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Don River Hydrology Update

Toronto and Region Conservation Authority

Project number: 60528844

December 2018

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1. Introduction

AECOM was retained by the Toronto and Region Conservation Authority (TRCA) to provide an update to the Don River hydrology model (RFP # 10002336), and to update design flow estimates for various design storm events, including the regulatory flood (Hurricane Hazel). The last Don River hydrology update was completed in 2004. TRCA has since collected 12 years of meteorological and stream flow information at several locations in the watershed, including a number of significant storm events (e.g. August 19, 2005 and July 8, 2013). In addition, a number of key projects are about to be undertaken, namely the "Don Mouth Naturalization and Port Lands Flood Protection Project" in the City of Toronto and the "Flood Remediation Study, Yonge Street and Elgin Mills Road" in the Town of Richmond Hill. These are significant flood remediation projects which may be impacted by changes in Regional Storm flows. The flows resulting from the current study will be used to define the design requirements for these projects.

Key objectives for the hydrology update are as follows:

- Completion of the hydrologic model on the PCSWMM platform;
- The development of a hydrology model based on the best available topographic, land use and cover, and soil information;
- The completion of a thorough calibration and validation process to the hydrology model using meteorological and flow monitoring data collected over the past 12 years;
- Complete a number of model simulations to define Regional Storm (Hurricane Hazel) and design storm flows, for both existing and future land use conditions;

1.1 Study Area

The study area is shown in Figure 1. The Don River watershed is approximately 350 km^2 in size, and is over 80% urbanized (Figure 2), with most of the undeveloped lands at the northern limits near the catchment headwaters. The Don River is split into two primary branches: the East and West Don Rivers. The headwaters are along the south slope of the Oak Ridges Moraine. The West Don River headwaters are in the City of Vaughan, and the river flows generally southward through the City of Toronto. The East Don River's headwaters are within the City of Vaughn and the Town of Richmond Hill, and flows generally southward through Vaughan, Richmond Hill, the City of Makham and the City of Toronto. The main tributaries to the East Don River are German Mills Creek and Taylor Massey Creek.

The majority of the watershed lacks stormwater management (SWM) controls, since development within the watershed largely predates modern stormwater management practices. The SWM facilities which do exist reside primarily within the Region of York (Figure 2), in the upstream portion of the watershed north of Highway 401. The high level of urbanization and the lack of SWM controls in the Don River watershed is reflected in the rapid response of flows in the river to rainfall, which has resulted in significant frequent flooding in the watershed, relative to other less urbanized areas. Figure 3 shows the details of the existing land use within the watershed.

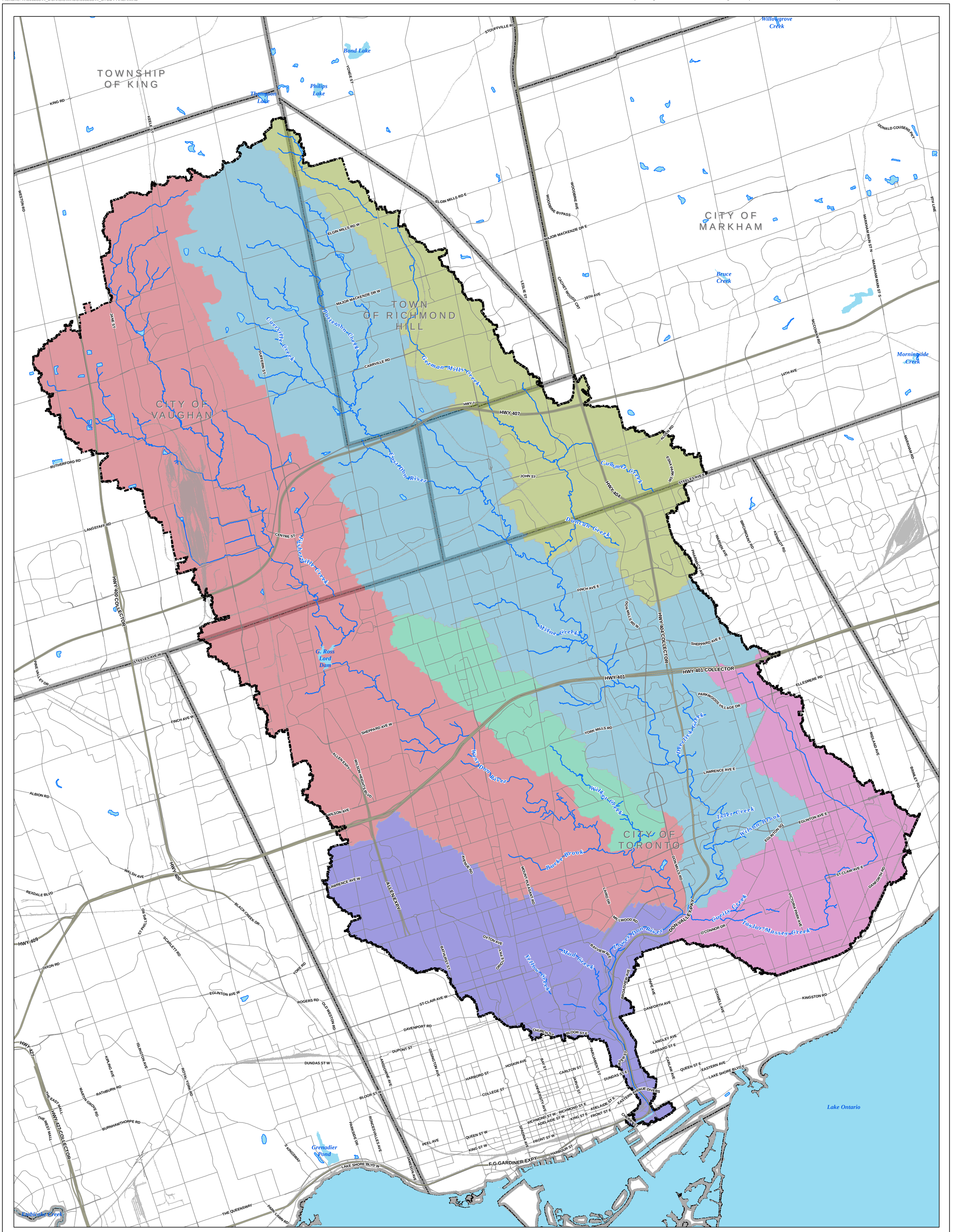
1.2 Previous Studies

The original modern model of the Don River was completed in the 1970's, and updated in the 1990's using the HYMO hydrologic model. The 1990's model was updated in 2004 by Marshall Macklin Monaghan, updating it to a Visual OTTHYMO model.

Previous studies include:

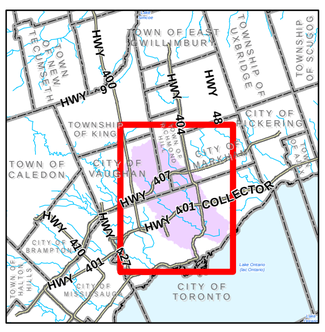
- *Hydrologic Model Study, Humber, Don and Rouge Rivers, Highland, Duffin, Petticoat and Curruther'sCreeks, James R. MacLaren Limited (Oct 1979);*
- *Regional Storm Hydrology Update, Lower Don river, Marshall Macklin Monaghan Limited (Oct 1990);*
- *Don River Hydrology and Hydraulic Update, Marshall Macklin Monaghan Limited (Aug 1992);*
- *Unit Flow Rates for Stormwater Control, Upper Don River Watershed, Marshall Macklin Monaghan Limited (Nov 1994);*
- *Don River Hydrology Update, Marshall Macklin Monaghan Limited (2004); and*
- *Don River Watershed Plan, Surface Water Hydrology/Hydraulics and Stormwater Management – Report on Current Conditions, TRCA (2009)*

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Key Map

2017 DON RIVER HYDROLOGY UPDATE

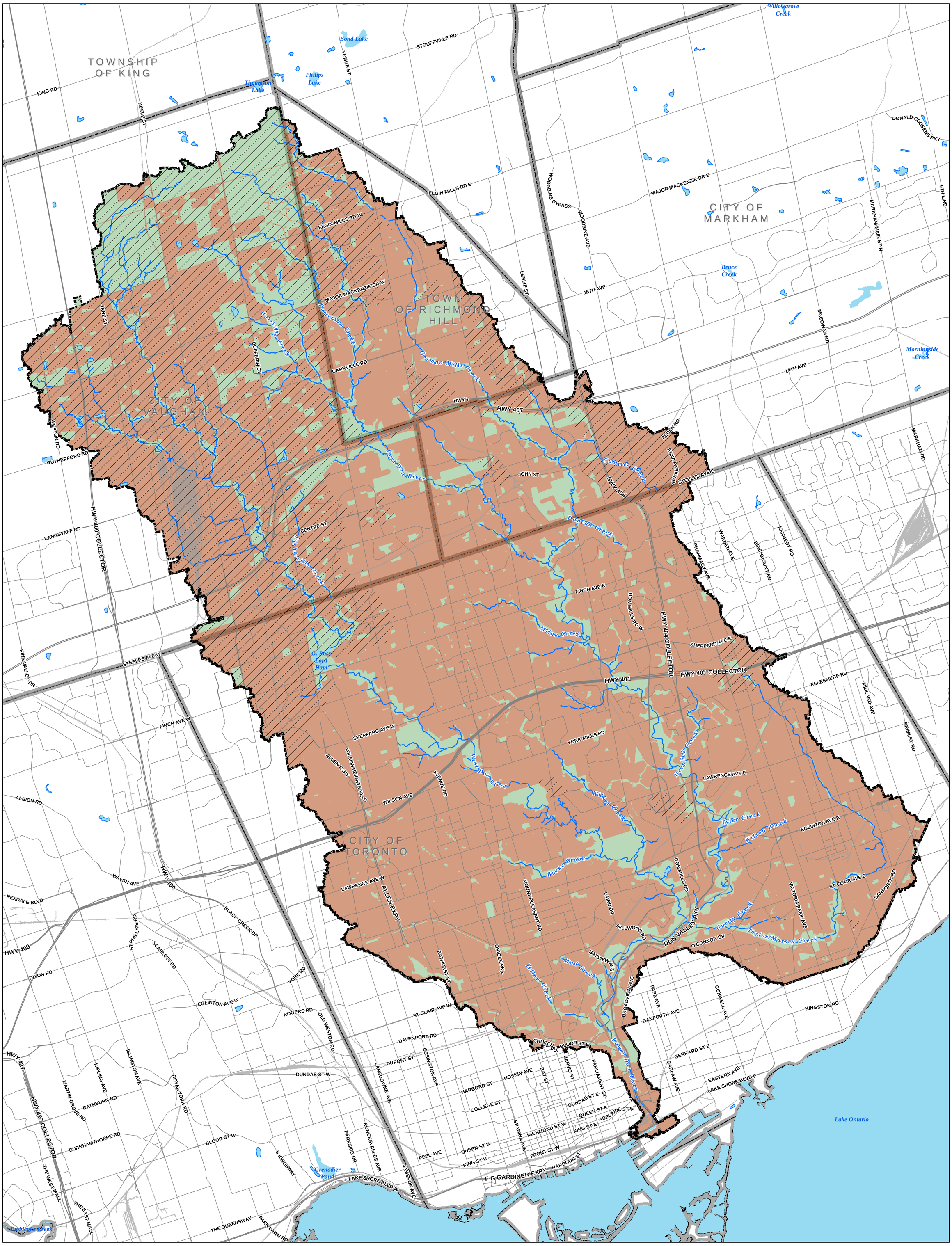
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STUDY AREA

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Figure: 1

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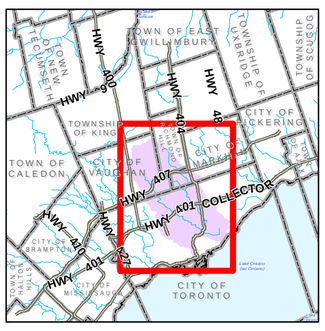
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Legend

- Study Area
- Roads
- Major Railways
- Municipalities
- Waterbodies
- Watercourses
- Airport; Cemetery; Commercial; Hydro Corridor; Industrial; Institutional; Recreational; Residential High; Residential LowMed; Road (ROW); Transportation; Water
- Naturalized Area; Estate Residential; Golf Course
- Area with SWM Control



Key Map

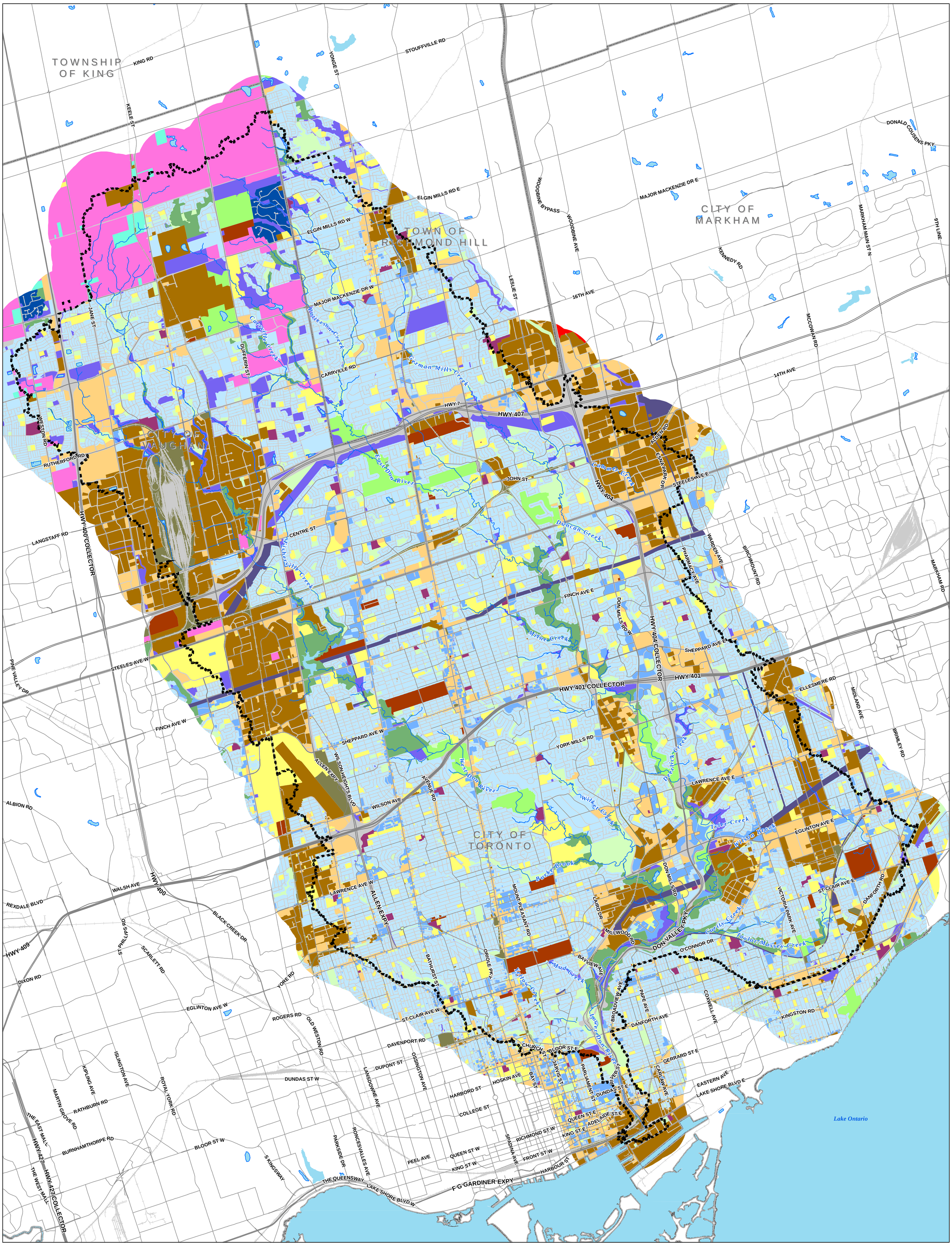
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DON RIVER WATERSHED URBANIZATION

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Figure: 2

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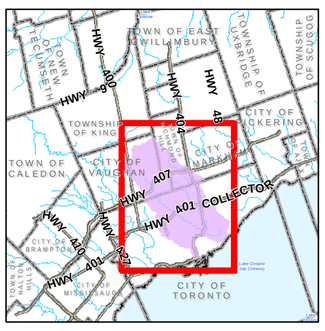
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Legend

- Study Area
- Roads
- Major Railways
- Municipalities
- Waterbodies
- Watercourses

Land Use

- Airport
- Cemetery
- Commercial
- Conservation Lands
- Estate Residential
- Farm
- Golf Course
- Hydro Corridor
- Industrial
- Institutional
- Open Space
- Park
- Recreational
- Residential High
- Residential LowMed
- Road (ROW)
- Rural Residential
- Transportation
- Water



Key Map

2017 DON RIVER HYDROLOGY UPDATE

Toronto and Region Conservation Authority, Ontario
Project No.: 60528844 Date: April 2018

EXISTING LAND USE

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Figure: 3

2. Model Development

2.1 Model Selection

Historically, large scale watershed models in Ontario have been conducted with models based on the HYMO format, such as OTTHYMO and Visual OTTHYMO, which have typically employed the SCS curve number methodology for determining runoff volume.

TRCA has chosen to update the Don Hydrology model using PCSWMM. Some of the key considerations that supported the use of PCSWMM for the present study are:

- Use of the EPA SWMM engine, a proven model;
- The highly urbanized nature of the watershed;
- The useful GIS interface and model development tools, and also the ability to incorporate native GIS tools as well into the model development (e.g. Arc Hydro);
- The ability to incorporate hydrology along with hydraulic routing in the same model;
- The ability to model ponds and crossings; and
- Relatively low cost, and widely used in Ontario

PCSWMM is employed for the present study keeping in mind that EPA SWMM was originally developed to model runoff from smaller urban areas, and many of the conceptual features of the SWMM based models reflect this original intent.

PCSWMM has a conceptual limitation for modeling large catchments, especially rural catchments, with overland sheet drainage lengths potentially exceeding reasonable limits; excessively large drainage lengths will tend to 'channelize' in reality, and start to invalidate the basic conceptual underpinnings of the overland flow in the model. However, at the outset of the project, it was felt that this potential limitation would not be too problematic since (a) the watershed is largely urban; and (b) the flow length could be limited by making the subcatchments sufficiently small.

AECOM considers the use of PC SWMM an appropriate model for the Don River hydrology update, given the physical characteristics of the watershed and subcatchments employed.

2.2 Model Structure

The PCSWMM model structure consists of:

- Approximately 896 individual subcatchments, each with unique subcatchment hydrology based on land use, imperviousness, soil conditions, and physical catchment attributes (slope, shape, etc);
- Rainfall data in 5 minute time steps, defined by approximately 29 rain gauges in the watershed. The rain gauges are used to define spatial variability of rain across the watershed for each 5 minute time step, and this spatial variability is used to define a unique hyetograph for each subcatchment in the model;
- Approximately 648 channel reaches, receiving the flow from the subcatchments and routing the flows in the model;
- Dynamic routing;
- Approximately 109 ponds represented as storage nodes in the model, with discharge characteristics reflective of the actual hydraulic controls in each pond;
- Approximately 128 road crossings, with flow conveyed the road crossings with conduits representing (a) the bridge/culvert opening, and (b) the road profile at overtopping.

2.3 Sub-Basin and Channel Discretization

Given the limitations of SWMM-based modeling for large watersheds, the primary concern with sub-basin discretization is to make catchments small enough such that (a) the conceptual framework of the SWMM model is still generally valid (i.e. rectangular catchment, sheet flow over a characteristic overland length to a central collecting channel), and (b) the internal routing is small enough to be adequately represented without additional internal routing elements, or artificially adjusting parameters outside their commonly understood reasonable range.

2.3.1 LiDAR Data

The TRCA LiDAR data was derived from the Airborne Imaging LiDAR data library, and the data was acquired on various dates between April 2014 and April 2015. The acquisition flights were designed so that the LiDAR dataset was acquired at 10 pts / m^2. Bare earth LiDAR data was provided to AECOM in the form of Digital Elevation Model (DEM) at both 0.5m x 0.5m and 1.0m x 1.0m raster resolution. Upon discussing with TRCA, it was decided that the 1.0m x 1.0m raster was of sufficient resolution for the subcatchment delineation. TRCA watercourse GIS information was supplemented by Land Information Ontario (LIO) watercourses data.

2.3.2 Arc Hydro Processing

Utilizing ArcHydro's DEM reconditioning functionality, the drainage pattern was imposed onto the DEM using supplemented watercourse information. Walls were also built onto the DEM to restrict flow path from crossing known boundaries such as highways, railroad etc. Once the initial flow path (conduits) and junctions was generated, additional junctions were defined at the locations of interest (flow gauges, ponds, crossings, and area with insufficient discretization) to provide a finer discretization of subcatchments.

Arc Hydro was then used to process the DEM and divide the watershed into subcatchments. The initial subcatchments created by this process are shown below.

2.3.3 QA / QC

A number of manual checks were performed, largely around the perimeter of the study area (to confirm the Don River watershed boundary between internal and external catchments) and to confirm drainage catchments only crossed major corridors (i.e rail lines, major roads such has Hwy 401, Hwy 407, and the Don Valley Parkway) at appropriate locations. Catchment areas to ponds were further refined if the pond catchment area was known from existing design reports or pond inventory details, in which case the catchments were manually adjusted using GIS editing tools (clipped / sliced / merged etc). If the catchment area to the pond was not known, additional processing was performed to provide the best estimate of the pond catchment area based on a combination of refining the flow path, flow path tracing, or sink analysis (whichever worked best in the area and appeared to generate the most realistic appropriate catchment). Out of the 110 storage elements in the model, refinement was performed on 81 of the drainage areas.

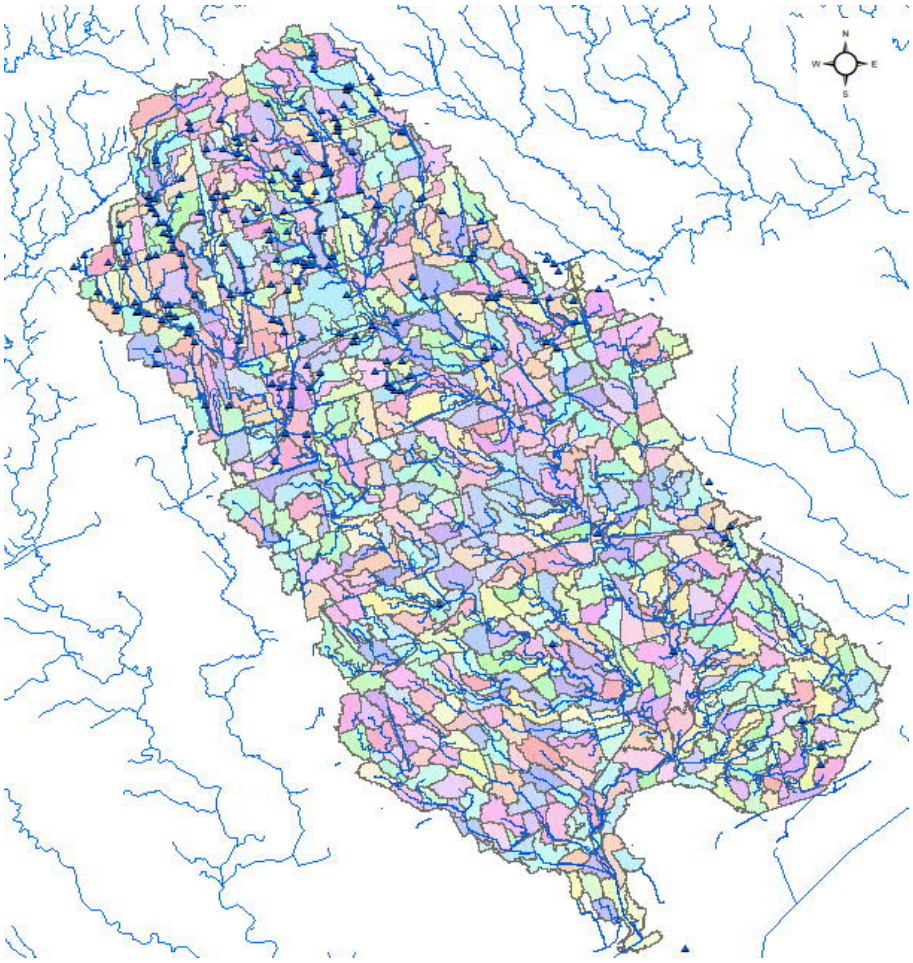


Figure 4: Subcatchment Discretization

2.4 Land Use

2.4.1 Development on the Watershed

The Don River is over 80% urbanized, with undeveloped areas located largely along the stream corridors and in the upstream headwater areas within the City of Vaughan and Town of Richmond Hill. The older developed areas are in the south portion of the catchment, with the more recently developed areas in the north. Only the more recently developed areas have forms of stormwater peak flow control. In Ontario prior to the 1970's, stormwater was typically discharged directly to creeks without storage or treatment. In the 1970's and 1980's, stormwater ponds began to be used to control peak flow to watercourses from new developing areas. Since the 1990's, stormwater ponds constructed in newly developing areas have been constructed to also control water quality and erosion. Essentially all development in the Don River watershed south of Highway 401 pre-dates the era that stormwater management ponds were constructed for developing areas. Currently, stormwater quantity control exists for approximately 30% of the existing urban area, exclusively in areas north of Highway 401.

The only area of future development considered in the model is the "Block 27" area of the City of Vaughan, located between Jane St and Keele St, and between Teston Rd and Kirby Rd. For existing conditions, the area is modeled as rural catchments, using Green & Ampt infiltration parameters, with overland lengths in the range of 180-300 m.





Under Future conditions, imperviousness is considered to be consistent with land use and impervious identified in the current version of the Block 27 Secondary Plan of the City of Vaughan.

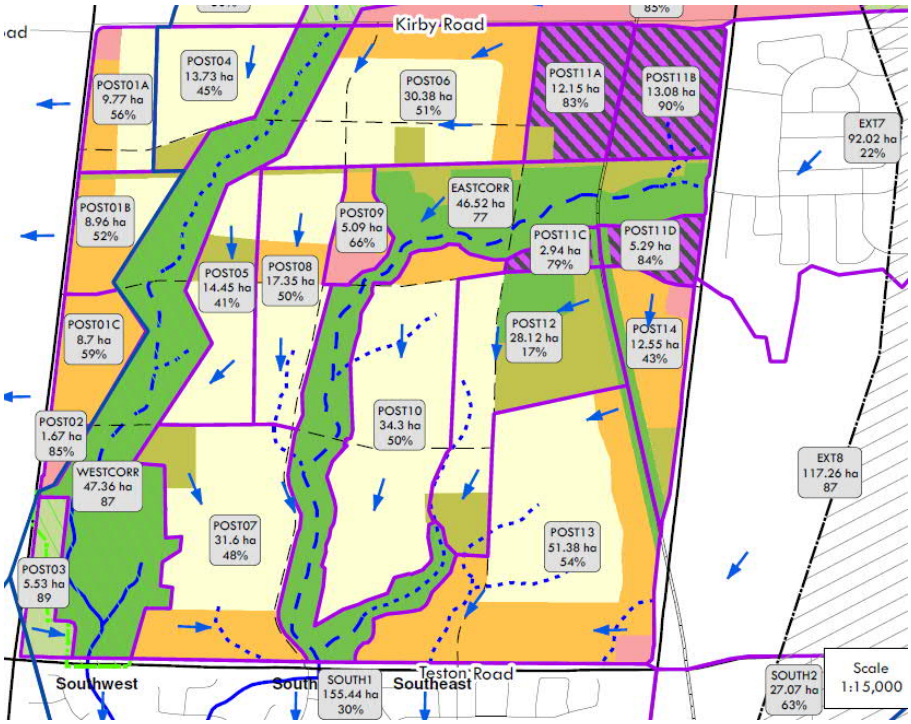
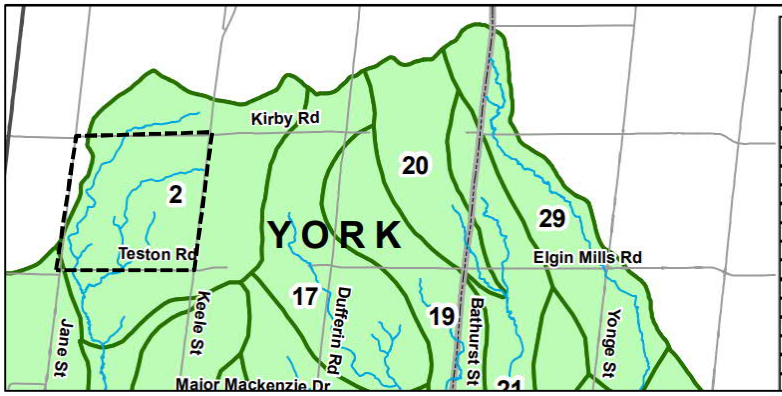


Figure 6: Development Areas and Future Imperviousness – City of Vaughan Block 27 Secondary Plan

Under Future conditions, the model considers generic stormwater management ponds to exist that are sized to control the peak flows to the required unit flow rates for the 2-year to 100-year design storm events (Stormwater Management Criteria, Aug 2012, TRCA).



Sub-Basin	Area ha	Unit Peak Flows (m³/s/ha) 2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
1	1496	0.0033*	0.0053*	0.0069*	0.0080*	0.0116*	0.0143*
2	902	0.0033*	0.0053*	0.0069*	0.0080*	0.0116*	0.0143*
3	356	0.0041	0.0081	0.0118	0.0153	0.0185	0.0224
4	346	0.0033*	0.0053*	0.0074	0.0098	0.0122	0.0152
5	397	0.0039	0.0073	0.0104	0.0131	0.0156	0.0186
6	713	0.0033	0.0063	0.0091	0.0114	0.0136	0.0163
7	348	0.0039	0.0074	0.0105	0.0132	0.0157	0.0188
8A	345	0.0045	0.0087	0.0123	0.0159	0.0192	0.023
8B	761	0.0041	0.0077	0.011	0.0139	0.0167	0.0199
17	627	0.0033*	0.0053*	0.0069*	0.0080*	0.0116*	0.0143*
18	961	0.004	0.0078	0.0113	0.0147	0.0178	0.0215
19	486	0.0033*	0.0053*	0.0069*	0.0080*	0.0116*	0.0143*
20	435	0.0045	0.0089	0.0128	0.0169	P.0205	0.0249
21	512	0.0033*	0.0053*	0.0069*	0.0080*	0.0116*	0.0143*
22	188	0.0046	0.0092	0.0132	0.0172	0.0209	0.0252
23	561	0.0033*	0.0056	0.0085	0.0111	0.0136	0.0166
24	303	0.0047	0.0092	0.0132	0.0173	0.021	0.0254

Figure 7: Unit Peak Flow Rates – From Stormwater Management Criteria, Aug 2012, TRCA

2.4.2 Percent Imperviousness

In previous hydrology updates, the percent imperviousness parameter was typically estimated based on land use and treated as a calibration parameter. For the current study, aerial images were used to quantify the contributing areas for each runoff surface. An impervious surface raster was created by processing the aerial image. Field codes were assigned in the raster of 0 or 1 depending on whether the surface is impervious or pervious. Building and road polygons were burned into the raster as impervious areas.

The procedure involved processing the colour spectrum of the aerial photos in GIS. First, training samples comprising the colour coverage of each various land cover classes (road, building, pervious) were created. The success of image classification results depends largely on the quality of the training samples. Based on past experience, shadows on impervious areas can easily be misinterpreted as pervious area in the classification process. Therefore, extra care was taken to ensure shadowed road, shadowed roof and shadowed pervious areas were included in the training samples. The training samples were then used to create a signature file, which was fed into the maximum likelihood classification process in GIS. The process assigned each pixel to one of the different classes based on the means and variances of the classes stored in the signature file. The result was a raster with field codes representing the land cover classes in the training samples. This raster generally includes certain misclassified cells (random noise) and small invalid regions. Building footprint polygons, available for the Don River Watershed from TRCA, were overlaid onto the raster to eliminate some of the misclassified cells. The classes of the raster were consolidated into two final classes, impervious and pervious, only. Post-classification processing such as filtering and removal of small isolated regions were performed to further improve and clean up the result raster. The cleaned up raster was evaluated against the original aerial photo visually to validate the results. Training samples and post-processing parameters were refined through several iterations to ensure the final impervious raster to be as accurate as possible over the study area. A sample result is shown below.



Figure 8: Imperviousness from Processed Aerial Image - Sample

The aerial photos from different municipalities are of different resolutions and quality. In addition, no information was available regarding the lighting conditions when these aerial photos were taken. Therefore, training samples were created and processing was conducted separately for aerial photos from different municipalities.

Table 1 below shows the resulting average imperviousness by land use for this process, and compares it to the standard values recommended by the TRCA (as identified in the Request for Proposals). The results show that actual imperviousness is typically smaller than the standard TRCA values. Since this will have a large influence on the volume of runoff in model results, TRCA advised AECOM to proceed with using the calculated impervious values in the hydrologic model. The imperviousness also was not taken as a standard value for each land use, but the specific impervious calculated by GIS for each catchment was used. It should be noted that the calculated impervious values are specific to the current study where high resolution aerial images are available. For hydrologic modeling where high resolution aerial images are not available, or for design purposes where the specific development is either unknown or should not be considered static, TRCA's standard values should be applied.

Table 1: Imperviousness by Land Use

Land Use Classification	Total Impervious Area (%)	
	TRCA (RFP)	Processing of Aerial Image
Airport	45	-
Cemetery	35	12
Commercial	95	75
Conservation Lands	0	4.9
Estate Residential	40	16
Farm	0	3.7
Federal Park	0	-
Golf Course	0	7.4
Hydro Corridor	10	9.6
Industrial	95	66
Institutional	80	44
Open Space	0	5.2
Park	10	8.7
Recreational	20	41
Residential High	80	54
Residential Low/Med	60	44
Road (ROW)	90	64
Rural Residential	20	4.6
Transportation	60	41
Wetland	100	-
Water	100	8.0
Natural Cover	0	-

The actual impervious area from the processed aerial images is generally slightly less than the TRCA standard values for all land uses. Note that a considerable difference exists for areas classified as "water" in the GIS land use layer. In the aerial photo, water does not have enough of a colour distinction to distinguish it from treed areas, and are generally classified as 'pervious' in the processed image, whereas the TRCA standard is to treat water surfaces as impervious. This can be addressed by burning the water GIS layer into the processed aerial image as impervious area, along with other known impervious areas such as buildings.AECOM also reviewed the range of imperviousness for specific land uses across different municipalities. For low and mid density residential land uses, the variation across municipalities is shown in Figure 9 below.

The results show that there is considerable range of imperviousness across the same land use, and there is a considerable difference in imperviousness for the same land use across different municipalities.

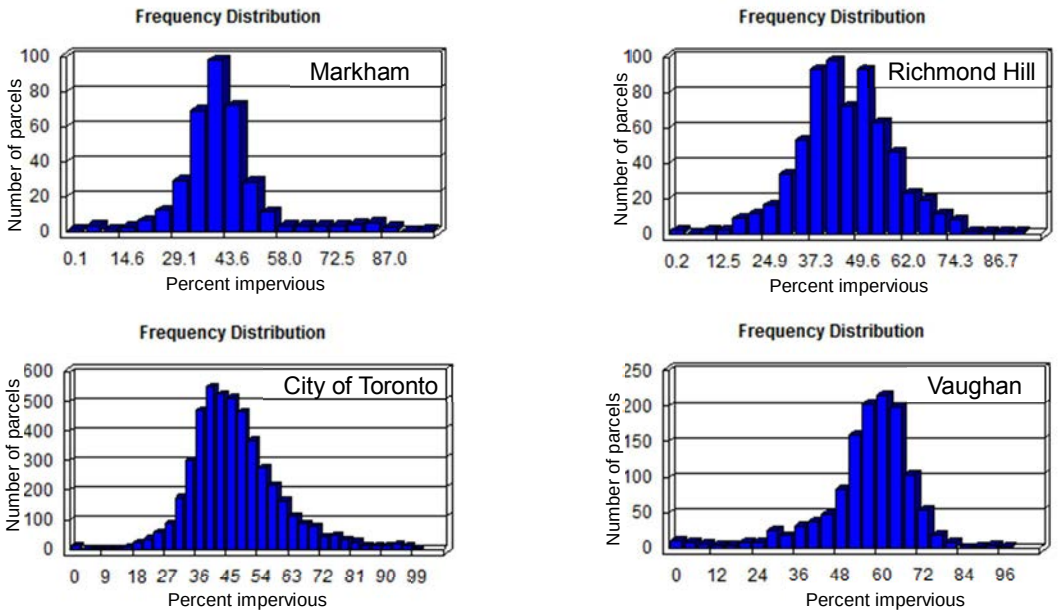


Figure 9: Imperviousness for Low and Mid Density Residential Lots

A summary of calculated imperviousness for different municipalities for non-residential land uses is shown in the Table below.

Table 2: Industrial, Commercial, and Institutional (ICI) Imperviousness

	Industrial	Commercial	Institutional
City of Markham	71%	61%	38%
Town of Richmond Hill	66%	72%	47%
City of Toronto	70%	79%	45%
City of Vaughan	61%	71%	40%
Don River Watershed	66%	75%	44%

2.4.2.1 QA/QC of Assessed Imperviousness

AECOM visually reviewed the imperviousness raster over a range of land uses and imperviousness across the entire study area, both during the development of the GIS processing tool, and with the final imperviousness raster.

A summary of the QA/QC of the final raster, involving a comparison of calculated imperviousness and visually assessed imperviousness, is provided in Appendix A. AECOM compared 5 random low density residential catchments, and 5 random non-residential catchments in each municipality in the study area (Markham, Richmond Hill, Vaughan, and the City of Toronto). In all instances, there is no discernable difference between the raster image impervious surfaces and the visually assessed impervious surface.

2.5 Channel Routing

Channel routing is an important component of the PCSWMM model as it affects the timing, attenuation, and translation of the hydrograph. The primary source of channel routing elements information is TRCA's HEC-RAS model, supplemented by a number of flood studies and reports to fill in the gaps not covered by the HEC-RAS model. These include:

- Don Mills Ditch Floodline Mapping Study (Cole Engineering, 2011);
- Don 2 Flood Plain Map Update- Hydraulic Analysis: Clarke Ave to Proctor Ave (Burnside, 2011);
- Don 5 Flood Plain Map Update - Storm Sewer Analysis: Charlton Ave to Conley Park and Steeles Ave to Fisherville Road (Burnside, 2011);
- Don 36- Flood Plain Map Update Storm Sewer Analysis: Manhattan Drive to Lawrence Ave (Burnside, 2010);
- Hydrologic Study of Mud Creek (GHD, 2013);
- MacMillan Yard Flooding Preliminary Analysis (MMM, 2006); and
- G. Ross Lord Dam Operations, Maintenance and surveillance Manual (TRCA, 2016)

The hydraulic model consists of:

- 648 channel reaches, with unique transects for each
- 128 culverts/bridges and road cross sections
- the reservoir at the G. Ross Lord dam.

The PCSWMM model uses dynamic wave routing to solve the full St. Venant equations, routing the flow through channel reaches and across roads, making use of all available realized storage in the model (routing in reaches and storage upstream of road crossings). The final models apply a dampened form of the 1D momentum equation, which specifically indicates how the inertial terms in the St. Venant equation are handled. Specifically, dampening the momentum equation reduces the inertial effects when flow becomes closer to critical (i.e. at higher velocities in steeper reaches), and ignores the inertial terms if flow is supercritical. This dampening was found to increase model stability and improve run times. Since it is only effective in steep fast flowing reaches, it is not considered to affect reaches where significant storage or attenuation exists, and therefore not expected to have a significant effect on attenuation and routing that exists in the river or model accuracy.

All the culverts/bridge, as well as the G. Ross Lord reservoir, were removed in the Regional Storm simulation as the benefits of these structures cannot be accounted for in accordance with the technical guidelines for flood plain mapping provided by Ministry of Natural Resources and Forestry (MNRF).

2.5.1 Characteristic Cross Sections

The model is discretized into reaches that are several hundred metres long. It is beyond the scope of a hydrologic model of this scale to include finely defined short reaches with cross section spacing similar to a hydraulic model used for floodline mapping. Rather, for each reach, a single cross section is desired that preserves the routing characteristics of the reach as a whole. This would be achieved with a characteristic cross section for the reach that preserves the actual reach volume and wetted perimeter over a range of depths.

The development of a characteristic cross section is discussed below, first for reaches where an existing HEC-RAS model exists, and secondly for headwater reaches where existing HEC-RAS model and cross sections don't exist.

2.5.1.1 Reaches Covered By HEC-RAS Models

Having cross sections already defined for the reach simplifies the process. AECOM used the existing defined HEC-RAS cross sections to assist in developing a characteristic cross section for each reach. The HEC-RAS cross sections were imported into PCSWMM, and then each individual cross section was spatially related to a reach in the hydrology model. A PCSWMM tool was then used that defines an 'average' cross section for each reach.

There was some manual adjustment of the resulting cross section, for example to eliminate some unrealistic rapid changes in the cross section, especially at the edges (Figure 10). To verify that the resulting cross section was typical for the reach, an additional plot was made comparing depth vs area for individual cross sections and for the new characteristic cross section in the reach. An example is shown in Figure 11 below.

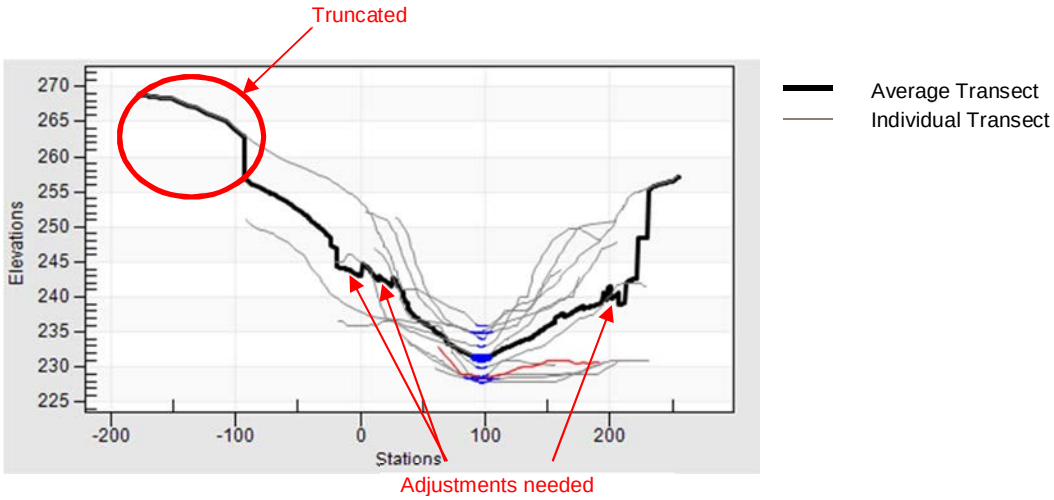


Figure 10: Averaging HEC-RAS Cross Sections in PCSWMM

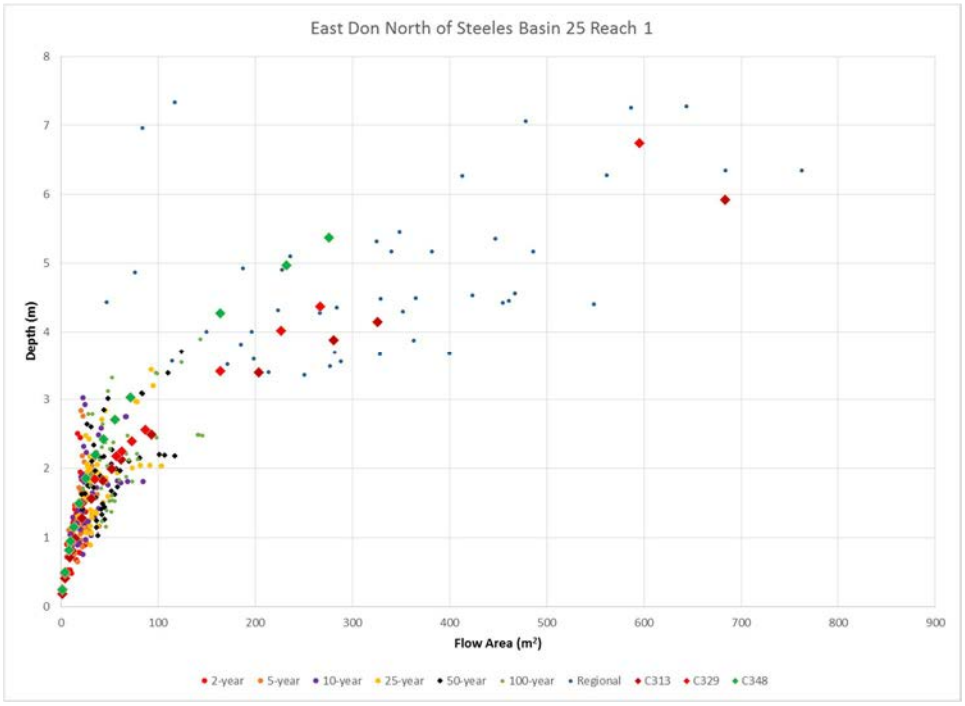


Figure 11: Depth vs Flow Area between HEC-RAS Cross Sections and Representative Cross Section in PCSWMM

2.5.1.2 Head Water Reaches Not Covered By HEC-RAS Models

The reaches where HEC-RAS models don't exist are typically in the upstream headwater reaches with small catchment areas, and are often a poorly defined overland flow route. The characteristic cross section used for these reaches is either a generic urban cross section (road, curb, and gutter) or a generic rural cross section (standard shallow ditch). During model calibration, the slope or cross section of the upper reaches was also manually adjusted to either (a) increase model stability, (b) prevent reverse flow, or (c) improve model calibration by either increasing or decreasing routing, as required. The initial model simulations indicated that the peak flow results were significantly affected if the generic reaches had slopes that were uncharacteristically flat, which causes momentary reverse flows. Once the slope of

generic reaches were increased sufficiently to be more characteristic of urban reaches and increased sufficiently to prevent backflow, and the width of the urban section reduced where required, the model calibration improved significantly and further adjustments of slope and cross section only led to minor peak flow differences.

2.5.2 Road Crossings

Road crossings are considered important to include in the existing conditions model if they provide storage/attenuation during rainfall events that would affect the calibration of the model. AECOM initially screened road crossings according to the potential impact, low or high that the crossing would have on routing. This initial screening considered:

- The difference in water level US and DS of the road, as evident in floodline mapping
- The relative amount of storage available in the valley upstream of the crossing
- The size of the crossing

Screening the crossings in this way focused the hydrologic model development on crossings where attenuation had a potential effect on hydrologic model results, and allowed crossings with no expected effect on hydrology to be ignored. If there was no differences in water level across the structure, the structure was assumed to have no influence on routing and attenuation, and was not included in the model. Initially, the difference in water level was limited to the 100-year and Regional levels as evidenced by floodline mapping; however, the comparison was extended to more frequent events through review with TRCA.

Using this approach, AECOM screened the number of crossings to a more manageable number to include in the model. TRCA reviewed this screening, provided commentary and requests for additional crossings where it was felt to be required. This screening resulted in 128 crossings to be included in the model. These were either represented as culverts, bridges, or a simple deck/roadway in the model. In addition, TRCA identified a few locations of sudden valley constrictions. These, although not road crossings, can potentially act as hydraulic bottleneck. The valley geometry was included in the cross section of the model conduits and its hydraulic effect accounted for through channel routing.

The final screening matrix is included in the report Appendix.

The structures were included in the PCSWMM model by creating ‘dummy’ junctions and conduits. Similar to the approach used by the NexFlood PCSWMM model of the Don watershed developed by TRCA, the conduit cross-section/transect, representing the opening and road profile of the crossings, were imported from the existing HEC-RAS models.

The hydraulic structures, as provided within the HEC-RAS hydraulic models, are considered representative of the geometry of the existing hydraulic structures. However, it was noted that differences exist between the invert elevation from the DEM (which measure only to the water surface) and measured\surveyed cross-sections (which include sub-surface channel geometry) in the HEC-RAS models. Adjustments to the hydraulic network were made as necessary to address significant discrepancies (significant invert differences, negative and zero slope etc), in order to ensure that there was no resulting impact upon the performance of the calibration model.

As noted previously, all road crossings were removed from the Regional Storm simulations, to be consistent with MNRF technical guidelines for flood plain mapping.

2.5.2.1 Culvert

Culverts were modeled as parallel conduits in the PCSWMM model, with one conduit representing the pipe geometry, and the second conduit representing the road profile where flows would eventually potentially overtop.

2.5.2.2 Bridge

Bridges were modeled through the use of 2 or more parallel conduits: one to convey bridge overtopping flow (high chord), and one or more to represent the opening(s) underneath the bridge deck. The high chord was best represented with an irregular cross-section (transect), and each opening below the bridge deck was represented with a custom cross section. Single span bridges were modeled similarly to culverts, with separate conduits representing the bridge opening and the potential road overtopping. For the bridge openings, custom shape curves were developed as symmetrical shapes with equivalent cross sectional area to the original opening across the entire range of depth. If there are several openings because of bridge piers, separate parallel channels can be created for each opening as shown in the screenshot below.

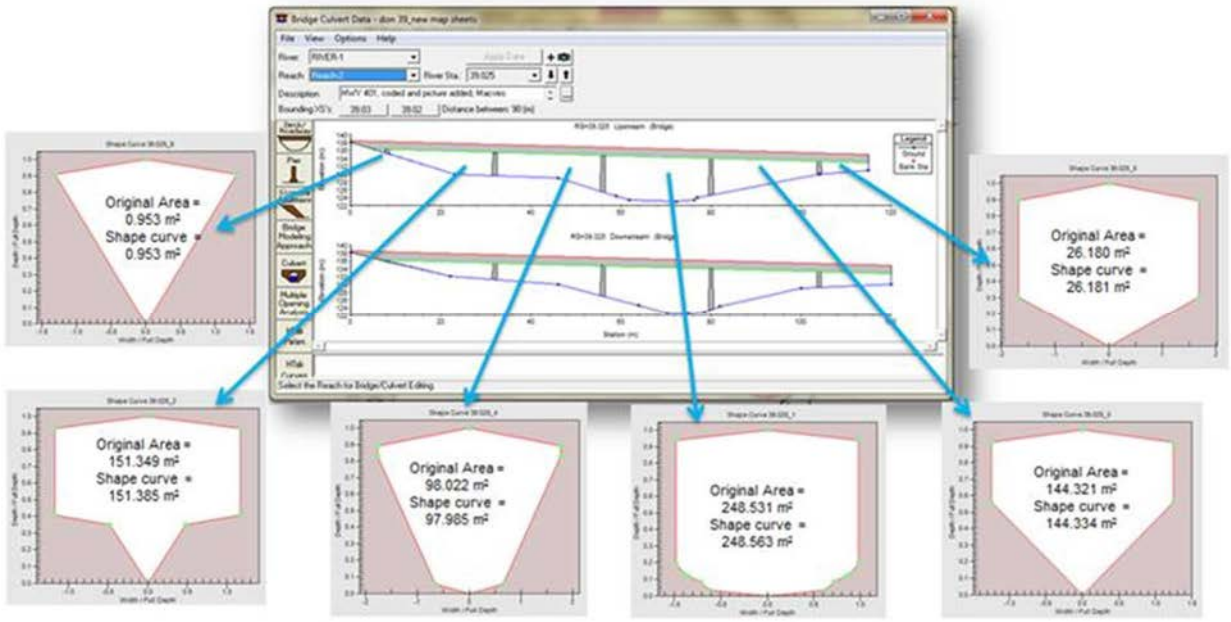


Figure 12: Bridge Opening Representation in PCSWMM

2.6 Stormwater Management Ponds

Stormwater management (SWM) ponds provide attenuation and affect timing of the hydrograph. Explicit incorporation of existing SWM ponds will reflect the real hydrological process in the watershed. The flows used for calibration measured at downstream stream gauges are affected by the attenuation in the ponds; as a result, it is important to include the ponds in the existing condition PC SWMM model used for calibration.

2.6.1 Pond Screening

All existing stormwater management pond locations were identified in shape files provided by TRCA. The shapefiles included name of the pond, a comment field describing the purpose of the pond, the year build, and the nearest road intersection, wet pond or dry pond, and pond function.

The pond function is classified by one of the following codes:

EFC (Erosion Flow Control)
FLO (Flood Control)

QEC (Quality and Erosion Control)
QEF (Quality, Erosion and Flood Control)
QFC (Quality and Flood Control)
QQC (Quantity Control)
QQE (Quality, Erosion and Flood Control)
QUA (Quality)

The shapefile also references a stormwater management report, if available, for each pond. AECOM reviewed the reports, and either confirmed or modified the classifications of the ponds according to the reports.

The catchment areas to the ponds were initially assessed using the catchment areas delineated by processing the topology using the Arc Hydro tools in GIS. If the catchment was similar in size to that reported in the stormwater management report, it was assumed to be correct. If the catchment was much larger than the catchment in the stormwater management report, the catchment was discretized further to reflect the actual pond catchment size.

AECOM maintained a pond database, identifying for each pond:

- A municipal ID
- Function (as per above code)
- Whether or not documentation (i.e. a SWM report) existed for the pond
- Whether or not there was a defined stage/storage/discharge relation available in the report
- The catchment area
- A note indicating whether or not the pond will be included in the updated hydrology model
- The rationale for including or not including it
- An ortho image of the pond location and catchment area

This database is provided in the Appendix of this report.

The original database identified 190 ponds. Of this, 10 were outside the Don River watershed boundary, and 26 were identified as quality or erosion control ponds only, and were not included in the hydrology model. Of the remaining 154 ponds, 76 had no design report or inventory sheet data, and 104 had no stage/storage/discharge table. Of the 154 ponds, 45 more were screened out or lumped with other ponds, resulting in a final number of 109 ponds in the model.

2.6.2 Ponds With Existing Reports and Design Details

For ponds with existing reports and design details, the stage / storage relation from these details was used in the storage node representing the pond in the model.

2.6.3 Ponds Without Design Details

For ponds without known design details or existing reports, the following approach was taken.

- If the outflow rate was known, or the size of the outlet was known, the model was run to determine the storage volume required to achieve this outflow rate for the 100-year design storm. This pair of points (flow rate, storage) was used to define the pond in the model.
- If the pond active storage volume was known, then model was run to determine the outflow rate resulting from using this volume for the 100-year design storm. This pair of points (flow rate, storage) was used to define the pond in the model.
- If neither storage volume or outflow rate were known, peak outflow rate was estimated based on the required unit flow rate for the 100-year design storm (Stormwater Management Criteria, Aug 2012, TRCA). The model was then run to determine the storage volume required to achieve this outflow rate for the 100-year design storm.

- For the above situation, the storage resulting storage volume was compared to the visible pond footprint area. If the pond visible footprint area could not reasonably provide the target storage volume, the active storage volume was revised based on the visible pond footprint area, and then treated as the second bullet above.

2.7 Initial Model Configuration

The model was initially populated with:

- Characteristic default parameters, using typical values that are widely used in urban hydrologic modeling in Ontario;
- Parameters that can be accurately measured from GIS or derived from available mapping; and
- Initial 'best guesses' for parameters that were used for calibration.

Of the three, only the latter parameters were changed from the initial model configuration. The model was run using the initial configuration to perform checks on continuity, run times, identify model efficiencies, and conduct initial quality checks.

2.7.1 Default Parameters

Default parameters were identified that broadly accepted values used in modeling in Ontario; the values of these parameters could be set, and the model result it affects (i.e. runoff volume, peak flow) could be calibrated with other parameters that have more broadly understood variability.

Default parameters used in the model include the following:

- N impervious = 0.013
- N Pervious = 0.25
- Depression storage, impervious =2 mm
- Depression storage, pervious = 5 mm
- Zero impervious area (i.e. the impervious area assumed to have no depression storage) = 25%
- Subarea routing = Pervious (i.e. assumes that a portion of the impervious area is routed to pervious surfaces)

2.7.2 Parameters Derived from GIS

There were several model parameters that could be accurately measured in GIS, which were also populated in the initial model configuration. Since these parameters could be measured accurately, they were not altered during the calibration.

Model parameters that are calculated from GIS include the following:

- Catchment area;
- Catchment width (initial value based on longest flow path x 2, resulted in average length of 112 m; and longest length of 326 m, then subject to calibration later);
- Catchment slope;
- Imperviousness

2.7.3 Parameters for Calibration

2.7.3.1 Percent Routed

The total impervious area was estimated very accurately in each subcatchment. One of the main parameters affecting the volume of runoff is the 'percent routed' term applied to the total impervious area. In this case, the 'percent routed' term refers to the portion of runoff from impervious surfaces to be directed to the other specified surfaces. AECOM configured the catchment hydrology in the model such that a specified 'percent routed' portion of the total impervious area discharged to pervious surfaces. Conceptually, this represents impervious areas where runoff is not directly connected to hard surfaces that drain directly to storm sewers or watercourses; this would include sidewalks, and roof areas with downspouts directed to rear yards or grass surfaces.

AECOM estimated the 'percent routed' term by determining the runoff volume monitored at the stream gauges for all calibration events, comparing to rainfall in the catchment for the event, and calculating the volumetric runoff coefficient for each event. The 'percent routed' term was set such that the net imperviousness [total impervious x (1 – percent routed)] was equal to the smallest volumetric runoff coefficient recorded. This implies that almost all of the runoff for the event was generated by the directly connected impervious area. AECOM felt that the resulting net imperviousness was low enough such that reducing net impervious further (i.e. assigning more runoff to pervious areas for the smallest calibration events) was not reasonable or warranted. Details of how the 'percent routed' term was calibrated for each gauged area are further discussed in Section 3.4.1.

2.7.3.2 Infiltration Parameters

AECOM configured the model to use the Green & Ampt infiltration method. The method uses three parameters to estimate runoff volumes from rainfall:

- Suction head (representing the capillary action of the soil);
- Saturated hydraulic conductivity (representing the downward infiltration capacity); and
- Initial moisture deficit (IMD, representing the soil moisture retained from recent rainfall).

This is a physically based infiltration model, which is slightly different from a simpler conceptual infiltration model more commonly used (i.e. the SCS – CN – method). The Green & Ampt method has been the subject of considerable development in soil physics and hydrology, owing to its simplicity and satisfactory performance for a great variety of water infiltration problems.

All three parameters are part of the model calibration; however, the IMD, dependent on antecedent moisture, is allowed to vary between different values subject to a measure of antecedent moisture in the catchment at the time of the event.

2.7.3.3 Antecedent Moisture

The antecedent moisture conditions prior to a rain event are generally understood to affect the runoff from pervious surfaces. Surface runoff is expected to increase when soils are holding more water and are closer to saturation.

In the model configuration, antecedent soil moisture is accounted for in the "initial moisture deficit" (IMD) parameter in the Green & Ampt infiltration assessment. The steps that AECOM took to calibrate the IMD term were:

- Initially, the IMD was assumed to be equal to a 'textbook' derived dry condition;
- The model was run for the calibration events. The volume of runoff from pervious surfaces for the 'dry' events (defined by the lack of rainfall in the weeks preceding the event) was low, and corresponded well to the IMD for dry soil conditions;
- and the volume of runoff was calibrated for the 'wetter' events(defined by the presence of significant rainfall in the weeks preceding the event) by decreasing the IMD;

- an antecedent precipitation index was calculated for each event, for each gauge location (using the rain gauges within or closest to the catchment area for the gauge);
- finally, the calibrated IMD was related to antecedent rainfall

Initially, characterizing the event as a 'dry' or 'wet' event was done based on the amount of rain in the preceding weeks, and the volumetric runoff coefficient of the event (i.e. higher runoff volumes flagged a 'wet' condition). Once it was established that a correlation existed between antecedent rainfall and runoff volume, a more formal relation was investigated for modeling purposes. Rather than just characterize the moisture condition as 'wet', 'normal' or 'dry' (as with the typical "AMC" characterization used in the SCS method, based on 5 days of rainfall preceding the event), a continuous variability between antecedent rainfall and runoff volume (as reflected in soil moisture conditions) was sought. On one hand, antecedent rainfall was characterized by a factor that exponentially diminishes the longer the antecedent rainfall occurred before the event, up to 30 days. On the other hand runoff potential was increased by reflecting wetter soil conditions in the model through the "initial moisture deficit" parameter in the Green & Ampt equation. The actual rainfall and stream gauge data was used to derive a relationship between the two (API vs IMD).

The antecedent rainfall is represented by the antecedent precipitation index (API) at the time of the event. For each gauge catchment, a continuous API is calculated from the 5 minute rainfall data using the relation

$$API_n = API_{n-1} \times 0.9992 + Rainfall_n$$

Where *n* is the current 5 minute time step, *n-1* is the previous time step, and $Rainfall_n$ is the rainfall in the current time step in mm.

This is equivalent to the following equation with a daily time step:

$$API_n = API_{n-1} \times 0.8 + Rainfall_n$$

This equation is referenced in the SWMHYMO users manual (Aug 1999), where the "depletion coefficient" is identified as ranging from 0.8 to 0.95 / day The antecedent precipitation index associated with each gauge and each calibration rainfall event is provided below.

Stream Gauge HY019

Event	Event rainfall mm	Antecedent Precipitation Index (mm)			
		Rain-gauge 44	Rain-gauge 23	Rain-gauge 08	Aver-age
2013-07-08	44.4	23.6	10.7	19.0	17.8
2013-07-31	45.2	9.9	8.9	6.3	8.3
2013-09-20	42.4	2.8	3.7	3.9	3.5
2014-07-27	46.2	2.6	2.4	3.5	2.8
2014-09-10	33.5	15.2	12.7	13.3	13.7
2015-05-30	50.1	0.0	0.0	0.2	0.1
2015-06-27	38.8	17.2	14.8	16.4	16.1
2015-10-28	63.4	9.4	7.9	8.5	8.9

Stream Gauge HY068

Event	Event rainfall mm	Antecedent Precipitation Index (mm)			
		Rain-gauge 27	Rain-gauge 44	Rain-gauge 22	Aver-age
2013-07-08	44.4	22.6	38.6	21.7	27.6
2013-07-31	45.2	9.2	10.4	10.4	10.0
2013-09-20	42.4	2.9	2.8	2.1	2.6
2014-07-27	46.2	3.3	2.7	2.4	2.8
2014-09-10	33.5	12.7	15.2	13.8	13.9
2015-06-27	38.8	22.3	17.4	20.5	20.1
2015-10-28	63.4	8.2	9.4	9.6	8.9

Stream Gauge 02HC005

Event	Event rainfall mm	Antecedent Precipitation Index (mm)			
		Rain-gauge 27	Rain-gauge 44	Rain-gauge 25	Aver-age
2013-07-08	44.4	22.6	38.6	56.1	39.1
2013-07-31	45.2	9.2	10.4	5.4	8.3
2013-09-20	42.4	2.9	2.8	3.2	3.0
2014-07-27	46.2	3.3	2.7	0.8	2.2
2014-09-10	33.5	12.7	15.2	14.3	14.0
2015-06-27	38.8	22.3	17.4	14.6	18.1
2015-10-28	63.4	8.2	9.4	8.4	8.3

Stream Gauge HY017

Event	Event rainfall mm	Rain-gauge YR-VA-02
2013-07-08	44.4	7.9
2013-07-31	45.2	2.8
2013-09-20	42.4	0.4
2014-07-27	46.2	1.1
2014-09-10	33.5	4.5
2015-10-28	63.4	2.3

Stream Gauge HY062

Event	Event rainfall mm	Antecedent Precipitation Index (mm)			
		Rain-gauge 40	Rain-gauge 42	Rain-gauge 23	Aver-age
2013-07-08	44.4	10.8	11.7	10.7	11.1
2013-07-31	45.2	5.2	7.8	8.8	7.3
2013-09-20	42.4	3.4	3.9	3.7	3.7
2014-07-27	46.2	7.9	2.8	2.4	4.4
2014-09-10	33.5	13.8	15.0	14.4	14.4
2015-06-27	38.8	12.1	16.6	14.9	14.5
2015-10-28	63.4	7.8	0.0	7.7	7.7

Stream Gauge HY056

Event	Event rainfall mm	Antecedent Precipitation Index (mm)			
		Rain-gauge 69	Rain-gauge RH2	Rain-gauge 21	Aver-age
2013-07-08	44.4	41.3	8.3	60.3	36.6
2013-07-31	45.2	14.5	3.0	8.6	8.7
2013-09-20	42.4	35.6	0.8	30.8	22.4
2014-07-27	46.2	1.7	1.1	7.6	3.5
2014-09-10	33.5	22.0	4.5	16.6	14.3
2015-05-30	50.1	1.2	0.1	0.2	0.5
2015-06-27	38.8	13.5	5.2	14.8	11.2
2015-10-28	63.4	8.9	3.8	9.5	7.4

2.7.3.4 Overland Flow Length

As described previously, the overland flow length is initially based on the catchment width (initial value based on longest flow path x 2). This parameter is then subject to calibration, since it is one of the primary factors that affect how rapidly the subcatchments drain to each subcatchment outlet. In addition, care is taken such that the overland flow length does not become excessively large, which could invalidate the conceptual framework of the overland routing in the model. Specifically, excessively large drainage lengths will tend to 'channelize' in reality, and start to invalidate the basic conceptual underpinnings of the overland flow in the model.

The initial subcatchment width and length assumptions resulted in an average subcatchment overland length of 112 m and longest length of 326 m; there is no explicit fixed maximum overland length recommended for the SWMM model, although it is commonly understood that sheet drainage for overland flow will channelize into gullies/rivulets before traveling 100 to 150 m overland. For the catchment with the largest overland lengths, sensitivity analyses were performed for shorter flow lengths, as well as the potential benefits of adding internal routing elements along with shorter flow lengths.

2.7.3.5 Channel Roughness

Initially, channel roughness is taken from the HEC-RAS cross sections that form the basis of the characteristic cross section for the reach, typically for the main channel n = 0.035, and overbank n = 0.06 to 0.08.

In cases where calibration indicates that there is too little lag or attenuation in the model, there is little opportunity to make channel roughness significantly larger; additional lag is better addressed at the catchment hydrology level. For example, initial values for catchment length were placed in the model based on realistic expected overland flow paths prior to channelization. Additional lag, if required, would be achieved by increasing the channel length. Typically, the initial model configuration showed too much attenuation in the model, as opposed to too little; as a result this parameter was generally not adjusted.

On the other hand, in cases where calibration indicates that there is too much lag or attenuation in the model, and where catchment hydrology parameters are already minimizing overland lengths, lag and attenuation are proposed to be decreased through calibration of Manning's n in the channel reaches. There is an opportunity to realistically reduce Manning's n for both the main channel and overbank. Several reaches, such as Wilket's Creek, are known to have stream protection and hardening works that have likely reduced roughness values considerably.

Table 3.5.1 shows final calibration parameters for the model, including ultimate values selected for Manning's n that provided sufficiently rapid response in the catchment to reflect the peak flows recorded at the gauges.

2.7.4 Areas with Special Consideration

There are locations in the watershed where the natural flow in the channel is severely altered by the man built environment, and flow doesn't follow the flow path of the historic channel. In these severely altered areas, AECOM reviewed hydraulic flow paths that drainage takes across each site.

2.7.4.1 MacMillan Rail Yard North of Highway 7, West of Keele St

Historic development of the rail yard has severely altered overland drainage in the area. In general, when the channel reaches the rail yard it is enclosed by a 2780 mm storm pipe over a length of several hundred metres and the flow is conveyed across the rail yard. When this 2780 mm pipe reaches capacity, excess flows will spill from the channel upstream of the pipe. Previous studies have looked at flooding of the rail yard during major storm events, detailing flooding and spill locations. AECOM reviewed these reports, along with available grading details in the vicinity of the culvert inlet to identify the spill crest location, spill direction, and culvert conveyance capacity just prior to spill.

The model was configured to accurately reflect:

- Flows up to approximately a 25-year storm were conveyed in the 2780 mm storm pipe, and larger flows begin to spill from the channel to the rail yard
- Draining spills southward overland across the rail yard over several hundred metres until it accumulates in low lying areas and eventually spills eastward. The drainage will re-join the main channel upstream of Highway 407.

2.7.4.2 Don Mills Ditch

The Don Mills Ditch is a man made channel that runs through a commercial and industrial area just east of the Don Valley Parkway and just north of Steeles Avenue. It is characterized by a highly altered channel, enclosed for significant portions. It is characterized in the model as a standard ditch section with capacity limited by a number of culvert structures included in the model.

2.7.4.3 Pond 248 – Highway 401 and Victoria Park

In the documentation for the pond, the control is described as overland storage releasing flow back into the minor system after the storm. The catchment area is defined as part of the Massey Creek catchment, based on the GIS processing of the surface and flow paths. However, Highway 401 creates a barrier to overland flow, and the conveyance is restricted to existing piped systems. A review of existing storm infrastructure indicates that the area north of Highway 401 is serviced by a 2100 mm storm trunk that conveys drainage westerly, becoming a 3000 mm once it crosses the Don Valley Parkway. The 3000 mm storm trunk crosses Highway 401 near Don Mills Rd, discharging into the Don River just south of Highway 401.

For design floods up to the 100-year storm, the modeling assumes storage in Pond 248 and surface ponding, released at a controlled rate to the existing storm infrastructure described above. Highway 401 is also assumed to continue to form a barrier for the Regional flood. While guidelines generally would consider removal of the storage or routing effects caused by roads, in this case the most reasonable modeling approach is to continue to consider the barrier created by Highway 401, and the storm infrastructure constructed to explicitly convey major flows westward to the Don River.

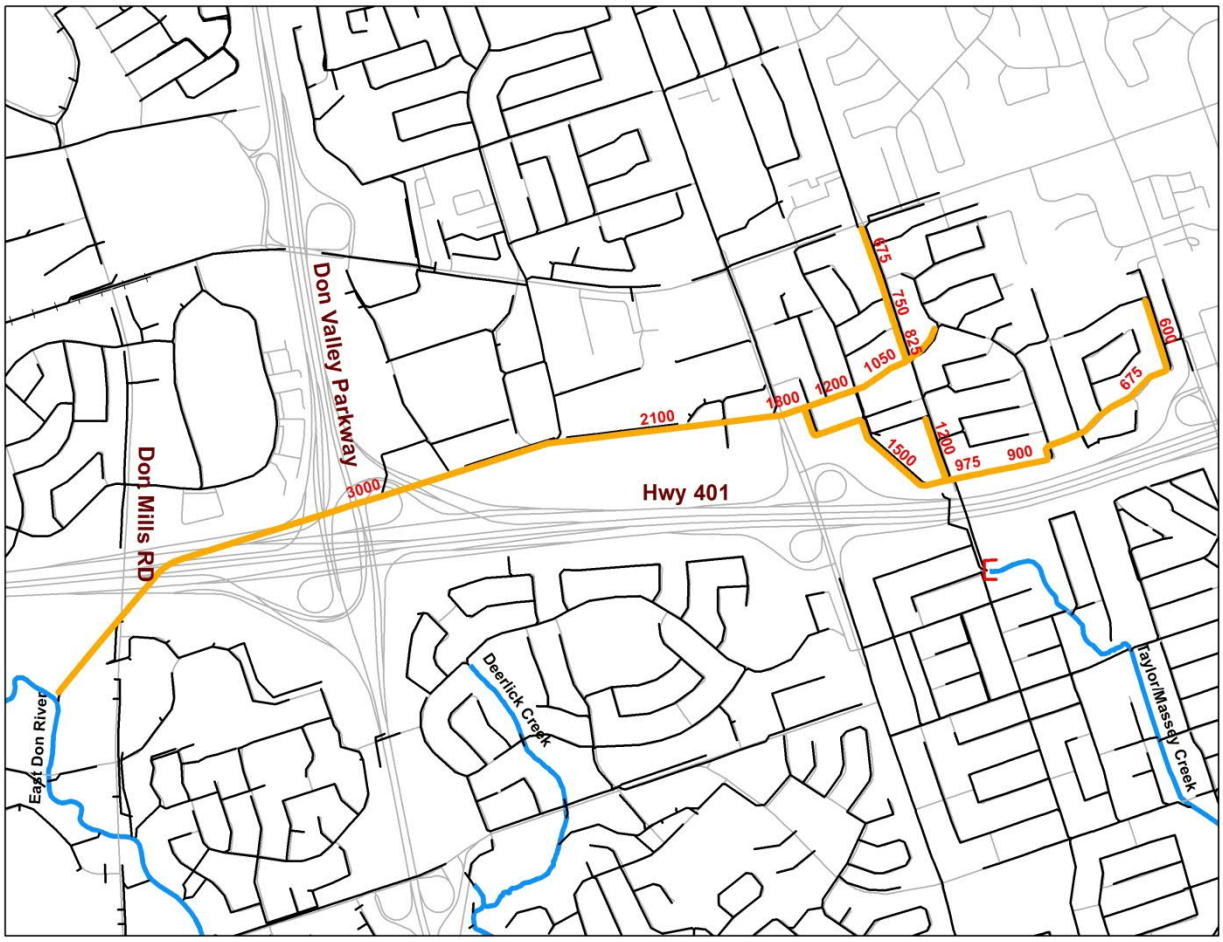


Figure 13: Highway 401 and Victoria Park

3. Model Calibration and Verification

The calibration of the hydrologic model represents a key component of the overall study process in order to build confidence in the use of the tool so that it can be applied in the impact assessment and management phases.

The model calibration objectives are:

- Preserve all known observable/quantifiable physical catchment characteristics such that the model parameters realistically and accurately reflect the real catchment
- Adjust model parameters initially such that the total runoff volume for all calibration events most closely matches the runoff volume measured at the gauges
- Adjust different model parameters such that the peak flow and shape of the hydrograph produced by the model most closely matches the hydrograph measured at the gauges
- Verify the model runoff and peak flow with verification events

Ultimately, the goal is to use the calibrated model to accurately estimate peak flows at points in the watershed for a range of design rainfall events (2-year through 350-year) and the regulatory event (Hurricane Hazel).

3.1 Precipitation Data

In order to capture the spatial and temporal distribution of rainfall across the Don River watershed, a network of rainfall gauges have been applied for the model calibration; the number and location of these stations are considered sufficient to achieve a model calibration which accounts for distinct and unique characteristics within each of the physiographic regions of the watershed, and within each subwatershed. Precipitation data was obtained from

- TRCA rain gauges; and
- Area municipality and Region of York rain gauges

Each rain gauge is a tipping bucket style gauge with data processed in 5 minute increments.

3.1.1 TRCA Rain Gauges

TRCA provided rain gauge data for a number of stations with data as far back as 2002. TRCA rain gauge locations are shown below.

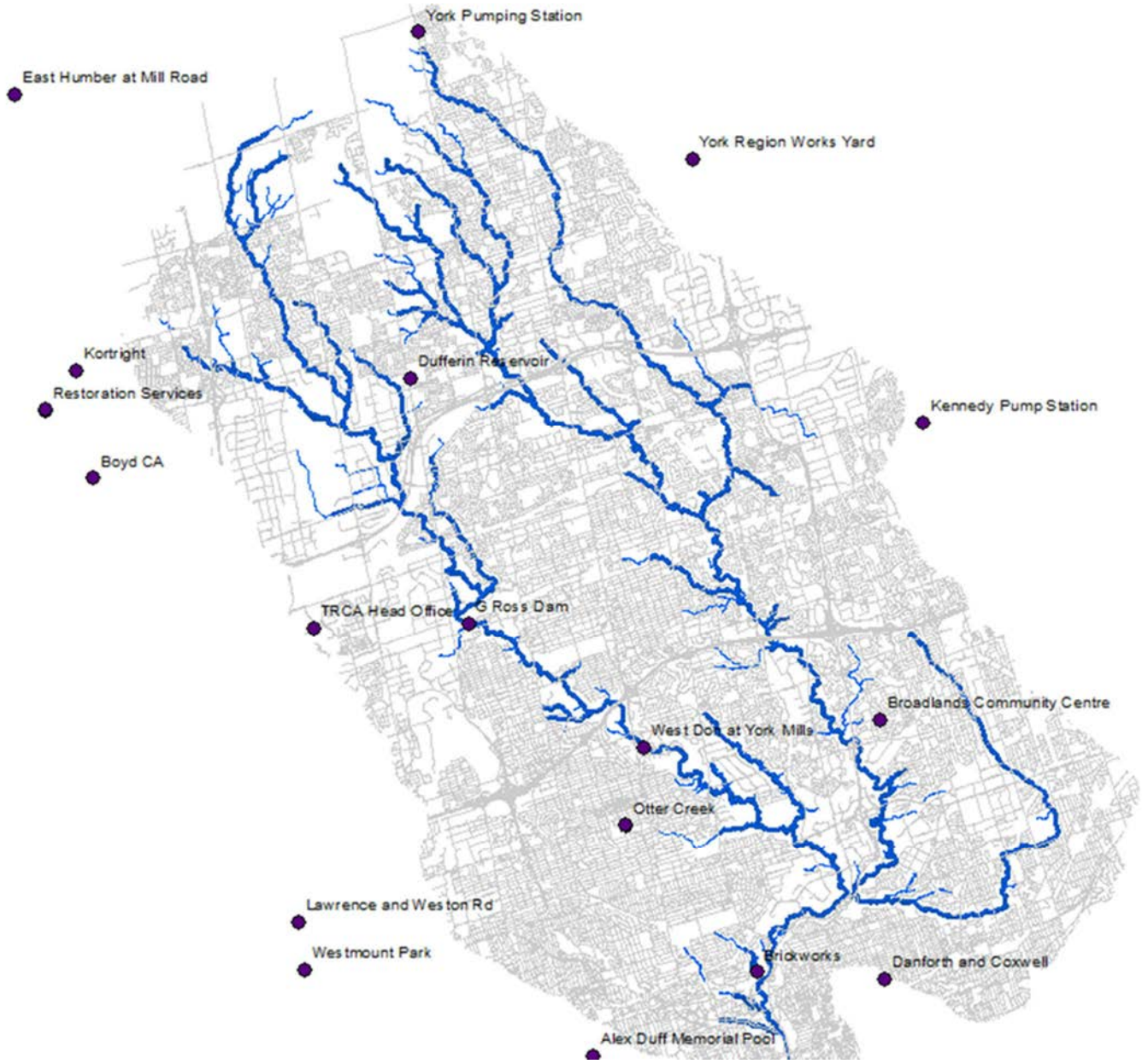


Figure 14: TRCA Rain Gauges

3.1.2 Municipal and York Region Rain Gauges

The TRCA rain gauges were augmented by municipal rain gauge data provided by the City of Toronto, Markham, and the Region of York.

The Figure below shows the locations of TRCA rain gauges, and City of Toronto rain gauges. The Figure shows additional City of Toronto gauges that were obtained to provide better spatial coverage (i.e. to best fill in the gaps in the TRCA gauge coverage).

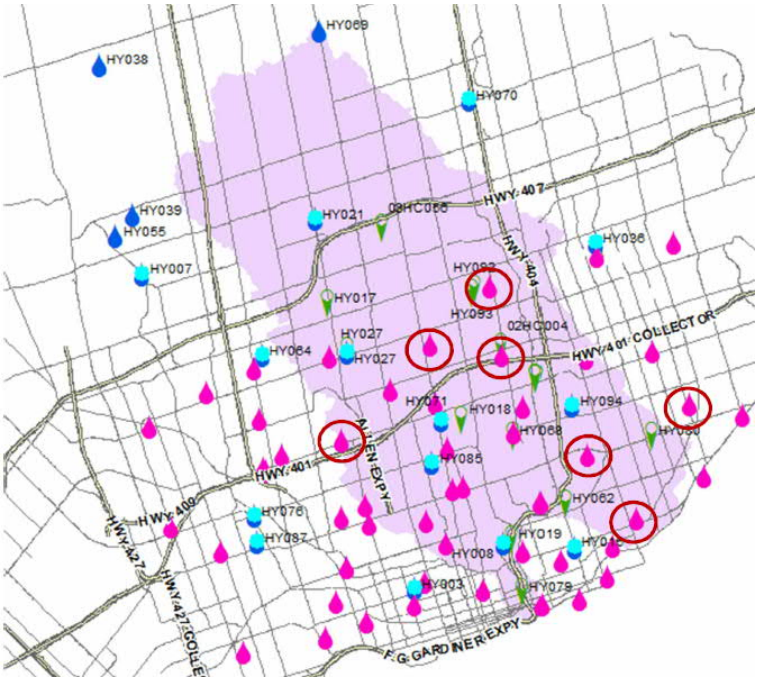


Figure 15: Selected Additional City of Toronto Rain Gauges

This provided uniform coverage for areas generally south of Highway 407, but left sparser coverage north of the highway. To improve the coverage of rain gauges north of Highway 407, AECOM contacted the Region of York and the municipalities of Markham, Richmond Hill, and Vaughan to identify additional rain gauges in the area. The location of additional gauges is shown below. AECOM requested and obtained data from the highlighted rain gauges.

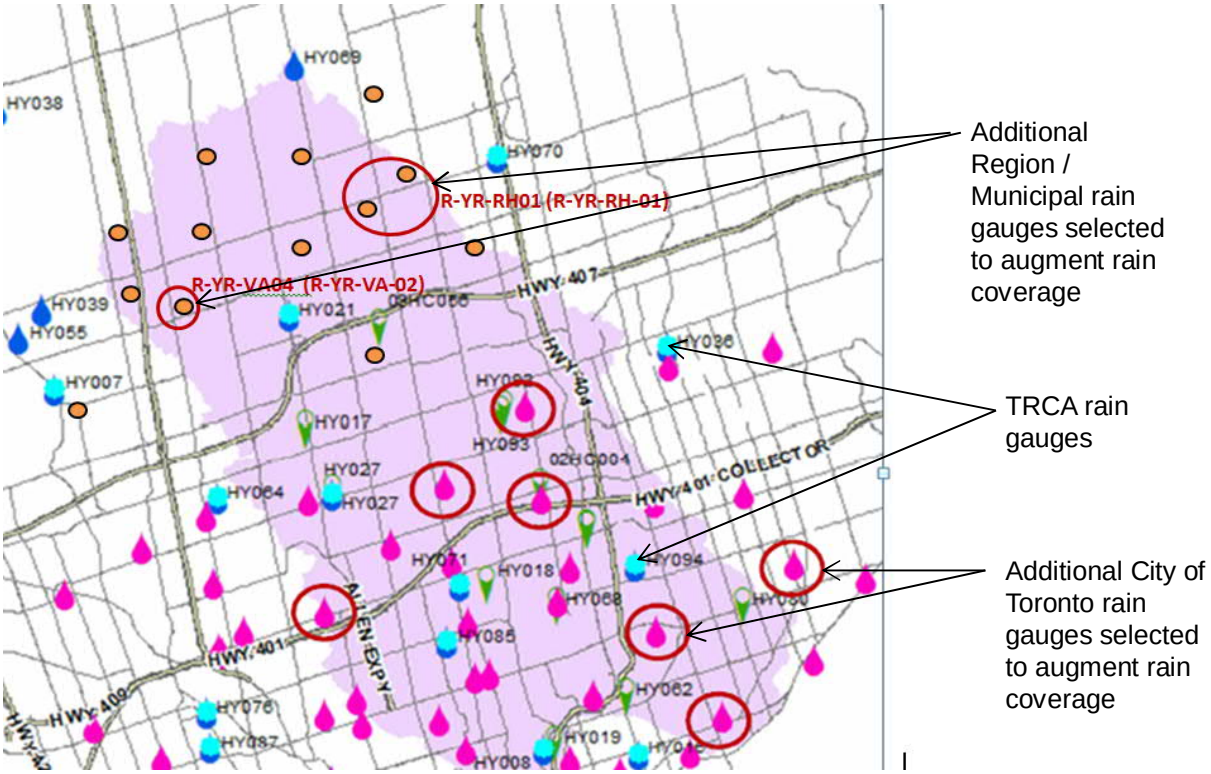


Figure 16: Selected Additional Regional and Municipal Rain Gauges

3.1.3 Precipitation Data Processing

Typically, one of the main sources of inaccuracy in hydrologic model calibration is the error introduced due to spatial variability of rainfall. The hydrologic model typically uses the rainfall recorded at rain gauge locations, and assumes that this gauged rainfall is representative of rainfall that occurred over all (or a portion) of the catchment. Often, catchments are split according to the portion closest to individual rain gauges (e.g. using Theissen polygons developed from the rain gauge locations).

Rather than using the traditional Theissen polygon technique, AECOM's approach in the present study was to interpolate rainfall intensities across the entire study area in order to reduce the effect of rainfall spatial variability on the predicted runoff. For each rainfall timestep, the intensities at the point locations of all the gauges were used to develop a smoothed 'surface' of rainfall intensities between the gauges across the entire study area. The average value of this surface over the area of each subcatchment determines the rainfall intensity at that subcatchment, for that time step. Repeating this procedure, developing a 'rainfall surface' for each time step, resulted in a unique hyetograph generated for each subcatchment.

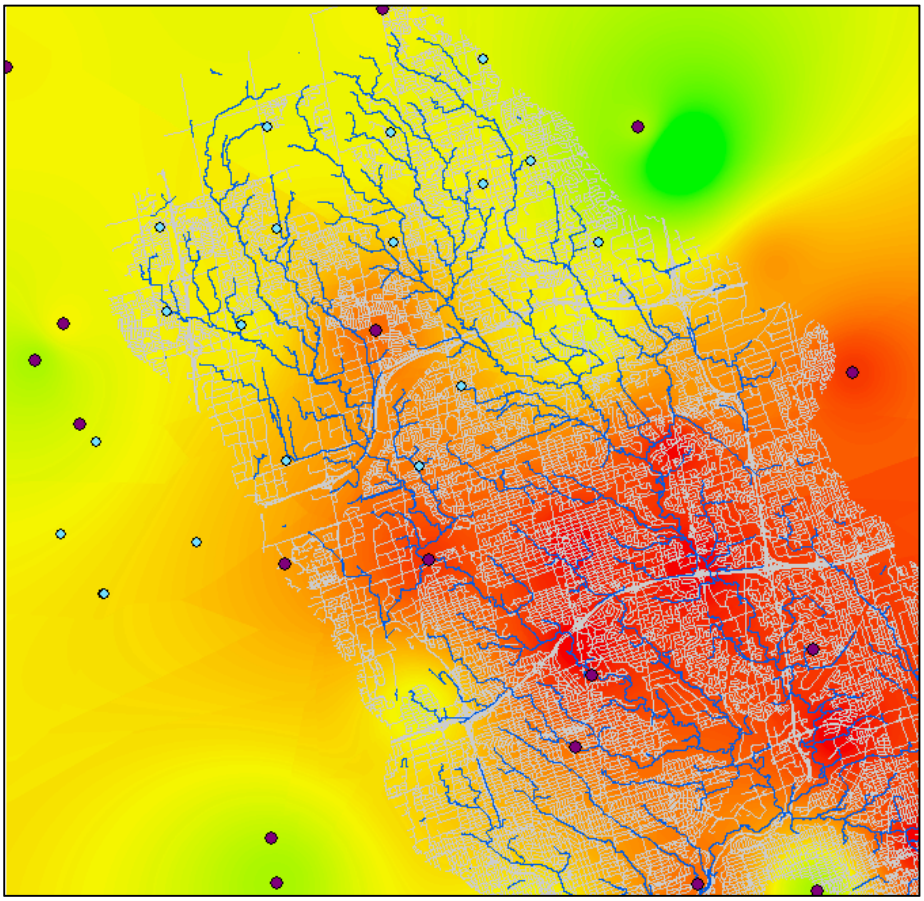


Figure 17: Rainfall Distributed Across the Don Watershed for Each Time Step

This technique leverages the known information at the gauges and makes the most reasonable inferences possible for the spatial distribution of rainfall over the watershed. By addressing the spatial distribution of rainfall as rigorously as possible, we are making an effort to address potentially the largest source of error in our calibration process: potential inaccurate representation of rainfall over catchments during calibration.

3.2 Streamflow Data

Streamflow data consisted of

- Water Survey of Canada stream gauges; and
- TRCA stream gauges

Locations of the gauges is shown in the Figure, below. Table 3 indicates the length of time each gauge has been installed.

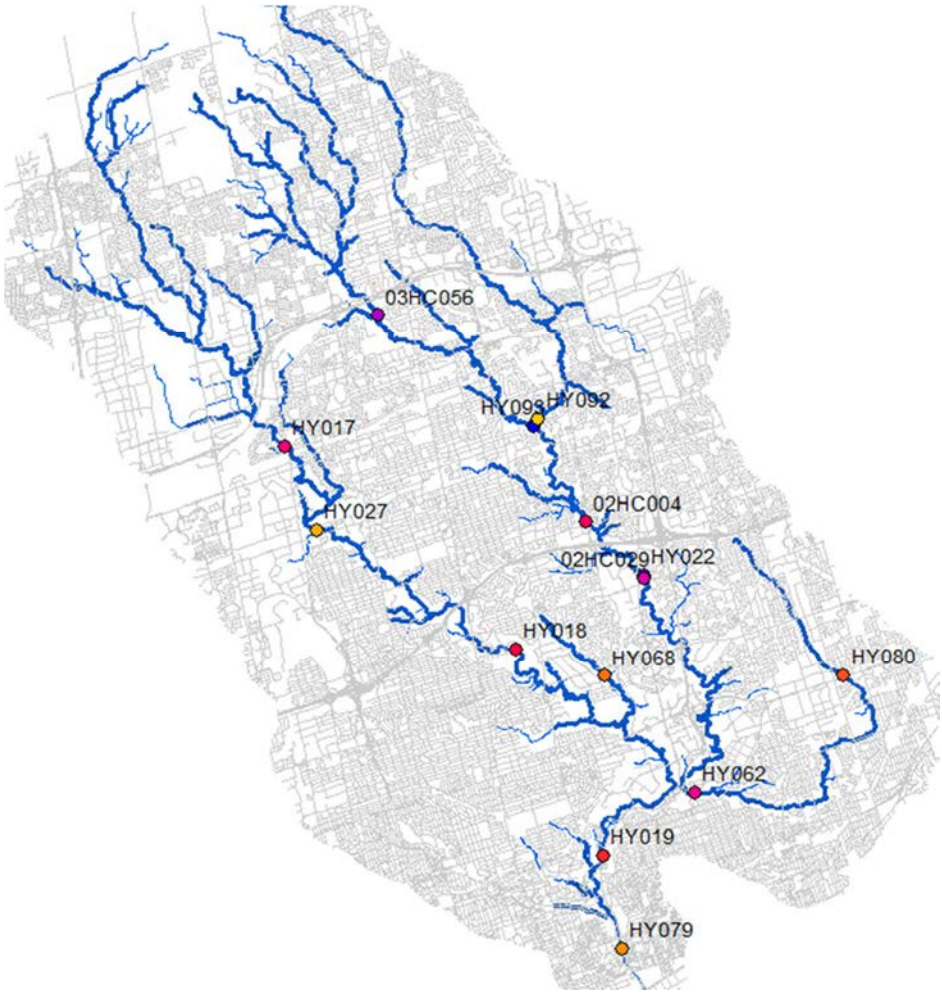


Figure 18: Stream Gauge Locations

3.2.1 TRCA Summary of Hydrometric Data Quality and Limitations

TRCA hydrometrics staff provided the following information in this section related to rainfall and stream gauge data collected in the Don River watershed and used for model calibration / verification in the present study.

Data used in this study and collected by TRCA and its partners is subject to a number of limitations which are inherent in the data collection and computation methodologies. Precipitation data was collected by either three-season or four-season tipping bucket and weigh gauge precipitation gauges. Total precipitation was automatically measured and collected in five minute intervals. Each gauge is calibrated twice annually and cleaned monthly to verify proper measurement and operation. Data collected at these

gauges may be susceptible to wetting errors, wind effects, dew/fog effects and calibration changes over time. In these cases, the data is qualified with an appropriate grade corresponding to the impact.

Water level data is collected in fifteen minute intervals at the outlined locations. This data is collected by standalone and real-time data loggers and corrected to correspond to discrete water level measurements, which are recorded monthly. Stage-discharge curves are developed for each streamflow location using area-velocity discrete flow measurements, as per Water Survey of Canada's (WSC) "Hydrometric Manual – Data Computations: Stage-Discharge Model Development and Maintenance" (2016). This procedure applies a simplified form of Manning's equation, expressed as follows:

$$Q = C(G - a)^B$$

Where:

- *Q* is the discharge;
- *C* is the calibration parameter affected by channel characteristics (e.g. width, slope, roughness);
- *G* is the stage;
- *a* is the gauge height of zero flow (i.e. control);
- *B* is the calibration parameter affected by the control geometry.

It is important to note that erosion and deposition are constantly changing the above-stated parameters, and that the curve is constantly checked with verification measurements; more measurements at a wider range of stages is expected to yield better results. Furthermore, the data recorded at these gauges may have been subject to ice conditions, blockages or beaver dams, equipment error, stage-discharge curve error among other impacts; generally, an acceptable margin of error is 5-10%. In any of these cases, the data is qualified with an appropriate grade corresponding to the impact (identifiers in brackets):

- Poor (11);
- Estimated Good (30);
- Good (31);
- Ice (3);
- Dam/Blockage (6);
- Preliminary (7);
- Outside Rating Curve, ORC (88);
- Equipment/Battery Failure (9,10).

TRCA Hydrometrics staff have made some observations based on field work for specific stream gauges in the Don River watershed, including limitations associated with data collection and usage. Due to staff availability, long-term limitations at some locations (15+ years of record) may not be fully understood.

HY017 (Glenshields)

At higher water levels (above ~181.7masl) the flows would spill out of bank and into a nearby park. The site also experienced some debris jam issues and could have backed up from culvert, creating a backwater effect to the level sensor. To avoid these issues, this gauge was relocated to a crossing at Dufferin St. and Steeles Ave. W and renamed HY100 (West Don at Steeles) in 2017, though the site could theoretically experience backwater if the reservoir at G Ross Lord Dam is above 178.2masl, as well as flows spilling out of bank around 180masl.

HY018 (Knightswood)

No significant issues have been encountered with discharge curve development; the site spills above ~121masl. The site has been both active and removed a few times in the past during the channel cleaning which may have artificially elevated the flows due to access ramps being constructed downstream of gauge (ca. April, 2015). The site is also downstream of the G Ross Lord dam which would lead to increased flows during drawdown.

HY068 (Wilket Creek)

Discharge temporarily collected but the channel geometry would frequently shift, requiring the curve to be rebuilt; the site was also prone to significant control changes due to large rocks accumulating below the gauge pool. Discharge curve is not currently being maintained at this site.

HY092 (German Mills at Cummer)

No significant issues have been encountered with rating curve development; site starts to leave channel around 12m (assumed elevation).

HY093 (East Don at Cummer)

Rating curve constantly shifted during first year or so after installation; the site was moved upstream of a small weir, but water started to flow underneath and around the weir shortly thereafter. Rating curve is deemed invalid from early 2018 onwards.

HY022 (East Don at York Mills)

Rating curve was maintained during Toronto Wet Weather Flows study (2008-2011); water was thought to flow under or around weir, but this has not been verified and the rating curve has not been maintained since.

HY062 (Taylor Massey South)

Rating curve is generally good, though flows would frequently break the bank and very large debris (e.g. full trees) would get caught on the upstream side of footbridge upstream of the gauge every year or two. This issue is not expected to have had a significant impact on flows.

HY019 (Don at Todmorden)

Rating curve maintained by WSC and can be reasonably be expected to be of good quality, though WSC has experienced difficulty verifying the very high end of the curve due to the flashiness of site and difficulty of access.

HY079 (Don at Dundas)

No curve here but the site is prone to frequent backwater from Lake Ontario when elevation is above 75.5m. Debris caught at Keating Channel may raise elevation as well.

3.2.2 Stream Gauge Data Coverage

Throughout the QA/QC process and in consultation with TRCA, the data at a few of the gauge locations was considered not usable. These are summarized below:

- HY022 – determined to be the same location as Water Survey of Canada gauge 02HC029. Data was not maintained at this gauge and therefore not usable for model calibration.
- HY079– at the downstream reach of the Don River. TRCA has reviewed the rating curve and recorded data at the gauge, and have determined that the recorded depth is subject to Lake Ontario water levels; the gauge cannot be used for model calibration.
- HY080 – no usable data available

Table 3: Stream Gauges Data Coverage

Station ID	Location	Start Date	End Date	Duration (Years)	Coverage
HY017	Don at Glenshields	2005-10-03 13:00	2014-12-31 23:45	10	Started end of 2005 season, ended in 2014
HY018	Don at Knightswood	2007-01-01 01:00	2015-12-15 09:00	9	Started 2007
HY019	Don at Todmorden	2002-01-01 00:00	2017-06-20 14:30	16	Good
HY022	East Don at York Mills	Data not provided			
HY062	Taylor Creek South	2004-08-05 12:00	2015-12-31 23:45	12	Good
HY068	Wilket Creek	2007-01-10 12:00	2015-12-31 23:45	9	Started 2007
HY079	Don at Dundas	Data not provided			
HY080	Taylor Creek North	Data not provided			
HY092	German Mills at Cummer	2015-05-11 14:00	2015-12-31 23:45	1	Only 2015
HY093	East Don at Cummer	2015-05-11 15:00	2015-12-31 23:45	1	Only 2015
02HC056	Don River East Branch Near Thornhill	2006-04-01 00:00	2017-06-20 14:30	14	Good
02HC005	Don River at York Mills	2002-01-01 00:15	2017-06-20 14:30	16	Good

Except the above noted gauges, the quality of stream gauge data collected was consider to be satisfactory for the selected calibration and verification events. The following sections provide details of the stream gauges that required special considerations.

3.2.3 HY018 vs 02CH005

The TRCA stream gauge HY018 and the Water Survey of Canada stream gauge 02HC005 are at approximately the same location downstream of the G. Ross Lord dam. AECOM reviewed the data for both gauges in concurrent periods to check for consistency, and to decide if one of the gauges should be used rather than the other one. The WSC gauge 02HC005 has a longer record; it covers all 13 calibration and verification events. The HY018 gauge, however, agrees closer with the recorded opening and closing times of gates in the G. Ross Lord dam operation database (i.e. the WSC gauge data requires a variable offset to 'line up' with HY018 data and gate operating times.

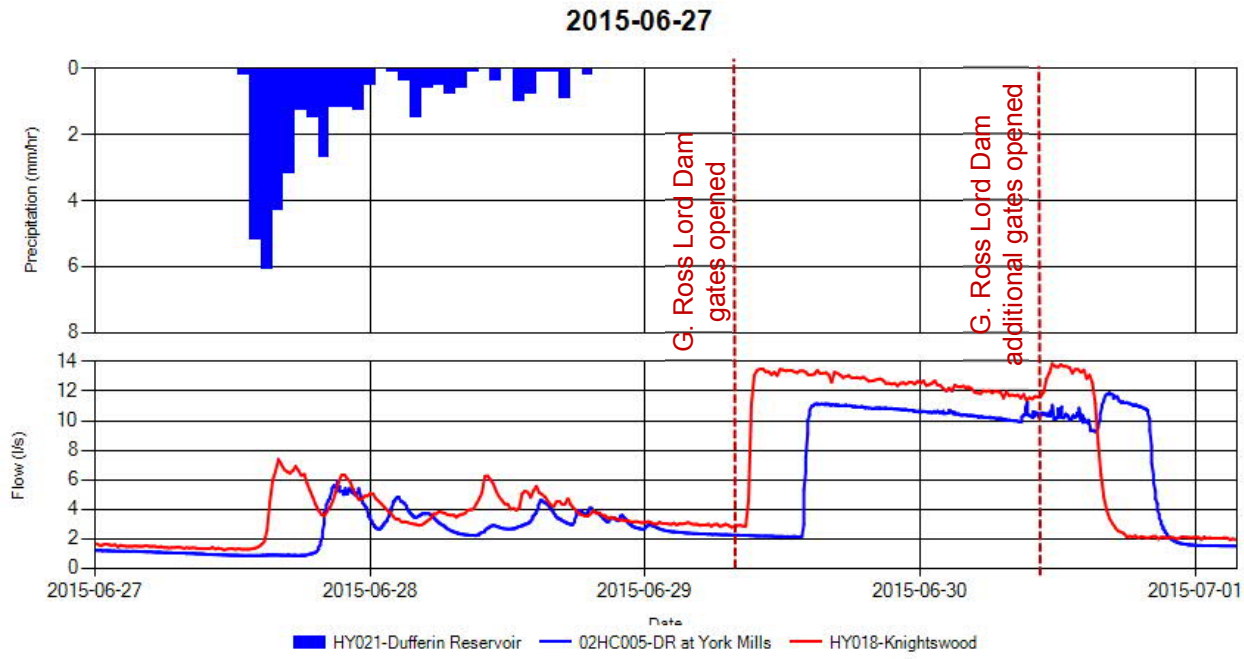


Figure 19: Timing of G. Ross Lord Gate Opening vs Flow at HY018 and 02HC005

The flow recorded by each of the two gauges for each event is similar, with HY018 generally recording 10-15% greater volume, and 10-15% greater peak flow.

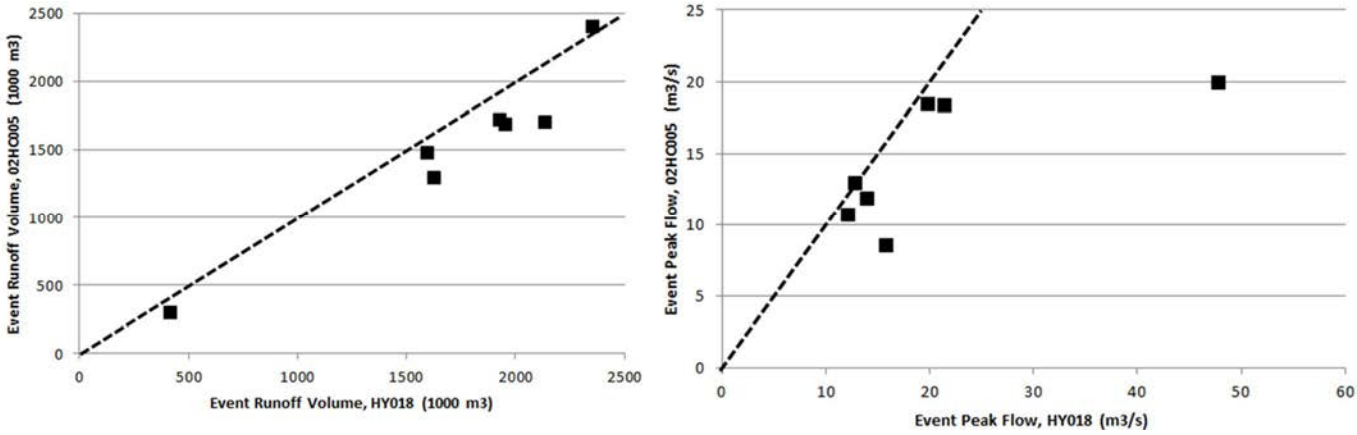


Figure 20: TRCA Stream Gauge HY018 vs WSC Stream Gauge 02HC005

TRCA indicated that the 02HC005 gauge likely has a more stable and better defined rating curve as the channel is concrete lined. Together with the fact that HY018 does not cover all the calibration / verification events, it was determined that calibration / verification will be conducted at 02HC005 in lieu of HY018, with the timing of 02HC005 adjusted to account for GMT time and day light savings.

3.2.4 HY019

It was noted that during large events such as July 8, 2013, the peak of the HY019 hydrograph appears to be 'cut-off' at around 193 m^3/s (Figure 21). TRCA's has confirmed that, due to the cross section of the channel widened substantially at a certain elevation, a huge increase in flow would be required to raise

the water level by a very small amount. It could be the cause of the flattening out of the response at the gauge.

Despite the gauge limitation, most of the data collected were still good for the purposed of calibration and verification. Calibration and verification were conducted with the best available information and that the resulting model still accurately represents the flow at the location.

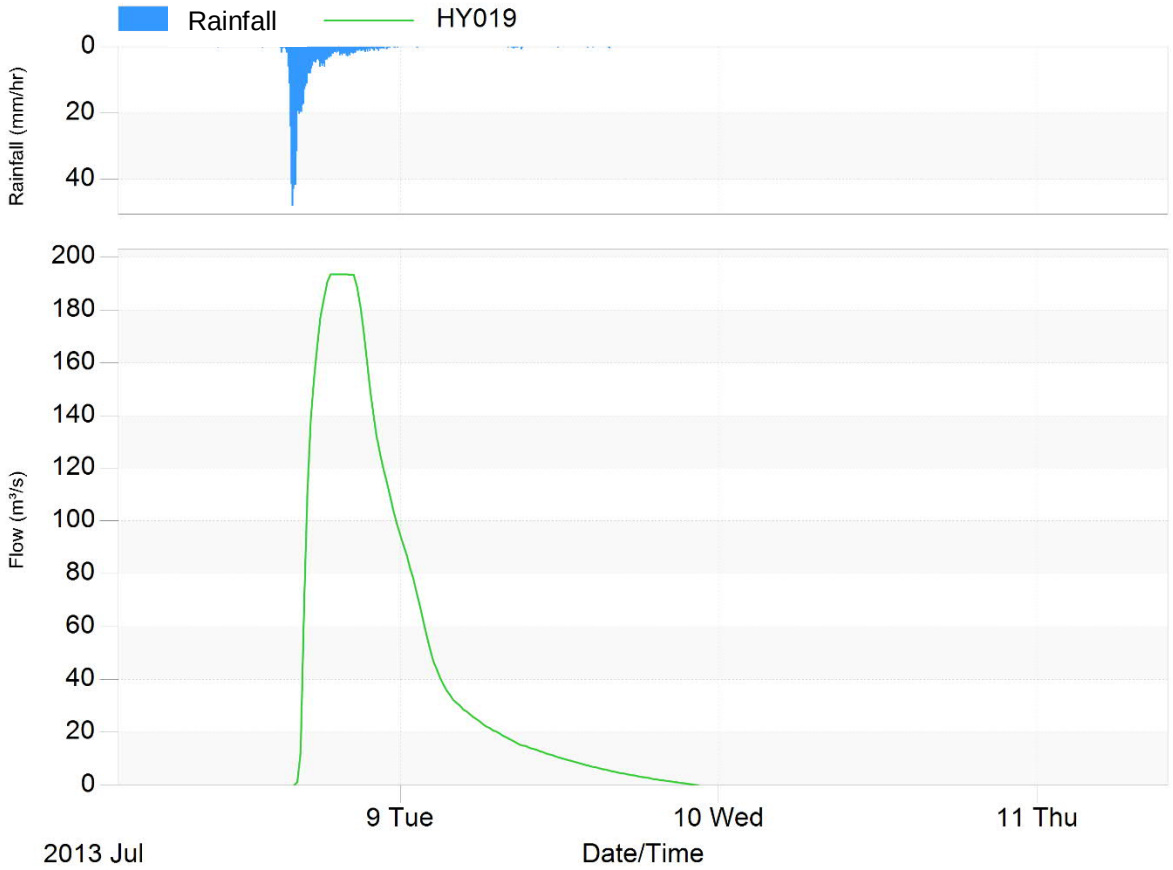


Figure 21: HY019 Peak Flow Flattened Out at High Flow

3.2.5 Baseflow Separation

Baseflow in the recorded hydrographs is typically almost negligible relative to the magnitude of peak flows recorded during an event. However, baseflow was removed from the stream gauge flow prior to using the flows to calibrating the model. Baseflow was separated using a straight line from the flow at the start of the event to the flow at the end of the event. A sample is provided below.

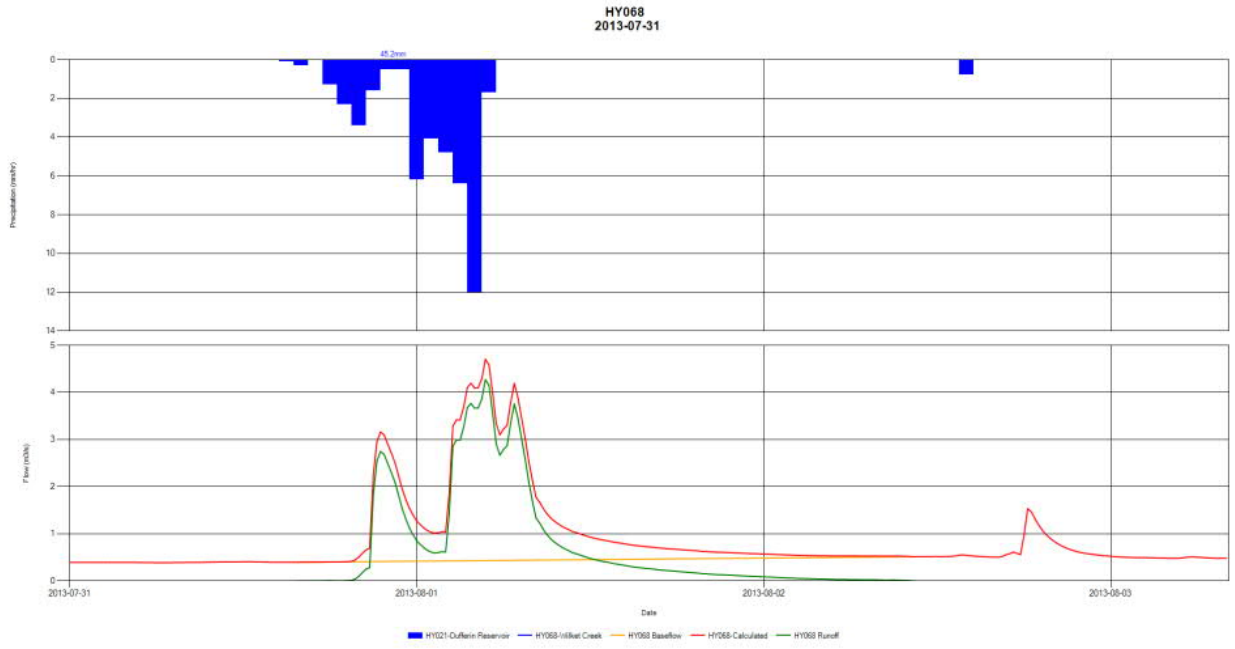


Figure 22: Baseflow Separation - Sample

3.2.6 G. Ross Lord Dam

G. Ross Lord Dam was constructed in 1973 to provide flood control for the West Don River from Finch Avenue south to the confluence with the East Don River at Don Mills Road. The dam operates in conjunction with downstream flood control channels to reduce the risk of flooding to flood prone communities.

Data for the dam (storage volumes, operating levels, rating curves for various gate openings, operating rules, etc) were obtained from the operations manual for the dam. The reservoir has an active storage of approximately 437 ha-m at a maximum operating water level of 181.36 m. The dam consists of two low level gates, two mud valves and two radial (upper level outlet spillway) gates. The two low level gates are used to control the water level above elevation 172.50 m. The two inoperable mud valves are used to convey baseflows. The low level gate operation is based on the rate of rise in water level measured at 15 minutes intervals. The rate of rise exceedance criteria and the gates operations procedures are included in the Appendix.

Data at the G Ross Lord Dam used in the current study included:

- Stage – storage relations;
- Stage – discharge relations for the range of possible gate openings; and
- Operating rules, describing when the gates are opened, typically in relation to how quickly the water level is rising in the reservoir
- Operating log, describing how the gates were operated during specific events.

The effect of the reservoir on downstream flows is evident in the measured flow at the downstream stream gauge. The location of the gauge relative to the dam is shown below.

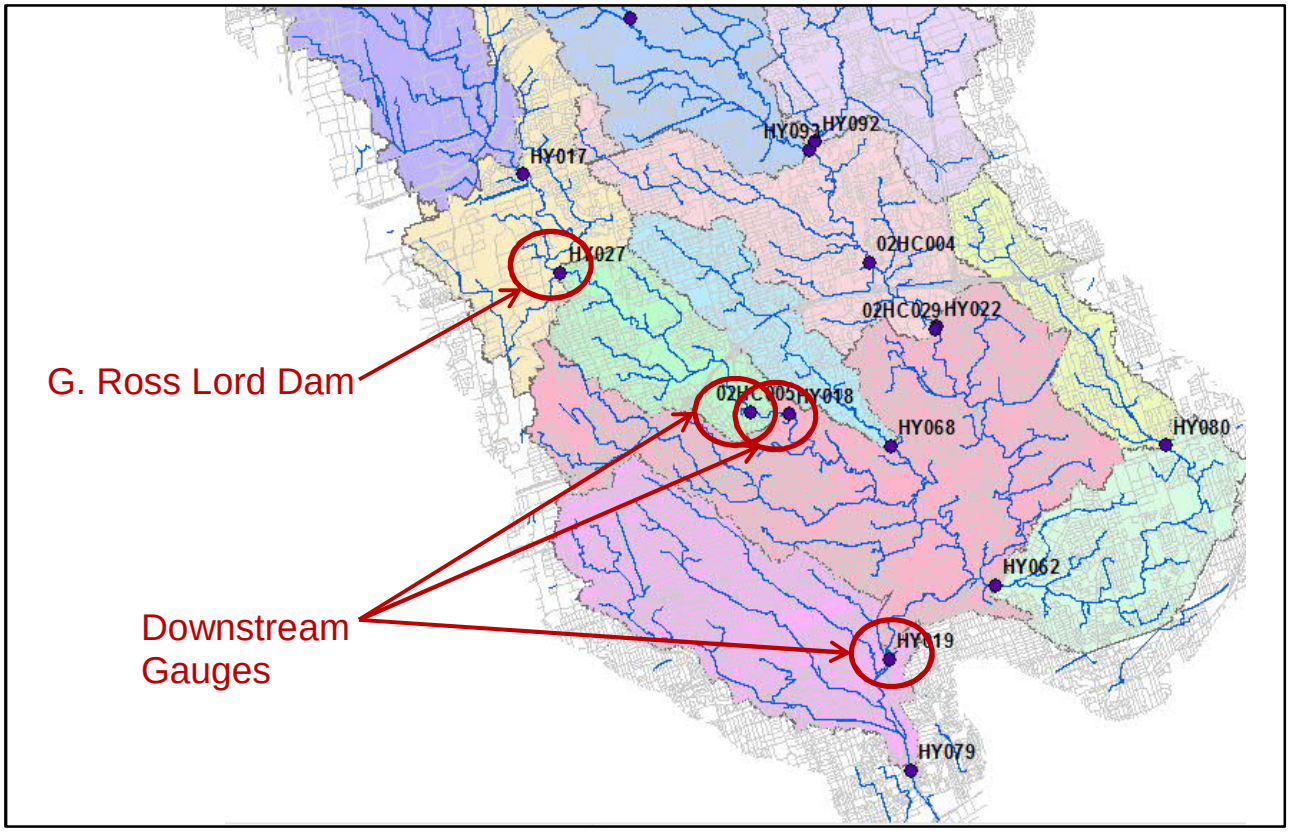


Figure 23: Stream Gauges Downstream of G. Ross Lord Dam

Table 4: G. Ross Lord Dam – Operating Log During Calibration / Verification Events

2010-07-23	Low level gate closed (opened 6 inches on July 25, 9:15 am, with WL 176.558)
2011-11-28	Low level gate closed (opened 2 inches on Nov 30, 4:00 pm, with WL 177.382; opened 4 inches Dec 1 at 5:00 pm, WL 177.193; opened 9 inches on Dec 2 3:30 pm with WL 175.895)
2012-07-25	Low level gate closed (opened 3 inches on July 26, 9:00 pm, with WL 176.420; second gate opened 3 inches July 27 at 12:38 pm with WL 176.074)
2012-09-04	Low level gate closed (opened 1 inch on Sept 5, 7:27 am?, with WL 177.024; shut 4:10 pm with WL 176.385; opened 15 inches on Sept 6 7:30 am with WL 176.306)
2013-05-28	Low level gate closed (opened 4 inches on May 29, 7:00 pm, with WL 176.763; 1 inch at 10:20 pm with WL 176.722; 4 inches on May 30 at 5:00 am with WL 176.152; 1 inch at 10:00 pm with WL 175.481; 4 inches on May 31 at 5:00 am with WL 174.585)
2013-07-08	Low level gate closed (opened 9 inches on July 9, 7:30 am, with WL 178.214; 18 inches at 1:10 pm with WL 178.181; 24 inches at 3:22 pm with WL 177.992; closed July 10 at 1:00 am with WL 176.583; opened 9 inches on July 10 at 7:10 pm with WL 176.672)
2013-07-31	Low level gate closed (opened 9 inches on Aug 1, 2:00 pm, with WL 175.867; closed Aug 2 12:45 pm with WP 174.471; opened 9 inches on Aug 3 at 2:38 pm with WL 174.443)
2013-09-20	Low level gate closed (opened 6 inches on Sept 22, 10??:40 am, with WL 176.846??; opened 1 inch at 9:36 am?pm? With WL 174.314)
2014-07-27	Low level gate closed (opened 6 inches on July 27, 11:40 pm, with WL 174.378)
2014-09-10	Low level gate closed (opened 9 inches on Sept 11, 3:08 am, with WL 175.807; opened 18 inches Sept 12, 8:43 am with WL 174.917)
2015-05-30	Low level gate closed (opened 12 inches on June 2, 8:00 am, with WL 176.126)
2015-06-27	Low level gate closed (opened 9 inches on June 29, 8:00 am, with WL 176.161; opened 12 inches on June 30 at 10:15 am with WL 173.591)
2015-10-28	Low level gate closed (both gates opened 12 inches on Oct 29, 10:33 am, with WL ???; both gates opened 18 inches at 6:00 pm, with WL ???)

The stream gauge data clearly shows that for every calibration event, the dam lower gates were not opened until after the event was over. A sample is provided below. The timing of the rise in flow downstream coincides with the time that the lower gates were opened as recorded in the dam log book. The initial hydrograph at the gauge responding is therefore considered to be entirely due to the response of the catchment downstream of the dam, with no flow in the dam beyond baseflow.

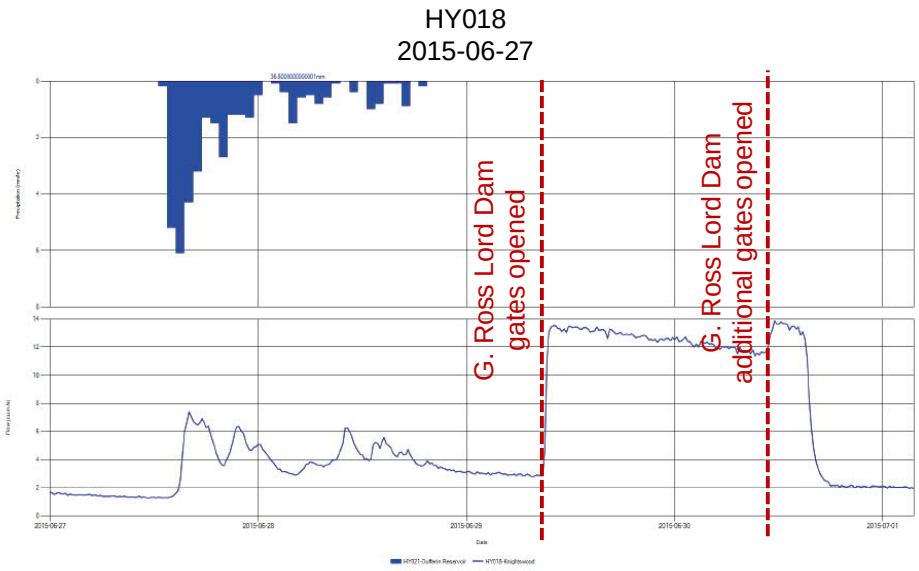


Figure 24: Timing of G. Ross Lord Gate Opening

The effect of the dam can also be seen in the upstream gauge HY017 for several events. On the receding limb of the hydrograph, after the rainfall is over, it would be expected that flow would gradually recede to baseflow. However, the reservoir (with lower gates closed) continues to rise after the peak flow; when the reservoir water level gets high enough, tailwater from the reservoir extends far enough upstream to cause an increase in water levels at the gauge location.



Figure 25: Location of Stream Gauge Upstream of G. Ross Lord Dam

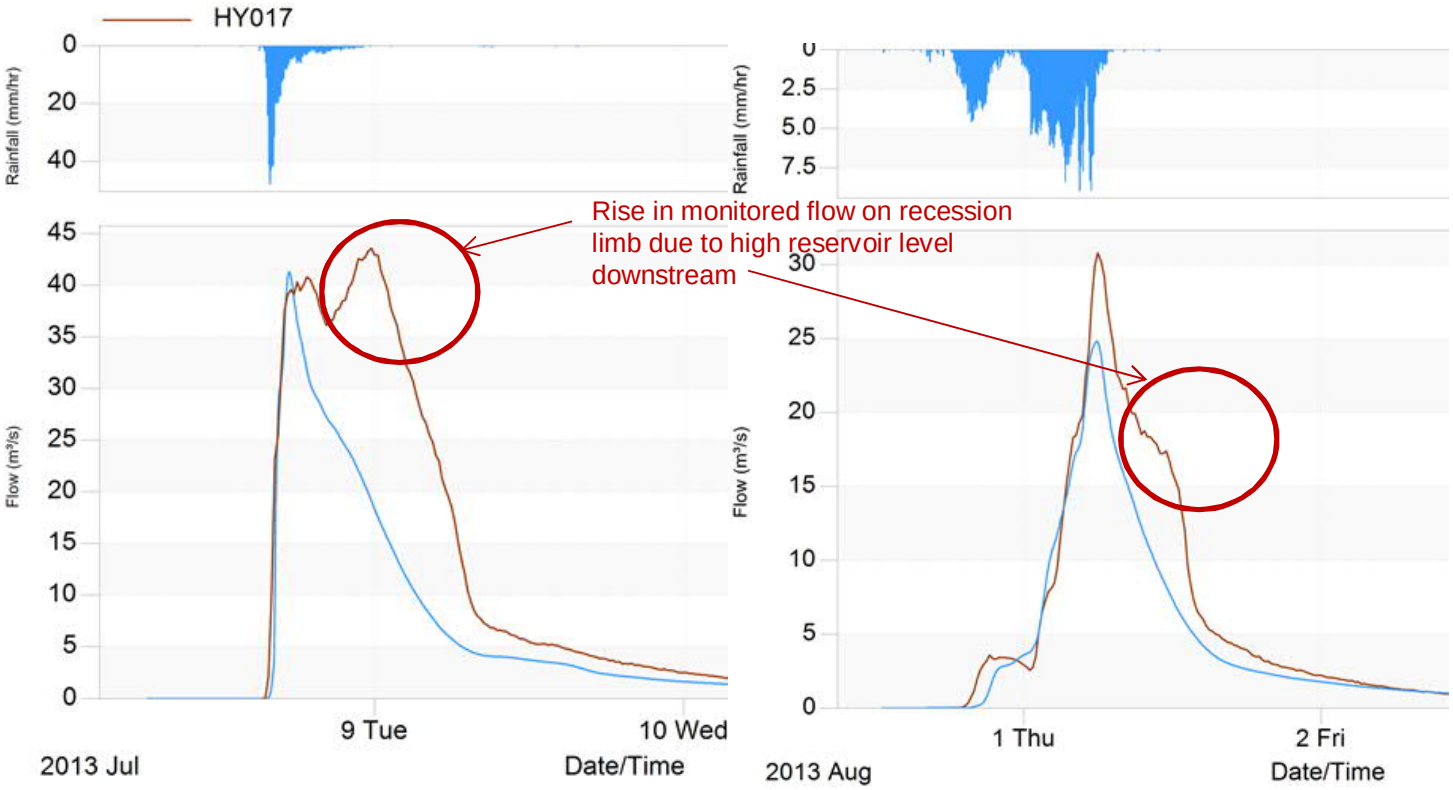


Figure 26: Effect of G. Ross Lord Water Levels on Upstream Stream Gauge Measurements

AECOM reviewed the existing HEC-RAS model of the reach provided by TRCA to verify if it was feasible that backwater from the reservoir could extend upstream to the stream gauge location. The Figure below shows the water surface profile in the existing model, with water levels in the reservoir ranging from low to high levels.

