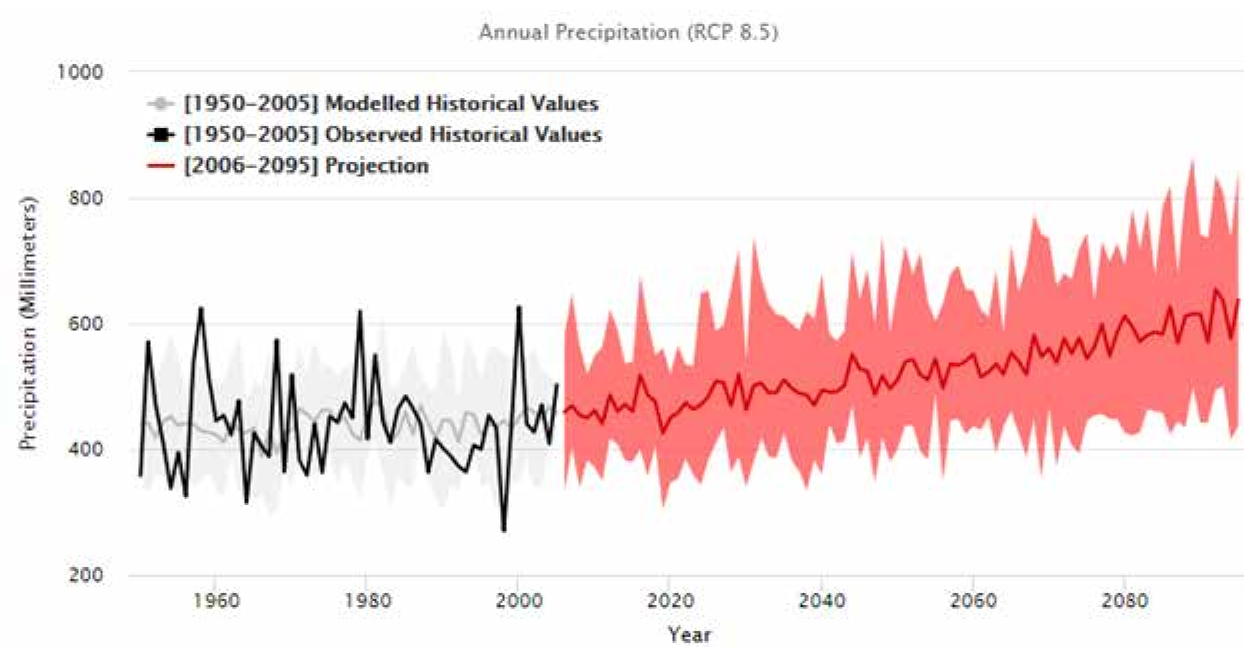

Figure 4-14: ClimateAtlas.ca Iqaluit projections for annual precipitation values to 2100 under IPCC RCP 8.5. (https://climateatlas.ca/data/city/246/annual_precip_2060_85)

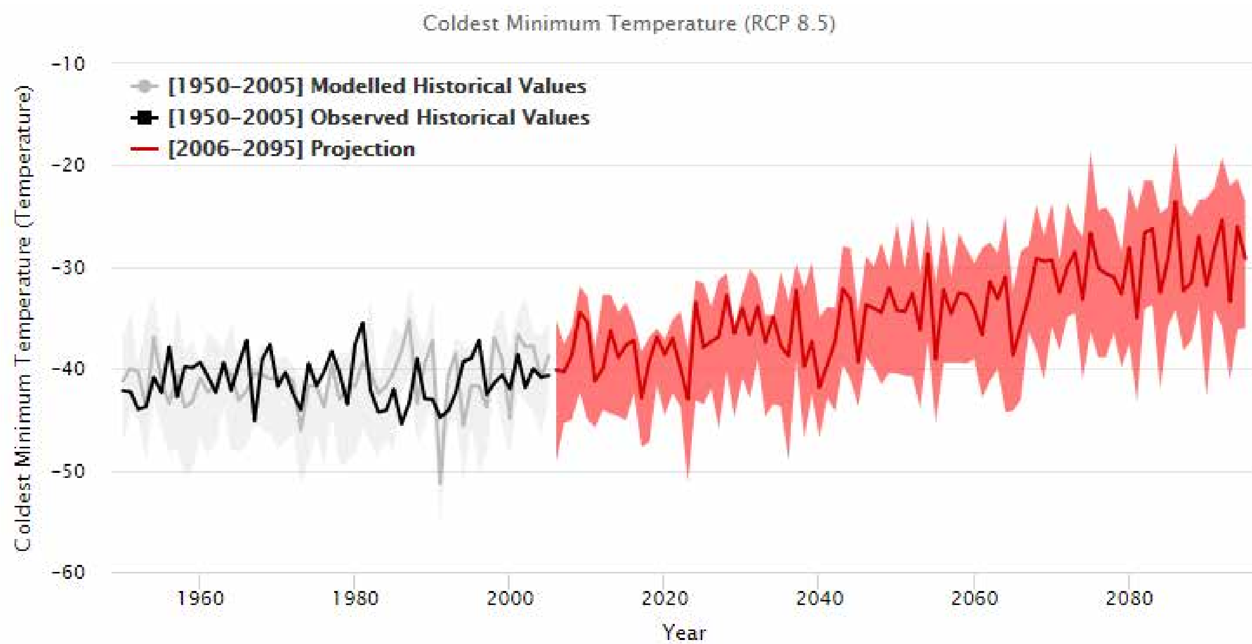

Figure 4-15: ClimateAtlas.ca Iqaluit projections for coldest minimum temperatures to 2100 under IPCC RCP 8.5. (https://climateatlas.ca/data/city/246/minmin_2060_85)

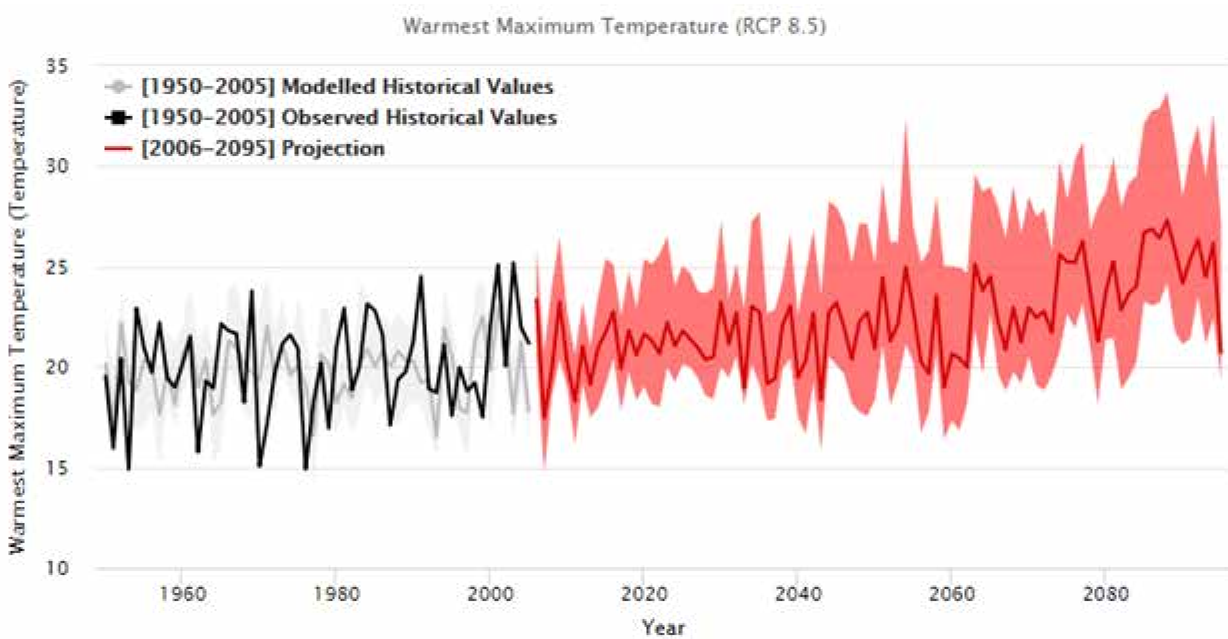

Figure 4-16: ClimateAtlas.ca Iqaluit projections for warmest maximum temperatures to 2100 under IPCC RCP 8.5. (https://climateatlas.ca/data/city/246/maxmax_2060_85)

5 NEW DRAINAGE MEASURES AND RETROFIT OPPORTUNITIES

5.1 Culvert Repairs

All the existing culvert crossings of the three main drainage courses in the City were examined during field inspections. The complete list of these existing culverts has been provided in section 3.4.6. While inspecting those culverts, several culverts were identified to be inoperative due to the structural defects. Table 5-1 below provides a list of all the culverts along the three major creeks that are critical to the drainage infrastructure and are in need of immediate attention. Further inspections will be required to determine whether repair or replacement is appropriate.

Table 5-1: Culverts Requiring Repair

Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
Airport Creek								
X3d	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor, multiple roof sags identified
X5a	NE	SW	3000	Corrugated Steel	Circular	Projected	N	Deformed Edges, Fine deposits on the upstream end, Culvert inoperative due to deposits
X7	NE	SW	600	Corrugated Steel	Circular	Projected	N	Deformed Edges. Significant amount of fine deposition in the Culvert.
X9	NE	SW	2100	Corrugated Steel	Circular	Projected	N	Torn out edges, significant amount of debris deposited at the upstream end. A furniture was identified in the Culvert
Apex River								
C1b	N	S	900	Corrugated Steel	Circular	Projected	N	Deformed Culvert appears oval in shape, significant roof sagging observed in the

Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
								middle. Surface corrosion on floor.
C3c	N	S		Corrugated Steel	Circular	Projected	N	Deformed Culvert, Roof sags identified at multiple locations
Lake Geraldine								
X2b	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Significant fine deposits at the downstream end. Culvert not usable
X3c	N	S	1500	Corrugated Steel	Circular	Projected	Y	Deformed Culvert, elliptical in shape
X3d	N	S	620	Corrugated Steel	Circular	Projected	N	Deformed Culvert, with multiple bulging along the length of Culvert
X4a	N	S	1350	Corrugated Steel	Circular	Projected	Y	Culvert half buried in the substrate, significant roof sagging, deformed culvert
X4b	N	S	1350	Corrugated Steel	Circular	Projected	Y	Culvert half buried in the substrate, significant roof sagging, multiple circumferential cracks, deformed Culvert
X6c	NW	SE	1300	Corrugated Steel	Circular	Projected	Y	Deformed at downstream end, multiple roof sags identified along the length of Culvert
X7	NW	SE	3200	Wooden Cribs	Arch	Projected	Y	Significant amount of fine and rock deposits in the Culvert. Culvert inoperable.

5.2 Culvert Replacement Valuations

Although the repairs suggested above may not require culvert replacement, it is useful to have a valuation of the replacement values of the existing infrastructure, especially for future asset management plans. The below valuations can be considered a Class 5 opinion of probable costs – concept level, with estimate range of -50% to +100%. Table 5-2 through Table 5-4 present the opinion of probable costs to replace the existing culverts for Airport Creek, Apex River, and Lake Geraldine Spillway.

Table 5-2: Airport Creek, Valuation of Culverts, Opinion of Probable Cost

Airport Creek

Crossing#	Dia. (mm)	Length (m)	Material	Shape	Configuration	Unit Cost	Cost
X1a	1800	15	Corrugated Steel	Circular	Projected	$ 2,924.20	$ 43,863.00
X1b	1800	15	Corrugated Steel	Circular	Projected	$ 2,924.20	$ 43,863.00
X2	2100	15	Corrugated Steel	Circular	Projected	$ 3,206.95	$ 48,104.25
X3a	1000	35	Corrugated Steel	Circular	Projected	$ 2,170.20	$ 75,957.00
X3b	1000	35	Corrugated Steel	Circular	Projected	$ 2,170.20	$ 75,957.00
X3c	1200	35	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 82,554.50
X3d	1200	35	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 82,554.50
X3e	1200	35	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 82,554.50
X3f	1200	35	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 82,554.50
X4	800	25	Corrugated Steel	Circular	Projected	$ 1,981.70	$ 49,542.50
X5a	3000	13	Corrugated Steel	Circular	Projected	$ 4,055.20	$ 52,717.60
X5b	3000	13	Corrugated Steel	Circular	Projected	$ 4,055.20	$ 52,717.60
X5c	3000	13	Corrugated Steel	Circular	Projected	$ 4,055.20	$ 52,717.60
X6	1200	23	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 54,250.10
X6b	600	23	Corrugated Steel	Circular	Projected	$ 1,793.20	$ 41,243.60
X7	600	30	Corrugated Steel	Circular	Projected	$ 1,793.20	$ 53,796.00
X8a	1000	67	Corrugated Steel	Circular	Projected	$ 2,170.20	$ 145,403.40
X8b	1600	67	Corrugated Steel	Circular	Projected	$ 2,735.70	$ 183,291.90
X8c	1000	67	Corrugated Steel	Circular	Projected	$ 2,170.20	$ 145,403.40
X9	2100	15	Corrugated Steel	Circular	Projected	$ 3,206.95	$ 46,500.78
X10a	3100	20	Corrugated Steel	Arch	Projected	$ 4,149.45	$ 82,989.00
X10b	1600	20	Corrugated Steel	Circular	Projected	$ 2,735.70	$ 54,714.00
X12a	1000	22	Corrugated Steel	Circular	Projected	$ 2,170.20	$ 47,744.40
X12b	1000	22	Corrugated Steel	Circular	Projected	$ 2,170.20	$ 47,744.40
X12c	1000	22	Corrugated Steel	Circular	Projected	$ 2,170.20	$ 47,744.40
X12d	2100	22	Corrugated Steel	Circular	Projected	$ 3,206.95	$ 70,552.90
X13	1600	22	Corrugated Steel	Circular	Projected	$ 2,735.70	$ 60,185.40

Table 5-3: Apex River, Valuation of Culverts, Opinion of Probable Cost

Apex River

Crossing#	Dia. (mm)	Length (m)	Material	Shape	Configuration	Unit Cost	Cost
Ia		#N/A	Corrugated Steel	Circular	Projected	#N/A	#N/A
C1a	900	10	Corrugated Steel	Circular	Projected	$ 2,075.95	$ 20,759.50
C1b	900	10	Corrugated Steel	Circular	Projected	$ 2,075.95	$ 20,759.50
C1c	900	10	Corrugated Steel	Circular	Projected	$ 2,075.95	$ 20,759.50
C1d	900	10	Corrugated Steel	Circular	Projected	$ 2,075.95	$ 20,759.50
C2a	1100	10	Corrugated Steel	Circular	Projected	$ 2,264.45	$ 22,644.50
C2b	1100	10	Corrugated Steel	Circular	Projected	$ 2,264.45	$ 22,644.50
C2c	1100	10	Corrugated Steel	Circular	Projected	$ 2,264.45	$ 22,644.50
C3a		10	Corrugated Steel	Circular	Projected	#N/A	#N/A
C3b		10	Corrugated Steel	Circular	Projected	#N/A	#N/A
C3c		10	Corrugated Steel	Circular	Projected	#N/A	#N/A

Table 5-4: Lake Geraldine Spillway, Valuation of Culverts, Opinion of Probable Cost

Lake Geraldine

Crossing#	Dia. (mm)	Length (m)	Material	Shape	Configuration	Unit Cost	Cost
X1a	700	13	Corrugated Steel	Circular	Projected	$ 1,887.45	$ 24,536.85
X1b	700	13	Corrugated Steel	Circular	Projected	$ 1,887.45	$ 24,536.85
X2a	1200	14.3	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 33,729.41
X2b	1200	14.3	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 33,729.41
X2c	1200	14.3	Corrugated Steel	Circular	Projected	$ 2,358.70	$ 33,729.41
X3a	1500	5.65	Corrugated Steel	Circular	Projected	$ 2,641.45	$ 14,924.19
X3b	1500	5.65	Corrugated Steel	Circular	Projected	$ 2,641.45	$ 14,924.19
X3c	1500	5.65	Corrugated Steel	Circular	Projected	$ 2,641.45	$ 14,924.19
X3d	620	5.65	Corrugated Steel	Circular	Projected	$ 1,812.05	$ 10,238.08
X3e	620	5.65	Corrugated Steel	Circular	Projected	$ 1,812.05	$ 10,238.08
X4a	1350	33	Corrugated Steel	Circular	Projected	$ 2,500.08	$ 82,502.48
X4b	1350	33	Corrugated Steel	Circular	Projected	$ 2,500.08	$ 82,502.48
X6a	1300	8	Corrugated Steel	Circular	Projected	$ 2,452.95	$ 19,623.60
X6b	800	8	Corrugated Steel	Circular	Projected	$ 1,981.70	$ 15,853.60
X6c	1300	8	Corrugated Steel	Circular	Projected	$ 2,452.95	$ 19,623.60
X8a	1950	20	Corrugated Steel	Circular	Projected	$ 3,065.58	$ 61,311.50
X8b	1950	20	Corrugated Steel	Circular	Projected	$ 3,065.58	$ 61,311.50
X10a	1350	32	Corrugated Steel	Arch	Beveled	$ 2,500.08	$ 80,002.40
X10b	1350	32	Corrugated Steel	Arch	Beveled	$ 2,500.08	$ 80,002.40

5.3 Drainage Improvements

City staff were consulted during the workshops to indicate issues with existing drainage patterns. Many of these issues were related to snow management and dealing with meltwater from snow piles. The list below outlines the issues indicated by the city:

- Flooding over bridge on Queen Elizabeth Way east of intersection with Astro Hill Terrace
- No definition to swale or ditch on south side of Astro Hill Terrace
- Poor drainage on Paunna Road, especially east of Atungauyait Drive
- No ditch and ice / water running on Niaqungusiqriaq Road, Palaugaa Drive, Queen Elizabeth Way and Sinaa Street
- Reshaping required along Iglulik Drive close to Queen Elizabeth Way intersection
- Potential flooding zones indicated on Queen Elizabeth Way and Coman Street, Iglulik Drive and Mivvik Street
- Generally, lack of definition of swales in the downtown area, and the flatness of downtown, cause drainage issues

Stantec windshield surveys identified the following issues:

- Overland water flowing across the road on Qaqqamiut Road adjacent to airport, intersection of Niaqunngusiariaq and Atungauyait Road, Anuri Road in Road to Nowhere subdivision (midway on east leg of the rectangle), Anuri Road in Road to Nowhere subdivision on the northeast corner of the community
- Ponding on road at the intersection of Anuri Road and Road to Nowhere
- Ponding and overland water flowing across the road on Helen Maksagak Drive just south to the intersection of Simonie Michael Crescent and Helen Maksagak Drive
- Overland water flowing across Hanson Road to the west of intersection of Hanson and Helen Maksagak Drive
- No ditches on Jack Anawak Road, in community close to Apex River. Severe ponding observed in the community overall
- Overland water flowing across the road on Ataani Road, just east of the intersection of Kuugalaaq Road and Ataani Road
- Overland water flowing across Nipisa Street just NW of the intersection of Nipisa Street and Siku Crescent

5.4 Low Impact Development Measures

Several terms have been used in stormwater literature in recent years to describe methods to reduce runoff: low-impact development (LID), green infrastructure (GI), and best management practices (BMPs) are just a few. The goal of all of these measures is to reduce runoff volume from surfaces, usually through infiltration, vegetative uptake, or evaporation of the water instead. A detailed description of these types of measures and their effectiveness at pollutant removal is available from the International BMP Database (http://www.bmpdatabase.org/).

Cold regions have generally been slower to take up these measures, usually out of concern for performance and maintenance issues during freezing temperatures, however there is now a significant body of evidence and direction on how to implement LID measures in cold regions. But there have not so far been any studies examining the use of LID measures in cold regions where permafrost exists.

Permafrost (or perennially frozen ground) can occur in any soil type, even bedrock and organics – it is ice that forms in the void spaces of the material itself and remains frozen over at least two years (AMAP, 1998). An active layer on top of the permafrost will melt during summer and refreeze in the winter. Permafrost is not always a single impenetrable layer – it often depends on the moisture holding capacity of the soil; permafrost soils that can hold a large amount of moisture are referred to as ice-rich permafrost. As Figure 5-1 shows, water can still infiltrate through unfrozen sections of the permafrost (taliks) however the overall infiltration rate versus the same soil in an unfrozen state is likely lower.

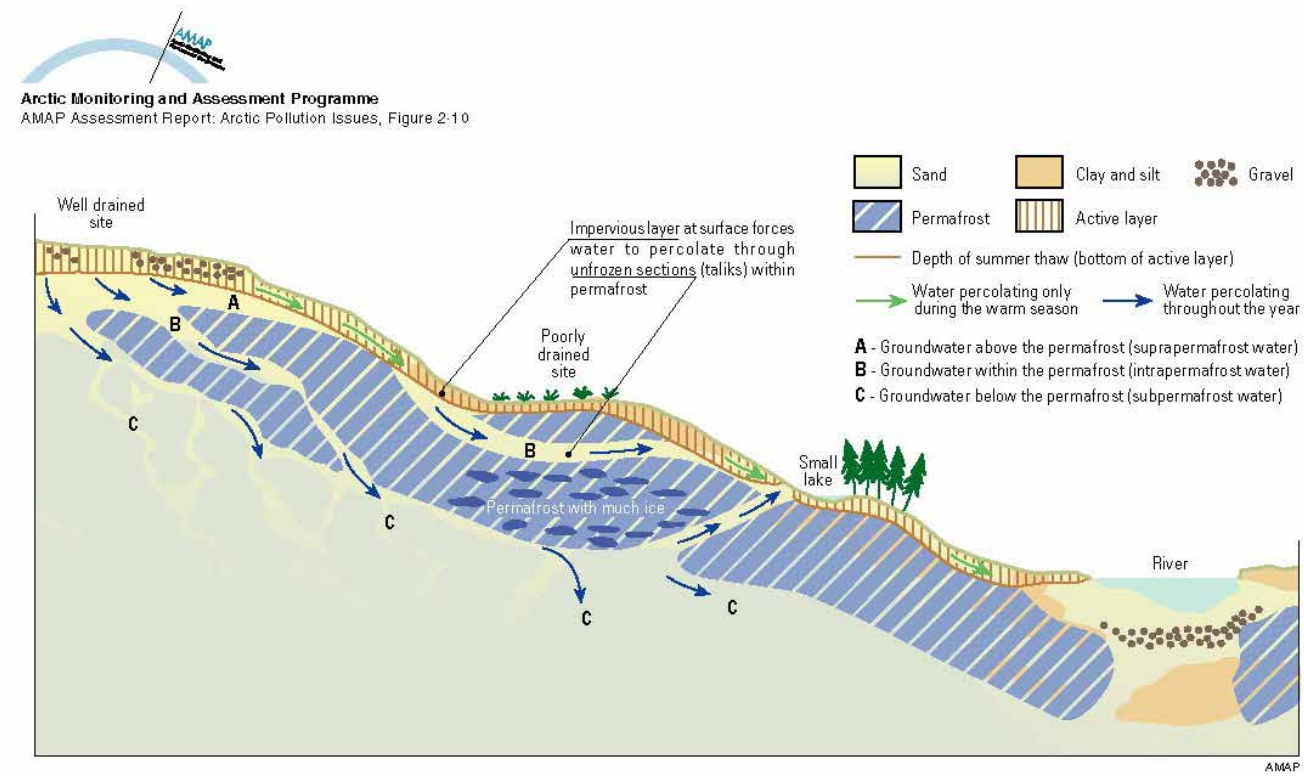

Figure 5-1: Occurrence of groundwater in permafrost areas, from (AMAP, 1998).

The only design literature addressing the topic of intentional infiltration into permafrost we have uncovered is from the *Stormwater BMP Design Supplement for Cold Climates* (Caraco & Claytor, 1997) and the *Alaska Storm Water Guide* (Collins, et al., 2011). Both documents discourage the use of infiltrative methods:

"*Infiltration practices are generally not feasible in extremely cold climates that experience permafrost.*"

"*In regions with permafrost, infiltration cannot be used, because the ground is relatively impermeable all year. In addition, infiltration BMPs may cause melting of the permafrost, which can cause cave-ins.*"

The *Alaska Storm Water Guide* contains a list of BMPs (referred to as storm water treatment practices in the Guide) and assesses their suitability for each climatic region of Alaska. The summary table is excerpted and presented here in Figure 5-2. Iqaluit is most similar to the "Arctic" region of Alaska. For more details on each of the BMPs/STPs, please refer to the source document.

Storm water treatment practices (STP)	Alaskan climatic regions				
	Coastal	Southcentral	Western	Interior	Arctic
Bioretention	○	○	□	○	✪
Infiltration	□	□	□	□	■
Filtering Practices	□	□	■	□	■
Dry ED Ponds	□	○	○	○	■
Constructed Wetlands	○	□	✪	✪	✪
Wet Ponds	○	□	■	■	■
Green Roofs	✪	□	■	■	■
Rain Tank/Cistern	✪	■	■	■	■
Permeable Pavers	□	□	■	■	■
Dry Swale	○	□	■	○	■
Filter Strips	✪	○	○	○	✪
Underground	□	□	■	■	■

Feasibility symbols:

○ Widely feasible

□ Might be feasible in certain situations

✪ Feasible only with major design adaptation

■ Infeasible and not recommended

Figure 5-2: Excerpt from *Alaska Storm Water Guide* (Collins, et al., 2011) "*Table 5-2: Feasibility of storm water BMPs, based on climatic region*"

There are several other factors specific to the Iqaluit region that would tend towards opposing the use of infiltrative LID methods.

Permafrost acts as an impermeable barrier which would drastically reduce infiltration rates. Infiltration of stormwater is not usually done in areas with low infiltration rates because water needs to remain on the surface for longer periods of time (2-7 days), during which time another storm event could occur.

Some soil types are not suitable for infiltration. The Geological Survey of Canada has published a map (Allard, et al., 2012) showing the surficial geology of Iqaluit and the vicinity – an excerpt of which appears below in Figure 5-3.

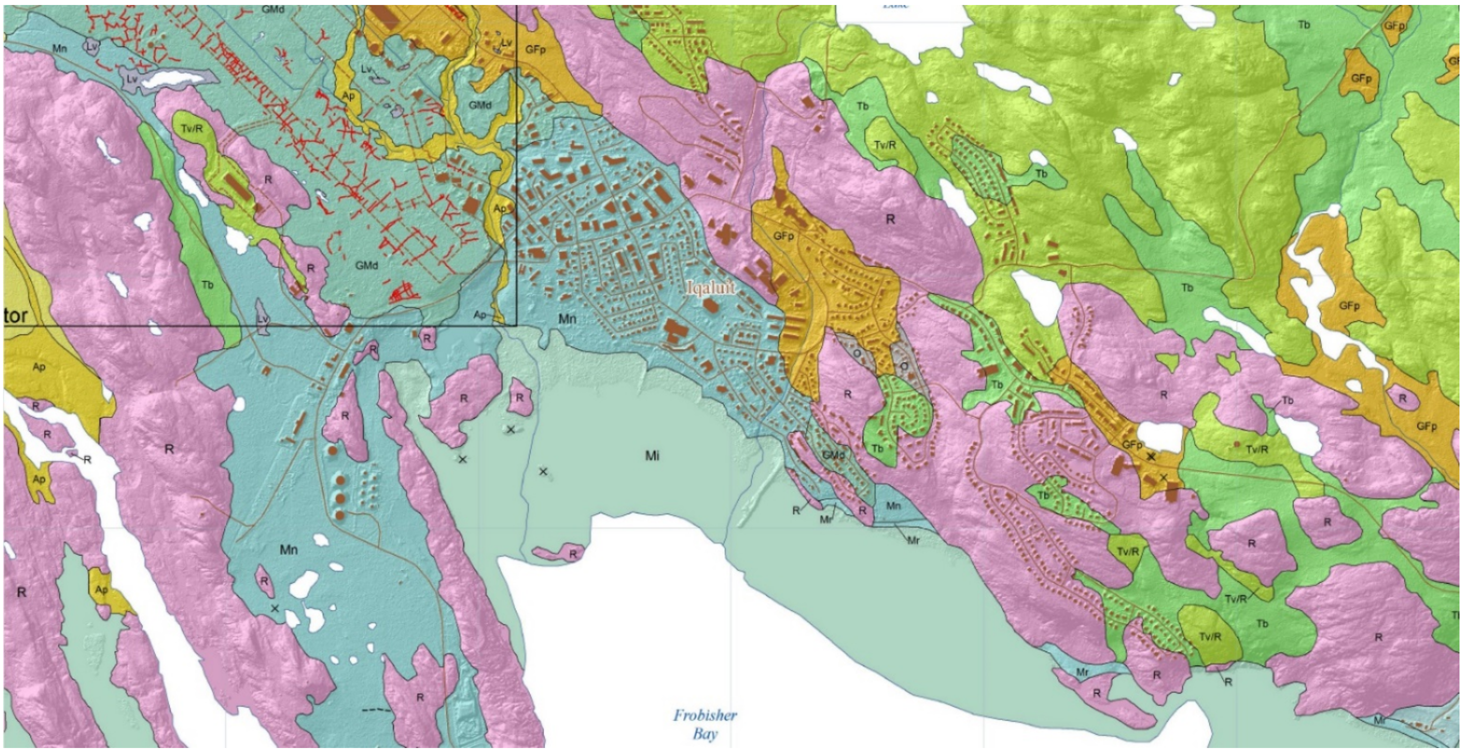

Figure 5-3: Surficial Geology of Iqaluit, excerpted from Geological Survey of Canada Geoscience Map 64 (Allard, et al., 2012).

The areas in pink are bedrock, greens are till (sand, stones, gravel), yellows are river sediments (mostly clays), greys are organic material, oranges are sandy and gravelly meltwater deposits, and blues and teals are marine deposited sediments such as silts and sands. Infiltration would be impossible at locations with bedrock at surface and would be impractical in soils with low infiltration rates (clayey or silty soils). Sandy soils are those most suited for infiltration.

The areas with marine deposited sediments are soils which are more likely to contain ice-rich permafrost. These soils would heave and sink more than other soil types if undergoing freeze-thaw cycles. Any infiltration of warm water into the soils could melt the permafrost and cause damage to nearby infrastructure. The Government of Nunavut itself in its guide to homeowners recommends against allowing water to pool around foundations, for fear that it could melt permafrost and result in differential settlement of the piles (Government of Nunavut Department of Environment, 2013).

In general, LID methods are therefore not recommended within the City of Iqaluit due to the expected effect on permafrost soils. If however, the City wishes to conduct a pilot project to determine whether an acceptable infiltration rate is possible, an area farther away from infrastructure and foundations with sandy soils is recommended.

6 RECOMMENDED STRATEGY FOR DRAINAGE MANAGEMENT

The following Recommendations:

- Implement recommended retrofits
- Implement Changes to Design Standards for future projects
- Create an Asset Management Plan (for further details and sub-tasks, see section 7).
- See implementation plan (section 8) for a specific list of tasks and timelines

6.1 Changes to Design Standards

The City of Iqaluit municipal design guidelines have been updated to include results from this report. The updates focused on drainage infrastructure such as culverts, swales and ditches.

As can be seen in section 3.4.5 and section 5, the City of Iqaluit is known to have overland flow issues specifically on major roadways. Moreover, most of the culverts identified in the field inspection / survey had corrosion, sedimentation and erosion issues. To ensure that these issues are addressed for the future upgrades / repairs, design standards have been updated to include:

- The level of service (LOS) for the ditch design;
- IDF curves, which will provide design basis for the future upgrades / new development;
- Culvert installation techniques, and apron design specifications;
- Overflow provisions to prevent overflow causing washout of critical infrastructure such as roadways;
- Drainage catchment areas specifications to identify drainage patterns;
- Erosion and sedimentation control methods;
- Outfall specifications;
- Lot grading details; and
- Swales and Roadways.

6.2 Operations and Maintenance (O&M)

Inspections and maintenance checklists should be used when inspecting drainage infrastructure. The checklist should include condition, size and the concern listed in form of options.

6.2.1 Procedures & Equipment Review

A review of the City's existing operations and procedures should be undertaken for the following tasks:

- Spring inspections for meltwater accumulation behind culverts
- Culvert clearance procedures / methods
- Ditch / swale clearing procedures / methods
- Snow piling locations and practices

Identification of the City's current practices (including equipment used, power or fuel requirements, labour requirements, and safety implications) and strategy (pre-planned schedule or ad hoc) will help establish current level of effort. An assessment should be made of whether the results of the current efforts is adequate or whether additional effort is required or whether proactive inspections could help prevent damages.

A survey of standard practices and equipment used in other northern communities (Alaska, NWT, YK, Greenland, Scandinavia, Russia) should also be conducted to determine whether better procedures or equipment could be used to improve efficiency.

6.2.2 Recommended O&M Activities

Spring

- Clear culverts of garbage / debris before melt where possible
- Oil-fired steamer or hot pressure washer to remove ice/snow blockages
- Start clearing at downstream end of drainage network so that clearing upstream culverts does not cause downstream flooding at blocked culverts
- Beware of re-freezing overnight
- Note collection of meltwater - spilling meltwater can cause erosion or road structure problems if spilling across roadways / driveways
- Inspect drainage system during spring melt to determine whether blockages

Summer

- Following the spring runoff, at the beginning of the summer season, the complete drainage system shall be inspected by a competent person and any deficiencies shall be identified.

  Note: *A competent person can include the community foreman, an equipment operator, or other qualified person as assigned by the authority having jurisdiction.*
- Any deficiencies that are identified shall be investigated and a corrective action plan shall be developed. The following activities shall be included in the corrective action plan as a minimum:
  - ponding in ditches shall be identified and corrective action taken. This can include re-sloping the ditch bottom or lowering a downstream culvert;
  - **Note:** *Ponded water left in the ditch will eventually undermine the nearby road base, possibly causing frost heaving or subsidence.*
  - in areas where overgrown vegetation is prevalent around culverts and other drainage channels, the vegetation shall be mowed or cut back;
  - blocked culverts should be flushed to remove sediment, rocks, and other debris. A water pump attached to a water tanker can be used. While doing so, start with culverts downstream and move upstream to minimize sedimentation during the process;
  - where practicable, damaged culvert ends shall be cut back, replaced, or else collapsed ends bent open; and
  - culverts that have shifted or moved shall be replaced or re-installed on a priority basis.

Fall

- Maintenance and repair of saturated areas of the drainage system should be carried out in the fall when water levels in the north are typically lowest. Avoid repair or replacement of culverts when water is running through them.
- When cleaning the culverts, start from the downstream culverts and move upstream. This will avoid debris sedimentation during the cleanup process.
- Culvert marking posts shall be inspected and replaced if damaged.
- Maintenance personnel should have completed all work that was identified during the spring inspection.

6.3 Snow Removal Management Plan

A snow removal management plan should be prepared and should consider as a minimum the following:

- snowmelt from removed snow should be prevented from re-entering the drainage system;

  Note: *Snow piles that melt and re-enter the drainage system as runoff can overwhelm the system and cause damage or flooding.*
- identification of the most critical culverts and their priority level for maintenance;

Note: *Because snow can melt so quickly, a plan must be in place to thaw critical culverts first. There needs to be a priority system in place so workers know the order to thaw culverts to effectively drain the snowmelt from the community. Snowmelt can cause a great deal of damage to road surfaces if the melt water overruns a road surface as a result of a clogged culvert.*

- if the terrain allows, snow berms or snow fences should be used to trap wind-blown snow outside of the community to reduce the amount of snow that enters the community to become additional runoff during spring melt; and

  Note: *Open countryside can be susceptible to wind-blown snow.*

- if snow berms are used, they should be maintained throughout the winter and should be pushed up when the snow trap becomes full and is no longer effective.

6.4 Other Recommendations

Other items which could be included in the O&M plan could include prioritized culverts for cleanout in spring, and sample inspection plans / routes for staff.

6.4.1 Culvert Marking

Culverts should be marked with a post painted in a bright colour (e.g. red or yellow). The post should be installed at the precise location of the culvert end. Marking posts should be installed with the following convention: when looking at the marker post from the road centre line, the culvert will be on the left (or right) side at the base of the post.

Note: *A marking post system improves the efficiency of maintenance activities and helps to reduce the risk of inadvertent damage to the culvert ends, which can restrict flow. A marking post system also helps prevent an ATV, snowmobile, or other vehicle from hitting the culvert end, causing damage to the culvert and/or personal injury to the vehicle operator.*

7 ASSET MANAGEMENT FRAMEWORK

The City of Iqaluit does not currently have an asset management plan in place. Stantec was tasked with developing a framework for a future asset management plan. The lack of a current plan, in combination with a lack of data on existing infrastructure, creates an impediment to managing, maintaining and monitoring the City's current drainage assets.

Asset management can be described as maintaining a desired level of service for assets at the lowest life cycle cost. In this case, level of service refers to the design event for which culverts were originally designed (e.g. 25 year rainstorm). Lowest life cycle cost refers to the best appropriate cost over the entre service life of an asset, including for initial capital cost (supply and installation), rehabilitation, periodic repair and eventual replacement.

This type of management is typically implemented through a written plan known as an asset management plan. The main objectives of an asset management plan should be to:

- Prolong asset life and aid in rehabilitating/repairing/replacing decisions through efficient and focused operations and maintenance.
- Meet user demands with a focus on system sustainability (i.e. ensure all components reach their service life)
- Set rates based on sound operational and financial planning
- Budget focused on activities critical to sustained performance
- Meet service expectations and regulatory requirements
- Improve response to emergencies
- Improve security and safety of assets
- Maintain desired level of service (e.g. prevent road washout up to the design event of the asset)

Without the proper procedures, management and training systems, operations and maintenance (O&M) activities may lack organization and precision, resulting in potential risk to human health and environmental contamination (e.g. of surrounding water bodies, lands, dwellings, or groundwater), or property damage. The following sections discuss the common elements of a robust drainage system management program.

7.1 Definitions

7.1.1 Level of Service

The level of service refers to the design event for which culverts or ditches were originally designed. Typically in the south of Canada, this would be in the vicinity of 25 years for a corrugated metal pipe (CMP) (i.e. a CMP would be designed to accommodate the flows resulting from a rainstorm of such large intensity that if could only be expected to occur once every 25 years on average). Generally, infrastructure is not designed for event return periods that are longer than their expected service life. Thus a CMP with an anticipated service life of 25 years is not designed for a 100 year event. However, this reasoning should not be used in the North, since CMPs are much more easily supplied, transported, handled and installed in the Arctic than concrete pipe (which would generally be considered to have a longer service life, e.g. 100 years).

Level of service is usually defined in a jurisdiction's design documentation in order to provide rules for developers or design engineers.

7.1.2 Service Life

Service life is the anticipated life of the infrastructure before it is expected to need replacement.

7.2 Collect Asset Information

The first step in managing assets is knowing their current state. Stantec recommends strongly that the City conduct a field survey in the near future to accurately measure major culverts (diameters, inverts, obverts and condition) and to at least locate smaller culverts, if not also measure their characteristics. This information should be stored in a central asset inventory database. Because some of this information may be difficult to obtain, estimates can be used where required. As assets are replaced and repaired, this information should be tracked in the inventory database, and the inventory will become more accurate.

Small jurisdictions may elect to use tabular spreadsheets as their inventory database, but this omits geospatial information which is better visualized on a map. Therefore we recommend that the City create an asset inventory (discussed in detail in the following section) and system map, in the form of a geographic information system (GIS)-based asset database.

Any GIS software with a vector representation and associated properties database would be appropriate for asset management; for more on asset management software options, see section 7.7. The importance of maintaining accurate, current maps of the collection system cannot be overstated. Efficient drainage system maintenance and repairs are unlikely if mapping is not adequate. A baseline drainage system map has been produced as part of this Master Drainage Plan from GIS data. Changes to the map should be tracked either on hard-copy or in GIS, and updated maps produced periodically. An attempt has been made in the production of the current map to clearly indicate the information that personnel need to carry out their assignments. Future updates to the drainage system maps should contain information on the following items:

- Culverts
- Ditches
- Road crossings
- Dams
- Flooding locations
- Snow piling locations

- Watershed areas
- Service area boundaries
- Other landmarks (roads, water bodies, etc.)

Specific procedures should be established for correction of errors and updating maps and drawings. Field personnel should be properly trained to recognize discrepancies between field conditions and map data and record changes necessary to correct the existing mapping system. Reviewers should check to see that maps and plans are available to the personnel in the office and to field personnel or contractors involved in all engineering endeavors.

7.2.1 Parts and Equipment Inventory

An inventory of spare parts, equipment, and supplies should be maintained by the City. The inventory should be based on equipment manufacturer's recommendations, supplemented by historical experience with maintenance and equipment problems. Without such an inventory, the collection system may experience long down times or periods of inefficient operations in the event of a breakdown or malfunction. This is particularly true during the springtime melt, therefore maintenance equipment should also be included in this inventory. Ensuring that all equipment has an associated operations and maintenance manual will help workers perform their tasks and reduce risk.

7.2.2 Infrastructure Attributes

Once the assets are added to the GIS database, attributes representing distinct properties should be added. To begin with, simple attributes may be added in the beginning:

- Material
- Diameter
- Length
- Invert and Obvert elevations (at upstream and downstream ends
- Age (installation date, estimate if required e.g. roughly 1970s) – This will aid in calculation of remaining life expectancy of the infrastructure. Pipe degradation can be predicted using computer software.
- Condition
- Flooding events
- Recent repairs / maintenance
- Estimate flags (indicating whether the information is measured or estimated)
- Other notes

For culverts that have no information available, estimates can be used, however flags should be used in the database to indicate that the values are estimates.

7.3 Performance Evaluation

Due to the dual challenges of recent development expansion spurred by population growth and potential precipitation pattern change due to global warming, the City faces the prospect of changing flow conditions on its existing infrastructure. As such, it is imperative that current and future flows be identified prior to the design of new infrastructure. In accordance with this, Stantec has provided IDF curves (section 4.3) based on past weather data from 1946 to 2017. Modified IDF curves accounting for climate change scenarios (section 4.4) have also been provided.

The City should update the Asset Management Plan (AMP) and Master Drainage Plan (MDP) periodically (e.g. every 5 years) to evaluate the capacity of the drainage system and ensure that capacity is maintained as per design. The updates to the AMP and MDP build upon ongoing activities and the everyday preventive maintenance that takes place in the system. These updates should consider potential changes to the system over the 5, 15, and 30 year horizons, including expected development, flow condition changes, and anticipated regulatory changes.

Once assets are mapped, performance evaluation shall be conducted. Performance evaluation represents the health of the system. Hydraulic and pressure modelling are two key monitoring indicators of drainage infrastructure health. The purpose of modeling is to determine system capacity requirements with respect to sewer design and structural conditions. Therefore, the input of accurate data on sizes, location, elevation, and condition of drainage system components such as culverts, ditches, and crossings are necessary. When possible, flow monitoring data should be used to calibrate the model. In addition, modeling is also useful in examining effects before and after rehabilitation. For example, models can be applied to “before” and “after” scenarios to estimate the effects of repairs. If a collection system is not experiencing any capacity related issues (i.e., overflows, bypasses, street flooding, etc.) then maintenance of a model may be optional for that system, although most medium and large systems should maintain a model of the larger diameter portion of their system. If any of the mentioned conditions are occurring, then development and maintenance of a model is essential to performing a capacity assessment in the problem areas.

Furthermore, establish a level of service “agreement” that describes your system’s performance targets. Use level of service standards to track system performance over time.

7.4 Lifecycle Management

Once the assets are mapped and added to the City’s database, the data should be updated if any work is performed. Capture any past and present work done on the associated infrastructure. Field books and spreadsheets should be used at this stage to properly document and organize the work done.

List assets according to how critical they are to system operations. Conduct failure analysis. Analyze failure risk / likelihood and consequences. Review and update system vulnerability assessment. The stormwater model that was developed as part of this MDP should be updated with the asset information and can be used to determine peak flows versus capacity.

Prioritize assets that have experienced failure in the past or that are beyond their service life. No two pipes are alike. If no past data can be obtained, statistical analysis and softwares can be used to come up with deterioration models which should list the survival probability curves based on users' manual criteria or material type and age of the pipe. In addition, life expectancy curves can also be used in this context.

Finally, develop a condition assessment and rating system. Assess remaining life by consulting projected useful life tables or decay curves. Any future plans and schedules should be based on condition and performance of the evaluated infrastructure.

7.5 Risk Assessments

The City should have a comprehensive plan in place for dealing with both routine and catastrophic emergencies. Routine emergencies include situations such as overflowing ditches and culvert failures (which could shut down roadways). Catastrophic emergencies include floods, tsunamis, earthquakes, and other natural events. Ideally, this plan is written, reviewed, and adjusted as needed at periodic intervals. The plan should utilize the most current information on the drainage system.

A structured analysis, or risk assessment, should be made of the drainage system, but should not be so complex or onerous that it is unusable by City staff. The risk assessment should identify areas where the drainage system is vulnerable to failure and determine the effect and relative severity to drainage systems operations, equipment, and public safety and health. The risk assessment should concentrate on such factors as topography, weather, drainage system size, and other site-specific factors which reflect the unique characteristics of the system. Once the areas of vulnerability are known, the city should have appropriate plans in place to ensure drainage system operations continue for the duration of the emergency. The city should track emergency situations to become better prepared for future emergencies and to assist with reporting and maintaining compliance with emergency-related requirements. Typical components of an emergency program may include:

- General information regarding emergencies, such as telephone numbers of collection system personnel, fire department, and ambulance.
- Identification of hazards
- Vulnerability analysis that identifies the various types of emergencies that could occur, such as natural disasters, power outages, or equipment failures.
- Emergency response procedures.
- Methods to reduce risk of emergencies.
- Responsibilities of staff and management.

7.6 Maintenance Planning

Maintenance may be planned or unplanned. There are essentially two types of planned maintenance; predictive and preventive. Predictive maintenance is a method that tries to look for early warning signs of equipment failure such that emergency maintenance is avoided. Preventive maintenance consists of scheduled maintenance activities performed on a regular basis. There are two types of unplanned maintenance, corrective and emergency. Corrective maintenance consists of scheduled repairs to problems identified under planned or predictive maintenance. Emergency maintenance are activities (typically repairs) performed in response to a serious equipment or line failure where action must be taken immediately. The goal of City should be to reduce corrective and emergency maintenance through the use of planned and predictive maintenance.

7.7 Asset Management Software

Asset management cannot be done in one standalone software. It is the integration of many software systems working together. Some of the typical software examples include:

- GIS – Geographic information system (examples include ArcGIS, QGIS, and MapWindow)
- CAD – Computer aided design (such as AutoCAD)
- WMS – Work management system (or CMMS or AMS)
- CIS – Customer information system / billing system
- ERP – enterprise resource planning
- LIMS – Laboratory information management system
- EDMS – Electronic Document Management System
- SCADA – Supervisory Control and Data Acquisition
- AVL – Automated Vehicle Location
- Financial System
- Supply Chain
- Capacity Models
- Risk Models
- 311 System

7.8 Management Information System

Finally, the ability of the city to effectively manage its drainage system is directly related to its ability to maintain access to the most current information concerning its infrastructure. Maintenance of this current information is an effort involving all members of the drainage system from the staff answering the telephone to the worker in the street. Operational information informs and clarifies financial information. This will make the financial information more useful for the policy makers, leading to better decisions. A satisfactory management information system should provide the owner or operator with the following advantages:

- Maintain preventive maintenance and inspection schedules
- Offer budgetary justification
- Track repairs and work orders
- Organize capital replacement plans. A growing number of drainage systems have shifted to computer-based collection system management
- Manage tools and equipment inventories

- Create purchase orders
- Record customer service inquiries, complaints, or requests
- Provide measurement of effectiveness of program and O&M activities

The effectiveness of the asset management system begins with data collection and ends with a transparent information system. The more data the city collects, the better the quality of data and risk prediction for the future. Asset management requires re-tweaking, fine-tuning, and re-visiting on a periodic basis to check how the system is performing.

8 IMPLEMENTATION PLAN

This section summarizes the findings from this report and aims to provide a plan for implementing these changes in a specific order.

