



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

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Data Collection

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Topographical Data (DEM)	Natural Resources Canada	Neal Cody	Received	
Geographical Feature Data	Natural Resources Canada	Neal Cody	Received	
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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		

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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		
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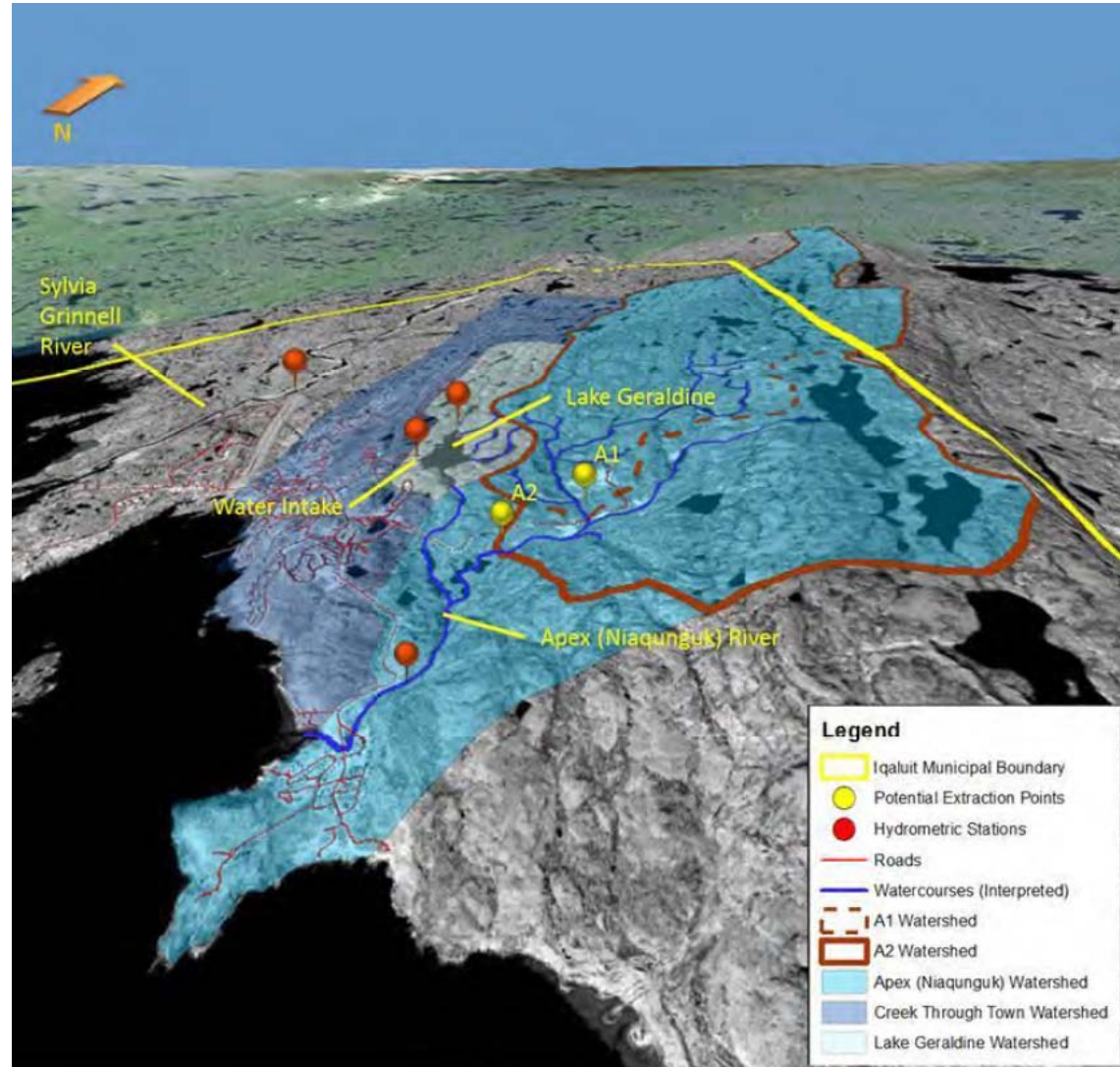
Field Data Collection Status



Historical Data Review

Data Review

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

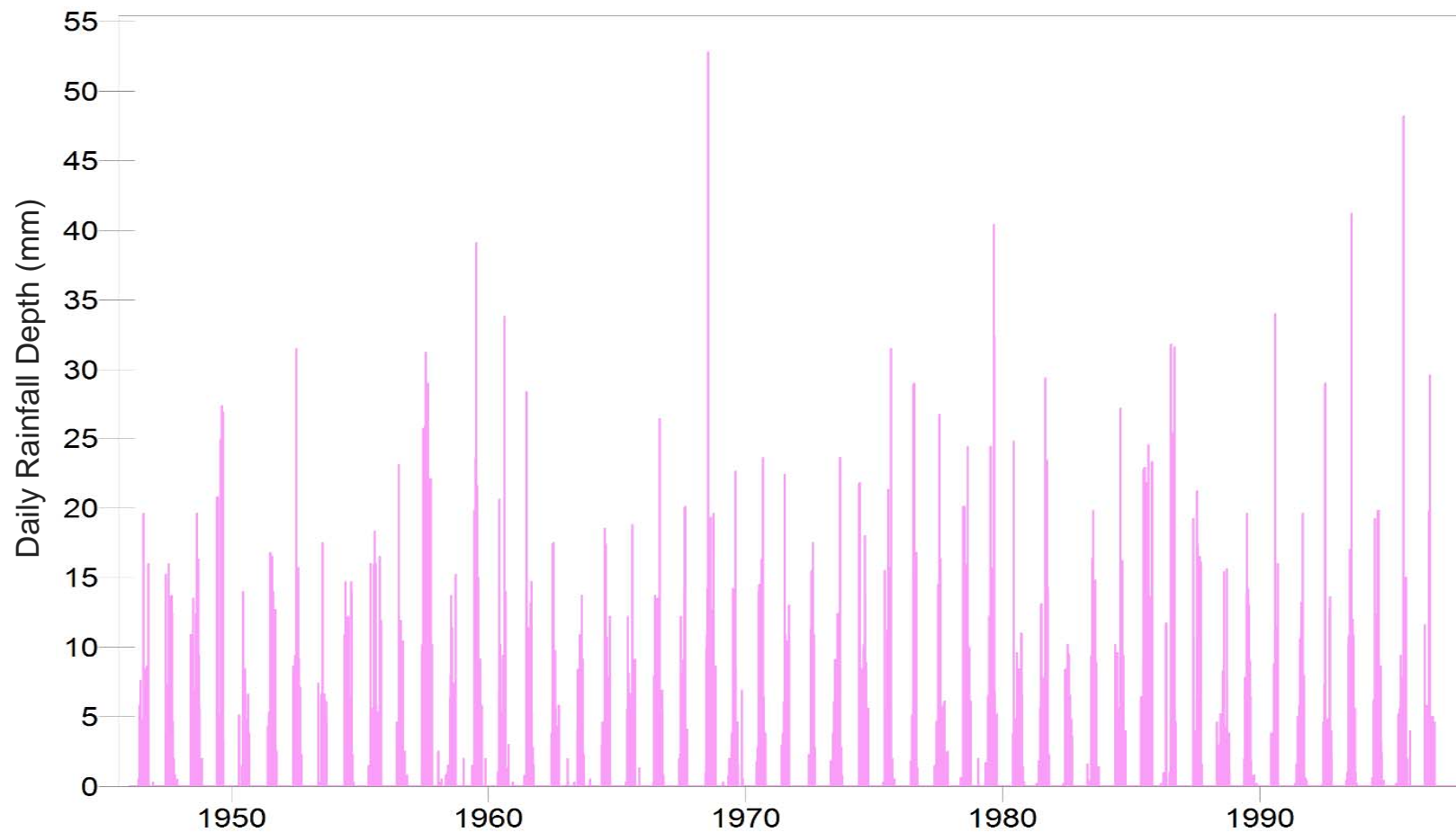


Precipitation

- 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)

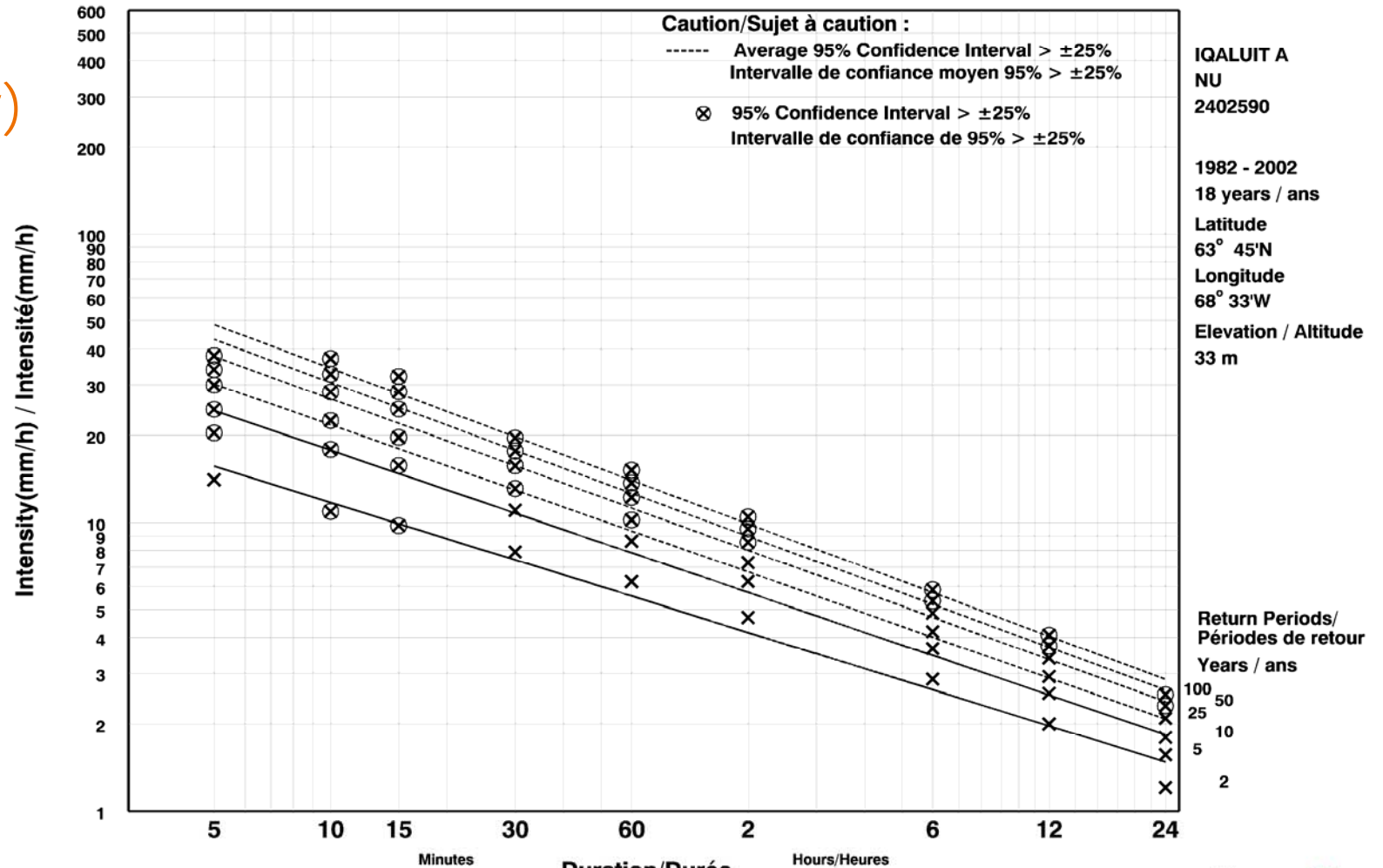


IDF Curves (Intensity- Duration- Frequency)

Data available
1982-2002

Short Duration Rainfall Intensity-Duration-Frequency Data Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