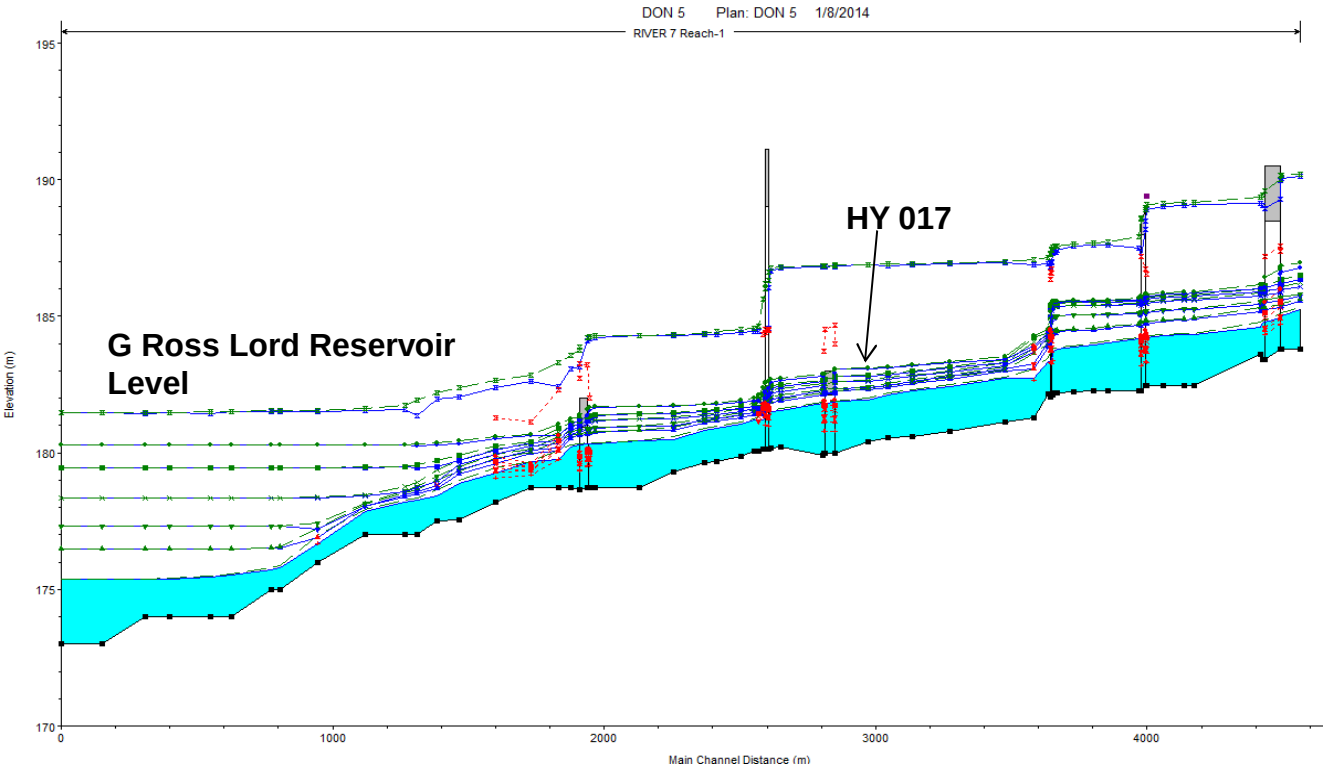


Figure 27: Hydraulic Profile from G. Ross Lord Dam to Upstream Stream Gauge

The existing model did not indicate any backwater effects extending as far upstream as the HY017 gauge. However, with minor adjustment of some parameters (for example, changing channel roughness from 0.035 to 0.04, and defining the low flow channel with more detail) the model did show that high reservoir levels could increase the depth at HY017 for a range of high flows, which would cause erroneously high flow measurements at the gauge.

AECOM considered this influence during the model calibration.

3.3 Events for Calibration

Due to the highly urbanized nature of the Don River watershed, as well as historical flood events were mainly summer thunderstorms and large frontal events, only summer and fall events were considered in the event selection process. Spring flows or late fall flows, where snowmelt may represent a significant portion of the flow, were excluded from the model calibration. AECOM selected rainfall events for calibration and verification based on the size of the event, the date of the event, and the uniformity of the event over a large number of gauges. The largest events were selected for calibration; it was determined that an appropriate number of events would be available if only events larger than 35 mm were considered. The more recent events were also selected for calibration, since it ensured that the largest number of stream and rain gauges were installed and operating. For this reason, only events after 2010 were considered for calibration. Finally, since spatial variability of rain is a large potential source of

calibration error, events were also screened based on similar rainfall volumes recorded across numerous rain gauges.

A summary of all rain events larger than 35 mm, highlighting the events selected for calibration and verification, are provided below. AECOM used 7 events for calibration, and 6 events for verification based on the screening. Upon TRCA's request, August 19, 2005 event was included in verification, bringing the total number of verification events to 7.

Table 5: Events Selected for Calibration and Verification

	HY003	HY007	HY008	HY016	HY021	HY027	HY036	HY038	HY039	HY055	HY064	HY069	HY070	HY071	HY076	HY083	HY085	HY087	HY094
July 9, 2010			36																
July 23, 2010					40.8		39.8		48.2	46.4	39.8	47.6	47.4						
July 24, 2010								44.2											
August 9, 2010												44.8							
August 22, 2010			63.6	59.8			43.6												
September 30, 2010								35.4											
March 11, 2011					42.1														
May 16, 2011					35.8		35.2	47.8	46.2	40.2	42.6								
June 26, 2011								36.6											
July 25, 2011					39.9		45.8												
August 9, 2011					36.1		51.6				69.8								
September 24, 2011					36.4														
September 30, 2011				36.4															
October 21, 2011								36.2											
November 30, 2011	49.6		46.4	49.6	50.8	36.6	48.2		52.8	48.4	46.2	42.4	49.8						
December 1, 2011								57.2											
June 2, 2012			45.4	36.8	36.7		35.6					42.8							
July 16, 2012							37.6												
July 17, 2012								56											
July 23, 2012							36.4												
July 26, 2012	35.2		44.8	43.2	54.0	40	39.6		75	83	47.4		35.2						
July 27, 2012								41.8											
July 31, 2012					47.4														
August 1, 2012						52.2					65.6	50.6	44						
August 28, 2012							38.4												
September 4, 2012					38.8														
September 5, 2012	41.2					53	49.8		40.8	41.4	63.8	45.2	62.4						
September 6, 2012								48.2											
September 8, 2012					36.3	39.6	40				38.2								
September 9, 2012	40		42.8	46.4															
November 3, 2012								64.8	74										
April 11, 2013									37										
May 29, 2013	50.6		60	56.2		56.6	40.6			41.2	57.4								
May 30, 2013									39.4										
June 11, 2013					40.5	36.6						42.4	35.4						
June 14, 2013													50.4						
June 28, 2013											70.6								
July 8, 2013	35.8																		
July 9, 2013	88.6		69.4	50.2	40.7	67.6		73.2		79	74.0								
July 10, 2013									115.4										
August 1, 2013					45.2	45	44	50	47	44	41.6	46.6	45.8						
August 28, 2013	43.2							35.2				44							
August 30, 2013									49										
September 21, 2013					41.9						43.0	42.4				52.1			
September 22, 2013				42.2				48.6	47.2	42.4			40						
June 26, 2014	40.6		49	51.6		52.8													
July 28, 2014					35.4	75.6	65.2	50.4		50.4	67.2	56.6	41.6			79.9			
July 29, 2014									63.2										
August 2, 2014						70.6													
September 2, 2014										43.2									
September 3, 2014																37.3			
September 6, 2014								67	65.4			58	43			61.7			
September 11, 2014					35.5	38.6	40.4	37.2			43.4	36	36			41.7			
October 16, 2014					36.8														
October 17, 2014						41.4					53.0								
June 1, 2015	39.8		43.6	49.8		64.8	55		60.6	52		44.4	51.4			45.7		43.8	40.4
June 8, 2015				37.2	35.5	36						35.6	37			40.4			
June 11, 2015									40.2										
June 23, 2015						55.2	41.2									36.5			36.2
June 28, 2015					36.8		48.6					47.4							
June 29, 2015	51.8		43	38.4		37.4		35.6								56.6		59.2	48.2
June 30, 2015									35.2										
August 11, 2015						52.6	47												
October 29, 2015	47.6		60.7	60.6		42.6	50.8					37				37.8		48	62.2
			38.8																

3.4 Calibration Methodology

The calibration methodology consisted of two separate considerations: (a) calibrating runoff volume, and (b) calibrating response time (peakiness, and peak flows) at the catchment and watershed level.

3.4.1 Calibrating Runoff Volume

Impervious Surfaces

The initial step in the volumetric calibration was to determine the portion of runoff that can be attributed to direct runoff from impervious surfaces. In the model, the percentage of the catchment with directly connected impervious surfaces is

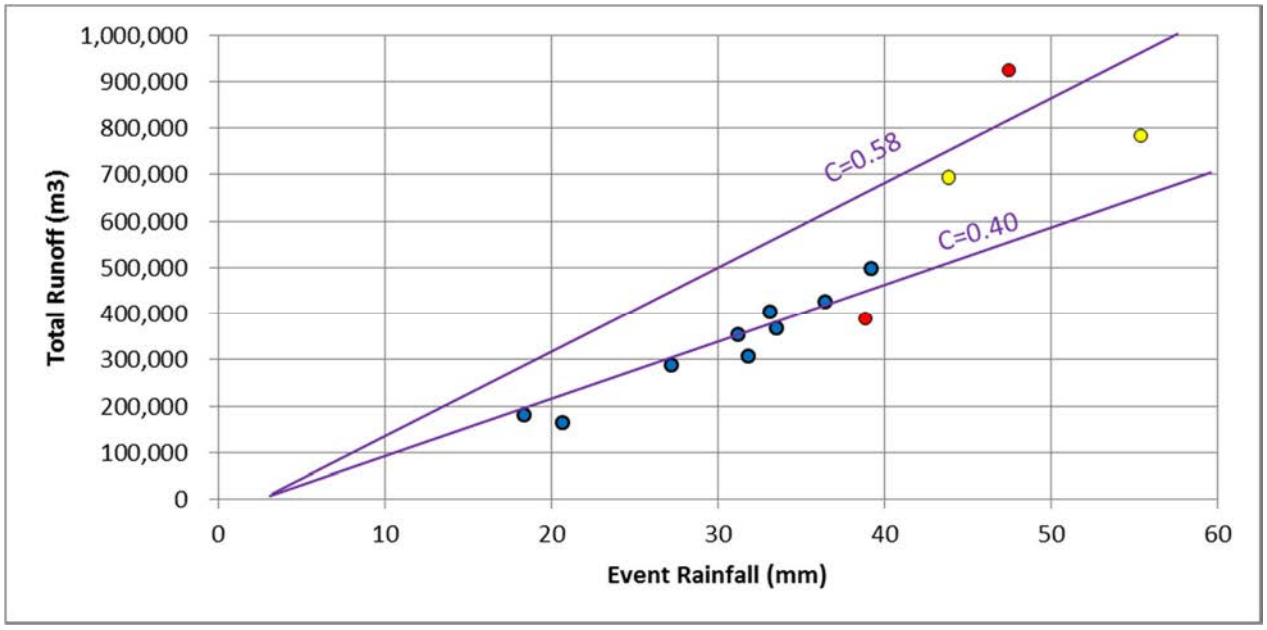
Directly connected imp = Total imp x (1 - *% imp area routed to pervious areas*)

The "% of the impervious area routed to pervious areas", or "% routed", can be physically related to roof areas that drain onto pervious surfaces; or sidewalks, driveways, parking lots, or paths that drain overland onto pervious surfaces. It is reasonable for this value to be as high as 50% for single family residential areas, although it would be much smaller for higher density or non-residential areas.

The total directly connected impervious area contributes a specific volume of runoff, which can only be significantly modified by the 'percent routed' value. The gauged volumes clearly show that, for most events, the runoff from the directly connected impervious portions account for most of the runoff recorded at the gauges for the events.

The directly connected impervious area has a very clear response to rainfall; the entire area (less a very small initial depression storage) has 100% runoff. If 35% of a subcatchment is directly connected impervious area, it would be expected that these surfaces generate a runoff volume close to 35% of the total rainfall volume over the catchment, regardless of the size of the rainfall event. Since it is reflected as a fixed percentage of runoff for every event, it should be evident as a straight line in volumetric plots of monitored rainfall vs monitored runoff, as illustrated below.

Gauge HY062



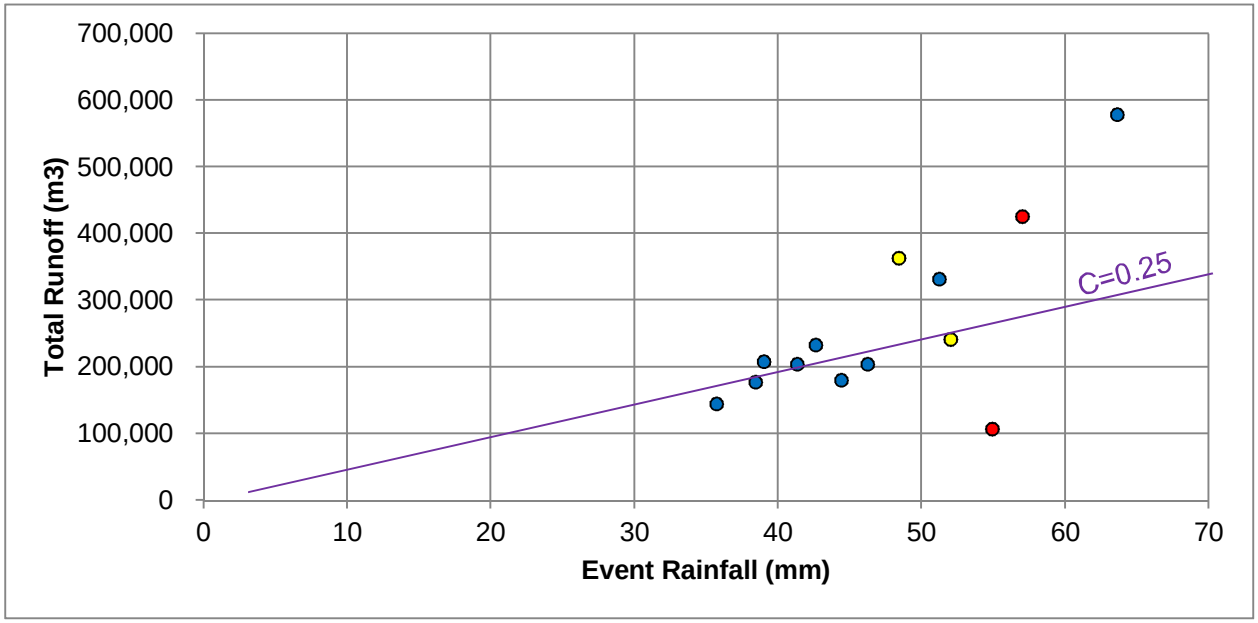
The volumetric plot for each event for Gauge HY062 indicates that at a minimum approximately 40% of the total rainfall in the watershed becomes runoff (after allowing for 2 mm of depression storage). As a result, it is initially assumed that 40% is generally representative of the base fixed runoff in this watershed

– i.e. representative of the directly connected impervious portion. Since the total imperviousness in the catchment is 55%, the "% routed" value is calibrated to 30%, such that

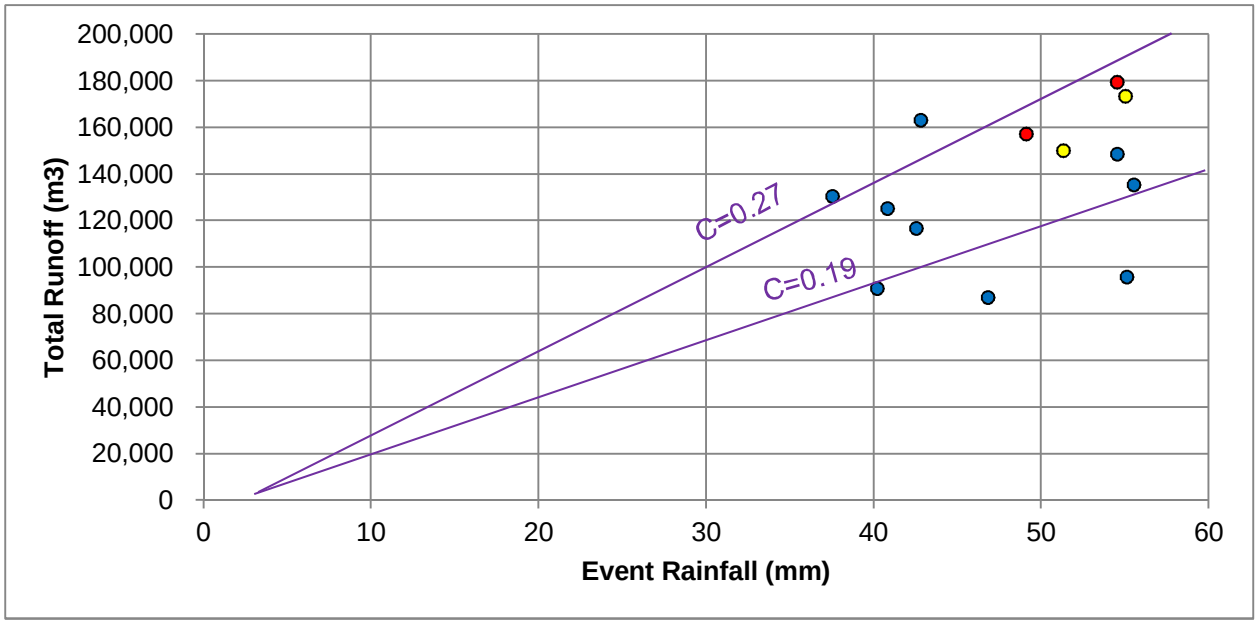
Directly connected imp = Total imp x (1 - *% imp area routed to pervious areas*)
0.40 = 0.55 x (1 - 0.30)

Similar volumetric plots and initial estimates for "%routed" (and total directly connected impervious area) for each stream gauge location are shown below.

Gauge 02HC005



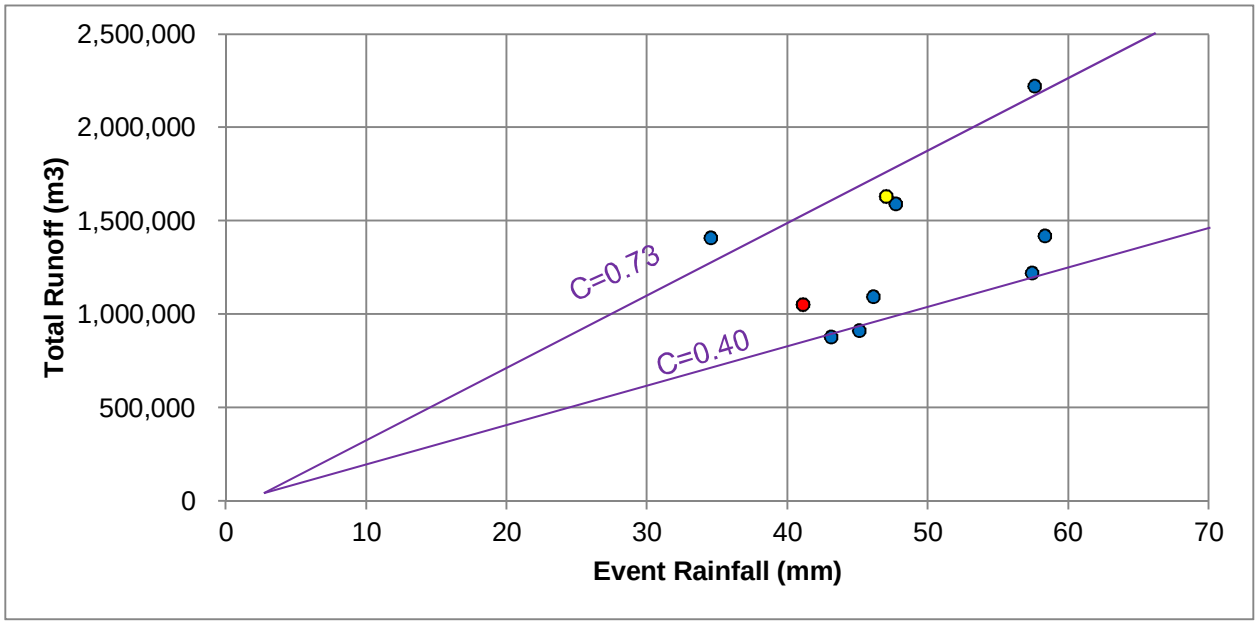
Directly connected imp = Total imp x (1 - *% imp area routed to pervious areas*)
0.24 = 0.41 x (1 - 0.40)



Directly connected imp = Total imp x (1 - *% imp area routed to pervious areas*)
0.19 = 0.43 x (1 - 0.55)

A similar procedure was followed for Gauges HY017 and 02HC056, with the difference that these catchments were split into urban areas and rural areas which were calibrated separately.

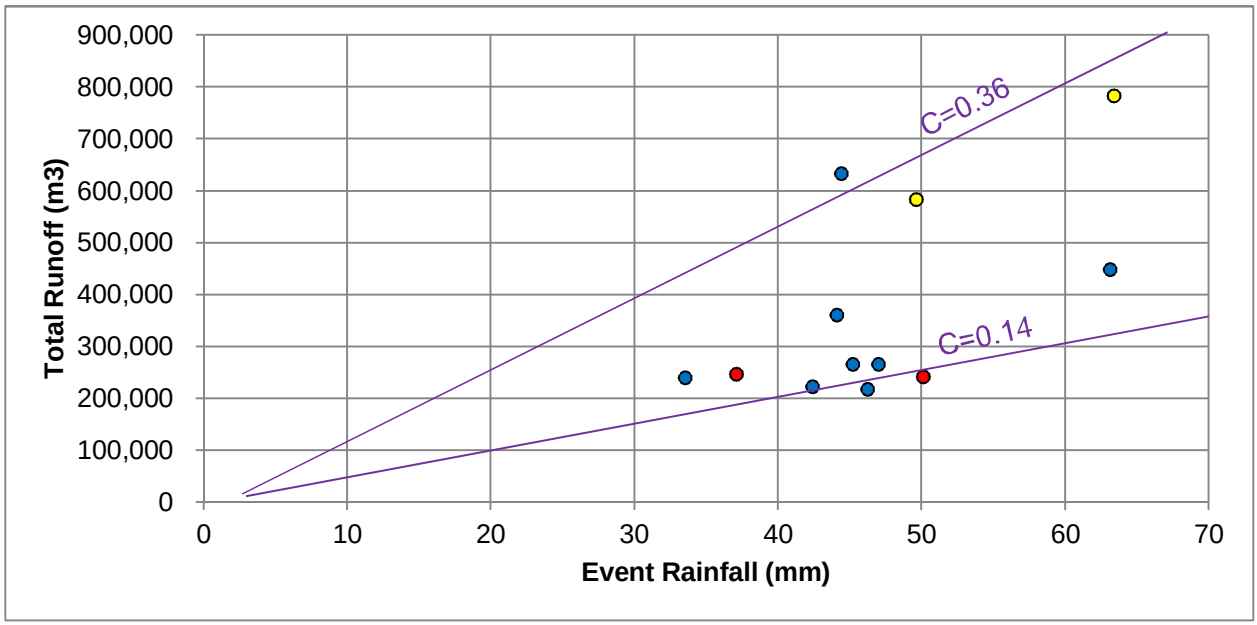
Gauge HY017- urban areas



Directly connected imp = Total imp x (1 - *% imp area routed to pervious areas*)

0.40 = 0.49 x (1 - 0.20)

Gauge 02HC056 - urban areas



Directly connected imp = Total imp x (1 - *% imp area routed to pervious areas*)

0.14 = 0.30 x (1 - 0.55)

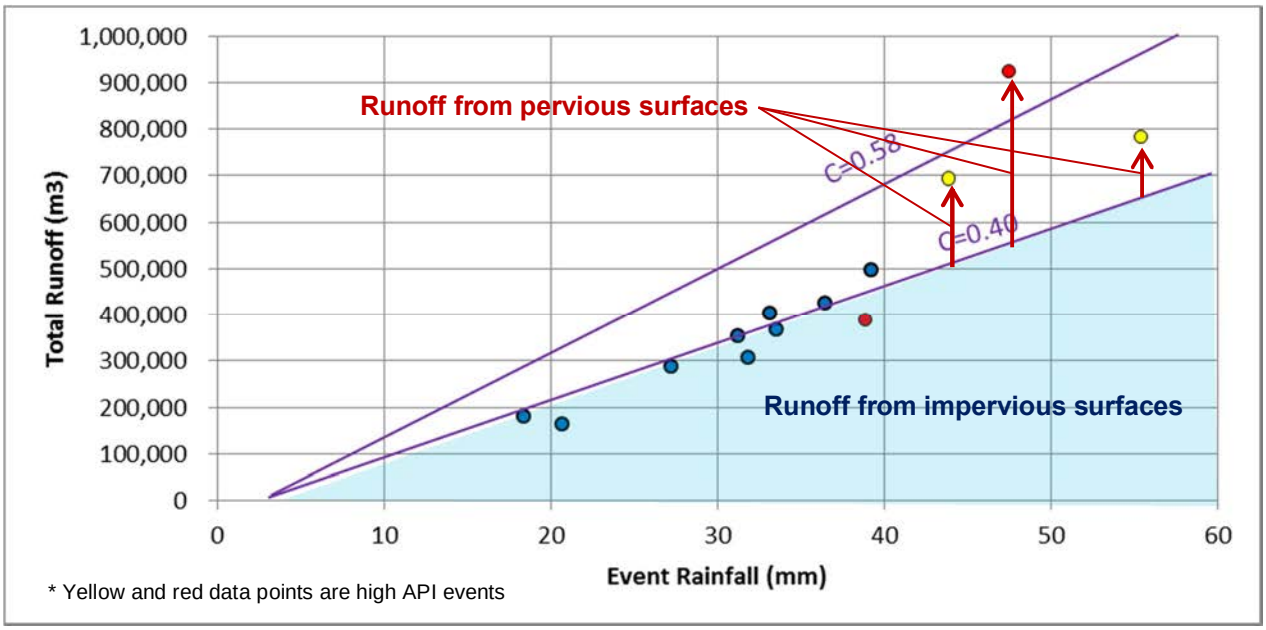
The model was run for only directly connected impervious runoff at this stage to verify that the shape of the hydrographs were reasonable, and the peak flows from impervious runoff was also reasonable, prior to adding pervious runoff to the model.

Pervious Surfaces

As illustrated in the example plot below, the volumetric plots and measured flows both indicate that for most of the calibration events there is very little runoff from pervious surfaces in the watershed. Both also indicate, however, that pervious runoff increases for (a) larger storms; and (b) storms that occur with high antecedent moisture conditions.

The volumetric plot for gauge HY062 shows both of these influences clearly. It is evident in other gauges as well – although less clearly. The volumetric plot clearly indicates a linear relation between rainfall volume and runoff volume, which is the expected response from directly connected impervious surfaces (i.e., all rainfall becomes runoff). For runoff from impervious surfaces, the runoff volume will plot as a straight line compared to rainfall. The volumetric plot also indicates that additonal runoff volume occurs for only a few events, which can be associated with high rainfall volumes and/or high antecedent rainfall, This is also an expected response from pervious areas, where runoff volume will increase under conditions where the soil is more saturated.

Gauge HY062



The general calibration methodology employed for pervious surfaces is as follows:

- For calibration events with small to negligible pervious runoff after accounting for the directly connected impervious runoff:
  - Use the 'textbook' value of dry IMD in the Green & Ampt infiltration parameters
  - Increase the saturated hydraulic conductivity in the Green & Ampt infiltration parameters only enough such that a minimal amount of pervious runoff is generated, consistent with stream gauge results
- Once the saturated hydraulic conductivity is calibrated from events with small to negligible pervious runoff, the larger calibration events with significant pervious runoff are examined:

- The larger calibration rainfall events are run in the model, and flow responses with the calibrated saturated hydraulic conductivity and dry IMD values are noted
- To account for the larger pervious runoff under wetter conditions, the IMD is decreased for each event until the model runoff volume most closely matches the monitored runoff volume

The final step in the volumetric calibration is to relate the calibrated IMD of each event to the calculated antecedent precipitation index of each event. Plotting the calibrated IMD vs the antecedent precipitation index for the calibration events produces the following suggested relation.

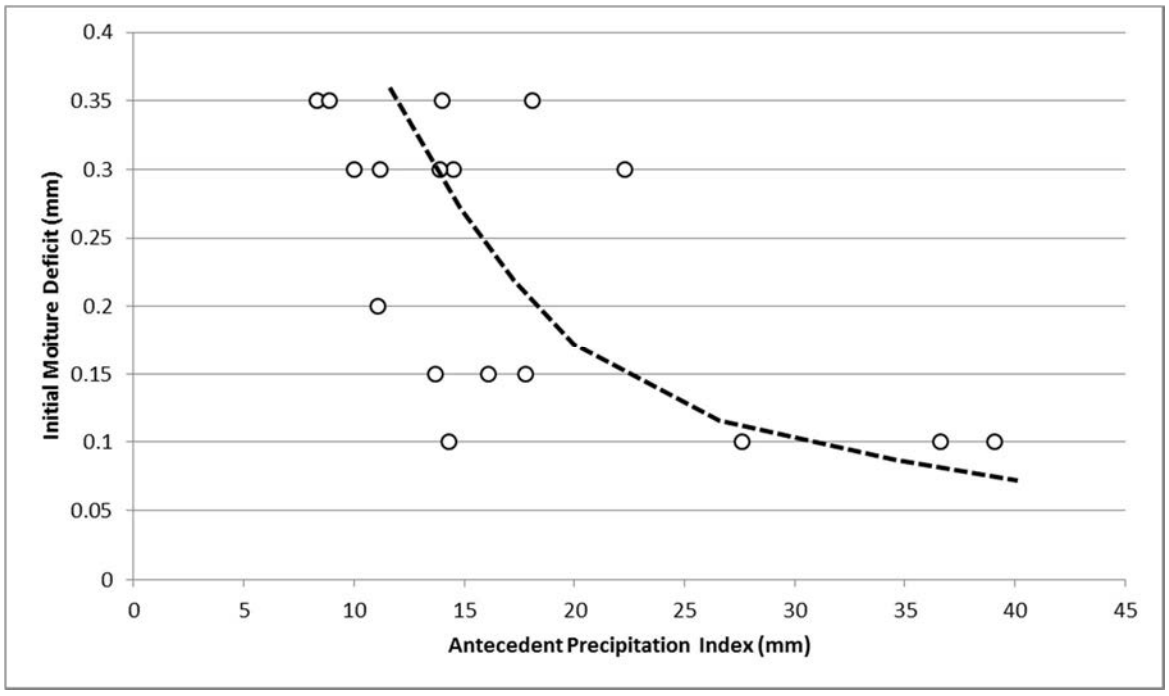


Figure 28: Calibrated Initial Moisture Deficit vs Antecedent Precipitation Index for Calibration Events

The stream gauge and rainfall data indicate that the volumetric runoff coefficients for Don River catchments do not increase significantly until very large rainfall volumes occur during the storm and preceding the storm. Since these events are fairly rare (i.e. a very large rainfall event preceded by very large antecedent rainfall), there are only a couple relevant observed events to form this relation. It is recommended that TRCA should continue to update this relation in the future, focusing on extremely large events that occurred in very wet catchment conditions.

3.4.2 Calibrating Peak Flow

Once the runoff volume was calibrated, other model parameters were further calibrated to improve the peak flow estimate. These parameters were adjusted to improve both the general shape of the response hydrograph (i.e. the 'peakiness' following individual rainfall peaks, the recession) and the overall maximum peak runoff for the event.

The primary terms considered for calibrating the timing of the response were the subwatershed length (through calibration of the 'width' parameter) and the Manning's n in the main channel. In general, the default parameters resulted in a modeled hydrograph that was, at every gauge, slightly less 'peaky' than the observed hydrograph at the stream gauge. The catchment width was initially increased (length

decreased) to try to provide a faster hydrograph response at the catchment level. However, this produced minimal increase in the rapidness of the response, likely since care was taken during the initial model set up to limit the overland flow length. A more significant increase in the 'peakiness' of the hydrograph was obtained when decreasing the Manning's n value in the main channel. To some extent, increasing the Manning's n also resulted in better alignment of the timing of the peak flows between the modeled and monitored response. Using this approach, the final calibrated model used Manning's roughness values of 0.015 to 0.03 in the main channel for much of the study area.

3.5 Calibration Results

3.5.1 Calibrated Model Parameters

The final calibrated model parameters are provided in the Table below:

Table 6: Final Calibrated Model Parameters

	% Routed (pervious)	Green & Ampt Parameters			Manning's n, channel
		Suction Head (mm)	Hydraulic Conductivity (mm/hr)	Initial Moisture Deficit	
02HC005	40%	89	3.3	0.1 (July 2013) 0.35 (rest of events)	0.015
02HC056 (urban)	55%	90	10	0.1 (July 2013, Sept 2014) 0.3 (rest)	0.025
HY017 (urban)	20%	90	10	0.1 (July 2013, urban area only) 0.3 (rest, urban area only)	0.03
HY027	55%	90	10	0.1 (July 2013) 0.3 (rest)	0.03
HY019	55%	89	3.3	0.15 (July 2013, Sept 2014, June 2015) 0.35 (rest)	0.02
HY062	30%	90	25	0.2 (July 2013) 0.3 (rest)	0.022
HY068	55%	90	40	0.1 (July 2013) 0.3 (rest)	0.02
HY092	20%	90	25	0.2 (July 2013) 0.3 (rest)	0.03

There is a considerable range in the calibrated hydraulic conductivity of the soils in each watershed. This reflects the fact that there was a considerable difference in the relative volume of runoff measured from each watershed: Gauge 02HC005 (Don River at York Mills- on the west branch downstream of G Ross Lord dam) recorded high relative volume of runoff for large events, while for Gauge HY068 (Wilket Creek) the relative runoff from larger events wasn't significantly different from smaller events.

The hydraulic conductivity provides a threshold that rainfall intensity needs to exceed before surface runoff can occur. The watershed upstream of Gauge will generate runoff (once the initial moisture deficit is filled) when rainfall exceeds 3.3 mm/hr; for the watershed upstream of Gauge HY068, the rainfall has to exceed 40 mm/hr. This reflects the actual gauged runoff in these watersheds for various large rainfall events used in calibration.

The calibrated values are within the range of textbook values for different soil types. Sand can have a hydraulic conductivity as high as 120 mm/hr, with loamy sand at 30 mm /hr. Sandy loam has a saturated hydraulic conductivity of 11 mm /hr. Sandy clay loam has a saturated hydraulic conductivity of 2 mm/hr.

The wide range in calibrated values is felt to reflect the equally wide range in historically applied values for a range of soil types.

3.5.2 Calibration Results for Individual Events and Gauges

Calibration results, including tables for goodness of fit for volume and peak flow at each gauge, are provided in the report Appendix.

3.5.3 Verification Results for Individual Events and Gauges

The model was verified with 6 independent storm events that were not used in the model calibration. The verification results, including tables for goodness of fit for volume and peak flow at each gauge, are provided in the report Appendix.

3.6 Discussion – Assessment of Calibration, Potential Sources of Errors

The calibration methodology is felt to have a degree of inherent conservativeness, since key infiltration parameters (i.e. saturated hydraulic conductivity) are consciously set during model calibration to be as small as possible while still providing good calibration results.

Potential calibration errors, and in turn potential model inaccuracies that would affect the flow estimates, are discussed below.

- **Infiltration may be under-estimated**. This would be primarily due to under-estimating saturated hydraulic conductivity. The modeled runoff will therefore be over-estimated, resulting in a conservative model.
- **Infiltration may be over-estimated.** This is potentially a more serious concern, since it would lead to the model under-predicting flows. It is potentially a risk, since the calibrated Green & Ampt parameters (suction head and saturated hydraulic conductivity) give much more infiltration than textbook values of these parameters for the soil type noted in local soils mapping. In defence of the higher infiltration rate in the calibrated model parameters, the model agrees with the monitored flow volumes. And the soils mapping may not be a good indication of remaining pervious ground cover conditions is a watershed that is largely urbanized, such as the Don watershed. Actual soils are highly disturbed, graded, potentially imported, and given various treatments in both public space and private lots that significantly alter their water holding and infiltration capacity.
- **Spatial variability of rain – i.e. rain gauges did not reflect actual rain in the catchment.** This is always a concern during calibration, especially with a catchment as large as the Don watershed, although the methodologies employed for the study minimize this potential error.
- **Gauge issues upstream of G Ross Lord dam.** The stream data analysis indicated that tailwater from the dam affected upstream flow measurements. The analysis allowed for this, but the hydraulic model could not clearly show the problem without adjusting channel roughness to force it to. This potential error only affects the branch upstream of the dam.
- **Inaccurate flow data.** Potential errors minimised through rigorous QA/QC of data by both the Water Survey of Canada and TRCA. By having some gauges in line, the downstream gauge partially verifies flow at the upstream gauges. In one instance, having two gauges (one WSC, one TRCA) at almost the same location showed measured volumes and peak flows within 15% of each other; this may be a general indication of gauge accuracy. It is generally a concern, as well, that the very high flows may be inaccurately recorded, since they will exceed the range that the rating curves have been physically calibrated, and the rating curve is extrapolated using known features of the cross section. In addition, at high flows a very small change in water level may represent a large change in flow (due to spread of the flow over a wider floodplain), which also makes the higher flow estimates inherently less reliable.

- **Too much flow assigned to 'directly connected imperious' areas.** One of the properties of the model is that very little flow results from pervious areas for most events, and it takes a very large rainfall event, or wet antecedent conditions, to generate significant pervious runoff. This is a direct result of configuring the model such that directly connected impervious areas account for much of the runoff volume for most storms. There was much evidence that this is an accurate assumption – based on accurate volumetric accounts of gauged rainfall and runoff, accurate imperviousness calculations, and in many cases extremely high resulting values for the portion of the impervious areas routed onto pervious areas. It would be difficult to assign less flow from impervious areas in most basins without increasing the "%routed to pervious" higher than 70%; as a result, it is unlikely that this is a major source of error.

Each of these potential sources for error was recognized, sensitivity assessments performed to gauge the potential effect on model results, and processes put in place to minimize the likelihood of each potential error.

4. Model Results – Design Storm and Regional Storm

The final calibrated and validated Don River hydrology model was used to estimate peak flows for the 2, 5, 10, 25, 50, 100 and 350- design storms and the Regional storm under existing and future land use scenarios at about 272 locations in the watershed. The purpose was to update the stormwater management quantity control criteria to mitigate the negative effects of future urban expansion in the watershed and to define the design requirements for other ongoing flood remediation projects within the Don River watershed.

4.1 Design Storm Simulation

The calibrated model was run with a set of design rainfall events, for return periods of 2-years to 100-years, including the following rainfall distributions:

- Chicago 3hr, 4hr, and 12 hr storms;
- SCS 6 hr, 12 hr, and 24 hr storms;
- AES 1 hr and 12 hr storms.

The storms were generated using an IDF curve from the Toronto City rain gauge (ID 6158355, located on the University of Toronto campus). The IDF curve uses rainfall from 1940 to 2017. The last IDF curve update provided by Environment Canada used data from 1940 to 2007. AECOM obtained rainfall data in 15 minute increments from the gauge through 2017, and updated the IDF curve based on this data; a memo outlining the updating of the Toronto City IDF curve is provided in the report Appendix.

For all distributions, the longer duration distribution produced larger flow estimates at the outlet of the Don River. The 12 hr Chicago storm and the 24 hr SCS storm both produced flows that were approximately 20-25% higher than the 12 hr AES storm. Results for existing land use and for future land use are provided in the report Appendix.

Both the TRCA Technical Guidelines for Flood Hazard Mapping (Sept 2015) and the MNR Technical Guide, Flood Hazard Limits (2002) state that areal reduction factors should be used for all design storms including 2-year through 100-year events. The TRCA guidelines do not specify the areal reduction factor; the MNR guide provides curves by both the World Meteorological Organization and the National Weather Service, which provide comparable reduction factors for similar sized watersheds.

Using the equivalent circular area method, the equivalent size of the Don River watershed at the Todmorden gauge is approximately 620 km^2, and the equivalent size at the Knightswood WSC gauges is approximately 360 km^2. This implies an areal reduction of the peak 1 hr rainfall of approximately 0.65 for the Todmorden gauge and 0.70 for the Knightswood gauge.

The modeled design storm flows (after aerial reduction) were compared to peak flow estimates obtained by a frequency analysis of gauged flows. This comparison was completed to further validate the model results, to ensure the results are within an acceptable range, and to help define an acceptable design storm distribution.

The results show that the 12 hr AES design flow estimate in the calibrated model is approximately equal to the flood frequency estimate for the 10 year flow, but progressively higher for larger events, and eventually 35% higher than the flood frequency estimate for the 100-year flow. AECOM's opinion is that the reason for this deviation for the larger events is that the most intense storms are likely to have greater spatial variability than the smaller events. The most intense portion of an extremely large rainfall event is likely to only extend over a small area: much smaller than 65% of the catchment (as represented by the WMO areal reduction factor). The model with WMO aerial reduction therefore assumes a much larger spatial extent of the extremely large storms compared to the potential smaller footprint of the real event. This will cause the model to progressively over-estimate the larger events (by progressively under-estimating the spatial variability of the larger events).

Detailed results of the flood frequency analysis (FFA) are presented in the next Section.

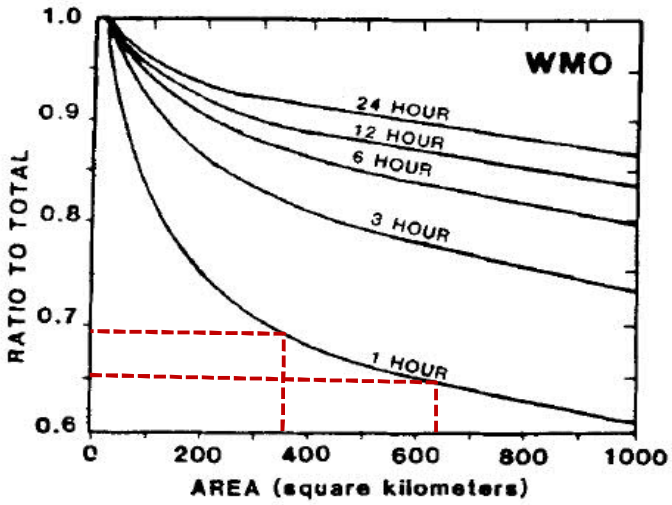


Figure 29: Areal Reduction Factor for Design Storms

AECOM recommends that the 12 hr AES storm should be used as the design storm distribution for the Don River. This recommendation is based on:

- The MNR Technical Guide, Flood Hazard Limits (2002) state that AES distribution is preferable to the Chicago and SCS distributions in Ontario.
- The AES storm distribution is based on an assessment of actual storm patterns in Ontario.
- Given the size of the watershed,a short duration high intensity storm event is less likely to simultaneously occur over the entire watershed; a 12-hr or 24-hr distribution is more suitable than a short distribution. Application of a design storm with a very short duration and high intensity (such as the Chicago or SCS Type II distributions) over a watershed of this size would require additional study regarding the higher spatial variability associated with these events.
- Previous hydrology updates in the Rouge River and Humber River have also recommended the 12 hr AES distribution for design storm analysis.
- The 12 hr AES results are slightly higher (36%) than the flood frequency analysis for the 100-yr storm event at the Todmorden gauge on the downstream portion of the Don River. The peakier SCS and Chicago distributions are 20-25% higher than the AES 12-hr results. The AES 12-hr results conform closer to monitored flows in the watershed. However, as noted in Section 3.2.2, there is the physical limitation at this gauge. The FFA results may be lower than the actual values. Therefore, the comparison between FFA results and modeled values is mainly for qualitative evaluation only.

4.2 Flood Frequency Analysis, Gauged Flow

A flood frequency analysis (FFA) is conducted for the annual series of peak flows at each flow monitor location. The purpose of FFA is to further validate the design flow predicted by the calibrated model by ensuring that the results are within acceptable range and the help define an acceptable design storm distribution.

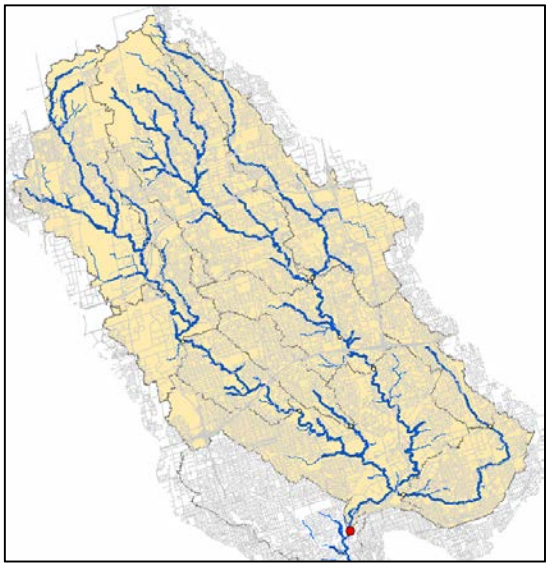
For each gauge location, trend assessments were also completed to check for stationarity of the data, which is a critical assumption in the frequency analysis. For stream gauges downstream of the G. Ross Lord Dam, only flows after construction of the dam (1973) were analysed.

For the annual series of instantaneous maxima at most gauges, approximately 25% of the values occurred during spring when snowmelt would have been a factor. These tended to be the smaller events in the overall series; all of the largest events were summer storm events. Since the hydrologic model is based on a rain event only (i.e. snowmelt or rain on snow is not considered), the frequency analysis is also only performed using events that were only due to rainfall and not snowmelt. This involved screening the series of peak flows. For years where the peak flow occurred in the spring, the largest summer event was substituted. In some cases, the peak instantaneous flow for the summer event was not available; in these cases, the peak daily flow was used with a derived peaking factor. The derived peaking factor was based on the observed peaking factor (instantaneous peak divided by daily peak) observed for the annual maxima in other years at the gauge. Although there is some uncertainty in the instantaneous peak flow in these years, these were the smaller events in the series, and as a result the errors in estimating the peak instantaneous flow for these years had small impact on the fit of the probability density function for the higher range of values.

For each stream gauge location, the design storm estimate is compared to the single station flood frequency analysis for the same return periods.

The resulting flood frequency analysis plots are provided below. The complete data sets are provided in the report Appendix.

Return Period (years)	Flow Estimate (m^3/s)	Confidence Limits 5% (m^3/s)	95% (m^3/s)
100	255	308	222
50	234	278	206
20	206	239	184
10	183	208	166
5	159	177	145
2	121	132	111



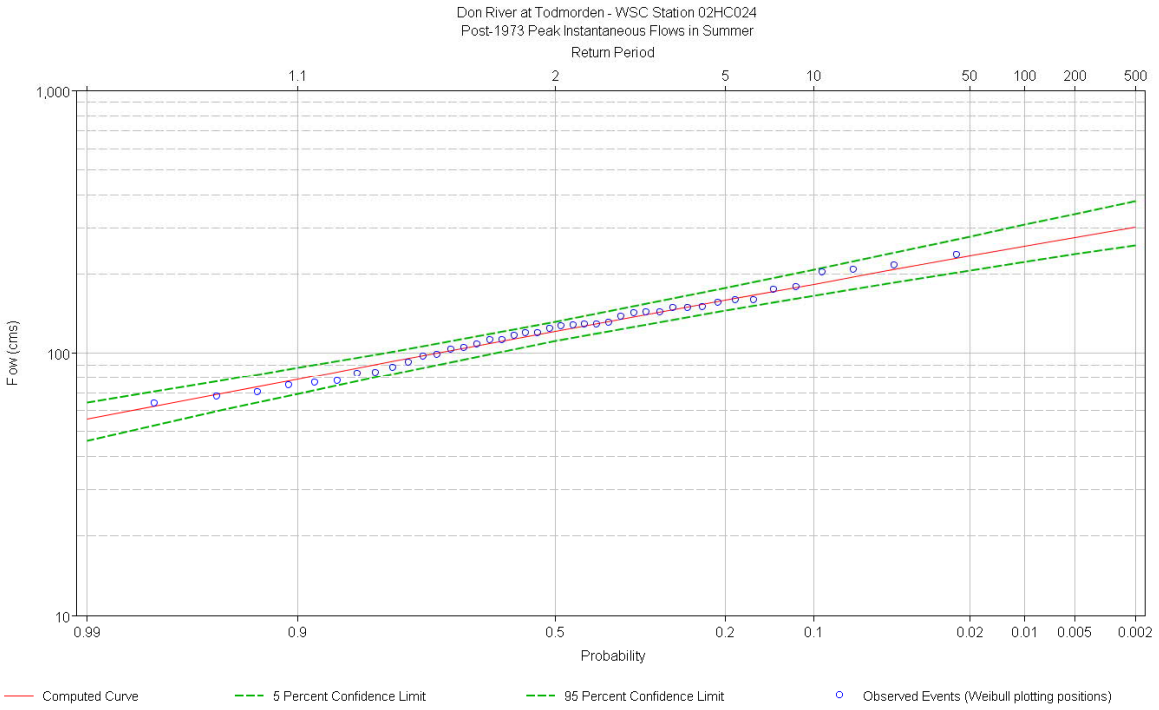
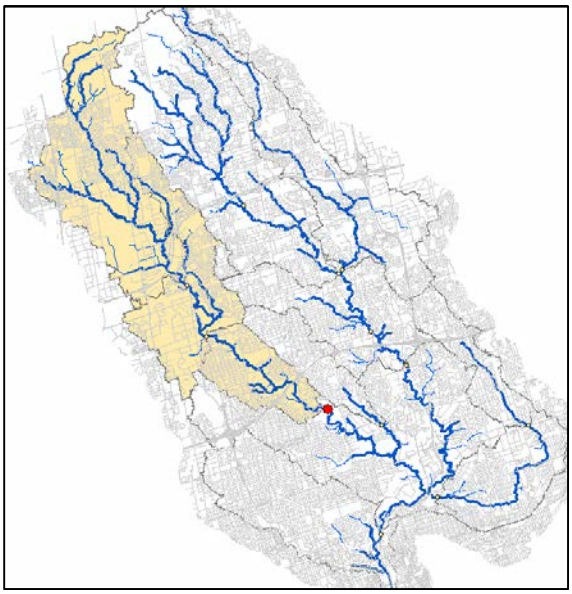


Figure 30: Flood Frequency Analysis- Don River at Todmorden- WSC Gauge 02HC024- Peak Summer Flows, Post 1973

Return Period (years)	Flow Estimate (m^3/s)	Confidence Limits 5% (m^3/s)	95% (m^3/s)
100	86	123	67
50	74	102	59
20	59	77	49
10	49	61	41
5	39	47	34
2	27	31	23



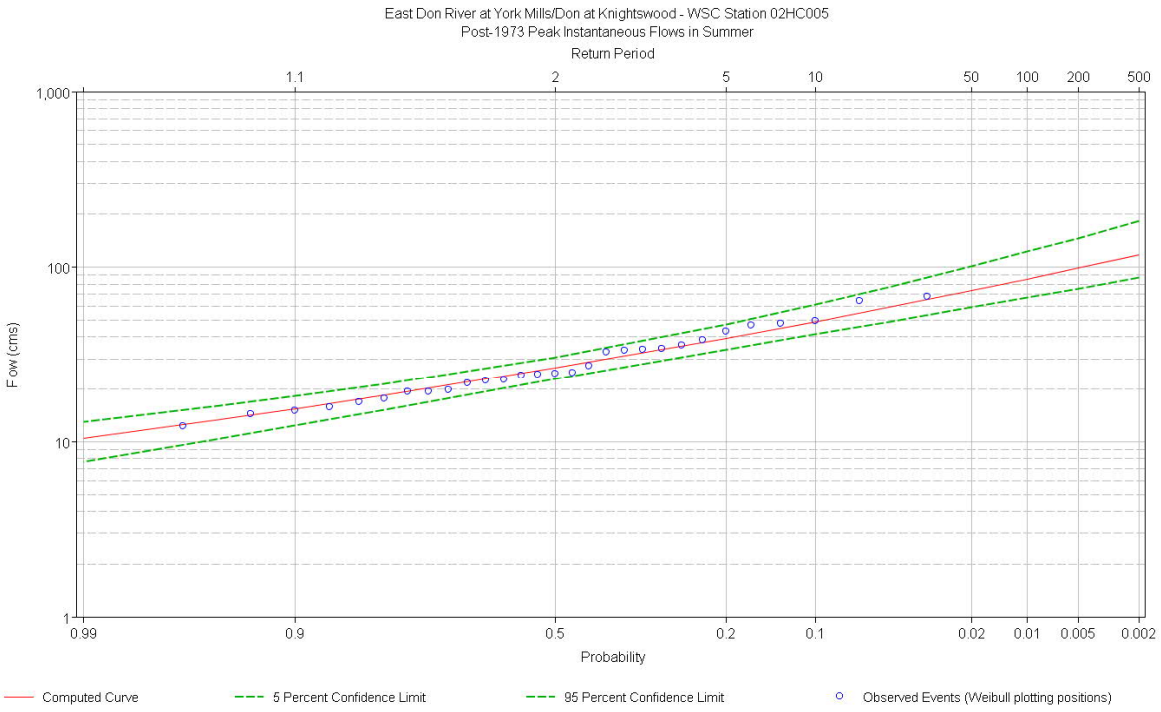
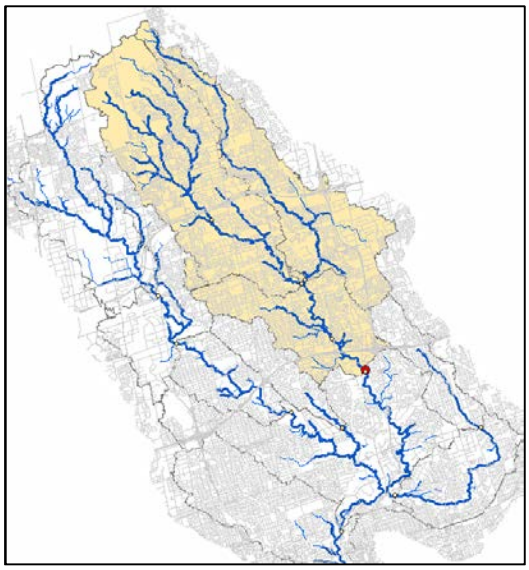


Figure 31: Flood Frequency Analysis- Don River at Knightswood - WSC Gauge 02HC005- Peak Summer Flows, Post 1973

Return Period (years)	Flow Estimate (m^3/s)	Confidence Limits 5% (m^3/s)	95% (m^3/s)
100	150	232	113
50	126	187	98
20	99	136	79
10	80	105	66
5	63	78	53
2	41	48	34



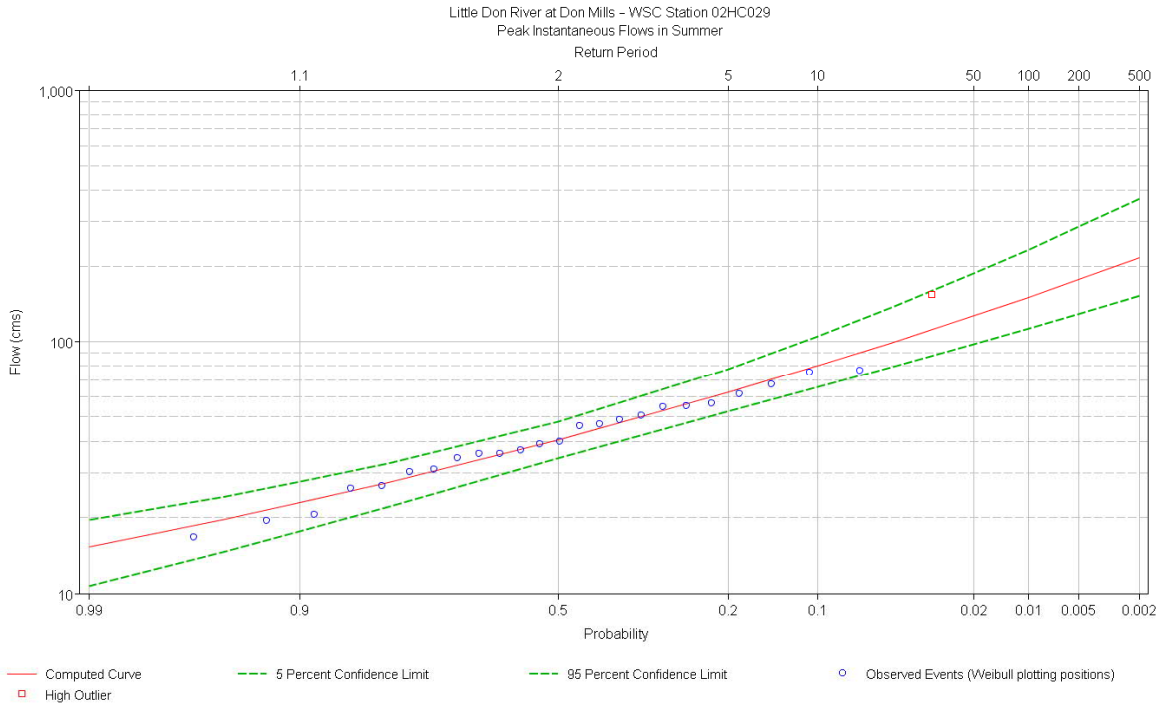


Figure 32: Flood Frequency Analysis- Little Don River at Don Mills - WSC Gauge 02HC029- Peak Summer Flows

4.2.1 Data Assessment, Trend Analysis

The flow on the west Don River for large events is influenced greatly by the G. Ross Lord dam; as a result, the data on the west branch and downstream reaches is split into two series (a) before construction of the G. Ross Lord dam in 1973, and after 1973.

For each gauge AECOM performed a trend analysis to review stationarity of the data, which may be caused by growth or changing rainfall patterns. The results show that there was a period of growth in the overall watershed prior to approximately 1973, but since 1973 there has been little evident trend in either annual peak daily flow or annual mean daily flow.

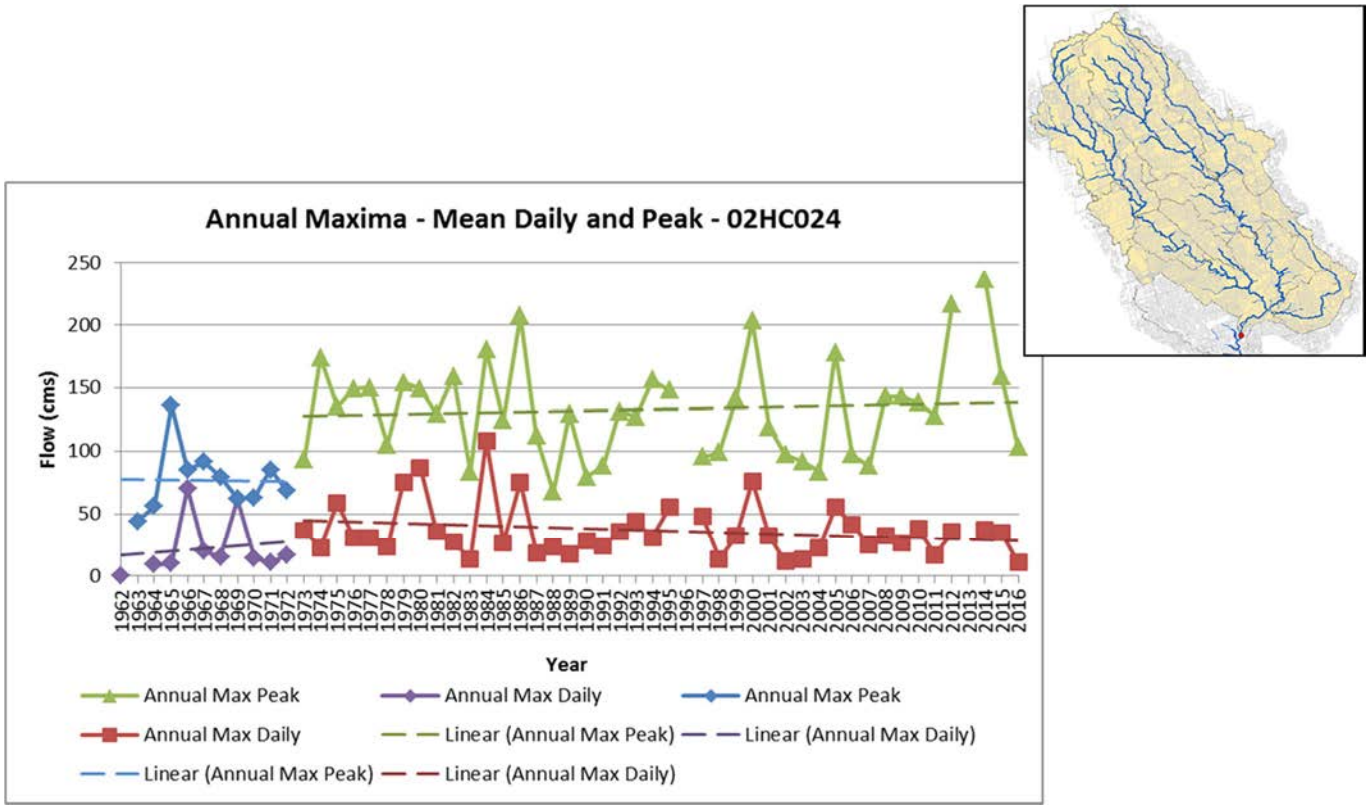


Figure 33: Trend in Flows

AECOM performed an additional analysis to examine trends in seasonal flow values. Monthly flow at three gauges was examined for an older 10-year period (1963-1972), and compared with the last 10-years of flow (2007-2016). The results show a clear shift in seasonal flow; historically, the monthly flow in the spring months was much larger than the rest of the year. This has changed, with smaller flow in the spring, and larger flows recorded in the summer months.

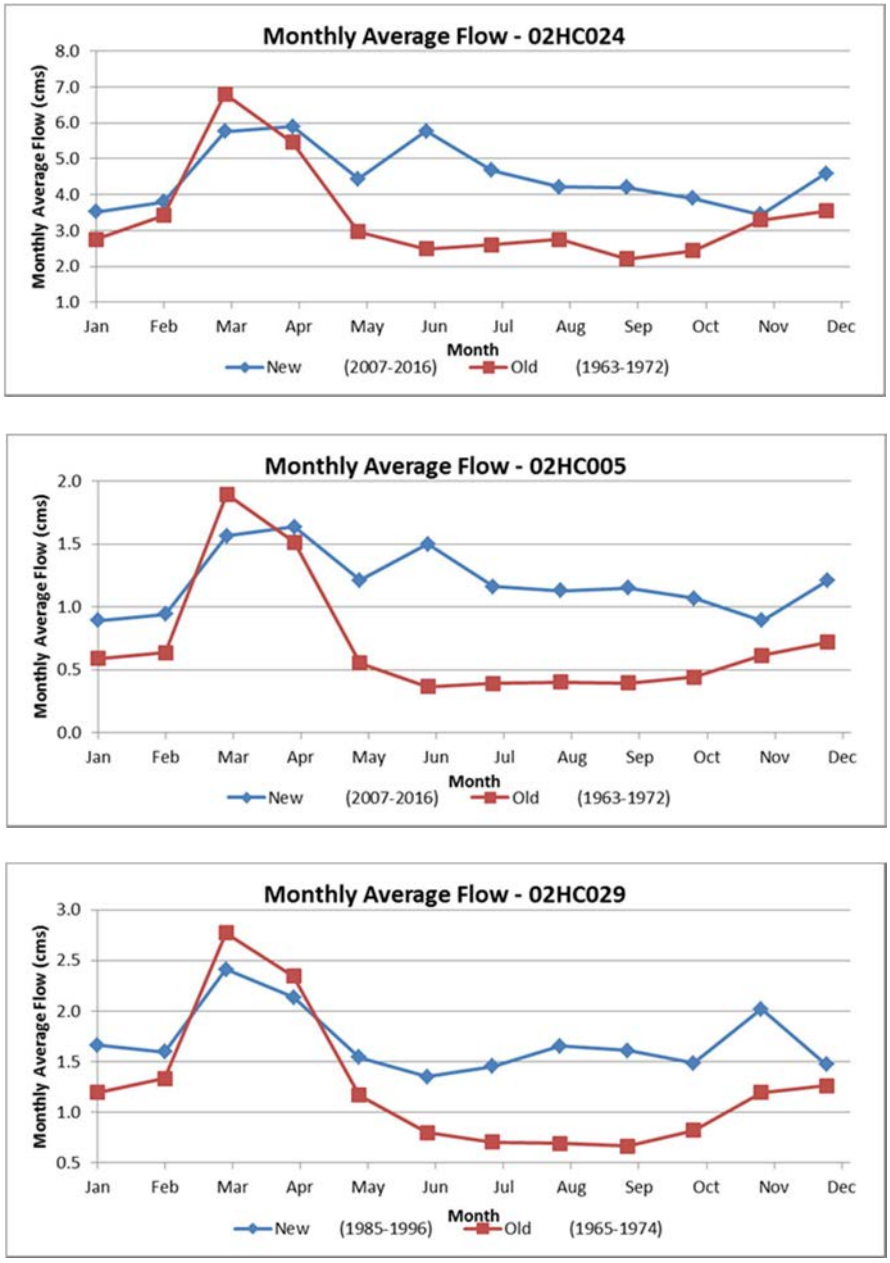
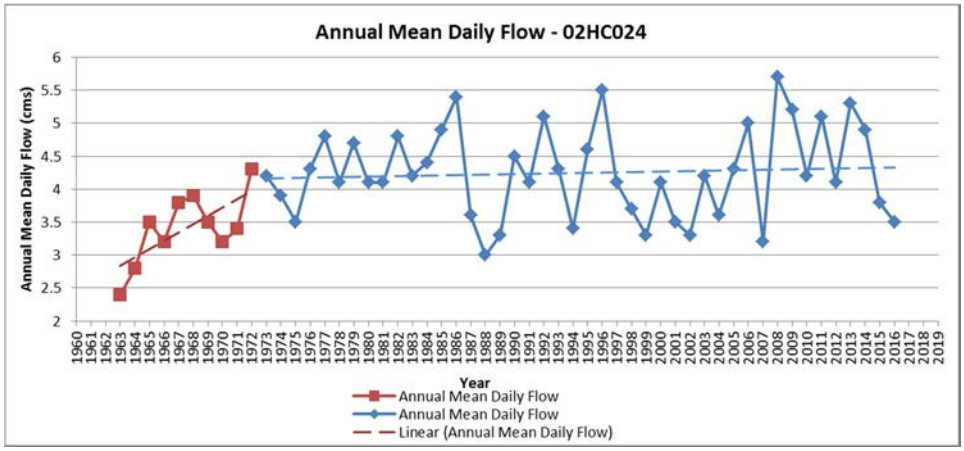
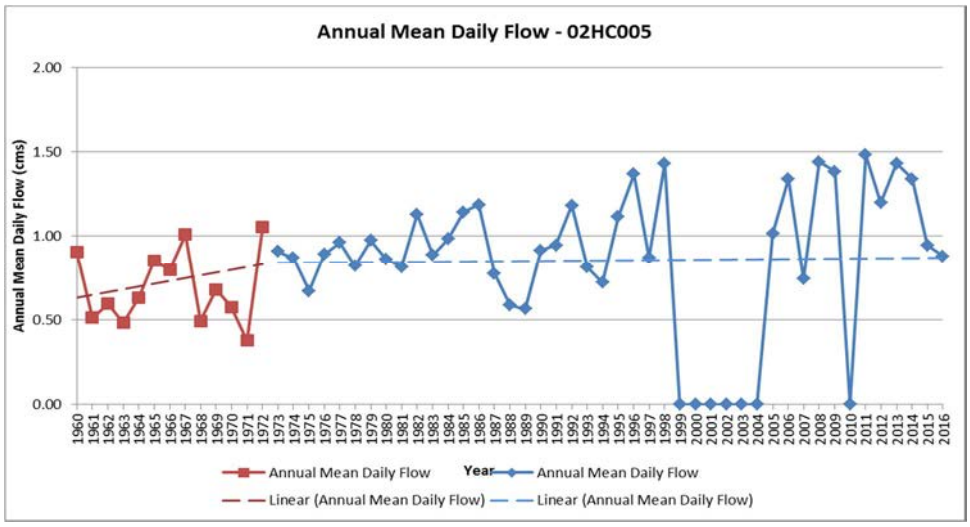


Figure 34: Change in Seasonal Flow Patterns

Additionally, trend in annual mean daily flow is examined below. The data generally shows increasing flows in the early 1970's, followed by a generally stationary period to the present day.





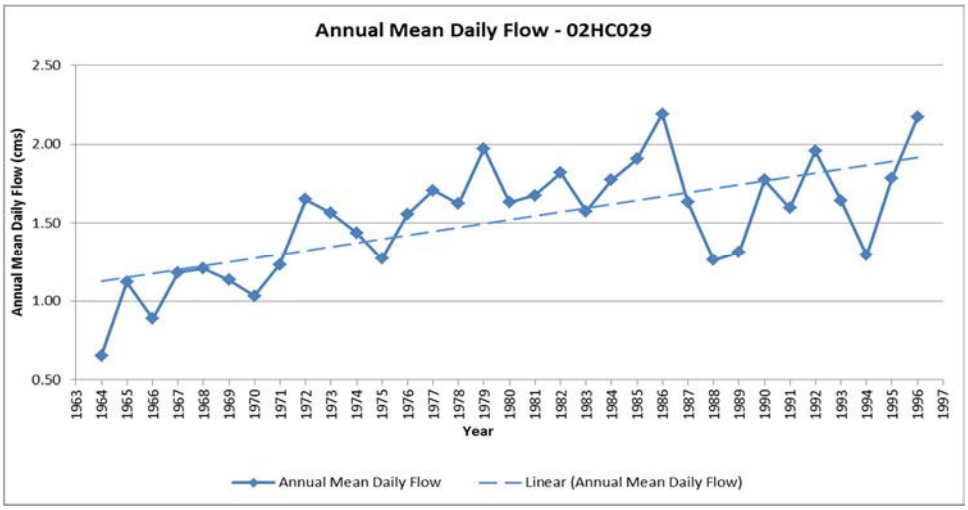


Figure 35: Trend in Annual Mean Daily Flow

4.3 Design Flow Estimates and Comparison with Model Results

The following Figures compare the flood frequency analysis estimates for various return periods (2-year through 100-year) with the model results for design storm events with the same return intervals (using the 12 hr AES rainfall distribution). The results show that overall the model flows are similar to the flood frequency flows, however the model flows are generally smaller for the more frequent flows (the 2-year and 5-year) and larger for the less frequent flows (50-year and 100-year).

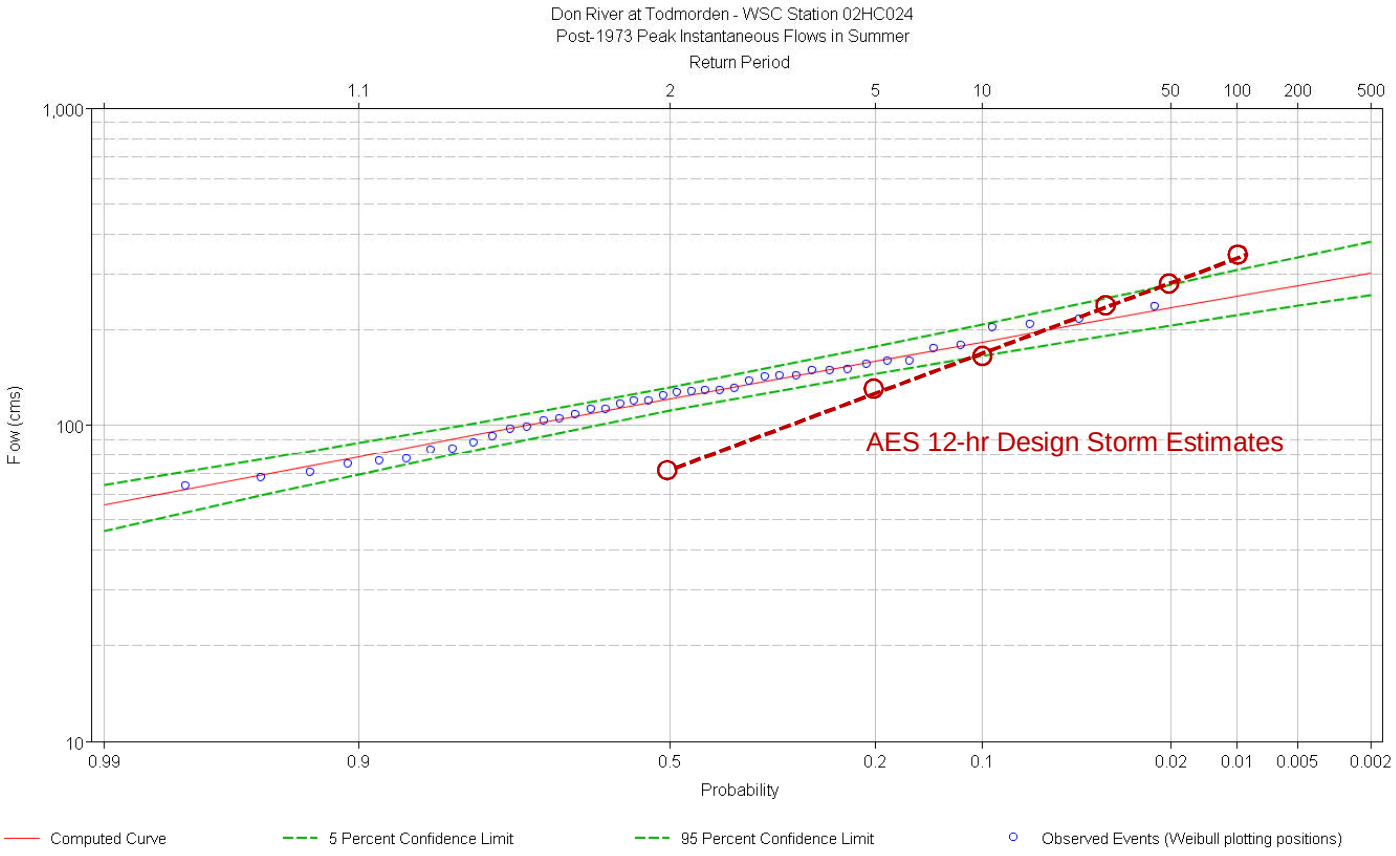


Figure 36: Flood Frequency Analysis vs Model Design Storm Estimate – Don River at Todmorden

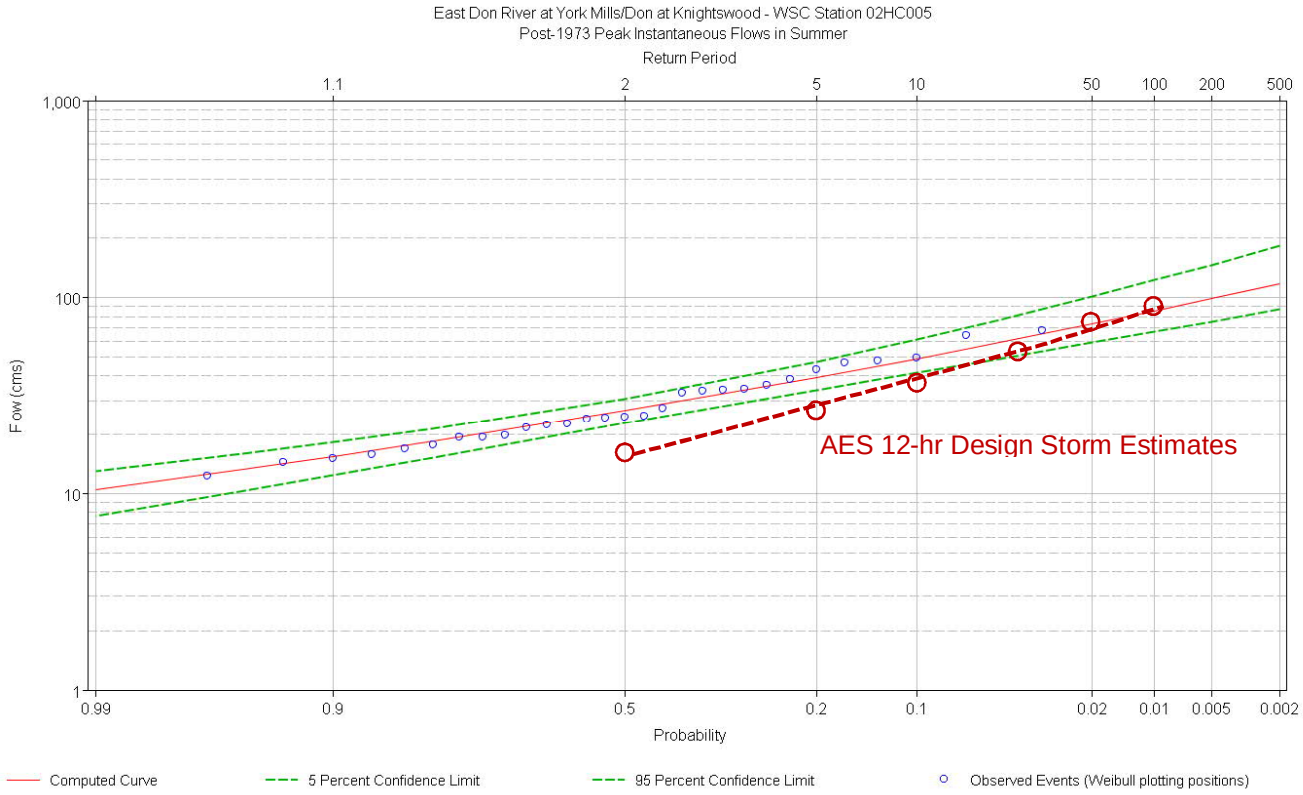


Figure 37: Flood Frequency Analysis vs Model Design Storm Estimate – Don River at Kingswood

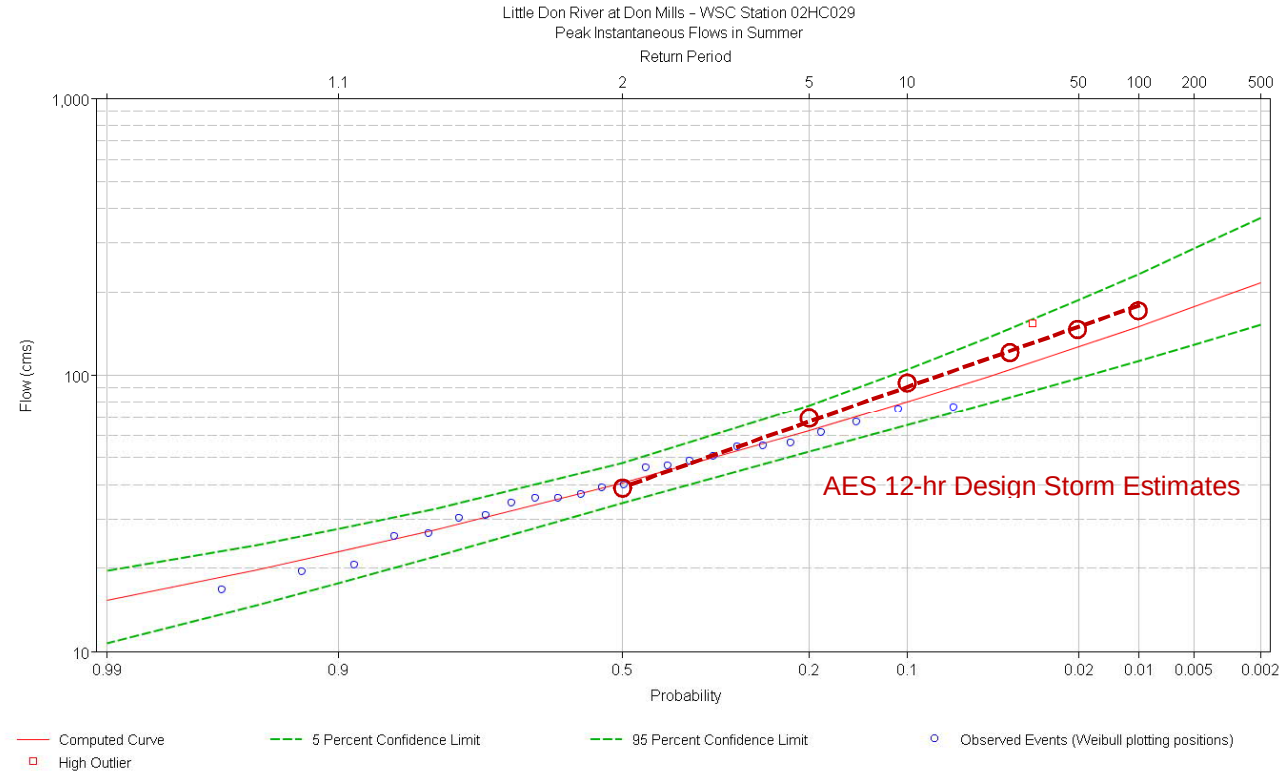


Figure 38: Flood Frequency Analysis vs Model Design Storm Estimate – Lower Don at Don Mills

4.4 Regional Storm Simulations

Once it was determined that the model was adequately calibrated and validated, and that design storm simulations were generally consistent with flood frequency estimates at the stream gauge locations, the model was run using the Regional storm.

The calibrated model is intended to be used to update flows used to define the Regulatory flood plain. In accordance with Provincial statues and TRCA's policies, the Regulatory flood plain in the TRCA jurisdiction is based on the Regional Storm, Hurricane Hazel, or the 100-year flood; whichever is greater.

The Regional flood estimate is also developed in accordance with MNRF's *Technical Guide, River & Stream Systems: Flooding Hazard Limit* (2002). As per these guidelines, the regional storm simulations consider the following:

- It may not be reasonable to assume that dams will continue to reduce peak flows in the future, since it may be replaced or removed. The preferred approach is to consider unregulated flows downstream of dams when identifying flood hazard limits downstream. For the present study, the G.Ross Lord dam is removed from the model for the Regional storm simulations.
- Stormwater management ponds may not be used to provide any reduction in peak flows for flood hazard assessments. For the present study, all ponds were removed from the model for the Regional storm simulations.
- Downstream of culverts or bridges, the natural flood line should be used to delineate flood hazards, making now allowance for the restriction in flow provided by the existing structure. For the present study, all bridges and culverts were removed from the model for the Regional storm simulations.

For the Regional storm, the model uses the full 48-hour hyetograph for Hurricane Hazel. As per the MNRF, the rainfall amounts were modified by an areal reduction factor based on catchment area. The areal reduction factor is taken from Table D-3 in the MNRF Technical Guidelines.

To account for the fact that the areal reduction factor changes with the size of the watershed, the model was run numerous times with different reduction factors such that the appropriate reduction factor could be considered at different locations in the watershed.

A sensitivity analysis was performed for the IMD parameter in the Green & Ampt equation, using the range of values calibrated for in the model. The results showed that the model results were not sensitive to IMD for the Regional storm, since the long 'initial wetting' of the 48 hour Hurricane Hazel storm that precedes the peak rainfall results in similar wetting of soils.

Model results for the Regional Storm are provided in Appendix I.

Table 7: Areal Reduction Factor for Hurricane Hazel (MNRF Technical Guidelines)

TABLE D-3 HURRICANE HAZEL - AREAL REDUCTION	
Area (km^2)	Reduction Factor Percentage
0 to 25	100.0 (no reduction)
26 to 45	99.2
46 to 65	98.2
66 to 90	97.1
91 to 115	96.3
116 to 140	95.4
141 to 165	94.8
166 to 195	94.2
196 to 220	93.5
221 to 245	92.7
246 to 270	92.0
271 to 450	89.4
451 to 575	86.7
576 to 700	84.0
701 to 850	82.4
851 to 1000	80.8
1001 to 1200	79.3
1201 to 1500	76.6
1501 to 1700	74.4
1701 to 2000	73.3
2001 to 2200	71.7
2201 to 2500	70.2
2501 to 2700	69.0
2701 to 4500	64.4
4501 to 6000	61.4
6001 to 7000	58.9
7001 to 8000	57.4

5. Peer Review

Computational Hydraulics International (CHI) provided an independent peer review of the PCSWMM/SWMM5 model developed for the Don River Hydrology Update. CHI identified a number of items requiring additional justification. AECOM responded to each of the suggested items and provided adequate justification for the model decisions selected and updated the model based on the recommendations.

Based on the thorough review of the submitted materials, CHI believed that the hydrologic and hydraulic representation of the Don River Watershed model is appropriate for the modeling objectives and is considered a reasonable and acceptable application of the PCSWMM and the SWMM5 model for similarly scoped studies.

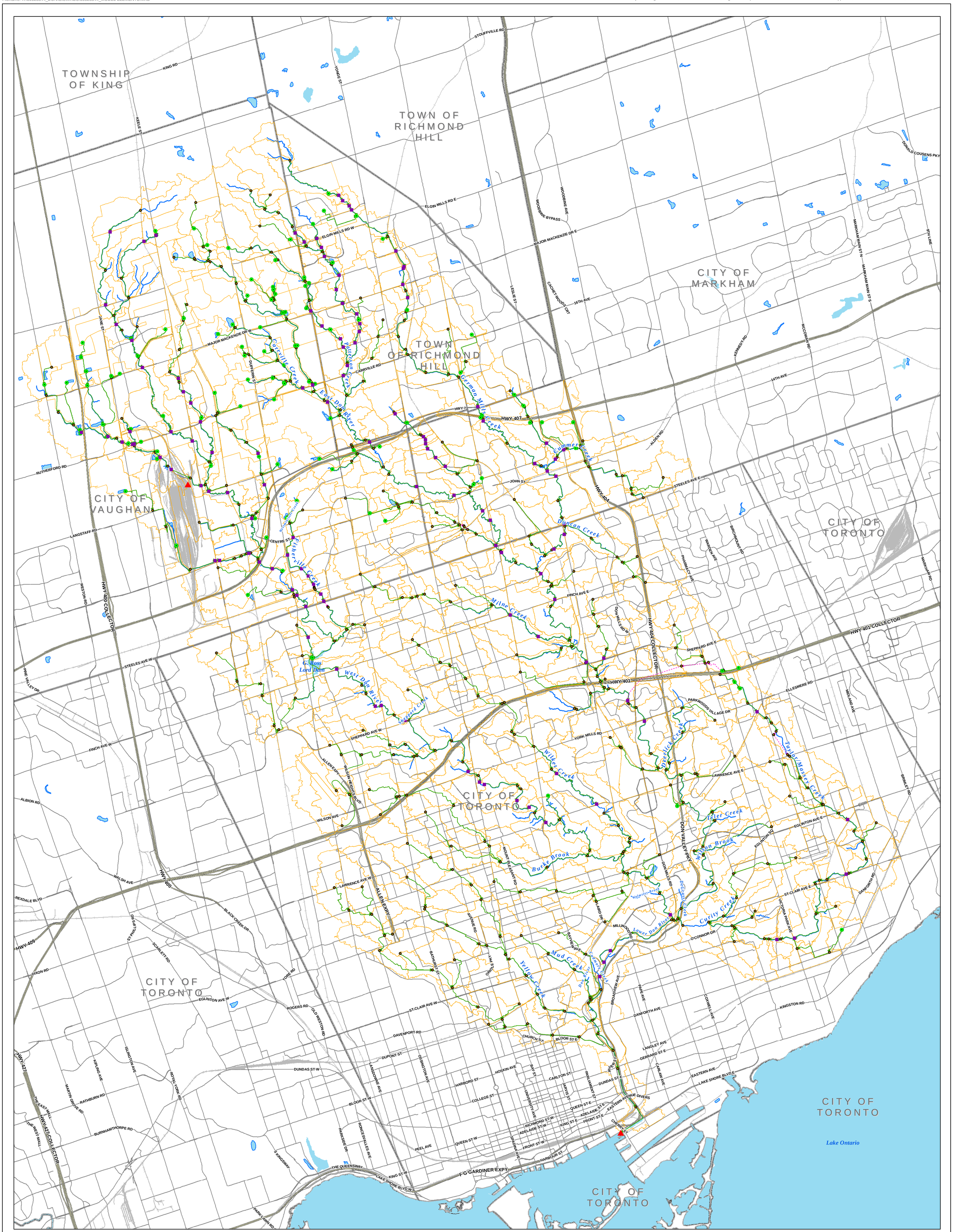
CHI's comments and AECOM's response are included in Appendix N.

6. Conclusions

AECOM has provided an updated hydrologic model for the Don River watershed. Key aspects of this hydrologic model development are as follows:

- AECOM concluded that PC SWMM was suitable software for the updated model;
- The model development included all known stormwater management facilities (109 ponds), the G Ross Lord dam, and incorporated 128 major road crossings to reflect potential attenuation in the model;
- Catchment delineation and initial model parameterization was performed in GIS pre-processing. The model used 896 individual subcatchments, each with unique subcatchment hydrology based on land use, imperviousness, and physical attributes. Several catchment parameters were calculated from GIS, including catchment area and % imperviousness, which was accurately calculated with a processed aerial image;
- The model was calibrated for seven of the largest rainfall events in the past 15 years. Rainfall for each event was assessed at all TRCA rain gauges in the watershed, augmented by rain gauges from the City of Toronto and Region of York. The rain gauges were used to develop a spatial distribution of rainfall across the watershed for each 5 minute time step of rainfall.
- The model was calibrated with stream gauge data collected at seven locations in the watershed.
- The model was verified with an additional six independent rainfall events which were not used in the model calibration.
- Model calibration and verification was found to be acceptable at each stream gauge, and generally within targeted accuracy for runoff volume and peak flow.
- A 12 hour AES rainfall distribution was found to be the most suitable deign storm distribution for the scale and nature of the Don River watershed.
- Flood frequency assessments were performed on stream gauges with sufficient record. The flows from the flood frequency analysis compared favourably to design storm events with the same return interval, once a suitable areal reduction factor was applied to the design storm in the model.
- The model was run for the Regulatory event, Hurricane Hazel, removing the ponds and crossings from the model.
- The model provides suitable estimates for design events of 2-year through 350-year return periods, and for the Regulatory event (Hurricane Hazel).

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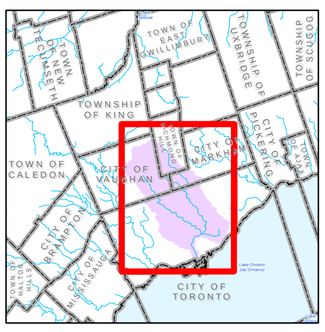
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Legend

- Freeway
- Major Road
- Major Railways
- Municipalities
- Waterbodies
- Watercourses
- Junctions
- Crossings
- Storages
- Outfalls

Conduits

- Natural Conduits
- Sewer
- Subcatchments



Key Map

2017 DON RIVER HYDROLOGY UPDATE

Toronto and Region Conservation Authority, Ontario
Project No.: 60528844 Date: April 2018

MODEL ELEMENTS

AECOM

Figure: E1

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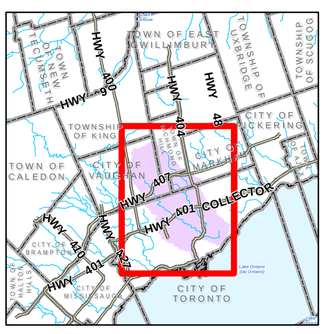
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Legend

- Freeway
- Major Road
- Major Railways
- Municipalities
- Waterbodies
- Watercourses
- Conduits
- Subcatchments
- Flow Nodes



Key Map

2017 DON RIVER HYDROLOGY UPDATE

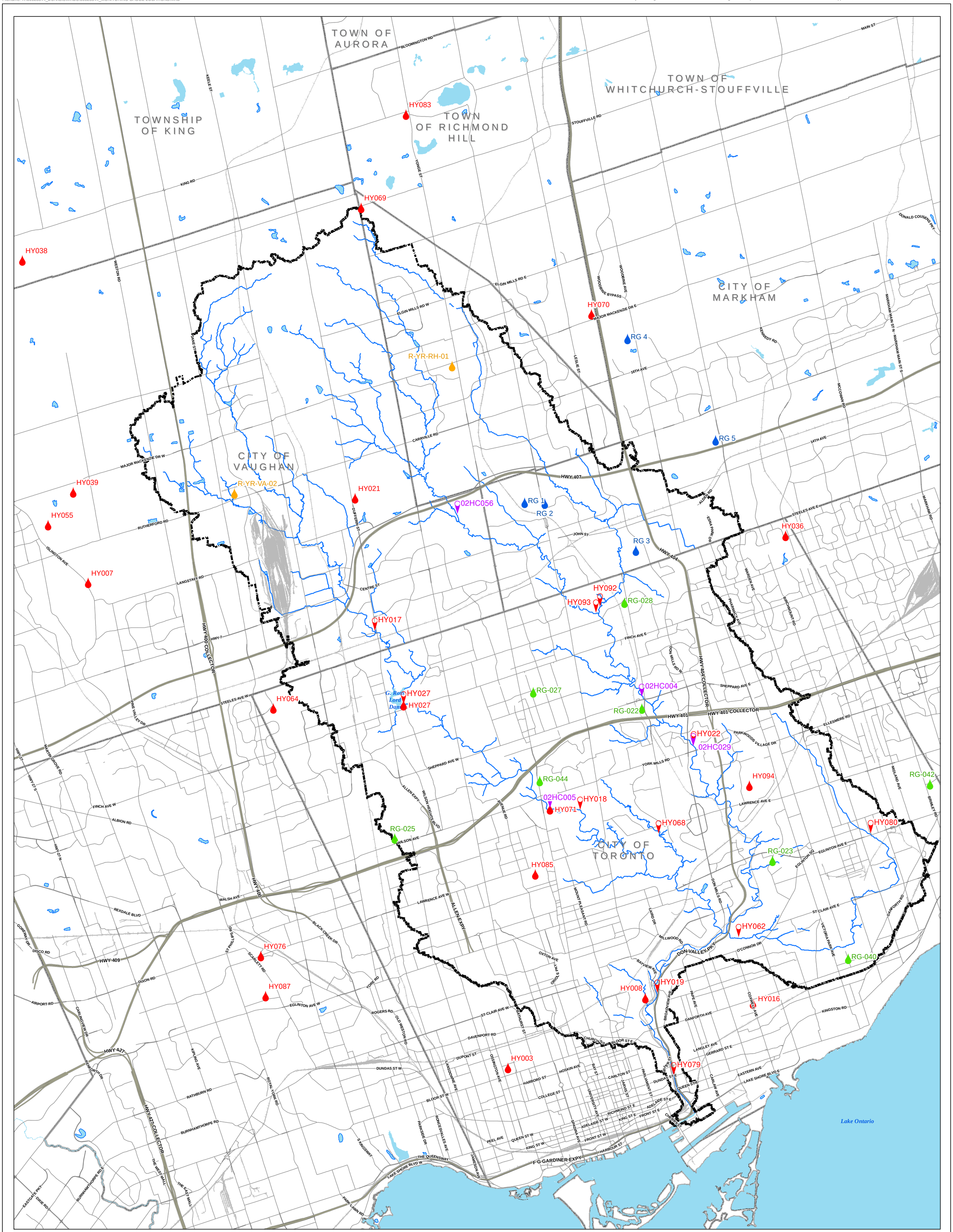
Toronto and Region Conservation Authority, Ontario
Project No.: 60528844 Date: April 2018

FLOW NODES

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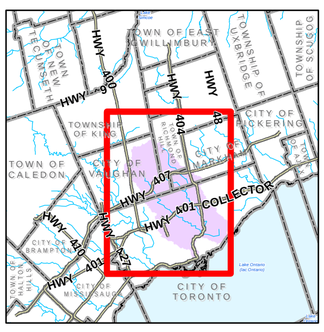
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- Major Road
- Major Railways
- Municipalities
- Waterbodies
- Watercourses

Stream Gauges

- TRCA
- WSC

Rain Gauges

- City of Markham
- City of Toronto
- Regional of York
- TRCA



Key Map

Basemap: Ontario Ministry of Natural Resources & City of Toronto
Additional Sources:
Ortho-Imagery:

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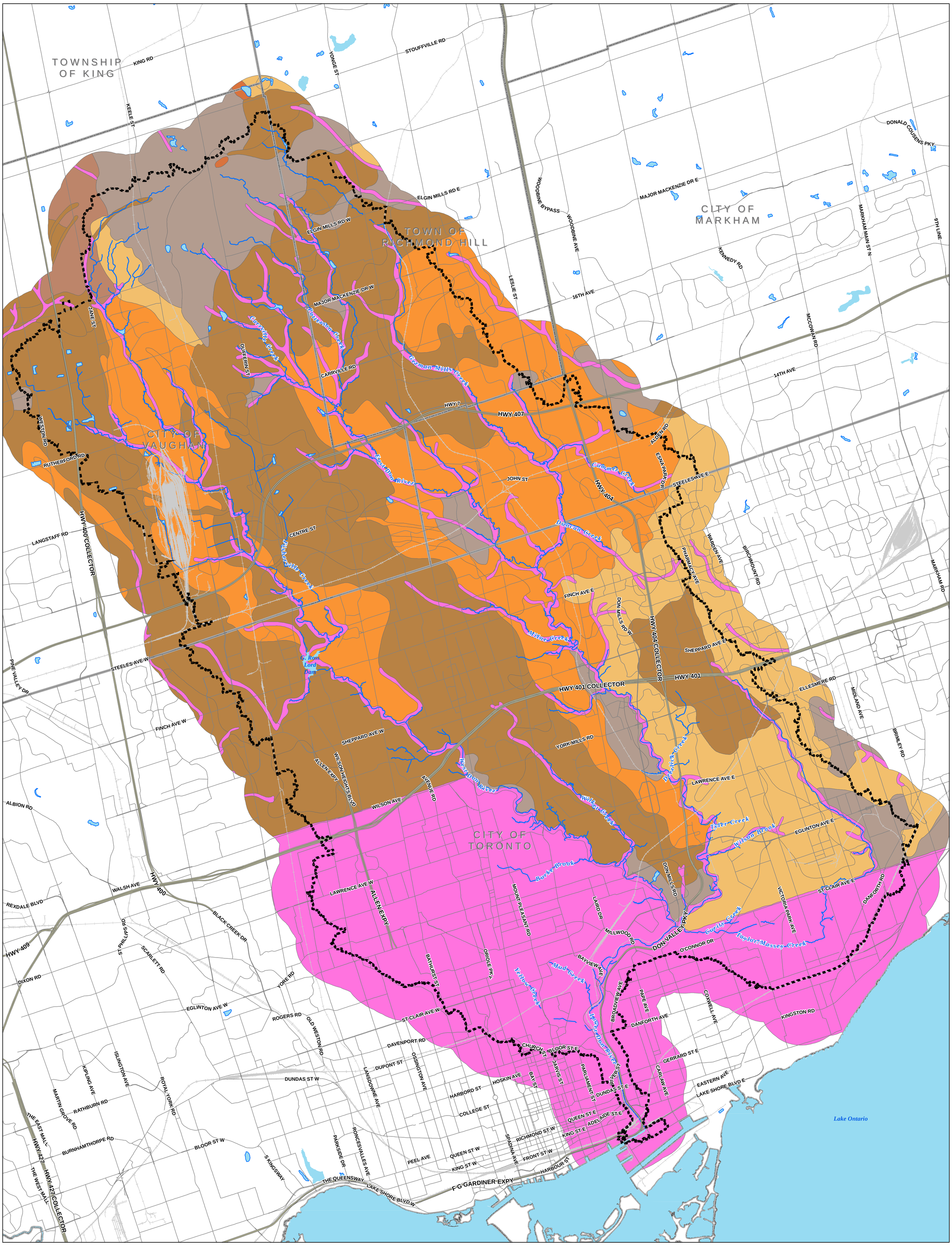
2017 DON RIVER
HYDROLOGY UPDATE
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MONITORING LOCATIONS

AECOM

Figure: E3

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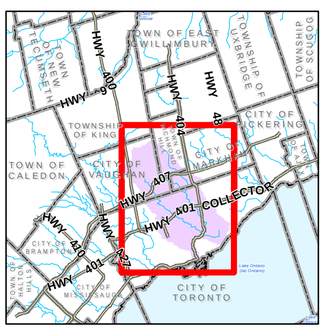
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Legend

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- Freeway
- Major Road
- Major Railways
- Municipalities
- Waterbodies
- Watercourses

Soil Type

- Unclassified
- Clay
- Clay Loam
- Loam
- Organic
- Silt Loam
- Sandy Loam



Key Map

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2017 DON RIVER
HYDROLOGY UPDATE
Toronto and Region Conservation Authority, Ontario
Project No.: 60528844 Date: April 2018

SURFICIAL SOIL MAPPING

AECOM

Figure: E4

Appendix A: Hydrology Parameters

Parameter Type		Measured	Measured	Calculated	Measured	Measured	Assumed	Assumed	Assumed	Calibrated	Assumed	Assumed	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated	Calibrated
																Dry	Wet	Wet (Regional)
Name	Outlet	Area (ha)	Width (m)	Flow Length [1] (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Zero Imperv (%)	Subarea Routing	Percent Routed (%)	Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit (frac.)		
S001	J001	40.29	3230.6	124.7	5.6	11.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S002	J001	47.91	4036.5	118.7	6.4	24.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S003	J002	56.85	3889.9	146.1	17.6	0.7	0.013	0.25	2	5	25	PERVIOUS	55	138	9.5	0.3	0.1	0.1
S004	J002	32.15	2379.6	135.1	16.2	0	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S005	J006	31.63	3521.2	89.8	18.0	11.6	0.013	0.25	2	5	25	PERVIOUS	55	115	10.7	0.3	0.1	0.1
S006	J006	22.29	2446.1	91.1	15.8	9.8	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S007	J026	32.84	2650.7	123.9	18.7	1.9	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S008	J023	39.35	2802.3	140.4	10.2	13.8	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S009	J031	64.42	5547.7	116.1	5.5	55.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S010	J031	26.51	2657.8	99.7	6.3	42.1	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S011	J638	17.12	2185.8	78.3	8.1	27.3	0.013	0.25	2	5	25	PERVIOUS	55	257	0.7	0.3	0.1	0.1
S012	J028	50.98	3695.1	138.0	11.6	3.4	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S013	J028	12.28	1165.9	105.3	20.3	0	0.013	0.25	2	5	25	PERVIOUS	55	129	10.0	0.3	0.1	0.1
S014	J041	52.07	3847.1	135.3	4.9	58.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S015	J041	2.82	2059.0	13.7	8.9	35.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S016	J637	22.70	2551.6	89.0	8.3	15.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S017	J042	56.05	5033.5	111.4	4.6	0.4	0.013	0.25	2	5	25	PERVIOUS	20	100	7.4	0.361	0.361	0.1
S018	J048	31.64	5214.2	60.7	11.8	13.4	0.013	0.25	2	5	25	PERVIOUS	55	221	2.4	0.3	0.1	0.1
S019	J627	3.69	927.0	39.8	8.5	49.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S020	J627	76.65	4441.9	172.6	4.8	57.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S021	J043	17.36	2411.7	72.0	5.6	0.1	0.013	0.25	2	5	25	PERVIOUS	20	114	3.0	0.335	0.335	0.1
S022	J043	34.67	3760.2	92.2	4.6	0.1	0.013	0.25	2	5	25	PERVIOUS	20	102	4.5	0.348	0.348	0.1
S023	J057	43.45	4640.0	93.6	5.5	3.5	0.013	0.25	2	5	25	PERVIOUS	20	100	7.3	0.361	0.361	0.1
S024	J046	20.83	4454.0	46.8	14.4	6.3	0.013	0.25	2	5	25	PERVIOUS	55	155	6.6	0.3	0.1	0.1
S025	J046	4.76	1396.5	34.1	12.8	0.8	0.013	0.25	2	5	25	PERVIOUS	55	215	1.0	0.3	0.1	0.1
S026	J068	38.70	3854.7	100.4	5.5	15.3	0.013	0.25	2	5	25	PERVIOUS	20	209	4.2	0.317	0.317	0.1
S027	J078	12.41	1902.6	65.2	6.0	16.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S028	J083	29.14	4640.6	62.8	10.1	43.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S029	J102	83.57	8285.6	100.9	11.0	41.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S030	J102	30.46	3949.3	77.1	6.7	64.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S031	SU134.1	135.68	5962.8	227.5	5.9	54.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S032	J111	22.25	2474.6	89.9	5.7	47.0	0.013	0.25	2	5	25	PERVIOUS	55	222	0.9	0.3	0.1	0.1
S033	J098	21.95	1950.9	112.5	8.1	2.5	0.013	0.25	2	5	25	PERVIOUS	55	223	0.9	0.3	0.1	0.1
S034	J098	19.29	1976.1	97.6	10.0	9.2	0.013	0.25	2	5	25	PERVIOUS	55	242	0.8	0.3	0.1	0.1
S035	J101	36.88	2969.2	124.2	5.3	51.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S036	J118	63.88	4331.2	147.5	5.2	55.8	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S037	J106	89.54	5731.0	156.2	5.6	48.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S038	J838	58.92	3052.9	193.0	5.0	65.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S039	J136	79.47	4447.7	178.7	5.3	49.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S040	J108	0.74	360.7	20.5	14.7	12.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S041	J130	6.15	1836.9	33.5	5.0	54.1	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S042	J125	53.27	4754.1	112.1	6.8	54.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S043	J133	0.44	241.9	18.2	8.1	76.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1

S044	J132	33.98	3436.3	98.9	5.7	54.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S045	J132	31.40	3307.4	94.9	5.5	56.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S046	J141	7.64	1244.0	61.4	10.2	55.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S047	J146	22.81	2316.5	98.5	9.3	27.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S048	J625	11.48	1267.6	90.6	11.5	8.5	0.013	0.25	2	5	25	PERVIOUS	55	320	0.3	0.3	0.1	0.1
S049	SU27	38.52	3458.3	111.4	5.1	52.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S050	J148	15.67	2433.5	64.4	11.7	35.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S051	J148	50.63	3258.0	155.4	8.4	33.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S052	J645	12.02	2381.5	50.5	5.4	59.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S053	J149	45.96	2970.9	154.7	8.6	12.1	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S054	J153	1.94	801.0	24.2	16.7	8.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S055	J159	6.30	4757.6	13.2	22.9	10.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S056	J159	45.55	4893.4	93.1	7.4	55.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S057	J622	5.31	1253.0	42.4	11.4	23.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S058	J167	53.92	4612.8	116.9	5.1	50.1	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S059	J644	56.01	3274.7	171.0	9.5	45.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S060	SU200	80.05	5863.2	136.5	8.6	46.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S061	J624	56.86	4900.5	116.0	11.9	20.0	0.013	0.25	2	5	25	PERVIOUS	55	299	0.4	0.3	0.1	0.1
S062	J179	33.86	4393.3	77.1	14.2	28.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S063	J179	78.29	4164.3	188.0	6.2	65.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S064	J216	31.98	2399.6	133.3	6.0	62.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S065	J188	1.88	1008.9	18.6	7.6	48.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S066	J184	42.04	3491.5	120.4	8.0	5.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S067	SU23019	32.66	2372.8	137.6	11.0	24.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S068	J593	0.30	257.6	11.6	20.7	1.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S069	J593	3.54	2025.2	17.5	23.0	1.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S070	J617	42.72	4433.8	96.4	6.4	42.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S071	J617	20.30	2960.1	68.6	9.2	39.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S072	J209	28.49	3354.6	84.9	11.6	44.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S073	SU245	49.13	3943.5	124.6	4.5	66.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S074	J616	15.22	1881.2	80.9	11.2	39.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S075	J201	35.86	4309.0	83.2	10.1	57.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S076	J212	43.90	3710.9	118.3	13.8	32.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S077	J218	10.63	1365.4	77.9	12.3	23.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S078	J218	49.62	4036.6	122.9	5.7	47.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S079	J207	45.67	4306.5	106.1	14.1	30.5	0.013	0.25	2	5	25	PERVIOUS	55	318	0.3	0.3	0.1	0.1
S080	J211	35.22	3071.1	114.7	14.8	17.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S081	J220	16.45	1894.9	86.8	12.3	34.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S082	J223	16.86	3143.2	53.6	13.1	29.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S083	J223	23.40	3699.0	63.3	9.6	38.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S084	J612	23.53	2045.1	115.1	5.6	74.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S085	J612	14.55	1938.4	75.1	5.5	29.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S086	J221	33.43	3141.0	106.4	11.0	24.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S087	J221	22.91	2760.1	83.0	10.9	25.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S088	J215	96.09	4380.3	219.4	5.5	71.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S089	J215	21.82	2591.7	84.2	6.0	76.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S090	J227	42.20	4093.6	103.1	5.3	84.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S091	J233	14.80	2424.6	61.0	9.1	47.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S092	J233	14.42	3724.5	38.7	5.4	71.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1

S093	J230	57.72	4775.4	120.9	6.9	70.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S094	J584	9.25	1892.8	48.9	6.7	66.8	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S095	J248	20.62	2858.7	72.1	10.1	28.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S096	J236	53.10	3678.0	144.4	7.1	66.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S097	J238	42.70	6149.9	69.4	6.4	62.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S098	J239	10.14	1933.7	52.4	6.4	72.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S099	J268	39.32	2708.5	145.2	7.1	31.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S100	J259	25.83	3419.2	75.5	7.9	39.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S101	J259	7.62	1655.9	46.0	6.3	29.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S102	J245	25.06	1977.6	126.7	8.6	49.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S103	J272	31.72	3939.3	80.5	4.7	72.1	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S104	J263	50.11	4100.0	122.2	7.1	34.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S105	J263	30.08	2887.8	104.2	5.8	49.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S106	J280	82.28	4324.7	190.3	5.2	78.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S107	J280	39.24	3152.7	124.5	6.1	77.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S108	J267	1.15	898.9	12.8	13.4	59.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S109	J267	62.19	4714.4	131.9	11.0	45.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S110	J262	77.94	6844.6	113.9	6.3	49.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S111	J262	84.68	4831.8	175.3	6.7	55.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S112	J275	57.75	3843.9	150.2	7.7	49.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S113	J281	95.67	5059.1	189.1	6.6	37.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S114	J608	35.52	4419.4	80.4	5.5	51.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S115	J277	35.65	3132.5	113.8	9.3	45.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S116	J277	42.71	3527.2	121.1	9.7	36.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S117	SU19	70.56	7611.6	92.7	7.0	56.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S118	J289	52.00	3099.8	167.8	4.3	73.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S119	J278	0.17	147.4	11.5	24.8	54.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S120	J278	34.70	3718.9	93.3	8.6	47.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S121	J286	56.79	3853.7	147.4	6.9	39.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S122	J285	77.75	3488.8	222.9	5.6	63.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S123	J295	34.26	2979.5	115.0	9.5	47.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S124	J282	18.47	1923.6	96.0	12.3	41.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S125	J288	7.97	1227.8	64.9	7.2	29.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S126	J293	4.34	1101.9	39.4	7.0	1.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S127	J293	74.63	4776.9	156.2	8.6	51.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S128	J299	44.97	3564.2	126.2	5.1	60.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S129	J299	48.59	4360.2	111.4	5.0	60.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S130	J294	75.58	7235.0	104.5	5.2	52.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S131	J294	28.16	2407.1	117.0	7.0	57.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S132	J298	75.81	3668.7	206.6	9.5	41.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S133	J295	15.03	2339.2	64.3	14.9	16.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S134	J605	15.65	1476.7	106.0	5.2	52.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S135	J605	56.69	5191.8	109.2	5.0	59.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S136	J284	21.73	2872.6	75.6	9.9	51.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S137	J302	34.61	3107.5	111.4	8.1	44.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S138	J300	24.54	3156.6	77.7	9.1	42.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S139	J301	93.35	4302.1	217.0	6.8	52.1	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S140	J301	45.72	2796.7	163.5	6.6	47.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S141	J310	9.88	2091.1	47.2	11.4	5.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

S142	J310	54.56	3882.9	140.5	7.1	36.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S143	J606	16.68	1731.7	96.3	8.4	58.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S144	J606	6.02	1439.6	41.8	8.0	45.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S145	J606	0.71	559.8	12.7	9.3	50.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S146	J317	39.65	3170.0	125.1	4.8	51.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S147	J309	45.76	8415.8	54.4	7.8	51.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S148	J311	80.63	3974.0	202.9	4.5	49.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S149	J314	1.92	881.6	21.8	4.3	48.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S150	J314	38.02	3055.5	124.4	4.6	46.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S151	J320	80.57	5495.5	146.6	7.1	43.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S152	J327	65.01	4222.9	153.9	8.6	44.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S153	J327	72.01	4405.4	163.5	7.3	43.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S154	J330	64.83	3550.3	182.6	8.2	38.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S155	J330	38.58	2818.5	136.9	5.7	43.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S156	J326	2.88	962.1	29.9	8.2	56.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S157	J325	38.54	2179.5	176.8	4.1	40.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S158	J329	7.97	1538.3	51.8	6.1	25.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S159	J334	50.33	3110.7	161.8	4.6	39.1	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S160	J334	34.40	2847.7	120.8	4.2	28.7	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S161	J332	91.09	5295.2	172.0	12.9	20.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S162	J332	20.32	6425.7	31.6	22.2	18.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S163	J333	78.44	6102.4	128.5	9.6	46.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S164	J336	11.23	1819.3	61.7	19.6	29.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S165	J336	21.34	3076.7	69.4	12.7	10.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S166	J335	39.32	5037.0	78.1	6.4	42.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S167	J343	54.94	4766.1	115.3	4.9	50.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S168	J343	38.76	4076.3	95.1	6.2	45.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S169	J352	77.21	3908.9	197.5	8.7	38.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S170	J340	69.14	4273.2	161.8	5.2	78.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S171	J342	73.84	4703.8	157.0	4.9	53.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S172	J342	45.20	4860.5	93.0	5.5	73.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S173	_GRossLordD	67.90	4753.0	142.9	8.4	12.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S174	_GRossLordD	22.87	2917.6	78.4	6.9	61.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S175	_GRossLordD	1.25	464.9	26.9	7.8	0.4	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S176	J351	0.09	147.5	6.1	22.2	6.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S177	J345	35.83	4101.2	87.4	8.0	51.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S178	J345	47.14	4445.8	106.0	7.7	73.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S179	J356	25.94	2939.1	88.3	10.2	51.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S180	J353	11.03	1567.2	70.4	12.0	35.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S181	J357	40.49	2460.5	164.6	5.7	50.1	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S182	J361	8.44	1311.2	64.4	8.9	38.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S183	J362	52.01	5335.0	97.5	8.2	43.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S184	J362	65.37	5715.5	114.4	9.5	51.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S185	J365	38.39	3503.6	109.6	4.6	67.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S186	J367	9.40	1856.8	50.6	11.7	46.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S187	J367	1.84	885.5	20.8	14.3	17.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S188	J363	49.66	3925.2	126.5	5.6	58.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S189	J363	28.27	4105.3	68.9	5.8	53.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S190	J370	3.28	928.7	35.3	14.8	50.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

S191	J370	17.37	2246.9	77.3	14.6	29.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S192	J372	31.06	5769.4	53.8	9.1	55.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S193	J372	1.07	461.8	23.2	20.1	1.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S194	J376	51.20	5075.7	100.9	5.4	49.4	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S195	J376	36.03	3069.3	117.4	11.8	37.8	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S196	J377	43.71	3374.7	129.5	6.0	55.2	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S197	J358	85.13	4643.9	183.3	5.1	77.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S198	J395	68.20	3468.9	196.6	6.6	51.4	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S199	J395	8.17	1544.3	52.9	6.2	36.8	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S200	J378	16.07	2219.6	72.4	5.8	50.4	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S201	J378	43.56	3413.6	127.6	7.1	58.3	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S202	J380	66.98	4917.8	136.2	11.6	35.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S203	J383	44.44	3649.4	121.8	7.0	60.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S204	J387	33.17	2843.9	116.6	6.0	46.7	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S205	J386	32.33	3250.5	99.5	10.8	37.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S206	J386	4.53	881.3	51.4	14.2	5.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S207	J388	65.58	3872.7	169.3	5.8	43.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S208	J391	27.46	3777.5	72.7	18.0	23.1	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S209	J391	50.59	3635.7	139.1	10.7	20.7	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S210	J394	4.63	1298.0	35.7	20.9	25.8	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S211	J397	53.62	3914.5	137.0	4.2	73.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S212	J396	46.19	3979.1	116.1	4.4	80.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S213	J385	6.10	1113.7	54.8	7.8	75.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S214	J385	72.81	4078.5	178.5	5.4	59.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S215	J406	30.20	3550.6	85.1	4.3	58.2	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S216	J398	41.43	3244.6	127.7	6.2	43.1	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S217	J398	60.89	4437.8	137.2	7.3	46.9	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S218	J400	36.80	3808.1	96.6	6.0	42.3	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S219	J401	67.11	4638.5	144.7	6.1	52.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S220	J401	63.82	4424.0	144.3	6.9	41.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S221	J415	35.57	3726.9	95.4	9.2	28.3	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S222	J415	54.71	3833.6	142.7	6.7	45.8	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S223	J403	13.65	1693.9	80.6	5.3	52.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S224	J403	54.46	5176.1	105.2	6.5	44.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S225	J414	0.43	274.5	15.7	3.7	81.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S226	J414	57.59	3447.9	167.0	6.0	42.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S227	J402	36.15	2797.1	129.2	16.7	24.0	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S228	J409	59.43	5987.1	99.3	9.9	40.7	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S229	J409	0.47	291.8	16.1	48.1	0.4	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S230	J407	119.56	6812.8	175.5	6.6	44.1	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S231	J418	35.79	3120.2	114.7	17.8	36.8	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S232	J416	32.49	3739.8	86.9	15.8	32.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S233	J413	7.84	1632.7	48.0	20.4	24.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S234	J417	78.01	3782.3	206.3	6.6	38.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S235	J419	71.47	5507.1	129.8	8.0	37.5	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S236	J419	40.36	3092.4	130.5	7.0	38.1	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S237	J424	26.00	4948.5	52.5	9.0	38.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S238	J424	6.88	847.8	81.1	18.6	6.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S239	J426	13.26	1648.5	80.4	8.8	12.2	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1

S240	J420	47.21	4340.8	108.8	8.2	60.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S241	J434	11.99	1816.8	66.0	22.9	13.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S242	J434	20.38	1736.5	117.4	9.5	47.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S243	J427	71.89	4290.4	167.6	12.7	42.0	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S244	J429	96.68	4932.1	196.0	5.8	62.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S245	J429	33.82	2275.7	148.6	4.5	57.1	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S246	J600	8.59	1782.3	48.2	16.6	22.6	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S247	J439	35.09	4150.3	84.5	9.5	41.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S248	J431	50.20	4164.9	120.5	18.1	25.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S249	J436	45.29	4096.1	110.6	4.1	40.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S250	J436	4.14	986.3	42.0	10.5	45.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S251	J599	35.35	3229.8	109.4	23.0	22.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S252	J599	0.90	434.2	20.7	20.8	11.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S253	J433	32.93	6004.3	54.8	2.5	52.2	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S254	J435	67.95	3893.8	174.5	7.3	48.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S255	J435	72.93	4737.8	153.9	5.9	45.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S256	J442	33.19	2424.5	136.9	17.6	28.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S257	J437	33.95	4014.1	84.6	4.7	50.4	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S258	J437	27.67	2453.4	112.8	6.2	51.9	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S259	J440	39.00	3318.5	117.5	4.2	62.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S260	J756	13.17	1529.2	86.1	12.9	15.9	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S261	J450	40.39	4431.6	91.1	6.6	42.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S262	J446	43.15	3410.9	126.5	6.2	47.3	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S263	J445	64.07	4056.3	158.0	8.5	74.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S264	J452	11.08	1494.0	74.2	9.2	55.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S265	J463	35.38	2642.8	133.9	17.1	22.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S266	J463	21.95	2402.6	91.4	18.5	26.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S267	J454	40.91	4314.0	94.8	9.0	37.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S268	J454	7.21	1086.8	66.3	19.0	6.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S269	J451	45.23	3403.0	132.9	13.5	34.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S270	J451	45.02	3387.1	132.9	8.2	45.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S271	J443	81.03	2996.6	270.4	6.4	68.9	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S272	J572	54.40	4445.8	122.4	3.4	47.4	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S273	J455	66.59	5028.7	132.4	7.9	30.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S274	J455	18.27	2055.0	88.9	17.9	21.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S275	J468	48.86	3279.9	149.0	3.7	42.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S276	J468	44.02	2738.2	160.8	3.9	85.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S277	J457	21.56	2074.0	104.0	8.3	41.3	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S278	J457	42.90	4253.2	100.9	6.0	58.4	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S279	J459	19.92	2634.4	75.6	16.9	16.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S280	J461	22.49	2576.9	87.3	6.4	39.1	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S281	J461	57.72	3685.8	156.6	5.5	49.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S282	J465	1.79	663.3	27.0	27.9	4.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S283	J465	73.35	5396.0	135.9	7.8	52.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S284	J472	56.14	3819.9	147.0	7.5	55.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S285	J474	17.06	1986.1	85.9	7.1	59.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S286	J474	50.83	4055.6	125.3	6.4	47.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S287	J464	35.08	3592.3	97.7	18.2	24.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S288	J464	34.04	4376.3	77.8	10.8	48.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

S289	J469	46.93	4256.3	110.3	10.1	36.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S290	J467	83.10	3819.4	217.6	10.2	48.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S291	J466	39.06	3680.1	106.1	10.0	7.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S292	J480	0.99	537.8	18.4	22.3	14.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S293	J480	45.14	5214.1	86.6	15.5	20.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S294	J470	9.65	1331.7	72.5	16.7	19.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S295	J470	84.83	6317.7	134.3	9.6	46.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S296	J473	48.66	3855.3	126.2	21.5	34.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S297	J473	4.49	1066.6	42.1	20.9	2.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S298	J471	38.69	3150.2	122.8	3.4	90.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S299	J471	53.94	3515.7	153.4	4.3	77.3	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S300	J481	41.16	3853.2	106.8	5.9	63.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S301	J475	18.51	2857.2	64.8	10.6	37.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S302	J477	36.76	3974.3	92.5	10.9	40.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S303	J486	4.62	1186.6	38.9	17.0	24.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S304	J486	86.60	4612.5	187.7	5.0	80.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S305	J499	62.91	4713.7	133.5	5.3	47.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S306	J494	20.27	2158.5	93.9	18.7	28.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S307	J500	74.15	5992.7	123.7	8.6	64.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S308	J500	49.42	5304.5	93.2	19.9	13.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S309	J512	24.49	2243.2	109.2	19.4	13.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S310	J498	55.09	4488.7	122.7	7.3	55.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S311	J503	58.66	4286.9	136.8	4.4	82.3	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S312	J503	31.57	4002.5	78.9	5.8	62.9	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S313	J504	38.14	3010.1	126.7	8.1	47.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S314	J493	1.53	671.8	22.8	5.6	81.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S315	J506	39.76	2431.4	163.5	5.8	61.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S316	J501	33.18	3592.8	92.4	8.7	50.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S317	J511	68.19	3813.2	178.8	11.0	41.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S318	J508	0.77	862.2	8.9	8.7	41.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S319	J509	46.09	4305.4	107.1	6.6	52.3	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S320	J509	59.30	6245.6	94.9	5.1	56.9	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S321	J523	17.19	2169.5	79.2	5.3	66.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S322	J516	39.00	5204.3	74.9	8.1	54.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S323	J519	30.49	3121.4	97.7	8.8	59.1	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S324	J514	5.55	1961.1	28.3	14.5	38.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S325	J527	0.31	194.9	15.9	27.2	38.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S326	J513	1.86	714.3	26.0	16.1	19.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S327	J513	34.86	2790.8	124.9	15.2	30.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S328	J520	46.00	2649.1	173.6	19.1	29.1	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S329	J518	50.13	4325.6	115.9	8.1	58.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S330	J521	24.01	2220.0	108.2	17.8	39.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S331	J521	0.85	434.2	19.6	19.5	5.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S332	J522	64.94	5005.1	129.7	12.8	39.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S333	J524	35.75	2887.2	123.8	7.8	47.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S334	J534	28.25	2341.7	120.6	5.0	54.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S335	J534	21.54	1658.2	129.9	7.4	54.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S336	J528	72.04	5589.5	128.9	15.6	32.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S337	J529	5.99	1452.7	41.2	13.4	48.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1

S338	J529	53.31	4061.7	131.3	6.0	69.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S339	J533	71.52	6957.5	102.8	6.1	56.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S340	J530	34.07	3760.0	90.6	5.5	68.9	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S341	J535	33.11	3020.4	109.6	5.5	60.4	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S342	J538	52.39	3862.4	135.6	6.6	56.1	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S343	J538	42.94	3911.0	109.8	6.9	67.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S344	J545	57.04	3961.9	144.0	5.7	75.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S345	J545	36.92	3169.1	116.5	5.7	68.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S346	J549	44.52	4587.5	97.0	6.6	66.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S347	J555	65.08	3519.7	184.9	9.9	55.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S348	J767	4.85	1203.6	40.3	16.7	35.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S349	J553	58.80	4028.0	146.0	14.8	54.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S350	J552	35.87	3390.9	105.8	21.0	34.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S351	J552	28.62	5159.7	55.5	18.1	36.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S352	J554	0.37	351.7	10.5	12.6	13.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S353	J554	4.93	1091.5	45.2	16.4	21.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S354	J560	41.26	2874.6	143.5	18.1	40.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S355	J560	0.51	290.6	17.6	15.6	11.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S356	J559	98.17	6064.4	161.9	8.2	57.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S357	J559	30.97	2950.5	105.0	8.0	57.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S358	J561	9.18	2312.6	39.7	25.1	34.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S359	J561	79.76	5199.2	153.4	12.5	46.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S360	J563	18.24	2540.6	71.8	9.5	55.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S361	J565	15.05	1806.7	83.3	13.9	18.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S362	J565	55.84	4871.8	114.6	16.0	44.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S363	J569	8.66	1360.0	63.7	10.4	18.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S364	J569	38.64	3027.2	127.6	23.6	30.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S365	J570	12.81	3455.4	37.1	14.8	22.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S366	J570	67.67	4730.0	143.1	11.1	51.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S367	J537	93.45	3867.3	241.6	8.9	51.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S368	J548	75.54	2908.8	259.7	8.8	43.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S369	J557	30.97	3214.5	96.3	17.9	36.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S370	J525	50.24	2733.9	183.8	9.0	45.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S371	J542	23.46	2560.7	91.6	8.0	60.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S372	J544	91.81	3946.2	232.7	7.7	54.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S373	J053	42.03	3473.4	121.0	6.5	44.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S374	J071	22.45	2982.2	75.3	8.3	37.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S375	J072	13.61	2175.1	62.6	7.3	59.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S376	J091	23.89	2841.7	84.1	8.5	11.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S377	J479	67.32	4145.8	162.4	5.9	58.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S378	J485	64.56	3110.4	207.6	6.1	43.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S379	J536	44.32	3318.4	133.6	7.6	62.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S380	J127	59.98	3126.1	191.9	7.9	59.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S381	J564	14.79	2801.1	52.8	12.7	49.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S382	J566	53.82	3093.5	174.0	8.5	68.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S383	J567	94.46	4516.3	209.2	9.9	66.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S384	J260	62.30	3581.3	174.0	4.7	83.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S385	J271	51.66	3610.1	143.1	4.1	80.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S386	J012	110.16	3641.3	302.5	5.3	2.1	0.013	0.25	2	5	25	PERVIOUS	20	137	8.2	0.361	0.361	0.1