Item	Years
Design standards have been updated to include IDF curves and typical section details for roads infrastructure. In addition, several updates regarding the swale, ditches and culverts etc. have also been updated. For complete list of all the updates, please see **Section 6.1**. A copy of design updates, for only the updated sections, are also attached to this report in **Appendix D**. Design guidelines for City of Iqaluit should be revised to include updates from this report.	1-2
Culvert deficiencies and repairs identified in Section 5.1 should be examined in further detail and corrected where appropriate.	2-3
Snow removal management plan has been described in **Section 6** of this report. Moving forward, city should implement this plan on an annual basis.	2-3
Spring / Fall maintenance plan has been described in **Section 6**. City should adapt this plan for all the future maintenances.	2-3
City should map all the existing drainage infrastructure in geospatial form or at the least spreadsheets. City should start with the most critical drainage infrastructure, the list of which can be seen in **Section 5**. Provided list also includes the concerns indicated by the city and observed by Stantec during field inspections and windshield surveys. Photographs from field inspection are appended to this report in **Appendix A**, while the details of the windshield surveys are provided in digital format, the information for which can be found on **Appendix E**. This map should contain all the information discussed in **Section 7** e.g. the lifecycle of the culverts, condition, and risk associated etc. etc.	2-3
Once the design updates are implemented, it should be conveyed to all the stakeholders such as developers and city personnel. City should conduct open houses and presentations to outreach to developers, consultants and stakeholders and inform them about the updates.	3-5
Results from weather station data analysis such as IDF curves, snow on ground, spring melt off analysis (**Section 4**) should be used for all future maintenance and repairs related to drainage infrastructure. In addition, the spring melt off and snow data can be used for road infrastructure design in the future.	3-5
All future maintenance / repairs should be logged in a register and have a record of. City should be the sole owner of this records. This will enable city to better manage assets in the future. For a complete list what should be logged, please refer to **Section 7** of this report.	3-5

Item	Years
Compile a list of asset inventory on hand. For complete details on what this list should include, please refer to **Section 7**.	5-7
Compile finances for all the maintenance activities conducted throughout the year. This will aid city in allocation of budget for all the future maintenance. For a complete information on how to compile finances register, please refer to **Section 7**.	7-10
Once the mapping for critical infrastructure is done, the city should continue mapping until all the existing drainage infrastructure is mapped. Based on the aerial imagery and model, the downtown is currently experiencing drainage issues the most, especially considering the city does not have ditches / swales in downtown area. After mapping the critical infrastructure, the city should map the downtown area first, and then start from airport from west up until the apex community in the east. This mapping information can be used further in model development in the future.	15-20
Once all the existing drainage infrastructure has been mapped, the city should evaluate the performance, by using a model. As part of this study, Stantec developed a model for City of Iqaluit. This model contains all the existing drainage infrastructure confirmed by field inspections, consultation with the city and windshield surveys. The model has been provided to city in digital format, information for which can be found in **Appendix E**. Additionally, city should revise this model as new infrastructure is added.	15-20
Perform risk assessments for all the existing drainage infrastructure. Information regarding the risk assessments can be found in **Section 7** of this report.	15-20
Change approach towards the asset management from being reactive to predictive. The city should be able to look at the risk and performance models to evaluate the condition of the existing drainage infrastructure before they fail. Requirements for predictive maintenance are included in **Section 7** of this report.	20-25
A list of software for asset management is included in **Section 7** of this report. The city should invest in obtaining these softwares. This will ensure that the records such as finances, model and risk predictions are interlinked and available to city at their discretion.	20-25
Number of reports for water quality in City of Iqaluit were looked at. Several concerns were identified in these reports, the summary of which can be seen in **Section 3.4.7**. City should counter these issues and increase the water quality from both the habitat and drinking standpoint.	20-25
Reports related to global warming and climate changes were consulted. Several reports speculated the rise in tidal levels in the next 90 years and placed some of the coastal building infrastructure at risk, the summary of which is provided in **Section 3.4.3**. City should relocate these building infrastructures.	20-25
City should monitor assets on annual basis. Details about what to monitor are provided in **Section 7** of this report.	20-25

8.1 Capital Planning

Capital planning will be completed by City of Iqaluit staff, based on available City resources, however the following priorities are suggested using the items listed from the implementation table above (within the next five years):

- Surveying and mapping of existing culverts to confirm details (this can be done within a capital repair program to confirm concept repairs)
- Assessment of failure consequence at each major stream crossing – to include impacts on safety, traffic, emergency services, maintenance services, government, businesses and residents, environment.
- Capital upgrades shall be prioritized using a risk approach, whereby Risk is defined as:
    - o **Risk = Likelihood of failure (as defined in this MDP) x Consequence of Failure** – an example of a risk matrix is shown below:

		Consequence				
		Insignificant	Minor	Moderate	Major	Severe
Likelihood	Almost certain	Medium	High	High	Extreme	Extreme
	Likely	Medium	Medium	High	Extreme	Extreme
	Possible	Low	Medium	Medium	High	Extreme
	Unlikely	Low	Low	Medium	High	High
	Rare	Low	Low	Low	Medium	High

- Highest risk items should be prioritized for upgrades
- In the interim condition, before high-risk infrastructure is identified, a high-level assessment of failure consequence can be applied to the repair schedule prepared in this report (high for major roads, medium for normal roads, low for paths):

Crossing#	Consequence of Failure
Airport Creek	
X3d	High - one of only 2 roads to airport
X5a	Low
X7	Medium
X9	Medium
Apex River	
C1b	Low
C3c	Low
Lake Geraldine	
X2b	Medium
X3c	High - major road
X3d	High - major road
X4a	Low
X4b	Low
X6c	Low
X7	Low

It is recommended that higher consequence culverts be repaired first, followed by medium and low-consequence culverts. Part of the capital budget should also be spent to survey City culverts and apply a more detailed consequence and risk assessment.

Nunami can be available to assist with inventory of drainage features through Iqaluit. In addition to that, Nunami understands that the City made plans in 2018 to complete some drainage work. This was cancelled due to shifting of funds to the 2018 Emergency Resupply of Lake Geraldine. The work proposed at this time included a number of items, one of which pertaining to Federal Road near the existing Public Works Garage. At this time, the City advised the road contractor to remove the culvert crossing Federal Road at this location, as plans were being made to re-grade the northeast ditch to change the flow direction. This culvert was removed; however, work was cancelled before regrading of this ditch was complete. Of the 2018 works, this is a priority.

Looking forward into the long-term planning, Nunami is available to provide a scope of work and proposal to complete any of the required work.

8.2 Potential Funding Option Review

We understand where and how facilities and infrastructure obtain capital funding, and therefore we can provide this practical, current, and region-specific knowledge to develop a funding plan. Through Nunami-Stantec and Stantec's North America Funding Program (NAFP), we can also access Canada's most comprehensive source of funding information. With this affiliation, we can help clients search, access, and apply for over $28 Billion of Canadian public and private funding sources from the Funding Portal's database. This tool is highly applicable for finding all (both public and private) grants and funding programs you could apply for to develop this new project.

As well as identifying the applicable funding sources and grants you are eligible to apply for, Stantec can help you evaluate which ones are most appropriate for you and then complete the paper or on-line applications to improve your chances of success.

While not the focus of this study, some sources of funding that may be applicable to this project include:

- Small Communities Fund (PTIC-SCF_ Canada. Infrastructure Canada)
- Green Municipal Fund (Water Quality and Conservation Canada. Federation of Canadian Municipalities)

Nunami is available to provide a scope of work and proposal to prepare a funding plan and applications for the City.

9 REFERENCES

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APPENDIX A
SURVEY PHOTOS

June 2018

September 2018

Airport Creek Photos

South of Crossing 1 (2 x 1800 mm dia.) - Early Spring Meltoff

Crossing 1 (2 x 1800 mm dia.) - Early Fall

June 2018 **September 2018**

Airport Creek Photos

South of Crossing 2 (2100 mm dia.) - Accumulated Garbage

Crossing 2 (2100 mm dia.)

June 2018

September 2018

Airport Creek Photos

South of Crossing 3 (4 x 1200 mm dia. and 2 x 1000 mm dia.) - Damaged Ends

North of Crossing 3 - damaged ends

June 2018

September 2018

Airport Creek Photos

North of Crossing 3 - Broken End

June 2018

September 2018

Airport Creek Photos

North of Crossing 3 - Deflected End

June 2018

September 2018

Airport Creek Photos

North of Crossing 3 - Wooden Pallet in Stream

June 2018

September 2018

Airport Creek Photos

South of Crossing 3 (4 x 1200 mm dia. and 2 x 1000 mm dia.) - Early Fall

June 2018 **September 2018**

Airport Creek Photos

South of Crossing 4 (800 mm dia.) - not receiving any flow

North of Crossing 4 (800 mm dia.) looking Upstream - Garbage in the pipe

June 2018

September 2018

Airport Creek Photos

North of Crossing 5 (3 x 300 mm dia.) - Garbage accumulated

North of Crossing 5 (3 x 300 mm dia.) looking Upstream - Garbage in the pipe

June 2018

September 2018

Airport Creek Photos

North of Crossing 5 (300 mm dia.) looking Upstream - Corroded pipe exposed after the removal of garbage

June 2018

Airport Creek Photos

September 2018

South of Crossing 5 (3 x 300 mm dia.) looking Downstream - Garbage accumulated

June 2018

September 2018

Airport Creek Photos

East of Crossing 6 (1200 mm dia.) & 6B (600 mm dia.)

East of Crossing 6B (600 mm dia.) - Appears to be garbage in the stream

June 2018 **September 2018**

Airport Creek Photos

East of Crossing 6 (1200 mm dia.)

East of Crossing 6 (1200 mm dia.)

June 2018 **September 2018**

Airport Creek Photos

North of Crossing 7 (600 mm dia.)

North of Crossing 7 (600 mm dia.)

June 2018 **September 2018**

Airport Creek Photos

South of Crossing 7 (600 mm dia.)

South of Crossing 7 (600 mm dia.)

June 2018

September 2018

Airport Creek Photos

South of Crossing 7 (600 mm dia.) - Sediment buildup in the pipe

June 2018 **September 2018**

Airport Creek Photos

East of Crossing 8 (2 x 1000 mm dia. and 1 x 1600 mm dia.) - Snow about to melt

East of Crossing 8 (2 x 1000 mm dia. and 1 x 1600 mm dia.)

June 2018

September 2018

Airport Creek Photos

East of Crossing 8 (1600 mm dia.) closeup - Sediment buildup inside the pipe

East of Crossing 8 (1000 mm dia.)

June 2018

September 2018

Airport Creek Photos

West of Crossing 8 behind the fence - Garbage

June 2018

September 2018

Airport Creek Photos

East of Crossing 9 (2100 mm dia.)

East of Crossing 9 (2100 mm dia.) looking Upstream

June 2018 **September 2018**

Airport Creek Photos

West of Crossing 9 (2100 mm dia.) - Furniture inside the pipe

West of Crossing 9 (2100) looking Downstream

June 2018 **September 2018**

Airport Creek Photos

June 2018	September 2018
 East of Crossing 10 (3100 mm dia.) & 10B (1600 mm dia.)	 East of Crossing 10 (3100 mm dia.) & 10B (1600 mm dia.)

June 2018

September 2018

Airport Creek Photos

East of Crossing 10 (3100 mm dia.) - Snow melt

East of Crossing 10 (3100 mm dia.) - Deflected Pipe

June 2018 **September 2018**

Airport Creek Photos

East of Crossing 10 (3100 mm dia.)

June 2018

September 2018

Airport Creek Photos

Dam near Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.)

North of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) looking Upstream - Garbage buildup infront of pipe

June 2018

September 2018

Airport Creek Photos

North of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) - Garbage in the stream

North of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) looking Upstream - Wooden Pallets and Garbage

June 2018

September 2018

Airport Creek Photos

South of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.)

South of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) looking Downstream - Garbage in the flow

June 2018

September 2018

Airport Creek Photos

East of Crossing 13 (1600 mm dia.)

East of Crossing 13 (1600 mm dia.) looking Downstream - Garage in the stream

June 2018

September 2018

Airport Creek Photos

East of Crossing 13 (1600 mm dia.) looking Downstream - Barrel inside the pipe, probably received during the stream flow

June 2018 **September 2018**

Airport Creek Photos

East of Crossing 13 (1600 mm dia.)

June 2018

September 2018

Airport Creek Photos

North of ** Location

June 2018

September 2018

Airport Creek Photos

Upstream of ** Location

June 2018 **September 2018**

Apex River

Road of Interst Looking Northwest

June 2018

September 2018

Apex River

Left Side of Road of Interest - Looking West

June 2018

September 2018

Apex River

Eastern most culvert on south side of road - Blocked Pipe

June 2018 **September 2018**

Apex River

Cluster 1 of 4 Culverts (4 x 9400 mm dia.) on south side of road - Blocked due to snow

Cluster 1 of 4 Culverts (4 x 9400 mm dia.) on north side of road - Garbage and broken pieces infront of pipe

June 2018 **September 2018**

Apex River

Cluster 2 of 3 Culverts (3 x 1100 mm dia.) on south side of road - Blocked due to snow

Cluster 2 of 3 Culverts (3 x 1100 mm dia.) on south side of road - Deflected on the top end

June 2018 **September 2018**

Apex River

Cluster 2 (3 x 1100 mm dia.) taken from North side of road - Blocked due to snow

Cluster 2 (3 x 1100 mm dia.) taken from South side of road - Damaged Ends

June 2018

September 2018

Apex River

Cluster 1 (4 x 9400 mm dia.) taken from north side of road - Blocked due to snow

June 2018 | September 2018

Apex River

Solo Culvert (1100 mm dia.) taken from North side of road

June 2018 **September 2018**

Apex River

Stream running on South side of road

Stream running on South side of road

June 2018

September 2018

Apex River

Road of Interest - Looking West

June 2018 **September 2018**

Apex River

North side of Cluster 3

June 2018

September 2018

Apex River

Northside of Cluster 3 - Deflected Pipe due to heavy loads

June 2018 **September 2018**

Apex River

Southside of Cluster 3 - Debris due to sedimentation in the culvert

June 2018
Lake Geraldine

North of Crossing 1 (2 x 700 mm dia.)

September 2018

Upstream of Crossing 1 (2 x 700 mm dia.) - Damaged Ends

June 2018
Lake Geraldine

September 2018

South of Crossing 1 (2 x 700 mm dia.) - Bike and Garbage in the stream

Downstream of Crossing 1 (2 x 700 mm dia.) - Damaged and broken pieces

June 2018
Lake Geraldine

September 2018

North of Crossing 2 (3 x 1200 mm dia.) - Garbage

Upstream of Crossing 2 (3 x 1200 mm dia.) - Garbage infront of the pipe

June 2018
Lake Geraldine

September 2018

South of Crossing 2 (3 x 1200 mm dia.) - Garbage in the stream, pipe not in good shape

Upstream of Crossing 2 (3 x 1200 mm dia.) - Broken End

June 2018
Lake Geraldine

September 2018

North of Crossing 3 (3 x 1500 mm dia. and 2 x 620 mm dia.) - Garbage right beside the pipe

Upstream of Crossing 3 (2 x 1500 mm dia. and 1 x 620 mm dia.) - Deflected Pipe with damaged ends

June 2018
Lake Geraldine

September 2018

South of Crossing 3 (3 x 1500 mm dia. and 2 x 620 mm dia.) - Bike in the stream

Upstream of Crossing 3 (1500 mm dia.) - Garbage and sediment buildup inside the pipe

June 2018
Lake Geraldine

September 2018

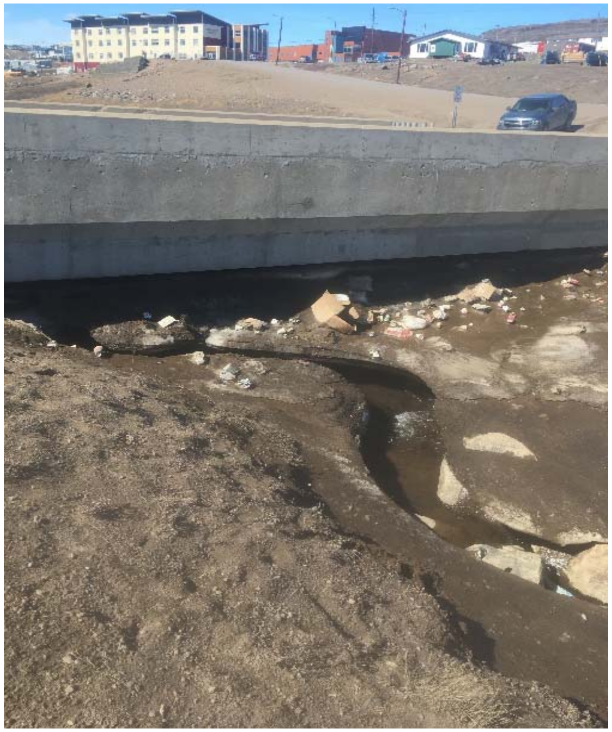
Crossing 4 (2 x 1350 mm dia.) looking North - Pipes half buried in the substrate

Upstream of Crossing 4 (2 x 1350 mm dia.) - Tire seen in the stream, pipes half buried in the substrate

June 2018 Lake Geraldine	September 2018
	
Crossing 4 (2 x 1350 mm dia.) looking South	Downstream of Crossing 4 (2 x 1350 mm dia.) - Garbage in the stream

June 2018
Lake Geraldine

September 2018



Crossing 5 looking West - Clear span bridge, 13 m wide over a channel with 7m wide bankful. Unstable bank on downstram left

June 2018
Lake Geraldine

September 2018

Crossing 6 looking South West - 2 x 1300 mm dia., 7 m long with one 800 mm dia. dia overflow pipe

Downstream of Crossing 6 - 2 x 1300 mm dia., 7 m long with one 800 mm dia. dia overflow pipe

June 2018
Lake Geraldine

September 2018

Crossing 6 (2 x 1300 mm dia. and 1 x 800 mm dia. overflow) looking South West - Blokced due to snow

Upstream of Crossing 6 (1300 mm dia.) - Deflected Pipe

June 2018
Lake Geraldine

September 2018

South of Crossing 7 (3200 mm dia.) looking North - Pipe not accessible due to sediment buildup

Upstream of Crossing 7 (3200 mm dia.) - Sediment Buildup inside the pipe

June 2018
Lake Geraldine

September 2018

South of Crossing 7 (3200 mm dia.) looking North - Sediment Buildup

Downstream of Crossing 7 (3200 mm dia.) - Garbage infront of pipe

June 2018
Lake Geraldine

September 2018

North of Crossing 8 (2 x 1950 mm dia. - 22m long) looking Southeast

Upstream of Crossing 8 (1950 mm dia.) - Sediment builup infront of pipe

June 2018
Lake Geraldine

September 2018

South of Crossing 8 (2 x 1950 mm dia.) looking North - Blocked due to snow

Downstream of Crossing 8 (2 x 1950 mm dia.)

June 2018
Lake Geraldine

September 2018

Crossing 9 looking South - Concrete dam, over 1 m drop. Complete barrier, no flow over structure, water flows through rock debris under structure

Upstream of Crossing 9 - Concrete dam, over 1 m drop. Complete barrier, no flow over structure, water flows through rock debris under structure

June 2018
Lake Geraldine

September 2018

Crossing 9 looking South - Concrete dam, over 1 m drop. Complete barrier, no flow over structure, water flows through rock debris under structure

Downstream of Crossing 9 -Concrete dam, over 1 m drop. Complete barrier, no flow over structure, water flows through rock debris under structure

June 2018
Lake Geraldine

September 2018

South of Crossing 10 (2x 1350 mm dia.) looking Downstream - 80 m long, steep installation

Upstream of Crossing 10 - 2 x 1350 mm dia., 80m long, steep installation

June 2018
Lake Geraldine

September 2018

South of Crossing 10 (2 x 1350 mm dia.) looking Downstream - Blocked due to snow

Downstream of Crossing 10 (2 x 1350 mm dia.)

June 2018
Lake Geraldine

Upstream of Crossing 10 Looking North - Wooden box identified on the stream

September 2018

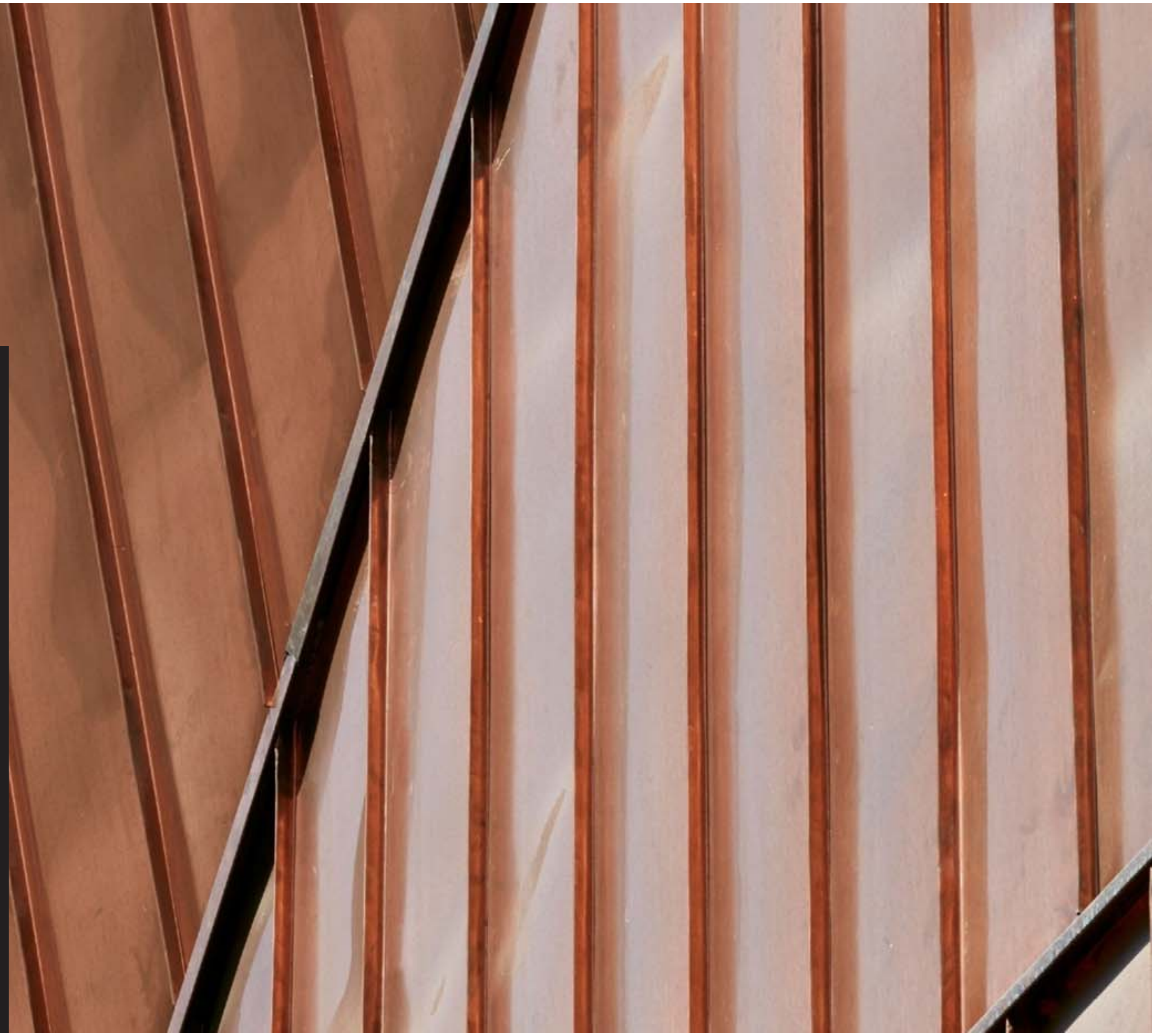
Upstream of Crossing 10 (1350 mm dia.) - Bars in the pipe

APPENDIX B
TECHNICAL WORKSHOP

Stantec

City of Iqaluit
Master Drainage Plan

Workshop #1



Agenda

1. Review project scope
2. Data Collection
3. Review of historical data and trends
4. Characterization of study area
5. Hydrologic/hydraulic model preliminary construction
6. Proponents’ Drainage issues/Concerns
7. Discussion & next steps

Safety Moment

Watch your footing on steep slopes, especially when covered in snow or ice.

Project Scope Review

Study Objectives

- Identify all major drainage areas, routes and channels within the City,
- Characterize the existing environmental conditions for all drainage areas within the City;
- Assess the effectiveness of existing drainage management infrastructure at conveying the drainage and reducing the negative impacts of drainage on the environment;
- Assess the impacts of climate change on the effectiveness of existing infrastructure;
- Identify new drainage measures, retrofit opportunities or improvements to existing infrastructure that could improve the level of flow capacity;
- Determine the framework for an Asset Management model that incorporates costs of capital,
- Operations and maintenance, and replacement with a life-cycle approach;
- Recommend strategy and policies for drainage management in the City; and,
- Recommend multi-year implementation plan

Project Tasks

1. Review and Characterize the Study Area
2. Evaluate the Effectiveness of Existing Infrastructure
3. Identify New Drainage Measures and Retrofit Opportunities
4. Identify Recommended Strategy for Drainage Management
5. Identify a Framework for a Drainage System Asset Management Plan
6. Develop an Implementation Plan for the Recommended Strategy

Drainage Issues and Challenges

- Incomplete or lack of drainage system inventory or configuration data
- Incomplete or lack of drainage system component condition data
- Lack of framework for assessment of drainage system components
- Existing flooding issues within the City
- Concerns with channel erosions and impact on water quality
- Water quality concern from trash impacting aesthetic aspects
- Inadequate slope, flat and depressed areas resulting in poor drainage
- Off-site areas draining through watercourses within the City
- Saturated roadway impacting driving and roadway conditions
- Snow drift and piling impacting spring runoff blockage conditions
- Culvert blockages due to freeze thaw cycles during spring runoff
- Potential climate change impact concerns of unusual precipitation conditions and loss of permafrost on flooding, operation and maintenance and water quality
- Inadequate funding for asset management, system improvements and system expansion

Project Schedule

Item	Task Description	Original Completion Date	Revised Completion Date	Revised March 27	Notes
1	Project Award	November 30, 2017	January 5, 2018	Complete	
2	Kickoff Meeting	December 6, 2017	January 12, 2018	Complete	
3	Review and Characterize Study Area	January 31, 2018	March 28, 2018	In progress	To be presented in the technical workshop
4	Evaluation of Existing Infrastructure	February 23, 2018	April 20, 2018	Week of June 15	• Should Nunami organize interview session with maintenance staff • Waiting for field review in spring.
5	Technical Workshop No. 1	March 13, 2018	April 6, 2018	Week of May 10	• To be confirmed • Should this pushed to week of June 14
6	Identification of New Drainage Measures and Retrofit Opportunities	April 6, 2018	May 4, 2018	July 6, 2018	• City to confirm order of magnitude of the work they were interested in completing in 2018 construction season. • This item has been shuffled to include Item 4: Evaluation of Existing Infrastructure.

Project Schedule

Item	Task Description	Original Completion Date	Revised Completion Date	Revised March 27	Notes
7	Identification of Recommended Strategy for Drainage Management	April 27, 2018	May 25, 2018	Week of July 31	
8	Identification of Framework for Drainage System Asset Management Plan	May 18, 2018	June 15, 2018	Week of August 20	Submitted prior to Technical Workshop No. 2
9	Technical Workshop No. 2	July 10, 2018	August 7, 2018	August 30, 2018	
10	Development of Implementation Plan	August 10, 2018	September 10, 2018	Week of September 24	
11	Draft Report	September 21, 2018	October 19, 2018	No change	
12	Draft Review Meeting	October 5, 2018	November 2, 2018	No change	
13	Final Report Submission	October 30, 2018	November 23, 2018	No change	

Data Collection

Data Collection Status

Data Requested	Requested From	Requested By	Status	Notes
Applicable CAD/GIS Data				
Aerial Imagery	City of Iqaluit	Matt Follett	Received	2010, 2012, 2013
Contour Data	City of Iqaluit	Matt Follett	Received	2013
Roads	City of Iqaluit	Matt Follett	On file	2013
Building Outlines	City of Iqaluit	Matt Follett	On file	2013
Watercourses	City of Iqaluit	Matt Follett	On file	2013
Waterbodies	City of Iqaluit	Matt Follett	On file	2013
Culvert Data - Locations, Sizes, condition, etc.	City of Iqaluit	Matt Follett		
Topographical Data (DEM)	Natural Resources Canada	Neal Cody	Received	
Geographical Feature Data	Natural Resources Canada	Neal Cody	Received	
Previous Reports/Studies:				
Drainage	City of Iqaluit	Matt Follett		
Culverts	City of Iqaluit	Matt Follett		
Flooding	City of Iqaluit	Matt Follett		
Developments	City of Iqaluit	Matt Follett		
Creeks (esp. Airport/Carney and Apex)	City of Iqaluit	Matt Follett	On file	Apex River and SG
Lake Geraldine Spillway	City of Iqaluit	Matt Follett	On file	Dam assessment
Erosion Studies/Reports	City of Iqaluit / GN	Matt Follett		
Water Quality Reports	City of Iqaluit / GN	Matt Follett		

Data Collection Status

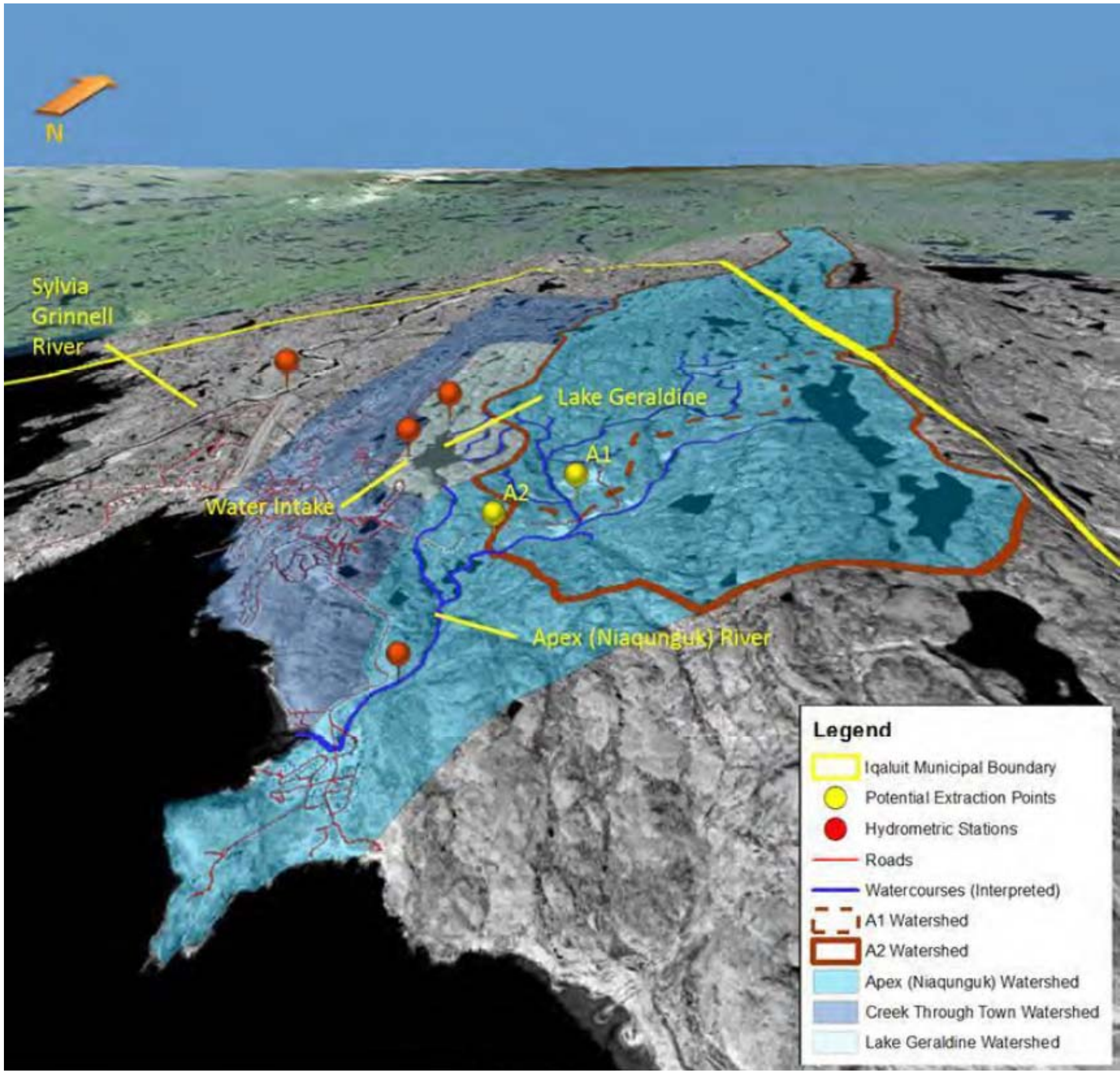
Data Requested	Requested From	Requested By	Status	Notes
Other Electronic Records:				
Work Orders (drainage or flooding related)	City of Iqaluit	Matt Follett		
Maintenance Records (drainage or flooding related)	City of Iqaluit	Matt Follett		
Planning Data:				
Land Use/Zoning	City of Iqaluit	Matt Follett	On file	City to provide CAD
Monitoring/Measurement Records				
Flooding Records	City of Iqaluit	Matt Follett		
Flow Monitoring Records	City of Iqaluit	Matt Follett		
Rainfall Records	City of Iqaluit	Matt Follett		
Apex River Levels and Flow	Water Survey of Canada	Neal Cody	Received	
Inflow and level into Lake Geraldine	Water Survey of Canada	Neal Cody	Received	
Lake Geraldine Level	Water Survey of Canada	Neal Cody	Received	
Sylvia Grinnell River Flow and Level	Water Survey of Canada	Neal Cody	Received	
Iqaluit Rainfall Records	Environment Canada	Neal Cody	Received	
Iqlauit Climate Records	Environment Canada	Neal Cody	Received	

Field Data Collection Status

Historical Data Review

Data Review

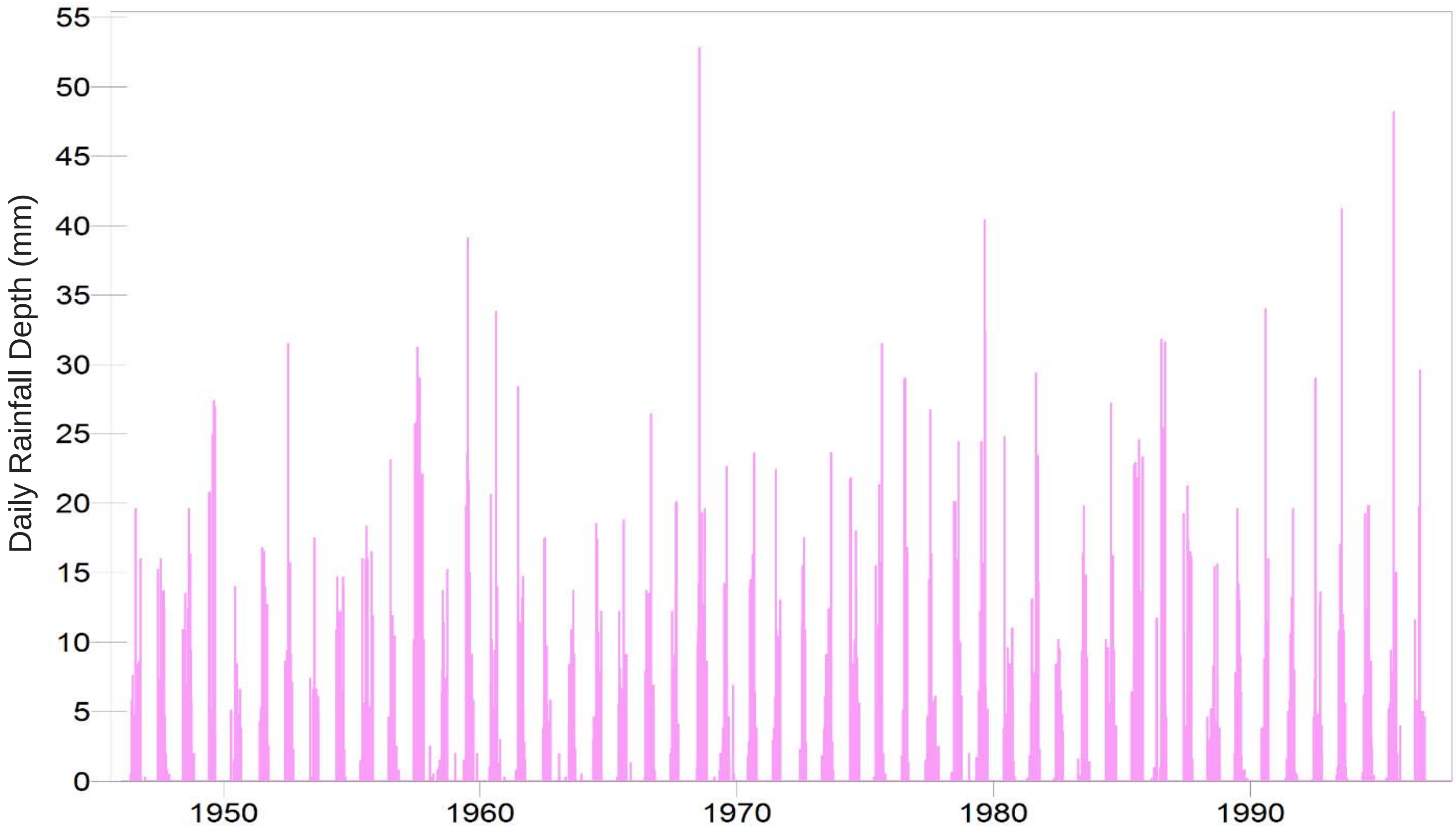
- Precipitation
- IDF (Intensity-Duration-Frequency) Curves
- Snowfall Depths
- Tidal Levels
- Streamflow
- Media Reports
- Flooding
- Other Reports & Literature



Precipitation

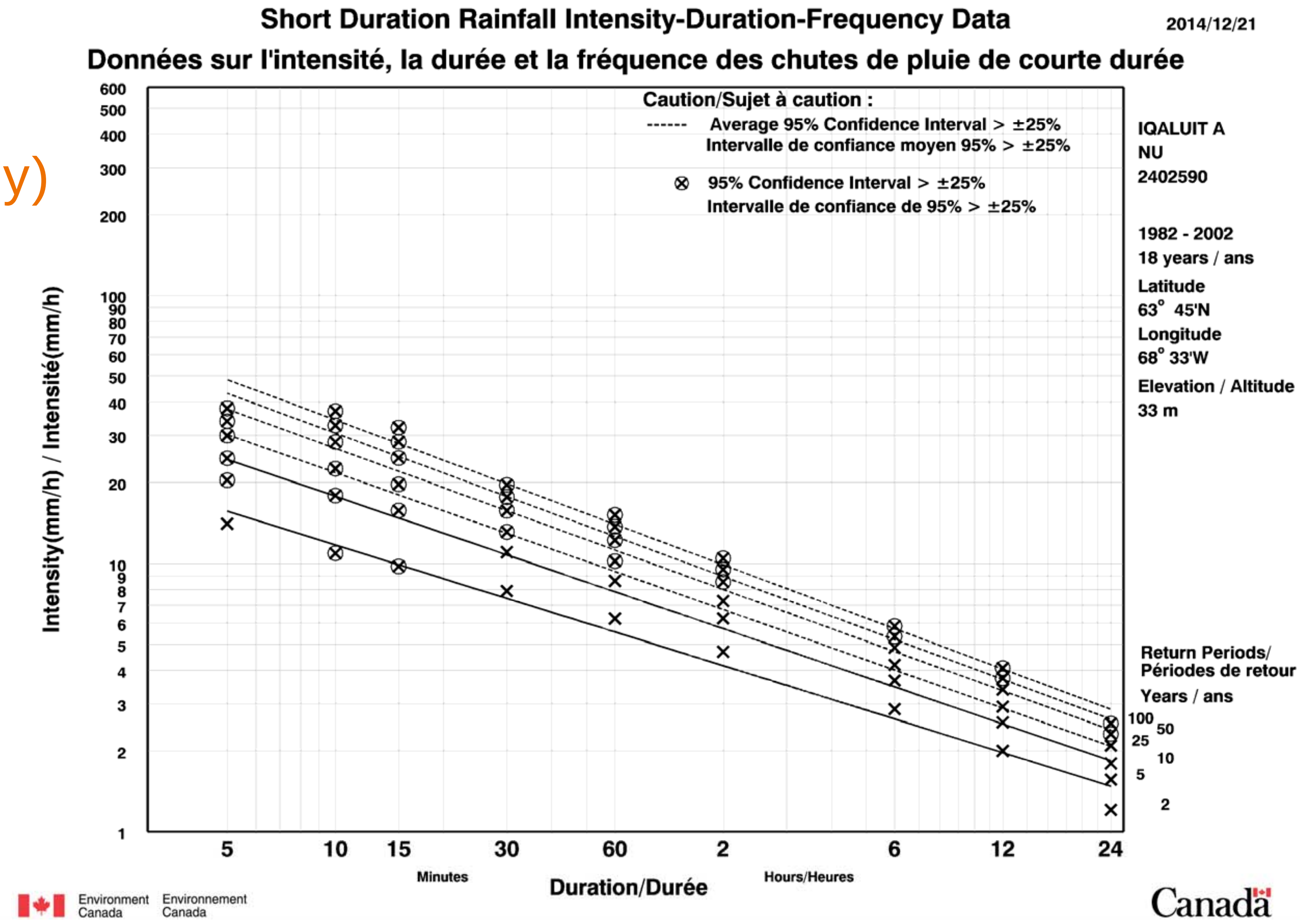
- Daily Records (1946-2018, 72 Years)
- 6-hour Records (1950-2018, 68 Years)
- Hourly Records (1982-2018, 36 Years)
- Fifteen-minute Records (2008-2018, 10 Years)

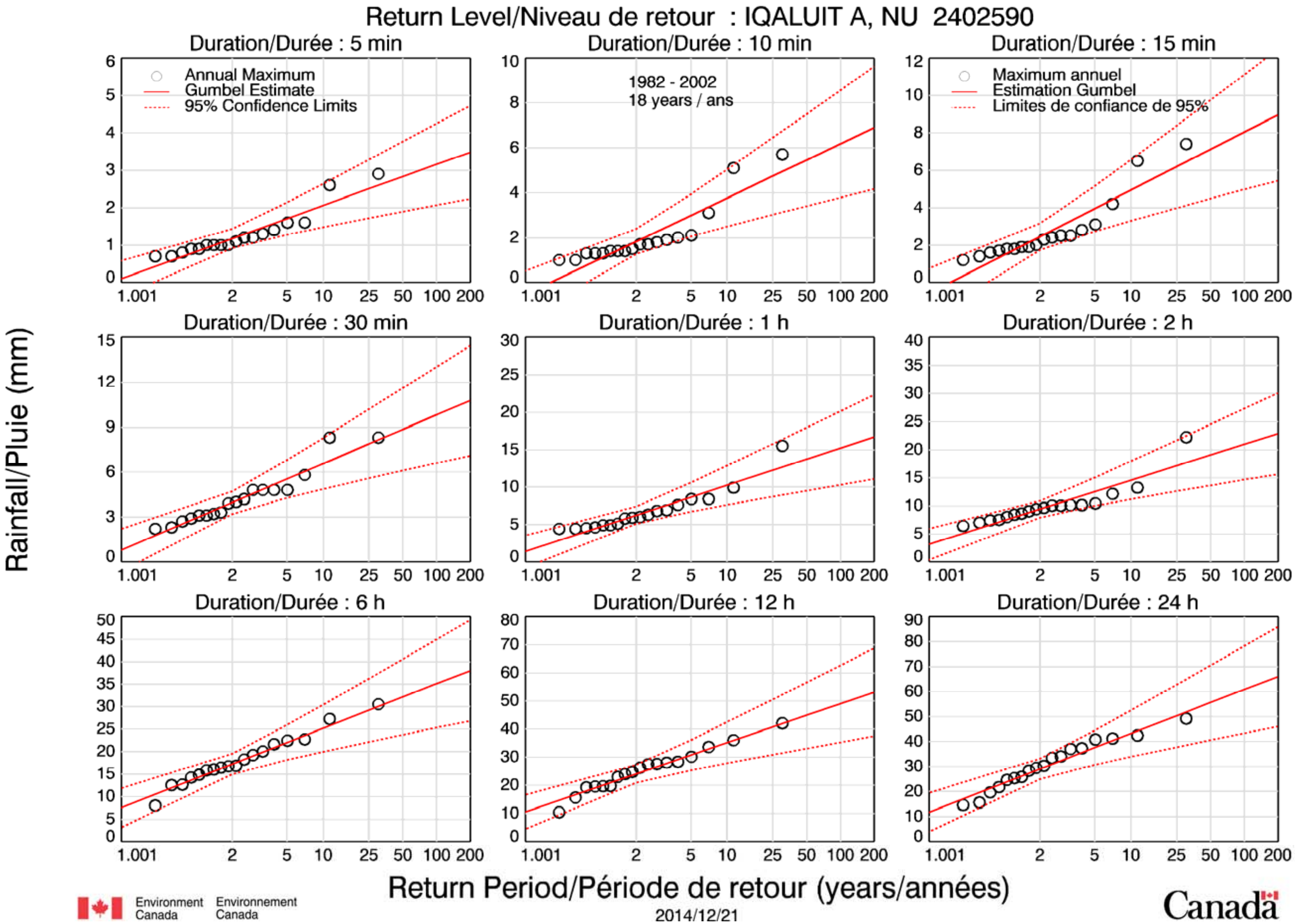
Daily Precipitation (1946-1996)



IDF Curves (Intensity-Duration-Frequency)