2014/12/21



**IQALUIT A
NU**
2402590

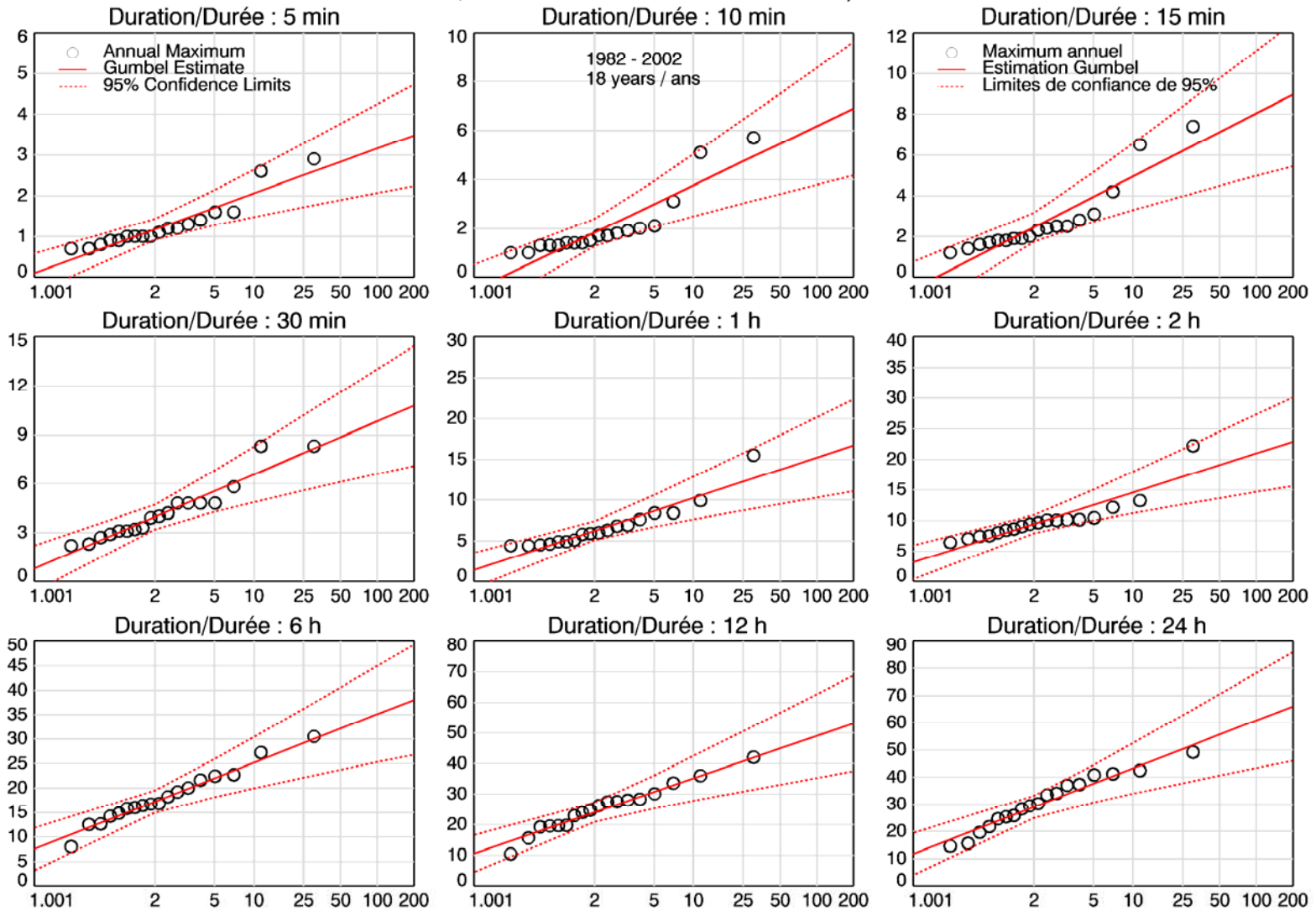
1982 - 2002
18 years / ans

Latitude
63° 45'N
Longitude
68° 33'W

Elevation / Altitude
33 m

Return Level/Niveau de retour : IQALUIT A, NU 2402590

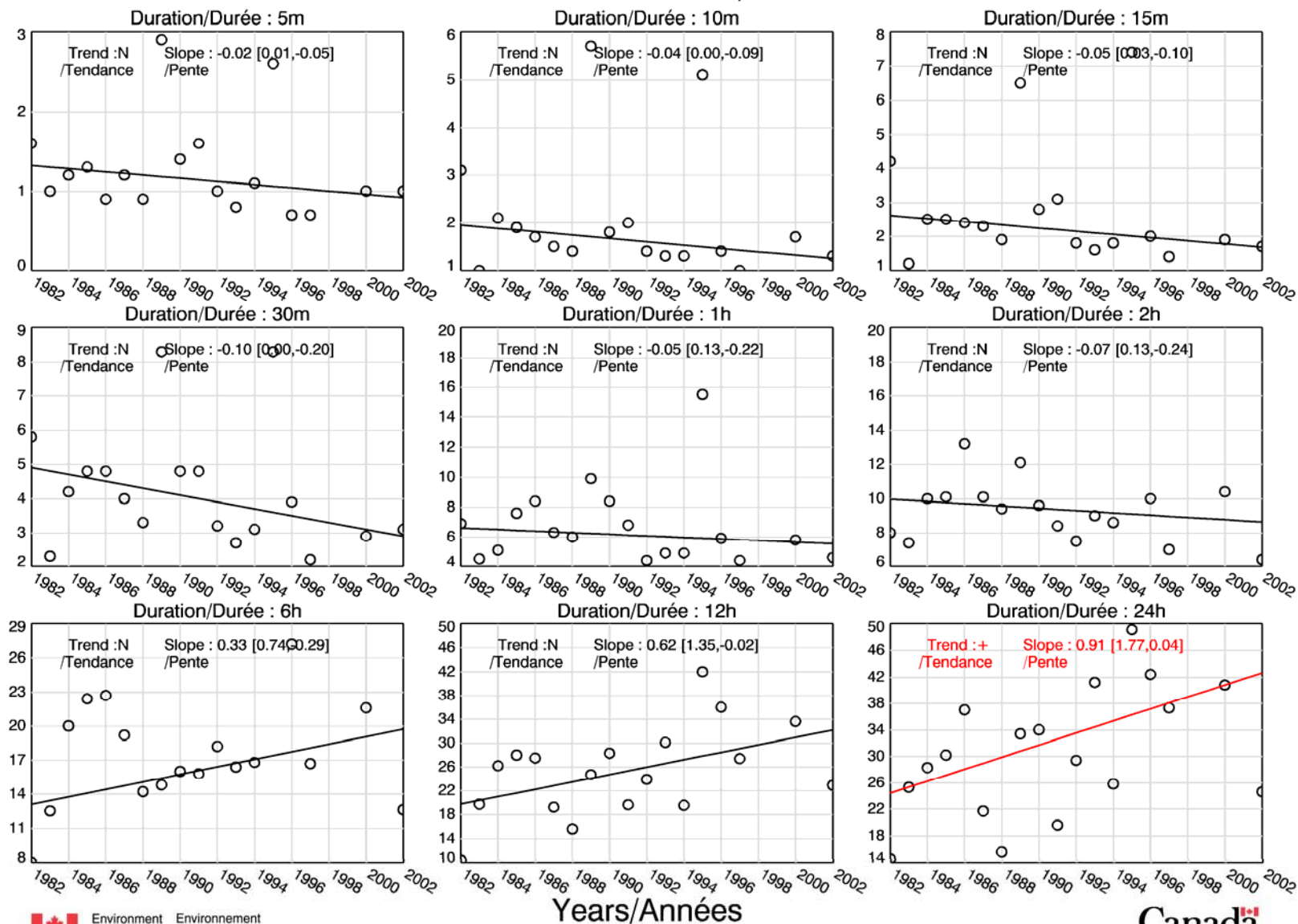
Rainfall/Pluie (mm)



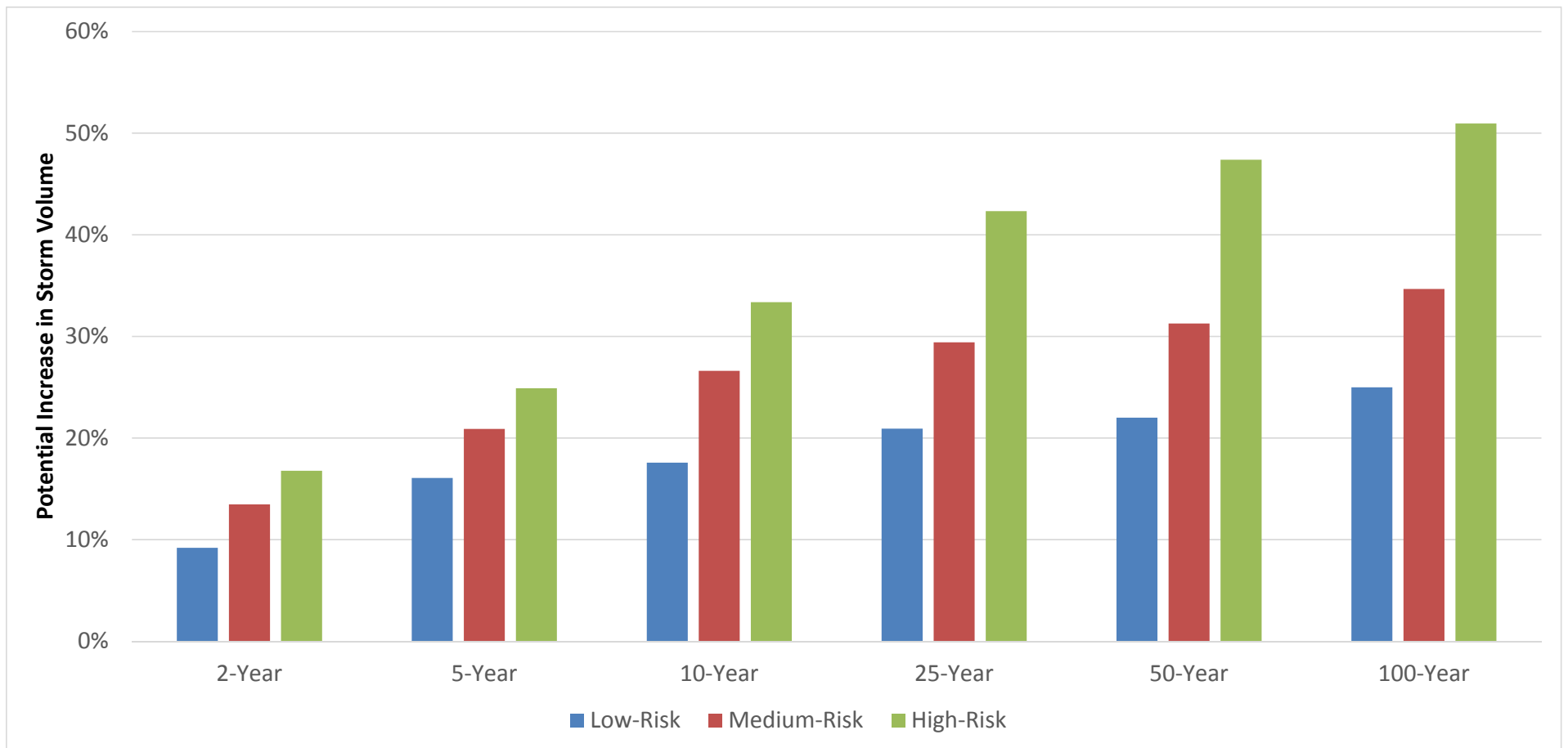
Return Period/Période de retour (years/années)

Trend/Tendance : IQALUIT A, NO 2402590

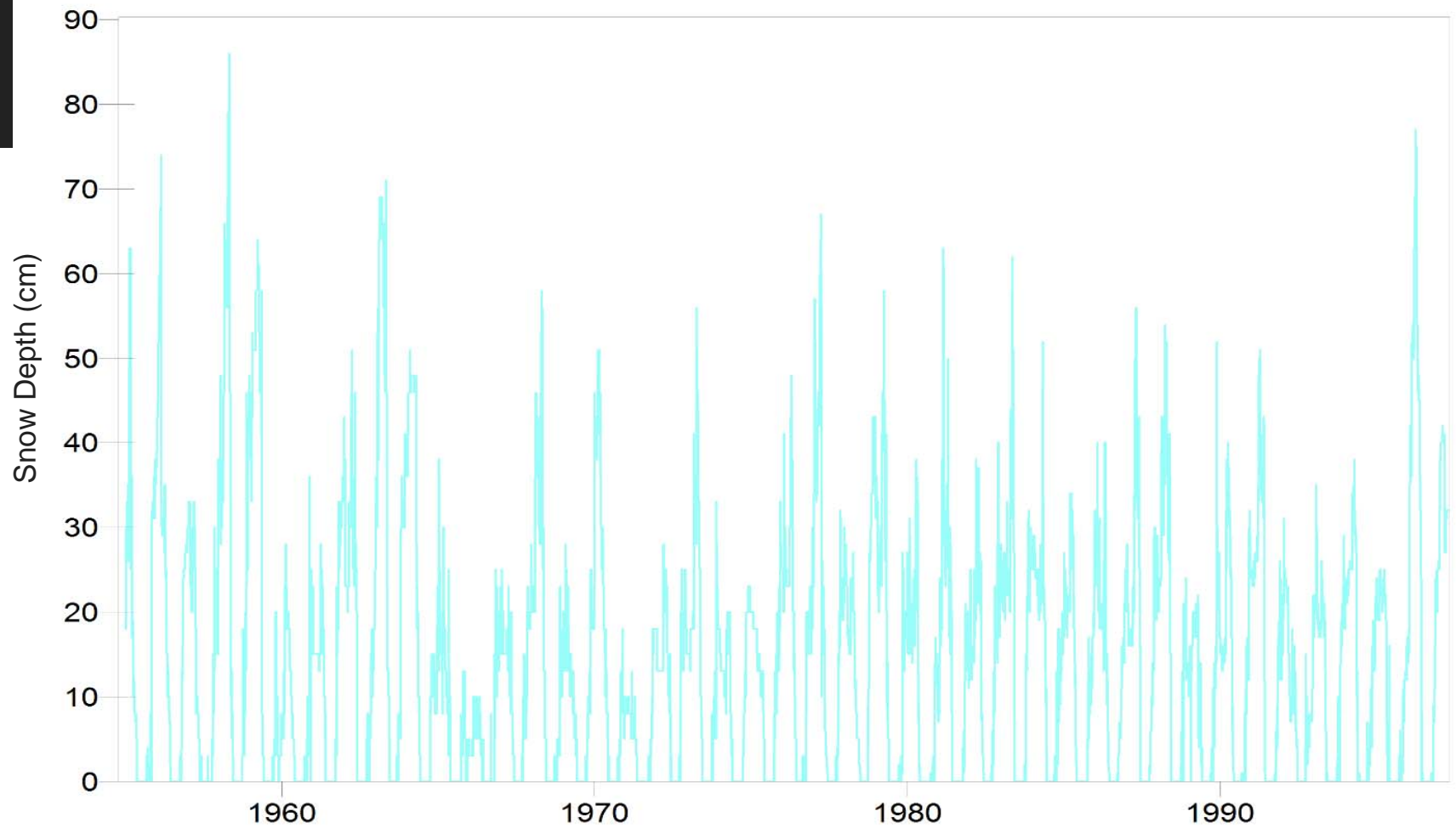
Annual Maximum/Maximum annuel (mm)