S387	J058	58.22	4054.7	143.6	6.6	3.5	0.013	0.25	2	5	25	PERVIOUS	20	189	5.2	0.34	0.34	0.1
S388	J035	53.52	4624.3	115.7	4.4	1.4	0.013	0.25	2	5	25	PERVIOUS	20	147	4.8	0.342	0.342	0.1
S389	J492	40.39	3418.9	118.1	5.6	48.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S390	J489	74.76	3558.1	210.1	6.1	60.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S391	J144	51.25	3462.2	148.0	8.7	50.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S392	J151	43.53	3434.8	126.7	11.5	34.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S393	J204	38.73	6386.1	60.6	15.8	6.1	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S394	J384	92.90	4761.2	195.1	9.0	35.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S395	J373	30.16	3603.1	83.7	6.4	40.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S396	J303	95.42	5915.9	161.3	5.1	60.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S397	J303	24.93	3646.0	68.4	5.4	53.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S398	J315	53.29	2275.9	234.2	5.6	59.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S399	J405	39.04	3407.9	114.6	4.8	73.9	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S400	J404	50.96	3480.2	146.4	4.5	35.7	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S401	J430	33.89	2130.9	159.0	4.2	48.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S402	J232	33.29	2702.3	123.2	12.7	32.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S403	J246	60.63	3950.7	153.5	13.4	18.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S404	J256	78.86	4150.7	190.0	11.2	32.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S405	J531	96.71	5434.0	178.0	5.8	59.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S406	J551	73.50	3795.3	193.7	6.0	48.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S407	J279	66.43	3199.1	207.7	7.6	54.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S408	J393	7.29	1377.5	52.9	8.9	45.4	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S409	J381	51.52	3896.9	132.2	5.7	40.6	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S410	J346	62.93	6096.5	103.2	7.8	64.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S411	J368	74.46	4883.4	152.5	5.2	42.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S412	J392	63.10	3484.5	181.1	10.3	37.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S413	J412	91.54	5268.7	173.7	11.3	28.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S414	J168	13.56	1997.1	67.9	5.5	57.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S415	J190	45.25	4432.3	102.1	6.9	62.8	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S416	J579	93.92	5136.4	182.9	4.5	43.4	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S417	J005	44.89	3251.3	138.1	16.8	2.2	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S418	J410	78.98	3792.6	208.2	4.3	45.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S419	J425	46.01	2603.5	176.7	4.4	54.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S420	J097	7.19	1562.2	46.0	7.9	37.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S421	J491	34.84	3445.3	101.1	7.0	66.6	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S422	J219	37.14	3099.6	119.8	8.7	43.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S423	J488	14.89	1935.7	76.9	9.2	64.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S424	J360	99.51	3917.5	254.0	4.6	49.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S425	J344	64.70	2549.9	253.7	5.2	42.2	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S426	J547	77.86	3344.3	232.8	8.6	53.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S427	J338	97.69	5253.2	186.0	5.6	81.9	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S428	J595	91.77	3761.1	244.0	5.6	38.6	0.013	0.25	2	5	25	PERVIOUS	55	214	1.0	0.3	0.1	0.1
S429	J478	46.20	2860.2	161.5	6.2	68.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S430	J453	66.19	2922.5	226.5	6.0	55.3	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S431	J003	99.99	5742.5	174.1	10.8	0.9	0.013	0.25	2	5	25	PERVIOUS	55	135	8.5	0.3	0.1	0.1
S432	J596	23.54	1900.9	123.8	17.4	7.1	0.013	0.25	2	5	25	PERVIOUS	55	117	10.2	0.3	0.1	0.1
S433	J539	60.22	3769.7	159.7	6.8	66.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S434	J161	30.21	2575.2	117.3	8.4	54.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S435	J195	61.97	3899.9	158.9	7.0	26.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1

S436	J331	19.87	3454.6	57.5	10.5	65.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S437	J013	49.54	5180.5	95.6	16.4	7.4	0.013	0.25	2	5	25	PERVIOUS	55	121	10.4	0.3	0.1	0.1
S438	J231	58.89	3051.5	193.0	4.5	80.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S439	J337	52.77	4316.4	122.3	5.1	41.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S440	J228	48.33	2712.0	178.2	4.7	75.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S442	J443	33.27	2544.4	130.8	6.8	56.5	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S443	J411	72.22	4694.5	153.8	11.1	33.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S444	J291	28.19	3087.8	91.3	11.3	31.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S445	J423	54.48	4122.5	132.2	5.6	47.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S447	J515	13.98	1522.8	91.8	7.4	64.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S448	J546	67.86	3448.1	196.8	7.8	58.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S449	J137	77.27	3167.8	243.9	5.0	45.8	0.013	0.25	2	5	25	PERVIOUS	55	222	0.9	0.3	0.1	0.1
S450	J174	46.06	2983.9	154.4	5.5	51.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S451	SU26	17.25	4210.9	41.0	7.0	43.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S452	J217	3.51	959.5	36.6	15.5	30.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S453	SU128	4.87	916.7	53.1	7.9	0.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S454	J114	22.81	2213.2	103.1	13.6	16.3	0.013	0.25	2	5	25	PERVIOUS	55	148	9.0	0.3	0.1	0.1
S455	J621	17.17	1224.7	140.2	5.9	67.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S456	SU271	39.60	2839.9	139.4	6.8	54.6	0.013	0.25	2	5	25	PERVIOUS	55	206	1.5	0.3	0.1	0.1
S457	SU271.4	27.82	1538.2	180.9	7.0	55.5	0.013	0.25	2	5	25	PERVIOUS	55	215	1.0	0.3	0.1	0.1
S458	SU303.1	36.55	4132.1	88.5	4.8	44.9	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S459	SU341.2	38.53	1954.6	197.1	9.7	46.8	0.013	0.25	2	5	25	PERVIOUS	55	127	9.0	0.3	0.1	0.1
S460	SU13040	37.51	2468.1	152.0	7.8	50.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S461	SU15007	7.75	1171.2	66.2	5.8	76.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S462	J244	30.90	2521.1	122.6	9.1	17.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S463	SU17015	16.35	1927.7	84.8	5.0	76.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S464	J052	47.87	2399.9	199.5	11.0	1.5	0.013	0.25	2	5	25	PERVIOUS	20	110	10.9	0.37	0.37	0.1
S465	J117	10.75	1158.9	92.8	17.8	0.4	0.013	0.25	2	5	25	PERVIOUS	55	164	8.2	0.3	0.1	0.1
S466	J810	24.31	1996.4	121.8	9.1	0.8	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S467	J812	11.05	1845.2	59.9	7.9	2.2	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S468	SU17031	6.42	1010.0	63.6	9.6	45.4	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S469	SU23023	9.04	1961.8	46.1	8.5	7.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S470	SU23024	32.64	2057.8	158.6	12.3	49.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S471	SU15	56.04	4066.6	137.8	8.6	53.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S472	SU16	17.15	1773.5	96.7	6.3	3.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S473	SU24	26.34	2585.4	101.9	5.9	55.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S474	SU25	82.66	5811.8	142.2	5.9	49.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S475	SU27.1	7.27	769.9	94.4	6.0	1.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S476	SU37	36.99	3833.2	96.5	5.6	58.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S477	SU108	28.33	2022.1	140.1	6.9	37.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S478	SU125	23.73	2475.1	95.9	5.8	50.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S479	SU136	71.78	3318.1	216.3	11.7	17.6	0.013	0.25	2	5	25	PERVIOUS	55	167	6.7	0.3	0.1	0.1
S480	SU139	22.35	876.8	254.9	7.7	44.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S481	J066	19.77	2876.5	68.7	10.9	29.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S482	SU154	14.84	1068.8	138.8	5.6	72.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S483	SU155	94.83	5190.2	182.7	5.8	55.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S484	SU172	8.63	1091.6	79.1	6.8	57.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S485	SU223	29.93	1472.2	203.3	10.7	73.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S486	SU226.2	200.66	6137.9	326.9	7.1	50.0	0.013	0.25	2	5	25	PERVIOUS	55	251	0.7	0.3	0.1	0.1

S487	SU244	32.44	1869.3	173.5	7.6	57.8	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S488	SU248	83.01	3427.0	242.2	5.4	44.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S489	SU271.5	31.84	2117.6	150.4	6.3	37.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S490	SU291	60.38	4411.6	136.9	5.3	57.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S491	SU348.2	44.33	2447.4	181.1	7.2	7.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S492	SU348.5	26.64	2139.5	124.5	8.1	29.9	0.013	0.25	2	5	25	PERVIOUS	55	203	5.8	0.3	0.1	0.1
S493	SU348.8	9.19	1161.7	79.1	7.8	45.9	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S494	SU349.2	54.61	3503.8	155.9	6.8	47.1	0.013	0.25	2	5	25	PERVIOUS	55	228	1.0	0.3	0.1	0.1
S495	SU406.1	62.56	2813.3	222.4	5.2	45.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S496	SU17024	35.59	3438.5	103.5	7.8	38.4	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S497	SU23020	6.09	1826.7	33.3	14.3	19.5	0.013	0.25	2	5	25	PERVIOUS	55	312	0.3	0.3	0.1	0.1
S498	SU23021	15.27	2750.6	55.5	12.1	37.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S499	J074	68.04	4163.5	163.4	6.3	38.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S500	J131	7.82	4044.7	19.3	13.3	28.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S501	J162	83.44	3842.5	217.2	4.9	62.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S502	SU127.1	30.27	2036.5	148.6	6.3	43.2	0.013	0.25	2	5	25	PERVIOUS	55	181	4.8	0.3	0.1	0.1
S503	SU4.3	42.44	2864.2	148.2	6.0	45.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S504	SU4.5	136.82	5604.1	244.1	9.8	34.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S505	SU50	43.56	3173.2	137.3	6.9	49.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S506	SU102	54.89	4426.3	124.0	6.6	41.9	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S507	SU210.1	35.31	2733.4	129.2	4.7	46.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S508	SU134.7	16.62	1814.6	91.6	6.3	59.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S509	SU134.6	13.33	1202.3	110.9	5.3	64.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S510	SU198	67.15	3002.6	223.6	6.0	61.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S511	J176	3.68	812.8	45.3	12.0	6.1	0.013	0.25	2	5	25	PERVIOUS	20	252	0.7	0.253	0.253	0.1
S512	SU210.2	67.11	3372.6	199.0	5.1	62.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S513	J076	0.61	444.9	13.7	7.2	0	0.013	0.25	2	5	25	PERVIOUS	55	210	1.0	0.3	0.1	0.1
S514	SU348.1	48.01	1833.6	261.8	6.6	59.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S515	SU348	65.30	3757.4	173.8	5.2	56.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S516	SU348.6	11.39	1465.8	77.7	12.3	23.0	0.013	0.25	2	5	25	PERVIOUS	55	200	4.9	0.3	0.1	0.1
S517	J116	0.85	452.6	18.8	18.8	12.7	0.013	0.25	2	5	25	PERVIOUS	55	231	4.8	0.3	0.1	0.1
S518	J034	26.48	2580.1	102.6	8.1	10.2	0.013	0.25	2	5	25	PERVIOUS	20	111	10.9	0.37	0.37	0.1
S519	SU17025	33.37	2379.7	140.2	7.4	47.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S520	SU23025	8.00	1288.9	62.1	11.0	9.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S521	J644	11.80	1940.5	60.8	10.0	38.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S522	J101	39.60	2985.1	132.7	4.8	55.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S523	SU66	12.60	2179.1	57.8	8.6	36.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S524	J021	7.23	1373.8	52.6	11.4	25.4	0.013	0.25	2	5	25	PERVIOUS	55	267	0.6	0.3	0.1	0.1
S525	SU146	46.18	2603.9	177.3	6.8	48.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S526	J188	12.94	2482.0	52.1	12.3	29.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S527	J092	22.82	2059.5	110.8	4.9	46.3	0.013	0.25	2	5	25	PERVIOUS	55	215	1.0	0.3	0.1	0.1
S528	J092	60.01	4748.0	126.4	5.6	54.8	0.013	0.25	2	5	25	PERVIOUS	55	224	0.9	0.3	0.1	0.1
S529	J099	13.52	3194.8	42.3	7.6	38.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S530	J118	23.41	3508.8	66.7	5.4	59.1	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S531	J153	10.38	1482.7	70.0	9.4	41.3	0.013	0.25	2	5	25	PERVIOUS	55	320	0.3	0.3	0.1	0.1
S532	SU226.3	34.33	2383.6	144.0	6.9	54.5	0.013	0.25	2	5	25	PERVIOUS	55	211	1.2	0.3	0.1	0.1
S533	J095	5.97	1210.9	49.3	6.3	66.4	0.013	0.25	2	5	25	PERVIOUS	55	264	0.6	0.3	0.1	0.1
S534	SU271.1	20.67	1205.7	171.4	7.6	61.0	0.013	0.25	2	5	25	PERVIOUS	55	228	0.9	0.3	0.1	0.1
S535	J583	17.46	2734.7	63.8	11.2	13.4	0.013	0.25	2	5	25	PERVIOUS	55	237	0.8	0.3	0.1	0.1

S536	J149	9.85	2199.9	44.8	7.8	51.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S537	J084	33.44	3926.4	85.2	12.9	27.6	0.013	0.25	2	5	25	PERVIOUS	55	247	0.8	0.3	0.1	0.1
S538	J133	16.81	5451.4	30.8	14.9	3.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S539	SU348.4	10.78	1277.2	84.4	6.9	59.0	0.013	0.25	2	5	25	PERVIOUS	55	231	0.9	0.3	0.1	0.1
S540	SU348.3	41.08	3968.8	103.5	6.9	44.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S541	J129	40.20	3642.1	110.4	6.4	2.8	0.013	0.25	2	5	25	PERVIOUS	55	244	0.8	0.3	0.1	0.1
S542	J129	0.77	482.1	16.0	21.3	7.3	0.013	0.25	2	5	25	PERVIOUS	55	320	0.3	0.3	0.1	0.1
S543	SU348.7	29.11	1680.3	173.2	7.2	45.5	0.013	0.25	2	5	25	PERVIOUS	55	210	1.0	0.3	0.1	0.1
S544	SU349.9	35.32	2513.2	140.5	6.5	55.4	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S545	SU349	5.54	886.5	62.5	8.7	7.2	0.013	0.25	2	5	25	PERVIOUS	55	210	1.0	0.3	0.1	0.1
S546	SU349.1	24.50	1980.4	123.7	8.8	35.7	0.013	0.25	2	5	25	PERVIOUS	55	171	4.9	0.3	0.1	0.1
S547	SU349.3	4.14	754.5	54.9	8.9	43.4	0.013	0.25	2	5	25	PERVIOUS	55	281	0.5	0.3	0.1	0.1
S548	SU349.4	36.06	2849.7	126.5	6.0	45.9	0.013	0.25	2	5	25	PERVIOUS	55	215	1.0	0.3	0.1	0.1
S549	SU349.5	13.52	1105.5	122.3	10.8	25.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S550	SU349.6	7.63	1440.2	53.0	11.1	41.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S551	SU349.8	37.24	1852.7	201.0	14.8	22.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S552	SU349.7	21.84	1742.5	125.3	9.9	13.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S553	J122	66.35	5179.3	128.1	15.0	2.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S554	SU350.2	20.75	2105.4	98.6	6.3	46.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S555	SU350.1	10.08	1084.1	93.0	7.7	54.4	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S556	SU404	4.91	623.9	78.7	9.3	59.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S557	J638	15.39	2048.8	75.1	7.5	36.9	0.013	0.25	2	5	25	PERVIOUS	55	201	2.0	0.3	0.1	0.1
S558	SU134	54.11	3754.9	144.1	6.0	42.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S559	J009	34.64	3927.8	88.2	7.7	17.2	0.013	0.25	2	5	25	PERVIOUS	20	110	10.9	0.37	0.37	0.1
S560	J009	84.96	4968.1	171.0	6.7	9.4	0.013	0.25	2	5	25	PERVIOUS	20	119	10.0	0.362	0.362	0.1
S561	J023	91.28	4616.1	197.7	12.7	7.7	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S562	J637	50.06	3966.3	126.2	5.0	43.8	0.013	0.25	2	5	25	PERVIOUS	55	203	1.7	0.3	0.1	0.1
S563	J042	64.90	4238.9	153.1	5.9	2.6	0.013	0.25	2	5	25	PERVIOUS	20	99	6.9	0.359	0.359	0.1
S564	SU81.1	44.01	3112.2	141.4	5.7	46.1	0.013	0.25	2	5	25	PERVIOUS	55	213	1.0	0.3	0.1	0.1
S565	J580	40.18	2756.7	145.8	19.9	5.7	0.013	0.25	2	5	25	PERVIOUS	55	149	8.5	0.3	0.1	0.1
S566	J580	61.28	3933.0	155.8	15.1	3.0	0.013	0.25	2	5	25	PERVIOUS	55	146	7.7	0.3	0.1	0.1
S567	J057	0.06	111.7	5.4	12.3	0.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S568	J078	5.99	1175.6	51.0	13.1	16.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S569	J065	16.26	1540.9	105.5	17.8	4.1	0.013	0.25	2	5	25	PERVIOUS	55	220	1.0	0.3	0.1	0.1
S570	J095	6.08	1166.4	52.1	8.5	10.3	0.013	0.25	2	5	25	PERVIOUS	55	233	0.9	0.3	0.1	0.1
S571	J111	32.58	3168.2	102.8	4.4	83.1	0.013	0.25	2	5	25	PERVIOUS	55	222	0.9	0.3	0.1	0.1
S572	J107	37.54	3453.0	108.7	6.1	41.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S573	J106	54.34	3420.8	158.9	5.6	55.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S574	J116	16.77	3214.4	52.2	12.7	27.3	0.013	0.25	2	5	25	PERVIOUS	55	199	4.8	0.3	0.1	0.1
S575	J130	20.52	4061.2	50.5	5.0	54.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S576	J141	7.32	2096.2	34.9	14.3	31.2	0.013	0.25	2	5	25	PERVIOUS	55	293	0.4	0.3	0.1	0.1
S577	J146	29.34	3680.2	79.7	10.8	31.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S578	SU27	21.03	2421.1	86.9	7.2	64.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S579	J645	77.20	3555.5	217.1	5.3	38.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S580	J167	11.72	2586.4	45.3	11.5	23.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S581	SU198.2	116.07	3649.4	318.1	5.8	55.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S582	J624	43.80	3346.3	130.9	8.5	41.4	0.013	0.25	2	5	25	PERVIOUS	55	320	0.3	0.3	0.1	0.1
S583	J185	32.07	4517.6	71.0	13.8	21.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S584	J185	34.91	4697.1	74.3	5.7	72.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1

S585	J209	6.74	1449.3	46.5	12.8	3.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S586	J206	12.44	3040.8	40.9	13.0	4.8	0.013	0.25	2	5	25	PERVIOUS	20	293	0.4	0.227	0.227	0.1
S587	J616	15.60	1798.0	86.8	9.2	45.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S588	J200	36.43	2997.2	121.5	8.5	32.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S589	J200	30.41	2554.9	119.0	6.7	53.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S590	J201	14.29	2626.1	54.4	8.9	37.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S591	J212	40.75	5644.7	72.2	7.5	45.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S592	J205	47.68	4094.9	116.4	7.2	47.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S593	J128	87.07	5079.9	171.4	7.0	69.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S594	J220	13.63	2332.0	58.4	12.6	35.4	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S595	J235	44.99	3818.4	117.8	9.4	20.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S596	J230	2.98	929.2	32.1	6.8	74.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S597	J584	26.53	3398.1	78.1	5.0	77.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S598	J248	2.49	1169.3	21.3	13.5	35.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S599	J268	82.04	6432.4	127.5	7.8	49.1	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S600	J247	90.88	6067.3	149.8	6.3	52.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S601	J247	14.67	2248.4	65.2	7.5	40.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S602	J276	74.98	7903.5	94.9	7.7	40.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S603	J263	30.79	2894.8	106.4	5.7	35.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S604	J275	16.11	1426.7	112.9	11.2	25.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S605	J281	45.26	3915.0	115.6	8.1	29.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S606	J608	54.84	4377.3	125.3	4.9	63.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S607	J255	89.68	5841.7	153.5	6.5	46.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S609	J273	33.65	3839.8	87.6	8.7	46.8	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S610	J613	27.76	3678.9	75.5	7.7	45.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S611	J613	77.57	5625.4	137.9	7.0	45.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S612	J288	4.57	1106.4	41.3	11.4	23.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S613	J284	56.20	5036.7	111.6	6.6	41.5	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S614	J317	8.82	1948.9	45.3	4.0	48.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S615	J309	86.18	6504.3	132.5	5.7	73.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S616	J311	1.06	832.9	12.7	4.8	56.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S617	J313	50.47	3587.0	140.7	4.6	58.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S618	J313	34.10	3223.9	105.8	5.1	47.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S619	J321	50.21	3713.6	135.2	6.6	57.4	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S620	J318	91.77	6257.3	146.7	4.1	66.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S621	J318	33.67	2985.5	112.8	4.9	55.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S622	J320	61.02	4677.0	130.5	5.5	45.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S623	J319	45.54	2773.9	164.2	10.2	30.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S624	J323	74.49	5011.0	148.7	8.9	41.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S625	J326	31.83	2611.2	121.9	4.9	54.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S626	J325	32.28	2400.3	134.5	4.3	43.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S627	J324	54.15	3838.1	141.1	4.6	47.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S628	J324	34.64	3013.4	115.0	5.4	48.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S629	J329	44.61	3641.6	122.5	6.2	45.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S630	J328	69.17	4843.3	142.8	6.8	46.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S631	J328	15.75	2399.5	65.6	6.7	46.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S632	J333	19.69	2850.9	69.1	11.9	29.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S633	J335	57.95	4688.0	123.6	9.3	38.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S634	J352	37.60	4759.4	79.0	6.5	58.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

S635	J340	46.81	2898.2	161.5	5.4	72.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S636	_GRossLordD	23.16	2553.6	90.7	9.8	14.7	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S637	J351	35.27	5456.3	64.6	14.6	27.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S638	J348	25.38	2783.7	91.2	6.1	63.7	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S639	J348	49.95	4058.3	123.1	5.3	38.1	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S640	_GRossLordD	21.27	2233.7	95.2	10.2	3.0	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S641	_GRossLordD	13.50	2108.3	64.0	9.8	38.4	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S642	J361	80.19	6947.9	115.4	7.3	54.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S643	J375	73.72	4078.3	180.8	5.4	52.6	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S644	J375	95.88	6802.6	140.9	5.2	46.1	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S645	J365	51.38	2945.0	174.5	6.9	41.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S646	J377	66.77	4392.5	152.0	6.0	60.1	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S647	J358	30.47	3314.4	91.9	7.0	76.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S648	J603	81.06	4637.6	174.8	9.5	40.3	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S649	J388	79.94	5610.6	142.5	4.8	51.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S650	J394	49.09	3293.4	149.1	11.8	30.8	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S651	J397	16.55	2105.8	78.6	5.0	56.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S652	J396	30.10	2701.2	111.4	5.0	73.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S653	J406	45.98	4891.5	94.0	4.8	52.6	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S654	J400	2.99	823.5	36.3	12.3	23.3	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S655	J399	81.44	4184.2	194.6	8.0	46.0	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S656	J402	82.17	4700.6	174.8	16.5	17.3	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S657	J416	48.20	3892.2	123.8	8.0	43.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S658	J413	22.96	2342.5	98.0	12.5	22.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S659	J417	52.71	5408.6	97.5	4.2	74.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S660	J426	66.80	4883.3	136.8	7.0	37.8	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S661	J421	72.45	3964.5	182.7	7.7	47.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S662	J421	15.64	2038.4	76.7	7.1	50.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S663	J420	33.81	3457.0	97.8	6.4	74.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S664	J600	62.40	3518.7	177.3	11.8	40.7	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S665	J439	16.39	3413.2	48.0	5.5	53.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S666	J431	36.31	4139.3	87.7	10.4	26.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S667	J433	38.86	3984.4	97.5	5.7	37.6	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S668	J442	31.31	2739.3	114.3	12.4	51.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S669	J440	1.15	855.5	13.4	4.4	82.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S670	SU315	95.14	4166.5	228.3	10.0	48.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S671	J448	58.00	4210.6	137.7	18.7	28.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S672	J448	21.95	3333.9	65.8	13.8	29.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S673	J449	90.11	7020.3	128.4	8.3	49.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S674	J446	30.28	3135.8	96.6	5.7	55.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S675	J452	83.94	5226.8	160.6	4.6	78.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S676	J572	92.78	8291.4	111.9	3.6	57.9	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S677	J459	33.83	4002.0	84.5	7.6	42.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S678	J458	69.47	4894.7	141.9	6.1	53.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S679	J458	33.51	3429.7	97.7	5.7	58.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S680	J469	77.62	4984.2	155.7	19.1	12.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S681	J467	2.94	872.7	33.7	13.7	1.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S682	J466	8.78	1262.6	69.5	24.4	2.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S683	J481	22.43	3001.0	74.7	9.8	8.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1

S684	J475	57.32	4263.8	134.4	11.6	40.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S685	J477	85.55	5611.4	152.5	14.1	23.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S686	J483	31.83	2649.8	120.1	14.8	34.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S687	J483	86.51	6127.6	141.2	6.2	57.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S688	J484	23.06	2222.1	103.8	9.0	10.6	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S689	J484	91.74	4945.9	185.5	5.8	66.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S690	J499	47.87	4122.1	116.1	4.5	55.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S691	J494	78.08	4770.5	163.7	12.2	47.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S692	J512	59.35	3329.6	178.3	12.7	51.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S693	J498	41.06	4938.5	83.1	6.0	63.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S694	J504	18.42	1623.8	113.4	8.5	50.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S695	J493	90.14	6235.4	144.6	5.6	65.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S696	J506	63.29	4162.3	152.1	4.8	73.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S697	J501	48.97	3677.7	133.2	7.3	43.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S698	J511	54.67	4188.7	130.5	24.2	15.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S699	J508	70.16	3651.1	192.2	7.7	54.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S700	J510	32.49	3306.7	98.3	18.8	28.5	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S701	J510	22.28	2081.3	107.0	11.2	48.9	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S702	J523	68.41	3496.4	195.7	4.7	58.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S703	J516	31.75	2719.3	116.8	11.0	61.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S704	J519	7.20	1079.2	66.7	14.3	54.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S705	J514	14.37	1689.2	85.1	19.5	32.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S706	J527	8.03	1911.1	42.0	16.2	28.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S707	J520	34.81	3667.0	94.9	11.9	44.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S708	J520	45.49	3228.8	140.9	12.0	42.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S709	J522	9.48	1861.3	50.9	7.8	33.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S710	J526	88.28	3614.8	244.2	11.5	48.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S711	J526	41.48	3402.2	121.9	13.3	30.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S712	J524	83.97	7632.7	110.0	7.8	54.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S713	J528	2.75	1106.5	24.9	12.2	25.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S714	J532	1.85	528.3	35.0	15.1	19.7	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S715	J533	41.53	3242.4	128.1	10.8	49.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S716	J535	48.89	3658.6	133.6	5.3	61.4	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S717	J549	32.24	3081.2	104.6	11.2	35.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S718	J555	40.02	3684.0	108.6	16.0	35.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S719	J563	58.36	3894.6	149.8	10.4	48.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S720	J571	80.53	5124.2	157.2	9.8	67.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S721	J571	39.72	3921.8	101.3	5.7	79.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S722	OF01	52.01	4327.0	120.2	6.2	55.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S723	J558	15.53	1894.4	82.0	16.2	41.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S724	J082	28.69	3194.4	89.8	7.1	48.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S725	J103	77.97	4386.3	177.8	6.5	47.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S726	J460	62.78	3999.6	157.0	5.5	47.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S727	J496	57.47	3806.0	151.0	7.3	41.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S728	J550	50.81	2953.2	172.1	17.1	42.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S729	J578	75.23	3511.9	214.2	6.3	39.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S730	J568	50.82	2754.3	184.5	13.7	57.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S731	J495	54.74	4110.4	133.2	8.9	54.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S732	J374	69.82	4506.8	154.9	8.7	44.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

S733	J270	62.80	3883.6	161.7	9.6	45.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S734	J105	88.50	4883.7	181.2	4.8	30.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S735	J390	51.98	4029.5	129.0	6.2	49.4	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S736	J618	33.80	2627.5	128.6	6.1	52.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S737	J382	23.58	1937.3	121.7	5.9	14.6	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S738	J497	70.12	4116.8	170.3	4.3	76.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S739	J507	70.80	3586.4	197.4	5.0	62.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S740	J081	3.76	1296.2	29.0	8.6	35.3	0.013	0.25	2	5	25	PERVIOUS	55	210	1.0	0.3	0.1	0.1
S741	J476	60.18	3876.9	155.2	4.9	63.6	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S742	J197	91.10	3045.0	299.2	7.5	33.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S743	J505	32.85	2466.3	133.2	7.0	48.6	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S744	J482	18.45	2287.8	80.6	4.7	17.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S745	J347	60.23	3102.2	194.2	5.6	39.2	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S746	J308	71.11	4067.9	174.8	6.6	45.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S747	J540	38.14	3874.4	98.4	15.9	33.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S748	J234	58.87	4139.2	142.2	13.7	20.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S749	J240	67.45	4958.1	136.0	11.4	27.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S750	J364	31.83	3389.7	93.9	11.4	35.2	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S751	J366	78.82	4639.4	169.9	12.8	30.4	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S752	J297	61.85	3244.8	190.6	6.7	71.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S753	J502	59.62	3485.1	171.1	5.5	74.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S754	J610	92.53	5314.7	174.1	6.5	60.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S755	J296	68.37	3631.3	188.3	6.8	44.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S756	J389	39.45	2970.3	132.8	5.4	52.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S757	J556	48.66	3897.0	124.9	13.2	53.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S758	J441	67.56	5086.4	132.8	4.9	46.2	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S759	J238	63.59	3668.9	173.3	5.7	52.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S760	J379	58.02	3108.9	186.6	6.3	54.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S761	J444	89.20	5386.1	165.6	12.1	27.3	0.013	0.25	2	5	25	PERVIOUS	55	90	40.0	0.3	0.1	0.1
S762	J304	39.31	3767.1	104.4	4.8	53.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S763	SU17001	8.22	1121.7	73.3	7.0	52.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S764	SU81	16.19	1670.2	96.9	5.6	43.2	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S765	SU210	66.95	4811.9	139.1	6.6	50.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S766	SU303	22.17	2016.5	109.9	6.0	34.8	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S767	J061	4.02	787.9	51.0	7.3	10.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S768	SU17021	31.74	2457.6	129.2	10.6	44.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S769	J038	10.06	2170.6	46.3	16.8	2.9	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S770	J119	8.73	1047.6	83.3	21.5	0.4	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S771	J202	42.78	3969.2	107.8	9.2	50.1	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S772	SU22.1	98.90	5586.4	177.0	3.7	81.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S773	SU227	87.37	3679.7	237.4	13.9	20.2	0.013	0.25	2	5	25	PERVIOUS	55	110	10.9	0.3	0.1	0.1
S774	J255	93.86	2898.8	323.8	6.2	62.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S775	SU405	52.56	3918.4	134.1	5.0	55.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S776	SU79	9.46	1785.0	53.0	7.9	44.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S777	SU17013	8.22	2565.9	32.0	12.3	24.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S778	J063	56.41	4570.8	123.4	5.3	64.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S779	J073	18.25	1824.1	100.1	6.4	49.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S780	J242	28.26	3455.1	81.8	5.4	57.3	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S781	J543	54.37	3696.2	147.1	21.2	18.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

S782	SU4	62.73	3596.6	174.4	8.6	37.5	0.013	0.25	2	5	25	PERVIOUS	55	176	5.5	0.3	0.1	0.1
S783	SU1.1	108.38	3422.1	316.7	7.4	58.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S784	SU128.1	120.46	5085.0	236.9	7.6	52.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S786	J100	62.18	3563.9	174.5	5.1	57.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S788	SU406	33.15	3596.8	92.2	5.8	54.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S789	J157	61.26	4488.7	136.5	5.2	45.8	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S790	J472	65.21	5373.3	121.4	6.6	54.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S791	J462	34.34	2275.2	150.9	6.1	52.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S792	J418	39.11	5100.2	76.7	11.8	33.3	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S793	J456	58.25	3865.5	150.7	5.1	57.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S794	J577	46.81	2900.8	161.4	4.8	60.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S795	J445	17.54	1878.7	93.4	5.2	59.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S796	J575	84.85	3531.7	240.3	4.5	53.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S797	J422	38.75	2792.0	138.8	13.3	27.8	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S798	_GRossLordD	64.90	3127.4	207.5	10.8	46.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S799	J383	0.97	355.2	27.3	21.3	12.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S800	J286	38.71	3679.3	105.2	7.6	45.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S801	J356	11.62	1898.1	61.2	12.5	36.4	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S802	J272	26.14	2503.1	104.4	8.8	55.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S803	J323	16.45	1988.6	82.7	9.6	30.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S804	J302	9.73	1354.2	71.9	15.3	9.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S805	J295	14.91	2031.9	73.4	13.6	38.1	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S806	SU17	60.00	3407.5	176.1	5.1	71.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S807	J227	21.19	2755.0	76.9	3.1	81.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S808	J222	51.60	3350.9	154.0	11.6	36.9	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S809	SU9	51.71	2371.7	218.0	9.3	36.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S810	J165	18.00	3260.7	55.2	9.1	46.1	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S811	J136	19.69	2918.6	67.5	7.3	43.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S812	SU146.1	58.18	2649.1	219.6	6.8	51.9	0.013	0.25	2	5	25	PERVIOUS	55	216	1.8	0.3	0.1	0.1
S813	J062	10.92	2736.0	39.9	11.6	30.6	0.013	0.25	2	5	25	PERVIOUS	55	209	3.4	0.3	0.1	0.1
S814	J067	14.37	2415.3	59.5	11.3	33.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S815	J015	7.06	1154.5	61.2	14.6	19.6	0.013	0.25	2	5	25	PERVIOUS	55	245	0.8	0.3	0.1	0.1
S816	J021	4.96	1107.9	44.8	8.2	44.8	0.013	0.25	2	5	25	PERVIOUS	55	251	0.7	0.3	0.1	0.1
S817	J588	52.07	4544.9	114.6	6.6	59.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S818	SU271.3	75.09	4363.0	172.1	6.3	57.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S819	SU128	14.12	1476.5	95.6	6.6	12.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S820	J065	2.99	886.5	33.7	12.6	7.0	0.013	0.25	2	5	25	PERVIOUS	55	236	0.8	0.3	0.1	0.1
S821	SU341.1	76.25	3836.5	198.8	14.9	11.2	0.013	0.25	2	5	25	PERVIOUS	55	180	4.9	0.3	0.1	0.1
S822	J597	50.70	3921.4	129.3	22.4	33.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S823	J598	17.32	1558.2	111.2	21.8	7.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S824	J432	28.84	2674.6	107.8	15.0	10.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S825	J449	13.21	4961.7	26.6	21.9	10.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S826	J769	6.55	1439.6	45.5	16.7	24.3	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S827	J387	9.10	1565.2	58.1	17.6	27.5	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S828	J601	24.73	2635.4	93.8	13.3	40.1	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S829	J602	35.55	3206.2	110.9	20.7	28.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S830	J604	26.96	2786.9	96.7	7.9	51.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S831	J316	4.97	931.3	53.4	7.6	39.1	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S832	J321	10.39	3274.7	31.7	5.9	70.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1

S833	J609	25.16	2385.7	105.5	8.0	41.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S834	J287	5.24	911.7	57.5	4.9	86.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S835	J285	0.18	214.1	8.4	21.9	21.3	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S836	J607	34.29	2738.2	125.2	7.7	15.1	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S837	J611	51.90	3961.0	131.0	16.5	29.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S838	SU95	54.04	4742.9	113.9	9.7	40.9	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S839	J269	58.37	4145.4	140.8	5.1	50.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S840	SU95.1	42.87	3024.9	141.7	4.1	25.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S841	J241	13.74	2857.1	48.1	6.6	59.5	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S842	J269	3.13	680.1	46.0	8.7	40.9	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S843	J292	9.08	1795.4	50.6	6.1	41.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S844	J290	0.59	393.0	15.0	15.4	15.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S845	J614	29.70	2807.0	105.8	9.0	48.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S846	J615	24.31	3264.7	74.5	7.6	72.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S847	J196	0.60	263.1	22.8	22.9	14.8	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S848	J214	1.76	510.8	34.5	18.9	17.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S849	J134	39.10	2993.2	130.6	6.3	55.0	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S850	J203	12.68	3282.3	38.6	10.1	51.6	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S851	J620	7.56	2494.6	30.3	8.4	56.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S852	J180	32.97	2446.5	134.8	5.9	65.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S853	J177	4.00	1318.3	30.3	17.6	15.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S854	J623	11.19	1623.3	68.9	7.2	42.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S855	J125	1.80	915.2	19.7	7.1	48.2	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S856	J193	9.54	1284.2	74.3	15.2	25.6	0.013	0.25	2	5	25	PERVIOUS	55	320	0.3	0.3	0.1	0.1
S857	J142	2.66	1401.6	19.0	10.1	45.7	0.013	0.25	2	5	25	PERVIOUS	55	320	0.3	0.3	0.1	0.1
S858	J626	5.07	1287.6	39.4	16.5	24.3	0.013	0.25	2	5	25	PERVIOUS	55	294	0.4	0.3	0.1	0.1
S859	J050	10.58	1695.9	62.4	6.1	41.1	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S860	J628	42.73	2834.4	150.8	6.8	44.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S861	J629	19.39	3269.7	59.3	6.5	57.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S862	J630	28.05	2959.6	94.8	6.1	48.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S863	J631	6.63	1142.7	58.0	11.4	30.8	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S864	J107	7.64	2028.9	37.7	10.3	16.6	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S865	J633	6.83	1155.3	59.1	7.8	31.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S866	J634	11.59	1711.3	67.7	6.7	45.9	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S867	J635	4.73	965.3	49.0	13.1	3.2	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S868	J632	29.62	2465.8	120.1	5.6	48.0	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S869	SU4.4	43.08	4052.1	106.3	5.6	41.3	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S870	J080	1.88	650.8	28.9	6.9	37.1	0.013	0.25	2	5	25	PERVIOUS	55	210	1.0	0.3	0.1	0.1
S871	J040	22.34	2290.9	97.5	7.5	40.4	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S872	J032	3.56	712.0	50.0	9.7	32.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S873	J639	4.68	1237.9	37.8	9.6	32.4	0.013	0.25	2	5	25	PERVIOUS	55	249	1.2	0.3	0.1	0.1
S874	J640	29.17	2220.4	131.4	8.4	33.2	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S875	J641	8.75	1512.0	57.9	7.3	21.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S876	J642	14.80	1788.2	82.8	5.5	19.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S877	J643	27.25	3035.0	89.8	5.7	22.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S878	J173	0.36	224.3	16.1	15.5	4.9	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S879	J155	2.06	766.2	26.9	8.0	38.1	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S880	J581	18.76	1754.8	106.9	9.8	37.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S881	SU226	55.14	4278.0	128.9	5.5	45.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

S882	J068	15.39	1614.7	95.3	6.8	38.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S883	J014	46.42	3267.9	142.0	12.7	18.1	0.013	0.25	2	5	25	PERVIOUS	55	190	5.2	0.3	0.1	0.1
S884	J253	53.04	3802.9	139.5	10.9	26.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S886	SU226.1	54.24	2960.9	183.2	5.7	61.7	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S887	J399	57.92	4652.9	124.5	14.2	25.0	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S888	J407	66.07	4546.3	145.3	5.8	44.1	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S889	J427	14.42	3098.9	46.5	12.3	42.0	0.013	0.25	2	25	25	PERVIOUS	40	89	3.3	0.35	0.1	0.1
S890	J339	18.71	2852.7	65.6	6.9	55.5	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S891	J283	31.05	3037.9	102.2	13.2	39.7	0.013	0.25	2	5	25	PERVIOUS	20	90	25.0	0.3	0.2	0.1
S892	J265	23.63	4980.7	47.4	13.5	58.7	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S893	J265	87.74	9813.0	89.4	8.9	48.0	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S894	J276	18.18	1806.3	100.7	12.7	31.8	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S895	J487	52.74	3954.3	133.4	8.5	40.9	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S896	J530	23.98	2537.9	94.5	11.0	47.0	0.013	0.25	2	5	25	PERVIOUS	30	90	40.0	0.3	0.2	0.1
S897	J305	24.17	3047.7	79.3	9.6	35.6	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S898	J241	42.77	3753.4	114.0	7.8	51.4	0.013	0.25	2	5	25	PERVIOUS	20	90	10.0	0.3	0.1	0.1
S899	SU95	8.43	1996.5	42.2	7.8	0.3	0.013	0.25	2	5	25	PERVIOUS	55	90	10.0	0.3	0.1	0.1
S910	SU304	3.51	813.4	43.2	7.4	50.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S911	J154	21.01	2539.8	82.7	11.4	29.5	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1
S914	J109	31.64	2550.8	124.0	4.8	75.6	0.013	0.25	2	5	25	PERVIOUS	55	89	3.3	0.35	0.15	0.1

1. Flow length was calculated as area divided by width

Appendix B: Crossing Screening Matrix

Structures to be excluded from consideration

Structures to be included

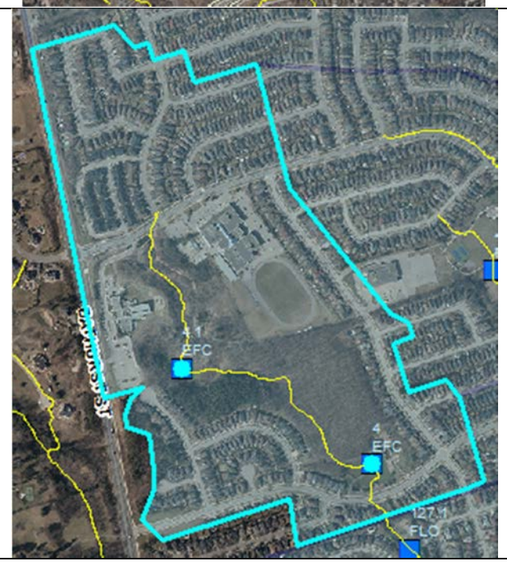
Flood Sheet	Branch	Crossing	Change in Depth Across the Crossing m	Approx US area of 'ponding' associated with increased depth m2	Is crossing significant for hydrology model?	Note/Comment
Don_01	Lower Don	Dundas St	0.08	n/a	No	
	Lower Don	Gerrard	0.27	n/a	No	
Don_01a	Lower Don	Queen St			No	
	Lower Don	Eastern Ave			No	
	Lower Don	Rail Line			No	
Don_02	Rosedale Valley Rd	Bloor St	0.7	not evident- channel is narrow	No	
	Rosedale Valley Rd	Sherbourne	0.8	not evident- channel is narrow	No	
	Rosedale Valley Rd	Mount Pleasant	0.8	not evident- channel is narrow	No	
Don_01w	West Don	Rail Line	0.04		No	
	West Don	Eglinton	0.5	not evident	No	no, minor impact to Regional flood levels, no impact to design storm events
Don_02						
Don_03	Lower Don	Prince Edward Viaduct	0.03		No	
		Pottery Road (44.025)			Yes	Eveident for minor events
Don_03w	Wilket Creek	Lawrence Ave	6	14000	Yes	
Don _03wa	Wilket Creek	Ped. Crossing (15.0825)			Yes	
Don_03wa	Wilket Creek	York Mills Rd			No	
Don_04	Mud Creek	Governor's Road		not evident- channel is narrow	No	
	Lower Don	Rail Line (44.115)			Yes	Eveident for minor events
	Lower Don	Rail Line (44.185)			Yes	Eveident for minor events
Don_04w	West Don	Bayview	1		No	
Don _4W	West Don	Old Bridge (abandoned) E. of Bayview Ave. (11.0345)	1		Yes	
Don _4W	West Don	Vehicle Bridge (11.0515)	1 (DE)		Yes	
Don_5W	West Don	Donino Ave. (11.0695)			Yes	
Don_5W	West Don	Mill St. (11.0745)			Yes	
Don_7W	West Don	Don River Blvd. (11.1145)			Yes	
	East Tributary	not sure	1	not evident- channel is narrow	No	
Don_05	Lower Don	Leaside Bridge- Millwood Rd	0.27		No	
Don_05w	West Don	Highway 401	1	18000	No	
	West Don	Wilson Ave	1.5	140000	Yes	
	West Don	Yonge St			No	
	West Don	Mill St			No	
Don_06	Taylor Massey Creek	O'Connor Dr	0.01		No	
Don_06w						
Don_07	West Don	Overlea Blvd	0.24		No	
	West Don	Vehical Bridge (16.095)			Yes	Eveident for minor events
	East Don	DVP	0.03		No	
Don_07w	West Don	Sheppard Ave	1.5	73400	No	No, crossing upstream (Don River Blvd) more critical.
	West Don	Bathurst St	1	small area to next US structure	Yes	
	West Don	pond access US of Bathurst?	3	60000	Yes	
Don_08	Lower Don					
Don_08w	West Don	Finch Ave	1.3	54000	Yes	
Don_09	East Don	Eglinton Ave E		not evident- channel is narrow	No	
	East Don	Rail Line	0.04		No	
	East Don	Rail Line	0.4		No	
	East Don	Rail Line	0.4		No	
Don_09w	West Don	Finch Ave	3	88000	No	No, structure is influenced by G.Ross Lord Dam
	West Don	Access road	2	290000	Yes	
Don_10	East Don	Rail Line	small		No	
	East Don	Lawrence Ave E	1.3	not evident- channel is narrow	No	
	East Don	DVP	1	not evident- channel is narrow	No	
Don_10w	Fisherville Creek	Fisherville Rd		narrow channel, shallow ponding/spill	Yes	Fisherville and Steels are the same structure. Have been modelled in SWMM. Summery report provided to AECOM
	Fisherville Creek	Steeles Ave		narrow channel, shallow ponding/spill	Yes	
Don_10w	Fisherville Creek	Conley St		narrow channel, shallow ponding/spill	Yes	
Don_10w	Fisherville Creek	Charlton Ave (D/S)			Yes	SWMM model has been completed for the structure. Summery report provided to AECOM
	West Don	Steeles Ave	1	48000	Yes	
	West Don	CN RAILWAY NORTH OF STEELES AVE (7.1195)	1.94		Yes	
	West Don	Hwy 401 / Dufferin	3	40000	Yes	
Don_11	East Don	York Mills Rd.			Yes	
	East Don	Donalda Golf Club Bridges (41.1303)			No	Appear to affect 2- and 5-year type events; perhaps include one for calibration purposes.
	East Don	Donalda Golf Club Bridges (41.1171)			No	Appear to affect 2- and 5-year type events; perhaps include one for calibration purposes.
	East Don	Donalda Golf Club Bridges (41.1141)			No	Appear to affect 2- and 5-year type events; perhaps include one for calibration purposes.
	East Don	Donalda Golf Club Bridges (41.1121)			No	Appear to affect 2- and 5-year type events; perhaps include one for calibration purposes.
	East Don	Donalda Golf Club Bridges (41.1071)			Yes	Appear to affect 2- and 5-year type events; perhaps include one for calibration purposes.

Don_11w	West Don	Hwy 407	1	unclear	Yes	
Don_11W	West Don	Glen Shields Ave	1	60000	Yes	
Don_11W	Fisherville Creek	Draper Blvd			Yes	
Don_11W	Fisherville Creek	Clarke Ave		narrow channel, shallow ponding/spill	Yes	
Don_11W	Fisherville Creek	Charlton Ave (U/S)		narrow channel, shallow ponding/spill	Yes	
Don_12	East Don	Don Mills Rd	0.5		No	
	East Don	Duncan Mill Rd	3	220000	Yes	
	East Don	Hwy 401	1.5	unclear	No	Profile impacted by valley contraction just upstream of the crossing.
Don_12w	Fisherville Creek	Beverley Glen Blvd		narrow channel, shallow ponding/spill	No	
	Fisherville Creek	King High Dr		narrow channel, shallow ponding/spill	No	
	Fisherville Creek	Centre Street		narrow channel, shallow ponding/spill	Yes	
	West Don	Hwy 407	1	100000	Yes	Repeat of 11w 407
	West Don	Hwy 7	0.5	44000	No	
Don_12w	West Don	Rivermede Rd	1.6	100000	Yes	
Don_12w		Vehicle concrete box culvert (6.105)	1		Yes	
Don_13	East Tributary	Sheppard Ave	7	17600	Yes	
	East Don	Leslie/Sheppard Ave/Subway Crossing	1.2		Yes	
Don_13w	west tributary	Baldwin	0.8	9000 - narrow channel	No	
	west tributary	Hwy 7	2	10000 - narrow channel	Yes	
	west tributary	Keele St (6.325)			Yes	
Don_14	Milne Creek	Forest Grove Dr.			Yes	
		Finch Ave /Bayview	10	50000	Yes	
Don_14w	West Don	Rail line	6.3	100000	Yes	
	east tributary	Langstaff Rd		narrow channel, shallow ponding/spill	Yes	
	east tributary	Connie Cr		narrow channel, shallow ponding/spill	Yes	
	east tributary	Dufferin		narrow channel, shallow ponding/spill	No	
Don_15	East Don	Finch Ave	3.5	230000	Yes	
	East Don	Cummer Ave	3.8	240000	Yes	
	East Don	Old Cummer (35.245)			Yes	Appears to affect 2- and 5-year type events
Don_15w						
Don_16	East Don	Garnier Court	0.3		No	
		Private Access Road (28.225)			Yes	
Don_16e	German Mills Creek	Leslie St	2.4	20000	Yes	
	German Mills Creek	Rail Line	1.2	65000	Yes	Structure not included in the HEC model due to size, however there is a major constriction in the valley at the crossing location which is affecting all water surface profiles.
Don_16w		Confederation Pkwy	1.1	47000	Yes	
	west	Jacob Keffer Pkwy	3.3	22700	Yes	
Don_17		Steeles Ave	0.74	56000	Yes	
		Bayview	2	30800	Yes	
		Rail Line	2.3	117000	Yes	
Don_17e		Steeles Ave	2.5	130000	Yes	
		John St	5	15700	Yes	
Don_17w	west	Rail Line	5	unclear	Yes	
	west	Rail Line	3	unclear	Yes	
	west	Keele Street (1.035)			Yes	
Don_18		John St	156.90 US		No	
		Royal Orchard Blvd (26.12)	166.36 DS		Yes	
	west	Henderson Ave	2.5	64000	Yes	
	east	Online Pond	3.3	4500	No	
Don_18e		Rail Line?	9	230000	Yes	
	west	Green Lane	0.15		Yes	impacts design storm events
	east	Bronte Rd	0.01		Yes	impacts design storm events
	east	Green Lane	2.7	8000	Yes	
	east	Leslie St	0.03		Yes	
Don_18w	west	Keele St	0.45	10000	Yes	
	west	Rutherford Rd	2	47000	Yes	
		Rutherford Rd	1.3	10000	Yes	
		Fieldgate Dr	1.1	10000	Yes	
Don_19		Yonge St	3.8	180000	Yes	
Don_19e		Acess Road/Ped. Crossing (30.057)			Yes	
		Hwy 407	2.8	18000	No	downstream crossing affects water levels through 407 crossing
		Hwy 7	3.4	49000	Yes	
Don_19w		Rutherford Rd	0.8	60000	Yes	
		Jane St	0.4	40000	Yes	
		Sweetriver Blvd. (1.471)			Yes	
		CNR Track Culvert (101.055)			Yes	
Don_20		Hwy 407	168.9 DS		No	
Don_20e		Bayview	0.4	26000	No	
		Red Maple Rd/16th Ave.	205.63 DS		No	
Don_20w	east	Keele St	1.5	16000	Yes	
		Merino Rd	1.1	12000	Yes	
		Naylon St	0.2		Yes	
		Gram St	0.3		No	
Don_21		Hwy 7	4	120000	Yes	
Don_21e		Rail line	0.6	20000	No	
		Observatory Lane	1	10000	No	

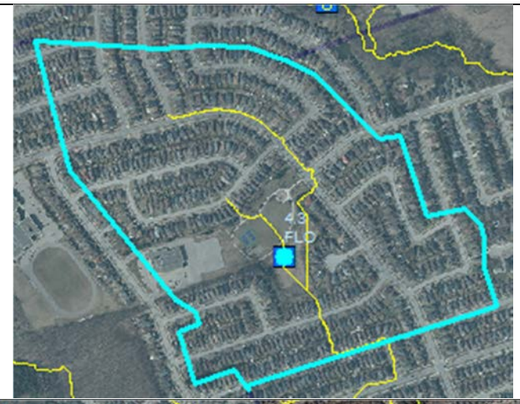
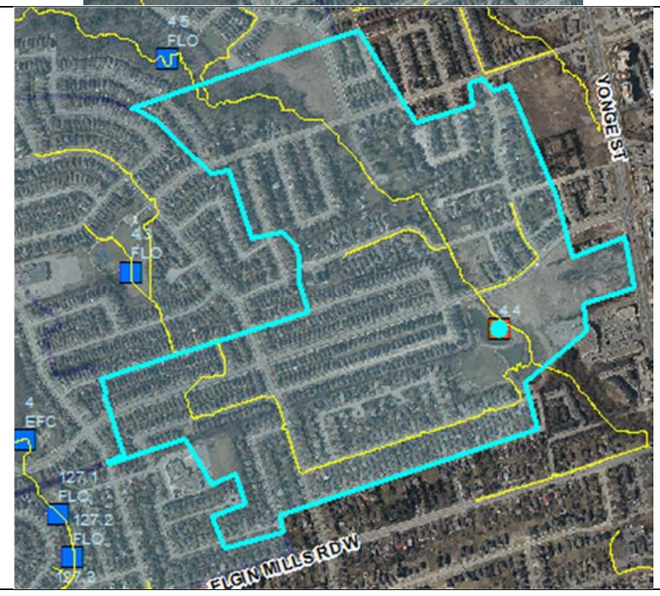
		Church St	0.5	20000	No	
		Weldrick Rd	0.3	5000	No	
Don_21w		Hwy 400	5 m?	160000	Yes	
		Vellore Woods Blvd	0		No	
Don_22	east	Carrville Dr	sheet 24		No	
	west	Bathurst St	4.4	70000	Yes	
	west	Rutherford Rd			No	
	west trib	Rutherford Rd	sheet 23		Yes	
Don_22e		Palmer Ave	1.7	8000	Yes	impacts design storm events
		Major Mackenzie	0.8	8000	Yes	impacts design storm events
		Centre St. (30.222)			Yes	
		Rail Line?	2.4	26000	Yes	
Don_23e		Crosby	Seet 23e		Yes	
Don_22w		Major Mackenzie	4.1	22000	Yes	
		McNaughton Rd	0.9	10000	No	Online Pond
		Cunningham Dr	3.8	50000	Yes	Online Pond?
		Cranston Park Ave	0.6		No	
Don_23		Rutherford Rd (181.08)			Yes	Appears to affect 2- and 5-year type events
		Rutherford Rd (18.29)			Yes	Appears to affect 2- and 5-year type events
Don_23e		Rail Line?	?	?	No	
Don_23w		Drummond Dr	2	60000	Yes	
	west	Teston Rd	1.6	20000	Yes	
	east	Queensberry Cr	0.8	10000	No	
	east	Teston Rd	0.6	10000	No	
Don_24		Carrville Rd	3.8	18000	Yes	
		Castle Rock Dr	4	15000	Yes	
	west	Weldrick Rd	2.3	17000	Yes	
	west	Pemberton / Walmer Rd	3	10000	Yes	Pemberton yes, Walmer no
	east	Weldrick Rd	2.8	20000	Yes	
	east	Kersey Cr	1.5	10000	Yes	
Don_24e		Canyon Hill Ave	2.5	10000	Yes	
		Naughton Dr	2	10000	Yes	
		Residental Laneway (30.270)			Yes	impacts design storm events, and upstream crossings
		Brookside Rd	3	10000	Yes	
Don_24w						
Don_25	west	McCallum Dr	7	40000	Yes	
	west	Major MacKenzie / Bathurst	6	?	Yes	
	east	May Ave	1.3	10000	Yes	
	east	Kersey Cr	3	30000	Yes	
	east	Major MakKenzie	7	70000	Yes	
Don_25e						
Don_25w	west	Kirby Rd	0.5	10000	No	
	east	Rail Line?	6.5	50000	Yes	
	east	Keele St	4	?	Yes	
Don_26e						
Don_27		Kerrybrook Dr	1.3	10000	Yes	
		Richmond St	0.8	10000	No	
		Mill St	4.6	?	Yes	
Don_27e						
Don_28		Regent St	2.5	20000	Yes	
	west	Elgin Mills Rd	4.5	50000	Yes	
	west	Bathurst St	4	30000	Yes	
	east	Oxford St			Yes	
	east	Elgin Mills Rd	2	5000	Yes	
	east	Canyon Hill Ave	3.7	10000	No	Online Pond
Don_30						
Don_31		Ped. Crossing (26.18)			Yes	
		Kirk Dr	4	15000	Yes	
		Access Rd. (26.25)			Yes	
		Access Rd. (26.31)			Yes	
		Access Rd. (26.37)			Yes	
		Access Rd. (26.43)			Yes	
		Langstaff Rd	Sheet 34		No	
Don_33		Rail Line	0.1		No	
Don_34		Yonge St / Hwy 407	1.4	10000	No	
		Garden Ave	0.5	20000	Yes	
Don_m1		Victoria Park	1.5	30000	Yes	
		Dawes Rd	2.5	70000	Yes	
Don_m2		Pharmacy Ave	1	35000	No	
Don_m3		St Clair	1.7	5000	No	
		Warden Ave	1.7	5000	No	
		Rail Line	0.5	35000	No	
		Birchmount	4	20000	Yes	
Don_m4		Foxridge Dr	0.7	30000	No	
Don_m5		Rail Crossing			Yes	

		Eglinton Ave	0.1		No	
		Birchmount Rd	0.1		No	
Don_m6		Lawrence Ave	?		No	
		Tower Dr	0.4		Yes	
		Warden Ave	0.2		No	
Don_m7		Rail Line	0.5	15000	Yes	
		Ellesmere Rd	0.1		No	
		Japonica Rd	0.1		No	
		Penworth Rd	0.1		No	

Appendix C: Pond Database Summary

Municipal ID	Function	Comments	**Documentations**	Tables	**Controlled Area (ha) [1]**	**Include in model?**	**Rationale**	**Ortho Image**
1.1	QFC	RH# 26-1 (Langstaff West Pond), Built, Overdesigned pond, Pond redesigned to save oak tree. MONITORED. Pond File is in CFN 44103	Yes	Yes	120.6	✓		
4.0	EFC	RH# 16-4 (Twickenham Pond D1), Built. Pond File is in CFN 44103	Yes	No	18.9		Ponds in series with the same function. Modeled as one lumped pond. Note: SWM report of 4.0 is for a pond outside of the Don watershed boundary	
4.1	EFC	RH# 16-5 (Elgin West Pond D2), Built. UNMONITORED. Pond File is in CFN 44103	Yes	Yes	40.7	✓		

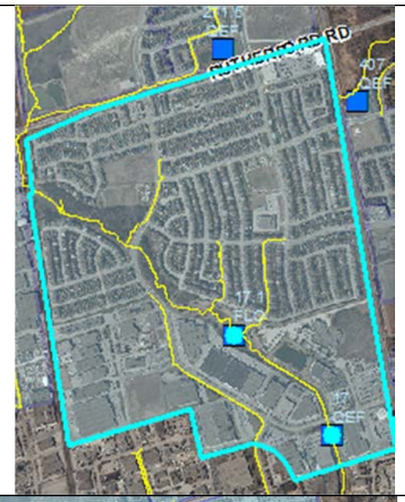
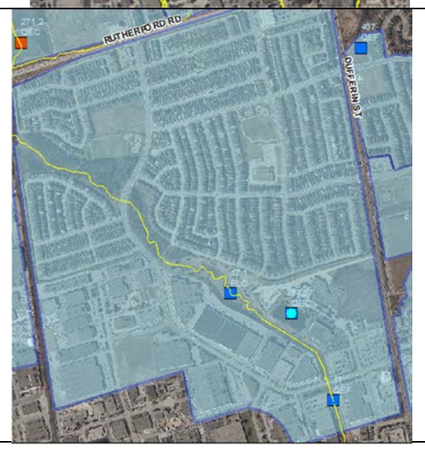
[1] *Area taken from pond inventory sheets. The actual drainage area in the model may differ slightly.*

4.3	FLO	RH# 16-6 (Elgin West Pond GM2), Built, Controls major system flows only, UNMONITORED. Pond File is in CFN 44103	Yes	Yes	38.1	✓		
4.4			No	No	90.2 [2]	✓		

[2] *Estimated area based on a combination of documentations, GIS data and topographic information*

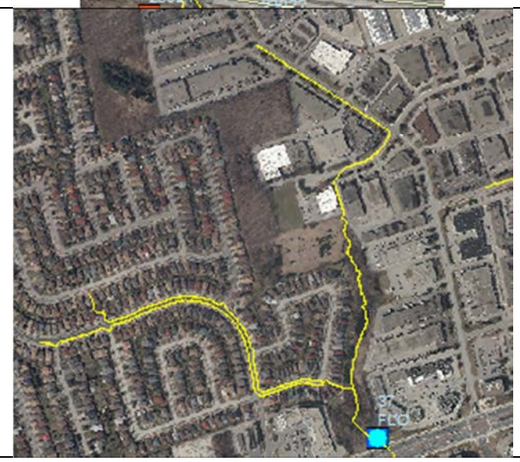
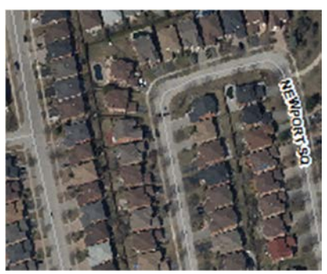
4.5	FLO	RH# 16-9 (Elgin West Pond GM4). UNMONITORED. Pond File is in CFN 44103	Yes	Yes	84.0	✓		
4.6	QEC	RH# 16-10 (Elgin West Pond GM4E), Minor system only - major flow bypass to pond Gm4. MONITORED. Pond File is in CFN 44103	Yes	No	33.4	X	Quality and/or erosion control only	
4.7	QEC	RH# 16-8 (Elgin West Pond GM4W), Minor system only - major flow bypass to pond Gm4, Sediment cleanout: May 2001; Resident complaint re: disruption of habitat during dredging. 100 yr elevation is actually given as high water elevation on diagram. UNMONITORED. Pond File is in CFN 44103	Yes	Yes	12.7	X	Quality and/or erosion control only	
4.8			No	No	Unknown	X	Out of watershed boundary	
4.9			No	No	Unknown	X	Out of watershed boundary	
9.0	FLO	Vaughan # 41 (Maple Neighbourhood Pond), Built, Maximum Release Rate pertains to 100 year event Max. Release Rate for regional event is 72.79 cms -There was an interim pond built which was to be removed when the subdivision development was completed and the final pond was built -Videos available, dated. Pond File is in CFN 44103	Yes	Yes	170.0	✓		

15.0	FLO	Vaughan # 125 (Pond 125 - Tudor Industrial Business Park), Built, Subdivision under construction, FID=65; SD Name=Tudor Industrial Business Park. Pond File is in CFN 44103	Yes	Yes	122.9 [2]	✓			
16.0	QFC	Vaughan # 119 (N/ houses and btwn Hammerstone Cres & Sadot Ct.) on VN revised 2009 pond map which illustrate the pond to be Built and labelled as wet and assumed, Original SWM report cannot be found, data based on Thornhill-Vaughan MDP (therefore information is missing). Pond File is in CFN 44103. VN map provided on Jan 2015 does not have this pond illustrated on the map. Oct 2015 (DK) - pond location (green dot) on SWMSoft should be relocated straight south to south of watercourse and btween residential houses.	Yes	Yes	Unknown	✓	Note: Original SWM report is not available		
17.0	QEF	Pond File is in CFN 44103. Oct 2015 (DK) - Map in TRCA's PDF reports indicates "pond" 17.0 to have an existing control structure. Not firm that there is a pond at this location. Confirmation is required for pond existance. Also check what control	Yes	Yes	20.0	✓	Ponds in series with the similar functions Model as one lumped pond.		

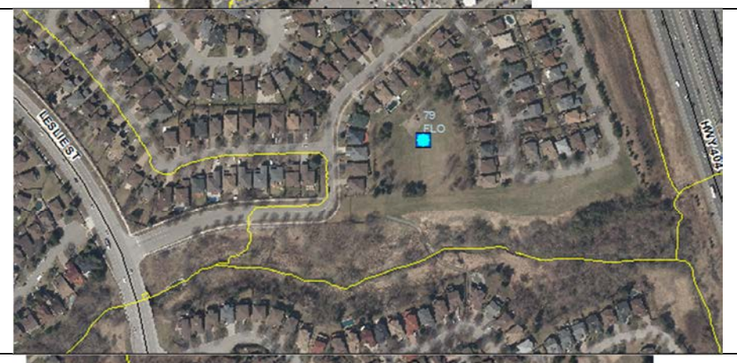
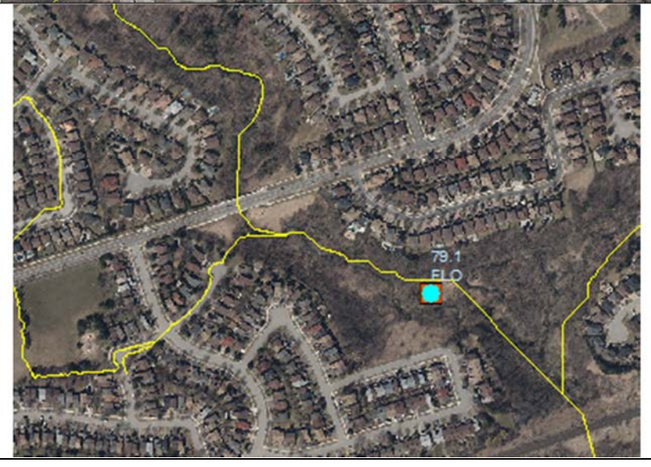
		structure is there. And this pond is not within VN revised 2009 pdf pond map.							
17.1	FLO	Pond File is in CFN 44103 Oct 2015 (DK) - a dry, on-line pond. This pond is not within Vaughan's 2014 pond map.	Yes	Yes	253.6				
17.2	QEC	Vaughan # 22 (Pond 22 - Aldridge Estates), Some capacity for quantity control up to the 25mm, 2 hour storm (ie: first flush) with the rest being diverted to Pond #2. This facility is located in part of the area for pond #1, Pond File is in CFN 44103	Yes	Yes	94.7	X	Quality and/or erosion control only		

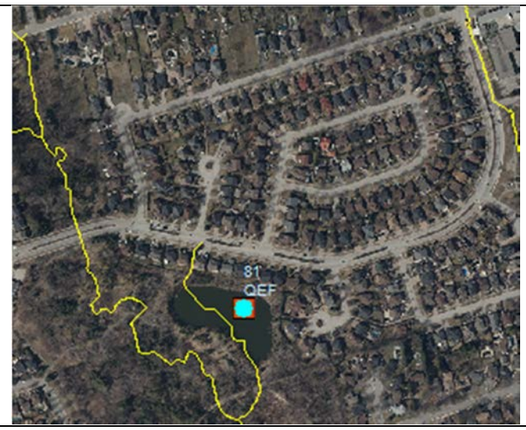
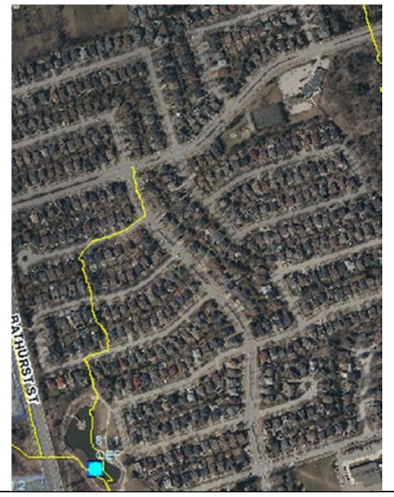
19.0	QEF	Vaughan # 36 (CNR Industrial Subdivision), Built, Pond was under construction at the January 22, 1991 visit. CN Industrial Phase 4, Scaffers Proj no 99E2083, FID63, In for Assumption as of 2011Aug. Pond File is in CFN 44103	Yes	Yes	128.9	✓		
22.1	QEF	Vaughan # 134 (Parktrail Industrial Subdivision), Pond not originally identified in MDP. Runoff allowed to 184.6 L/s/ha for lot area (100 yr) & 42 L/s/ha for roofs. 65M3692 19T99V01 Consultant EMC Project No 97125S FID85, Pond File is in CFN 44104	Yes	Yes	62.1	✓		
24.0	FLO	RH# 27-1 (Doncrest Pond), Built, Slides available, digital photo available. UNMONITORED, Pond File is in CFN 44104	Yes	Yes	83.0	✓		

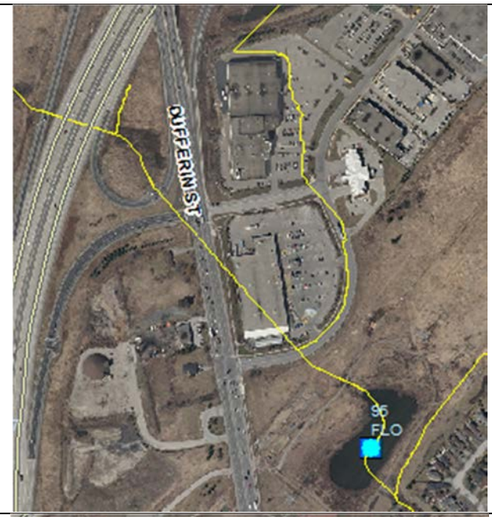
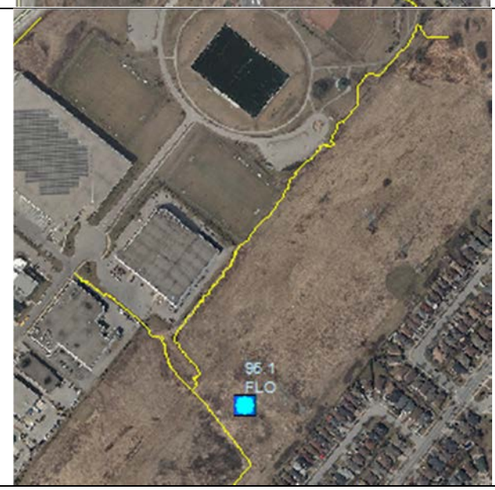
25.0	FLO	RH# 22-1 (Ada Mackenzie Park Pond), Built, Dual Pond Facility -Flood Control information (above) is for minor system only Major System Information -Max. Active Storage 9500 cubic metres -Max. Water Level Fluctuation 2.2 metres -Max. Release Rate 0.2 cms. MONITORED, Pond File is in CFN 44104	Yes	Yes	78.0	✓		
26.0	FLO	Vaughan # 23 (Maple Neighbourhood 2 Pond), Built, On-line river restoration with a series of wetlands, pools, riffles marches and ponds. Maximum active storage volume and maximum release rates, stated above, pertain to the 100 year event. Max. active storage volume for regional event: 55830 cubic metres	No	No	Unknown	✓	In series with 17018 with same functions. Modeled as one lumped pond with 17018.	
27.0	QQE	Markham Pond 9 (East Pond - Galleria Development (Leichcroft Farm)). Pond File is in CFN 44104	Yes	Yes	206.0	✓		

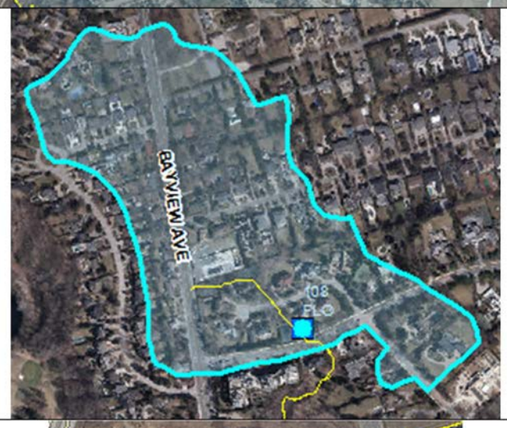
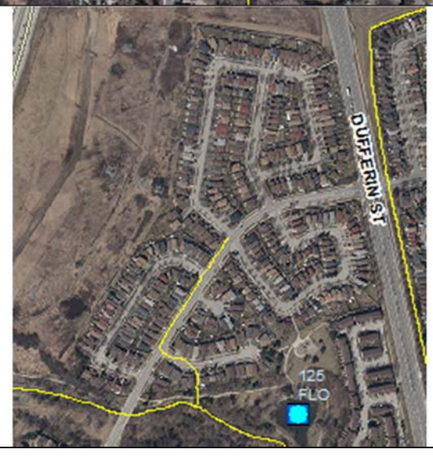
27.1	QEF	Markham #10, Pond File is in CFN 44104	Yes	Yes	5.9	✓		
37.0	FLO	RH# 27-2 (Beaver Creek Pond A), Built, Outlet partially blocked. Pipe outlet structure. UNMONITORED, Pond File is in CFN 44104	Yes	Yes	80.0	✓		
37.1	FLO	RH# 28-1 (Beaver Creek Pond B), Built, Blocked pond - growing over. Pond File is in CFN 44104	Yes	Yes	85.0	X	Out of watershed boundary	
37.3			No	No	Unknown	X	Out of watershed boundary	
43.0	QEC	Vaughan #49 (Killian & Lamar Developments), Built. Pond File is in CFN 44104	Yes	Yes	91.5	X	Quality and/or erosion control only	
45.0	FLO	Vaughan # 5 (Lakeview Estates Ltd), Built, This is a proposed interim facility until lands to the north are developed. This faciliity is designed to take flows from both the minor and major system of catchment "B" (post-dev. catchment "B" is 7.58 ha in total of which 1.41 ha will be uncontrolled. Pond File is in CFN 44104	Yes	Yes	6.2	X	The pond was intended to be an interim detention facility until the land is fully developed. The original SWM report was dated 1991. Based on the age of the document and from orthophoto, the interim pond has been decommissioned. Note: The GIS location of the pond is in the wrong location.	The GIS location  Location indicated by SWM report as the ultimate facility. 
50.0	FLO	Vaughan # 120 (Thornhill/Vaughan Neighbourhood (A4) - Pond 1), Built, Major system only	Yes	No	24.3	✓	Ponds are in series with same functions, but without individual stage-storage-discharge table.	

		New concept presented in "Review of the A4 Neighbourhood Detention Requirements" prepared by MacLaren Engineers in August 1986, Pond File is in CFN 44104					Modeled as one lumped pond.	
50.1	FLO	Vaughan # 121 (Thornhill/Vaughan Neighbourhood (A4) - Pond 2), Built, New concept presentied in "Review of the A4 Neighbourhood Detention Requirements" prepared by MacLaren Engineer August 1986 - Major system only, Pond File is in CFN 44104	Yes	No	10.4			
50.2	FLO	Vaughan #122 (Thornhill/Vaughan Neighbourhood (A4) - Pond 3), Built, 0,37 cms discharges uncontrolled (minor system) to 443 Centre Street Subdivision - Pond outflow focused in concept which was presented in "Review of the A4 Neighbourhood Detention Requirements" Prepared by MacLaren Engineers, Aug. 1986. Pond File is in CFN 44104	Yes	No	12.5			
50.3	FLO	Vaughan # 1 (Thornhill/Vaughan Neighbourhood (A4) - Pond 4), Built, Adjacent subdivision is known as Pondview. Pond File is in CFN 44104	Yes	No	2.3 [2]	✓		

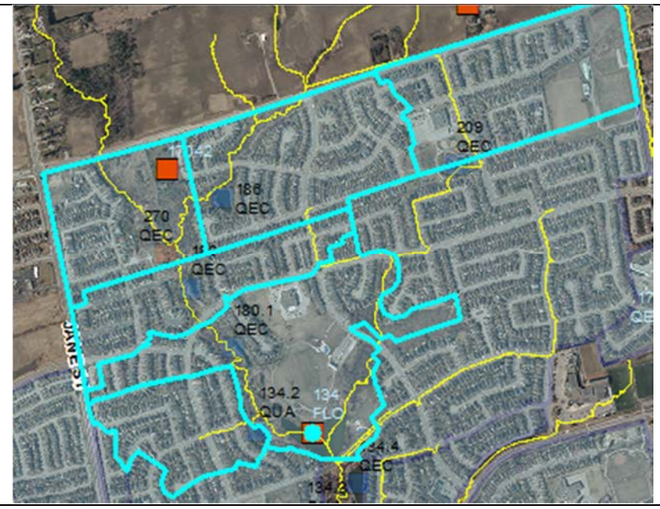
66.0	FLO	Contains 2 depressions (area 1 and area 2)	Yes	Yes	11.2	✓		
79.0	FLO	Markham #23, Pond File is in CFN 44104	Yes	Yes	Unknown	✓	Only control 2-year storm Note: GIS location shows the SWMF is located in the park area. However the pond inventory sheet and the SWM report suggests that the storage is online and was provided through excavating fill from the floodplain. Modeled as online pond in the riverine area.	
79.1	FLO	Markham #24, Pond File is in CFN 44104	No	No	Unknown	X	No evidence for an online pond Not a maintained outlet structure	
80.0	QEF	Markham #25, retrofit, Pond File is in CFN 44104	Yes	Yes	46.0	X	Out of watershed boundary	

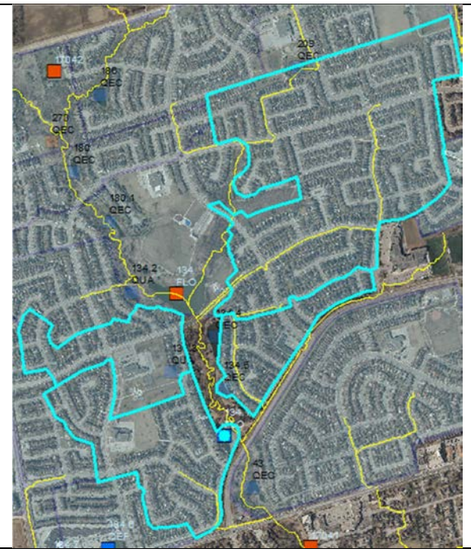
81.0	QEF	RH# 17-3 (Heritage Estates Pond), Built, Slightly overcontroled to accomodate areas outleting "uncontrolled" (12.6 ha uncontrolled area) -Slides Available. UNMONITORED, Pond File is in CFN 44104	No	No	44.0	✓			
81.1	QEF	RH# 17-1 (Rumble Pond). drawings in CFN 46579. UNMONITORED, Pond File is in CFN 44104	Yes	Yes	44.0	✓	Note: Patterson Creek was realigned to by-pass the pond. Pond serves residential area east of Bathurst St. only.		

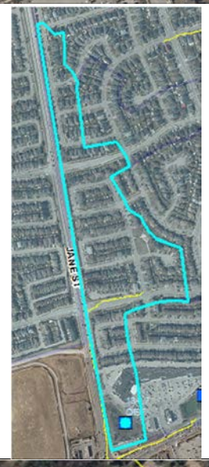
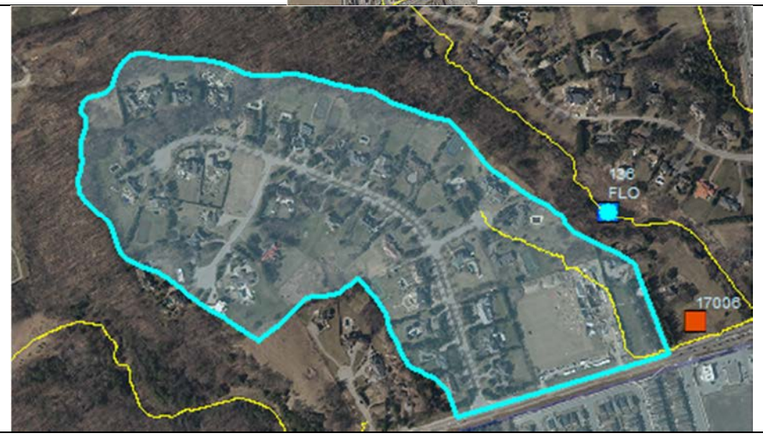
95.0	FLO	Vaughan #8 (Trullwrook Investments - Pond A), Retrofit, Pond outlet redesigned due to changes in upstream catchment area (original drainage area 53.37 ha increased to 75 ha) which came about because of field investigations (i.e.: weir enlarged in order to handle regional storm & increased drainage area) Identi,. ..New wet pond 8, FID 51, input 2010-May (old dry pond name: Concord Storm Drainage - Pond A); 19T-98v12; 65M-3531. Pond File is in CFN 44104	Yes	Yes	75.0	✓				
95.1	FLO	Vaughan # 9 (Concord Storm Drainage - Pond B), Built, It was determined that less area drains to this pond. New field investigations were performed and drainage area decreased from 93.66 ha to 50.5 ha. Due to the decrease inthe upstream drainage catchment, no changes to this pond were required. Identified, Pond File is in CFN 44104	Yes	Yes	50.5	✓				

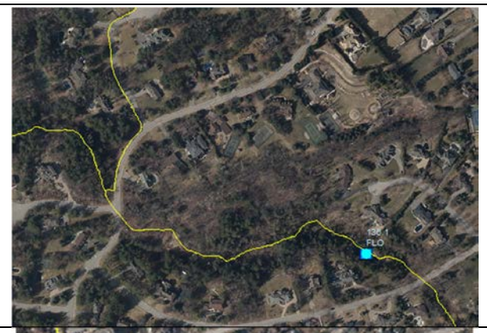
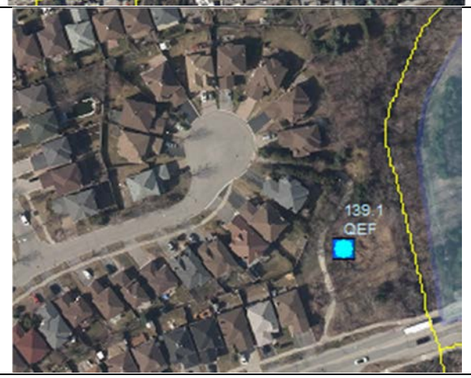
102.0	QQC	RH# 17-2 (Pioneer Park Pond), Built, Pond designed to control the Don Head Estates subdivsion (37.2 ha) for the 2 to 100 year design storms. Pond is retrofitted for quality and erosion. MONITORED, Pond File is in CFN 44104. Preliminary Design Brief is in CFN 39676C. Hydrology and Hydraulic Model Files are attached on Laserfiche under CFN 39676 B.	Yes	Yes	694.0	✓	Note: Provided drainage area is the proposed development but the pond was designed to controlled flow of the entire watershed upstream Post-rehab tributary area is similar to AECOM's delineation		
108.0	FLO	Toronto # TO3 (Hyde Park Circle), On-Line Detention, Built, Can not locate original file. Outlet is inlet control stm M.H. with 100mm opening to 250mm opening. Built for 100y control. Pond File is in CFN 44104	Yes	Yes	18.3	✓			
125.0	FLO	Vaughan # 15 (Thornhill/Vaughan Community - Pond D (Maryta Payne Park)), Built, Cross reference with pond file #95 -Level of control based on West Don River year flows -Part of Concord development, Pond File is in CFN 44104	Yes	Yes	280.0	✓	Note: SWM report suggested that Pond 125.0 provide flow control to the minor system flow of area east of Dufferin St. However, the minor system area was not provided and therefore only the flow from the major system was considered in delineating contributing area to the pond.		
127.1	FLO	RH# 16-3 (Silverpines Pond 2), Built, Pond #2, pond #3	Yes	No	Unknown	✓			

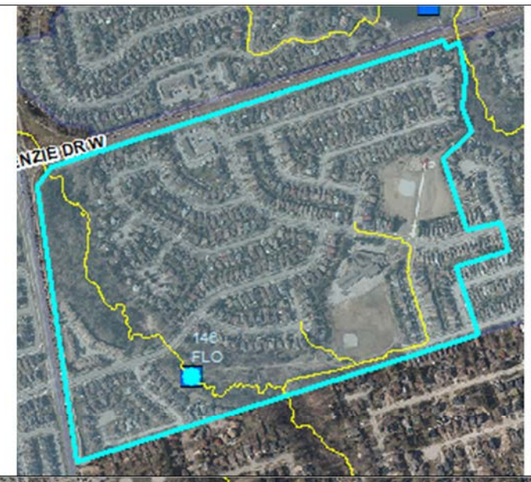
		and pond #4 are in series but all minor and major flows are directed to pond #4 (slight attenuation in flows provided by pond #2 and pond #3). UNMONITORED, Pond File is in CFN 44104						
127.2	FLO	RH# 16-2 (Silverpines Pond 3), Built, Pond #2, pond #3 and pond #4 are in series but all major and minor flows are directed to pond #4 (sligh attenuation in flows provided by pond #2 and pond #3). UNMONITORED	Same as 127.1	No	Unknown			
127.3	FLO	RH# 16-1 (Silverpines Pond 4), Built, Pond #2, pond #3 and pond #4 are in series but all minor and major flows are directed to pond #4 (slight attenuation in flows provided by pond #2 and pond #3) visited pond on July 9, 99 - large piece of aluminum blocking outlet, emailed John Nemeth. UNMONITORED, Pond File is in CFN 44104	Yes	No	30.6		Ponds are in series with same function, with no stage-storage-discharge information. Modeled as one lumped pond.	
128.0	FLO	Oct 2015 (DK) - no apparent "North Pond". PDF files show a ~2300 csp for Major MacKenzie crossing and a underpass under Major MacKenzie for vehicle access. But no SWM pond design provided. It can be concluded that there is not SWM Pond. Also, area immediately north of MM is the new Vaughan Hospital site. This SWMSoft record should be removed.	Yes	No	35.0	✓		

128.1	QFC	VN#73 (pond 73 Existing pond/Status Unknown) in VN revised 2009 pond map, Built, Maximum release rate is for 100 year event Maximum release rate for regional event: 16.1 cms - Will alsoserve to control sediments both during and after construction -Erosion protection and energy dissipation is provided in the design of the control struct, Max Flood Release rate = 8.4cms, flood outlet structure = 7: 1m x 0.2 m stop logs 450 mm pipe reverse "V" notch weir ,	Yes	Yes	114.0	✓		
134.0	FLO	Vaughan # 55 (Mackenzie Glen - Upper Pond), Built, Over controlled	No	No	Unknown	✓	Significant drainage area and storage volume from ortho. Note: The multiple drainage area is due to numerous quality and/or erosion controls ponds in the development.	Pull MESP. 

134.1	FLO	Vaughan # 52 (Mackenzie Glen - Mcnaughton Road Pond), Built, Over controlled.	Yes	No	936.8	✓	Significant drainage area and storage volume from ortho. Note: The multiple drainage area is due to numerous quality and/or erosion controls ponds in the development.	
134.2	QUA	6.66ha ext drainage area; 200mm hickenbottom outlet	Yes	No	18.8	X	Quality and/or erosion control only See ponds 134.0 and 134.1, above.	
134.3	QUA	Not shown on either VN pond maps. As of Nov. 2015, need to confirm if pond exists. TRCA pond record information as seen. PDF includes pond info, but illustration of pond is for Pond 134.1. Pond outlet is 250mm Hickenbotton and for 7mm runoff.	Yes	No	24.6	X	Quality and/or erosion control only See ponds 134.0 and 134.1, above.	
134.4	QEC	Vaughan # 54 (Mackenzie Glen - Pond 4), 7 mm runoff	Yes	No	87.5	X	Quality and/or erosion control only See ponds 134.0 and 134.1, above.	
134.5	QEC	Vaughan # 53 (Mackenzie Glen - Pond 5), 8 mm runoff	Yes	No	15.5	X	Quality and/or erosion control only See ponds 134.0 and 134.1, above.	

134.6	QEF	Vaughan # 50 (Mackenzie Glen - Pond Z1), Quality facility and peak shaver, Near shopping plaza	Yes	Yes	13.2	✓		
134.7	QEF	Vaughan #51 (Mackenzie Glen - Pond Z2), Quality facility and peak shaver, facility is in shopping mall area.	Yes	Yes	13.4	✓		
136.0	FLO	Vaughan # 14 (Pond 1 - Woodland Acres), Pond designed for quantity control and siltation control	Yes	No	33.36	✓	Note: online pond, drainage area in the model will include upstream area	

136.1	FLO	As of Nov. 2015, not within both VN pond maps. Need to confirm if this pond is owned by Vaughan. If not, then it should be a private pond.	Yes	No	Unknown	X	Pond do not seems to have any inlet/outlet control structures for quantity control.	
139.0	QEF	RH# 23-1 (Harding Park East Pond), Wet Pond and Wetland, Built, Retrofitted in 1997. UNMONITORED	Yes	No	16.8	✓		
139.1	QEF	RH# 23-2 (Harding Park West Pond), Proposed enlargment of pond. UNMONITORED	Yes	Yes	2.2	X	Insignificant drainage area	

146.0	FLO	RH# 24-1 (Don Head West Pond), Built, this pond identified for retrofit in RH Stormwater Retrofit Study - room for off-line facility. UNMONITORED	Yes	Yes	48.0	✓		
146.1	FLO	RH# 24-2 (Don Head East Pond), Built, this pond identified for retrofit as part of RH Stormwater Retrofit Study - room for off-line facility. UNMONITORED	Yes	Yes	57.1	✓		
154.0	QEF	Vaughan # 42 (Vaughan Joint Operations Centre - Pond 1), Built.	Yes	Yes	13.5	✓		

154.1	QEF	Vaughan # 43 (York Region Maintanence Yard Pond), Built,	No	No	2.02	X	Insignificant drainage area	
155.0	QEF	Vaughan # 45B (West Maple Creek Pond B), Built, 2 celled facility -Maximum Release Rate pertains to 100 year event -Maximum Release Rate for regional event: 3.119 cms	Yes	Yes	83.4	✓		
155.1	QEC	Vaughan #126 (Pond 126 - West Maple Creek Lands Ltd.), FID=72; Block 135; SD NAME=West Maple Creek Lands Ltd.	Yes	Yes	17.6	X	Quality and/or erosion control only	
155.2		Vaughan 45A	Same as 155	Same as 155.1	Unknown	X	Does not exist	

172.0	QEF	Vaughan # 58 (Pond 58), Built, Dual Celled Facility - Quality control includes 3 Stormceptor Oil/Grit Separators	Yes	Yes	6.3	✓		
180.0	QEC	Vaughan # 56A (Pond 56"A"-Jane Mackenzie), Sized to include 4.25 ha external drainage - Estimated maintenance frequency for sediment forebay: 5 - 7 years	Yes	Yes	22.1	X	Quality and/or erosion control only	
180.1	QEC	Vaughan # 56B (Pond 56 "B" -Jane Mackenzie), Estimated maintenance frequency for sediment forebay: 5 - 10 years	Yes	Yes	7.2	X	Quality and/or erosion control only	
186.0	QEC	Vaughan # 57 (Pond 57), First flush flows will be directed towards pond while excess flows from larger events will bypass the pond (by means of a flowsplitter manhole) - Oil/grit separators will be provided for portions of the development which cannot drain to the proposed pond	Yes	Yes	14.6	X	Quality and/or erosion control only	

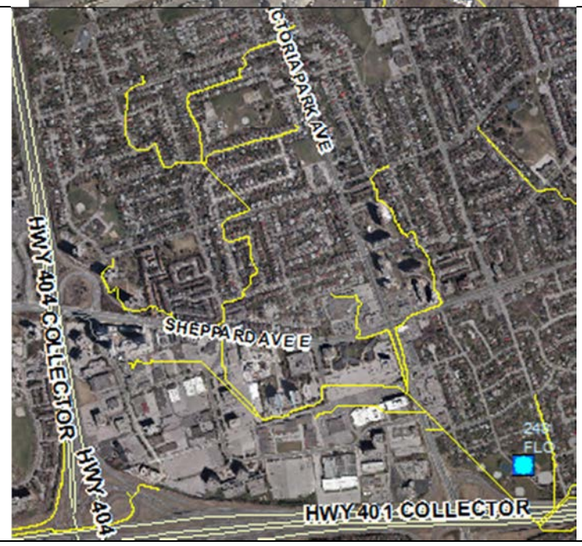
198.0	QEF	Vaughan# 72-2 (VN pdf: Pond 72-2)(Assumed), Note: In VN SWMSoft there is one pond ID= 72 with the note: "Ponds 72-2 (north,19T97v33,65M3391) and 72-3 (south,19T97v26,65M3348) " in the comment. In VN pdf they are separated.	Yes	Yes	67.1 [2]	✓		
198.2	QEF	Vaughan# 72-3 (Pond 72-3) Note: In VN SWMSoft there is one pond ID= 72 with the note: "Ponds 72-2 (north,19T97v33,65M3391) and 72-3 (south, 19T97v26,65M3348)" in the comment. In VN pdf they are separated.	Yes	Yes	91.0	✓		
200.0	FLO	Quantity control is wtihin constructed NCD. Pond is not shown on both VN pond maps. Vaughan may not be aware of this pond or has included it with their pond 71 (Jan. 2015 pond map). Type: On-Line Quantity; Outlet: Perm/Weir; Max Release Rate: 6.0cms	Yes	Yes	35.0	✓		
200.1	QEC	Vaughan # 142 (Vaughan Centre, Ph 1), Uncertain of status of MESP - has floodline been approved? No response last TRCA letter dated August 23, 1996, 65M3445,19T95079,FormerlyMunPondId71,Assumed2009.	Yes	Yes	38.0	X	Quality and/or erosion control only	

200.2	QEF	Vaughan # 138 (Jane Rutherford Industrial SD Ph4), Northwest Jane Rutherford Realty Corp Ltd, Jane Rutherford Industrial SD Phase 4, 19T-95079, 65M-3766, SWM Pond, FID 89.	Yes	No	14.0	X	Documentation in Pond 200.0 suggests that Pond 200.2 does not have a quantity component.	
209.0	QEC	Vaughan #59 (Pond 59 - Royal Princeton SWM Pond), Maximum Active Storage Volume of 2921 cubic metres is bypass condition -Paradise Trails and part of the Royal Princeton Estates share the same water quality pond - Mackenzie Glen Pond provides quantity control - Flow splitter manhole part of design - First	Yes	Yes	28.7	X	Quality and/or erosion control only	
210.0	QEF	Vaughan #75 (Columbus Trails Sudiv, Phas 2, Pond A), Engineer's estimate = $550, 000 including earthworks. 65M2247, 19T96v10, FormerlyMunPond129, Developer Venturon Development Corp.	No	Yes	66.7	✓		

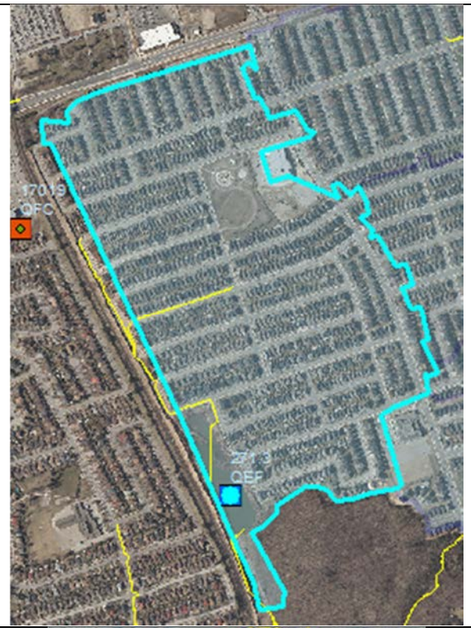
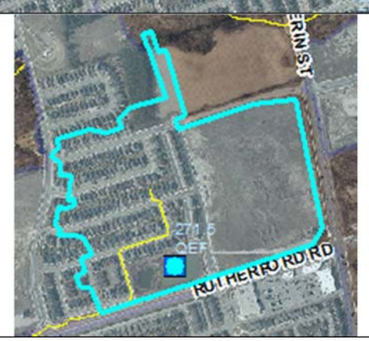
210.1	FLO	Vaughan #76 (Columbus Trails Sudiv, Ph 2, Pond C), Engineer's estimate = $60, 000 (including earthworks. 65M3346, 19T96v10, Columbus Trails Subdiv Ph 2, Venturon Developmt Corp	No	Yes	35.3	✓		
210.2	QEF	Vaughan #131 (Pond 131 - Maple View Farm, Ph 1), FID=81. Assumed=yes, Maple View Farms, 19T97v01, 65M3389 65M3623	Yes	Yes	69.0	✓		
223.0	QEF	Vaughan# 40 (VN pdf: Pond 40)(Assumed),	Yes	Yes	27.8	✓		
224.8	QEC	RH# 9-1 (Jefferson Pond 13), Don River watershed	Yes	No	3.78 [2]	X	Quality and/or erosion control only	

		flow rates to be used for release rates. MONITORED						
224.9	QEC	RH# 9-2 (Duke of Richmond Pond 12), (wet pond / wetland), Don River watershed unit flow rates to be used for quantity pond release rates. MONITORED. Pond File is in CFN 44100	Same as 224.8	No	45.11 [2]	X	Quality and/or erosion control only	
226.0	QEF	Vaughan # 11 (Sugarbush Developments Ph 1), MESP at draft stage only (as of April 1998); TRCA has commented on first draft, but no revisions have been submitted to date. Sugarbush Developments Ph 1, 19T97v20, 65M3521	Yes	Yes	58.0	✓		
226.1	QEF	Vaughan # 12 (Sugarbush Developments Ph 1), MESP at draft stage only as of April 1998. Sugarbush Developments Ph 1, 19T97v20, 65M3521.	Yes	Yes	49.0	✓		

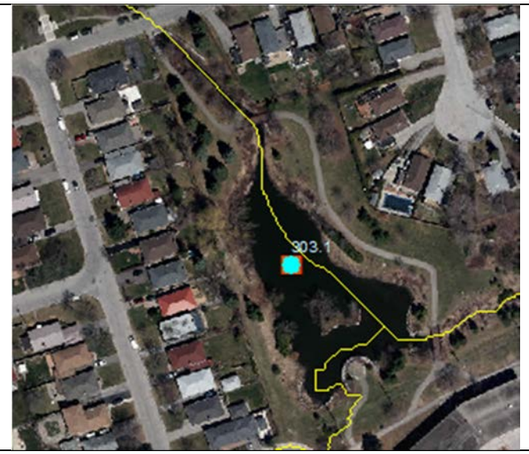
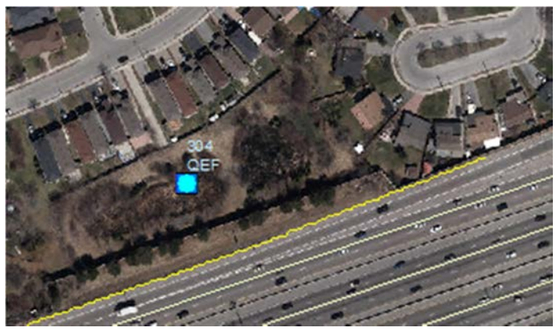
226.2	QEF	Vaughan # 124 (Bath-Von SWM Pond), MESP at draft stage only as of April 1998, 19T89053, Bath-Von, 65M3618.	Yes	Yes	198.0	✓		
226.3	QEF	Vaughan #128 (Rutherford Contwo), MESP at draft stage only as of April 1998	Yes	Yes	35.0	✓		
227.0	QEF	Vaughan# 30 (VN pdf: Pond 30)(Assumed),	Yes	Yes	55.0	✓		

244.0	QEF	Vaughan # 31 (Maplewood Villages Ltd), controlled drainage as follows: 30 ha minor system and 13.3 ha major system. Maplewood Villages Ltd, Maple Highlands, Ventral Park Lodge, 65R23829, 19T99v05,65M2556.	Yes	Yes	30.0	✓		
245.0	QEF	Vaughan # 39 (Keefer Industrial Subdivision), Tendered construction cost includes - inlet pipes and headwalls - outlet structure - fine grading of pond bottom - access road and spillway Earthworks are not included in the cost	No	Yes	98 [2]	✓		
248.0	FLO	Toronto # SC21 (Wishing Well Pond), Pond designed in conjunction with 4 relief storm sewers to allevaite flooding in the area for up to the 25 year storm.	Yes	No	405.0	✓	The SWM report describes a drainage area consistent with the drainage line from DEM.	
249.0	QEC	Toronto # SC27 (Sisters St. Joseph Pond), Pond has extra storage for future development of adjacent Providence lands *approx.	Yes	Yes	28.3	X	Quality and/or erosion control only	

		8.52 ha). Orifice and pipe are for quality control. Drop structure inlet for major (uncontrolled) flows. Estimated maintenance frequency is 15 years. Max release rate from orifice is 0.056cms during 25mm storm. Max release rate from drop structure is 6.56cms.						
270.0	QEC	Vaughan# 56C (VN pdf: Pond 56 C)(Assumed), Quality control will be taken care of by the Mackenzie Glen Facility.	No	No	8.95 [2]	X	Quality and/or erosion control only	
271.0		Vaughan# Block 18-6 (VN pdf:Block 18-6) (Proposed wet pond). TRCA Pond was created and added to SWMSoft. No info available.	No	No	41.11	✓	SWM report of Pond 271.1 suggests that 271.0 has quantity control component Additional info provided by TRCA is related to 271.1, not 271.0	
271.1	QEF	Vaughan# Block 18-3 (VN pdf: Block 18-3)(Proposed wet pond), Detailed design brief completed and complies with block 18 MESP. Pond File in CFN 54310	Yes	Yes	16.5	✓		
271.2	QEC	Vaughan# Block 18-2 (VN pdf: Block 18-2) (Proposed wet pond). Detailed design brief completed and complies with block 18 MESP.	No	No	36.1	X	Quality and/or erosion control only	

271.3	QEF	Vaughan# Block 18-4 (VN pdf: Block 18-4) (Proposed wet pond). Detailed design brief completed and complies with block 18 MESP.	Yes	Yes	68.8	✓		
271.4	QEF	Vaughan# Block 18-5 (VN pdf: Block 18-5) (Proposed wet pond). Detailed design brief completed and complies with block 18 MESP. Pond File in CFN 54310	Yes	Yes	37.9	✓		
271.5	QEF	Vaughan Block 18-1. Pond File in CFN 54310	Yes	Yes	25.6	✓		
286.0	QEC	No match with municipal pond. Outlet is 8cm Hickenbottom riser outlet.	Yes	No	3.4	X	Quality and/or erosion control only	

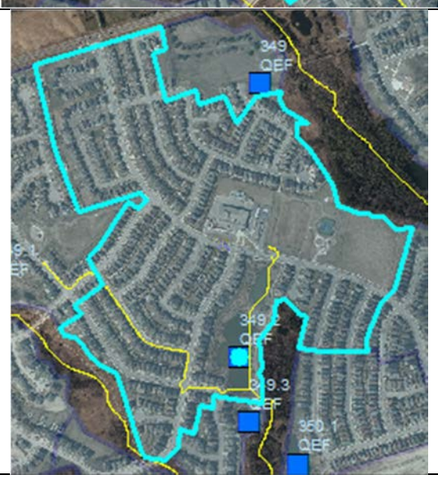
291.0	QEF	Vaughan #17 (Pond 17), Pond File in CFN 54310	Yes	Yes	40.3	✓		
296.0	QEC	Vaughan # 21 (Concord Storm Drainage - Pond A), Built, Pond outlet redesigned due to changes in upstream catchment area (original drainage area 53.37 ha increased to 75 ha) which came about because of field investigations (i.e.: weir enlarged in order to handle regional storm & increased drainaget	No	Yes	90.0	X	Quality and/or erosion control only	
303.0		Municipal ID: scwp054 (Terraview / Willowfield)	No	No	Unknown	✓	Retrofit project.	

303.1		Municipal ID: scwp054 (Terraview / Willowfield)	No	No	Unknown	✓	Retrofit project.	
304.0	QEF	Municipal ID: scwp049 (Greywood South Pond). Outlet is Ditch Inlet Catchbasin with max release rate of 0.33cms. Erosion control detains 25mm storm event for 24 hours, and outlets through a hickenbottom water quality structure fitted with a 75mm orifice plate, with max release rate of 0.0074cms). Pond File is in CFN 42828	Yes	No	3.3	✓		
315.0	QEF	Municipal ID: nywp004 (Moccasin Trail Park), in addition to the provided CFN, try 29167. 25mm storm is detained for 48 hours. Extended detention release rate is controlled by 200mm orifice plate. Stage-Storage-Discharge curve is available. Controls 25y runoff to a flow rate that is compatible with the capacities of receiving culverts.	Yes	Yes	85.5	✓		

341.1	QEF	Vaughan# 140 (VNpdf: Pond 140 Existing / status unknown),	Yes	Yes	75.5	✓		
341.2	QEF	Vaughan# 139 (VN Jan 2015 pond map) - Unassumed & wet pond.	Yes	Yes	39.0	✓		
348.0	QEF	Vaughan# 25 in Block 11-2, (VN pdf: Block 11-2), (Proposed wet pond), Block plan has been approved, pond design is based on preliminary design set out by Block 11 MESP. Detailed design brief to follow.	Same as 3481,2Ç[a]	No	63.3	✓		
348.1	QEF	Vaughan# Block 11-6, (VN pdf: Block 11-6), (Proposed wet pond), Block plan has been approved, pond design is based on preliminary design set out by Block 11 MESP. Detailed design brief to follow. Pond File in CFN 54310	Yes	Yes	42.4	✓		

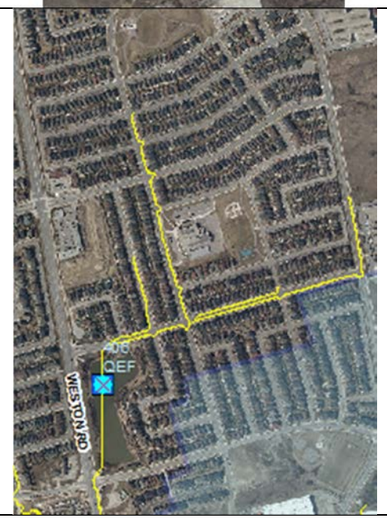
348.2	QEF	Vaughan# Block 11-7 (VN pdf: Block 11-7), (Proposed wet pond), Block Plan has been approved, pond design is based on preliminary design set out by MESP. Detailed design to follow. Pond File in CFN 54310	Yes	Yes	43.6	✓			
348.3	QEF	Vaughan# 35, Block 11-1, (VN pdf: Block 11-1), (Proposed wet pond), Block plan has been approved, pond design is based on preliminary design set out by Block 11 MESP. Detailed design brief to follow.	Yes	Yes	35.0	✓			
348.4	QEF	Vaughan# Block 11-3, (VN pdf: Block 11-3), (Proposed wet pond), Block plan has been approved, pond design is based on preliminary design set out by Block 11 MESP. Detailed design brief to follow.	Yes	Yes	9.5	✓			
348.5	QEF	Vaughan# Block 11-4, (VN pdf: Block 11-4), (Proposed wet pond), Block plan has been approved, pond design is based on preliminary design set out by Block 11 MESP. Detailed design brief to follow.	Yes	Yes	24.0	✓			

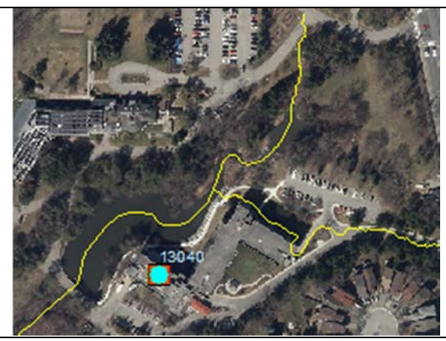
348.6	QEF	Vaughan# 142 (Existing pond/status unknown), Block plan has been approved, pond design is based on preliminary design set out by Block 11 MESP. Detailed design brief to follow.	Yes	Yes	10.7	✓		
348.7	QEF	Vaughan Block 11-5, Pond File in CFN 54310	Yes	Yes	28.5	✓		
348.8	QEF	Vaughan# 143 (VN revised 2009 pond map - Existing / status unknown), Block plan has been approved, pond design is based on preliminary design set out by Block 11 MESP. Detailed design brief to follow. Pond File in CFN 54310	Yes	Yes	7.5	✓	Note: GIS pond location is wrong. The location has been fixed in the image on the right.	
349.0	QEF	Vaughan# Block 12-8 (VN pdf: Block 12-8), (Proposed wet pond). Block plan has been approved, pond design is based on preliminary design set out by Block 12 MESP & EIS. Detailed design brief to follow.	Yes	Yes	5.6	✓		

349.1	QEF	Vaughan# Block 12-9 (VN pdf: Block 12-9), (Proposed wet pond). Pond File is in CFN 54315	Yes	Yes	24.2	✓			
349.2	QEF	Vaughan# Block 12-6 (VN pdf: Block 12-6) (Proposed wet pond), Block plan has been approved, pond design is based on preliminary design set out by Block 12 MESP & EIS. Detailed design brief to follow.	Yes	Yes	53.97	✓	Note: Pond 349.2 and 349.3 location was mixed up in the GIS information.		
349.3	QEF	Vaughan # 63 (2005) Block 12-7 (VN pdf: Block 12-7), (Proposed wet pond). Block plan has been approved, pond design is based on preliminary design set out by Block 12 MESP & EIS. Detailed design brief to follow.	Yes	Yes	4.3	✓	Refer to Pond 349.2		

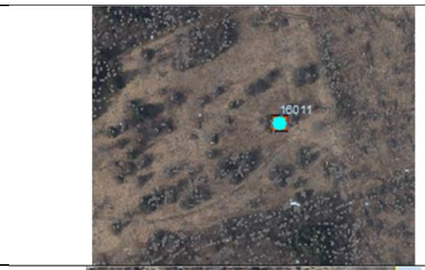
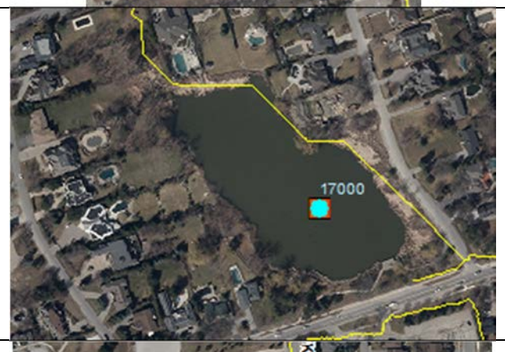
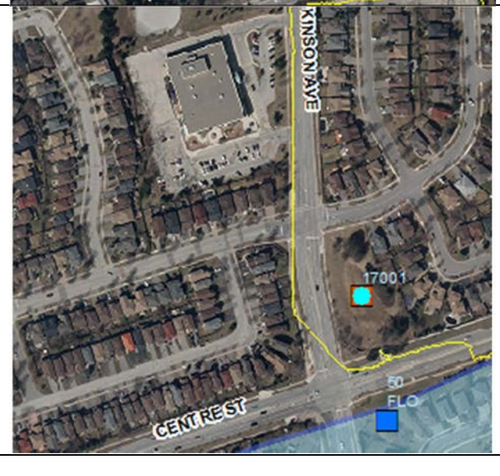
349.4	QEF	Vaughan# Block 12-3 (VN pdf: Block 12-3), (Proposed wet pond). Block plan has been approved, pond design is based on preliminary design set out by Block 12 MESP & EIS. Detailed design brief to follow.	Yes	Yes	50.2	✓		
349.5	QEF	Pond not on both VN pond maps. Plan is approved; Single Celled; Above the 100 year storm flood level	Yes	Yes	13.5	✓		
349.6	QEF	Vaughan# Block 12-4 (VN pdf: Block 12-4), (Proposed wet pond). Block plan has been approved, pond design is based on preliminary design set out by Block 12 MESP & EIS. Detailed design brief to follow.	Yes	Yes	7.7	✓		
349.7	QEF		Yes	Yes	22.4	✓		

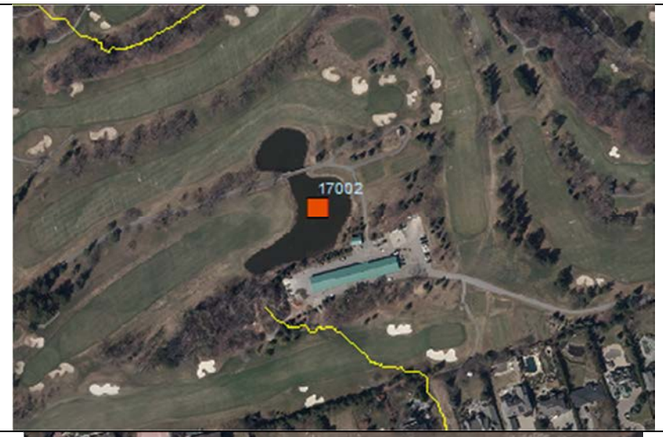
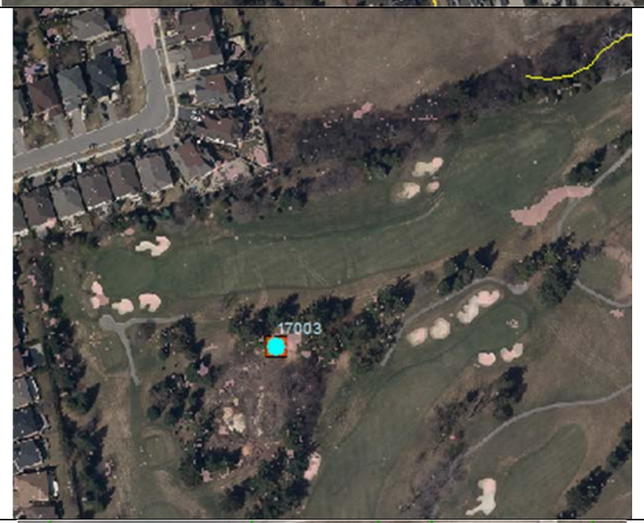
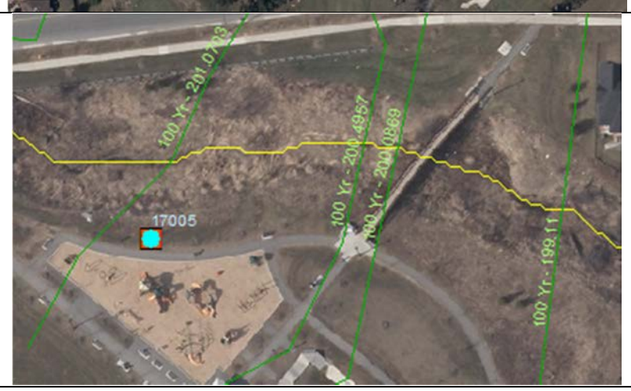
349.8	QEF	Plan is approved; Single Celled; Above the 100 year flood level; Level 1 Quality control; Sediment forebay is present; Hickenbottom outlet release rate is 0.05cms; Post to pre (2-100 year) flood control; Outlet pipe release rate is 0.537cms; 25mm storm event for erosion control; Release rate is 0.05cms	Yes	Yes	37.6	✓		
349.9	QEF	Vaughan# Block 12-1 (VN pdf: Block 12-1), (Proposed wet pond), Regional Capture device is proposed insted of an emergency spillway, due to the fact that the pond will be outletting to an existing culvert.	Yes	Yes	34.2	✓		
350.1	QEF	Vaughan# Block 12-5 (VN pdf: Block 12-5), (Proposed wet pond). Block plan has been approved, pond design is based on preliminary design set out by Block 12 MESP & EIS. Detailed design brief to follow.	Yes	Yes	10.1	✓		
350.2	QEF	Vaughan# Block 12-2 (VN pdf: Block 12-2), (Proposed wet pond). Block plan has been approved, pond design is based on preliminary design set out by Block 12 MESP & EIS. Detailed design brief to follow. Vaughan pond # 48.	Yes	Yes	21.1	✓		
403.0	QEF		Yes	Yes	5.3	X	Out of watershed boundary	

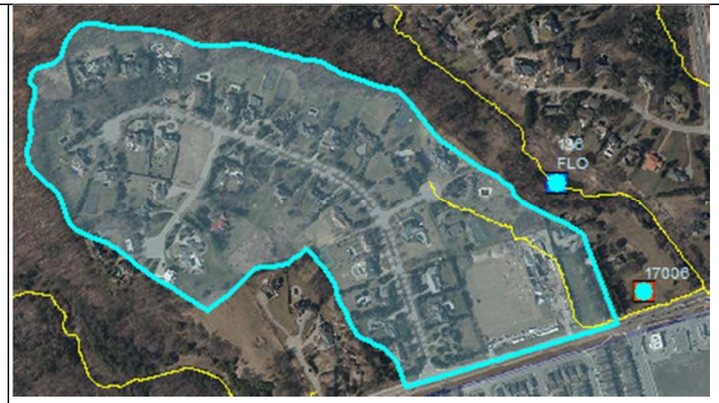
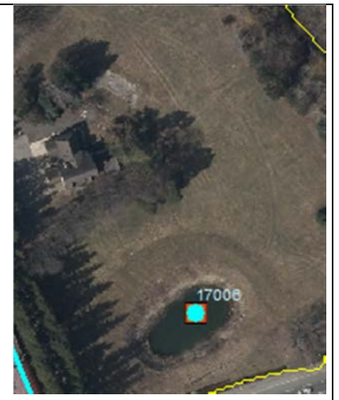
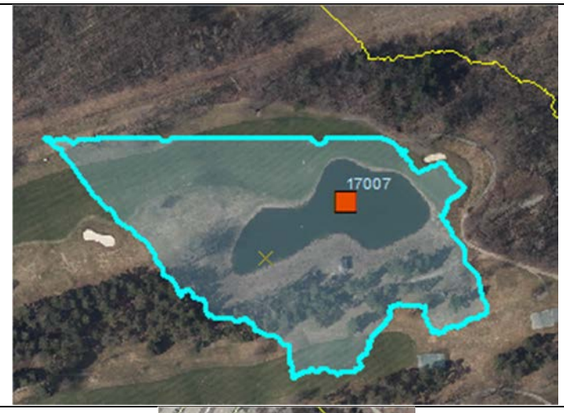
404.0	QEF	Pond File in CFN 54310	Yes	Yes	4.0	✓		
405.0	QEF	Pond File in CFN 54310	Yes	Yes	6.9	✓		
406.0	QEF	Pond File in CFN 54310	Yes	Yes	51.8	✓		

406.1	QEF	Pond File in CFN 54310	Yes	Yes	101.9	✓		
407.0	QEF	Pond File in CFN 54310	Yes	Yes	17.9	X	The pond was intended to be a temporary facility. The area is currently serviced by Pond 226.3.	
13025	QUA	Markham #50	No	No	Unknown	X	Quality and/or erosion control only	
13040		Apr.12.16 Markham pond waiting for report M.E	Yes	Storag e only	Unknown	✓		

15005	QEC	Municipal ID: nywp0010 (Earl Bales Park), 2 900mm overflow pipe outlets at 2% slope. Outlet is 3 vertical concrete riser structures connected to 2 525mm PVC reverse sloped pipe. Operation and maintenance outlined in report. Stage-Storage-Discharge relationship available from report. Could be TRCA pond 396.	Yes	No	550 [2]	X	Quality and/or erosion control only	
15007	QEF	Municipal ID: scwp048. No match with TRCA ponds. Permanent pool does not account for quality criteria, so water is pre-treated with a hydrodynamic separation unit designed by Contech Stormwater 360 in order to meet Level 1 requirements. Outlet structure is 90mm orifice with invert el 141.30, and 400mm orifice with invert el 142.5. Maximum combined discharge is 0.3cms. Emergency spillway is lowest point of grading around the SWM facility, chosen instead of a conventional spillway to deter flow concentration during a large event.	Yes	Yes	6.7	✓		
15008		Municipal ID: scwp043 (Bell Estates Pond). No match with TRCA Ponds	No	No	Unknown	X	Appears to have insignificant drainage area.	

16011			No	No	Unknown	X	Sink analysis do not show any appreciable depression on the surface to provide storage.	
16012	QQC	Underground storage chamber, not a pond	No	No	Unknown	X	Sink analysis do not show any appreciable depression on the surface to provide storage.	
17000		Vaughan#2 (Oakbank Thornbank Pond), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	Not a SWM pond. Exclude.	
17001		Vaughan#129 (Pond 129 - Rosdale North), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	✓	Sink analysis indicate depression area for storage.	

17002		Vaughan# 3, (VN revised 2009 pond map - Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available. CONFIRM if pond is for irrigation/SWM function.	No	No	4.02 ^{3}	X	Insignificant drainage area		
17003		Vaughan# 4, (VN revised 2009 pond map - Existing / status unknown),TRCA Pond was created and added to SWMSoft. No info available. CONFIRM if pond is for irrigation or SWM functions.	No	No	Unknown	X	Sink analysis do not show any appreciable depression on the surface to provide storage.		
17005		Vaughan# 144 (VN revised 2009 pond map - Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available. CONFIRM if pond exists.	No	No	Unknown	X	Storage area behind the crossing. Based on timing of development, online ponds would be phased out.		

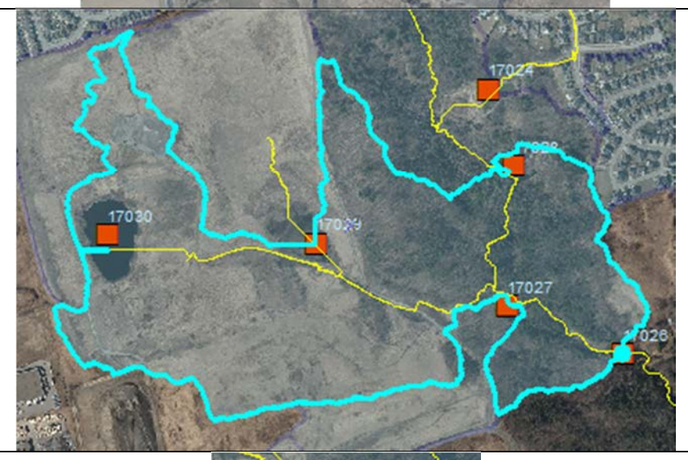
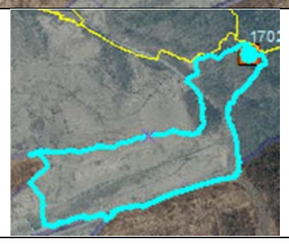
17006		Vaughan# 13 (VN revised 2009 pond map - Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available. CONFIRM if provides SWM controls.	No	No	Unknown	X	Neighbouring area is serviced by Pond 136.0. Pond 17006 may service one property only.	 136 FLO 17006	
17007		Vaughan# 150 (VN revised 2009 pond map - Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available. CONFIRM if pond is for irrigation or SWM.	No	No	2.84 [3]	X	Insignificant drainage area		
17012		Vaughan# 16 (Keele/407), also 407 Pond ID E-71.1-407 and desigh ID D1	No	No	0.4 [3]	X	Insignificant drainage area		

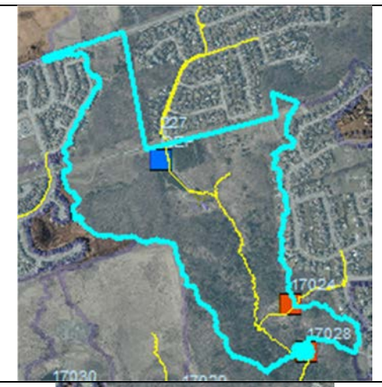
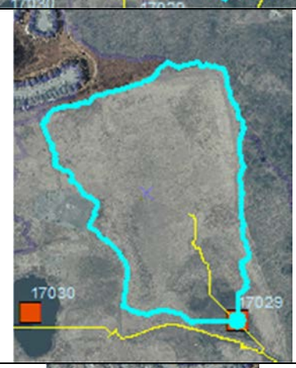
[3] *Estimated drainage area based on DEM*

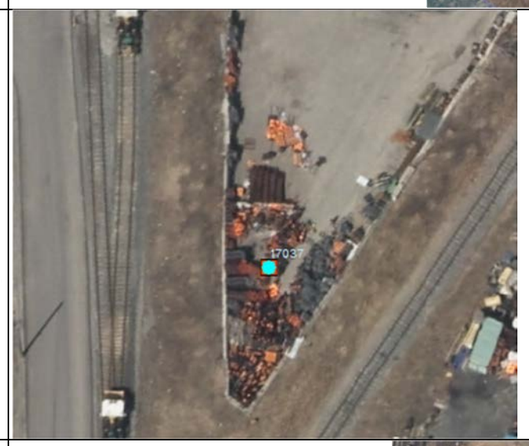
17013		Vaughan #18, also 407 Pond ID W-72.6.O.7E and design ID D3	No	No	8.22 ^{3}	✓	Google earth image suggests that the pond services Highway 407. Inlet/outlet structures seem large.	
17015	QFC	Vaughan# 20 (Langstaff Eco-Park), TRCA Pond was created and added to SWMSoft. No info available.	No	No	16.4 ^{3}	✓		
17018	FLO	Vaughan# 24 (Fieldgate Pond), (Two small ponds on either side of Don River), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	✓	In series with Pond 26 with same functions. Modeled as one lumped pond with Pond 26.	