Data available 1982-2002

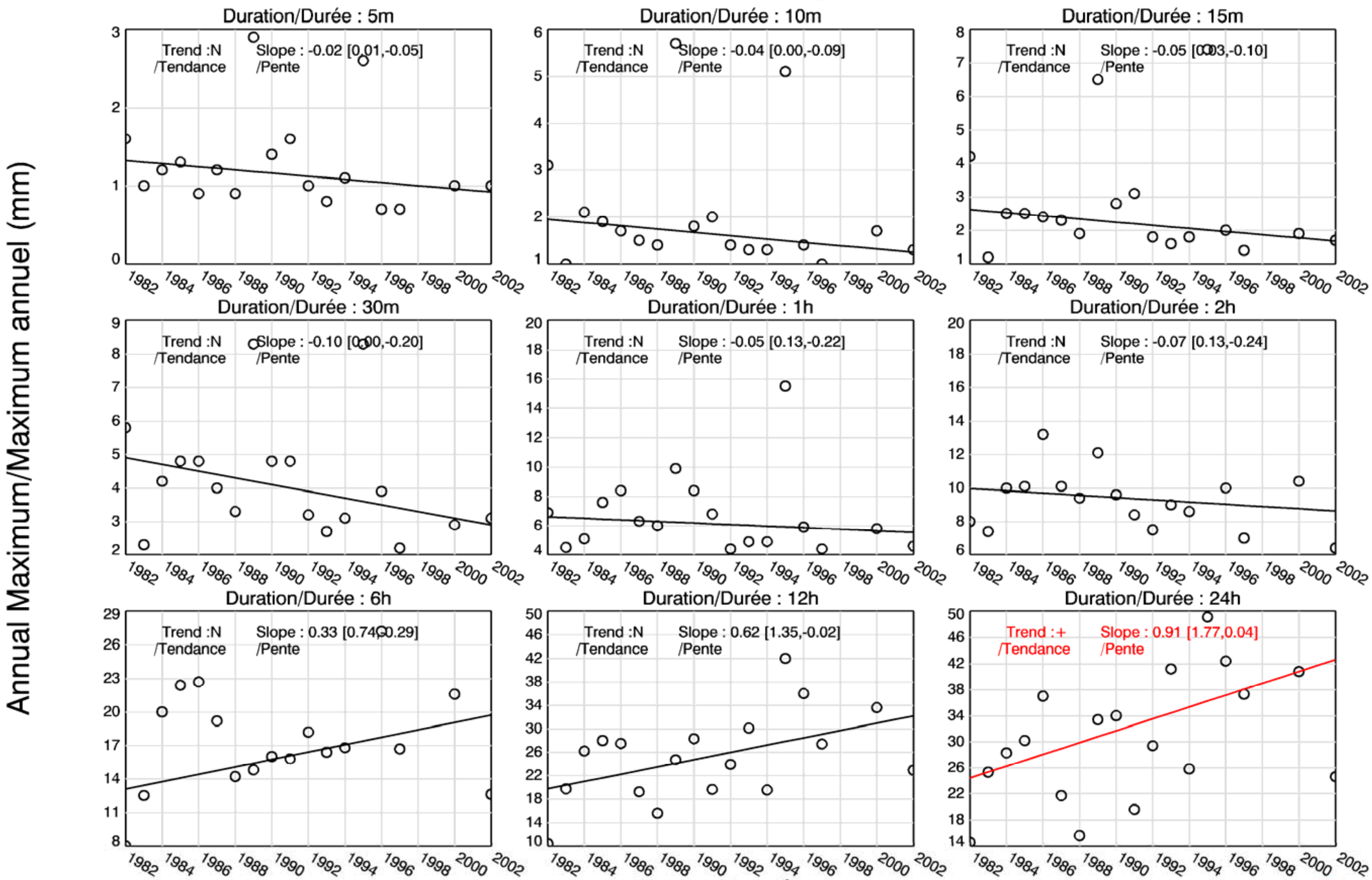




Environment Canada Environnement Canada

Canada

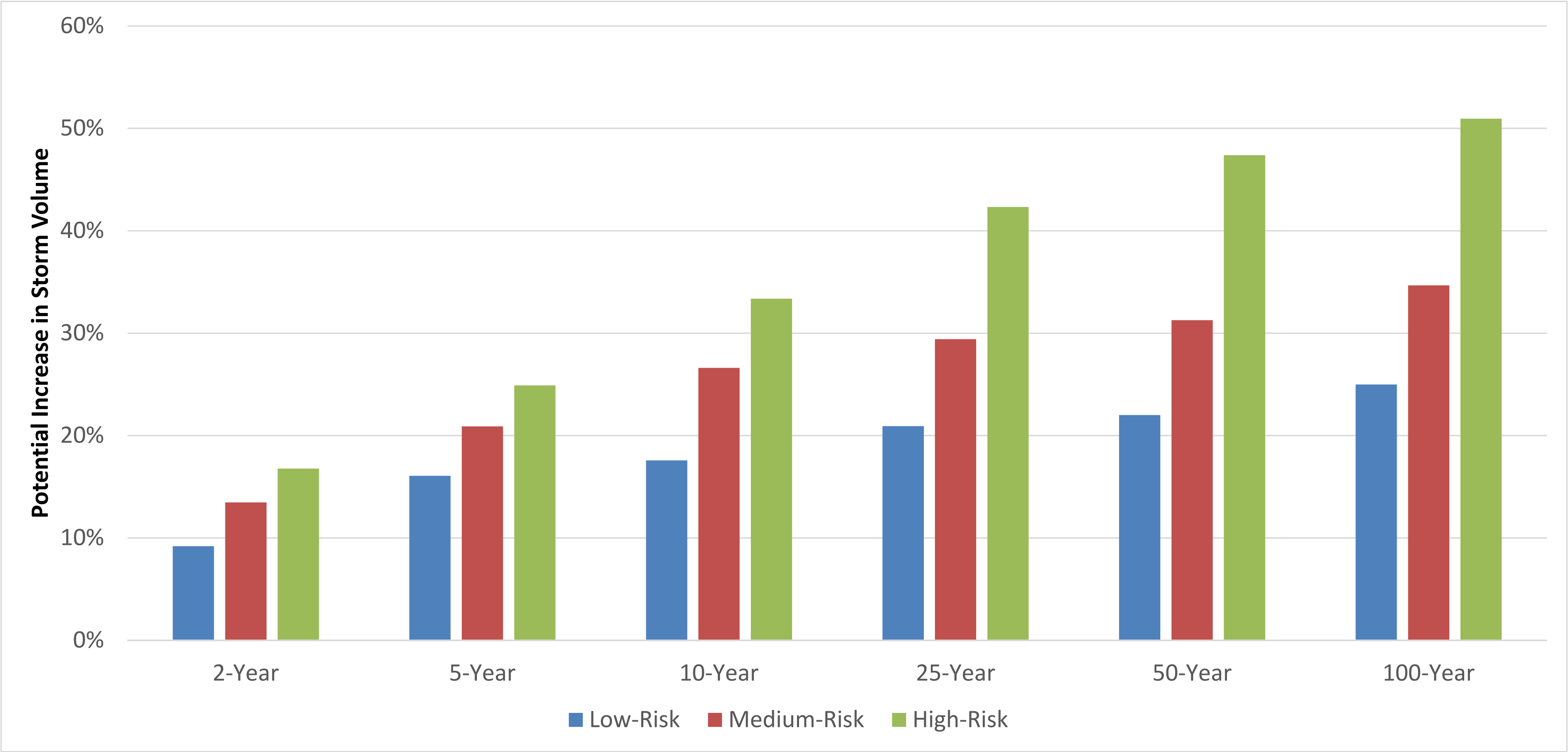
Trend/Tendance : IQALUIT A, NU 2402590



Environment Canada Environnement Canada

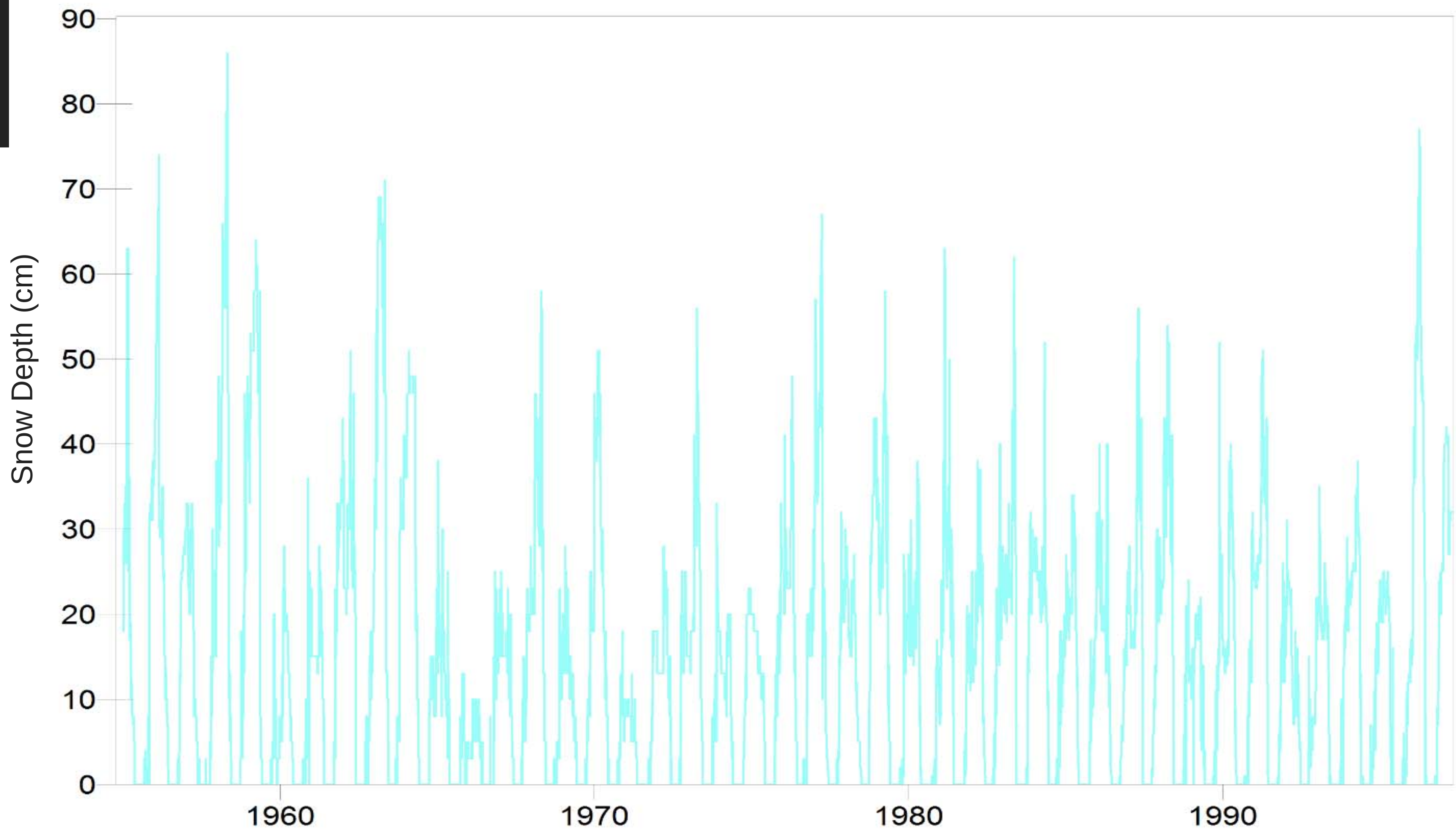
Canada

Climate Change Impacts

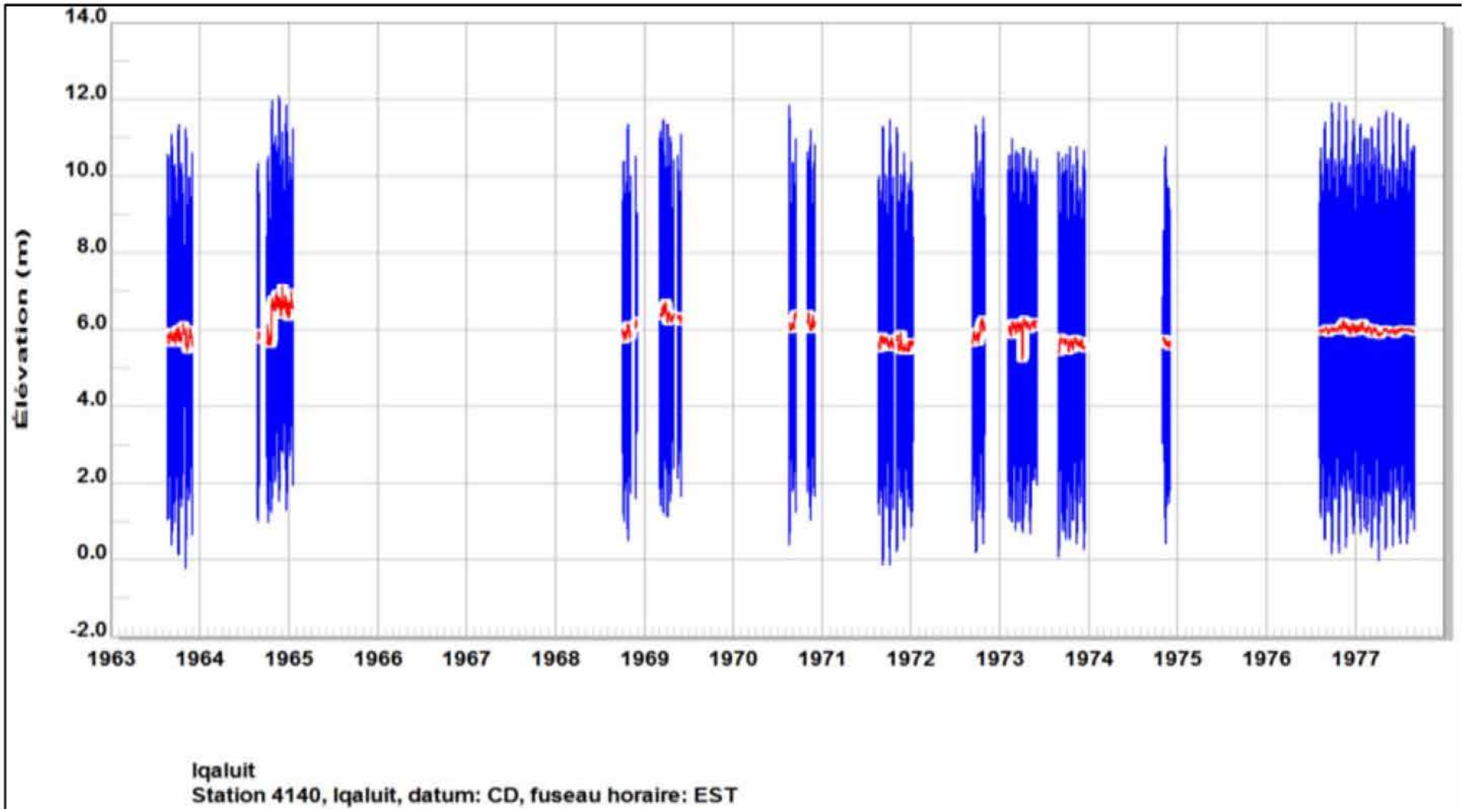


Snowfall Depths 1955-1996

Note: the peak snow depth in 2018 was 31 cm



Tidal Levels

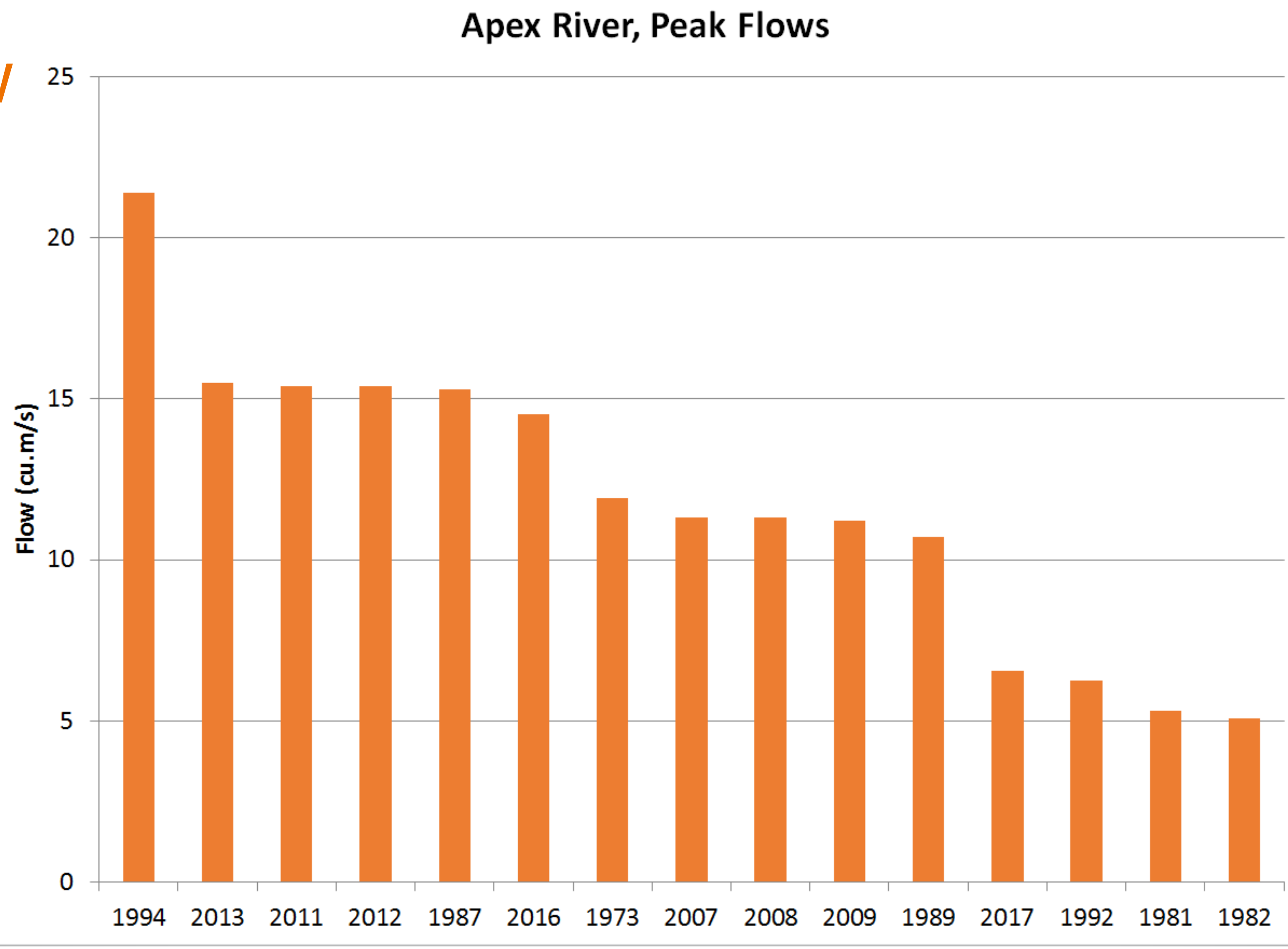


Streamflow

Available from Water Survey of Canada

- Three in Iqaluit area:

1. Apex River
2. Inflow to Lake Geraldine
3. Sylvia Grinnell River



Flooding

- No formal flooding records available
- Media records searched
- Very few media reports of flooding, and none indicating significant damage

Media Review

- Internet Search
- Social Media Search
- Historical Newspapers Search

A two-day rainfall that could reach 60 to 70 mm by the evening of July 22 in Iqaluit has swollen local creeks, such as the Kuugalaaq, which runs through downtown. (PHOTO BY THOMAS ROHNER)

Flooding

6:30 Muppet Show
7:00 Upchat Line
7:30 The Rare Breed
8:00 CBC Film Festival:
Second Wind

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SPRING IN FROBISHER BAY

It's springtime in Frobisher Bay and the bugs are sneaking from their long winter retreats. To the delight of children on Qulanni Street, the critters are lurking in the many puddles. These children found some after a concentrated poking and searching effort.

Flooding

The weather office told us last week that a new record for rainfall was set last August. These youngsters seem to be enjoying the mud created by all that water.

A massive downpour that started July 21 has washed out the Apex bypass road. (PHOTO BY THOMAS ROHNER)

Report Reviews

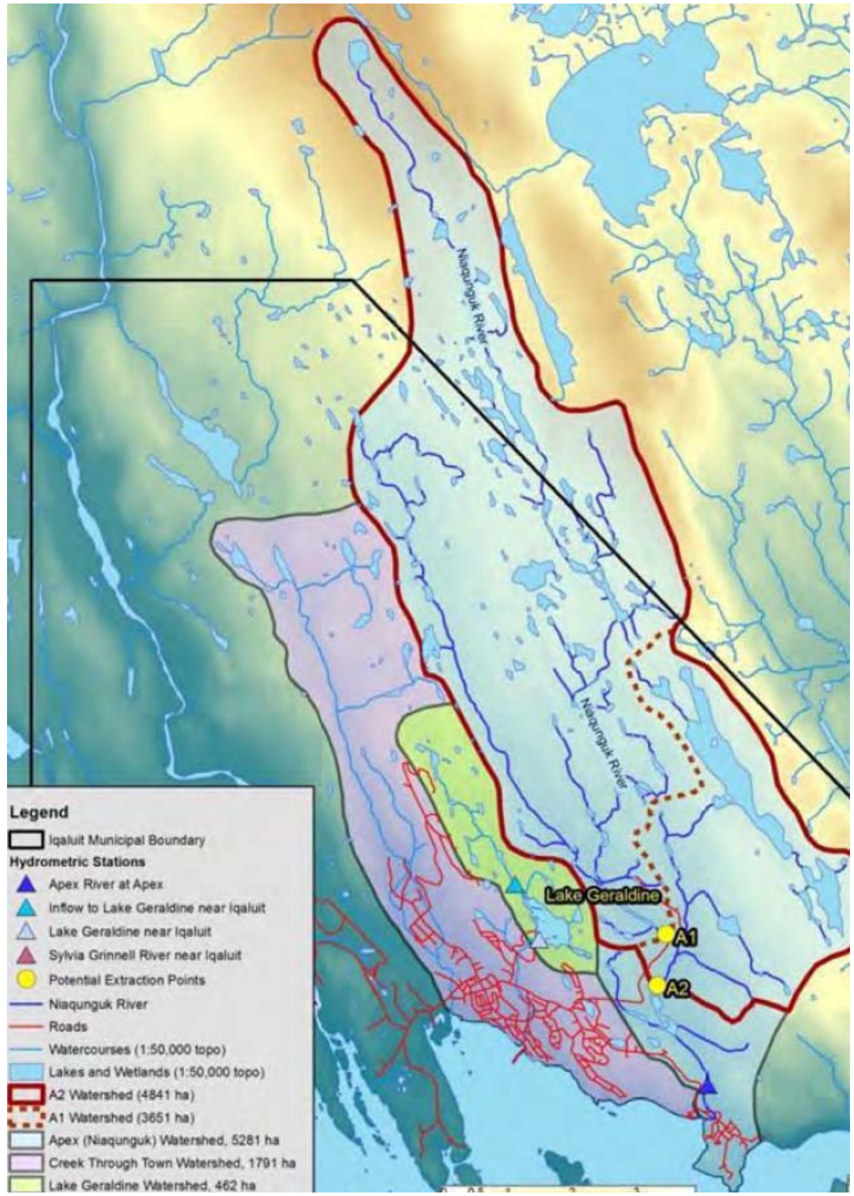
- Several previous Stantec Studies
- Other studies available online
- Some academic literature and papers

Particularly helpful:

- Water source supplementation studies
- Airport drainage study

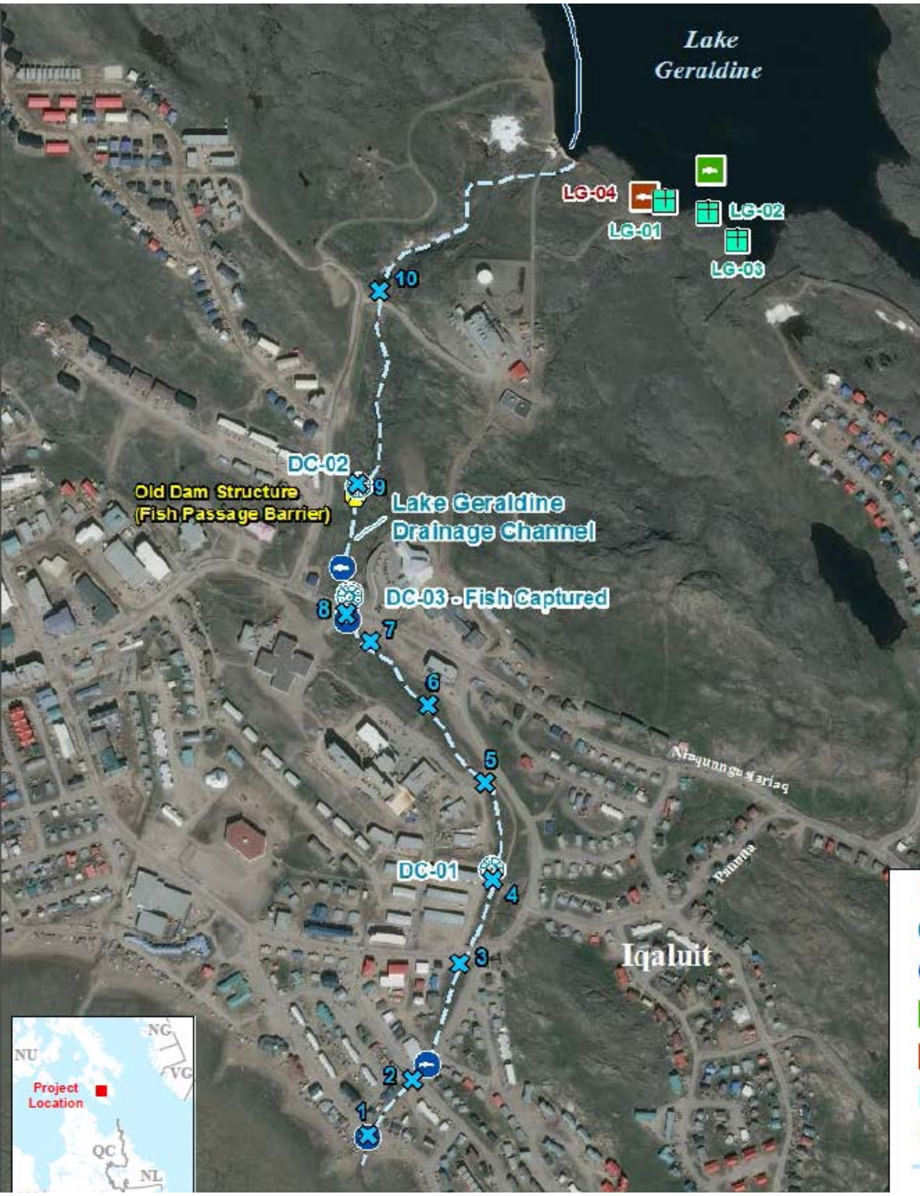
A two-day rainfall that could reach 60 to 70 mm by the evening of July 22 in Iqaluit has swollen local creeks, such as the Kuugalaaq, which runs through downtown. (PHOTO BY THOMAS ROHNER)

Characterization of Study Area



Niaqunguk River
Niaqunguk River
Lake Geraldine
A1
A2
Legend
Iqaluit Municipal Boundary
Hydrometric Stations
Apex River at Apex
Inflow to Lake Geraldine near Iqaluit
Lake Geraldine near Iqaluit
Sylvia Grinnell River near Iqaluit
Potential Extraction Points
Niaqunguk River
Roads
Watercourses (1:50,000 topo)
Lakes and Wetlands (1:50,000 topo)
A2 Watershed (4841 ha)
A1 Watershed (3651 ha)
Apex (Niaqunguk) Watershed, 5281 ha
Creek Through Town Watershed, 1791 ha
Lake Geraldine Watershed, 462 ha


Lake Geraldine
Lake Geraldine Drainage Channel
Apex River Proposed Water Withdrawal Location (A2)
Apex River
Road to Nowhere
Dead Dog Lake
Iqaluit
Niaqunngusiariaq
Paurnaq
Niaqunngusiariaq
N



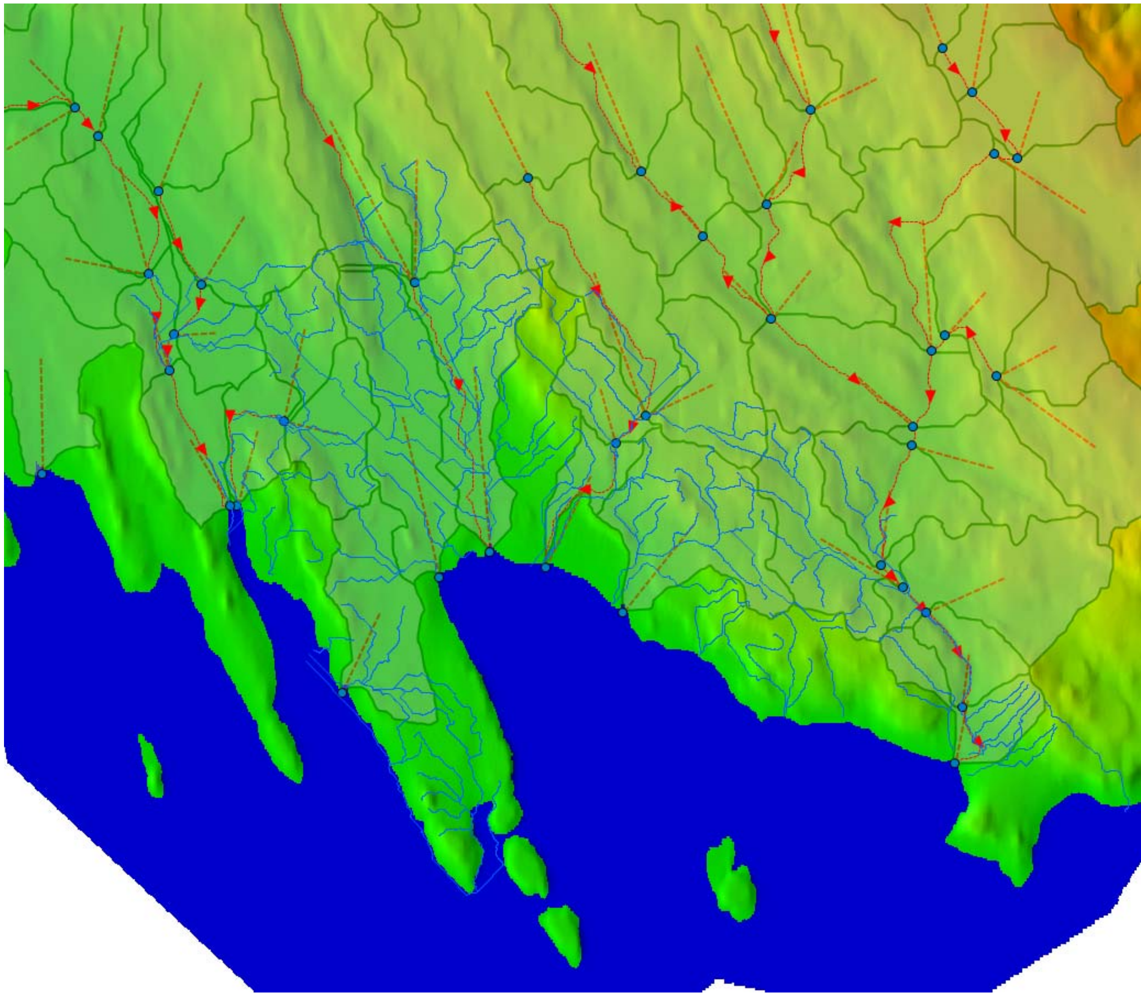
Feature No.	Feature	Location (in UTM 19 V)	Notes
1	Sinaa Road Crossing	524114.64 m E, 7068411.83 m N	Two circular culverts, 1,100 mm dia and 800 mm dia, no drop
2	Nipisa Street Crossing	524186.05 m E, 7068498.85 m N	Three 1,200 mm dia culverts, 14 m long with gabion wall headwall at inlet. Flow through one pipe only
3	Queen Elizabeth Road Crossing	524261.72 m E, 7068684.52 m N	Five pipes, three 1,650 mm dia oval culverts, with two 620 mm dia circular overflow pipes above them 0.22 m drop from culvert into 0.29 m pool may be barrier to small fish or at some flow levels
4	Pedestrian Crossing near Paunna Road	524313.69 m E, 7068819.42 m N	Two 1,550 mm dia culverts, 7 m long, half buried in the substrate
5	Astro Hill Road Crossing	524302.97 m E, 7068975.12 m N	Clear span bridge structure, 13 m wide over a channel with 7 m wide bankful Unstable bank on downstream left
6	Astro Hill Pedestrian Crossing	524210.46 m E, 7069099.66 m N	Two 1,300 mm dia culverts, 7 m long with one 400 mm dia overflow pipe
7	Overhead Pipe Crossing	524118.39 m E, 7069199.35 m N	Footings constructed of wooden cribs on rock riprap, encroaching on channel width
8	Road to Apex Crossing	524080.36 m E, 7069242.08 m N	Two 2,200 mm dia culverts, 22 m long
9	Old Dam Structure	524099.06 m E, 7069449.71 m N	Concrete dam, over 1 m drop. Complete barrier, no flow over structure—water flows through rock debris under structure
10	Saputi Road Crossing	524132.93 m E, 7069756.41 m N	Two 1,500 mm dia oval pipes, 80 m long, steep installation

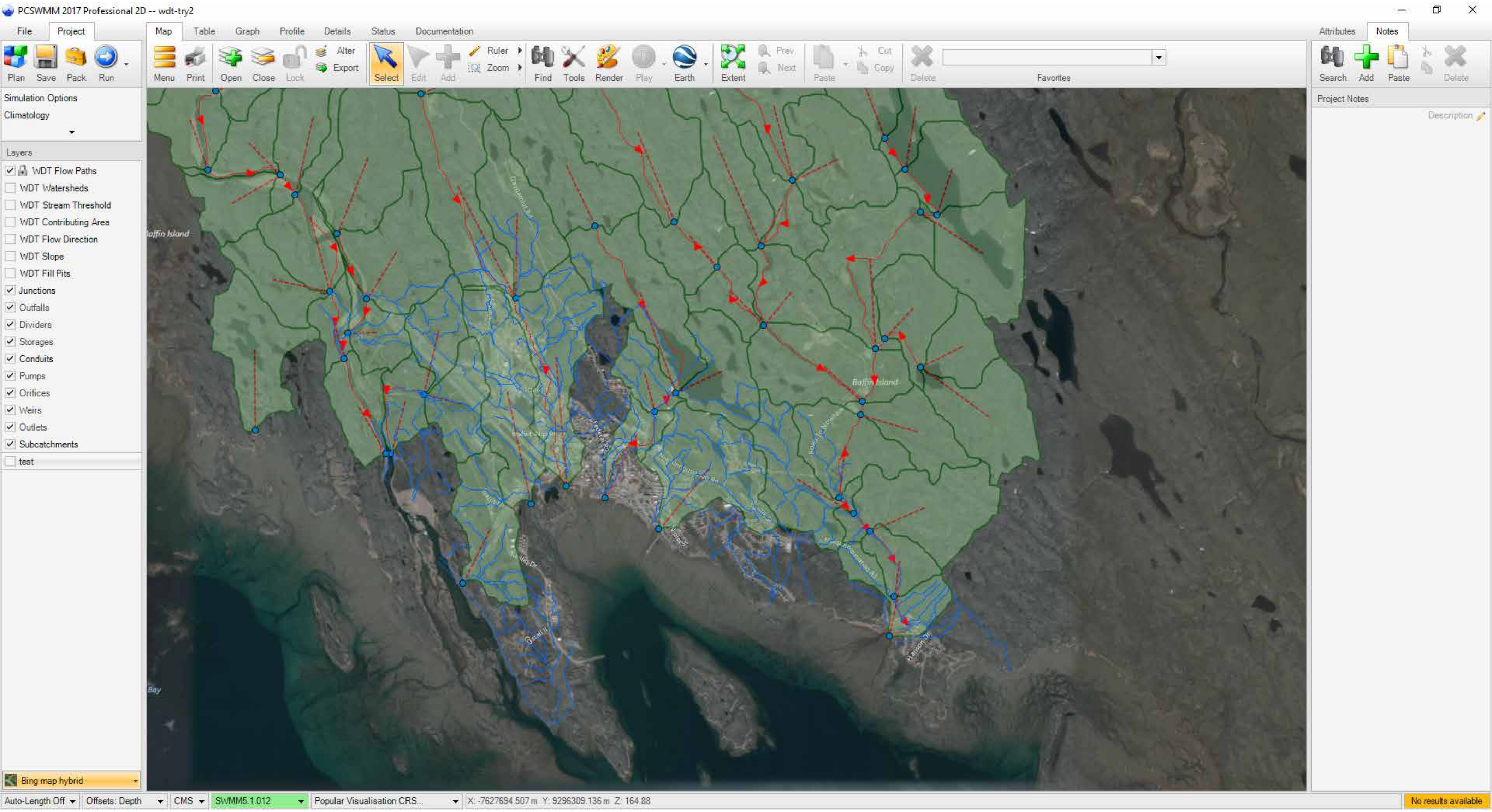
[Airport Creek Aerial]

Preliminary Model Construction

Model Construction

- Sufficient GIS source data collected
- Preliminary models built
- Crucial elements missing: culvert data (locations, sizes, conditions, slopes, inverts, lengths)

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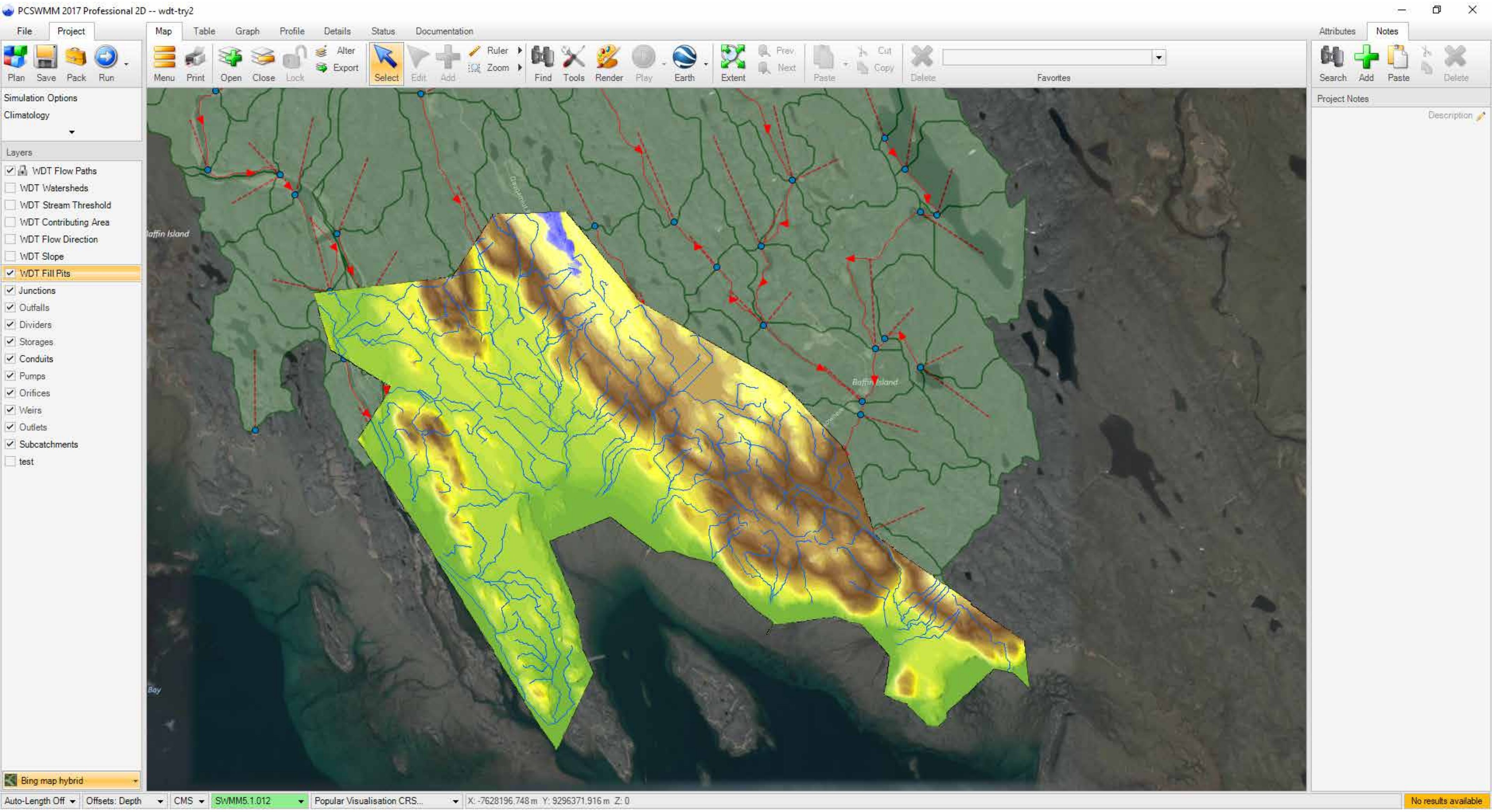
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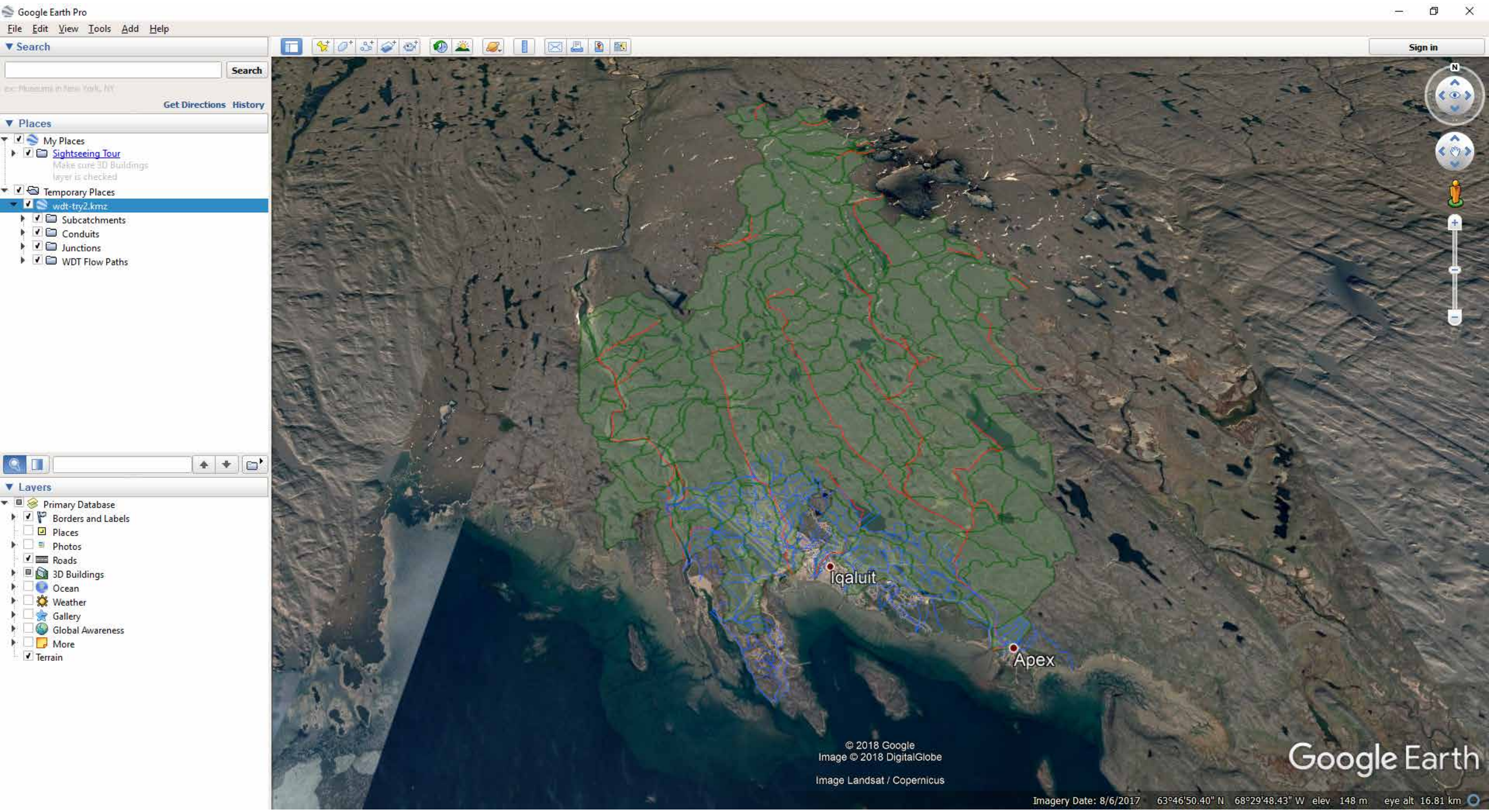
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Apex
© 2018 Google
Image © 2018 DigitalGlobe
Image Landsat / Copernicus
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Imagery Date: 8/6/2017 63°46'50.40" N 68°29'48.43" W elev 148 m eye alt 16.81 km

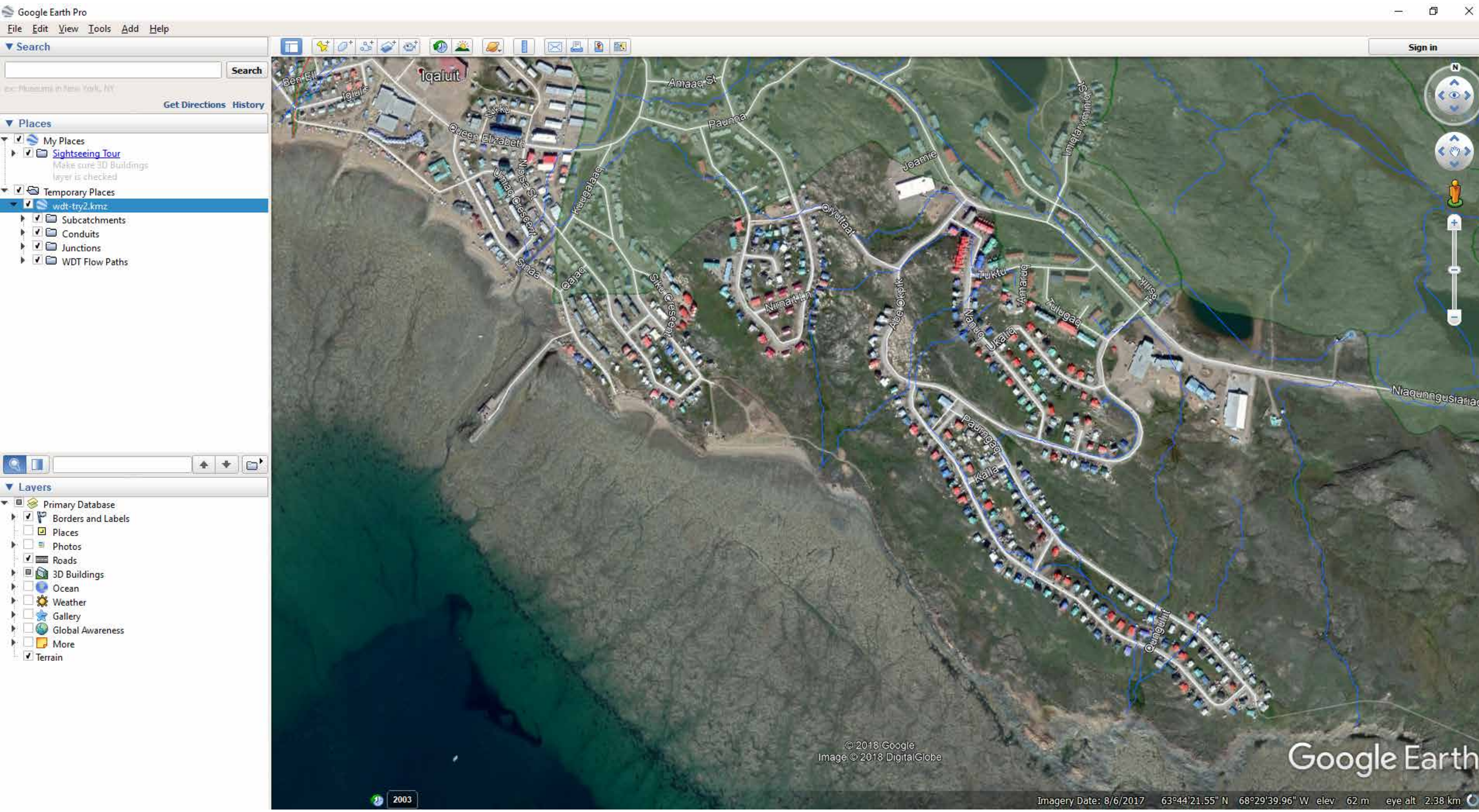
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Image © 2018 DigitalGlobe
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© 2018 Google
Google Earth
63°44'43.54" N 68°30'27.86" W elev 30 m eye alt 32 m


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Image © 2018 DigitalGlobe
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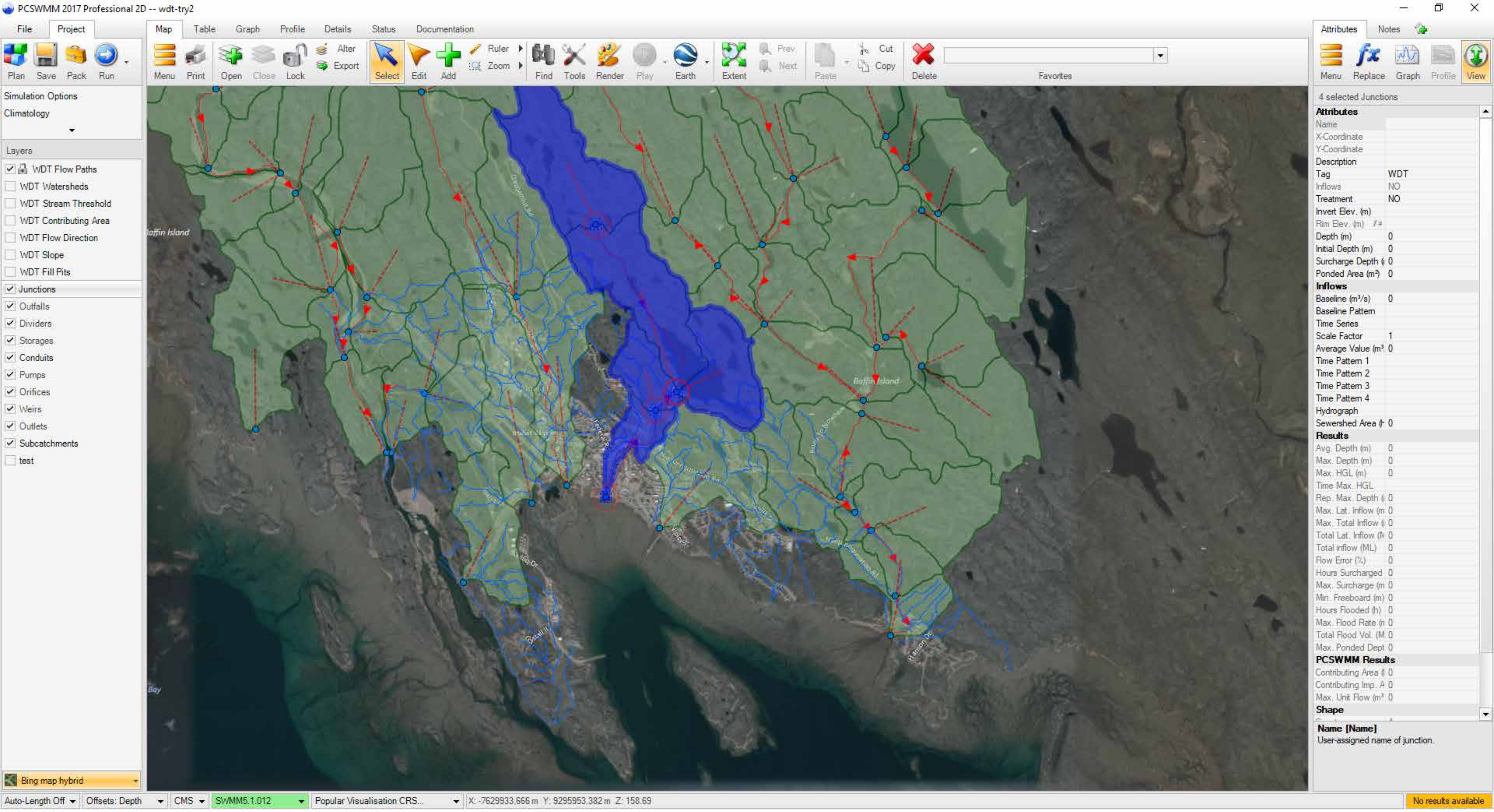