Climate Change Impacts

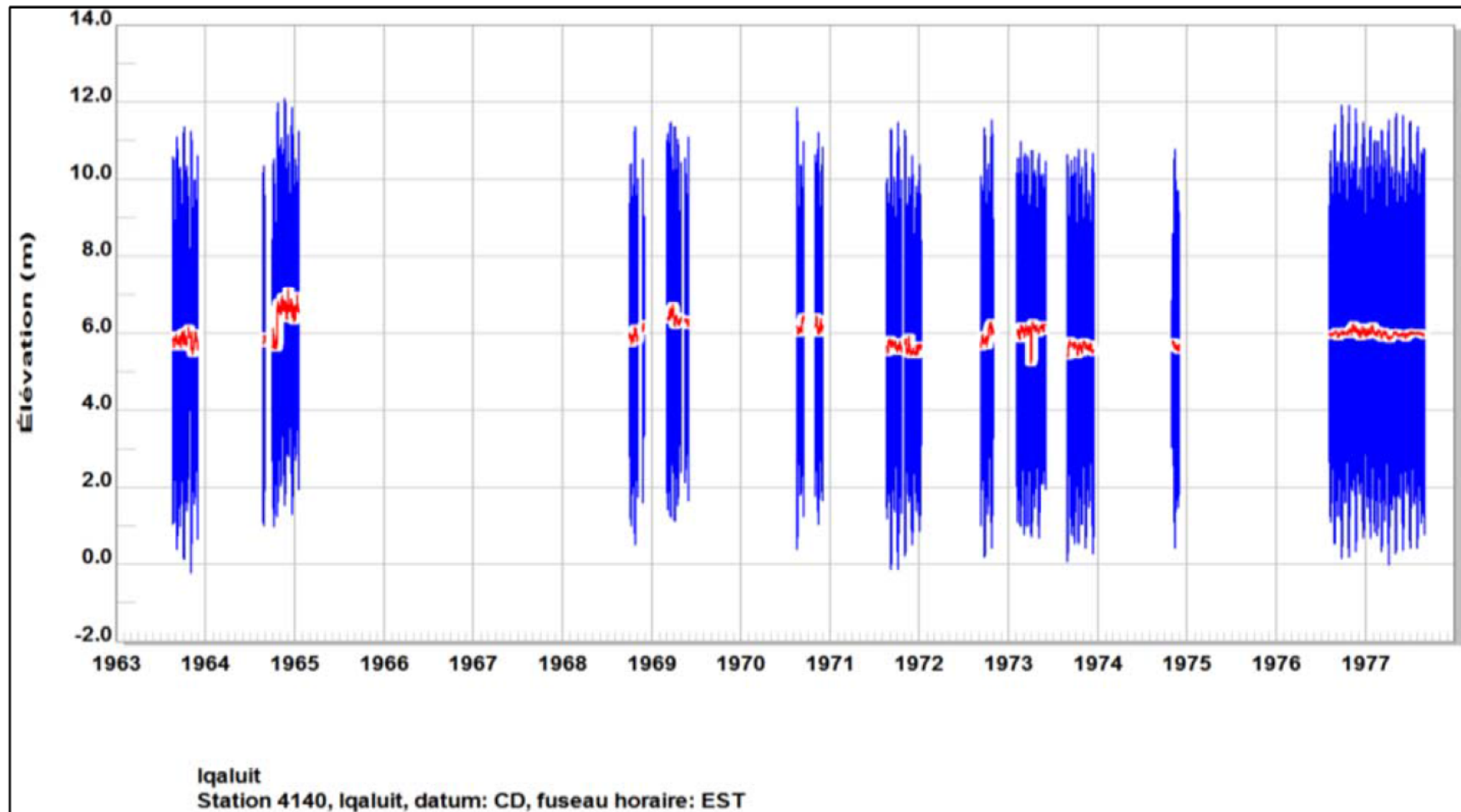


Snowfall Depths 1955-1996



Note: the
peak snow
depth in
2018 was
31 cm

Tidal Levels

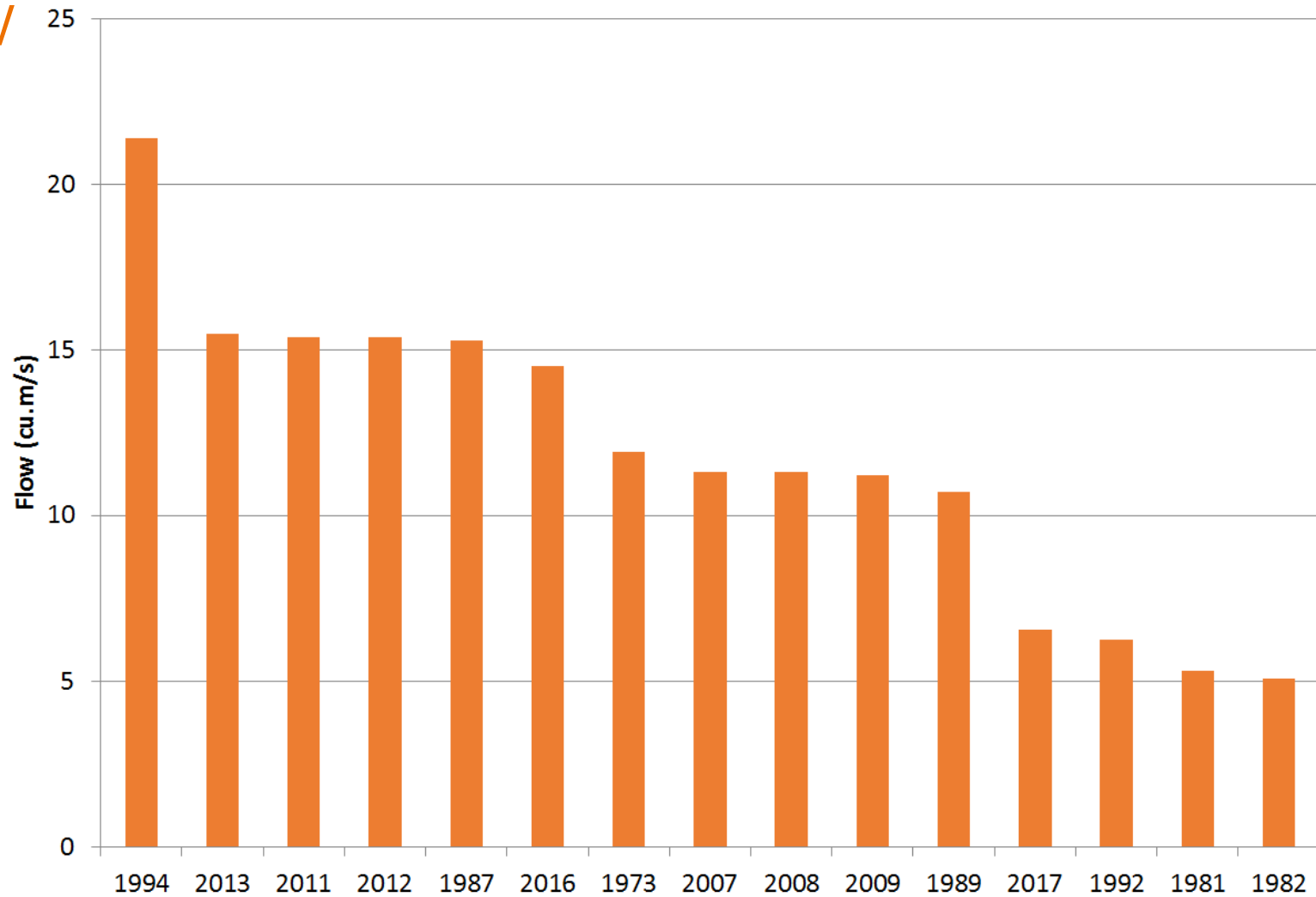


Streamflow

Available from Water
Survey of Canada

- Three in Iqaluit area:
 1. Apex River
 2. Inflow to Lake Geraldine
 3. Sylvia Grinnell River

Apex River, Peak Flows



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

ΔΑΨΥΧ Δ'β-ωσ

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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



Photo by Nellie Erkkö

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

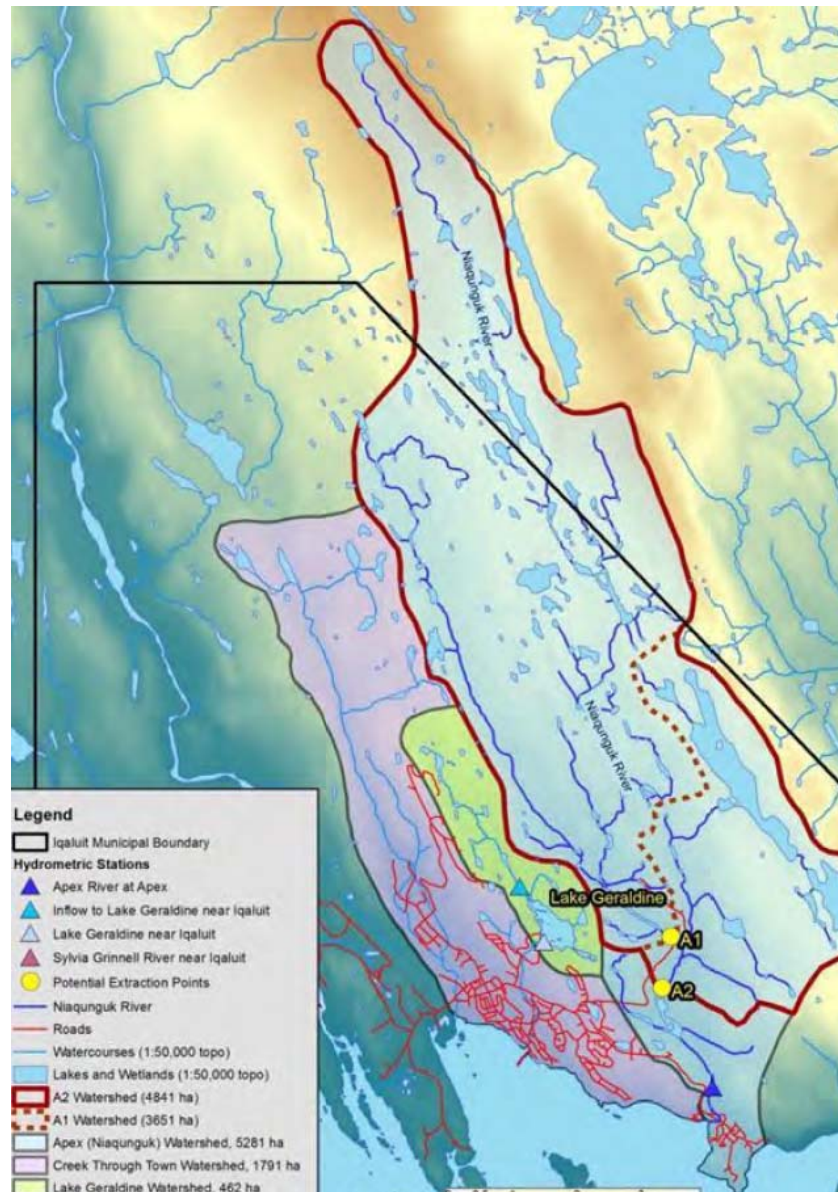
Particularly helpful:

- Water source supplementation studies
- Airport drainage study



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Characterization of Study Area







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

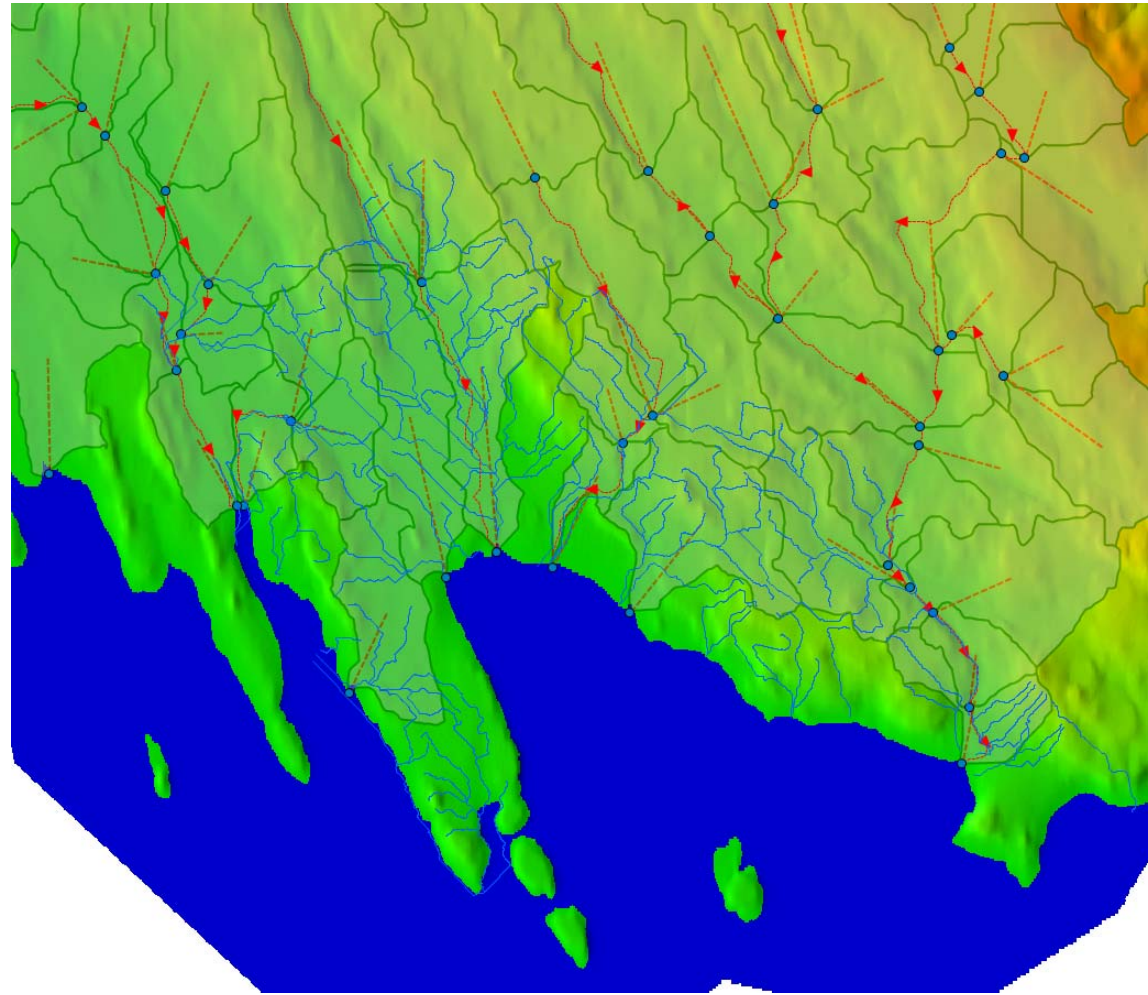


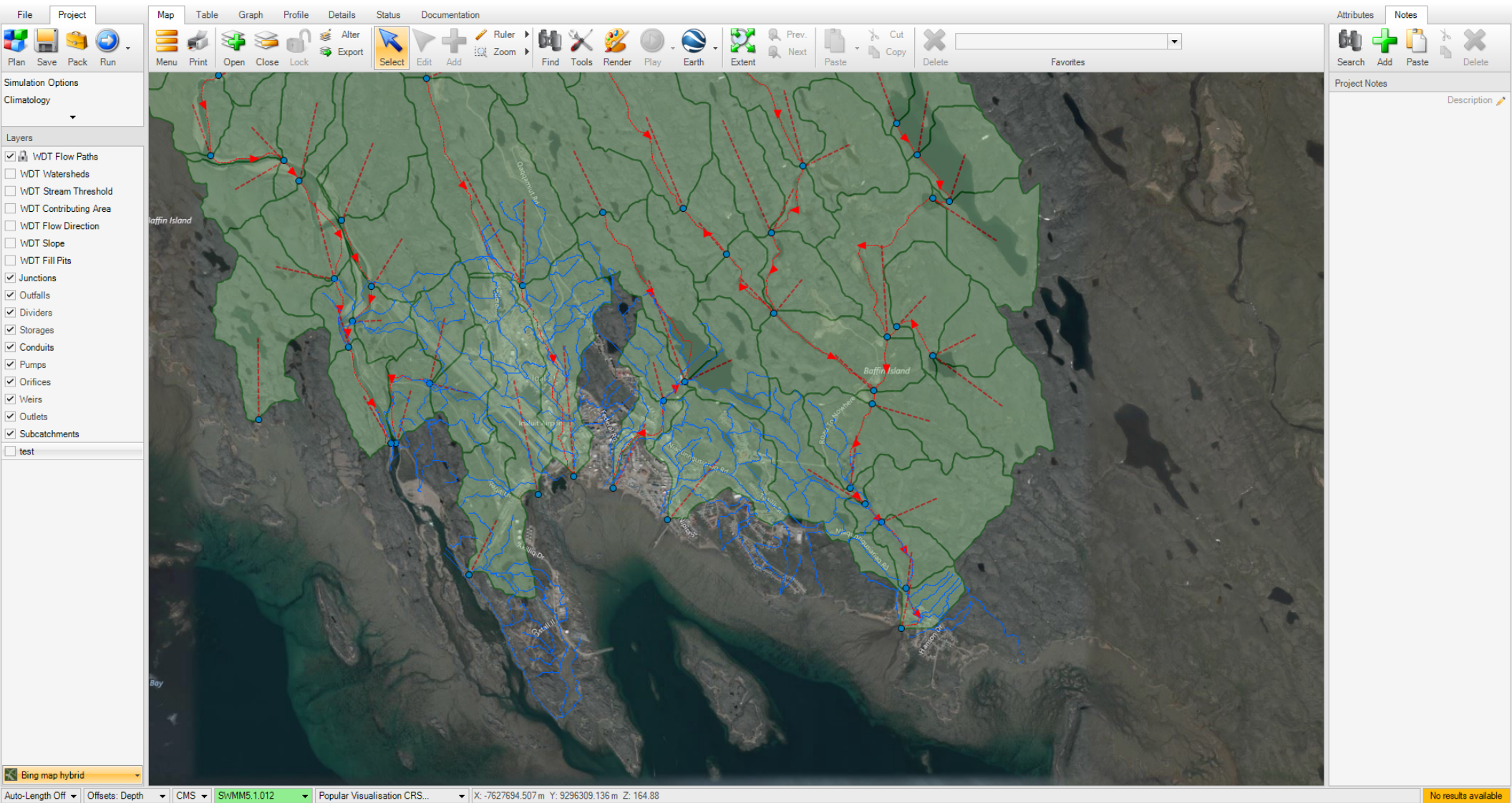
[Airport Creek Aerial](#)

