City of Toronto
Basement Flooding Capacity Assessment Studies

Generating Wet Weather Flows Using RTK

March 11, 2021

Stantec

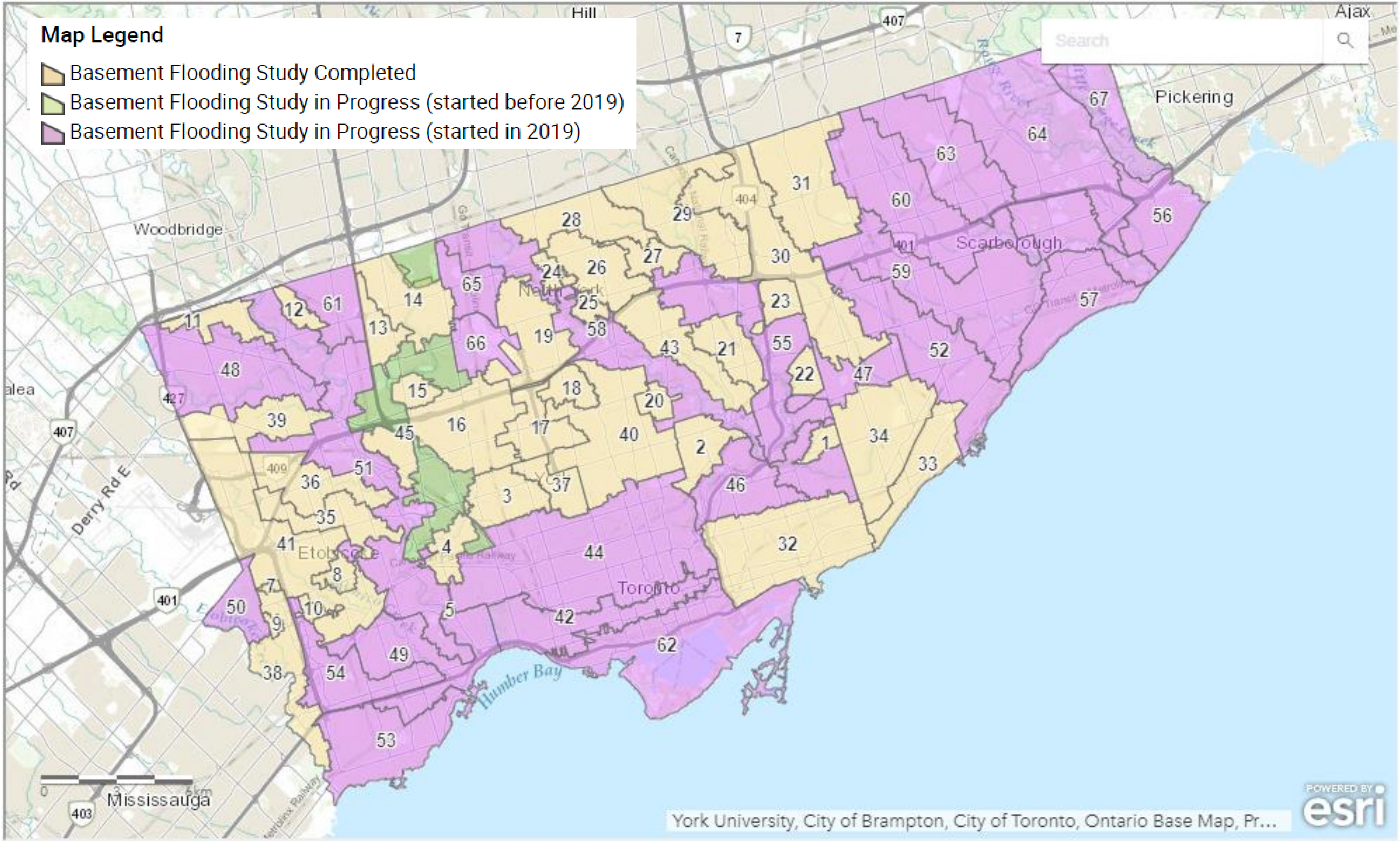
Toronto Basement Flooding Capacity Assessment Studies (CAS)

Project Overview

The What, Where, When & Why?

The What?

- The Capacity Assessment Studies (CAS) are part of a larger programme – the Basement Flooding Protection Programme (BFPP)
- Reducing surface flooding & stormwater entering all sewer systems
- Identifying capacity shortfalls & recommending sewer system improvements / infrastructure upgrades
- The identification & development of Schedule A/A+ Assignments


Map Legend
Basement Flooding Study Completed
Basement Flooding Study in Progress (started before 2019)
Basement Flooding Study in Progress (started in 2019)
Woodbridge
Pickering
Ajax
Scarborough
North York
Etobicoke
Toronto
Mississauga
Humber Bay
Derry Rd E
York University, City of Brampton, City of Toronto, Ontario Base Map, Pr...
Search
0 3 6km

The What, Where, When & Why?

The When?

- Schedule is a primary driver
- The primary goal is to upgrade infrastructure as quickly as possible
- The approximate timeline for each Project is expected to be 42 months (including study and pre-design components)
- Started CAS phase in Jan 2018, due date Sept 2021

The What, Where, When & Why?

The Why?

- The August 19, 2005 event
- 4,200 basement flooding complaints
- Creation of the BFPP in (2006)
- Develop comprehensive plans to reduce risk of flooding in 31 Study Areas that experience flooding in severe storms
- Expanded in 2013 to 67 Study Areas

The Why, What, Where & When?

Summary

"Solutions … to increase the capacity of municipal underground and overland drainage systems. The objective of this effort is to reduce the risk of future basement and surface flooding, by reducing the risks of flooding coming from shortfalls in the capacity of the municipal drainage systems."

…

And we need them NOW!