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WDT Slope
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Junctions
Outfalls
Dividers
Storages
Conduits
Pumps
Orifices
Weirs
Outlets
Subcatchments
test
Bing map hybrid
Baffin Island
4 selected Junctions
Attributes
Name
X-Coordinate
Y-Coordinate
Description
Tag WDT
Inflows NO
Treatment NO
Invert Elev. (m)
Rim Elev. (m)
Depth (m) 0
Initial Depth (m) 0
Surcharge Depth 0
Ponded Area (m²) 0
Inflows
Baseline (m³/s) 0
Baseline Pattern
Time Series
Scale Factor 1
Average Value (m³ 0
Time Pattern 1
Time Pattern 2
Time Pattern 3
Time Pattern 4
Hydrograph
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Results
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Max. Depth (m) 0
Max. HGL (m) 0
Time Max. HGL
Rep. Max. Depth 0
Max. Lat. Inflow 0
Max. Total Inflow 0
Total Lat. Inflow 0
Total inflow (ML) 0
Flow Error (%) 0
Hours Surcharged 0
Max. Surcharge 0
Min. Freeboard (m) 0
Hours Flooded (h) 0
Max. Flood Rate 0
Total Flood Vol. 0
Max. Ponded Dept 0
PCSWMM Results
Contributing Area 0
Contributing Imp. 0
Max. Unit Flow 0
Shape
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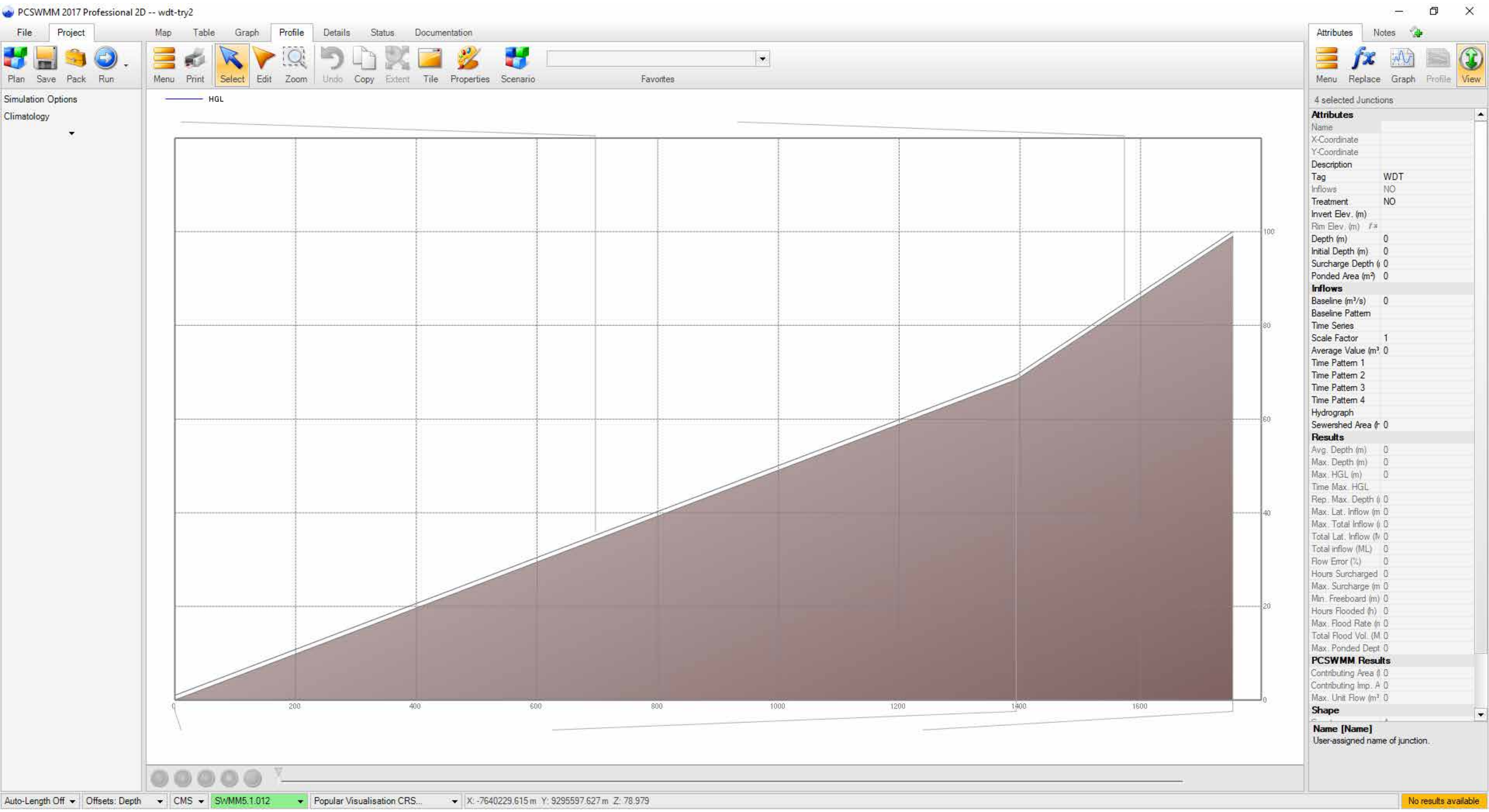
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Treatment NO
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Rim Elev. (m)
Depth (m) 0
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Inflows
Baseline (m³/s) 0
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Time Pattern 1
Time Pattern 2
Time Pattern 3
Time Pattern 4
Hydrograph
Results
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Max. Depth (m) 0
Max. HGL (m) 0
Time Max. HGL
Total inflow (ML) 0
Flow Error (%) 0
Hours Surcharged 0
Min. Freeboard (m) 0
Hours Flooded (h) 0
PCSWMM Results
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User-assigned name of junction.
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Offsets: Depth
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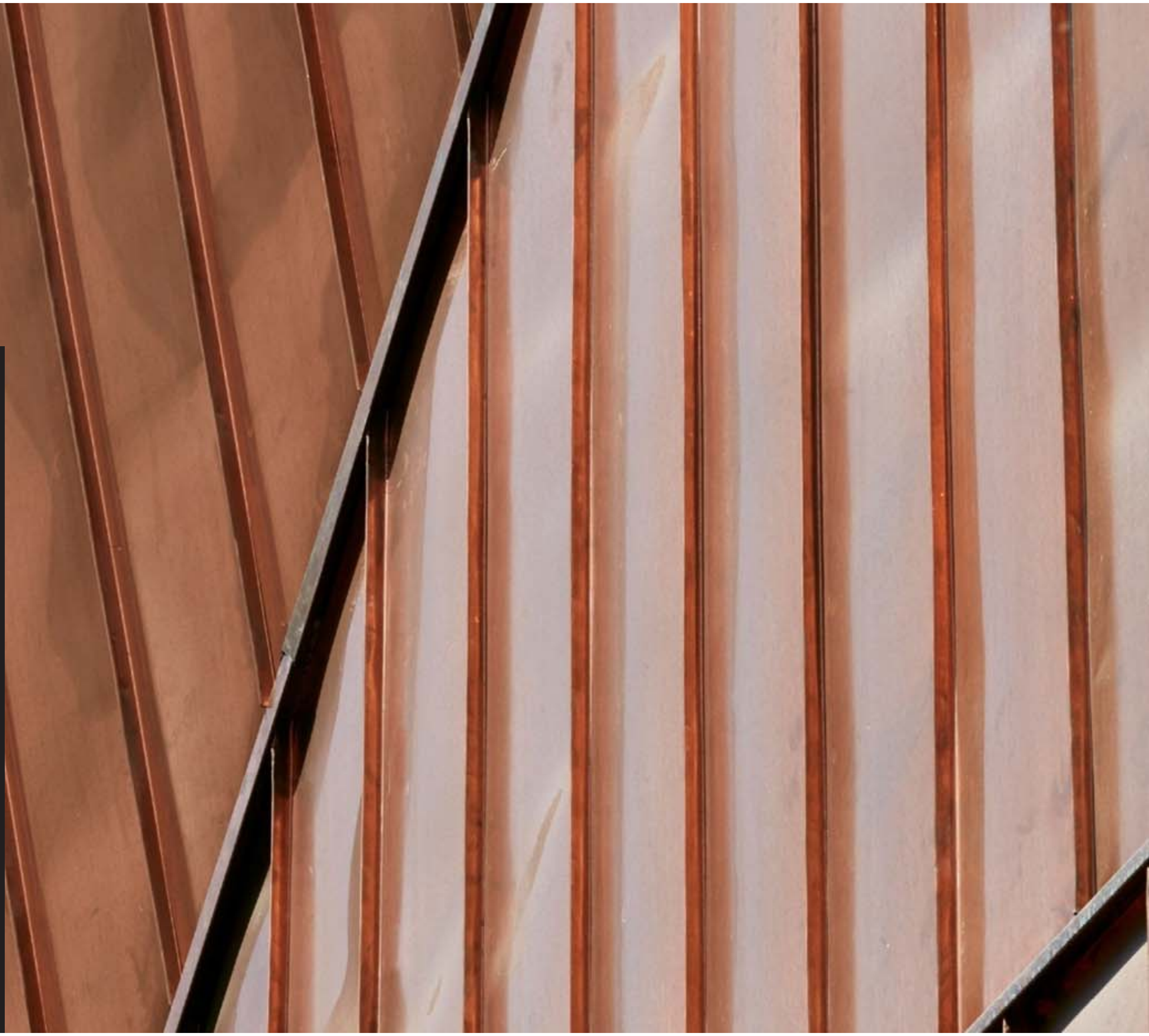
Proponents' Drainage Issues/Concerns

Existing Drainage Concerns?

Next Steps

Discussion / Questions



Stantec

City of Iqaluit
Master Drainage Plan

Workshop #2

Agenda

1. Review project scope
2. Data Collection
3. Proponents’ Drainage issues/Concerns
4. Review of historical data and trends
5. Framework for Asset Management Plan
6. Recommended Design Standards Update
7. Discussion & next steps

Safety Moment

Watch your footing on steep slopes, especially when covered in snow or ice.

Project Scope Review

Study Objectives

- Identify all major drainage areas, routes and channels within the City,
- Characterize the existing environmental conditions for all drainage areas within the City;
- Assess the effectiveness of existing drainage management infrastructure at conveying the drainage and reducing the negative impacts of drainage on the environment;
- Assess the impacts of climate change on the effectiveness of existing infrastructure;
- Identify new drainage measures, retrofit opportunities or improvements to existing infrastructure that could improve the level of flow capacity;
- Determine the framework for an Asset Management model that incorporates costs of capital,
- Operations and maintenance, and replacement with a life-cycle approach;
- Recommend strategy and policies for drainage management in the City; and,
- Recommend multi-year implementation plan

Project Tasks

1. Review and Characterize the Study Area
2. Evaluate the Effectiveness of Existing Infrastructure
3. Identify New Drainage Measures and Retrofit Opportunities
4. Identify Recommended Strategy for Drainage Management
5. Identify a Framework for a Drainage System Asset Management Plan
6. Develop an Implementation Plan for the Recommended Strategy

Drainage Issues and Challenges

- Incomplete or lack of drainage system inventory or configuration data
- Incomplete or lack of drainage system component condition data
- Lack of framework for assessment of drainage system components
- Existing flooding issues within the City
- Concerns with channel erosions and impact on water quality
- Water quality concern from trash impacting aesthetic aspects
- Inadequate slope, flat and depressed areas resulting in poor drainage
- Off-site areas draining through watercourses within the City
- Saturated roadway impacting driving and roadway conditions
- Snow drift and piling impacting spring runoff blockage conditions
- Culvert blockages due to freeze thaw cycles during spring runoff
- Potential climate change impact concerns of unusual precipitation conditions and loss of permafrost on flooding, operation and maintenance and water quality
- Inadequate funding for asset management, system improvements and system expansion

Project Schedule

Item	Task Description	Original Completion Date	Revised Completion Date	Revised March 27	Notes
1	Project Award	November 30, 2017	January 5, 2018	Complete	
2	Kickoff Meeting	December 6, 2017	January 12, 2018	Complete	
3	Review and Characterize Study Area	January 31, 2018	March 28, 2018	In progress	To be presented in the technical workshop
4	Evaluation of Existing Infrastructure	February 23, 2018	April 20, 2018	Week of June 15	• Should Nunami organize interview session with maintenance staff • Waiting for field review in spring.
5	Technical Workshop No. 1	March 13, 2018	April 6, 2018	Week of May 10	• To be confirmed • Should this pushed to week of June 14
6	Identification of New Drainage Measures and Retrofit Opportunities	April 6, 2018	May 4, 2018	July 6, 2018	• City to confirm order of magnitude of the work they were interested in completing in 2018 construction season. • This item has been shuffled to include Item 4: Evaluation of Existing Infrastructure.

Project Schedule

Item	Task Description	Original Completion Date	Revised Completion Date	Revised March 27	Notes
7	Identification of Recommended Strategy for Drainage Management	April 27, 2018	May 25, 2018	Week of July 31	
8	Identification of Framework for Drainage System Asset Management Plan	May 18, 2018	June 15, 2018	Week of August 20	Submitted prior to Technical Workshop No. 2
9	Technical Workshop No. 2	July 10, 2018	August 7, 2018	August 30, 2018	
10	Development of Implementation Plan	August 10, 2018	September 10, 2018	Week of September 24	
11	Draft Report	September 21, 2018	October 19, 2018	No change	
12	Draft Review Meeting	October 5, 2018	November 2, 2018	No change	
13	Final Report Submission	October 30, 2018	November 23, 2018	No change	

Data Collection

Data Collection Status

Last Updated:	27-Mar-18			
Data Requested	**Requested From**	**Requested By**	**Status**	**Notes**
Applicable CAD/GIS Data				
Aerial Imagery	City of Iqaluit	Matt Follett	Received	2010, 2012, 2013
Contour Data	City of Iqaluit	Matt Follett	Received	2013
Roads	City of Iqaluit	Matt Follett	On file	2013
Building Outlines	City of Iqaluit	Matt Follett	On file	2013
Watercourses	City of Iqaluit	Matt Follett	On file	2013
Waterbodies	City of Iqaluit	Matt Follett	On file	2013
Culvert Data - Locations, Sizes, condition, etc.	City of Iqaluit	Matt Follett	To be collected on field	
Topographical Data (DEM)	Natural Resources Canada	Neal Cody	Received	
Geographical Feature Data	Natural Resources Canada	Neal Cody	Received	
Previous Reports/Studies:				
Drainage	City of Iqaluit	Matt Follett	None Available	
Culverts	City of Iqaluit	Matt Follett	None Available	
Flooding	City of Iqaluit	Matt Follett	None Available	
Developments	City of Iqaluit	Matt Follett	Received	
Creeks (esp. Airport/Carney and Apex)	City of Iqaluit	Matt Follett	On file	Apex River and SG
Lake Geraldine Spillway	City of Iqaluit	Matt Follett	On file	Dam assessment
Erosion Studies/Reports	City of Iqaluit / GN	Matt Follett	None Available	
Water Quality Reports	City of Iqaluit / GN	Matt Follett	None Available	

Data Collection Status

Monitoring/Measurement Records				
Flooding Records	City of Iqaluit	Matt Follett	None Available	
Flow Monitoring Records	City of Iqaluit	Matt Follett	None Available	
Rainfall Records	City of Iqaluit	Matt Follett	None Available	
Apex River Levels and Flow	Water Survey of Canada	Neal Cody	Received	
Inflow and level into Lake Geraldine	Water Survey of Canada	Neal Cody	Received	
Lake Geraldine Level	Water Survey of Canada	Neal Cody	Received	
Sylvia Grinnell River Flow and Level	Water Survey of Canada	Neal Cody	Received	
Iqaluit Rainfall Records	Environment Canada	Neal Cody	Received	
Iqlauit Climate Records	Environment Canada	Neal Cody	Received	

Field Data Collection

Spring Snow and Melt Observations

- Mounted Go-Pro Camera to car and conducted 3 drive-arounds in city on the following dates:
  - 24 May 2018
  - 07 June 2018
  - 12 June 2018

- Conducted field inspection using handheld camera in September 2018 to assess the existing infrastructure condition
- Identified crossing locations, condition assessment and culvert sizes

Stantec

Proponent's Drainage Issues / Concerns

Airport Creek

June 2018

Airport Creek Photos

South of crossing 1 (2x 1800 mm dia.) – Early Spring Meltoff

September 2018

Crossing 1 (2 x 1800 mm dia.) - Early Fall

June 2018

Airport Creek Photos

September 2018

South of Crossing 2 (2100 mm dia.) - Accumulated Garbage

Crossing 2 (2100 mm dia.)

June 2018

Airport Creek Photos

South of Crossing 3 (4 x 1200 mm dia. and 2 x 1000 mm dia.) - Damaged Ends

September 2018

North of Crossing 3 - damaged ends

June 2018

Airport Creek Photos

September 2018

North of Crossing 3 - Broken End

June 2018

Airport Creek Photos

September 2018

North of Crossing 3 - Deflected End

June 2018

Airport Creek Photos

September 2018

North of Crossing 3 - Wooden Pallet in Stream

June 2018

Airport Creek Photos

September 2018

South of Crossing 3 (4 x 1200 mm dia. and 2 x 1000 mm dia.) - Early Fall

June 2018

Airport Creek Photos

South of Crossing 4 (800 mm dia.) –not receiving any flow

September 2018

North of Crossing 4 (800 mm dia.) looking Upstream -Garbage in the pipe

June 2018

Airport Creek Photos

September 2018

North of Crossing 5 (3 x 300 mm dia.) - Garbage accumulated

North of Crossing 5 (3 x 300 mm dia.) looking Upstream -Garbage in the pipe

June 2018

Airport Creek Photos

September 2018

North of Crossing 5 (300 mm dia.) looking Upstream -Corroded pipe exposed after the removal of garbage

June 2018

Airport Creek Photos

September 2018

South of Crossing 5 (3 x 300 mm dia.) looking Downstream - Garbage accumulated

June 2018

Airport Creek Photos

September 2018

East of Crossing 6 (1200 mm dia.) & 6B (600 mm dia.)

East of Crossing 6B (600 mm dia.) -Appears to be garbage in the stream

June 2018

Airport Creek Photos

East of Crossing 6 (1200 mm dia.)

September 2018

East of Crossing 6 (1200 mm dia.)

June 2018

Airport Creek Photos

North of Crossing 7 (600 mm dia.)

September 2018

North of Crossing 7 (600 mm dia.)

June 2018

Airport Creek Photos

September 2018

South of Crossing 7 (600 mm dia.)

South of Crossing 7 (600 mm dia.)

June 2018

Airport Creek Photos

September 2018

South of Crossing 7 (600 mm dia.) -Sediment buildup in the pipe

June 2018

Airport Creek Photos

East of Crossing 8 (2 x 1000 mm dia. and 1 x 1600 mm dia.) -Snow about to melt

September 2018

East of Crossing 8 (2 x 1000 mm dia. and 1 x 1600 mm dia.)

June 2018

Airport Creek Photos

September 2018

East of Crossing 8 (1600 mm dia.) closeup - Sediment buildup inside the pipe

East of Crossing 8 (1000 mm dia.)

June 2018

Airport Creek Photos

September 2018

West of Crossing 8 behind the fence - Garbage

June 2018

September 2018

Airport Creek Photos

East of Crossing 9 (2100 mm dia.)

East of Crossing 9 (2100 mm dia.) looking Upstream

June 2018

Airport Creek Photos

West of Crossing 9 (2100 mm dia.) - Furniture inside the pipe

September 2018

West of Crossing 9 (2100) looking Downstream

June 2018

September 2018

Airport Creek Photos

East of Crossing 10 (3100 mm dia.) & 10B (1600 mm dia.)

East of Crossing 10 (3100 mm dia.) & 10B (1600 mm dia.)

June 2018

Airport Creek Photos

East of Crossing 10 (3100 mm dia.) -Snow melt

September 2018

East of Crossing 10 (3100 mm dia.) -Deflected Pipe

June 2018

Airport Creek Photos

September 2018

East of Crossing 10 (3100 mm dia.)

June 2018

Airport Creek Photos

Dam near Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.)

September 2018

North of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) looking Upstream -Garbage buildup infront of pipe

June 2018

Airport Creek Photos

September 2018

North of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) - Garbage in the stream

North of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) looking Upstream -Wooden Pallets and Garbage

June 2018

Airport Creek Photos

September 2018

South of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.)

South of Crossing 12 (3 x 1000 mm dia. and 1 x 2100 mm dia.) looking Downstream -Garbage in the flow

June 2018

Airport Creek Photos

September 2018

East of Crossing 13 (1600 mm dia.)

East of Crossing 13 (1600 mm dia.) looking Downstream -Garage in the stream

June 2018

Airport Creek Photos

September 2018

East of Crossing 13 (1600 mm dia.) looking Downstream -Barrel inside the pipe, probably received during the stream flow

June 2018

Airport Creek Photos

September 2018

East of Crossing 13 (1600 mm dia.)

Stantec

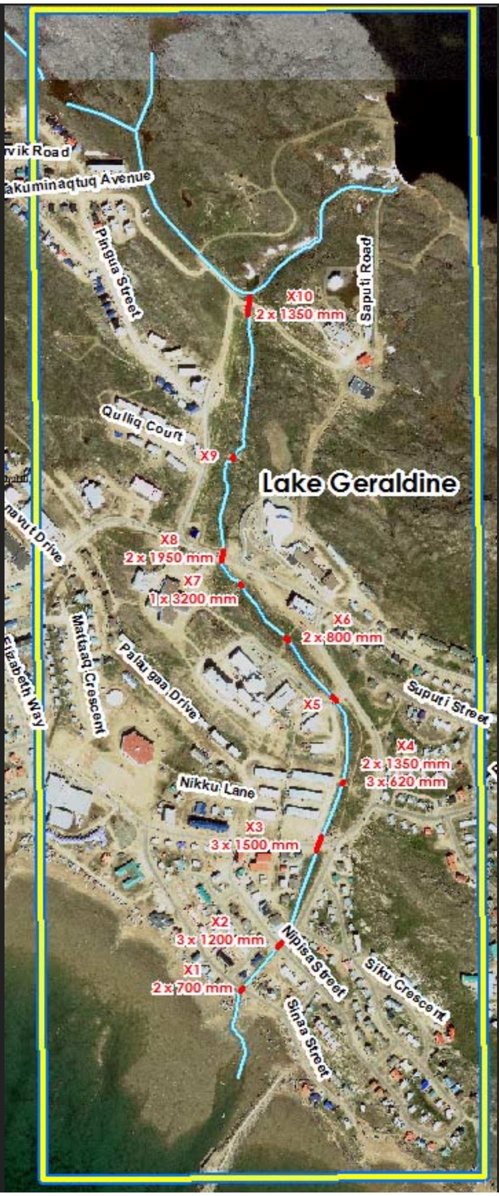
Airport Creek

Summary

Airport Creek								
Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
X1a	N	S	1800	Corrugated Steel	Circular	Projected	N	Surface Corrosion on floor
X1b	N	S	1800	Corrugated Steel	Circular	Projected	N	Surface Corrosion on floor
X2	N	S	2100	Corrugated Steel	Circular	Projected	Y	Deformed Edges, surface corrosion on floor
X3a	NE	SW	1000	Corrugated Steel	Circular	Projected	N	Torn out edges, surface corrosion on floor
X3b	NE	SW	1000	Corrugated Steel	Circular	Projected	N	Torn out edges, surface corrosion on floor
X3c	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X3d	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor, multiple roof sags identified
X3e	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X3f	NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X4	NE	SW	800	Corrugated Steel	Circular	Projected	N	
X5a	NE	SW	3000	Corrugated Steel	Circular	Projected	N	Deformed Edges, Fine deposits on the upstream end, Culvert inoperational due to deposits
X5b	NE	SW	3000	Corrugated Steel	Circular	Projected	N	Culvert end worn out, broken pieces
X5c	NE	SW	3000	Corrugated Steel	Circular	Projected	N	Deformed Edges, Garbage identified in the Culvert. Culvert flooe significantly corroded at the upstream end.
X6	NW	SE	1200	Corrugated Steel	Circular	Projected	Y	
X6b	NW	SE	600	Corrugated Steel	Circular	Projected	N	
X7	NE	SW	600	Corrugated Steel	Circular	Projected	N	Deformed Edges. Signifcant amount of fine deposition in the Culvert.
X8a	NW	SE	1000	Corrugated Steel	Circular	Projected	N	
X8b	NW	SE	1600	Corrugated Steel	Circular	Projected	Y	Mud deposit at the downstream end
X8c	NW	SE	1000	Corrugated Steel	Circular	Projected	N	Surface Corrosion on the floor of Culvert
X9	NE	SW	2100	Corrugated Steel	Circular	Projected	N	Torn out edges, significant amount of debris deposited at the upstream end. A furniture was identified in the Culvert
X10a	NW	SE	3100	Corrugated Steel	Arch	Projected	N	Garbage deposits at the upstream end
X10b	NW	SE	1600	Corrugated Steel	Circular	Projected	N	
X12a	N	S	1000	Corrugated Steel	Circular	Projected	N	Deformed Culvert, elliptical in shape, surface corrosion on floor
X12b	N	S	1000	Corrugated Steel	Circular	Projected	N	Worn Out Edges, surface corrosion on floor
X12c	N	S	1000	Corrugated Steel	Circular	Projected	N	Surface corrosion on floor
X12d	N	S	2100	Corrugated Steel	Circular	Projected	N	Deformed Culvert, deflected sidewall at 2 O'clock, at the downstream end.
X13	NW	SE	1600	Corrugated Steel	Circular	Projected	N	Deteriorated Edges at the downstream end

Proponent’s Drainage Issues / Concerns

Lake Geraldine



June 2018
Lake Geraldine

North of Crossing 1 (2 x 700 mm dia.)

September 2018

Upstream of Crossing 1 (2 x 700 mm dia.) - Damaged Ends

June 2018
Lake Geraldine

South of Crossing 1 (2 x 700 mm dia.) - Bike and Garbage in the stream

September 2018

Downstream of Crossing 1 (2 x 700 mm dia.) -
Damaged and broken pieces

June 2018
Lake Geraldine

September 2018

North of Crossing 2 (3
x 1200 mm dia.) - Garbage

Upstream of Crossing 2 (3 x 1200 mm dia.) - Garbage infront of the pipe

June 2018
Lake Geraldine

September 2018

South of Crossing 2 (3 x 1200 mm dia.) - Garbage in the stream, pipe not in good shape

Upstream of Crossing 2 (3 x 1200 mm dia.) - Broken End

June 2018
Lake Geraldine

North of Crossing 3 (3 x 1500 mm dia. and 2 x 620 mm dia.) -Garbage right beside the pipe

September 2018

Upstream of Crossing 3 (2 x 1500 mm dia. and 1 x 620 mm dia.) -Deflected Pipe with damaged ends

June 2018
Lake Geraldine

South of Crossing 3 (3 x 1500 mm dia. and 2 x 620 mm dia.) -Bike in the stream

September 2018

Upstream of Crossing 3 (1500 mm dia.) -Garbage and sediment buildup inside the pipe

June 2018
Lake Geraldine

Crossing 4 (2 x 1350 mm dia.) looking North -Pipes half buried in the substrate

September 2018

Upstream of Crossing 4 (2 x 1350 mm dia.) -Tire seen in the stream, pipes half buried in the substrate

June 2018
Lake Geraldine

September 2018

Crossing 4 (2 x 1350 mm dia.) looking South

Downstream of Crossing 4 (2 x 1350 mm dia.) -
Garbage in the stream

June 2018
Lake Geraldine

September 2018

Crossing 5 looking West
-Clear span bridge, 13 m wide over a channel with 7m wide bankful. Unstable bank on downstram left

June 2018
Lake Geraldine

Crossing 6 looking South West - 2 x 1300 mm dia., 7 m long with one 800 mm dia. dia overflow pipe

September 2018

Downstream of Crossing 6 -2 x 1300 mm dia., 7 m long with one 800 mm dia. dia overflow pipe

June 2018
Lake Geraldine

Crossing 6 (2 x 1300 mm dia. and 1 x 800 mm dia. overflow) looking South West -Blokced due to snow

September 2018

Upstream of Crossing 6 (1300 mm dia.) -Deflected Pipe

June 2018
Lake Geraldine

South of Crossing 7 (3200 mm dia.) looking North -Pipe not accessible due to sediment buildup

September 2018

Upstream of Crossing 7 (3200 mm dia.) -Sediment Buildup inside the pipe

June 2018
Lake Geraldine

South of Crossing 7 (3200 mm dia.) looking North -
Sediment Buildup

September 2018

Downstream of Crossing 7 (3200 mm dia.) -Garbage infront of pipe

June 2018
Lake Geraldine

North of Crossing 8 (2 x 1950 mm dia. -22m long) looking Southeast

September 2018

Upstream of Crossing 8 (1950 mm dia.) -Sediment builup infront of pipe

June 2018
Lake Geraldine

September 2018

South of Crossing 8 (2 x 1950 mm dia.) looking North
–Blocked due to snow

Downstream of Crossing 8 (2 x 1950 mm dia.)

June 2018
Lake Geraldine

September 2018

Crossing 9 looking South - Concrete dam, over 1 m drop.
Complete barrier, no flow over structure, water flows through rock debris under structure

Upstream of Crossing 9 -Concrete dam, over 1 m drop. Complete barrier, no flow over structure, water flows through rock debris under structure

June 2018
Lake Geraldine

September 2018

Crossing 9 looking South - Concrete dam, over 1 m drop.
Complete barrier, no flow over structure, water flows through rock debris under structure

Downstream of Crossing 9 -Concrete dam, over 1 m drop.
Complete barrier, no flow over structure, water flows through rock debris under structure

June 2018
Lake Geraldine

September 2018

South of Crossing 10 (2x 1350 mm dia.) looking Downstream –80 m long, steep installation

Upstream of Crossing 10 -2 x 1350 mm dia., 80m long, steep installation

June 2018
Lake Geraldine

September 2018

South of Crossing 10 (2 x 1350 mm dia.) looking Downstream -Blocked due to snow

Downstream of Crossing 10 (2 x 1350 mm dia.)

June 2018
Lake Geraldine

Upstream of Crossing 10 Looking North - Wooden box identified on the stream

September 2018

Upstream of Crossing 10 (1350 mm dia.) -Bars in the pipe

Stantec

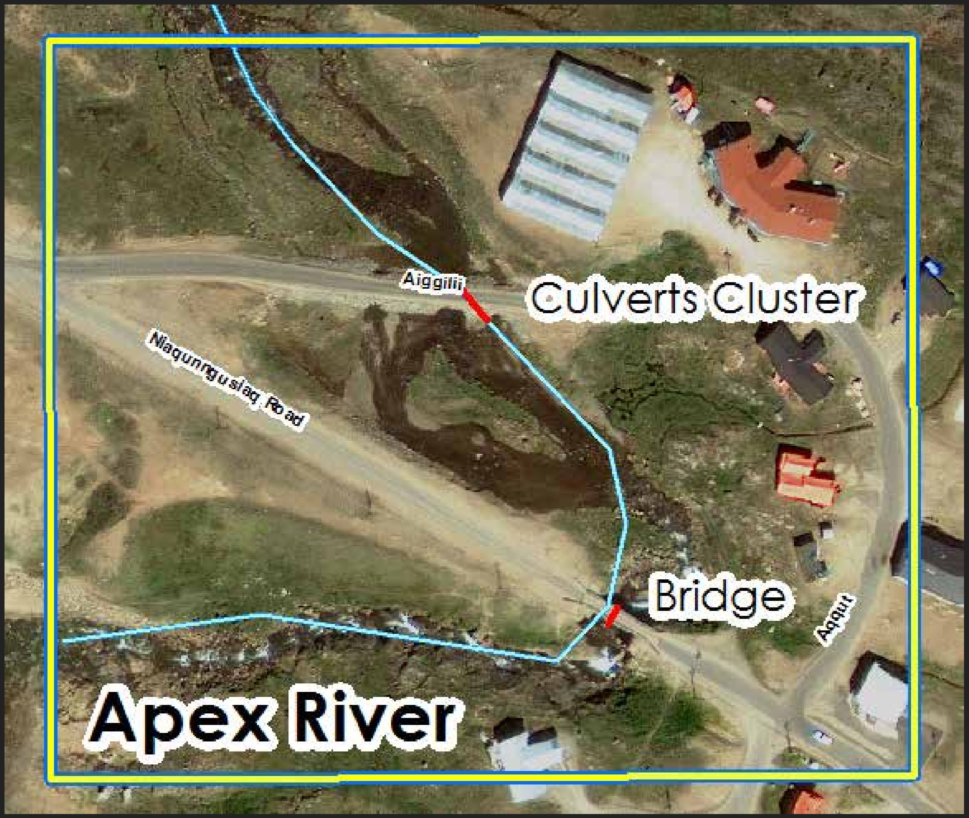
Lake Geraldine

Summary

Lake Geraldine									
Crossing#	Type	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
X1a		NE	SW	700	Corrugated Steel	Circular	Projected	Y	Torn out edges, boulder obstructing the flow. Fine and gravel deposits identified in the Culvert.
X1b		NE	SW	700	Corrugated Steel	Circular	Projected	Y	Torn out edges, surface corrosion on floor
X2a		NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Deformed edges, Surface corrosion on floor.
X2b		NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Significant fine deposits at the downstream end. Culvert not usable
X2c		NE	SW	1200	Corrugated Steel	Circular	Projected	Y	Torn out edges, roof sag identified at downstream end. Fine and gravel deposits observed at the upstream end.
X3a		N	S	1500	Corrugated Steel	Circular	Projected	Y	Cardboard and barrel identified in stream, blocked Culvert due to fine and gravel deposits
X3b		N	S	1500	Corrugated Steel	Circular	Projected	Y	Surface corrsoion on floor, Bicycle identified in stream at the downstream end, Fine and gravel deposits observed.
X3c		N	S	1500	Corrugated Steel	Circular	Projected	Y	Deformed Culvert, elliptical in shape
X3d		N	S	620	Corrugated Steel	Circular	Projected	N	Deformed Culvert, with multiple bulging along the length of Culvert
X3e		N	S	620	Corrugated Steel	Circular	Projected	N	Minor deformities at edges
X4a		N	S	1350	Corrugated Steel	Circular	Projected	Y	Culvert half buried in the substrate, significant roof sagging, deformed Culvert
X4b		N	S	1350	Corrugated Steel	Circular	Projected	Y	Culvert half buried in the substrate, significant roof sagging, multiple circumferential cracks, deformed Culvert
X5	Bridge	NW	SE						Unstable bank on downstream left
X6a		NW	SE	1300	Corrugated Steel	Circular	Projected	Y	
X6b		NW	SE	800	Corrugated Steel	Circular	Projected	N	Deformed Culvert, elliptical in shape
X6c		NW	SE	1300	Corrugated Steel	Circular	Projected	Y	Deformed at dowstream end, multiple roof sags identified along the length of Culvert
X7	Footings	NW	SE	3200	Wooden Cribs	Arch	Projected	Y	Significant amount of fine and rock deposits in the Culvert. Culvert inoperable.
X8a		N	S	1950	Corrugated Steel	Circular	Projected	N	
X8b		N	S	1950	Corrugated Steel	Circular	Projected	Y	
X9	Dam	N	S						Concrete wingwall is broken ,and not tied in long enough. Undermined structure. Further degradation of dam couold result in possible collapse.
X10a		N	S	1350	Corrugated Steel	Arch	Beveled	N	Culvert significantly corroded at the floor, minor gravel deposits observed
X10b		N	S	1350	Corrugated Steel	Arch	Beveled	N	Culvert significantly corroded at the floor, minor gravel deposits observed

Proponent's Drainage Issues / Concerns

Apex River



June 2018

September 2018

Apex River

Road of Interest Looking Northwest

June 2018

September 2018

Apex River

Left Side of Road of Interest - Looking West

June 2018 **September 2018**

Apex River

Eastern most culvert on south side of road - Blocked Pipe

June 2018

Apex River

Cluster 1 of 4 Culverts (4 x 9400 mm dia.) on south side of road - Blocked due to snow

September 2018

Cluster 1 of 4 Culverts (4 x 9400 mm dia.) on north side of road - Garbage and broken pieces infront of pipe

June 2018

Apex River

Cluster 2 of 3 Culverts (3 x 1100 mm dia.) on south side of road - Blocked due to snow

September 2018

Cluster 2 of 3 Culverts (3 x 1100 mm dia.) on south side of road - Deflected on the top end

June 2018

Apex River

Cluster 2 (3 x 1100 mm dia.) taken from North side of road - Blocked due to snow

September 2018

Cluster 2 (3 x 1100 mm dia.) taken from South side of road - Damaged Ends

June 2018

September 2018

Apex River

Cluster 1 (4 x 9400 mm dia.) taken from north side of road - Blocked due to snow

June 2018 **September 2018**

Apex River

Solo Culvert (1100 mm dia.) taken from North side of road

June 2018

Apex River

Stream running on
South side of road

September 2018

June 2018 **September 2018**

Apex River

Road of Interest - Looking West

June 2018

September 2018

Apex River

North side of Cluster 3

June 2018

September 2018

Apex River

Northside of Cluster 3 - Deflected Pipe due to heavy loads

June 2018

Apex River

September 2018

Southside of Cluster 3 - Debris due to sedimentation in the culvert

Apex River

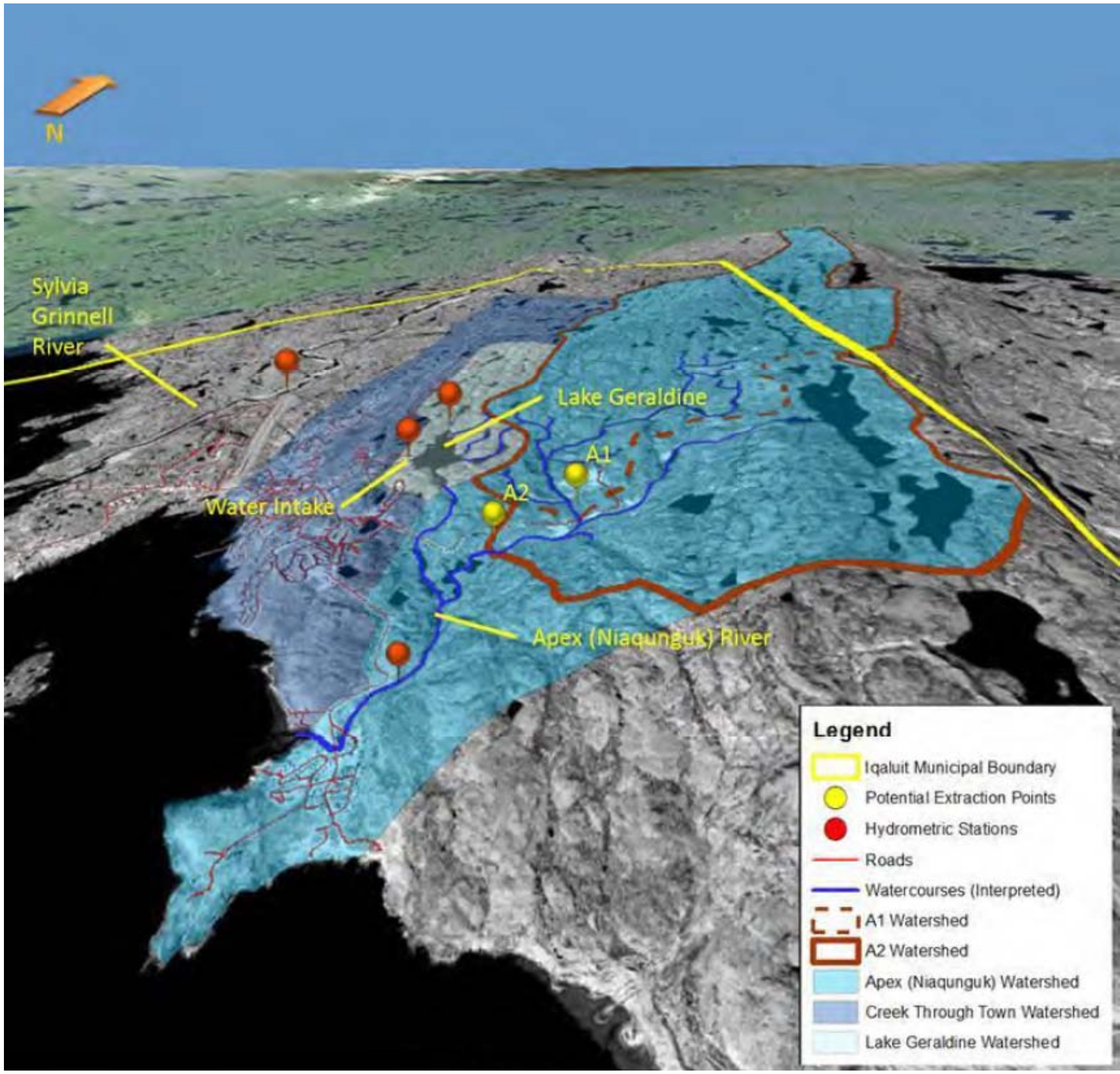
Summary

Apex River								
Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
Ia				Corrugated Steel	Circular	Projected	N	Broken Culvert, Surface corrosion on the floor
C1a	N	S	9400	Corrugated Steel	Circular	Projected	N	Deformed Edges, Surface corrosion on floor, minor roof sagging
C1b	N	S	9400	Corrugated Steel	Circular	Projected	N	Deformed Culvert, appears oval in shape, significant roof sagging observed in the middle. Surface corrosion on floor.
C1c	N	S	9400	Corrugated Steel	Circular	Projected	N	Surface corrosion on floor, torn out edges
C1d	N	S	9400	Corrugated Steel	Circular	Projected	N	Surface corrosion on floor, torn out edges
C2a	N	S	1100	Corrugated Steel	Circular	Projected	Y	Torn out edges, Surface corrosion on floor
C2b	N	S	1100	Corrugated Steel	Circular	Projected	Y	Torn out edges, Surface corrosion on floor, gravel deposits
C2c	N	S	1100	Corrugated Steel	Circular	Projected	Y	Torn out edges, Surface corrosion on floor and side walls
C3a	N	S		Corrugated Steel	Circular	Projected	N	Surface corrosion on floor, roof sagging in the middle
C3b	N	S		Corrugated Steel	Circular	Projected	Y	Surface corrosion on floor, worn out ends
C3c	N	S		Corrugated Steel	Circular	Projected	N	Deformed Culvert, Roof sags identified at multiple locations

Historical Climate Data Review

Data Review

- Precipitation
- IDF (Intensity-Duration-Frequency) Curves
- Snowfall Depths
- Media Reports
- Flooding
- Other Reports & Literature



Historical Climate Data Collected

Climate ID	Element Name	Start Year	End Year
2402590	DAILY MAXIMUM TEMPERATURE	1946	2008
2402590	DAILY MINIMUM TEMPERATURE	1946	2008
2402590	DAILY MEAN TEMPERATURE	1946	2008
2402590	SIX HOURLY PRECIPITATION	1950	2007
2402590	DAILY TOTAL RAINFALL	1946	2002
2402590	DAILY TOTAL SNOWFALL	1946	2002
2402590	DAILY TOTAL PRECIPITATION	1946	2007
2402590	SNOW ON GROUND	1955	2007
2402590	DAY WITH THUNDERSTORMS	1955	2002
2402590	DAY WITH FREEZING RAIN	1955	2008
2402590	DAY WITH HAIL	1955	2002
2402590	GREATEST RAINFALL	1946	2002
2402590	DATE OF GREATEST RAINFALL (EARLIEST)	1946	2002
2402590	GREATEST SNOWFALL	1946	2002
2402590	DATE OF GREATEST SNOWFALL (EARLIEST)	1946	2002
2402590	GREATEST PRECIPITATION	1946	2007
2402590	DATE OF GREATEST PRECIPITATION (EARLIEST)	1946	2007
2402590	DIRECTION OF EXTREME GUST (16PTS) TO DEC1976	1952	1976
2402590	DEW POINT TEMPERATURE	1953	2014
2402590	WIND SPEED	1953	2014
2402590	DRY BULB TEMPERATURE	1953	2014
2402590	WET BULB TEMPERATURE	1953	2014
2402590	RELATIVE HUMIDITY	1953	2014
2402590	TOTAL CLOUD OPACITY	1953	2014
2402590	TOTAL CLOUD AMOUNT	1953	2014
2402590	WEATHER INDICATOR	1953	2014
2402590	THUNDERSTORMS (T)	1963	2011
2402590	RAIN (R)	1953	2013
2402590	RAIN SHOWERS (RW)	1953	2013
2402590	DRIZZLE (L)	1953	2013
2402590	FREEZING RAIN (ZR)	1953	2013
2402590	FREEZING DRIZZLE (ZL)	1953	2013
2402590	SNOW (S)	1953	2014
2402590	SNOW GRAINS (SG)	1953	2012
2402590	ICE CRYSTALS (IC)	1953	2014
2402590	ICE PELLETS (IP)	1953	2010
2402590	ICE PELLETS SHOWERS (IPW)	1953	2008
2402590	SNOW SHOWERS (SW)	1953	2013
2402590	SNOW PELLETS (SP)	1956	2013
2402590	HAIL (A)	1964	1964
2402590	HOURLY PRECIPITATION	1982	2002

Historical Climate Data Collected

2402590	ADJUSTMENT FACTOR	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 5 MIN	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 10 MIN	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 15 MIN	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 30 MIN	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 1 HOUR	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 2 HOURS	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 6 HOURS	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 12 HOURS	1982	2002
2402590	BRIGHT SUNSHINE	1957	2006
2402590	CHART CHANGE HOUR	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 24 HOURS	1982	1990
2402591	DAILY MAXIMUM TEMPERATURE	2008	2015
2402591	DAILY MINIMUM TEMPERATURE	2008	2015
2402591	DAILY MEAN TEMPERATURE	2008	2015
2402591	DAILY MAXIMUM RELATIVE HUMIDITY	2008	2013
2402591	DAILY MINIMUM RELATIVE HUMIDITY	2008	2013
2402591	SIX HOURLY PRECIPITATION	2010	2015
2402591	DAILY TOTAL RAINFALL	2015	2015
2402591	DAILY TOTAL SNOWFALL	2015	2015
2402591	DAILY TOTAL PRECIPITATION	2010	2015
2402591	SNOW ON GROUND	2015	2015
2402591	DAY WITH THUNDERSTORMS	2015	2015
2402591	DAY WITH FREEZING RAIN	2008	2015

2402591	DAY WITH HAIL	2015	2015
2402591	DEW POINT TEMPERATURE	2008	2015
2402591	WIND SPEED	2008	2015
2402591	WEATHER INDICATOR	2008	2015
2402591	RAIN (R)	2008	2015
2402591	DRIZZLE (L)	2008	2015
2402591	FREEZING RAIN (ZR)	2008	2015
2402591	FREEZING DRIZZLE (ZL)	2008	2015
2402591	SNOW (S)	2008	2015
2402591	PRECIPITATION - UNCLASSIFIED TYPE (P)	2014	2015
2402592	DAILY MAXIMUM TEMPERATURE	2004	2018
2402592	DAILY MINIMUM TEMPERATURE	2004	2018
2402592	DAILY MEAN TEMPERATURE	2004	2018
2402592	DAILY MAXIMUM RELATIVE HUMIDITY	2004	2013
2402592	DAILY MINIMUM RELATIVE HUMIDITY	2004	2013
2402592	SIX HOURLY PRECIPITATION	2004	2018
2402592	DAILY TOTAL RAINFALL	2005	2018
2402592	DAILY TOTAL SNOWFALL	2005	2018
2402592	DAILY TOTAL PRECIPITATION	2004	2018
2402592	SNOW ON GROUND	2004	2018
2402592	DAY WITH THUNDERSTORMS	2015	2018
2402592	DAY WITH THUNDERSTORMS	2005	2007
2402592	DAY WITH FREEZING RAIN	2015	2018
2402592	DAY WITH FREEZING RAIN	2005	2007
2402592	DAY WITH HAIL	2015	2018
2402592	DAY WITH HAIL	2005	2007
2402592	GREATEST RAINFALL	2005	2007
2402592	DATE OF GREATEST RAINFALL (EARLIEST)	2005	2007
2402592	GREATEST SNOWFALL	2005	2007
2402592	DATE OF GREATEST SNOWFALL (EARLIEST)	2005	2007
2402592	GREATEST PRECIPITATION	2005	2007
2402592	DATE OF GREATEST PRECIPITATION (EARLIEST)	2005	2007

Historical Climate Data Collected

2402592	DEW POINT TEMPERATURE	2004	2018
2402592	WEATHER INDICATOR	2004	2015
2402592	HOURLY PRECIPITATION AMOUNT	2004	2018
2402592	PRECIPITATION AMOUNT – 15 MINUTES	2008	2018
2402592	WIND SPEED AT 2 M – 15 MINUTE INTERVAL	2008	2018
2402592	SNOW DEPTH (AT MINUTE 60)	2004	2018
2402592	SNOW DEPTH (AT MINUTE 15)	2015	2018
2402592	SNOW DEPTH (AT MINUTE 30)	2015	2018
2402592	SNOW DEPTH (AT MINUTE 45)	2015	2018
2402594	DAILY MAXIMUM TEMPERATURE	1997	2007
2402594	DAILY MINIMUM TEMPERATURE	1997	2007
2402594	DAILY MEAN TEMPERATURE	1997	2007
2402594	DAILY TOTAL RAINFALL	1997	2016
2402594	DAILY TOTAL SNOWFALL	1997	2016
2402594	DAILY TOTAL PRECIPITATION	1997	2016
2402594	SNOW ON GROUND	1997	2016
2402594	DAY WITH THUNDERSTORMS	1997	2007
2402594	DAY WITH THUNDERSTORMS	2012	2014
2402594	DAY WITH FREEZING RAIN	1997	2015
2402594	DAY WITH HAIL	1997	2007
2402594	DAY WITH HAIL	2015	2015

2402594	GREATEST RAINFALL	1997	2007
2402594	DATE OF GREATEST RAINFALL (EARLIEST)	1997	2007
2402594	GREATEST SNOWFALL	1997	2007
2402594	DATE OF GREATEST SNOWFALL (EARLIEST)	1997	2007
2402594	GREATEST PRECIPITATION	1997	2007
2402594	DATE OF GREATEST PRECIPITATION (EARLIEST)	1997	2007
2402596	DEW POINT TEMPERATURE	2014	2018
2402596	WIND SPEED	2014	2018
2402596	WEATHER INDICATOR	2014	2018
2402596	RAIN (R)	2014	2017
2402596	RAIN SHOWERS (RW)	2014	2017
2402596	DRIZZLE (L)	2014	2017
2402596	FREEZING RAIN (ZR)	2014	2017
2402596	FREEZING DRIZZLE (ZL)	2015	2017
2402596	SNOW (S)	2014	2018
2402596	SNOW GRAINS (SG)	2015	2017
2402596	ICE CRYSTALS (IC)	2014	2018
2402596	ICE PELLETS (IP)	2014	2017
2402596	SNOW SHOWERS (SW)	2014	2017
2402596	SNOW PELLETS (SP)	2016	2017