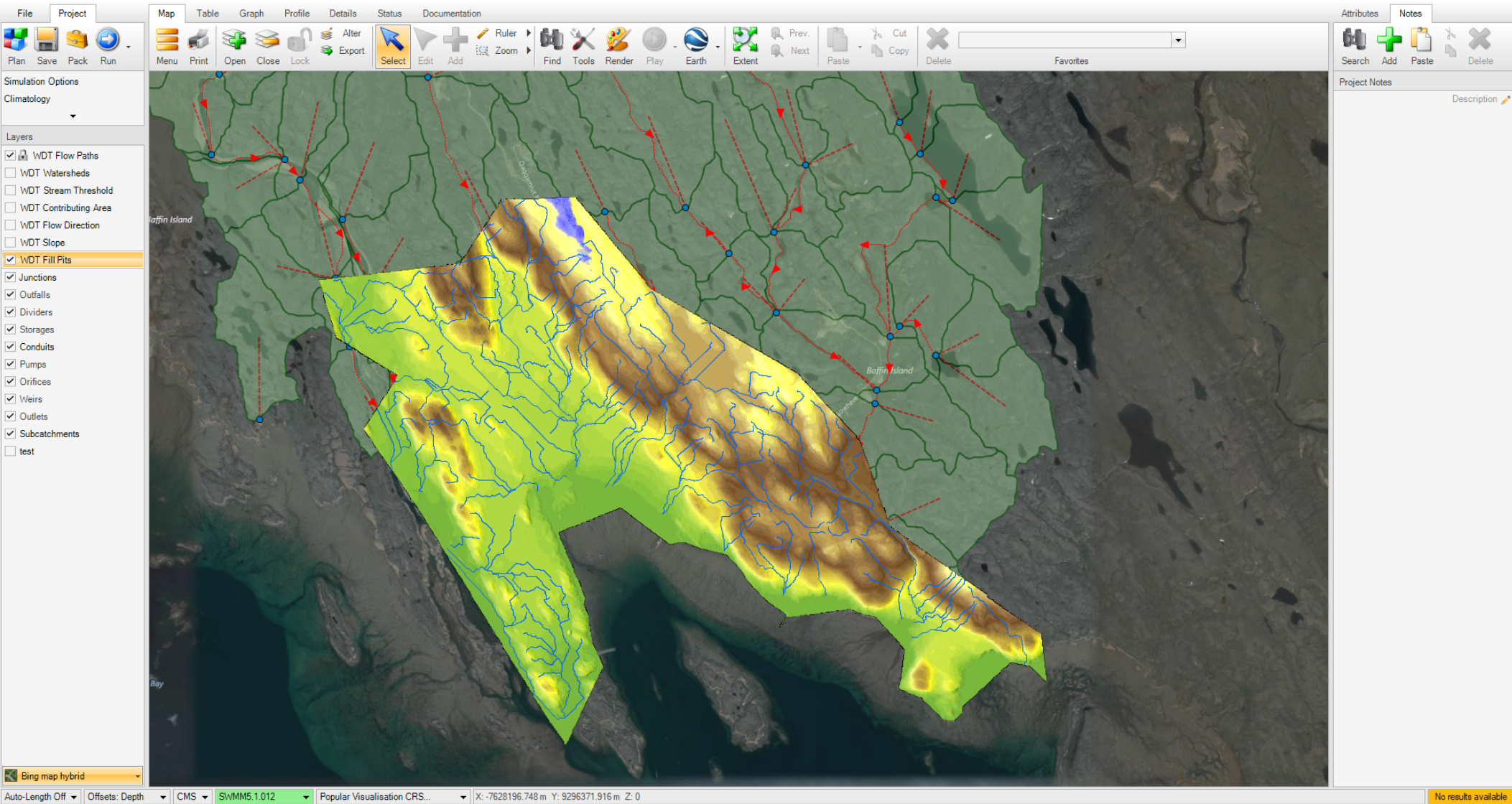
Preliminary Model Construction

Model Construction

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





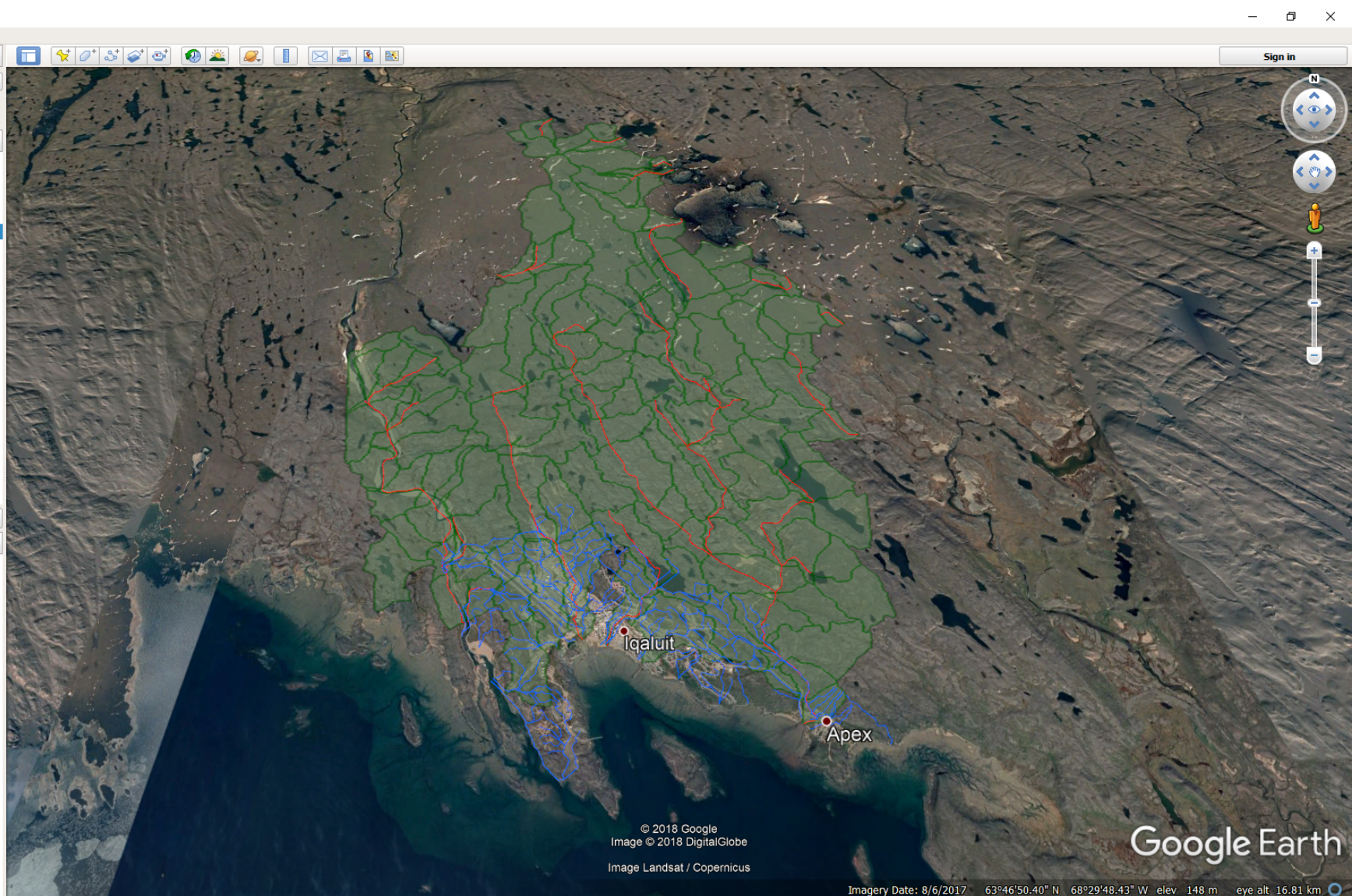


▼ Search
Search
Museums in New York, NY
Get Directions History

- ▼ Places
- My Places
 - Sightseeing Tour
 - Make sure 3D Buildings layer is checked
 - Temporary Places
 - wdt-try2.kmz
 - Subcatchments
 - Conduits
 - Junctions
 - WDT Flow Paths

Layers

- Primary Database
- ☒ Borders and Labels
 - ☐ Places
 - ☐ Photos
 - ☒ Roads
 - ☐ 3D Buildings
 - ☐ Ocean
 - ☐ Weather
 - ☐ Gallery
 - ☐ Global Awareness
 - ☐ More
 - ☒ Terrain



▼ Search

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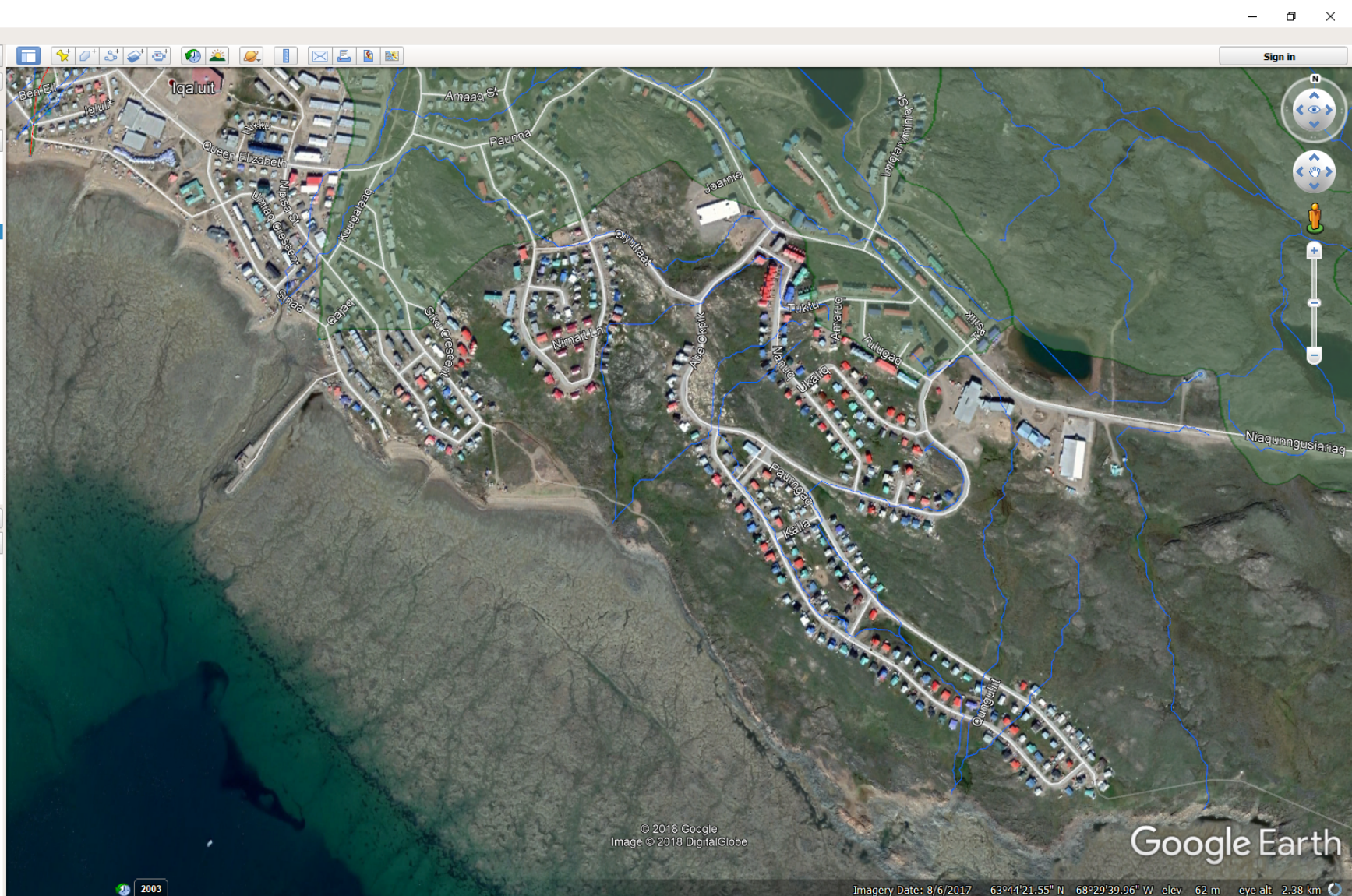
Temporary Places

- ✓ wdt-try2.kmz
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Layers

Primary Database

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FileProject

PlanSavePackRun

Simulation Options

Climatology

Layers

☒ WDT Flow Paths
☐ WDT Watersheds
☐ WDT Stream Threshold
☐ WDT Contributing Area
☐ WDT Flow Direction
☐ WDT Slope
☐ WDT Fill Pits
☒ Junctions
☒ Outfalls
☒ Dividers
☒ Storages
☒ Conduits
☒ Pumps
☒ Orifices
☒ Weirs
☒ Outlets
☒ Subcatchments
☐ test

Bing map hybrid

MapTableGraphProfileDetailsStatusDocumentation

MenuPrintOpenCloseLockAlterExport

SelectEditAddRulerZoomFindToolsRenderPlayEarthExtentPrevNextPasteCopyDelete

MenuReplaceGraphProfileView

4 selected Junctions

Attributes

Notes

Attributes

Name

X-Coordinate

Y-Coordinate

Description

Tag

Inflows

Treatment

Invert Elev. (m)

Rim Elev. (m)

Depth (m)

Initial Depth (m)

Surcharge Depth (m)

Ponded Area (m²)

Inflows

Baseline (m³/s)

Baseline Pattern

Time Series

Scale Factor

Average Value (m³)

Time Pattern 1

Time Pattern 2

Time Pattern 3

Time Pattern 4

Hydrograph

Sewershed Area (m²)

Results

Avg. Depth (m)

Max. Depth (m)

Max. HGL (m)

Time Max. HGL

Rep. Max. Depth (m)

Max. Lat. Inflow (m)

Max. Total Inflow (m)

Total Lat. Inflow (m)

Total inflow (ML)

Flow Error (%)

Hours Surcharged

Max. Surcharge (m)

Min. Freeboard (m)

Hours Flooded (h)

Max. Flood Rate (m)

Total Flood Vol. (M)

Max. Ponded Depth

PCSWMM Results

Contributing Area (m²)

Contributing Imp. A

Max. Unit Flow (m³)

Shape

Name [Name]

User-assigned name of junction.

Auto-Length Off

Offsets: Depth

CMS

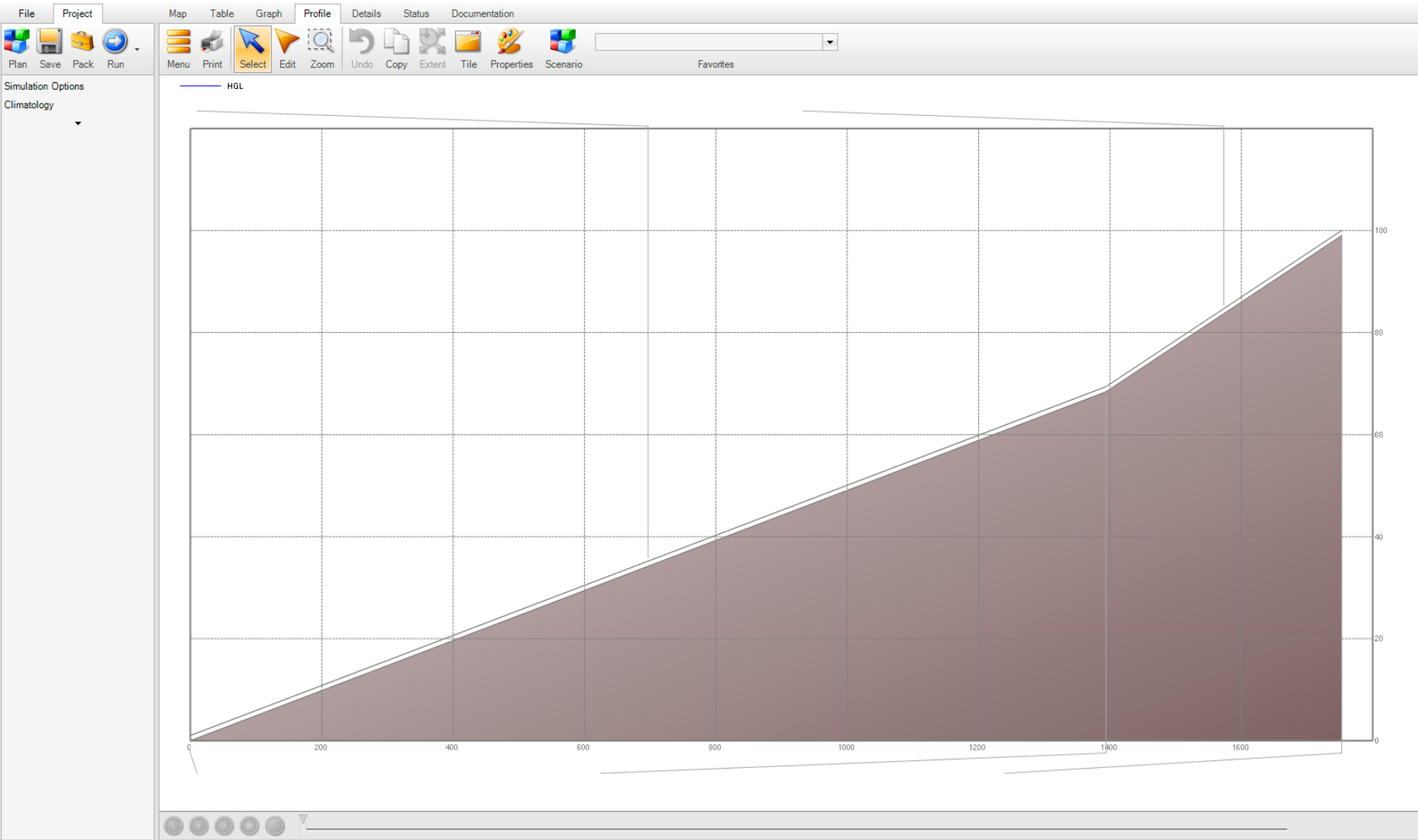
SWMM5.1.012

Popular Visualisation CRS...