Toronto Basement Flooding Capacity Assessment Studies

The Problem

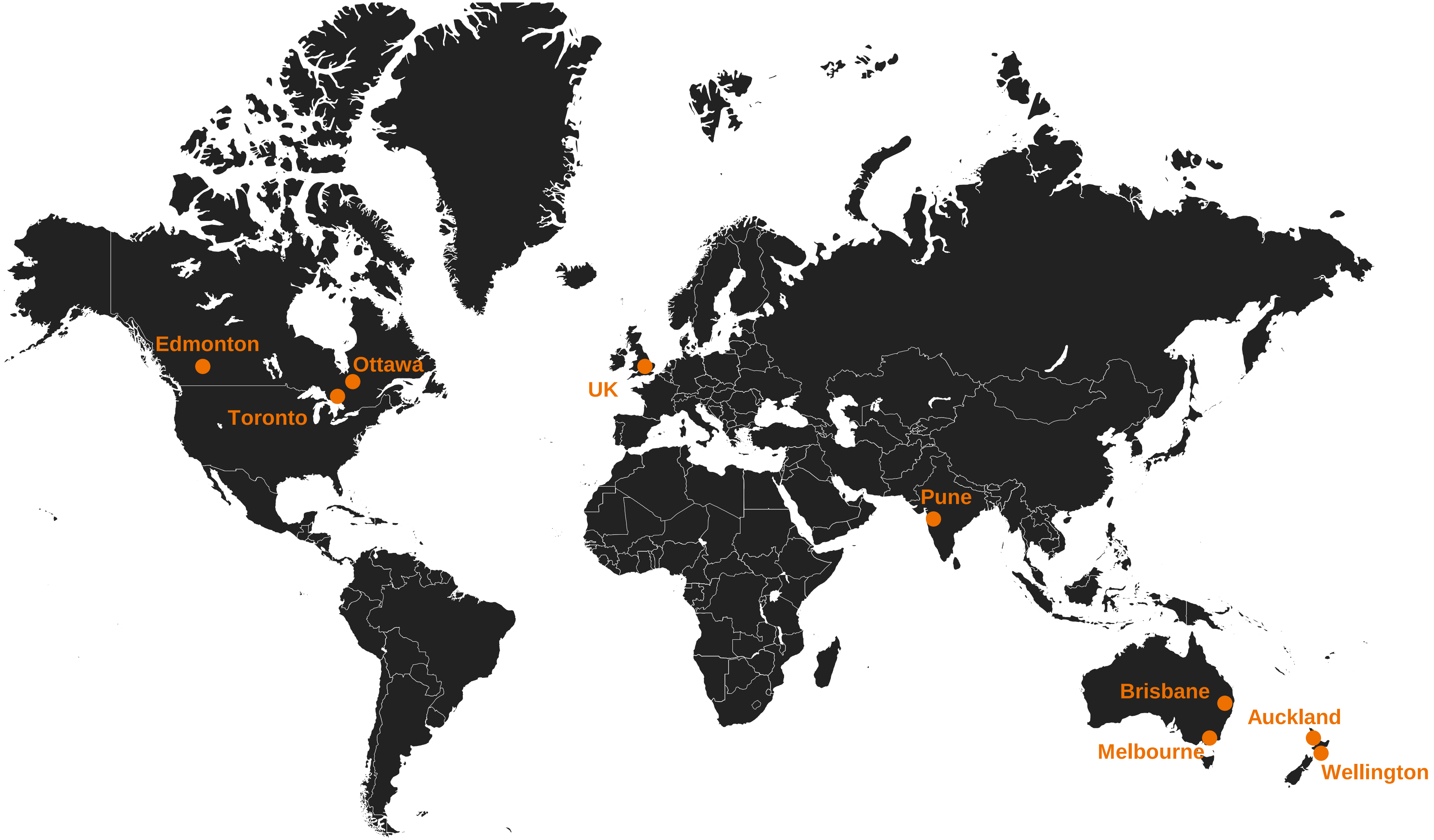
Programme

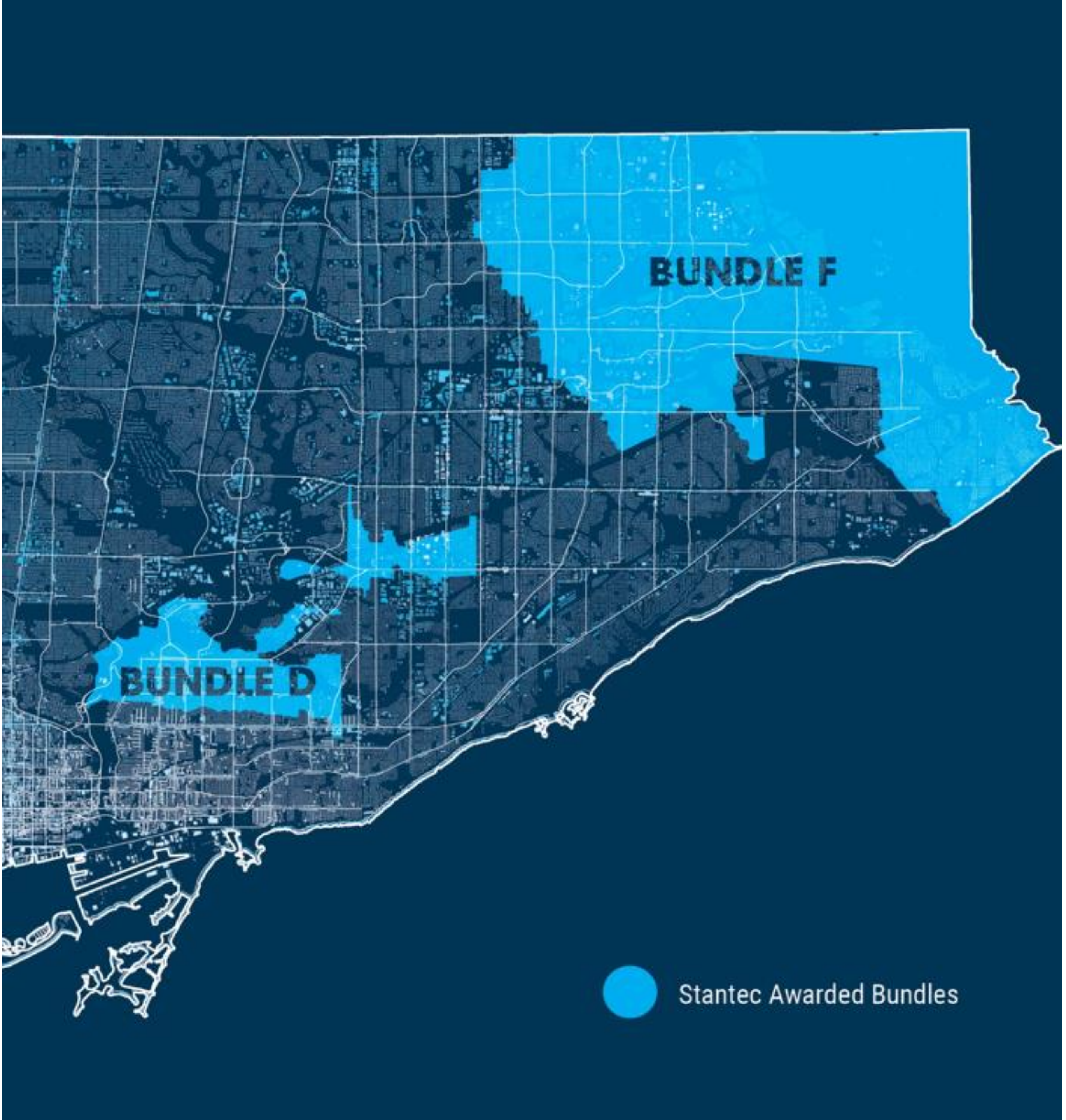
Question: How could we deliver this programme in the timeframe?