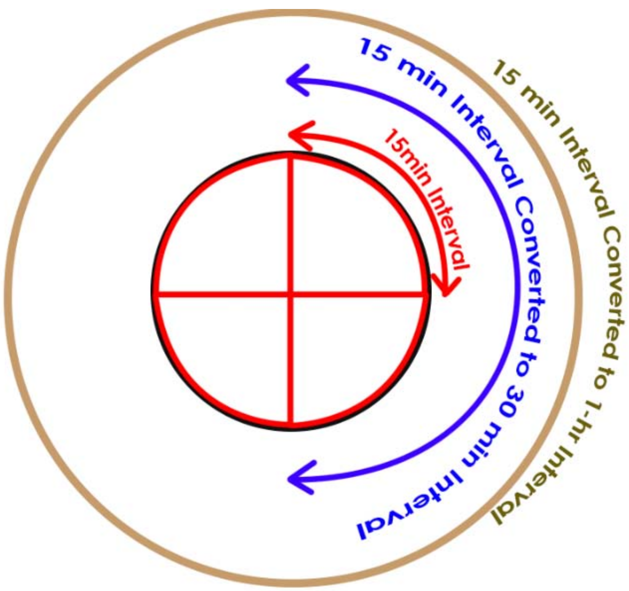
Precipitation

- Daily Records (1946-2018, 72 Years)
- 12-hour Records (1950-2018, 68 Years)
- 6-hour Records (1950-2018, 68 Years)
- 2-hour Records (1982-2018, 36 Years)
- 1-hour Records (1982-2018, 36 Years)
- 15-minute Records (1982-2018, 10 Years)
- 10-minute Records (1982-2002, 10 Years)
- 5-minute Records (1982-2002, 10 Years)

Station	Filename	Years	Comments	lest Interval Avai
2402590	DLY02	1992 - 2007	Only has total rainfall for a day and 6 hourly precipitations for 6 hours in the morning, Max of daily and 6 hourly taken, daily rainfall for year 1998 and after until 2007 was recorded 0, probably due to fault in sensoir	6 hour from 6am to 12pm only
2402591	DLY02	2008-2015	6 hourly converted into 12 hour and 24 hour, 6 hourly data for years 2008, 2009 and 2015 shows zero values	6 hour for entire day
2402592	DLY02	2004-2018	6 hourly converted into 12 hour and 24 hour	6 hour for entire day
2402590	DLY03	1982-2002	Doesnot have continuous data	5 min
2402590	DLY04	1950-1997	6 hourly converted into 12 hour and 24 hour	6 hour for entire day
2402592	DLY04	2005-2007	Only has total rainfall for a day and no 6 hourly precipitations	Daily
2402594	DLY04	1997-2007	Only has total rainfall for a day and no 6 hourly precipitations	Daily
2402594	DLY44	2004-2016	Only has total rainfall for a day and no 6 hourly precipitations	Daily
2402590	HLY01	1953-2014	Doesnot have any precipitation data	N/A
2402591	HLY01	2008-2015	Doesnot have any precipitation data	N/A
2402592	HLY01	2008-2018	15 min converted to 30min, 1h, 2h, 6h, 12h, and 24h.	15min
		2004-2018	60min converted to 2h, 6h, 12h, and 24h.	60min
2402596	HLY01	2014-2018	Doesnot have any precipitation data	N/A
2402590	HLY03	1982-2002	Hourly Rainfall converted to 2h, 6h, 12h and 24h	Hour
2402590	HLY10	1957-2006	Lists SUNSHINE only	N/A
2402590	MLY04	1946-2007	Only shows the max precipitation/snow/rain in a month	Month
2402592	MLY04	2005-2007	Only shows the max precipitation/snow/rain in a month	Month
2402594	MLY04	1997-2007	Only shows the max precipitation/snow/rain in a month	Month

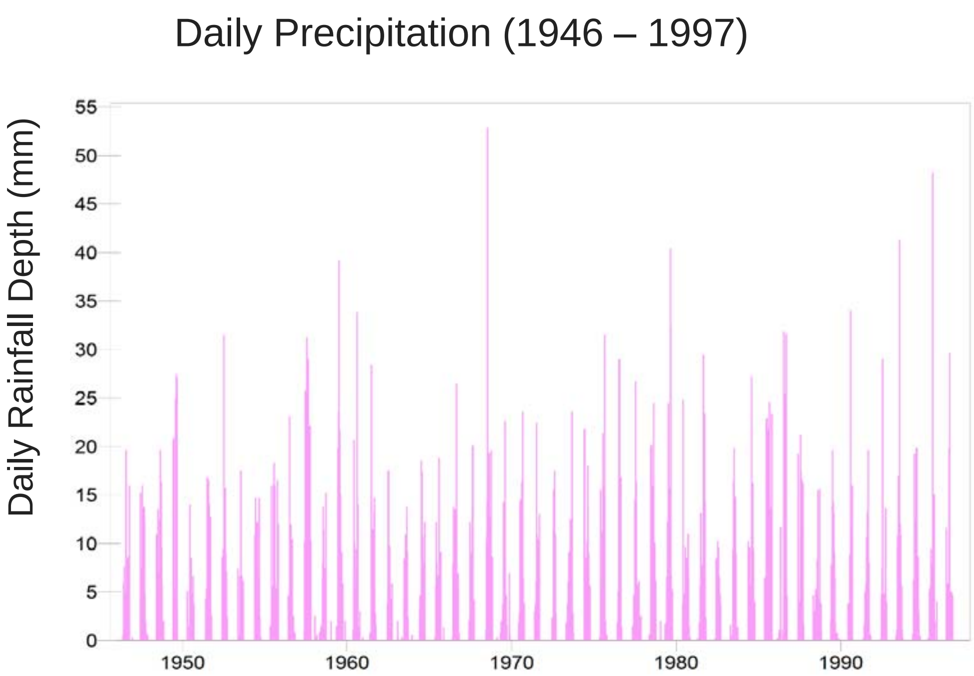
Precipitation Data Conversion

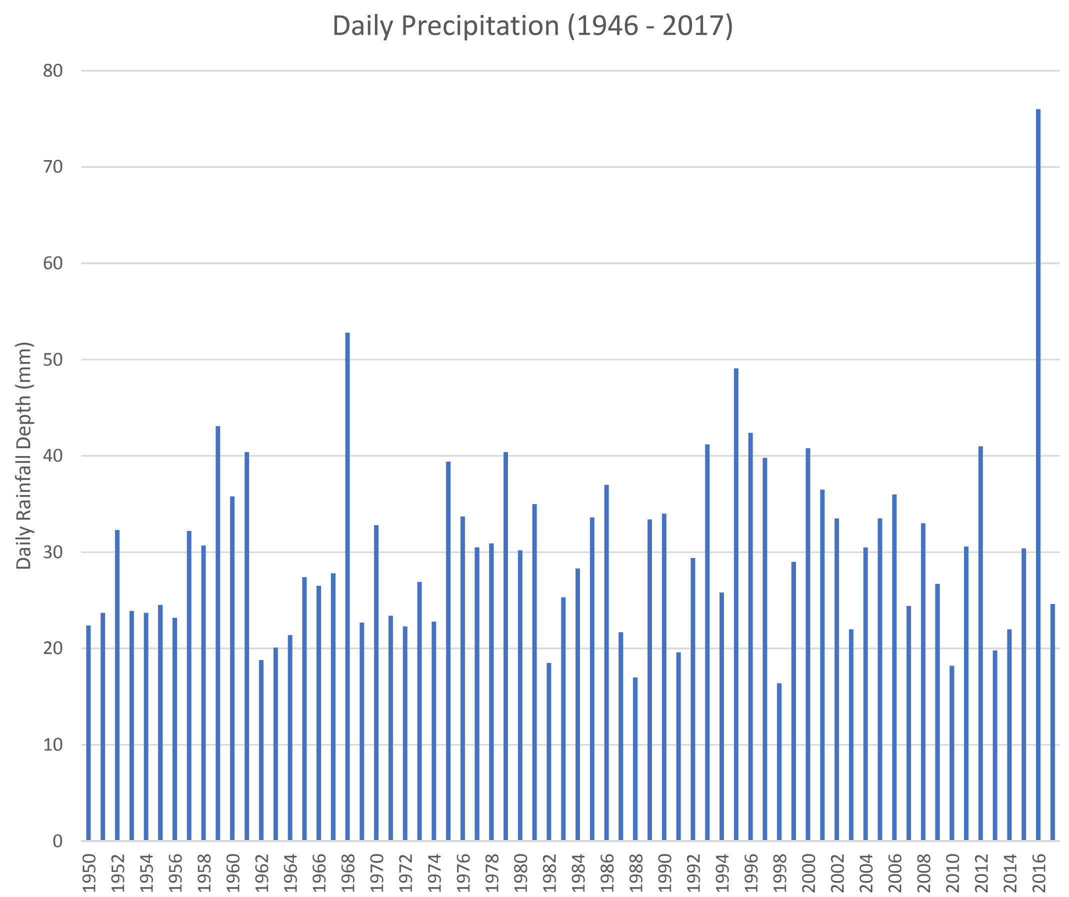
- Analyzed Data to get the maximum precipitation values in a given year
- Converted precipitation data compared with the existing Data



File	DLY04	DLY04	DLY04		HLY03		HLY01	HLY01		
Station	2402590	2402590	2402590		2402590		2402592	2402592		
Based on Interval of	24h	24h	6h		1h		1h	15min	Max 24h	
Interval	24h	24h	24h		24h		24h	24h		
Method	Max of element 10	Max of element 12	Added sections 6,7,8 and 9	Comparison	Built from Element 123 only	Comparison	Built from Element 262 only	Added sections 263-266		w/o outliers
1966	26.4	26.4	26.5	0%					26.5	26.5
1967	20.1	20.1	27.8	-28%					27.8	27.8
1968	52.8	52.8	52.8	0%					52.8	52.8
1969	22.6	22.6	22.7	0%					22.7	22.7
1970	23.6	23.6	32.8	-28%					32.8	32.8
1971	22.4	22.4	23.4	-4%					23.4	23.4
1972	17.5	19.1	22.3	-14%					22.3	22.3
1973	23.6	23.9	26.9	-11%					26.9	26.9
1974	21.8	21.8	22.8	-4%					22.8	22.8
1975	31.5	31.5	39.4	-20%					39.4	39.4
1976	29	32	33.7	-5%					33.7	33.7
1977	26.7	26.7	30.5	-12%					30.5	30.5
1978	24.4	24.4	30.9	-21%					30.9	30.9
1979	40.4	40.4	40.4	0%					40.4	40.4
1980	24.8	30.2	30.2	0%					30.2	30.2
1981	29.4	29.4	35	-16%					35	35
1982	10.2	18.5	18.5		14.6				18.5	18.5
1983	19.8	19.8	24.1		25.3	5%			25.3	25.3
1984	27.2	27.2	28		28.3	1%			28.3	28.3
1985	24.5	27.2	33.6		30.2	-10%			33.6	33.6
1986	31.8	31.8	36		37	3%			37	37
1987	21.2	21.2	21.2		21.7	2%			21.7	21.7
1988	15.6	17	17		15.6	-8%			17	17
1989	19.6	22.4	33.2		33.4	1%			33.4	33.4
1990	34	34	34		34	0%			34	34
1991	19.6	19.6	19.6		19.6	0%			19.6	19.6
1992	29	29	29		29.4	1%			29.4	29.4
1993	41.2	41.2	41.2		41	0%			41.2	41.2
1994	19.8	19.8	23.6		25.8	9%			25.8	25.8
1995	48.2	48.2	48.2		49.1	2%			49.1	49.1
1996	29.6	29.6	41.8		42.4	1%			42.4	42.4
1997	0	6.6	8.4		37.3				39.8	39.8

Daily Precipitation





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Summary

Precipitation Data

YEAR	5min	10min	15min	30min	1h	2h	6h	12h	24h
1946									21.3
1947									16
1948									19.6
1949									27.4
1950							10.2	19.9	22.4
1951							16.3	22.7	23.7
1952							14.5	28.5	32.3
1953							15.2	17.7	23.9
1954							9.7	13.5	23.7
1955							15	17.8	24.5
1956							10.7	17.8	23.2
1957							17	28.4	32.2
1958							13.7	23.9	30.7
1959							15.7	24.3	43.1
1960							17.8	33.8	35.8
1961							15	25.7	40.4
1962							11.7	15.3	18.8
1963							9.7	14.5	20.1
1964							12.2	18.6	21.4
1965							14	24.4	27.4
1966							17.3	25.2	26.5
1967							20.1	27	27.8
1968							31.5	49	52.8
1969							13.5	19.9	22.7
1970							15.2	22.6	32.8
1971							9.4	17.8	23.4
1972							8.6	14.5	22.3
1973							10.4	17.1	26.9
1974							9.4	13.7	22.8
1975							21.6	28	39.4
1976							15.7	30.9	33.7
1977							16.3	19.3	30.5
1978							14	22.2	30.9
1979							19.2	30.2	40.4
1980							15.7	24.1	30.2
1981							20	26.2	35
1982	1.6	3.1	4.2	5.8	6.9	8	14.4	13.6	18.5
1983	1	1	1.4	2.3	4.5	7.4	19.6	19.6	25.3
1984	1.1	2.1	2.5	4.2	5.1	10	20	26.2	28.3

YEAR	5min	10min	15min	30min	1h	2h	6h	12h	24h
1982	1.6	3.1	4.2	5.8	6.9	8	14.4	13.6	18.5
1983	1	1	1.4	2.3	4.5	7.4	19.6	19.6	25.3
1984	1.1	2.1	2.5	4.2	5.1	10	20	26.2	28.3
1985	1.3	1.9	2.5	4.8	7.6	10.1	36	28	33.6
1986	0.9	1.6	2.4	4.8	8.4	13.2	30.2	29.7	37
1987	1.1	1.5	2.3	4	6.3	10.1	19.2	19.2	21.7
1988	0.9	1.4	1.9	3.3	6	9.4	14.2	15.6	17
1989	2.9	5.7	6.5	8.3	9.9	12.1	23.7	24.6	33.4
1990	1.4	1.8	2.8	4.8	8.4	9.6	19.1	28.3	34
1991	1.6	2	3.1	4.8	6.8	8.4	15.8	19.6	19.6
1992	1	1.4	1.8	3.2	4.4	7.5	18.2	23.9	29.4
1993	0.8	1.3	1.6	2.7	4.9	9	16.8	30.1	41.2
1994	1.1	1.3	1.8	3.1	4.9	8.6	16.8	19.5	25.8
1995	2.5	5.1	7.4	8.3	15.5	22.2	30.4	42	49.1
1996	0.6	1.2	1.8	3.9	5.9	10	27.2	36	42.4
1997	0.7	1	1.4	2.2	4.4	7	16.7	27.4	39.8
1998	1	1	1	1.1	1.6	2.6	7	4.8	16.4
1999	0.6	0.6	0.6	0.8	1.4	2.2	12	8	29
2000	1	1.7	1.9	2.9	5.8	10.4	22.5	33.6	40.8
2001	1	1.8	1.9	2.3	4.1	5.4	12	14.3	36.5
2002	1	1.3	1.7	3.1	4.6	6.4	15.9	22.9	33.5
2003							10		22
2004							16		30.5
2005					12.9	12.9	12.9	12.9	33.5
2006					2.8	5.6	9	36	36
2007					5.1	10.2	17.6	21	24.4
2008				6.6	6.6	7.8	25	25.3	33
2009			1.6	3	5.4	9.5	19	24.7	26.7
2010			2.5	4.4	6.7	9.7	15	18	18.2
2011			2.2	4.3	5.3	8.3	11	16	30.6
2012			3.2	5.5	8.4	12.2	33.4	22	41
2013			7.2	10.4	11	11.5	14.5	18.1	19.8
2014			2.7	4.3	5.5	7.6	25.5	32	22
2015			7.9	7.9	7.9	9.1	23.2	20.3	30.4
2016			2.5	4.9	8.3	13.3	33.7	43	76
2017			2.5	3.5	5	7	12.7	19	24.6

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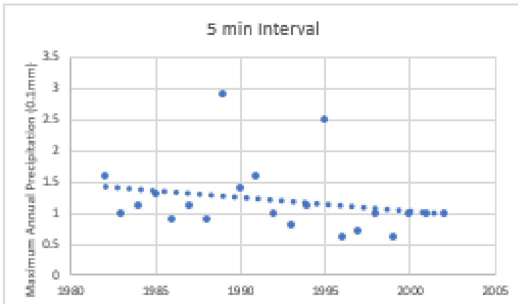
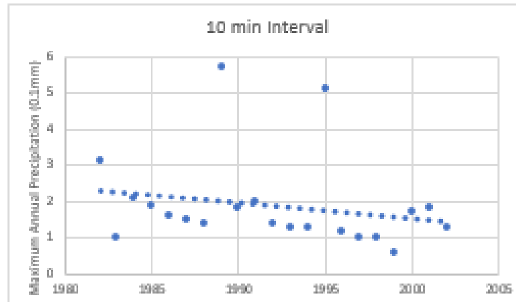
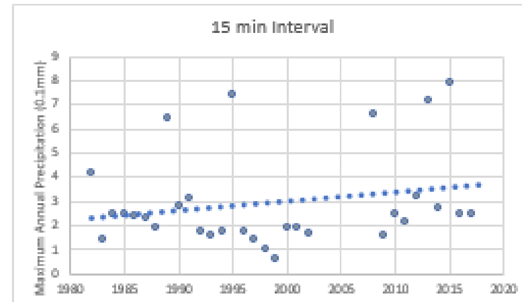
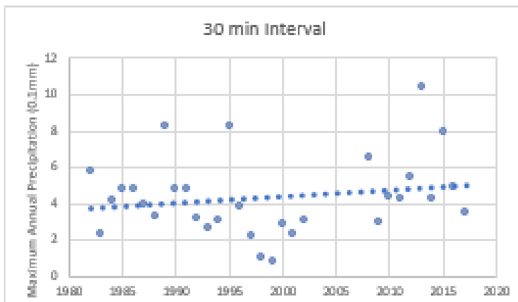
Precipitation Data

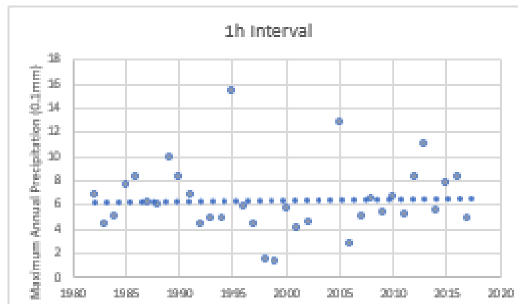
Summary – Trends

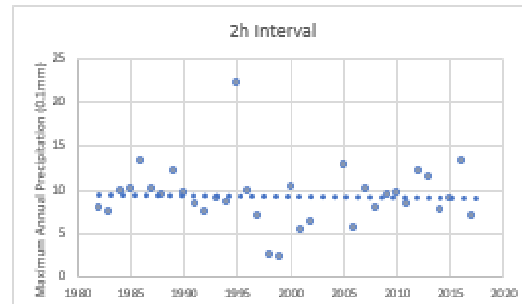


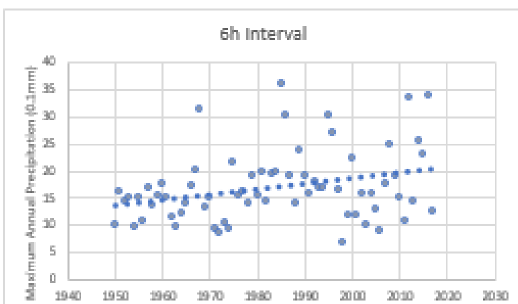


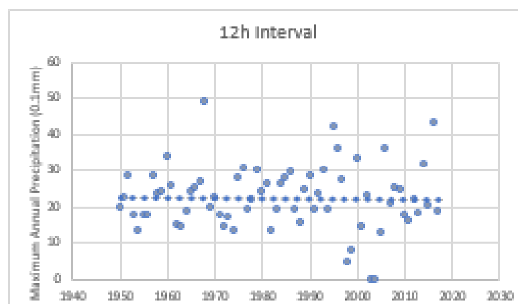


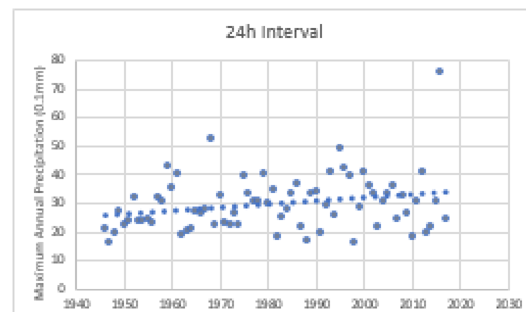




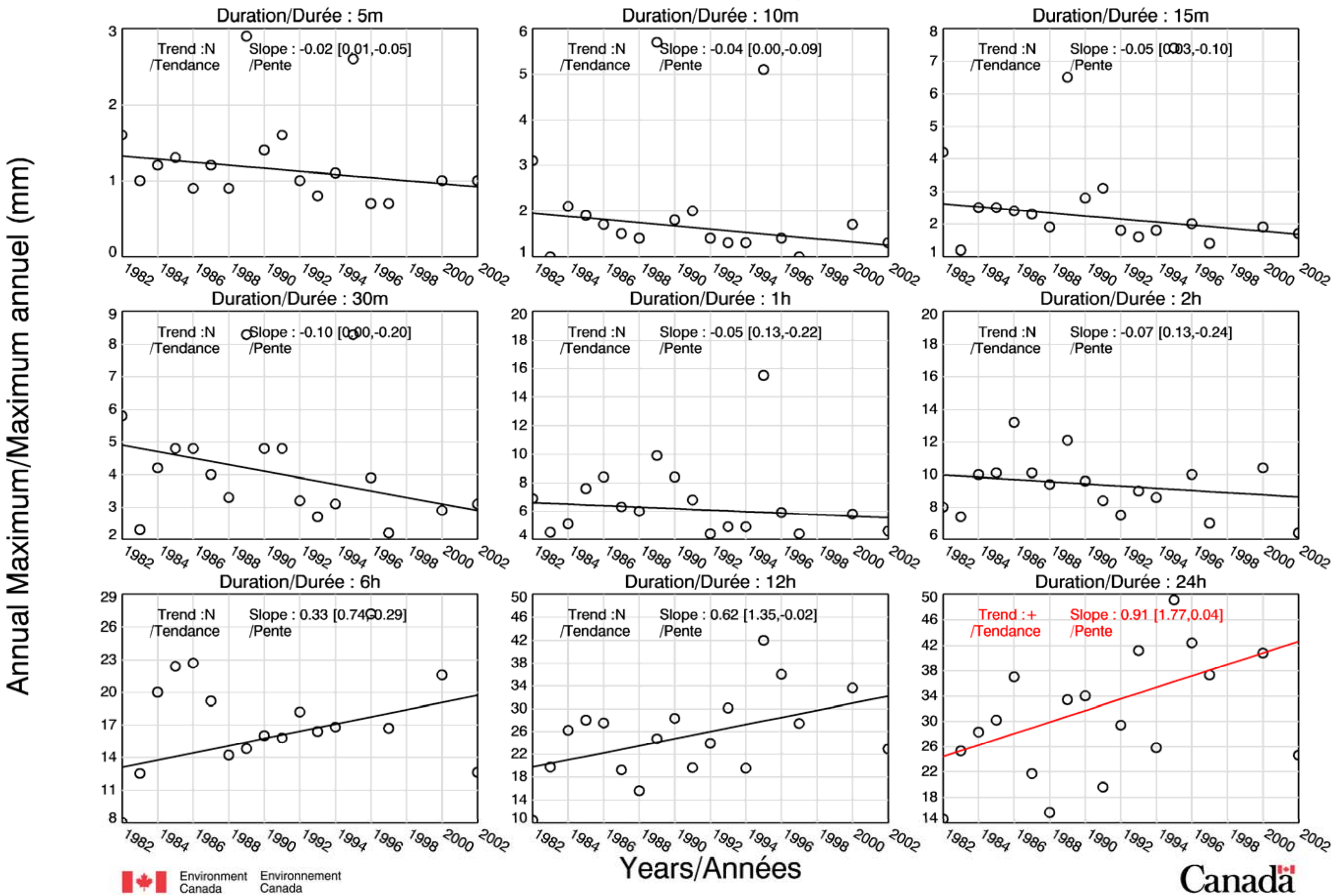








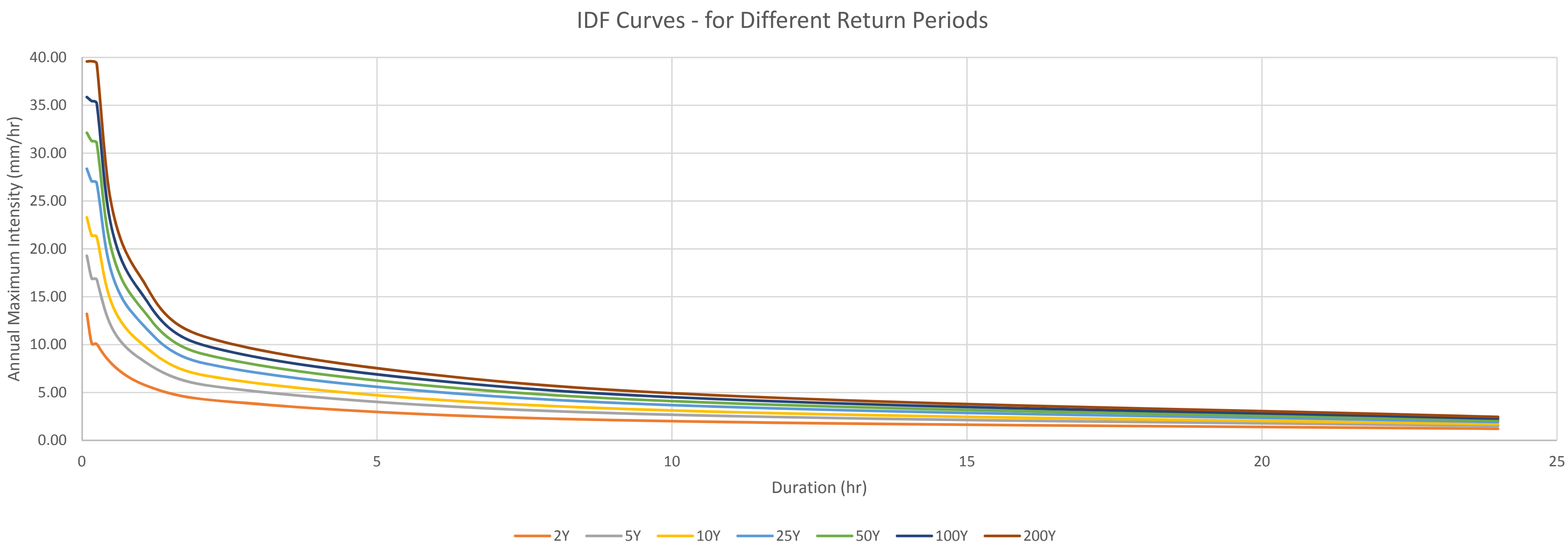
Trend/Tendance : IQALUIT A, NU 2402590



Historical Climate Data Review

IDF Curves

IDF Curves – Gumbel Estimate



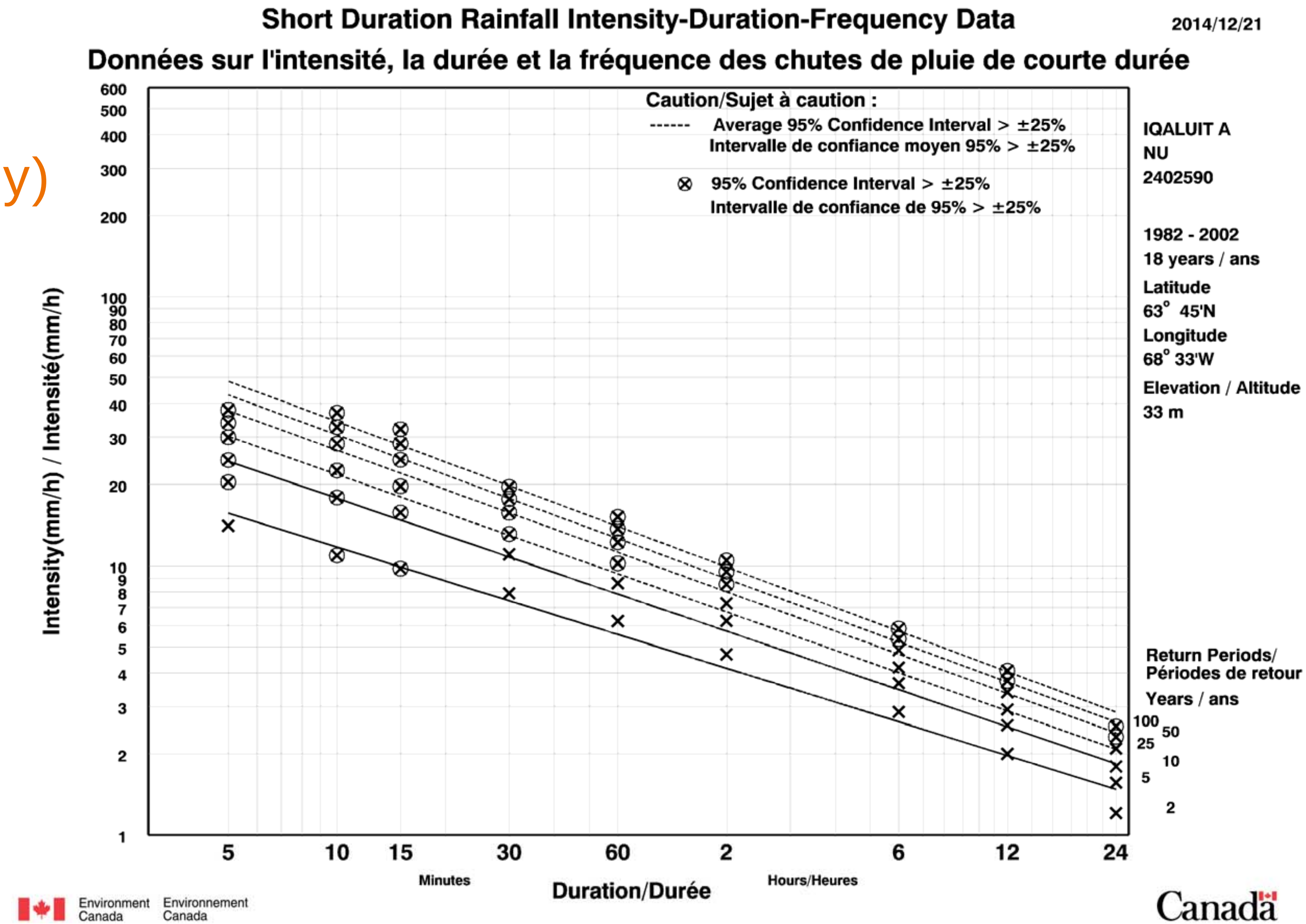
IDF Parameters

Rate = a*(t-c)^b	Return Frequency						
Parameters	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
a	42.80	140.98	239.19	401.74	546.08	714.81	898.34
b	-7.83	-17.54	-21.33	-24.80	-26.72	-28.39	-29.74
c	-0.47	-0.63	-0.70	-0.77	-0.80	-0.83	-0.86
R^2	0.992	0.993	0.989	0.983	0.980	0.977	0.975

Rate = a*(t-c)^b where t= duration in minutes

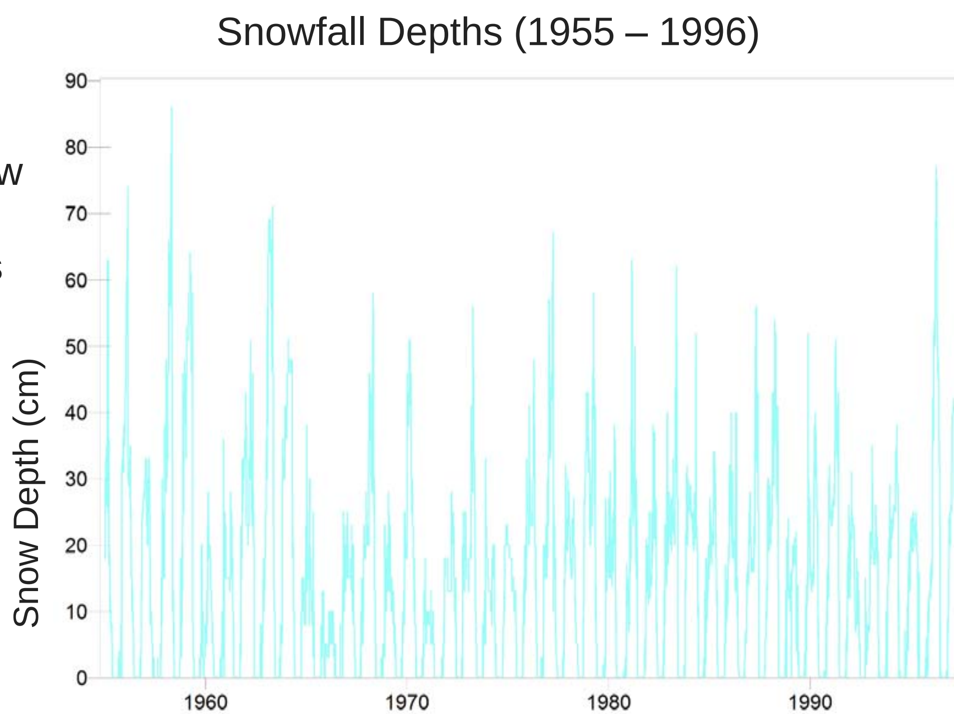
IDF Curves (Intensity-Duration-Frequency)

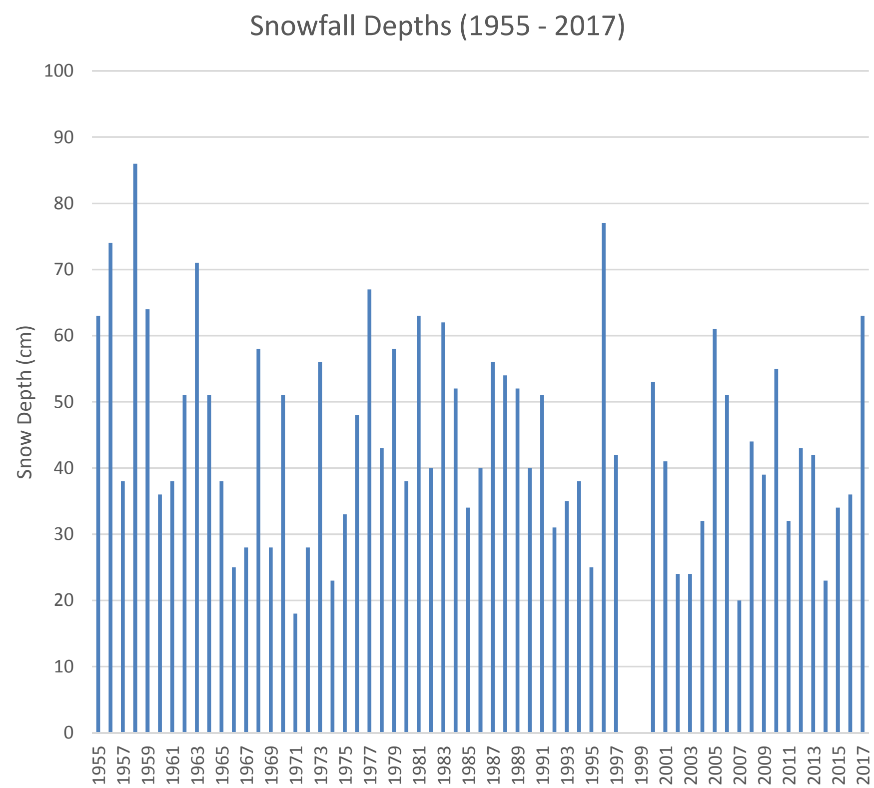
Data available 1982-2002



Snowfall Depths

Note: the peak snow depth in 2018 was 31 cm





Framework for Asset Management Plan

Framework

- Review/Collect Asset Information
  - Existing Information Sources
  - Identify and Describe Assets – Culvert Map
  - Data collection through Field Inspections – Culvert Sizes
  - Condition Assessment – Assign Ranks
  - Performance Monitoring
  - Valuation Data
- Establish Levels of Service
  - Identify future flow demands
  - Establish measures and Targets

Framework

- Lifecycle Management
  - Estimate Remaining Life
- Operations and Maintenance
  - Schedule Operation Activities
  - Maintain infrastructure Risk Register
  - Define Asset Hierarchy
- Renewal / Replacement Program
  - Based on the asset ranking and hierarchy

Design Standards Updates

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Updates

Design Standards

H.3.1 Flow Rates

1. The stormwater management system shall be designed as a separate system. Effluent from sanitary sewers or any potentially contaminated drainage shall not be discharged in the ditches or swales.
2. ~~The Minor System shall be designed to accommodate the runoff generated from a 1:5 year or more frequent rainfall event without overflowing swales or ditches~~The five-year rainfall intensity table for the City shall be used for minor storm sewers. Duration time shall equal inlet time plus flow time.
3. The Rational Method shall be used in estimating flows for the design of storm ditches and swales for areas less than 10~~65~~ hectares.

Q	=	CIA / 360
where Q	=	the design peak flow rate in cubic metres per second
I	=	the intensity of rainfall in millimetres per Hour
A	=	the contributing area in hectares
C	=	the runoff coefficient

4. Minimum runoff coefficients shall be according to the following table:

Land Use/Surface Characteristics	Runoff Coefficient, C
Open Space	0.15
Residential Lots	0.35~~2~~
Industrial	0.70
Commercial	0.70
Multiple Family	0.70
Undeveloped Land	0.1
Pavement, concrete, buildings	0.95
Gravel Roadways	0.3

5. Due to the large variation in lot sizes for commercial and industrial areas, a weighted runoff coefficient for these types of developments can be calculated using the following formula:

$$C = \frac{(0.9 \times \text{Impervious Area}) + (0.15 \times \text{Pervious Area})}{\text{Total Area}}$$

6. The intensity for the rational formula ~~is~~ is selected from the Intensity Duration Frequency (IDF) curve, with a duration chosen to coincide with the time of concentration (tc)~~IDF curves provided~~~~selected from the available rainfall data using the time of concentration (T_c). T_c is the sum of inlet time and travel time. The inlet time is the time for the overland flow to reach the ditch. The maximum inlet time for residential areas shall be 10 minutes. Inlet times for commercial or industrial areas shall be calculated on a site specific basis.~~ The time concentration for runoff flow is the time required for runoff flow to become established and reach the design location from the furthest point within the contributing catchment area.
7. Determination of tc requires estimation of two components, the inlet time and travel time. The inlet time is the time for flow from the extreme limits of the catchment to reach the point of inflow into the defined conveyance system. It is dependent upon the imperviousness and the size of catchment. The travel time is the length of time required for flow to travel within the conveyance system from the point of inflow to the design location.
8. Rainfall IDF curves for City of Iqaluit for selected return frequency events are presented in the tabular form in **Tables xx and xy**, visual representation of which can be seen on **Figure xx**. The IDF curves are based on data collected at xx station between 1950 and 2017. ~~The IDF curves are presented in Figure xx.~~
9. Minimum velocity shall be 1m/s. Where velocities in excess of 3 m/s are attained, special provisions shall be made to protect against displacement by erosion or impact.

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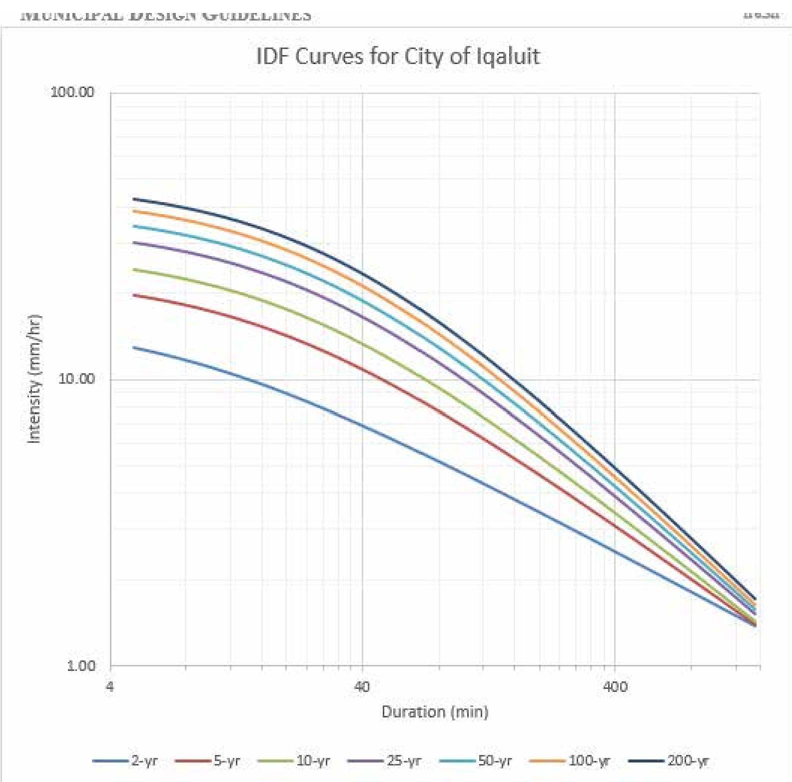
Design Standards

Updates



Curb and Gutter

H.3.2

Drainage discharge locations shall be positioned so that they do not impact surface water intake, and so that water samples can be easily taken.

H.3.3 Outletsfalls

1. At the end of an outfall sewer, energy dissipaters are often necessary to avoid downstream erosion and damage of creeks, ravines or river banks from high exit flow velocities. Outfall structures are required at locations where it is necessary to convert supercritical flow to subcritical, to dissipate flow energy and to establish suitably tranquil flow conditions downstream.
2. When sewers discharge at subcritical flow, then smaller concrete structures with suitable baffles, aprons and rip-rap will be acceptable. For all outfalls, it is required that a rigorous hydraulic analysis be completed, to ensure that the exit velocities will not damage natural watercourses. The final exit velocities, where the flow passes from an apron or erosion control medium to the natural channel, shall not exceed 1.0 m/s and may be further limited depending on site specific soil and flow conditions.
3. Appropriate erosion control measures are to be provided at and downstream of the outfall to prevent erosion in the downstream channel.
4. All sewer outlets shall be constructed with provisions to prevent the entrance of children or other unauthorized persons. A grate with vertical bars spaced at no more than 150 mm shall be installed with adequate means for locking in a closed position. Provide for opening or removal of the gate for cleaning or replacing the bars. Grates should be designed to break away under extreme hydraulic loads in the case of blockage.
5. Guardrails or fences of corrosion resistant material shall be installed along concrete headwalls and wingwalls to provide protection against persons falling.
6. Outfalls, which are often located in parks, ravines, or on river banks should be made as safe and attractive as is reasonably possible. The appearance of these structures is important and cosmetic treatment or concealment is to be considered as part of the design. Concrete surface treatment is recommended to present a pleasing appearance. Bushhammered or exposed aggregate concrete is recommended. Live stakes or bioengineering is encouraged wherever applicable.
7. The location of the riparian zone shall be considered when locating outfalls according to the requirements of the authority having jurisdiction.

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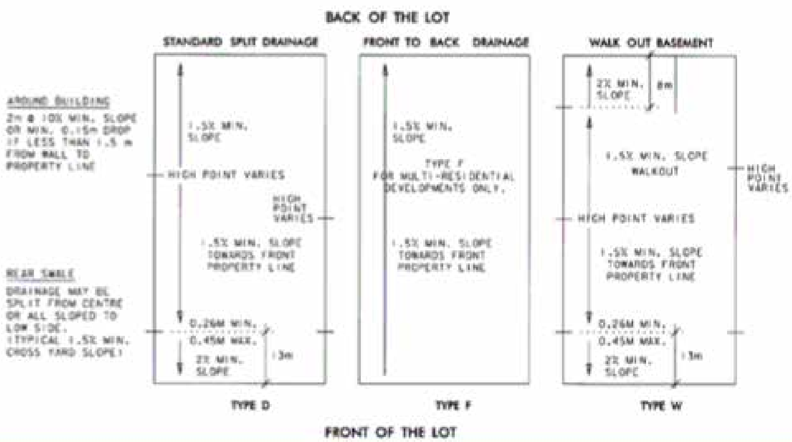
Updates

Design Standards

Typical Lot Grading Details – Split/Front to Back Drainage



8) The relative surface elevations must allow for the slope of the ground adjacent to the building to be at a minimum of 10% for a distance of 2.0 m or to the property line, on all sides of the house, with the slope directing drainage away from the building and then for reasonable slopes in the order of 1.5% to 2.0% from all points within the property to the property boundary at which the drainage may escape.

9) Property line elevations are to be established such that lots have a minimum overall slope of 2.0%, from the high point to the front or back property lines for split drainage situations,

~~H.4.8~~H.4.4 Roadways

Grading of streets comprising the major drainage system shall follow the guidelines listed below:

1. Continuity of over flow routes between adjacent developments shall be maintained.
2. Collectors shall have at least one lane that is not inundated.
3. The depth of peak flows and ponding in developed area streets, conveyance channels and swales, are to be limited so that major system flows will not constitute a significant hazard to the public, or result in significant erosion or other property damage. Where erosion is anticipated, an ESC Plan should be designed to suit site specific situations.
4. An overflow must be provided from all sags or depressions such that there will be a freeboard of at least 150 mm above the overflow elevation to the proposed ground surface elevation at adjacent buildings and maximum depth of ponding is limited to 350mm.
5. The maximum water surface level of surface flows and ponding in streets is below the lowest anticipated landscape grade or opening at any adjacent buildings, with a freeboard provision generally in the order of 350 mm with a minimum of 150 mm.
6. Depths of flow and ponding are less than 350 mm in roadways and other public rights-

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Design Standards

Updates

H.4.7H.4.3 Swales

12) Drainage swales on municipal or private property shall be constructed prior to any development of subdivision lots. Complete swale construction shall be a prerequisite to the issuance of the Substantial Certificate of Completion.

13) Swales may be used on public rights-of-way, including easements, for the collection and conveyance of major and minor runoff to appropriate points of interception or release. Swales on public rights-of- way, except easements, should not to be provided with concrete flow channels or hard surface treatments, except where such measures are required to address flow velocity or erosion concerns.

1)14) The use of swales crossing private properties for collection of runoff and drainage control is not permitted unless proper justification is produced and documented indicating that no other alternative is feasible. If the Engineer approves use of such swales they are to be covered by easements in favour of the City, to the satisfaction of the Engineer.

2)15) Drainage swales located on private property shall be covered by an easement in favour of the City. A minimum clearance of 200mm should be provided between the edge of the swale and the property line. Major rainfall event flows shall be contained within the easement.

16) Drainage swales crossing several properties for the collection of runoff shall not be permitted unless special circumstances warrant.

17) When swales crossing several properties cannot reasonably be avoided, then the following requirements shall be satisfied:

a) Grass swales serving lots on one side only

i) Location: Rear of upstream lot in a 2.0 m easement

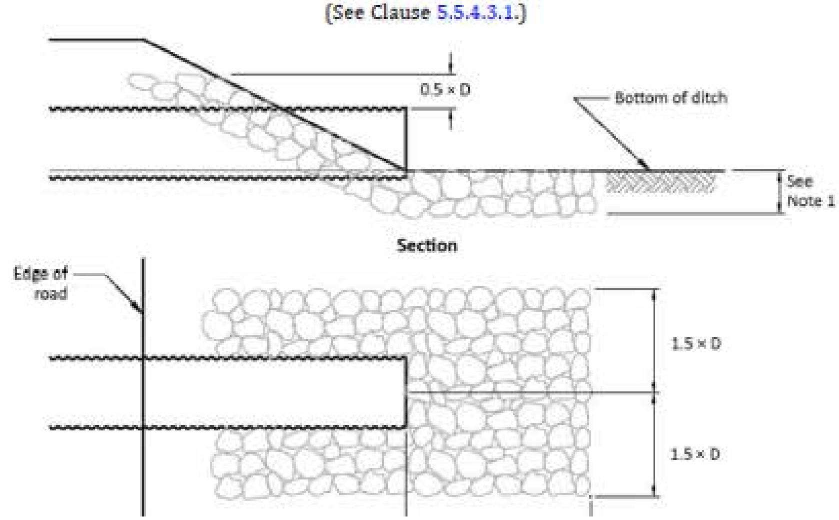
6. Ditches shall have a flat bottom, width as per applicable design standard and shall be designed to accommodate 1:5 year rainfall event.

7. ~~Culvert sizing is the responsibility of the Design Engineer. Culverts and ditches shall be designed to accommodate a 1:25 year rainfall event.~~ The minimum inside diameter of cross road culverts is 18 inches. Smaller diameter culverts may be allowed if it can be demonstrated that glaciation will not be a problem, the pipe will handle peak flows, pipe cover is adequate and the ditch depths are sufficient. Actual culvert sizing shall be based on IDF curves shown on Figure XX and icing potential. Ditches shall be allowed to back up during such an event to the height of the subgrade.

8. Culverts shall be new galvanized corrugated steel pipe with a minimum wall thickness of 1.6mm or as required to meet the design loading criteria.

13. Culverts shall be installed according to the manufacturer's recommendations and industry accepted practices. Care shall be taken to avoid damage to culverts during installation. Where applicable, culverts shall have adequate soil cover to maintain their structural strength. Culverts shall be clearly marked to avoid damage from road maintenance equipment. Figure xx provides an example of a culvert apron.

Figure 13
Example of a culvert apron
(See Clause 5.5.4.3.1.)