X: -7629933.666 m Y: 9295953.382 m Z: 158.69

No results available

No results available



Attributes Notes

Menu Replace Graph Profile View

4 selected Junctions

Attributes

Name	
X-Coordinate	
Y-Coordinate	
Description	
Tag	WDT
Inflows	NO
Treatment	NO
Invert Elev. (m)	
Rim Elev. (m)	f x
Depth (m)	0
Initial Depth (m)	0
Surcharge Depth (m)	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 (m²)	0
Results	
Avg. Depth (m)	0
Max. Depth (m)	0
Max. HGL (m)	0
Time Max. HGL	
Rep. Max. Depth (m)	0
Max. Lat. Inflow (m)	0
Max. Total Inflow (m)	0
Total Lat. Inflow (m)	0
Total Inflow (ML)	0
Flow Error (%)	0
Hours Surcharged	0
Max. Surcharge (m)	0
Min. Freeboard (m)	0
Hours Flooded (h)	0
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Max. Ponded Depth	0
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Contributing Imp. A	0
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Shape	
Name [Name]	
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Proponents' Drainage Issues/Concerns



Existing Drainage Concerns?

Next Steps



Discussion / Questions





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



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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



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



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

September 2018



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



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

September 2018



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



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

September 2018



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



South of
Crossing 7
(600 mm dia.)

September 2018



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



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

September 2018



East of Crossing 8 (1000 mm dia.)

June 2018
Airport Creek Photos



West of
Crossing 8
behind the
fence -
Garbage

September 2018

June 2018
Airport Creek Photos



East of
Crossing 9
(2100 mm
dia.)

September 2018



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
Airport Creek Photos



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

September 2018



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



East of
Crossing 10
(3100 mm
dia.)

September 2018

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



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

September 2018



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



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

September 2018



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



East of
Crossing 13
(1600 mm
dia.)

September 2018



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



East of Crossing 13
(1600 mm
dia.)

September 2018



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



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

September 2018



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

June 2018
Lake Geraldine



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

September 2018



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



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

September 2018



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
downstream 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 -Blocked 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 buildup in front of pipe

June 2018
Lake Geraldine



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

September 2018



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

June 2018
Lake Geraldine



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

September 2018



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



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

September 2018



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



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

September 2018



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

June 2018
Lake Geraldine



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

September 2018



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



Lake Geraldine

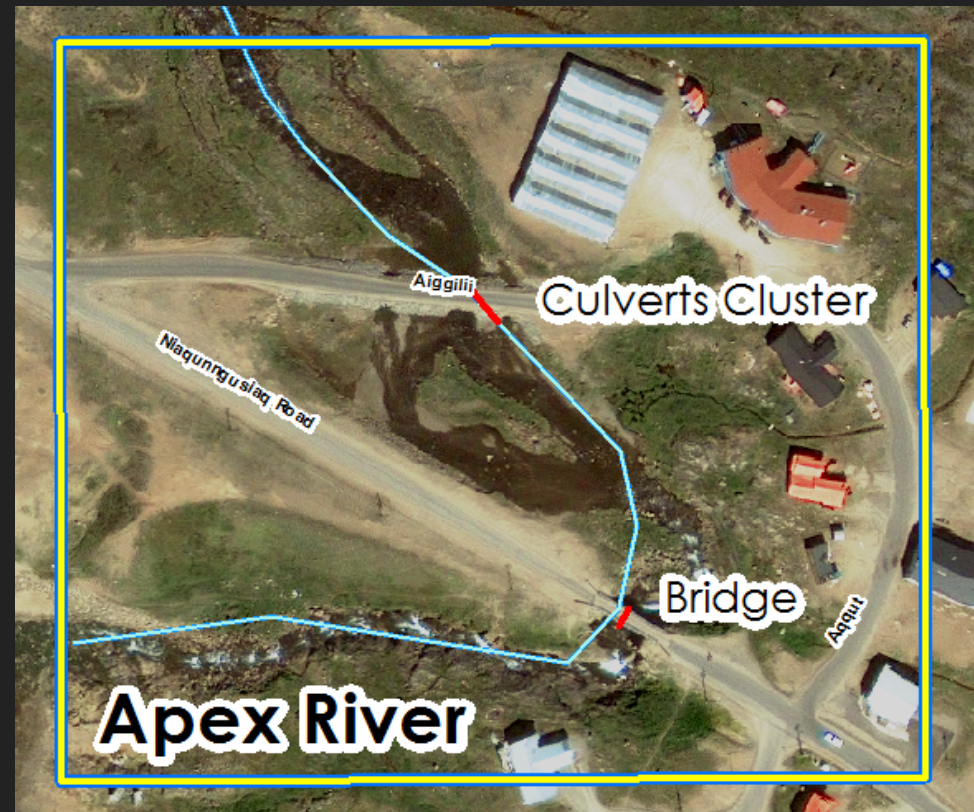
Summary

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 corrosion 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 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	
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



Proponent's Drainage Issues / Concerns

Apex River



June 2018
Apex River



Road of Interest Looking Northwest

September 2018

June 2018
Apex River



Left Side of Road of Interest - Looking West

September 2018

June 2018

Apex River



Eastern most culvert on south side of road - Blocked Pipe

September 2018

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 in front 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
Apex River



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

September 2018

June 2018
Apex River

September 2018



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

Apex River



Road of Interest - Looking West

September 2018

Apex River
June 2018

September 2018



North side of Cluster 3

Apex River
June 2018

September 2018



Northside of Cluster 3 - Deflected Pipe due to heavy loads

Apex River

June 2018

September 2018



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

Summary

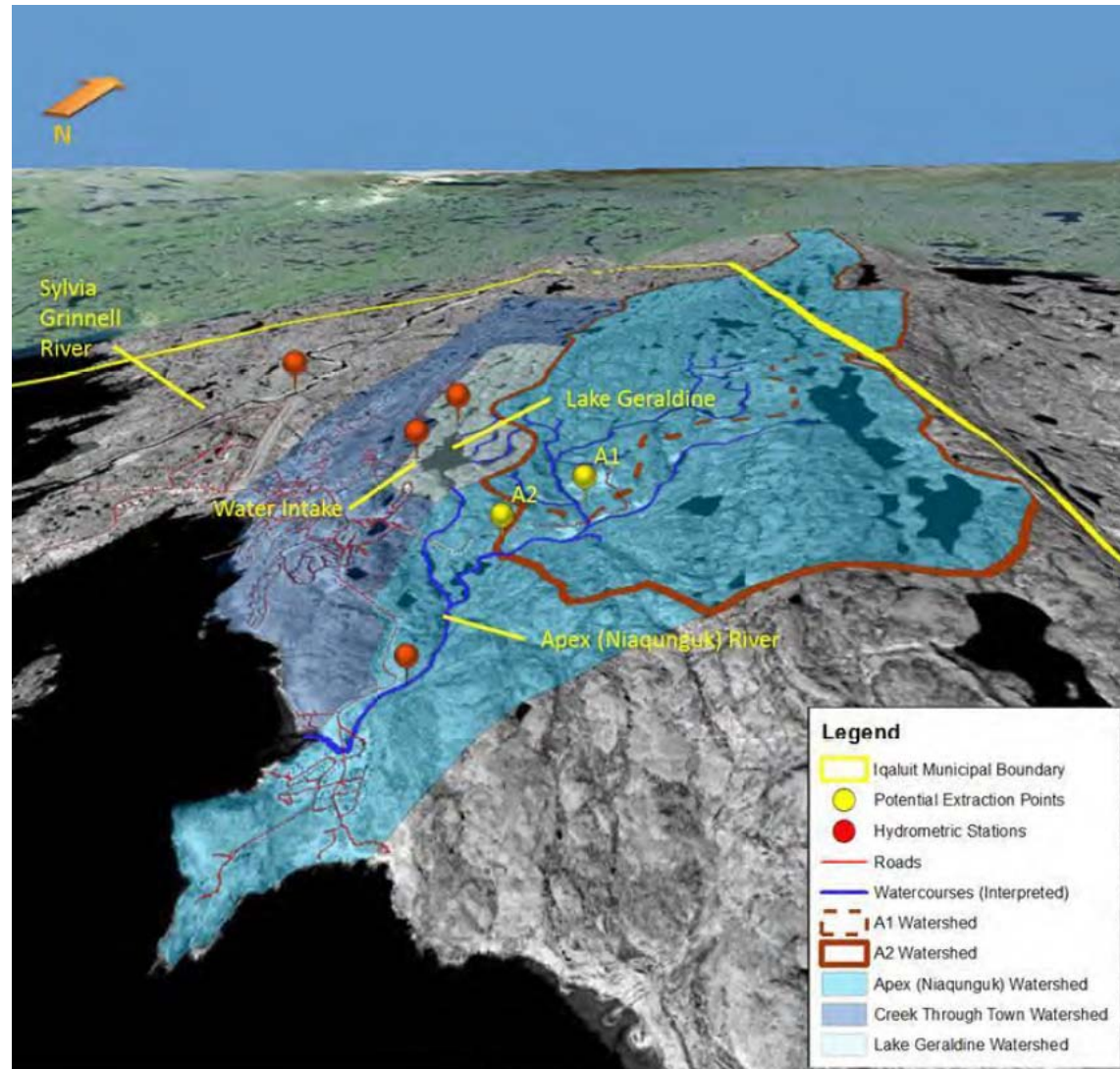
Apex River								
Crossing#	Upstream	Downstream	Dia. (mm)	Material	Shape	Configuration	Submerged	Condition
Ia				Corrugated Steel	Circular	Projected	N	Broken Culvert, Surface corrosion on the floor
C1a	N	S	9400	Corrugated Steel	Circular	Projected	N	Deformed Edges, Surface corrosion on floor, minor roof 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

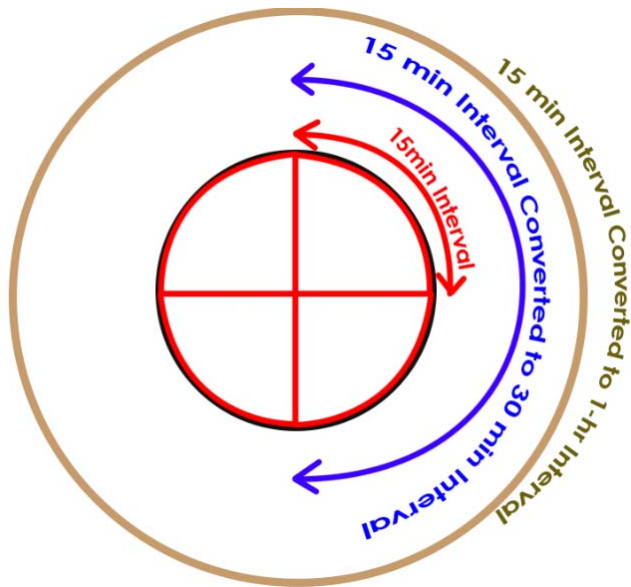
Precipitation

- 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	test Interval Avail
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 sensor	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



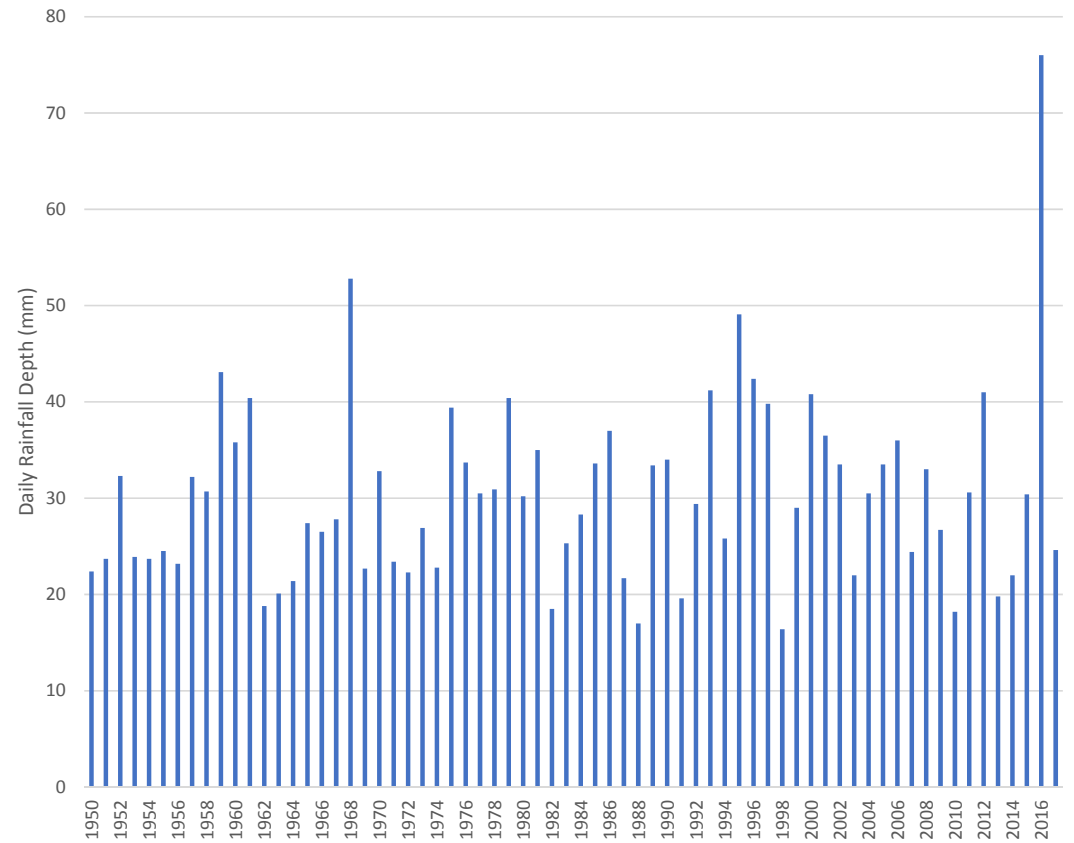
File	DLY04	DLY04	DLY04		HLY03		HLY01	HLY01		
Station	2402590	2402590	2402590		2402590		2402592	2402592		
Based on Interval of	24h	24h	6h		1h		1h	15min		
Interval	24h	24h	24h		24h		24h	24h	Max 24h	
Method	Max of element 10	Max of element 12	Added sections 6,7,8 and 9	Comparison	Built from Element 123 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

Daily Precipitation (1946 – 1997)



Daily Precipitation (1946 - 2017)