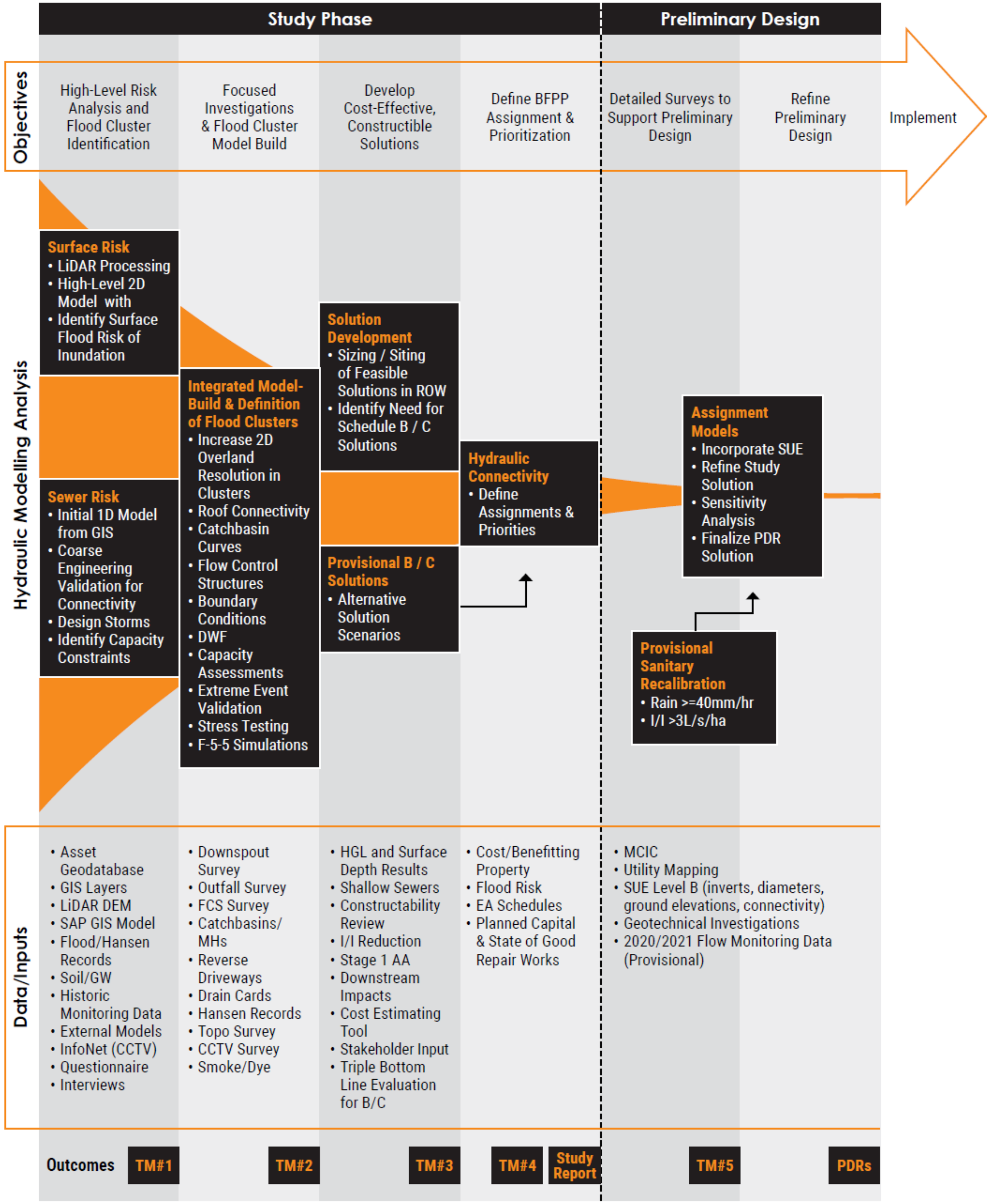
- Data is key. However…
- Model calibration of a network this size can take years & cost $Ms
- Scale of survey programme would be enormous to plan & execute
- Calibration activities themselves would take significant resourcing
- There is <u>no guarantee of data quality & calibration output</u>
- There simply wasn't the time… so what was the alternative?
- RTK Approach (fairly common in N. America)