Next Steps

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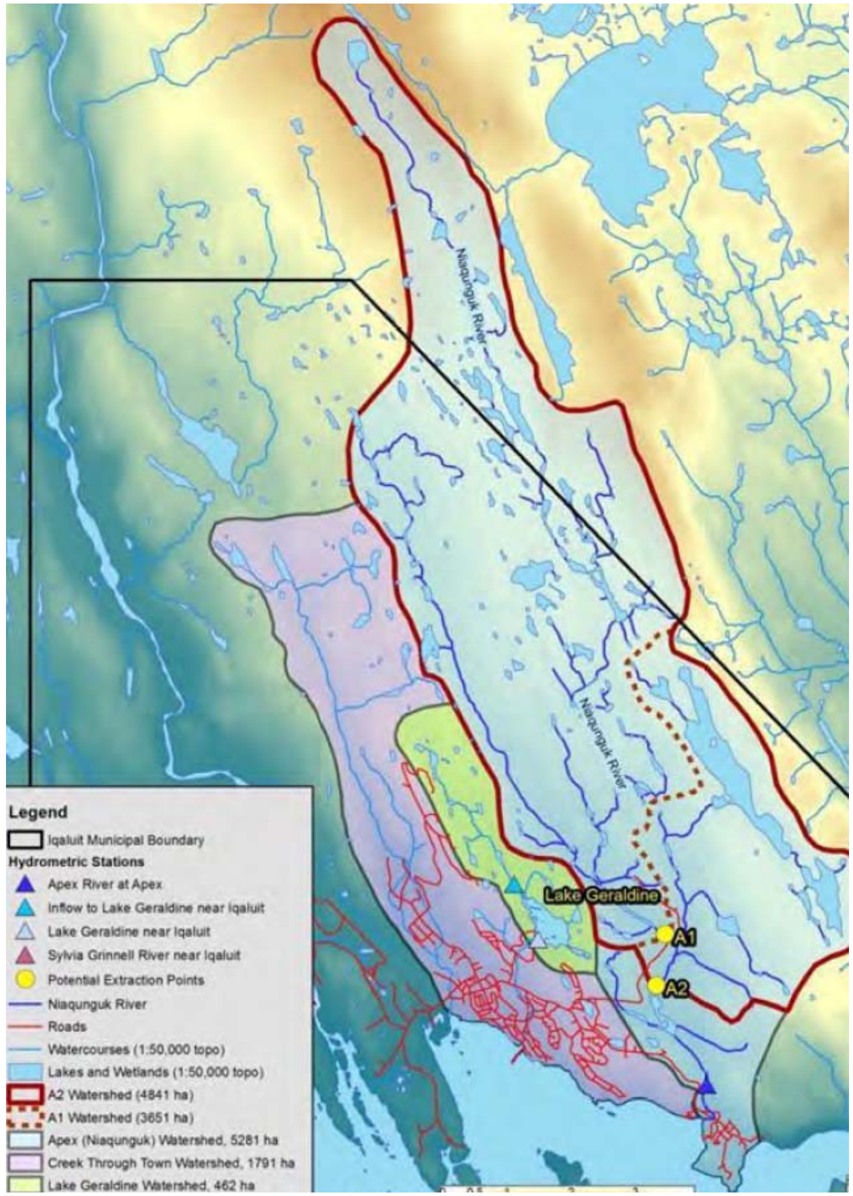
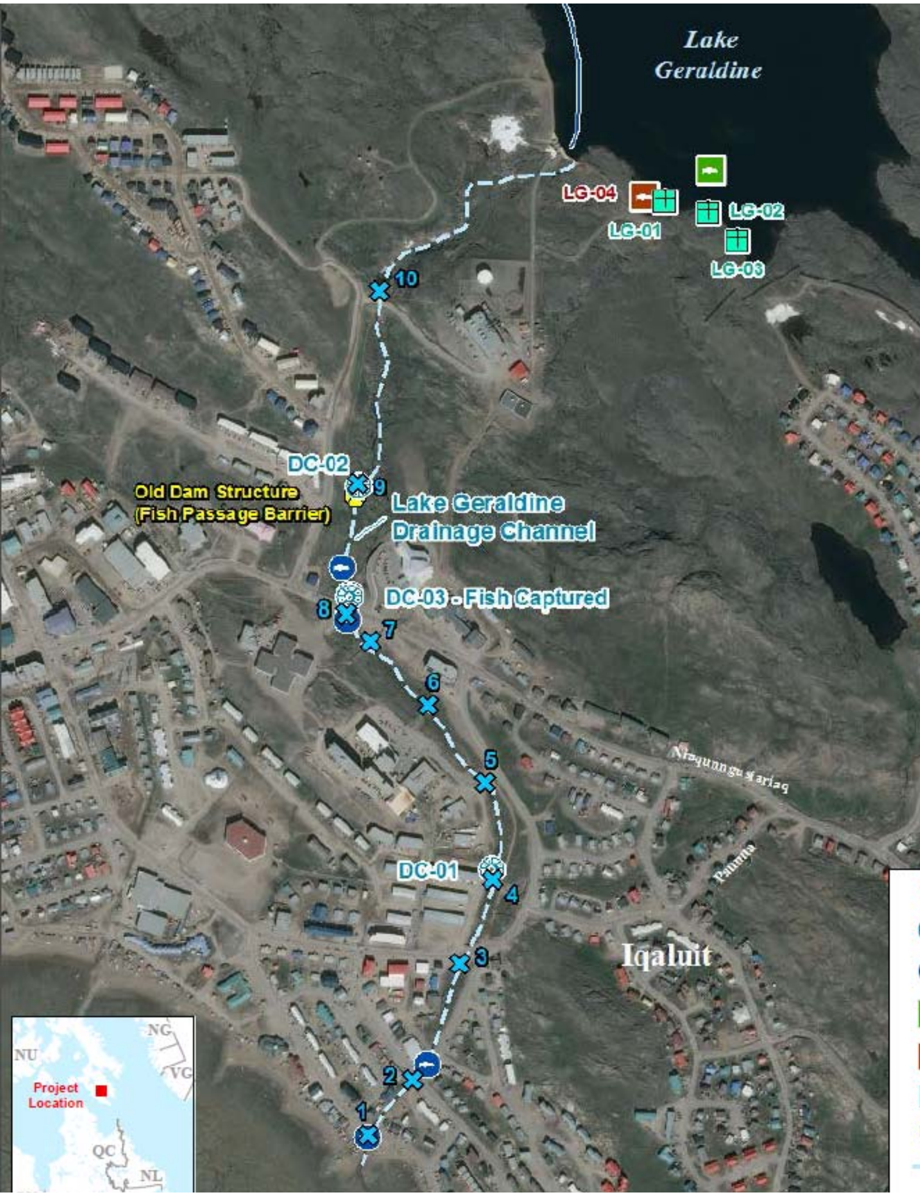
Next Steps

Discussion / Questions

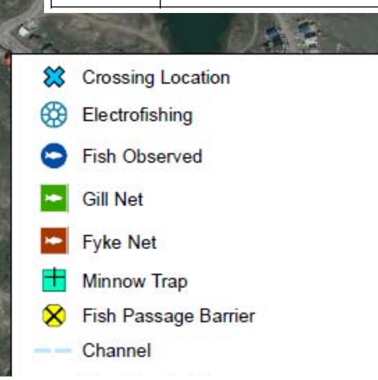
Characterization of Study Area


Legend
Iqaluit Municipal Boundary
Hydrometric Stations
Apex River at Apex
Inflow to Lake Geraldine near Iqaluit
Lake Geraldine near Iqaluit
Sylvia Grinnell River near Iqaluit
Potential Extraction Points
Niaqunguk River
Roads
Watercourses (1:50,000 topo)
Lakes and Wetlands (1:50,000 topo)
A2 Watershed (4841 ha)
A1 Watershed (3651 ha)
Apex (Niaqunguk) Watershed, 5281 ha
Creek Through Town Watershed, 1791 ha
Lake Geraldine Watershed, 462 ha
Niaqunguk River
Niaqunguk River
Lake Geraldine
A1
A2

N
Lake Geraldine
Apex River
Lake Geraldine Drainage Channel
Apex River Proposed Water Withdrawal Location (A2)
Road to Nowhere
Niaqunngusiariaq
Dead Dog Lake
Iqaluit
Paurna
Niaqunngusiariaq



Feature No.	Feature	Location (in UTM 19 V)	Notes
1	Sinaa Road Crossing	524114.64 m E, 7068411.83 m N	Two circular culverts, 1,100 mm dia and 800 mm dia, no drop
2	Nipisa Street Crossing	524186.05 m E, 7068498.85 m N	Three 1,200 mm dia culverts, 14 m long with gabion wall headwall at inlet. Flow through one pipe only
3	Queen Elizabeth Road Crossing	524261.72 m E, 7068684.52 m N	Five pipes, three 1,650 mm dia oval culverts, with two 620 mm dia circular overflow pipes above them 0.22 m drop from culvert into 0.29 m pool may be barrier to small fish or at some flow levels
4	Pedestrian Crossing near Paunna Road	524313.69 m E, 7068819.42 m N	Two 1,550 mm dia culverts, 7 m long, half buried in the substrate
5	Astro Hill Road Crossing	524302.97 m E, 7068975.12 m N	Clear span bridge structure, 13 m wide over a channel with 7 m wide bankful Unstable bank on downstream left
6	Astro Hill Pedestrian Crossing	524210.46 m E, 7069099.66 m N	Two 1,300 mm dia culverts, 7 m long with one 400 mm dia overflow pipe
7	Overhead Pipe Crossing	524118.39 m E, 7069199.35 m N	Footings constructed of wooden cribs on rock riprap, encroaching on channel width
8	Road to Apex Crossing	524080.36 m E, 7069242.08 m N	Two 2,200 mm dia culverts, 22 m long
9	Old Dam Structure	524099.06 m E, 7069449.71 m N	Concrete dam, over 1 m drop. Complete barrier, no flow over structure—water flows through rock debris under structure
10	Saputi Road Crossing	524132.93 m E, 7069756.41 m N	Two 1,500 mm dia oval pipes, 80 m long, steep installation

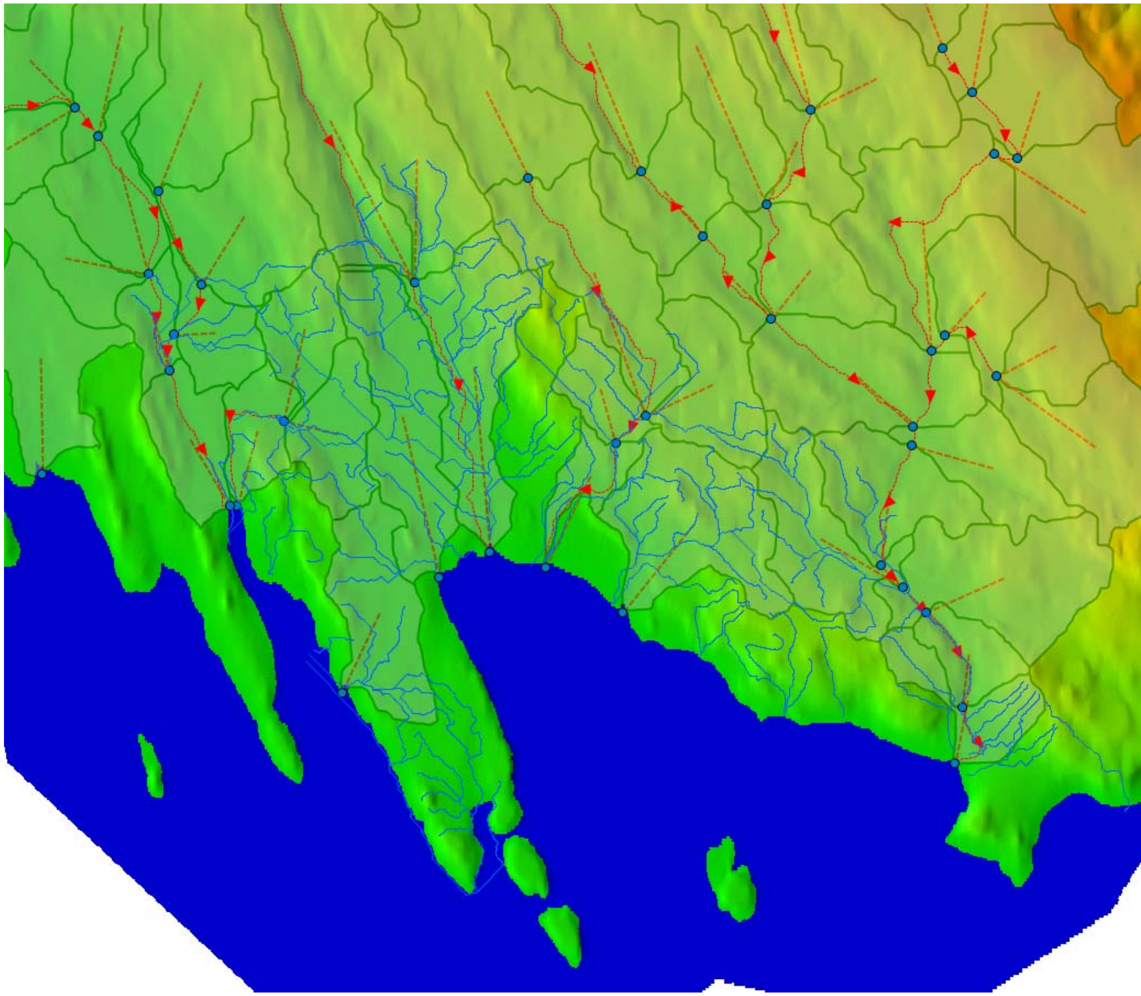


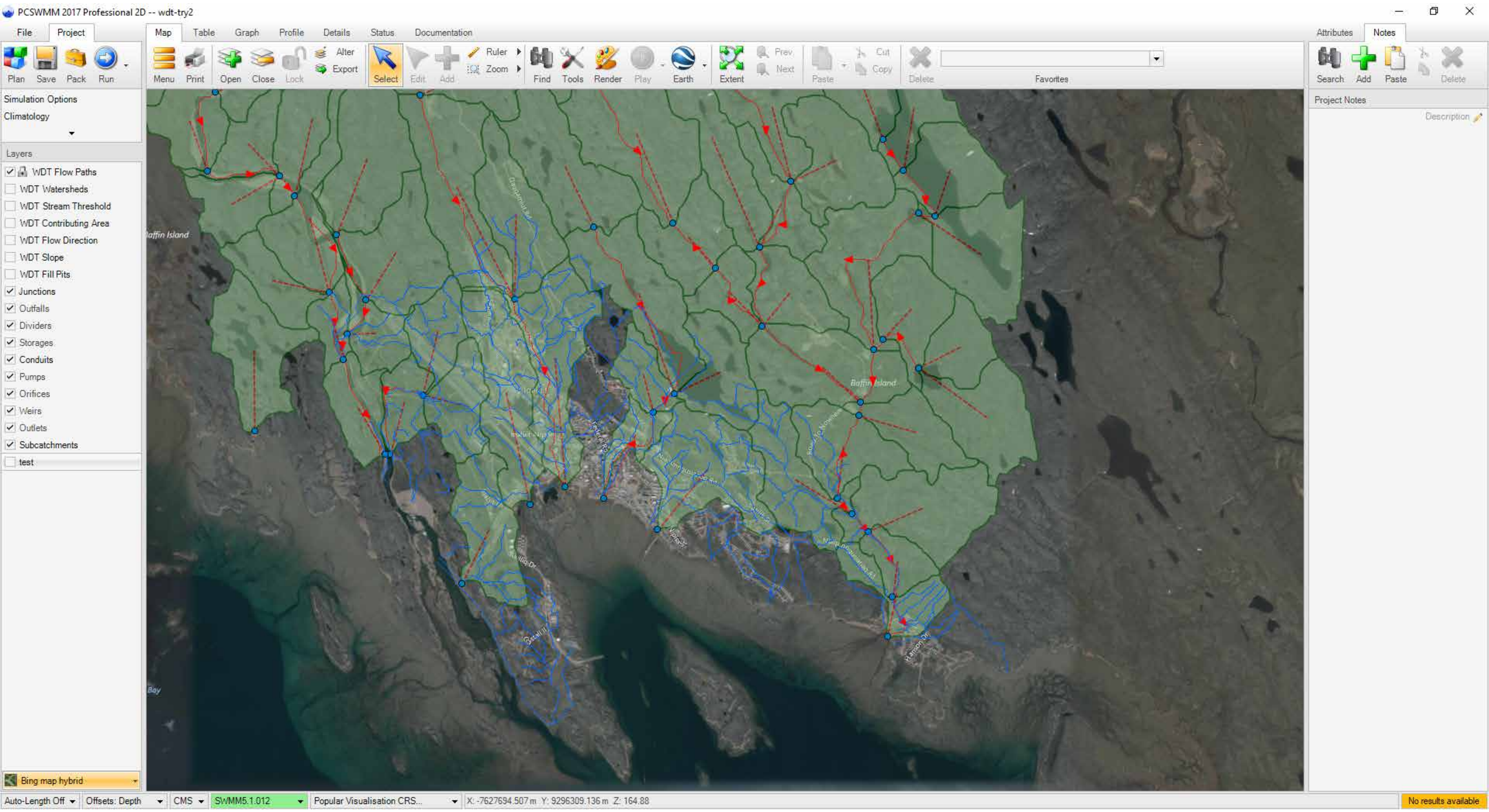
[Airport Creek Aerial]

Preliminary Model Construction

Model Construction

- Sufficient GIS source data collected
- Preliminary models built
- Crucial elements missing: culvert data (locations, sizes, conditions, slopes, inverts, lengths)





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WDT Flow Direction
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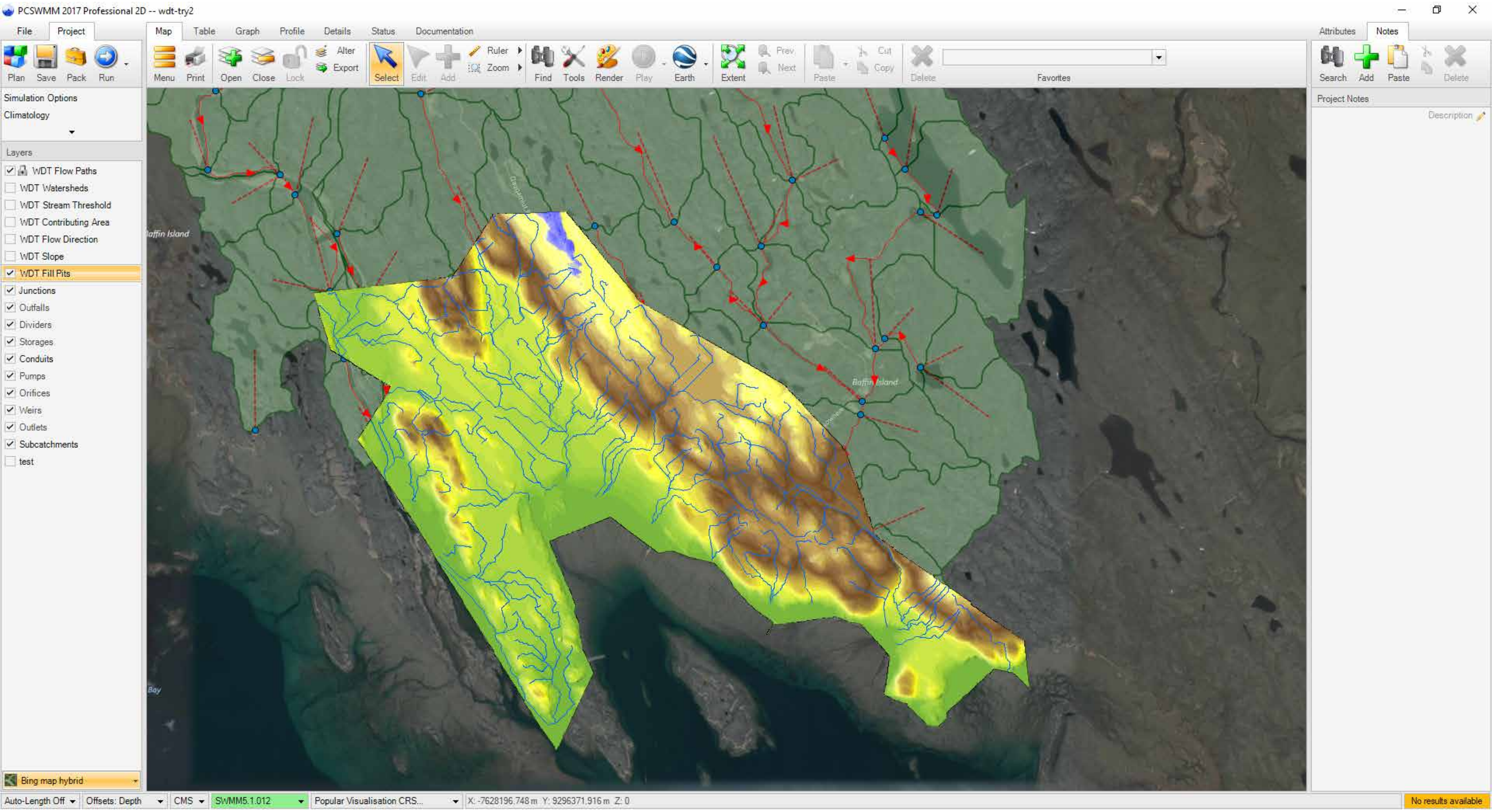
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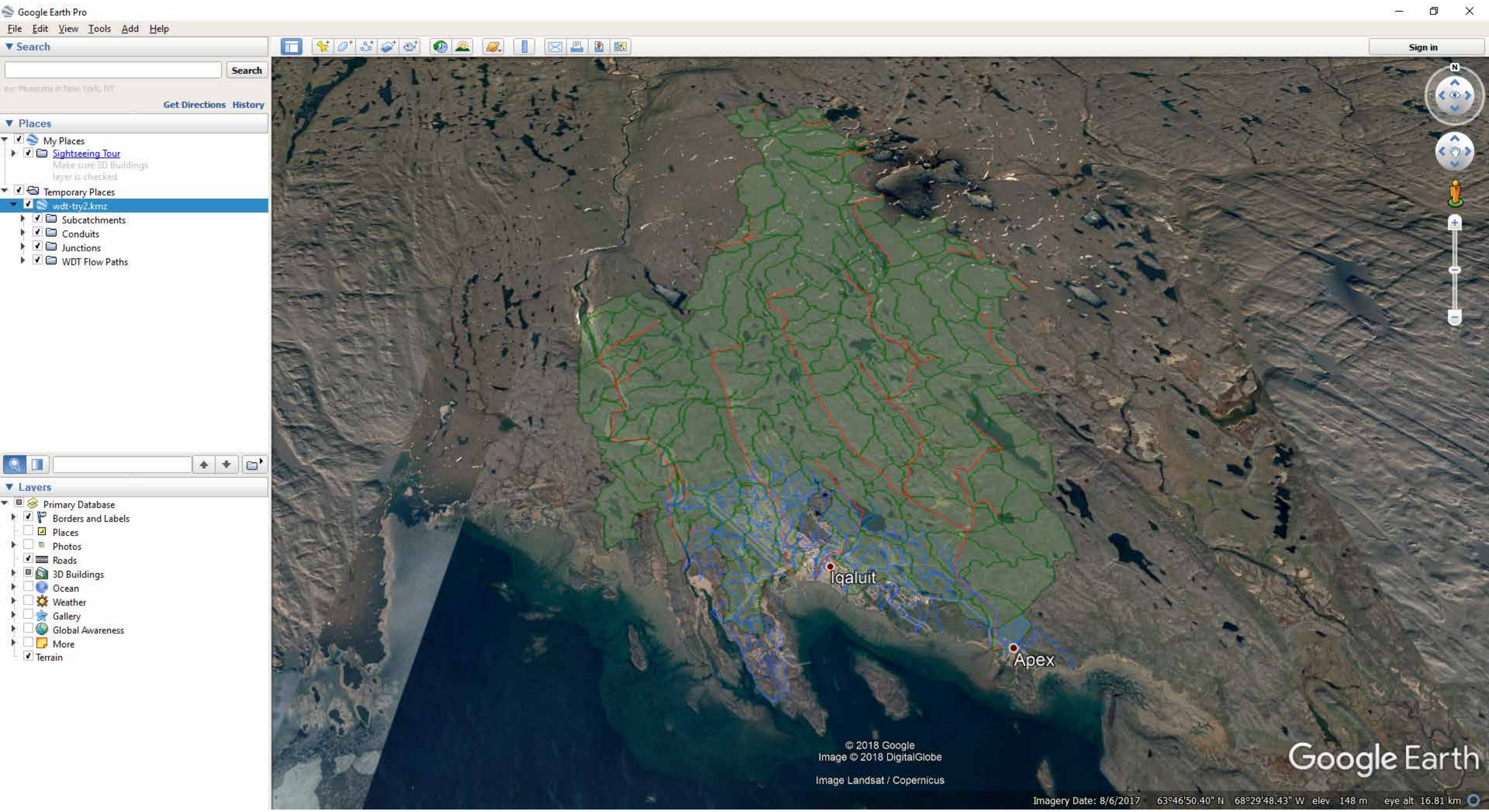

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Apex
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Image © 2018 DigitalGlobe
Image Landsat / Copernicus
Google Earth
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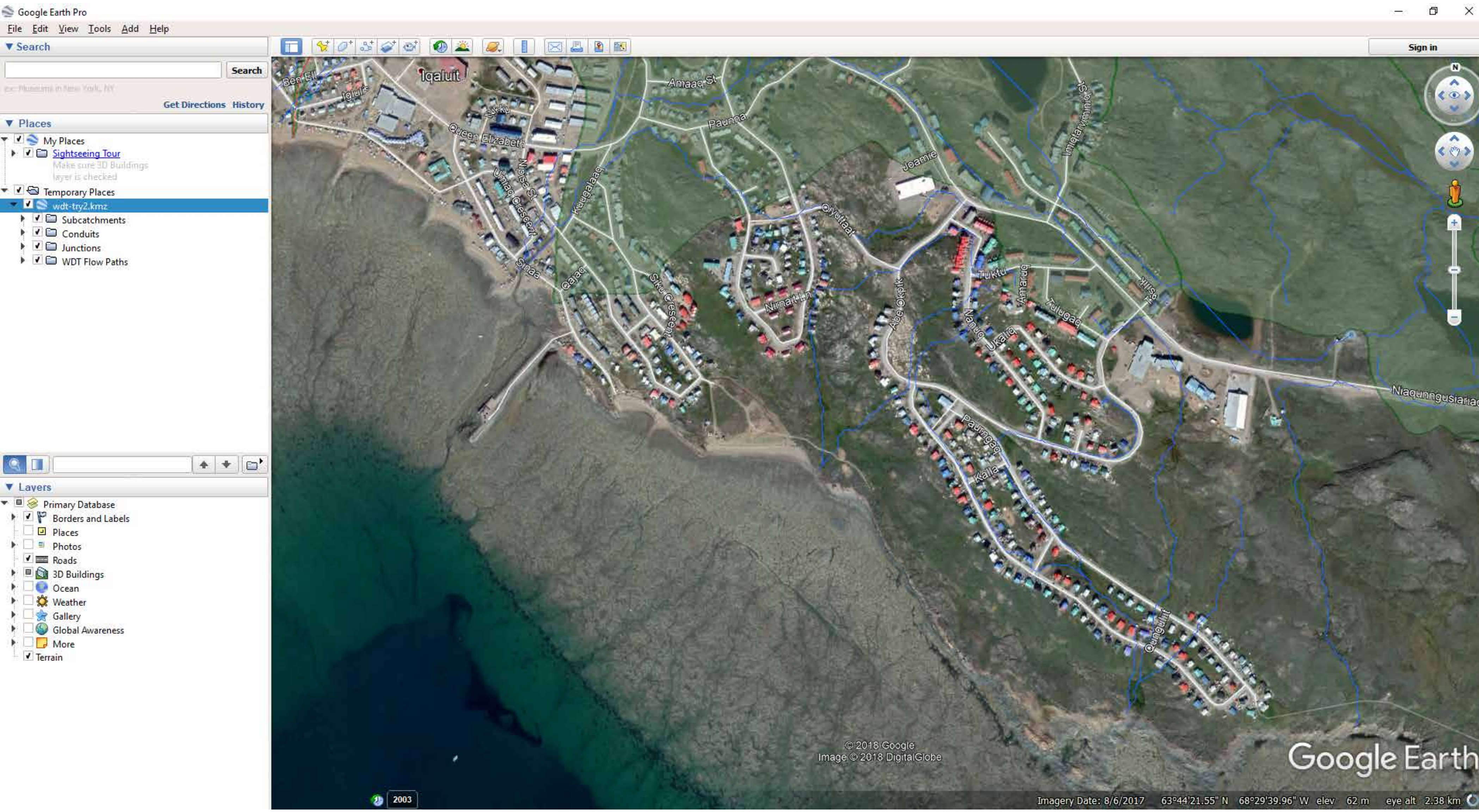
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Image © 2018 DigitalGlobe
Google Earth
2003
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© 2018 Google
Google Earth
Report a problem
63°44'43.54" N 68°30'27.86" W elev 30 m eye alt 32 m


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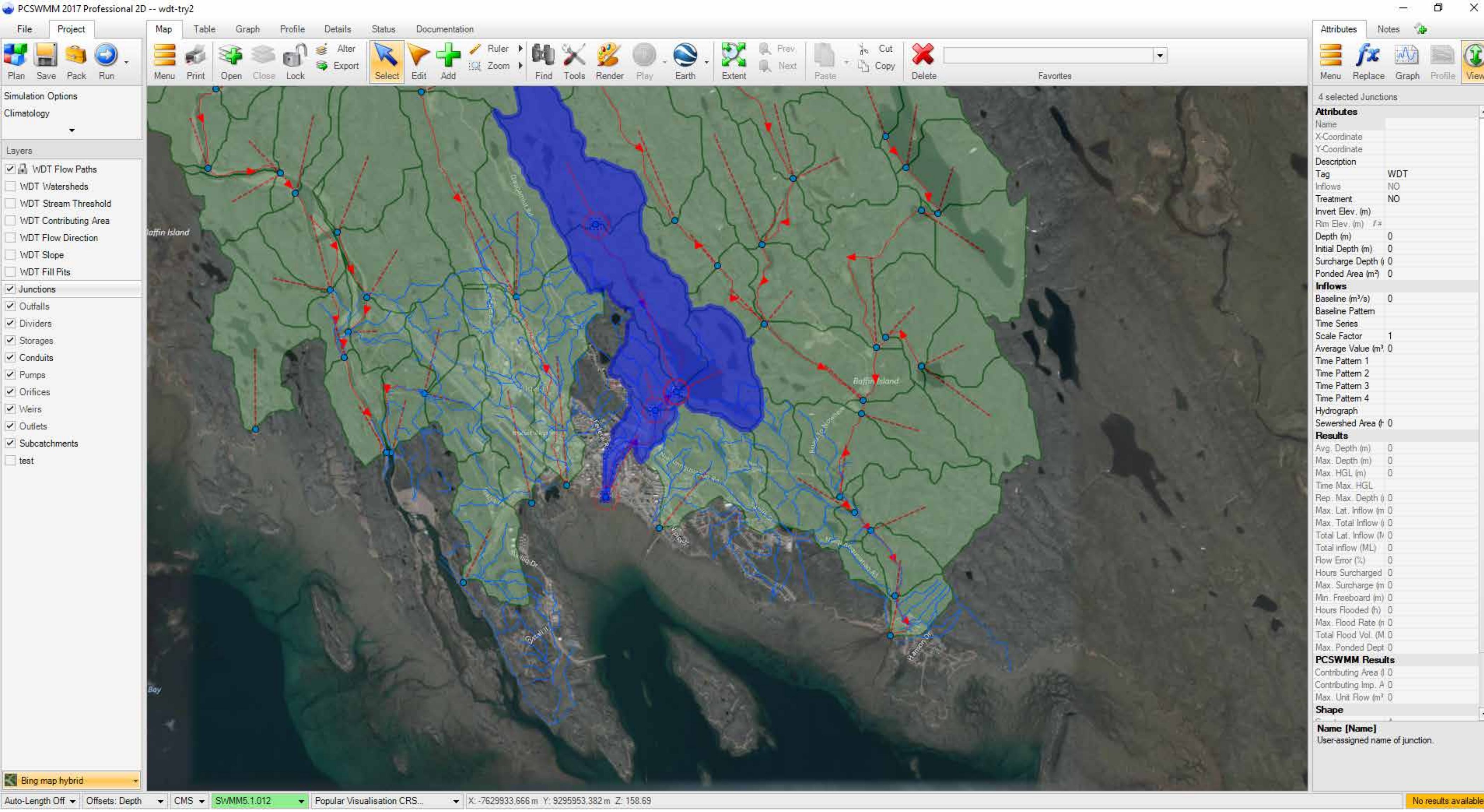
Image © 2018 DigitalGlobe
Google Earth
2003
63°44'41.94" N 68°30'24.32" W elev 31 m eye alt 217 m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WDT Contributing Area
WDT Flow Direction
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Outlets
Subcatchments
test
Bing map hybrid
Baffin Island
4 selected Junctions
Attributes
Name
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Y-Coordinate
Description
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Inflows NO
Treatment NO
Invert Elev. (m)
Rim Elev. (m)
Depth (m) 0
Initial Depth (m) 0
Surcharge Depth 0
Ponded Area (m²) 0
Inflows
Baseline (m³/s) 0
Baseline Pattern
Time Series
Scale Factor 1
Average Value (m³ 0
Time Pattern 1
Time Pattern 2
Time Pattern 3
Time Pattern 4
Hydrograph
Sewershed Area 0
Results
Avg. Depth (m) 0
Max. Depth (m) 0
Max. HGL (m) 0
Time Max. HGL
Rep. Max. Depth 0
Max. Lat. Inflow 0
Max. Total Inflow 0
Total Lat. Inflow 0
Total inflow (ML) 0
Flow Error (%) 0
Hours Surcharged 0
Max. Surcharge 0
Min. Freeboard (m) 0
Hours Flooded (h) 0
Max. Flood Rate 0
Total Flood Vol. 0
Max. Ponded Dept 0
PCSWMM Results
Contributing Area 0
Contributing Imp. 0
Max. Unit Flow 0
Shape
Name [Name]
User-assigned name of junction.
Auto-Length Off
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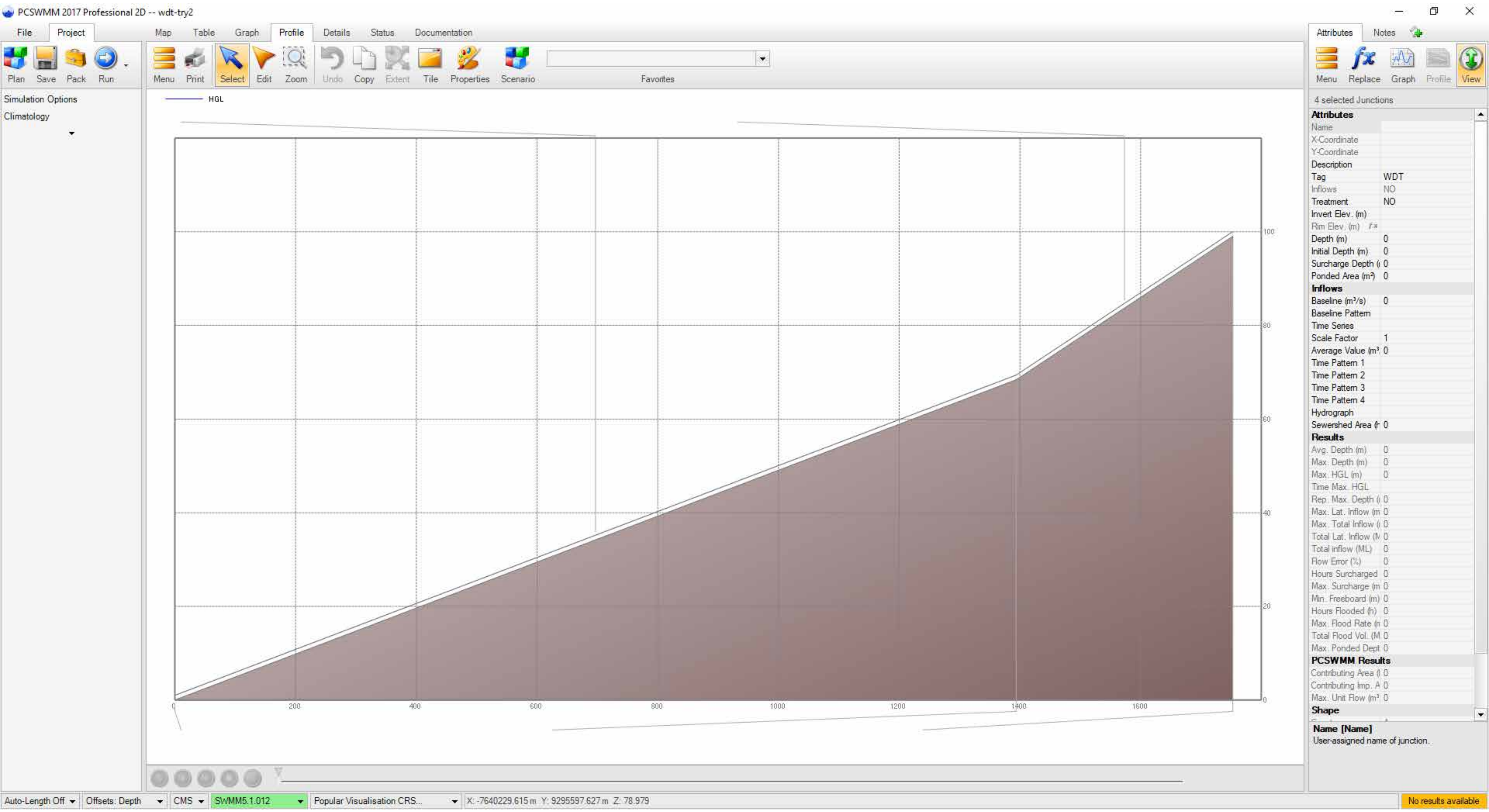
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Treatment NO
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Rim Elev. (m)
Depth (m) 0
Initial Depth (m) 0
Surcharge Depth 0
Ponded Area (m²) 0
Inflows
Baseline (m³/s) 0
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Time Series
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Average Value (m³ 0
Time Pattern 1
Time Pattern 2
Time Pattern 3
Time Pattern 4
Hydrograph
Sewershed Area 0
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Max. HGL (m) 0
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Rep. Max. Depth 0
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Max. Total Inflow 0
Total Lat. Inflow 0
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Flow Error (%) 0
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Min. Freeboard (m) 0
Hours Flooded (h) 0
Max. Flood Rate 0
Total Flood Vol. (M 0
Max. Ponded Dept 0
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Contributing Area 0
Contributing Imp. A 0
Max. Unit Flow (m³ 0
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APPENDIX C
HISTORICAL CLIMATE DATA

Requested Data from Environment Canada

Climate ID	Element Name	Start Year	End Year
2402590	DAILY MAXIMUM TEMPERATURE	1946	2008
2402590	DAILY MINIMUM TEMPERATURE	1946	2008
2402590	DAILY MEAN TEMPERATURE	1946	2008
2402590	SIX HOURLY PRECIPITATION	1950	2007
2402590	DAILY TOTAL RAINFALL	1946	2002
2402590	DAILY TOTAL SNOWFALL	1946	2002
2402590	DAILY TOTAL PRECIPITATION	1946	2007
2402590	SNOW ON GROUND	1955	2007
2402590	DAY WITH THUNDERSTORMS	1955	2002
2402590	DAY WITH FREEZING RAIN	1955	2008
2402590	DAY WITH HAIL	1955	2002
2402590	GREATEST RAINFALL	1946	2002
2402590	DATE OF GREATEST RAINFALL (EARLIEST)	1946	2002
2402590	GREATEST SNOWFALL	1946	2002
2402590	DATE OF GREATEST SNOWFALL (EARLIEST)	1946	2002
2402590	GREATEST PRECIPITATION	1946	2007
2402590	DATE OF GREATEST PRECIPITATION (EARLIEST)	1946	2007
2402590	DIRECTION OF EXTREME GUST (16PTS) TO DEC1976	1952	1976
2402590	DEW POINT TEMPERATURE	1953	2014
2402590	WIND SPEED	1953	2014
2402590	DRY BULB TEMPERATURE	1953	2014
2402590	WET BULB TEMPERATURE	1953	2014
2402590	RELATIVE HUMIDITY	1953	2014
2402590	TOTAL CLOUD OPACITY	1953	2014
2402590	TOTAL CLOUD AMOUNT	1953	2014
2402590	WEATHER INDICATOR	1953	2014
2402590	THUNDERSTORMS (T)	1963	2011
2402590	RAIN (R)	1953	2013
2402590	RAIN SHOWERS (RW)	1953	2013
2402590	DRIZZLE (L)	1953	2013
2402590	FREEZING RAIN (ZR)	1953	2013
2402590	FREEZING DRIZZLE (ZL)	1953	2013
2402590	SNOW (S)	1953	2014
2402590	SNOW GRAINS (SG)	1953	2012
2402590	ICE CRYSTALS (IC)	1953	2014
2402590	ICE PELLETS (IP)	1953	2010
2402590	ICE PELLETS SHOWERS (IPW)	1953	2008
2402590	SNOW SHOWERS (SW)	1953	2013
2402590	SNOW PELLETS (SP)	1956	2013
2402590	HAIL (A)	1964	1964
2402590	HOURLY PRECIPITATION	1982	2002
2402590	ADJUSTMENT FACTOR	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 5 MIN	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 10 MIN	1982	2002

2402590	GREATEST AMOUNT OF PRECIP IN 15 MIN	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 30 MIN	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 1 HOUR	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 2 HOURS	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 6 HOURS	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 12 HOURS	1982	2002
2402590	BRIGHT SUNSHINE	1957	2006
2402590	CHART CHANGE HOUR	1982	2002
2402590	GREATEST AMOUNT OF PRECIP IN 24 HOURS	1982	1990
2402591	DAILY MAXIMUM TEMPERATURE	2008	2015
2402591	DAILY MINIMUM TEMPERATURE	2008	2015
2402591	DAILY MEAN TEMPERATURE	2008	2015
2402591	DAILY MAXIMUM RELATIVE HUMIDITY	2008	2013
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2402591	SIX HOURLY PRECIPITATION	2010	2015
2402591	DAILY TOTAL RAINFALL	2015	2015
2402591	DAILY TOTAL SNOWFALL	2015	2015
2402591	DAILY TOTAL PRECIPITATION	2010	2015
2402591	SNOW ON GROUND	2015	2015
2402591	DAY WITH THUNDERSTORMS	2015	2015
2402591	DAY WITH FREEZING RAIN	2008	2015
2402591	DAY WITH HAIL	2015	2015
2402591	DEW POINT TEMPERATURE	2008	2015
2402591	WIND SPEED	2008	2015
2402591	WEATHER INDICATOR	2008	2015
2402591	RAIN (R)	2008	2015
2402591	DRIZZLE (L)	2008	2015
2402591	FREEZING RAIN (ZR)	2008	2015
2402591	FREEZING DRIZZLE (ZL)	2008	2015
2402591	SNOW (S)	2008	2015
2402591	PRECIPITATION - UNCLASSIFIED TYPE (P)	2014	2015
2402592	DAILY MAXIMUM TEMPERATURE	2004	2018
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2402592	DAILY MEAN TEMPERATURE	2004	2018
2402592	DAILY MAXIMUM RELATIVE HUMIDITY	2004	2013
2402592	DAILY MINIMUM RELATIVE HUMIDITY	2004	2013
2402592	SIX HOURLY PRECIPITATION	2004	2018
2402592	DAILY TOTAL RAINFALL	2005	2018
2402592	DAILY TOTAL SNOWFALL	2005	2018
2402592	DAILY TOTAL PRECIPITATION	2004	2018
2402592	SNOW ON GROUND	2004	2018
2402592	DAY WITH THUNDERSTORMS	2015	2018
2402592	DAY WITH THUNDERSTORMS	2005	2007
2402592	DAY WITH FREEZING RAIN	2015	2018
2402592	DAY WITH FREEZING RAIN	2005	2007
2402592	DAY WITH HAIL	2015	2018
2402592	DAY WITH HAIL	2005	2007

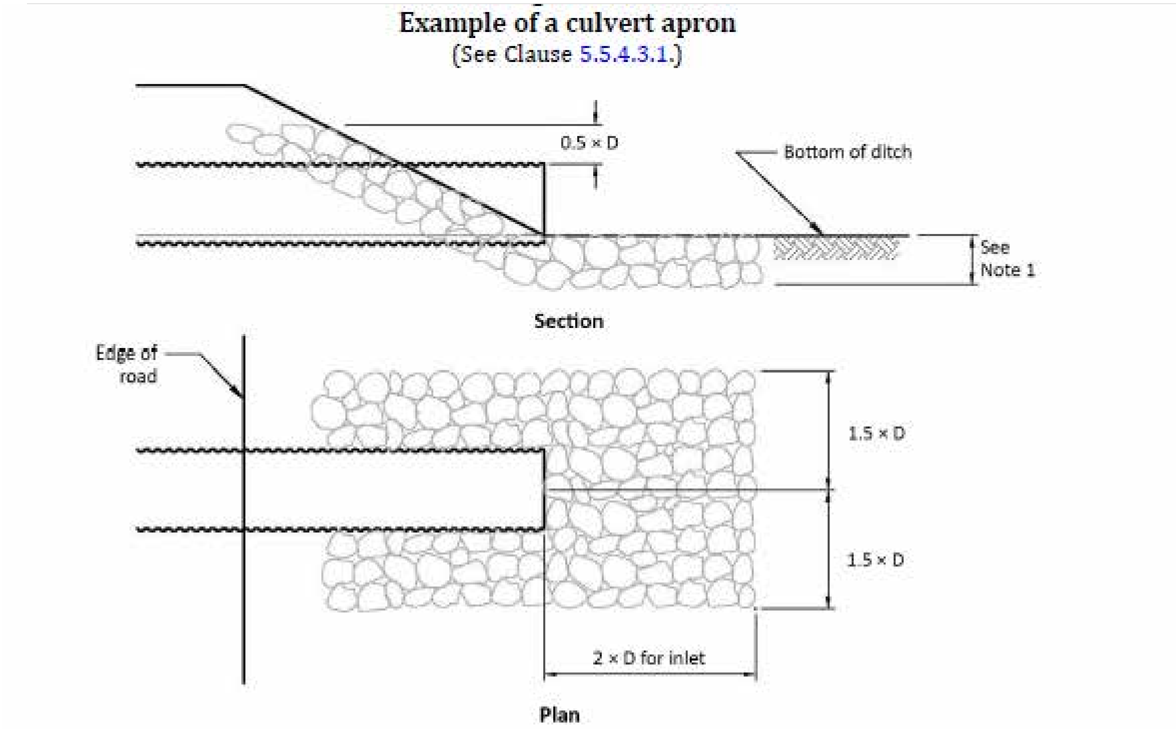
2402592	GREATEST RAINFALL	2005	2007
2402592	DATE OF GREATEST RAINFALL (EARLIEST)	2005	2007
2402592	GREATEST SNOWFALL	2005	2007
2402592	DATE OF GREATEST SNOWFALL (EARLIEST)	2005	2007
2402592	GREATEST PRECIPITATION	2005	2007
2402592	DATE OF GREATEST PRECIPITATION (EARLIEST)	2005	2007
2402592	DEW POINT TEMPERATURE	2004	2018
2402592	WEATHER INDICATOR	2004	2015
2402592	HOURLY PRECIPITATION AMOUNT	2004	2018
2402592	PRECIPITATION AMOUNT – 15 MINUTES	2008	2018
2402592	WIND SPEED AT 2 M – 15 MINUTE INTERVAL	2008	2018
2402592	SNOW DEPTH (AT MINUTE 60)	2004	2018
2402592	SNOW DEPTH (AT MINUTE 15)	2015	2018
2402592	SNOW DEPTH (AT MINUTE 30)	2015	2018
2402592	SNOW DEPTH (AT MINUTE 45)	2015	2018
2402594	DAILY MAXIMUM TEMPERATURE	1997	2007
2402594	DAILY MINIMUM TEMPERATURE	1997	2007
2402594	DAILY MEAN TEMPERATURE	1997	2007
2402594	DAILY TOTAL RAINFALL	1997	2016
2402594	DAILY TOTAL SNOWFALL	1997	2016
2402594	DAILY TOTAL PRECIPITATION	1997	2016
2402594	SNOW ON GROUND	1997	2016
2402594	DAY WITH THUNDERSTORMS	1997	2007
2402594	DAY WITH THUNDERSTORMS	2012	2014
2402594	DAY WITH FREEZING RAIN	1997	2015
2402594	DAY WITH HAIL	1997	2007
2402594	DAY WITH HAIL	2015	2015
2402594	GREATEST RAINFALL	1997	2007
2402594	DATE OF GREATEST RAINFALL (EARLIEST)	1997	2007
2402594	GREATEST SNOWFALL	1997	2007
2402594	DATE OF GREATEST SNOWFALL (EARLIEST)	1997	2007
2402594	GREATEST PRECIPITATION	1997	2007
2402594	DATE OF GREATEST PRECIPITATION (EARLIEST)	1997	2007
2402596	DEW POINT TEMPERATURE	2014	2018
2402596	WIND SPEED	2014	2018
2402596	WEATHER INDICATOR	2014	2018
2402596	RAIN (R)	2014	2017
2402596	RAIN SHOWERS (RW)	2014	2017
2402596	DRIZZLE (L)	2014	2017
2402596	FREEZING RAIN (ZR)	2014	2017
2402596	FREEZING DRIZZLE (ZL)	2015	2017
2402596	SNOW (S)	2014	2018
2402596	SNOW GRAINS (SG)	2015	2017
2402596	ICE CRYSTALS (IC)	2014	2018
2402596	ICE PELLETS (IP)	2014	2017
2402596	SNOW SHOWERS (SW)	2014	2017
2402596	SNOW PELLETS (SP)	2016	2017

APPENDIX D
DESIGN GUIDELINES

4. Material for temporary signs, such as subdivision layout signs, shall be approved by the City prior to installation.

E-9 DRAINAGE AND CULVERTS

1. Drainage systems shall meet the flow requirements outlined in Section H for both local and collector cross sections.
2. Ditches for roadways shall have back slopes no steeper than 3H:IV, and no flatter than 2H:1V.
3. Swale and ditch grades shall match the road grades wherever possible.
4. Swale and ditch grades shall have a minimum grade of 0.5% wherever possible. Grades less than 0.5% shall be subject to review and approval by the City Engineer.
5. Drainage channels shall be provided with ditch checks and/or other means of erosion control as necessary.
6. Ditches shall have a flat bottom, width as per applicable design standard and shall be designed to accommodate 1:5 year rainfall event.
7. The minimum inside diameter of cross road culverts is 18 inches. Smaller diameter culverts may be allowed if it can be demonstrated that glaciation will not be a problem, the pipe will handle peak flows, pipe cover is adequate and the ditch depths are sufficient. Actual culvert sizing shall be based on IDF curves shown on Figure H.3.1 and icing potential. Ditches shall be allowed to back up during such an event to the height of the subgrade.
8. Culverts shall be new galvanized corrugated steel pipe with a minimum wall thickness of 1.6mm or as required to meet the design loading criteria.
9. All culverts shall have appropriate end treatments depending on application. Inverts shall be extended to the toe of the side slope.
10. The culvert grade shall not be less than the ditch grades at the inlet and outlet.
11. Culverts shall have a sufficient amount of cover to protect against damage from the expected traffic loading. Minimum cover shall be 300mm or one-half the diameter of the culvert, whichever is greater as measured from the finished shoulder grade tot he top of the culvert.
12. Where multiple culverts are needed at a single location, the upstream inverts shall be designed to reduce the risk of icing of the culverts. To reduce the risk of culvert icing, the culverts can be placed at slightly different elevations to prevent blockage of all the culverts at the same time.
13. Culverts shall be installed according to the manufacturer's recommendations and industry accepted practices. Care shall be taken to avoid damage to culverts during installation. Where applicable, culverts shall have adequate soil cover to maintain their structural strength. Culverts shall be clearly marked to avoid damage from road maintenance equipment. Figure E-9-1 provides an example of a culvert apron.