17019	QFC	Vaughan# 135 (Mapleglen Residence/New Civic Centre), (Consultant EMC, Proj no 207152-1, DA Otello, FID 86). TRCA Pond was created and added to SWMSoft. No info available	No	No	1.4 ^{3}	X	Insignificant drainage area			
17020		Vaughan# 25 (VN pdf: Pond 25 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	Sink analysis and ortho show no depression area.			
17021	QEF	Vaughan# 26 (VN pdf: Pond 26 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	Yes	Yes	79.17	✓				

17022		Vaughan# 27 (VN pdf: Pond 27 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	39.1 ^{3}	X	Area is serviced by Pond 17021 based on additional pond info from TRCA	
17023		Vaughan# 128 (VN pdf: Pond 128 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	10.0 ^{3}	X	Area is serviced by Pond 17021 based on additional pond info from TRCA	
17024		Vaughan# 141 (Northdale Ridge Ph 1) (Assumed) (2 cell wet pond).	No	Yes	35.1 ^{3}	✓		

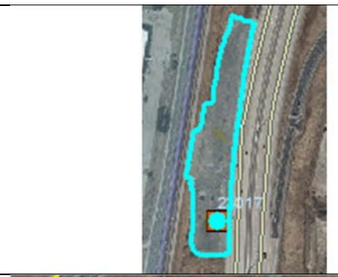
17025	QEF	Vaughan# 143 (Dreamwood SWM Facility)(Unassumed), TRCA Pond was created and added to SWMSoft. No info available	Yes	Yes	29.87	✓		
17026		Vaughan# 145 (VN pdf: Pond 145 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	75.6 [3]	X	None of these (i.e. 17026 to 17030) appear to be SWM ponds They all seem like natural features A lag will be 'calibrated' into the model in this area - recognizing that there is natural storage.	
17027		Vaughan# 146 (VN pdf: Pond 146 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	10.0 [3]	X		

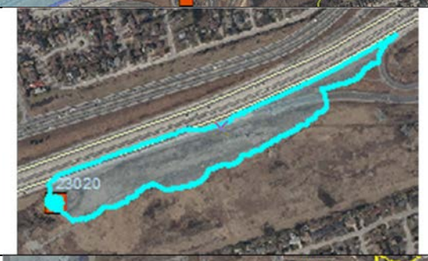
17028		Vaughan# 147 (VN pdf: Pond 147 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	65.0 ^{3}	X		
17029		Vaughan# 148 (VN pdf: Pond 148 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	22.8 ^{3}	X		
17030		Vaughan# 149 (VN pdf: Pond 149 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	11.1 ^{3}	X		

17031		Vaughan# Block 20-1 (VN pdf: Block 20-1)(Proposed wet pond), TRCA Pond was created and added to SWMSoft. No info available.	No	No	13.8 ^{3}	✓		
17037		Vaughan# 35 (Pond 35 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	Sink analysis and ortho show no depression area. Note: Maybe the GIS location is wrong. There's a pond north of it that has not part of the GIS data. (See second screen capture on the right)	 
17038		Vaughan# 38 (Pond 35 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available	No	No	1.6 ^{3}	X	Insignificant drainage area	

17040		Vaughan# 46 (VN pdf: Pond 46)(Unassumed), TRCA Pond was created and added to SWMSoft. No info available	No	No	3.1 ^{3}	X	Insignificant drainage area	
17041		Vaughan# 47 (Pond47 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	Sink analysis and ortho show no depression area.	
17042		Vaughan# 166 (VN pdf: Pond 166 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	The area is serviced by multiple quality and/or erosion control ponds, as well as a flow control pond further downstream already. This pond may service one property only.	

17043		Vaughan# 60 (VN pdf: Pond 60 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	0.7 ^{3}	X	Insignificant drainage area and may service one property only.	
17044		Vaughan# 165 (VN pdf: Pond 165 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	Remnant farm operation; no specific flood control.	
17051		Vaughan# 69 (VN pdf: Pond 69 Existing / status unknown), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	Sink analysis and ortho show no depression area.	

17052		Vaughan# 140 (Lanterna Group Subdivision), (Outlets to meandering man-made channel), TRCA Pond was created and added to SWMSoft. No info available.	No	No	Unknown	X	Area serviced by two ponds downstream already. 17052 is very small with unknown function. Additional information provided by TRCA shows that drainage area of Pond 198.2 includes area west of Weston Rd.	100-yr pipe bringing flows?		Find file.
17145	QUA	Vaughan #10, 407 Pond ID E-73.5-407, Desigh ID D4	No	No	44.1	X	Quality and/or erosion control only			
17148	QEC		No	No	53.71 [2]	X	Quality and/or erosion control only			
23017		Used to be Vaughan #19 Existing / Status Unknown and TRCA 17014, 407 Pond ID W-72.0.CE	No	No	1.5 [3]	X	Lumped with Pond 17013 downstream.			
23018		Pond ID E-75.5-407	No	No	Unknown	X	Area is already serviced by Pond 16. Additional area to Pond 23018 will comes from the highway and the area is typically insignificant.			

23019		Pond ID W-76.0.O.7E	No	No	74.7 ^{3}	✓		
23020		Used to be Vaughan #7 Existing/Status Unknown and TRCA 17004, 407 Pond ID E-76.8.O.YO	No	No	6.0 ^{3}	✓		
23021			No	No	15.0 ^{3}	✓		
23022		Pond ID E-80.1-407	No	No	0.5 ^{3}	X	Insignificant drainage area	
23023		Pond ID E-81.4-407	No	No	7.2 ^{3}	✓		

23024		Pond ID E-81.8.O.LE	No	No	32.6 ^{3}	✓		
23025		Pond ID E-404-407	No	No	8.0 ^{3}	✓		
23026		Pond ID E-83.4-407	No	No	Unknown	X	Out of watershed boundary	
30001			No	No	Unknown	✓		
30002			No	No	Unknown	X	No evidence that there is storage at this location. There doesn't seem to be anything that restricts flows online. There is a huge conduit under Bayview that takes the flow a couple hundred metres south but it doesn't seem to be a flow restriction.	

30003			No	No	Unknown	X	Out of watershed boundary	
MTO Pond at Steeles and Highway 404			No	No	Unknown	X	The function of the pond is unclear.	
Private pond on the Tangerine site			No	No	Unknown	X	Very small private pond that has been screened out.	

Appendix D: Pond Stage Storage Discharge

Pond 1.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1	0.27
2.12	0.42
2.5	1.13
3	2.7
3.5	4.52
4	6.39
4.2	7.11
5	9.7
5.25	10.37
5.5	10.94
6.05	54.7

Storage Curve	
Depth	Area
(m)	(m^2)
0	9841
1	9841
2.12	11576
2.5	12779
3	13650
3.5	14732
4	15612
4.2	16775
5	17555
5.25	18704
5.5	20028
6.05	20028

Description: Database

Pond 102

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.283
1	0.567
1.5	1.3
2	2.12
2.5	2.54
3	25.485
3.5	26.9
4	28.31
4.5	31.14
4.95	155.7

Storage Curve	
Depth	Area
(m)	(m^2)
0	1480
0.5	1480
1	5921
1.5	9868
2	12335
2.5	32070
3	44405
3.5	59207
4	39472
4.5	96212
4.95	96212

Description: Database

Pond 108

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
3	0.18
3.3	11.45

Storage Curve	
Depth	Area
(m)	(m^2)
0	2333
3	2333

Description: Used Otthymo 100 year output. Assumed max water level fluctuation is 100 year level

Description: Assumed max storage in inventory sheet is 100 year storage. Assumed max water level fluctuation in inventory sheet is 100 year depth

Pond 125

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.2	0.59
0.4	1.36
0.6	2.8
0.8	4.42
1	5.78
1.2	6.8
1.4	7.36
1.6	7.87
1.76	39.35

Storage Curve	
Depth	Area
(m)	(m^2)
0	4500
0.2	4500
0.4	5060
0.6	5490
0.8	6105
1	6535
1.2	7155
1.4	7650
1.6	8140
1.76	8140

Description: Database

Pond 127.3

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.1	1.12
2.1	5.88
2.31	29.4

Description: Pond 127.1, 127.2, 127.3
Outflow based on the most downstream pond - Pond 127.3

Pond 127.1

Storage Curve	
Depth	Area
(m)	(m^2)
0	1705
1.1	1705
2.1	5925
2.31	5925

Description: Lumped cuve for 127.1, 127.2, 127.3
Database info from 4.1
It was determined that information for Pond 2, 3, 4 = 127.1, 127.2, 127.3

Pond 128

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.5	1.8
2.2	4
2.3	5.4
2.5	6.8
2.8	12.8
3.08	64

Description: Information contained in 128.1
Assumed depth

Storage Curve	
Depth	Area
(m)	(m^2)
0	29333
1.5	29333
2.2	37143
2.3	40000
2.5	45000
2.8	56667
3.08	56667

Description: Info contained in 128.1 database
Assumed depth

Pond 128.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.5	2.7
2	5.3
2.5	6.8
2.6	8.4
3	16.1
3.3	80.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	11333
1.5	11333
2	26000
2.5	36000
2.6	50000
3	155000
3.3	155000

Description: Assumed depth

Descriptior Assumed depth

Pond 13040

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.9
0.55	4.49

Storage Curve	
Depth	Area
(m)	(m^2)
0	7424
0.5	7424

Description: Assumed unit rate discharge, sub-basin 26

Descriptior Database for storage

Pond 134

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.46	14.18
1.61	70.9

Storage Curve	
Depth	Area
(m)	(m^2)
0	42123
1.46	42123

Description:

Descriptior Database of 134.1, 134.5

Pond 134.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1	52
1.1	260

Description: Estimated discharge for 100 year

Storage Curve	
Depth	Area
(m)	(m^2)
0	35600
1	35600

Description: Database

Pond 134.6

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.01	0.66
0.21	0.85
0.41	1.03
0.61	1.2
0.81	1.35
0.89	6.75

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
0.01	0
0.21	9550
0.41	2500
0.61	2500
0.81	6000
0.89	6000

Description: Database

Pond 134.7

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.1	0.29
0.2	0.81
0.3	1.5
0.4	2.3
0.5	3.22
0.6	4.23
0.7	5.33
0.77	26.65

Storage Curve	
Depth	Area
(m)	(m^2)
0	3200
0.1	3200
0.2	4000
0.3	4000
0.4	4000
0.5	4000
0.6	4000
0.7	4500
0.77	4500

Description: Database

Pond 136

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
3	9.8
3.3	49

Storage Curve	
Depth	Area
(m)	(m²)
0	944
3	944

Description: Estimated discharge for 100 year

Description: database

Pond 139

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
0.3	0.31
0.7	0.42
1.1	0.51
1.3	0.55
1.5	0.58
1.65	2.9

Storage Curve	
Depth	Area
(m)	(m²)
0	247
0.3	247
0.7	1233
1.1	2189
1.3	4256
1.5	1480
1.65	1480

Description:

Description: database Assumed cylinder beyond highest elevation

Pond 146

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
2.2	1.8
2.5	3.8
2.8	7
3.1	11.2
3.41	56

Storage Curve	
Depth	Area
(m)	(m²)
0	2804
2.2	2804
2.5	8220
2.8	8223
3.1	8223
3.41	8223

Description: database

Pond 146.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2.3	4.4
2.6	8.1
2.9	14.3
3.2	23
3.3	24.8
3.63	124

Storage Curve	
Depth	Area
(m)	(m^2)
0	2950
2.3	2950
2.6	6167
2.9	10279
3.2	8223
3.3	12335
3.63	12335

Description: database

Pond 15

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.9
1	2.2
1.5	4.1
2	6.1
2.5	7.9
3	9.2
3.25	9.8
3.5	15.1
4	35.1
4.5	63.1
5	97.3
5.5	137.2
6	181
6.5	229.3
7.15	1146.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	200
0.5	200
1	1400
1.5	5800
2	10600
2.5	19000
3	33800
3.25	30400
3.5	58000
4	55800
4.5	60800
5	92400
5.5	106000
6	106000
6.5	130000
7.15	130000

Description: database

Pond 15007

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.4	0.03
1.6	0.1
1.7	0.18
1.85	0.24
1.95	0.27
2.1	0.3
2.31	1.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	1239
1.4	1239
1.6	1605
1.7	1670
1.85	1940
1.95	2520
2.1	1753
2.31	1753

Description: Database
Assumed cylinder beyond highest elevation

Pond 154

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.14	0.011
0.64	0.031
1.14	0.042
1.64	0.14
2.14	0.191
2.24	0.2
2.46	1

Storage Curve	
Depth	Area
(m)	(m^2)
0	4500
0.14	4500
0.64	2560
1.14	3000
1.64	3500
2.14	4120
2.24	4400
2.46	4400

Description: database

Pond 155

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.2	0.12
0.4	0.31
0.57	0.5
1.15	1
1.435	1.25
1.48	1.5
1.872	2
2.166	2.499
2.54	3.001
2.807	3.991
2.937	4.997
3.1	6.459
3.255	7.972
3.345	8.888
3.68	44.44

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
0.2	0
0.7	4808
1.2	9694
1.7	11083
2.2	12472
2.7	13400
3.2	14327
3.45	14795
3.795	14795

Description: database

Pond 16

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1	0.4
1.4	1
1.6	1.7
1.75	2.6
1.85	3.3
1.93	4.2
2.12	21

Storage Curve	
Depth	Area
(m)	(m^2)
0	6000
1	6000
1.4	6250
1.6	7500
1.75	10000
1.85	12000
1.93	12500
2.12	12500

Description: database
Assumed
Depth

Pond 17

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.56	2.43
1.95	2.86
2.16	3.33
2.75	5.85
2.83	7.16
3.11	35.8

Storage Curve	
Depth	Area
(m)	(m^2)
0	2564
1.56	2564
1.95	26667
2.16	36190
2.75	53729
2.83	96250
3.11	96250

Description: Pond 17.0, 17.1 Database
Assumed stage of 17.0

Pond 17001

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.027
2	0.118
2.2	0.59

Description: 2 and 100 year flow calculated from unit flow rate
Sub basin 27

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
0.5	0
2	7600
2.2	7600

Description: Assumed no storage for 2 year
Estimated storage for 100 year

Pond 17013

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.034
2	0.164
2.2	0.82

Description: 2 and 100 year flow calculated from unit flow rate
Sub basin 8B

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
0.5	0
2	6200
2.2	6200

Description: Assumed no storage for 2 year
Esimated storage for 100 year

Pond 17015

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.304
2.2	1.52

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	11800
2.2	11800

Description: Unit peak flow of sub basin 5

Description: Estimated storage for 100 year

Pond 17021

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.1	0.043
0.2	0.084
0.3	0.11
0.4	0.132
0.5	0.15
0.6	0.166
0.7	0.181
0.8	0.195
0.9	0.208
1	0.22
1.1	0.231
1.2	0.242
1.3	0.253
1.4	0.263
1.5	0.272
1.6	0.393
1.7	0.576
1.8	0.789
1.9	1.022
2	3.133
2.1	6.332
2.2	10.083
2.42	50.415

Storage Curve	
Depth	Area
(m)	(m^2)
0	12040
0.1	12040
0.2	12030
0.3	15170
0.4	15170
0.5	15160
0.6	15170
0.7	15170
0.8	15170
0.9	15170
1	15170
1.1	15160
1.2	15170
1.3	15170
1.4	15170
1.5	15170
1.6	15170
1.7	15160
1.8	15170
1.9	15170
2	18310
2.1	18300
2.2	18310
2.42	18310

Description: database

Pond 17024

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.8	0.25
1	0.36
2.3	0.45
3.5	0.52
4	3
4.4	15

Storage Curve	
Depth	Area
(m)	(m^2)
0	3350
0.8	3350
1	16600
2.3	3000
3.5	3917
4	1600
4.4	1600

Description: Database
Assumed cylinder beyond highest elevation

Pond 17025

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.025
1	0.037
1.5	0.151
2	0.312
2.5	0.617
3	1.76
3.3	8.8

Storage Curve	
Depth	Area
(m)	(m^2)
0	3788
0.5	3788
1	4652
1.5	11284
2	13354
2.5	15238
3	17128
3.3	17128

Description: database

Pond 17031

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.092
2.2	0.46

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	2760
2.2	2760

Description: Estimated storage for 100 year

Description: Unit peak flow of sub basin 17

Pond 172

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.2	0.005
0.4	0.008
0.6	0.009
0.8	0.011
1	0.066
1.2	0.269
1.4	0.574
1.6	0.895
1.8	1.23
2	1.569
2.2	7.85

Storage Curve	
Depth	Area
(m)	(m^2)
0	140
0.2	140
0.4	160
0.6	775
0.8	725
1	1225
1.2	1485
1.4	1275
1.6	1855
1.8	1835
2	2060
2.2	2060

Description: database

Pond 19

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.28	0.061
0.38	0.081
0.72	0.125
1.08	0.16
1.32	0.179
1.58	0.197
1.88	0.217
2.08	0.229
2.53	0.409
2.58	0.577
3.08	1.169
3.58	1.517
3.83	1.658
3.93	2.335
4.08	11.248
4.18	23.98
4.28	40.826
4.38	60.843
4.82	304.22

Storage Curve	
Depth	Area
(m)	(m^2)
0	792
0.72	792
1.32	16683
2.08	21250
2.58	24920
3.08	29300
3.58	38880
3.83	42880
3.93	20000
4.08	70267
4.18	49600
4.28	45000
4.38	58000
4.82	58000

Description: database

Pond 198

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.7	0.17
0.75	0.18
0.9	0.32
1.2	0.38
2	0.85
2.2	4.25

Storage Curve	
Depth	Area
(m)	(m^2)
0	13601
0.7	13601
0.75	16420
0.9	16413
1.2	16417
2	16415
2.2	16415

Description: database, Assumed cylinder beyond highest elevation

Pond 198.2

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.8	0.2
0.85	0.2
1.1	0.46
1.55	0.57
2	1.24
2.2	6.2

Storage Curve	
Depth	Area
(m)	(m^2)
0	14599
0.8	14599
0.85	17200
1.1	17192
1.55	17193
2	17193
2.2	17193

Description: database

Pond 200

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.03	1.37
2.53	1.4
2.72	2.85
3.03	13.6
3.33	68

Storage Curve	
Depth	Area
(m)	(m^2)
0	244
1.03	244
2.53	10167
2.72	16450
3.03	16200
3.33	16200

Description: database, Assumed cylinder beyond highest elevation

Pond 210

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2.5	2.2
2.75	11

Description: Estimated discharge for 100 year

Storage Curve	
Depth	Area
(m)	(m^2)
0	13865
1	16710
1.5	18547
2	20497
2.5	23000
2.75	23000

Description: database

Pond 210.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.3	0.07
1.3	0.12
2.3	0.16
2.53	0.8

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
0.3	650
1.3	3725
2.3	4875
2.53	4875

Description: database

Pond 210.2

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.2	0.051
0.4	0.072
0.6	0.186
0.8	0.32
1	0.407
1.2	0.477
1.4	0.538
1.6	0.733
1.8	1.021
2	1.351
2.1	1.524
2.31	7.62

Storage Curve	
Depth	Area
(m)	(m^2)
0	14155
0.2	14155
0.4	14865
0.6	15545
0.8	16230
1	16920
1.2	17580
1.4	18165
1.6	18725
1.8	19285
2	19845
2.1	20270
2.31	20270

Description: database

Pond 22.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.4	0.125
0.65	0.177
0.9	0.217
1.15	0.25
1.25	0.263
1.4	0.28
1.65	1.491
1.9	1.62
2.15	1.74
2.4	1.852
2.65	1.957
2.9	2.057
3.15	2.153
3.4	2.244
3.65	2.332
3.9	2.417
4.15	2.499
4.4	2.578
4.84	12.89

Storage Curve	
Depth	Area
(m)	(m^2)
0	9807
0.4	11640
0.65	12360
0.9	13080
1.15	13833
1.25	14134
1.4	14585
1.65	15313
1.9	16041
2.15	16808
2.4	17574
2.65	18376
2.9	19177
3.15	19921
3.4	20664
3.65	21429
3.9	22193
4.15	23100
4.4	24006
4.84	26006
5.324	26006

Description: database

Pond 223

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.054
1	0.077
2	0.108
2.5	0.121
3	0.133
3.5	0.143
3.88	0.151
4	0.179
4.25	0.292
4.5	0.45
4.95	2.25

Storage Curve	
Depth	Area
(m)	(m^2)
0	70
0.5	70
1	268
2	696
2.5	1186
3	5584
3.5	6992
3.88	8232
4	8808
4.25	9376
4.5	10060
4.95	10060

Description: database

Pond 226

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.6	0.121
1.7	1.74
1.87	8.7

Storage Curve	
Depth	Area
(m)	(m^2)
0	11580
0.6	11580
1.7	14079
1.87	14079

Description: database

Pond 226.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.45	0.16
1.5	1.1
1.65	5.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	20107
0.45	20107
1.5	20147
1.65	20147

Description: database

Pond 226.2

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.211
1.25	0.303
2.5	0.87
3.5	1.969
4	4.263
5.46	21.32

Storage Curve	
Depth	Area
(m)	(m^2)
0	6880
1.46	6880
2.21	22009
3.46	28321
4.46	28319
4.96	32910
5.46	32910

Description: database

Pond 226.3

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.84	0.21
1.1	0.29
1.11	0.39
1.42	0.49
1.55	0.59
1.64	0.73
1.95	5.14
2.14	25.7

Storage Curve	
Depth	Area
(m)	(m^2)
0	9651
0.84	9651
1.1	12550
1.42	13006
1.55	13700
1.64	14856
1.95	14274
2.14	14274

Description: database,Assumed cylinder beyond highest elevation

Pond 227

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.14
1	0.225
1.5	0.365
1.6	1.03
1.7	1.79
1.8	2.11
2.5	2.32
2.75	11.6

Storage Curve	
Depth	Area
(m)	(m^2)
0	1266
0.5	1266
1	2818
1.5	4556
1.6	12620
1.7	12630
1.8	12620
2.5	12623
2.75	12623

Description: database

Pond 23019

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	12.5
2.2	62.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	1850
2	1850

Description: Estimated storage based on pond footprint

Pond 23020

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.101
2.2	0.505

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	4150
2.2	4150

Description: Unit flow rate of sub basin 23

Description: Estimated storage for 100 year

Pond 23021

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.218
2.2	1.09

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	10050
2.2	10050

Description: Unit flow rate of sub basin 30

Description: Estimated storage for 100 year

Pond 23023

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.157
2.2	0.785

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	5900
2.2	5900

Description: Unit flow rate of sub basin 31

Description: Estimated storage for 100 year

Pond 23024

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.568
2.2	2.84

Description: Unit flow rate of sub basin 31

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	23500
2.2	23500

Description: Estimated storage for 100 year

Pond 23025

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.139
2.2	0.695

Description: Unit flow rate of sub basin 31

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	5300
2.2	5300

Description: Estimated storage for 100 year

Pond 24

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.29
1	0.74
1.5	1.18
2	1.56
2.5	3.09
3	10.08
3.3	50.4

Storage Curve	
Depth	Area
(m)	(m^2)
0	200
0.5	200
1	3600
1.5	6000
2	6600
2.5	6400
3	6600
3.3	6600

Description: database

Pond 244

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.8	0.074
1	0.08
1.65	0.35
1.85	0.44
2.04	2.2

Storage Curve	
Depth	Area
(m)	(m^2)
0	5609
0.8	5609
1	5610
1.65	7228
1.85	7230
2.04	7230

Description: database

Pond 245

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
3.5	1.27
3.85	6.35

Storage Curve	
Depth	Area
(m)	(m^2)
0	13556
1.35	13556
3.5	22047
3.85	22047

Description: database

Pond 248

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	10
0.65	50

Storage Curve	
Depth	Area
(m)	(m^2)
0	7500
1.4	7500

Description: Flow backs into the depression area in the park when the pipe is full. Flow is restricted by the d/s pipe, not by the outlet.

Description: database

Pond 25

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.25	1.8
0.74	2
1.2	2.1
1.32	10.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	32000
0.25	32000
0.74	7755
1.2	13696
1.32	13696

Description: Database
Assumed cylinder beyond highest elevation

Pond 26

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	205
2.2	1025

Description: Pond 26, 17018
Estimated discharge for 100 year

Storage Curve	
Depth	Area
(m)	(m^2)
0	5123
2	5123

Description: Pond 26, 17018
Estimated volume from pond footprint

Pond 27

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.39	2.1
1.52	3.5
1.62	5
1.98	12.6
2.15	18.5
2.37	92.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	15108
1.39	15108
1.52	16923
1.62	17000
1.98	18056
2.15	15294
2.37	15294

Description: Database
Assumed cylinder beyond highest elevation

Pond 27.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.65	0.02
0.85	0.07
1.2	0.12
1.5	0.15
1.65	0.75

Storage Curve	
Depth	Area
(m)	(m^2)
0	2077
0.65	2077
0.85	2350
1.2	2514
1.5	3000
1.65	3000

Description: Database

Pond 271

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
3	1.2
3.3	6

Storage Curve	
Depth	Area
(m)	(m^2)
0	6113
3	6113

Description: Pond 271 Assumed stage

Description: Database in 271.1

Pond 271.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.05	0.004
0.1	0.008
0.15	0.008
0.2	0.01
0.25	0.012
0.3	0.014
0.35	0.015
0.4	0.016
0.45	0.017
0.5	0.018
0.55	0.019
0.6	0.02
0.65	0.021
0.7	0.022
0.75	0.199
0.8	0.205
0.85	0.21
0.9	0.215
0.95	0.22
1	0.225
1.05	0.23
1.1	0.234
1.15	0.238
1.2	0.243
1.25	0.247
1.3	0.478
1.35	0.486
1.4	0.494
1.45	0.501
1.5	0.509
1.55	0.517
1.6	0.524
1.65	0.531
1.7	0.539
1.75	0.546
1.8	0.553
1.9	0.664
1.95	1.22
2	1.87
2.05	2.625
2.1	3.451
2.31	17.26

Storage Curve	
Depth	Area
(m)	(m^2)
0	3660
0.05	3660
0.1	3680
0.15	3660
0.2	3660
0.25	3680
0.3	3660
0.35	5020
0.4	5040
0.45	5020
0.5	5040
0.55	5020
0.6	5040
0.65	5020
0.7	5040
0.75	5020
0.8	5040
0.85	5020
0.9	5040
0.95	5020
1	5040
1.05	5020
1.1	5020
1.15	5040
1.2	5020
1.25	5040
1.3	5020
1.35	5040
1.4	5020
1.45	5040
1.5	5020
1.55	5040
1.6	5020
1.65	5040
1.7	5020
1.75	5040
1.8	5020
1.85	5020
1.9	5040
1.95	5020
2	5040
2.05	5020
2.1	5040
2.31	5040

Description: Database

Pond 271.3

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.05	0.016
0.1	0.032
0.15	0.042
0.2	0.057
0.25	0.054
0.3	0.062
0.35	0.069
0.4	0.075
0.45	0.081
0.5	0.086
0.55	0.09
0.6	0.094
0.65	0.098
0.7	0.476
0.75	0.485
0.8	0.512
0.85	0.536
0.9	0.56
0.95	0.582
1	0.604
1.05	0.887
1.1	0.917
1.15	0.946
1.2	0.975
1.25	1.002
1.3	1.029
1.35	1.055
1.4	1.08
1.45	1.105
1.5	1.13
1.55	1.19
1.6	3.364
1.65	6.181
1.7	9.516
1.75	13.3
1.8	17.484
1.85	22.032
1.9	26.918
2.09	134.59

Storage Curve	
Depth	Area
(m)	(m^2)
0	19180
0.05	19180
0.1	19160
0.15	19180
0.2	19160
0.25	19180
0.3	19160
0.35	19160
0.4	19180
0.45	19160
0.5	19180
0.55	27640
0.6	27620
0.65	27640
0.7	27620
0.75	27640
0.8	27620
0.85	27620
0.9	27640
0.95	27620
1	27640
1.05	27640
1.1	27620
1.15	27640
1.2	27620
1.25	27640
1.3	27620
1.35	27620
1.4	27640
1.45	27620
1.5	27640
1.55	27640
1.6	27620
1.65	27640
1.7	27620
1.75	27640
1.8	27620
1.85	27620
1.9	27640
2.09	27640

Description: Database

Pond 271.4

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.05	0.007
0.1	0.013
0.15	0.02
0.2	0.018
0.25	0.021
0.3	0.024
0.35	0.027
0.4	0.029
0.45	0.031
0.5	0.033
0.55	0.035
0.6	0.037
0.65	0.039
0.7	0.04
0.75	0.042
0.8	0.073
0.85	0.075
0.9	0.076
0.95	0.08
1	0.082
1.05	0.084
1.1	0.107
1.15	0.11
1.2	0.112
1.25	0.115
1.3	0.117
1.35	0.119
1.4	0.121
1.45	0.124
1.5	0.126
1.55	0.128
1.6	0.13
1.65	0.132
1.7	0.134
1.75	0.136
1.8	0.138
1.85	0.532
1.9	1.505
1.95	2.765
2	4.257
2.05	5.95
2.1	7.821
2.31	39.11

Storage Curve	
Depth	Area
(m)	(m^2)
0	16340
0.05	16340
0.1	16340
0.15	16360
0.2	16340
0.25	16340
0.3	16340
0.35	16340
0.4	16360
0.45	16340
0.5	16340
0.55	11880
0.6	11880
0.65	11880
0.7	11880
0.75	11880
0.8	11880
0.85	11880
0.9	11880
0.95	11880
1	11880
1.05	11880
1.1	11880
1.15	11900
1.2	11880
1.25	11880
1.3	11880
1.35	11880
1.4	11880
1.45	11880
1.5	11880
1.55	11880
1.6	11880
1.65	11880
1.7	11880
1.75	11880
1.8	11880
1.85	13800
1.9	12520
1.95	12520
2	12500
2.05	12520
2.1	12520
2.31	12520

Description: Database

Pond 271.5

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.05	0.008
0.1	0.016
0.15	0.024
0.2	0.022
0.25	0.027
0.3	0.03
0.35	0.034
0.4	0.037
0.45	0.04
0.5	0.042
0.55	0.167
0.6	0.179
0.65	0.189
0.7	0.2
0.75	0.21
0.8	0.219
0.85	0.343
0.9	0.356
0.95	0.368
1	0.38
1.05	0.392
1.1	0.403
1.15	0.414
1.2	0.425
1.25	0.36
1.3	1.018
1.35	1.871
1.4	2.88
1.45	4.025
1.5	5.291
1.65	26.46

Storage Curve	
Depth	Area
(m)	(m^2)
0	9940
0.05	9940
0.1	9960
0.15	9940
0.2	9960
0.25	9940
0.3	9940
0.35	9960
0.4	9940
0.45	9960
0.5	9940
0.55	12040
0.6	12020
0.65	12040
0.7	12040
0.75	12020
0.8	12040
0.85	12040
0.9	12020
0.95	12040
1	12020
1.05	12040
1.1	12040
1.15	12020
1.2	12040
1.25	12040
1.3	12020
1.35	12040
1.4	12040
1.45	12020
1.5	12040
1.65	12040

Description: Database

Pond 291

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.05	0.003
0.1	0.01
0.15	0.02
0.2	0.039
0.25	0.051
0.3	0.06
0.35	0.068
0.4	0.076
0.45	0.082
0.5	0.089
0.55	0.094
0.6	0.1
0.65	0.105
0.7	0.11
0.75	0.115
0.8	0.119
0.85	0.124
0.9	0.15
0.95	0.196
1	0.255
1.05	0.325
1.1	0.404
1.15	0.491
1.2	0.586
1.25	0.687
1.3	0.795
1.35	0.912
1.4	1.036
1.45	1.165
1.5	1.3
1.55	1.441
1.6	1.587
1.65	1.738
1.7	1.894
1.75	2.055
1.8	2.22
1.85	2.576
1.9	3.105
1.95	3.757
2	4.515
2.05	5.369
2.1	6.31
2.15	7.344
2.2	8.434
2.42	42.17

Storage Curve	
Depth	Area
(m)	(m^2)
0	7400
0.05	7400
0.1	7520
0.15	7600
0.2	7780
0.25	7860
0.3	7980
0.35	8100
0.4	8220
0.45	8320
0.5	8440
0.55	8560
0.6	8640
0.65	8720
0.7	8820
0.75	8920
0.8	9020
0.85	9100
0.9	9180
0.95	9300
1	9360
1.05	9480
1.1	9560
1.15	9660
1.2	9740
1.25	9840
1.3	9940
1.35	10020
1.4	10120
1.45	10200
1.5	10300
1.55	10400
1.6	10460
1.65	10560
1.7	10640
1.75	10720
1.8	10800
1.85	10880
1.9	10880
1.95	11160
2	11140
2.05	11220
2.1	11300
2.15	11380
2.2	11460
2.42	11460

Description: Database

Pond 30001

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
3	45.18
3.3	225.9

Storage Curve	
Depth	Area
(m)	(m^2)
0	29965
3	29965

Description: Estimated discharge for 100 year 3m x 3m box culvert at Major Mac

Description: Estimated storage with pond footprint

Pond 303

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	26
2.2	130

Storage Curve	
Depth	Area
(m)	(m^2)
0	4030
2	4030

Description: Estimated discharge for 100 year

Description: Estimated storage with pond footprint

Pond 303.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	12.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	3153
2	3153

Description: Estimated discharge for 100 year

Description: Estimated storage with pond footprint

Pond 304

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1	0.33
1.1	1.65

Storage Curve	
Depth	Area
(m)	(m^2)
0	130
1	130

Description: Database

Pond 315

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.2	0.04
0.7	0.07
1.7	0.11
2.2	6.61
2.45	6.89
2.7	34.45

Storage Curve	
Depth	Area
(m)	(m^2)
0	4920
0.2	5250
0.7	5575
1.7	7035
2.2	8345
2.45	8965
2.7	8965

Description: Database

Pond 341.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.06
0.61	0.19
0.67	0.39
0.74	0.69
0.8	0.98
0.85	1.3
1.3	9.09
1.31	9.34
1.43	45.45

Storage Curve	
Depth	Area
(m)	(m^2)
0	18556
0.5	18556
0.61	32836
0.67	29167
0.74	33857
0.8	32000
0.85	35800
1.3	36844
1.43	36844

Description: Database

Pond 341.2

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
0.73	0.062
0.85	0.178
0.97	0.238
1.13	0.299
1.25	0.383
1.34	0.517
2.48	3.344
2.5	3.439
2.75	17.195

Storage Curve	
Depth	Area
(m)	(m²)
0	10327
0.73	10327
0.85	10442
0.97	11567
1.13	12063
1.25	12167
1.34	12444
2.48	14272
2.5	25000
2.75	25000

Description: Database

Pond 348

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
3	1.361
3.3	6.80475

Storage Curve	
Depth	Area
(m)	(m²)
0	13337
3	13337

Description: Pond 348
Sub basin 18
Unit peak flow rate = 0.0215 m3/s/ha
Drainage area = 63.3 ha
Assumed stage

Description: Database of 348.1

Pond 348.1

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
4.3	1.015
4.73	5.074

Storage Curve	
Depth	Area
(m)	(m²)
0	6124
4.3	6124

Description: Pond 348.1
Sub basin 18
Unit peak flow rate = 0.0215 m3/s/ha
Drainage area = 47.2 ha

Description: Database

Pond 348.2

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
2	0.937
2.2	4.687

Storage Curve	
Depth	Area
(m)	(m²)
0	10039
2	10039

Description: Pond 348.2
Sub basin 18
Unit peak flow rate = 0.0215 m3/s/ha
Drainage area = 43.6 ha

Description: Database

Pond 348.3

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
0.45	0.038
1	0.165
1.5	0.648
2	0.76
2.2	3.8

Storage Curve	
Depth	Area
(m)	(m²)
0	10044
0.45	10044
1	11115
1.5	12578
2	12580
2.2	12580

Description: Database

Pond 348.4

Outlet Curve	
Depth	Discharge
(m)	(m³/s)
0	0
0.4	0.007
0.85	0.076
1.3	0.094
1.7	0.107
2.2	14.37

Storage Curve	
Depth	Area
(m)	(m²)
0	3250
0.4	3250
0.85	4011
1.3	3407
1.7	3405
2.2	3405

Description: Database

Pond 348.5

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.25	0.013
0.55	0.021
0.7	0.024
0.85	0.187
1.5	0.258
2.3	15.459

Storage Curve	
Depth	Area
(m)	(m^2)
0	7620
0.25	7620
0.55	7623
0.7	9127
0.85	9133
1.5	9926
2.3	9926

Description: Database

Pond 348.6

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.016
0.75	0.084
0.95	0.095
1	0.098
1.5	0.122
1.7	3.13

Storage Curve	
Depth	Area
(m)	(m^2)
0	4000
0.5	4000
0.75	4812
0.95	5265
1	5260
1.5	5262
1.7	5265
1.87	5265

Description: Database

Pond 348.7

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.613
2.2	3.064

Storage Curve	
Depth	Area
(m)	(m^2)
0	9000
2	9000

Description: Sub basin 18
Unit peak flow rate = 0.0215 m3/s/ha
Drainage area = 28.5 ha

Description: Database

Pond 348.8

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.4	0.007
0.6	0.009
0.75	0.059
0.8	0.062
0.95	0.068
1	0.153
1.1	0.161
1.5	0.19
1.65	0.95

Storage Curve	
Depth	Area
(m)	(m^2)
0	2450
0.4	2450
0.6	2825
0.75	3327
0.8	3620
0.95	3607
1	3600
1.1	3610
1.5	3607
1.65	3607

Description: Database
Assumed cylinder beyond highest elevation

Pond 349

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.35	0.01
0.65	0.03
0.95	0.045
1.2	0.08
1.32	0.4

Storage Curve	
Depth	Area
(m)	(m^2)
0	2817
0.35	2817
0.65	2787
0.95	2620
1.2	2568
1.32	2568

Description: Database
Assumed cylinder beyond highest elevation

Pond 349.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.45	0.03
0.55	0.08
0.85	0.107
1.1	0.125
1.45	0.147
1.6	0.28
1.85	0.304
2.035	1.52

Storage Curve	
Depth	Area
(m)	(m^2)
0	8744
0.45	8744
0.55	18770
0.85	6190
1.1	6296
1.45	5737
1.6	5420
1.85	5860
2.035	5860

Description: Database

Pond 349.2

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.7	0.01
1.25	0.286
1.75	0.432
2.1	0.772
2.31	3.86

Storage Curve	
Depth	Area
(m)	(m^2)
0	13570
0.7	13570
1.25	15113
1.75	15260
2.1	13177
2.31	13177

Description: Database
Assumed cylinder beyond highest elevation

Pond 349.3

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.4	0.01
0.75	0.023
1.1	0.034
1.5	0.061
1.65	0.305

Storage Curve	
Depth	Area
(m)	(m^2)
0	1892
0.4	1892
0.75	1814
1.1	1729
1.5	1907
1.65	1907

Description: Database

Pond 349.4

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.65	0.01
1.1	0.967
1.55	1.563
2	2.225
2.2	11.125

Storage Curve	
Depth	Area
(m)	(m^2)
0	10705
0.65	10705
1.1	10489
1.55	10722
2	9993
2.2	9993

Description: Database
Assumed cylinder beyond highest elevation

Pond 349.5

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.5	0.02
0.95	0.073
1.35	0.11
1.7	0.196
1.87	0.98

Storage Curve	
Depth	Area
(m)	(m^2)
0	4836
0.5	4836
0.95	4582
1.35	4837
1.7	4014
1.87	4014

Description: Database
Assumed cylinder beyond highest elevation

Pond 349.6

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.45	0.01
0.85	0.041
1.2	0.061
1.5	0.11
1.65	0.55

Storage Curve	
Depth	Area
(m)	(m^2)
0	3000
0.45	3000
0.85	2887
1.2	3091
1.5	2937
1.65	2937

Description: Database
Assumed cylinder beyond highest elevation

Pond 349.7

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.4	0.03
0.7	0.119
1.05	0.179
1.5	0.32
1.65	1.6

Storage Curve	
Depth	Area
(m)	(m^2)
0	9847
0.4	9847
0.7	11193
1.05	9006
1.5	10447
1.65	10447

Description: Database

Pond 349.8

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.55	0.05
1.05	0.199
1.5	0.301
1.8	0.537
1.98	2.685

Storage Curve	
Depth	Area
(m)	(m^2)
0	12025
0.55	12025
1.05	11292
1.5	11722
1.8	11300
1.98	11300

Description: Database
Assumed cylinder beyond highest elevation

Pond 349.9

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.75	0.05
1.4	0.267
1.95	0.502
2.3	0.735
2.53	3.675

Storage Curve	
Depth	Area
(m)	(m^2)
0	8019
0.75	8019
1.4	7428
1.95	7835
2.3	7474
2.53	7474

Description: Database
Assumed cylinder beyond highest elevation

Pond 350.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.25	0.01
0.5	0.053
0.75	0.081
1.7	0.144
1.87	0.72

Storage Curve	
Depth	Area
(m)	(m^2)
0	7096
0.25	7096
0.5	6120
0.75	5676
1.7	3555
1.87	3555

Description: Database

Pond 350.2

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.4	0.01
0.8	0.112
1.15	0.169
1.5	0.302
1.65	1.51

Storage Curve	
Depth	Area
(m)	(m^2)
0	9290
0.4	9290
0.8	8077
1.15	8517
1.5	9006
1.65	9006

Description: Database

Pond 37

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.5	37
1.65	185

Storage Curve	
Depth	Area
(m)	(m^2)
0	5133
1.5	5133

Description: Database

Pond 4

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.897
2.2	4.485

Description: Unit peak flow of sub basin 21

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	28250
2.2	28250

Description: Pond 4, 4.1 Estimated storage

Pond 4.3

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2.6	1.3
2.86	6.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	5769
2.6	5769

Description: Database

Pond 4.4

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.64	1
1.14	2.4
1.64	4.13
2.14	6.16
2.64	10.5
3.14	19.301
3.45	96.505

Storage Curve	
Depth	Area
(m)	(m^2)
0	1750
0.64	1750
1.14	8640
1.64	12920
2.14	20120
2.64	17532
3.14	28420
3.454	28420

Description: Database

Pond 4.5

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1	2.73
1.33	3.49
2	5.63
2.67	8.97
3	10.52
3.62	12.54
4	23.09

Storage Curve	
Depth	Area
(m)	(m^2)
0	1070
1	1070
1.33	2848
2	4552
2.67	7045
3	8970
3.62	11855
4	11842
4.4	11842

Description: Database
Assumed cylinder beyond highest elevation

Pond 404

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.32	0.007
0.4	0.008
0.52	0.019
0.58	0.024
0.7	0.032
0.74	0.045
0.8	0.054
0.88	0.27

Storage Curve	
Depth	Area
(m)	(m^2)
0	1413
0.32	1413
0.4	1262
0.52	1533
0.58	2000
0.7	1617
0.74	2475
0.8	2033
0.88	2033

Description: Database
Assumed cylinder beyond highest elevation

Pond 405

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.53	0.48
1.68	2.4

Storage Curve	
Depth	Area
(m)	(m^2)
0	2000
0.75	2000
1.53	2521
1.68	2521

Description: Database

Pond 406

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.1	0.51
2	1.33
2.2	6.65

Storage Curve	
Depth	Area
(m)	(m^2)
0	26091
1.1	26091
2	21167
2.2	21167

Description: Database
Assumed cylinder beyond highest elevation

Pond 406.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.15	0.19
1.9	0.53
2.09	2.65

Storage Curve	
Depth	Area
(m)	(m^2)
0	13652
1.15	13652
1.9	13467
2.09	13467

Description: Database
Assumed cylinder beyond highest elevation

Pond 50.3

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1.2	0.42
1.32	2.1

Pond 50

Storage Curve	
Depth	Area
(m)	(m^2)
0	6625
1.2	6625
1.32	6625

Description: Lumped 50.0, 50.1, 50.2, 50.3
Database

Pond 66

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
1	0.931
1.1	4.655

Description: Assumed stage

Pond 50

Storage Curve	
Depth	Area
(m)	(m^2)
0	1670
1	1670

Description: Database
Assumed stage

Pond 79

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.05	2.85
0.5	4.25
1	7.45
1.5	12.66
1.77	13.7
1.947	68.5

Storage Curve	
Depth	Area
(m)	(m^2)
0	2714
0.5	2714
1	8756
1.5	14580
1.77	18548
1.95	18548

Description: Database

Pond 81

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
2	0.232
2.2	1.16

Storage Curve	
Depth	Area
(m)	(m^2)
0	0
2	10750
2.2	10750

Description: Unit peak flow of sub basin 21

Description: Estimated storage for 100 year

Pond 81.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.3	0.03
0.6	0.17
0.95	0.45
1.2	0.73
1.4	0.96
1.65	1.26
1.9	1.61
2.05	1.86
2.255	9.3

Storage Curve	
Depth	Area
(m)	(m^2)
0	6550
0.3	6550
0.6	5450
0.95	5429
1.2	7200
1.4	7500
1.65	8400
1.9	6800
2.05	9333
2.255	9333

Description: Database

Pond 9

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.4	0.48
0.9	1.5
1.4	2.45
1.65	2.75
1.9	3.22
2.15	3.38
2.4	3.67
2.65	4
2.9	4.2
3	4.28
3.15	4.58
3.4	5.94
3.65	7.68
3.9	11.33
4.15	15.31
4.4	17.21
4.65	17.74
4.9	31.09
5.15	54.69
5.4	85.09
5.94	425.45

Storage Curve	
Depth	Area
(m)	(m^2)
0	250
0.4	250
0.9	150
1.4	1640
1.65	3808
1.9	3812
2.15	6152
2.4	6152
2.65	10016
2.9	10020
3	15290
3.15	15287
3.4	15296
3.65	20580
3.9	20612
4.15	25944
4.4	25948
4.65	31200
4.9	31200
5.15	38824
5.4	38824
5.94	38824

Description:

Pond 95

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.3	0.042
0.8	0.077
1.05	0.09
1.3	0.142
1.55	0.156
1.8	0.169
2.05	0.181
2.3	0.193
2.55	0.204
2.8	0.214
3.05	0.223
3.3	1.386
3.55	5.758
3.8	12.173

Storage Curve	
Depth	Area
(m)	(m^2)
0	5167
0.3	5167
0.8	5890
1.05	6622
1.3	7058
1.55	7706
1.8	8569
2.05	9200
2.3	10250
2.55	12050
2.8	13650
3.05	14850
3.3	15950
3.55	17000
3.8	17950

Description:

Pond 95.1

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.25	0.05
0.5	0.08
0.75	0.11
1	0.13
1.25	0.14
1.5	0.16
1.75	0.17
2	0.19
2.25	0.2
2.5	0.21
2.75	0.22
3	0.23
3.25	0.24
3.5	1.07
3.75	5.13
4	11
4.4	55

Storage Curve	
Depth	Area
(m)	(m^2)
0	68
0.25	68
0.5	292
0.75	764
1	1768
1.25	3636
1.5	6304
1.75	8952
2	11412
2.25	13684
2.5	15956
2.75	17792
3	19196
3.25	20596
3.5	22096
3.75	23696
4	25936
4.4	25936

Description: Database

GRoss Dam

G Ross Lord Dam Lower Gates

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.15	13.36
0.3	27
0.45	41
0.6	54.6
0.75	69.2
0.9	83.8
1.05	91.4
1.2	92
1.45	93
1.7	95
1.95	96
2.2	97
2.45	98
2.7	100
2.95	101
3.2	102
3.45	103
3.7	104
3.95	105
4.2	106
4.45	107
4.7	109
4.95	110
5.2	111
5.45	112
5.7	113
5.95	114
6.2	115
6.45	116
6.7	117
6.95	118
7.2	119

Description: G Ross Lord Dam lower gates

G Ross Lord Dam spillway gates

Outlet Curve	
Depth	Discharge
(m)	(m^3/s)
0	0
0.15	9.706
0.3	18.883
0.45	27.863
0.6	36.63
0.75	44.445
0.9	50.658
1.05	56.511
1.2	62.671
1.35	69.035
1.5	75.553
1.65	82.279
1.8	89.136
1.95	96.195
2.046	100.713
2.351	115.693
2.655	131.254
2.96	147.357
3.265	163.966
3.57	181.049
3.875	198.577
4.179	216.523
4.484	234.862
4.789	253.57
5.094	272.627
5.399	292.011
5.703	311.704
6.008	331.687

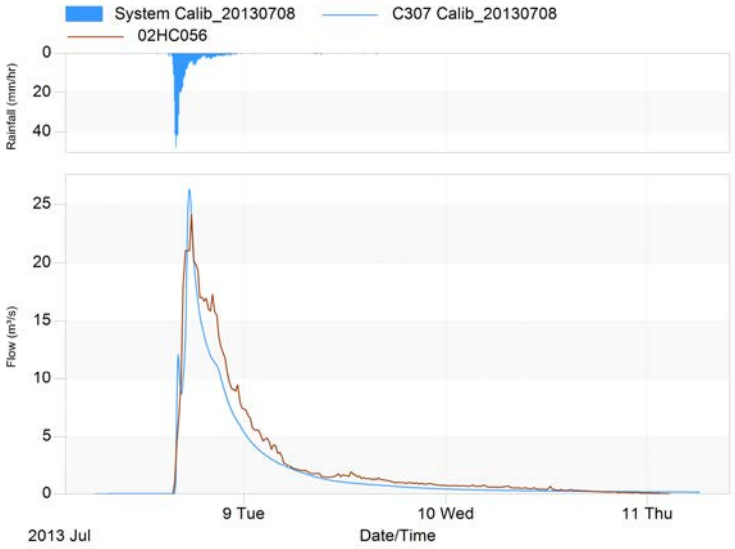
Description spillway gates: G Ross Lord Dam spillway gates

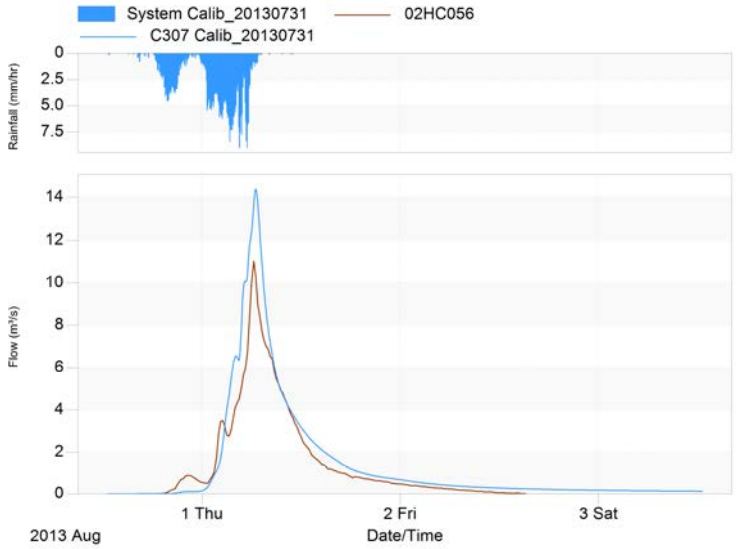
Storage Curve	
Depth	Area
(m)	(m^2)
0	150000
0.3	166667
0.6	180000
0.7	250000
0.9	170000
1.2	216667
1.7	203040
2.2	236620
2.7	267640
3.2	309940
3.7	355880
4.2	387420
4.7	417880
5.2	449720
5.7	483520
6.2	518660
6.7	550320
7.2	592060
7.7	634740
8.2	690400
8.7	763320
9.2	830420
9.7	887540
10.2	946540
10.7	1011180
11.2	1072200

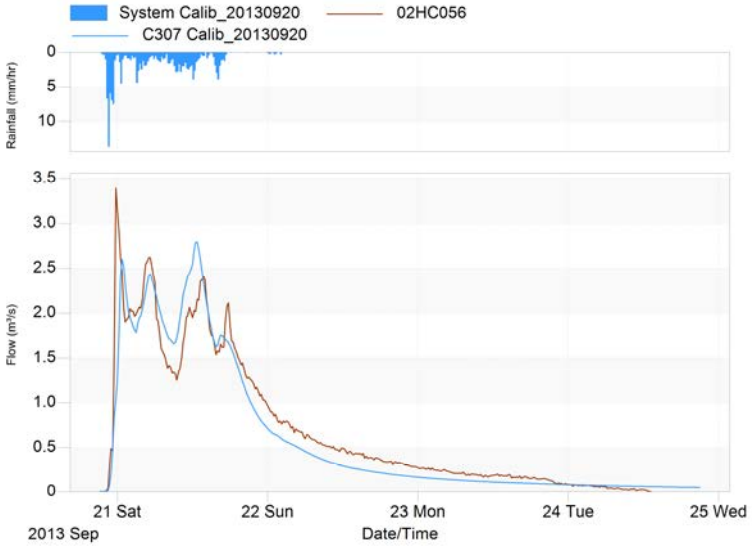
Description: Dam Operation manual

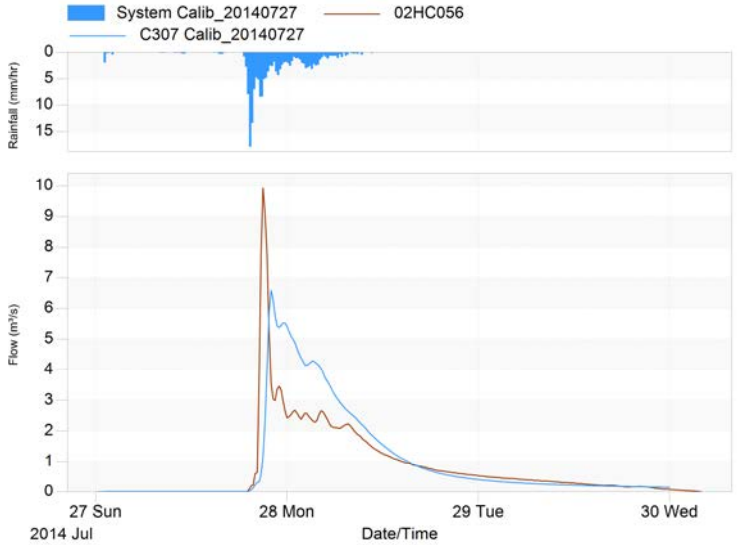
Appendix E: Calibration Plots

02HC056

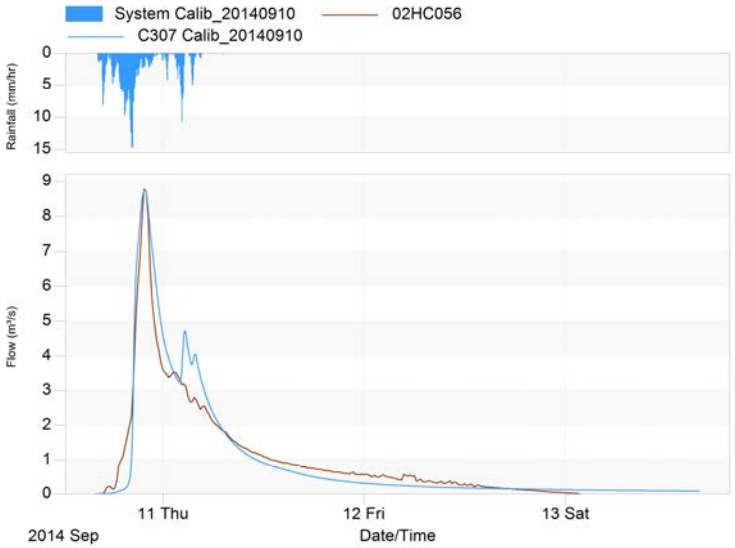

System Calib_20130708
C307 Calib_20130708
02HC056
Rainfall (mm/hr)
0
20
40
Flow (m³/s)
25
20
15
10
5
0
9 Tue
10 Wed
11 Thu
2013 Jul
Date/Time

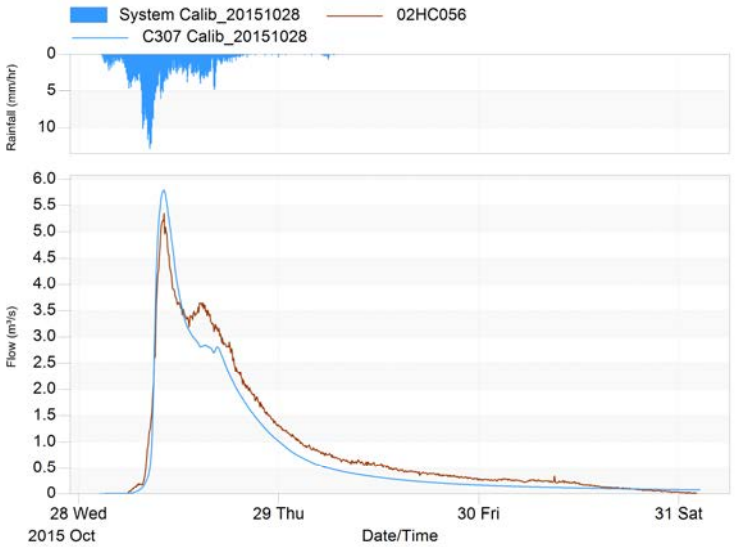

System Calib_20130731
C307 Calib_20130731
02HC056
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
14
12
10
8
6
4
2
0
1 Thu
2 Fri
3 Sat
2013 Aug
Date/Time


System Calib_20130920
C307 Calib_20130920
02HC056
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
2013 Sep
Date/Time

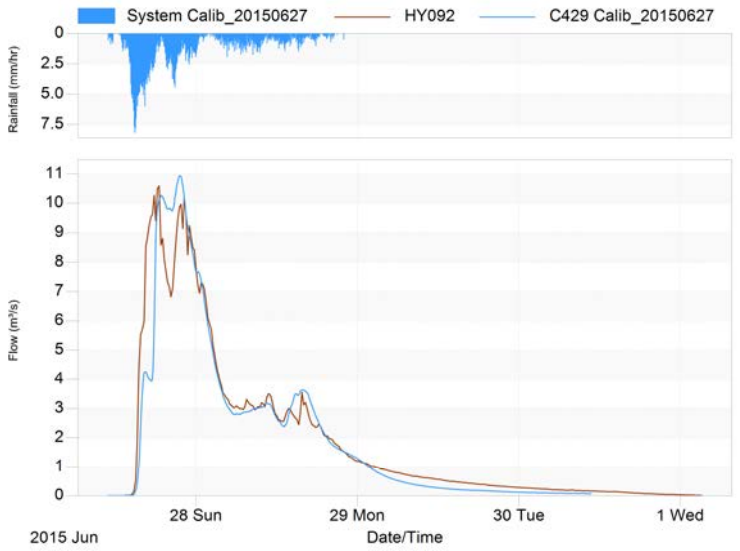

System Calib_20140727
C307 Calib_20140727
02HC056
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
10
9
8
7
6
5
4
3
2
1
0
27 Sun
28 Mon
29 Tue
30 Wed
2014 Jul
Date/Time

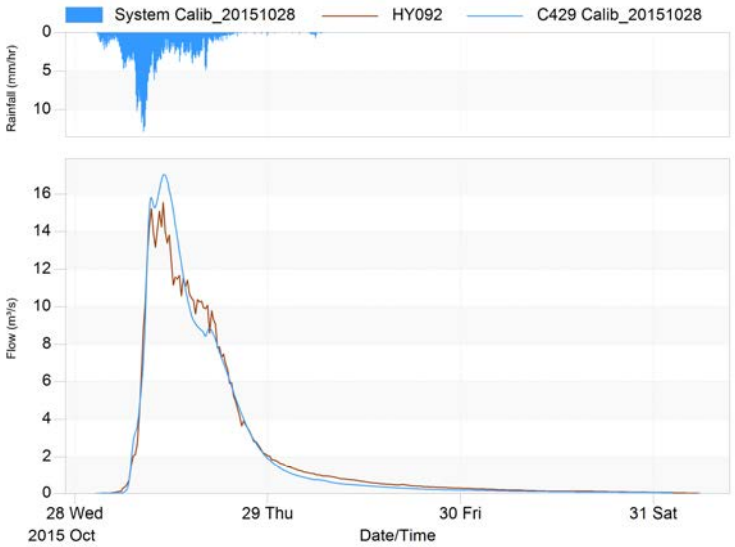
02HC056


System Calib_20140910
02HC056
C307 Calib_20140910
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
9
8
7
6
5
4
3
2
1
0
11 Thu
12 Fri
13 Sat
2014 Sep
Date/Time

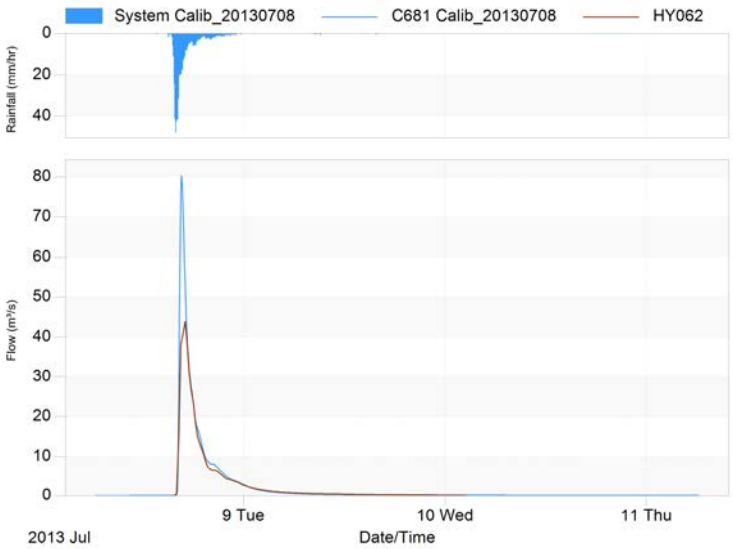

System Calib_20151028
02HC056
C307 Calib_20151028
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
28 Wed
29 Thu
30 Fri
31 Sat
2015 Oct
Date/Time

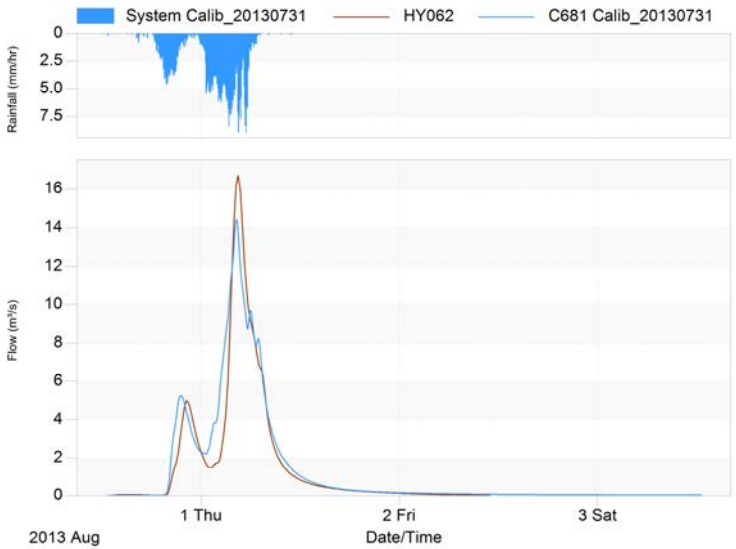
HY092

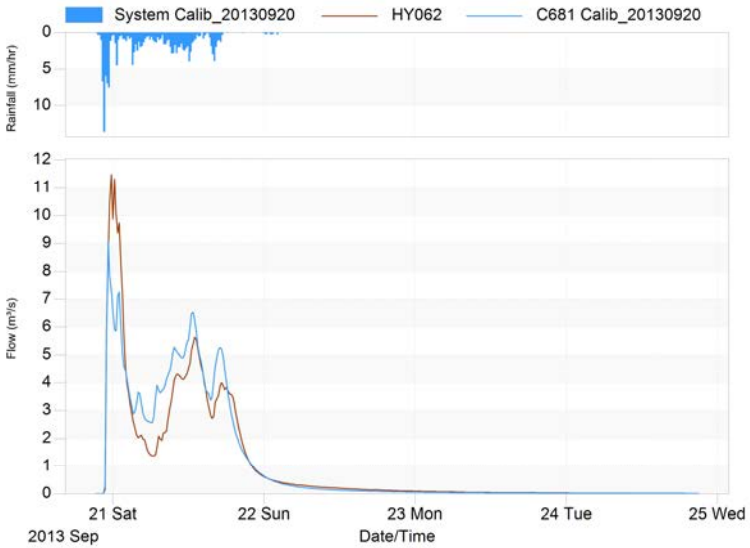

System Calib_20150627
HY092
C429 Calib_20150627
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
11
10
9
8
7
6
5
4
3
2
1
0
28 Sun
29 Mon
30 Tue
1 Wed
2015 Jun
Date/Time

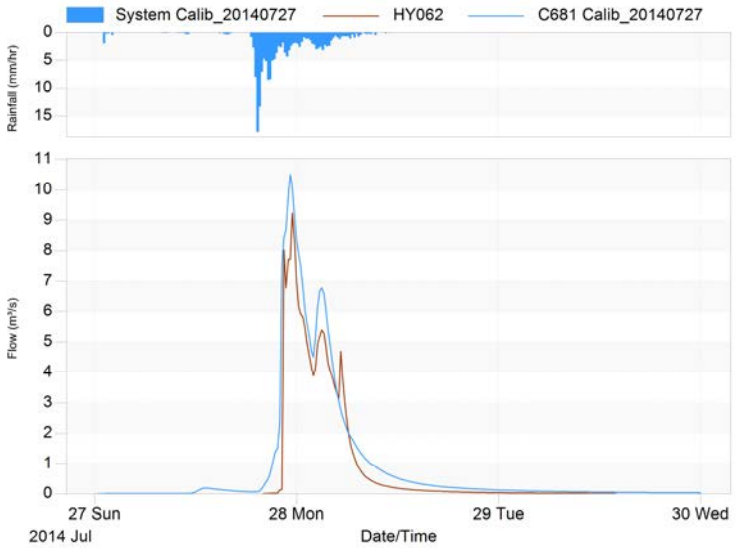

System Calib_20151028
HY092
C429 Calib_20151028
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
16
14
12
10
8
6
4
2
0
28 Wed
29 Thu
30 Fri
31 Sat
2015 Oct
Date/Time

HY062

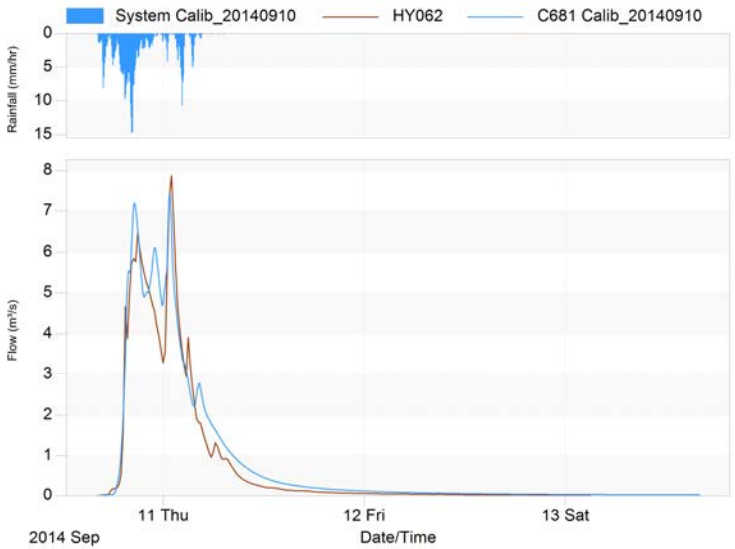

System Calib_20130708
C681 Calib_20130708
HY062
Rainfall (mm/hr)
0
20
40
Flow (m³/s)
80
70
60
50
40
30
20
10
0
9 Tue
10 Wed
11 Thu
2013 Jul
Date/Time

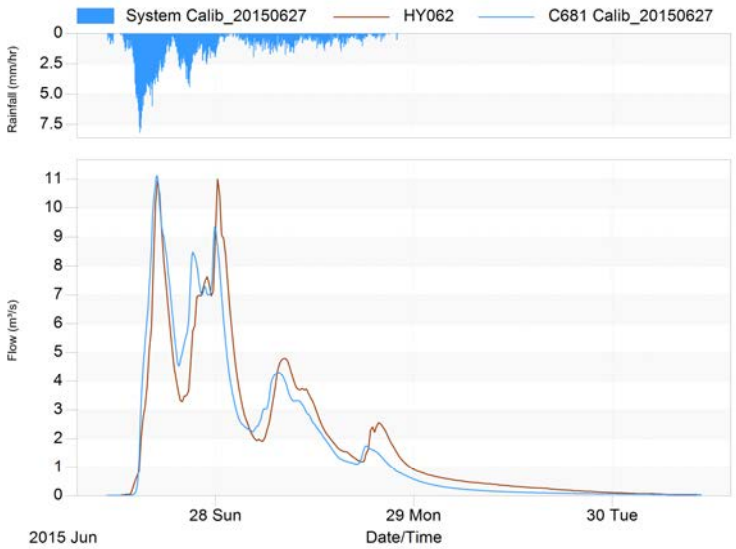

System Calib_20130731
HY062
C681 Calib_20130731
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
16
14
12
10
8
6
4
2
0
1 Thu
2 Fri
3 Sat
2013 Aug
Date/Time

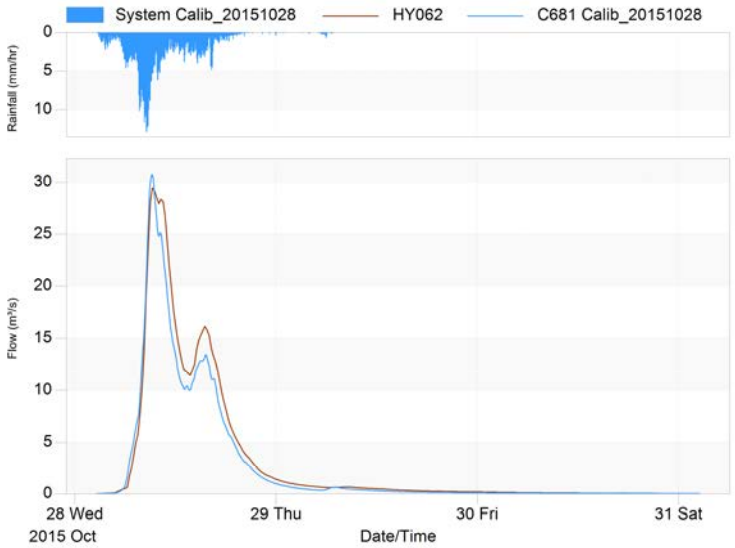

System Calib_20130920
HY062
C681 Calib_20130920
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
12
11
10
9
8
7
6
5
4
3
2
1
0
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
2013 Sep
Date/Time


System Calib_20140727
HY062
C681 Calib_20140727
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
11
10
9
8
7
6
5
4
3
2
1
0
27 Sun
28 Mon
29 Tue
30 Wed
2014 Jul
Date/Time

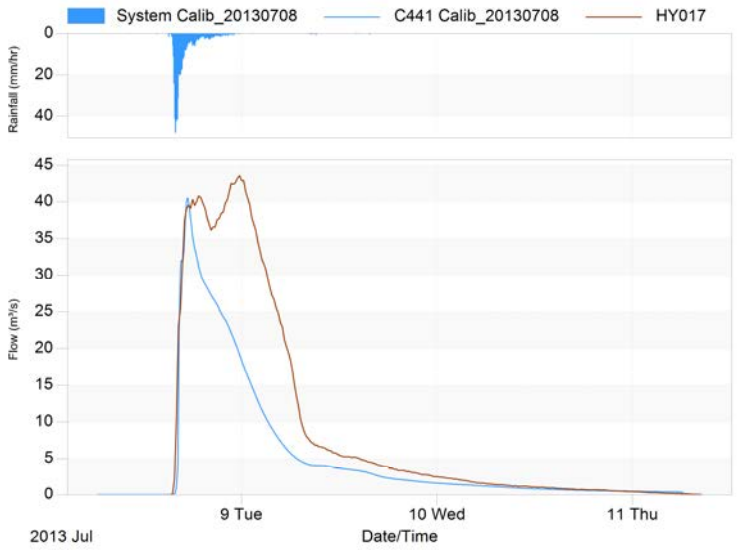
HY062

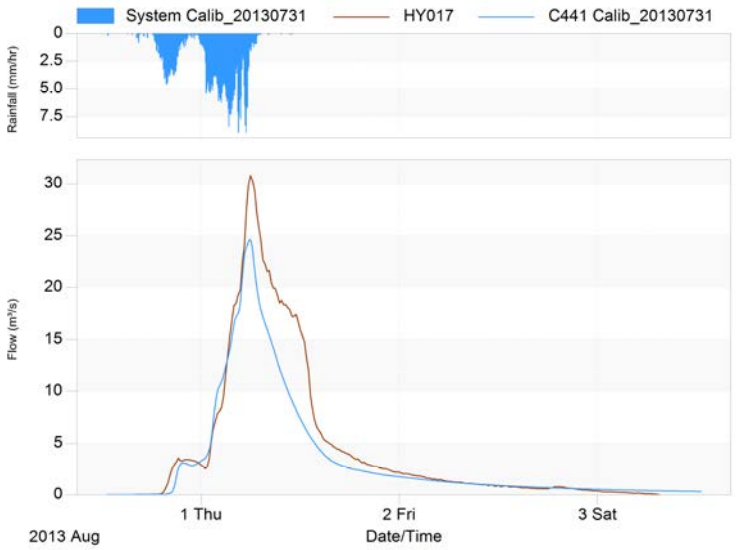

System Calib_20140910
HY062
C681 Calib_20140910
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
0
1
2
3
4
5
6
7
8
11 Thu
12 Fri
13 Sat
2014 Sep
Date/Time

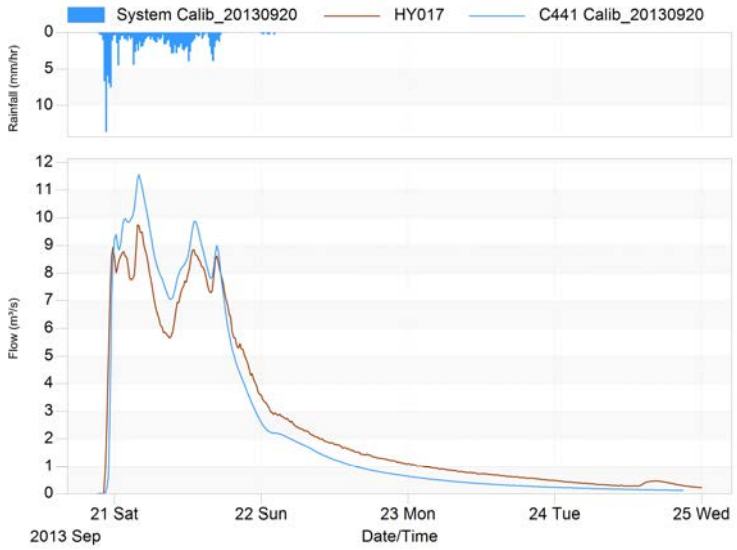

System Calib_20150627
HY062
C681 Calib_20150627
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
0
1
2
3
4
5
6
7
8
9
10
11
28 Sun
29 Mon
30 Tue
2015 Jun
Date/Time

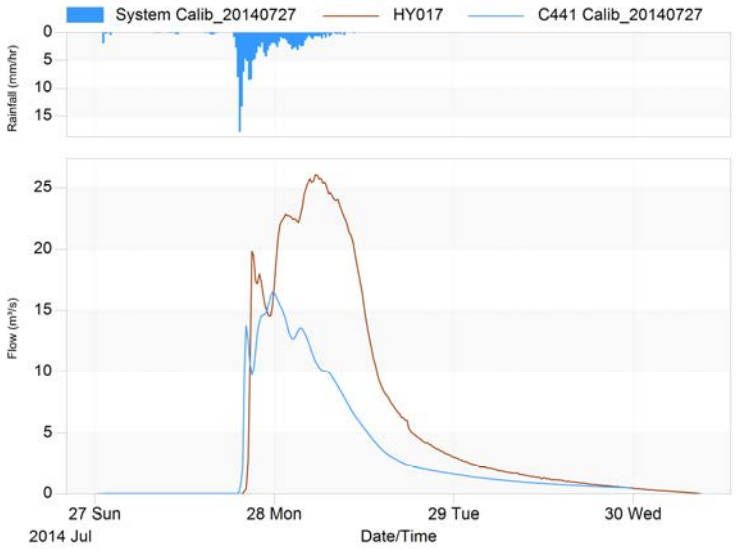

System Calib_20151028
HY062
C681 Calib_20151028
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
0
5
10
15
20
25
30
28 Wed
29 Thu
30 Fri
31 Sat
2015 Oct
Date/Time

HY017

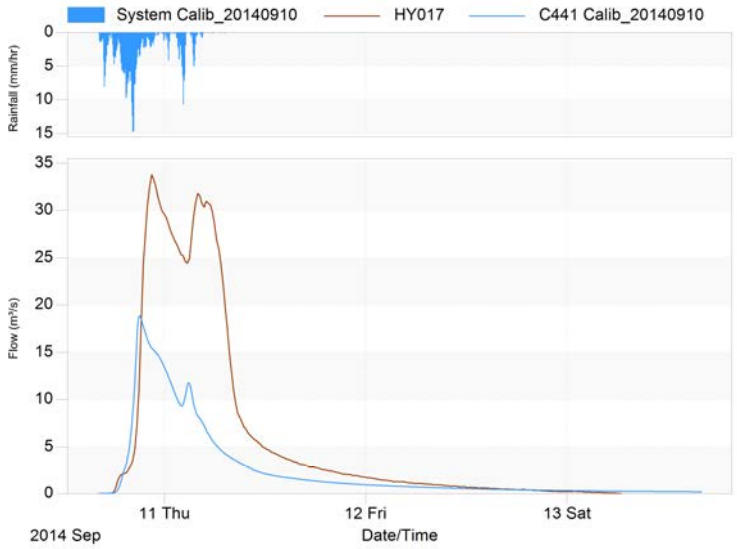

System Calib_20130708
C441 Calib_20130708
HY017
Rainfall (mm/hr)
0
20
40
Flow (m³/s)
45
40
35
30
25
20
15
10
5
0
9 Tue
10 Wed
11 Thu
2013 Jul
Date/Time


System Calib_20130731
HY017
C441 Calib_20130731
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
30
25
20
15
10
5
0
1 Thu
2 Fri
3 Sat
2013 Aug
Date/Time

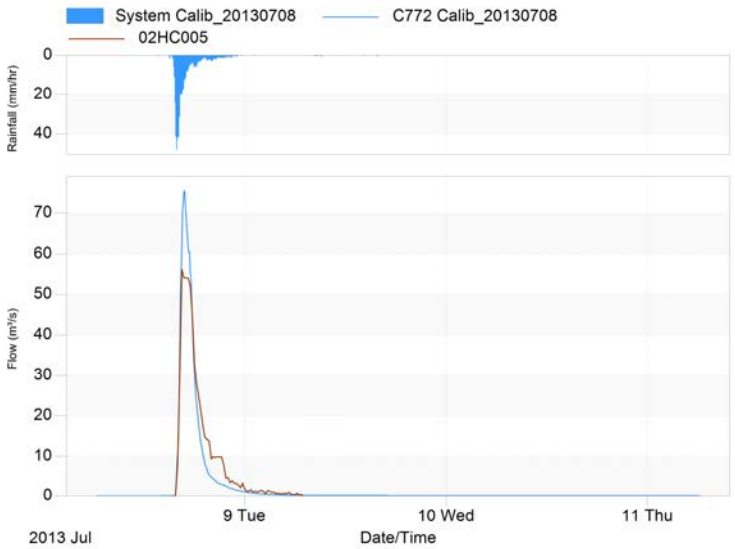

System Calib_20130920
HY017
C441 Calib_20130920
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
12
11
10
9
8
7
6
5
4
3
2
1
0
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
2013 Sep
Date/Time

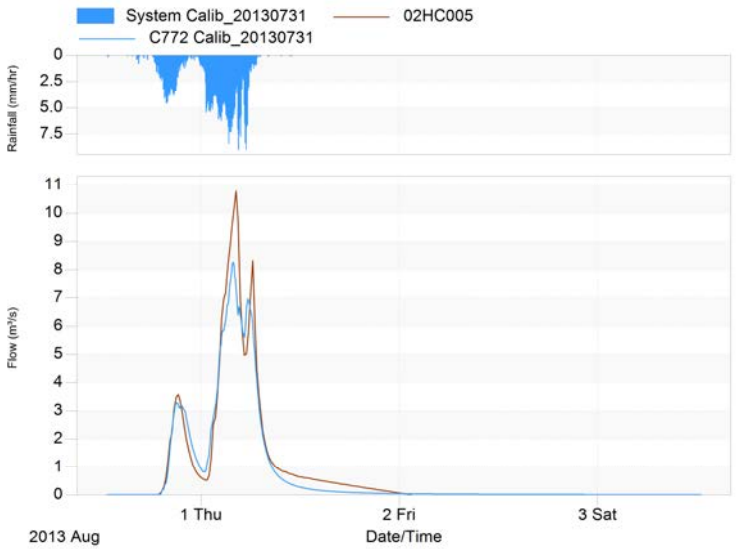

System Calib_20140727
HY017
C441 Calib_20140727
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
25
20
15
10
5
0
27 Sun
28 Mon
29 Tue
30 Wed
2014 Jul
Date/Time

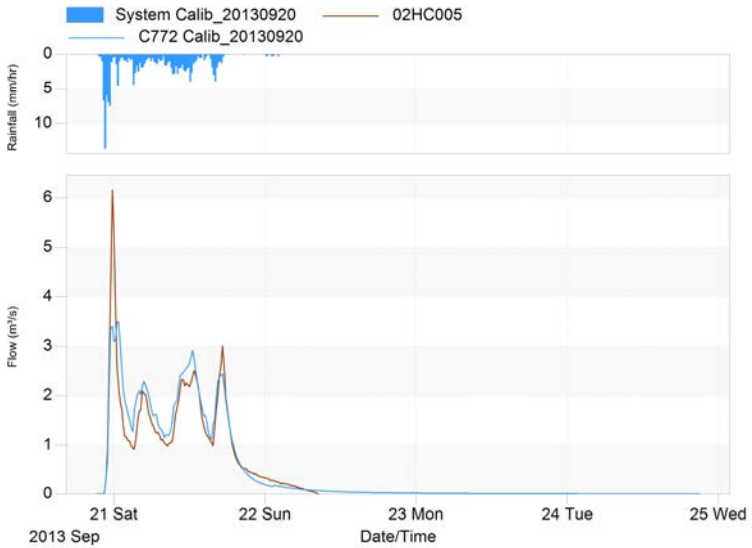
HY017

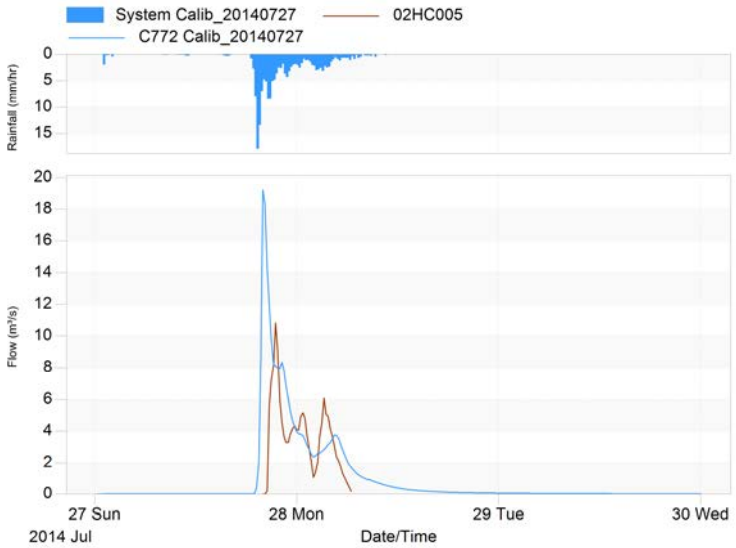

System Calib_20140910
HY017
C441 Calib_20140910
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
35
30
25
20
15
10
5
0
11 Thu
12 Fri
13 Sat
2014 Sep
Date/Time

02HC005

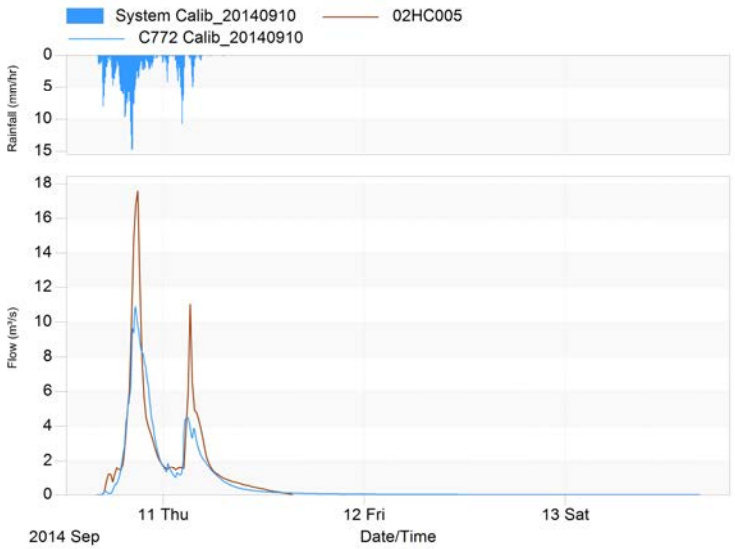

System Calib_20130708
C772 Calib_20130708
02HC005
Rainfall (mm/hr)
0
20
40
Flow (m³/s)
70
60
50
40
30
20
10
0
9 Tue
10 Wed
11 Thu
2013 Jul
Date/Time

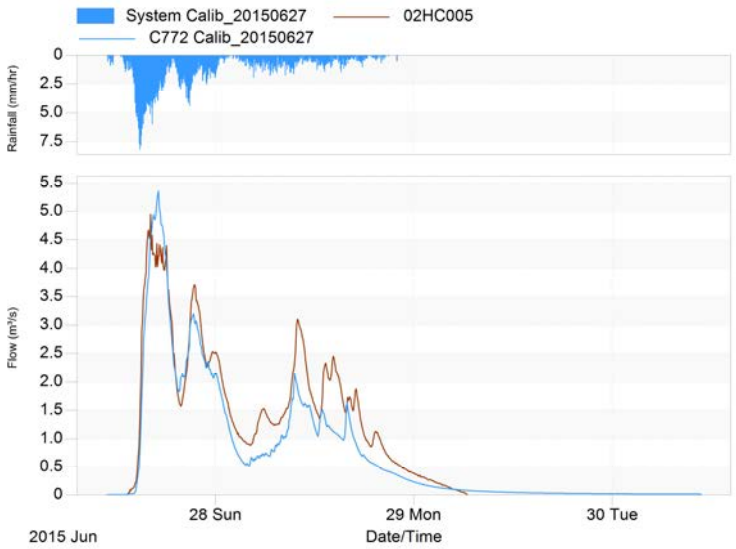

System Calib_20130731
02HC005
C772 Calib_20130731
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
11
10
9
8
7
6
5
4
3
2
1
0
1 Thu
2 Fri
3 Sat
2013 Aug
Date/Time

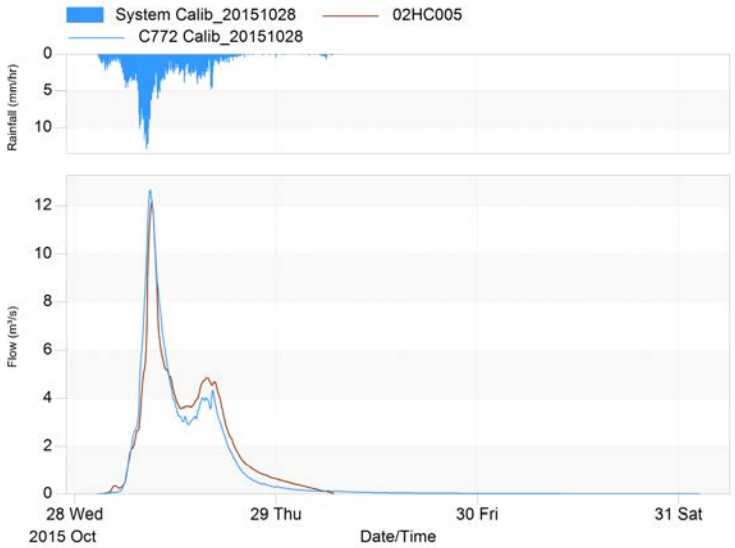

System Calib_20130920
02HC005
C772 Calib_20130920
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
6
5
4
3
2
1
0
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
2013 Sep
Date/Time


System Calib_20140727
02HC005
C772 Calib_20140727
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
20
18
16
14
12
10
8
6
4
2
0
27 Sun
28 Mon
29 Tue
30 Wed
2014 Jul
Date/Time

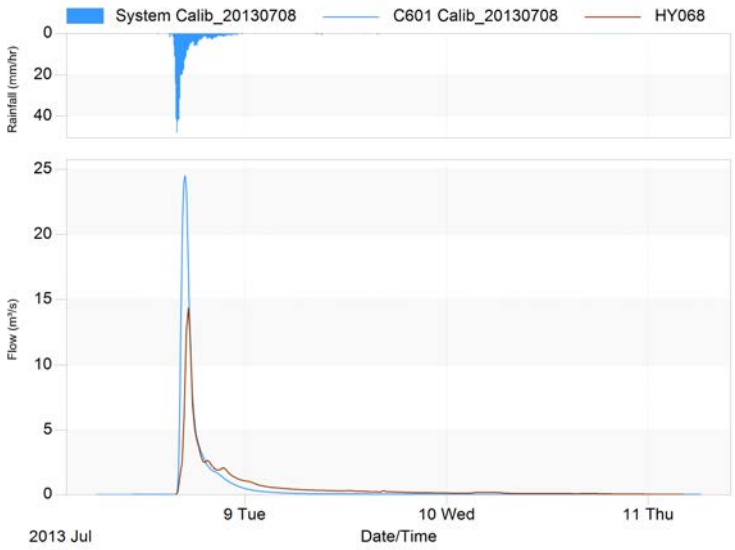
02HC005

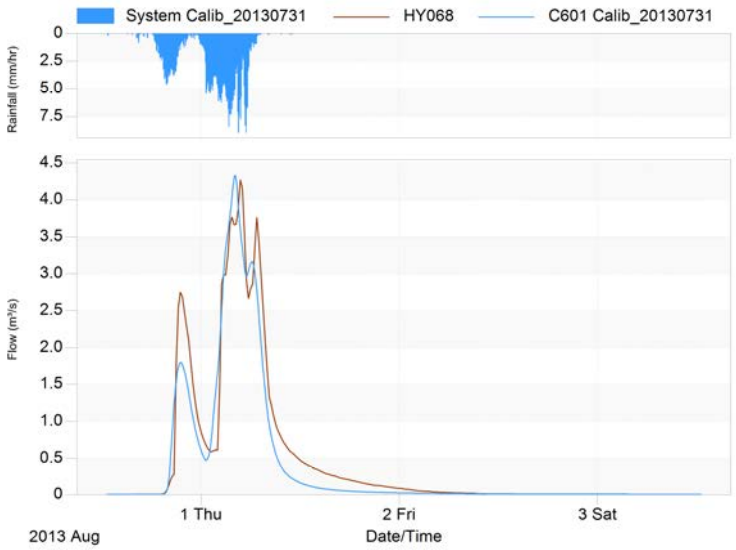

System Calib_20140910
02HC005
C772 Calib_20140910
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
18
16
14
12
10
8
6
4
2
0
11 Thu
12 Fri
13 Sat
2014 Sep
Date/Time

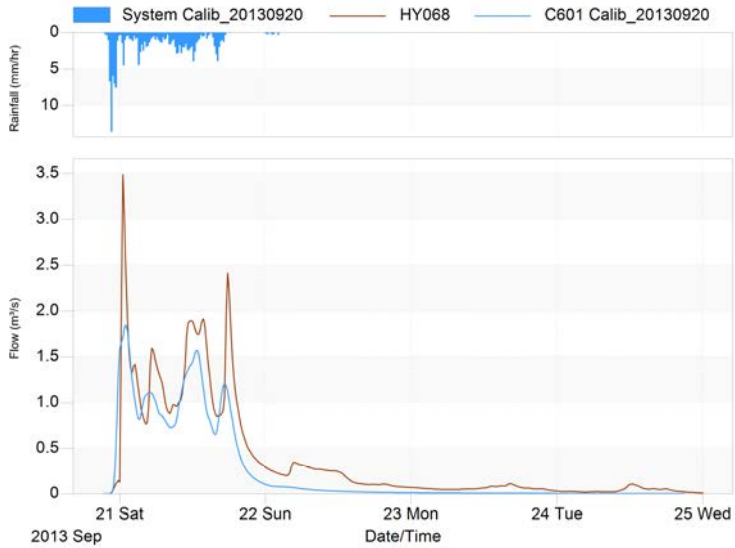

System Calib_20150627
02HC005
C772 Calib_20150627
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
28 Sun
29 Mon
30 Tue
2015 Jun
Date/Time

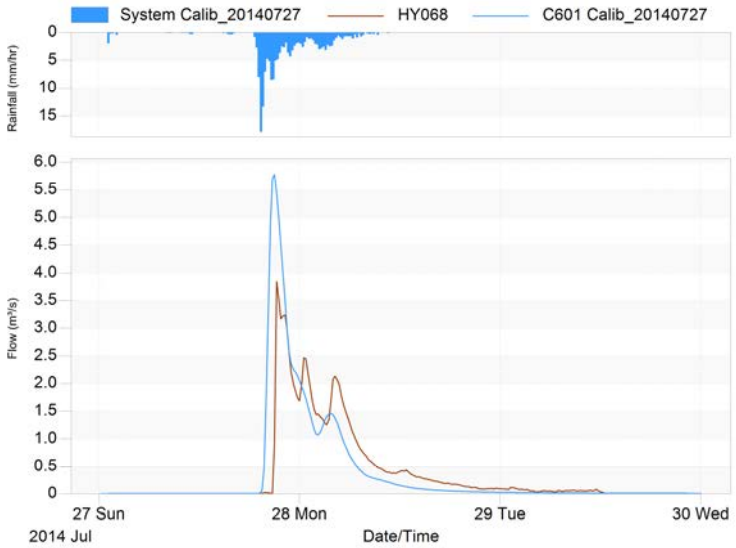

System Calib_20151028
02HC005
C772 Calib_20151028
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
12
10
8
6
4
2
0
28 Wed
29 Thu
30 Fri
31 Sat
2015 Oct
Date/Time

HY068

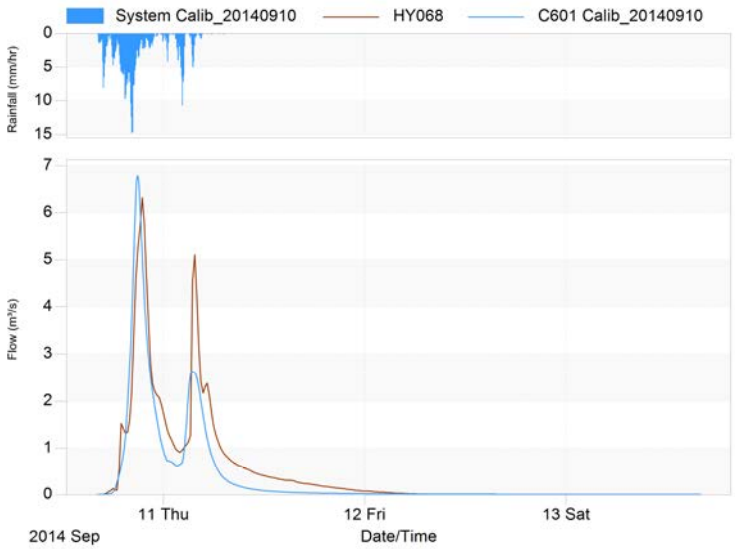

System Calib_20130708
C601 Calib_20130708
HY068
Rainfall (mm/hr)
0
20
40
Flow (m³/s)
25
20
15
10
5
0
9 Tue
10 Wed
11 Thu
2013 Jul
Date/Time

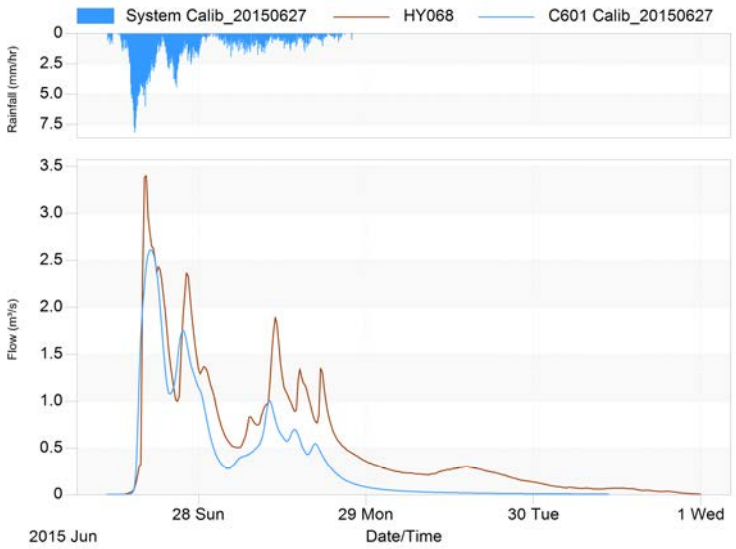

System Calib_20130731
HY068
C601 Calib_20130731
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1 Thu
2 Fri
3 Sat
2013 Aug
Date/Time

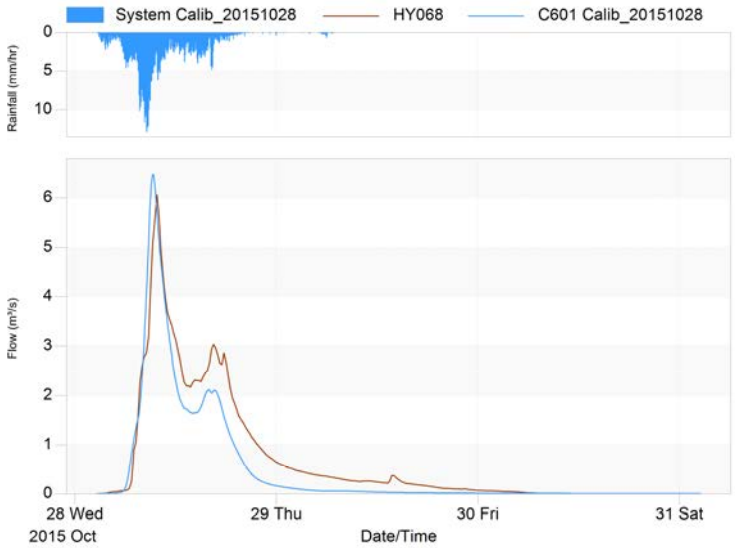

System Calib_20130920
HY068
C601 Calib_20130920
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
2013 Sep
Date/Time


System Calib_20140727
HY068
C601 Calib_20140727
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
27 Sun
28 Mon
29 Tue
30 Wed
2014 Jul
Date/Time

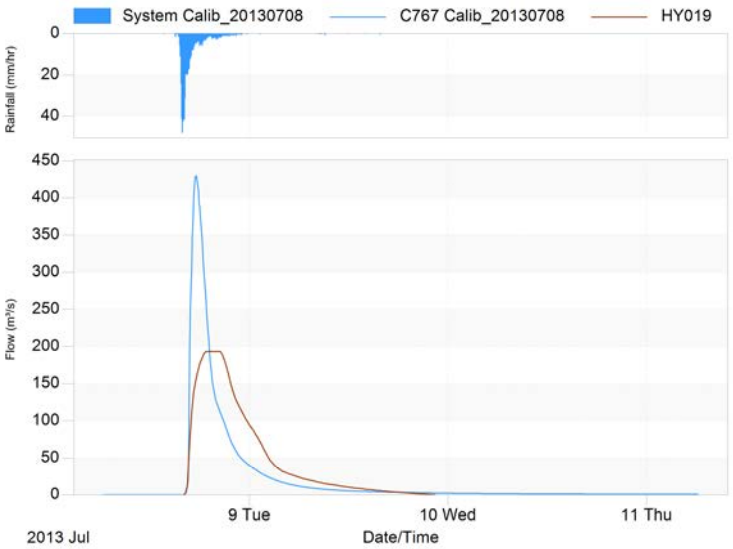
HY068

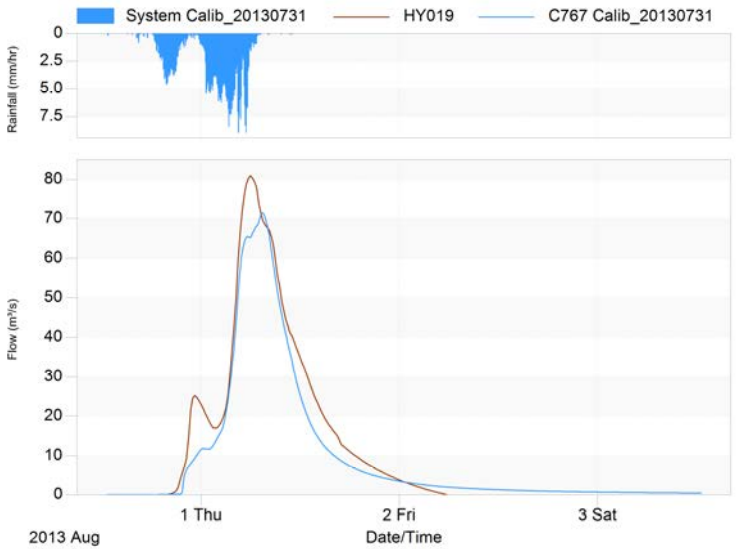

System Calib_20140910
HY068
C601 Calib_20140910
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
7
6
5
4
3
2
1
0
11 Thu
12 Fri
13 Sat
2014 Sep
Date/Time

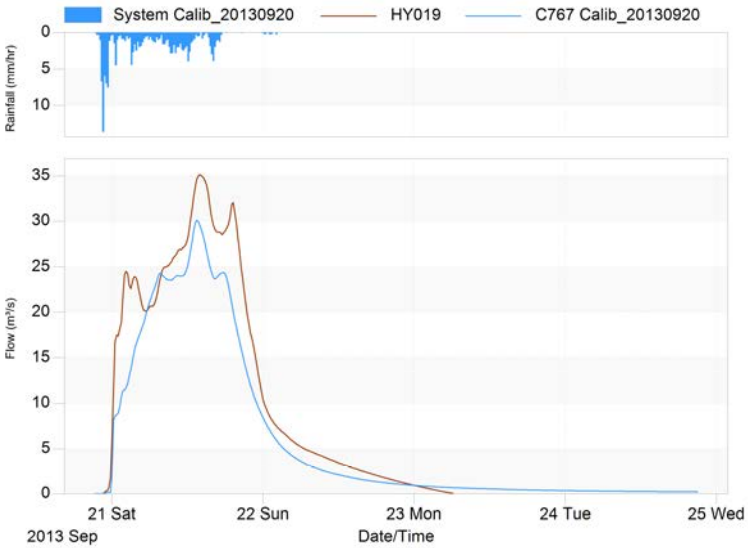

System Calib_20150627
HY068
C601 Calib_20150627
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
28 Sun
29 Mon
30 Tue
1 Wed
2015 Jun
Date/Time

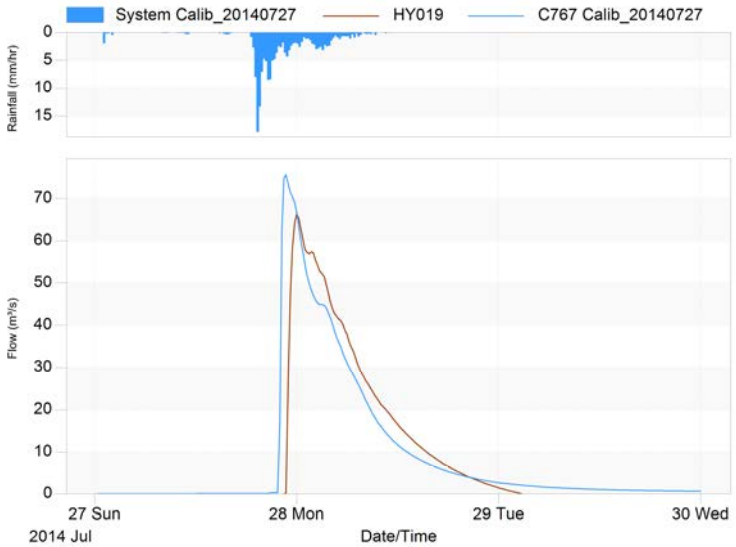

System Calib_20151028
HY068
C601 Calib_20151028
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
6
5
4
3
2
1
0
28 Wed
29 Thu
30 Fri
31 Sat
2015 Oct
Date/Time

HY019


System Calib_20130708
C767 Calib_20130708
HY019
Rainfall (mm/hr)
0
20
40
Flow (m³/s)
450
400
350
300
250
200
150
100
50
0
9 Tue
10 Wed
11 Thu
2013 Jul
Date/Time

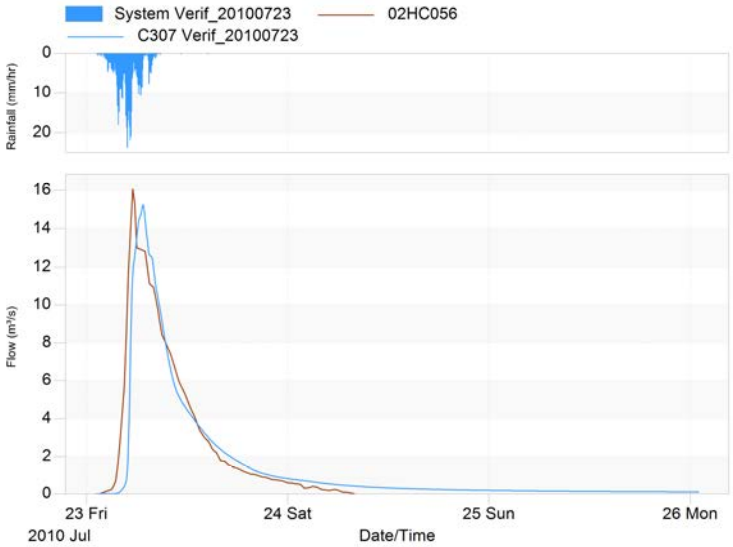

System Calib_20130731
HY019
C767 Calib_20130731
Rainfall (mm/hr)
0
2.5
5.0
7.5
Flow (m³/s)
80
70
60
50
40
30
20
10
0
1 Thu
2 Fri
3 Sat
2013 Aug
Date/Time

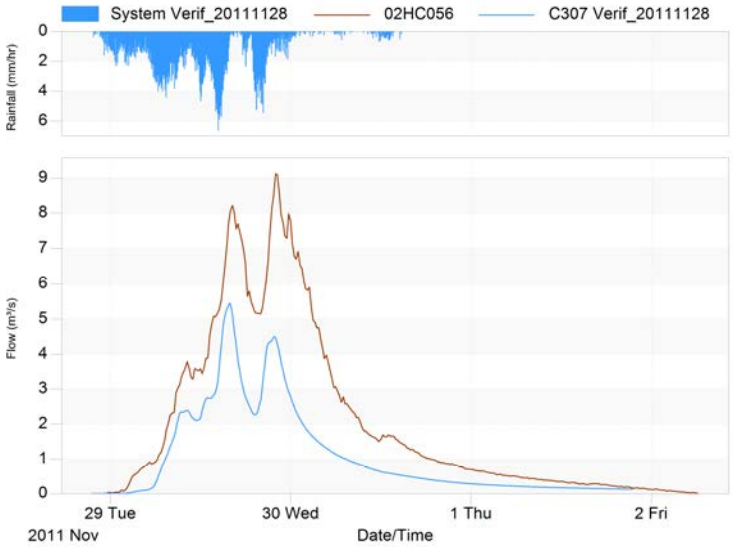

System Calib_20130920
HY019
C767 Calib_20130920
Rainfall (mm/hr)
0
5
10
Flow (m³/s)
35
30
25
20
15
10
5
0
21 Sat
22 Sun
23 Mon
24 Tue
25 Wed
2013 Sep
Date/Time

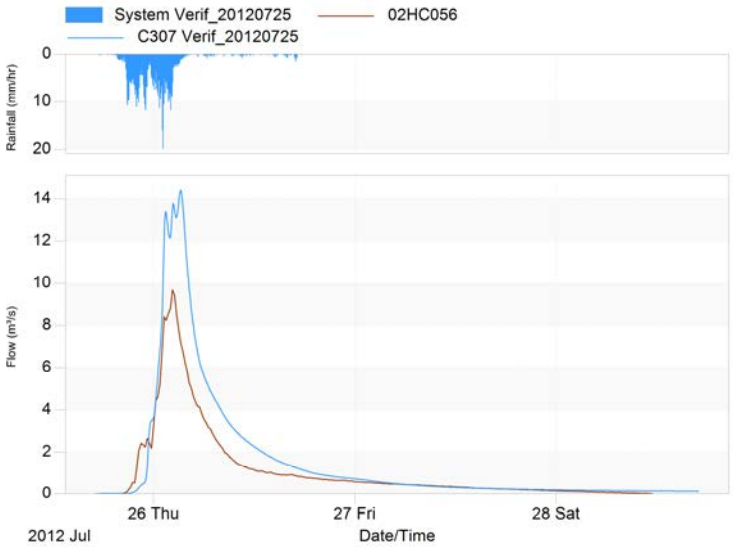

System Calib_20140727
HY019
C767 Calib_20140727
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
70
60
50
40
30
20
10
0
27 Sun
28 Mon
29 Tue
30 Wed
2014 Jul
Date/Time

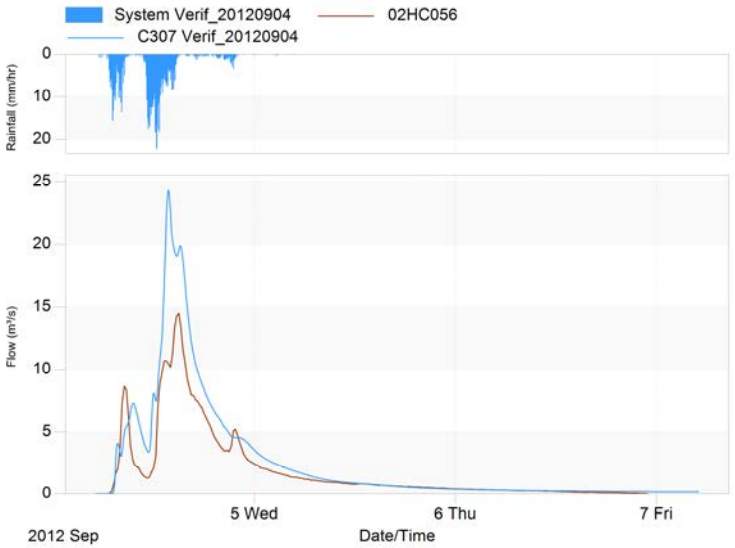
Appendix F: Verification Plots

02HC056

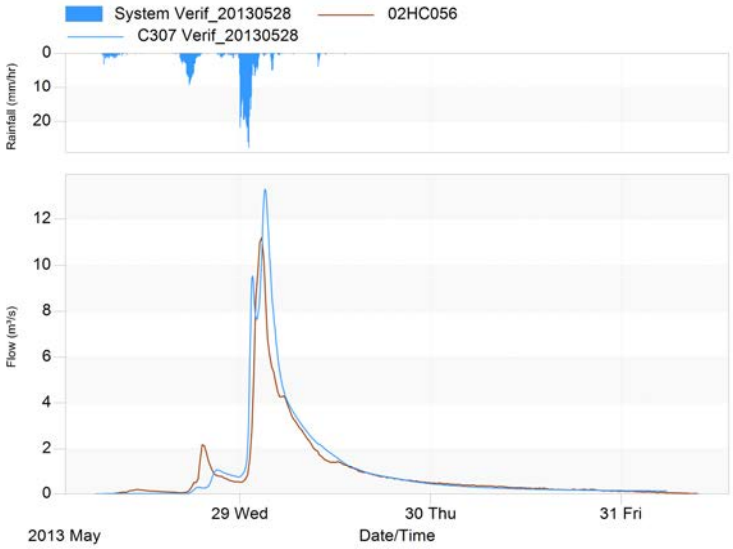

System Verif_20100723
02HC056
C307 Verif_20100723
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
16
14
12
10
8
6
4
2
0
23 Fri
24 Sat
25 Sun
26 Mon
2010 Jul
Date/Time

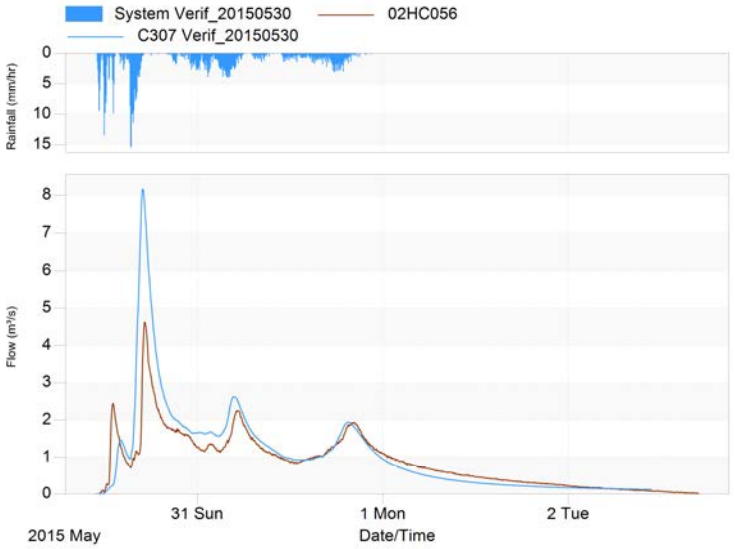

System Verif_20111128
02HC056
C307 Verif_20111128
Rainfall (mm/hr)
0
2
4
6
Flow (m³/s)
9
8
7
6
5
4
3
2
1
0
29 Tue
30 Wed
1 Thu
2 Fri
2011 Nov
Date/Time


System Verif_20120725
02HC056
C307 Verif_20120725
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
14
12
10
8
6
4
2
0
26 Thu
27 Fri
28 Sat
2012 Jul
Date/Time

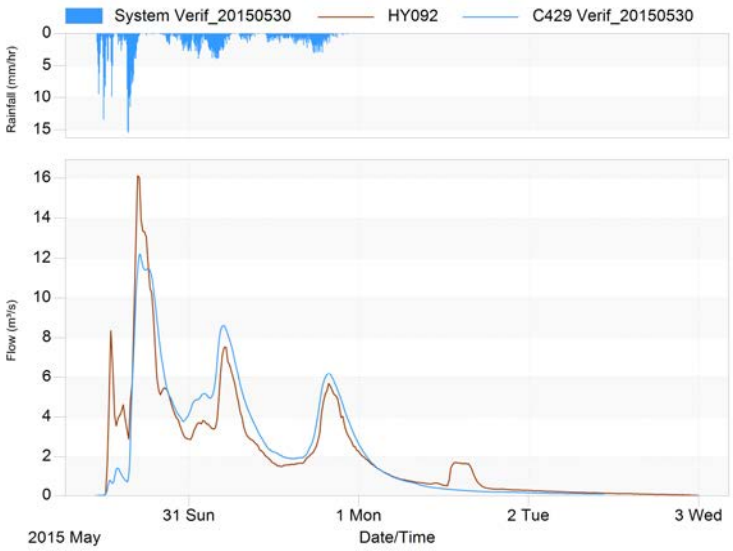

System Verif_20120904
02HC056
C307 Verif_20120904
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
25
20
15
10
5
0
5 Wed
6 Thu
7 Fri
2012 Sep
Date/Time

02HC056

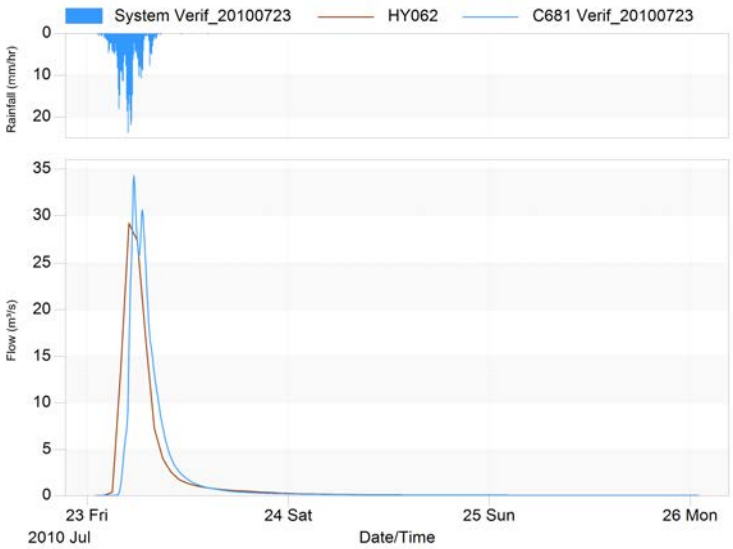

System Verif_20130528
02HC056
C307 Verif_20130528
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
12
10
8
6
4
2
0
29 Wed
30 Thu
31 Fri
2013 May
Date/Time

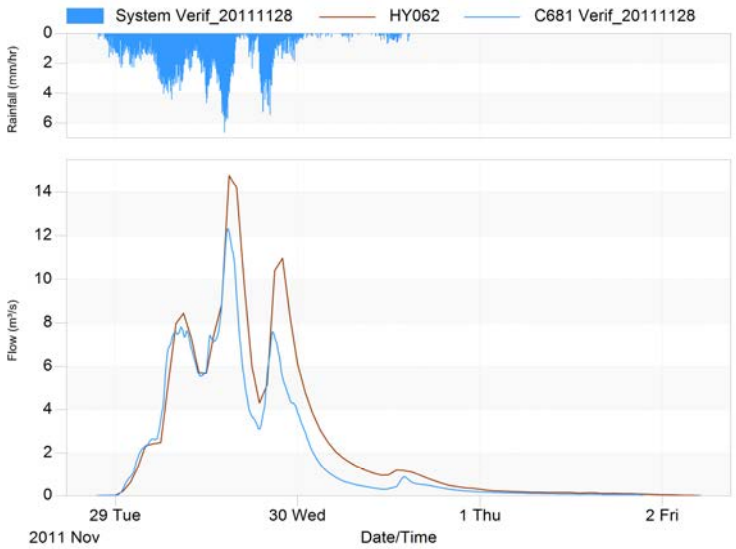

System Verif_20150530
02HC056
C307 Verif_20150530
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
8
7
6
5
4
3
2
1
0
31 Sun
1 Mon
2 Tue
2015 May
Date/Time

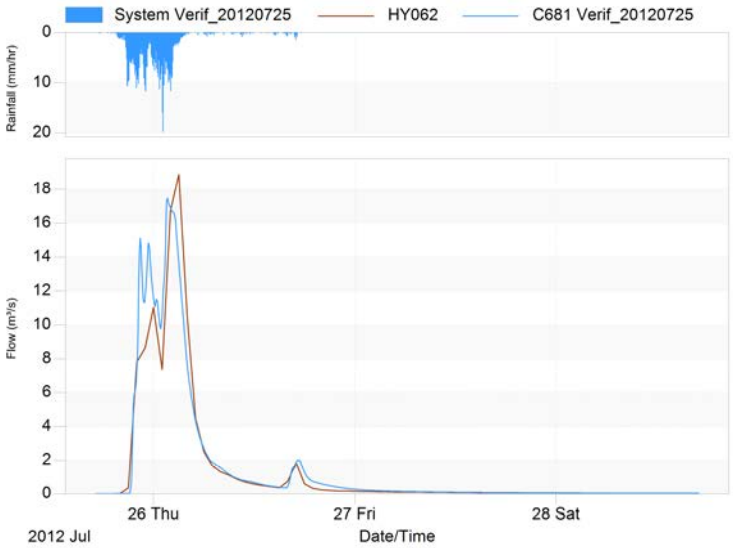
HY092

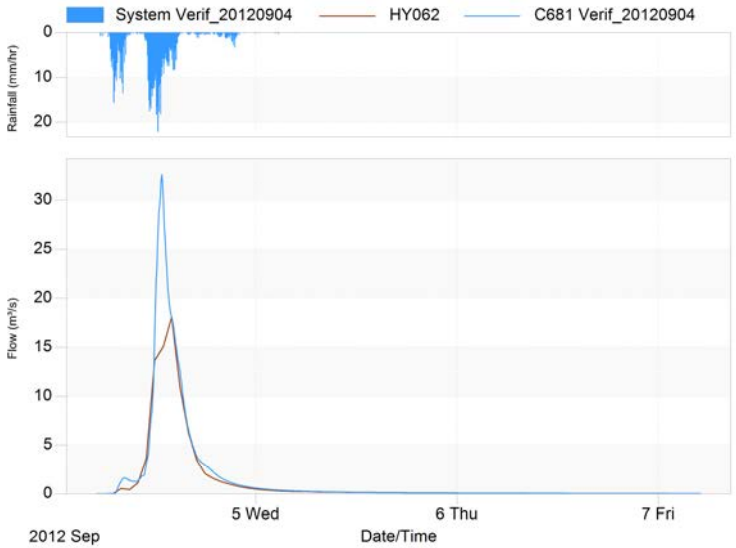

System Verif_20150530
HY092
C429 Verif_20150530
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
16
14
12
10
8
6
4
2
0
31 Sun
1 Mon
2 Tue
3 Wed
2015 May
Date/Time

HY062

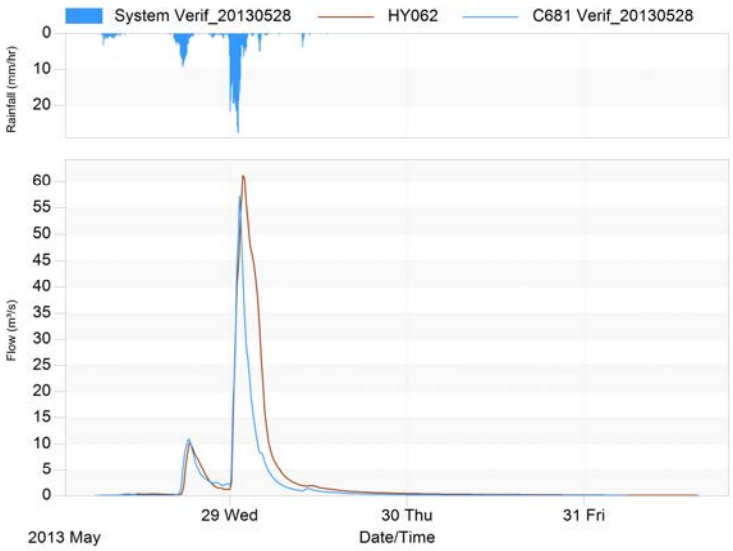

System Verif_20100723
HY062
C681 Verif_20100723
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
35
30
25
20
15
10
5
0
23 Fri
24 Sat
25 Sun
26 Mon
2010 Jul
Date/Time

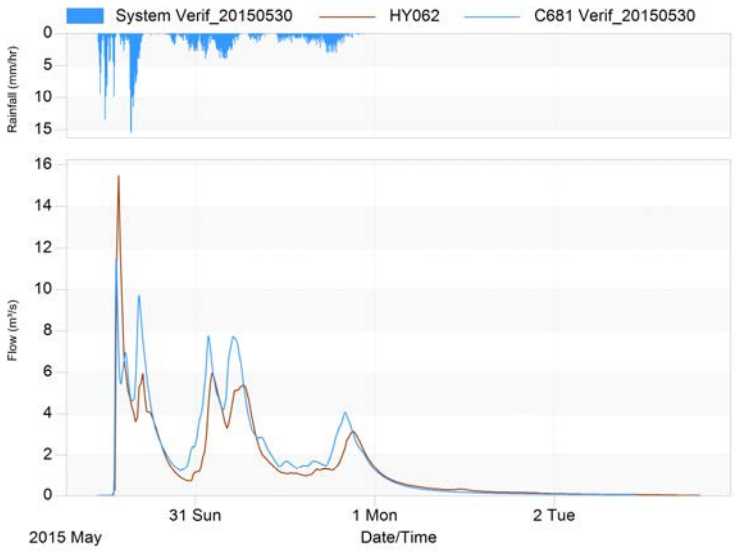

System Verif_20111128
HY062
C681 Verif_20111128
Rainfall (mm/hr)
0
2
4
6
Flow (m³/s)
14
12
10
8
6
4
2
0
29 Tue
30 Wed
1 Thu
2 Fri
2011 Nov
Date/Time