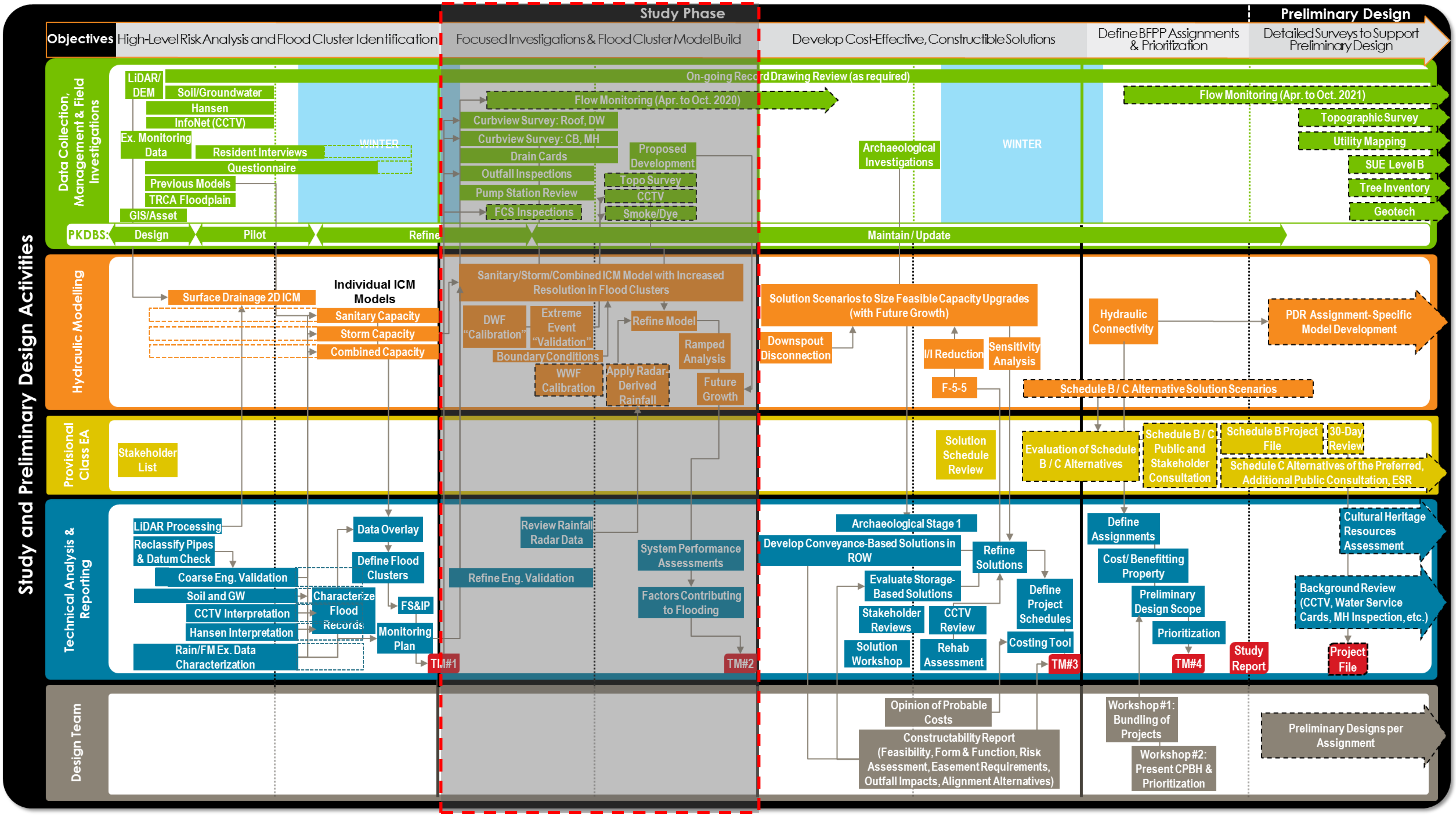
Resourcing - We're Better Together

With programme key, additional resources were sought to help deliver




BUNDLE F
BUNDLE D
Stantec Awarded Bundles


Study Phase
Preliminary Design
Objectives
High-Level Risk Analysis and Flood Cluster Identification
Focused Investigations & Flood Cluster Model Build
Develop Cost-Effective, Constructible Solutions
Define BFPP Assignment & Prioritization
Detailed Surveys to Support Preliminary Design
Refine Preliminary Design
Implement
Hydraulic Modelling Analysis
Surface Risk
• LiDAR Processing
• High-Level 2D Model with
• Identify Surface Flood Risk of Inundation
Sewer Risk
• Initial 1D Model from GIS
• Coarse Engineering Validation for Connectivity
• Design Storms
• Identify Capacity Constraints
Integrated Model-Build & Definition of Flood Clusters
• Increase 2D Overland Resolution in Clusters
• Roof Connectivity
• Catchbasin Curves
• Flow Control Structures
• Boundary Conditions
• DWF
• Capacity Assessments
• Extreme Event Validation
• Stress Testing
• F-5-5 Simulations
Solution Development
• Sizing / Siting of Feasible Solutions in ROW
• Identify Need for Schedule B / C Solutions
Provisional B / C Solutions
• Alternative Solution Scenarios
Hydraulic Connectivity
• Define Assignments & Priorities
Assignment Models
• Incorporate SUE
• Refine Study Solution
• Sensitivity Analysis
• Finalize PDR Solution
Provisional Sanitary Recalibration
• Rain >=40mm/hr
• I/I >3L/s/ha
Data/Inputs
• Asset Geodatabase
• GIS Layers
• LiDAR DEM
• SAP GIS Model
• Flood/Hansen Records
• Soil/GW
• Historic Monitoring Data
• External Models
• InfoNet (CCTV)
• Questionnaire
• Interviews
• Downspout Survey
• Outfall Survey
• FCS Survey
• Catchbasins/ MHs
• Reverse Driveways
• Drain Cards
• Hansen Records
• Topo Survey
• CCTV Survey
• Smoke/Dye
• HGL and Surface Depth Results
• Shallow Sewers
• Constructability Review
• I/I Reduction
• Stage 1 AA
• Downstream Impacts
• Cost Estimating Tool
• Stakeholder Input
• Triple Bottom Line Evaluation for B/C
• Cost/Benefitting Property
• Flood Risk
• EA Schedules
• Planned Capital & State of Good Repair Works
• MCIC
• Utility Mapping
• SUE Level B (inverts, diameters, ground elevations, connectivity)
• Geotechnical Investigations
• 2020/2021 Flow Monitoring Data (Provisional)
Outcomes
TM#1
TM#2
TM#3
TM#4
Study Report
TM#5
PDRs



Study Phase
Preliminary Design
Objectives
High-Level Risk Analysis and Flood Cluster Identification
Focused Investigations & Flood Cluster Model Build
Develop Cost-Effective, Constructible Solutions
Define BFPP Assignments & Prioritization
Detailed Surveys to Support Preliminary Design
Study and Preliminary Design Activities
Data Collection, Management & Field Investigations
LiDAR/ DEM
Soil/Groundwater
Hansen
InfoNet (CCTV)
Ex. Monitoring Data
Resident Interviews
Questionnaire
Previous Models
TRCA Floodplain
GIS/Asset
WINTER
On-going Record Drawing Review (as required)
Flow Monitoring (Apr. to Oct. 2020)
Curbview Survey: Roof, DW
Curbview Survey: CB, MH
Drain Cards
Outfall Inspections
Pump Station Review
FCS Inspections
Proposed Development
Topo Survey
CCTV
Smoke/Dye
Archaeological Investigations
WINTER
Flow Monitoring (Apr. to Oct. 2021)
Topographic Survey
Utility Mapping
SUE Level B
Tree Inventory
Geotech
PKDBS:
Design
Pilot
Refine
Maintain/Update
Hydraulic Modelling
Individual ICM Models
Surface Drainage 2D ICM
Sanitary Capacity
Storm Capacity
Combined Capacity
Sanitary/Storm/Combined ICM Model with Increased Resolution in Flood Clusters
DWF "Calibration"
Extreme Event "Validation"
Refine Model
Boundary Conditions
Ramped Analysis
WWF Calibration
Apply Radar-Derived Rainfall
Future Growth
Solution Scenarios to Size Feasible Capacity Upgrades (with Future Growth)
Downspout Disconnection
I/I Reduction
Sensitivity Analysis
F-5-5
Hydraulic Connectivity
PDR Assignment-Specific Model Development
Schedule B / C Alternative Solution Scenarios
Provisional Class EA
Stakeholder List
Solution Schedule Review
Evaluation of Schedule B / C Alternatives
Schedule B / C Public and Stakeholder Consultation
Schedule B Project File
30-Day Review
Schedule C Alternatives of the Preferred, Additional Public Consultation, ESR
Technical Analysis & Reporting
LiDAR Processing
Reclassify Pipes & Datum Check
Coarse Eng. Validation
Soil and GW
CCTV Interpretation
Hansen Interpretation
Rain/FM Ex. Data Characterization
Data Overlay
Define Flood Clusters
Characterize Flood Records
FS&IP
Monitoring Plan
TM#1
Review Rainfall Radar Data
Refine Eng. Validation
System Performance Assessments
Factors Contributing to Flooding
TM#2
Archaeological Stage 1
Develop Conveyance-Based Solutions in ROW
Refine Solutions
Evaluate Storage-Based Solutions
Stakeholder Reviews
CCTV Review
Define Project Schedules
Solution Workshop
Rehab Assessment
Costing Tool
TM#3
Define Assignments
Cost/ Benefitting Property
Preliminary Design Scope
Prioritization
TM#4
Study Report
Cultural Heritage Resources Assessment
Background Review (CCTV, Water Service Cards, MH Inspection, etc.)
Project File
Design Team
Opinion of Probable Costs
Constructability Report (Feasibility, Form & Function, Risk Assessment, Easement Requirements, Outfall Impacts, Alignment Alternatives)
Workshop #1: Bundling of Projects
Workshop #2: Present CPBH & Prioritization
Preliminary Designs per Assignment

Stantec Involvement

What did we do?

- Responsible for all Study Areas within Bundles F & D, TM1 - 4
- A total of 7 Study Areas, both STM and SAN
- NZ team asked to assist with Bundle F Study Areas for TM2
- Wellington team lead SAN, Auckland team lead STM
- NZ team now responsible for all SAN activities within TM3