1) *Riprap should be 300 mm for diameters less than 1400 mm, and 600 mm for diameters greater than 1400 mm.*
2) *Riprap should be hand placed.*
3) *The minimum culvert diameter should be 400 mm.*
4) *The minimum size of riprap should be 0.3 m thickness.*
5) *Filter cloth should be installed under the entire riprap apron.*

Figure E-9-1: Example of Culvert Apron

14. Care shall be taken to avoid damage to permafrost during the installation of culverts. Where disturbance to the permafrost is unavoidable, designs shall incorporate a means to re-establish and reinsulate the permafrost.
15. Culvert inlets should be placed at the same elevation of the natural stream bed to facilitate the passage of fish. Where culverts are to allow for the passage of fish, designs shall take into account the requirements of the authority having jurisdiction.
16. Where there is a risk of drainage overflow causing washout of critical infrastructure such as a roadway, the drainage system design shall include a means to prevent overflow of the system (e.g., overflow culverts). The level of risk, as determined during the planning process in accordance with Clause 4.5, can be used to determine whether or not protection against system overflow is required and what should be.

E-10 QUALITY ASSURANCE

Quality control testing related to the roadway construction shall include but not necessarily limited to sieve analysis, densities, mix design, core sampling and concrete testing. Quality control shall be performed by an independent party and certified by a professional engineer licensed to practice in the Territory of Nunavut.

H STORMWATER MANAGEMENT SYSTEM

H-1 GENERAL

These guidelines are intended as a guide only. The Design Engineer is responsible to ensure that the water system is designed and constructed according to accepted engineering practice.

These Guidelines shall not be considered as a substitute for a detailed material and construction specification prepared by the Design Engineer.

The stormwater management system should be designed with major and minor drainage systems. In general, a minor system consists of swales, ditches and culverts that have been designed in order to avoid property damage and flooding due to runoff generated by a 1 in 5 year rainfall event. When the capacity of the minor system is exceeded, the major system must provide a continuous overland flow route allowing the excess runoff to reach the designated ponding areas or water body.

The drainage conveyance should follow the natural starting point of flow on a surface (e.g., natural ground, roof, road, or parking lot) and sequentially follow the flow to a collection point (natural or constructed), such as a swale or ditch, and ultimately into a channel (natural or constructed).

Drainage systems shall be designed to maintain natural drainage conveyance patterns wherever practicable. Drainage systems shall be designed with a preference for detention over retention when directing drainage.

Where available, natural wetlands should be utilized to provide storage and thus slow the flow to the drainage area outlet. Wetlands can also be used to provide a degree of treatment by settling suspended solids out of the runoff.

Drainage storage by a constructed pond or pool should only be considered where

a) there is a need to slow the velocity of the flow in order to prevent erosion in areas where the soil is particularly vulnerable to erosion or the use of riprap, baffles, or vegetated ditches is not possible; or

b) there is an opportunity to use the retained water for other purposes as deemed appropriate by the authority having jurisdiction (e.g., fire fighting).

H.1.1 Identifying Drainage Catchment Areas

Drainage catchment areas and drainage patterns shall be identified. Available topographic mapping shall be used in order to identify the directions of sloping ground throughout the community.

H.1.2 Erosion Controls

Erosion stability and channel design shall at minimum calculate, tabulate and report for representative sections and lining characteristics at peak flow of the design storm for the following items:

1. Maximum shear stress;

2. Shear stress in critical bends;
3. Side slope stability for channels with side slopes steeper than 3:1;
4. Permissible or critical shear stress for proposed channel lining or armor;
5. General shape of rock substrate (e.g. rounded rock tends to be more easily mobilized than angular rock.)
6. Gradation of the rock substrate; and
7. Effective Manning's "n" and transitional lining characteristics for composite channel linings, particularly where low flow channels are required (e.g., for low base-flow streams and other perennial flows subject to icing).

Designs shall mitigate erosion caused by drainage discharges. The following features can be used to manage erosion:

1. Sediment traps (geotextile elements) / Silt Fencing: These are installed to reduce the velocity of flow and allow for the deposition of sediments doe the deposition of sediments before they can enter a fish bearing body of water. These are made from filter fabric that is buried at the bottom, stretched and supported by posts. Silt fences shall not be designed to withstand high heads.

   Silt fences are appropriate for the majority of construction sites that are not more than moderately sloped. The design life a silt fence is 6 months or less. The maximum contributory sheet flow drainage area should not exceed 0.1 hectares per 30 metres of silt fence. Use of a silt fence is usually more complex, expensive, and maintenance-prone than other sediment control measures.

   Silt fence might not be the most appropriate control measure for uneven terrain or when vegetative mat contains high density of roots that preclude keying in the fabric.

   Silt fences should be installed at right angles to the slope and along contours. Silt fences should be installed at the bottom of a slope or on a bench on a slope. Because of the difficulty of installing silt fence on frozen ground, installation should take place, where possible, before the ground freezes. Posts should be securely installed with the fabric attached to the uphill side of the post. The filter fabric should be securely attached to the posts. The filter fabric should be keyed into the surrounding earth. Silt fences should not be used in locations with concentrated flow, including streams or other storm water conveyances. Silt fence should only be used to contain sediment on-site.

2. Structural elements placed in the way of the flow, including
   a. Riprap: Large stone placed on embankments or slopes to provide stability to that slope. This keeps the embankment material in place and does not allow it to erode and potentially enter the Stormwater system. Deisgn guidelines for rip rap are listed in section H.3.3.
   b. Gabions;

c. Concrete structures; and

d. Wood cribbing;

3. Vegetation;
4. Surface Roughening: The practice of creating horizontal depressions on slopes, this reduces runoff velocities and increases infiltration which helps to prevent erosion of the slope. Roughening methods include stair-step grading, grooving, and tracking. Equipment such as bulldozers with rippers or tractors with disks may be used.
5. General Surfacing: Once an area has been developed, there are several methods of erosion control in the form of resurfacing an area. This can be done by seeding, sodding, the placement of rock, concrete and asphalt.
6. Rolled Erosion Control Products: Long sheets, or coverings that can unrolled onto unvegetated cut of fill slopes where erosion control or stabilization is needed. Designer shall ensure that RECP's are anchored, spacing depends on type of material and slope steepness. In addition, a firm continuous contact between RECP and soil must be maintained to prevent erosion below RECP.

   RECPs function best in providing a protective cover on slopes and channels where the erosion hazard is high and plant growth is likely to be slow, generally on slopes steeper than 3H:1V and greater than 10 feet of vertical relief.

7. Rock Flume: A rock flume is a riprap-lined channel to convey water down a relatively steep slope without causing erosion problems on or below the slope.

   Drainage area should not exceed 10 acres per rock flume.

   Remove all unsuitable material, such as trees, brush, roots, or other obstructions before installation. Shape the channel to proper grade and cross-section as shown in the plans, with no abrupt deviations from design grade or horizontal alignment. Compact all fills to prevent unequal settlement. Design the rock flume for the local conditions and have the hydraulic capacity for rain storms and break-up. Consider placing geotextile under the riprap where appropriate.

H.1.3 Sediment Controls

Sediment control shall be incorporated into designs to ensure proper functioning of the drainage components. Sediment control can be accomplished through the use of natural features such as ponds and wetlands or through constructed features such as siltation traps and re-vegetation of ditches. The choice of re-vegetation seed mixes should mimic, to the extent possible, native local vegetation.

H-2 ORGANIZATIONS ISSUING STANDARDS:

ASTM – American Society for Testing and Materials

CSA – Canadian Standards Association

H-3 MINOR SYSTEM

H.3.1 Flow Rates

1. The stormwater management system shall be designed as a separate system. Effluent from sanitary sewers or any potentially contaminated drainage shall not be discharged in the ditches or swales.
2. The five-year rainfall intensity table for the City shall be used for minor storm sewers. Duration time shall equal inlet time plus flow time.
3. The Rational Method shall be used in estimating flows for the design of storm ditches and swales for areas less than 10 hectares.

$$Q = \frac{CIA}{360}$$

where Q = the design peak flow rate in cubic metres per second

I = the intensity of rainfall in millimetres per Hour

A = the contributing area in hectares

C = the runoff coefficient

4. Minimum runoff coefficients shall be according to the following table:

Land Use/Surface Characteristics	Runoff Coefficient, C
Open Space	0.15
Residential Lots	0.35
Industrial	0.70
Commercial	0.70
Multiple Family	0.70
Undeveloped Land	0.1
Pavement, concrete, buildings	0.95
Gravel Roadways	0.3

5. Due to the large variation in lot sizes for commercial and industrial areas, a weighted runoff coefficient for these types of developments can be calculated using the following formula:

$$C = \frac{(0.9 \text{ X Impervious Area}) + (0.15 \text{ X Pervious Area})}{\text{Total Area}}$$

6. The intensity for the rational formula is selected from the Intensity Duration Frequency (IDF) curve, with a duration chosen to coincide with the time of concentration (tc). The time concentration for runoff flow is the time required for runoff flow to become established and reach the design location from the furthest point within the contributing catchment area.

7. Determination of tc requires estimation of two components, the inlet time and travel time. The inlet time is the time for flow from the extreme limits of the catchment to reach the point of inflow into the defined conveyance system. It is dependent upon the imperviousness and the size of catchment. The travel time is the length of time required for flow to travel within the conveyance system from the point of inflow to the design location.

8. Rainfall IDF curves for City of Iqaluit for selected return frequency events are presented in the tabular form in **Tables H.3.1 and H.3.2**, visual representation of which can be seen on **Figure H.3.1**. The IDF curves are based on data collected at 3 station between 1950 and 2017.

9. IDF curves for the future climate change scenarios are presented in **Figure H.3.2** along with the two-parameter equation for curve fitting. Designers shall use the non-climate change IDF curves from **Table H.3.1** and **H.3.2** for design purposes and Climate Change IDF Curves from **Figure H.3.2** for a “stress test” to determine future climate change impacts on infrastructure.

10. In areas, where snow is piled intentionally or accumulates naturally, a design check should also be done for peak daily melt rate using a conversion of 1cm of snow = 1 mm of runoff. This is to ensure that the runoff from snow piles during the melt period is also accounted for, in the design.

11. Minimum velocity shall be 1m/s. Where velocities in excess of 3 m/s are attained, special provisions shall be made to protect against displacement by erosion or impact.
12. Pipe sizing shall be determined by using Manning's Formula. A maximum manning's "n" of 0.013 for smooth walled storm pipe and "n" of 0.016 for concrete gutters and paved roads is to be used.
13. For areas larger than 10 hectares, acceptable computer modeling of the area must be submitted for review.

Table H.3.1 - IDF Curves - Intensity Table
3 Rain Gauges, Period 1946 - 2017
Maximum Years of Record = 71
IDF Intensity (mm/hr)

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
5		12.85	19.57	24.11	29.89	34.19	38.45	42.71
6		12.41	19.03	23.49	29.14	33.35	37.52	41.68
7		12.00	18.54	22.91	28.44	32.55	36.64	40.70
8		11.64	18.08	22.36	27.77	31.80	35.79	39.78
9		11.31	17.64	21.84	27.14	31.08	35.00	38.89
10		11.01	17.23	21.34	26.54	30.40	34.23	38.05
11		10.73	16.85	20.88	25.97	29.76	33.51	37.25
12		10.47	16.48	20.44	25.43	29.14	32.82	36.48
13		10.23	16.14	20.02	24.91	28.55	32.15	35.75
14		10.00	15.81	19.62	24.42	27.99	31.52	35.04
15		9.79	15.50	19.24	23.95	27.45	30.91	34.37
16		9.60	15.21	18.88	23.50	26.93	30.33	33.72
17		9.41	14.93	18.53	23.07	26.44	29.78	33.10
18		9.24	14.66	18.20	22.65	25.96	29.24	32.51
19		9.08	14.40	17.88	22.26	25.50	28.73	31.93
20		8.92	14.16	17.57	21.87	25.07	28.23	31.38
21		8.77	13.93	17.28	21.51	24.64	27.75	30.85
22		8.63	13.70	17.00	21.16	24.24	27.29	30.34
23		8.50	13.49	16.73	20.82	23.85	26.85	29.84
24		8.37	13.28	16.47	20.49	23.47	26.42	29.36
25		8.25	13.08	16.22	20.17	23.10	26.01	28.90
26		8.14	12.89	15.98	19.87	22.75	25.61	28.46
27		8.03	12.70	15.75	19.57	22.41	25.22	28.03
28		7.92	12.53	15.52	19.29	22.08	24.85	27.61
29		7.82	12.36	15.31	19.01	21.76	24.49	27.20
30		7.72	12.19	15.10	18.75	21.46	24.14	26.81

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
31		7.63	12.03	14.89	18.49	21.16	23.80	26.43
32		7.53	11.88	14.70	18.24	20.87	23.47	26.07
33		7.45	11.73	14.51	18.00	20.59	23.15	25.71
34		7.36	11.58	14.32	17.76	20.32	22.84	25.36
35		7.28	11.44	14.14	17.54	20.05	22.54	25.02
36		7.20	11.31	13.97	17.31	19.79	22.25	24.70
37		7.13	11.17	13.80	17.10	19.55	21.97	24.38
38		7.05	11.05	13.64	16.89	19.30	21.69	24.07
39		6.98	10.92	13.48	16.69	19.07	21.42	23.77
40		6.91	10.80	13.32	16.49	18.84	21.16	23.48
41		6.84	10.68	13.17	16.30	18.61	20.91	23.19
42		6.78	10.57	13.03	16.11	18.40	20.66	22.91
43		6.72	10.46	12.88	15.93	18.19	20.42	22.64
44		6.65	10.35	12.75	15.75	17.98	20.18	22.38
45		6.59	10.25	12.61	15.58	17.78	19.95	22.12
46		6.54	10.14	12.48	15.41	17.58	19.73	21.87
47		6.48	10.04	12.35	15.25	17.39	19.51	21.63
48		6.43	9.95	12.23	15.08	17.20	19.30	21.39
49		6.37	9.85	12.10	14.93	17.02	19.09	21.15
50		6.32	9.76	11.98	14.77	16.84	18.89	20.92
51		6.27	9.67	11.87	14.63	16.67	18.69	20.70
52		6.22	9.58	11.75	14.48	16.50	18.50	20.48
53		6.17	9.49	11.64	14.34	16.33	18.31	20.27
54		6.12	9.41	11.53	14.20	16.17	18.12	20.06
55		6.08	9.33	11.43	14.06	16.01	17.94	19.86
56		6.03	9.25	11.32	13.93	15.86	17.76	19.66
57		5.99	9.17	11.22	13.80	15.70	17.59	19.47
58		5.95	9.09	11.12	13.67	15.56	17.42	19.28
59		5.90	9.01	11.03	13.54	15.41	17.25	19.09
60		5.86	8.94	10.93	13.42	15.27	17.09	18.91
61		5.82	8.87	10.84	13.30	15.13	16.93	18.73
62		5.78	8.80	10.75	13.18	14.99	16.77	18.55
63		5.74	8.73	10.66	13.07	14.86	16.62	18.38
64		5.71	8.66	10.57	12.96	14.73	16.47	18.21
65		5.67	8.59	10.48	12.85	14.60	16.32	18.05
66		5.63	8.53	10.40	12.74	14.47	16.18	17.88
67		5.60	8.46	10.32	12.63	14.35	16.04	17.73
68		5.56	8.40	10.23	12.53	14.22	15.90	17.57

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
69		5.53	8.34	10.15	12.42	14.11	15.76	17.42
70		5.49	8.28	10.08	12.32	13.99	15.63	17.27
71		5.46	8.22	10.00	12.23	13.87	15.50	17.12
72		5.43	8.16	9.92	12.13	13.76	15.37	16.98
73		5.40	8.10	9.85	12.03	13.65	15.24	16.83
74		5.37	8.05	9.78	11.94	13.54	15.12	16.69
75		5.33	7.99	9.71	11.85	13.43	15.00	16.56
76		5.30	7.94	9.64	11.76	13.33	14.88	16.42
77		5.28	7.88	9.57	11.67	13.23	14.76	16.29
78		5.25	7.83	9.50	11.58	13.13	14.65	16.16
79		5.22	7.78	9.43	11.50	13.03	14.53	16.03
80		5.19	7.73	9.37	11.41	12.93	14.42	15.91
81		5.16	7.68	9.30	11.33	12.83	14.31	15.78
82		5.13	7.63	9.24	11.25	12.74	14.20	15.66
83		5.11	7.58	9.18	11.17	12.64	14.10	15.54
84		5.08	7.54	9.12	11.09	12.55	13.99	15.43
85		5.06	7.49	9.06	11.01	12.46	13.89	15.31
86		5.03	7.44	9.00	10.94	12.37	13.79	15.20
87		5.01	7.40	8.94	10.86	12.29	13.69	15.08
88		4.98	7.35	8.88	10.79	12.20	13.59	14.97
89		4.96	7.31	8.82	10.72	12.12	13.49	14.87
90	1.5	4.93	7.27	8.77	10.64	12.03	13.40	14.76
120	2	4.35	6.22	7.42	8.91	10.02	11.10	12.18
180	3	3.63	4.94	5.79	6.83	7.61	8.36	9.12
240	4	3.18	4.18	4.82	5.61	6.20	6.78	7.35
300	5	2.87	3.66	4.17	4.80	5.27	5.73	6.18
360	6	2.64	3.28	3.70	4.22	4.61	4.98	5.36
420	7	2.46	2.98	3.34	3.77	4.10	4.42	4.74
480	8	2.31	2.75	3.05	3.43	3.71	3.98	4.26
540	9	2.19	2.56	2.82	3.14	3.39	3.63	3.87
600	10	2.08	2.40	2.62	2.91	3.13	3.34	3.55
660	11	1.99	2.26	2.46	2.71	2.91	3.09	3.28
720	12	1.91	2.14	2.32	2.54	2.72	2.88	3.06
780	13	1.84	2.04	2.20	2.40	2.55	2.70	2.86
840	14	1.78	1.95	2.09	2.27	2.41	2.55	2.69
900	15	1.73	1.87	1.99	2.16	2.29	2.41	2.54
960	16	1.67	1.79	1.90	2.05	2.17	2.29	2.41
1020	17	1.63	1.73	1.83	1.96	2.07	2.18	2.29

Time		Return Frequency						
Minutes	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
1080	18	1.58	1.67	1.76	1.88	1.98	2.08	2.18
1140	19	1.54	1.61	1.69	1.81	1.90	1.99	2.09
1200	20	1.51	1.56	1.63	1.74	1.83	1.91	2.00
1260	21	1.47	1.51	1.58	1.68	1.76	1.83	1.92
1320	22	1.44	1.47	1.53	1.62	1.69	1.77	1.84
1380	23	1.41	1.43	1.48	1.56	1.64	1.70	1.78
1440	24	1.38	1.39	1.44	1.52	1.58	1.64	1.71

IDF Parameter

Rate = a*(b^t)*(t^c)	Return Frequency						
Parameter	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
a	5.876	8.466	10.188	12.369	13.989	15.598	17.203
b	0.988	0.985	0.983	0.981	0.980	0.979	0.979
c	-0.409	-0.428	-0.436	-0.442	-0.446	-0.448	-0.450

Where t = duration in hours

Figure H.3.1: Intensity Duration Frequency Curve – City of Iqaluit

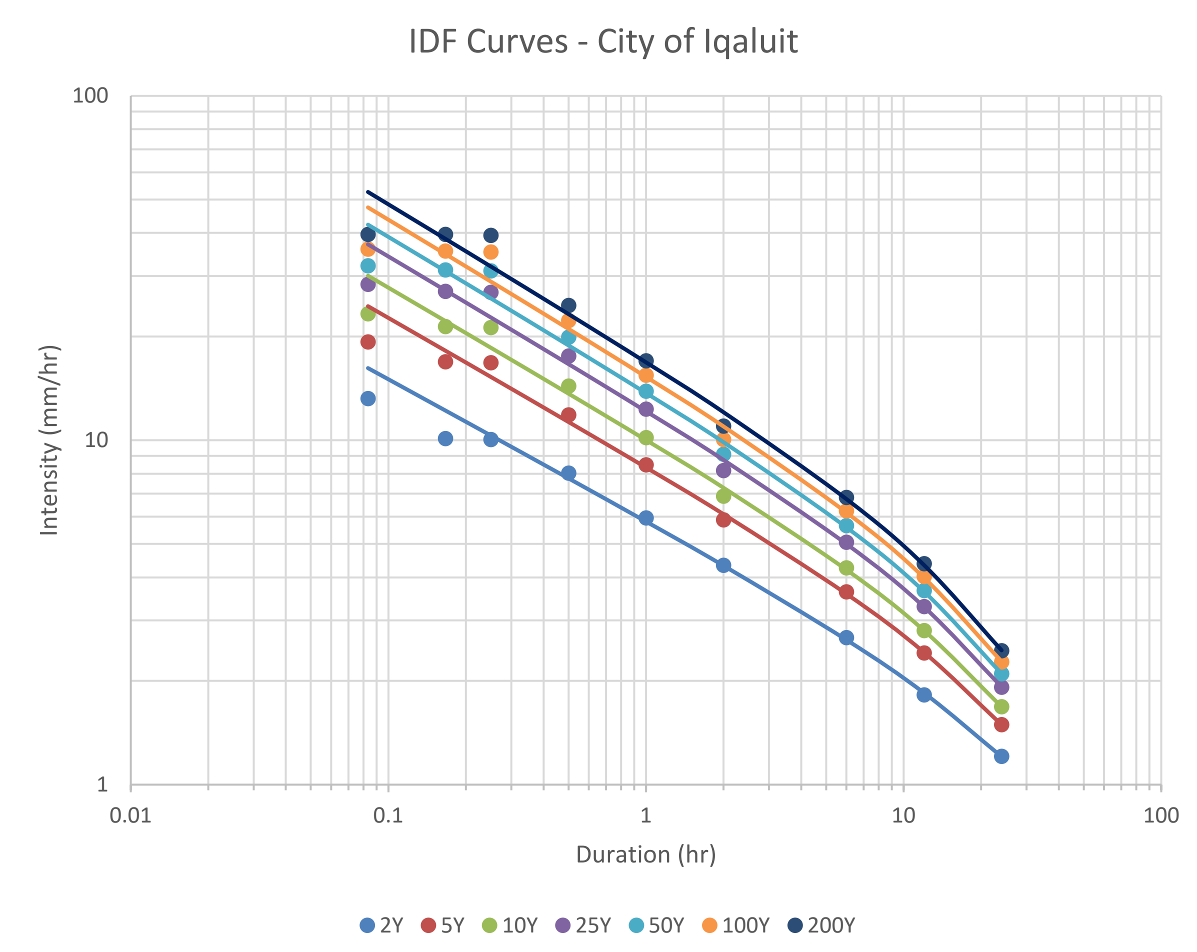


Table H.3.2 - IDF Curves - Intensity Table - Summary
3 Rain Gauges, Period 1946 - 2017
Maximum Years of Record = 71

Duration		Return Frequency						
Min	Hours	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
5	0.083	13.22	19.28	23.29	28.36	32.13	35.86	39.58
10	0.167	10.11	16.89	21.38	27.05	31.26	35.44	39.60
15	0.25	10.06	16.79	21.25	26.88	31.06	35.21	39.34
30	0.5	8.03	11.85	14.37	17.56	19.93	22.27	24.61
60	1	5.95	8.49	10.18	12.30	13.88	15.45	17.01
120	2	4.34	5.87	6.88	8.16	9.11	10.05	10.99
360	6	2.67	3.63	4.26	5.05	5.65	6.23	6.82
720	12	1.82	2.41	2.80	3.29	3.66	4.02	4.38
1440	24	1.21	1.49	1.68	1.92	2.10	2.27	2.45

Figure H.3.2: Intensity Duration Frequency Curve – Climate Change Scenario City of Iqaluit

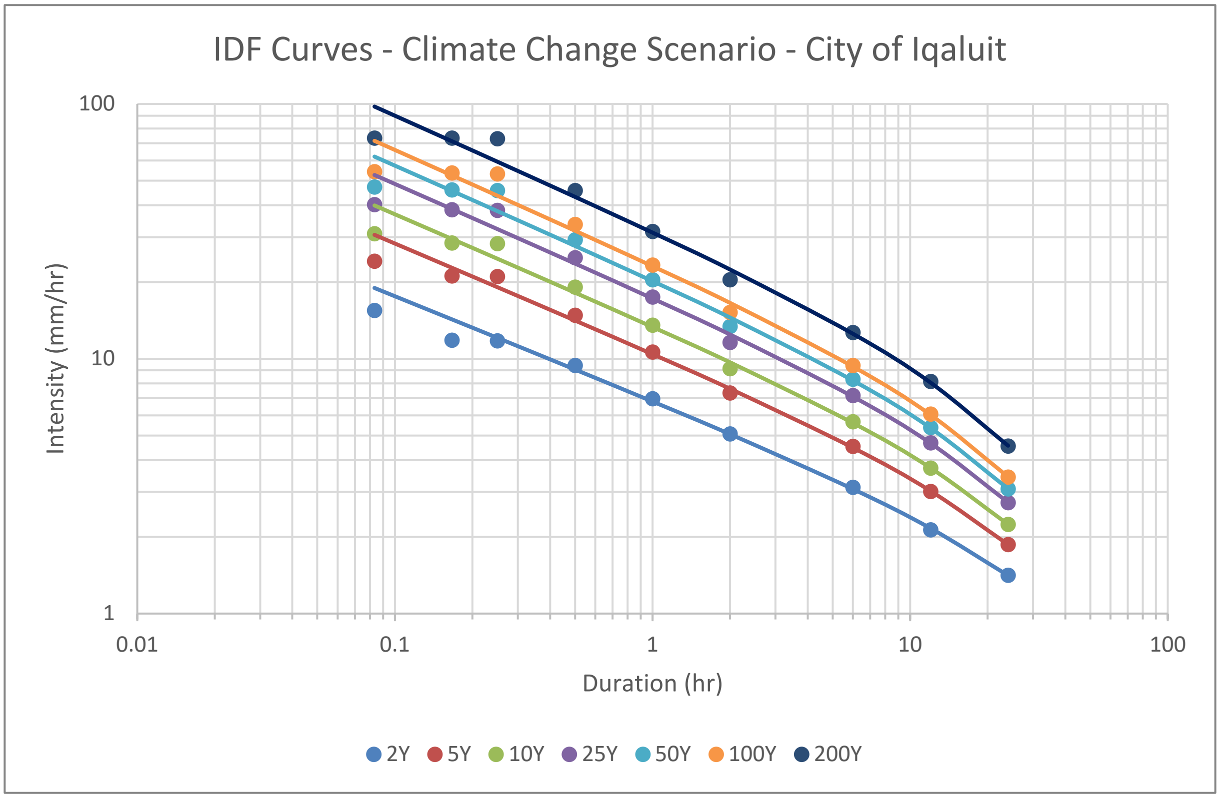


Table H.3.3
IDF Parameters – Climate Change Scenario

Rate = a*(b^t)*(t^c)	Return Frequency						
Parameter	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
a	6.875	10.583	13.550	17.564	20.564	23.553	31.940
b	0.988	0.985	0.983	0.981	0.980	0.979	0.979
c	-0.409	-0.428	-0.436	-0.442	-0.446	-0.448	-0.450

Where t = duration in hours

H.3.2 Curb and Gutter

Drainage discharge locations shall be positioned so that they do not impact surface water intake, and so that water samples can be easily taken.

H.3.3 Outfalls

1. At the end of an outfall sewer, energy dissipaters are often necessary to avoid downstream erosion and damage of creeks, ravines or river banks from high exit flow velocities. Outfall structures are required at locations where it is necessary to convert supercritical flow to subcritical, to dissipate flow energy and to establish suitably

tranquil flow conditions downstream.

2. When sewers discharge at subcritical flow, then smaller concrete structures with suitable baffles, aprons and rip-rap will be acceptable. For all outfalls, it is required that a rigorous hydraulic analysis be completed, to ensure that the exit velocities will not damage natural watercourses. The final exit velocities, where the flow passes from an apron or erosion control medium to the natural channel, shall not exceed 1.0 m/s and may be further limited depending on site specific soil and flow conditions.
3. Appropriate erosion control measures are to be provided at and downstream of the outfall to prevent erosion in the downstream channel.
4. All sewer outlets shall be constructed with provisions to prevent the entrance of children or other unauthorized persons. A grate with vertical bars spaced at no more than 150 mm shall be installed with adequate means for locking in a closed position. Provide for opening or removal of the gate for cleaning or replacing the bars. Grates should be designed to break away under extreme hydraulic loads in the case of blockage.
5. Guardrails or fences of corrosion resistant material shall be installed along concrete headwalls and wingwalls to provide protection against persons falling.
6. Outfalls, which are often located in parks, ravines, or on river banks should be made as safe and attractive as is reasonably possible. The appearance of these structures is important and cosmetic treatment or concealment is to be considered as part of the design. Concrete surface treatment is recommended to present a pleasing appearance. Bush hammered or exposed aggregate concrete is recommended. Live stakes or bioengineering is encouraged wherever applicable.
7. The location of the riparian zone shall be considered when locating outfalls according to the requirements of the authority having jurisdiction.

H-4 MAJOR SYSTEM

H.4.1 General

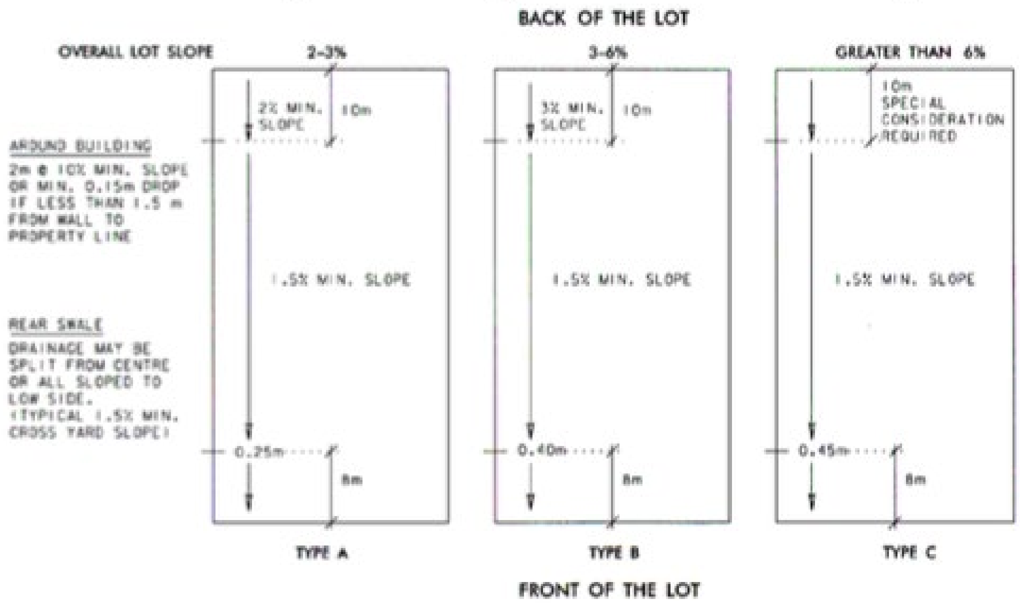
The major conveyance system accommodates flows not intercepted by or beyond the capacity of the minor drainage system through planned surface flow routes and storage facilities. The intent of the major system is to provide surface flow management in order to minimize flooding and property damage from a 1:100 year rainfall event. The design of the major drainage system must not be limited to the immediate development area but must consider overland flows that may enter the area from adjacent land as well as down stream effects on adjacent development and receiving water bodies.

H.4.2 Lot Grading

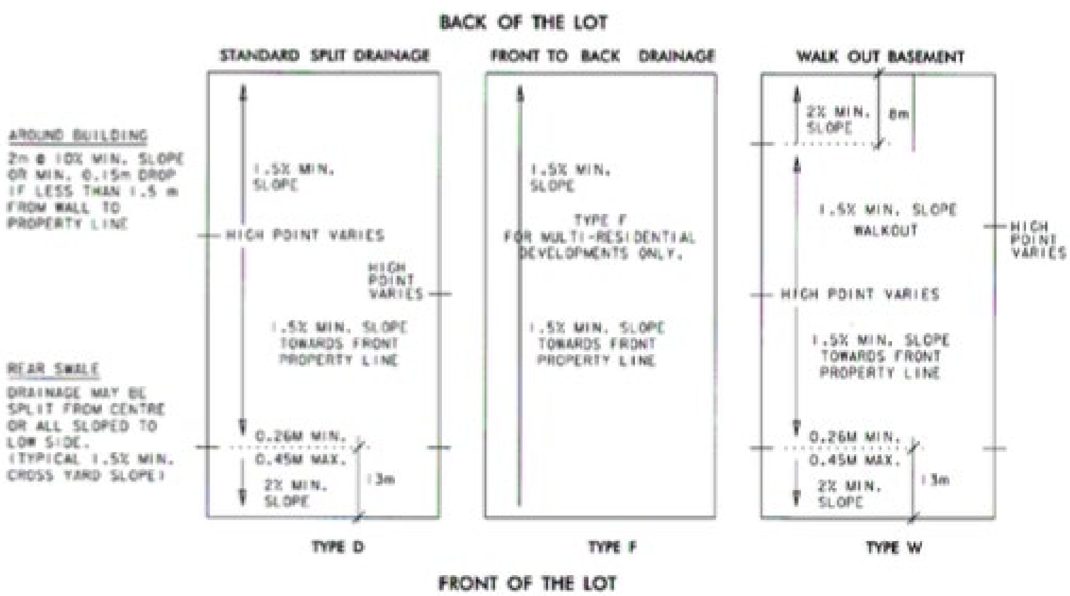
Proper lot grading is the first step towards a well-planned major drainage system. The goal of the lot grading shall be to ensure that water flows away from the building. Flow from lots shall always have an escape route to a public right-of-way. The lot-grading plan shall develop a proper balance between the road elevation, proposed building elevations, surrounding development and existing topography.

1) The level-of-service requirements for lot grading include provision of protection against surface flooding and property damage for the 1 in 100 year return frequency design storm. Through control of surface elevations, designs should be such that maximum flow or ponding surface elevations are 150 mm below the lowest anticipated finished ground elevations at buildings. An overflow route or sufficient ponding volume must be provided from or at all sags or depressions to provide for this 150 mm freeboard with the maximum depth of ponding is limited to 350 mm.
2) The establishment of a lot grading plan is one of the principal means for establishing a critical component of the major drainage system. The lot grading plan is a specific requirement within the detailed Engineering Drawings for a subdivision under the terms of a standard servicing agreement. Lot grading plans are required for most property developments involving building construction or surface improvements and may be a requirement of a development permit or pursuant to requirements of bylaws, regulations, other approvals or agreements.
3) Site grading shall ensure proper drainage of individual private properties or establish an effective surface drainage system for a whole development area. A lot grading plan will establish the drainage relationship between adjacent properties and its approval is an effective basis for the control of grading of the properties.
4) In the design of lot grading plans, the designer must achieve a proper relationship and balance between the street elevation, building grade elevation, surrounding development and existing topography.
5) The implications of required noise attenuation berms and other elevation controlling features are to be fully addressed by the designer. It is also important to ensure that the lot grading design and the anticipated house or building designs are complementary. Reverse slope driveways and other features that would be likely to capture runoff or fail to drain during major rainfall events should be discouraged.
6) The Developer must ensure that builders are informed of any potential problems or restrictions respecting building design and lot grading. The lot grading plan will be used as one of the principle means by which this information is communicated.
7) Details of grading within lots. Refer figures below for typical lot grading details for various standard drainage arrangements for detached residential developments.

Typical Lot Grading Details – Rear To Front Drainage



Typical Lot Grading Details – Split/Front to Back Drainage



8) The relative surface elevations must allow for the slope of the ground adjacent to the building to be at a minimum of 10% for a distance of 2.0 m or to the property line, on all sides of the house, with the slope directing drainage away from the building and then for reasonable slopes in the order of 1.5% to 2.0% from all points within the property to the property boundary at which the drainage may escape.

9) Property line elevations are to be established such that lots have a minimum overall slope of 2.0%, from the high point to the front or back property lines for split drainage situations, or between the higher and lower, front and rear property lines with through drainage. The

minimum grade (2%) should normally be exceeded if topography allows.

10) Split drainage or through drainage (front to rear or rear to front drainage) will be allowed when a lot is located such that there is a road, lane, or public right-of-way at both the front and back of the lot.
11) Rear to front drainage is preferred in alleyless subdivisions. Split drainage in alleyless subdivisions will be permitted only if all of the following conditions are met:

    - it is not feasible to achieve rear-to-front drainage due to extreme natural topography;
    - the receiving downstream lot has an overall grade of 3.0% or more;
    - there is no concentration of flow from upstream lots to downstream lots;
    - only one lot drains to another lot;
    - runoff from the roof of the upstream lot is directed to a storm service or the upstream lot's grading is designed with the ridge as close to the rear property line as possible.

    In situations where split drainage may be problematic due to the above conditions not being met, the use of a swale for the interception of split drainage and its conveyance to a public right of way will be permitted.

H.4.3 Swales

12) Drainage swales on municipal or private property shall be constructed prior to any development of subdivision lots. Complete swale construction shall be a prerequisite to the issuance of the Substantial Certificate of Completion.
13) Swales may be used on public rights-of-way, including easements, for the collection and conveyance of major and minor runoff to appropriate points of interception or release. Swales on public rights-of- way, except easements, should not to be provided with concrete flow channels or hard surface treatments, except where such measures are required to address flow velocity or erosion concerns. A standard swale / ditch example for driveways and public right of way (ROW) has been provided in appendix A of this design guidelines.
14) The use of swales crossing private properties for collection of runoff and drainage control is not permitted unless proper justification is produced and documented indicating that no other alternative is feasible. If the Engineer approves use of such swales they are to be covered by easements in favour of the City, to the satisfaction of the Engineer.
15) Drainage swales located on private property shall be covered by an easement in favour of the City. A minimum clearance of 200mm should be provided between the edge of the swale and the property line. Major rainfall event flows shall be contained within the easement.
16) Drainage swales crossing several properties for the collection of runoff shall not be permitted unless special circumstances warrant.
17) When swales crossing several properties cannot reasonably be avoided, then the following requirements shall be satisfied:

a) Grass swales serving lots on one side only
   i) Location**:** Rear of upstream lot in a 2.0 m easement
   ii) Cross Section: V-shape, 150 mm minimum depth and 4H:1V maximum side slope
   iii) Longitudinal slope: 1.5% minimum
b) Grass swales serving lots on both sides
   i) Location: Common rear property line as centre of a 4.0 m easement.
   ii) Cross-section: Trapezoidal with 1.0 m bottom, 150 mm minimum depth and 4H:1V maximum slope.
   iii) Longitudinal slope: 1.5% minimum
c) Grass swales with concrete gutter, serving lots on one or both sides
   i) Location: Upstream lot with the gutter preferably centred on the 2.0 meter easement.
   ii) Cross-section of gutter: V-shape, 75mm to 150mm deep, 500mm to 610mm wide with 4H:1V maximum slope. 100mm minimum thickness with 3-10 M longitudinal bars and 3.0 m spaced control joints.
   iii) Longitudinal slope: 0.75% minimum.
   iv) Note: alternate design considerations with respect to minimum slope requirements for swales will be considered when swales are located within existing developments or at locations where infill development is proposed.
d) Other parameters and requirements
   i) Capacity: Contain the 1:5 year storm flow within the concrete gutter and the 1:100 year storm major flow within the easement.
   ii) Interception: Provide a catchbasin upstream of a walkway to intercept the 1:5 year storm flow. Limit the depth of ponding to 150 mm with 5H:1V maximum side slope all around the CB cover.
   iii) No. of lots draining to swale – Depending on the concrete gutter and swale capacities, and the CB's 1:5 year storm flow inlet capacity.
   iv) Bends: Bends greater that 45 degrees shall be avoided, and no bend greater than 90 deg. shall be allowed. When 45 deg. bend is exceeded, provide a 1.0 minimum centreline radius and adequate curbing to contain the design flows within the gutter and easement.
   v) Conveyance: The grading of the boulevard and sidewalk shall be such that the major flow will not be allowed to flow down the sidewalk.
   vi) Erosion and sediment control: Grass swales preferably shall be sodded, or at the least, shall be topsoiled and seeded, Interim measures shall be provided to protect exposed surfaces from erosion until the grass cover is established.
   vii) Swales that convey flows from more than two lots must not be routed along the side yard of a single family or duplex residential lot.
   viii) Future swale extensions shall be identified and evaluated to ensure that anticipated constraints and capacities are addressed.
   ix) Details: Show on the Lot Grading Plan, the cross-section, inverts, slopes and lot grades along the swale.
   x) Calculations for the swale's minor and major flow capacities shall be submitted with the engineering drawings.

18) The minimum design slope for swales is 1%.

H.4.4 Roadways

Grading of streets comprising the major drainage system shall follow the guidelines listed below:

1. Continuity of over flow routes between adjacent developments shall be maintained.
2. Collectors shall have at least one lane that is not inundated.
3. The depth of peak flows and ponding in developed area streets, conveyance channels and swales, are to be limited so that major system flows will not constitute a significant hazard to the public, or result in significant erosion or other property damage. Where erosion is anticipated, an ESC Plan should be designed to suit site specific situations.
4. An overflow must be provided from all sags or depressions such that there will be a freeboard of at least 150 mm above the overflow elevation to the proposed ground surface elevation at adjacent buildings and maximum depth of ponding is limited to 350mm.
5. The maximum water surface level of surface flows and ponding in streets is below the lowest anticipated landscape grade or opening at any adjacent buildings, with a freeboard provision generally in the order of 350 mm with a minimum of 150 mm.
6. Depths of flow and ponding are less than 350 mm in roadways and other public rights-of-way.
7. For arterial roadways, the water depth at the crown of the road shall not exceed 150 mm.
8. The theoretical street carrying capacity can be calculated using modified Manning's formula with an "n" value applicable to the actual boundary conditions encountered. Recommended values are n = 0.013 for roadway and n = 0.05 for grassed boulevards.

I STREET LIGHTING

I-1 STANDARD AND GUIDELINES

These guidelines are intended as a guide only. The Design Engineer is responsible to ensure that the water system is designed and constructed according to accepted engineering practice.

These Guidelines shall not be considered as a substitute for a detailed material and construction specification prepared by the Design Engineer.

The street lighting design shall be in accordance with the “Guide for the Design of Roadway Lighting” published by the Transportation Association of Canada (TAC) as well as applicable standards published by the Illuminating Engineering Society of North America (IES).

All roadway lighting systems shall be installed in strict compliance with the Canadian Electrical Code.

These Guidelines only apply in areas where street lighting is specified.

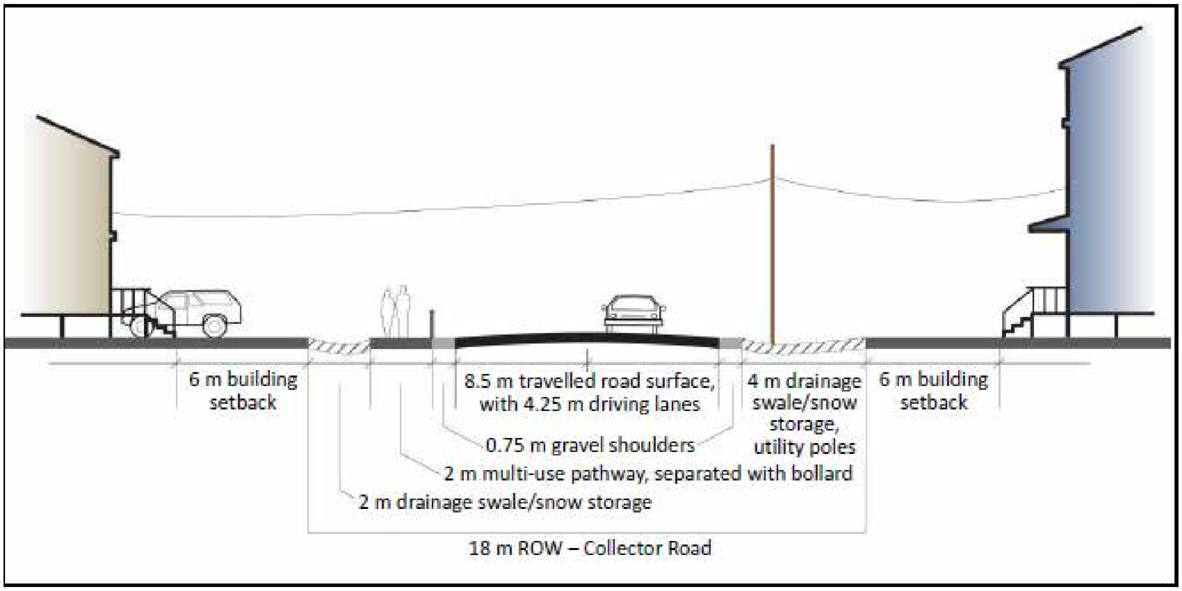
Appendix A

Excerpt taken from CAN / CSA – S503 – 15 Community drainage system planning, design and maintenance in northern communities, indicates proper width of ditch / swale for public right of way.

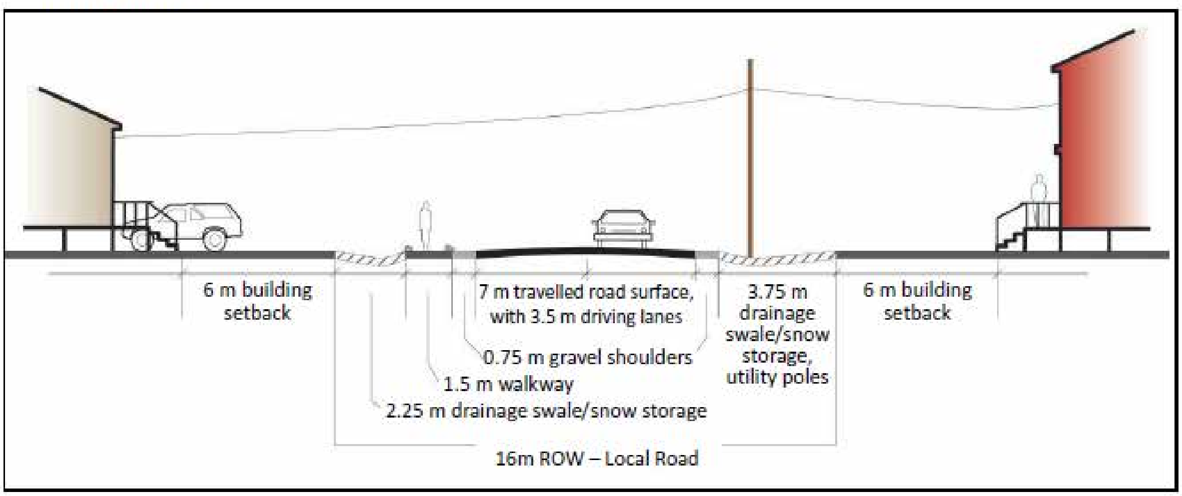
Profile view showing driveways and drainage ditches/swales

(See Clause 4.1.)

Collector road rights-of-way should be at least 18 m wide to allow for road lanes, shoulders, pedestrian walkways, drainage ditches, and utility poles.



Local road (two-way) rights-of-way should be at least 16 m wide to accommodate road lanes, shoulders drainage ditches, and utility poles.