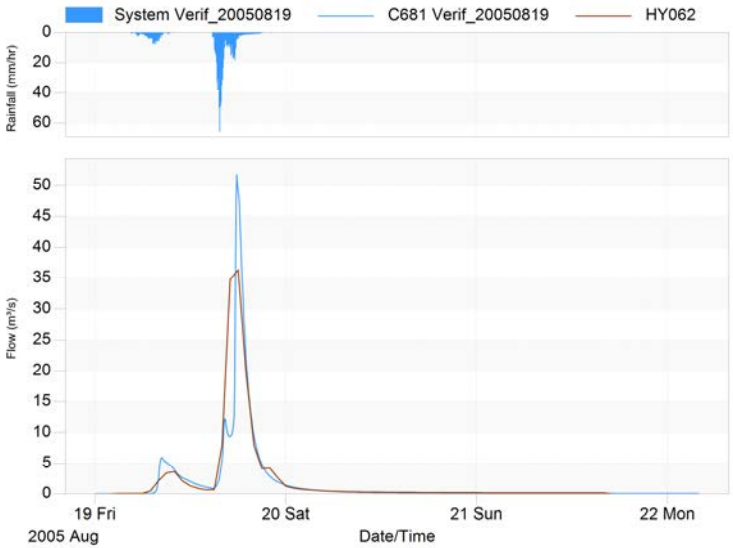

System Verif_20120725
HY062
C681 Verif_20120725
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
18
16
14
12
10
8
6
4
2
0
26 Thu
27 Fri
28 Sat
2012 Jul
Date/Time


System Verif_20120904
HY062
C681 Verif_20120904
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
30
25
20
15
10
5
0
5 Wed
6 Thu
7 Fri
2012 Sep
Date/Time

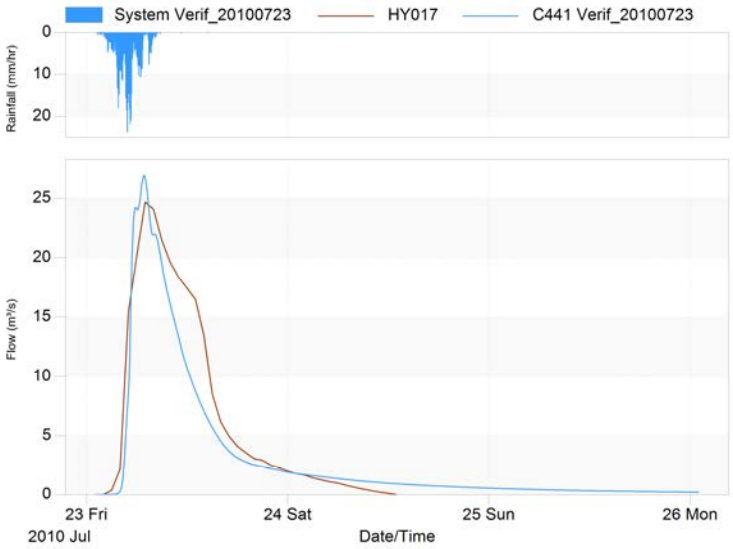
HY062

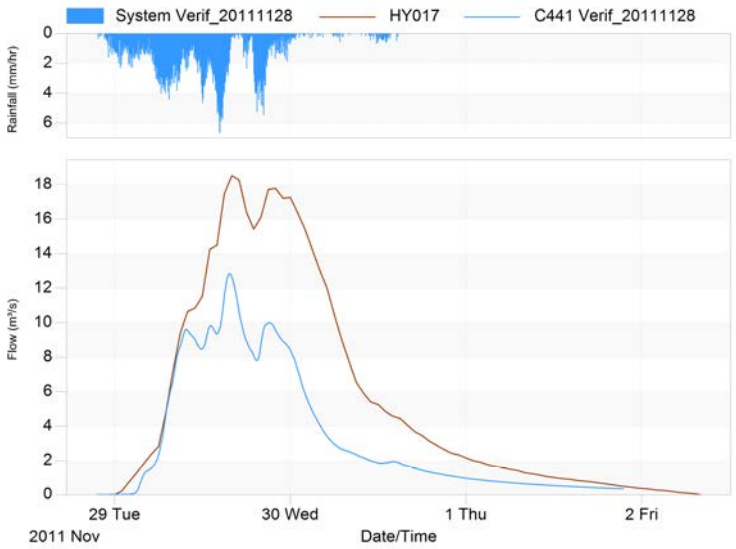

System Verif_20130528
HY062
C681 Verif_20130528
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
60
55
50
45
40
35
30
25
20
15
10
5
0
29 Wed
30 Thu
31 Fri
2013 May
Date/Time

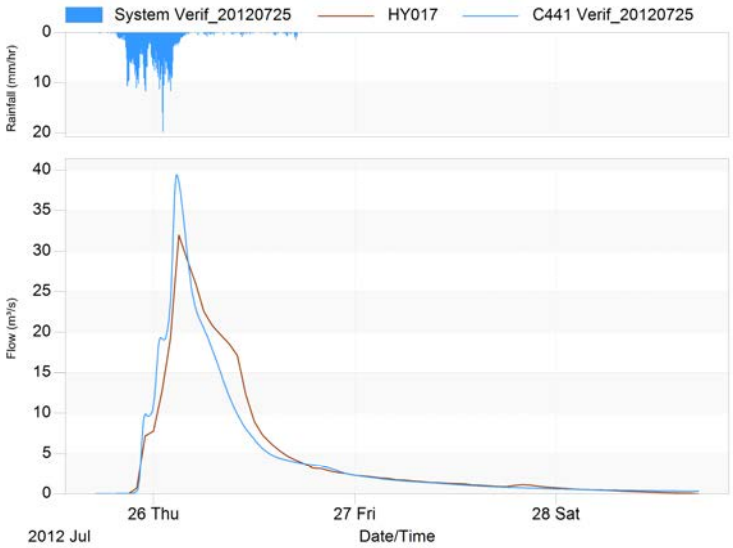

System Verif_20150530
HY062
C681 Verif_20150530
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
16
14
12
10
8
6
4
2
0
31 Sun
1 Mon
2 Tue
2015 May
Date/Time

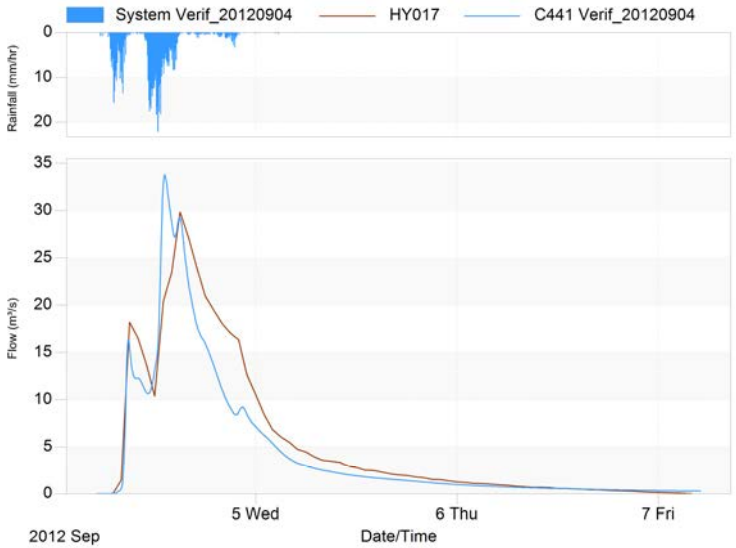

System Verif_20050819
C681 Verif_20050819
HY062
Rainfall (mm/hr)
0
20
40
60
Flow (m³/s)
50
45
40
35
30
25
20
15
10
5
0
19 Fri
20 Sat
21 Sun
22 Mon
2005 Aug
Date/Time

HY017

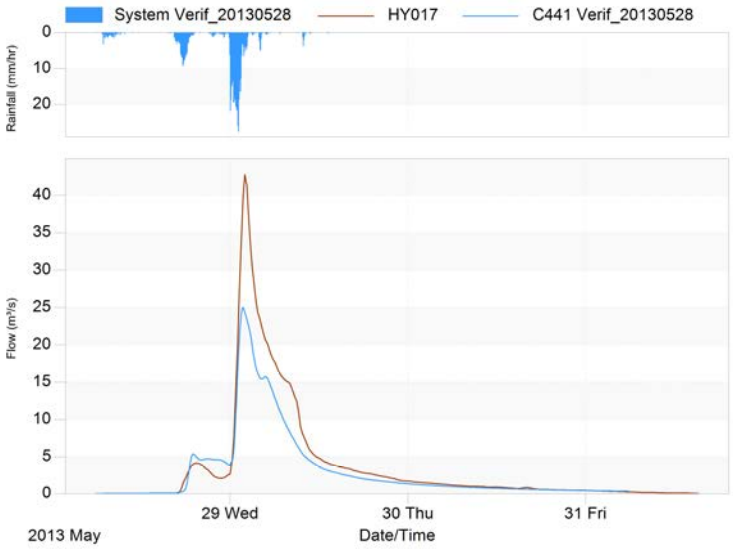

System Verif_20100723
HY017
C441 Verif_20100723
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
25
20
15
10
5
0
23 Fri
24 Sat
25 Sun
26 Mon
2010 Jul
Date/Time


System Verif_20111128
HY017
C441 Verif_20111128
Rainfall (mm/hr)
0
2
4
6
Flow (m³/s)
18
16
14
12
10
8
6
4
2
0
29 Tue
30 Wed
1 Thu
2 Fri
2011 Nov
Date/Time

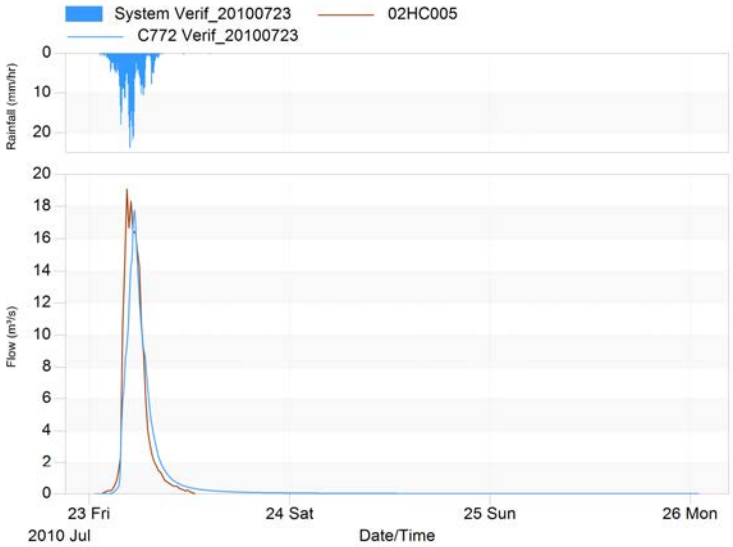

System Verif_20120725
HY017
C441 Verif_20120725
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
40
35
30
25
20
15
10
5
0
26 Thu
27 Fri
28 Sat
2012 Jul
Date/Time

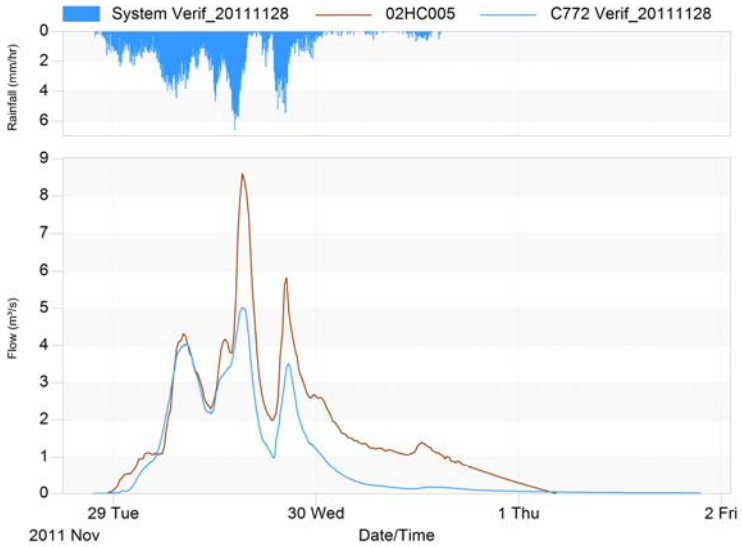

System Verif_20120904
HY017
C441 Verif_20120904
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
35
30
25
20
15
10
5
0
5 Wed
6 Thu
7 Fri
2012 Sep
Date/Time

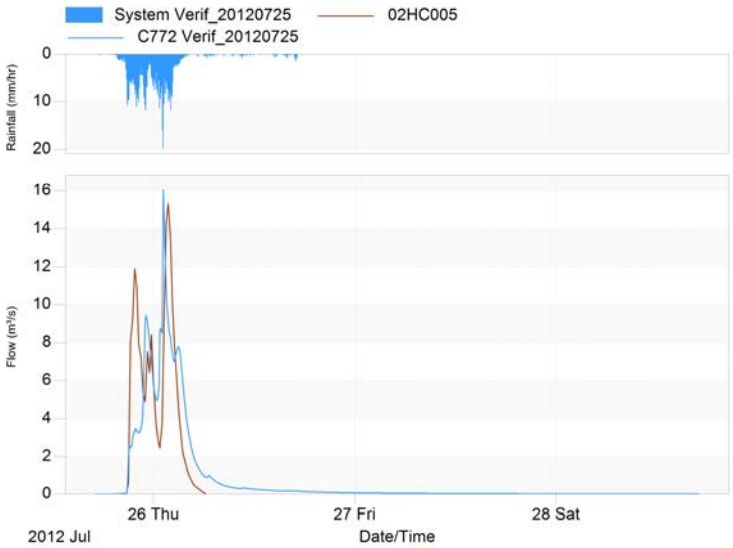
HY017

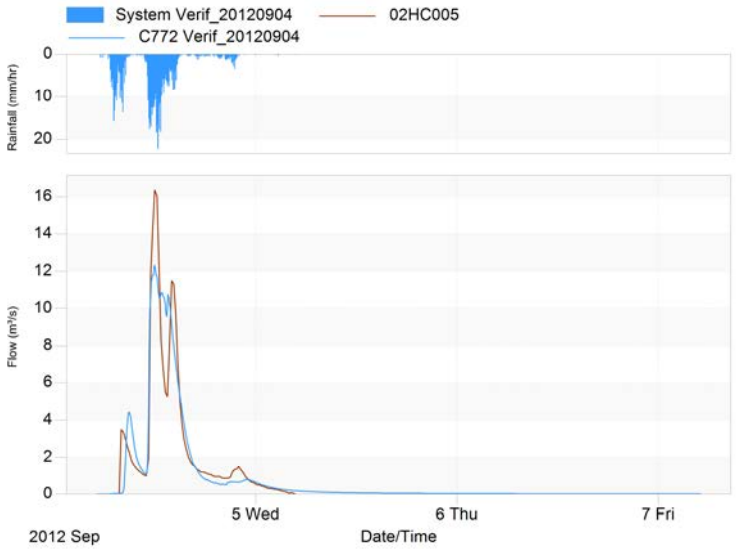

System Verif_20130528
HY017
C441 Verif_20130528
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
40
35
30
25
20
15
10
5
0
29 Wed
30 Thu
31 Fri
2013 May
Date/Time

02HC005

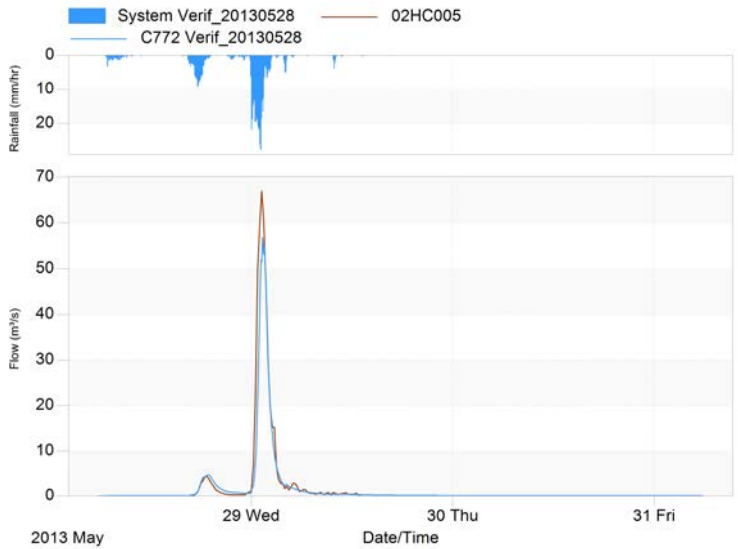

System Verif_20100723
02HC005
C772 Verif_20100723
Rainfall (mm/hr)
Flow (m³/s)
23 Fri
24 Sat
25 Sun
26 Mon
2010 Jul
Date/Time

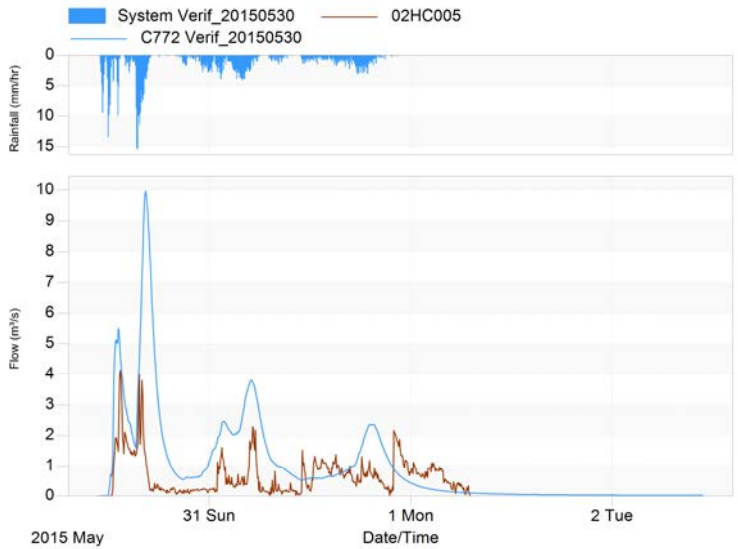

System Verif_20111128
02HC005
C772 Verif_20111128
Rainfall (mm/hr)
Flow (m³/s)
29 Tue
30 Wed
1 Thu
2 Fri
2011 Nov
Date/Time

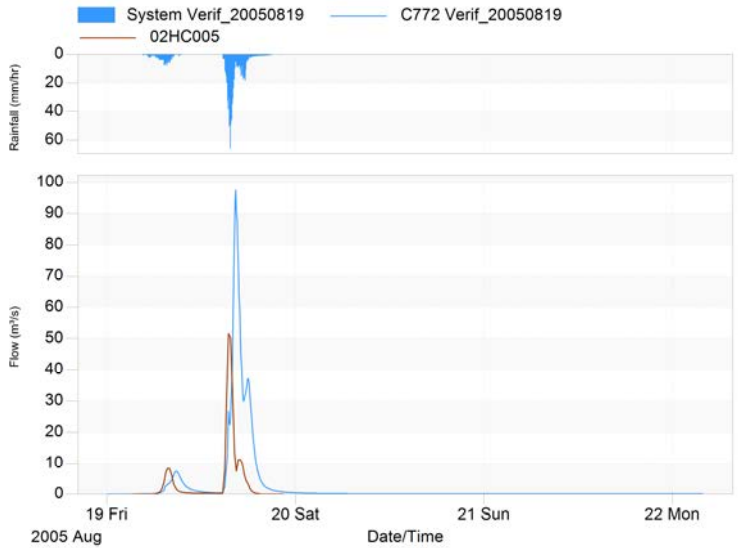

System Verif_20120725
02HC005
C772 Verif_20120725
Rainfall (mm/hr)
Flow (m³/s)
26 Thu
27 Fri
28 Sat
2012 Jul
Date/Time


System Verif_20120904
02HC005
C772 Verif_20120904
Rainfall (mm/hr)
Flow (m³/s)
5 Wed
6 Thu
7 Fri
2012 Sep
Date/Time

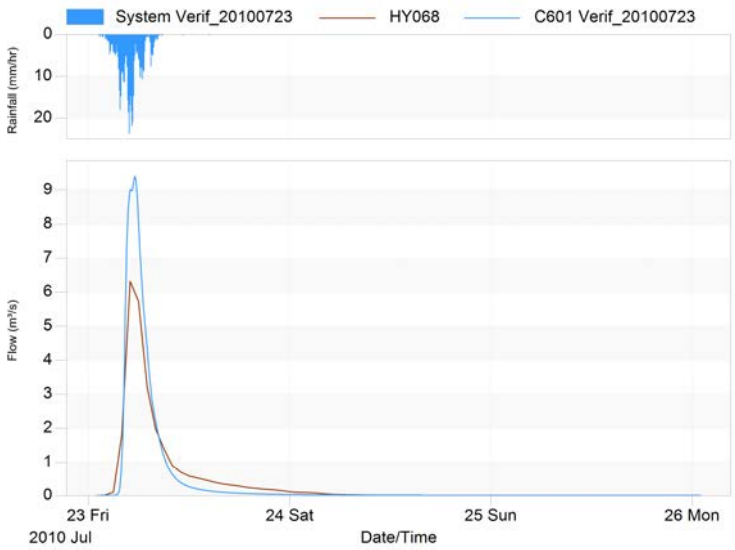
02HC005

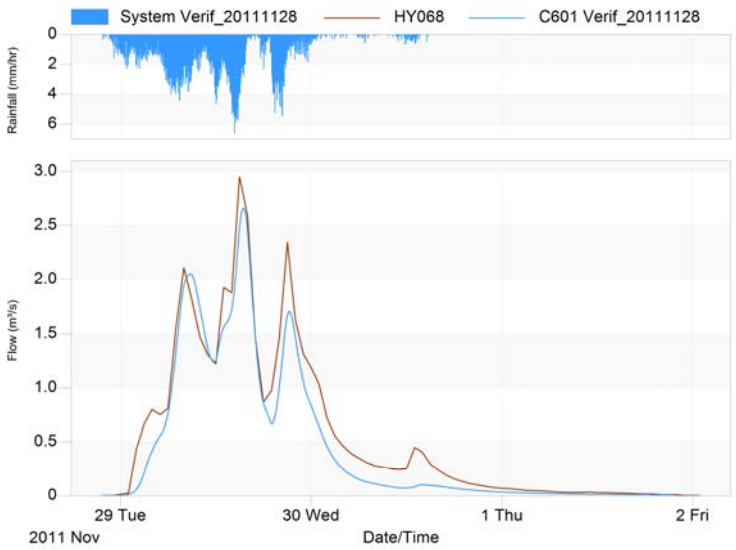

System Verif_20130528
02HC005
C772 Verif_20130528
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
70
60
50
40
30
20
10
0
29 Wed
30 Thu
31 Fri
2013 May
Date/Time

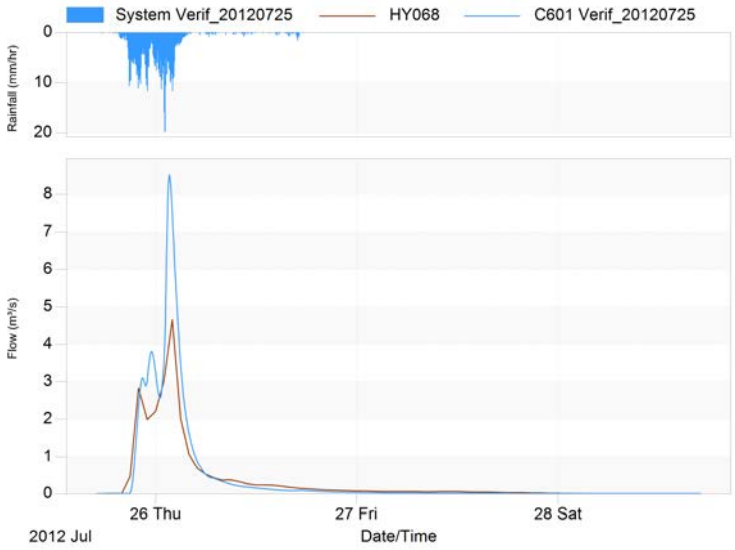

System Verif_20150530
02HC005
C772 Verif_20150530
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
10
9
8
7
6
5
4
3
2
1
0
31 Sun
1 Mon
2 Tue
2015 May
Date/Time

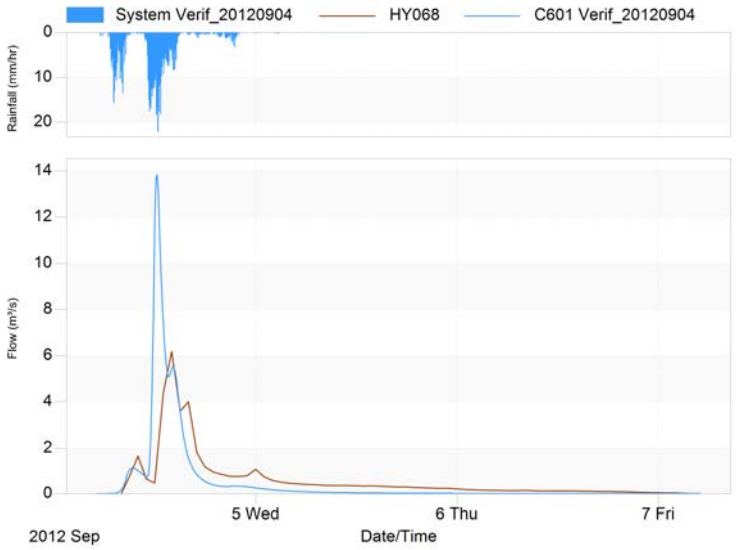

System Verif_20050819
C772 Verif_20050819
02HC005
Rainfall (mm/hr)
0
20
40
60
Flow (m³/s)
100
90
80
70
60
50
40
30
20
10
0
19 Fri
20 Sat
21 Sun
22 Mon
2005 Aug
Date/Time

HY068

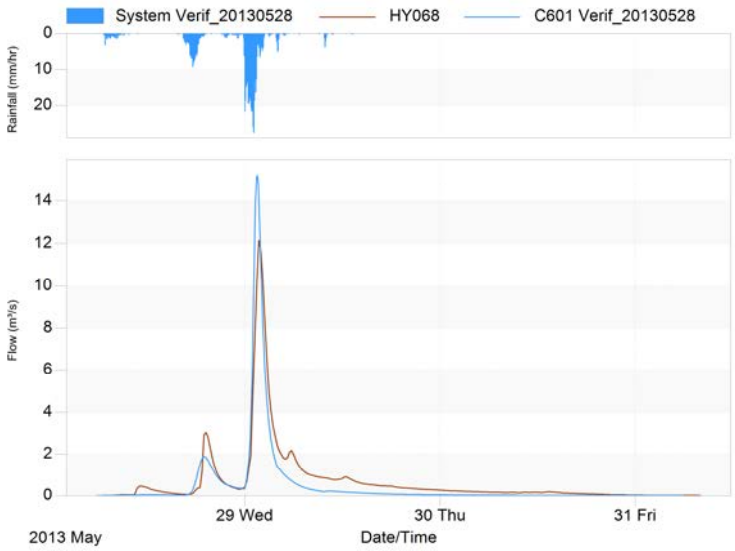

System Verif_20100723
HY068
C601 Verif_20100723
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
0
1
2
3
4
5
6
7
8
9
23 Fri
24 Sat
25 Sun
26 Mon
2010 Jul
Date/Time

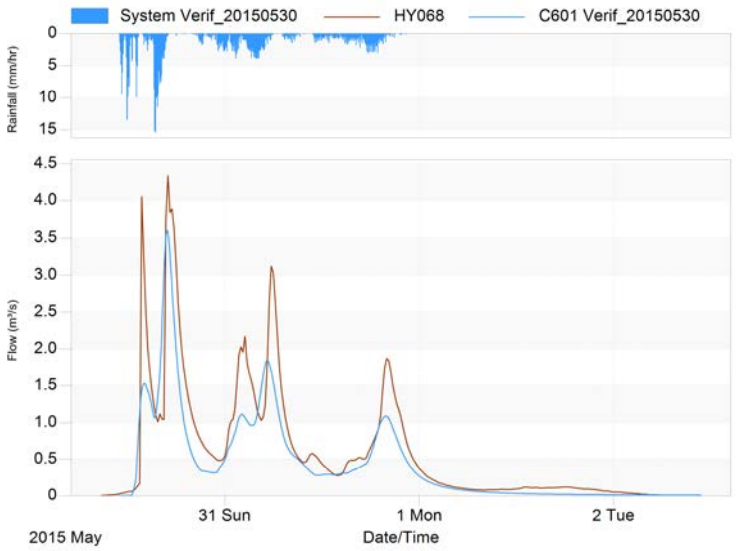

System Verif_20111128
HY068
C601 Verif_20111128
Rainfall (mm/hr)
0
2
4
6
Flow (m³/s)
0
0.5
1.0
1.5
2.0
2.5
3.0
29 Tue
30 Wed
1 Thu
2 Fri
2011 Nov
Date/Time


System Verif_20120725
HY068
C601 Verif_20120725
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
0
1
2
3
4
5
6
7
8
26 Thu
27 Fri
28 Sat
2012 Jul
Date/Time

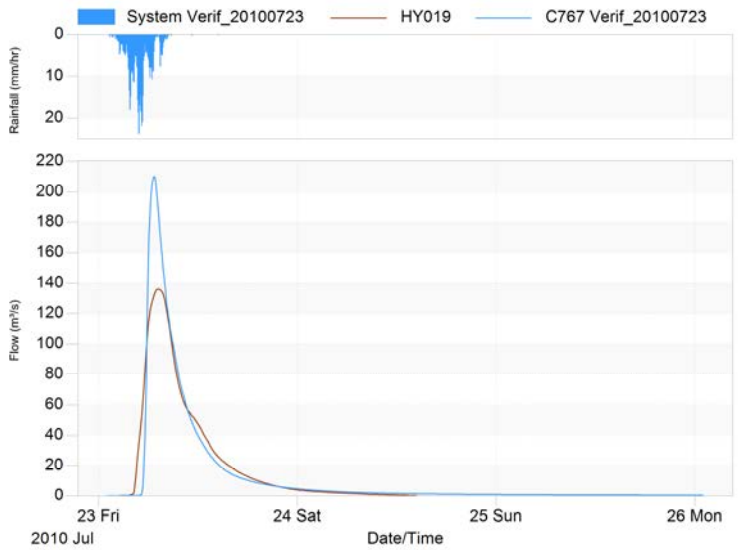

System Verif_20120904
HY068
C601 Verif_20120904
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
0
2
4
6
8
10
12
14
5 Wed
6 Thu
7 Fri
2012 Sep
Date/Time

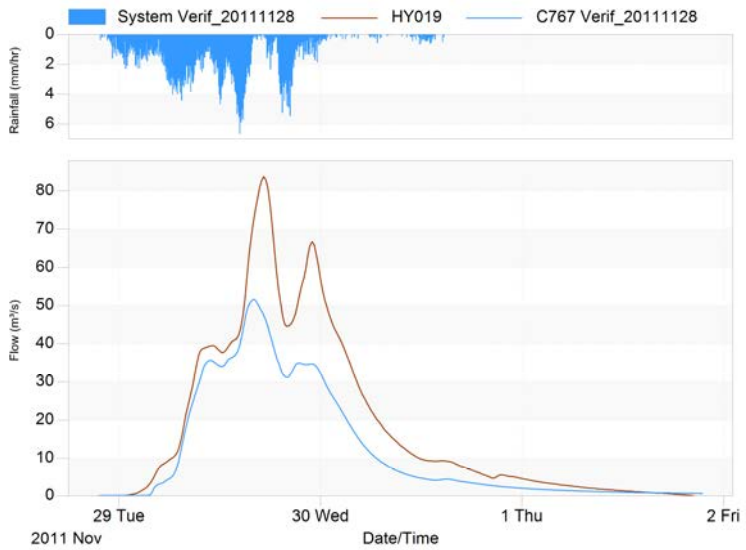
HY068

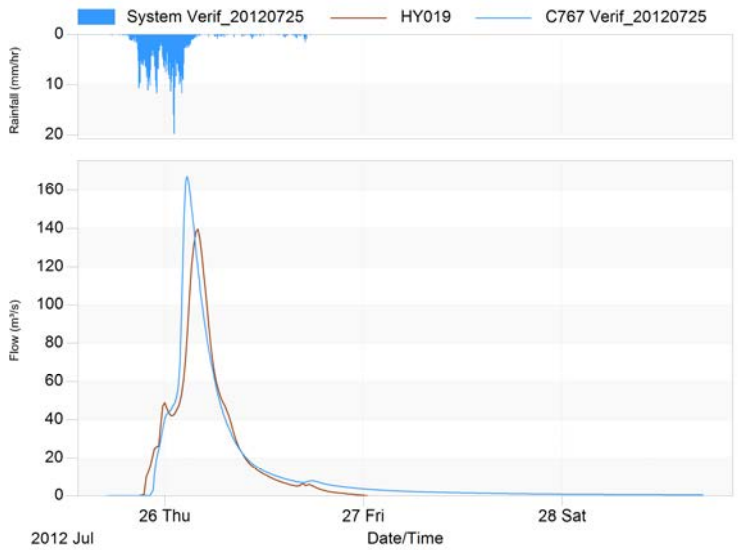

System Verif_20130528
HY068
C601 Verif_20130528
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
14
12
10
8
6
4
2
0
29 Wed
30 Thu
31 Fri
2013 May
Date/Time

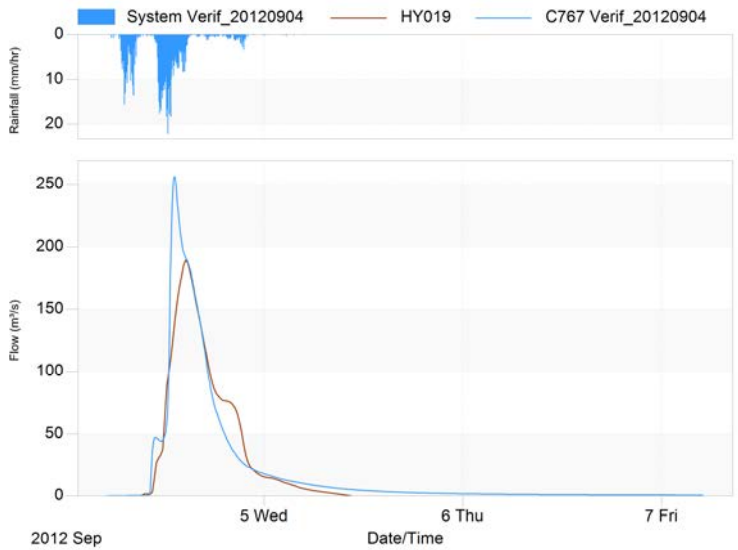

System Verif_20150530
HY068
C601 Verif_20150530
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
31 Sun
1 Mon
2 Tue
2015 May
Date/Time

HY019

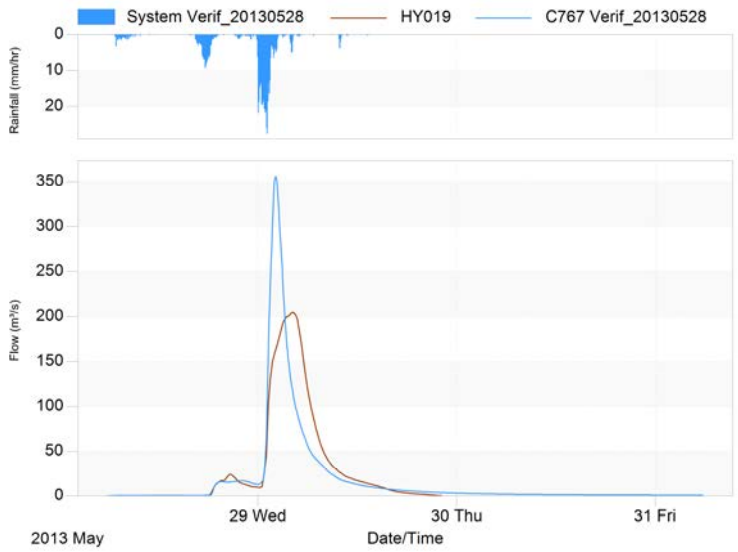

System Verif_20100723
HY019
C767 Verif_20100723
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
220
200
180
160
140
120
100
80
60
40
20
0
23 Fri
24 Sat
25 Sun
26 Mon
2010 Jul
Date/Time

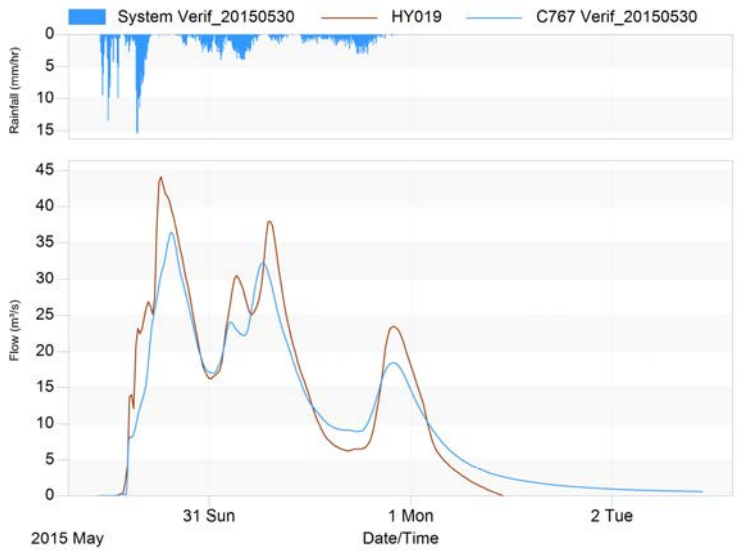

System Verif_20111128
HY019
C767 Verif_20111128
Rainfall (mm/hr)
0
2
4
6
Flow (m³/s)
80
70
60
50
40
30
20
10
0
29 Tue
30 Wed
1 Thu
2 Fri
2011 Nov
Date/Time

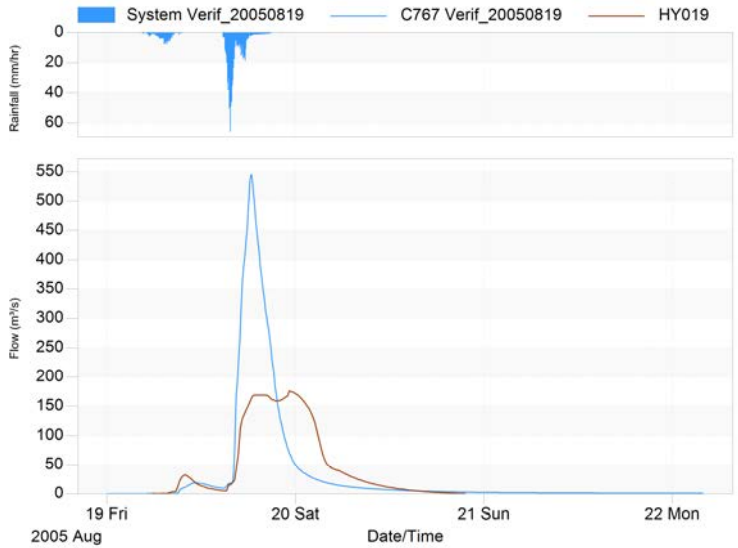

System Verif_20120725
HY019
C767 Verif_20120725
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
160
140
120
100
80
60
40
20
0
26 Thu
27 Fri
28 Sat
2012 Jul
Date/Time


System Verif_20120904
HY019
C767 Verif_20120904
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
250
200
150
100
50
0
5 Wed
6 Thu
7 Fri
2012 Sep
Date/Time

HY019


System Verif_20130528
HY019
C767 Verif_20130528
Rainfall (mm/hr)
0
10
20
Flow (m³/s)
350
300
250
200
150
100
50
0
29 Wed
30 Thu
31 Fri
2013 May
Date/Time


System Verif_20150530
HY019
C767 Verif_20150530
Rainfall (mm/hr)
0
5
10
15
Flow (m³/s)
45
40
35
30
25
20
15
10
5
0
31 Sun
1 Mon
2 Tue
2015 May
Date/Time


System Verif_20050819
C767 Verif_20050819
HY019
Rainfall (mm/hr)
0
20
40
60
Flow (m³/s)
550
500
450
400
350
300
250
200
150
100
50
0
19 Fri
20 Sat
21 Sun
22 Mon
2005 Aug
Date/Time

Appendix G: Design Flow – Existing

Existing Conditions **2 Year**

Flow Nodes	Areal Reduction Factor (%)						Peak Flow (m^3/s)								
							2004 Flow	Chicago			SCS			AES	
	1 hr	3 hr	4 hr	6 hr	12 hr	24 hr		3 hr	4 hr	12 hr	6 hr	12 hr	24 hr	1 hr	12 hr
2	100	100	100	100	100	100	1.411	0.95	1.05	1.29	1.09	1.20	1.27	0.72	0.94
4	100	100	100	100	100	100	9.599	7.69	8.80	10.10	9.05	9.31	8.95	6.83	3.79
3.1	86	94	95	95.5	96	97	2.4	3.09	3.48	3.88	3.63	3.78	4.04	2.35	2.51
1	89.5	95	96	97	97.5	98	3.65	9.52	10.17	10.59	9.85	10.86	10.75	8.09	5.22
5.3	86	94	95	95.5	96	97	11.24	8.57	9.56	11.22	9.98	10.34	10.34	6.70	5.89
5.2	83.5	92	93	94	95	96	13.94	12.62	13.56	14.60	13.65	14.46	14.66	10.40	10.98
8.1	100	100	100	100	100	100	-	4.20	4.75	5.19	5.03	5.26	5.15	3.97	2.72
6	100	100	100	100	100	100	5.82	24.39	26.28	27.17	25.61	25.78	24.87	23.05	7.63
5.1	83.5	92	93	94	95	96	17.79	14.11	14.78	16.37	15.59	16.15	16.47	10.31	14.49
7.2	78.5	89	90	92.5	94	94.5	23.55	24.56	27.12	30.83	28.20	31.69	33.36	20.35	20.37
7.1	77.5	88	89	92	93.5	94	20.94	23.21	25.33	30.42	27.23	30.66	32.47	17.13	21.77
9.3	75	86.5	88	91	92.5	93.8	25.44	28.84	31.50	38.06	33.92	37.51	39.95	20.35	23.75
9.1	71.5	84	86	88.5	90.5	92.5	28.29	38.35	45.20	53.79	48.60	55.17	58.90	29.61	27.87
10	100	100	100	100	100	100	19.27	12.29	13.50	15.55	14.16	15.33	15.39	10.91	4.17
11.7	71.5	84	86	88.5	90.5	92.5	40.09	12.57	14.77	20.61	17.60	20.29	22.96	5.34	16.44
11.3	71.5	84	86	88.5	90.5	92.5	27.6	12.53	14.73	20.95	17.56	20.79	23.36	6.74	16.43
11.2	67	80	82	85.5	88.5	91	32.01	16.29	17.96	22.08	20.00	21.38	24.22	11.65	16.00
11.1	65	78.5	80	84	87.5	90	27.51	16.79	18.39	23.72	21.08	23.30	24.01	10.68	15.18
14	89.5	95	96	97	97.5	98	15.36	8.74	9.63	11.01	10.41	10.96	10.55	7.56	4.55
12	89.5	95	96	97	97.5	98	22.66	20.96	22.74	26.92	24.54	25.75	25.49	17.04	6.97
15.1	83.5	92	93	94	95	96	21.46	13.81	16.44	19.16	18.77	20.32	20.05	10.64	6.24
13.1	65	78.5	80	84	87.5	90	33.33	28.91	31.62	41.85	37.02	41.78	43.50	17.98	15.56
16.2	65	78.5	80	84	87.5	90	54.78	37.58	41.00	53.98	47.70	53.68	55.82	23.34	20.67
16.1	65	78.5	80	84	87.5	90	54.36	46.91	50.78	66.54	58.74	66.34	69.69	30.87	26.10
20	100	100	100	100	100	100	2.04	2.27	2.69	2.91	2.67	2.70	2.62	2.06	0.53
19	89.5	95	96	97	97.5	98	1.67	1.52	1.81	2.01	1.78	1.89	1.87	1.16	0.56
21.1	89.5	95	96	97	97.5	98	3.91	3.41	3.55	3.85	3.69	3.77	3.80	2.88	2.33
23.4	89.5	95	96	97	97.5	98	5.57	4.27	4.49	5.10	4.68	4.80	4.89	3.42	2.86
22	100	100	100	100	100	100	8.362	11.12	12.57	13.48	12.88	13.01	12.72	10.50	3.35
23.3	86	94	95	95.5	96	97	10.15	14.85	16.78	19.08	17.11	17.84	17.90	12.26	5.46
18.1	86	94	95	95.5	96	97	3.78	3.81	4.13	5.32	4.69	5.08	5.31	2.54	2.08
17	100	100	100	100	100	100	1.13	0.22	0.34	0.52	0.28	0.33	0.35	0.14	0.27
23.2	86	94	95	95.5	96	97	10.61	16.95	19.39	22.37	19.63	20.02	19.59	13.67	7.53
23.1	83.5	92	93	94	95	96	12.25	17.43	18.91	22.97	20.14	21.50	22.33	11.60	10.20
24	100	100	100	100	100	100	2.15	6.46	7.21	7.75	7.50	7.69	7.30	5.87	0.82
29	89.5	95	96	97	97.5	98	7.15	5.31	5.78	6.02	5.75	6.07	5.93	4.33	3.11
30.1	78.5	89	90	92.5	94	94.5	26.4	8.94	9.62	11.23	10.54	11.32	11.21	5.81	8.97
31	89.5	95	96	97	97.5	98	34.83	11.82	12.37	13.69	13.03	13.27	12.96	9.13	9.07
25.2	81	91	92	93.5	94.5	95.5	14.4	17.13	18.61	22.80	19.93	21.37	22.27	11.14	10.12

25.1	78.5	89	90	92.5	94	94.5	13.73	16.07	17.43	21.60	18.91	20.54	21.45	10.24	10.00
26	100	100	100	100	100	100	16.493	12.74	13.29	14.72	13.69	13.92	13.62	11.36	2.38
32.2	73.5	85.5	87	89.5	91.5	93.5	61.23	17.85	18.88	22.28	20.75	22.22	22.48	11.63	17.06
33	100	100	100	100	100	100	14.35	19.32	21.11	21.21	20.27	19.63	18.46	17.87	6.25
49.2	78.5	89	90	92.5	94	94.5	22.26	19.82	21.51	27.33	23.88	26.48	28.43	12.73	11.92
34.3	71.5	84	86	88.5	90.5	92.5	46.4	18.78	20.26	23.91	22.34	23.99	26.51	13.98	20.84
27	100	100	100	100	100	100	25.11	27.51	31.20	33.03	32.01	32.58	31.09	24.56	4.41
49.1	77.5	88	89	92	93.5	94	16.7	19.73	21.41	27.24	23.84	26.38	28.31	12.38	11.95
28.2	77.5	88	89	92	93.5	94	38.76	30.90	35.03	39.39	37.29	39.29	39.00	24.99	15.45
28.1	75	86.5	88	91	92.5	93.8	43.52	32.39	35.85	40.90	38.12	40.05	40.20	25.88	15.37
34.1	71.5	84	86	88.5	90.5	92.5	44.03	19.99	21.97	24.78	23.01	25.86	30.01	15.40	22.24
35.2	67	80	82	85.5	88.5	91	74.36	46.08	50.96	60.14	54.96	59.53	65.05	35.20	35.21
36	100	100	100	100	100	100	19.662	23.61	25.33	28.69	26.42	26.80	25.89	20.58	7.07
35.1	67	80	82	85.5	88.5	91	61.79	47.12	51.14	60.74	55.57	59.96	65.51	34.48	35.58
37.1	89.5	95	96	97	97.5	98	21.123	15.46	16.01	17.34	16.70	16.98	16.88	13.02	6.96
39.5	67	80	82	85.5	88.5	91	70.85	58.74	63.73	75.76	69.38	74.76	80.51	43.11	39.99
39.4	67	80	82	85.5	88.5	91	70.85	59.92	64.50	77.82	70.95	76.78	82.57	42.25	40.96
38	100	100	100	100	100	100	8.323	13.65	14.18	14.86	14.45	14.62	14.24	13.01	1.99
39.3	67	80	82	85.5	88.5	91	74.63	62.46	67.09	81.14	73.93	79.87	85.68	42.99	41.89
40	100	100	100	100	100	100	7.851	10.19	11.48	12.23	11.89	12.21	11.65	8.26	1.03
41.3	67	80	82	85.5	88.5	91	76.94	63.24	67.82	82.26	74.87	81.02	86.75	42.72	42.38
41.1	65	78.5	80	84	87.5	90	79.34	68.02	72.53	92.23	82.17	90.53	97.56	40.54	45.42
42	89.5	95	96	97	97.5	98	15.744	10.70	11.64	13.45	12.53	12.95	12.69	8.61	5.87
43.2	83.5	92	93	94	95	96	48.061	36.67	42.33	49.39	46.54	49.30	48.57	30.47	19.87
43.1	63	77	79	83.5	86.5	89	98.91	81.34	86.65	110.82	98.76	111.06	119.16	49.43	55.12
44.2	62.5	75	77	81.5	85	88	143.83	122.00	131.28	169.56	149.74	168.23	179.46	74.94	75.11
44.1	62.5	75	77	81.5	85	88	141.27	121.76	130.84	168.84	149.44	167.73	179.11	74.75	75.37
45	100	100	100	100	100	100	16.508	7.11	8.00	8.75	8.39	8.57	8.14	6.65	1.27
48.4	62.5	75	77	81.5	85	88	143.82	121.68	130.61	168.59	149.28	167.47	178.96	74.59	75.47
46	86	94	95	95.5	96	97	33.71	30.38	32.53	37.94	34.89	35.57	34.79	23.28	7.51
48.3	62.5	75	77	81.5	85	88	149.18	125.19	134.53	174.19	153.92	172.75	184.63	76.35	79.78
47	83.5	92	93	94	95	96	45.3	29.95	32.06	38.17	34.91	36.27	36.43	21.40	12.99
48.2	62.5	75	77	81.5	85	88	172.46	131.84	141.75	182.46	161.88	180.83	193.73	81.45	85.71
48.1	62.5	75	77	81.5	85	88	163.86	109.47	117.54	150.23	133.92	149.26	160.55	67.23	81.31

Existing Conditions **5 Year**

Flow Nodes	Areal Reduction Factor (%)						Peak Flow (m^3/s)								
							2004 Flow	Chicago			SCS			AES	
	1 hr	3 hr	4 hr	6 hr	12 hr	24 hr		3 hr	4 hr	12 hr	6 hr	12 hr	24 hr	1 hr	12 hr
2	100	100	100	100	100	100	2.279	2.94	3.13	3.80	2.85	2.99	2.95	2.07	1.34
4	100	100	100	100	100	100	13.25	18.27	19.16	20.48	17.92	17.49	16.28	16.12	4.90
3.1	86	94	95	95.5	96	97	3.88	5.66	6.57	6.99	6.17	6.35	6.39	4.25	3.37
1	89.5	95	96	97	97.5	98	5.13	14.39	15.18	16.00	14.36	15.13	14.55	12.49	6.84
5.3	86	94	95	95.5	96	97	15.88	17.26	17.95	19.60	17.42	17.36	16.80	13.87	7.83
5.2	83.5	92	93	94	95	96	19.39	20.05	20.83	21.76	19.72	20.71	20.34	17.56	14.13
8.1	100	100	100	100	100	100	-	7.02	8.05	8.39	7.75	7.68	7.27	6.39	3.19
6	100	100	100	100	100	100	6.97	38.95	41.59	42.26	38.64	37.83	35.54	37.09	10.36
5.1	83.5	92	93	94	95	96	25.61	19.87	20.59	23.04	21.30	22.24	22.12	15.51	18.33
7.2	78.5	89	90	92.5	94	94.5	32.49	40.54	43.82	49.33	44.06	48.46	47.81	33.93	26.16
7.1	77.5	88	89	92	93.5	94	29	38.22	39.36	45.37	40.71	43.51	43.26	31.09	28.42
9.3	75	86.5	88	91	92.5	93.8	36.56	50.13	51.80	57.59	53.40	54.87	55.27	39.22	31.34
9.1	71.5	84	86	88.5	90.5	92.5	41.03	78.04	89.69	103.35	91.60	97.74	97.50	62.38	37.78
10	100	100	100	100	100	100	28.38	26.11	28.15	31.40	27.57	27.96	25.99	23.88	6.92
11.7	71.5	84	86	88.5	90.5	92.5	60.48	34.15	36.88	44.97	39.45	42.93	45.96	17.84	28.63
11.3	71.5	84	86	88.5	90.5	92.5	38.98	34.00	36.91	45.54	39.90	42.91	46.56	17.72	29.08
11.2	67	80	82	85.5	88.5	91	48.53	33.40	36.64	46.56	40.52	43.70	48.04	22.23	29.64
11.1	65	78.5	80	84	87.5	90	40.25	33.67	37.56	47.27	39.39	43.16	47.35	21.39	28.70
14	89.5	95	96	97	97.5	98	23.06	15.93	18.43	21.31	17.36	17.00	15.62	13.36	6.17
12	89.5	95	96	97	97.5	98	32.12	42.76	47.00	52.39	45.82	45.32	43.01	37.37	14.25
15.1	83.5	92	93	94	95	96	33.2	27.06	33.97	36.67	33.94	34.31	32.77	21.01	10.51
13.1	65	78.5	80	84	87.5	90	50.4	59.57	65.67	81.76	70.23	73.83	72.05	42.44	29.96
16.2	65	78.5	80	84	87.5	90	82.21	76.78	84.35	104.76	90.08	94.05	91.98	53.73	35.37
16.1	65	78.5	80	84	87.5	90	80.96	96.75	105.31	128.65	111.18	117.33	115.69	70.01	45.58
20	100	100	100	100	100	100	3.41	5.54	6.14	6.82	5.19	5.23	4.96	4.80	0.83
19	89.5	95	96	97	97.5	98	2.89	3.32	3.72	3.99	3.55	3.58	3.37	2.69	1.10
21.1	89.5	95	96	97	97.5	98	6.33	4.96	5.11	5.42	5.14	5.13	5.09	4.20	3.68
23.4	89.5	95	96	97	97.5	98	9.22	7.87	8.38	9.24	8.21	8.38	8.09	6.92	4.64
22	100	100	100	100	100	100	12.754	20.24	23.05	24.03	21.65	21.26	20.06	19.19	5.16
23.3	86	94	95	95.5	96	97	14.87	30.71	33.91	36.74	32.42	32.49	31.06	26.21	8.60
18.1	86	94	95	95.5	96	97	6.29	9.50	10.25	11.65	10.02	10.05	10.02	7.53	3.91
17	100	100	100	100	100	100	2.05	2.31	3.01	3.33	2.17	2.23	2.00	1.37	0.54
23.2	86	94	95	95.5	96	97	17.57	37.21	40.89	44.26	38.20	37.00	35.17	31.39	12.49
23.1	83.5	92	93	94	95	96	19.26	39.57	41.84	48.03	41.53	41.69	41.06	29.24	17.66
24	100	100	100	100	100	100	3.57	13.58	15.52	16.08	14.50	14.07	12.92	12.54	2.02
29	89.5	95	96	97	97.5	98	34	8.02	9.07	9.65	8.49	8.74	8.22	6.43	4.11
30.1	78.5	89	90	92.5	94	94.5	45.58	14.01	14.40	15.94	14.74	14.89	15.23	9.27	12.02
31	89.5	95	96	97	97.5	98	55.2	18.51	20.10	22.83	19.78	19.11	17.55	13.71	12.12
25.2	81	91	92	93.5	94.5	95.5	22.77	39.01	41.31	47.66	41.26	41.53	40.88	28.01	17.78

25.1	78.5	89	90	92.5	94	94.5	20.43	35.29	37.26	43.37	37.86	38.81	38.24	25.17	18.12
26	100	100	100	100	100	100	24.191	22.47	23.80	25.21	22.82	22.22	20.80	21.62	6.29
32.2	73.5	85.5	87	89.5	91.5	93.5	95.79	26.94	28.51	33.13	29.72	30.83	30.31	18.64	22.80
33	100	100	100	100	100	100	21.18	31.27	34.57	35.03	30.26	28.50	26.15	28.24	8.28
49.2	78.5	89	90	92.5	94	94.5	34.16	45.36	47.79	55.53	48.80	50.14	49.44	32.73	23.48
34.3	71.5	84	86	88.5	90.5	92.5	87.11	28.45	31.13	35.75	32.25	36.25	36.74	21.94	28.06
27	100	100	100	100	100	100	27.53	52.67	60.85	62.59	55.66	53.96	50.35	46.42	9.58
49.1	77.5	88	89	92	93.5	94	25.84	44.94	47.40	55.27	48.69	50.10	49.45	31.97	24.09
28.2	77.5	88	89	92	93.5	94	49.1	57.44	65.51	71.50	63.46	64.51	62.44	47.51	32.33
28.1	75	86.5	88	91	92.5	93.8	56.26	60.79	68.07	75.01	66.12	66.88	65.28	50.16	32.61
34.1	71.5	84	86	88.5	90.5	92.5	75.84	32.11	35.92	40.71	35.06	40.95	41.94	25.01	30.19
35.2	67	80	82	85.5	88.5	91	114.62	80.46	90.65	103.94	89.61	97.58	98.70	62.40	59.03
36	100	100	100	100	100	100	29.227	46.40	50.58	54.29	47.58	45.84	43.00	43.41	14.03
35.1	67	80	82	85.5	88.5	91	97.46	79.91	87.33	102.37	89.00	95.03	97.12	60.38	60.61
37.1	89.5	95	96	97	97.5	98	32.512	20.22	20.75	21.86	20.89	20.79	20.48	17.85	13.59
39.5	67	80	82	85.5	88.5	91	111.23	96.87	104.99	122.37	107.55	114.07	116.36	73.05	70.26
39.4	67	80	82	85.5	88.5	91	111.23	100.34	108.26	126.42	111.39	117.80	119.99	73.58	73.12
38	100	100	100	100	100	100	13.053	19.34	20.18	20.65	19.52	19.21	18.53	18.87	5.23
39.3	67	80	82	85.5	88.5	91	115.63	105.00	112.84	132.60	116.26	122.53	124.54	74.98	76.33
40	100	100	100	100	100	100	12.305	19.70	22.84	23.57	21.08	20.49	18.88	16.30	2.96
41.3	67	80	82	85.5	88.5	91	118.6	107.02	114.74	134.92	118.60	124.79	126.64	74.97	78.37
41.1	65	78.5	80	84	87.5	90	121.86	124.32	131.73	157.89	139.67	148.46	154.12	87.17	92.71
42	89.5	95	96	97	97.5	98	22.949	20.18	22.84	25.74	21.73	21.43	19.96	16.42	8.05
43.2	83.5	92	93	94	95	96	72.461	68.37	82.08	93.48	79.99	79.73	75.42	55.95	27.95
43.1	63	77	79	83.5	86.5	89	151.39	153.08	163.92	197.22	172.76	183.01	187.82	103.95	107.77
44.2	62.5	75	77	81.5	85	88	219.14	235.85	255.18	313.81	270.10	285.54	290.65	162.66	140.46
44.1	62.5	75	77	81.5	85	88	211.86	231.90	252.33	308.73	267.74	283.39	288.24	159.81	141.30
45	100	100	100	100	100	100	25.741	14.67	17.19	17.87	16.08	15.59	14.30	13.88	2.87
48.4	62.5	75	77	81.5	85	88	215.51	231.67	251.88	308.49	267.37	283.07	287.93	159.57	141.56
46	86	94	95	95.5	96	97	51.45	62.05	67.81	74.31	64.59	62.07	58.66	51.97	17.36
48.3	62.5	75	77	81.5	85	88	222.09	233.08	252.23	306.75	267.65	282.75	287.81	161.50	150.64
47	83.5	92	93	94	95	96	60.317	62.03	67.13	76.11	66.16	65.03	62.37	49.28	23.89
48.2	62.5	75	77	81.5	85	88	255.55	239.49	257.53	312.13	273.55	289.20	294.86	168.39	160.94
48.1	62.5	75	77	81.5	85	88	239.41	199.06	213.18	257.14	228.19	241.07	247.71	131.58	150.73

Existing Conditions **10 Year**

Flow Nodes	Areal Reduction Factor (%)						Peak Flow (m^3/s)								
							2004 Flow	Chicago			SCS			AES	
	1 hr	3 hr	4 hr	6 hr	12 hr	24 hr		3 hr	4 hr	12 hr	6 hr	12 hr	24 hr	1 hr	12 hr
2	100	100	100	100	100	100	3.401	5.22	5.35	6.29	4.92	4.96	4.69	3.87	1.67
4	100	100	100	100	100	100	16.33	23.44	23.85	25.02	22.78	22.11	20.86	21.96	5.64
3.1	86	94	95	95.5	96	97	6.34	7.74	8.94	9.36	8.22	8.36	8.12	5.74	3.89
1	89.5	95	96	97	97.5	98	5.98	17.22	17.96	18.82	17.27	17.66	16.94	15.31	7.90
5.3	86	94	95	95.5	96	97	19.19	22.21	22.69	24.58	21.95	21.61	20.64	18.18	9.04
5.2	83.5	92	93	94	95	96	23.96	23.81	24.75	26.32	23.88	24.73	24.01	21.50	15.98
8.1	100	100	100	100	100	100	-	9.20	10.38	10.65	9.58	9.34	8.71	8.14	3.46
6	100	100	100	100	100	100	8.38	48.72	51.88	52.37	47.59	45.97	42.70	46.36	12.54
5.1	83.5	92	93	94	95	96	32	24.26	25.06	27.94	25.70	26.52	25.99	19.15	20.78
7.2	78.5	89	90	92.5	94	94.5	40.2	52.14	56.01	62.42	55.95	59.92	57.50	43.74	30.41
7.1	77.5	88	89	92	93.5	94	35.33	47.63	50.10	60.00	51.72	54.69	52.87	36.66	33.13
9.3	75	86.5	88	91	92.5	93.8	44.12	61.07	64.47	77.00	65.69	69.09	66.74	46.64	36.97
9.1	71.5	84	86	88.5	90.5	92.5	51.12	107.77	123.63	141.00	123.99	129.87	125.62	87.16	45.00
10	100	100	100	100	100	100	34.48	37.88	40.77	44.63	38.60	37.95	34.36	35.30	9.26
11.7	71.5	84	86	88.5	90.5	92.5	76.13	49.30	51.83	62.98	54.32	58.16	61.00	32.19	37.15
11.3	71.5	84	86	88.5	90.5	92.5	46.21	49.25	52.49	63.73	55.06	59.17	61.95	32.08	37.78
11.2	67	80	82	85.5	88.5	91	63.45	52.47	60.52	72.29	56.49	61.68	65.19	38.33	39.72
11.1	65	78.5	80	84	87.5	90	48.25	53.46	59.40	76.55	64.66	71.48	75.76	35.20	38.95
14	89.5	95	96	97	97.5	98	29.79	25.57	30.31	34.71	25.62	24.22	21.50	20.96	7.34
12	89.5	95	96	97	97.5	98	42.852	59.49	65.32	71.50	61.68	60.31	56.30	52.94	19.04
15.1	83.5	92	93	94	95	96	40.31	37.57	43.94	47.20	42.75	42.68	40.03	28.81	13.33
13.1	65	78.5	80	84	87.5	90	65.5	84.20	92.70	111.38	94.85	97.38	93.30	62.14	41.49
16.2	65	78.5	80	84	87.5	90	104.95	108.29	118.33	141.82	121.00	123.48	118.70	78.54	48.17
16.1	65	78.5	80	84	87.5	90	102.44	131.86	143.21	171.19	146.10	151.31	146.46	98.53	61.99
20	100	100	100	100	100	100	4.44	9.23	9.67	10.73	8.04	8.07	7.46	8.00	1.06
19	89.5	95	96	97	97.5	98	4.44	4.65	5.17	5.47	4.87	4.80	4.44	3.80	1.56
21.1	89.5	95	96	97	97.5	98	8.03	5.87	6.06	6.52	5.99	5.94	5.80	5.04	4.35
23.4	89.5	95	96	97	97.5	98	12.35	10.53	11.36	12.29	11.05	11.07	10.47	9.46	5.84
22	100	100	100	100	100	100	15.633	27.22	30.98	31.88	28.15	27.38	25.44	25.63	6.58
23.3	86	94	95	95.5	96	97	18.57	42.22	46.65	49.83	43.77	43.17	40.50	36.58	10.84
18.1	86	94	95	95.5	96	97	8.52	13.71	13.89	14.80	13.83	13.87	13.54	11.32	5.05
17	100	100	100	100	100	100	3.23	4.49	5.28	5.59	4.21	4.19	3.72	2.95	0.71
23.2	86	94	95	95.5	96	97	24.14	52.37	57.28	60.77	52.10	50.28	47.67	45.11	15.56
23.1	83.5	92	93	94	95	96	25.7	56.70	59.44	66.58	57.86	57.15	55.12	44.14	22.52
24	100	100	100	100	100	100	4.61	18.77	21.59	22.11	19.33	18.53	16.88	17.39	3.18
29	89.5	95	96	97	97.5	98	37.66	10.64	12.02	12.77	10.96	11.02	10.20	8.56	4.80
30.1	78.5	89	90	92.5	94	94.5	60.86	17.98	20.31	23.01	19.99	20.33	18.64	12.43	14.09
31	89.5	95	96	97	97.5	98	63.87	26.58	28.85	32.52	26.93	25.42	23.31	20.70	14.23
25.2	81	91	92	93.5	94.5	95.5	30.8	55.67	58.28	65.52	57.17	56.65	54.67	42.16	22.88

25.1	78.5	89	90	92.5	94	94.5	26.2	48.72	50.93	57.70	50.95	51.48	49.71	36.55	23.85
26	100	100	100	100	100	100	34.511	30.89	34.98	37.74	29.47	28.32	26.30	28.53	9.13
32.2	73.5	85.5	87	89.5	91.5	93.5	121.6	33.86	35.63	43.25	35.80	36.38	35.39	24.21	26.68
33	100	100	100	100	100	100	30.59	42.23	46.55	47.33	38.94	36.32	32.92	37.51	9.58
49.2	78.5	89	90	92.5	94	94.5	47.53	61.37	63.79	72.02	64.46	65.44	63.43	45.73	31.56
34.3	71.5	84	86	88.5	90.5	92.5	113.64	37.86	42.70	50.37	41.15	46.19	45.35	29.30	32.76
27	100	100	100	100	100	100	33.25	72.08	82.15	83.68	72.57	70.64	64.96	63.23	13.17
49.1	77.5	88	89	92	93.5	94	33.69	60.74	63.23	71.73	64.33	65.36	63.40	44.94	32.89
28.2	77.5	88	89	92	93.5	94	64.89	75.42	85.31	92.01	80.93	84.68	81.33	62.85	43.95
28.1	75	86.5	88	91	92.5	93.8	73.9	79.89	88.89	96.84	84.42	87.55	85.70	66.49	44.63
34.1	71.5	84	86	88.5	90.5	92.5	98.84	43.49	48.75	56.22	45.97	52.75	52.22	33.10	35.36
35.2	67	80	82	85.5	88.5	91	150.9	107.11	118.16	135.78	115.31	124.87	126.60	84.06	76.00
36	100	100	100	100	100	100	36.295	64.21	70.23	74.33	63.54	60.71	56.22	60.92	18.32
35.1	67	80	82	85.5	88.5	91	125.49	104.29	113.55	133.08	113.12	120.21	122.05	79.37	78.65
37.1	89.5	95	96	97	97.5	98	40.646	22.71	23.28	24.45	23.18	22.98	22.52	20.04	16.81
39.5	67	80	82	85.5	88.5	91	144.28	123.78	133.72	155.67	134.03	141.55	143.35	93.92	92.35
39.4	67	80	82	85.5	88.5	91	144.28	128.29	137.71	160.24	138.50	146.03	147.33	95.13	96.96
38	100	100	100	100	100	100	16.001	22.34	23.16	23.56	22.06	21.58	20.89	21.93	7.03
39.3	67	80	82	85.5	88.5	91	148.96	137.04	146.22	169.73	146.50	151.54	152.16	99.25	101.87
40	100	100	100	100	100	100	15.174	27.00	31.20	31.78	27.56	26.35	24.30	22.21	4.07
41.3	67	80	82	85.5	88.5	91	152.44	139.30	148.12	171.98	149.20	154.72	154.80	99.10	105.17
41.1	65	78.5	80	84	87.5	90	154.96	162.71	174.36	203.71	177.03	186.85	191.12	119.12	127.71
42	89.5	95	96	97	97.5	98	28.789	29.92	32.70	35.18	29.12	28.13	26.02	25.05	9.51
43.2	83.5	92	93	94	95	96	89.634	100.48	117.43	129.72	107.95	105.83	98.20	81.86	33.64
43.1	63	77	79	83.5	86.5	89	190.32	201.54	223.04	254.20	221.77	231.99	233.69	142.91	146.39
44.2	62.5	75	77	81.5	85	88	279.03	320.89	351.92	412.15	356.39	371.45	370.77	231.54	188.66
44.1	62.5	75	77	81.5	85	88	265.08	313.19	338.41	406.08	347.54	362.25	362.99	225.64	190.16
45	100	100	100	100	100	100	32.932	20.60	24.07	24.65	21.65	20.70	18.99	19.14	3.84
48.4	62.5	75	77	81.5	85	88	268.8	312.18	337.10	404.51	346.05	360.72	361.66	225.16	190.40
46	86	94	95	95.5	96	97	58.79	86.60	94.55	101.91	86.48	82.51	77.43	74.42	23.74
48.3	62.5	75	77	81.5	85	88	276.33	305.89	329.66	396.13	339.89	355.08	356.53	221.93	202.33
47	83.5	92	93	94	95	96	73.638	87.59	94.77	105.50	89.69	87.53	82.28	72.36	31.85
48.2	62.5	75	77	81.5	85	88	313.55	311.20	335.23	404.00	346.91	363.27	365.94	225.21	215.79
48.1	62.5	75	77	81.5	85	88	294.74	265.79	284.15	321.22	302.98	316.23	326.69	179.07	205.67

Existing Conditions **25 Year**

Flow Nodes	Areal Reduction Factor (%)						Peak Flow (m^3/s)								
							2004 Flow	Chicago			SCS			AES	
	1 hr	3 hr	4 hr	6 hr	12 hr	24 hr		3 hr	4 hr	12 hr	6 hr	12 hr	24 hr	1 hr	12 hr
2	100	100	100	100	100	100	6.228	8.36	8.47	9.77	8.06	8.06	7.67	6.33	2.23
4	100	100	100	100	100	100	21.91	30.40	31.85	34.08	29.18	27.71	25.45	27.09	6.55
3.1	86	94	95	95.5	96	97	11.65	10.32	11.84	12.29	10.67	10.84	10.48	7.31	4.43
1	89.5	95	96	97	97.5	98	7.24	19.53	20.22	21.26	19.76	19.94	19.42	17.53	9.00
5.3	86	94	95	95.5	96	97	30.87	27.77	28.45	30.57	27.61	27.02	25.86	22.78	10.55
5.2	83.5	92	93	94	95	96	35.96	27.84	29.10	30.96	28.34	29.23	28.54	24.75	18.11
8.1	100	100	100	100	100	100	-	11.83	13.03	13.25	11.70	11.40	10.69	10.12	3.94
6	100	100	100	100	100	100	23.64	59.29	63.01	63.55	57.65	55.80	52.13	55.70	15.67
5.1	83.5	92	93	94	95	96	41.38	29.04	29.91	33.07	30.75	31.78	31.22	23.06	23.55
7.2	78.5	89	90	92.5	94	94.5	64.39	65.04	69.81	79.66	70.10	73.90	70.89	54.53	35.81
7.1	77.5	88	89	92	93.5	94	47.11	65.47	69.26	82.11	71.27	74.27	71.11	48.31	39.83
9.3	75	86.5	88	91	92.5	93.8	66.86	85.09	90.36	106.32	92.17	95.41	91.33	61.41	45.53
9.1	71.5	84	86	88.5	90.5	92.5	66.93	143.89	166.04	186.16	165.94	172.76	166.59	115.40	56.93
10	100	100	100	100	100	100	42.32	52.27	56.97	61.29	53.32	51.81	46.97	49.18	12.86
11.7	71.5	84	86	88.5	90.5	92.5	95.07	69.45	72.52	83.86	75.50	79.15	82.05	45.37	49.23
11.3	71.5	84	86	88.5	90.5	92.5	58.02	70.00	73.63	85.23	77.08	81.16	84.14	45.21	52.20
11.2	67	80	82	85.5	88.5	91	81.86	84.69	97.42	113.88	85.89	86.82	91.40	64.34	57.22
11.1	65	78.5	80	84	87.5	90	61.21	81.12	100.28	117.96	91.07	98.83	105.11	54.67	57.52
14	89.5	95	96	97	97.5	98	37.74	42.35	49.38	55.15	39.63	37.36	33.29	34.00	8.85
12	89.5	95	96	97	97.5	98	53.547	79.13	87.06	94.57	82.21	80.68	75.72	70.57	24.72
15.1	83.5	92	93	94	95	96	53.38	48.24	53.94	56.73	52.27	52.30	50.10	37.06	16.53
13.1	65	78.5	80	84	87.5	90	84.13	111.36	121.50	144.20	123.36	126.27	122.60	84.11	63.95
16.2	65	78.5	80	84	87.5	90	137.1	141.37	152.86	180.87	155.63	158.95	155.09	106.05	68.98
16.1	65	78.5	80	84	87.5	90	132.34	171.63	185.75	219.22	188.71	195.18	190.46	129.40	83.60
20	100	100	100	100	100	100	5.89	13.77	14.08	15.58	12.45	12.48	11.74	12.35	1.35
19	89.5	95	96	97	97.5	98	15.56	6.14	6.82	7.20	6.31	6.20	5.82	4.99	2.13
21.1	89.5	95	96	97	97.5	98	25.74	6.97	7.20	7.94	7.14	7.10	6.96	6.02	5.36
23.4	89.5	95	96	97	97.5	98	33.66	13.53	14.82	15.92	14.37	14.37	13.65	12.14	7.43
22	100	100	100	100	100	100	19.37	35.81	40.45	41.41	36.31	35.39	33.01	32.78	8.47
23.3	86	94	95	95.5	96	97	45.16	55.82	61.98	65.59	57.82	57.04	53.82	47.98	13.89
18.1	86	94	95	95.5	96	97	12.73	20.41	21.42	23.78	20.20	20.19	19.47	15.49	6.79
17	100	100	100	100	100	100	5.7	7.10	7.90	8.25	6.77	6.73	6.10	4.87	0.92
23.2	86	94	95	95.5	96	97	52.95	70.80	77.80	81.64	69.99	69.18	65.91	60.65	20.59
23.1	83.5	92	93	94	95	96	37.19	75.24	78.68	87.36	77.14	76.17	73.86	60.36	29.66
24	100	100	100	100	100	100	6.54	25.37	28.86	29.41	25.52	24.55	22.74	22.88	4.61
29	89.5	95	96	97	97.5	98	44.2	14.01	15.59	16.55	14.03	14.02	13.06	11.15	5.70
30.1	78.5	89	90	92.5	94	94.5	87.1	21.26	21.59	26.43	22.15	22.68	23.00	18.15	16.79
31	89.5	95	96	97	97.5	98	94.85	38.02	40.94	46.25	37.32	35.85	33.02	30.17	16.63
25.2	81	91	92	93.5	94.5	95.5	43.36	73.62	76.93	85.68	76.05	75.28	73.05	57.33	30.21

25.1	78.5	89	90	92.5	94	94.5	34.36	62.72	65.68	74.19	65.91	66.55	64.48	48.01	31.49
26	100	100	100	100	100	100	43.902	46.67	50.82	53.36	44.36	42.12	38.64	44.22	12.44
32.2	73.5	85.5	87	89.5	91.5	93.5	179.03	46.83	50.44	59.28	49.12	50.05	47.32	31.00	31.91
33	100	100	100	100	100	100	39.05	56.96	61.89	62.94	50.47	47.43	43.27	49.37	11.23
49.2	78.5	89	90	92.5	94	94.5	60.84	77.26	80.27	90.15	81.49	82.72	80.43	58.19	42.51
34.3	71.5	84	86	88.5	90.5	92.5	161.56	51.22	57.45	69.68	56.33	60.41	59.02	39.02	39.02
27	100	100	100	100	100	100	43.98	95.70	106.49	108.33	92.53	89.41	83.71	81.12	17.60
49.1	77.5	88	89	92	93.5	94	43.85	76.54	79.62	89.86	81.42	82.67	80.45	57.20	44.31
28.2	77.5	88	89	92	93.5	94	85.07	95.75	107.09	115.59	101.66	103.02	100.89	79.05	58.91
28.1	75	86.5	88	91	92.5	93.8	96.71	101.87	111.96	122.24	106.83	107.73	106.23	84.06	59.95
34.1	71.5	84	86	88.5	90.5	92.5	136.87	59.29	65.40	77.22	61.54	66.84	65.58	44.80	42.05
35.2	67	80	82	85.5	88.5	91	208.26	138.65	151.78	173.50	147.53	155.10	155.80	107.52	97.81
36	100	100	100	100	100	100	45.353	86.13	94.02	98.62	85.34	82.49	76.49	81.72	23.55
35.1	67	80	82	85.5	88.5	91	167.85	137.19	148.82	173.16	147.44	154.06	154.64	101.21	101.34
37.1	89.5	95	96	97	97.5	98	51.123	24.86	25.24	26.30	25.36	25.29	25.02	22.16	19.88
39.5	67	80	82	85.5	88.5	91	194.86	158.49	170.65	197.10	170.23	177.68	178.49	117.41	119.55
39.4	67	80	82	85.5	88.5	91	194.86	163.25	174.89	201.76	175.40	183.31	183.67	118.88	126.03
38	100	100	100	100	100	100	19.83	25.29	27.29	32.01	24.76	24.35	23.66	24.78	9.27
39.3	67	80	82	85.5	88.5	91	199.8	174.52	186.69	212.37	185.86	193.64	192.81	125.06	132.75
40	100	100	100	100	100	100	18.931	36.19	40.66	41.35	35.36	34.16	31.88	28.66	5.38
41.3	67	80	82	85.5	88.5	91	204.61	176.77	188.63	214.63	188.49	196.60	195.66	124.84	137.40
41.1	65	78.5	80	84	87.5	90	203.55	204.76	218.26	256.13	223.02	236.12	242.31	152.33	169.99
42	89.5	95	96	97	97.5	98	36.454	40.42	42.55	44.54	37.51	36.45	34.03	34.73	11.53
43.2	83.5	92	93	94	95	96	111.651	140.66	159.18	171.83	143.46	141.58	132.41	113.65	40.80
43.1	63	77	79	83.5	86.5	89	250.09	257.01	276.75	328.15	281.06	293.64	298.74	184.02	193.55
44.2	62.5	75	77	81.5	85	88	360.69	412.15	441.25	525.25	452.75	474.34	480.16	302.49	249.01
44.1	62.5	75	77	81.5	85	88	340.45	405.56	434.62	517.89	447.26	468.43	471.73	295.36	250.94
45	100	100	100	100	100	100	40.732	28.01	32.21	32.85	28.42	27.51	25.51	24.99	5.07
48.4	62.5	75	77	81.5	85	88	344.99	403.68	431.78	513.93	445.65	466.53	469.14	294.00	251.18
46	86	94	95	95.5	96	97	77.79	116.37	126.90	135.34	115.39	111.43	104.90	100.27	31.42
48.3	62.5	75	77	81.5	85	88	354.2	393.89	419.44	498.95	435.03	455.91	459.49	283.00	265.83
47	83.5	92	93	94	95	96	99.321	118.00	128.18	141.54	120.90	118.88	112.13	99.24	41.49
48.2	62.5	75	77	81.5	85	88	396.07	401.55	427.75	508.18	443.28	465.55	470.83	285.36	283.08
48.1	62.5	75	77	81.5	85	88	371.7	316.61	337.30	404.28	352.12	368.51	372.89	229.10	273.47

Existing Conditions **50 Year**

Flow Nodes	Areal Reduction Factor (%)						Peak Flow (m^3/s)								
							2004 Flow	Chicago			SCS			AES	
	1 hr	3 hr	4 hr	6 hr	12 hr	24 hr		3 hr	4 hr	12 hr	6 hr	12 hr	24 hr	1 hr	12 hr
2	100	100	100	100	100	100	8.079	10.91	11.07	12.68	11.07	11.29	11.03	8.41	3.10
4	100	100	100	100	100	100	26.01	36.96	38.39	40.31	36.47	35.53	33.38	33.39	8.57
3.1	86	94	95	95.5	96	97	15.98	12.43	14.05	14.46	12.82	13.16	12.89	8.43	4.89
1	89.5	95	96	97	97.5	98	9.5	21.07	21.84	23.07	21.49	21.77	21.36	18.72	10.43
5.3	86	94	95	95.5	96	97	38.83	31.72	32.54	34.85	32.26	32.00	31.15	26.24	12.69
5.2	83.5	92	93	94	95	96	44.94	30.58	32.16	34.40	31.89	33.12	32.71	27.15	20.52
8.1	100	100	100	100	100	100	-	13.83	14.95	15.18	13.52	13.33	12.68	11.57	4.71
6	100	100	100	100	100	100	35.24	66.92	71.07	71.79	65.80	64.39	61.28	62.23	19.44
5.1	83.5	92	93	94	95	96	63	32.37	33.50	37.64	34.89	36.93	36.66	25.63	26.60
7.2	78.5	89	90	92.5	94	94.5	98.23	77.47	83.85	98.77	84.83	88.47	84.83	63.19	40.95
7.1	77.5	88	89	92	93.5	94	56.91	79.53	84.42	98.66	88.44	92.15	89.81	59.37	45.84
9.3	75	86.5	88	91	92.5	93.8	75.99	102.97	108.93	125.84	113.88	118.21	116.07	75.61	53.47
9.1	71.5	84	86	88.5	90.5	92.5	85.42	171.70	200.07	225.62	204.08	214.39	208.87	135.92	71.50
10	100	100	100	100	100	100	48.45	63.60	70.84	76.17	67.25	66.06	60.95	59.78	16.55
11.7	71.5	84	86	88.5	90.5	92.5	113.56	81.01	85.21	100.51	90.69	96.72	101.82	57.10	61.83
11.3	71.5	84	86	88.5	90.5	92.5	67.97	82.34	86.45	102.11	92.67	99.61	104.76	56.78	67.60
11.2	67	80	82	85.5	88.5	91	103.09	112.21	128.45	149.54	118.59	119.21	115.26	85.90	80.84
11.1	65	78.5	80	84	87.5	90	71.37	117.39	129.18	152.25	128.59	129.16	130.37	81.01	82.12
14	89.5	95	96	97	97.5	98	43.91	57.83	66.18	73.15	54.30	52.99	48.84	45.68	10.32
12	89.5	95	96	97	97.5	98	62.065	94.51	104.32	112.79	101.12	101.02	96.81	83.77	30.25
15.1	83.5	92	93	94	95	96	62.77	54.54	64.71	70.25	61.13	61.77	57.68	43.01	19.46
13.1	65	78.5	80	84	87.5	90	100.68	133.58	145.90	173.85	150.24	153.38	152.04	99.56	93.14
16.2	65	78.5	80	84	87.5	90	162.31	167.80	182.33	216.55	186.55	191.40	190.23	124.61	101.21
16.1	65	78.5	80	84	87.5	90	156.41	200.48	216.48	256.15	224.20	234.95	234.33	152.11	110.11
20	100	100	100	100	100	100	7	17.22	17.42	18.34	16.63	16.83	16.33	15.63	1.67
19	89.5	95	96	97	97.5	98	27.14	7.31	8.07	8.49	7.60	7.56	7.19	5.83	2.87
21.1	89.5	95	96	97	97.5	98	25.92	8.10	8.40	9.42	8.67	8.87	8.75	6.70	6.16
23.4	89.5	95	96	97	97.5	98	42.58	15.83	17.43	18.70	17.22	17.43	16.86	14.12	9.25
22	100	100	100	100	100	100	22.326	42.66	47.82	49.06	43.51	42.94	40.65	38.01	10.24
23.3	86	94	95	95.5	96	97	55.92	66.32	73.38	77.26	70.01	70.00	67.27	56.23	17.37
18.1	86	94	95	95.5	96	97	16.5	25.10	26.31	29.16	25.84	26.23	25.95	20.44	8.47
17	100	100	100	100	100	100	6.88	9.23	10.13	10.65	9.15	9.25	8.65	6.32	1.20
23.2	86	94	95	95.5	96	97	66.06	85.03	92.99	96.64	86.07	86.38	83.59	72.27	26.24
23.1	83.5	92	93	94	95	96	46.09	89.16	93.80	103.70	93.93	94.17	92.84	71.75	37.74
24	100	100	100	100	100	100	7.73	30.56	34.31	35.08	30.93	30.45	29.02	26.94	5.96
29	89.5	95	96	97	97.5	98	51.86	16.65	18.26	19.42	16.76	17.04	16.25	13.10	6.45
30.1	78.5	89	90	92.5	94	94.5	106.93	26.71	29.45	35.99	28.04	28.98	26.87	18.79	19.56
31	89.5	95	96	97	97.5	98	105.84	48.16	52.01	59.16	48.78	48.36	45.74	38.25	19.37
25.2	81	91	92	93.5	94.5	95.5	53.51	86.61	91.06	101.92	91.98	92.52	91.33	68.17	38.44

25.1	78.5	89	90	92.5	94	94.5	41.28	73.65	77.40	87.74	79.48	81.40	80.25	56.38	39.79
26	100	100	100	100	100	100	45.646	56.50	59.52	62.23	55.52	54.73	52.79	54.13	15.55
32.2	73.5	85.5	87	89.5	91.5	93.5	202.61	57.50	61.51	73.08	61.09	63.36	61.89	39.57	36.03
33	100	100	100	100	100	100	40.37	69.10	74.32	75.69	61.31	59.49	55.39	58.80	12.79
49.2	78.5	89	90	92.5	94	94.5	65.36	89.21	93.04	104.88	96.21	98.86	97.54	67.02	54.15
34.3	71.5	84	86	88.5	90.5	92.5	191.8	63.12	70.35	85.60	69.52	74.89	74.22	47.13	42.82
27	100	100	100	100	100	100	52.96	113.64	123.08	124.78	107.11	104.79	99.55	94.20	21.70
49.1	77.5	88	89	92	93.5	94	51.55	88.51	92.48	104.78	96.29	98.95	97.71	65.86	56.41
28.2	77.5	88	89	92	93.5	94	97.87	110.88	123.94	135.63	120.02	123.68	123.24	90.46	74.86
28.1	75	86.5	88	91	92.5	93.8	111.9	117.50	128.94	142.19	125.67	128.99	129.67	96.33	76.08
34.1	71.5	84	86	88.5	90.5	92.5	162.82	72.60	79.20	95.45	76.19	82.35	81.56	54.11	46.23
35.2	67	80	82	85.5	88.5	91	247.14	161.51	176.12	209.05	175.69	187.08	190.66	126.05	117.03
36	100	100	100	100	100	100	52.712	102.89	112.93	118.11	105.31	104.14	98.91	97.05	29.01
35.1	67	80	82	85.5	88.5	91	201.19	162.48	174.66	206.80	177.96	189.02	192.09	120.20	122.34
37.1	89.5	95	96	97	97.5	98	59.368	28.07	31.81	39.88	30.14	28.98	27.17	23.18	22.27
39.5	67	80	82	85.5	88.5	91	234.59	185.88	200.71	238.43	203.60	215.03	217.48	136.94	143.97
39.4	67	80	82	85.5	88.5	91	234.59	190.67	205.02	243.06	208.78	220.58	222.95	138.32	151.94
38	100	100	100	100	100	100	22.858	38.73	46.97	50.76	36.87	35.07	29.39	33.77	12.04
39.3	67	80	82	85.5	88.5	91	240.33	201.31	215.93	256.68	219.38	231.82	233.82	145.11	160.16
40	100	100	100	100	100	100	21.922	43.16	47.67	48.71	42.08	41.38	39.41	33.59	7.12
41.3	67	80	82	85.5	88.5	91	245.7	203.70	218.06	259.25	222.08	234.69	236.68	144.79	166.04
41.1	65	78.5	80	84	87.5	90	240.71	236.25	251.70	296.34	263.16	283.13	293.77	176.78	208.43
42	89.5	95	96	97	97.5	98	42.527	46.80	49.68	51.78	44.74	44.65	42.58	41.02	13.52
43.2	83.5	92	93	94	95	96	144.441	171.14	190.20	204.42	175.31	176.99	169.15	136.57	47.53
43.1	63	77	79	83.5	86.5	89	292.15	301.81	323.52	379.38	338.30	358.00	368.64	218.62	235.14
44.2	62.5	75	77	81.5	85	88	421.69	478.31	517.19	616.05	540.59	574.12	586.43	355.38	317.19
44.1	62.5	75	77	81.5	85	88	396.48	472.60	510.28	609.93	534.19	567.52	579.56	347.44	318.36
45	100	100	100	100	100	100	49.679	33.95	38.44	39.36	34.51	33.98	32.20	29.33	6.51
48.4	62.5	75	77	81.5	85	88	401.66	469.42	506.26	605.67	529.82	562.66	574.94	345.61	318.55
46	86	94	95	95.5	96	97	88.95	138.99	151.75	161.70	141.48	140.05	135.13	119.69	38.82
48.3	62.5	75	77	81.5	85	88	411.32	456.70	490.88	587.71	516.61	549.05	561.17	330.83	331.27
47	83.5	92	93	94	95	96	114.895	142.09	154.87	170.64	150.28	150.99	145.44	119.76	49.90
48.2	62.5	75	77	81.5	85	88	463.07	464.87	498.52	597.92	525.58	560.37	573.75	333.13	349.00
48.1	62.5	75	77	81.5	85	88	428.85	371.75	396.71	478.53	421.61	448.86	461.48	253.17	375.37

Existing Conditions **100 Year**

Flow Nodes	Areal Reduction Factor (%)						Peak Flow (m^3/s)								
							2004 Flow	Chicago			SCS			AES	
	1 hr	3 hr	4 hr	6 hr	12 hr	24 hr		3 hr	4 hr	12 hr	6 hr	12 hr	24 hr	1 hr	12 hr
2	100	100	100	100	100	100	10.25	13.17	13.41	16.72	13.80	14.39	14.20	10.24	4.82
4	100	100	100	100	100	100	30.41	41.43	42.97	45.72	41.69	41.24	39.85	38.26	10.98
3.1	86	94	95	95.5	96	97	19.74	14.26	16.11	16.40	14.62	15.12	14.96	9.37	5.59
1	89.5	95	96	97	97.5	98	11.09	22.39	23.18	24.53	23.04	23.44	23.17	19.87	11.75
5.3	86	94	95	95.5	96	97	48.5	34.88	35.83	38.14	36.01	36.09	35.60	28.98	15.60
5.2	83.5	92	93	94	95	96	54.14	32.92	34.75	37.28	34.89	36.42	36.33	29.15	22.92
8.1	100	100	100	100	100	100	-	15.54	16.55	16.78	15.09	15.01	14.46	12.80	5.42
6	100	100	100	100	100	100	48.85	73.83	78.86	82.12	73.23	72.34	69.28	67.57	22.77
5.1	83.5	92	93	94	95	96	85.05	35.38	36.65	41.82	38.93	41.37	41.43	27.68	30.07
7.2	78.5	89	90	92.5	94	94.5	133.9	90.61	98.49	114.93	101.24	106.59	103.34	73.41	46.62
7.1	77.5	88	89	92	93.5	94	67.91	90.87	96.50	117.81	103.89	110.36	108.12	69.08	53.76
9.3	75	86.5	88	91	92.5	93.8	106.84	116.24	122.73	147.64	131.59	139.27	137.67	86.99	63.74
9.1	71.5	84	86	88.5	90.5	92.5	105.79	197.15	230.59	260.19	237.53	250.23	246.98	153.51	85.12
10	100	100	100	100	100	100	54.83	74.54	84.38	90.26	81.34	80.77	75.99	69.87	19.87
11.7	71.5	84	86	88.5	90.5	92.5	135.23	92.30	96.94	113.89	104.31	112.35	120.05	64.30	74.53
11.3	71.5	84	86	88.5	90.5	92.5	78.81	93.59	98.55	117.96	106.68	115.66	124.60	64.27	83.37
11.2	67	80	82	85.5	88.5	91	119.91	138.39	157.83	182.59	151.45	157.56	156.71	105.66	101.28
11.1	65	78.5	80	84	87.5	90	82.53	138.41	138.96	162.75	145.21	152.66	159.80	98.93	123.31
14	89.5	95	96	97	97.5	98	50.7	72.93	82.14	90.03	69.22	69.65	66.03	56.92	11.62
12	89.5	95	96	97	97.5	98	68.408	108.10	119.77	129.17	118.15	119.57	116.33	95.30	35.44
15.1	83.5	92	93	94	95	96	73.54	64.60	74.31	80.34	71.29	72.69	70.61	47.70	22.10
13.1	65	78.5	80	84	87.5	90	112.09	158.84	174.43	204.89	180.83	187.23	188.87	112.56	118.75
16.2	65	78.5	80	84	87.5	90	185.02	196.88	215.64	254.31	219.83	227.71	228.76	140.76	129.36
16.1	65	78.5	80	84	87.5	90	179.63	225.58	243.93	287.79	256.58	271.31	273.80	170.40	139.66
20	100	100	100	100	100	100	8.15	19.01	19.63	21.30	19.02	19.62	19.04	17.72	2.63
19	89.5	95	96	97	97.5	98	31.54	8.29	9.09	9.54	8.64	8.68	8.40	6.60	3.78
21.1	89.5	95	96	97	97.5	98	31.35	9.11	9.43	10.65	9.85	10.21	10.22	7.26	7.15
23.4	89.5	95	96	97	97.5	98	62.88	17.85	19.64	21.02	19.65	20.07	19.72	15.77	11.18
22	100	100	100	100	100	100	25.398	49.00	54.37	55.89	49.88	49.65	47.59	42.59	11.76
23.3	86	94	95	95.5	96	97	84.04	75.32	82.58	86.87	79.52	80.15	78.30	63.36	20.76
18.1	86	94	95	95.5	96	97	19.12	29.06	30.65	34.23	30.89	31.91	32.19	23.85	9.94
17	100	100	100	100	100	100	8.33	11.22	12.22	12.91	11.29	11.52	11.01	7.99	1.61
23.2	86	94	95	95.5	96	97	92.93	97.08	105.18	108.72	98.21	98.82	96.69	82.02	31.58
23.1	83.5	92	93	94	95	96	57.64	101.02	106.42	118.03	108.52	110.59	110.88	82.00	45.52
24	100	100	100	100	100	100	8.95	35.26	40.36	41.71	36.31	36.43	35.06	30.46	7.12
29	89.5	95	96	97	97.5	98	53.44	18.96	20.56	21.87	19.24	19.76	19.16	14.62	7.13
30.1	78.5	89	90	92.5	94	94.5	132.45	33.81	36.68	44.31	36.24	38.23	37.02	20.83	22.11
31	89.5	95	96	97	97.5	98	117.97	58.29	62.37	70.41	60.51	61.46	59.98	45.88	22.16
25.2	81	91	92	93.5	94.5	95.5	64.1	98.61	104.26	116.43	107.24	109.47	109.85	77.49	46.41

25.1	78.5	89	90	92.5	94	94.5	48.28	83.32	87.74	99.72	91.76	95.15	95.24	63.62	47.70
26	100	100	100	100	100	100	52.221	63.36	67.58	70.61	63.76	64.10	62.63	60.97	18.27
32.2	73.5	85.5	87	89.5	91.5	93.5	242.29	67.47	73.12	83.59	73.98	77.71	77.47	46.96	40.05
33	100	100	100	100	100	100	46.43	80.41	85.86	87.53	72.40	72.08	68.54	67.32	14.17
49.2	78.5	89	90	92.5	94	94.5	77.94	99.77	104.31	118.04	109.44	113.75	113.65	75.20	65.03
34.3	71.5	84	86	88.5	90.5	92.5	228.53	74.47	82.36	99.43	82.12	89.92	90.29	55.16	48.77
27	100	100	100	100	100	100	60.48	128.69	136.37	138.37	119.97	119.25	114.90	105.46	25.85
49.1	77.5	88	89	92	93.5	94	59.69	99.16	103.82	118.10	109.63	113.94	113.94	73.23	67.69
28.2	77.5	88	89	92	93.5	94	108.1	125.28	139.11	153.15	137.61	143.94	145.79	100.64	89.68
28.1	75	86.5	88	91	92.5	93.8	126.77	131.75	144.36	159.86	143.50	149.53	152.78	106.82	91.18
34.1	71.5	84	86	88.5	90.5	92.5	194.41	84.99	92.02	111.53	90.63	98.86	99.39	62.90	52.19
35.2	67	80	82	85.5	88.5	91	287.76	185.35	201.36	239.46	205.11	221.76	229.13	140.37	134.85
36	100	100	100	100	100	100	60.029	118.07	129.98	135.79	123.82	124.40	120.03	110.47	34.06
35.1	67	80	82	85.5	88.5	91	239.04	186.18	198.45	236.16	206.56	222.71	229.35	134.30	141.62
37.1	89.5	95	96	97	97.5	98	65.402	40.47	46.10	55.69	46.68	46.20	44.18	25.70	24.36
39.5	67	80	82	85.5	88.5	91	278.51	216.27	230.81	274.72	238.77	256.61	263.67	152.22	165.72
39.4	67	80	82	85.5	88.5	91	278.51	220.86	235.18	279.98	244.04	262.52	269.25	153.32	175.12
38	100	100	100	100	100	100	26.006	51.81	62.17	66.01	54.41	55.01	51.33	47.19	13.77
39.3	67	80	82	85.5	88.5	91	284.59	234.34	249.24	296.65	258.87	277.95	284.64	158.59	184.72
40	100	100	100	100	100	100	25.033	49.37	53.94	55.14	48.05	47.85	46.19	37.91	8.63
41.3	67	80	82	85.5	88.5	91	291.64	237.02	251.86	299.96	261.99	281.34	287.93	158.08	191.84
41.1	65	78.5	80	84	87.5	90	282.92	262.20	280.69	332.16	298.84	325.18	339.91	197.38	240.61
42	89.5	95	96	97	97.5	98	48.761	53.55	55.92	59.05	51.48	52.50	50.61	45.40	15.36
43.2	83.5	92	93	94	95	96	165.184	198.24	217.00	232.10	204.98	209.96	204.16	156.11	53.32
43.1	63	77	79	83.5	86.5	89	343.59	335.31	360.88	426.91	384.15	413.68	430.43	247.26	269.91
44.2	62.5	75	77	81.5	85	88	489.94	537.91	581.23	696.45	618.78	665.14	687.48	400.20	388.96
44.1	62.5	75	77	81.5	85	88	459.77	533.45	574.75	688.90	612.50	657.95	680.29	391.37	389.90
45	100	100	100	100	100	100	56.638	39.36	44.03	45.14	39.87	39.77	38.21	33.12	7.80
48.4	62.5	75	77	81.5	85	88	466.16	530.07	570.17	684.70	608.41	653.63	675.58	388.46	389.94
46	86	94	95	95.5	96	97	100.6	159.78	175.00	186.18	166.30	167.38	163.63	135.81	45.81
48.3	62.5	75	77	81.5	85	88	477.62	515.64	552.59	662.50	591.54	636.58	658.56	370.69	403.42
47	83.5	92	93	94	95	96	130.518	163.53	178.79	196.76	177.15	180.92	177.15	137.93	57.99
48.2	62.5	75	77	81.5	85	88	531.58	525.30	561.80	673.65	602.33	649.24	671.45	372.49	422.15
48.1	62.5	75	77	81.5	85	88	494.93	422.40	451.58	546.38	487.34	526.80	549.75	284.96	402.81

Existing Conditions **350 Year**

Flow Nodes	Areal Reduction Factor (%)						Peak Flow (m^3/s)							
							Chicago			SCS			AES	
	1 hr	3 hr	4 hr	6 hr	12 hr	24 hr	3 hr	4 hr	12 hr	6 hr	12 hr	24 hr	1 hr	12 hr
2	100	100	100	100	100	100	21.66	22.45	22.45	24.52	25.82	26.63	10.20	9.97
4	100	100	100	100	100	100	56.81	61.87	61.87	61.46	62.41	61.02	38.17	17.41
3.1	86	94	95	95.5	96	97	18.00	18.70	18.99	18.51	19.24	19.41	9.36	11.21
1	89.5	95	96	97	97.5	98	24.90	25.49	25.97	25.88	26.51	26.57	19.85	14.89
5.3	86	94	95	95.5	96	97	40.68	41.90	42.56	43.14	43.95	44.31	28.92	22.72
5.2	83.5	92	93	94	95	96	37.83	39.95	40.96	41.22	43.39	43.99	29.11	31.74
8.1	100	100	100	100	100	100	18.79	19.69	19.69	18.37	18.58	18.35	12.78	7.26
6	100	100	100	100	100	100	96.51	106.00	106.00	107.03	110.81	108.37	67.46	29.63
5.1	83.5	92	93	94	95	96	41.64	43.67	44.77	47.87	51.38	52.40	27.64	38.88
7.2	78.5	89	90	92.5	94	94.5	117.20	129.11	134.60	138.90	148.30	147.84	73.20	61.45
7.1	77.5	88	89	92	93.5	94	122.27	131.76	137.91	144.57	152.40	153.87	68.89	81.01
9.3	75	86.5	88	91	92.5	93.8	152.02	162.32	170.62	178.06	186.88	190.52	86.78	91.87
9.1	71.5	84	86	88.5	90.5	92.5	257.80	299.76	317.29	316.56	337.84	341.88	153.15	116.90
10	100	100	100	100	100	100	101.40	114.97	114.97	115.36	118.14	116.54	69.66	27.94
11.7	71.5	84	86	88.5	90.5	92.5	114.43	119.70	126.70	129.87	139.78	151.02	64.18	103.68
11.3	71.5	84	86	88.5	90.5	92.5	118.48	124.52	131.80	135.67	146.34	158.26	64.14	117.15
11.2	67	80	82	85.5	88.5	91	195.22	221.36	239.39	229.76	250.30	262.02	105.33	141.55
11.1	65	78.5	80	84	87.5	90	172.74	191.16	208.21	206.27	224.15	246.43	98.31	175.11
14	89.5	95	96	97	97.5	98	108.45	118.67	120.94	109.32	115.52	115.01	56.68	14.59
12	89.5	95	96	97	97.5	98	138.90	153.87	156.82	157.14	161.98	161.36	95.08	48.33
15.1	83.5	92	93	94	95	96	83.46	92.41	94.74	90.50	93.36	93.17	47.61	28.18
13.1	65	78.5	80	84	87.5	90	214.04	232.70	253.46	252.36	269.96	286.88	112.29	179.41
16.2	65	78.5	80	84	87.5	90	263.89	284.56	309.94	306.03	327.18	345.19	140.43	195.46
16.1	65	78.5	80	84	87.5	90	282.69	302.73	329.74	327.78	350.98	364.26	170.05	214.74
20	100	100	100	100	100	100	25.27	26.77	26.77	27.54	28.90	28.75	17.68	6.54
19	89.5	95	96	97	97.5	98	10.26	11.13	11.35	10.85	11.09	11.11	6.59	5.51
21.1	89.5	95	96	97	97.5	98	11.89	12.58	12.82	13.92	15.14	15.48	7.25	10.38
23.4	89.5	95	96	97	97.5	98	22.06	24.17	24.63	24.84	25.80	26.13	15.74	15.72
22	100	100	100	100	100	100	63.18	68.76	68.76	64.30	65.07	63.75	42.49	15.18
23.3	86	94	95	95.5	96	97	93.70	101.49	103.10	100.05	102.38	102.49	63.22	28.03
18.1	86	94	95	95.5	96	97	38.33	40.80	41.45	43.45	46.41	48.65	23.79	17.62
17	100	100	100	100	100	100	15.56	16.89	16.89	17.72	19.54	20.67	7.95	5.40
23.2	86	94	95	95.5	96	97	120.34	128.16	130.20	122.50	128.38	131.51	81.83	44.53
23.1	83.5	92	93	94	95	96	127.12	134.44	137.83	142.82	149.50	154.92	81.81	63.69
24	100	100	100	100	100	100	48.22	53.50	53.50	50.43	51.98	51.63	30.39	10.15
29	89.5	95	96	97	97.5	98	23.74	25.30	25.78	24.80	25.78	25.63	14.59	8.67
30.1	78.5	89	90	92.5	94	94.5	49.29	52.74	54.99	56.33	60.88	61.73	20.72	25.28
31	89.5	95	96	97	97.5	98	78.79	81.97	83.54	84.60	86.63	87.61	45.72	28.27
25.2	81	91	92	93.5	94.5	95.5	124.60	131.63	135.45	140.45	147.64	153.13	77.31	64.98

25.1	78.5	89	90	92.5	94	94.5	104.90	111.01	115.73	120.32	127.43	131.09	63.48	66.65
26	100	100	100	100	100	100	78.93	84.26	84.26	84.06	87.03	87.23	60.84	24.35
32.2	73.5	85.5	87	89.5	91.5	93.5	91.70	100.22	105.61	108.37	118.70	121.55	46.81	50.51
33	100	100	100	100	100	100	106.48	111.92	111.92	101.66	104.93	103.31	67.14	17.38
49.2	78.5	89	90	92.5	94	94.5	123.95	130.45	136.00	141.11	149.78	153.33	75.04	90.47
34.3	71.5	84	86	88.5	90.5	92.5	99.52	108.12	114.45	113.34	125.27	128.57	54.99	61.44
27	100	100	100	100	100	100	157.62	165.99	165.99	150.96	153.70	151.79	105.22	35.15
49.1	77.5	88	89	92	93.5	94	123.52	130.04	136.11	141.38	149.96	153.66	73.09	104.24
28.2	77.5	88	89	92	93.5	94	155.70	171.91	179.92	177.48	191.29	196.83	100.42	136.00
28.1	75	86.5	88	91	92.5	93.8	162.56	177.89	186.99	184.63	198.20	205.80	106.60	125.21
34.1	71.5	84	86	88.5	90.5	92.5	112.55	120.43	127.47	126.30	138.98	143.09	62.73	65.91
35.2	67	80	82	85.5	88.5	91	238.07	256.76	277.68	275.21	304.06	318.59	140.02	182.40
36	100	100	100	100	100	100	152.67	168.19	168.19	167.09	171.74	169.73	110.20	46.06
35.1	67	80	82	85.5	88.5	91	234.47	248.24	268.46	270.54	296.89	311.86	133.95	191.29
37.1	89.5	95	96	97	97.5	98	65.05	69.08	70.40	72.78	74.71	75.75	25.57	29.09
39.5	67	80	82	85.5	88.5	91	277.88	295.28	319.34	322.39	353.22	370.06	151.82	220.17
39.4	67	80	82	85.5	88.5	91	283.83	301.00	325.52	325.42	354.83	369.68	152.93	232.44
38	100	100	100	100	100	100	81.49	95.71	95.71	91.10	94.83	93.33	46.97	17.74
39.3	67	80	82	85.5	88.5	91	300.97	318.03	343.94	342.91	372.73	388.19	158.21	244.98
40	100	100	100	100	100	100	62.56	67.34	67.34	61.55	62.60	61.79	37.82	11.93
41.3	67	80	82	85.5	88.5	91	305.14	321.99	348.22	347.35	377.45	392.95	157.69	254.31
41.1	65	78.5	80	84	87.5	90	324.66	344.18	374.89	386.44	423.38	448.01	196.98	321.64
42	89.5	95	96	97	97.5	98	68.98	72.05	73.43	71.47	74.94	73.96	45.32	19.32
43.2	83.5	92	93	94	95	96	254.14	273.28	280.16	271.53	284.06	283.52	155.71	67.59
43.1	63	77	79	83.5	86.5	89	415.79	449.58	491.23	578.18	561.80	628.02	246.73	356.60
44.2	62.5	75	77	81.5	85	88	670.72	726.15	799.87	820.46	880.36	926.14	399.34	549.22
44.1	62.5	75	77	81.5	85	88	664.92	717.94	790.82	803.62	873.18	920.20	390.47	550.86
45	100	100	100	100	100	100	51.26	56.09	56.09	51.99	52.93	52.12	33.04	10.70
48.4	62.5	75	77	81.5	85	88	660.99	713.05	785.43	797.15	866.35	913.08	387.63	550.44
46	86	94	95	95.5	96	97	207.46	226.77	230.37	225.02	232.50	232.77	135.57	62.82
48.3	62.5	75	77	81.5	85	88	641.70	688.91	758.85	770.07	837.62	882.21	369.89	565.76
47	83.5	92	93	94	95	96	212.26	232.93	238.80	241.38	252.45	253.11	137.57	77.47
48.2	62.5	75	77	81.5	85	88	652.67	697.87	768.71	781.76	848.18	887.99	371.68	588.40
48.1	62.5	75	77	81.5	85	88	538.05	577.61	636.24	643.92	712.93	760.84	284.36	559.70

Appendix H: Design Flow – Future

Future Conditions 12 hr AES

Flow Nodes	Areal Reduction Factor (%)	Peak Flow (m^3/s) 2 Year AES 12 hr	5 Year AES 12 hr	10 Year AES 12 hr	25 Year AES 12 hr	50 Year AES 12 hr	100 Year AES 12 hr	350 Year AES 12 hr
2	100	1.18	1.65	2.03	2.54	3.27	4.38	7.90
4	100	3.79	4.90	5.64	6.55	8.57	10.98	17.41
3.1	96	2.40	3.25	3.73	4.35	4.77	5.48	9.13
1	97.5	5.22	6.84	7.90	9.00	10.43	11.75	14.89
5.3	96	5.84	7.76	8.99	10.51	12.63	15.55	22.68
5.2	95	10.96	14.10	15.96	18.08	20.50	22.90	31.18
8.1	100	2.72	3.19	3.46	3.94	4.71	5.42	7.26
6	100	7.63	10.36	12.54	15.67	19.44	22.77	29.63
5.1	95	14.48	18.32	20.76	23.54	26.59	30.06	38.71
7.2	94	20.36	26.15	30.40	35.81	40.94	46.62	61.44
7.1	93.5	21.77	28.42	33.13	39.83	45.83	53.75	73.50
9.3	92.5	23.75	31.33	36.96	45.53	53.47	63.74	91.87
9.1	90.5	27.87	37.78	45.00	56.93	71.50	85.12	116.90
10	100	4.17	6.92	9.26	12.86	16.55	19.87	27.94
11.7	90.5	16.40	28.61	37.14	49.23	61.83	74.53	103.67
11.3	90.5	16.40	29.07	37.78	52.20	67.60	83.37	117.19
11.2	88.5	15.97	29.63	39.71	57.22	80.84	101.28	141.53
11.1	87.5	15.14	28.69	38.94	57.52	82.12	123.31	175.10
14	97.5	4.55	6.17	7.34	8.85	10.32	11.62	14.59
12	97.5	6.97	14.25	19.04	24.72	30.25	35.44	48.33
15.1	95	6.24	10.51	13.33	16.53	19.46	22.10	28.18
13.1	87.5	15.51	29.94	41.48	63.95	93.14	118.75	178.94
16.2	87.5	20.67	35.37	48.17	68.98	101.21	129.36	195.90
16.1	87.5	26.10	45.58	61.99	83.60	110.11	139.66	214.82
20	100	0.53	0.83	1.06	1.35	1.67	2.63	6.54
19	97.5	0.56	1.10	1.56	2.13	2.87	3.78	5.51
21.1	97.5	2.33	3.68	4.35	5.36	6.16	7.15	10.38
23.4	97.5	2.86	4.64	5.84	7.43	9.25	11.18	15.72
22	100	3.35	5.16	6.58	8.47	10.24	11.76	15.18
23.3	96	5.46	8.60	10.84	13.89	17.37	20.76	28.03
18.1	96	2.08	3.91	5.05	6.79	8.47	9.94	17.62
17	100	0.27	0.54	0.71	0.92	1.20	1.61	5.40
23.2	96	7.53	12.49	15.56	20.59	26.24	31.58	44.53
23.1	95	10.20	17.66	22.52	29.66	37.74	45.52	63.69
24	100	0.82	2.02	3.18	4.61	5.96	7.12	10.15
29	97.5	3.11	4.11	4.80	5.70	6.45	7.13	8.67
30.1	94	8.97	12.02	14.09	16.79	19.56	22.11	25.28
31	97.5	9.07	12.12	14.23	16.63	19.37	22.16	28.27
25.2	94.5	10.12	17.78	22.88	30.21	38.44	46.41	64.98
25.1	94	10.00	18.12	23.85	31.49	39.79	47.70	66.65

26	100	2.38	6.29	9.13	12.44	15.55	18.27	24.35
32.2	91.5	17.06	22.80	26.68	31.91	36.03	40.05	50.51
33	100	6.25	8.28	9.58	11.23	12.79	14.17	17.38
49.2	94	11.92	23.48	31.56	42.51	54.15	65.03	90.47
34.3	90.5	20.84	28.06	32.76	39.02	42.82	48.77	61.44
27	100	4.41	9.58	13.17	17.60	21.70	25.85	35.15
49.1	93.5	11.95	24.09	32.89	44.31	56.41	67.69	94.11
28.2	93.5	15.45	32.33	43.95	58.91	74.86	89.68	123.02
28.1	92.5	15.37	32.61	44.63	59.95	76.08	91.18	125.21
34.1	90.5	22.24	30.19	35.36	42.05	46.23	52.19	65.91
35.2	88.5	35.21	59.03	76.00	97.81	117.03	134.85	182.40
36	100	7.07	14.03	18.32	23.55	29.01	34.06	46.06
35.1	88.5	35.58	60.61	78.65	101.34	122.34	141.62	191.29
37.1	97.5	6.96	13.59	16.81	19.88	22.27	24.36	29.09
39.5	88.5	39.99	70.26	92.35	119.55	143.97	165.72	220.17
39.4	88.5	40.96	73.12	96.96	126.03	151.94	175.12	232.44
38	100	1.99	5.23	7.03	9.27	12.04	13.77	17.74
39.3	88.5	41.89	76.33	101.87	132.75	160.16	184.72	244.98
40	100	1.03	2.96	4.07	5.38	7.12	8.63	11.93
41.3	88.5	42.38	78.37	105.17	137.40	166.04	191.84	254.31
41.1	87.5	45.42	92.71	127.71	169.99	208.43	240.61	321.64
42	97.5	5.87	8.05	9.51	11.53	13.52	15.36	19.32
43.2	95	19.87	27.95	33.64	40.80	47.53	53.32	67.59
43.1	86.5	55.12	107.77	146.39	193.55	235.14	269.91	356.60
44.2	85	75.11	140.46	188.66	249.01	317.19	388.96	549.30
44.1	85	75.37	141.30	190.16	250.94	318.36	389.90	550.90
45	100	1.27	2.87	3.84	5.07	6.51	7.80	10.70
48.4	85	75.47	141.56	190.40	251.18	318.55	389.94	550.47
46	96	7.51	17.36	23.74	31.42	38.82	45.81	62.82
48.3	85	79.78	150.64	202.33	265.83	331.27	403.38	565.76
47	95	12.99	23.89	31.85	41.49	49.90	57.99	77.47
48.2	85	85.71	160.94	215.79	283.08	349.00	422.09	588.39
48.1	85	81.31	150.73	205.67	273.47	377.52	402.65	559.61

Appendix I: Regional Flow

Regional (Hurrican Hazel)

Flow Nodes	Areal Reduction Factor	Peak Flow (m^3/s)		
		Existing Conditions		Future Conditions
	%	2004	2018	2018
2	100.0	46.73	85.20	90.25
4	100.0	51.51	59.60	59.60
3.1	98.2	65.04	116.94	122.57
1	99.2	146.74	79.32	79.74
5.3	98.2	110.88	191.48	198.16
5.2	97.1	252.39	246.32	253.15
8.1	100.0	62.84	63.27	63.27
6	100.0	97.87	112.09	111.94
5.1	97.1	313.13	288.09	293.08
7.2	95.4	402.29	366.59	365.39
7.1	94.8	378.01	293.16	294.70
9.3	94.2	436.96	339.01	340.03
9.1	92.0	479.73	422.40	423.40
10	100.0	69.74	77.48	77.48
11.7	92.0	543.01	422.22	423.29
11.3	92.0	615.23	471.43	472.61
11.2	89.4	561.10	579.24	581.57
11.1	86.7	527.17	528.01	529.60
14	99.2	88.01	66.48	66.48
12	99.2	92.88	112.35	112.35
15.1	97.1	137.29	97.95	97.95
13.1	86.7	595.50	536.85	538.24
16.2	86.7	671.38	590.84	592.52
16.1	86.7	620.15	627.11	628.54
20	100.0	29.63	52.68	52.68
19	99.2	58.38	50.30	50.30
21.1	99.2	62.25	105.68	105.68
23.4	99.2	119.00	158.44	158.44
22	100.0	35.37	30.95	30.95
23.3	98.2	153.68	194.50	194.50
18.1	98.2	118.09	157.86	157.86
17	100.0	39.28	68.43	68.43
23.2	98.2	271.77	357.64	357.64
23.1	97.1	276.98	414.80	414.80
24	100.0	24.24	34.62	34.62
29	99.2	86.13	45.58	45.58
30.1	95.4	126.43	107.14	107.14
31	99.2	154.98	114.14	114.14
25.2	96.3	296.23	414.58	414.58
25.1	95.4	266.49	432.80	432.80
26	100.0	82.58	79.44	79.44
32.2	93.5	282.49	185.50	185.50

33	100.0	75.33	54.41	54.41
49.2	95.4	331.61	486.66	486.66
34.3	92.0	352.65	218.18	218.18
27	100.0	86.19	101.76	101.76
49.1	94.8	326.33	470.13	470.13
28.2	94.8	388.81	531.73	531.73
28.1	94.2	391.55	494.22	494.22
34.1	92.0	380.20	232.45	232.45
35.2	89.4	782.73	670.29	670.29
36	100.0	92.24	103.20	103.20
35.1	89.4	719.68	673.06	673.06
37.1	99.2	110.81	123.00	123.00
39.5	89.4	811.32	712.41	712.41
39.4	89.4	835.65	725.61	725.61
38	100.0	35.99	44.37	44.37
39.3	89.4	856.49	739.15	739.15
40	100.0	37.31	27.03	27.03
41.3	89.4	878.59	749.14	749.14
41.1	86.7	861.86	921.37	921.42
42	99.2	88.53	74.77	74.77
43.2	97.1	293.25	235.64	235.64
43.1	84.0	1146.02	1028.92	1029.08
44.2	82.4	1860.09	1572.27	1573.37
44.1	82.4	2043.81	1506.04	1507.39
45	100.0	71.18	23.88	23.88
48.4	82.4	1681.45	1497.64	1498.71
46	98.2	121.46	149.39	149.39
48.3	82.4	1728.34	1503.93	1505.38
47	97.1	167.00	178.40	178.40
48.2	82.4	1806.99	1550.14	1551.81
48.1	82.4	1694.32	1504.48	1506.40

Appendix J: Meeting Minutes

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Meeting Minutes

Subject	2017 Don River Hydrology Update
Date	January 12, 2017
Time	10:30 am - 1:00 pm
Location	AECOM Richmond Hill Office 4th Floor, 30 Leek Cresent, Richmond Hill, ON L4B 4N4
Attendees	Nicolas Lorrain, TRCA (NL) Rhianydd Phillips, TRCA (RP) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	January 13, 2017
Prepared by	Olivia Chung
Distribution	NL/RP/SR/BR/OC, Wiifred Ho (WH, TRCA)

Item	Description	Action By
1.	**Health and Safety**	
2.	**Introductions**	
3.	**Project Team**	
	· SR and NL introduced their team and roles in the project.	
4.	**Project understanding and work plan**	
	· NL indicated that WH was unable to attend the meeting due to injury. A conference call will be setup to discuss technical issues in the presence of WH in the week of Januray 15.	TRCA
	· SR inquired about the stream and rain gauge data quality, as well as the type of gauges. NL confirmed that TRCA has QA/QC all stream gauge data prior to transfer to AECOM and that the stream gauges are area velocity probes. NL suggested that AECOM to communicate any specific gauge data questions to NL during the review process. NL will follow up with TRCA hydrometrics team to clarify/resolve any issue.	
	· TRCA will provide the gauge location mapping to AECOM.	TRCA
	· SR inquired about the availability of radar data for precipitation. NL indicated that TRCA has radar data available upon request. NL also commented that radar data should only be used for qualitative assessment and not to be used to fill in any gaps in the precipitation data.	
	· NL indicated that additional water survey data is available upon request. However, the data is 1 – 2 year behind in the QA/QC process.	
	· SR inquired about TRCA's NexFlood model. NL commented that the NexFlood model was coarsely calibrated for specific flood clusters and its input and catchment delineation would not be appropriate for this study. In fact, hydrologic model resulted from this project will provide input for the next version of the NexFlood model.	
	· BR provided rationale for the level of details in catchment delineation. It was agreed that the level of detail would be a balance between accuracy and	

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usability and manageballility for subsequent end-users of the model.

- SR inquired about the Rouge and Humber model regarding catchment delineation. NL will provide AECOM with the draft Rouge report and the draft Humber model. NL also suggested AECOM to discuss the specifics and lesson learned in these two models with WH in the upcoming conference call.
- SR discussed challenges and past experience associated with modeling a collection of ponds, each individually serves relatively small drainage areas. SR inquired about the lumped pond approaching in the model. NL confirmed that TRCA is open to the idea as long as AECOM is able to provide sufficient justifications.
- SR inquired about ponds with missing documentations. NL indicated that TRCA has already exhausted all the data source in compiling the pond database. AECOM should make assumption for the ponds with missing data.
- NL indicated that all the ponds in the Don River Watershed were designed to adhere to a unit-release rate. Pond assumptions can be made based on pond footprint, drainage area and the unit-release rate.
- NL suggested AECOM to review the existing hydrology model regarding pond modeling.
- SR inquired about the dam operations. NL confirmed that it is possible for the dam to have more than one operation on a given event. Dam operation log will be provided to AECOM, along with any existing operating rules. TRCA
- SR discussed the accuracy of crossings information in HEC-RAS model, especially the bridge soffit data. NL commented that crossing information were primarily based on site visit and design information, not topographic survey. BR suggested AECOM to identify the critical crossing location based on floodplain mapping in order to determine whether and where site visit and survey may be required. TRCA will provide floodplain mapping in all available formats. TRCA
- SR noted that the floodplain mapping will also help to identify the crossings near headwater that are not include in the HEC-RAS model. AECOM will assess the hydrologic significance of these crossings and communicate the next step for these crossings with TRCA. NL suggested discuss the issue with WH.
- Eventually, the calibrated model will be run with design rainfall events. TRCA suggested the comparison of FFA results at stream gauges with design storm events, which may assist in determining the appropriate rainfall distributions for the final model.
- SR noted that the river profile in HEC-RAS will be reviewed to ensure that they represent the physical world. NL confirmed that the Lower Don HEC-RAS model was a HEC-2 conversion and the profile was created simply by connecting the cross-sections at crossings. Care should be exercised when using the HEC-RAS models.
- SR inquired about any TRCA standard/direction to incorporate climate change into the model. NL confirmed that TRCA currently does not have a specific standard for this and therefore it is not necessary for this project.

5. <u>Data shareing protocol</u>

- Data Agreement signed and external hard drive with background data transferred to AECOM. External hard drive will be returned to TRCA in the next meeting. AECOM
- NL suggested that further data transfer to be done through basecamp. TRCA will set up a basecamp group. AECOM will provide alternatives if basecamp is found to be insufficient for the purpose. TRCA

6. <u>Communication Protocol</u>

- SR is the main point of contact with AECOM
- NL and WH to be cc'd with all the correspondence

- NL suggested conference calls on a bi-weekly basis to maintain a constant dialogue. The calls are tentatively scheduled on Tuesdays at 9 am, starting Janurary 17. TRCA will set up the conference call and send out invites. — TRCA
- NL confirmed that it is acceptable for AECOM to directly contact the municipalities and Region of York for data requests if necessary.