Toronto Basement Flooding Capacity Studies

Wet Weather Flows – The RTK Approach

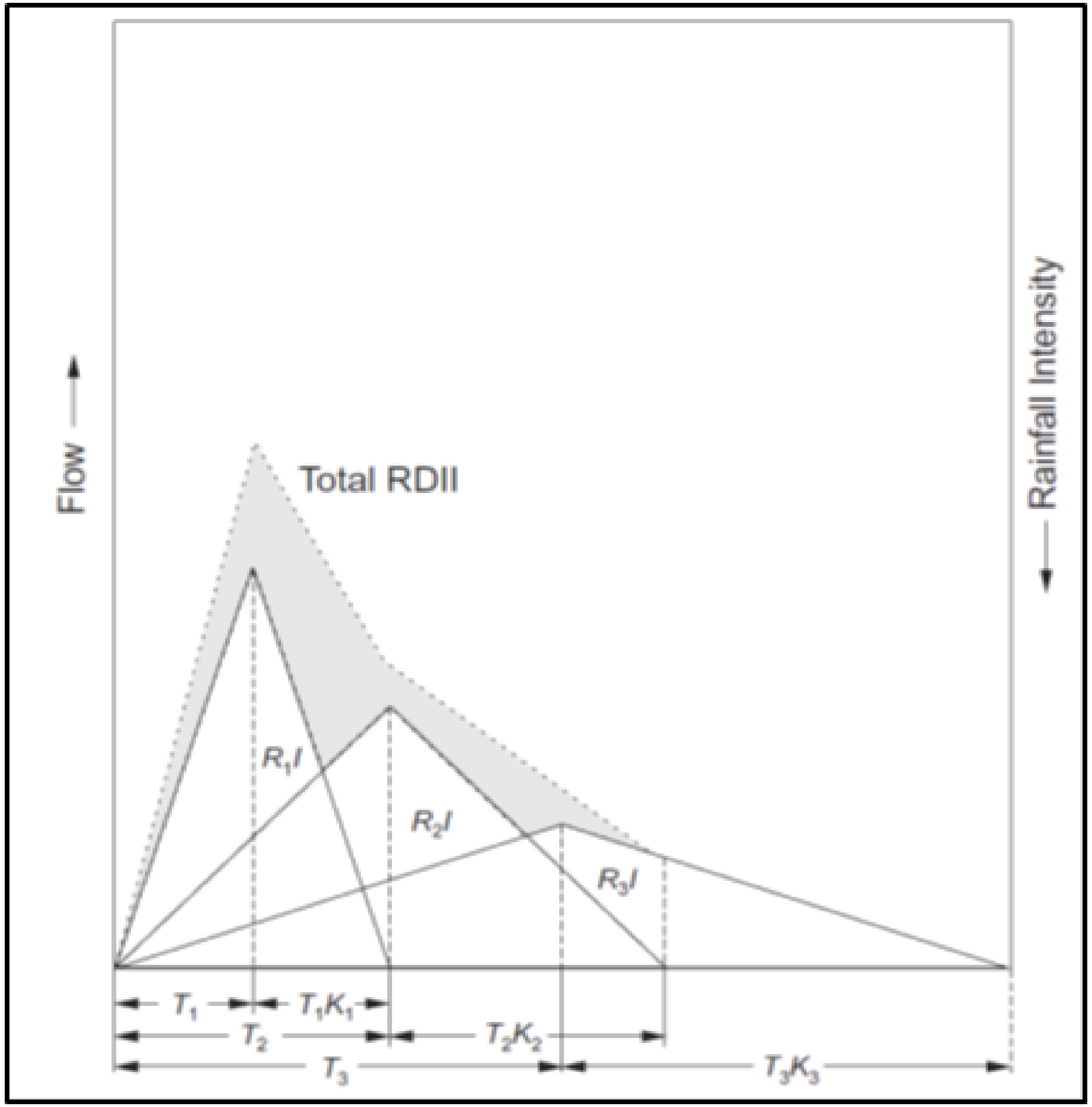
Confirming the approach

- Bundle F had no rainfall events of significance in 2020
- Historic data was only in trunk meters, and of small events in 2019
- Needed flows for large magnitude events
- Develop ‘representative’ RTK parameters – <u>not calibrated</u>
- The RFP called for a different approach to WWF modelling, whereby calibration was eliminated in favour of using a 3L/s/ha value as a representative extreme event ‘stressor’ of the SAN collection system

M

- I
  g
- I
- (
  r er
  r
- ocal'
  r ely

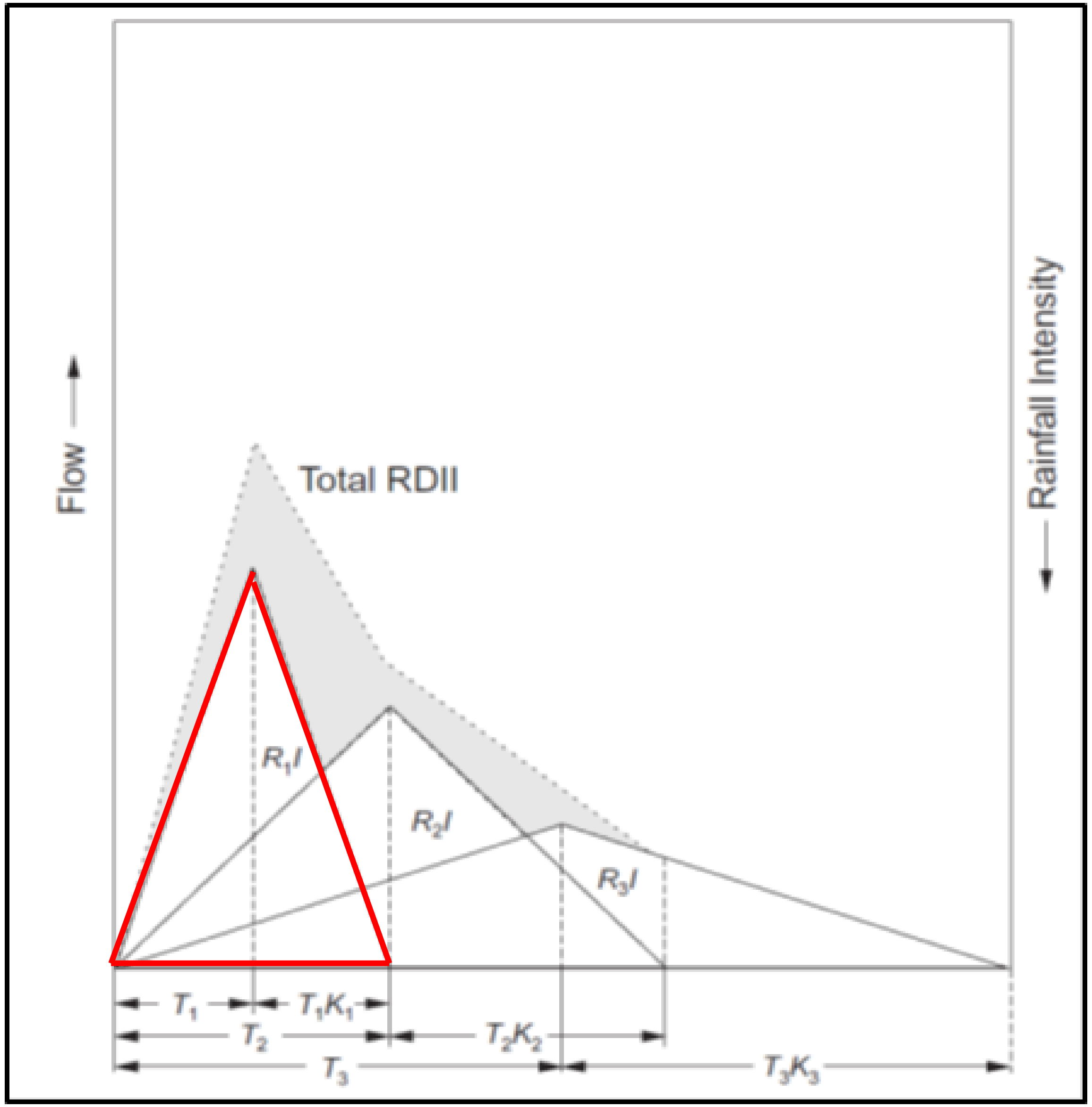
The RTK Method #1



The RTK method generates a hydrograph based on precipitation and catchment data. The total RDII into the system is determined by combining triangular unit hydrographs from 3 theoretical characteristics of flow response:

1. Rapid inflow
2. Delayed inflow
3. Slow infiltration

The RTK Method #2

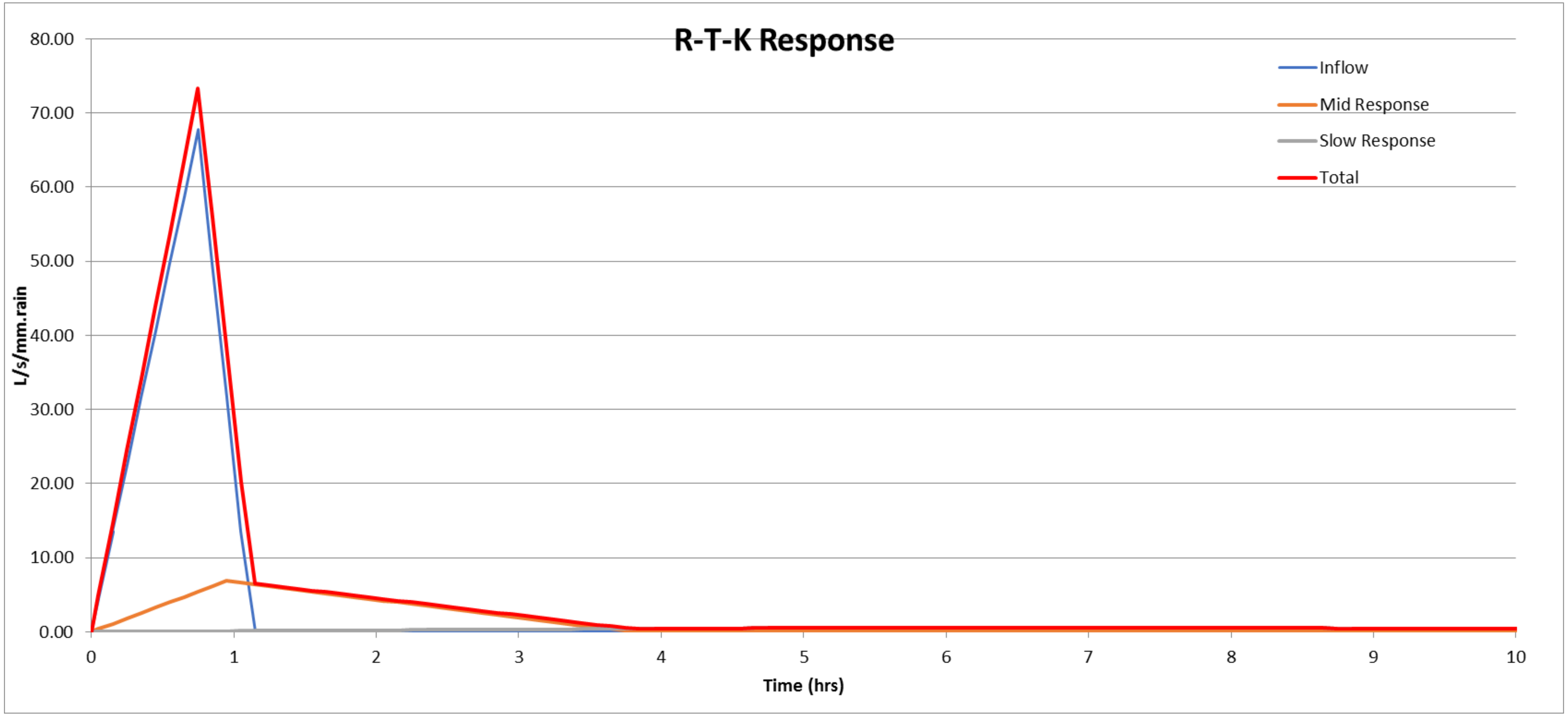


The parameters describe the shape and volume for each component:

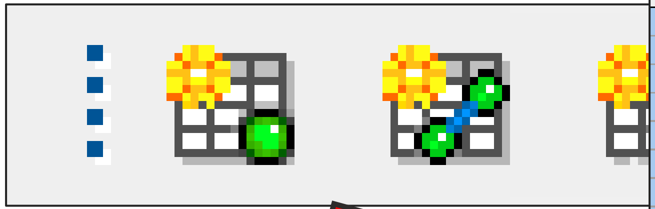
- ‘R’ is the proportion of rainfall falling on the subcatchment that directly enters the sewer system,
- ‘T’ is the time from the onset of rainfall to the peak, and
- ‘K’ is the ratio of “time to recession” to the “time to peak” of the hydrograph.

Baseline RTK & Adjusting R1

R1	T1	K1	R2	T2	K2	R3	T3	K3	Total R
0.020	0.750	1.000	0.015	1.000	2.000	0.005	0.020	0.750	4.0%

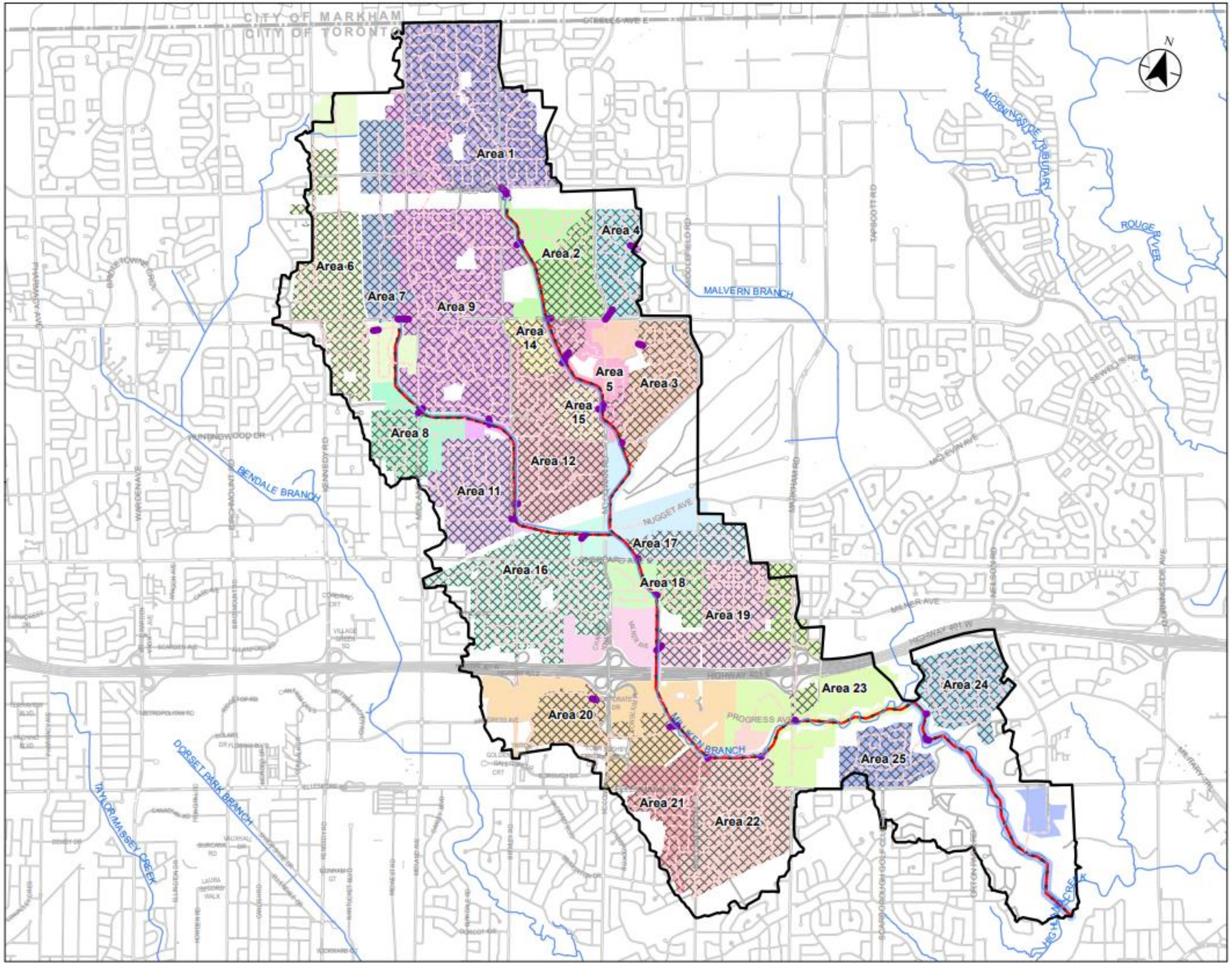


Application within the models



Evaporation profile	Trade profile	RTK hydrograph	SPR calculation
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 3	HOST_Soils
1		Area 7	HOST_Soils
1		[illegible]	HOST_Soils
1		[illegible]	HOST_Soils
1		[illegible]	HOST_Soils
1		Area 7	HOST_Soils
1		Area 7	HOST_Soils