Summary

Precipitation Data

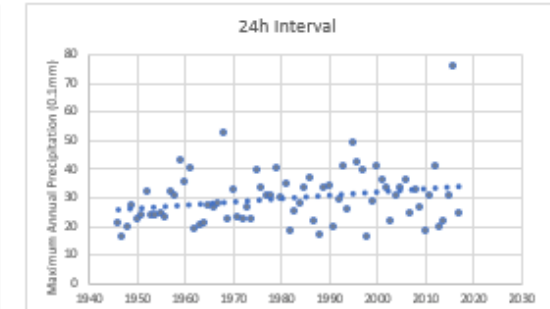
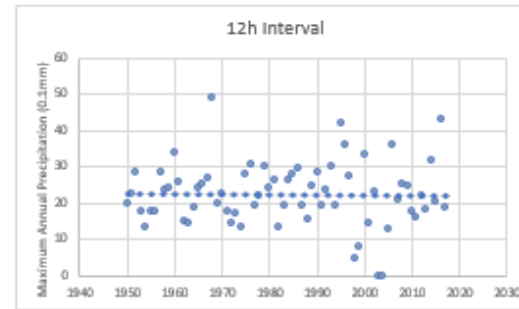
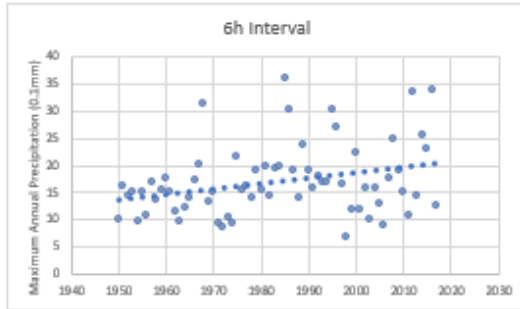
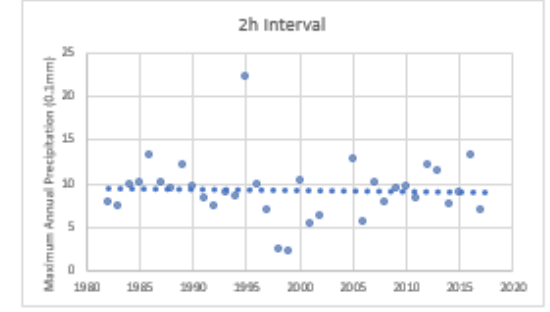
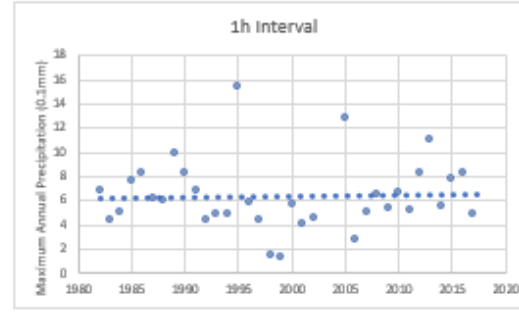
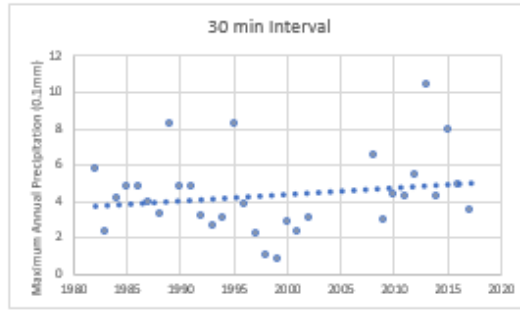
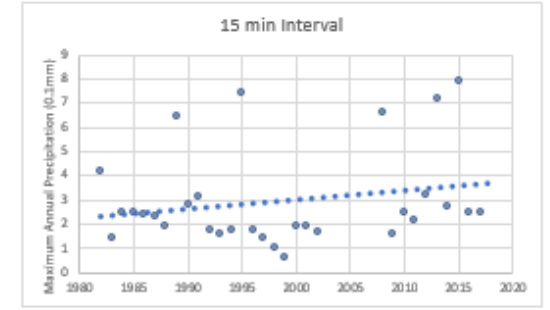
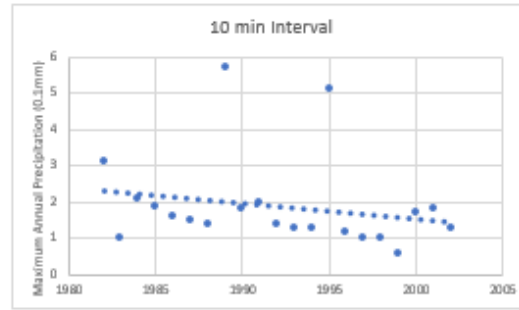
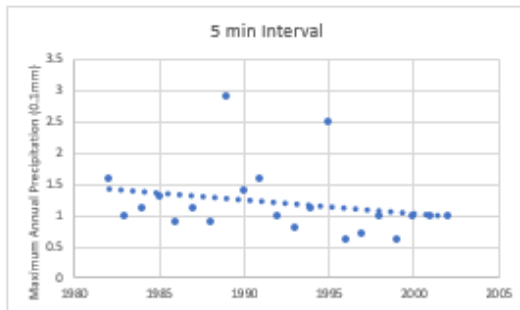
YEAR	5min	10min	15min	30min	1h	2h	6h	12h	24h
1946									21.3
1947									16
1948									19.6
1949									27.4
1950							10.2	19.9	22.4
1951							16.3	22.7	23.7
1952							14.5	28.5	32.3
1953							15.2	17.7	23.9
1954							9.7	13.5	23.7
1955							15	17.8	24.5
1956							10.7	17.8	23.2
1957							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

Precipitation Data

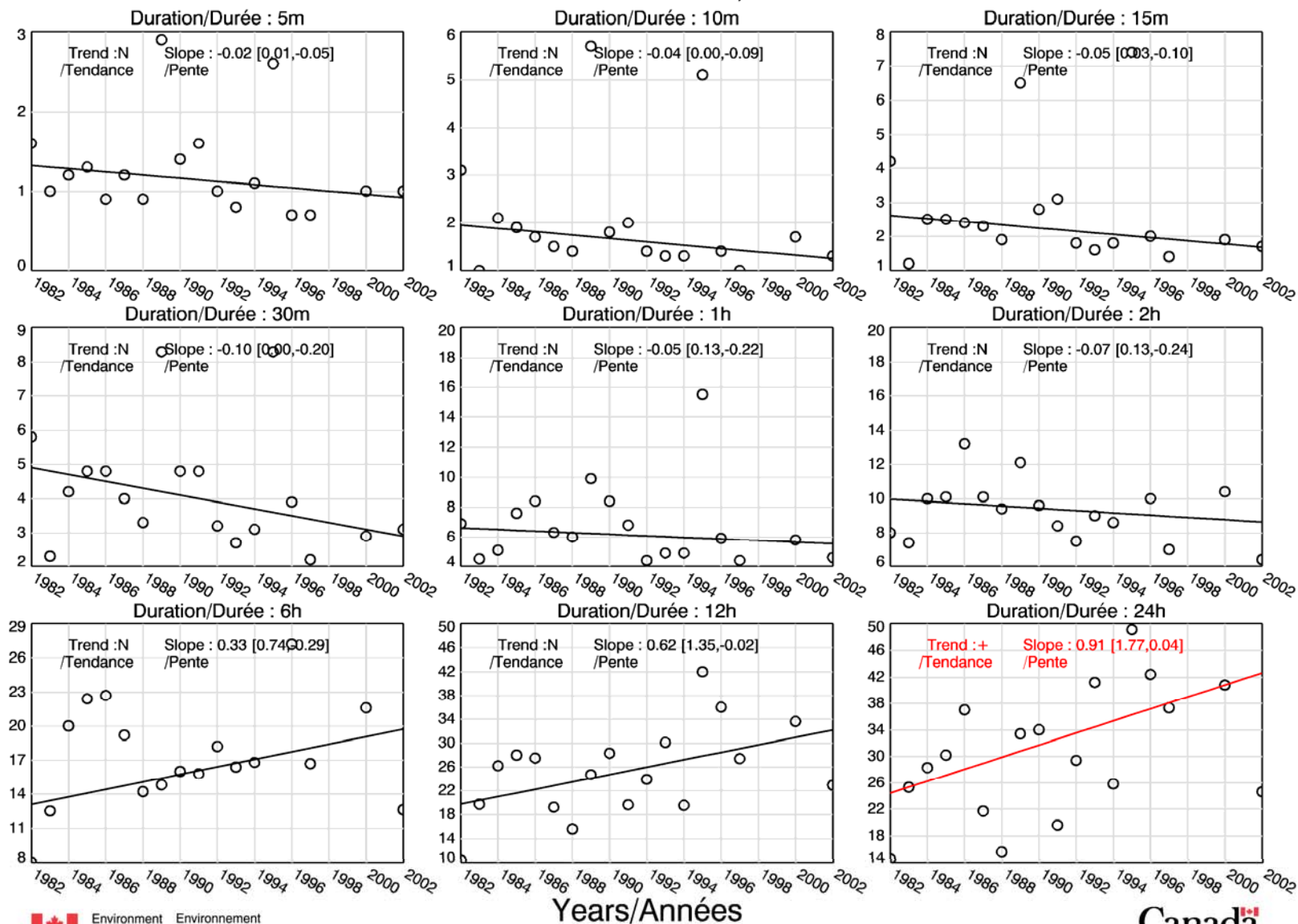
Summary – Trends

Precipitation Data



Trend/Tendance : IQALUIT A, NO 2402590

Annual Maximum/Maximum annuel (mm)



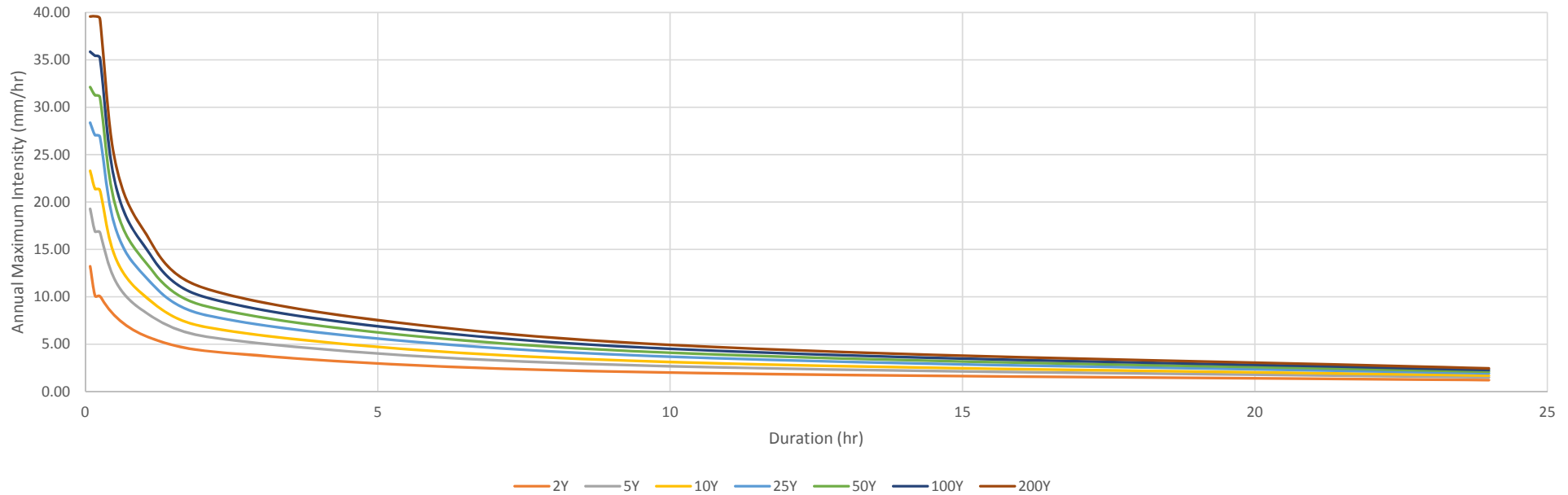


Historical Climate Data Review

IDF Curves

IDF Curves – Gumbel Estimate

IDF Curves - for Different Return Periods



IDF Parameters

Rate = $a \cdot (t-c)^b$	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

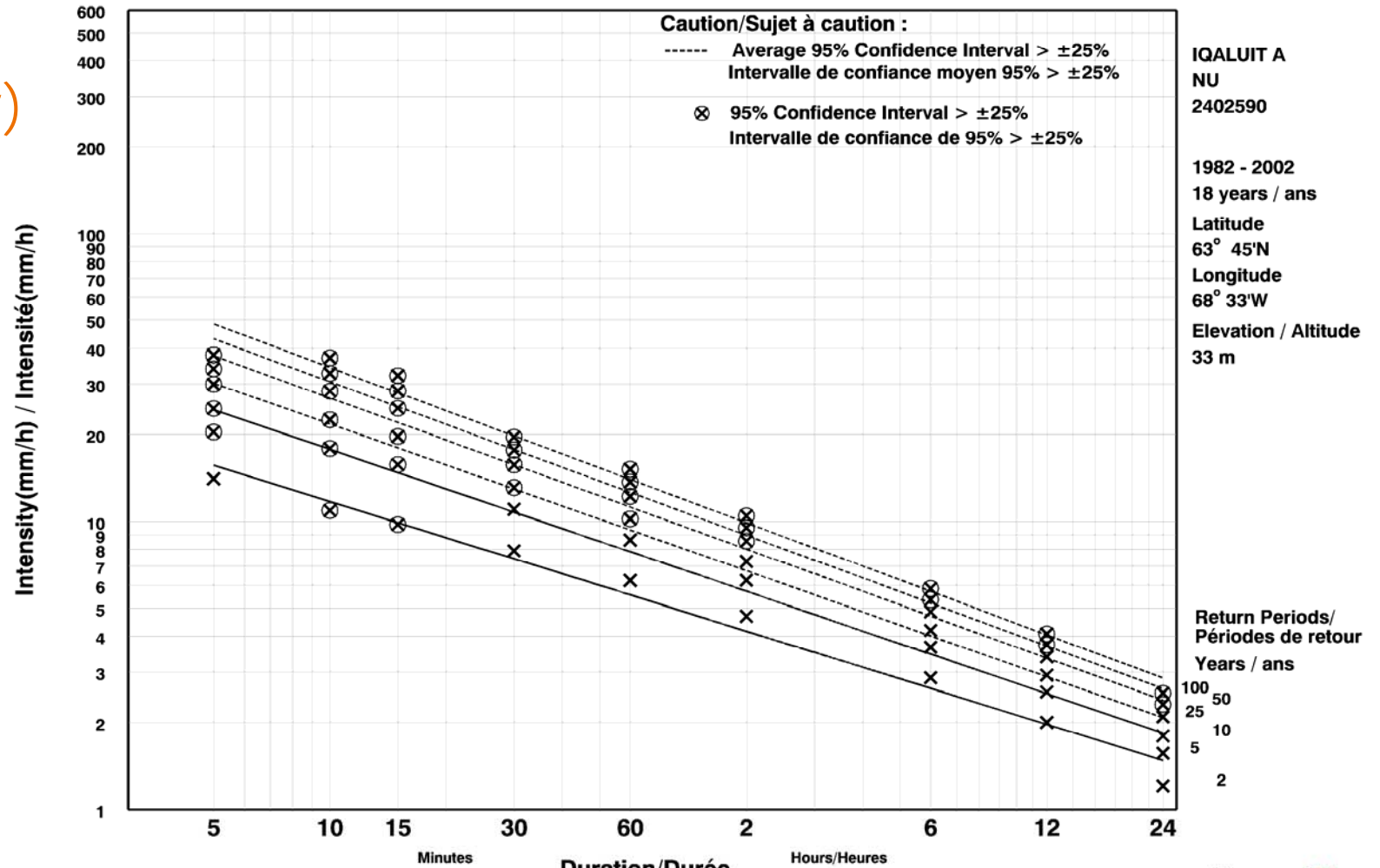
Rate = $a \cdot (t-c)^b$ where t= duration in minutes

IDF Curves (Intensity- Duration- Frequency)

Data available
1982-2002

Short Duration Rainfall Intensity-Duration-Frequency Data Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