7. Schedule

- SR inquired on any significant milestone date involving any 3rd party or stakeholder. NL confirmed that none is expected at the moment.
- OC will send an updated project schedule based on the actual start date. — AECOM

8. Other business

- TRCA is still collecting stream and rain gauge data and will be transferred to AECOM once all data has been QA/QC. Additional data to be provided to AECOM includes: — TRCA
  - Pond database and mapping
  - NexFlood forecasting model
  - Available draft Rouge and Humber report and model
  - Dam operation records
  - Floodplain mappings (sheets, CAD and GIS)
- Modelling output to be provided in GIS format
- WH will provide details on standard modeling process/procedure established through the Rouge and Humber model devleopment. — TRCA
- NL informed that TRCA will retian a 3rd party to conduct a peer review on the model upon completion.
- OC will provide a detailed breakdown of the workplan. — AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update
Date	January 17, 2017
Time	9:00 am - 10:00 am
Location	Conference Call
Attendees	Nicolas Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	January 17, 2017
Prepared by	OC/BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Infiltration** · The Rouge model used standard Green & Ampt parameters for all calibration events, rather than calibrating the parameters based on moisture conditions. · The Rouge model used 25mm event hot start and standard drying time in its design event modeling, which was felt to represent AMC II conditions. There is no clear precedent or standard approach to providing G&A parameters that reflect typical AMC II conditions. · The Humber VO2 model assessed AMC based on rainfall prior to the event, then used theortical relations between antecedent rainfall and infiltration parameters. · AECOM will assess the infiltration parameter sensitivity for the rural area in the process of model development, evaluating how antecedent moisture conditions can affect results. If it is established that antecedent moisture is critical in calibrating the model and producing design events, AECOM will develop and discuss feasible approaches with TRCA. · If antecedent moisture condition assumptions are critical for design events, AECOM will consider an approach to establishing design AMC conditions through analyzing the historic range of conditions for several real events.	AECOM AECOM
2.	**Rainfall Data** · TRCA confirmed that the rain gauge coverage is more extensive in the Don watershed than the Rouge · TRCA does not have a standard requirement for how to distribute rain gauge information across the watershed as a whole. There are a number of different possible spatial techniques (Krieging, Spline techniques, inverse distance weighting…). · The Rouge model used thiessan polygon to assign rain gauges to subcatchments, while the Humber model utilized VO's built-in rainfall distribution techniques. · AECOM's past experience is that the success of calibration is largely dependent on the rainfall data.	

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	· When selecting calibration and validation events, preference will be given to the events with less spatial variation to minimize uncertainty.	
3.	TRCA will provide the technical memos by AMEC for the Humber Model and the Rouge hydrology report, as well as the Watershed Report Cards.	TRCA
4.	**<u>Calibration</u>** · TRCA suggested that the May 2000 event would be a good candidate for calibration events. · TRCA confirmed that summer thunderstorms are the critical events for the Don River watershed. There is likely no need to analyze spring events. Calibration and validation events will be selected between April and October. · TRCA noted that the routing elements of the watershed may behave significantly different at different times of the year (reflecting changes in overbank roughness). AECOM will consider characterizing the valley corridor conditions according to the different time of the year during calibration · TRCA confirmed that the goal is to have 5 calibration events and 5 validation events. · TRCA noted that it is important to consider watershed conditions at the time of the event, if calibration/verification events are used which occurred some time in the past. TRCA confirmed that historical airphoto and official plans are available upon request. AECOM will request the relevant data after a list of calibration and validation events has been compiled in order to appropriately characterize subcatchments at the time of the historical events. · AECOM will use the WaPug guidelines for evaluating goodness of fit, initially focusing on getting the runoff volume accurate.	AECOM AECOM AECOM
5.	**<u>Model Parameters</u>** <u>Soil Characteristics</u> · TRCA commented the Rouge model was felt to improperly characterize soil conditions based on using the surficial geology mapping. TRCA feels that this mapping is more useful for GW assessments, but not the most appropriate for surface hydrology. The preference is to use OMAF soil mapping, and only use the surficial geology mapping to fill in gaps if required. <u>Overland Flow Lengths</u> · A discussion occurred regarding the difficulties in using SWMM for catchment scale modeling in rural areas, relating to the 'width' parameter. As the catchment becomes larger, this parameter loses the physical interpretation, and must become strictly a calibration parameter (similar to number of linear reservoirs in a HYMO model). TRCA has shown that the overland length can have a very large impact on peak flows at the local catchment level. AECOM to assess at the watershed level; AECOM's initial suggestion was that limiting the catchment size may be able to preserve some of the physical meaning of this parameter; AECOM to further assess as the study progresses	AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	January 31, 2017
Time	9:00 am – 9:45 am
Location	Conference Call
Attendees	Nicolas Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	February 1, 2017
Prepared by	OC/BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Background data review** · TRCA confirmed that the current and future landuse GIS data were extracted from municipalities' official plans, with future conditions reflective of a 2031 planning horizon. TRCA's planning department has reviewed, discussed with area municipalities, and signed off on land use—little value expected in AECOM pursuing further refinement with area municipalities – not recommended. TRCA to confirm that info in future land use shape file is based on 2031 planning horizon. · AECOM requested for the watercourses GIS shapefile to be included in next data transfer. AECOM's intent is to use the watercourse to define low flow channel and junctions location. TRCA will provide the watercourse GIS data but noted that the watercourses GIS information has not been updated since the early 2000s and that AECOM should use the information with caution. For example, watercourses in the headwater areas may no longer exist due to development. · AECOM proposed to use the river definition in the provided HEC-RAS models as alternative. This approach can also ensure that the structures can be easily integrated into the PCSWMM model. TRCA noted that while most of the East Don and West Don HEC-RAS models north of Steeles Avenue have the river reaches properly defined, other models, especially in the Lower Don area, were developed using old topographic data and may not represent the current watercourses accurately. · AECOM has completed a preliminary review of the HEC-RAS models provided and mapped the coverage of the models. It was noted that there are a few instances where the models covers the same river reaches. AECOM inquired about the precedence of model in such cases. No clear direction in general- but if AECOM proceeds to use, will discuss specific instances with TRCA · AECOM inquired about the availability of the GIS information regarding paved area (buildings, driveway, parking lots etc.). TRCA responded that in-house paved area information is not available. TRCA will contact municipalities regarding paved area.	TRCA AECOM TRCA

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	· In the case that paved area data is not available, AECOM will proceed to define impervious area based on airphoto as outlined in the proposal. AECOM will provide a histogram showing the range of percentage imperviousness for different land use obtained by this method to compare to the table included in the RFP's TOR. · AECOM inquired about whether TRCA has specific direction on the use the hummocky terrain and Oak Ridges Moranine boundary GIS data. TRCA indicated that these two layers are provided as supplemental info and might not be critical to use if hydrologic parameters are adequately defined by other ways – but they can serves as cues in the model development process. · TRCA inquired about AECOM's experience regarding translating model between HYMO-based and SWMM-based models. In particular, the representation of total and directly connected imperviousness in HYMO in SWMM. AECOM, although has not conducted direct comparison between the two model engine on their treatment on impervious area, suggested to utilize the subarea routing and percentage routed properties of a subcatchment in SWMM to differential indrieclty connected impervious areas from that of the directly connected ones.	AECOM
2.	**<u>Basecamp</u>** · TRCA confirmed that the intent of basecamp is data transfer, and we are not expected to use the project management functionality of basecamp. Email communication, phone, and scheduled meetings will be sufficient for this project.	
3.	**<u>Stream gauge data availability</u>** · AECOM inquired whether TRCA has developed rating curve for the gauges that only record water level. TRCA responded that most of the water level gauges are used for flood forecasting. Some of them may have rating curves developed. When providing flow data, TRCA will follow up and provide any supplemental info such as available rating curves which might be required to translate recorded depth information to flow. · It was agreed that pseudo-stage-storage-discharge curve can be developed with HEC-RAS if needed. · TRCA informed that monitoring prior to 2005 was conducted by Water Survey Canada (WSC). The gauge coverage is not as good as the current network. Unless there is a exceptional large event prior to 2005, it was suggested that AECOM should attempt to use post-2005 events for calibration, and only use pre-2005 events for validation, if possible. · AECOM suggested that there may be limited use in specific events prior to 2005 for calibration, since adequate rainfall information will not be available. The best use of WSC data could be used in frequency analysis, confirming flows from design events in the calibrated model.	TRCA
4.	**<u>PCSWMM difficulty in processing large amounts of LiDAR data</u>** · AECOM has experienced "out of memory" error from PCSWMM when attempting to process the LiDAR DEM on the 32-bit version of the software. AECOM inquired about whether the consultants on the Rouge and Humber project has experienced the same problem. · TRCA informed that the Rouge and Humber projects do not have LiDAR data. · It was known that the 64-bit version of PCSWMM is more efficient in its runtime memory usage and may be able to process the large LiDAR DEM.	

	· AECOM will 1. Try to process the data on a computer running the 64-bit version of PCSWMM. 2. Contact CHI regarding the issue. 3. Examine the feasibility of clipping the DEM and using smaller subareas with PC SWMM 4. Process the LiDAR data in ArcGIS if the above fail.	AECOM
5.	**<u>Block 44 Development</u>** · TRCA informed that Block 44 has been under on-going development and the change in land use may not be reflected in the GIS data and the municipalities latest Official Plan. It was suggested that a sensitivity analysis be conducted to the hydrologic response of the closest gauge to the catchment parameters in this area.	AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	February 28, 2017
Time	9:00 am – 9:50 am
Location	Conference Call
Attendees	Nicolas Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	March 1, 2017
Prepared by	OC/BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes – action items** · TRCA reviewed and approved the minutes for the January 31, 2017 phone call. · TRCA indicated that the change in land use between current and future scenario is not significant and it is not essential to know the actual year of planning horizon for the future scenario for the current project. · TRCA is still collecting background data to be transferred to AECOM. It was noted that o Dam operation data were collected for the 2005 – 2016 period. Some of these historic data were written manually and may be difficult to decipher. o Stream gauges data will be provided in 3 different sets. Some sets will have "corrected" discharge values, with generally more confidence in discharge, reflecting aspects such as more detailed field investigations into cross sections and rating curves, greater amounts of QA/QC, etc. Some sets will have discharge and water levels in raw format. AECOM to consider relative accuracy of data received for different locations when calibrating the hydrologic model. o TRCA will provide the gauge location shapefiles. · AECOM inquired about the process to produce the corrected stream gauge data. It was agreed that TRCA can connect AECOM to their hydrometric staff for specific inquires after the initial review of the gauge data. · When considering the relative accuracy of the calibration at various locations, AECOM to consider which gauges produce flows based on large extrapolation of the rating curves developed from actual observation and measurements. · AECOM indicated that knowing the data integrity will also aid in the calibration process in determining whether a calibrated results was an acceptable match to the observed data.	TRCA AECOM TRCA

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2.	**<u>Background data review</u>** ***Land use*** · AECOM compared the data provided in shapefiles for current and future land use and concluded that growth is insignificant relative to the entire Don River Watershed. · AECOM noted a few minor imperfections in the land use dataset, although none of them would result in any significant impact on the model development and calibration. (handout summarizing this attached to meeting agenda). · TRCA noted that with the exception of Block 44, changes in imperviousness due to change in land use is insignificant during the period where monitoring data is available for calibration and validation. · Discussion regarding whether it is required to correct the existing condition land use in the model for calibration, to reflect the land use that existing at the time of the rain event used for calibration. TRCA suggested that AECOM can focus the land use change assessment on the drainage areas to individual stream gauges. Based on this, the significance of the land use changes can be assessed, and a decision can be made regarding whether these land use changes need to be reflected in the model for calibration. · To this end, AECOM indicated that historic orthophoto in 5 year increment would be useful in understanding potential discrepancy between calibrated and observed flow related to changing land use. TRCA will send AECOM a list of what orthophotos can be provided. AECOM to review this list along with their requirements, and select any additional orthophotos that they wish to be provided. ***Soil*** · AECOM noted that the southern, largely urbanized portion of the Don River Watershed does not have soil type classification. AECOM proposed to extrapolate the surrounding soil type to fill in the gap. · It was agreed that infiltration is not a big factor in the water balance in that area. Further, based upon TRCA's experience with the Rouge hydrology update, the initial moisture deficit characterization, related to antecedent rainfall, as opposed to the infiltration parameters, is the most relevant calibration parameter related to rainfall abstractions in the pervious areas. · TRCA will follow up with their staff regarding infiltration map. · TRCA will provide AECOM with the email correspondence and technical memos from the Rouge hydrology update as reference and guidance related to rainfall abstractions in pervious areas. ***Orthophotos*** · TRCA informed that the City of Toronto orthophoto to be provided is of 30cm resolution. AECOM confirmed that the resolution is sufficient for characterization of impervious area.	TRCA AECOM TRCA TRCA

3.	**<u>Utilize LiDAR to estimate impervious area</u>** · AECOM presented its proposed methodology and results from previous projects to identify impervious area by performing image classification on orthophotos. · AECOM inquired about the approach of identifying impervious surfaces based on LiDAR directly. TRCA responded that the LiDAR-based method is not ready for implementation yet and that the current LiDAR data was not collected with such application in mind and therefore might not be able to be employed in the LiDAR-based method. · TRCA informed that a comparison may be conducted internally to compare AECOM's results with the LiDAR-based methodology in the future. · TRCA indicated that it would be acceptable for AECOM to proceed with their proposed methodology. · TRCA noted that due to the difference in property characteristics between areas developed in different eras, it would be expected that the resulting average imperviousness would be different for the same land use across different municipalities; AECOM will show this comparison, after completion of the exercise. · AECOM confirmed that the resulting imperviousness would be parcel-based, as opposed to a general lookup table based on land use.	AECOM
4.	**<u>Subcatchment delineation – PCSWMM vs GIS (ArcHydro)</u>** · AECOM confirmed that the 64-bit version of PCSWMM cannot process the DEM of the entire watershed. · AECOM presented the results of subcatchment delineation with a clipped out portion of the DEM using both PCSWMM and ArcHydro. AECOM noted the difference in the delineation process, as well as the pros and cons of each software. (Table distributed with agenda). · TRCA will review this evaluation, and provide any comments or input regarding software to be used for subcatchment delineation and parameterization. · AECOM informed that the DEM will likely have to be processed in sections. TRCA suggested that AECOM will need to ensure that the boundaries between the sections are aligned properly to avoid overlapping or omitting drainage areas.	TRCA AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	March 14, 2017
Time	9:30 am – 9:45 am
Location	Conference Call
Attendees	Nicolas Lorrain, TRCA (NL) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	March 15, 2017
Prepared by	OC/BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes – action items** ***Data collection status*** · TRCA will complete all data collection by the end of this week and is planning to send all collected data to AECOM in one transfer next week. · In order to move forward with the project, AECOM proposed TRCA to transfer any available data next Monday even if there are still outstanding data to be collected. · TRCA will provide an update on the data collection status by Friday, March 17 and transfer any available data to AECOM starting next Monday, March 20. ***Orthophoto*** · TRCA noted that their orthophoto database goes all the way back to the 40s and that the orthophotos prior to the 1990s are not georeferenced. · AECOM clarified that historic orthophotos will be used to estimate how the land use within the watershed has been changed from current conditions. They will be used after the suitable calibration and validation events has been selected, as well as during frequency analysis of the long-term monitoring data. For now, a list of available orthophoto will be sufficed. AECOM will request specific orthophotos after the monitoring data has been reviewed. ***Subcatchment delineation – PCSWMM vs ArcHydro*** · TRCA has processed the Don Watershed LiDAR data internally and results were similar to AECOM's trial run. · It was agreed that both PCSWMM and ArcHydro result in similar delineation and are equally acceptable tools. · TRCA prefers the use of ArcHydro moving forward for this project for the added functionality and consistency with other projects within the watershed. · TRCA informed that its staff found it too difficult to process the 0.5m-DEM and therefore a 1m-DEM was used. TRCA noted that the	TRCA TRCA/AECOM

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	delineation results based on the 0.5m- or 1m-DEM are essentially the same for the purpose of this project. · TRCA noted that as part of the in-house delineation process, the DEM was refined by burning in the watercourses and adjustments were made at the culverts and embankments. · To ensure consistency across different projects, TRCA will send the delineated subcatchments, as well as the refined LiDAR, to AECOM in the upcoming data transfer. · AECOM will refine the TRCA subcatchments based on the flow gauge and pond locations. · TRCA can connect AECOM to their staff for specific inquires after the initial review of subcatchments.	TRCA AECOM
2.	**<u>A.O.B.</u>** ***Project Schedule*** · In view of the delay in background data collection, AECOM proposed to revise the project schedule. · It was agreed that AECOM will provide TRCA with a revised project schedule based on the date when the background data are provided to AECOM. ***Invoice*** · TRCA noted that no invoice has been received so far. · AECOM confirmed that an invoice will be prepared for next month.	AECOM AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	March 28, 2017
Time	9:00 am – 9:30 am
Location	Conference Call
Attendees	Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	April 4, 2017
Prepared by	OC/BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes – action items** ***Data collection status*** · AECOM confirmed that additional data has been received through basecamp and is in the process of reviewing the data. · TRCA confirmed that there are still outstanding data being collected and will transfer to AECOM as soon as they become available. ***TRCA Subcatchments*** · TRCA noted that the 30 ha and 50 ha delineation was based on the same LiDAR data set. However, the 30 ha delineation provides more details and conforms to drainage features such as ditches and MTO ponds. · TRCA noted several locations, including Downsview station and along major highway and bridges, that the subcatchments delineation may not be entirely accurate and should be subjected to further review. · AECOM noted that the 1m x 1m LiDAR has not been provided along with the subcatchments. TRCA will follow up. ***Dam Operation Records*** · TRCA noted that dam operation record may be difficult to decode. The discharge will need to be calculated based on the recorded head/depth and the gate opening (in inches). The discharge curve can be found in the operation manual provided as part of the data transfer. ***Paved Area*** · TRCA confirmed that building footprint GIS data is available and will be provided to AECOM in next data transfer. · TRCA agreed that AECOM can contact municipalities to obtain other types of paved area, such as edge of pavement, driveways etc. ***Historical Orthophoto*** · It was agreed that AECOM will request for specific years of orthophoto after screening the monitoring data for suitable	TRCA AECOM TRCA AECOM TRCA AECOM AECOM/TRCA

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	calibration and validation events. TRCA will then provide the closest available orthophoto requested.	
2.	**A.O.B.** · It was agreed that TRCA and AECOM will maintain a continuing dialogue for any matters regarding the project.	

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	April 11, 2017
Time	9:00 am – 10:30 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	April 14, 2017
Prepared by	OC/BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · TRCA has reviewed the previous minutes and has no comments.	
2.	**Data review** · AECOM will provide the revised table for tracking data transfer status. · TRCA informed that request for building footprint data has been submitted to the GIS department. Data should be available within the coming week. · TRCA informed that the gauge location shapefile and 1m x 1m LiDAR are readily available and will be provided to AECOM.	AECOM TRCA TRCA
3.	**Pond catchment area** · AECOM has reviewed the pond modeling approach in the NexFlood Model. It appears that the NexFlood model was intended to simulate the function of the collective ponds and the physical parameters of subcatchments (such as catchment area) are not necessarily accurate. TRCA confirmed that it was the case. · AECOM presented a proposed approach to model ponds in the current study and inquired whether TRCA felt the proposed approach had the proper level of detail. It is a fairly detailed approach, and AECOM's estimate was that it would take approximately 2 weeks to implement. TRCA felt it was appropriate - AECOM to keep TRCA involved in how implementation is progressing, and discuss progress / any obstacle, etc. · TRCA informed that the pond GIS information include the functions of the individual pond and suggested that AECOM could exclude ponds that were designed to provide quality and/or erosion control only. AECOM to review and advise. · TRCA further suggested that ponds in remote location far away from stream gauges and with small catchment areas can potentially be excluded as well- depending on their influence on flows at points of interest in the model. AECOM will be able to assess the pond	AECOM AECOM AECOM

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	locations relative to the stream gauges after receiving the gauge location GIS data from TRCA. AECOM to review and advise. · TRCA noted that sufficient documentation is required for ponds that are lumped in the model. · AECOM will report progress on pond screening and finalizing the pond modeling approach after reviewing gauge locations.	AECOM AECOM
4.	**<u>Drainage lines crossing highways/railroads</u>** · Confirmed some findings regarding TRCA subcatchment boundaries along highways/railroads that TRCA mentioned during last call. AECOM to continue confirming catchments and flow paths.	AECOM
5.	**<u>Preliminary screening of road crossings for significant routing/attenuation</u>** · AECOM presented the preliminary process of screening crossings to be included in the model. · AECOM will send the crossing screening table to TRCA for review AECOM's proposed approach.	AECOM
6.	**<u>Other items</u>** · AECOM will provide an updated project schedule based on the changes in data collection timeline.	AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	May 11, 2017
Time	9:00 am – 9:50 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	May 12, 2017
Prepared by	OC/BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · TRCA has reviewed the previous minutes and has no comments. · AECOM will update the data transfer tracking table and forward to TRCA · Road crossing screening o TRCA suggested including further upstream cross sections in the road crossing screening process. For instance, there may be cases where an upstream surface elevation indicates the presence of a ponding and storage/attenuation upstream of the crossing. o AECOM responded that the purpose of the screening is to determine whether a crossing has any routing impact, in the above scenario, any storage would be characterized by the conduit cross section. o TRCA suggested AECOM to finalize the road crossing screening table and forward to TRCA for comments and feedback.	AECOM AECOM
2.	**Data review** Rain gauge spatial coverage · AECOM pointed out that a portion of the southeast quadrant of the watershed is not covered by any rain gauge. Precipitation data will have to be extrapolated, or assumed equal to the closest gauge, in order to cover that area. · TRCA was suggested that rain gauges in the Highland Creek/Rouge River watershed could be used to supplement the current coverage. Rain gauges operated by the City of Toronto as part of its basement flooding protection program could also be a source to fill in the gap. · TRCA confirmed that there is no TRCA rain gauge in the Highland Creek watershed.	

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	· AECOM will provide a map indicating the City of Toronto rain gauges that could be used to supplement the current set of rain gauges, as well as AECOM's contact person in the City from the basement flooding study to acquire monitoring data. · TRCA will follow up with the City to obtain additional rain gauge data. Stream gauge data temporal coverage · AECOM noted that there are a couple more gauges operated by WSC within the Don River watershed. These gauges are discontinued, and will not be useful from the standpoint of model calibration. Nevertheless, this historical data can be used for frequency analysis, and for comparison with active upstream and downstream gauges to verify the model. AECOM has acquired the data from these gauges, so there is no additional data request to TRCA. · TRCA commented that the flow at Todmorden gauge would be influence by dam operation. The dam was constructed in 1973. It was agreed that the data should be divided into pre-dam and post-dam period when conducting analysis. · It was noted that was not good agreement between frequency analysis and design event simulation results in the Rouge and Humber hydrology update. · AECOM noted that frequency analysis would be performed on all available gauges. However, emphasis may be put on the results of certain gauges, subject to gauge data quality and other factors. · TRCA informed that the frequency analyses conducted for Etobicoke Creek and Duffins Creek worked out better than the other studies. These frequency analyses were focused on single gauges with long period of record, and a large spectrum of design storm distributions were assessed to find the most suitable comparison to the FFA flows. TRCA will forward the Etobicoke Creek / Duffins Creek hydrology update reports to AECOM. · It was also noted that the RFP stipulates the consultant to provide the frequency analysis flow to a 25-year event (post meeting note: 50-year) and that the margin of error increases with larger events. TRCA noted that the design storm flows for the 2- and 5-year events in the Humber are typically closer to the FFA results; the design storm 10- and 25-year flows are typically far larger than the 95% level of confidence for the FFA results; and the 100-year design storm flows still tend to be much larger than the FFA estimate, but fall within 95% confidence limits of the frequency analysis. · It was agreed that further discussion on frequency analysis will be brought up again in later phase of the project.	AECOM TRCA TRCA
3.	**<u>Pond screening</u>** · AECOM noted that most of the ponds' drainage area can be delineated with a finer channel definition. · AECOM noted a few data inconsistency in the pond data that required manually going through the available documentations in order to ensure data accuracy. · AECOM presented a pond screening table to document the process and rationale of excluding ponds or lumping multiple ponds as one in the model. This screening Table will be provided in the final report.	

	· AECOM provided a table summarizing the number of ponds for which reports and design details are available. TRCA thought this number seemed lower than expected; TRCA will review and confirm whether more documentation is available for additional ponds. AECOM will send TRCA the latest pond location shapefile, which includes fields summarizing data availability for each pond. TRCA will review the information and confirm whether there is additional information.	AECOM TRCA
4.	**<u>Other items</u>** · TRCA informed that the funding to the Don Flood Protection Work will be announced in the coming weeks. Once that happens, there will be a real push to get the flow and design information in place for the Don River Watershed, especially in the Lower Don. · TRCA commented that, depending on how the project progresses, AECOM may be required to prepare a technical memo focused on the model calibration and validation, have TRCA sign off the memo, and run the Regional storm before other tasks in order to provide a Regional storm flow in a timely manner. · AECOM commented that a qualifier may be required to be attached to such release of flow results. · AECOM inquired about the implication to the project with the above reordering of tasks, in the case that some developers/stakeholders are not content with the updated Regional event flow. · It was agreed that if the Regional flow is significantly different from that of the previous hydrology model, AECOM will be required to provide and document rationales for the difference. · TRCA noted that its engineering department fully acknowledges that there may be difference in flow between the current model and the previous. It is not the intent of current model to match the flow in previous model, as long as everything is well-documented, verified and defendable. · TRCA will have a meeting regarding the flood protection work and will provide AECOM and update of its status early next week.	TRCA

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	May 23, 2017
Time	10:15 am – 11:00 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR)
Prepared	May 23, 2017
Prepared by	BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · TRCA has reviewed the previous minutes and has no comments. · AECOM has updated the data transfer tracking table and forwarded to TRCA on May 12 · Road crossing screening – AECOM still finalizing screening table—will forward to TRCA for comments when complete · Rain gauges-- AECOM has plotted City of Toronto gauges, and done preliminary assessments for 'catchment' area per rain gauge with existing TRCA gauges, and after including a limited number of City gauges. AECOM will forward a plan showing recommended additional gauges, period of interest, with City of Toronto contact. TRCA to follow up with City. · Status of lower Don flood protection work o TRCA met with TRCA management team for lower Don flood protection works. o TRCA has developed a strategy for interim flows for the lower Don flood protection works, in advance of completion of the present study. The interim flows for lower Don are proposed to consist of unrouted flows from an upstream reach of the 2004 hydrology update, which would result in a 10% increase in flows at the mouth (1860 m3/s) along with a 0.5 m freeboard requirement. o TRCA made it clear that this is not a 'target' for the present study. o TRCA to meet with Waterfront Toronto and City of Toronto to gain acceptance of this interim flow. AECOM not required to be present at this meeting, but may be required at subsequent meeting(s) with Waterfront Toronto and City of Toronto—TRCA will advise.	AECOM AECOM/ TRCA TRCA

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	o TRCA advised that land use in lower Don area is currently industrial, but should be changed to reflect future planned land use scenarios for lower Don (which are contingent on flood protection works). TRCA will forward recommended land use to AECOM. o TRCA advised that the calibration of the Don model will be peer reviewed – TRCA currently setting up procurement for the peer review process	TRCA
2.	**<u>Pond Screening</u>** · AECOM is currently lumping 12 ponds into 5 ponds · Originally 190 ponds were identified. AECOM currently proposing to model 120 ponds, and not model 57 based on understanding of current function. AECOM still deciding what to do for 6 ponds. · AECOM to forward the current table created to summarize pond screening and pond info- AECOM to post on BaseCamp. This is a working document, in progress. · In the previous meeting, AECOM provided a table summarizing the number of ponds for which reports and design details are available. TRCA thought that the ponds with reports and design details seemed lower than expected; AECOM has sent TRCA the latest pond location shapefile, which includes fields summarizing data availability for each pond. TRCA will review this, along with the pond screening posted on BaseCamp, and confirm whether there is additional information that AECOM is missing for ponds	AECOM TRCA
3.	**<u>Road Crossing Screening</u>** · AECOM is continuing completion of the road crossing screening Table; an initial portion was previously sent to TRCA. When complete, AECOM will forward the complete table to TRCA for comments.	AECOM
4.	**<u>Catchment Delineation</u>** · AECOM has delineated catchments to ponds using final channel definition, with processing of the DEM. · AECOM still assessing the degree that highway barriers /rail grade separation will be built into the conditioned DEM (as walls), or addressed by manually editing catchments	
5.	**<u>Upcoming Work</u>** · Processing ortho photos for imperviousness o There have been previous discussions about AECOM requesting historic ortho photos, if/when required. AECOM has also now flagged potential calibration events. AECOM will review the dates of these events, the location of gauges, and historic development. AECOM will request specific ortho photo dates, if required for model calibration. o There was pervious processing of orthophotos for the Don watershed plan – approximately 10 years ago. TRCA expects that the current work will be more accurate, but will forward the previous for comparison · Review of flow data	AECOM TRCA

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	June 6, 2017
Time	9:00 am – 9:35 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	June 7, 2017
Prepared by	BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · AECOM will finish the road screening table and forward to TRCA for comments. · AECOM will finalize the additional rain gauge data request and forward to TRCA. Further discussion in the next agenda item. · AECOM has uploaded the pond screening table to Basecamp subsequent to previous conference call. TRCA has returned comments and flagged the ponds that TRCA will gather additional information. · AECOM will request the years of ortho photo once calibration and validation events selection is complete.	AECOM AECOM TRCA AECOM
2.	**Rain gauges** · AECOM presented a map showing TRCA and City of Toronto rain gauges, and highlighted the City of Toronto gauges have be selected to improve the rain gauge coverage of the watershed. · TRCA inquired about the additional gauge selection criteria. AECOM responded that the selection was largely subjective to make sure there are rain gauges for each stream gauge drainage area. AECOM is aware of the optimal rain gauge density recommended by the Humber Hydrology Update and have reviewed the cited literature. It was felt that a standard rain gauge density is not applicable in the current project. · AECOM noted that coverage for the area north of Steeles Ave could be improved with rain gauges operated by City of Vaughan, Town of Richmond Hill and City of Markham. TRCA will follow up with its official contacts at the municipalities.	TRCA
3.	**Review of flow data** · AECOM presented a preliminary review of the flow data. AECOM indicated that stream gauges data are limited prior to 2013.	

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	Therefore, calibration and validation event selection will focus on events from 2013 onward. AECOM will have to relax the 35 mm total rainfall threshold and the spatial uniformity requirement in order to gather enough recent events for model calibration and validation. · AECOM noted that only water level was available for two of the stream gauges and that other gauges data have data gap that needs to be filled. AECOM requested TRCA to provide available rating curve and presented a general methodology to develop pseudo-rating curve in the cases where rating curve is not available. TRCA will follow up with its staff to obtain the rating curves. · AECOM also noted that the WSC stream gauges data is still outstanding. TRCA responded that requests has been sent to WSC and is waiting to be processed.	AECOM TRCA
4.	**<u>Catchment delineation and ortho photo processing</u>** · AECOM provided updates on the current status of catchment delineation and ortho photo processing. TRCA suggested that AECOM can send the pieces to TRCA for comments and feedback as they are completed prior to the actual model assembly. · AECOM noted that model assembly can proceed before data collection is complete. TRCA agreed to the proposed workflow.	
5.	**<u>Other items</u>** · AECOM inquire about whether TRCA has a checklist for purpose of the peer or overall review. It would be beneficial for AECOM to have a copy of the checklist to ensure the deliverable meets the expectation. · TRCA will forward AECOM a copy of the RFP of Rouge peer review and the Etobicoke Creek peer review.	TRCA

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Meeting
Date	July 5, 2017
Time	10:00 am – 11:30 am
Location	TRCA Offices
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR)
Prepared	July 17, 2017
Prepared by	BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · AECOM and TRCA reviewed the previous minutes. There are no additional comments, and some action items are continuing, which will carry forward in subsequent minutes. · Road crossing screening – AECOM has completed in draft and has posted on Basecamp. TRCA to provide initial comments. AECOM expects the process of determining which road crossings to include in the model to be iterative; initial model runs will look at which of the initial crossings modeled create attenuation in the flood estimate, and the results will be used to evaluate if additional crossings are required. · Rain gauges-- AECOM has forwarded a plan showing recommended additional gauges, period of interest. TRCA identified opportunities for additional gauges in the catchment area north of Steeles. TRCA to follow up with City (Dave Kellershohn), Vaughan, Richmond Hill, and Markham	TRCA AECOM TRCA
2.	**Pond Screening** · AECOM is currently lumping 12 ponds into 5 ponds · Originally 190 ponds were identified. AECOM currently proposing to model 120 ponds, and not model 57 based on understanding of current function. AECOM still deciding what to do for 6 ponds. · AECOM has posted on BaseCamp. · TRCA has gone through many of the ponds, highlighting as either as green or yellow. Green highlighted rows indicate ponds where TRCA has reviewed AECOM's information and agreed that AECOM should proceed on this basis for the pond. Yellow highlighted rows are ponds where TRCA can potentially provide more information. TRCA will update and finalize their review.	TRCA

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3.	**<u>Frequency and Trend Analysis</u>** · AECOM showed preliminary frequency analysis results for east, west, and lower Don WSC gauges. Plots were shown for peak summer flows, split by pre and post 1973 (construction of G. Ross Lord dam) · AECOM showed preliminary results for trends in peak flow, and trends in monthly flow volumes. Non-stationarity of flow may be due to changing watershed conditions or differences in rainfall volumes/patterns	
4.	**<u>Catchment Delineation</u>** · AECOM posted preliminary delineation on Basecamp. · AECOM still assessing the degree that highway barriers /rail grade separation require manual editing for catchment. AECOM showed several areas where we are confirming how the catchments drain across major corridors. · More information on specific ponds could modify catchment boundaries further · TRCA discussed the large rail area north of Hwy 7, between Keele St and Creditstone Rd. TRCA suggested it might be possible to characterize the rail drainage with a lumped catchment for the whole rail yard, with a single culvert and single spill towards Hwy 7. There are studies on file dealing with this area – TRCA will pull these reports or info from these reports and either provide to AECOM or advise	TRCA
5.	**<u>Imperviousness</u>** · AECOM conducted spot reviews of imperviousness for several catchments, comparing the impervious area raster file with ortho photos. Several of these comparisons were shown at the meeting. · The accuracy of the impervious area delineation in the raster file varies with the quality of the orthophoto used to create it. · In all areas, AECOM found that the imperviousness in the raster file we developed was extremely accurate compared to orthophotos · AECOM's approach will be to have the actual existing imperviousness used for each catchment when calibrating the model. The directly connected impervious portion will be calibrated (percent routed between impervious and pervious areas)	
5.	**<u>Upcoming Work</u>** · AECOM will provide a Table of Contents for TRCA's review · Model network creation · Subcatchment adjustments · Pond, routing elements, subcatchment characterization · Creation of suitable hydraulic reference points – major confluences, major structures, flood vulnerable areas	AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Meeting
Date	August 9, 2017
Time	9:00 am – 10:00 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	August 9, 2017
Prepared by	BR
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · AECOM and TRCA reviewed the previous minutes. There are no additional comments, and some action items are continuing, which will carry forward in subsequent minutes. · Road crossing screening - TRCA has provide comments – identifying a number of additional cross sections recommended, based on (a) TW also expected during lower return period flows, more likely to be seen during calibration; and (b) reaches that were overlooked. AECOM will move forward with the updated list of reaches to be modelled. May be refined as sensitivity analysis is performed during model runs. · Rain gauges - TRCA has received rain gauge info from City of Toronto, Richmond Hill, Markham, and will forward to AECOM. AECOM is pursuing Region of York rain data internally, with our staff currently working with the Region. Currently reviewing what we have with the Region, and obtaining permission to use. · Pond screening – TRCA has completed their review; AECOM has received all the pond details that TRCA is able to provide. AECOM to proceed based on procedures identified in current pond screening matrix. · Rail area north of Hwy 7, west of Keele – TRCA will forward details regarding previous modeling in the area. AECOM to evaluate, then review their recommended modeling approach with TRCA	TRCA AECOM AECOM

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	· Table of Contents – AECOM to forward to TRCA	AECOM
2.	**<u>Stream Gauges</u>** · The team reviewed stream gauge data that AECOM has received, and discussed potential gaps. o TRCA advised that gauge HY093 has recently been moved, there was a problem with development of a rating curve at its original location, and the data collected at its former location should be considered not usable. o TRCA will forward a rating curve for gauge HY092. o Gauge HY022 is likely the same gauge as 02HC005 – TRCA will confirm. o HY079 was installed primarily for flood warning purposes. Due to installation location and the type of equipment used, the data collected includes lots of noise and maybe subjected to lake effect. Only use may be during model validation, to confirm timing of peak flows in the lower Don. o Gauge HY080- no data received yet- TRCA will look at this gauge further and advise o AECOM requested clarification regarding flow data received in spreadsheets, vs flow data in text files-- suggested that text file is raw data, whereas Excel file may be data after QA/QC? TRCA to review and confirm.	TRCA TRCA TRCA TRCA
3.	**<u>Catchment Delineation</u>** · AECOM discussed location of nodes, and procedure for adding dummy nodes/links for crossings that are to be represented in the model. · AECOM asked TRCA whether additional nodes would be required to have adequate coverage for flood vulnerable areas. TRCA felt that no additional nodes were likely required, but will forward the flood vulnerable area database to AECOM to verify. · TRCA had questions regarding modeling approaches for crossings in PCSWMM – how obstructions such as guardrails would be incorporated. When developing the model at crossings, AECOM will illustrate modeling approaches at typical crossings for TRCA's comment.	TRCA
4.	**<u>Model Development</u>** · AECOM reviewed methodology for determining characteristic channel cross sections for reaches. · TRCA felt approach was generally OK. Suggested 'reaches' in the model could be defined by reviewing channel planform (using topo and/or floodline mapping), moving down the channel and grouping XS together with similar gross characteristics. · Approach should consider 'pinch points' explicitly, where upstream storage would be significantly affected. Sheet Don_20e was referenced by TRCA as an example · Discussion regarding characteristic cross sections where a HEC-RAS model doesn't exist--- These areas are typically urban sections, where a defined channel doesn't often even exist. Could cut section from DEM—but in most cases, if storage/attenuation can be considered negligible, they would only need to be in place as routing elements for timing of the hydrograph, and a standard urban section may be appropriate. · TRCA pointed out that the NEXFLOOD model merely applied the flow to the DS node in these areas with no specific routing element. · AECOM to document their suggested procedure for characteristic channel sections and routing elements in a memo, which TRCA will	AECOM

	review internally. · TRCA has had some internal review of AECOM's methodology and results for calculating imperviousness. Questions regarding green roofs (how are they processed?) and whether season of photo is affecting results. AECOM also to complete a further comparison vs manual assessments for varying land use, and document approach. · Catchment parameterization – many parameters will be drawn from GIS – but a key calibration parameter will be catchment width. Discussion regarding theoretical model limitations when overland length exceeds 150 m—and 'sheet flow' no longer applies. TRCA in the past has also looked at implementing the standard L=(A/1.5)^5 drainage length formula recommended in OTTHYMO/SWMHYMO. This will be a topic of discussion during model calibration.	AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Meeting
Date	September 13, 2017
Time	9:15 am – 10:00 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Serge Ristic, AECOM (SR) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	September 13, 2017
Prepared by	OC
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · AECOM and TRCA reviewed the previous minutes. There are no additional comments, and some action items are continuing, which will carry forward in subsequent minutes. · Rain gauges – AECOM has received rain gauge info from City of Toronto, Richmond Hill and Markham on Aug 9. AECOM continues to pursue the Region of York rain data internally. · Table of Contents – AECOM has forwarded the draft TOC to TRCA on Sept 11. AECOM will proceed to populate the content of the report. TRCA will continue to provide input in the process. The report will be treated as living document. · Stream gauges o TRCA has provided data for HY092 and associated rating curves to AECOM on Sept 13. o TRCA will confirm whether HY022 and 2HC005 are the same gauge o HY080 – there has been no data received to-date. AECOM will assume no data is available and exclude the gauges from calibration. o TRCA informed that the different data format from the WC gauges was due to a change in data logging method and cover different time periods.	AECOM TRCA

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	· Flood vulnerable area – TRCA will forward the database to AECOM. · Imperviousness o Green roofs are currently treated as impervious cover under the current methodology. o AECOM will select one random sample from the main land use groups (residential, industrial, commercial) and perform a visual assessment between the impervious cover against the ortho photo to ensure accuracy of the impervious cover. o AECOM will complete the associated section in the report and circulate to TRCA for review and comment. o The storage and routing effect of a small number of green roofs is likely to be negligible in the scale of the current study. Any storage and routing effects will be captured and distributed over the watershed through the calibration process.	TRCA AECOM AECOM
2.	**<u>Crossing Modeling</u>** · AECOM presented the crossing modeling methodology in the NexFlood model. · TRCA do not have a preference on whether AECOM import crossing information from NexFlood or HEC-RAS. However, TRCA cautioned that QA/QC would be required if importing information from NexFlood as there is no documentation on crossing modeling in the NexFlood model.	
3.	**<u>Rail area north of Hwy 7, west of Keele</u>** · The overflow area mainly affect the timing of the hydrograph only. The area is close enough to the Glenshields stream gauge to potentially affect calibration results. · TRCA reviewed previous assessments, and provided a summary to AECOM. Existing 2750 mm culvert spills for 100 year storm- spill generally would flow to rail yard. Rail yard internal drainage only 10-year capacity before spilling. · A separate technical discussion will be devoted to the details of this area.	AECOM/TRCA
4.	**<u>Characteristic Reaches</u>** · AECOM has sent TRCA the memo detailing one of the proposed methodology to characterize reaches. · AECOM will investigate other potential methodologies and report back to TRCA · TRCA suggested AECOM to discuss the selected methodology with TRCA before implementation.	 AECOM AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Meeting
Date	September 27, 2017
Time	9:00 am – 09:35 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Olivia Chung, AECOM (OC)
Prepared	October 2, 2017
Prepared by	OC
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · AECOM and TRCA reviewed the previous minutes. There are no additional comments, and some action items are continuing, which will carry forward in subsequent minutes. · Rain gauges – AECOM has been granted access to the York Region rain gauges. · Stream gauges – TRCA believe that HY022 and 2HC005 are the same gauge and that TRCA simply uses the WSC database. AECOM will proceed with the assumption that the two gauges are the same. Post-meeting notes: TRCA found out that the two gauges are on separate branches of the Don River and that data of both gauges has been provided to AECOM. · Flood vulnerable area – The database is mainly for documentation only. The resolution of the current subcatchment delineation is mostly likely to be sufficient. TRCA will forward the database to AECOM. · Imperviousness – AECOM will follow up on the documentation. · CNR MacMillan yard – AECOM can contact TRCA for detail methodology discussion. · Characteristic reaches – AECOM define transect of each conduits based on the average HEC-RAS cross section within the conduits. TRCA informed that the inverts, overbank and elevation in the NexFlood model sometimes do not line up with the topography,	TRCA AECOM

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	resulting in sections of the model be always flooded. AECOM will document the methodology in the report and conduct internal QA/QC and spot check. · Crossings – AECOM has completed coding all the crossings into the model with a few exceptions. AECOM will forward the revised crossing screening table for TRCA to provide further directions on the outstanding crossings. TRCA suggested AECOM to QA/QC the high chord and low chord of the crossings to make sure that the elevations make sense.	AECOM AECOM/TRCA
2.	**<u>Model development and upcoming work</u>** · AECOM will QA/QC stage of the crossings and transects. · To facilitate project progress, AECOM will provide a biweekly submission of the interim model for TRCA's review and comment. · Upcoming tasks includes coding ponds into the model, process rain and flow data to select appropriate calibration and validation events, base flow separation. · AECOM will select appropriate base flow separation methods after reviewing the stream gauge data of the selected events. · AECOM will come up with a strategy to include seasonal characteristics in the design event simulations.	AECOM
3.	**<u>Other businesses</u>** · TRCA requested to have the updated project schedule. AECOM will forward the schedule.	AECOM

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Meeting Minutes

Subject	2017 Don River Hydrology Update Technical Meeting
Date	October 27, 2017
Time	9:00 am – 12:00 pm
Location	Don Room/101 Exchange@MTRCA
Attendees	Nick Lorrain (NL), TRCA Wilfred Ho (WH), TRCA Sameer Dhalla (SD), TRCA Serge Ristic (SR), AECOM Brian Richert (BR), AECOM Olivia Chung (OC), AECOM
Prepared	November 3, 2017
Prepared by	OC
Distribution	NL/WH/SR/BR/OC

Item	Description	Action By
1.	**Previous minutes** · There were no comments on previous minutes. · Flood vulnerable area – TRCA has provided AECOM with the database. · Monitoring data processing o AECOM considers the rain gauge data collection process to be completed and has completed processing all the requested rain gauge data. o AECOM informed that the additional rain gauges were selected based on the record coverage to coincide with the potential events from initial screening using TRCA rain gauges. o 13 events between 2010 and 2015 have been selected as candidate calibration and validation events, pending adequate flow data from each of the monitor sites. o AECOM has reviewed the TWWP flow monitoring data. It was found that the gauges were all in close proximity with the TRCA and WC stream gauges. In addition, the TWWP data provided spans 2008 to 2011, which only overlaps with two of the 13 candidate events. It was therefore decided not to include the TWWP gauges in the calibration. o AECOM noted that stream gauge HY022 (calibration and validation) and HY079 (validation only) data is still missing. TRCA to follow up. o AECOM noted that radar data will be used for the upcoming basement flooding study for the City of Toronto. However, substantial work is required to process radar data. The quantitative use of the radar data is not anticipated for the current	TRCA

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	study but may offer some qualitative verification, especially if specific calibration events require further study to provide more confidence in the model. o TRCA noted that radar data will be made available through TRCA's NexRAD system to the study team to help characterize calibration/validation events. Once we have the candidate events TRCA will pull the data and send to AECOM. · Imperviousness – AECOM reported that the QA/QC process is continuing and corresponding section in the report has been written.	AECOM/TRCA
2.	**<u>Model development</u>** a) Ponds o AECOM reported that there were about 20 ponds with very little information, such as discharge only, storage only or no information at all. AECOM presented methodology to fill in the missing information. o AECOM highlighted Pond 248 as a special instance for discussion. AECOM would like to confirm with TRCA how the pond operates. Based on the observations that Highway 401 is unlikely to be overtopped and that there is no other overland outlet in the area, available GIS storm sewer information suggests that major system flow is detained in the park area north of the highway, and subsequently discharged westward into the West Don River through pipes at Don Mills Roads when capacity becomes available. o GIS sewer information also shows one pipe across 401 southward to Pharmacy. However, size information is unavailable for this particular pipe. o Flood line mapping information only extends to south of Hwy 401, and has limited use to verify how flows may cross Hwy 401. o The question is whether to remove the pond and the flow restriction of the pipes for the Regional event. Options are: § Remove the pond and pipe and allow flow to discharge uncontrolled to West Don. This is consistent with the modeling of other ponds but will not accurately reflect actual flows – which, if discharged to the West Don, would be controlled to the capacity of the existing minor system through necessity § Retain the pond and pipe in the model for the Regional event § Assume uncontrolled Regional flow to be discharged into Massey Creek. It was noted that allowing uncontrolled flow to discharge into Massey Creek will result in a bigger impact to the downstream system than discharging into West Don. o AECOM noted that from past project experience along Highway 401, it is highly unlikely that the highway would be overtopped. o TRCA will attempt to collect reports or previous studies done on the pond but also noted that the documentation might not be available. TRCA will inform AECOM whether any documentation can be recovered.	TRCA

	o TRCA inquired if there are other ponds with similar issues, discharging across a major corridor. AECOM responded that Pond 248 is the only one. o AECOM noted that the area south of Pond 248 and Highway 401 is a completed basement study area in Toronto: Area 30. It is possible to request the InfoWorks model from the City. However, any additional work in this area should only be done to the extent that a defendable approach can be confirmed and the project schedule not impacted. o TRCA noted that that in specific locations TRCA has completed routing assessments upstream of large embankments, like 401 crossings. In these instances flood elevations on the upstream side are based on routed flows (i.e. or boundary conditions) while un-routed flows are used immediately downstream. o It was decided that AECOM should request the Area 30 model from the City of Toronto to have a better understanding of where the water goes and report back on modeling approach on the pond. o Brief discussion was made for the two retrofitted ponds in Terraview Park and Willowfield Gardens Park, south of Highway 401, east of Pharmacy Avenue. TRCA indicated that the ponds were retrofitted years ago. TRCA will inquire internally for the reports and forward any documentation to AECOM. o TRCA noted that some of the depth-area curves do not increase monotonically. AECOM responded that it is due to the mathematical process of converting from depth-storage to depth-area. The depth-area curves thus do not represent the physical configuration of the ponds. The storage volume increases monotonically when SWMM calculate volume based on area. o TRCA advised AECOM to include the clarification in the report for subsequent users of the model. *Post-meeting notes:* *TRCA has looked into Pond 248, and based on the existing Don River catchment mapping the drainage area is directed to the East Don River (not West Don) as noted at the meeting by AECOM. Now that the direction of flow has been established further discussion on a modelling approach between TRCA and AECOM needs to occur.* b) CNR MacMillan Yard o AECOM noted that in the current model, the spill drains to the same outlet as the minor system. Based on WH's previous conclusion on the area, AECOM will revise the model such that the overflow from the pipe will be directed southward through the yard. o TRCA noted that AECOM could use the spill elevation in the model previously provided. o BR and WH will have a separate discussion to go through the model specifics in detail. c) Don Mills Ditch o TRCA noted that a detailed PCSWMM study has been conducted for the area. TRCA will provide AECOM with the model and documentations to be incorporated into the current model. d) Missing structures	AECOM TRCA AECOM AECOM/TRCA TRCA

	o TRCA noted that review of the interim model on the East Don watershed has been completed. It was noted that some structures were missing in the model. o AECOM noted that some of the structures were screened out based on the significance of their routing effect. o TRCA will digitize the missing structures and forward to AECOM. o AECOM will either include the missing structures or document rationale of exclusion. e) Methodology for representing piers in PCSWMM o AECOM presented an example of how bridges are modeled - Piers were not inputted into PCSWMM as structures. Instead, bridges were modeled as multiple parallel conduits, with equivalent cross sectional area representing the bridge openings. o TRCA has accepted this bridge modeling methodology in other studies. f) Catchment flow width discussion was deferred to item 4 below.	TRCA AECOM
3.	**<u>Initial Model Runs</u>** · AECOM presented the initial, uncalibrated model parameters in the initial model runs. Results were compared to the flow frequency analysis results. It was noted that the modeled flows were generally higher than that from the frequency analysis. · The flows from initial model run are somewhat consistent with the calibrated Humber model. · AECOM noted that the purposed of the initial run was to verify model connectivity and to perform initial comparisons with from previous model and flow frequency analysis as sanity checks. Therefore, the flow values from the initial run should not be taken as 'results'. · AECOM noted that the initial model runs has excluded all ponds but has crossings in place.	
4.	**<u>Catchment flow width</u>** · AECOM noted that SWMM was initially developed for small, urban catchments. It idealizes catchments into rectangular catchments and assumes that flow travel along the flow length reaches the outlet at the same time, ignoring the travel time along the width of the catchments once flow is collected and the end of the flow length. · For large urban catchments, internal routing may be significant enough that it should be taken into account. · AECOM provided an assessment of potential effects of internal routing, reviewing the SWMM idealized rectangular catchment and considering the effect of incorporating travel time along the width of the catchment once flow is collected. AECOM found that if the idealized rectangular catchment was subdivided into numerous smaller areas, and a lag time was introduced for each of these subareas reflecting their individual travel time along the idealized rectangular catchment width, that significant attenuation was introduced. · AECOM brought this issue up for discussion early, since the initial model runs suggest that flows may be high at the catchment level, and we may eventually be looking for ways to introduce more attenuation at the subcatchment level. However, <u>this may not be the case, subject to model calibration</u>. · AECOM presented options to introduce a significantly larger amount of lag/routing at the subcatchment level, if eventually required, and noted the following: o Flipping the width and length can be used to introduce additional catchment lag- AECOM's initial assessment was that this did not produce significant attenuation, unless accompanied with an increase in Manning's roughness.	

	o Otherwise introduce additional routing elements (conduits, storage) in each catchment · It was understood that it is a limitation of SWMM to model large catchments. However, the overall effect at the hydrologic flow node reference points for the current study remains to be seen during calibration. · AECOM noted that, if significant additional attenuation is ultimately desired at the subcatchment level, the model parameters may be calibrated beyond traditional range. · TRCA stated that parameters beyond traditionally expected range are generally not acceptable. · TRCA will review the example provided in the presentation. · AECOM will contact CHI for opinion on the various options for internal routing of large catchments. · TRCA noted that CHI typically refers inquiries regarding catchment flow length to a paper by Guo and Urbonas (2009). · Discussion on catchment flow width will continue as AECOM calibrates the model.	TRCA AECOM
5.	**<u>Upcoming work</u>** · Continue QA QC flow data · Verify calibration and validation events – expected to have the list of calibration events in the next two weeks. · Identify appropriate baseflow separation methodology – AECOM will look at flow data and process before commenting on baseflow separation. · Introduce calibration standards – WaPUG · TRCA will provide AECOM with its initial review comments of the model. The comments will reflect today's meeting discussion.	AECOM AECOM TRCA

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Meeting Minutes

Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	November 15, 2017
Time	9:20 – 10:30
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Sam Neale, AECOM (SN)
Prepared	November 15, 2017
Prepared by	Sam Neale
Distribution	All Attendees, Olivia Chung

Item	Description	Action By
1.	**<u>Previous Minutes</u>** · AECOM and TRCA reviewed the previous minutes and the following action items remain: **a. Stream Gauges** i. <u>Missing data for HY022 and HY079 status</u> *HY022: TRCA to provide (in progress)* *HY079: Gauge not reliable due to Lake affect. Will be used for verification, but not calibration.* *HY080: Issues with data, will not be provided.* **b. Radar data** i. <u>AECOM to send TRCA the candidate events</u> AECOM provided candidate events in the material distributed for the meeting. TRCA indicated that they have radar data processed for each event. Rather than wait until the need to look at radar data is established for specific events during calibration, it was decided that it was easier for TRCA just to provide the available radar data for the entire set of calibration/verification events. *TRCA to deliver hard drive to AECOM office (30 Leek Crescent, Richmond Hill preferable)* **c. Imperviousness** i. <u>QA/QC Process complete</u> *Text has been completed, requires formatting.* *BR to provide to TRCA.*	TRCA TRCA AECOM

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	d. Pond 248 ii. <u>InfoWorks model request status</u> *AECOM to proceed with model calibration and will reassess whether a higher level of detail is required, necessitating requesting City's InfoWorks model.* iii. <u>Modelling approach for Regional Storm</u> *AECOM/TRCA agreed to include the 3000 m diversion pipe in the model.* **e. Pond 303 and 303.1 (Terraview Park and Willowfield Gardens Park)** *Diversion to be included in model*. **g. Don Mills Ditch, missing structures** i. <u>TRCA has provided details in the interim model review comments</u> *AECOM to follow up regarding further comment questions.* **h. Catchment flow width** i. <u>AECOM to contact CHI – status</u> *Item has been deferred until calibration.*	AECOM AECOM AECOM
Memo Items	BR summarized each of the items from the November 7, 2017 Memo documenting TRCA model comments and AECOM responses. Responses were circulated. Memo items discussed during the meeting are summarized below.	
	<u>Item 2: Rumble Pond</u> · *Modelled as an offline pond in the latest version of the model.* · *BR to follow up with Olivia to confirm source of data for pond characteristics (i.e. Don unit release rates or report)* Discussion about function of pond--- speculate that flows are controlled by a SCADA system and released after the event – at night, to address thermal concerns- · TRCA to pull EA file for Rumble Pond to review how it is intended to function	AECOM TRCA
	<u>Item 3: Mill Pond</u> · Adequately addressed with flow restriction from the road crossing, and storage represented in the upstream 80 m wide conduit in the model	
	<u>Item 5: G. Ross Lord dam Storage elements</u> · *AECOM's position is to ignore the gates as they were only opened following the storm events, with the exception of the 2014-07-27 event at HY018. TRCA agrees that gates can be assumed to be closed for modelling purposes. This was also assumed in the 2004 hydrology report.* · *Baseflow for the dam is conveyed by two 16 in. bypass pipes, which are always open.*	

	Item 8: comments from the City of Markham ***e.*** *MTO ponds at Steeles and Highway 404 to be excluded from study, since they only control highway drainage, and catchment areas/release rates will be very difficult to obtain. AECOM to document this in the report and provide a rationale for exclusion.* f. Online pond upstream/at J617 *Pond only provides 2-year quantity control and has been screened out. TRCA agrees.* g. Pond S097 (South of Steeles) *Very small private pond that has been screened out. TRCA agrees.*	AECOM
	Item 9: Subwatershed Study Block 27 · *TRCA to provide land use PDF from subwatershed report currently under review.*	TRCA
2.	**Model Development** · *Updated model to be provided by the end of the week (November 17, 2017)*	AECOM
3.	**Event Selection** *a.* 8 events for calibration, 5 for validation*Largest events uniform events selected. Proceeding with 13 events. More recent events with higher quality data used for calibration and 5 historical storms (~4 years old) used for validation.* b. HY018 and 02HC005 – and G Ross Lord Dam *HY018 operating since 2014 and doesn't cover entire calibration/validation record (covers 6-7 of the events) 02HC005 covers all of the events. TRCA indicated that the 02HC005 gauge also likely has a more stable and better defined rating curve as the channel is concrete lined. BR summarized issues with discrepancies in the time series data between the 2 gauges vs their response to open/closing of the dam upstream. Determined that the 02HC005 time series likely needs to be adjusted for GMT time and day light savings. AECOM to proceed with using 02HC005 gauge in lieu of HY018.* c. Baseflow separation completed (with exception of item b above) *PDF was circulated to TRCA yesterday illustrating how baseflow has been separated*	AECOM
4.	**Upcoming work** · *Model calibration to commence over the next 2 weeks*	AECOM
5.	**Other items** · *WH is reviewing structure table and will send back to Olivia.*	TRCA

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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	November 29, 2017
Time	9:00 am – 10:00 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Olivia Chung, AECOM (OC)
Prepared	December 4, 2017
Prepared by	Olivia Chung
Distribution	All Attendees

Item	Description	Action By
1.	**Previous Minutes** Action items from last minutes: **a. Stream Gauges HY022** i. TRCA has informed that HY022 is an inherited WSC stream gauge. Data was not converted nor maintained. The level data is good but the flow data is unusable. It was agreed not to include HY022 in the calibration and validation. **b. Radar data** i. TRCA informed that there are various radar product available and each has different strength and properties for analysis. ii. AECOM noted that radar information is only to be used qualitatively in the current project in assessing any potential gap in the rain gauge coverage of specific events. iii. TRCA will send the two radar products readily available to AECOM. iv. AECOM noted that if radar information suggests significant data gap exists in the rain gauge coverage for a particular event, the event may be excluded from calibration or validation. **c. Imperviousness** i. AECOM has submitted the corresponding section of the report.	TRCA

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	d. Pond 248 i. Model has been revised to direct flow to East Don. **e. Rumble Pond** i. AECOM confirmed that Rumble Pond has been coded as offline pond and that most up-do-date information was used for stage-storage-discharge. **f. Don Mills Ditch** i. AECOM has revised the model based on City of Markham's suggestions and provided response to the interim model review. ii. There are a few structures that AECOM will review. **g. Catchment flow width** i. AECOM reported that hydrograph timing in the initial model runs of calibration events seems to be ok. **h. Block 27 subwatershed report** i. TRCA has provided the report. The information will be used in the future scenario. **i. Structures** i. TRCA has provided further feedback on the outstanding structures. AECOM will review and address.	AECOM AECOM
2.	**<u>Calibration</u>** **a. Rainfall processing** i. Rainfall process has been completed. For each event, unique hyetographs were generated for each subcatchment. **b. Runoff volume calibration** i. AECOM presented the process of estimating the % impervious routed parameter based on stream gauge data and catchment characteristics. It was also shown that there is high variability in the pervious runoff coefficients within each gauge. The variability maybe attributed to antecedent moisture conditions. ii. TRCA has conducted some investigations on including the rainfall data leading to an event to account for initial moisture deficit in the soil. TRCA will provide the memo of study for AECOM's reference. **c. Goodness of fit of current results** i. AECOM showed plots of a couple initial calibration runs and noted that while model simulations matches pretty well with observed data at some events, some will require more work.	TRCA
4.	**<u>Upcoming work</u>** a. Current calibration effort focuses on runoff volume	AECOM
5.	**<u>Other items</u>** a. AECOM noted that in the best case scenario, calibration can be completed in one week. The next schedule interim model submission is December 8. b. TRCA noted that AECOM could contact WH anytime if there are problems during calibration.	AECOM

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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	December 13, 2017
Time	9:00 am – 10:00 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Olivia Chung, AECOM (OC)
Prepared	December 16, 2017
Prepared by	Olivia Chung
Distribution	All Attendees

Item	Description	Action By
1.	**Previous Minutes** Action items from last minutes: **a. Radar Data** i. TRCA has transferred radar data to AECOM. b. **Block 27 Subwatershed report** i. AECOM received, and will use for future scenario **c. Structures** i. AECOM will review and address **d. Methodology to account for initial moisture deficit** i. AECOM to review Rouge methodology and peer review **e. Interim model submission** i. AECOM has uploaded the interim model to basecamp on December 8.	 AECOM AECOM
2.	**Calibration** a. AECOM presented the interim calibration results at each stream gauge. b. AECOM noted that the stream gauge data at HY017 was affected by the dam downstream. There is a second peak in almost all events as a result of the filling of the reservoir. Calibrating objective of this gauge is mainly focused on matching the first peak. c. AECOM summarized that there was currently too much attenuation of short duration peaks in general and upcoming calibration effort will focus on reducing the attenuation. d. TRCA suggested that it could be a result of connectivity issue of the local subcatchments immediately adjacent to the gauges	

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2.	e. AECOM responded that the model has already been adjusted to ensure the stream gauges capture the flow from local subcatchments. f. AECOM has traced the hydrographs from upstream to downstream and the attenuation was mainly due to routing. The peaks were shifted and no long coincide, resulting in a flattening of the peaks in the combined hydrograph. g. TRCA suggested to change the roughness of the channel. h. TRCA will inform on the conditions of Wilket Creek to aid the calibration of HY068. i. AECOM noted that the effect of channel roughness would be investigated in the next iteration of calibration but would be cautious not to stray too far from the physical representation of the model. j. TRCA noted that calibration should attempt to best match the large events. Given the purpose of the study, certain amount of leniency can be exercised on the smaller events. k. The next iteration of calibration was expected to be finished by December 15. l. AECOM concluded that the objective is to produce a defensible calibration results. m. AECOM noted that the monitored data is a 10 year storm at best and that it would be a substantial amount of extrapolation involved when using the model to estimate the 100 year and Regional storm event. n. TRCA noted that Aug 19 2005 event has been added to the list of validation events to verify credibility of the model against large storm events. AECOM to run as verification event.	TRCA AECOM AECOM
3.	**<u>Upcoming work</u>** a. Finalize calibration b. Verification c. Design storms- comparison with FFA d. Regional flow without structures e. Future conditions scenario	AECOM

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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	January 17, 2018
Time	9:30 am – 10:30 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Olivia Chung, AECOM (OC)
Prepared	January 19, 2017
Prepared by	OC/BR
Distribution	All Attendees

Item	Description	Action By
1.	**<u>Previous Minutes</u>** · TRCA will indicate if there is any concern over the previous minutes. · AECOM noted that most of the action items from previous minutes were related to calibration and discussion on those items would be deferred to item 2: **a. Structures** i. One remaining extra structure from the structure table was included in the model, as per offline discussions between AECOM and TRCA. AECOM will provide justification for remaining structures not included in the final report. All outstanding structures have been included in the latest version of the model. **b. Review IMD methodology from Rouge report and peer review** i. Deferred to item 2 **c. Wilket Creek** i. AECOM noted that channel roughness upstream of stream gauge HY068 has already been adjusted during calibration to match the peakiness of observed flow data. TRCA could provide field observations of the channel but it was no longer critical to incorporate the information into the model. ii. TRCA informed that the channel of Wilket Creek was highly engineered. It was mainly lined with rubbles or amour stone, depending on the elevation of the channel. **d. Finalized calibration** i. Deferred to item 2 **e. Aug 2005 event as verification event** i. Deferred to item 3	

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2.	**Calibration** a. AECOM summarized the peer review comments on the Rouge hydrology update regarding IMD. b. AECOM presented methodology employed in the current study to correlate API, IMD and pervious runoff coefficient for each events of each stream gauges. i. It was found that significant pervious runoff only occurred during very large events in the developed areas. Among the calibration events, only the July 8, 2013 event resulted in significant pervious runoff in all stream gauges. ii. Pervious runoff volume was calibrated mainly by adjusting the Green-Ampt hydraulic conductivity parameter. Initially, the parameter was set very high to simulate little pervious runoff, and decreased as much as possible while still maintaining good calibration results. iii. AECOM noted that the calibrated values of hydraulic conductivity initially seemed large, but were smaller than the textbook values of silty and sandy soil types, so they are not unreasonable. The calibration methodology results in a conservative model for larger events. c. AECOM presented the calibrated parameters and results. i. TRCA noted that the hydraulic conductivity of HY068 was much higher than the rest of the gauges. ii. AECOM responded that impervious area runoff accounted for most of the total runoff for HY068. The hydraulic conductivity presented was a calibrated value that best match the monitored data. The simulated peaks would be too high compared to monitored data, especially for the July 8 2013 event, if hydraulic conductivity was reduced. Moreover, the calibrated value was still lower than the 'textbook' values for sandy soils, and not unreasonable large. iii. AECOM noted that the observed hydrographs of HY017 were influenced by the filling of the downstream reservoir. iv. AECOM noted that the maximum measured flow of 02HC005 appeared to be clipped for the July 8 2013 event. v. Similarly, the maximum measured flow of HY019 appeared to be clipped for the July 8 2013 event at around 200 m^3/s. vi. TRCA noted that the cross section of the channel widened substantially at a certain elevation, which roughly corresponded to 195 – 200 m^3/s. A huge increase in flow would be required to raise the water level by a very small amount. It could be the cause of the flattening out of the response at the gauge. vii. TRCA to search for more information regarding the limitation of the gauge to help justify the observations of the gauge's response.	TRCA
3.	**Verification** a. AECOM presented results of the verification events. i. The results of verification showed that the calibrated model could predict the hydrologic response well for small and medium size events, while it tended to overestimate the response of large events. AECOM noted that the model was intentionally conservative with the presented methodology to calibrate pervious runoffs.	

	b. AECOM summarized that i. For calibration events, the modelled volumes matched the observed data very well. There were a few underestimations, most of which were due to the gauged data being influenced by the filling of the reservoir. ii. For verification events, the modelled volumes also matched well with observed data. iii. For calibration events, the modelled peaks generally matched well with observed data. iv. For verification events, the modelled peaks matched well with observed data for smaller events. For larger events, the modelled peaks were high compared to observed data, but not out-of-the-question high. AECOM reiterated that it was a result of a conservative calibration methodology.	
4.	**<u>Upcoming work</u>** a. Verification – Aug 19, 2005 i. AECOM reported that it was work in progress. b. Design Storms – comparison with FFA i. AECOM informed that the model peaks of the 100 year design storm event were significantly larger than the results of flow frequency analysis (FFA). ii. The 100-year peak flow at HY019 (Todmorden) was about 3-4 times larger than the results of FFA. iii. AECOM confirmed that the FFA at HY019 was conducted with post-1973 record. iv. TRCA noted that given the gauge's limitation, the historical record might not have captured the actual peak flow of the larger events, skewing the results of the FFA. v. AECOM noted that it could also be a result of a conservative model since the modelled peaks were also about two times higher at other FFA locations. However, even with a conservative model, the preliminary Regional flows were still lower than the flows from the last Don hydrology update. vi. TRCA noted that their experience in previous hydrology updates in other watersheds has been that Regional flow estimates tend to decrease compared to previous models when the watershed were modelled in greater details. vii. AECOM noted that model had locations that were 'flooded' under design storm events needed to be resolved. viii. TRCA noted that in the last model submission of the Regional run, storages elements were removed but the road crossings were still in place. In addition, there were short conduits connecting the storage elements to the downstream node where instability has been observed. ix. TRCA suggested AECOM to double check the model to ensure that model instabilities is not affecting the model results. x. TRCA to provide AECOM with a table, noting the locations where they noticed model instabilities. xi. Discussion was held regarding the various ways of removing structures and storage elements. xii. In view of timing, any technical discussions regarding the removal of ponds and structures were to be taken offline between BR and WH.	AECOM AECOM AECOM TRCA

	c. Future conditions scenario i. AECOM noted that there would not be a huge amount of changes in the future conditions scenario, given that the Don River watershed is highly urbanized. ii. TRCA noted that the only development application would be Block 40 in Vaughan iii. TRCA noted that any developments within the City of Toronto would be beneficial to the watershed due to policy changes. For the purpose of the current study, there is no need to incorporate any development within the City of Toronto.	
5.	a) Model review i. AECOM noted that there have been some updates in the model since last submission. A revised version of the model will be uploaded to Basecamp after in the afternoon for TRCA's review. ii. TRCA noted that the review would be completed and comments provided to AECOM by Jan 26, 2018. b) Radar data i. TRCA asked whether radar data was used to examine some of the calibration and/or verification events that had the poorest fit. AECOM will use this data to assess if rain gauges provided reasonable characterization of the actual spatial variability of rain (as evidenced by radar data) for events with poor calibration. c) Report i. AECOM noted that now that a substantial portion of the study has been completed, some sections of the report such as data review, data gap analysis, model building process etc. will be completed. AECOM to issue a revised TOC.	AECOM TRCA AECOM AECOM

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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	February 2, 2018
Time	9:30 am – 10:15 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Olivia Chung, AECOM (OC)
Prepared	February 13, 2017
Prepared by	Olivia Chung
Distribution	All Attendees

Item	Description	Action By
1.	**Previous Minutes** · TRCA had no comments on previous minutes. · Review action items a. Additional info on HY019 i. TRCA will follow up with hydrometric group and provide formal response to AECOM to be appended to the final report. b. Aug 19 2005 verification event i. AECOM will finalize all calibration and verification results after resolving all the flooded nodes and unstable conduits. c. Flooded nodes i. Currently under review d. Model instability - TRCA i. TRCA has provided a table listing conduits with instability. ii. AECOM is reviewing the information. Response will be appended to the table. iii. TRCA noted that increasing slope of some of the conduits might improve stability. iv. Once the instability comments are addressed, the model can be considered approved by TRCA and can move on to the next task. e. Radar data review - AECOM i. TRCA has looked at some of the events on the NOA website and have noticed some gaps in the rainfall. It may help to explain over-predicting volume and peak. ii. AECOM noted that the radar data would also be used for confirming whether the rain gauges were functioning	TRCA AECOM AECOM

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	properly during an event. iii. AECOM noted that radar data would not be used in additional analysis but be used to provide higher confident in the calibration results. f. Revised TOC - AECOM i. AECOM is currently revising the TOC according to discussion recorded in previous minutes. ii. TRCA noted that the report should include all minutes and any other correspondence with TRCA that provides direction. iii. All correspondence will be appended in the final report. iv. AECOM will provide revised TOC for TRCA's review.	AECOM
2.	**<u>Discussion items</u>** a. Soil Parameters i. TRCA has another project that explored the relationship between antecedent moisture conditions, IMD and CN values. ii. It was found that the relationship between IMD and CN varies between soil types and is not 1-to-1 conversion. For instance, sand cannot have a CN higher 30. iii. It was noted that MNR guidelines do not provide any details in this matter. iv. AECOM noted that relating API and IMD was part of the calibration of the Don model. A unique API was calculated for each gauge for each event. It was observed that there was no response from pervious area unless storm was very big or if API was very large. Both factors were taken into account during calibration. v. Ideally more large events and more 'wet' events should be used in calibration. However, July 8, 2013 was the only event that was big and wet enough to have a significant pervious runoff in the monitoring data. AECOM has done the best we could with the available data. vi. The next question is what IMD to use for the Regional event. Traditionally, AMCIII conditions is used for CN models. It was noted that there is no guidance IMD and Green-Ampt parameters for the Regional event. vii. AECOM noted that the IMD value was not critical for the Regional storm. Hurricane Hazel has a long lead up and the soil is saturated by the time the peak of the event arrives, Hydraulic conductivity is the more important parameter for the Regional storm. viii. TRCA note some previous studies used artificial composite data set to extend Hazel to a 48-hour event. ix. AECOM will compare the results between the 'dry' IMD, 'wet' IMD and 48-hour Hazel.	AECOM
4.	**<u>Upcoming work</u>** a. Design Storm i. BR has informal discussion with WH regarding what distribution and duration of design storm to use. ii. It was noted that the Bloor IDF published by Environment Canada only included data up to 2007. iii. TRCA is interested in having AECOM to update IDF curves to include data up to 2015. iv. AECOM noted that it would be approximately a week of	

	work to extract data at different duration and conduct frequency analysis. v. AECOM noted that the IDF curves was unlikely to change too much by including data up to 2015 as there was no extraordinary events between 2007 and 2015 and none of the recent big storms hit the Bloor gauge. vi. TRCA believed that it would still be beneficial to include the additional 18 years of information since the IDF has not been updated since the early 2000s. vii. AECOM noted that the source of the TRCA design storm was unknown. viii. AECOM was unable to find the source of the TRCA 12-hour AES distribution. ix. TRCA noted that the source came from the Queen's University. *Post-meeting note:* *It was the source of 6-hour and 24-hour AES storm that was unknown, not 12-hour.* x. TRCA noted that the process of IDF update will need to be clearly documented. xi. AECOM has put together the suite of storms to be used in the Don model. xii. TRCA noted that the IDF curves in the City of Toronto Wet Weather Flow Master Plan were derived based on data from multiple rain gauges. xiii. AECOM noted that if AECOM was to update the IDF curves, the curves were not to replace those published by EC. The updated curves would be used specifically for the current project only. xiv. TRCA will bring the IDF issue up in an internal meeting and provide AECOM with directions next week. b. Model Delivery i. TRCA agreed that everything (proposed condition, design events) could be provided in one single package c. Removing road for Regional Storm i. AECOM noted that road crossing removal was not spelt out in the RFP's term of reference. ii. It was decided that AECOM would remove road crossings and would delete dummy junctions and reconnect DS conduits to upstream junctions.	TRCA AECOM
5.	d. Other items i. TRCA informed that the consultants of Don mouth naturalization have been informed to use previous Regional Storm flow for their design. However, there is still pressure to complete the Don hydrology update documentation. ii. The report needs to be in place in a month or two, with two weeks for TRCA's review. iii. AECOM will provide an updated project schedule to reflect the above discussion. e. Scheduling bi-weekly calls i. AECOM will organize the upcoming calls	AECOM

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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	February 14, 2018
Time	9:30 am – 9:55 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Olivia Chung, AECOM (OC)
Prepared	February 20, 2017
Prepared by	Olivia Chung
Distribution	All Attendees, Wilfred Ho

Item	Description	Action By
1.	**<u>Previous Minutes</u>** · Review action items a. HY019 documentation i. TRCA has provided a summary of gauge limitations by the hydrometric group. It was noted that the summary was very general, without specific details such as maximum flow. ii. AECOM noted that due to the generic nature of the summary, no quantifiable comments could be inferred. iii. It was agreed that despite the gauge limitation, most of the data collected were still good for the purposed of calibration. Calibration was conducted with the best available information and that the resulting model still accurately represents the flow at the location. b. Aug 19 2005 verification event i. Pending addressing all the flooded nodes and unstable conduits. c. Flooded nodes i. In progress d. Model instability i. AECOM noted that there were 60 – 70 items in the list. Each will be checked and addressed. ii. AECOM will update the excel table WH had prepared as part of the model review, with documentation as to how all the model instability's will be addressed. e. Revised TOC i. AECOM will forward revised TOC to TRCA later today. f. IDF curves update i. TRCA informed that it would like AECOM to proceed with	AECOM AECOM AECOM AECOM

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	the IDF curves update to incorporate additional data collected since the last update. ii. TRCA indicated that the update methodology would need to be documented clearly for future reference. iii. TRCA will email AECOM outlining the scope of work. iv. AECOM to provide a work plan and cost for TRCA's approval. v. AECOM will look at the data at various gauges relevant to the Don watershed and decide on whether the update will be based on data from one single gauge (Bloor) or multiple gauges. g. Revised project schedule i. TRCA has no comments on the revised scheduled provided earlier in the week. ii. AECOM noted that the updated project schedule provided did not include in the IDF update. The project schedule would have to be revised to reflect the time required to complete the new task. iii. It was agreed that a large part of the report could still be completed independent to the update. iv. AECOM will re-establish the appropriate storm distribution before running the design event simulations.	TRCA AECOM AECOM AECOM
2.	**<u>Upcoming work</u>** · AECOM noted that most of the upcoming work are pending finalizing the flooded notes and unstable conduits.	

AECOM
Meeting Minutes

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30 Leek Cres., 4th Floor
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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	March 1, 2018
Time	9:30 am – 9:45
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Sam Neale, AECOM (SN)
Prepared	March 1, 2018
Prepared by	Sam Neale
Distribution	All Attendees, Olivia Chung (OC)

Item	Description	Action By
1.	**<u>Previous Minutes</u>** • AECOM and TRCA reviewed the previous minutes and the following action items remain: a. Model instability i. OC completed review. ii. Brian to verify comment responses and provide to TRCA in the next couple of days. b. Flooded nodes i. OC completed review. ii. Brian to verify comment responses and provide to TRCA in the next couple of days. c. Aug 19 2005 verification event i. Once model approved by TRCA, AECOM will run verification event d. Revised TOC i. TRCA to provide TOC comments in the new couple of days e. IDF curves update i. AECOM proposed work plan includes data collection from Environment Canada gauge in Toronto and frequency analysis/curve fitting of events ii. Two weeks of staff time and approximately $10,000 budget iii. SR to email work plan to TRCA iv. TRCA to provide work order authorization documents for signature f. Revised project schedule i. Anticipate to wrap project up by the end of the month.	AECOM AECOM TRCA/AECOM TRCA AECOM TRCA AECOM

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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	March 14, 2018
Time	9:30 am – 9:55 am
Location	Conference Call
Attendees	Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Olivia Chung, AECOM (OC)
Prepared	February 20, 2017
Prepared by	OC/BR
Distribution	All Attendees, Nick Lorrain

Item	Description	Action By
1.	**Previous Minutes** a) Review action items i) Model instability – AECOM has uploaded response table ii) Flooded nodes – AECOM has completed review iii) Aug 19 2005 verification event – AECOM has run the event iv) Revised TOC – TRCA has provided comments v) IDF curves update – Defer to discussion items below	
2.	**Discussion items** a) Areal reduction for Regional flood – methodology i) Areal reduction factor (ARF) for each point of interest was estimated using the longest length of the watershed as diameter to calculate the circular area. ii) Instead of running the regional model with a suite of ARFs, the model was run with no ARF and the ARF for the entire watershed. This generates the two bounding regional flow corresponding to no reduction and maximum reduction for the watershed. iii) The flow reduction for each point of interest was prorated based on the two bounding points above. iv) TRCA informed that for smaller models with shorter run time, a suite of ARFs were run and the results extracted for each point of interested using lookup tables. v) TRCA suggested to perform a few spot check to ensure that the AECOM methodology is appropriate. Spot check locations could be at the quarter and three quarters of the watershed. b) IDF curves i) Environment Canada (EC) Toronto City Center gauge • Processed data coverage only up to 2015	AECOM

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	• Raw tip data not available • 15 min timestep ii) EC Pearson gauge • Data coverage to current date • Raw tip data available iii) AECOM is currently considering whether to process Toronto City Center gauge data only or to process the Pearson gauge data as well to see the impact of the additional 2 years of data.	
3.	**Upcoming work** a) IDF curves update b) Regional event i) It was agreed that the Hurricane Hazel should be run with 12-hr duration, as well as 48-hr duration Regional event with a low intensity rainfall leading up to the main event. ii) TRCA is finishing up some work regarding the relationship between AMC method and physical-based Green-Ampt method and will forward the documentation to AECOM for reference upon completion. c) Future condition scenario	AECOM TRCA
4.	**Other items** a) AECOM is still aiming to submit the draft report by end of the month b) TRCA will forward the IDF curves update work order paperwork to AECOM.	TRCA

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Subject	2017 Don River Hydrology Update Bi-Weekly Call
Date	March 29, 2018
Time	11:00 am – 11:35 am
Location	Conference Call
Attendees	Nick Lorrain, TRCA (NL) Wilfred Ho, TRCA (WH) Brian Richert, AECOM (BR) Serge Ristic, AECOM (SR) Olivia Chung, AECOM (OC)
Prepared	April 3, 2017
Prepared by	OC/BR
Distribution	All Attendees

Item	Description	Action By
1.	**Previous Minutes** Review action items a) Regional event - AECOM • Instead of interpolating between no ARF and watershed ARF, the Regional model was run with the whole suite of 15 ARFs and lookup table was used to extract peak flow at the flow nodes. • Sensitivity runs on event duration and IMD have been completed. Results will be presented in one of the discussion items. b) AMC - Green-Ampt relationship documentation – TRCA • TRCA will provide the documentation as supplemental information for AECOM's preparation of the draft report. c) IDF curves update paperwork • AECOM has received the necessary paper work. The IDF curves update has been mostly completed. Results will be presented in one of the discussion items.	TRCA
2.	**Discussion items** a) IDF curves update i) Only 15-minutes, non quality controlled data was available at the Toronto City rain gauge. ii) AECOM checked the unprocessed 15-min data and removed erroneous data prior to the frequency analysis. iii) HYFRAN software was used in the frequency analysis. iv) Same curve-fitting method as the previous Environment Canada (EC) IDF, Gumbel distribution, was used. v) AECOM noted that the curve-fitting exercised was first conducted with data up to 2004 to ensure that the curve-fitting methodology used in the current update was the same as EC's methodology.	

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	vi) The updated IDF curves exhibit a 2% – 11% increase from previous IDF curves. vii) In the absence of 5- and 10-min interval data, the intensity at 5- and 10-min were estimated by applying the same increase as the 15-min duration of the same return period. viii) The updated IDF curves utilized the 3-parameter equation to fit the data, as opposed to the 2-parameter equation currently used by EC. The third parameter provides additional control over the curvature of the line and therefore a better curve fit with the data. ix) The next step is to apply the suite of design storm to the model. x) It was agreed that a standalone memo documenting the IDF curves update process would be included in the Don report as appendix. xi) TRCA noted that a 350-year IDF curve was required for the special policy areas (SPAs). AECOM noted that it could be done by interpolating the HYFRAN output between return period of 200 and 1000 year. xii) AECOM noted that MTO has its own strategy and action for climate change adaptation for highway drainage, based on a 75 years of average service life of highway infrastructures. There are generally a 5% - 10% increase in volume in MTO's updated IDF curves, which is comparable to the current Don IDF curves update. xiii) TRCA noted that the MTO IDF curves could be referenced in the report. xiv) AECOM noted that the 2% - 11% increase is not due to long term trend in rainfall but one big storm event that drove the curve up. b) Regional event sensitivity analysis i) AECOM presented the peak flow plots of the following Regional event scenarios: (1) 12-hr duration (2) 60-hr duration (48 hour low intensity lead up to the 12 hour main event) (3) 60-hr duration with lowered initial moisture deficit (IMD) for 'wet' conditions ii) Results shows that there were minor increases in peak flow due to the lead up 48 hours of rain and insignificant increase between 'dry' and 'wet' IMD. iii) AECOM noted that the sensitivity analysis was conducted with no ARF. The peak flows were for comparison purpose and not to be taken literally. c) Future scenario i) AECOM informed that in developing the future scenario, subcatchment impervious value would be taken from the Block 27 Subwatershed Study as it has more information based on the expected form of development.	AECOM AECOM
3.	**<u>Upcoming work</u>** a) Future condition scenario b) Draft report – the goal is to submit the draft report by mid-April.	
4.	**<u>Other items</u>** a) TRCA informed that the model will be peer reviewed and the procurement process has started. TRCA does not anticipate any major issue with the model but noted that the documentation should be in place to facilitate the review.	

Appendix K: G. Ross Lord Dam Gates Operations Procedure

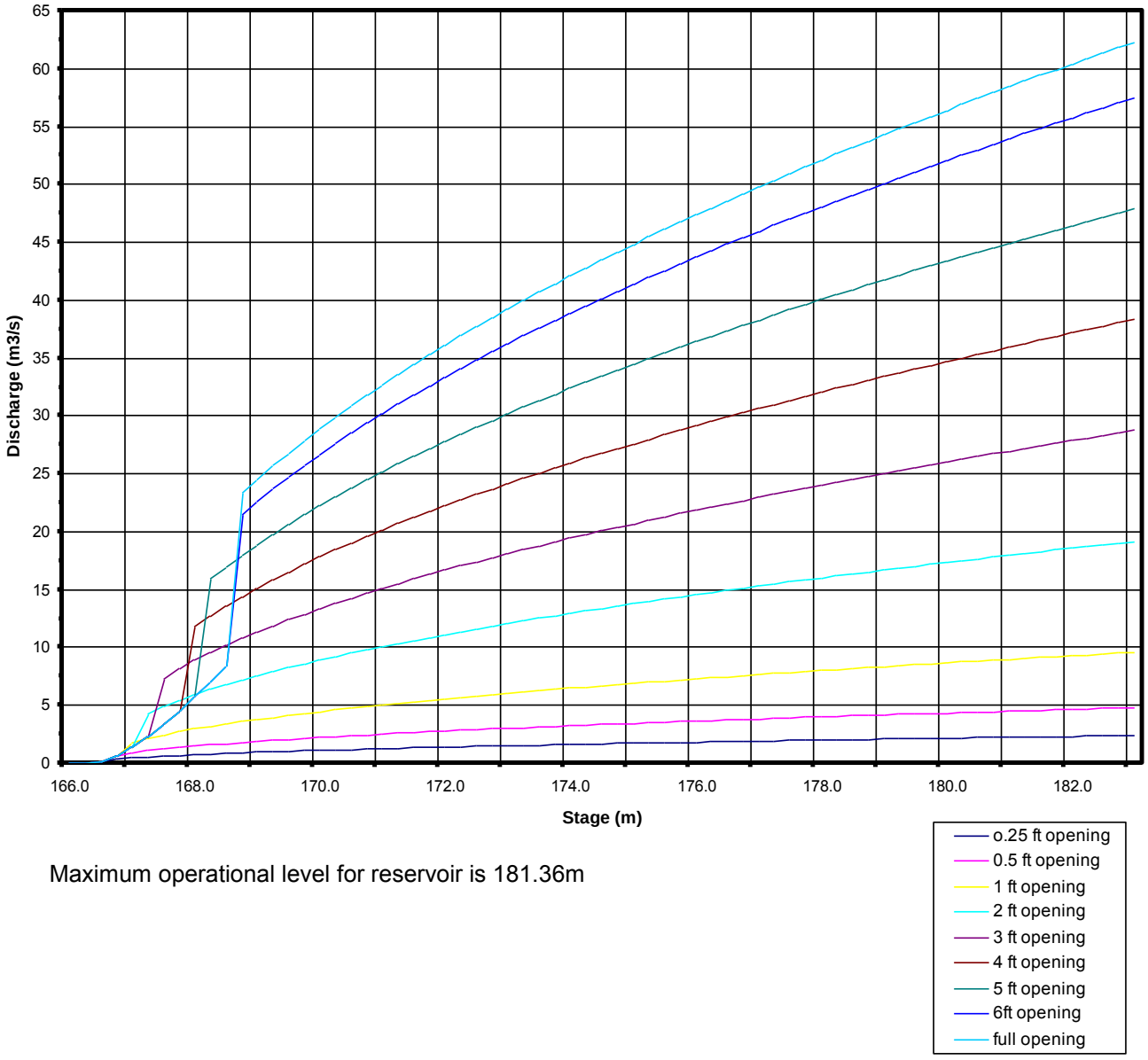
Table A.2 - Low Level Outlet Rating Curves (Metric) - One Gate Operating

Stage (m)	Discharge (m^3/s) --- With Variable Gate Opening (inch)								
	3in	6in	12in	24in	36in	48in	60in	72in	78in (full)
166.50	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
166.75	0.3	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
167.00	0.4	0.9	1.8	1.3	1.3	1.3	1.3	1.3	1.3
167.25	0.5	1.1	2.1	4.3	2.3	2.3	2.3	2.3	2.3
167.50	0.6	1.2	2.4	4.9	7.3	3.3	3.3	3.3	3.3
167.75	0.7	1.4	2.7	5.4	8.1	4.5	4.5	4.5	4.5
168.00	0.7	1.5	3.0	5.9	8.9	11.8	5.7	5.7	5.7
168.25	0.8	1.6	3.2	6.4	9.5	12.7	15.9	7.0	7.0
168.50	0.8	1.7	3.4	6.8	10.2	13.6	17.0	8.4	8.4
168.75	0.9	1.8	3.6	7.2	10.8	14.4	18.0	22	23
169.00	0.9	1.9	3.8	7.6	11.3	15.1	18.9	23	25
169.25	1.0	2.0	4.0	7.9	11.9	15.8	19.8	24	26
169.50	1.0	2.1	4.1	8.3	12.4	16.5	21	25	27
169.75	1.1	2.1	4.3	8.6	12.9	17.2	21	26	28
170.00	1.1	2.2	4.5	8.9	13.4	17.8	22	27	29
170.25	1.2	2.3	4.6	9.2	13.8	18.4	23	28	30
170.50	1.2	2.4	4.8	9.5	14.3	19.0	24	29	31
170.75	1.2	2.4	4.9	9.8	14.7	19.6	24	29	32
171.00	1.3	2.5	5.0	10.1	15.1	20	25	30	33
171.25	1.3	2.6	5.2	10.3	15.5	21	26	31	34
171.50	1.3	2.7	5.3	10.6	15.9	21	27	32	34
171.75	1.4	2.7	5.4	10.9	16.3	22	27	33	35
172.00	1.4	2.8	5.6	11.1	16.7	22	28	33	36
172.25	1.4	2.8	5.7	11.4	17.0	23	28	34	37
172.50	1.5	2.9	5.8	11.6	17.4	23	29	35	38
172.75	1.5	3.0	5.9	11.8	17.8	24	30	36	38
173.00	1.5	3.0	6.0	12.1	18.1	24	30	36	39
173.25	1.5	3.1	6.2	12.3	18.5	25	31	37	40
173.50	1.6	3.1	6.3	12.5	18.8	25	31	38	41
173.75	1.6	3.2	6.4	12.7	19.1	25	32	38	41
174.00	1.6	3.2	6.5	13.0	19.4	26	32	39	42
174.25	1.6	3.3	6.6	13.2	19.8	26	33	40	43
174.50	1.7	3.3	6.7	13.4	20	27	33	40	43
174.75	1.7	3.4	6.8	13.6	20	27	34	41	44
175.00	1.7	3.4	6.9	13.8	21	28	34	41	45
175.25	1.7	3.5	7.0	14.0	21	28	35	42	45
175.50	1.8	3.5	7.1	14.2	21	28	35	43	46
175.75	1.8	3.6	7.2	14.4	22	29	36	43	47
176.00	1.8	3.6	7.3	14.6	22	29	36	44	47
176.25	1.8	3.7	7.4	14.8	22	30	37	44	48
176.50	1.9	3.7	7.5	14.9	22	30	37	45	49
176.75	1.9	3.8	7.6	15.1	23	30	38	45	49
177.00	1.9	3.8	7.7	15.3	23	31	38	46	50
177.25	1.9	3.9	7.7	15.5	23	31	39	46	50
177.50	2.0	3.9	7.8	15.7	24	31	39	47	51
177.75	2.0	4.0	7.9	15.8	24	32	40	48	51
178.00	2.0	4.0	8.0	16.0	24	32	40	48	52
178.25	2.0	4.0	8.1	16.2	24	32	40	49	53
178.50	2.0	4.1	8.2	16.4	25	33	41	49	53
178.75	2.1	4.1	8.3	16.5	25	33	41	50	54
179.00	2.1	4.2	8.3	16.7	25	33	42	50	54
179.25	2.1	4.2	8.4	16.9	25	34	42	51	55
179.50	2.1	4.3	8.5	17.0	26	34	43	51	55
179.75	2.1	4.3	8.6	17.2	26	34	43	52	56
180.00	2.2	4.3	8.7	17.3	26	35	43	52	56
180.25	2.2	4.4	8.8	17.5	26	35	44	53	57
180.50	2.2	4.4	8.8	17.7	26	35	44	53	57
180.75	2.2	4.5	8.9	17.8	27	36	45	53	58
181.00	2.2	4.5	9.0	18.0	27	36	45	54	58
181.25	2.3	4.5	9.1	18.1	27	36	45	54	59
181.50	2.3	4.6	9.1	18.3	27	37	46	55	59

G. Ross Lord Dam and Reservoir Operation Manual, Acres Consulting Services Limited, January 1975
Maximum operational level for reservoir is 181.36m

NOTES:

1. Based upon TRCA staff experience the capacity of the channel downstream of G.Ross Lord Dam is approximately 51 m^3/s, above which houses will be flooded and flood warnings and evacuation will be required.
2. Flows, reservoir elevations and downstream channel capacity should continue to be monitored, and the table above should be updated accordingly.



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Figure A.2 – Low Level Outlet Rating Curves (Metric) – One Gate Operating

Table A.3 - Low Level Outlet Rating Curves (Metric) - Two Gate Operating

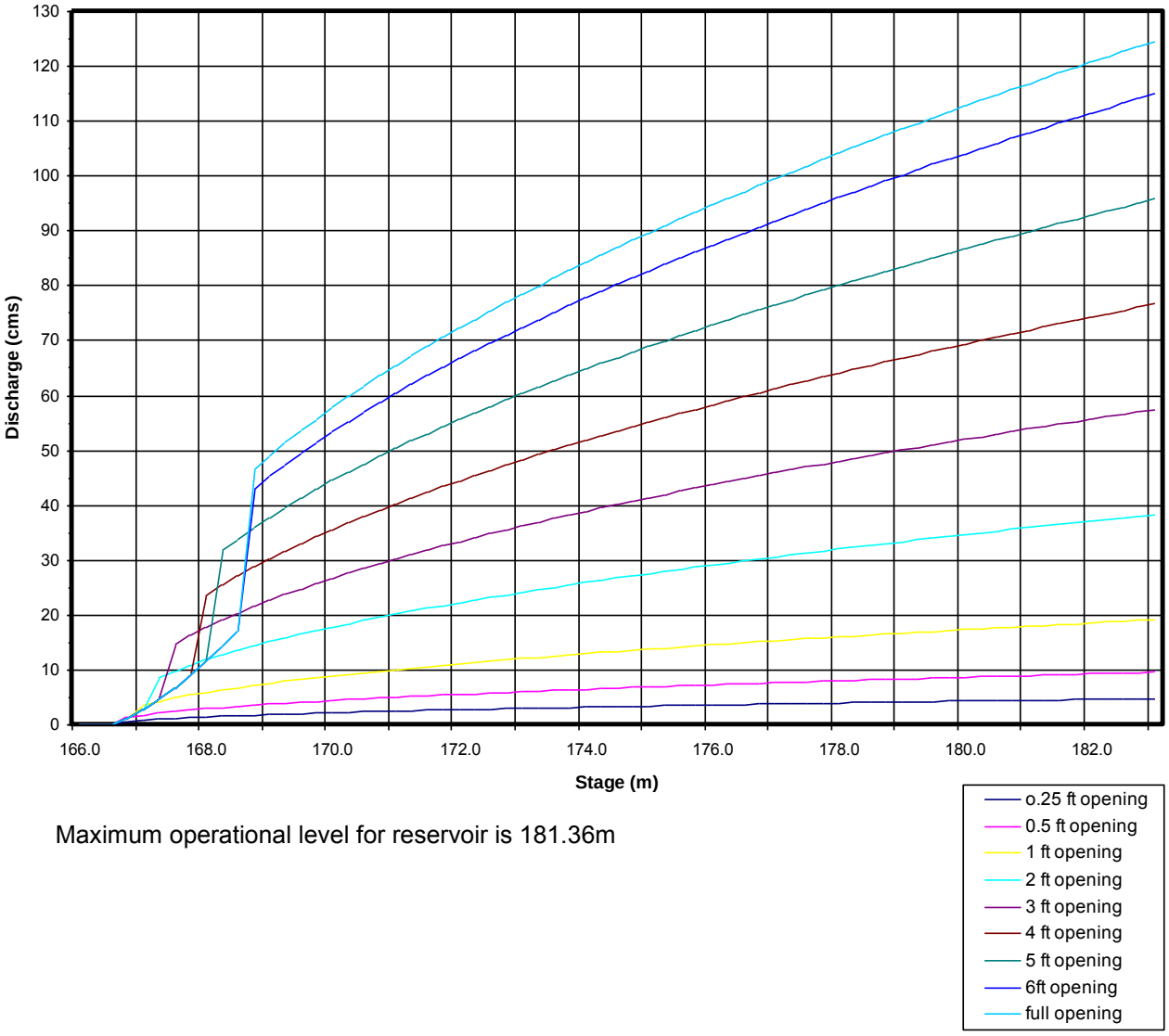
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167.00	0.9	1.8	3.6	2.7	2.7	2.7	2.7	2.7	2.7
167.25	1.1	2.1	4.3	8.6	4.6	4.6	4.6	4.6	4.6
167.50	1.2	2.4	4.9	9.8	14.7	6.8	6.8	6.8	6.8
167.75	1.4	2.7	5.4	10.8	16.3	9.2	9.2	9.2	9.2
168.00	1.5	3.0	5.9	11.8	17.7	24	11.7	11.7	11.7
168.25	1.6	3.2	6.4	12.7	19	25	32	14.4	14.4
168.50	1.7	3.4	6.8	13.6	20	27	34	17.3	17.3
168.75	1.8	3.6	7.2	14.4	22	29	36	43	47
169.00	1.9	3.8	7.6	15.1	23	30	38	45	49
169.25	2.0	4.0	7.9	15.8	24	32	40	47	51
169.50	2.1	4.1	8.3	16.5	25	33	41	50	54
169.75	2.1	4.3	8.6	17.2	26	34	43	52	56
170.00	2.2	4.5	8.9	17.8	27	36	45	53	58
170.25	2.3	4.6	9.2	18.4	28	37	46	55	60
170.50	2.4	4.8	9.5	19.0	29	38	48	57	62
170.75	2.4	4.9	9.8	19.6	29	39	49	59	64
171.00	2.5	5.0	10.1	20	30	40	50	60	65
171.25	2.6	5.2	10.3	21	31	41	52	62	67
171.50	2.7	5.3	10.6	21	32	42	53	64	69
171.75	2.7	5.4	10.9	22	33	43	54	65	71
172.00	2.8	5.6	11.1	22	33	44	56	67	72
172.25	2.8	5.7	11.4	23	34	45	57	68	74
172.50	2.9	5.8	11.6	23	35	46	58	70	75
172.75	3.0	5.9	11.8	24	36	47	59	71	77
173.00	3.0	6.0	12.1	24	36	48	60	72	78
173.25	3.1	6.2	12.3	25	37	49	62	74	80
173.50	3.1	6.3	12.5	25	38	50	63	75	81
173.75	3.2	6.4	12.7	25	38	51	64	76	83
174.00	3.2	6.5	13.0	26	39	52	65	78	84
174.25	3.3	6.6	13.2	26	40	53	66	79	86
174.50	3.3	6.7	13.4	27	40	54	67	80	87
174.75	3.4	6.8	13.6	27	41	54	68	82	88
175.00	3.4	6.9	13.8	28	41	55	69	83	90
175.25	3.5	7.0	14.0	28	42	56	70	84	91
175.50	3.5	7.1	14.2	28	43	57	71	85	92
175.75	3.6	7.2	14.4	29	43	58	72	86	93
176.00	3.6	7.3	14.6	29	44	58	73	87	95
176.25	3.7	7.4	14.8	30	44	59	74	89	96
176.50	3.7	7.5	14.9	30	45	60	75	90	97
176.75	3.8	7.6	15.1	30	45	61	76	91	98
177.00	3.8	7.7	15.3	31	46	61	77	92	100
177.25	3.9	7.7	15.5	31	46	62	77	93	101
177.50	3.9	7.8	15.7	31	47	63	78	94	102
177.75	4.0	7.9	15.8	32	48	63	79	95	103
178.00	4.0	8.0	16.0	32	48	64	80	96	104
178.25	4.0	8.1	16.2	32	49	65	81	97	105
178.50	4.1	8.2	16.4	33	49	65	82	98	106
178.75	4.1	8.3	16.5	33	50	66	83	99	107
179.00	4.2	8.3	16.7	33	50	67	83	100	109
179.25	4.2	8.4	16.9	34	51	67	84	101	110
179.50	4.3	8.5	17.0	34	51	68	85	102	111
179.75	4.3	8.6	17.2	34	52	69	86	103	112
180.00	4.3	8.7	17.3	35	52	69	87	104	113
180.25	4.4	8.8	17.5	35	53	70	88	105	114
180.50	4.4	8.8	17.7	35	53	71	88	106	115
180.75	4.5	8.9	17.8	36	53	71	89	107	116
181.00	4.5	9.0	18.0	36	54	72	90	108	117
181.25	4.5	9.1	18.1	36	54	73	91	109	118
181.50	4.6	9.1	18.3	37	55	73	91	110	119

G. Ross Lord Dam and Reservoir Operation Manual, Acres Consulting Services Limited, January 1975

Maximum operational level for reservoir is 181.36m

NOTES:

1. Based upon TRCA staff experience the capacity of the channel downstream of G.Ross Lord Dam is approximately 51 m^3/s, above which houses will be flooded and flood warnings and evacuation will be required.
2. Flows, reservoir elevations and downstream channel capacity should continue to be monitored, and the table above should be updated accordingly.



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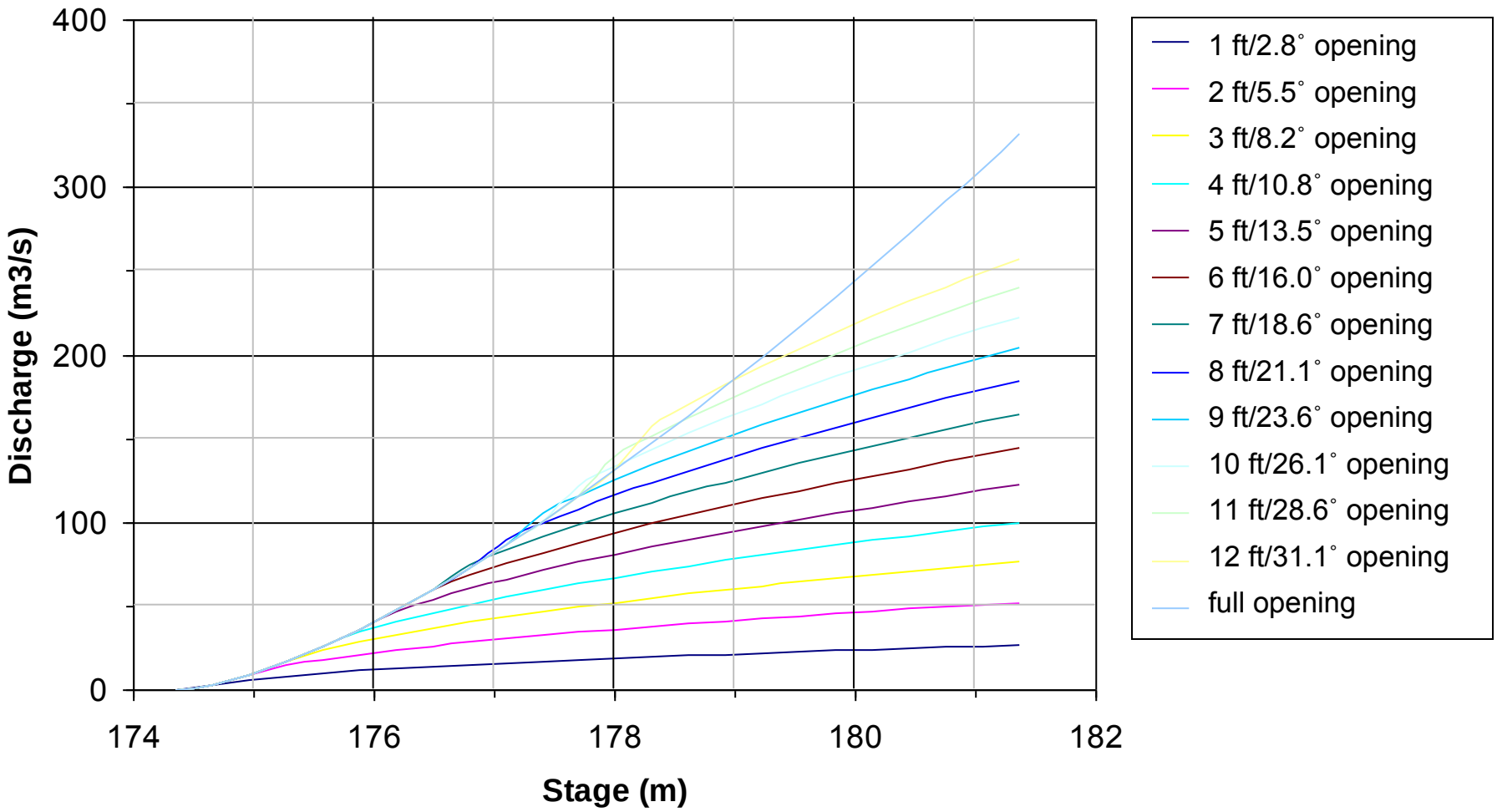
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Figure A.3 – Low Level Outlet Rating Curves (Metric) – Two Gates Operating

Table A.4 - Spillway Gates Rating Curves (Metric) - One Gate Operating

Stage (m)	Discharge (m^3/s) --- With Variable Gate Opening (ft/degree)												
	1'/2.8°	2'/5.5°	3'/8.2°	4'/10.9°	5'/13.5°	6'/16.0°	7'/18.6°	8'/21.1°	9'/23.6°	10'/26.1°	11'/28.6°	12'/31.1°	full
174.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
174.653	3.308	3.308	3.308	3.308	3.308	3.308	3.308	3.308	3.308	3.308	3.308	3.308	3.308
174.957	6.386	9.318	9.318	9.318	9.318	9.318	9.318	9.318	9.318	9.318	9.318	9.318	9.318
175.262	8.403	14.531	17.046	17.046	17.046	17.046	17.046	17.046	17.046	17.046	17.046	17.046	17.046
175.567	10.073	18.063	24.169	26.135	26.135	26.135	26.135	26.135	26.135	26.135	26.135	26.135	26.135
175.872	11.528	21.078	29.004	35.095	36.372	36.372	36.372	36.372	36.372	36.372	36.372	36.372	36.372
176.177	12.832	23.768	33.184	41.099	47.172	47.611	47.611	47.611	47.611	47.611	47.611	47.611	47.611
176.481	14.024	26.222	36.954	46.338	54.244	60.301	59.744	59.744	59.744	59.744	59.744	59.744	59.744
176.786	15.126	28.491	40.426	51.090	60.466	68.360	74.406	72.683	72.683	72.683	72.683	72.683	72.683
177.091	16.157	30.611	43.665	55.492	66.134	75.504	83.383	89.423	86.360	86.360	86.360	86.360	86.360
177.396	17.128	32.606	46.711	59.618	71.401	82.036	91.399	99.262	105.302	100.713	100.713	100.713	100.713
177.701	18.048	34.496	49.596	63.518	76.355	88.122	98.753	108.105	115.954	121.999	115.693	115.693	115.693
178.005	18.925	36.296	52.341	67.226	81.053	93.859	105.620	116.246	125.585	133.422	139.476	131.254	131.254
178.310	19.764	38.015	54.965	70.769	85.533	99.311	112.104	123.861	134.480	143.806	151.632	157.701	147.357
178.615	20.569	39.665	57.481	74.166	89.826	104.522	118.276	131.063	142.816	153.425	162.738	170.557	163.966
178.920	21.344	41.252	59.902	77.433	93.952	109.525	124.185	137.927	150.710	162.458	173.057	182.356	181.049
179.225	22.093	42.784	62.236	80.584	97.930	114.343	129.865	144.506	158.242	171.023	182.764	193.351	198.577
179.529	22.817	44.264	64.493	83.630	101.774	118.997	135.345	150.838	165.468	179.202	191.978	203.711	216.523
179.834	23.519	45.699	66.679	86.580	105.497	123.503	140.646	156.954	172.430	187.055	200.786	213.557	234.862
180.139	24.202	47.091	68.801	89.443	109.110	127.873	145.785	162.877	179.160	194.627	209.249	222.977	253.570
180.444	24.865	48.445	70.863	92.225	112.620	132.119	150.776	168.625	185.684	201.953	217.415	232.034	272.627
180.749	25.512	49.763	72.869	94.932	116.037	136.252	155.631	174.213	192.020	209.058	225.319	240.778	292.011
181.053	26.142	51.048	74.825	97.571	119.366	140.278	160.361	179.656	198.186	215.965	232.991	249.247	311.704
181.358	26.758	52.302	76.734	100.145	122.614	144.206	164.976	184.963	204.196	222.692	240.453	257.471	331.687



Maximum operational level for reservoir is 181.36m

Figure A.4 – Spillway Gates Rating Curves (Metric) – One Gate Operating

Table A.5 - Spillway Gates Rating Curves (Metric) - Two Gates Operating

Stage (m)	Discharge (m^3/s) --- With Variable Gate Opening (ft/degree)												
	1'/2.8°	2'/5.5°	3'/8.2°	4'/10.9°	5'/13.5°	6'/16.0°	7'/18.6°	8'/21.1°	9'/23.6°	10'/26.1°	11'/28.6°	12'/31.1°	full
174.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
174.653	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625
174.957	12.773	18.685	18.685	18.685	18.685	18.685	18.685	18.685	18.685	18.685	18.685	18.685	18.685
175.262	16.807	29.061	34.230	34.230	34.230	34.230	34.230	34.230	34.230	34.230	34.230	34.230	34.230
175.567	20.146	36.126	48.338	52.552	52.552	52.552	52.552	52.552	52.552	52.552	52.552	52.552	52.552
175.872	23.056	42.156	58.008	70.189	73.236	73.236	73.236	73.236	73.236	73.236	73.236	73.236	73.236
176.177	25.665	47.536	66.368	82.198	94.343	95.998	95.998	95.998	95.998	95.998	95.998	95.998	95.998
176.481	28.047	52.443	73.909	92.676	108.488	120.602	120.627	120.627	120.627	120.627	120.627	120.627	120.627
176.786	30.253	56.982	80.853	102.181	120.931	136.720	148.811	146.958	146.958	146.958	146.958	146.958	146.958
177.091	32.314	61.222	87.330	110.983	132.268	151.008	166.766	178.846	174.856	174.856	174.856	174.856	174.856
177.396	34.256	65.213	93.423	119.236	142.802	164.073	182.797	198.525	210.605	204.207	204.207	204.207	204.207
177.701	36.096	68.993	99.192	127.036	152.711	176.244	197.507	216.210	231.908	243.999	234.914	234.914	234.914
178.005	37.850	72.591	104.682	134.453	162.106	187.718	211.239	232.491	251.170	266.843	278.953	266.893	266.893
178.310	39.527	76.031	109.930	141.538	171.067	198.623	224.208	247.722	268.959	287.611	303.264	315.401	300.071
178.615	41.138	79.330	114.962	148.332	179.651	209.045	236.552	262.126	285.632	306.851	325.476	341.114	334.380
178.920	42.688	82.505	119.804	154.867	187.903	219.050	248.369	275.854	301.421	324.917	346.114	364.713	369.760
179.225	44.185	85.567	124.473	161.169	195.859	228.686	259.731	289.011	316.485	342.046	365.527	386.701	406.158
179.529	45.634	88.528	128.987	167.261	203.548	237.994	270.691	301.677	330.937	358.404	383.956	407.421	443.523
179.834	47.039	91.397	133.359	173.161	210.995	247.005	281.292	313.908	344.861	374.110	401.572	427.114	481.810
180.139	48.403	94.182	137.601	178.886	218.219	255.746	291.570	325.753	358.321	389.255	418.498	445.953	520.976
180.444	49.730	96.889	141.725	184.450	225.240	264.239	301.551	337.249	371.367	403.906	434.830	464.068	560.982
180.749	51.024	99.526	145.739	189.865	232.073	272.503	311.262	348.426	384.040	418.117	450.638	481.556	601.791
181.053	52.285	102.095	149.651	195.142	238.732	280.556	320.723	359.311	396.372	431.931	465.982	498.494	643.368
181.358	53.517	104.604	153.468	200.290	245.228	288.413	329.952	369.926	408.393	445.384	480.906	514.942	685.681

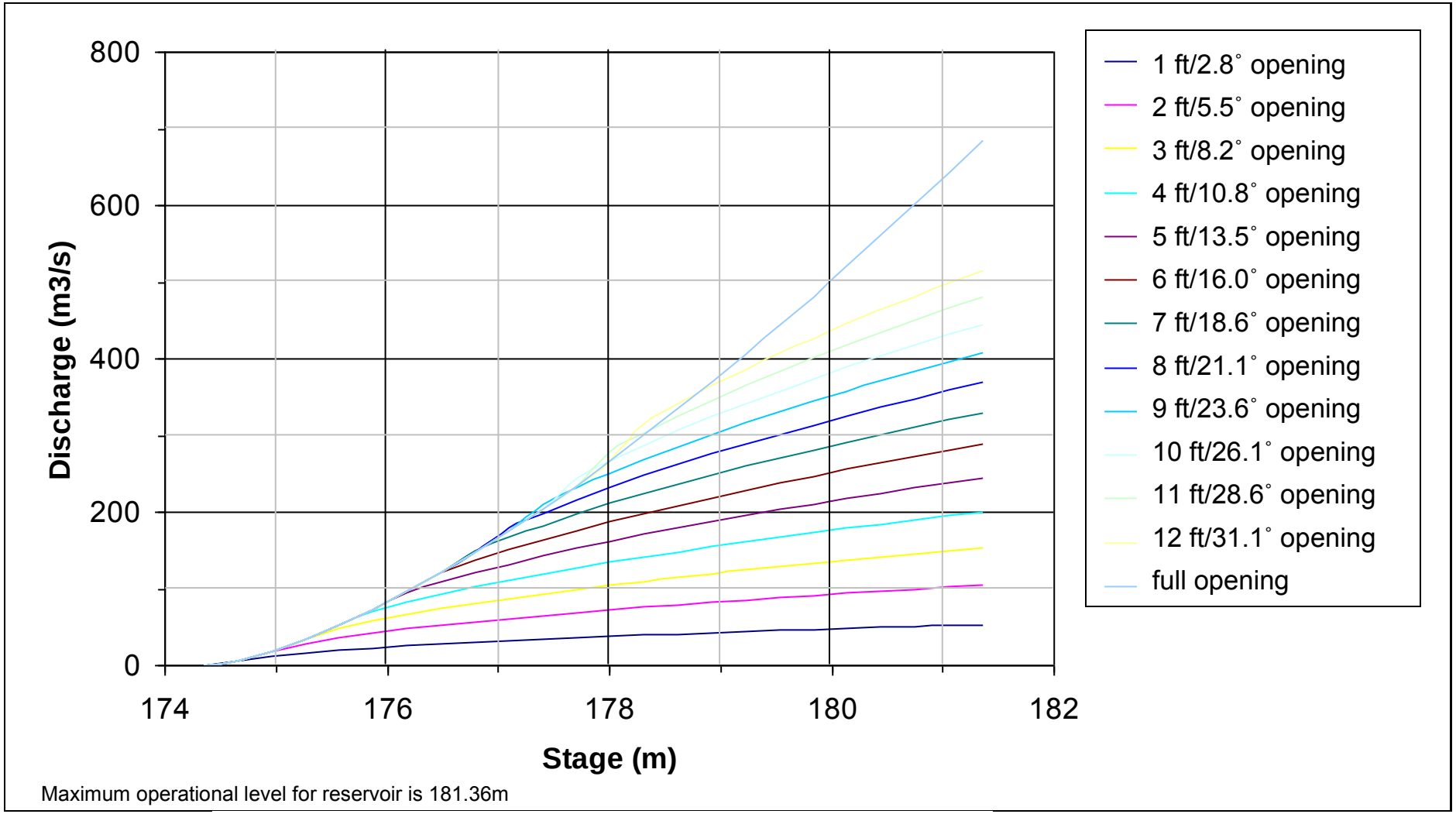


Figure A.5 - Spillway Gates Rating Curves (Metric) - Two Gates Operating

Appendix L: QA/QC Calculated Imperviousness

1.1.1 Percent Imperviousness

Aerial images were used to quantify the contributing areas for each runoff surface. An impervious surface raster was created by processing the aerial image. Field codes were assigned in the raster of 0 or 1 depending on whether the surface is impervious or pervious. Building and road polygons were burned into the raster as impervious areas.

The procedure involved processing the colour spectrum of the aerial photos in GIS. First, training samples comprising the colour coverage of each various land cover classes (road, building, pervious) were created. The success of image classification results depends largely on the quality of the training samples. Based on past experience, shadows on impervious areas can easily be misinterpreted as pervious area in the classification process. Therefore, extra care was taken to ensure shadowed road, shadowed roof and shadowed pervious areas were included in the training samples. The training samples were then used to create a signature file, which was fed into the maximum likelihood classification process in GIS. The process assigned each pixel to one of the different classes based on the means and variances of the classes stored in the signatures file. The result was a raster with field codes representing the land cover classes in the training samples. This raster generally includes certain misclassified cells (random noise) and small invalid regions. Building footprint polygons, available for the Don River Watershed from TRCA, were overlaid onto the raster to eliminate some of the misclassified cells. The classes of the raster were consolidated into two final classes, impervious and pervious, only. Post-classification processing such as filtering and removal of small isolated regions were performed to further improve and clean up the result raster. The cleaned up raster was evaluated against the original aerial photo visually to validate the results. Training samples and post-processing parameters were refined through several iterations to ensure the final impervious raster to be as accurate as possible over the study area.

The aerial photos from different municipalities are of different resolutions and quality. In addition, no information was available regarding the lighting conditions when these aerial photos were taken. Therefore, training samples were created and processing was conducted separately for aerial photos from different municipalities.

Table X below shows the resulting average imperviousness by land use for this process, and compares it to the standard values recommended by the TRCA (as identified in the Request for Proposals). The results show that actual imperviousness is typically smaller than the standard TRCA values. Since this will have a large influence on the volume of runoff in model results, AECOM proceeded to use the calculated impervious values in the hydrologic model. The imperviousness also was not taken as a standard value for each land use, but the specific impervious calculated by GIS for each catchment was used.

Table 1: Imperviousness by Land Use

Land Use Classification	Total Impervious Area (%)	
	TRCA (RFP)	Processing of Aerial Image
Airport	45	-
Cemetery	35	12
Commercial	95	75
Conservation Lands	0	4.9
Estate Residential	40	16
Farm	0	3.7
Federal Park	0	-
Golf Course	0	7.4
Hydro Corridor	10	9.6
Industrial	95	66
Institutional	80	44

Open Space	0	5.2
Park	10	8.7
Recreational	20	41
Residential High	80	54
Residential Low/Med	60	44
Road (ROW)	90	64
Rural Residential	20	4.6
Transportation	60	41
Wetland	100	-
Water	100	8.0
Natural Cover	0	-

AECOM also reviewed the range of imperviousness for specific land uses across different area municipalities. For low and mid density residential land uses, the variation across municipalities is shown below.

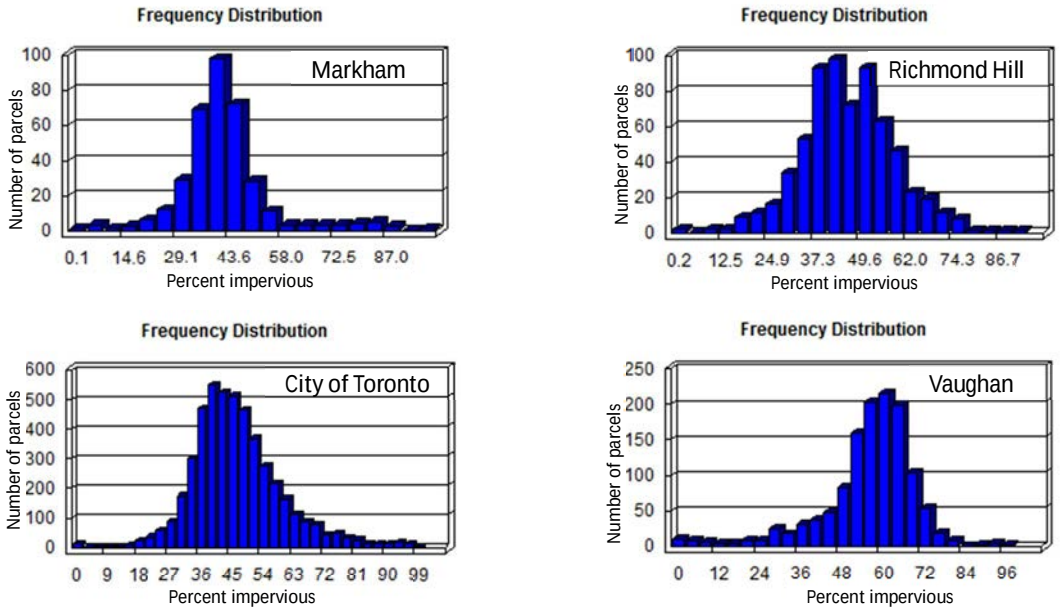


Figure 1: Imperviousness for Low and Mid Density Residential Lots

The results show that there is considerable range of imperviousness across the same land use, and there is a considerable difference in imperviousness for the same land use across different municipalities.

A summary of calculated imperviousness for different municipalities for non-residential land uses is shown in the Table below.

Table 2: Industrial, Commercial, and Institutional (ICI) Imperviousness

	Industrial	Commercial	Institutional
City of Markham	71%	61%	38%
Town of Richmond Hill	66%	72%	47%
City of Toronto	70%	79%	45%
City of Vaughan	61%	71%	40%
Don River Watershed	66%	75%	44%

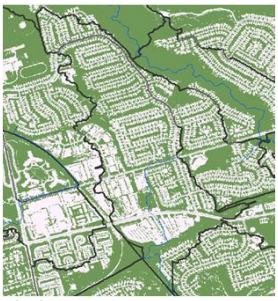
1.1.1.1 QA/QC of Assessed Imperviousness

AECOM visually reviewed the imperviousness raster over a range of land uses and imperviousness across the entire study area, both during the development of the GIS processing tool, and with the final imperviousness raster.

A summary of the QA/QC of the final raster, involving a comparison of calculated imperviousness and visually assessed imperviousness, is provided in the attached Appendices. AECOM compared 5 random low density residential catchments, and 5 random non-residential catchments in each municipality in the study area (Markham, Richmond Hill, Vaughan, and the City of Toronto). In all instances, there is no discernable difference between the raster image impervious surfaces and the visually assessed impervious surface.