RTK hydrograph ID	R1	T1	K1	R2	T2	K2	R3	T3	K3
West Point	0.035	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
sland Road	0.032	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_9	0.034	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_8	0.033	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_6	0.032	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_5	0.023	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_4	0.032	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_2	0.050	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_10b	0.045	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_10a	0.031	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area_1	0.026	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area 7	0.024	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area 3	0.030	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
Area 11	0.030	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
A56_RTK_0.03	0.030	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000
A56_InitialRTK	0.020	0.750	1.000	0.015	1.000	2.000	0.005	3.000	3.000



Stantec

Legend

- Study Area
- Sanitary Pumping Station
- Trunk Sanitary Sewer (≥ 600 mm)
- Trunk Sanitary Sewer (< 600 mm)
- Link Used for Flow Rate Calculation
- Area Used for Flow Rate Calculation

RTK Subwatershed Area

Area 1, Area 2, Area 3, Area 4, Area 5, Area 6, Area 7, Area 8, Area 9, Area 11, Area 12, Area 14, Area 15, Area 16, Area 17, Area 18, Area 19, Area 20, Area 21, Area 22, Area 23, Area 24, Area 25

0 500 1,000 m
1:35,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 CSRS MTM 10
2. Contains information licensed under Toronto Water Asset Mapping User Agreement.
3. Contains information made available under the Toronto and Region Conservation Authority Open Data Licence v 1.0, Open Government Licence – Toronto, and Open Government Licence – Ontario.

Project Location
City of Toronto

165660138 REVA
Prepared by EH on 2020-10-02

Client/Project
CITY OF TORONTO
BASEMENT FLOODING CAPACITY STUDIES
BUNDLE F - STUDY AREA 60

Figure No.
4.5

Title
Sanitary RTK Subsewersheds

Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.

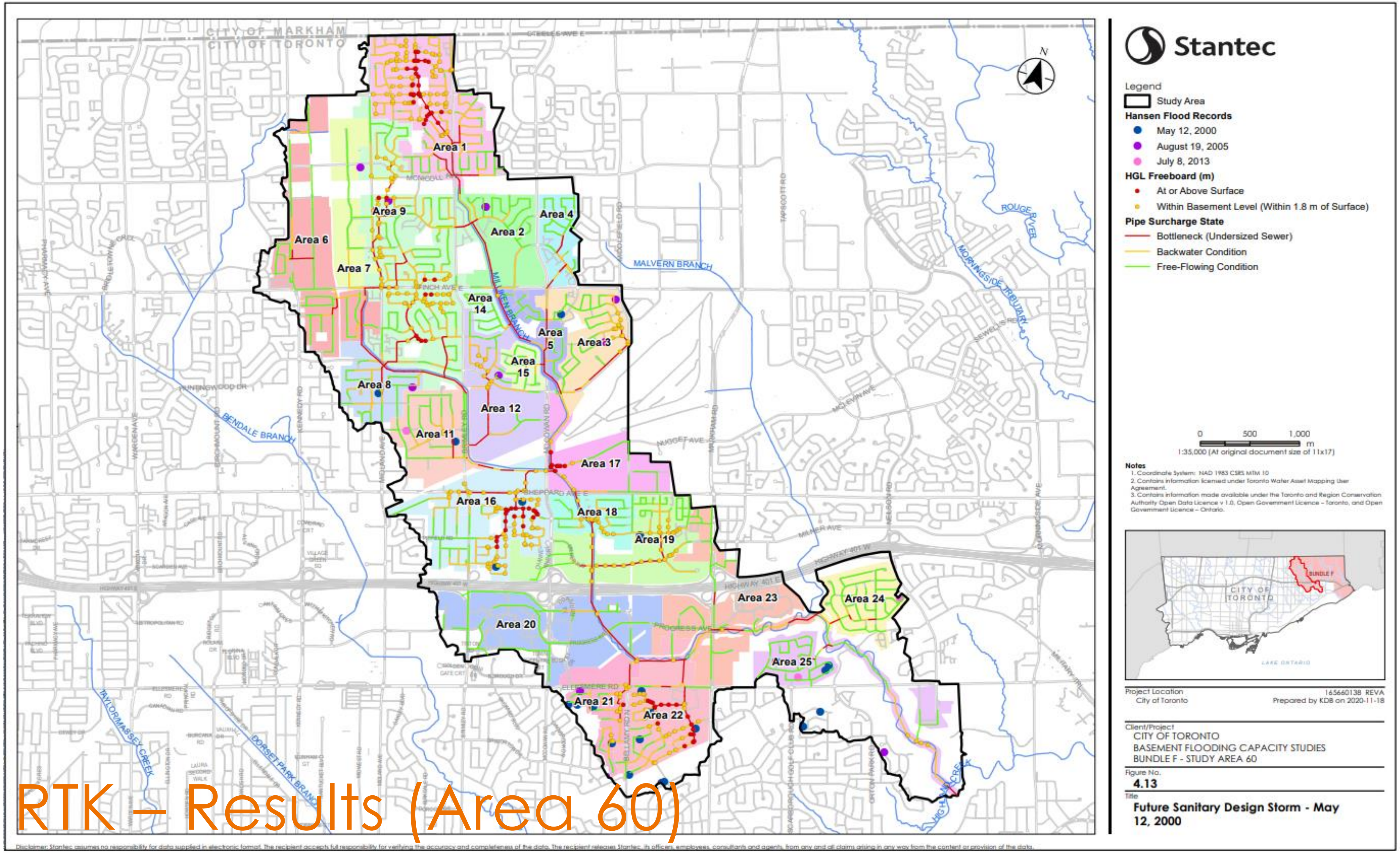
Toronto Basement Flooding Capacity Studies