APPENDIX E
DIGITAL DATA

Provided with this report are the digital files used for this study. A USB stick has been provided, which includes the following:

- Model Files
- Windshield Surveys
- Field Inspection Photgraphs
- Culvert Crossings Database

Stantec

Stantec Consulting Ltd.
10160 112 Street
Edmonton AB T5K 2L6
Tel: (780) 917-7000
www.stantec.com

The Contractor shall verify and be responsible for all dimensions. DO NOT scale the drawing - any errors or omissions shall be reported to Stantec without delay.

Consultant

Permit/Seal

Client/Project
IQALUIT
PROJECT
Iqaluit, Nunavut

Project No.: 144902610
File Name: IQALUIT-CITY_MAP
Scale: 1:5,500

Dwn.	Dsgn.	Chkd.	YYYY.MM.DD
			2018.10.30

Title

Legend
Outfalls
Storages
Conduits
Creeks Culverts
Stantec Confrimed Culverts
City-Indicated Culverts
Suspected Culverts
LiDAR Flow Paths
Stantec Ditch
Water Flow
Subcatchments
Other
Airport
Geraldine
Apex
Baffin Island
N
2 km


Baffin Island
Baffin Island
Road To Nowhere
Legend
Outfalls
Storages
Conduits
Other
Creeks Culverts
Stantec Confrimed Culverts
City-Indicated Culverts
Suspected Culverts
LiDAR Flow Paths
Stantec Ditch
Water Flow
Subcatchments
Other
Airport
Geraldine
Apex
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Legend
Storages
Conduits
Watercourses
Creeks Culverts
Stantec Confrimed Culverts
City-Indicated Culverts
Suspected Culverts
LiDAR Flow Paths
Stantec Ditch
Water Flow
Subcatchments
Other
Airport
Geraldine
Apex
Qaqqamiut Rd
Iqaluit
Iqaluit Airport
Baffin Island
Road To Nowhere
Akilliq Dr
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Legend
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Watercourses
Creeks Culverts
Stantec Confrimed Culverts
City-Indicated Culverts
Suspected Culverts
LiDAR Flow Paths
Stantec Ditch
Water Flow
Subcatchments
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Airport
Geraldine
Apex
Qaggamiut Rd
Iqaluit
Iqaluit Airport
Baffin Island
Road To Nowhere
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Water Flow
Subcatchments
Other
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Geraldine
Apex
Iqaluit
Iqaluit Airport
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Road To Nowhere
Queen Elizabeth Way
Baffin Island
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APPENDIX F
IQALUIT BASELINE
WATER QUALITY REPORT

Water quality around Iqaluit

Introduction:

INAC helps protect water quality in Canada's North. INAC is responsible for the management of water resources in and around Nunavut and the Northwest Territories much like provinces and municipalities are on other Canadian coastlines.

Water quality data is needed in order to properly manage water resources. INAC collects water quality information and undertakes water quality monitoring. Water quality monitoring is carried out in order to address major development and water planning and management issues. Good water quality data is important for monitoring ecosystem and human health. In addition to these monitoring networks, specific targeted studies are undertaken to respond to particular issues or concerns raised in environmental assessments and license hearings. These targeted studies are often done under the Northern Water Research Studies Program (NWRSP).

INAC's role as the northern water manager requires a broad and long term view of the resource, its potential uses and future demands. Broad-based research programs which seek to understand the watershed as a whole have been undertaken.

The city of Iqaluit is the capital of Nunavut and is the largest community in the province with a population of approximately 6,200. It is located on the southeast end of Baffin Island at the head of Frobisher Bay. A continuous increase in the population size of the community of Iqaluit has led to extensive development in the area, making water quality a concern. In response to growing water quality concerns, INAC developed and implemented a research program that involved monitoring surface water quality in the community in 2004. Water quality data was collected until 2009.

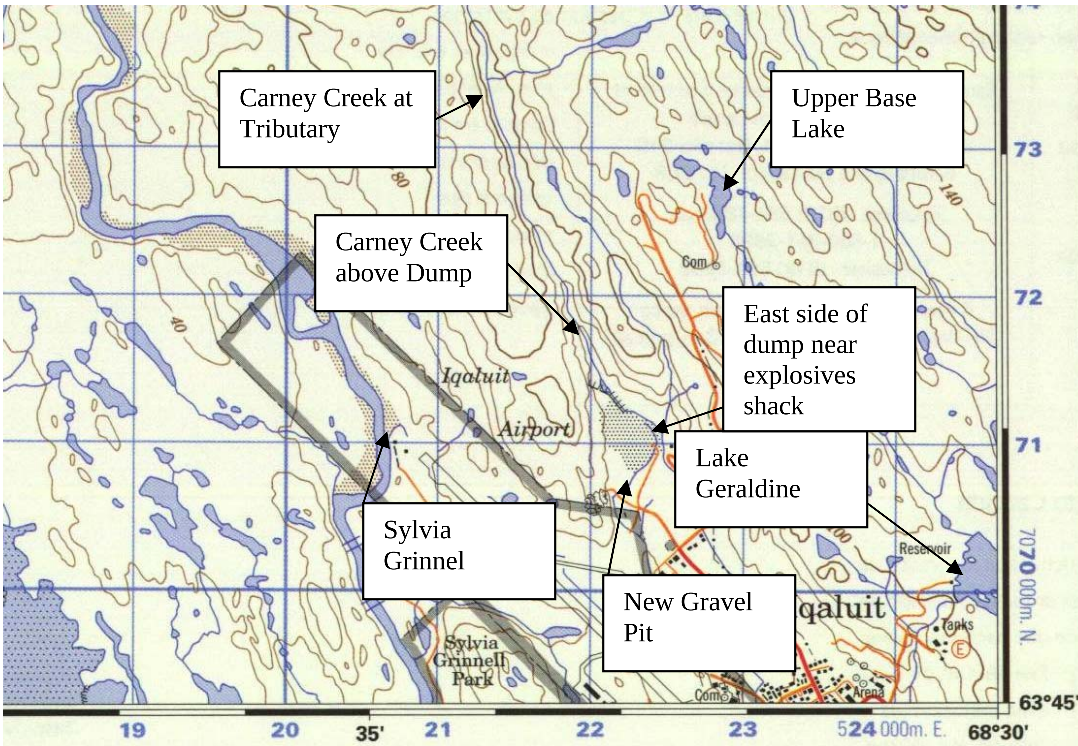
Prior to 2006, 6 sites were monitored, but due to an increase in construction another 4 sites were added to the program. Some of the sites (Sylvia Grinnell, the New Gravel Pit, and the Carney Creek Outlet) required more attention than others due to the areas being linked to the former US base, which is now the community's airport.

Methodology

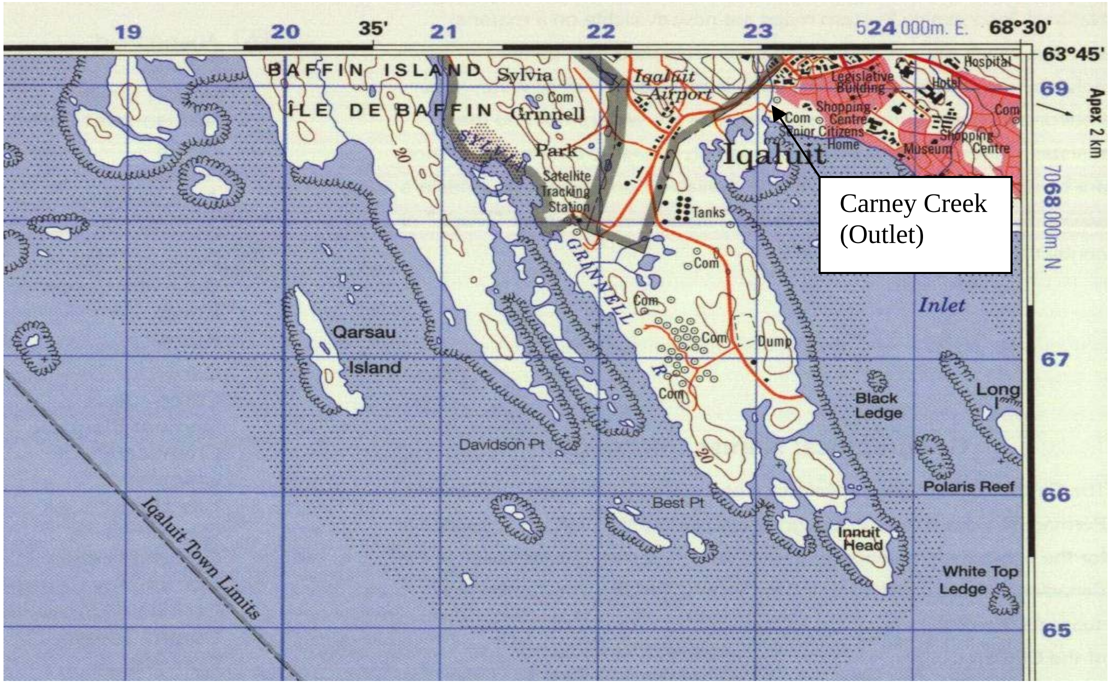
Sampling Sites:

Sampling locations were selected for baseline data collection only and are dispersed throµghout the community of Iqaluit. Seven sites were sampled in 2004 and 2005. These sites included two locations at Sylvia Grinnell, one location at Lake Geraldine, three locations at Carney Creek and one location at Apex River. Ten sites were sampled from 2006-2009: two locations at Sylvia Grinnell, one location at Lake Geraldine, three locations at Carney Creek, one location at Apex River, one location at Upper Base Lake, one location at the River northwest of the Gravel Site, and one location at Gravel Source

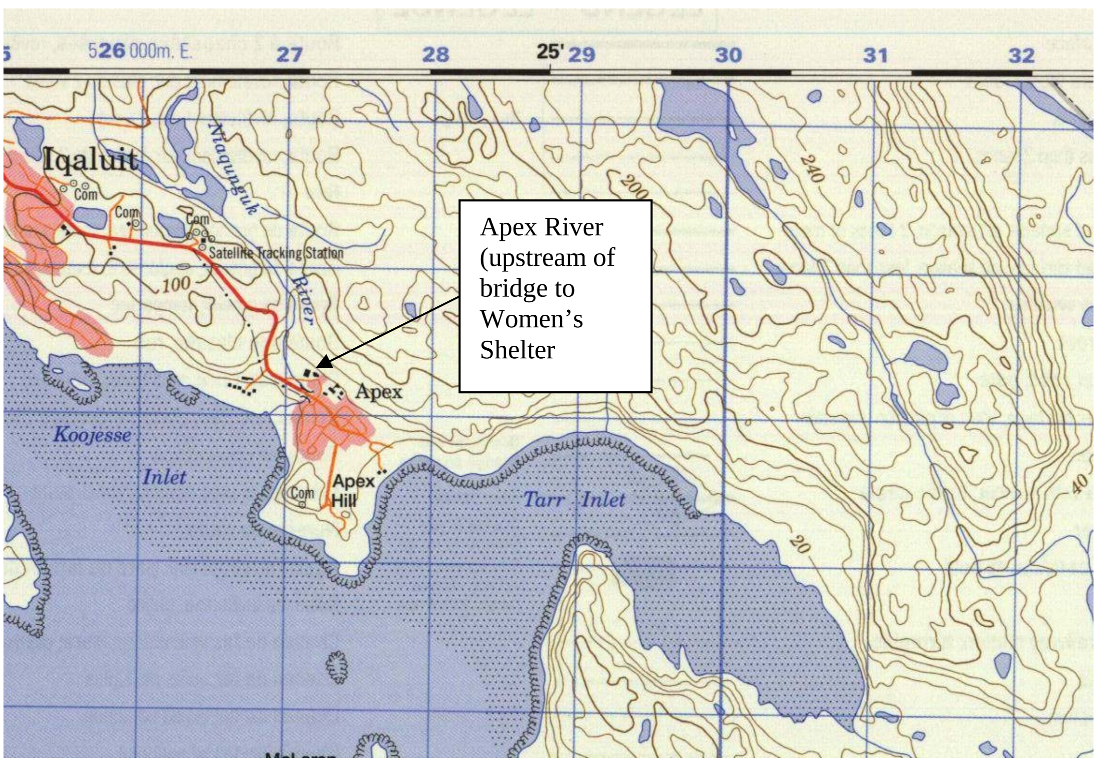
Lake. An additional two sites were sampled in 2008/2009 and were located at the new Gravel Pit and on the East Side of the Dump. Sites were chosen based on proximity to town and in areas of potential contamination. Upper Carney Creek, Sylvia Grinnell, and Apex River locations were selected as "clean" uncontaminated sites where as Upper Base Lake, Carney Creek (Above Dump), the new Gravel Pit, and the East side of the Dump were selected as potentially contaminated sites.



Map 1- Carney Creek (Tributary), Carney Creek (Above Dump), Sylvia Grinnell, and Lake Geraldine locations sampled for baseline water quality data by INAC from 2004-2009 in Iqaluit, Nunavut



Map 2- Carney Creek (Outlet) location sampled for baseline water quality data by INAC from 2004-2009 in Iqaluit, Nunavut



Map 3- Apex River location sampled for baseline water quality data by INAC from 2004-2009 in Iqaluit, Nunavut

Sampling Parameters:

Each sample was tested for a variety of physical, chemical, and biological parameters, including nutrients, metals, and organics. The full suite of parameters is listed in Table 1.

Table 1- Physical, chemical and biological parameters tested by Taiga Environmental Laboratory for each of the 10 locations from 2004-2009 around the community of Iqaluit.

Type	**Parameter**	**Unit**
Physical/Chemical	Total Suspended Solids (TSS)	mg/L
	Total Dissolved Solids (TDS)	mg/L
	Hardness	mg/L
	Alkalinity	mg/L
	Colour	CU
	Conductivity	µS/cm
	pH	pH units
Nutrients	Ammonia as Nitrogen (NH4)	mg/L
	Nitrate as Nitrogen (NO3)	mg/L
	Nitrite as Nitrogen (NO2)	mg/L
	Total Nitrogen (nitrate+nitrite)	mg/L
	Total Organic Carbon (TOC)	mg/L
	Turbidity	NTU
	Total Phosphorus (P)	mg/L
	Chemical Oxygen Demand (COD)	mg/L
Major Ions	Calcium (Ca)	mg/L
	Chloride (Cl)	mg/L
	Fluoride (F)	mg/L
	Magnesium (Mg)	mg/L
	Potassium (K)	mg/L
	Silica, Reactive	mg/L
	Sodium (Na)	mg/L
	Sulphate (SO4)	mg/L
Organics	Cyanide	mg/L
	Hexane Extractable Material (HEM)	mg/L
	Benzene	mg/L
	Ethylbenzene	mg/L
	Toluene	mg/L
	Xylenes	mg/L
	Oil and Grease (visible)	
Metals	Aluminum (Al)	µg/L

	Antimony (Sb)	µg/L
	Arsenic (As)	µg/L
	Barium (Ba)	µg/L
	Beryllium (Be)	µg/L
	Cadmium (Cd)	µg/L
	Cesium (Cs)	µg/L
	Chromium (Cr)	µg/L
	Cobalt (Co)	µg/L
	Copper (Cu)	µg/L
	Iron (Fe)	µg/L
	Lead (Pb)	µg/L
	Lithium (Li)	µg/L
	Manganese (Mn)	µg/L
	Molybdenum (Mo)	µg/L
	Nickel (Ni)	µg/L
	Rubidium (Rb)	µg/L
	Selenium (Se)	µg/L
	Silver (Ag)	µg/L
	Strontium (Sr)	µg/L
	Thallium (Tl)	µg/L
	Titanium (Ti)	µg/L
	Uranium (U)	µg/L
	Vanadium (V)	µg/L
	Zinc (Zn)	µg/L

Sampling Summaries

June/September 2004 Sampling Results

Sylvia Grinnell

In June of 2004, Sylvia Grinnell was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Nitrate + Nitrite as Nitrogen was found at a higher than normal concentration (0.2 mg/L) compared to the 1999 CCME guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded a guideline of 0.017 µg/L. Copper and Lead also surpassed their guidelines (2-4.0 µg/L and 1-7.0 µg/L, respectively) with concentrations of 4.3 µg/L and 8.35 µg/L, respectively. In September of 2004, Sylvia Grinnell yielded elevated levels of Total Suspended Solids (4.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Cadmium was also found at a higher than normal concentration (0.1 µg/L) compared to a guideline of 0.017 µg/L.

Lake Geraldine

In June of 2004, Lake Geraldine was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Nitrate + Nitrite as Nitrogen was also found at a higher than normal concentration (0.2 mg/L) compared to a guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded the 1999 CCME guidelines (0.017 µg/L). In September of 2004, Lake Geraldine yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guideline (0.002 mg/L). Cyanide was also found at a higher than normal concentration (0.145 mg/L) compared to a guideline of 0.005 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded its limit of 0.017 µg/L.

Apex River

In June of 2004, the Apex River was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Nitrate + Nitrite as Nitrogen was also found at a higher than normal concentration (0.2 mg/L) compared to the 1999 guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded its guideline of 0.017 µg/L. In September of 2004, the Apex River yielded elevated levels of Total Suspended Solids (3.5 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Cyanide was found at a higher than normal concentration (0.155 mg/L) compared to a guideline of 0.005 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded its limit of 0.017 µg/L.

Carney Creek (Outlet)

In June of 2004, Carney Creek (at the Outlet) was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Toluene was also found at a higher than normal concentration (0.005 mg/L) compared to the 1999 guideline of 0.002 mg/L. Nitrate + Nitrite as Nitrogen had a concentration of 0.2 mg/L and exceeded a guideline of 0.06 mg/L. Cadmium was present at 0.1 µg/L compared to a guideline of 0.017 µg/L. In September of 2004, Carney Creek (at the Outlet) yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Cyanide was also found at a higher than normal concentration (0.145 mg/L) compared to a guideline of 0.005 mg/L. Cadmium and Manganese exceeded their guidelines (0.017 µg/L and 50 µg/L, respectively) with concentrations of 0.1 µg/L and 88.5 µg/L, respectively.

Carney Creek (Above the Dump)

In June of 2004, Carney Creek (Above the Dump) was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Nitrate + Nitrite as Nitrogen was found at a higher than normal concentration (0.2 mg/L) compared to the 1999 CCME guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded its guideline of 0.017 µg/L. In September of 2004, Carney Creek (Above the Dump) yielded elevated levels of

Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Cyanide was also found at a higher than normal concentration (0.150 mg/L) compared to a guideline of 0.005 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded a guideline of 0.017 µg/L.

Carney Creek (Upper)

In June of 2004, Carney Creek (Upper) was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Toluene was also present at a concentration of 0.005 mg/L and exceeded the 1999 CCME guideline of 0.002 mg/L. Nitrate + Nitrite as Nitrogen was found at a higher than normal concentration (0.2 mg/L) compared to a guideline value of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L compared to a guideline of 0.017 µg/L. In September of 2004, Carney Creek (Upper) yielded elevated levels of Total Suspended Solids (4.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Cyanide was also found at a higher than normal concentration (0.150 mg/L) compared to a guideline of 0.005 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded its limit of 0.017 µg/L.

July/September 2005 Sampling Results

Sylvia Grinnell

In July of 2005, Sylvia Grinnell had elevated levels of Total Suspended Solids (7.5 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.002 mg/L. Cadmium was also present at a higher than normal concentration (0.075 µg/L) compared to the guideline value of 0.017 µg/L. Silver exceeded the CCME (1999) guideline (0.1 µg/L) with a concentration of 0.35 µg/L. In September of 2005, Sylvia Grinnell had elevated levels of Toluene (0.005 mg/L) compared to the CCME (1999) guideline of 0.002 mg/L. Total Suspended Solids were also found at a higher than normal concentration (20 mg/L) when compared to a guideline value of 0.002 mg/L. Turbidity was found to be 1.62 NTU compared to a guideline of 1 NTU. Cyanide was found at a concentration of 0.195 mg/L compared to a CCME (1999) guideline of 0.005 mg/L.

Lake Geraldine

In July of 2005, Lake Geraldine yielded elevated levels of Total Suspended Solids (3 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.002 mg/L. Cadmium was also present in a higher than normal concentration (0.05 µg/L) compared to the guideline value of 0.017 µg/L. Silver exceeded the CCME (1999) guideline (0.1 µg/L) with a concentration of 0.2 µg/L. In September of 2005, Lake Geraldine was found to have elevated levels of Toluene (0.005 mg/L) compared to a CCME (1999) guideline value of 0.002 mg/L. Total Suspended Solids were also found to be at a higher than normal concentration (4.0 mg/L) when compared to the guideline value of 0.002 mg/L. Cyanide was present at a concentration of 0.194 µg/L compared to a guideline of 0.017 µg/L.

Apex River

In July 2005, the Apex River yielded an elevated level of Total Suspended Solids (3 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.002 mg/L. Cadmium was also present at a higher than normal concentration (0.05 µg/L) compared to the guideline value of 0.017 µg/L. Silver exceeded the CCME (1999) guideline (0.1 µg/L) with a concentration of 0.2 µg/L. In September of 2005, the Apex River was found to have an elevated level of Toluene (0.005 mg/L) compared to the CCME (1999) guideline value of 0.002 mg/L. Total Suspended Solids were also found to exceed a guideline value of 0.002 mg/L with a concentration of 3.5 mg/L. Cyanide was present at a concentration of 0.188 mg/L compared to a guideline value of 0.005 mg/L. Cadmium was found at a higher than normal concentration (0.05 µg/L) compared to a CCME (1999) guideline of 0.017 µg/L.

Carney Creek (Outlet)

In July of 2005, Carney Creek (at the Outlet) had elevated levels of Nitrate + Nitrite as Nitrogen (0.10 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.06 mg/L. A higher than normal concentration of Toluene (0.005 mg/L) was also present compared to the guideline value of 0.002 mg/L. Total Suspended Solids exceeded the guideline value (0.002 mg/L) with a concentration of 3 mg/L. Turbidity was found to have a concentration of 1.08 NTU compared to the CCME (1999) guideline of 1 NTU. Cadmium had a concentration of 0.05 µg/L compared to a 0.017 µg/L guideline value. Manganese was also found to have an elevated level of 113 µg/L compared to the CCME (1999) guideline (50 µg/L). In September of 2005, Carney Creek (at the Outlet) yielded elevated levels of Ammonia as Nitrogen (0.0065 mg/L) compared to a CCME (1999) guideline of 0.005 mg/L. Toluene was also found at a higher than normal concentration (0.005 mg/L) compared to a guideline value of 0.002 mg/L. Total Suspended Solids exceeded a guideline value of 0.002 mg/L with a concentration of 5.5 mg/L. Cyanide was present at a concentration of 0.1945 mg/L compared to a guideline of 0.005 mg/L. Cadmium was found at a concentration of 0.05 µg/L compared to a CCME (1999) guideline of 0.017 µg/L. Elevated levels of Copper (4.95 µg/L) were present as well compared to a guideline value of 2-4.0 µg/L. A higher concentration of Manganese was present (65.05 µg/L) and exceeded the guideline value of 50 µg/L.

Carney Creek (Above the Dump)

In July of 2005, Carney Creek (Above the Dump) was found to have elevated levels of Toluene (0.005 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline value of 0.002 mg/L. Total suspended solids were also found at higher than normal concentrations (3 mg/L) compared to the guideline value (0.002 mg/L). Cadmium exceeded the guideline (0.017 µg/L) with a concentration of 0.05 µg/L. In September of 2005, Carney Creek (Above the Dump) yielded higher than normal concentrations of Toluene (0.005 mg/L) compared to a CCME (1999) guideline value of 0.002 mg/L. Cyanide was also present at an elevated concentration (0.189 mg/L) compared to a guideline value of 0.005 mg/L. Cadmium was found at a concentration of 0.05 µg/L compared to a guideline value of 0.017 µg/L.

Carney Creek (Upper)

In July of 2005, Carney Creek (Upper) was found to have elevated levels of Ammonia as Nitrogen (0.006 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.005 mg/L. Toluene was also present in a higher than normal concentration (0.005 mg/L) when compared to the guideline value of 0.002 mg/L. Total suspended solids exceeded the CCME (1999) guideline (0.002 mg/L) with a concentration of 3 mg/L. Cadmium was found at a concentration of 0.05 µg/L compared to a guideline value of 0.017 µg/L. In September of 2005, Carney Creek (Upper) yielded elevated levels of Toluene (0.005 mg/L) compared to a CCME (1999) guideline value of 0.002 mg/L. Total Suspended Solids also exceeded a guideline value of 0.002 mg/L with a concentration of 3 mg/L. Cyanide was present at a concentration of 0.203 mg/L compared to a guideline value of 0.005 mg/L.

Note: The field and lab blanks were a cause of concern due to the high copper and silver concentrations. The bottles must have been contaminated before the samples were taken so the rest of the results may have been affected by this as well.

July/Aµgust 2006 Sampling Results

Sylvia Grinnell

In July of 2006, Sylvia Grinnell yielded an elevated level of Total Suspended Solids (4.5 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Cadmium was also found at a higher than normal concentration (0.05 µg/L) compared to a guideline value of 0.017 µg/L. In Aµgust of 2006, Sylvia Grinnell yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guideline value of 0.002 mg/L. Cadmium was also present at an elevated concentration of 0.05 µg/L compared to the guideline of 0.017 µg/L.

Lake Geraldine

In July of 2006, Lake Geraldine yielded an elevated level of Total Suspended Solids (4 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.002 mg/L. Cadmium exceeded the guideline value (0.017 µg/L) with a concentration of 0.19 µg/L. In Aµgust of 2006, Lake Geraldine yielded elevated levels of Ammonia as Nitrogen (0.010 mg/L) compared to the 1999 CCME guideline of 0.005 mg/L. Total Suspended Solids were present at a higher than normal concentration (3.0 mg/L) compared to a guideline value of 0.002 mg/L. Turbidity was 1.91 NTU and exceeded the 1999 CCME guideline of 1.0 NTU. Cadmium was present at a concentration of 0.05 µg/L and exceeded the guideline of 0.017 µg/L. Iron was found to be at an elevated concentration of 406 µg/L compared to the 1999 CCME guideline of 300 µg/L. Manganese was present at a concentration of 66 µg/L and exceeded a guideline value of 50 µg/L.

Apex River

In July of 2006, the Apex River yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.002 mg/L. Cadmium was also present at a higher than normal concentration (0.42 µg/L) compared to a guideline value of 0.017 µg/L. In Aµgust of 2006, the Apex River yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guideline of 0.002 mg/L. Cadmium was also found at a concentration of 0.05 µg/L and exceeded a guideline value of 0.017 µg/L.

Carney Creek (Outlet)

In July of 2006, Carney Creek (at the Outlet) was found to have elevated levels of Nitrate + Nitrite as Nitrogen (0.08 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.06 mg/L. Total Suspended Solids were present at a concentration of 8.0 mg/L compared to a guideline value of 0.002 mg/L. Turbidity was found to be 1.71 NTU compared to the CCME (1999) guideline of 1 NTU. Iron was present at a higher than normal concentration (500 µg/L) and exceeded the guideline of 300 µg/L. Manganese exceeded the CCME (1999) guideline (50 µg/L) with a concentration of 142 µg/L. In Aµgust of 2006, Carney Creek (Outlet) yielded elevated levels of Nitrate + Nitrite as Nitrogen (0.15 mg/L) compared to the 1999 CCME guideline of 0.06 mg/L. Total Suspended Solids were found at a concentration of 4.0 mg/L and exceeded the guideline of 0.002 mg/L. Turbidity was found to be 2.70 NTU compared to a guideline of 1.0 NTU. Cadmium was present at a higher than normal concentration (0.05 µg/L) compared to the 1999 CCME guideline of 0.017 µg/L. Iron was found at an elevated concentration of 805 µg/L and exceeded the guideline of 300 µg/L. Manganese was found at 181 µg/L compared to the 1999 CCME guideline of 50 µg/L.

Carney Creek (Above the Dump)

In July of 2006, Carney Creek (Above the Dump) yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.002 mg/L. Cadmium was also present at a higher than normal concentration (0.05 µg/L) and exceeded the CCME (1999) guideline of 0.017 µg/L. In Aµgust of 2006, Carney Creek (Above the Dump) yielded elevated levels of Nitrate + Nitrite as Nitrogen (0.14 mg/L) compared to the 1999 CCME guideline of 0.06 mg/L. Total Suspended Solids were present at 3.0 mg/L and exceeded the guideline of 0.002 mg/L. Cadmium was found at a concentration of 0.05 µg/L compared to a guideline value of 0.017 µg/L.

Carney Creek (Upper)

In July of 2006, Carney Creek (Upper) yielded elevated levels of Ammonia as Nitrogen (0.006 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.005 mg/L. Total Suspended Solids (4.0 mg/L) were found to exceed the CCME (1999) guideline of 0.002 mg/L. Turbidity was found to be 1.39 NTU compared to a guideline of 1 NTU. Cadmium was present at a concentration of 0.05 µg/L compared to a guideline value of 0.017 µg/L.

Upper Base Lake

In July of 2006, Upper Base Lake yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline of 0.002 mg/L. Cadmium was also present at a higher than normal concentration (0.05 µg/L) compared to a guideline value of 0.017 µg/L. In Aµgust of 2006, Upper Base Lake was found to have higher than normal concentrations of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guideline of 0.002 mg/L. Cadmium was present at a concentration of 0.1 µg/L compared to the guideline of 0.017 µg/L. Silver was found at a concentration of 0.4 µg/L and exceeded the 1999 CCME guideline of 0.1 µg/L.

River North-West of Gravel Site

In July of 2006, the River North-West of the Gravel Site yielded higher than normal concentrations of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline (0.002 mg/L). Cadmium was also present at an elevated level (0.05 µg/L) compared to the 1999 CCME guideline (0.017 µg/L).

Gravel Source Lake

In July of 2006, Gravel Source Lake yielded elevated levels of Ammonia as Nitrogen (0.006 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.005 mg/L). Total Suspended Solids were also present at higher than normal concentrations (3.0 mg/L) compared to the 1999 CCME guideline of 0.002 mg/L.

July 2007 Sampling Results

Sylvia Grinnell

In July of 2007, Sylvia Grinnell yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Cadmium was present at a concentration of 0.05 µg/L and exceeded the 1999 CCME guideline of 0.017 µg/L. Selenium was found at a concentration of 1.3 µg/L compared to a guideline value of 1.0 µg/L.

Lake Geraldine

In July of 2007, Lake Geraldine was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Cadmium was also present at higher than normal concentrations (0.1 µg/L) and exceeded the 1999 CCME guideline of 0.017 µg/L. Selenium was found at a concentration of 1.8 µg/L and exceeded a guideline of 1.0 µg/L.

Apex River

In July of 2007, the Apex River yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Cadmium was also present at a higher than normal concentration (0.1 µg/L) and exceeded the 1999 CCME guideline of 0.017 µg/L. Selenium was found at a concentration of 1.2 µg/L compared to the guideline value of 1.0 µg/L.

Carney Creek (Outlet)

In July of 2007, Carney Creek (at the Outlet) was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Turbidity was found to be 1.35 NTU and exceeded the 1999 CCME guideline of 1.0 NTU. Cadmium was present at higher than normal concentrations (0.05 µg/L) compared to a guideline of 0.017 µg/L. Selenium was found at a concentration of 4.6 µg/L and exceeded the 1999 CCME guideline of 1.0 µg/L.

Carney Creek (Above the Dump)

In July of 2007, Carney Creek (Above the Dump) yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Cadmium was also present at higher than normal concentrations (0.05 µg/L) and exceeded the 1999 CCME guideline of 0.017 mg/L. Selenium was found to have a concentration of 1.6 µg/L compared to a guideline of 1.0 µg/L.

Upper Base Lake

In July of 2007, Upper Base Lake was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Cadmium was also present at a higher than normal concentration (0.05 µg/L) compared to the 1999 CCME guideline (0.017 µg/L). Selenium was found at a concentration of 1.7 µg/L and exceeded a guideline of 1.0 µg/L.

<u>July/August 2008 Sampling Results</u>

Sylvia Grinnell

In July of 2008, Sylvia Grinnell was found to have elevated levels of Total Suspended Solids (7.5 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.75 mg/L) compared to the 1999 CCME guideline value of 0.06 mg/L. Cadmium was present at a concentration of 0.05 µg/L and exceeded the guideline of 0.017 µg/L. In Aµgust of 2008, Sylvia Grinnell yielded an elevated level of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guideline value of 0.002 mg/L. Turbidity exceeded a guideline of 1 NTU with a value of 1.155 NTU. Total Nitrogen was also present at a higher than normal concentration (0.12 mg/L) compared to the guideline (0.06 mg/L). Toluene had a concentration of 0.005 mg/L and exceeded a guideline of 0.002 mg/L. Cadmium had a concentration of 0.05 µg/L compared to a guideline of 0.017 µg/L.

Lake Geraldine

In July of 2008, Lake Geraldine was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.09 mg/L) compared to the 1999 CCME guideline value of 0.06 mg/L. Cadmium was present at a concentration of 0.05 µg/L and exceeded the guideline of 0.017 µg/L. In August of 2008, Lake Geraldine yielded an elevated level of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guideline (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.09 mg/L) compared to the guidelines (0.06 mg/L). Toluene was present at a concentration of 0.005 mg/L and exceeded the 1999 CCME guideline (0.002 mg/L). Cadmium was found at a concentration of 0.05 µg/L compared to a guideline value of 0.017 µg/L.

Apex River

In July of 2008, the Apex River was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Nitrate + Nitrite as Nitrogen was also found at a higher than normal concentration (0.09 mg/L) compared to the 1999 CCME guideline value of 0.06 mg/L. Total Nitrogen also exceeded the guideline value (0.06 mg/L) with a concentration of 0.13 mg/L. Cadmium was present at a concentration of 0.05 µg/L compared to a guideline value of 0.017 µg/L. In August of 2008, the Apex River yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Total Nitrogen was found in a higher than normal concentration (0.09 mg/L) and exceeded a guideline value of 0.06 mg/L. Toluene was present at a concentration of 0.005 mg/L compared to a guideline of 0.002 mg/L. Cadmium was found at an elevated level of 0.05 µg/L compared to the 1999 CCME guidelines (0.017 µg/L).

Carney Creek (Outlet)

In July of 2008, Carney Creek (at the Outlet) was found to have elevated levels of Total Suspended Solids (6.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Turbidity exceeded the guideline value (1 NTU) with a value of 1.95 NTU. Nitrate + Nitrite as Nitrogen was also present at a higher than normal concentration (0.31 mg/L) compared to the 1999 CCME guideline value of 0.06 mg/L. Total Nitrogen also exceeded the guideline (0.06 mg/L) with a concentration of 0.36 mg/L. Cadmium was found to have a concentration of 0.05 µg/L compared to the guideline value of 0.017 µg/L. Iron and Manganese exceeded the CCME guidelines (300 µg/L and 50 µg/L, respectively) with concentrations of 425 µg/L and 132 µg/L, respectively. In Aµgust of 2008, Carney Creek (at the Outlet) yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Turbidity exceeded a guideline of 1 NTU with a value of 1.11 NTU. Nitrate + Nitrite as Nitrogen was found at a higher than normal concentration (0.1 mg/L) compared to a guideline of 0.06 mg/L. Total Nitrogen was present at a concentration of 0.25 mg/L and exceeded a guideline of 0.06 mg/L. Toluene was found to have an elevated level (0.005 mg/L) compared to the 1999 CCME guideline (0.002 mg/L). Cadmium and Manganese also exceeded their guidelines (0.017 µg/L and 50 µg/L, respectively) with values of 0.05 µg/L and 55.8 µg/L, respectively.

Carney Creek (Above the Dump)

In July of 2008, Carney Creek (Above the Dump) was found to have elevated levels of Total Suspended Solids (16.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L).Turbidity exceeded the 1999 CCME guidelines (I NTU) with a value of 3.32 NTU. Nitrate + Nitrite as Nitrogen was also found at a higher than normal concentration (0.14 mg/L) compared to a guideline of 0.06 mg/L. Total Nitrogen was present at a concentration of 0.29 mg/L compared to a guideline value of 0.06 mg/L. Cadmium was found at a concentration of 0.05 µg/L and exceeded the 1999 CCME guideline (0.017 µg/L). Iron was present at a concentration of 428 µg/L compared to a guideline value of 300 µg/L. In Aµgust of 2008, Carney Creek (Above the Dump) yielded an elevated level of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Total Nitrogen was also present at a higher than normal concentration (0.13 mg/L) and exceeded the guideline value of (0.06 mg/L). Toluene was found at a concentration of 0.005 mg/L compared to a guideline of 0.002 mg/L.

Carney Creek (Upper)

In July of 2008, Carney Creek (Upper) was found to have elevated levels of Total Suspended Solids (14.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Turbidity exceeded the 1999 CCME guideline (1 NTU) with a value of 1.21 NTU. Nitrate + Nitrite as Nitrogen was also found at a higher than normal concentration (0.09 mg/L) compared to a guideline value of 0.06 mg/L. Total Nitrogen was present at a concentration of 0.26 mg/L and exceeded the 1999 CCME guideline (0.06 mg/L). Cadmium was found at a concentration of 0.07 µg/L compared to a guideline value of 0.017 µg/L. In Aµgust of 2008, Carney Creek (Upper) yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Nitrate + Nitrite as Nitrogen was also found at a higher than normal concentration (0.12 mg/L) and exceeded the 1999 CCME guidelines (0.06 mg/L). Total Nitrogen exceeded its guideline (0.06 mg/L) as well with a concentration of 0.12 mg/L. Toluene was present at a concentration of 0.005 mg/L compared to the guideline value of 0.002 mg/L. Cadmium was found at 0.05 µg/L and exceeded its guideline of 0.017 µg/L.

Upper Base Lake

In July 2008, Upper Base Lake was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.14 mg/L) compared to the 1999 CCME guidelines (0.06 mg/L). Cadmium was present at a concentration of 0.05 µg/L and exceeded the guideline value of 0.017 µg/L. In Aµgust of 2008, Upper Base Lake yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Total Nitrogen was found at a higher than normal concentration (0.11 mg/L) and exceeded the guideline value of 0.06 mg/L. Toluene had a concentration of 0.005 mg/L compared to a guideline of 0.002 mg/L. Cadmium was present at a concentration of 0.05 µg/L and exceeded the 1999 CCME guideline value of 0.017 µg/L.

River North-West of Gravel Site

In July of 2008, the River North-West of the Gravel Site was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.12 mg/L) compared to the 1999 CCME guideline value of 0.06 mg/L. Cadmium was present at a concentration of 0.05 µg/L and exceeded the guideline (0.017 µg/L). In Aµgust of 2008, the River North-West of the Gravel Site yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.07 mg/L) and exceeded the 1999 CCME guideline (0.06 mg/L). Toluene was present at a concentration of 0.005 mg/L compared to a guideline value of 0.002 mg/L. Cadmium was found at 0.05 µg/L and exceeded its guideline of 0.017 µg/L.

Gravel Source Lake

In July of 2008, Gravel Source Lake was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Cadmium was also found at a higher than normal concentration (0.05 µg/L) compared to the 1999 CCME guideline (0.017 µg/L). In Aµgust of 2008, Gravel Source Lake yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Total Nitrogen was found at a higher than normal concentration (0.07 mg/L) as well, compared to a guideline of 0.06 mg/L. Toluene was present at 0.005 mg/L and exceeded the 1999 CCME guideline of 0.002 mg/L. Cadmium had a concentration of 0.05 µg/L compared to a guideline of 0.017 µg/L.

New Gravel Pit (Near the Blasting Site)

In July of 2008, the New Gravel Pit (Near the Blasting Site) sampling site was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Nitrate + Nitrite as Nitrogen was also found at a higher than normal concentration (0.08 mg/L) compared to the 1999 CCME guidelines (0.06 mg/L). Total Nitrogen was found at a concentration of 0.23 mg/L and exceeded the guideline value of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L compared to a guideline of 0.017 µg/L. In Aµgust of 2008, the New Gravel Pit (Near the Blasting Site) yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Total Nitrogen was found at a higher than normal concentration (0.145 mg/L) and exceeded its guideline of 0.06 mg/L. Nitrate + Nitrite as Nitrogen also exceeded its guideline (0.06 mg/L) with a value of 0.095 mg/L. Toluene had a concentration of 0.005 mg/L compared to a guideline of 0.002 mg/L. Cadmium was present with a concentration of 0.05 µg/L and exceeded its CCME guideline of 0.017 µg/L.

East Side of the Dump (Near the Explosives Shack)

In July of 2008, the East Side of the Dump (Near the Explosives Shack) sampling site was found to have elevated levels of Total Suspended Solids (4.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Turbidity also exceeded the 1999 CCME guideline (1 NTU) with a value of 1.47 NTU. Total Nitrogen was present at a concentration of 0.15 mg/L compared to a guideline of 0.06 mg/L. Cadmium was found at a concentration of 0.1 µg/L and exceeded a guideline of 0.017 µg/L.

<u>August 2009 Sampling Results</u>

Sylvia Grinnell

In August of 2009, Sylvia Grinnell was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.115 mg/L) compared to the 1999 CCME guideline (0.06 mg/L).

Lake Geraldine

In Aµgust of 2009, Lake Geraldine yielded elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.09 mg/L) compared to the 1999 CCME guideline (0.06 mg/L). Cadmium was present at a concentration of 0.1 µg/L and exceeded a guideline of 0.017 µg/L.

Apex River

In August of 2009, the Apex River was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.23 mg/L) compared to the 1999 CCME guideline (0.06 mg/L). Cadmium was present at a concentration of 0.05 µg/L and exceeded a guideline value of 0.017 µg/L.

Carney Creek (Outlet)

In August of 2009, Carney Creek (at the Outlet) was found to have elevated levels of Nitrate + Nitrite as Nitrogen (0.12 mg/L) compared to the 1999 CCME Protection of Aquatic Life guideline (0.06 mg/L). Total Suspended Solids were also found to be at a higher than normal concentration (6.0 mg/L) compared to the 1999 guideline (0.002 mg/L). Turbidity exceeded its guideline (1 NTU) with a value of 2.10 NTU. Total Nitrogen was present at a concentration of 0.30 mg/L compared to a guideline of 0.06 mg/L. Cadmium was recorded at 0.1 µg/L and exceeded its guideline of 0.017 µg/L. Iron and Manganese had elevated levels (581 µg/L and 159 µg/L, respectively) compared to guidelines of 300 µg/L and 50 µg/L, respectively.

Carney Creek (Above the Dump)

In August of 2009, Carney Creek (Above the Dump) yielded elevated levels of Nitrate + Nitrite as Nitrogen (0.12 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.06 mg/L). Total Suspended Solids were also found at a higher than normal concentration (3.0 mg/L) compared to the 1999 guidelines (0.002 mg/L). Total Nitrogen was present at a concentration of 0.16 mg/L and exceeded its guideline of 0.06 mg/L. Cadmium was found at 0.1 µg/L compared to a guideline of 0.017 µg/L.

Carney Creek (Upper)

In August of 2009, Carney Creek (Upper) was found to have elevated levels of Nitrate + Nitrite as Nitrogen (0.11 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.06 mg/L). Total Suspended Solids were also found at a higher than normal concentration (3.0mg/L) compared to the 1999 guideline (0.002 mg/L). Total Nitrogen was present at a concentration of 0.18 mg/L and exceeded its guideline of 0.06 mg/L. Cadmium was found with a concentration of 0.1 µg/L compared to a guideline of 0.017 µg/L.

Upper Base Lake

In August of 2009, Upper Base Lake was found to have elevated levels of Total Suspended Solids (3.0 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.002 mg/L). Total Nitrogen was also found at a higher than normal concentration (0.15 mg/L) compared to the 1999 guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L and exceeded the guideline value of 0.017 µg/L.

New Gravel Pit (Near the Blasting Site)

In August of 2009, the New Gravel Pit (Near the Blasting Site) sampling site was found to have elevated levels of Nitrate + Nitrite as Nitrogen (0.13 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.06 mg/L). Total Suspended Solids were also found at a higher than normal concentration (3.0 mg/L) compared to the 1999 guidelines (0.002 mg/L). Total Nitrogen had a concentration of 0.16 mg/L and exceeded a guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L and surpassed its limit of 0.017 µg/L.

East Side of the Dump (Near the Explosives Shack)

In August of 2009, the East Side of the Dump (Near the Explosives Shack) sampling site was found to have elevated levels of Nitrate + Nitrite as Nitrogen (0.12 mg/L) compared to the 1999 CCME Protection of Aquatic Life guidelines (0.06 mg/L). Total Suspended Solids were also found at a higher than normal concentration (3.0 mg/L) compared to the 1999 CCME guidelines (0.002 mg/L). Total Nitrogen had a concentration of 0.15 mg/L and exceeded its guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.1 µg/L and surpassed its limit of 0.017 µg/L.

June 2010 Sampling Results

Sylvia Grinnell

In June of 2010, Sylvia Grinnell was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.11 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines (0.005 and 0.06 mg/L, respectively). Cadmium was also present at a higher than normal concentration (0.05 µg/L) compared to a guideline of 0.017 µg/L.

Lake Geraldine

In June of 2010, Lake Geraldine was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.11 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines of 0.005 mg/L and 0.06 mg/L. Total Nitrogen had a concentration of 0.09 mg/L and exceeded its guideline of 0.06 mg/L. Cadmium was present at 0.1 µg/L compared to a guideline of 0.017 µg/L.

Apex River

In June of 2010, the Apex River was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.13 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines (0.005 and 0.06 mg/L, respectively). Total Nitrogen had a concentration of 0.09 mg/L compared to a guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.05 µg/L and exceeded its limit of 0.017 µg/L.

Carney Creek (Outlet)

In June of 2010, Carney Creek at the Outlet was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.18 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines of 0.005 mg/L and 0.06 mg/L, respectively. Toluene was present at a higher than normal concentration

(0.005 mg/L) compared to a guideline of 0.002 mg/L. Total Nitrogen had a concentration of 0.13 mg/L and exceeded its limit of 0.06 mg/L. Aluminum, Cadmium, and Iron had concentrations of 286, 0.1, and 926 µg/L compared to guidelines of 100, 0.017, and 300 µg/L. Manganese was present at 141 µg/L and exceeded a limit of 50 µg/L.

Carney Creek (Above the Dump)

In June of 2010, Carney Creek (Above the Dump) was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.13 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines of 0.005 mg/L and 0.06 mg/L, respectively. Toluene was also found to exceed the CCME guideline of 0.002 mg/L with a value of 0.005 mg/L. Total Nitrogen had a value of 0.08 mg/L compared to a guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.05 µg/L and exceeded its guideline of 0.017 µg/L.

Carney Creek (Upper)

In June of 2010, Carney Creek (Upper) was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.12 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines of 0.005 mg/L and 0.06 mg/L, respectively. Toluene was also found to exceed the CCME guideline of 0.002 mg/L with a value of 0.005 mg/L. Total Nitrogen had a value of 0.12 mg/L compared to a guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.05 µg/L and exceeded its guideline of 0.017 µg/L.

Upper Base Lake

In June of 2010, Upper Base Lake was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) as well as Nitrate + Nitrite as Nitrogen (0.13 mg/L) compared to the 1994 CCME Protection of Aquatic Life guideline values of 0.005 mg/L and 0.06 mg/L, respectively. Toluene was present at a higher than normal concentration (0.005 mg/L) compared to a guideline of 0.002 mg/L. Total Nitrogen also exceeded its guideline (0.06 mg/L) with a value of 0.12 mg/L. Cadmium had a concentration of 0.05 mg/L compared to a guideline of 0.017 µg/L.

New Gravel Pit (Near the Blasting Site)

In June of 2010, the New Gravel Pit (Near the Blasting Site) was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.18 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines of 0.005 mg/L and 0.06 mg/L, respectively. Toluene was also found to exceed its guideline (0.002 mg/L) with a concentration of 0.005 mg/L. Total Nitrogen had a value of 0.14 mg/L compared to a guideline of 0.06 mg/L. Cadmium was present at a concentration of 0.05 µg/L compared to the CCME guideline of 0.017 µg/L.

East Side of the Dump (Near the Explosives Shack)

In June of 2010, the sampling site on the East side of the dump (Near the explosives shack) was found to have elevated levels of Ammonia as Nitrogen (0.01 mg/L) and Nitrate + Nitrite as Nitrogen (0.14 mg/L) compared to the 1994 CCME Protection of Aquatic Life guidelines of 0.005 mg/L and 0.06 mg/L, respectively. Toluene was also found at a higher than normal concentration (0.005 mg/L) compared to a CCME guideline of 0.002 mg/L. Total Nitrogen was present at a concentration of 0.11 mg/L compared to its guideline (0.06 mg/L). Aluminum exceeded the guideline (100 µg/L) with a concentration of 1670 µg/L. Cadmium, Iron, and Lead had concentrations of 0.1, 1810, and 1.1 µg/L compared to guidelines of 0.017, 300, and 1 µg/L, respectively.

<u>Note:</u> Parameters that exceeded the CCME guidelines may have done so due to the minimum detection limit (MDL) for this particular lab (Taiga Environmental Laboratory); For example, the MDL for Cadmium is 0.05 µg/L which exceeds the acceptable limit of 0.017 µg/L. Of the parameters that exceeded regulations- concentrations were not high enough to be a cause of concern with the water quality. PCB concentrations also exceeded the CCME guidelines due to the MDL for this parameter. Again, concentrations were not high enough to take any action. Hexane extractable material was found at different locations and although there is no guideline for it, it is something that should be addressed because as there should not be any HEM present in the water.

Most of the parameters tested were low enough to be background levels except for the PCB's and HEM's present. The PCB and HEM concentrations found in the samples must have come from an outside source. Possible contamination may be attributed to a former contaminated site located above Carney Creek or from a former metal dump which the creek flows through.