Municipality: Markham

Land Use: Low Density Residential



Subwatershed 599
Imperviousness from processed orthophoto = 49 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 71
Imperviousness from processed orthophoto = 39 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 776
Imperviousness from processed orthophoto = 44 %



Visual assessment of imperviousness - no detectable difference



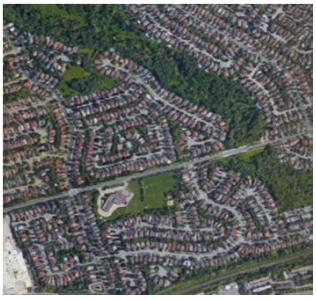
Subwatershed 435
Imperviousness from processed orthophoto = 26 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 591
Imperviousness from processed orthophoto = 45 %



Visual assessment of imperviousness - no detectable difference

Municipality: Richmond Hill

Land Use: Low Density Residential

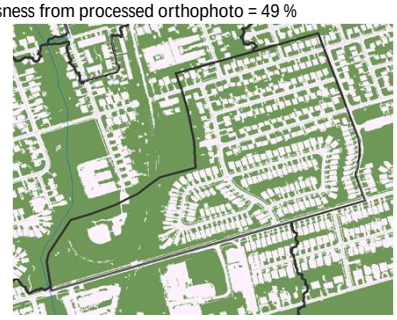


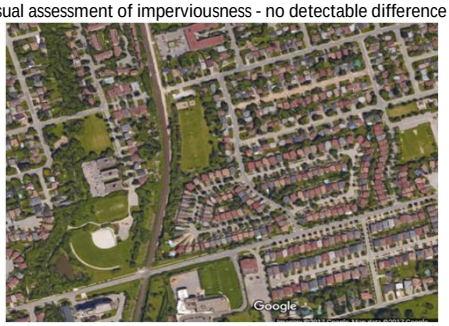


Subwatershed 724

Imperviousness from processed orthophoto = 49 %

Visual assessment of imperviousness - no detectable difference



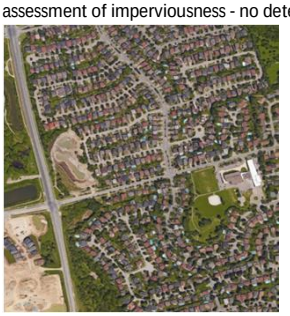


Subwatershed 480

Imperviousness from processed orthophoto = 45 %

Visual assessment of imperviousness - no detectable difference





Subwatershed 481

Imperviousness from processed orthophoto = 29 %

Visual assessment of imperviousness - no detectable difference





Subwatershed 502

Imperviousness from processed orthophoto = 43 %

Visual assessment of imperviousness - no detectable difference





Subwatershed 373

Imperviousness from processed orthophoto = 45 %

Visual assessment of imperviousness - no detectable difference

Municipality: Vaughan

Land Use: Low Density Residential



Subwatershed 454

Imperviousness from processed orthophoto = 16 %



Visual assessment of imperviousness - no detectable difference

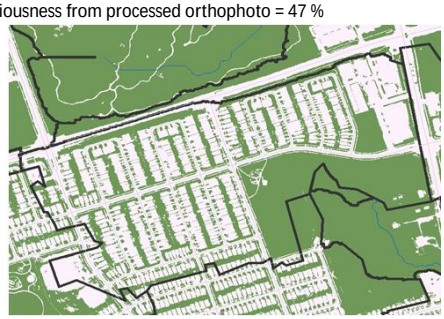


Subwatershed 494

Imperviousness from processed orthophoto = 47 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 456

Imperviousness from processed orthophoto = 55 %



Visual assessment of imperviousness - no detectable difference

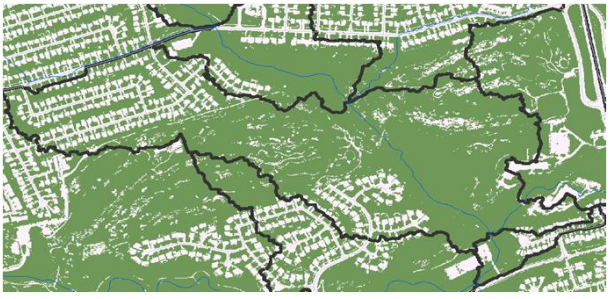


Subwatershed 514

Imperviousness from processed orthophoto = 48 %



Visual assessment of imperviousness - no detectable difference



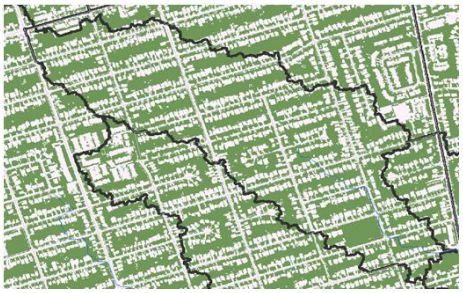
Subwatershed 595

Imperviousness from processed orthophoto = 21 %



Visual assessment of imperviousness - no detectable difference

Municipality: City of Toronto
Land Use: Low Density Residential



Subwatershed 439
Imperviousness from processed orthophoto = 53 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 699
Imperviousness from processed orthophoto = 54 %



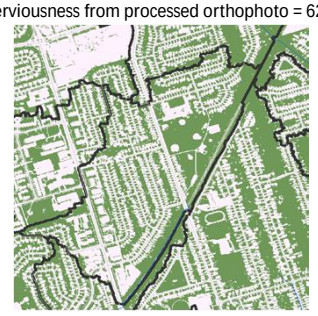
Visual assessment of imperviousness - no detectable difference



Subwatershed 315
Imperviousness from processed orthophoto = 62 %



Visual assessment of imperviousness - no detectable difference



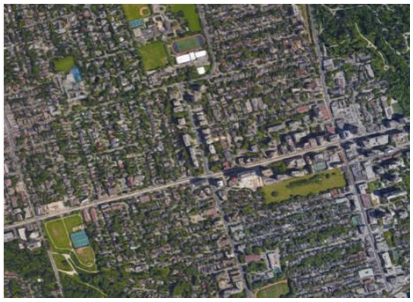
Subwatershed 445
Imperviousness from processed orthophoto = 48 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 356
Imperviousness from processed orthophoto = 58 %



Visual assessment of imperviousness - no detectable difference

Municipality: Markham

Land Use: Industrial / Commercial



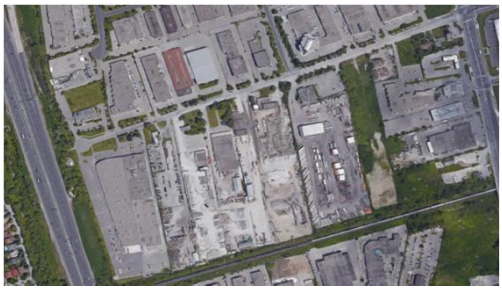


Subwatershed 63

Imperviousness from processed orthophoto = 65 %

Visual assessment of imperviousness - no detectable difference

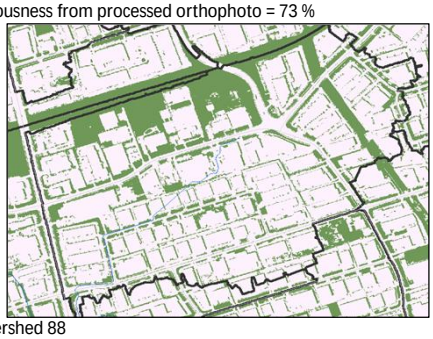




Subwatershed 584

Imperviousness from processed orthophoto = 73 %

Visual assessment of imperviousness - no detectable difference

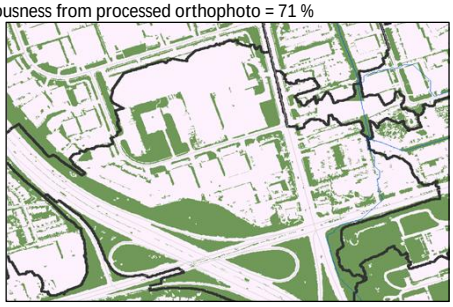




Subwatershed 88

Imperviousness from processed orthophoto = 71 %

Visual assessment of imperviousness - no detectable difference





Subwatershed 96

Imperviousness from processed orthophoto = 67 %

Visual assessment of imperviousness - no detectable difference





Subwatershed 93

Imperviousness from processed orthophoto = 70 %

Visual assessment of imperviousness - no detectable difference

Municipality: Richmond Hill

Land Use: Industrial / Commercial



Subwatershed 783

Imperviousness from processed orthophoto = 58 %



Visual assessment of imperviousness - no detectable difference

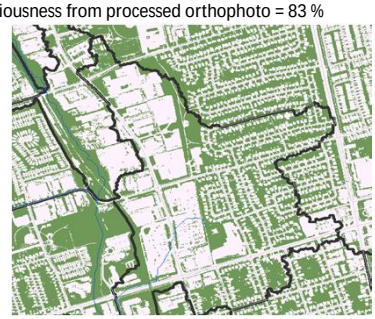


Subwatershed 571

Imperviousness from processed orthophoto = 83 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 20

Imperviousness from processed orthophoto = 57 %



Visual assessment of imperviousness - no detectable difference

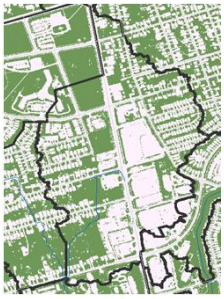


Subwatershed 9

Imperviousness from processed orthophoto = 55 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 528

Imperviousness from processed orthophoto = 55 %



Visual assessment of imperviousness - no detectable difference

Municipality: Vaughan

Land Use: Industrial / Commercial



Subwatershed 772

Imperviousness from processed orthophoto = 81 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 438

Imperviousness from processed orthophoto = 80 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 752

Imperviousness from processed orthophoto = 72 %



Visual assessment of imperviousness - no detectable difference

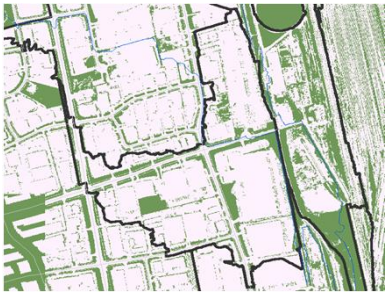


Subwatershed 106

Imperviousness from processed orthophoto = 78 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 385

Imperviousness from processed orthophoto = 80 %



Visual assessment of imperviousness - no detectable difference

Municipality: City of Toronto
Land Use: Industrial / Commercial



Subwatershed 203
Imperviousness from processed orthophoto = 61 %



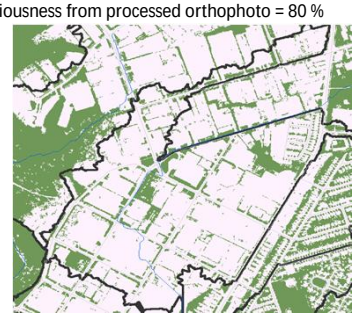
Visual assessment of imperviousness - no detectable difference



Subwatershed 304
Imperviousness from processed orthophoto = 80 %



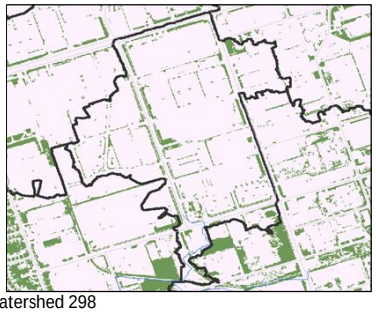
Visual assessment of imperviousness - no detectable difference



Subwatershed 311
Imperviousness from processed orthophoto = 82 %



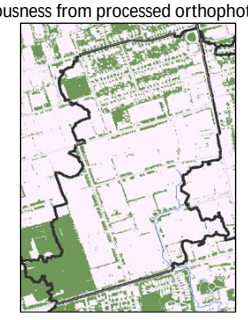
Visual assessment of imperviousness - no detectable difference



Subwatershed 298
Imperviousness from processed orthophoto = 91 %



Visual assessment of imperviousness - no detectable difference



Subwatershed 738
Imperviousness from processed orthophoto = 77 %



Visual assessment of imperviousness - no detectable difference

Appendix M: IDF Curve Update

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Memorandum

To	Nick Lorrain, TRCA	Page	1
CC			
Subject	Don River Hydrology IDF Curve Data Processing		
From	Sophia Eugeni (AECOM), Brian Richert, P. Eng. (AECOM)		
Date	October 12, 2018	Project Number	60528844

1. Introduction

As part of the Don River Hydrology Update, TRCA retained AECOM to perform additional work to update the IDF (Intensity Duration Frequency) curve for the Toronto City rain gauge (gauge ID 6158355). The gauge is located at the University of Toronto campus. The existing IDF curve was determined using data from the years 1940 to 2007. The update includes recent data available from Environment and Climate Change Canada for each year up to 2017. This report presents the procedure used to process and analyse the data as well as the results of the analysis.

2. Data Collection

The IDF analysis conducts a frequency analysis on annual series of maximum rainfall intensities over a range of durations. For example, the 5 minute IDF analysis identifies the peak 5 minute rainfall intensity in each year, then performs a frequency analysis on the annual series of maxima, identifying intensities for various annual probabilities of exceedance. These annual probabilities of exceedance are typically referred to by the 'return period' associated with the probabilities, as below:

Table 1 - Return Periods and Associated Probabilities

Annual Probability of Exceedance	Return Period
0.5	2 years
0.2	5 years
0.1	10 years
0.04	25 years
0.02	50 years
0.01	100 years
0.00286	350 years

The process is repeated for rainfall durations of 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 6 hours, 12 hours, and 24 hours.

The existing IDF data (depths of rain in millimeters for all of each year's time series) from the years 1940 to 2007 were obtained from the existing IDF curve data. The remaining values for 2008 to 2017 were extracted from the 15 minute processed, non-quality controlled raw data obtained from the Climate Services / Meteorological Services of Canada branch of Environment and Climate Change Canada. The 5 minute and 10 minute data was not accessible, as the raw tip data was not made available.

3. Data Processing Procedure

An excel spreadsheet was created to process the raw data. The raw data was separated into columns and then consolidated into a single numerical term. This allowed one term to contain all of the data, including data, time and data point. It was organized using the following structure: **YYYYMMDDHH#ddd.dd**. Where the components within the term are further defined below:

- YYYY: The four digits in this position identify the year
- MM: The two digits in this position identify the month
- DD: The two digits in this position identify the date
- HH: The two digits in this position identify the hour of the day
- #: The number in this position identifies the 15 minute period the data was collected in
- ddd.d: The four digits contain the data for the specified time period

These terms were then sorted and deconstructed, so that a chronological array of information was developed.

Rainfall was reported in two different types of data formats in the raw data. The first (elements 262-266) represents rainfall depth in millimeters (to a resolution of 0.1 mm) in each 15 minute interval. Data in this format was reported for the years 2013 to 2017. The second data format (elements 267-270) represents the rainfall weight present in the gauge in each 15 minute interval. The data is stored to a resolution of 0.1 in units of kg/m^2 which equates to millimeters of depth (Environment and Climate Change Canada, 2017, pp. 32-33). The depth of rain in the system at a point in time for these datasets can be established by taking the difference of the gauge weight reading at the beginning and end of each 15 minute interval. The data collected in this format was available for years 2003-2017. The methods used to process the data based on the format received are presented below.

3.1 Processing Elements 263-266

After the data had been chronologically sorted and deconstructed, the 15 min precipitation depth in mm was extracted from the data point, creating a continuous time series of rainfall data with a 15 minute time step. The average rainfall intensities over larger durations were calculated using moving averages of the 15 minute time series.

3.2 Processing Elements 267-270

The rainfall depths for data collected by these gauges were calculated by subtracting the gauge reading prior to the 15 minute interval of interest. Taking the difference between the gauge readings determined the depth of precipitation that had accumulated during that time 15 minute time interval. Logical operators were used to remove obvious outliers such as the error -99999 data terms,

negative differences and calculated depth values over 100 mm (caused by jumps, dips or missing data in the reading measurements which could potentially be attributed to snow/ice or other gauge errors). Similarly to the first dataset, the average rainfall intensities over larger durations were calculated using moving averages of the 15 minute time series.

3.3 Data Analysis and Verification

For each year, the maximum annual rainfall intensity was extracted from the time series for each rainfall duration, along with the corresponding date of the maximum precipitation.

Each depth of precipitation and the date of occurrence for the maximum events were verified against that day's quality controlled data presented in the *Daily Data Report* for the Toronto City ON Gauge (6158355) (Government of Canada). If the total precipitation amount recorded on the Daily Data Report significantly conflicted with the processed data or was denoted as missing, the entry was deleted and the year's next highest precipitation depth was considered. This instances where this occurred are identified below:

- December 16th, 2008
- May 7th, 2009
- December 4th, 2009
- May 7th, 2010
- October 12th, 2010
- February 7th, 2016
- February 16th, 2016

As data in both forms was present for the years 2013 to 2017, the maximum depth of precipitation per year was found using both methods and compared to ensure consistency of results. The values were determined to have a maximum variance of 0.1 mm for any given year between the two methods, and the maximum values were found to occur on the same days. Therefore the precipitation depths can be considered to be consistently calculated for both types of data received. The processed data used to generate the IDF curve inputs is presented within **Appendix B.**

4. Frequency Analysis

HYFRAN software was used to perform a frequency analysis on the processed data for 1940 to 2017 for each time series. The Gumbel (Method of Moments) Distribution was selected for analysis to be consistent with the methods used to determine the existing IDF curve. A 95% confidence interval was applied during the analysis.

As the 5 and 10 minute data was not available up to 2017, only the available data was considered during the frequency analysis for those time series. An overall increase from the previous IDF curves ranging from 2-11% was observed in the updated IDF curves, when comparing the 2004 and 2017 curves as shown in **Table 2**. The increase noted in the 15 minute duration of the same period was applied to each 5 minute and 10 minute interval data. The results and software outputs for the analysis are included within **Appendix C**.

Table 2 - Difference in IDF Curve Data

	Statistical Analysis Results – Data Points on Previous IDF Curve to 2004 (mm/hr)						Statistical Analysis Results – Data Points on Updated IDF Curve to 2017 (mm/hr)						
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**350-yr**
5 min	109.2	151.9	180.1	215.8	242.3	268.5	110.4	157.8	187.7	225.1	256.4	285.9	351.2
10 min	76.1	101.6	118.5	139.8	155.7	171.4	77.1	105.0	123.3	145.7	164.4	182.5	221.6
15 min	61.7	85.0	100.5	120.1	134.6	148.9	62.4	88.0	104.8	125.8	142.4	158.4	192.4
30 min	39.1	54.6	64.9	77.9	87.5	97.0	39.8	55.8	66.2	79.0	89.4	99.0	120.1
60 min	23.8	32.6	38.5	45.9	51.4	56.8	24.4	33.5	39.5	46.9	52.7	58.3	70.4
120 min	14.0	18.7	21.8	25.7	28.7	31.6	14.4	20.0	23.7	28.2	31.8	35.3	42.7
360 min	5.7	7.6	8.9	10.4	11.6	12.8	5.9	8.0	9.3	11.0	12.3	13.6	16.4
720 min	3.4	4.4	5.1	6.0	6.6	7.2	3.5	4.6	5.3	6.1	6.8	7.5	8.9
1440 min	1.9	2.5	2.8	3.3	3.6	3.9	2.0	2.5	2.9	3.3	3.7	4.0	4.8

5. IDF Curve Generation

The HYFRAN software generated the rainfall depth for each time series and design storm. As the program only provided certain storm events, the 25 year and 350 year estimates were determined through applying interpolation and curve fitting methods to the results. This data was then used to evaluate the corresponding rainfall intensity for each period by dividing the rainfall depth by the duration of time series in hours. The curve results were then plotted on a graph.

A three-parameter equation curvefit of the results were used to generate lines of best fit for each design storm. The three-parameter equation was used in the updated IDF curve instead of the two-parameter equation originally used by Environment Canada, as the third parameter allows for additional control over the line's curvature and resulted in a line that fit closer to the data points over the entire range of rainfall durations. The form of the three parameter equation is:

$$i = \frac{a}{(t_d + b)^c}$$

Where i is the rainfall intensity in mm/h and t_d is the rainfall duration in minutes.

The best fit a, b and c parameters for each return interval are provided below in Table 1.

Table 3 - IDF Curve Parameters

Parameter	2 year	5 year	10 year	25 year	50 year	100 year	350 year
a	696.56	1074.38	1335.70	1499.06	1499.06	1499.06	1498.13
b	5.031	5.500	5.836	5.000	3.781	2.813	1.219
c	0.805	0.830	0.841	0.835	0.816	0.801	0.771

The trendlines were included in the IDF Curve plot as the solid lines shown on **Figure 1.**

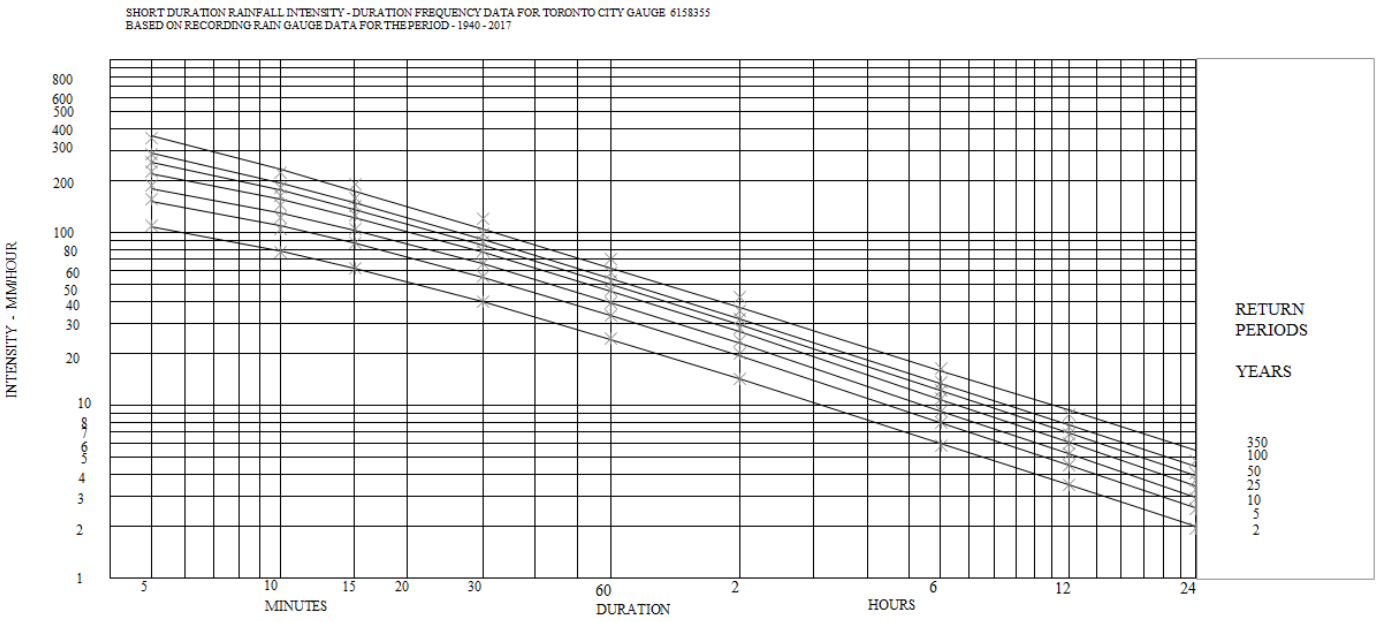


Figure 1 - Updated IDF Curve for Toronto City Gauge 6158355

6. Comparison of 2007 IDF Curve and Updated 2017 IDF Curve

As expected, the updated IDF curve follows a similar trend to the existing curve with a slight increase (2% - 11%) observed in the updated curve values. The figure below plots the 100-year event curves from the existing 2007 IDF curve and the updated 2017 IDF Curve to allow for a more direct comparison.

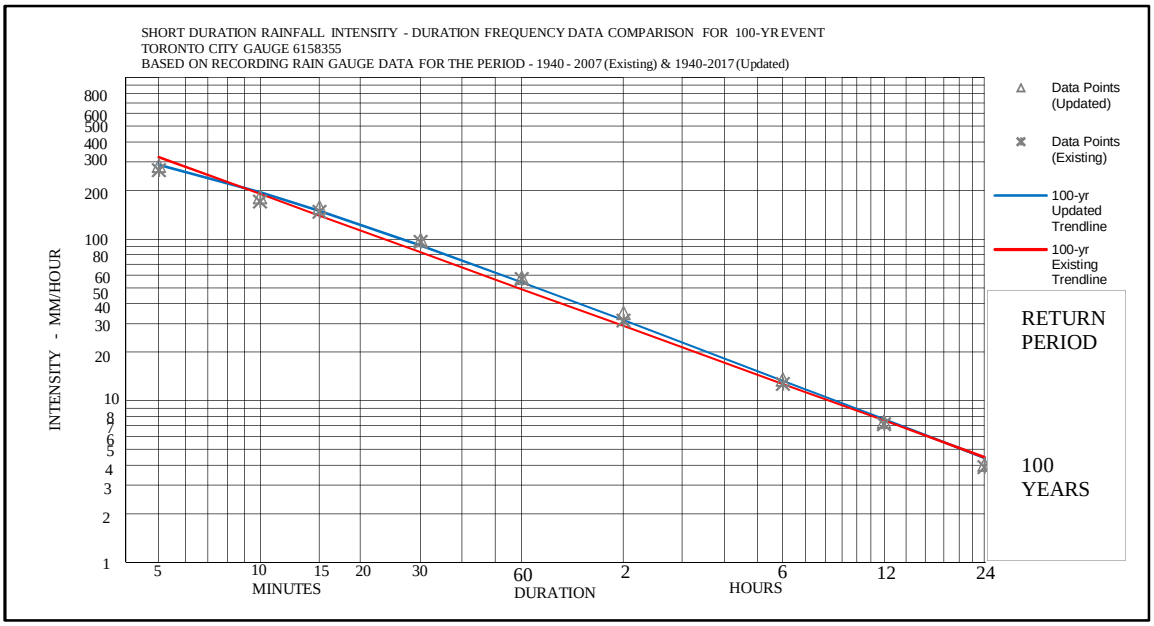


Figure 2 - Comparison of 100-yr Curves

The updated trendline was observed to demonstrate more of a curve than the existing data trendline, which appears linear on the logarithmic scale as a result of the curvefitting method used.

7. Summary

The existing IDF curve was updated according to more recent data attained from Environment and Climate Change Canada's Toronto City rain gauge. The new IDF curve presents data from the years 1940 to 2017. The data was processed using Excel and analysed statistically using the software HYFRAN's Gumbel (Method of Moments) with a confidence interval of 95%.

After the results were attained for each time series and design storm, they were converted into rainfall intensities and plotted on a logarithmic scale. As the HYFRAN software did not generate results for the 25 year or 350 year events, the results were interpolated using curve fitting methods. Lines of best fit were generated using a curve fitting process and a, b, and c parameters were calculated for each design storm to determine a trendline relationship between rainfall intensity, and rainfall duration.

AECOM Signatures

Report Prepared By:

Sophia Eugeni
Civil Engineering Intern

Report Prepared By:

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Senior Water Resources Engineer

References

Environment and Climate Change Canada. (2017). *Technical Documentation - Digital Archive of Canadian Climatological Data.* Retrieved from ftp://ftp.tor.ec.gc.ca/Pub/Documentation_Technical/Technical_Documentation.pdf

Government of Canada. (n.d.). *Daily Data Report for the Toronto City ON Gauge.* Retrieved 2018, from http://climate.weather.gc.ca/climate_data/daily_data_e.html?hlyRange=2002-06-04%7C2018-03-26&dlyRange=2002-06-04%7C2018-03-26&mlyRange=2003-07-01%7C2006-12-01&StationID=31688&Prov=ON&urlExtension=_e.html&searchType=stnName&optLimit=yearRange&StartYear=184

Appendix A
IDF Curves

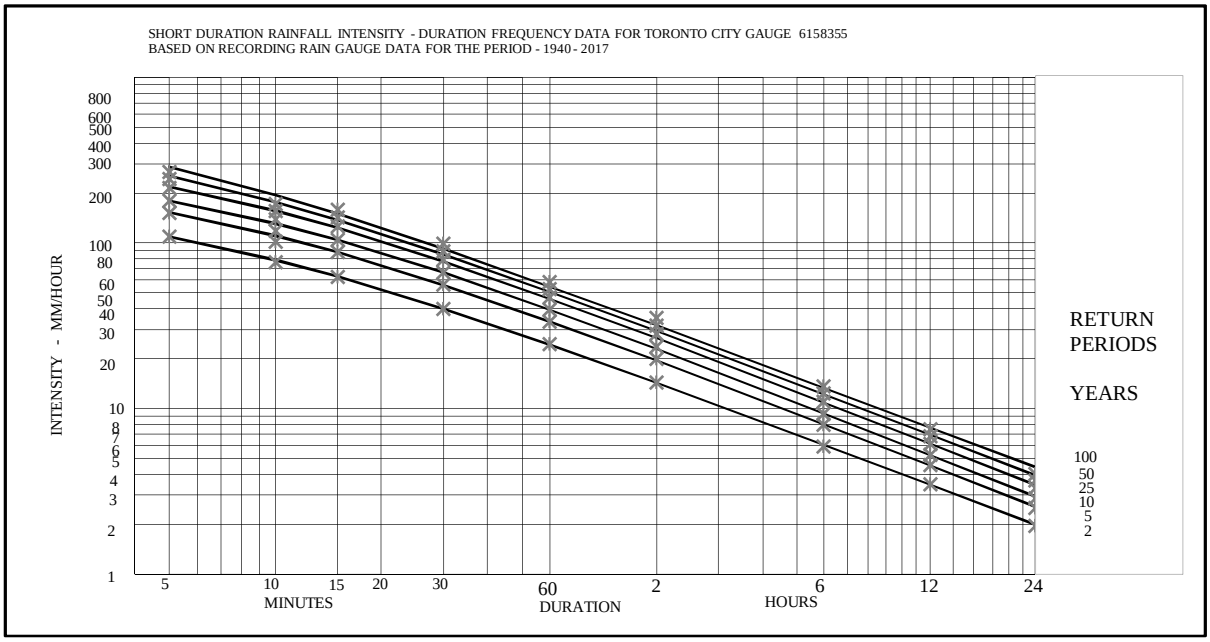


Figure 1 - Updated IDF Curve

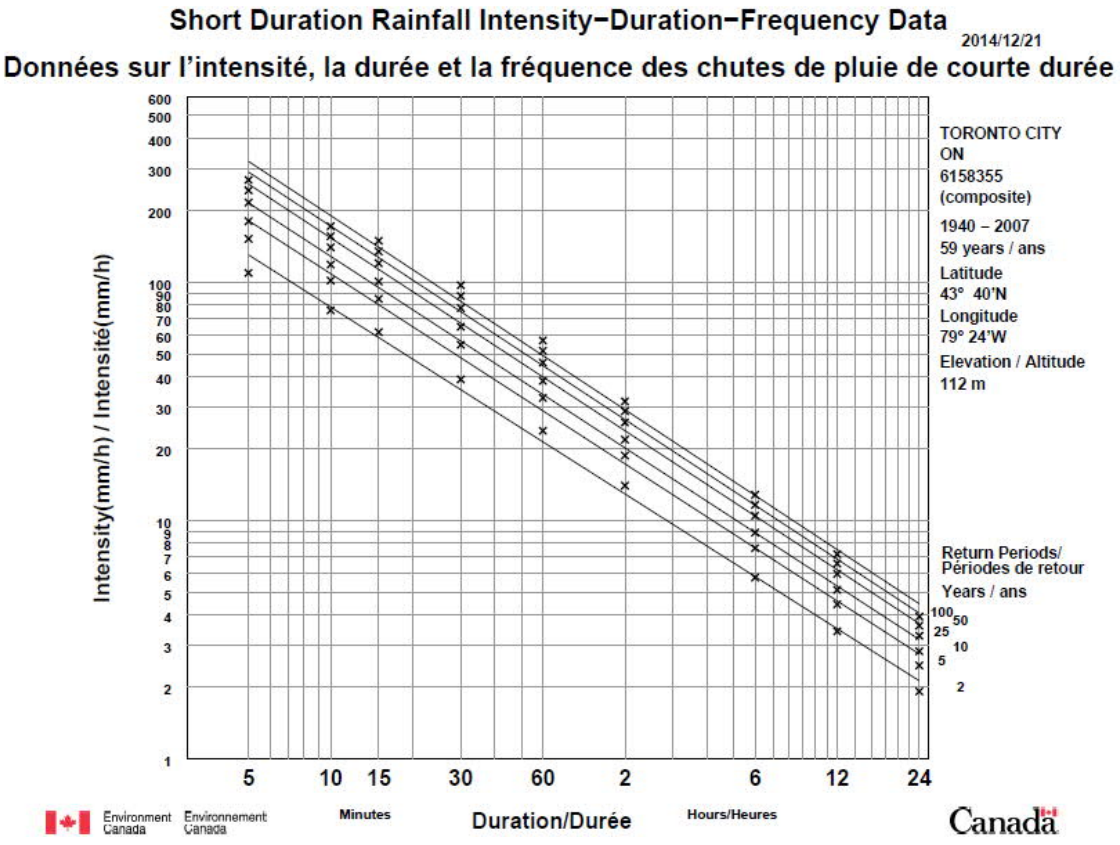


Figure 2 - Existing IDF Curve

Appendix B
Processed Data

Values for IDF Fit: Maximum rainfall depth in millimeters

	Duration (Minutes)								
Year	5	10	15	30	60	120	360	720	1440
1940	13.7	15.7	21.3	30.5	30.5	30.5	31.7		35.1
1941	11.4	18.3	21.6	37.1	45.7	56.4	62.2	62.2	62.2
1942	14.2	23.1	28.7	33.5	37.6	40.6	51.6	51.6	70.1
1943	6.6	12.4	14.7	17.8	22.6	22.9	32	34.3	47.5
1944	11.7	15.7	20.8	21.8	26.7	35.6	41.7	51.6	51.6
1945	6.3	9.1	10.4	12.7	17.3	22.6	38.9	60.7	67.6
1946	7.6	15	16	19.8	33.3	39.4	42.2	42.2	42.4
1947	6.3	11.9	13.5	13.5	14.7	19.3	29.7	37.6	61
1948	7.9	10.9	13	16.8	19.6	30	30	43.4	46
1949	4.6	7.4	9.1	12.4	18.5	18.8	33.5	39.6	42.2
1950	13.5	14.7	18.3	27.4	36.8	37.3	37.8	43.4	46.2
1951	10.4	13.5	15.5	23.1	30	31	34.8	46.5	49.5
1952	11.4	15.2	22.9	32.3	33.8	33.8	33.8	37.1	42.9
1953	8.1	9.7	13.5	15.7	23.1	26.7	27.7	41.7	43.2
1954	8.1	8.4	10.2	13	23.4	40.4	67.1	83.1	97
1955	8.6	14.7	18	23.1	25.7	28.7	41.7	57.9	63.8
1957	10.2	14	17.3	22.1	28.7	32.8	40.6	48.5	63.5
1960	8.4	11.9	14	16.8	22.1	36.8	61.5	61.5	61.5
1961	10.4	10.9	11.4	17.3	23.9	27.9	38.1	38.4	38.4
1962	22.4	25.7	28.7	38.4	40.6	41.9	41.9	56.6	56.6
1963	7.1	11.2	13.2	13.7	14.5	19	21.6	28.4	37.8
1964	9.7	10.9	11.2	15.7	16.5	18.3	38.1	39.1	48.5
1965	9.1	10.4	12.2	12.7	17.8	18.5	24.4	24.4	34
1967	15	16.5	18.3	21.1	21.8	23.1	27.9	31.5	41.1
1968	7.9	11.7	15.5	24.4	37.1	56.1	67.6	71.1	71.1
1969	8.1	10.4	10.4	11.7	14	20.8	32	36.6	37.3
1970	18.3	22.1	25.4	26.4	26.4	35.1	48.8	60.7	75.2
1971	6.1	8.9	12.2	16.8	19	21.3	26.9	31.7	34.8
1972	5.3	9.1	10.9	15	21.8	30.7	31.5	31.5	40.4
1973	6.6	9.9	14.7	16.8	23.1	26.9	29.7	36.6	44.7
1974	20.8	26.7	34.3	44.7	50	50	51.1	58.4	58.7
1975	7.6	13	17	24.4	30.5	35.6	52.3	57.1	57.1
1976	6.9	8.9	9.7	11.7	13.7	19.8	22.4	33	40.6
1977	20.8	27.9	38.9	40.9	45	45	50	59.9	59.9
1978	7.2	10.2	12	13.4	17.4	21	24.8	29.6	30.2
1979	13.1	15.1	15.1	21.6	24.5	24.6	24.6	35.6	36.6
1980	5.8	9.4	11	20.4	31.9	33.4	34	37.1	38
1981	16.2	21.8	29.9	34.5	36.4	38	46.2	46.4	60.9

	Duration (Minutes)								
Year	5	10	15	30	60	120	360	720	1440
1982	12.4	19.8	27.4	29.3	30.6	32.9	44.1	47	47
1983	13.8	16.4	17.3	21.3	22	24.4	28.8	30.6	30.6
1984	9.4	10.2	10.9	15.2	15.2	16.7	24.7	30.9	32.2
1985	8.5	12.3	12.7	13.8	16.7	23.3	25.2	25.4	38.4
1986	13.7	18.9	27.7	45.8	58.9	62.6	77.8	78	82.4
1987	6.7	10.2	14.1	15.9	16	17	24.7	27.6	29.6
1988	7.8	12	12.8	13.4	13.6	16.9	27.4	34	36.8
1989	6.2	8.8	9.2	13.7	23.3	34.6	47.2	47.4	47.4
1990	7.4	9.4	10.4	11.8	13.7	15.6	21.3	29.9	45.1
1991	12.1	19	21.2	24.6	26.1	26.2	32.7	35	38.6
1992	6.4	9	11.2	18.7	24.6	26.7	38.6	39.4	42.4
1993	9.7	12.7	14.9	17.3	25.7	35.1	-	-	54
1994	13.3	15.6	19.6	20.7	22	22.2	26.6	30	32.3
1995	8	12	17.6	25.6	31.6	38.8	42	55.6	67.6
1996	11.1	15.5	17.7	22.9	31.6	35.5	41.3	67.8	78
1997	4.2	6.1	8	9.3	11.6	20.5	25.4	35.8	39
1998	7.5	10.4	13.5	14.6	16.4	16.8	17.7	28.4	36.8
2002	7.2	11.5	15.7	20.4	20.4	26.6	27.3	33.7	33.9
2003	6	9.2	10.2	11	13.4	20.6	27	33.2	33.4
2004	6.8	9.8	10.4	11.6	12.8	14.2	23.6	28.6	29
2005	8.4	13.2	18.4	21.6	24.8	24.8	25.4	32.6	35.8
2006	6.4	11	12.4	15.6	22.8	27.4	31.6	42.6	44.7
2007	9.2	16.2	22.6	35	40.6	41.6	42.6	56.4	58.6
2008	-	-	16.9	30.4	35.0	52.1	52.1	52.1	52.1
2009	-	-	14.3	20.4	30.4	30.4	32.8	32.8	58.9
2010	-	-	11.4	20	35.4	41.2	44.9	57.6	61.6
2011	-	-	15.6	15.6	19.3	23.1	27.1	34	48.9
2012	-	-	15.3	18.4	22.9	26.3	37.9	40.6	45.5
2013	-	-	20.3	32.2	49.5	87.6	95.6	96.5	97.1
2014	-	-	12.3	21.6	17.2	22.8	34.1	34.1	34.8
2015	-	-	20.6	21.7	22.1	22.1	34.8	53.3	58.2
2016	-	-	47.3	47.3	47.3	47.5	47.5	47.5	47.5
2017	-	-	8.5	12.8	23	26.3	32.1	51.4	52.9

Appendix C
Statistical Analysis Outputs

5 Minutes Time Series

Graphics | Results | Adequacy | Characteristics

Project: C:\Program Files (x86)\NRS-ETE\HYFRANPLUS\TRCA IDF 5min.hyf Size: 61

Title: TRCA IDF 27mar18

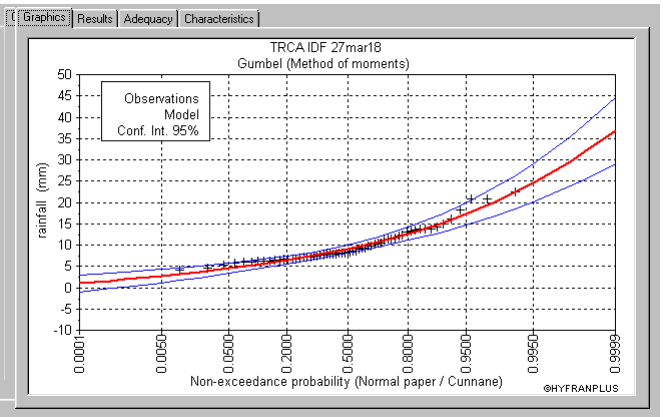
T	q	XT	Standard	Confidence interval
10000.0	0.9999	36.8	3.94	29.1 - 44.6
2000.0	0.9995	31.8	3.27	25.4 - 38.2
1000.0	0.9990	29.6	2.98	23.8 - 35.4
200.0	0.9950	24.6	2.31	20.0 - 29.1
100.0	0.9900	22.4	2.02	18.4 - 26.3
50.0	0.9800	20.2	1.73	16.8 - 23.6
20.0	0.9500	17.3	1.36	14.6 - 19.9
10.0	0.9000	15.0	1.08	12.9 - 17.1
5.0	0.8000	12.7	0.796	11.1 - 14.2
3.0	0.6667	10.8	0.601	9.61 - 12.0
2.0	0.5000	9.10	0.473	8.18 - 10.0
1.4286	0.3000	7.37	0.434	6.52 - 8.22
1.2500	0.2000	6.46	0.462	5.56 - 7.37

Estimated parameters: u: 7.9539 alpha: 3.1358

Confidence level: 95 %

q = non-exceedance probability Other return period p.d.f.

D Description | Data | Basic statistics | Hypothese tests | Graphics



	Observation	Identifier	Empirical probability	Code
1	13.7	N/D	0.8431	
2	11.4	N/D	0.7124	
3	14.2	N/D	0.8922	
4	6.6	N/D	0.1895	
5	11.7	N/D	0.7451	
6	6.3	N/D	0.1242	
7	7.6	N/D	0.3529	
8	6.3	N/D	0.1405	
9	7.9	N/D	0.4020	
10	4.6	N/D	0.0261	
11	13.5	N/D	0.8268	
12	10.4	N/D	0.6634	
13	11.4	N/D	0.7288	
14	8.1	N/D	0.4510	
15	8.1	N/D	0.4673	

Insert the inactive data in the calculation of empirical probabilities.

Graphics | Results | Adequacy | Characteristics

Project: C:\Program Files (x86)\NRS-ETE\HYFRANPLUS\TRCA IDF 5min.hyf

Title: TRCA IDF 27mar18

	Characteristics of the population	Characteristics of the sample
Number of data [n] :		61
Minimum :	None	4.20
Maximum :	None	22.4
Average :	9.76	9.76
Standard deviation :	4.02	4.02
Median :	9.10	8.40
Coefficient of variation [Cv] :	0.412	0.412
Skewness coefficient [Cs] :	1.14	1.36
Kurtosis coefficient [Ck] :	2.40	4.31

10 Minutes Time Series

Graphics | Results | Adequacy | Characteristics

Project Size: 61

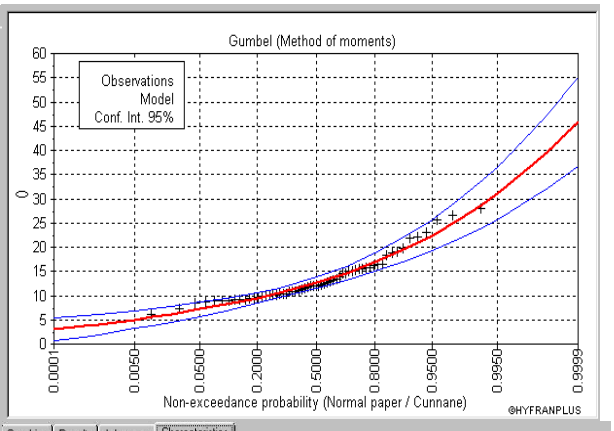
Title

T	q	XT	Standard	Confidence interval
10000.0	0.9999	45.9	4.71	36.6 - 55.1
2000.0	0.9995	39.8	3.91	32.2 - 47.5
1000.0	0.9990	37.2	3.56	30.2 - 44.2
200.0	0.9950	31.2	2.76	25.8 - 36.6
100.0	0.9900	28.6	2.42	23.8 - 33.3
50.0	0.9800	25.9	2.08	21.9 - 30.0
20.0	0.9500	22.4	1.63	19.3 - 25.6
10.0	0.9000	19.7	1.29	17.2 - 22.3
5.0	0.8000	16.9	0.952	15.1 - 18.8
3.0	0.6667	14.7	0.719	13.3 - 16.1
2.0	0.5000	12.7	0.566	11.6 - 13.8
1.4286	0.3000	10.6	0.520	9.59 - 11.6
1.2500	0.2000	9.52	0.553	8.43 - 10.6

Estimated parameters: u: 11.3014 alpha: 3.75216

Confidence level: 95 %

q = non-exceedance probability Other return period p.d.f.



	Observation	Identifier	Empirical probability	Code
1	15.7	N/D	0.7614	
2	18.3	N/D	0.8431	
3	23.1	N/D	0.9412	
4	12.4	N/D	0.5490	
5	15.7	N/D	0.7778	
6	9.1	N/D	0.1242	
7	15	N/D	0.6797	
8	11.9	N/D	0.4673	
9	10.9	N/D	0.3529	
10	7.4	N/D	0.0261	
11	14.7	N/D	0.6471	
12	13.5	N/D	0.6144	
13	15.2	N/D	0.7124	
14	9.7	N/D	0.2059	
15	8.4	N/D	0.0425	

Graphics | Results | Adequacy | Characteristics

Project :

Title :

	Characteristics of the population	Characteristics of the sample
Number of data [n] :		61
Minimum :	None	6.10
Maximum :	None	27.9
Average :	13.5	13.5
Standard deviation :	4.81	4.81
Median :	12.7	12.0
Coefficient of variation [Cv] :	0.357	0.357
Skewness coefficient [Cs] :	1.14	1.26
Kurtosis coefficient [Ck] :	2.40	3.96

15 Minutes Time Series

Graphics | Results | Adequacy | Characteristics

Project: Size: 71

Title: TRCA IDF 15mm

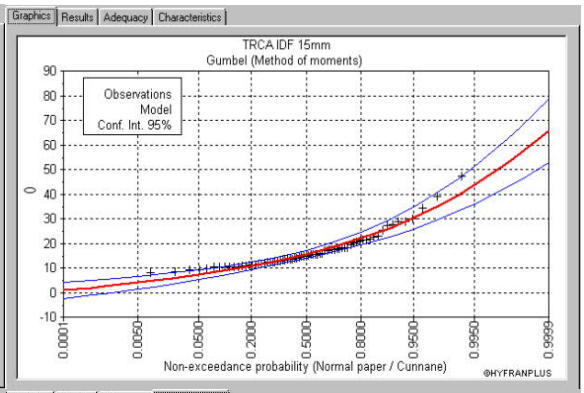
T	q	XT	Standard	Confidence interval
10000.0	0.9999	65.8	6.61	52.8 - 78.7
2000.0	0.9995	56.6	5.48	45.9 - 67.4
1000.0	0.9990	52.7	5.00	42.9 - 62.5
200.0	0.9950	43.5	3.87	35.9 - 51.1
100.0	0.9900	39.6	3.39	32.9 - 46.2
50.0	0.9800	35.6	2.91	29.9 - 41.3
20.0	0.9500	30.3	2.28	25.9 - 34.8
10.0	0.9000	26.2	1.80	22.7 - 29.8
5.0	0.8000	22.0	1.34	19.4 - 24.6
3.0	0.6667	18.6	1.01	16.6 - 20.6
2.0	0.5000	15.6	0.793	14.0 - 17.1
1.4286	0.3000	12.4	0.729	11.0 - 13.8
1.2500	0.2000	10.8	0.776	9.25 - 12.3

Estimated parameters: u: 13.4721; alpha: 5.67761

Confidence level: 95 %

q = non-exceedance probability

Other return period | p.d.f.



Description | Data | Basic statistics | Hypothese tests | Graphics

	Observation	Identifier	Empirical probability	Code
1	21.3	N/D	0.8230	
2	21.6	N/D	0.8371	
3	28.7	N/D	0.9213	
4	14.7	N/D	0.4719	
5	20.8	N/D	0.7949	
6	10.4	N/D	0.1067	
7	16	N/D	0.5983	
8	13.5	N/D	0.3876	
9	13	N/D	0.3596	
10	9.1	N/D	0.0365	
11	18.3	N/D	0.7107	
12	15.5	N/D	0.5421	
13	22.9	N/D	0.8652	
14	13.5	N/D	0.4017	
15	10.2	N/D	0.0787	

☑ Insert the inactive data in the calculation of empirical probabilities.

Graphics | Results | Adequacy | Characteristics

Project:

Title: TRCA IDF 15mm

	Characteristics of the population	Characteristics of the sample
Number of data [n]:		71
Minimum:	None	8.00
Maximum:	None	47.3
Average:	16.7	16.7
Standard deviation:	7.28	7.28
Median:	15.6	14.9
Coefficient of variation [Cv]:	0.435	0.435
Skewness coefficient [Cs]:	1.14	1.84
Kurtosis coefficient [Ck]:	2.40	6.79

30 Minutes Time Series

Graphics | Results | Adequacy | Characteristics

Project: Size: 71

Title: TRCA IDF 30min

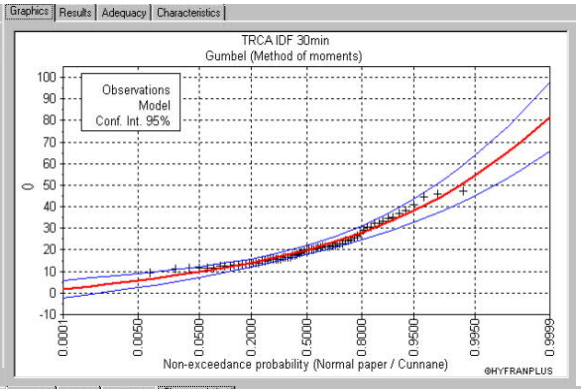
T	q	XT	Standard	Confidence interval
10000.0	0.9999	81.7	8.14	65.8 - 97.7
2000.0	0.9995	70.5	6.75	57.3 - 83.7
1000.0	0.9990	65.7	6.15	53.6 - 77.7
200.0	0.9950	54.4	4.77	45.0 - 63.7
100.0	0.9900	49.5	4.17	41.3 - 57.7
50.0	0.9800	44.7	3.58	37.6 - 51.7
20.0	0.9500	38.1	2.81	32.6 - 43.6
10.0	0.9000	33.1	2.22	28.8 - 37.5
5.0	0.8000	27.9	1.64	24.6 - 31.1
3.0	0.6667	23.7	1.24	21.3 - 26.1
2.0	0.5000	19.9	0.976	18.0 - 21.9
1.4286	0.3000	16.1	0.897	14.3 - 17.8
1.2500	0.2000	14.1	0.955	12.2 - 15.9

Estimated parameters: u: 17.3816; alpha: 6.98848

Confidence level: 95 %

q = non-exceedance probability

Other return period | p.d.f.



Description | Data | Basic statistics | Hypothese tests | Graphics

	Observation	Identifier	Empirical probability	Code
1	30.5	N/D	0.8371	
2	37.1	N/D	0.9213	
3	33.5	N/D	0.8792	
4	17.8	N/D	0.4438	
5	21.8	N/D	0.6545	
6	12.7	N/D	0.1067	
7	19.8	N/D	0.4860	
8	13.5	N/D	0.1910	
9	16.8	N/D	0.3596	
10	12.4	N/D	0.0927	
11	27.4	N/D	0.7949	
12	23.1	N/D	0.6966	
13	32.3	N/D	0.8652	
14	15.7	N/D	0.3174	
15	13	N/D	0.1489	

☑ Insert the inactive data in the calculation of empirical probabilities.

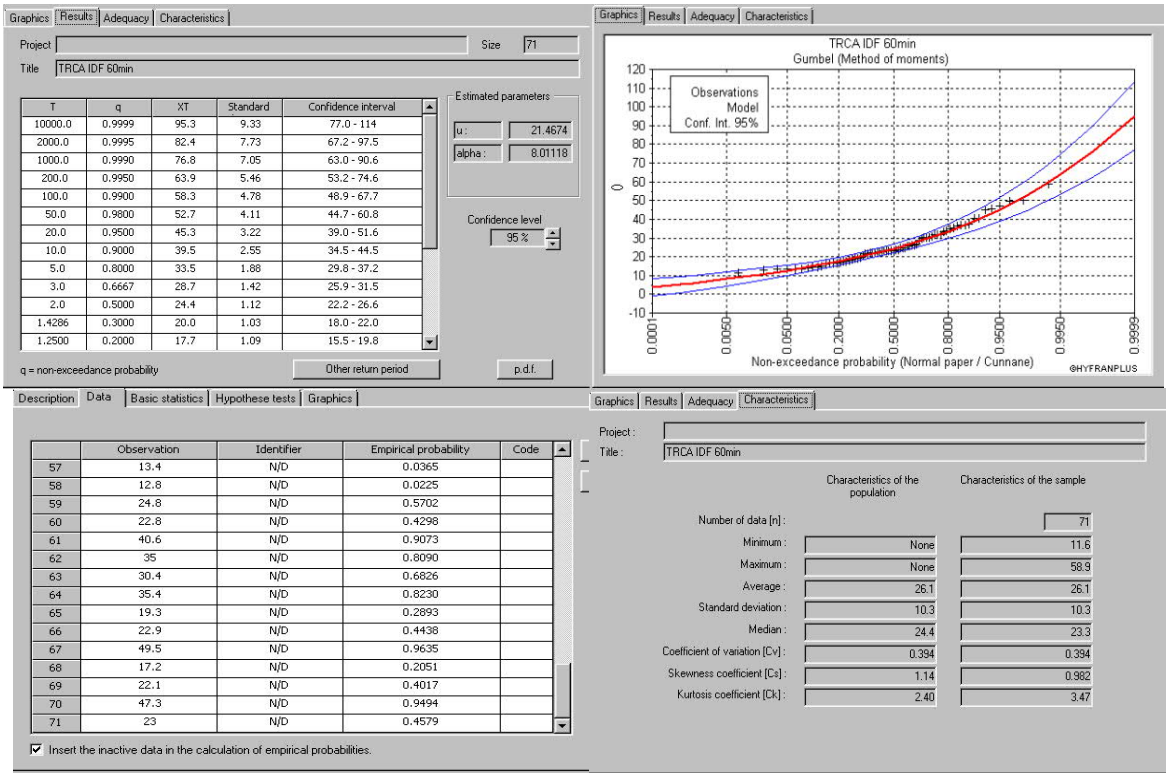
Graphics | Results | Adequacy | Characteristics

Project:

Title: TRCA IDF 30min

	Characteristics of the population	Characteristics of the sample
Number of data [n]:		71
Minimum:	None	9.30
Maximum:	None	47.3
Average:	21.4	21.4
Standard deviation:	8.96	8.96
Median:	19.9	20.0
Coefficient of variation [Cv]:	0.419	0.419
Skewness coefficient [Cs]:	1.14	1.16
Kurtosis coefficient [Ck]:	2.40	3.60

60 Minutes Time Series



Graphics | Results | Adequacy | Characteristics

Project: Size: 71

Title: TRCA IDF 60min

T	q	XT	Standard	Confidence interval
10000.0	0.9999	95.3	9.33	77.0 - 114
2000.0	0.9995	82.4	7.73	67.2 - 97.5
1000.0	0.9990	76.8	7.05	63.0 - 90.6
200.0	0.9950	63.9	5.46	53.2 - 74.6
100.0	0.9900	58.3	4.78	48.9 - 67.7
50.0	0.9800	52.7	4.11	44.7 - 60.8
20.0	0.9500	45.3	3.22	39.0 - 51.6
10.0	0.9000	39.5	2.55	34.5 - 44.5
5.0	0.8000	33.5	1.88	29.8 - 37.2
3.0	0.6667	28.7	1.42	25.9 - 31.5
2.0	0.5000	24.4	1.12	22.2 - 26.6
1.4286	0.3000	20.0	1.03	18.0 - 22.0
1.2500	0.2000	17.7	1.09	15.5 - 19.8

Estimated parameters: u: 21.4674; alpha: 8.01118

Confidence level: 95 %

q = non-exceedance probability | Other return period | p.d.f.

Description | Data | Basic statistics | Hypothese tests | Graphics

	Observation	Identifier	Empirical probability	Code
57	13.4	N/D	0.0365	
58	12.8	N/D	0.0225	
59	24.8	N/D	0.5702	
60	22.8	N/D	0.4298	
61	40.6	N/D	0.9073	
62	35	N/D	0.8090	
63	30.4	N/D	0.6826	
64	35.4	N/D	0.8230	
65	19.3	N/D	0.2893	
66	22.9	N/D	0.4438	
67	49.5	N/D	0.9635	
68	17.2	N/D	0.2051	
69	22.1	N/D	0.4017	
70	47.3	N/D	0.9494	
71	23	N/D	0.4579	

☑ Insert the inactive data in the calculation of empirical probabilities.

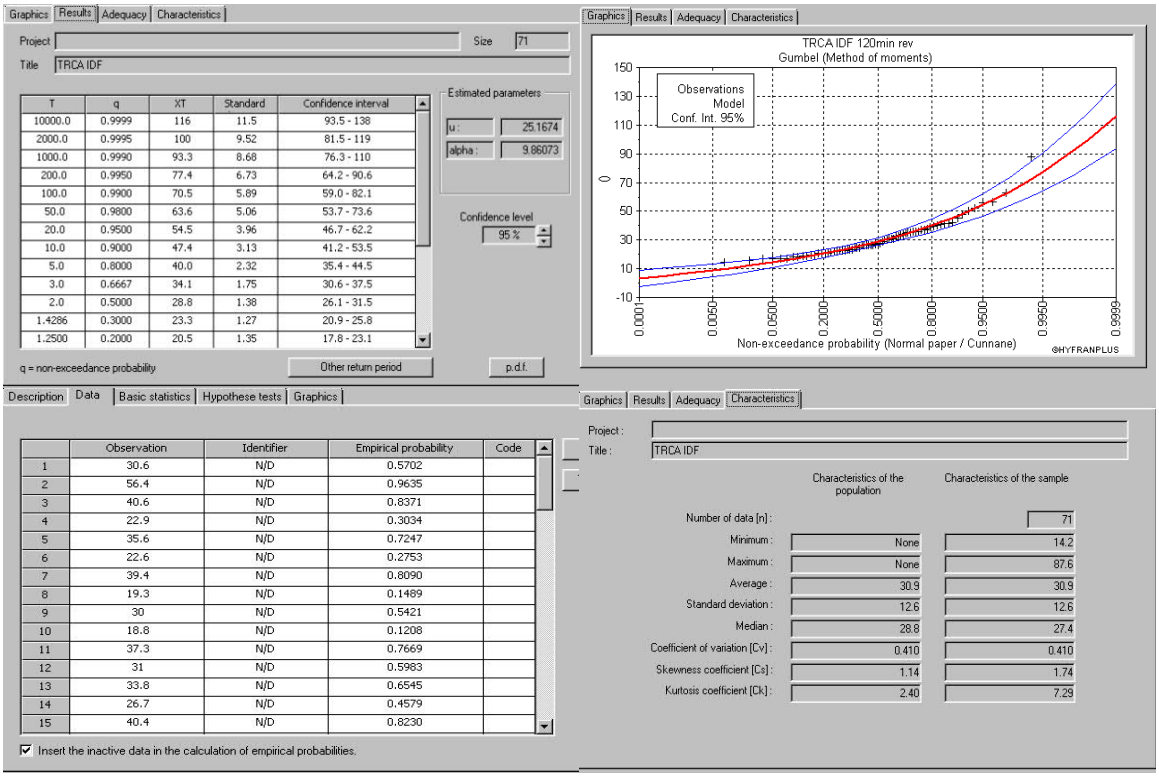
Graphics | Results | Adequacy | Characteristics

Project:

Title: TRCA IDF 60min

	Characteristics of the population	Characteristics of the sample
Number of data [n]:		71
Minimum:	None	11.6
Maximum:	None	58.9
Average:	26.1	26.1
Standard deviation:	10.3	10.3
Median:	24.4	23.3
Coefficient of variation [Cv]:	0.394	0.394
Skewness coefficient [Cs]:	1.14	0.982
Kurtosis coefficient [Ck]:	2.40	3.47

120 Minutes Time Series



Graphics | Results | Adequacy | Characteristics

Project: Size: 71

Title: TRCA IDF

T	q	XT	Standard	Confidence interval
10000.0	0.9999	116	11.5	93.5 - 138
2000.0	0.9995	100	9.52	81.5 - 119
1000.0	0.9990	93.3	8.68	76.3 - 110
200.0	0.9950	77.4	6.73	64.2 - 90.6
100.0	0.9900	70.5	5.89	59.0 - 82.1
50.0	0.9800	63.6	5.06	53.7 - 73.6
20.0	0.9500	54.5	3.96	46.7 - 62.2
10.0	0.9000	47.4	3.13	41.2 - 53.5
5.0	0.8000	40.0	2.32	35.4 - 44.5
3.0	0.6667	34.1	1.75	30.6 - 37.5
2.0	0.5000	28.8	1.38	26.1 - 31.5
1.4286	0.3000	23.3	1.27	20.9 - 25.8
1.2500	0.2000	20.5	1.35	17.8 - 23.1

Estimated parameters: u: 25.1674; alpha: 9.86073

Confidence level: 95 %

q = non-exceedance probability | Other return period | p.d.f.

Description | Data | Basic statistics | Hypothese tests | Graphics

	Observation	Identifier	Empirical probability	Code
1	30.6	N/D	0.5702	
2	56.4	N/D	0.9635	
3	40.6	N/D	0.8371	
4	22.9	N/D	0.3034	
5	35.6	N/D	0.7247	
6	22.6	N/D	0.2753	
7	39.4	N/D	0.8090	
8	19.3	N/D	0.1489	
9	30	N/D	0.5421	
10	18.8	N/D	0.1208	
11	37.3	N/D	0.7669	
12	31	N/D	0.5983	
13	33.8	N/D	0.6545	
14	26.7	N/D	0.4579	
15	40.4	N/D	0.8230	

☑ Insert the inactive data in the calculation of empirical probabilities.

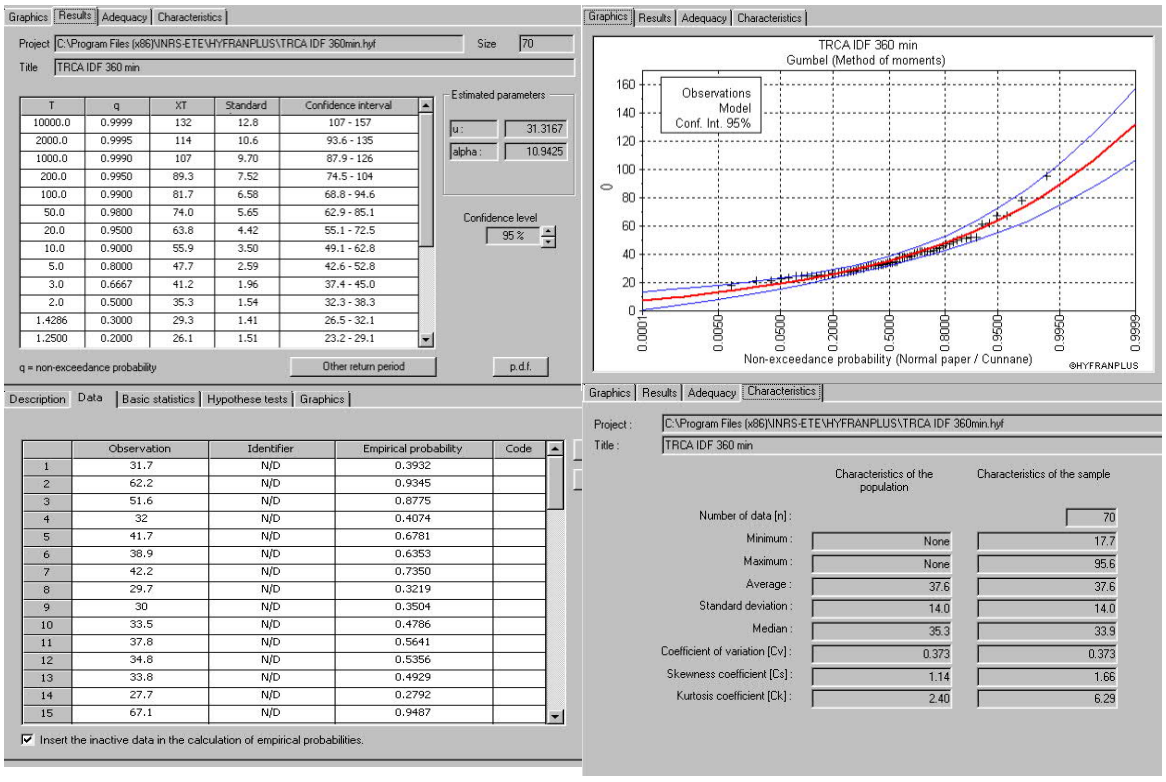
Graphics | Results | Adequacy | Characteristics

Project:

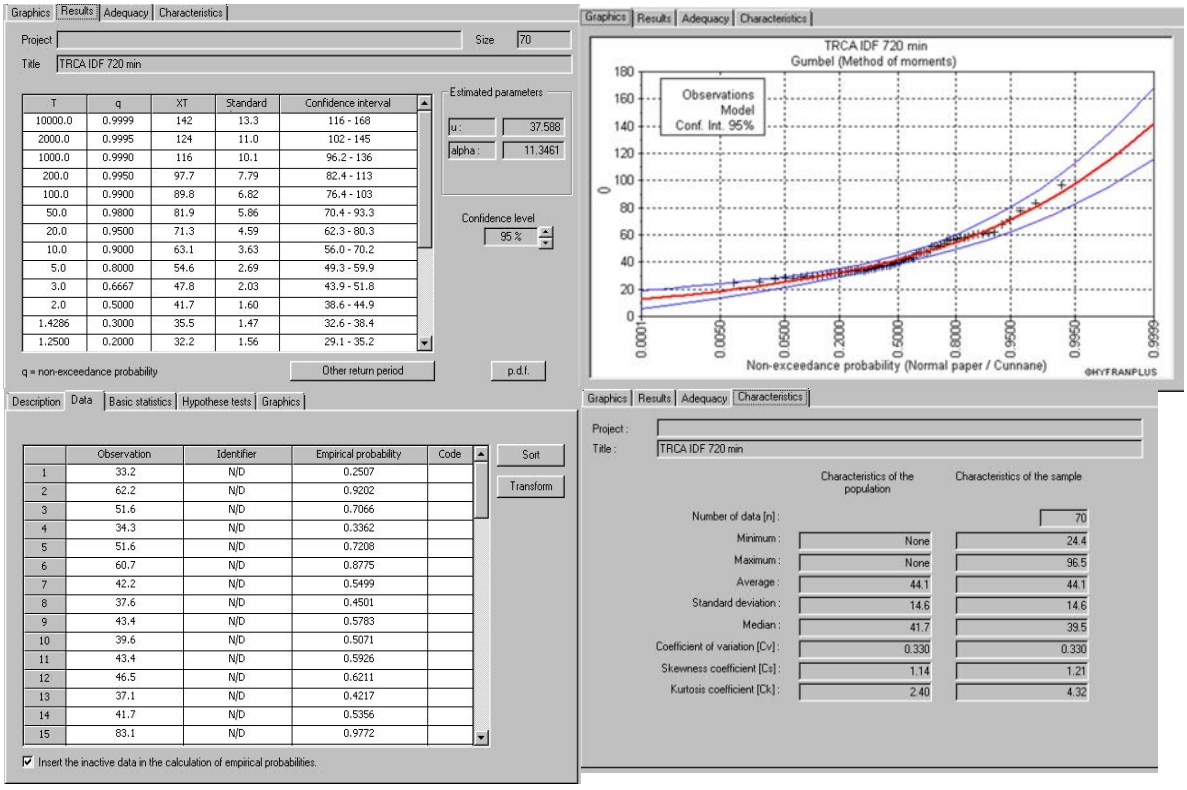
Title: TRCA IDF

	Characteristics of the population	Characteristics of the sample
Number of data [n]:		71
Minimum:	None	14.2
Maximum:	None	87.6
Average:	30.9	30.9
Standard deviation:	12.6	12.6
Median:	28.8	27.4
Coefficient of variation [Cv]:	0.410	0.410
Skewness coefficient [Cs]:	1.14	1.74
Kurtosis coefficient [Ck]:	2.40	7.29

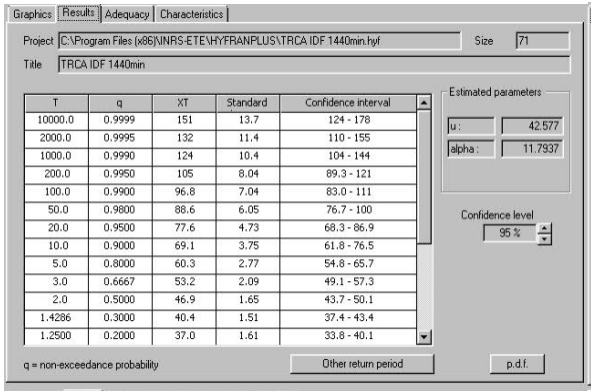
360 Minutes Time Series



720 Minutes Time Series



1440 Minute Time Series


Graphics | Results | Adequacy | Characteristics

Project C:\Program Files (x86)\INRS-ETE\HYFRANPLUS\TRCA IDF 1440min.hyf Size 71

Title TRCA IDF 1440min

T	q	XT	Standard	Confidence interval
10000.0	0.9999	151	13.7	124 - 178
2000.0	0.9995	132	11.4	110 - 155
1000.0	0.9990	124	10.4	104 - 144
200.0	0.9950	105	8.04	89.3 - 121
100.0	0.9900	96.8	7.04	83.0 - 111
50.0	0.9800	88.6	6.05	76.7 - 100
20.0	0.9500	77.6	4.73	68.3 - 86.9
10.0	0.9000	69.1	3.75	61.8 - 76.5
5.0	0.8000	60.3	2.77	54.8 - 65.7
3.0	0.6667	53.2	2.09	49.1 - 57.3
2.0	0.5000	46.9	1.65	43.7 - 50.1
1.4286	0.3000	40.4	1.51	37.4 - 43.4
1.2500	0.2000	37.0	1.61	33.8 - 40.1

Estimated parameters

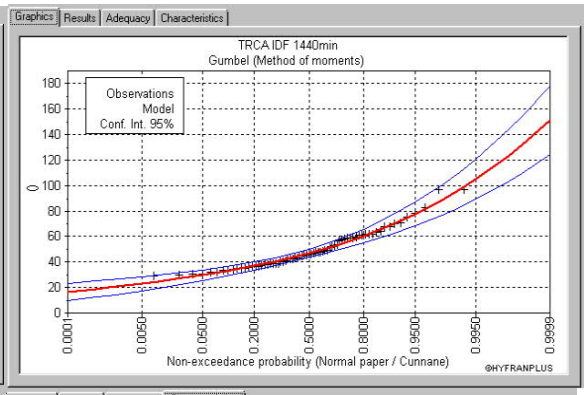
u : 42.577

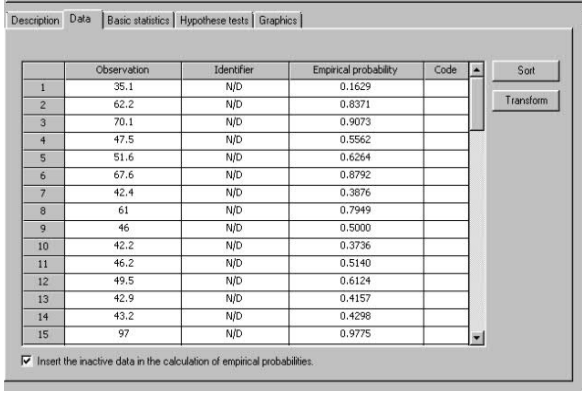
alpha : 11.7937

Confidence level 95 %

q = non-exceedance probability

Other return period p.d.f.

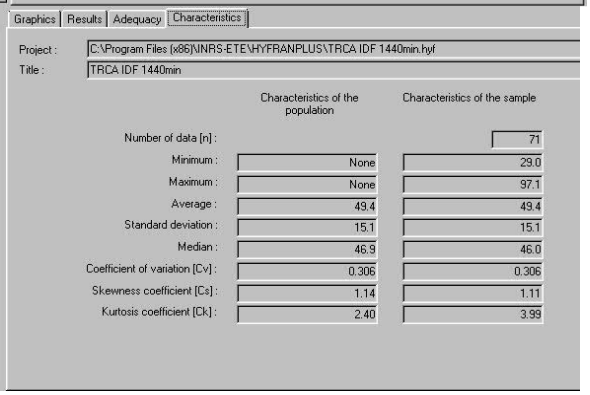



Description | Data | Basic statistics | Hypothese tests | Graphics

	Observation	Identifier	Empirical probability	Code
1	35.1	N/D	0.1629	
2	62.2	N/D	0.8371	
3	70.1	N/D	0.9073	
4	47.5	N/D	0.5562	
5	51.6	N/D	0.6264	
6	67.6	N/D	0.8792	
7	42.4	N/D	0.3876	
8	61	N/D	0.7949	
9	46	N/D	0.5000	
10	42.2	N/D	0.3736	
11	46.2	N/D	0.5140	
12	49.5	N/D	0.6124	
13	42.9	N/D	0.4157	
14	43.2	N/D	0.4298	
15	97	N/D	0.9775	

Sort Transform

Insert the inactive data in the calculation of empirical probabilities.


Graphics | Results | Adequacy | Characteristics

Project : C:\Program Files (x86)\INRS-ETE\HYFRANPLUS\TRCA IDF 1440min.hyf

Title : TRCA IDF 1440min

	Characteristics of the population	Characteristics of the sample
Number of data [n] :		71
Minimum :	None	29.0
Maximum :	None	97.1
Average :	49.4	49.4
Standard deviation :	15.1	15.1
Median :	46.9	46.0
Coefficient of variation [Cv] :	0.306	0.306
Skewness coefficient [Cs] :	1.14	1.11
Kurtosis coefficient [Ck] :	2.40	3.99

Appendix N: Peer Review

Peer Review of the 2018 Don River Watershed Hydrology Update

Report

November 26, 2018

Prepared For:
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CHI Project Number: E754



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1.0 Executive Summary

Computational Hydraulics International (CHI) was retained by the Toronto and Region Conservation Authority (TRCA) in June 2018 to provide an independent peer review of the PCSWMM/SWMM5 model developed by AECOM (consultant) as a part of the Don River Watershed Hydrology Update.

Based on our review, we believe the hydrologic and hydraulic representation is appropriate for the modeling objectives, and most input parameter values fall within the attribute ranges expected for the type of system modeled and for applications in this area.

On August 14th, 2018 CHI sent a technical memorandum to TRCA detailing our preliminary comments on the models and report that were reviewed. The consultant subsequently addressed CHI's comments and updated the models and report accordingly.

There is still some uncertainty whether the soil infiltration parameters used in some subcatchments have been over-estimated. We understand the consultant has explored several options (apart from field tests) to justify the values and are seeking confirmation on this issue. CHI's comments on the applicability of the calibrated model for 350-year and regional storm analysis are detailed in section 8.2. The consultant calibrated and verified the model with 13 events, of which two 50-year storms as well as the August 19th 2005event exceeded a 100-year return period. While there is some uncertainty in extrapolating flow response for very high return period design storms, conducted model calibration/verification with these available storm events meets or exceeds the current state of the practice.

Based on our review of the submitted materials, CHI believes that the Don River Watershed model generally represents a good-quality effort, for what we could consider a reasonable and acceptable application of the PCSWMM and the SWMM5 model for similarly scoped studies.

2.0 Introduction

Computational Hydraulics International (CHI) was retained by the Toronto and Region Conservation Authority (TRCA) in June 2018 to provide an independent peer review of the Don River PCSWMM/SWMM5 model developed by AECOM (consultant) as a part of the Don River Watershed Hydrology Update.

2.1 Scope of Work

The CHI work plan (file "CHI Proposal for Peer Review of 2018 Don River Watershed Hydrology Update _ TRCA RFP # 10007756.pdf", dated May 28, 2018) was prepared in response to the City's Terms of Reference (file "RFP10007756 2018 Don Hydrology Peer Review.pdf"). The overall objectives of the model peer review included:

- Review of the hydrologic and hydraulic representation of existing conditions for accuracy;
- Confirmation that the "science" of modeling was applied correctly.

2.2 Material Reviewed

The base modeling files transmitted on July 16th, 2018 can be found in Appendix A – Submission Background Data.

3.0 Peer Review Process

Three primary components of the model were reviewed including the model setup, the hydrology model and the hydraulic model.

Simulation options and model setup options, including: the selected infiltration method, runoff and routing time steps and associated files were reviewed for appropriateness. Model setup selection was then compared with those from similar studies taking into consideration the resolution of the input data and quality of the modeling data available.

Hydrology components in the model that were examined included subcatchment discretization, parameter assumptions, evaporation and infiltration processes, sub-area routing and calibration. To confirm the hydrological assumptions used in the model setup were appropriate for the application, multiple tests were conducted, re-estimating parameters based on industry accepted assumptions. A sensitivity analysis was completed for 10 hydrologic parameters to determine their influence on the watershed response.

The hydraulic model review centered on the channel routing approach used to represent the flow transitions from sheet to channelized flow. Stormwater management facility setup including stormwater ponds and the G. Ross Lord dam were scrutinized, ensuring the available storage data was correctly added to the model.

Rainfall and flow time series data used for the calibration and validation simulations was examined to ensure the data was free of anomalies and that daylight savings was correctly accounted for in the observed data.

Once the initial review was completed, a memo was sent to TRCA who, in turn relayed the comments to AECOM to be addressed. This memo can be found in Appendix E – Correspondence.

An additional analysis was conducted that compared the previous hydrology model completed in 2004 to the updated model completed in 2018.

4.0 Initial Peer Review

Initial comments from the findings of CHI's review were provided to TRCA as a memo on August 8th, 2018 (Appendix E). This initial review identified 16 action items suggested for improving the integrity and reliability of the model based on the peer review process described in section 3.0 . The main suggestion action items listed in Table 1 were provided to AECOM by TRCA.

Table 1 -Suggested action items provided by CHI based on initial review of model

Suggested action item #	Comment
1	Review HEC-RAS transects and compare with merged PCSWMM transects and ensure slopes in the merged sections have been preserved.
2	Indicate in the report the locations where there was a bridge or culvert in the HEC-RAS model that was not included in the PCSWMM model. Evaluate their sensitivity and provide justification as to why these structures were not included in the model.
3	Assign urban and rural transects in downstream areas representative transects based on the DEM.
4	Confirm the loss coefficients assigned to the piped conduits and bridge shape curves are supposed to be 0. If so, explain why.
5	Edit lumped storage rating curves OL155 and OL95 to have a non-zero flow at depth zero.
6	Confirm jagged storage area/depth curves is representative of the total storage volume.
7	Check that the rainfall time series and flow are timed correctly for 2013 (i.e. both not corrected for daylight savings time).
8	Add a description of how G. Ross Lord Dam rating curves were developed in the report
9	Provide justification as to why many areas marked as having primarily clay soils have infiltration values represented of loam.
10	Provide justification as to why the infiltration parameters (specifically hydraulic conductivity and suction head) values are so varied across the watershed. For example, adjacent gage watersheds HY068 and HY019 have hydraulic conductivity values of 40 mm/hr and 3.3 mm/hr respectively.
11	It is recommended to explore whether some of the higher hydraulic conductivity estimates are caused by potential under-estimation of upstream storage (due to exclusion of limiting hydraulic structures) and rain gage reporting time steps not matching flow monitoring data time step (Is there a correlation between 15-minute

	flow data from HY062, HY068, HY092 gages and higher hydraulic conductivity values for their watersheds).
12	As a good modelling practice use a DEM resampled to a coarser resolution (5-10 m) for subcatchment slope calculation.
13	Provide justification of large variation in percent sub-area routed among the different drainage areas
14	Provide an explanation for the development of a relationship between Antecedent Precipitation Index (API) and Initial Moisture Deficit (IMD) values as it was not used in the model. Ideally, the relationship could have been used in the verification runs. Instead, it seems the verification runs used IMD values similar to values for the remaining events as indicated in Table 6 of the consultant's report. Justification for the approach that is based on computed API for the verification events is requested.
15	It is recommended to include a reference in the report for the API equation on Page 21.
16	Add additional clarification on the assigned IMD values representing the wet conditions.

In response to CHI's initial review memo, AECOM responded to each item, providing either an explanation for the model setup approach or by noting the edits made to the model based on the suggestion. AECOM's response to each comment and CHI's subsequent response can be found in Appendix E – Correspondence.

Most of AECOM's responses provided were found to be satisfactory, however there was still uncertainty with the choice of the soil infiltration parameters, specifically the potential over-estimation of the saturated hydraulic conductivity assigned to the watershed addressed in items 9, 10 and 11 listed in Table 1.

It was observed by CHI that many areas marked on the soils map consisting of primarily clay however, in many areas, the model used infiltration values characteristic of loam soil. The primary concern associated with this comment was associated with the representation of the watershed processes. It was also found the infiltration values were varied across the watershed, with drastically different infiltration parameters for adjacent subcatchments.

AECOM justified the selection of infiltration parameters saying they were calibrated from the volume of runoff measured at the flow gages relative to the volume of rainfall, and discrepancies in the soils map were potentially due to imported topsoil, lot grading and gardens cultivating the surface. It was also noted that infiltration parameters are varied across the watershed because the actual runoff response is varied across the watershed. This was deemed a satisfactory response by CHI.

5.0 Model Simulation Options and Model Setup

5.1 Review the Selected Model Procedures and Methodologies

The choice of measurement units was metric, and processes represented in the base model included rainfall/runoff (hydrology) and flow routing (hydraulics). The various simulation options were reviewed, and the following comments were noted, grouped by parameter type.

5.1.1 Infiltration Model

The Modified Green-Ampt infiltration model was selected for computing infiltration in SWMM5. CHI agrees with the choice of this infiltration model, as it is the most physically-based model compared to the other infiltration options. Also, it is the most appropriate option for handling variable water content conditions in the unsaturated soil zone.

5.1.2 Routing Method

The Dynamic Wave option was selected with damped inertial terms in the solution of flow routing equations (i.e., "partial" damping). These are acceptable choices for the modeling objectives, and the other parameters selected for use with the dynamic wave solution are reasonable.

5.1.3 Reporting Time Step

A reporting time step of five minutes was used. CHI believes the selected value is appropriate for the alternative scenarios evaluated considering that a five-minute time step was used for the rain gages. However, one consideration is the reporting time step used for calibration and verification events. In these cases, it is better if model reporting time step matches the recording interval of the flow monitoring time series. This will make sure generation and extraction of simulation results at the same response frequency of observed flow.

5.1.4 Simulation Time Steps

In SWMM5, there are three choices for computational time steps with two for hydrologic routing and one for hydraulic flow routing. In the base model (Ex_DesignEvents.inp), both Wet and Dry hydrologic routing time steps were set to one minute. The wet time step is appropriate. Note that because the model is being run for a single event, as opposed to continuous simulation, the dry time step would likely not be used by the model.

The hydraulic flow routing time step was set to one second, which is appropriate for the dynamic wave solution. Depending on the time it takes to run the model (and the output file size), a smaller time step can be used, particularly if it is desired to reduce the overall continuity error.

5.1.5 Parameter Defaults

The SWMM5 defaults for the other simulation options are acceptable for the modeling objectives.

5.1.6 Associated Files

The base model (Ex_DesignEvents.inp) did not use external files; each time series dataset was directly included in the model input file. For the calibration and verification scenarios, an external time series database file was read.

6.0 Model Hydrology

The study area, located in Toronto, Ontario, encompasses approximately 350 km^2. The focus of the study was to build, calibrate and validate a hydrologic and hydraulic model in PCSWMM using the latest GIS land use, soil coverage and time series data.

6.1 Catchment Discretization

SWMM's non-linear reservoir routing method has improved accuracy when the subcatchment flow length represents the sheet flow length limit. While there is no universal agreement on the maximum

value for the sheet flow length, 100 m has been used by many modellers. This requires the subcatchment areas to be in the range of 20-40 ha, which assumes 100 m overland sheet flow length (represented in the hydrologic module) and a 1000-2000 m concentrated flow pathway along the subcatchment centre (represented in the hydraulic module).

Subcatchments in the calibrated Don River model have a median flow length of 110 m and median area of 35 ha. Although the highest values for subcatchment flow length and area are approximately 3 times the accepted values, the overall average value agrees with the acceptable SWMM modelling criteria. Stream thresholds defined in Arc-Hydro (approach used by the consultant) do not always ensure the delineated watersheds are smaller than the threshold area depending on the topography.

For a SWMM model to represent realistic flow responses, the spatial resolution of the hydraulic system should be commensurate with the scale of the hydrologic model. That is, if the hydraulic network was derived from available HEC-RAS models, then it may not provide the same detail as hydrology represented by subcatchments with a high level of discretization. In Arc-Hydro, the watershed delineation tool directly generates only catchmentpolygons. The current Don River model has been improved by adding flow conveyances in the peripheral areas upstream of the existing HEC-RAS hydraulics. Having hydraulic components to route runoff from each subcatchment accounts for the accurate peak flows as well as timing of the peaks. That way, when properly calibrated, the modeled flows will have lower uncertainty throughout the model, not only at the calibrated locations.

6.2 Validate Subcatchment Parametrization for Appropriateness

A total of 896 subcatchments were included in the hydrology model, representing a total catchment area of 350km^2

6.2.1 SWMM Parameter Distribution

The range and distribution of subcatchment parameter values were reviewed. Table 2 summarizes the range and average values of the key hydrology parameters. Typically, a digital elevation model (DEM) is used to determine subcatchment areas and the overland flow characteristics (i.e., flow path length, width, and slope). Land use zoning information and aerial photography are typically used to determine imperviousness along with subarea roughness and depression storage values. Infiltration parameters are typically based on soil texture from soil survey mapping or local geotechnical investigations.

Table 2 - Summary of selected hydrology parameters

Hydrology Parameter	Maximum	Minimum	Average	Medium
Area (ha)	200.66	0.06	39.25	35.70
Width (m)	9813.0	111.7	3175.8	3194.6
Flow Length (m)	326.9	5.4	112.7	111.4
Slope (%)	48.1	2.5	9.2	7.6
Imperviousness (%)	90.8	0.0	41.7	44.7
Impervious Roughness Factor	0.013	0.013	0.013	0.013
Pervious Roughness Factor	0.25	0.25	0.25	0.25
Impervious Depression Storage (mm)	2	2	2	2
Pervious Depression Storage (mm)	25	5	5.893	5
Suction Head (mm)	320.0	88.9	101.6	90.0

Saturated Hydraulic Conductivity (mm/hr)	40.00	0.25	10.40	6.82
Initial Deficit (fraction)	0.37	0.23	0.32	0.30

The modeling level of detail can be expressed in terms of both the spatial resolution and distribution of subcatchment areas. The latter is shown in Figure 1. Ideally, it is desirable to delineate all subcatchments with similar sizes, however it is rarely possible to do so in practice. The outliers represented by the maximum and minimum areas are typical of similar studies. The level of detail in the model is considered acceptable for the modeling objectives.

The subcatchment parameters shown in Table 2 are generally within an acceptable range for the modeling objectives. Ideally, the maximum length of overland flow should be less than 100 m, as this is generally acknowledged as the practical limit of sheet flow (i.e., for hydrologic flow routing). Beyond this length, flow becomes channelized and hydraulic flow routing is recommended.

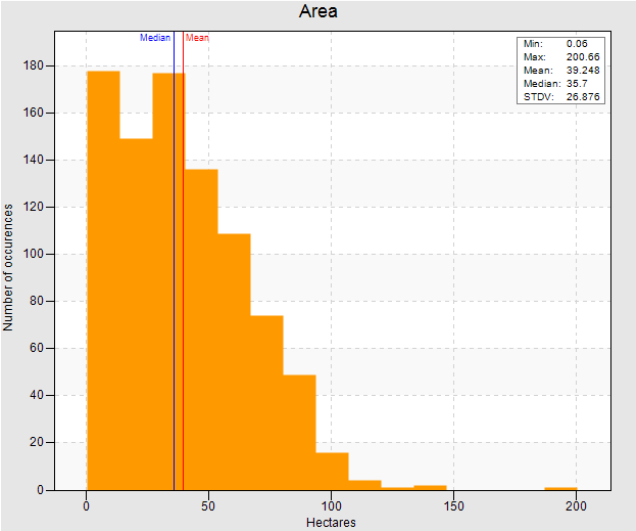


Figure 1 - Distribution of subcatchment areas

The subcatchment parameters are generally within an acceptable range for the modeling objectives.

It was recommended that the saturated hydraulic conductivity and suction head values be confirmed. It was observed the Soils_omaf.SHP map indicates soils within the watershed are primarily clay and clay loam with some loam (i.e., the acceptable range for conductivity is 0.25 – 1.02 mm/hr). The conductivity values in the original model ranged from 0.25 – 40.00 mm/hr with an average value of 10.4 mm/hr. While it is understood that surficial soils in urban areas can be highly disturbed and may contain imported soil, this large difference should be justified in the report.

6.3 Evaporation

Evaporation processes were not represented in the Don River model. Considering all the simulations applied individual storm events, evaporation is generally negligible, especially during precipitation when the relative humidity is near saturation. Therefore, it is acceptable not to include the evaporation processes.

6.4 Percent Imperviousness

To ensure the percent imperviousness values were representative of the watershed surface, a copy of the base model (EX_DesignEvents.inp) was made, and the percent imperviousness values were re-estimated using the CurrentLandUse_trca.SHP file provided, referred to as the modified impervious scenario. Assumed percent imperviousness values can be found in Appendix B – Hydrology Check. In the Don River Model Hydrology Model completed by AECOM, the percent imperviousness values were estimated using aerial photography.

This analysis compared AECOMs imperviousness values obtained from the aerial photos to the traditional method of using a lookup table based on land use. For this comparison, the percent change between the base model and the modified impervious scenario was calculated and compared to the upper threshold of accepted uncertainty for subcatchment percent imperviousness. Subcatchments with a percent change larger than 50% were flagged and visually checked using Google Earth. A 50% threshold was used based on the accepted level of uncertainty for percent imperviousness (James, 2005).

In total 52 subcatchments were flagged as potentially not representative of the underlying land use, making up a total of 1755.93 ha, or 5% of the total watershed area. It is noted there is a potential source of error when identifying the percent imperviousness using a land-use map includes the non-representative values due to broad land-use categories. Figure 2 shows an example of an area being marked as being industrial, normally associated with high imperviousness, whereas the parcel contains large sections of pervious area. This is likely why an aerial estimation was used for this study.

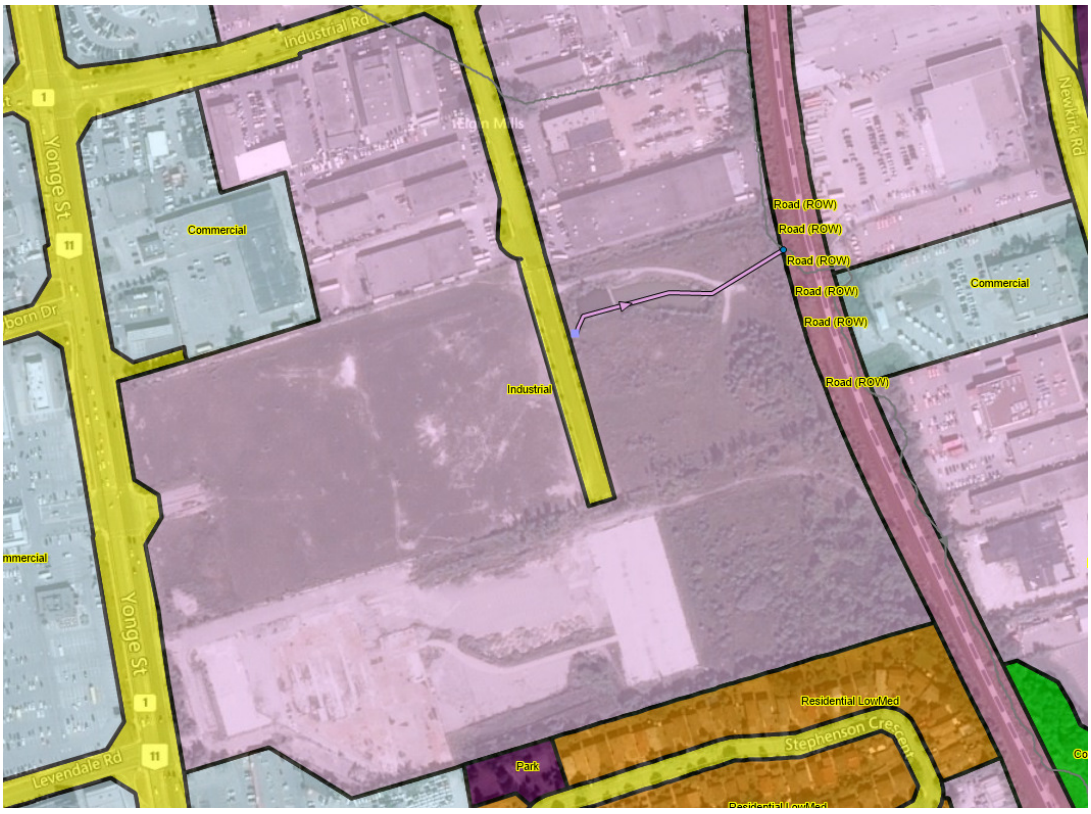


Figure 2 - Example showing an industrial land-use category not representative of the impervious area

Another example, shown in Figure 3, illustrates another scenario where the transportation land-use does not represent expected percent imperviousness normally associated with having high imperviousness. In this case there are large sections of green space, treed areas and railway tracks not generally associated as being highly impervious.



Figure 3 - Example showing a transportation land-use category not representative of the impervious area

To test the effects that the flagged subcatchments would make to the watershed response, a scenario was created based on the base model where the re-estimated percent imperviousness values were used for the flagged subcatchments, and the difference was measured at three flow monitoring locations: Knightswood (C583), Todmorden (C767) and Glenshields (C441). The resultant comparison plots can be seen in Figure 4 - Figure 6. The largest discrepancy between the base model hydrograph and the scenario that used the re-estimated values was at Knightswood where there was an R^2 value of 0.986. Based on this analysis, it can be concluded that, although there are subcatchments that do not look like they are representative of the percent imperviousness, the actual area affected is small and does not significantly change the flows in the watershed. The error values are presented in Table 3.

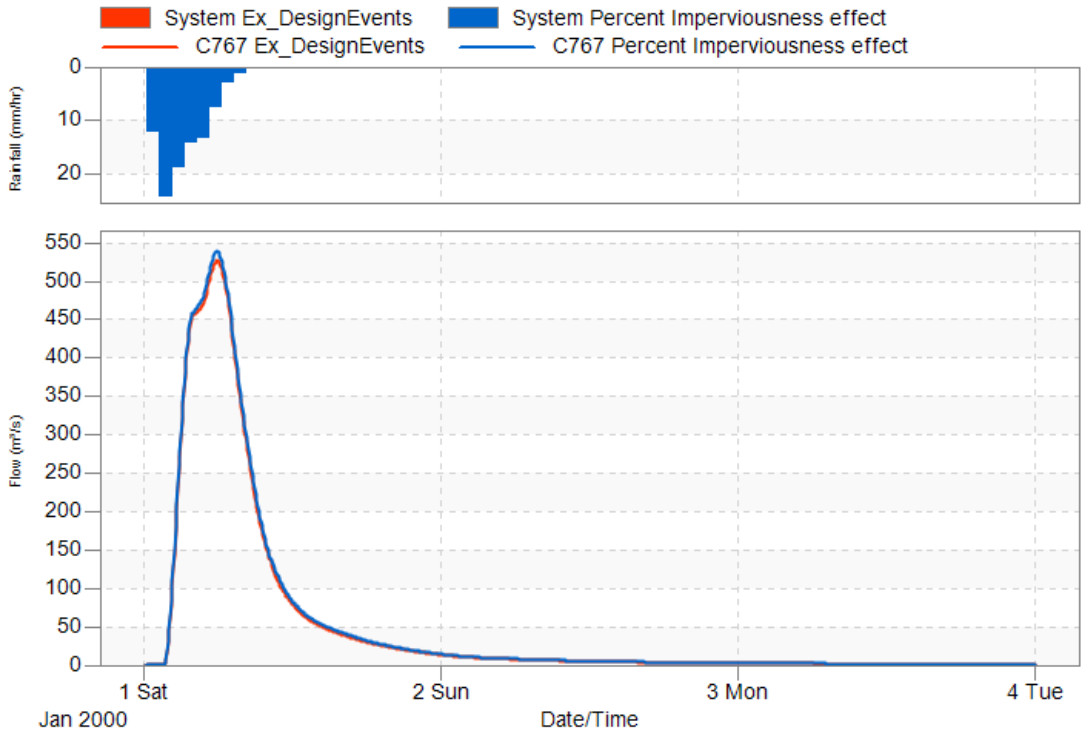


Figure 4 – Percent imperviousness scenario hydrograph comparison at Todmorden

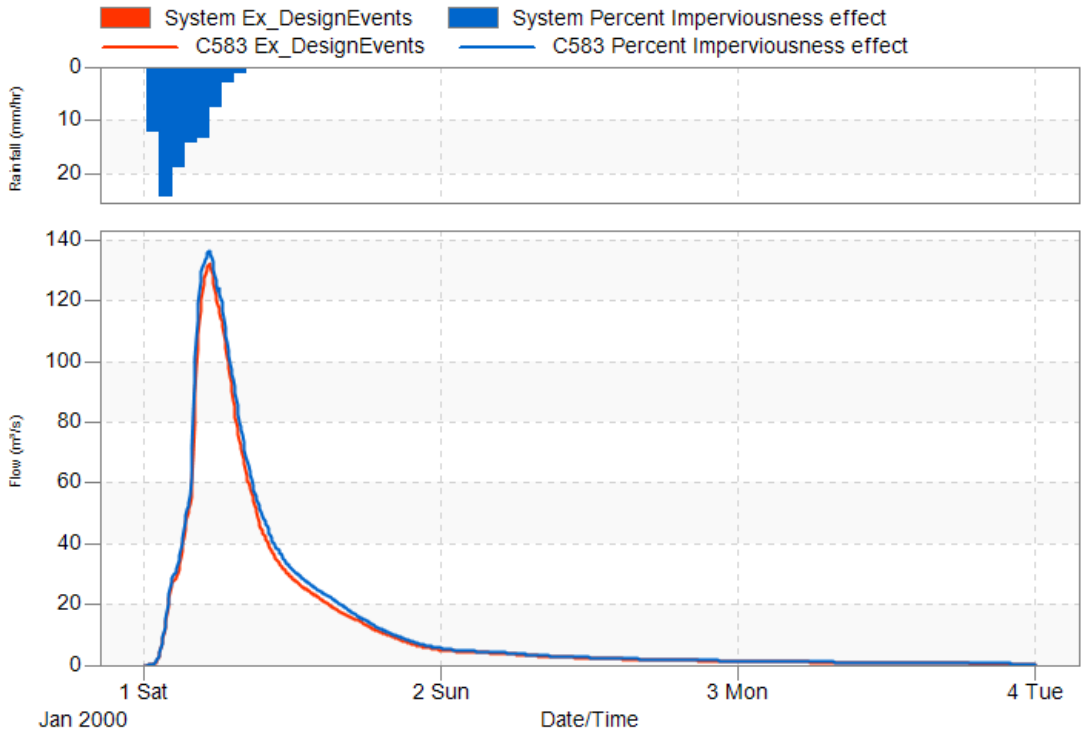


Figure 5 - Percent imperviousness scenario hydrograph comparison at Knightswood

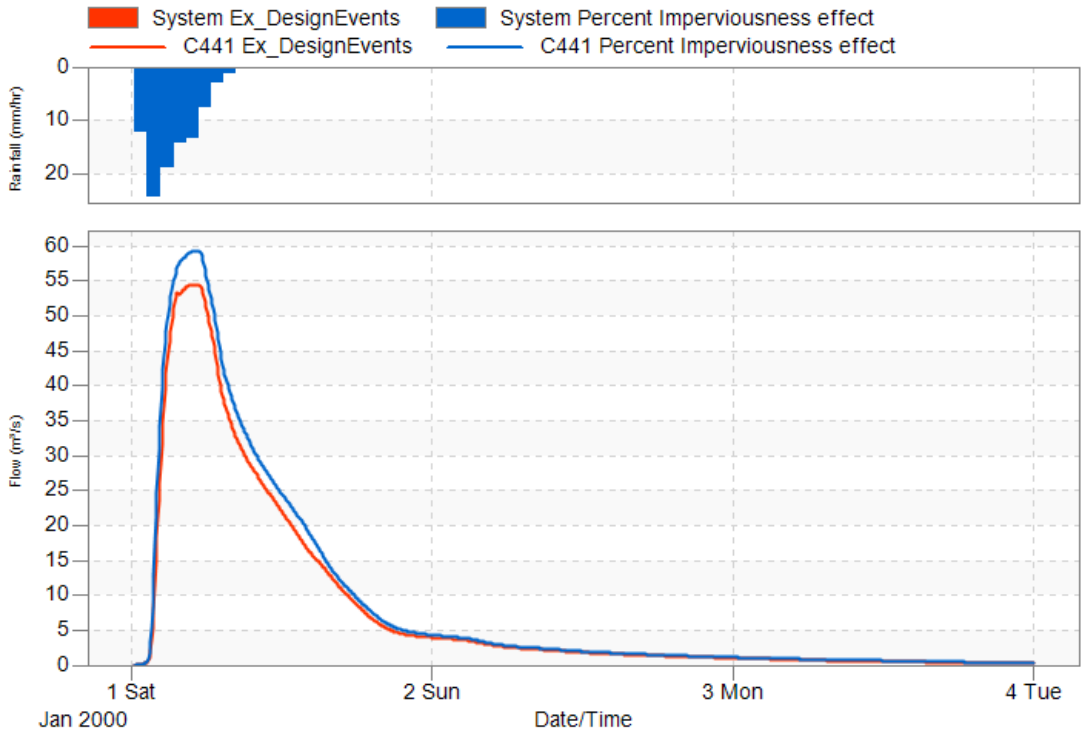


Figure 6 - Percent imperviousness scenario hydrograph comparison at Glenshields (C441)

Table 3 - Comparison error values between the base model and the re-estimated percent imperviousness scenario

	Knightswood	**Todmorden**	**Glenshields**
	C583 Ex_DesignEvents	**C767 Ex_DesignEvents**	**C441 Ex_DesignEvents**
Integral square error rating	Excellent	Excellent	Excellent
Integral square error (ISE)	0.519	0.194	0.681
Nash-Sutcliffe efficiency (NSE)	0.994	0.999	0.986
Coefficient of determination (R^2)	0.999	1	0.998
Standard error of estimate (SEE)	2.15	3.00	1.78
Simple least squares (LSE)	4000	7780	2740
Root mean square error (RMSE)	30.9	43.0	26.7
Root mean square error dimensionless (RMSE dim)	0.0709	0.019	0.112

Reviewing the comparison of results, it can be concluded that the subcatchment percent imperviousness estimation selected in the base model was representative of the overall study area.

Subcatchments flagged as having a discrepancy between the assigned and the re-estimated values did not significantly change the watershed hydrology response, as the majority of the subcatchments flagged were small in comparison to the overall study area.

The complete list of subcatchments flagged as having the percent imperviousness value out of the expected range is included in Appendix B – Hydrology Check.

6.5 Slope

High resolution DEMs may yield misleading or inaccurate slopes due to the presence of undulations when slope calculator tools (such as those within PCSWMM) take an average of every slope value represented by the DEM surface, see Figure 7. To check the slopes in the model, the DEM was first resampled with a 1 m resolution and then again with a 2 m resolution. This was done to prevent undulations in the DEM from influencing the overall DEM slope, as may be the case when using a high-resolution DEM. The re-sampled DEMs were then used to re-estimate the subcatchment slopes.

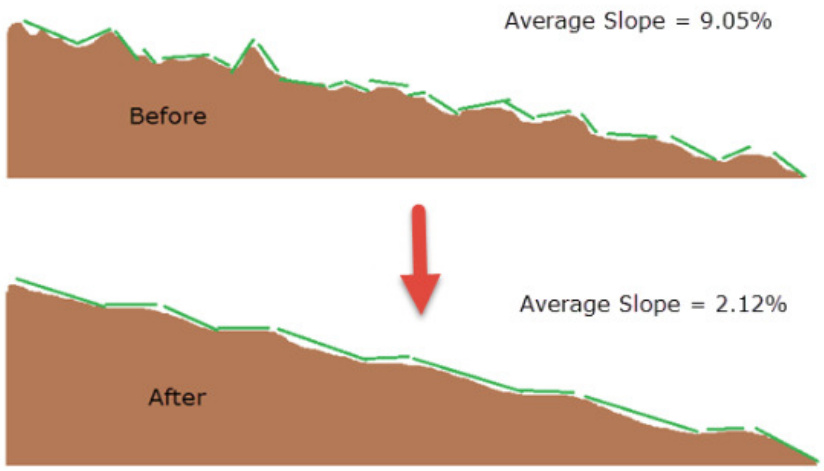


Figure 7 - Slope differences based on DEM resolution

It was found that the average slopes estimated using both DEMs were close to the values in the base model. Slopes estimated using the 1 m DEM were on average, 0.6% larger than the slopes assigned in the base model, with an average difference of 8%. Slopes estimated using the 2 m DEM were, on average, 0.2% smaller, with an average difference of 2%. The distribution plots in Figure 8 and Figure 9 show the subcatchment slope distribution for the Ex_DesignStorms.inp model and the 0.2% slope scenario. It can be concluded that the assigned slope value for the base subcatchments are reasonable for the study area.

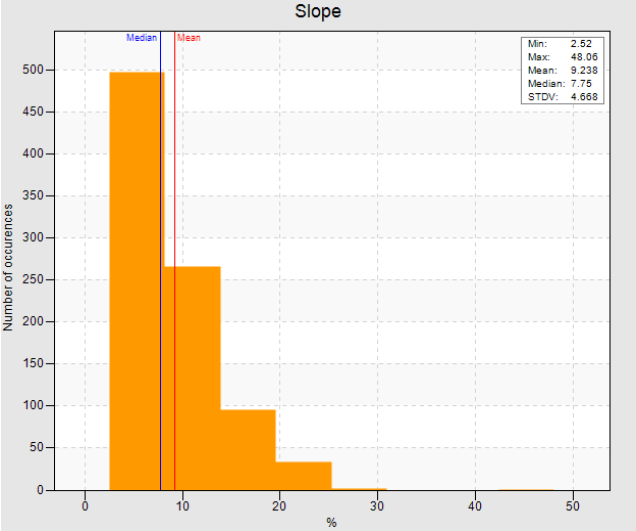


Figure 8 - Slope distribution from original model (Ex_DesignEvents.inp)

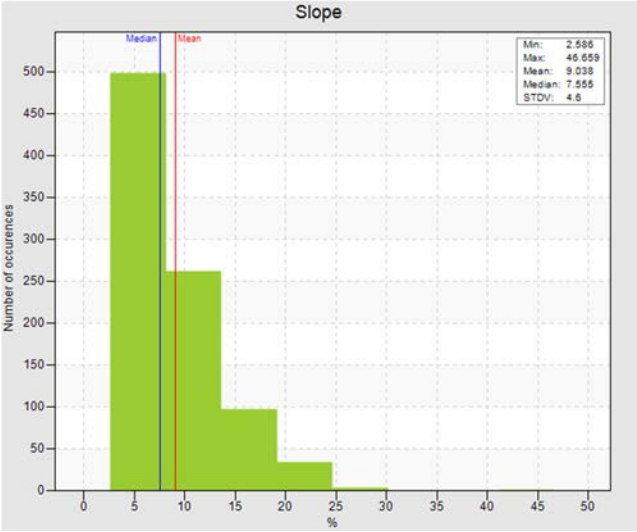


Figure 9 - Slope distribution and statistics using re-sampled 2 m DEM

6.6 Assumptions Made for the Subcatchments with Sub-area Routing

The model accounts for the sub-area routing percentage by comparing total rainfall volume and runoff volume for smaller events at each gage location. This methodology provides different values for sub-area percent routed for drainage areas of each gage location.

Some justification of large variation in % routed among different drainage areas (in the range of 20-55%), shown in Figure 10, based on distribution of different land uses would decrease the uncertainty of results.

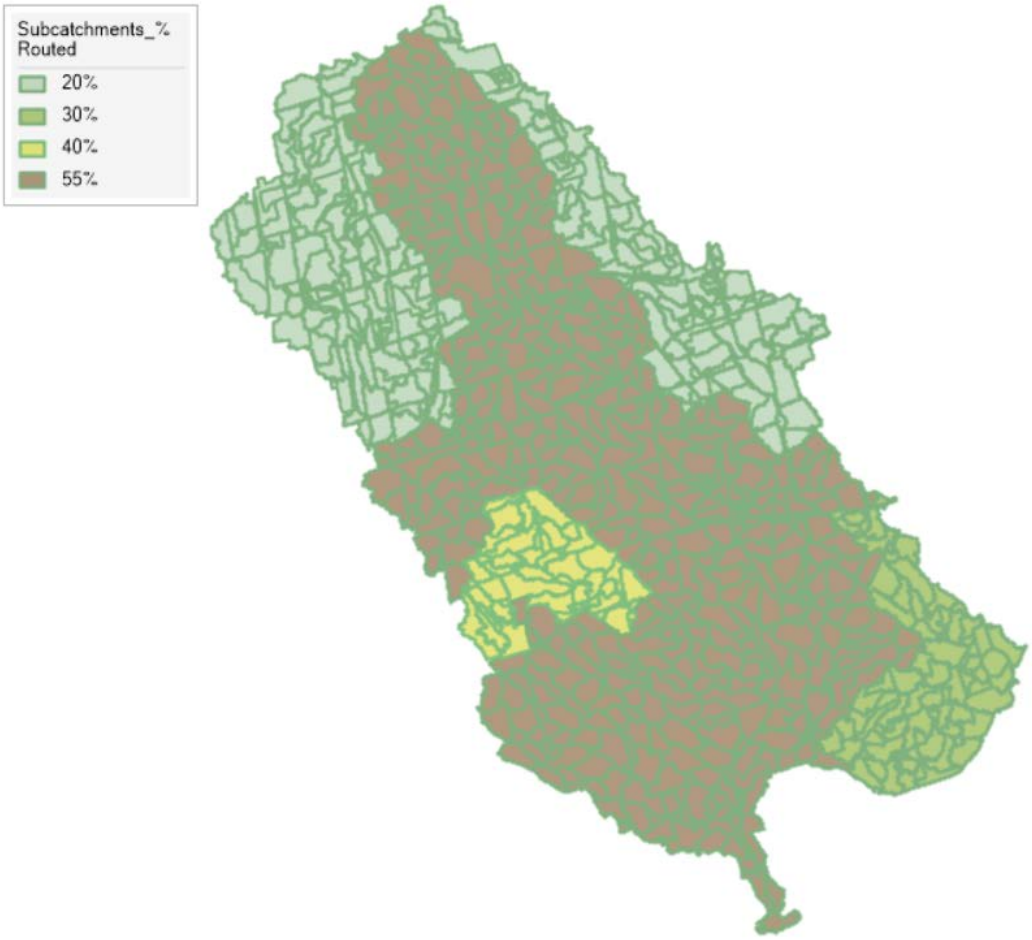


Figure 10 - Don River subcatchments rendered based on the subcatchments routed

6.7 Infiltration Parameters

To ensure the Green and Ampt infiltration parameter values (i.e., suction head, conductivity and initial moisture deficit) were representative of the underlying soils, an infiltration scenario was created based on the base model (Ex_DesignEvents.inp), by using the re-estimated Green and Ampt values with the Soils_omag.SHP file provided, shown in Figure 11.

The percent change between the base model and the infiltration scenario was calculated and compared to the upper threshold of accepted uncertainty for the Green and Ampt infiltration parameters, shown in Figure 12. Subcatchments with a percent change larger than 50% hydraulic conductivity value were flagged and visually checked. A 50% threshold was used based on the accepted level of uncertainty for the hydraulic conductivity (James, 2005).

Similarly, the acceptable tolerance for initial deficit values is between 50% and 100%, so subcatchments with an initial deficit value 100% greater than the base model value, were flagged and checked against the soils map.

Suction head values in the base model ranged from 88.9 – 320.04 mm with an average value of 101.55 mm. Re-estimated Suction head values ranged from 88.9 – 320.04 mm with an average value of 221.55 mm. It was suggested that infiltration parameters including conductivity and suction head values should be reviewed by the consultant.

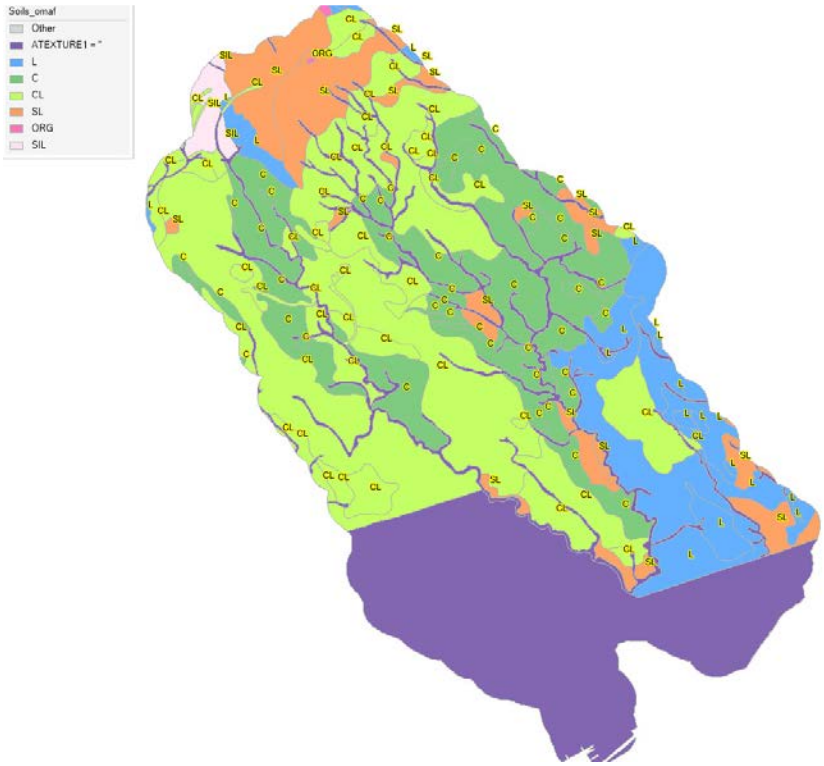


Figure 11 - Don River Soils layer. Note the southern portion (rendered in purple) was assumed to be a sandy loam

Soil Texture Class	Hydraulic Conductivity (mm/hr)	Suction Head (mm)	Porosity (fraction)	Field Capacity (fraction)	Wilting Point (fraction)	Initial Deficit (fraction)
Sand	120.34	49.02	0.437	0.062	0.024	0.413
Loamy Sand	29.97	60.96	0.437	0.105	0.047	0.390
Sandy Loam	10.92	109.98	0.453	0.190	0.085	0.368
Loam	3.30	88.90	0.463	0.232	0.116	0.347
Silt Loam	6.60	169.93	0.501	0.284	0.135	0.366
Sandy Clay Loam	1.52	219.96	0.398	0.244	0.136	0.262
Clay Loam	1.02	210.06	0.464	0.310	0.187	0.277
Silty Clay Loam	1.02	270.00	0.471	0.342	0.210	0.261
Sandy Clay	0.51	240.03	0.430	0.321	0.221	0.209
Silty Clay	0.51	290.07	0.479	0.371	0.251	0.228
Clay	0.25	320.04	0.475	0.378	0.265	0.210

Source: Rawls, W.J. et al., (1983). J. Hyd. Engr., 109:1316.

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Source: Rawls, W.J. et al., (1983). J. Hyd. Engr., 109:1316.

Figure 12 - Assumed Green and Ampt infiltration parameters

Figure 13 shows the distribution of subcatchments that differed by 50% 75% and 95% more than the estimated value.

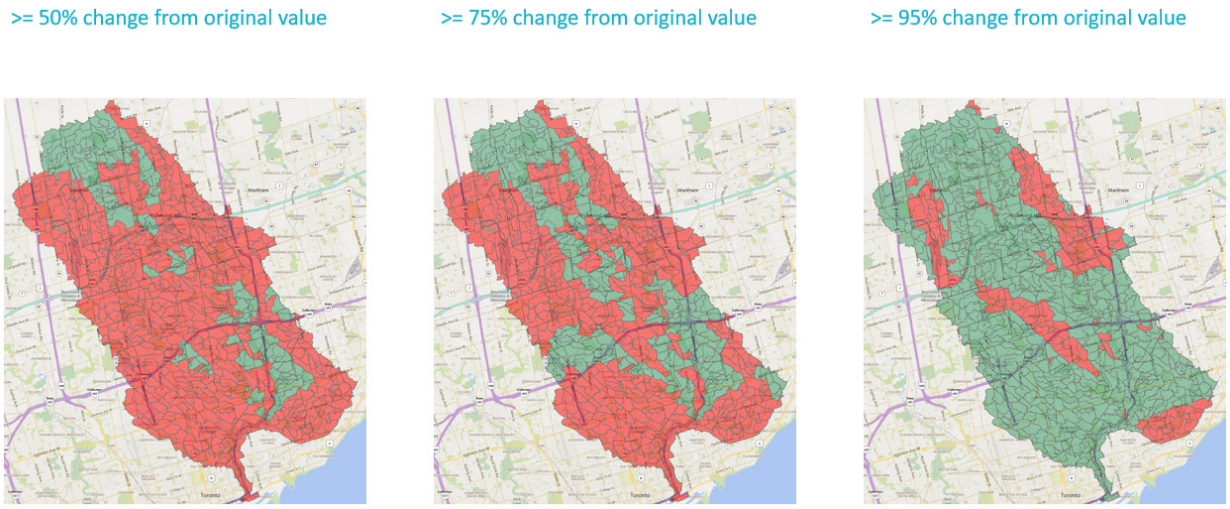


Figure 13 - Red subcatchments represent the subcatchments that fall outside of the specified range indicated in the map heading

6.7.1 Hydraulic Conductivity

The information depicted in the file Soils_omaf.SHP indicates the watershed is primarily clay and clay loam with some loam (acceptable range 0.25 – 1.02 mm/hr), however conductivity values in the original model ranges from 0.25 – 40 mm/hr with an average value of 10.4 mm/hr. Re-estimated subcatchment conductivity values ranged from 0.25 – 10.92 mm/hr with an average value of 1.76 mm/hr. Distribution plots can be found in Figure 14 and Figure 15.

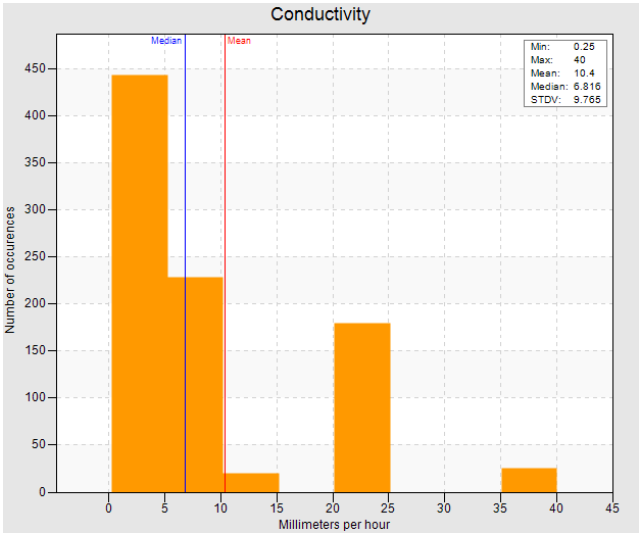


Figure 14 - Conductivity range for original model (file: Ex_DesignEvents.inp)

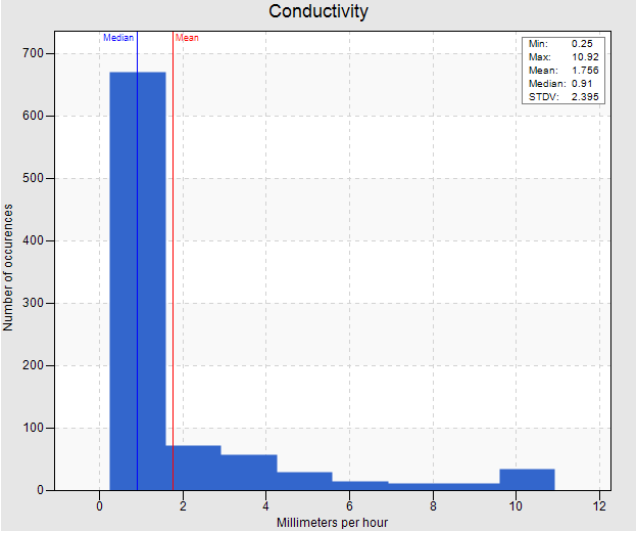


Figure 15 - Conductivity range for re-estimated model (modified file: Ex_DesignEvents.inp)

6.7.2 Use of Antecedent Precipitation to Estimate Green-Ampt Infiltration Parameters

Developing a curve between antecedent precipitation index (API) and calibrated initial moisture deficit (IMD) values is useful, if the curve will be used in historical event simulations or alternative simulations. Because assigning IMD values for subcatchments can be challenging unless the simulation period is preceded by one or two weeks of dry periods (in that situation, IMD can be the value for dry conditions based on the soil type, such that the value is closer to the wilting point).

It is not clear in the consultant's draft report what is the purpose of the development of a relationship between Antecedent Precipitation Index (API) and Initial Moisture Deficit (IMD) values, as the relationship was not used in the model. Ideally, the relationship could have been used in the verification runs. Ideally, the relationship could have been used in the model verification. Instead, it seems the verification runs used IMD values like values for the remaining events as indicated in Table 6 of the consultant's report. Justification for the approach that is based on computed API for the verification events is requested.

It was recommended to include a reference in the report for the API equation on Page 21 of the model report <*Rpt_061418.pdf*>. Also, some clarification on assigned IMD values based on the event API would improve the final report. For example, the Gage HY062 watershed had the highest API values for the September 10th, 2014 and June 27th, 2015 events, but a lower IMD value representing wet conditions was assigned only for the July 8th, 2013 event. Similarly, a lower IMD value was not assigned for the September 20th, 2013 event for the Gage 02HC056 watershed. Some discussion on this deviation would improve the report. Also, as explained above, assigning IMD based on soil type would be more appropriate.

6.8 Sensitivity Analysis

Sensitivity analysis was performed on the base model (Ex_DesignEvents.inp), using the flow gage locations listed in Table 4.

Table 4 – Flow gage locations used for sensitivity analysis

Location Name	Gage
C493	G. Ross Lord Dam
C441	Don @ Glenshield
C307	Don River East Branch near Thornhill
C423	East Don @ Cummer
C429	German Mills @ Cummer
C478	Little Don River near Lansing
C535	East Don @ York Mills
C601	Wilket Creek
C681	Taylor Creek South
C596	Taylor Creek North
C772	Don @ York Mills
C583	Don @ Knightswood
C736_2	Don @ Dundas
C767	Don @ Todmorden

A total of 10 hydrology parameters were tested using the Ex_DesignEvents.inp, Calib_20120725 and Calib_2013.07.31 scenarios including: overland flow width, overland flow slope, imperviousness, surface roughness (impervious and pervious fractions), depression storage (impervious and pervious fractions); and infiltration parameters including suction head, saturated hydraulic conductivity, and initial soil water deficit.

The sensitivity scenarios tested a range of relative changes to the original parameter values, including ±100%, ±75%, ±50% and ±25%. For the gage location discharges, the sensitivity to peak flow rate and peak flow depth was examined for each parameter analyzed. It was assumed for parameters to be considered sensitive, a change of ± 5% in peak flow or peak depth had to be observed.

At all locations, the sensitive parameters influencing the peak flows and depths were the subcatchment imperviousness, followed by saturated hydraulic conductivity and initial deficit. At several locations suction head and/or depression storage for the pervious area (Dstore Perv.) were also found to be sensitive.

While percent imperviousness is generally considered accurate when it is based on aerial images, the percentage of sub-area routing parameter is better quantified through calibration. The report should be updated to provide explanation as to why it was not included in the calibration.

As expected, imperviousness shows a positive correlation to the peak values (i.e., increasing the subcatchment imperviousness increases the peak flow and depth in the major and minor system). The opposite effect occurred with infiltration parameters. Sensitive parameters summary is compiled in Table 5 through Table 10.