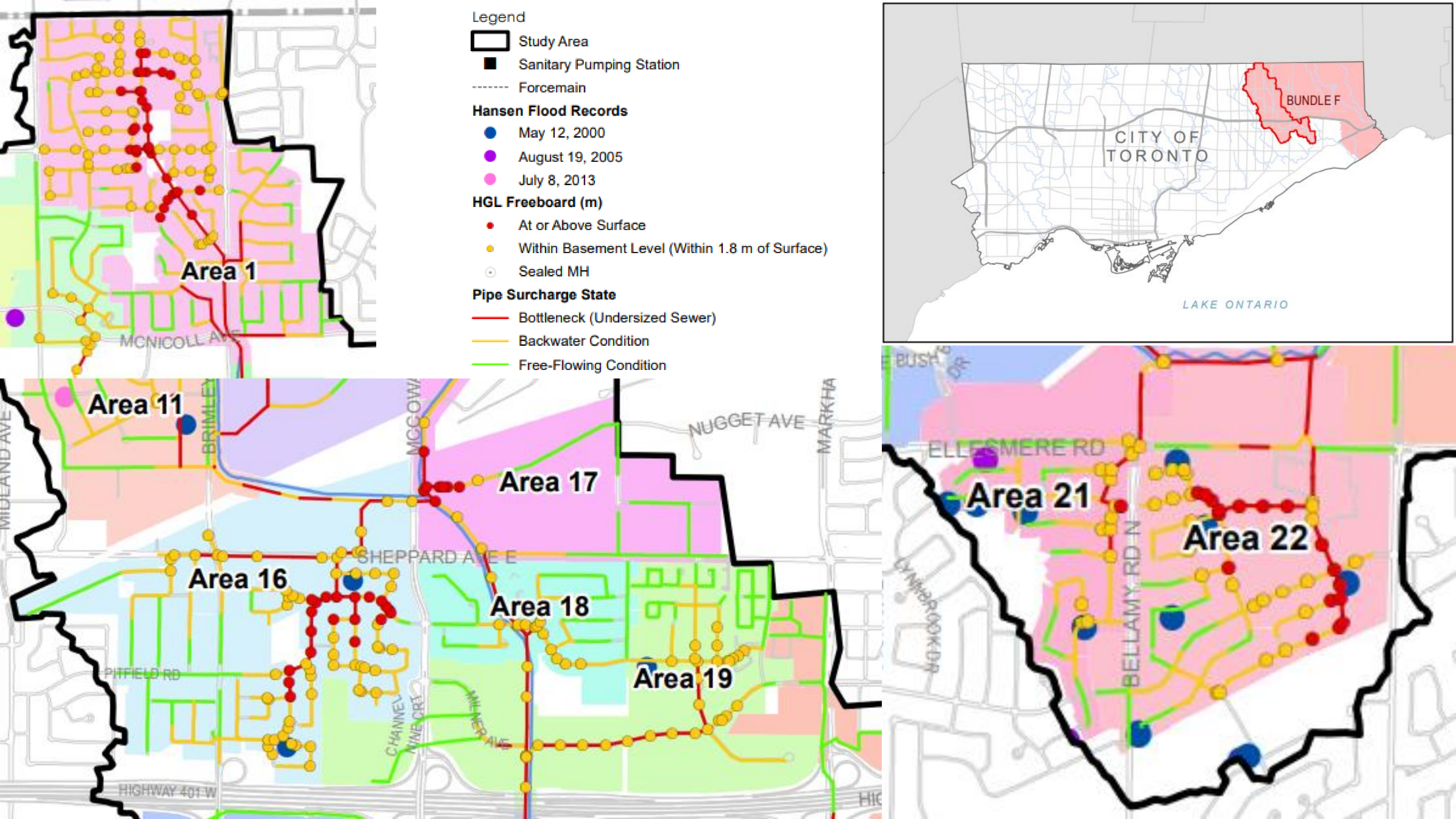
The RTK Approach – Results & Discussion

RTK – Results (Study Area 60)

RTK ID	Contrib. Area (ha)	R1	Total R	Peak Pipe DWF (m^3/s)	DWF Rate (L/s/ha)	Total May 2000 Pipe (m^3/s)	Total Rate (L/s/ha)	WWF Rate (L/s/ha)
A60_Area_1*	118.22	0.048	7%	0.039	0.33	0.364	3.08	2.75
A60_Area_2	17.95	0.025	5%	0.012	0.66	0.062	3.47	2.81
A60_Area_3	39.50	0.040	6%	0.034	0.85	0.151	3.82	2.96
A60_Area_4	24.64	0.030	5%	0.017	0.71	0.090	3.65	2.94
A60_Area_5	23.36	0.042	6%	0.006	0.29	0.073	3.67	3.37
A60_Area_6	48.66	0.030	5%	0.038	0.77	0.177	3.64	2.86
A60_Area_7	17.47	0.025	5%	0.006	0.37	0.052	2.98	2.61
A60_Area_8	22.28	0.033	5%	0.012	0.55	0.081	3.62	3.07
A60_Area_9	155.90	0.044	6%	0.060	0.38	0.514	3.29	2.91
A60_Area_11	42.06	0.030	5%	0.024	0.57	0.152	3.62	3.04
A60_Area_12	38.36	0.040	6%	0.030	0.78	0.139	3.64	2.86
A60_Area_14	14.07	0.020	4%	0.003	0.21	0.044	3.13	2.92
A60_Area_15	16.26	0.022	4%	0.009	0.57	0.058	3.56	2.98
A60_Area_16	84.57	0.041	6%	0.042	0.50	0.284	3.36	2.86
A60_Area_17	13.76	0.024	4%	0.009	0.63	0.048	3.47	2.84
A60_Area_18	18.66	0.022	4%	0.006	0.32	0.059	3.15	2.83
A60_Area_19	38.41	0.037	6%	0.016	0.41	0.129	3.37	2.96
A60_Area_20	17.66	0.033	5%	0.029	1.64	0.083	4.68	3.04
A60_Area_21	32.74	0.050	7%	0.031	0.94	0.121	3.69	2.75
A60_Area_22	53.51	0.050	7%	0.029	0.54	0.154	2.87	2.33
A60_Area_23	12.64	0.035	6%	0.027	2.13	0.063	4.99	2.86
A60_Area_24	41.43	0.022	4%	0.019	0.45	0.142	3.42	2.96
A60_Area_25	28.04	0.020	4%	0.008	0.28	0.088	3.15	2.87

RTK – Results (Area 60)





Legend
Study Area
Sanitary Pumping Station
Forcemain
Hansen Flood Records
May 12, 2000
August 19, 2005
July 8, 2013
HGL Freeboard (m)
At or Above Surface
Within Basement Level (Within 1.8 m of Surface)
Sealed MH
Pipe Surcharge State
Bottleneck (Undersized Sewer)
Backwater Condition
Free-Flowing Condition
Area 1
MCNICOLL AVE
Area 11
BRIMLEY
MIDLAND AVE
MCCOWAN
NUGGET AVE
MARKHAM
Area 17
SHEPPARD AVE E
Area 16
Area 18
Area 19
PITFIELD RD
CHANNEL NINE CRT
MILNER AVE
HIGHWAY 401 W
CITY OF TORONTO
BUNDLE F
LAKE ONTARIO
ELLESMERE RD
Area 21
Area 22
BELLAMY RD N

RTK – Discussion #1

- The RTK method allowed the project to progress <u>much quicker</u> than a traditional flow survey & calibration approach would have
- Resulted in <u>significant cost savings</u> as well
- Allowed the client to meet key drivers around programme & develop Schedule A/A+ Assignments

RTK – Discussion #2

There were also limitations. The approach often created <u>overly conservative flows and predicted flooding where there were no flood records to validate against</u>. In several instances we were unable to achieve the target flow of 3L/s/ha without increasing the ‘R1’ value significantly. Issues found were:

1. Flow being lost from the system via bifurcations or surface flooding
2. Incapacity in the receiving trunk sewer or pumping station
3. Incapacity in the “local” sewer i.e., pipe incapacity

RTK – Discussion #3

- Some good correlation, some over, some under
- Stage 1 did not reveal many systemic issues in Study Area
- Difficult to perform RTK analysis given the sensitivity of the network to flooding to the surface
- Even with modifications to account for these, results were ‘mixed’
- Without FM data or further investigations, there is little to go on to deviate from the selected parameters
- These are deemed conservative RTK values

RTK – Discussion #4

Was it worth it?

Questions?