2014/12/21



**IQALUIT A
NU**
2402590

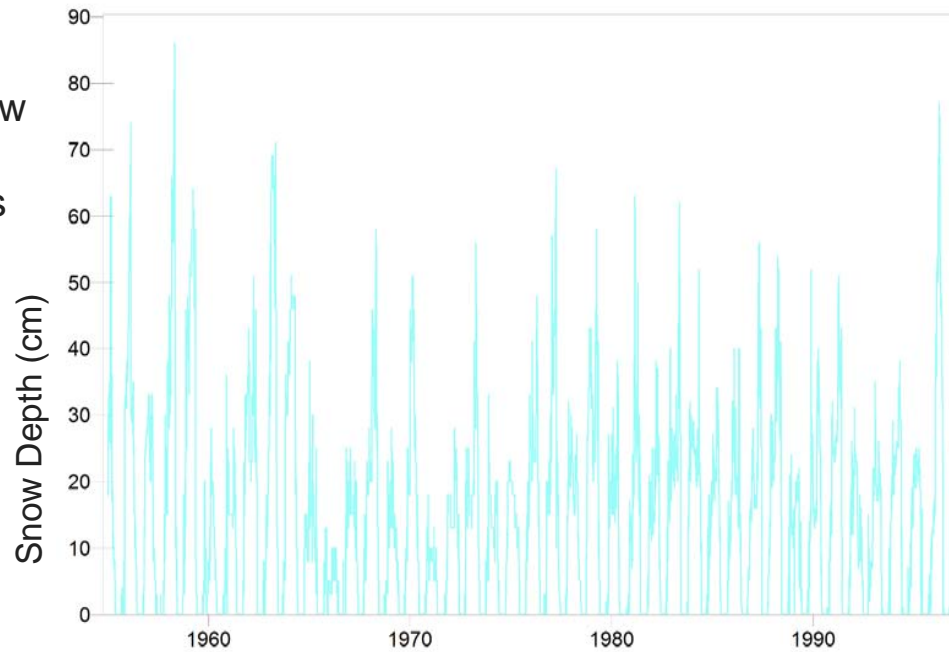
1982 - 2002
18 years / ans

Latitude
63° 45'N
Longitude
68° 33'W

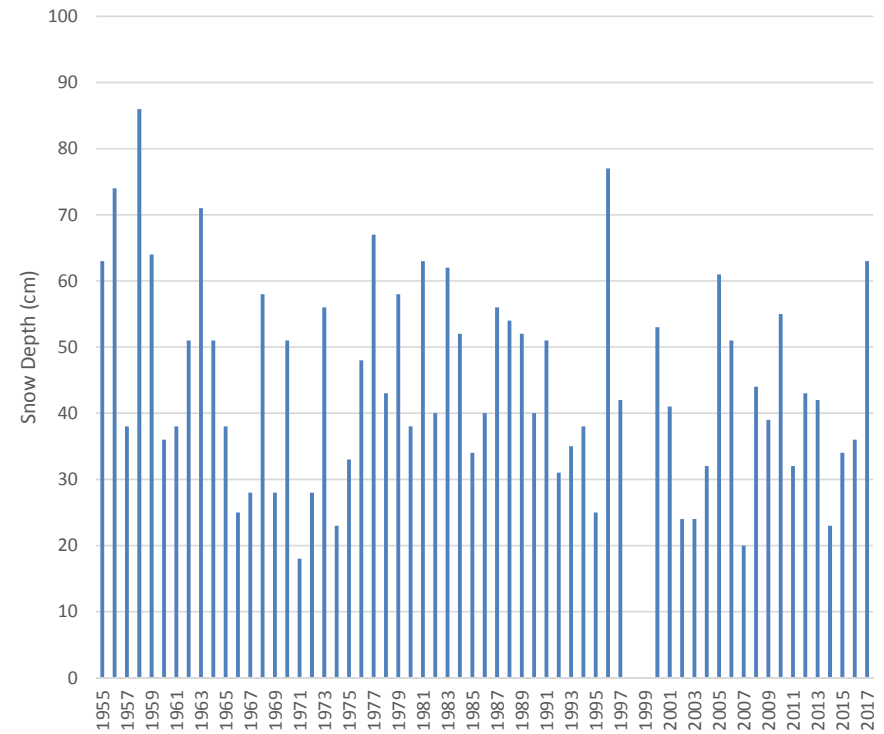
Elevation / Altitude
33 m

Snowfall Depths

Snowfall Depths (1955 – 1996)



Snowfall Depths (1955 - 2017)





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

Updates

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~~

CITY OF IQUALUIT MUNICIPAL DESIGN GUIDELINES



~~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 1065 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

CITY OF IQUALUIT MUNICIPAL DESIGN GUIDELINES



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

Land Use/Surface Characteristics	Runoff Coefficient, C
<u>Open Space</u>	<u>0.15</u>
Residential Lots	<u>0.352</u>
<u>Industrial</u>	<u>0.70</u>
<u>Commercial</u>	<u>0.70</u>
<u>Multiple Family</u>	<u>0.70</u>
Undeveloped Land	0.1
Pavement, concrete, buildings	<u>0.95</u>
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:

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

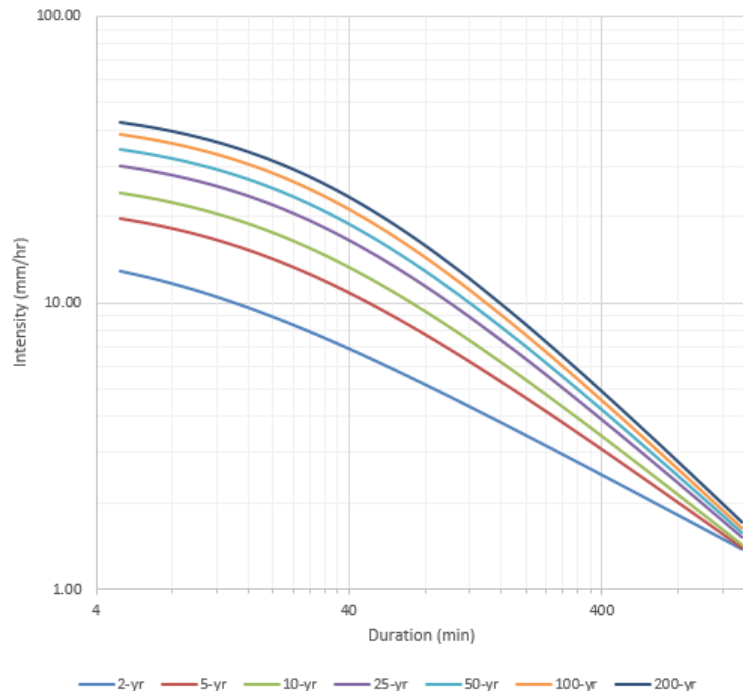
6. ~~The intensity for the rational formula is selected from the Intensity Duration Frequency (IDF) curve, with a duration chosen to coincide with the time of concentration (tc). The IDF curves provided selected from the available rainfall data using the time of concentration (Tc). Tc is the sum of inlet 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.~~

- 6.8. ~~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.~~

IDF Curves for City of Iqaluit



Curb and Gutter

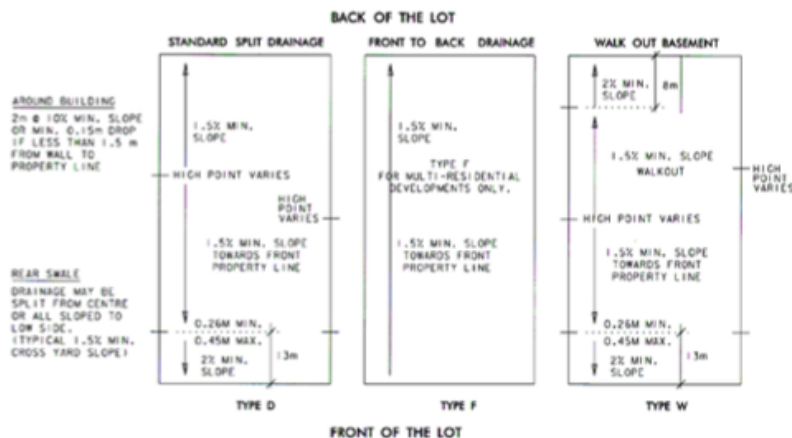
H.3.2

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 Outlets/falls

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.

Typical Lot Grading Details – Split/Front to Back Drainage



H.4.8H.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-

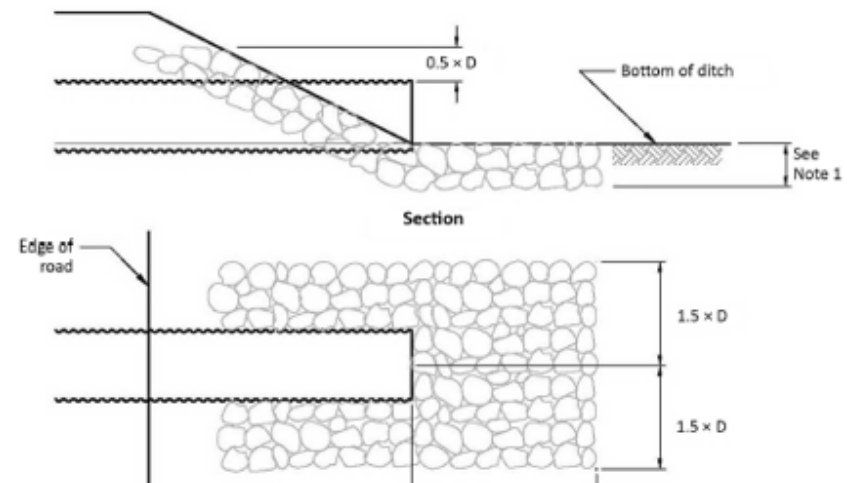
- 8) The relative surface elevations must allow for the slope of the ground adjacent to the building to be at a minimum of 10% for a distance of 2.0 m or to the property line, on all sides of the house, with the slope directing drainage away from the building and then for reasonable slopes in the order 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.4.7H.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 be provided with concrete flow channels or hard surface treatments, except where such measures are required to address flow velocity or erosion concerns.
- 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 unstream lot in a 7.0 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



Next Steps

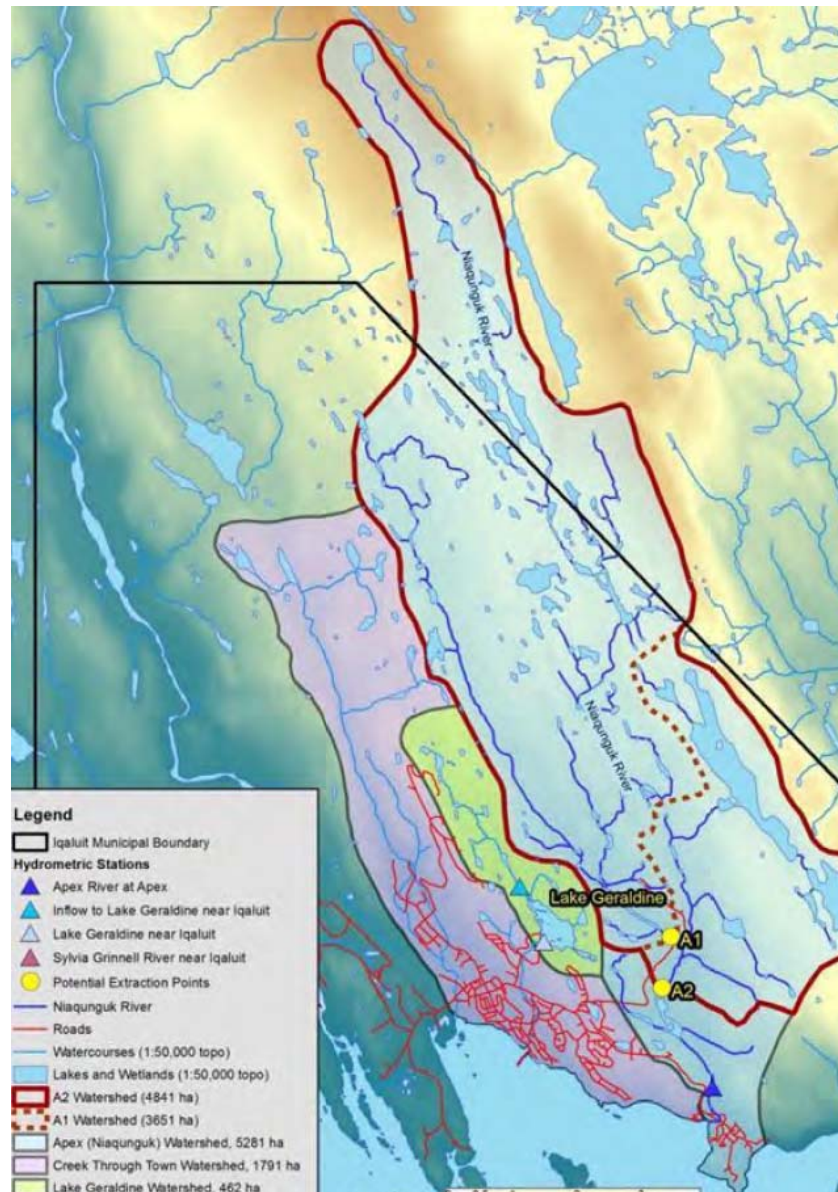


Discussion / Questions





Characterization of Study Area







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



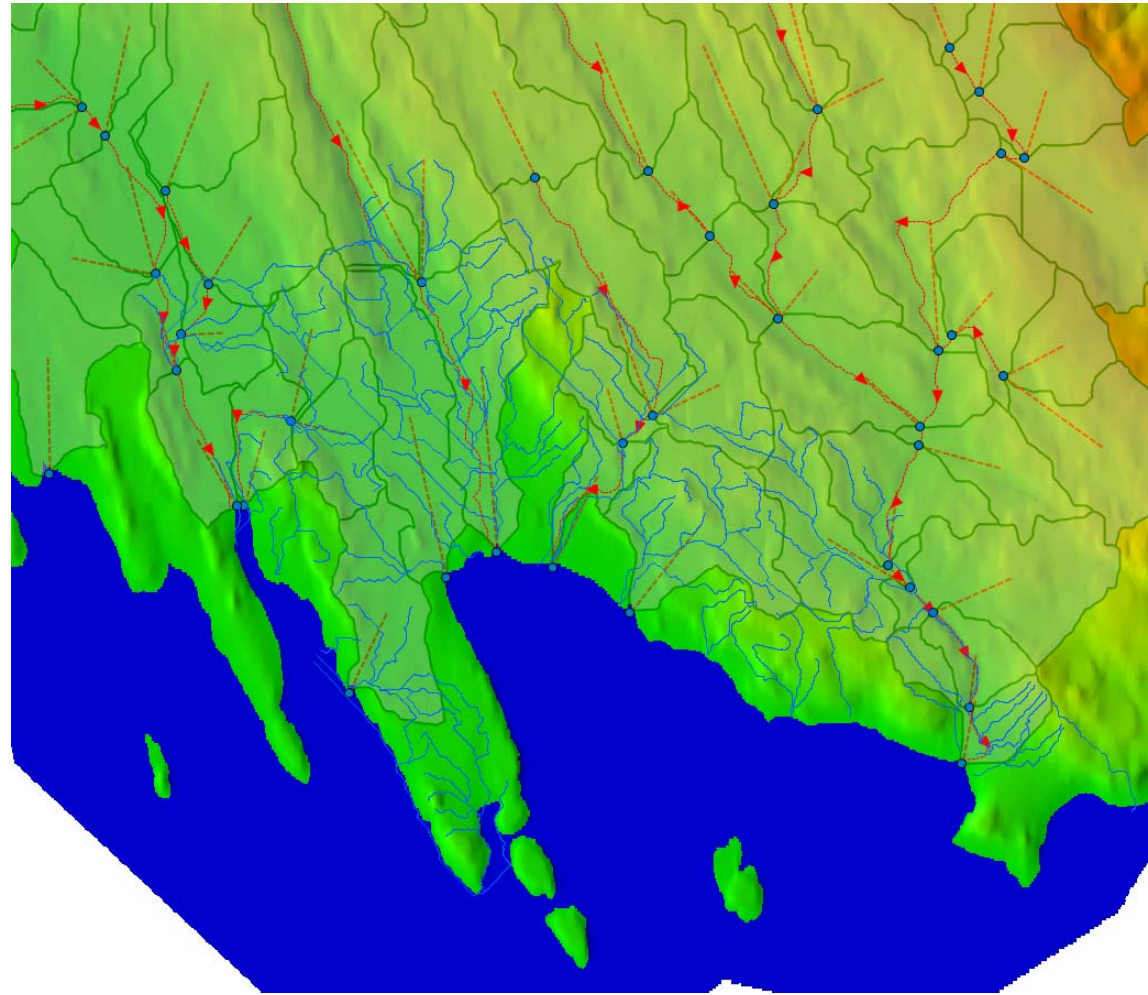
[Airport Creek Aerial](#)



Preliminary Model Construction

Model Construction

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



FileProject

Simulation Options

Climatology

Layers

☒ WDT Flow Paths
☐ WDT Watersheds
☐ WDT Stream Threshold
☐ WDT Contributing Area
☐ WDT Flow Direction
☐ WDT Slope
☐ WDT Fill Pits
☒ Junctions
☒ Outfalls
☒ Dividers
☒ Storages
☒ Conduits
☒ Pumps
☒ Orifices
☒ Weirs
☒ Outlets
☒ Subcatchments
☐ test

Bing map hybrid

MapTableGraphProfileDetailsStatusDocumentation

Search

Add

Paste

Delete

Project Notes

Description

Auto-Length Off

Offsets: Depth

CMS

SWMM5.1.012

Popular Visualisation CRS...

X: -7627694.507 m Y: 9296309.136 m Z: 164.88

No results available

FileProject

Plan
 Save
 Pack
 Run

Simulation Options

Climatology

Layers

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☐ WDT Watersheds
☐ WDT Stream Threshold
☐ WDT Contributing Area
☐ WDT Flow Direction
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☒ WDT Fill Pits
☒ Junctions
☒ Outfalls
☒ Dividers
☒ Storages
☒ Conduits
☒ Pumps
☒ Orifices
☒ Weirs
☒ Outlets
☒ Subcatchments
☐ test

Bing map hybrid

MapTableGraphProfileDetailsStatusDocumentation

Menu
 Print
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 Add
 Ruler
 Zoom
 Find
 Tools
 Render
 Play
 Earth
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 Prev.
 Next
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Favorites

AttributesNotes

Search
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Project Notes

Description

Auto-Length Off

Offsets: Depth

CMS

SWMM5.1.012

Popular Visualisation CRS...

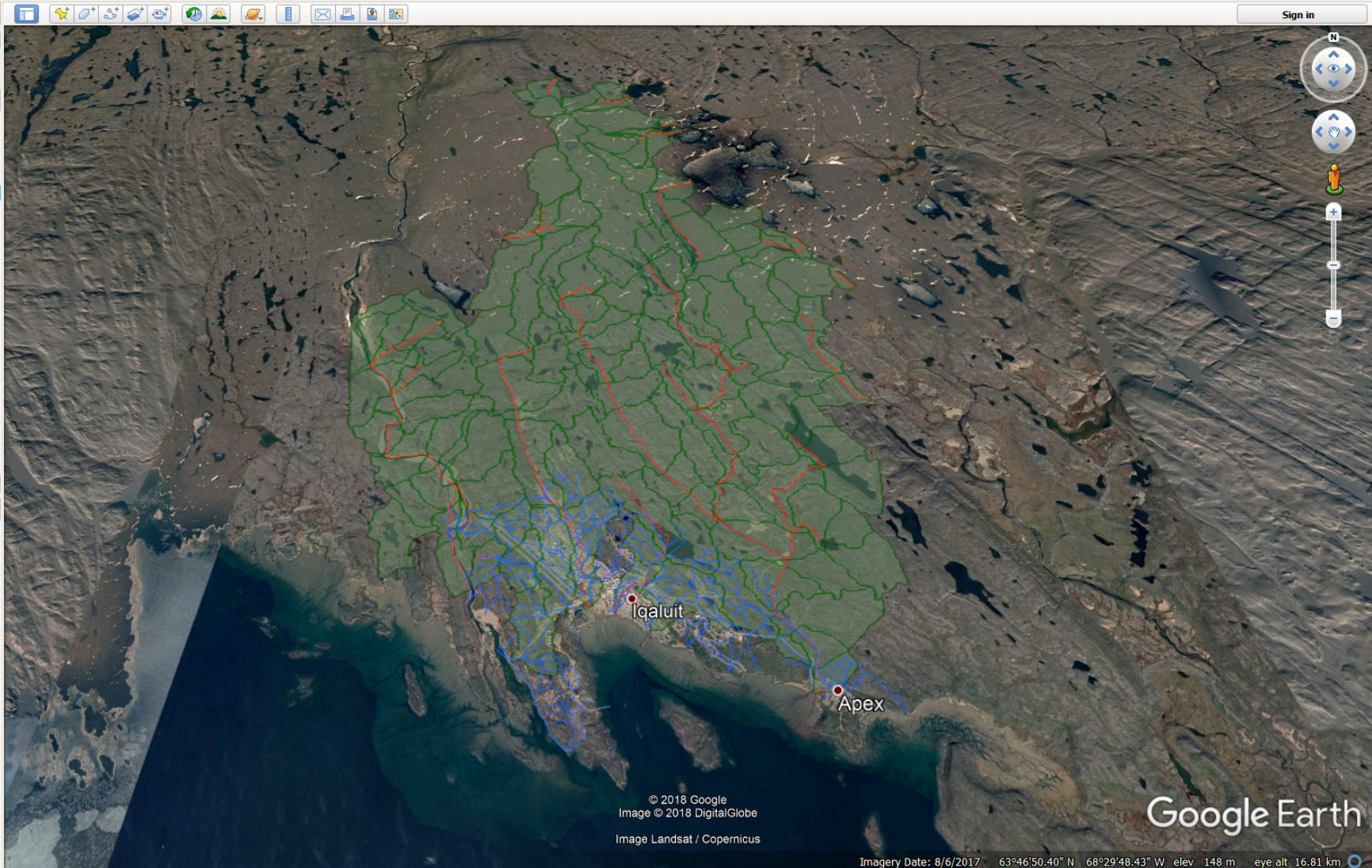
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▼ Search
Search
Museums in New York, NY
Get Directions History

▼ Places
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
Temporary Places
wdt-try2.kmz
Subcatchments
Conduits
Junctions
WDT Flow Paths

▼ Layers
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
Terrain



▼ Search

Search

Museums in New York, NY

Get Directions History

▼ Places

My Places

- ✓ Sightseeing Tour
Make sure 3D Buildings layer is checked

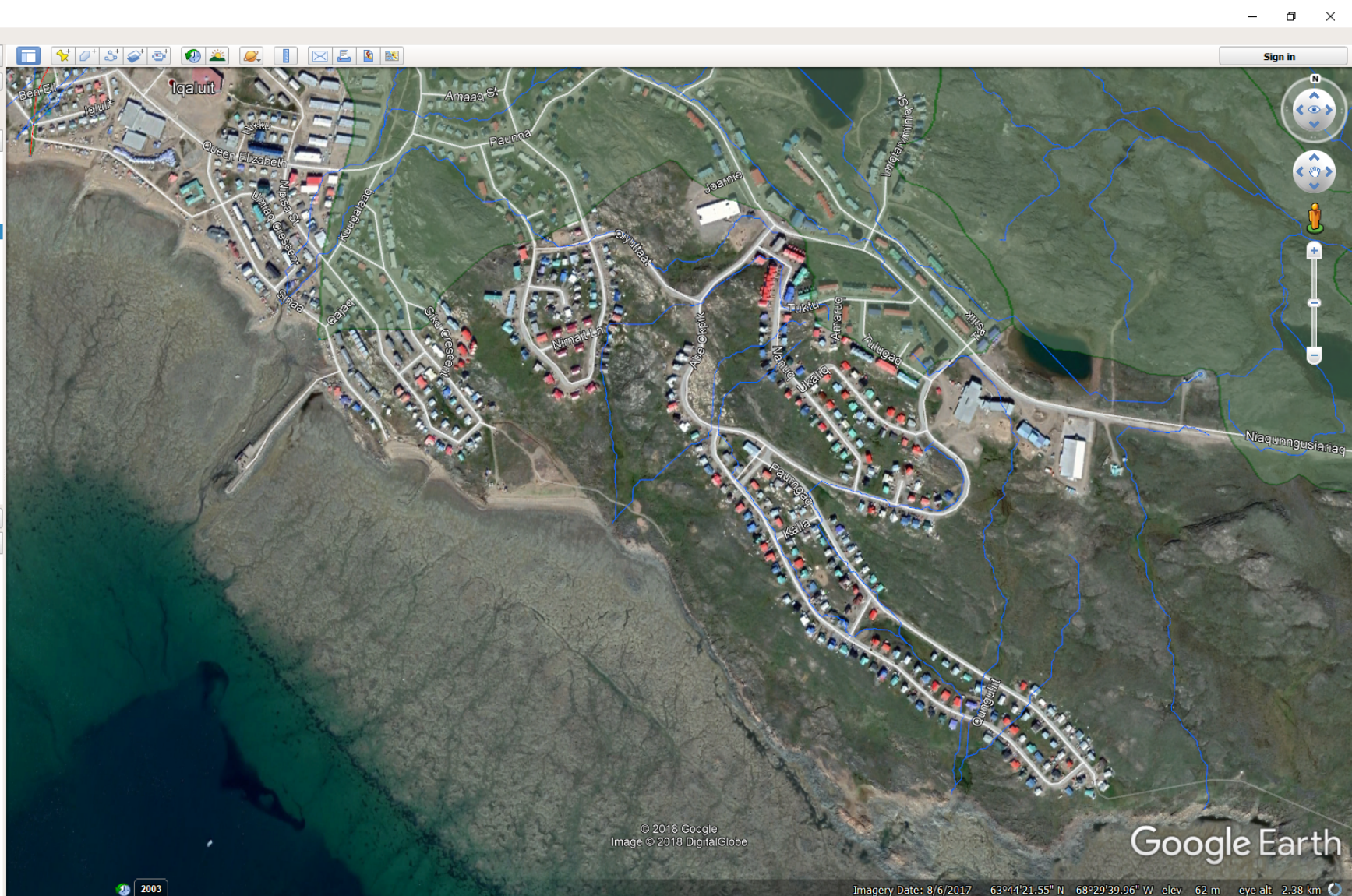
Temporary Places

- ✓ wdt-try2.kmz
 - ✓ Subcatchments
 - ✓ Conduits
 - ✓ Junctions
 - ✓ WDT Flow Paths

Layers

Primary Database

- ✓ Borders and Labels
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- ✓ Ocean
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- More
- ✓ Terrain





▼ Search

Search

Museums in New York, NY

Get Directions History

▼ Places

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Layers

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- ✓ More
- ✓ Terrain



FileProject

PlanSavePackRun

Simulation Options

Climatology

Layers

☒ WDT Flow Paths
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☐ WDT Contributing Area
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☒ Outfalls
☒ Dividers
☒ Storages
☒ Conduits
☒ Pumps
☒ Orifices
☒ Weirs
☒ Outlets
☒ Subcatchments
☐ test

Bing map hybrid

MapTableGraphProfileDetailsStatusDocumentation

MenuPrintOpenCloseLockAlterExport

SelectEditAdd

RulerZoom

FindToolsRenderPlayEarth

ExtentPrevNext

PasteCutCopyDelete

4 selected Junctions

AttributesNotes

MenuReplaceGraphProfileView

Attributes

Name

X-Coordinate

Y-Coordinate

Description

Tag

Inflows

Treatment

Invert Elev. (m)

Rim Elev. (m)

Depth (m)

Initial Depth (m)

Surcharge Depth (m)

Ponded Area (m²)

Inflows

Baseline (m³/s)

Baseline Pattern

Time Series

Scale Factor

Average Value (m³)

Time Pattern 1

Time Pattern 2

Time Pattern 3

Time Pattern 4

Hydrograph

Sewershed Area (m²)

Results

Avg. Depth (m)

Max. Depth (m)

Max. HGL (m)

Time Max. HGL

Rep. Max. Depth (m)

Max. Lat. Inflow (m)

Max. Total Inflow (m)

Total Lat. Inflow (m)

Total inflow (ML)

Flow Error (%)

Hours Surcharged

Max. Surcharge (m)

Min. Freeboard (m)

Hours Flooded (h)

Max. Flood Rate (m)

Total Flood Vol. (M)

Max. Ponded Depth

PCSWMM Results

Contributing Area (m²)

Contributing Imp. A

Max. Unit Flow (m³)

Shape

Name [Name]

User-assigned name of junction.

Auto-Length Off

Offsets: Depth

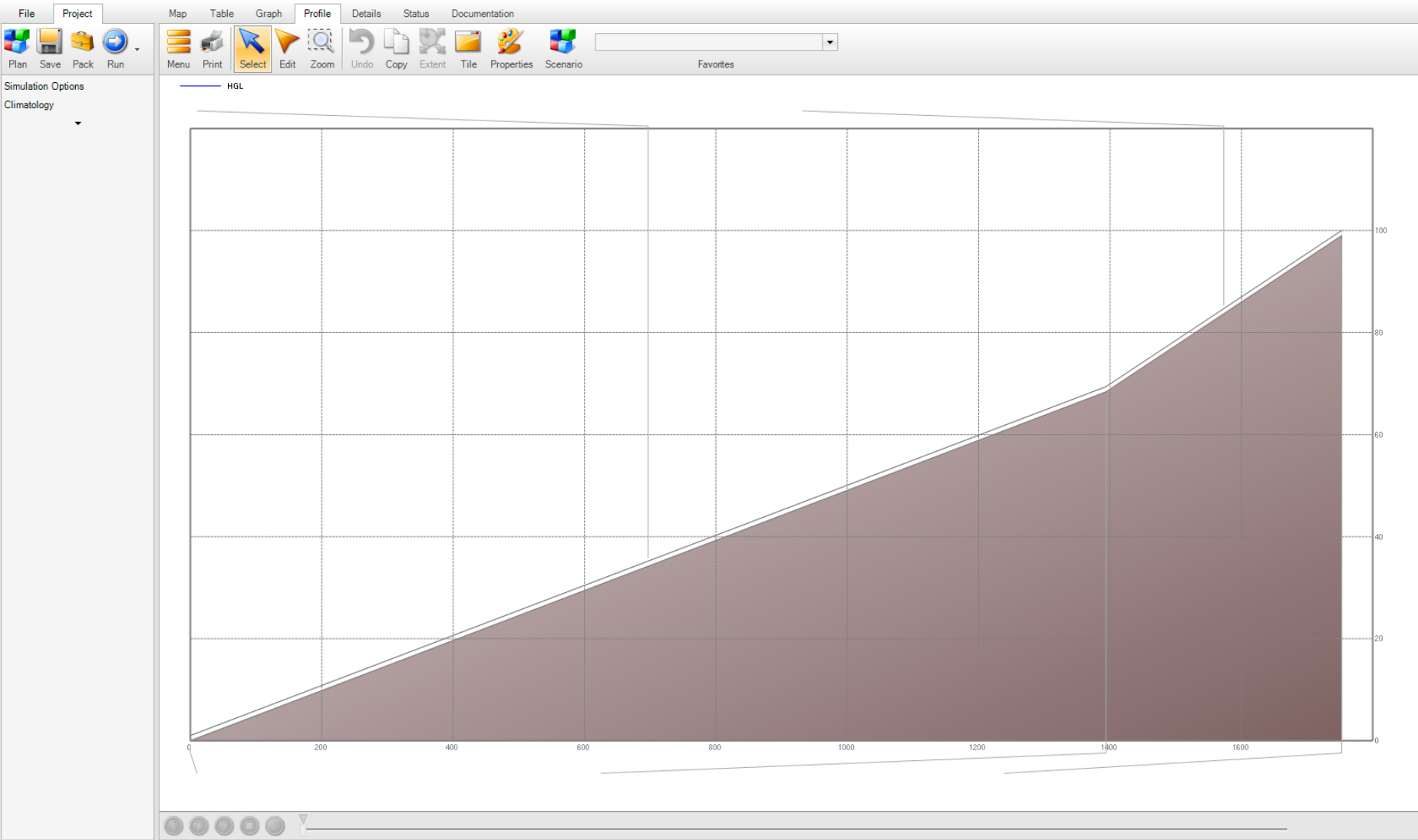
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SWMM5.1.012

Popular Visualisation CRS...

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No results available



Attributes

Notes

4 selected Junctions

Attributes

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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 (m)	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 (m²)	0
Results	
Avg. Depth (m)	0
Max. Depth (m)	0
Max. HGL (m)	0
Time Max. HGL	
Rep. Max. Depth (m)	0
Max. Lat. Inflow (m)	0
Max. Total Inflow (m)	0
Total Lat. Inflow (m)	0
Total inflow (ML)	0
Flow Error (%)	0
Hours Surcharged	0
Max. Surcharge (m)	0
Min. Freeboard (m)	0
Hours Flooded (h)	0
Max. Flood Rate (m)	0
Total Flood Vol. (M)	0
Max. Ponded Dept	0
PCSWMM Results	
Contributing Area (m²)	0
Contributing Imp. A	0
Max. Unit Flow (m³)	0
Shape	
Name [Name]	User-assigned name of junction.