Table 5 - Sensitivity ranking for maximum flow at flow gage locations (file: "Ex_DesignEvents.inp")

Flow		Sensitivity Ranking (>5% change in resultant flow)									
Location Name	Gauge	1	2	3	4	5	6	7	8	9	10
C307	Don River East Branch near Thornhill	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C441	Don @ Glenshield	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C423	East Don @ Cummer	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C429	German Mills @ Cummer	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C478	Little Don River near Lansing	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C535	East Don @ York Mills	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C601	Wilket Creek	Imperv.	-	-	-	-	-	-	-	-	-
C681	Taylor Creek South	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C596	Taylor Creek North	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C772	Don @ York Mills	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv	-	-	-	-	-
C583	Don @ Knightswood	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv	-	-	-	-	-
C736_2	Don @ Dundas	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv	-	-	-	-	-
C767	Don @ Todmorden	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv	-	-	-	-	-
C493_2	G.Ross Lord Dam	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-

Table 6 - Sensitivity ranking for maximum depth at flow gage locations (file: "Ex_DesignEvents.inp")

Depth		Sensitivity Ranking (>5% change in resultant depth)									
Location Name	Gauge	1	2	3	4	5	6	7	8	9	10
C307	Don River East Branch near Thornhill	Imperv.	Conduct.	Initial Deficit	Suction head	-	-	-	-	-	-
C441	Don @ Glenshield	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C423	East Don @ Cummer	Imperv.	Conduct.	Initial Deficit	Suction head	-	-	-	-	-	-
C429	German Mills @ Cummer	Imperv.	-	-	-	-	-	-	-	-	-
C478	Little Don River near Lansing	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C535	East Don @ York Mills	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C601	Wilket Creek	Imperv.	-	-	-	-	-	-	-	-	-
C681	Taylor Creek South	Imperv.	Conduct	Initial Deficit	Suction head	-	-	-	-	-	-
C596	Taylor Creek North	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C772	Don @ York Mills	Imperv.	Conduct.	Initial Deficit	Suction head	Dstore Perv.		-	-	-	-
C583	Don @ Knightswood	Imperv.	Conduct.	Initial Deficit	Suction head	-	-	-	-	-	-
C736_2	Don @ Dundas	Imperv.	Conduct.	Initial Deficit	Suction head	-	-	-	-	-	-
C767	Don @ Todmorden	Imperv.	Conduct.	Initial Deficit	Suction head	-	-	-	-	-	-
C493_2	G.Ross Lord Dam	Imperv.	Conduct.	-	-	-	-	-	-	-	-

Table 7 - Sensitivity ranking for maximum flow at flow gage locations (file: "Calib_20120725")

Flow		Sensitivity Ranking (>5% change in resultant flow)									
Location Name	Gauge	1	2	3	4	5	6	7	8	9	10
C307	Don River East Branch near Thornhill	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	N Perv	Width	-	-	-
C441	Don @ Glenshield	Imperv.	Conduct.	-	-	-	-	-	-		-
C423	East Don @ Cummer	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	N Perv	Width	Slope	-	-
C429	German Mills @ Cummer	Imperv.	-	-	-	-	-	-	-	-	-
C478	Little Don River near Lansing	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	N Perv	Width	-	-	-
C535	East Don @ York Mills	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	N Perv	Width	-	-	-
C601	Wilket Creek	Imperv.	-	-	-	-	-	-	-	-	-
C681	Taylor Creek South	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C596	Taylor Creek North	Imperv.	-	-	-	-	-	-	-	-	-
C772	Don @ York Mills	Imperv.	-	-	-	-	-	-	-	-	-
C583	Don @ Knightswood	Imperv.	-	-	-	-	-	-	-	-	-
C736_2	Don @ Dundas	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C767	Don @ Todmorden	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C493_2	G.Ross Lord Dam	-	-	-	-	-	-	-	-	-	-

Table 8 - Sensitivity ranking for maximum depth at flow gage locations (file: "Calib_20120725")

Depth		Sensitivity Ranking (>5% change in resultant depth)									
Location Name	Gauge	1	2	3	4	5	6	7	8	9	10
C307	Don River East Branch near Thornhill	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C441	Don @ Glenshield	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C423	East Don @ Cummer	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	N Perv	Width	-	-	-
C429	German Mills @ Cummer	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C478	Little Don River near Lansing	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C535	East Don @ York Mills	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C601	Wilket Creek	Imperv.	-	-	-	-	-	-	-	-	-
C681	Taylor Creek South	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C596	Taylor Creek North	Imperv.	-	-	-	-	-	-	-	-	-
C772	Don @ York Mills	Imperv.	-	-	-	-	-	-	-	-	-
C583	Don @ Knightswood	Imperv.	-	-	-	-	-	-	-	-	-
C736_2	Don @ Dundas	Imperv.	Conduct.	Initial Deficit	-	-	-	-	-	-	-
C767	Don @ Todmorden	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C493_2	G.Ross Lord Dam	-	-	-	-	-	-	-	-	-	-

Table 9 - Sensitivity ranking for maximum flow at flow gage locations (file: "Calib_2013.07.31")

Flow		Sensitivity Ranking (>5% change in resultant flow)									
Location Name	Gauge	1	2	3	4	5	6	7	8	9	10
C307	Don River East Branch near Thornhill	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	N Perv	Width	-	-	-
C441	Don @ Glenshield	Imperv.	-	-	-	-	-	-	-		-
C423	East Don @ Cummer	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	N Perv	Width	-	-	-
C429	German Mills @ Cummer	Imperv.	-	-	-	-	-	-	-	-	-
C478	Little Don River near Lansing	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C535	East Don @ York Mills	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C601	Wilket Creek	Imperv.	-	-	-	-	-	-	-	-	-
C681	Taylor Creek South	Imperv.	-	-	-	-	-	-	-	-	-
C596	Taylor Creek North	Imperv.	-	-	-	-	-	-	-	-	-
C772	Don @ York Mills	Imperv.	-	-	-	-	-	-	-	-	-
C583	Don @ Knightswood	Imperv.	-	-	-	-	-	-	-	-	-
C736_2	Don @ Dundas	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C767	Don @ Todmorden	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C493_2	G.Ross Lord Dam	-	-	-	-	-	-	-	-	-	-

Table 10 - Sensitivity ranking for maximum depth at flow gage locations (file: "Calib_2013.07.31")

Depth		Sensitivity Ranking (>5% change in resultant depth)									
Location Name	Gauge	1	2	3	4	5	6	7	8	9	10
C307	Don River East Branch near Thornhill	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C441	Don @ Glenshield	Imperv.	-	-	-	-	-	-	-	-	-
C423	East Don @ Cummer	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C429	German Mills @ Cummer	Imperv.	Conduct.	-	-	-	-	-	-	-	-
C478	Little Don River near Lansing	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C535	East Don @ York Mills	Imperv.	Conduct.	Initial Deficit	Suction Head	Dstore Perv.	-	-	-	-	-
C601	Wilket Creek	Imperv.	-	-	-	-	-	-	-	-	-
C681	Taylor Creek South	Imperv.	-	-	-	-	-	-	-	-	-
C596	Taylor Creek North	Imperv.	-	-	-	-	-	-	-	-	-
C772	Don @ York Mills	Imperv.	-	-	-	-	-	-	-	-	-
C583	Don @ Knightswood	Imperv.	Conduct.	Initial Deficit	-	-	-	-	-	-	-
C736_2	Don @ Dundas	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C767	Don @ Todmorden	Imperv.	Conduct.	Initial Deficit	Suction Head	-	-	-	-	-	-
C493_2	G.Ross Lord Dam	-	-	-	-	-	-	-	-	-	-

Sensitivity plots used for this analysis can be found in

Appendix C – Sensitivity Plots for Model Ex_DesignEvents.

6.9 Selection of Calibration Parameters

The model calibration has been undertaken considering multiple flow monitoring locations, which contributes to better accuracy and lower uncertainty in model results. However, it seems the Sensitivity-based Radio Tuning Calibration (SRTC) tool in PCSWMM was not used and discrete parameter values (instead of continuous values) were considered for calibration.

Infiltration parameters as presented in Table 6 under section 3.5.1 in the report <*Rpt_061418.pdf*>, found in Table 11, show that calibrated parameter values are different based on the gage location, rather than soil type.

Table 11 - Table 6 from Rpt_061418.pdf showing the calibrated parameter values based on gage locations

	% Routed (pervious)	Green & Ampt Parameters			Manning's n, channel
		Suction Head (mm)	Hydraulic Conductivity (mm/hr)	Initial Moisture Deficit	
02HC005	40%	89	3.3	0.1 (July 2013) 0.35 (rest of events)	0.015
02HC056 (urban)	55%	90	10	0.1 (July 2013, Sept 2014) 0.3 (rest)	0.025
HY017 (urban)	20%	90	10	0.1 (July 2013, urban area only) 0.3 (rest, urban area only)	0.03
HY027	55%	90	10	0.1 (July 2013) 0.3 (rest)	0.03
HY019	55%	89	3.3	0.15 (July 2013, Sept 2014, June 2015) 0.35 (rest)	0.02
HY062	30%	90	25	0.2 (July 2013) 0.3 (rest)	0.022
HY068	55%	90	40	0.1 (July 2013) 0.3 (rest)	0.02
HY092	20%	90	25	0.2 (July 2013) 0.3 (rest)	0.03

While it is understood that surficial soil conditions can be greatly affected in urban areas, some justification of calibrated values based on local soil types will increase the reliability of model results. This is important considering the large variability in hydraulic conductivity among gage watersheds. For example, adjacent gage watersheds HY068 and HY019 have hydraulic conductivity values of 40 mm/hr and 3.3 mm/hr, respectively.

In addition to the reporting time step mentioned previously, it was suggested to use a rain gage recording interval that matches the flow monitoring data time step. This would ensure simulation of flow response in the model similar to flow monitoring data. Flow estimation with five-minute rainfall data could provide larger five-minute peak flows (there would be some attenuation within the hydraulics) in comparison to 15-minute flow monitoring data. For example, flow timeseries data attached to the calibration/verification model scenario packaged files indicate flow data from gages HY019, HY062, HY068 and HY092 have 15-minute time interval. However, the consultant explored this suggestion and found changing rainfall interval to 15 minutes for the appropriate subcatchments did not change the model results significantly, potentially due to their response time.

6.10 Rainfall Analysis

6.10.1 Development and Use of the Updated IDF Curves

The IDF curve for the Toronto City rain gage (ID 6158355) was updated by the consultant with more recent rainfall data. The existing IDF curve for this station was developed by Environment Canada (EC) using rainfall data from the period 1940-2007. The consultant combined the existing annual maximum calculated by EC and recent 15-min interval rainfall data for period 2008-2017 for the IDF update. It is unclear in the draft report how the 5-min and 10-min annual maximum for 2008-1017 was used. It does

not seem they were removed in fitting the Gumbel distribution later but replaced with certain values. The report <*Rpt_061418.pdf*> needs to be clearer on this.

HYFRAN software was used by the consultant to generate an updated IDF curve. The Gumbel distribution was chosen to fit the annual maximum of each duration, to be consistent with the distribution used by EC. CHI further investigated the distribution fitting utilizing the IDFCC tool (https://www.idf-cc-uwo.ca/). This tool supports user defined stations and accepts annual maximum intensities for each duration as input. It can calculate return period intensities and depths by fitting a Gumbel distribution with method of moments for each duration. The tool can generate almost identical return period intensities as HYFRAN except for the 5-min and 10-min durations, whereas for IDFCC they were simply removed and for HYFRAN they were filled somehow. The intensities (mm/hr) are listed in Table 12.

Table 12 - Intensities (mm/hr) of design storms calculated from the IDFCC tool and HYFRAN software

	IDFCC						HYFRAN					
T (years)	**2**	**5**	**10**	**25**	**50**	**100**	**2**	**5**	**10**	**25**	**50**	**100**
5 min	109.2	151.9	180.1	215.8	242.3	268.6	110.4	157.8	187.7	225.1	256.4	285.9
10 min	76.1	101.6	118.5	139.8	155.7	171.4	77.1	105	123.3	145.7	164.4	182.5
15 min	62.2	88.0	105.0	126.5	142.5	158.4	62.4	88	104.8	125.8	142.4	158.4
30 min	39.9	55.7	66.2	79.5	89.3	99.1	39.8	55.8	66.2	79	89.4	99
1 h	24.4	33.5	39.5	47.1	52.7	58.3	24.4	33.5	39.5	46.9	52.7	58.3
2 h	14.4	20.0	23.7	28.4	31.8	35.3	14.4	20	23.7	28.2	31.8	35.3
6 h	5.9	8.0	9.3	11.1	12.3	13.6	5.9	8	9.3	11	12.3	13.6
12 h	3.5	4.6	5.3	6.2	6.8	7.5	3.5	4.6	5.3	6.1	6.8	7.5
24 h	2.0	2.5	2.9	3.4	3.7	4.0	2	2.5	2.9	3.3	3.7	4

The rainfall depths of design storms used in the model were calculated from the standard three-parameter (a, b, c) IDF curve equation. This equation was interpolated for each return period based on intensity for each duration (including 5-min and 10-min). Therefore, the 5-min and 10-min data will impact the fitted a, b, c values and the calculated total depths of design storms. It was confirmed that the standard practice at TRCA is to use computed intensities with a, b, c equations instead of the direct Gumbel fitted values for design storms.

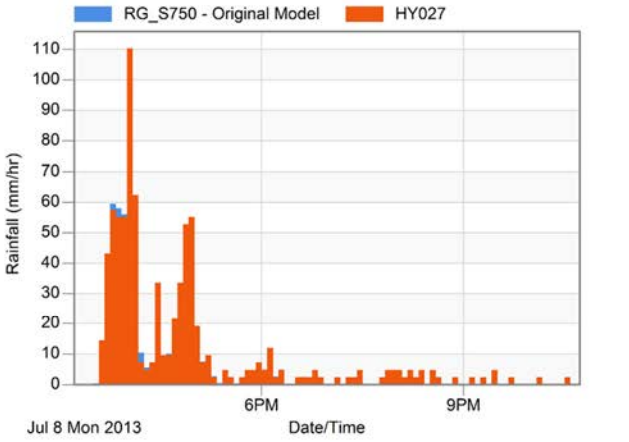
6.10.2 Radar Rainfall Comparison

To confirm the timing of the rainfall was correct (e.g. daylight savings was correctly accounted for), a rainfall comparison using NOAA NEXRAD gage-corrected, DHSR radar data, was completed to check that the timings of large peaks matched the reflectivity data.

Spot checks using radar rainfall for several events indicate the rain gage time series was not adjusted for daylight savings time in the 2013 rainfall timeseries, making several of the hyetographs off by one hour (refer to Appendix D – Rainfall Review). This discrepancy may potentially change the hydraulic response of the model, unless the flow time series matched the rainfall (i.e. also did not account for daylight savings). It is unknown if the flow gages accounted for the time change but it is advised that it be checked. Based on this, it is recommended that all time series used in the calibration and validation scenarios are checked by the consultant.

6.10.3 Quality Assurance/Quality Control for Observed Rainfall

Rainfall time series data used for the review was included directly with the input file. Rainfall timeseries was imported from DonHydrology.mdf provided. Rainfall for 3 selected events were compared to the assigned rainfalls at the subcatchment locations where the rain gages are located. For the analysis, the July 8th, 2013 event was selected and compared to rain gages HY027, HY021 and HY008. In all cases, the rainfall hyetographs reasonably matched the interpolated rain gage data used in the model. These comparisons are depicted in Figure 16, Figure 17 and Figure 18.



	HY027	RG_S750 - Original Model
Maximum Rainfall (mm/hr)	110.4	104.4
Minimum Rainfall (mm/hr)	0	0
Mean Rainfall (mm/hr)	8.946	8.791
Duration of Exceedances (h)	7.512	7.512
Duration of Deficits (h)	2.762	0.08333
Number of Exceedances	1	1
Number of Deficits	16	1
Volume of Exceedances (mm)	67.2	66.04
Volume of Deficits (mm)	0	0
Total Rainfall (mm)	67.2	66.04

	RG_S750 - Original Model
Integral square error rating	Excellent
Integral square error (ISE)	1.36
Nash-Sutcliffe efficiency (NSE)	0.996
Coefficient of determination (R^2)	0.997
Standard error of estimate (SEE)	1.14
Simple least squares (LSE)	120
Simple least squares dimensionless (LSE dim)	N/A
Root mean square error (RMSE)	4.81
Root mean square error dimensionless (RMSE dim)	0.114

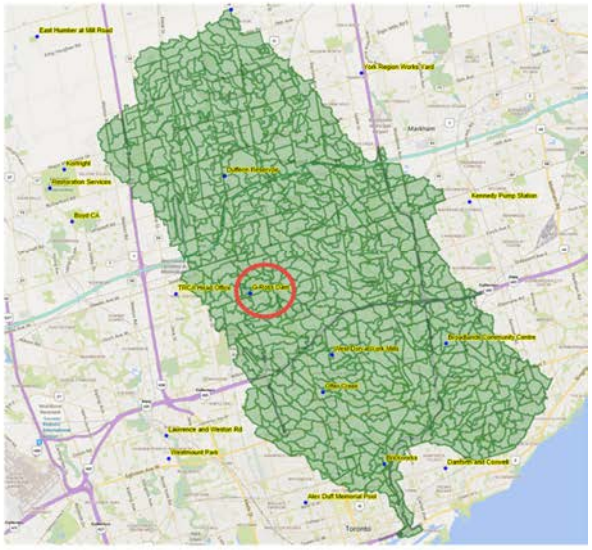
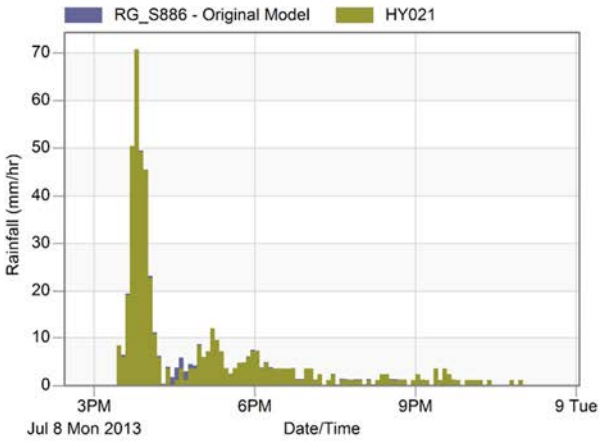


Figure 16 - Rainfall comparison for G. Ross Lord Dam - July 8th, 2013



	HY021	RG_S886 - Original Model
Maximum Rainfall (mm/hr)	70.8	69.44
Minimum Rainfall (mm/hr)	0	0
Mean Rainfall (mm/hr)	4.235	4.341
Duration of Exceedances (h)	9.61	9.61
Duration of Deficits (h)	3.276	0.9428
Number of Exceedances	1	1
Number of Deficits	14	5
Volume of Exceedances (mm)	40.7	41.71
Volume of Deficits (mm)	0	0
Total Rainfall (mm)	40.7	41.71

	RG_S886 - Original Model
Integral square error rating	Excellent
Integral square error (ISE)	1.03
Nash-Sutcliffe efficiency (NSE)	0.998
Coefficient of determination (R^2)	0.998
Standard error of estimate (SEE)	0.465
Simple least squares (LSE)	25.3
Simple least squares dimensionless (LSE dim)	N/A
Root mean square error (RMSE)	2.21
Root mean square error dimensionless (RMSE dim)	0.239

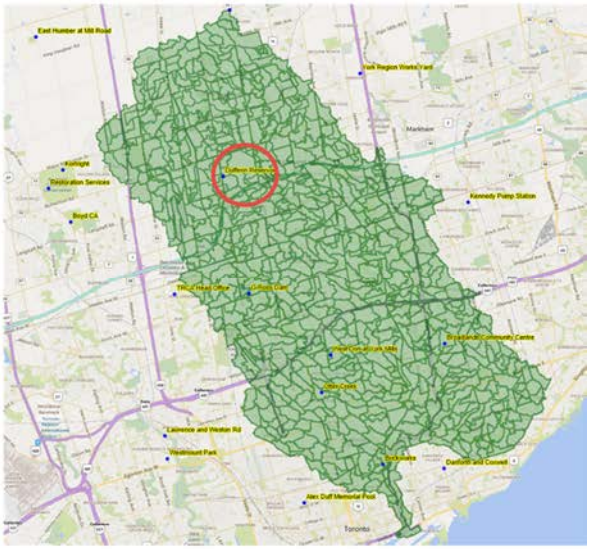
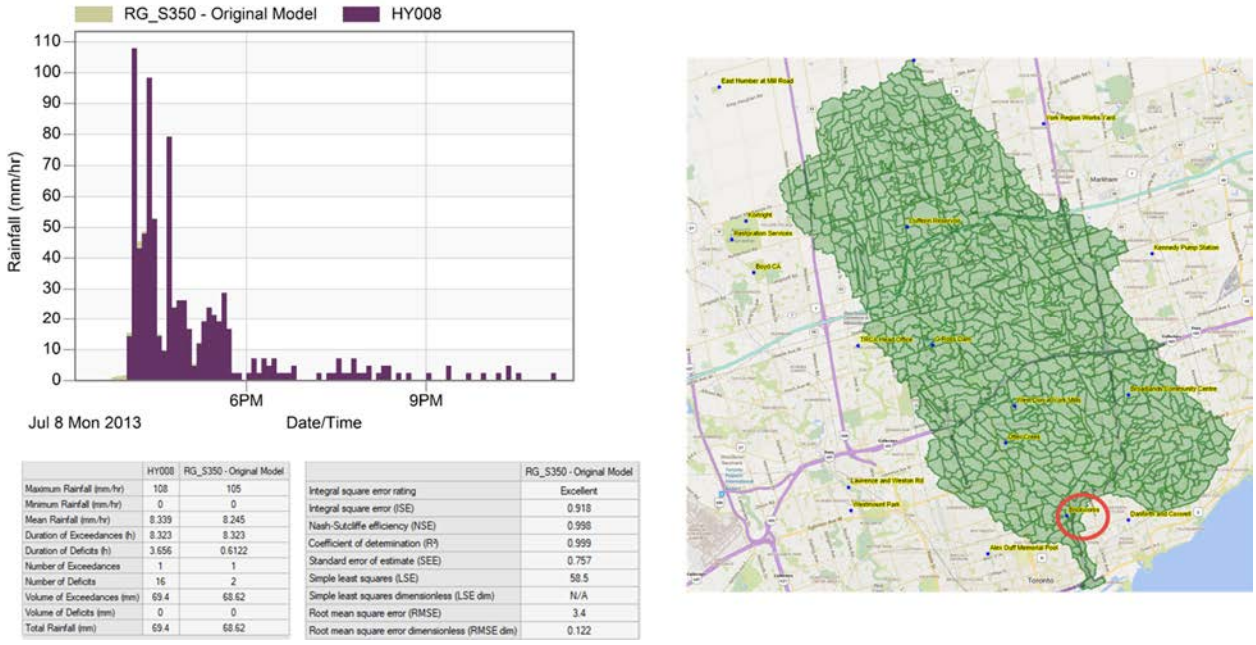


Figure 17 - Rainfall comparison for Dufferin Reservoir - July 8th, 2013



	HY008	RG_S350 - Original Model
Maximum Rainfall (mm/hr)	108	105
Minimum Rainfall (mm/hr)	0	0
Mean Rainfall (mm/hr)	8.339	8.245
Duration of Exceedances (h)	8.323	8.323
Duration of Deficits (h)	3.656	0.6122
Number of Exceedances	1	1
Number of Deficits	16	2
Volume of Exceedances (mm)	69.4	68.62
Volume of Deficits (mm)	0	0
Total Rainfall (mm)	69.4	68.62

	RG_S350 - Original Model
Integral square error rating	Excellent
Integral square error (ISE)	0.918
Nash-Sutcliffe efficiency (NSE)	0.998
Coefficient of determination (R^2)	0.999
Standard error of estimate (SEE)	0.757
Simple least squares (LSE)	58.5
Simple least squares dimensionless (LSE dim)	N/A
Root mean square error (RMSE)	3.4
Root mean square error dimensionless (RMSE dim)	0.122

Figure 18 - Rainfall comparison for Brickworks - July 8th, 2013

6.10.4 Rain Gages Assignment During Calibration/Validation

The model calibration has been undertaken considering multiple flow monitoring locations which contributes to better accuracy and lower uncertainty in model results. Discrete parameter values (instead of continuous values as used in SRTC tool) have been considered for calibration. This may be because the selected calibration events were far apart from each other and it was decided to estimate initial moisture deficit for each event separately.

7.0 Model Hydraulics

Hydraulics in the model are represented with a high level of detail, matching the discretization of the hydrology component. Some observations that may require attention include: conduits represented with shape curves not assigned head loss coefficients, initial water depth not being defined for the G. Ross Lord dam in the calibration and verification events, and some junction inverts based on the DEM elevation on the road pavement instead of being defined from the channel bottom (e.g. J852).

Averaging HEC-RAS cross sections, as completed for the Don River model, should provide realistic representation of volume and roughness characteristics of channel sections. However, by joining smaller HEC-RAS reach segments into longer SWMM conduits, local variation in channel slopes may potentially change the peak/timing of flow.

Exclusion of some hydraulic components (culverts/bridges) included in the HEC-RAS models may alter the hydraulic routing in the Don River Model. It was hypothesized that if more flow constricting components were not modeled, it could result in increased downstream flow rates (for example, small culverts can reduce the peak flow by storing more flow volume in upstream channel segments). Based on this, it was recommended the imported bridges/culverts are checked with the original HEC-RAS cross sections by the consultant. The consultant confirmed that all the critical hydraulic components were included in the model based on a detailed screening process and further discussions with TRCA.

7.1 Channel Routing Approach

The current Don River model has been improved in the updated model by AECOM through the addition of flow conveyances in the peripheral areas upstream of the existing HEC-RAS hydraulics. Having hydraulic components route runoff from each subcatchment accounts for the accurate peak flows as well as timing of the peaks. When properly calibrated, the modeled flows will have lower uncertainty throughout the model.

Since the watershed delineation was undertaken in Arc-Hydro, stream conduits may not have matched with HEC-RAS reach segments.

There are some conduits that are assigned an urban transect that reflects the major drainage system within the road rights-of-way including curb/gutter, shown in Figure 19. While it is suitable for more upstream areas where runoff is conveyed along the roadway, these transects should not be used for the more downstream conveyance system. For example, some conduits within the southwest corner of the watershed (e.g. C728, C729, C722) carry more than 40 m^3/s flow under 100-year design storm. This may not be realistic as flow at this stage should be conveyed through a more natural transect (i.e., channel with floodplain) that provides greater attenuation.

Similarly, rural transects used in the model may be too simple as they do not represent varying wetted perimeter in the flow pathways under different flow ranges. Extracting flow pathway cross sections from the DEM would be more appropriate as that will better define the floodplain portion of the channel. Derrick Creek is an example requiring a more natural stream cross section.

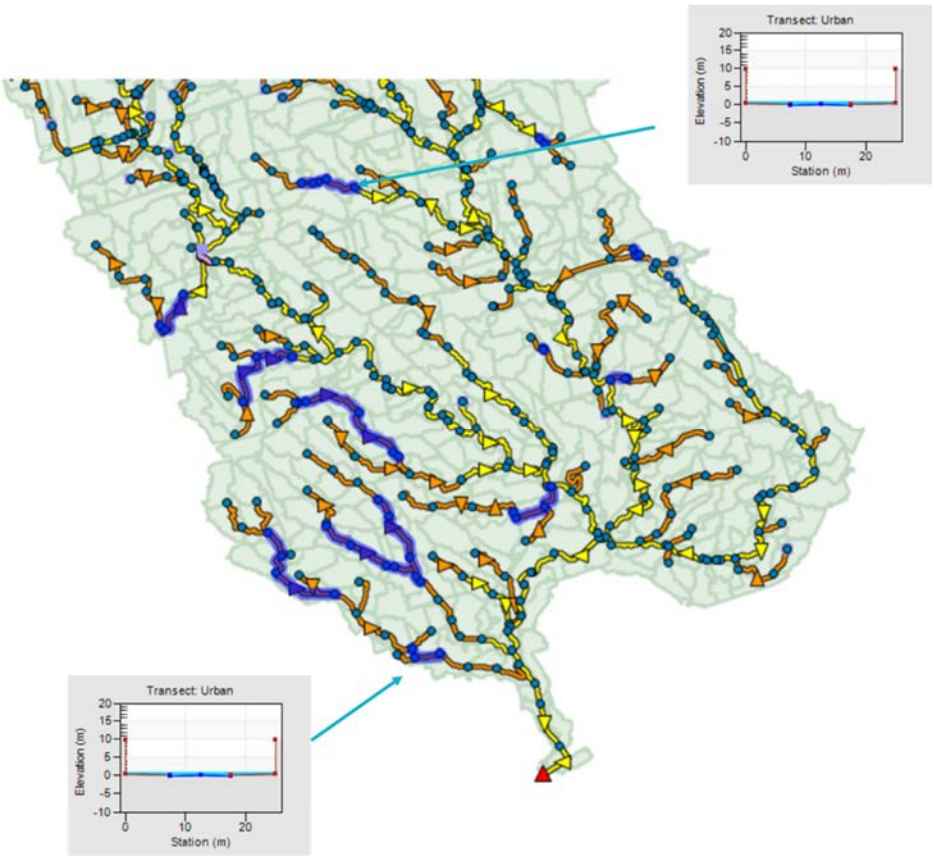


Figure 19 - Representation of overland flow paths using urban transects

It was noted that the piped systems and conduits represented with shape curves have not been assigned loss coefficients. A sensitivity analysis was preformed and found these losses were not significant to the model results.

Some additional observations that were identified during the review process:

- Conduits C320_2, C342, C350, and C352 have channel roughness greater than the overbank roughness values;
- Initial water depth is not defined for the Ross Lord dam (calibration and verification events) and therefore assumes it is empty prior to rainfall;
- Several junction invert elevations are based on the DEM elevation of the road pavement (e.g. J852), rather than the adjacent channel bottom, which would result in accurate conduit slopes.

The consultant addressed and commented on these in their response.

7.2 "Lumped" Stormwater Management Facilities

Storage outlet curves use a TABULAR/HEAD relationship, with the majority set up to represent the same invert elevations as the downstream junctions. This is a potential issue in cases when the downstream conduit has a higher water level, resulting in backwater effects. The resulting impact of these backwater effects will be more significant during conditions when downstream water levels are high.

There are two rating curves (OL155 and OL95) with non-zero flow at a depth of zero, resulting in the outlet flows oscillating when the storage node is near empty. There are also a few ponds with jagged storage area/depth curves. One example of the jagged lines in a storage curve is shown in Figure 20.

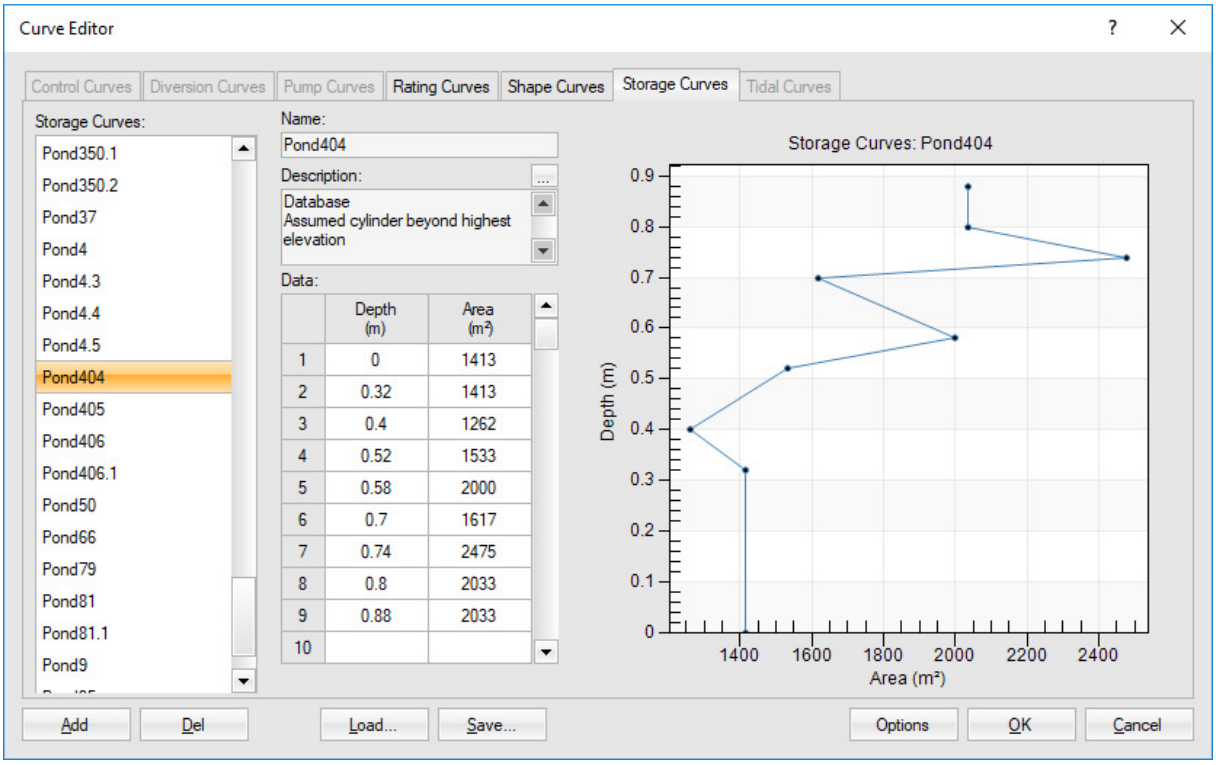


Figure 20 - Example of jagged storage pond curve

To evaluate the impact of the jagged storage curves on model results, CHI compiled a table of them using the base model (Ex_DesignEvents.inp). CHI then selected five ponds (names SU349.1, SU25, SU146.1, SU406, and SU_GRossLordDam) for the consultant to correct to their physical storage curves and review the difference with the base model results. The list of ponds with jagged line storage curves is shown in Table 13. Area[i] decreases to Area[i+1] when the corresponding depths increase from Depth[i] to Depth[i+1]. The modeled average and maximum depths are also listed to choose the five ponds for verification. Whenever the model average and/or maximum depth is higher than Depth[i], the jagged line storage curve may have an impact on model results, since the pond surface areas are different from actual conditions.

Table 13 - Stormwater ponds with jagged storage curves

Number	Pond Name	Area[i]	Area[i+1]	Depth[i]	Depth[i+1]	Modeled Avg Depth	Modeled Max Depth
1	'SU4.5'	11855	11842	3.62	4	0.19	1.34
2	'SU227'	12630	12620	1.7	1.8	0.3	1.31
3	'SU17024'	16600	3000	1	2.3	0.2	0.93
4	'SU4.4'	20120	17532	2.14	2.64	0.51	2.05

Number	Pond Name	Area[i]	Area[i+1]	Depth[i]	Depth[i+1]	Modeled Avg Depth	Modeled Max Depth
5	'SU349.4'	10705	10489	0.65	1.1	0.65	1.16
6	'SU349.1'	18770	6190	0.55	0.85	0.39	0.73
7	'SU349.2'	15260	13177	1.75	2.1	1	2.03
8	'SU350.2'	9290	8077	0.4	0.8	0.43	0.7
9	'SU349.8'	12025	11292	0.55	1.05	0.21	0.4
10	'SU349.7'	11193	9006	0.7	1.05	0.08	0.14
11	'SU17021'	12040	12030	0.1	0.2	0.21	0.64
12	'SU102'	59207	39472	3.5	4	1.05	3.45
13	'SU341.1'	32836	29167	0.61	0.67	0.33	0.62
14	'SU349.9'	8019	7428	0.75	1.4	0.65	1.51
15	'SU271.4'	16360	16340	0.15	0.2	0.75	1.34
16	'SU172'	775	725	0.6	0.8	0.34	1.27
17	'SU25'	32000	7755	0.25	0.74	0.09	0.35
18	'SU24'	6600	6400	2	2.5	0.63	2.61
19	'SU134.6'	9550	2500	0.21	0.41	0	0.05
20	'SU271.1'	3680	3660	0.1	0.15	0.62	1.71
21	'SU406.1'	13652	13467	1.15	1.9	0.62	1.38
22	'SU226.3'	14856	14274	1.64	1.95	0.5	1.55
23	'SU271.3'	19180	19160	0.05	0.1	0.52	1.11
24	'SU27'	18056	15294	1.98	2.15	0.38	1.66
25	'SU271.5'	9960	9940	0.1	0.15	0.31	0.68
26	'SU226.2'	28321	28319	3.46	4.46	1.48	4.43
27	'SU9'	250	150	0.4	0.9	1.3	4.3
28	'SU198'	16420	16413	0.75	0.9	0.58	1.66
29	'SU154'	4500	2560	0.14	0.64	0.74	2
30	'SU15'	33800	30400	3	3.25	1.8	4.92
31	'SU291'	11160	11140	1.95	2	0.54	1.62
32	'SU15007'	2520	1753	1.95	2.1	0.64	1.71
33	'SU349.6'	3000	2887	0.45	0.85	0.34	0.68
34	'SU146.1'	10279	8223	2.9	3.2	1.15	4.15
35	'SU19'	42880	20000	3.83	3.93	1.31	2.42
36	'SU81.1'	6550	5450	0.3	0.6	0.46	1.79
37	'SU139'	4256	1480	1.3	1.5	0.08	0.8
38	'SU198.2'	17200	17192	0.85	1.1	0.7	2.04
39	'SU200'	16450	16200	2.72	3.03	1.41	3.56
40	'SU348.4'	4011	3407	0.85	1.3	0.67	1.7
41	'SU348.6'	5265	5260	0.95	1	0.31	0.64
42	'SU348.8'	3620	3607	0.8	0.95	0.44	0.88
43	'SU349'	2817	2787	0.35	0.65	0.35	0.88
44	'SU349.3'	1892	1814	0.4	0.75	0.49	1.3
45	'SU349.5'	4836	4582	0.5	0.95	0.21	0.41
46	'SU350.1'	7096	6120	0.25	0.5	0.26	0.52

Number	Pond Name	Area[i]	Area[i+1]	Depth[i]	Depth[i+1]	Modeled Avg Depth	Modeled Max Depth
47	'SU404'	1413	1262	0.32	0.4	0.3	0.82
48	'SU406'	26091	21167	1.1	2	0.53	1.36
49	'SU_GRoss LordDam'	250000	170000	0.7	0.9	2.13	3

There are four ponds in the model representing lumped ponds and they are all in series (i.e., a composite model representation that reflects the cumulative storage area/depth curve of each pond, from upstream to downstream). There are no concerns regarding the representation of these ponds.

The consultant commented on these storage curves as presented in Appendix E.

7.3 G. Ross Lord Dam Representation

The G. Ross Lord Dam is a flood control facility on the West Don River located on the northeast corner of Dufferin Street and Finch Avenue west in Downsview, ON. The dam operates in conjunction with downstream flood control channels to reduce the risk of flooding to flood-prone communities such as Hogg's Hollow. The dam is approximately 365.76 m long, 19.81 m high with a crest length of 366 m (G Ross OMS - Final, Sept. 2008).

The G. Ross Lord dam includes six outlets as per the operations manual (April 2016): two mud valves, two low level gates, two upper level outlet spillway gates. The two mud valves are used to convey baseflows and are not modeled. The two spillway gates are closed in the non-regional event models (calibration/validation and analysis models) and removed in the regional event model. The rating curve was developed for the two low level gates based on rate of rise and one gate opening and two gate opening tables (Tables A.2 and A.3 in the consultant draft report) to regulate dam outflow. The lower level gates rating curve and spillway rating curve were not calibrated because the dam was closed for the calibration events. It is requested that a description of how both rating curves were developed be included in the consultant's report.

8.0 Results of the Updated Model

8.1 Peak Flows from the Approved 2004 and the Updated 2018 Don River Model

The comparison of the peak flows between the approved 2004 model and the updated 2018 model is presented in Figure 21 through Figure 26, for duration 12-hr and return periods 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr. In general, the 2018 model peak flows are lower than the 2004 model at the comparison locations due to:

- the two models used different design storms: 12-hr SCS in the 2004 model and 12-hr AES in the updated model. The peaks of 12-hr AES distribution are lower than the 12-hr SCS distribution;
- the updated model includes the current hydrology conditions and more accurate hydraulic routing method dynamic wave routing.

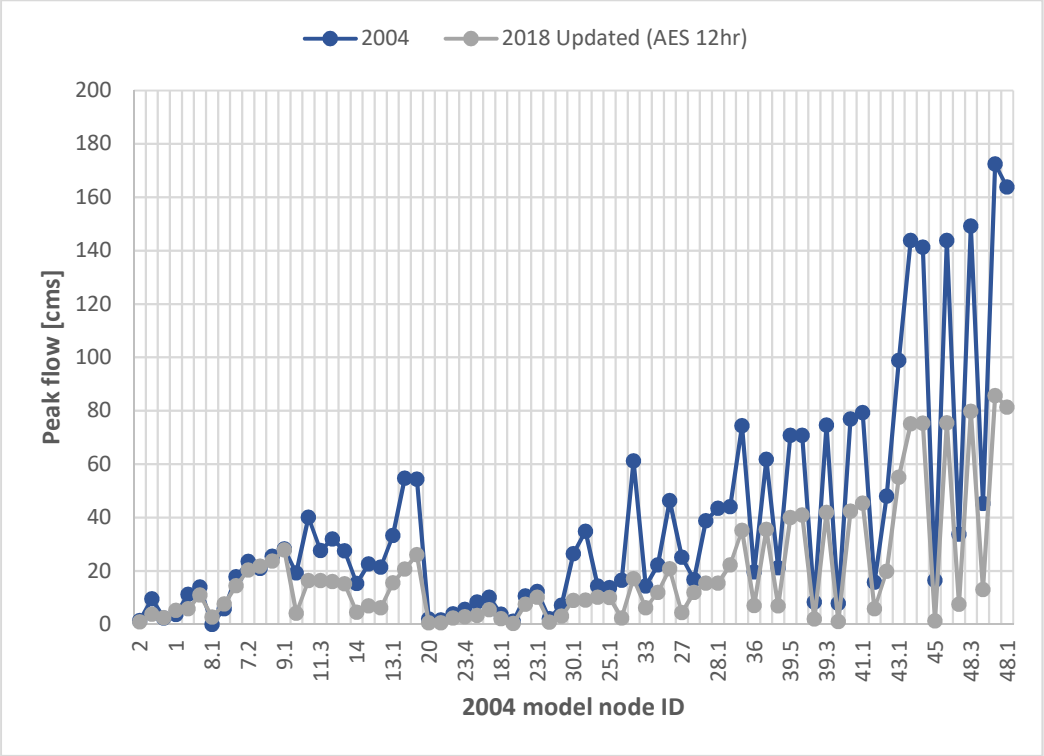


Figure 21 Peak flows from the 2004 model and 2018 model for 2-yr 12-hr design storm

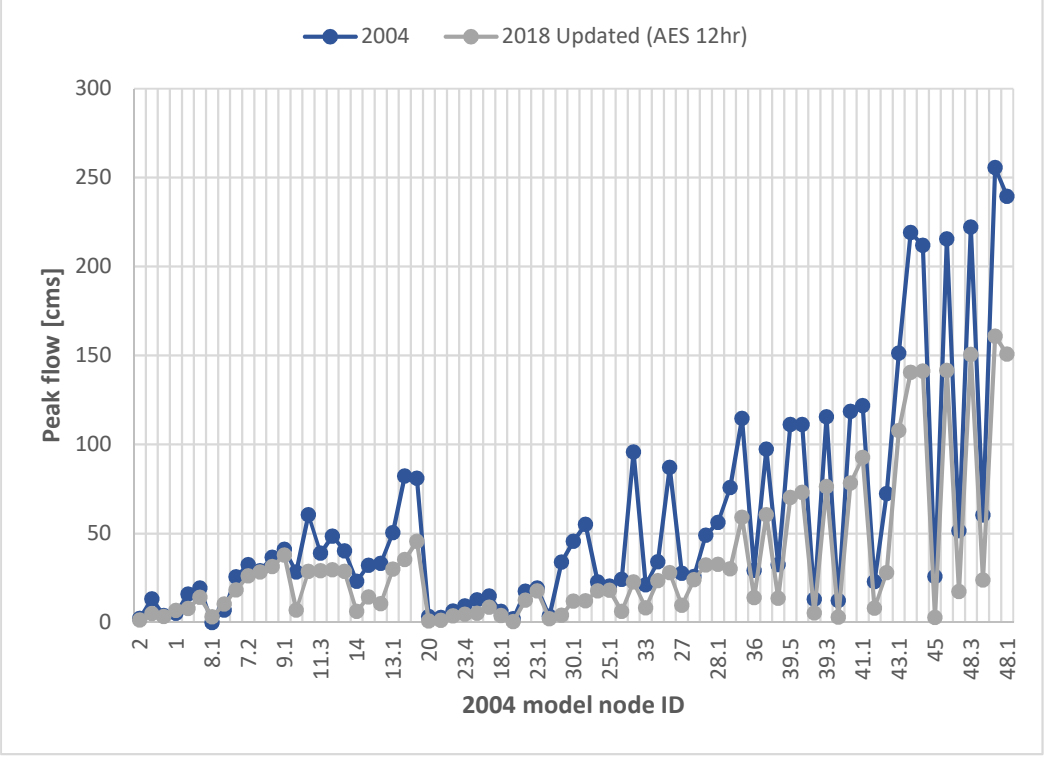


Figure 22 Peak flows from the 2004 model and 2018 model for 5-yr 12-hr design storm

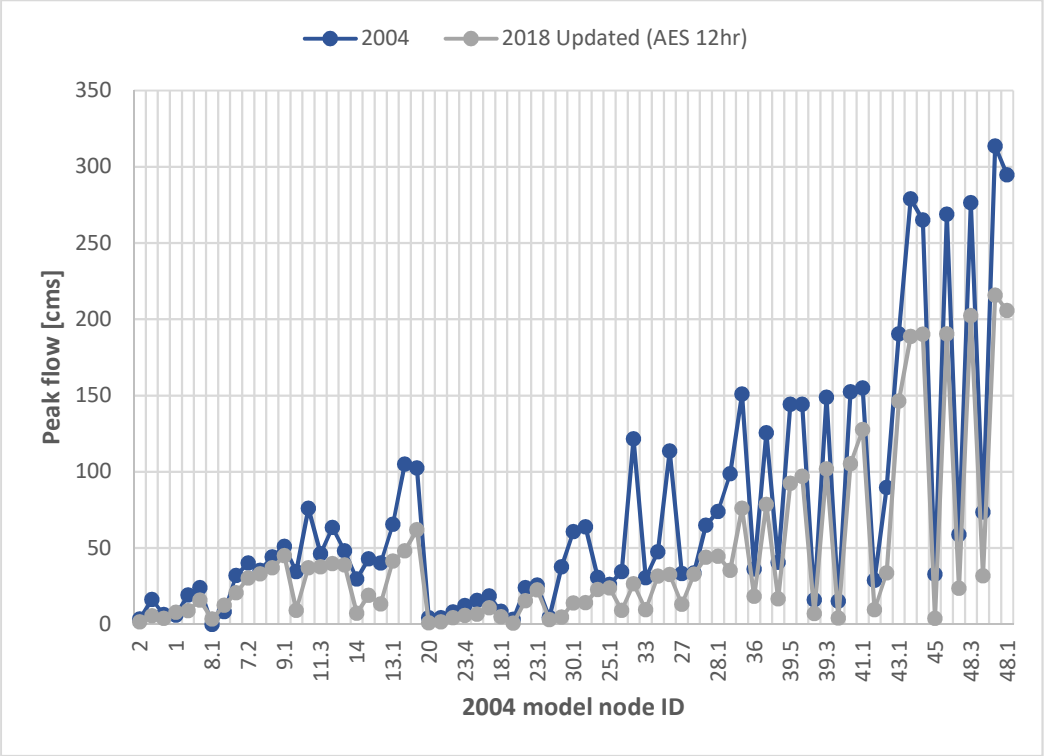


Figure 23 Peak flows from the 2004 model and 2018 model for 10-yr 12-hr design storm

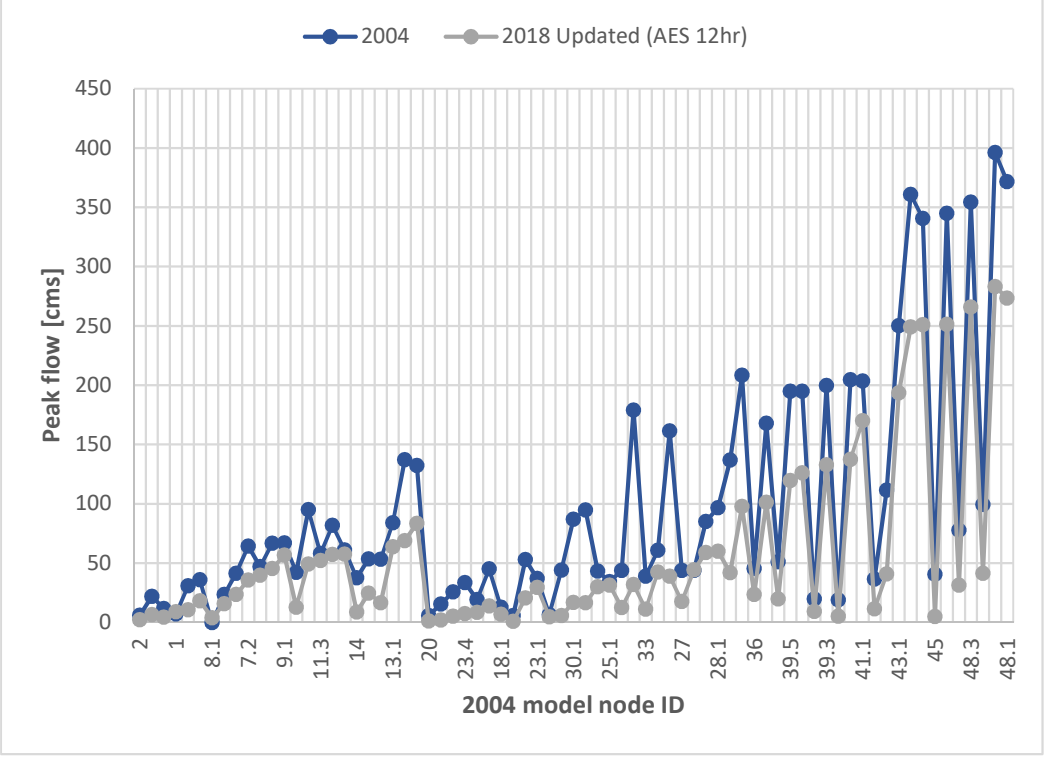


Figure 24 Peak flows from the 2004 model and 2018 model for 25-yr 12-hr design storm

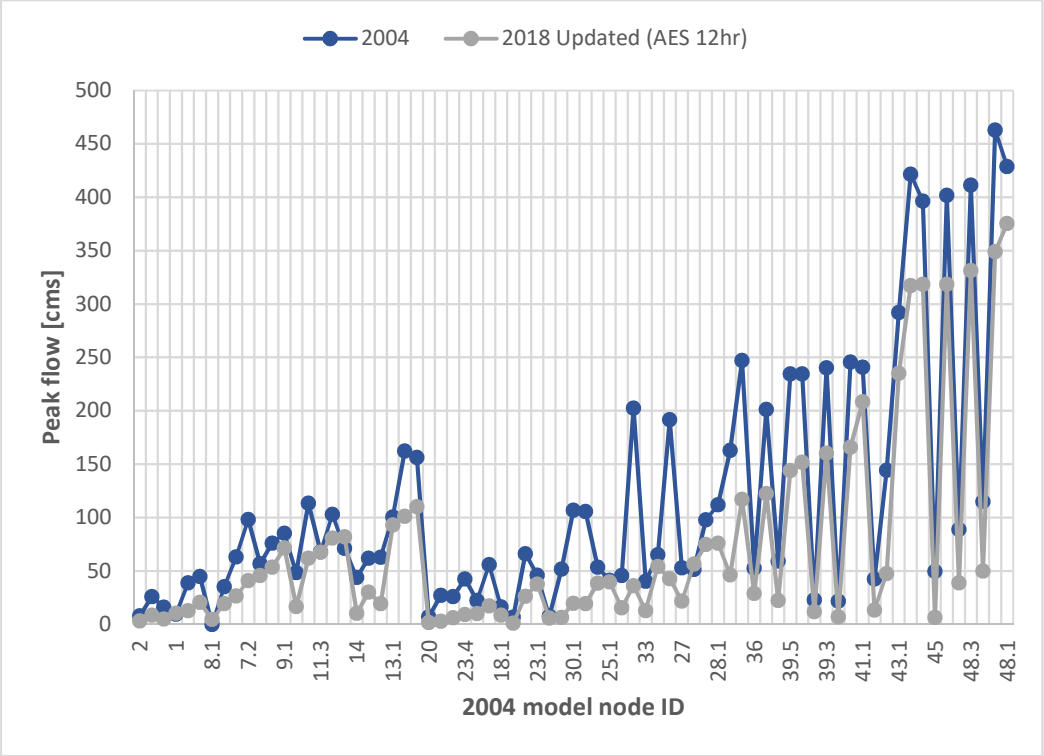


Figure 25 Peak flows from the 2004 model and 2018 model for 50-yr 12-hr design storm

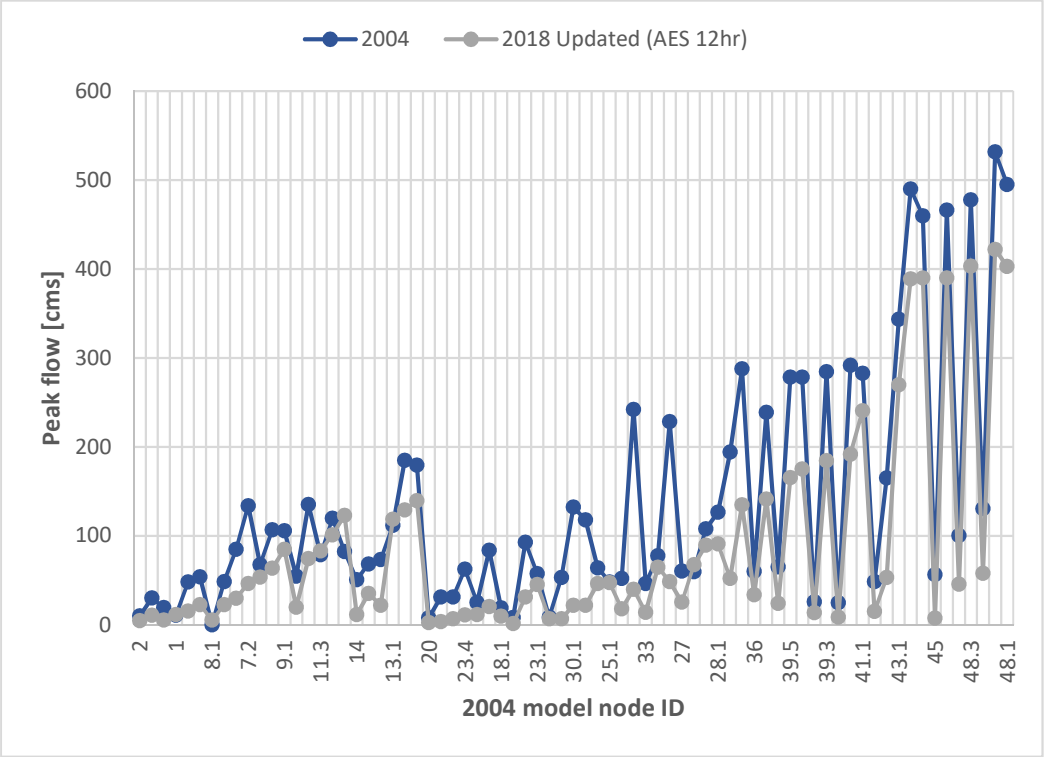


Figure 26 Peak flows from the 2004 model and 2018 model for 100-yr 12-hr design storm

8.2 Applicability of the Calibrated Model

Future applications of the calibrated model depend on the magnitude of the rainfall events selected for model calibration and validation. Table 14 summarizes the rainfall event statistics for the calibration and verification events for selected rain gages.

The calibration and verification events were further evaluated by plotting them against the updated IDF curves. Figure 27 through Figure 30 compare the events with the IDF curves based on individual duration used in IDF curve definition. Average event rainfall intensities for 5-15 min interval and 12 hours are of more importance as they are associated with the peak flow response and total flow volumes.

Table 14 - Statistics for calibration and verification rainfall events

Event					RG-25	RG-22	RG-23	RG-27	HY021	HY027	HY069	HY070
ID	Type	Event start	Duration (h)									
1	Verification	8/19/2005 0:00	76	Max (mm/hr)	93.6	-	-	223.2	216	-	38.4	69.6
				Total (mm)	72.4	-	-	119.6	115.4	-	29.4	60.6
2	Verification	7/23/2010 1:00	72	Max (mm/hr)	45.6	-	-	55.2	52.8	48	38.4	45.6
				Total (mm)	50.8	-	-	67.8	49.2	48.6	49.4	54.8
3	Verification	11/28/2011 21:30	72	Max (mm/hr)	21	-	12	-	9.6	12	14.4	16.8
				Total (mm)	57.5	-	49.25	-	51.8	36.8	42.4	50
4	Verification	7/25/2012 17:00	72	Max (mm/hr)	0	54	60	54.86	60	72	21.6	21.6
				Total (mm)	0	47.5	34.75	50.29	54.8	40	37	35.4
5	Verification	9/4/2012 5:00	72	Max (mm/hr)	63	81	57	115.8	106.8	64.8	43.2	60
				Total (mm)	33.25	40.5	41.5	71.63	68.7	53.2	45.4	62.6
6	Verification	5/28/2013 5:45	72	Max (mm/hr)	87	57	54	70.1	37.2	72	36	45.6
				Total (mm)	77	55.75	60.5	64.52	38.3	59	30.2	34.4
7	Calibration	7/8/2013 6:15	72	Max (mm/hr)	123	114	108	97.54	70.8	110.4	57.6	48
				Total (mm)	71.5	50.25	50.75	53.09	41.7	68.2	25.8	20.6
8	Calibration	7/31/2013 12:30	72	Max (mm/hr)	12	75	18	27.43	31.2	26.4	50.4	50.4
				Total (mm)	38.75	51.5	33.75	51.05	46	45.2	47.8	46.8
9	Calibration	9/20/2013 21:00	96	Max (mm/hr)	18	18	33	18.29	74.4	24	45.6	55.2
				Total (mm)	33	31.25	33.75	42.42	42.6	35.6	43.4	40.2
10	Calibration	7/27/2014 0:00	72	Max (mm/hr)	75	6	6	76.2	21.6	122.4	69.6	52.8
				Total (mm)	46.25	18.25	15.5	44.96	36.8	76	56.8	41.8
11	Calibration	9/10/2014 16:00	72	Max (mm/hr)	30	39	9	57.91	31.2	26.4	33.6	48
				Total (mm)	39	43.75	19.5	48.77	37.8	40.8	40.6	39
12	Verification	5/30/2015 10:45	72	Max (mm/hr)	30.48	57.96	33.53	64.01	26.4	81.6	45.6	48
				Total (mm)	43.18	49.94	39.62	55.63	47.5	64.8	44.6	51.4
13	Calibration	6/27/2015 10:45	72	Max (mm/hr)	12.19	12.24	12.19	12.19	10.8	9.6	21.6	14.4
				Total (mm)	45.97	45.11	46.48	41.91	36.8	37.4	47.6	32.8

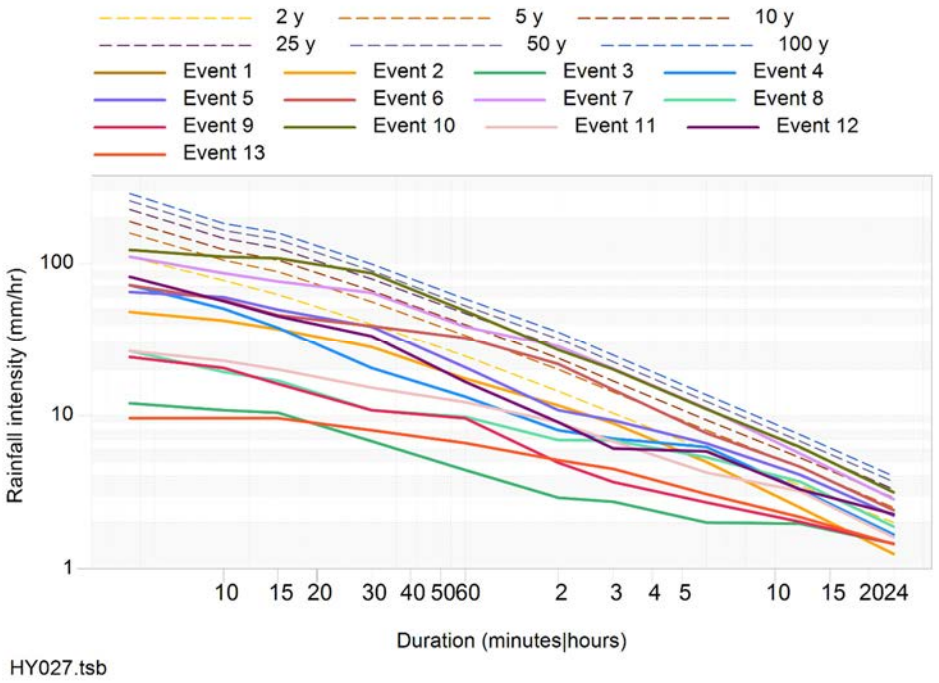


Figure 27 - Rainfall intensities for design storms and calibration/verification events – rain gage HY027

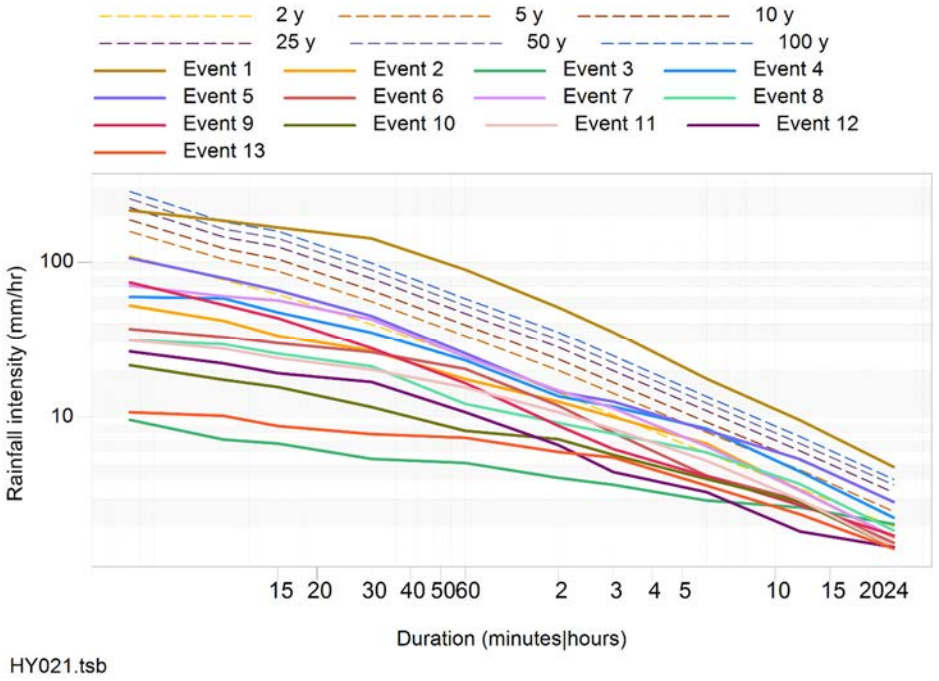


Figure 28 - Rainfall intensities for design storms and calibration/verification events – rain gage HY021

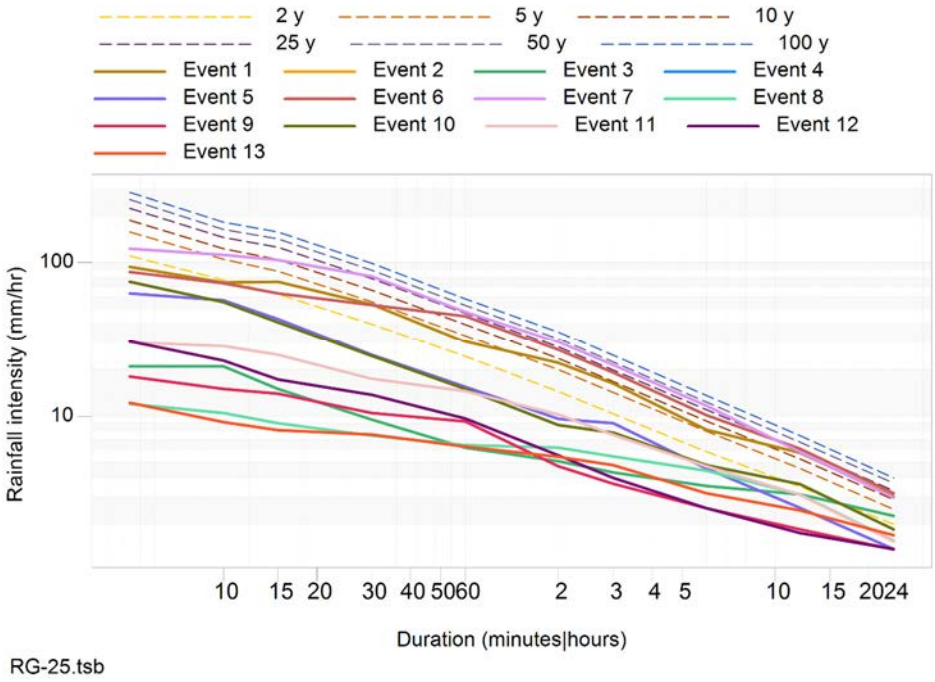


Figure 29 - Rainfall intensities for design storms and calibration/verification events – rain gage RG-25

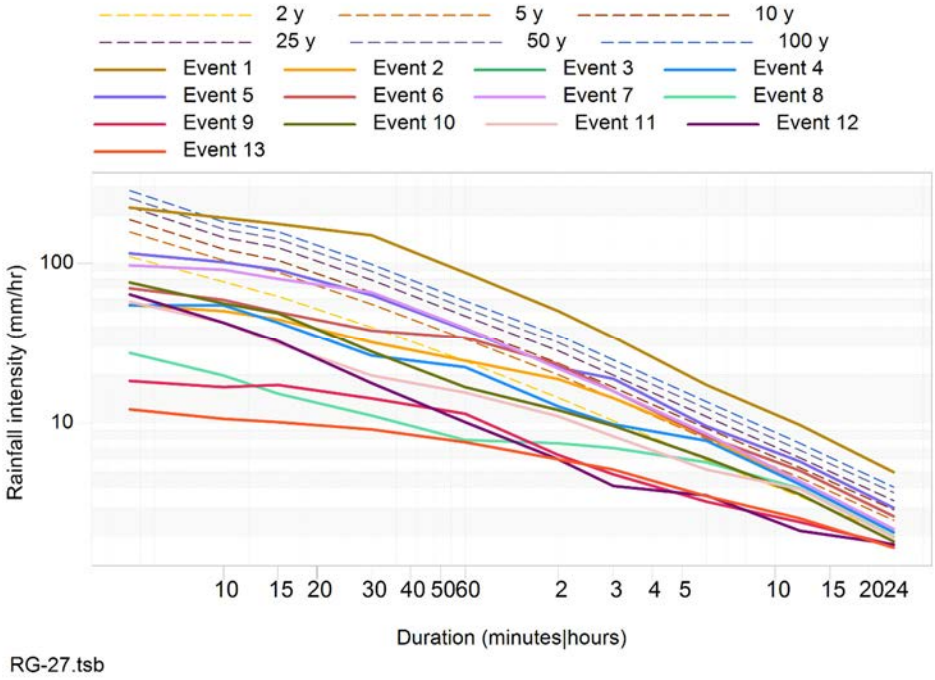


Figure 30 - Rainfall intensities for design storms and calibration/verification events – rain gage RG-27

Except for the August 19th 2005 event, events selected for calibration and verification represent the more frequent, common storms. This is a challenge for any modeller interested in developing a model to

simulate extreme events with a large return period. While it is difficult in any monitoring program to get enough large events for calibration and verification, even when there are large events during the monitoring program, the data may have uncertainties/gaps due to equipment malfunction or loss, and flow gages may require using extrapolated rating curves. Since the available storm events for calibration/verification of the Don River Hydrology model are mostly below the 50-year return period, it may introduce some uncertainty to model simulations of higher return period design storms, especially the 350-year design storm or the regional storm. However, it is noted that two 50-year storms as well as the August 2005 event exceeded the 100-year return period. Capturing such large events in the monitoring program generally exceeds the expectations of the current state of the practice for model calibration/verification efforts.

Conclusions and Recommendations

CHI was retained by TRCA to review the Don River Hydrology Model Update completed by AECOM. A thorough review was conducted, examining the model simulation options, setup, hydrology, hydraulics and rainfall input.

Based on CHI's initial review of the model, 16 items were suggested requiring additional justification for certain model parameter selection and improvements to the watershed representation. AECOM responded to each of the suggested items and, in most cases, provide adequate justification for the model decisions selected and updated the model based on the recommendations.

The largest uncertainty identified in the review was related to the infiltration parameterization in the watershed as it was identified as not being representative of the soils information provided. The primary concern associated with this comment was in the amount of water that is lost due to infiltration versus the water stored in the system. Adjacent subcatchments were also found to have large discrepancies in infiltration parameters.

AECOM justified the selection of infiltration parameters clarifying the infiltration parameters were calibrated from the volume of runoff measured at the flow gages relative to the volume of rainfall, and discrepancies in the soils map was potentially due to imported topsoil, lot grading and gardens cultivating the surface. It was also noted that infiltration parameters are varied across the watershed because the actual runoff response is varied across the watershed.

Although this justification was found to be acceptable to CHI, it is recommended that a future investigation be conducted to confirm the soil properties in the model are representative of the watershed.

Based on CHIs thorough review of the submitted materials, we believe the Don River Watershed model represents a good-quality effort, for what we could consider a reasonable and acceptable application of the PCSWMM and the SWMM5 model for similarly scoped studies.

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Appendix A – Submission Background Data

Submission:

- Models:
    - HEC-RAS of 2- to 100-year and Regional scenarios for:
        - Don Mills Ditch;
        - Don River south of Steeles;
        - East Don River north of Steeles;
        - Mud Creek;
        - West Don north of Steeles;
        - CN MacMillan Railyard;
    - Visual OttHYMO with available documentation:
        - Don Mills Ditch (Cole, 2011) and supplemental data (City of Markham);
        - Mud Creek (Geomorphic Solutions, 2012);
        - Yonge and Elgin Mills Flood Mitigation EA;
        - Watershed (Marshall, Macklin and Monaghan, 2004), includes supporting GIS information.
- Gage information:
    - TRCA (rainfall, stream, and supplemental GIS);
    - City of Markham (rainfall);
    - City of Toronto (rainfall, stream);
    - Town of Richmond Hill (rainfall);
    - Water Survey of Canada (stream).
- Geomatics:
    - LiDAR information (1m x 1m ESRI grid);
    - Vector files:
        - Current land use;
        - Future land use;
        - Hummocky terrain;
        - 2013 natural cover;
        - Oak Ridges Moraine boundary;
        - Physiography;
        - Roads;
        - OMAFRA soil mapping;
        - Surficial geology.
- Orthographic photography:
    - Markham (2015);
    - Richmond Hill (2015);
    - Vaughan (2015).
- Other Documentation:
    - G Ross Lord Dam:

        - Operations, Maintenance and Surveillance Manual;
        - Operations logs.
    - TRCA flood event documentation
    - Don River Watershed Plan (TRCA, 2008);
    - Reports for other watershed hydrologic models:
        - Duffins Creek;
        - Etobicoke Creek;
        - Humber River;
        - Rouge River.
    - Block 27 Subwatershed Study Final Report (Cole, 2017).
- NEXRAD data for calibration/verification events.
- SWM pond dataset.

From AECOM:

- York Region Rain Gage data;
- Geomatics:
    - Flow nodes;
    - Flow paths;
    - HEC-RAS cross-section cut-lines;
    - Rain gage locations;
    - Stream gage locations.
- Work sheets:
    - Synthetic design storm hyetographs;
    - Results tables;
    - Crossing structure screening/inventory;
    - SWM pond screening/inventory
    - Hydrologic parameters;
    - Pond curves;
    - Summary of potential calibration events.

Missing:

- Orthographic photography for City of Toronto.

Appendix B – Hydrology Check

To ensure the percent imperviousness values were representative of the watershed surface, a copy of the original EX_DesignEvents model was made, and the percent imperviousness values were re-estimated using the CurrentLandUse_trca.SHP file provided, referred to as the modified impervious scenario. Assumed percent imperviousness values can be found in **Error! Reference source not found.**.

Table B1 - Assumed percent impervious values for each land-use defined in the SURFACE_DE attribute

SURFACE_DE	IMPERV
Road (ROW)	100
Airport	50
Cemetery	10
Commercial	95
Conservation Lands	0
Estate Residential	15
Farm	0
Golf Course	10
Hydro Corridor	5
Industrial	93
Open Space	10
Park	0
Recreational	10
Residential High	50
Residential LowMed	30
Rural Residential	10
Transportation	100
Water	100

Flagged subcatchments considered acceptable if they fell into the following categories:

1. Had an impervious portion of the subcatchment not represented in the impervious land use layer where the larger estimated value was representative of the missing areas.
2. Subcatchments assigned a % impervious value of 0, where the new estimated value was > 5%. In this case the percent impervious difference was assumed to be negligible.

Figure B1 shows the subcatchments in the Don River Watershed that were flagged as being potentially non-representative of the area. The total area of the watershed that was mis-represented was 1755.93 ha, approximately 5% of the watershed.

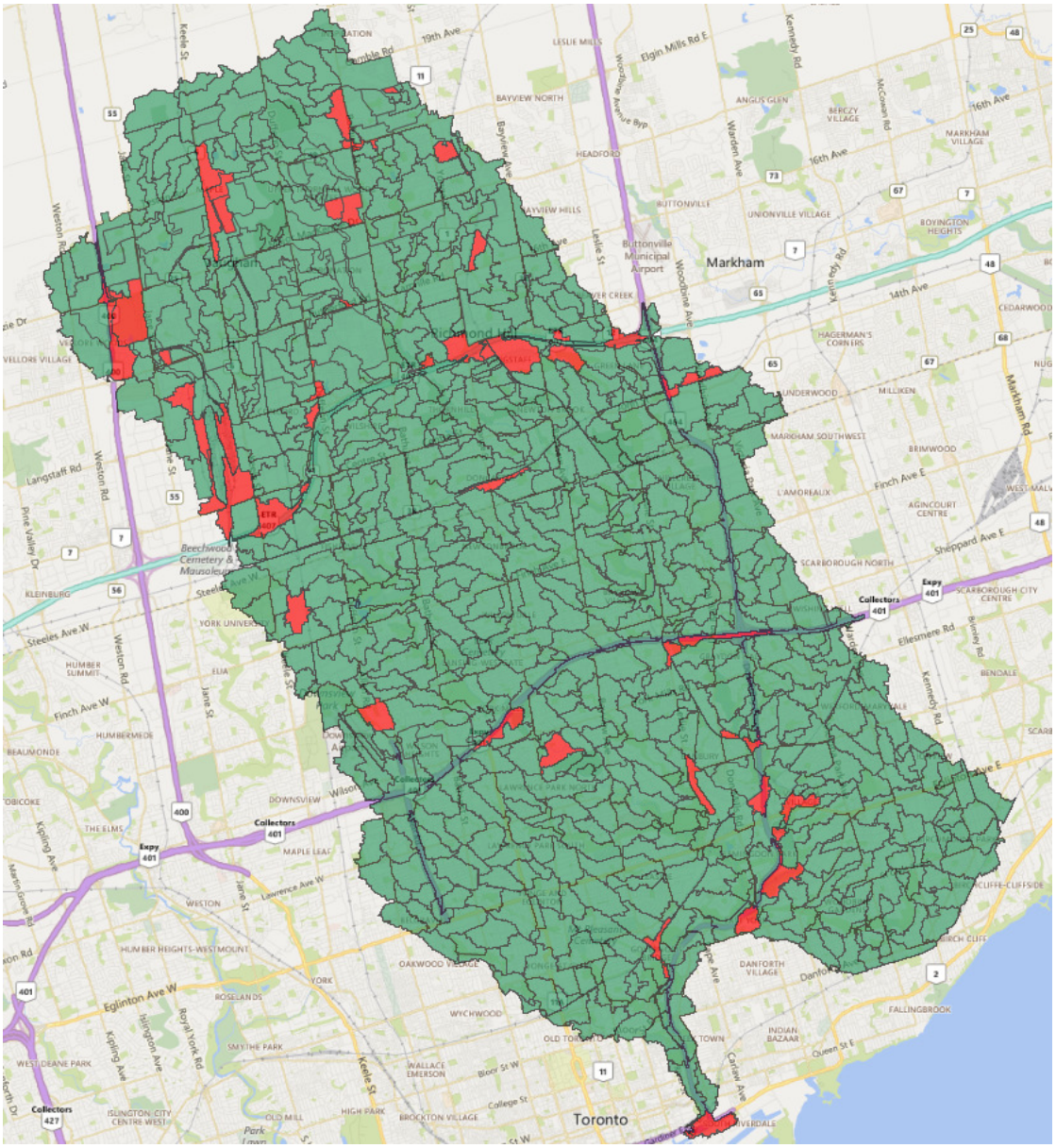


Figure B1 - Subcatchments flagged as potentially not representing the percent imperviousness

Table B2 lists the subcatchments that were flagged as potentially not representative of the impervious surface within the subcatchment.

Table B2 - Flagged subcatchments exceeding 50% change for percent impervious between the base model and one re-estimated using the CurrentLandUse_trca.shp layer.

Subcatchment Name	Original model Imperv. (%)	Re-estimated Imperv. (%)	Percent Change (%)	Notes
S010	42.08	76.729	82%	Impervious area may not be representative.

S015	35.92	89.833	150%	Landuse layer indicates the subcatchment lies within transport category, but it looks like there is a lot of trees in the transport polygon.
S028	43.15	71.855	67%	May not be fully representing industrial area.
S029	40.95	70.998	73%	May not be fully representing industrial area.
S059	45.86	69.438	51%	Likely not representing actual impervious area.
S060	46.43	75.544	63%	Potentially not representing actual impervious area.
S075	57.51	94.405	64%	Likely not representing actual impervious area.
S085	29.69	52.832	78%	Likely not representing actual impervious area.
S117	56.03	96.152	72%	Likely not representing actual impervious area.
S127	51.25	80.789	58%	Likely not representing actual impervious area.
S131	57.25	94.724	65%	Likely not representing actual impervious area.
S188	58.49	90.059	54%	Impervious area may not be representative.
S191	29.32	55.846	90%	Pervious area may not be representative
S192	55.82	84.47	51%	Impervious area may not be representative.
S233	24.66	40.947	66%	Impervious area may not be representative.
S241	13.71	46.465	239%	Impervious area may not be representative.
S248	25.86	43.403	68%	Impervious area may not be representative.
S287	24.41	41.369	69%	Impervious area may not be representative.
S294	19.37	29.967	55%	Impervious area may not be representative.
S327	30.02	51.017	70%	Impervious area may not be representative.
S351	36.33	64.038	76%	Impervious area may not be representative.
S376	11.44	20.66	81%	Impervious area may not be representative.
S393	6.06	13.205	118%	Impervious area may not be representative.
S400	35.74	74.369	108%	Impervious area may not be representative.
S453	0.55	10.043	1726%	Impervious area may not be representative.
S470	49.69	84.531	70%	Impervious area may not be representative.
S475	1.68	94.748	5540%	Impervious area may not be representative.
S500	28.31	76.288	169%	Impervious area may not be representative.
S521	38.13	95.059	149%	Impervious area may not be representative.
S524	25.35	50.275	98%	Impervious area may not be representative.
S526	29.2	84.605	190%	Impervious area may not be representative.
S551	22.52	0.271	99%	Impervious area may not be representative.
S552	13.58	0	100%	Impervious area may not be representative.
S612	23.6	52.112	121%	Impervious area may not be representative.
S668	51.56	77.552	50%	Impervious area may not be representative.
S677	42.26	68.61	62%	Impervious area may not be representative.
S698	15.03	35.981	139%	Impervious area may not be representative.
S722	55.77	92.794	66%	Impervious area may not be representative.
S742	33.01	50.237	52%	Impervious area may not be representative.

S754	60.36	96.494	60%	Impervious area may not be representative.
S768	44.53	93.063	109%	Impervious area may not be representative.
S778	64.74	97.831	51%	Impervious area may not be representative.
S784	52.51	86.597	65%	Impervious area may not be representative.
S792	33.3	53.674	61%	Impervious area may not be representative.
S816	44.79	73.428	64%	Impervious area may not be representative.
S841	59.48	89.646	51%	Impervious area may not be representative.
S856	25.57	46.169	81%	Impervious area may not be representative.
S858	24.27	41.702	72%	Impervious area may not be representative.
S867	3.16	21.277	573%	Impervious area may not be representative.
S873	32.36	54.163	67%	Impervious area may not be representative.
S883	18.08	32.247	78%	Impervious area may not be representative.
S892	58.66	93.107	59%	Impervious area may not be representative.

Table B3 - Soil characteristics SI units (Rawls, W.J. et al., 1983)

Soil Texture Class	Hydraulic Conductivity (mm/hr)	Suction Head (mm)	Porosity (fraction)	Field Capacity (fraction)	Wilting Point (fraction)	Initial Deficit (fraction)
Sand	120.34	49.02	0.437	0.062	0.024	0.413
Loamy Sand	29.97	60.96	0.437	0.105	0.047	0.39
Sandy Loam	10.92	109.98	0.453	0.19	0.085	0.368
Loam	3.3	88.9	0.463	0.232	0.116	0.347
Silt Loam	6.6	169.93	0.501	0.284	0.135	0.366
Sandy Clay Loam	1.52	219.96	0.398	0.244	0.136	0.262
Clay Loam	1.02	210.06	0.464	0.31	0.187	0.277
Silty Clay Loam	1.02	270	0.471	0.342	0.21	0.261
Sandy Clay	0.51	240.03	0.43	0.321	0.221	0.209
Silty Clay	0.51	290.07	0.479	0.371	0.251	0.228
Clay	0.25	320.04	0.475	0.378	0.265	0.21

Appendix C – Sensitivity Plots for Model Ex_DesignEvents.inp

Error! Reference source not found. Figure C1 to C28 shows sensitivity plots for each of the hydrology parameter tested using the Ex_DesignEvents.inp scenario. In all plots, the base model value (0%, 0%) is plotted along with the resulting values from a range of parameter adjustments. For the gage location discharges, the sensitivity to peak flow rate and peak flow depth was examined for each parameter analyzed.

Sensitivity Analysis Plots for Scenario Ex_DesignEvents.inp

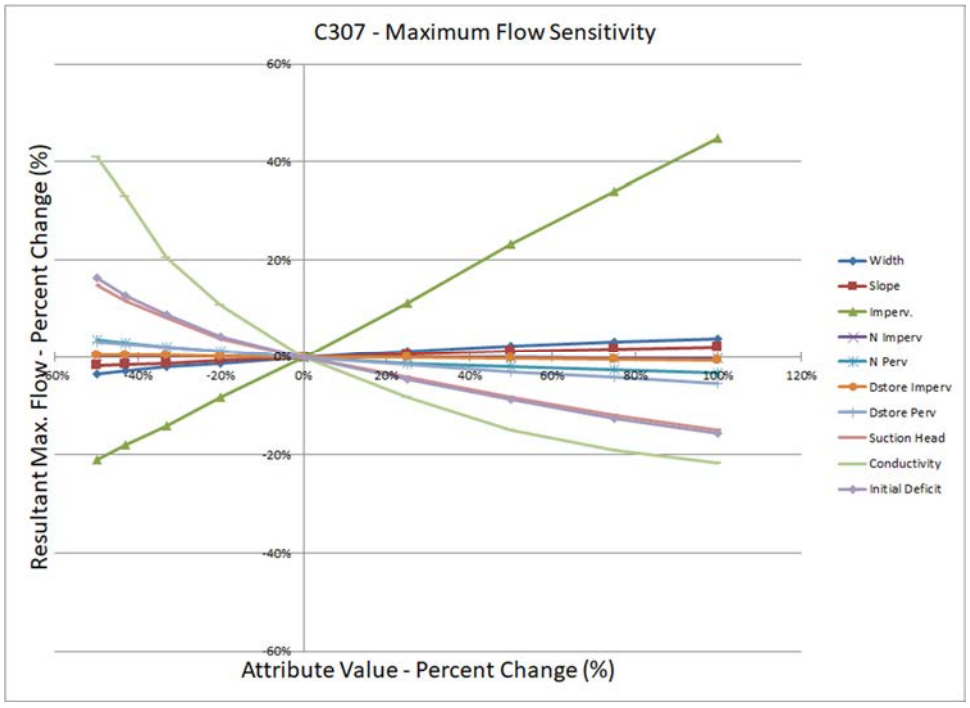


Figure C1 - Peak flow sensitivity at Don River East Branch near Thornhill (C307 - Ex_DesignEvents.inp)

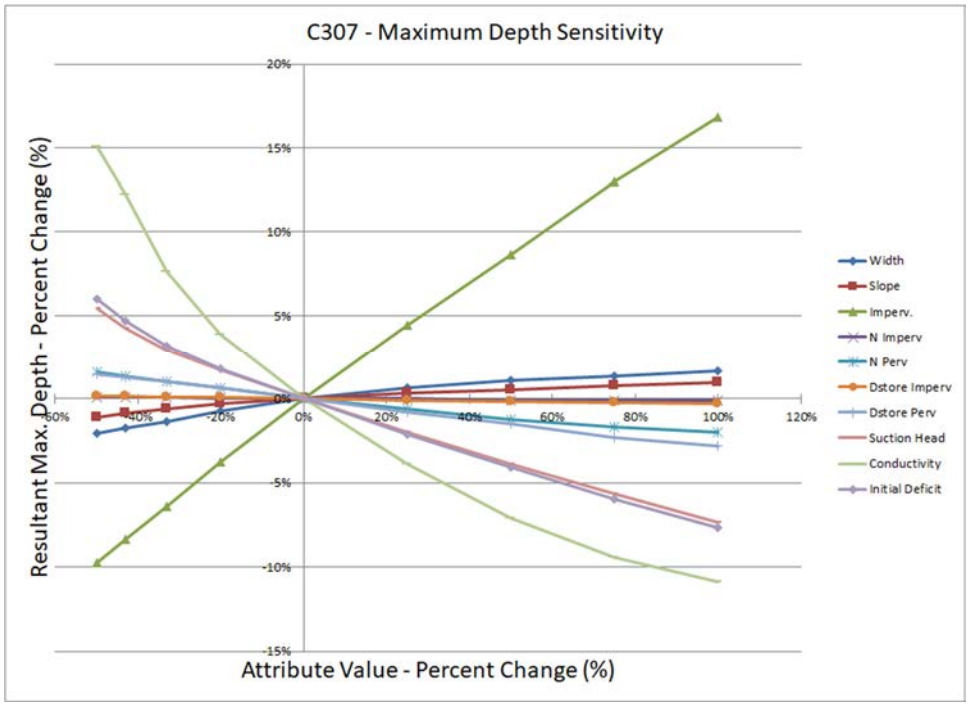


Figure C2 - Peak depth sensitivity at Don River East Branch near Thornhill (C307- Ex_DesignEvents.inp)

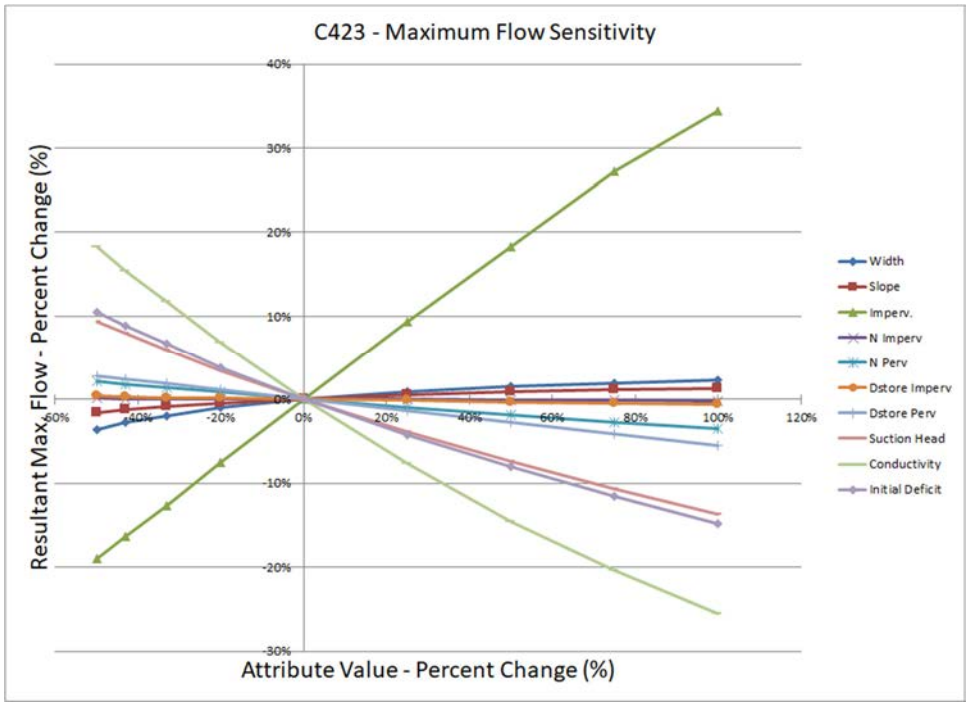


Figure C3 - Peak flow sensitivity at East Don @ Cummer (C423- Ex_DesignEvents.inp)

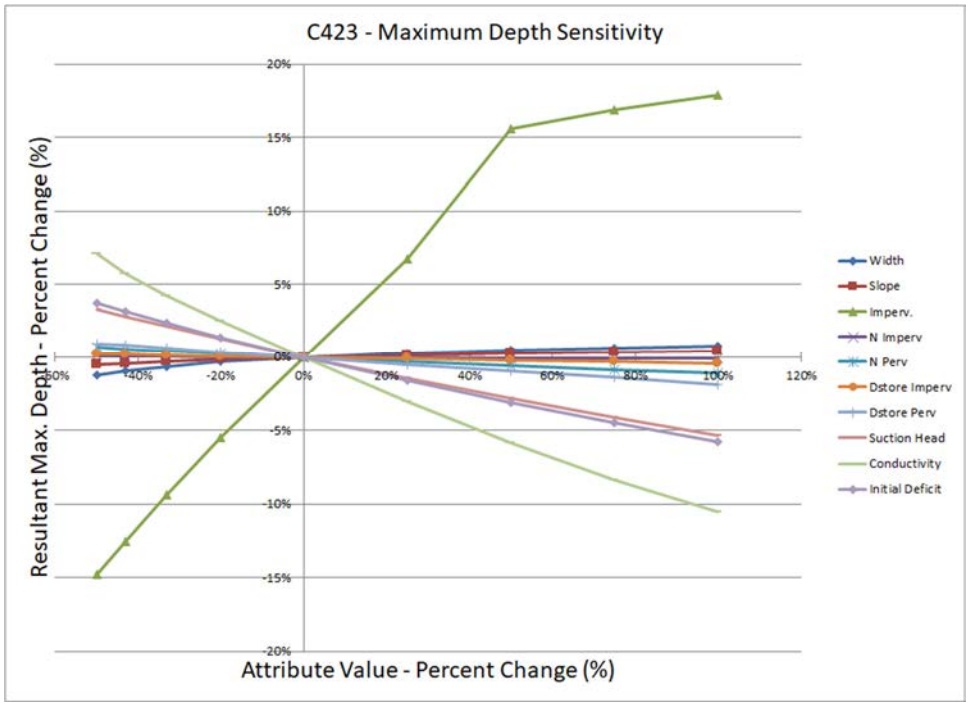


Figure C4 - Peak depth sensitivity at East Don @ Cummer (C423- Ex_DesignEvents.inp)

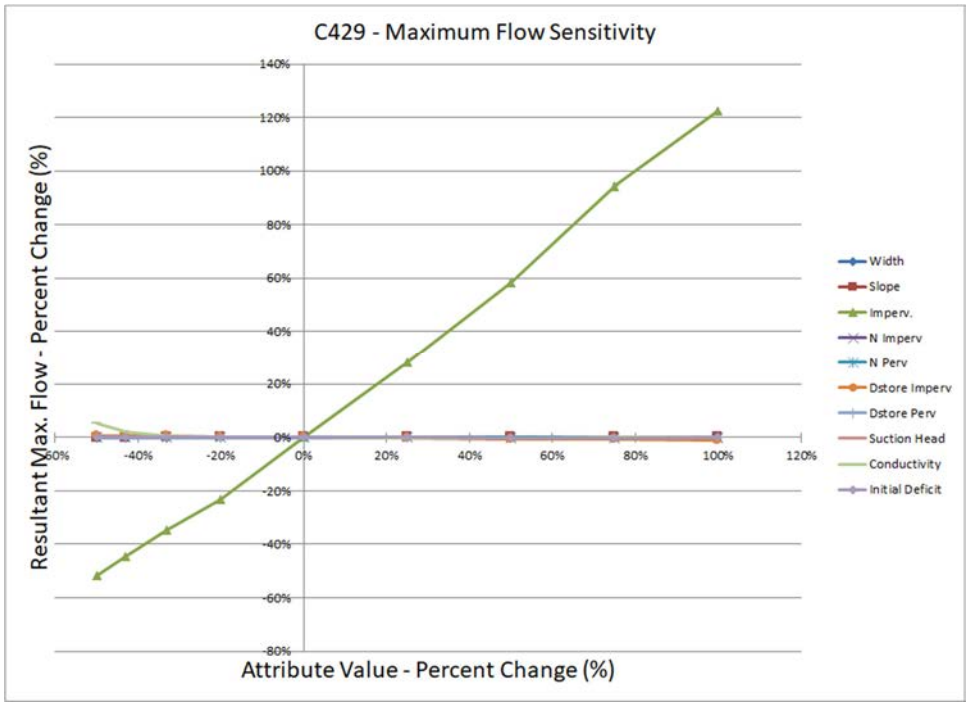


Figure C5 - Peak flow sensitivity at German Mills @ Cummer (C429- Ex_DesignEvents.inp)

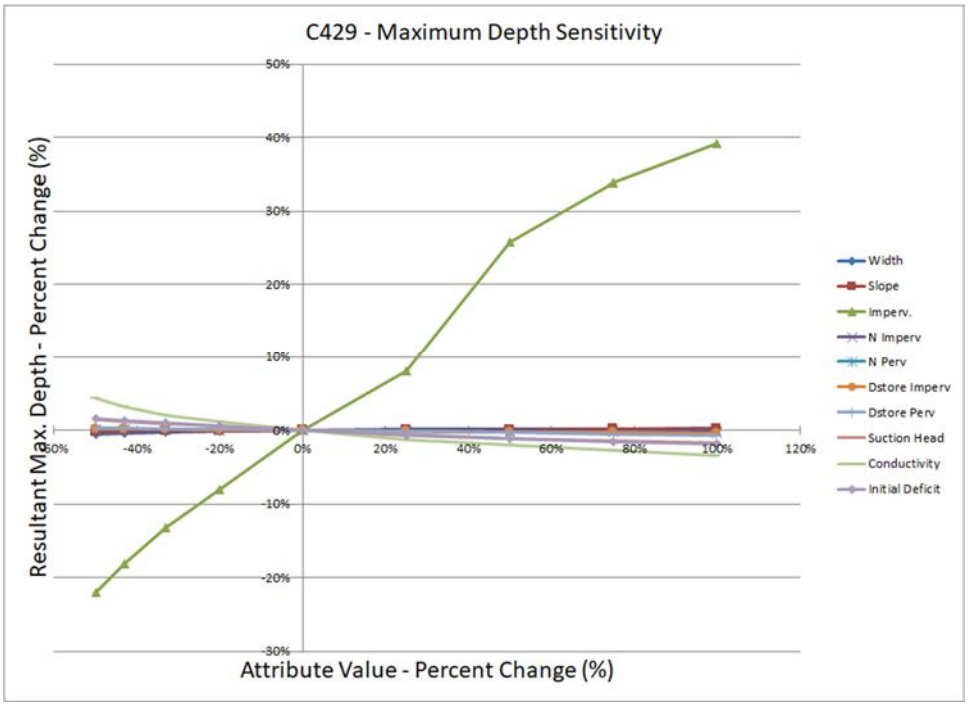


Figure C6 - Peak depth sensitivity at German Mills @ Cummer (C429- Ex_DesignEvents.inp)

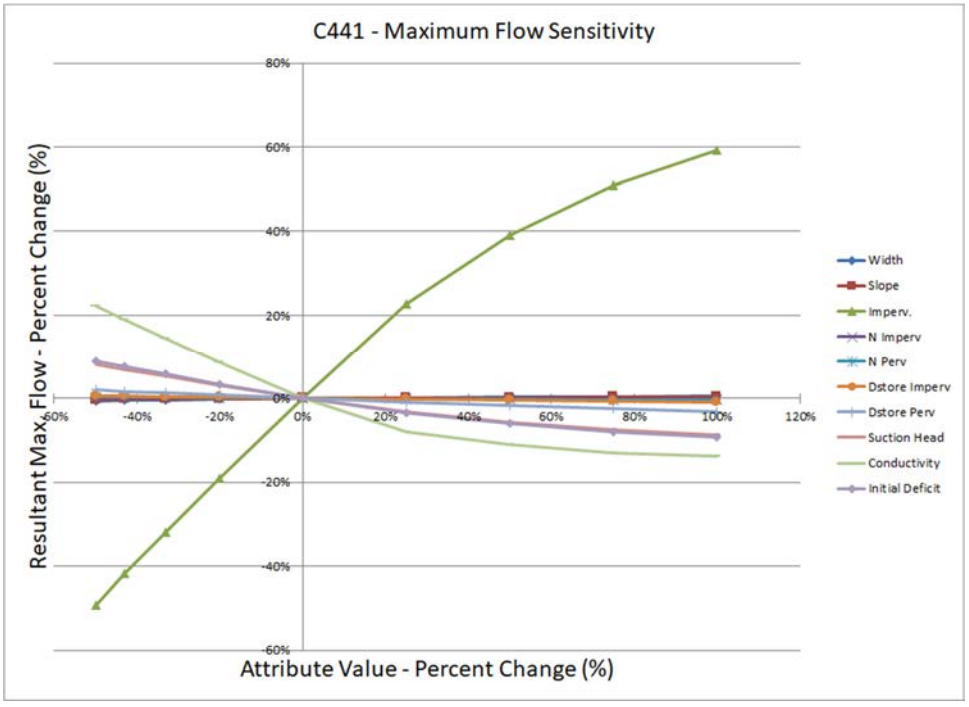


Figure C7 - Peak flow sensitivity at Don @ Glenshield (C441- Ex_DesignEvents.inp)

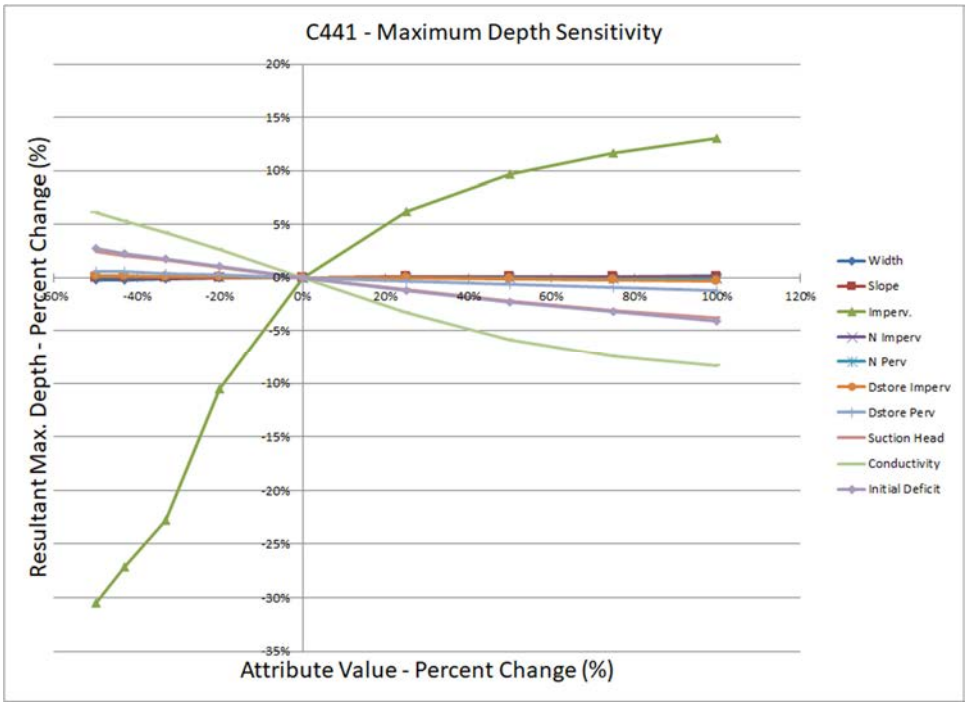


Figure C8 - Peak depth sensitivity at Don @ Glenshield (C441- Ex_DesignEvents.inp)

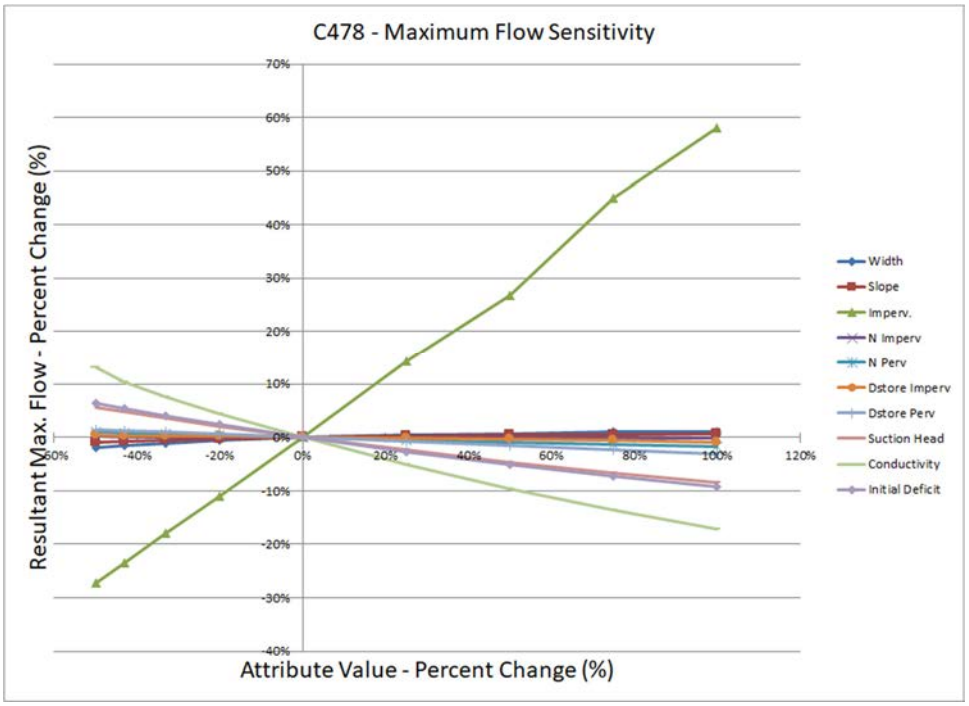


Figure C9 - Peak flow sensitivity at Little Don River near Lansing (C478- Ex_DesignEvents.inp)

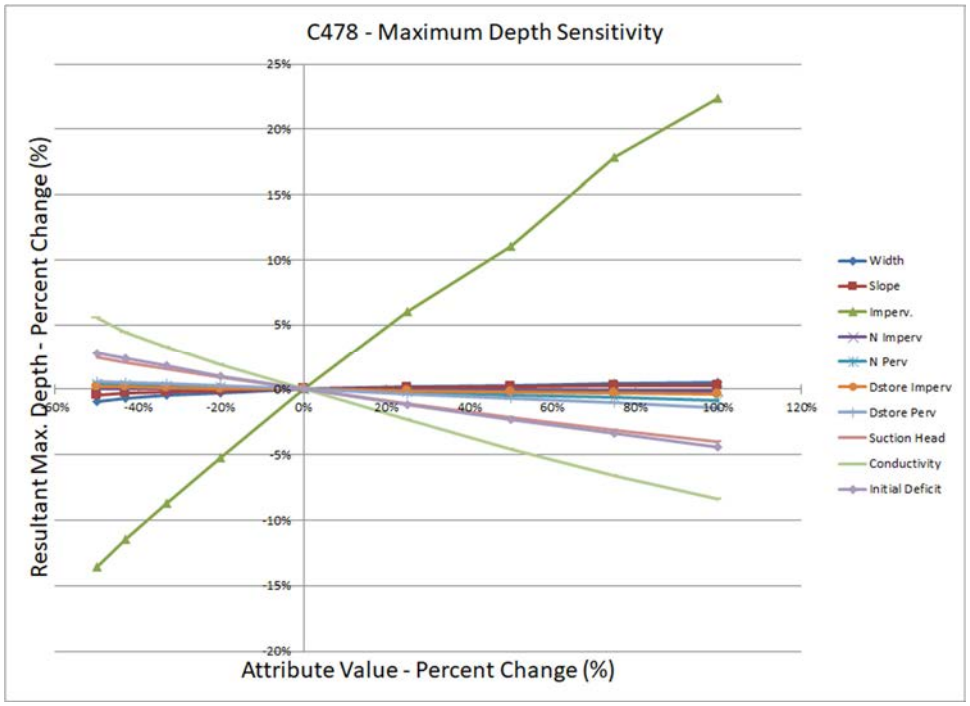


Figure C10 - Peak depth sensitivity at Little Don River near Lansing (C478- Ex_DesignEvents.inp)

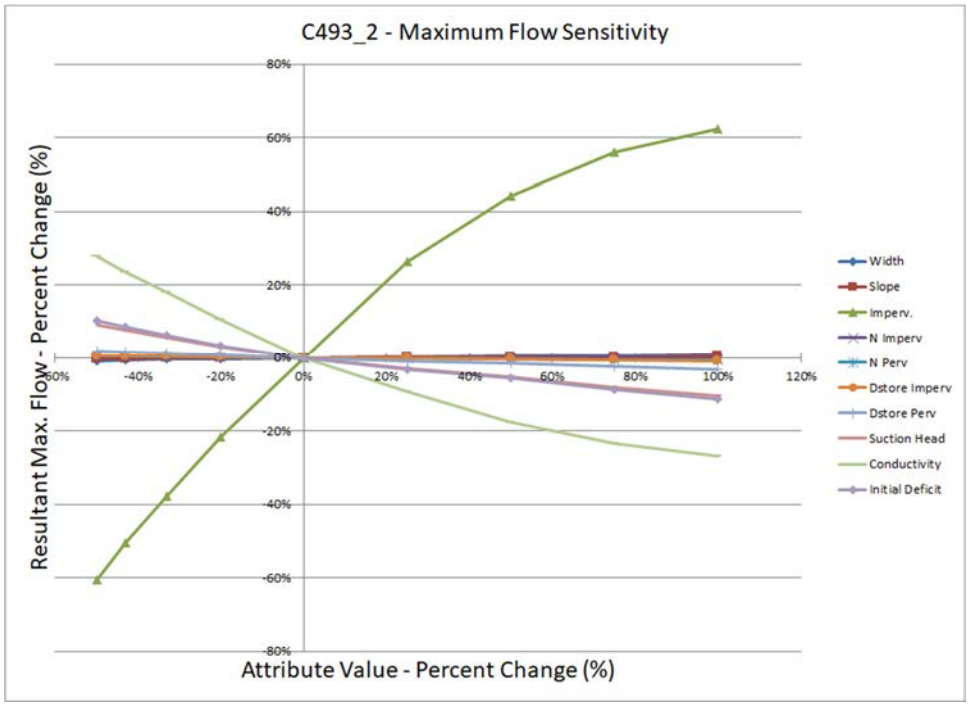


Figure C11 - Peak flow sensitivity at G. Ross Lord Dam (C493_2- Ex_DesignEvents.inp)

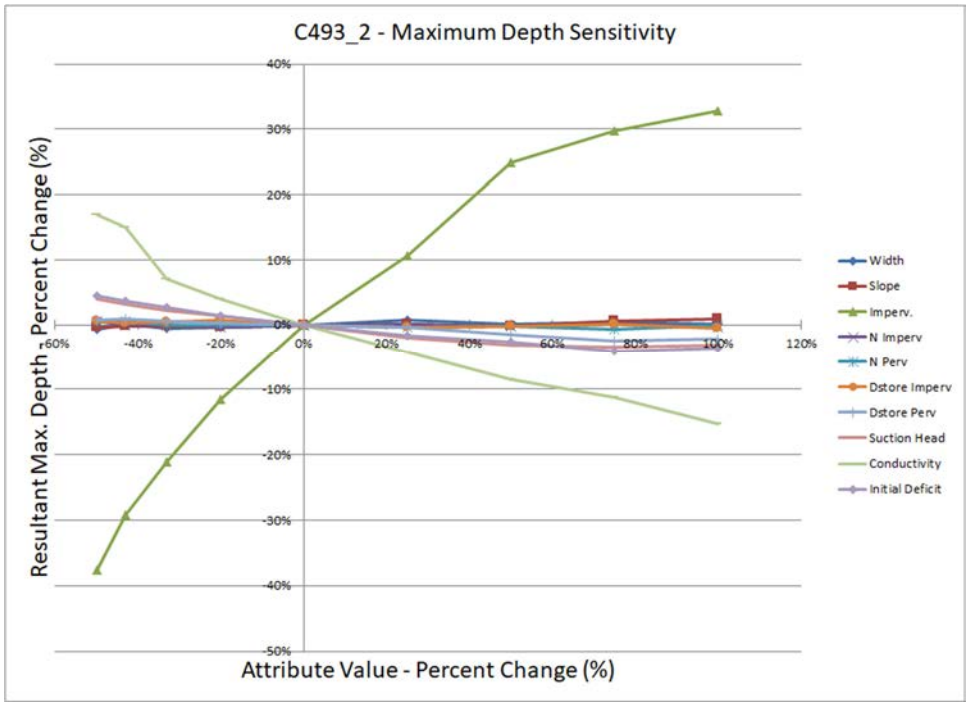


Figure C12 - Peak depth sensitivity at G. Ross Lord Dam (C493_2- Ex_DesignEvents.inp)

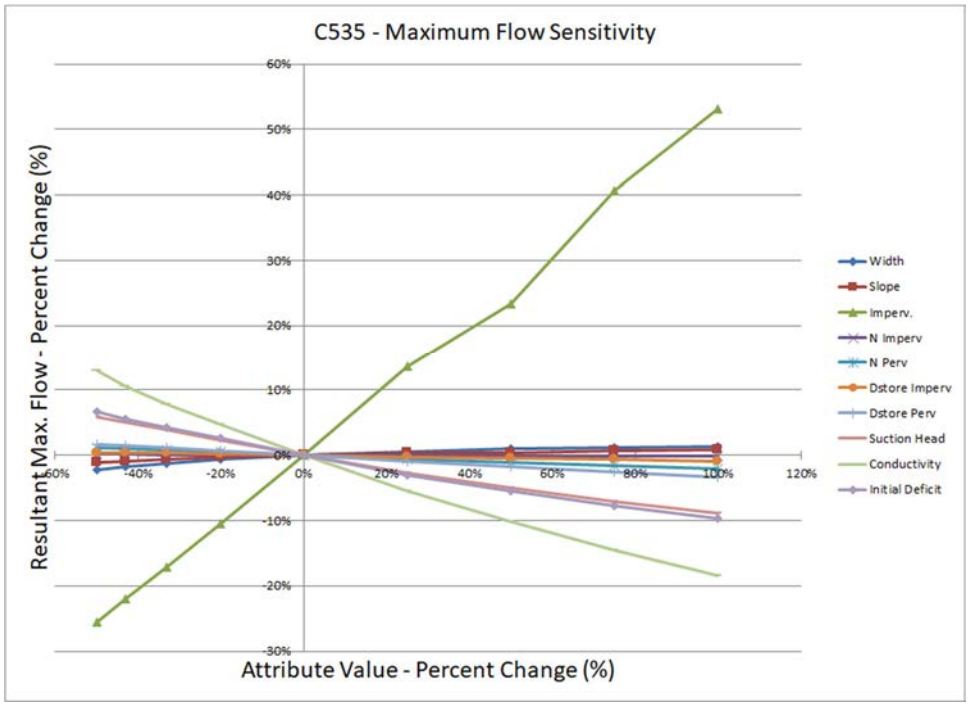


Figure C13 - Peak flow sensitivity at East Don @ York Mills (C535- Ex_DesignEvents.inp)

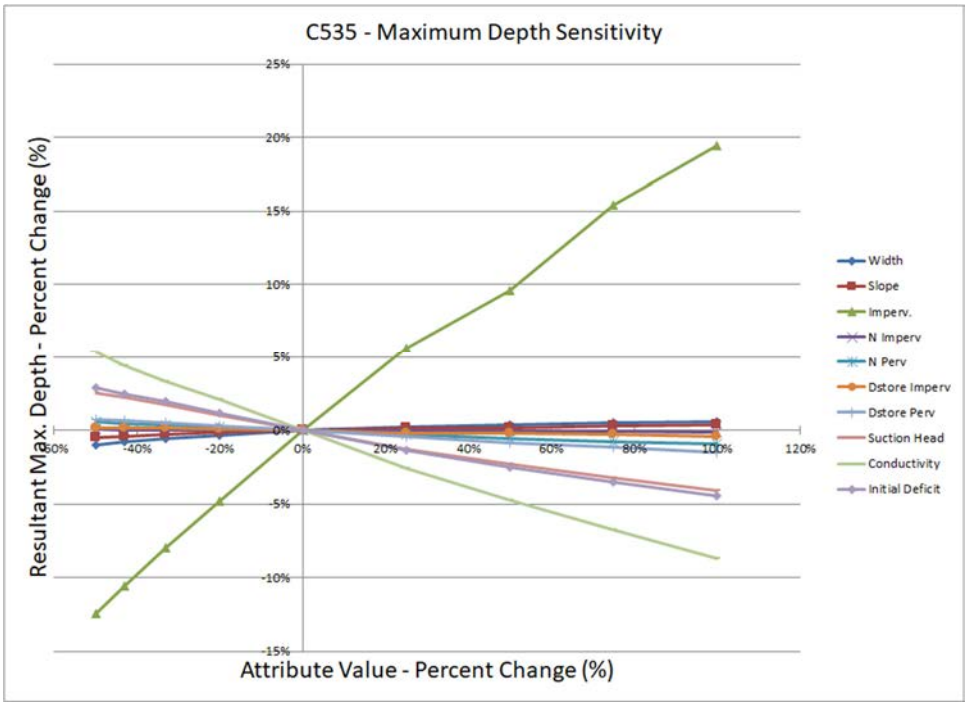


Figure C14 - Peak depth sensitivity at East Don @ York Mills (C535- Ex_DesignEvents.inp)

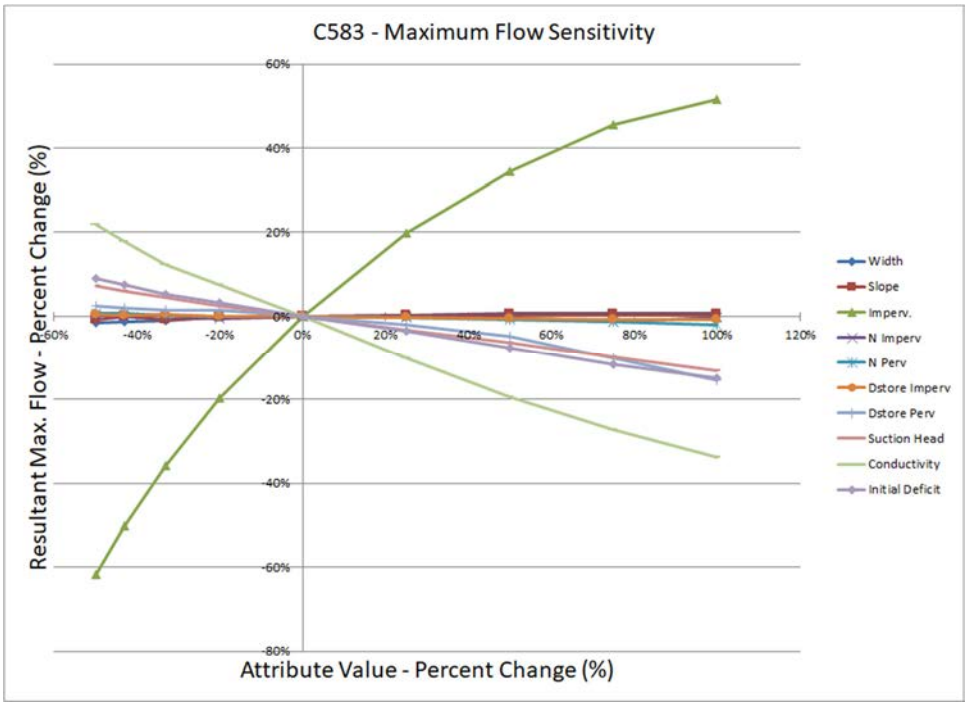


Figure C15 - Peak flow sensitivity at Don @ Knightswood (C583- Ex_DesignEvents.inp)

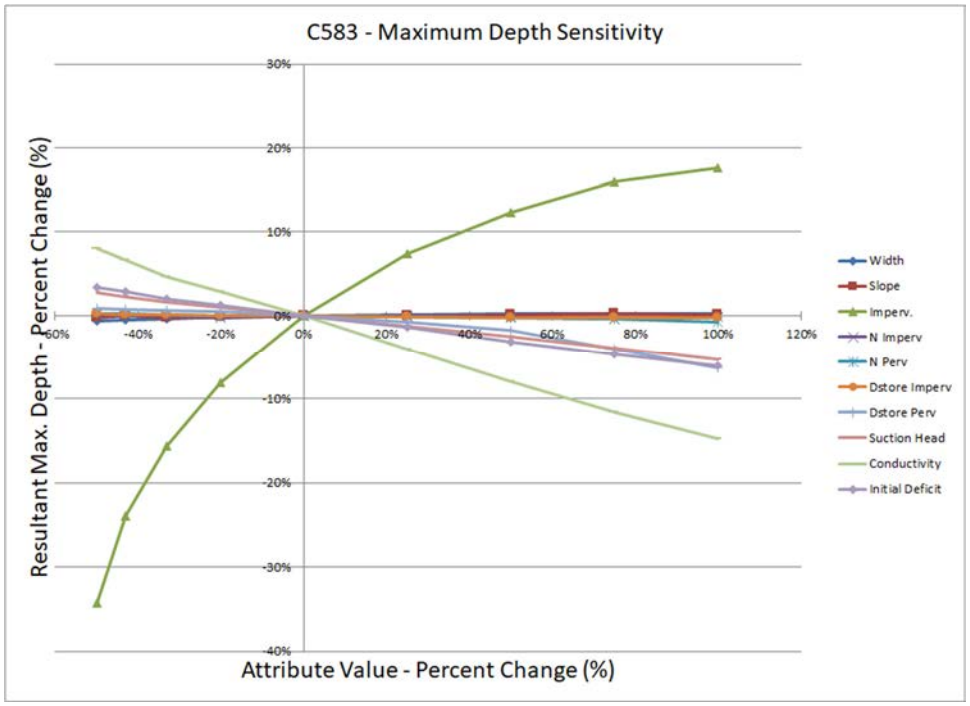


Figure C16 - Peak depth sensitivity at Don @ Knightswood (C583- Ex_DesignEvents.inp)

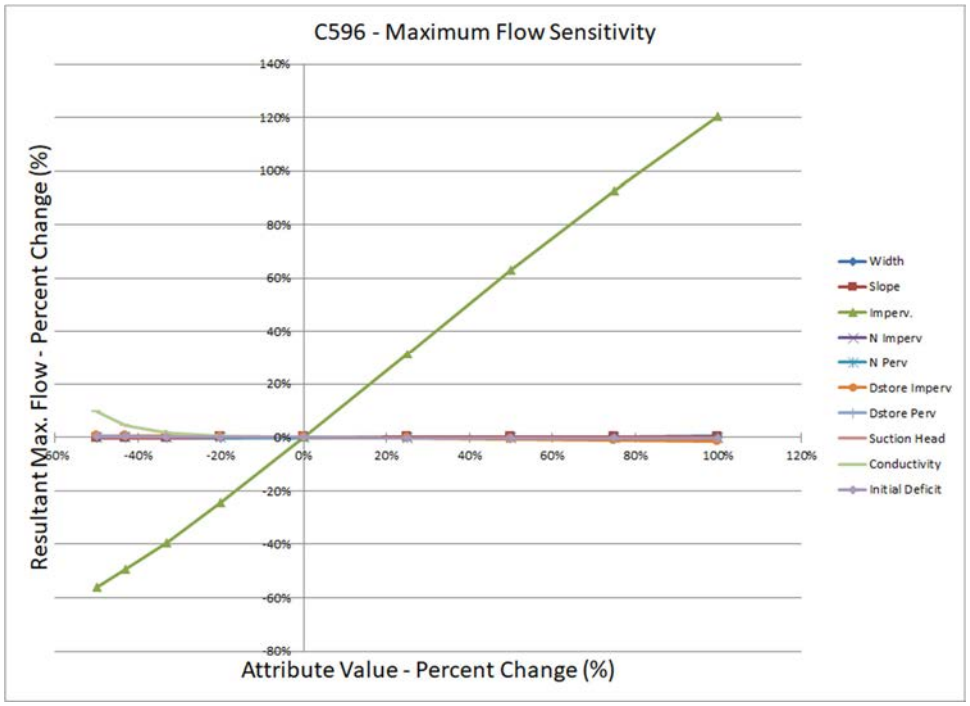


Figure C17 - Peak flow sensitivity at Taylor Creek North (C596- Ex_DesignEvents.inp)

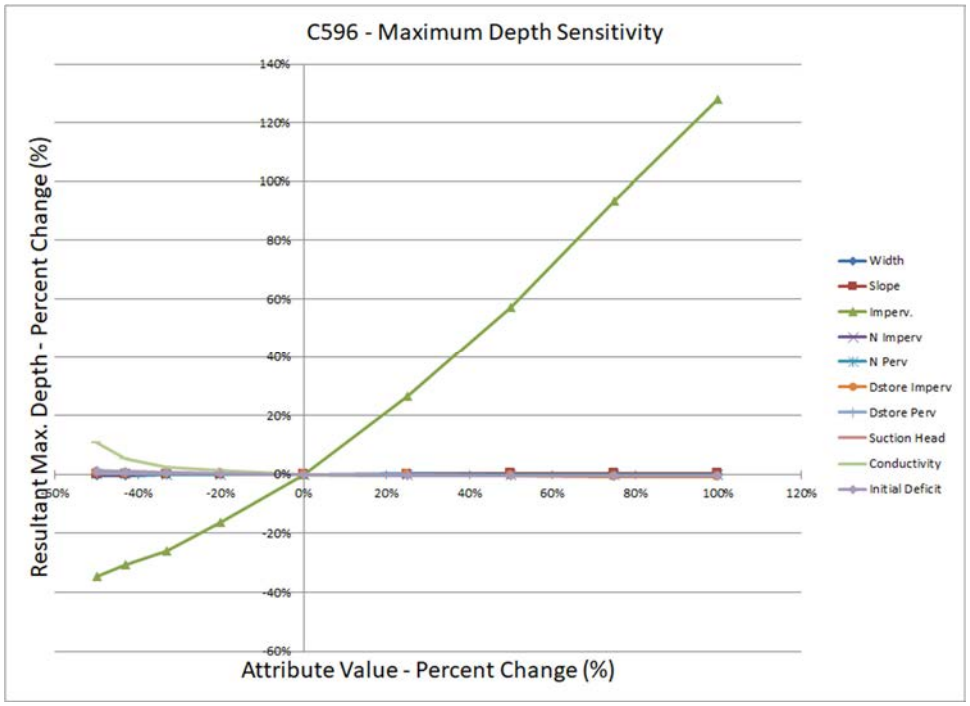


Figure C18 - Peak depth sensitivity at Taylor Creek North (C596- Ex_DesignEvents.inp)

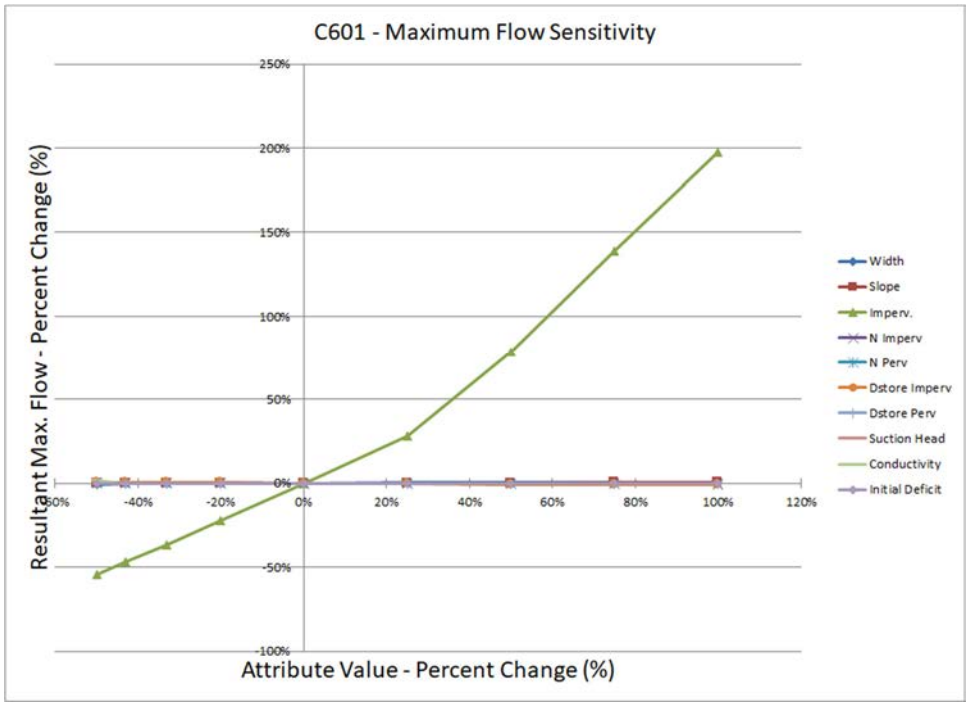


Figure C19 - Peak flow sensitivity at Wilket Creek (C601- Ex_DesignEvents.inp)

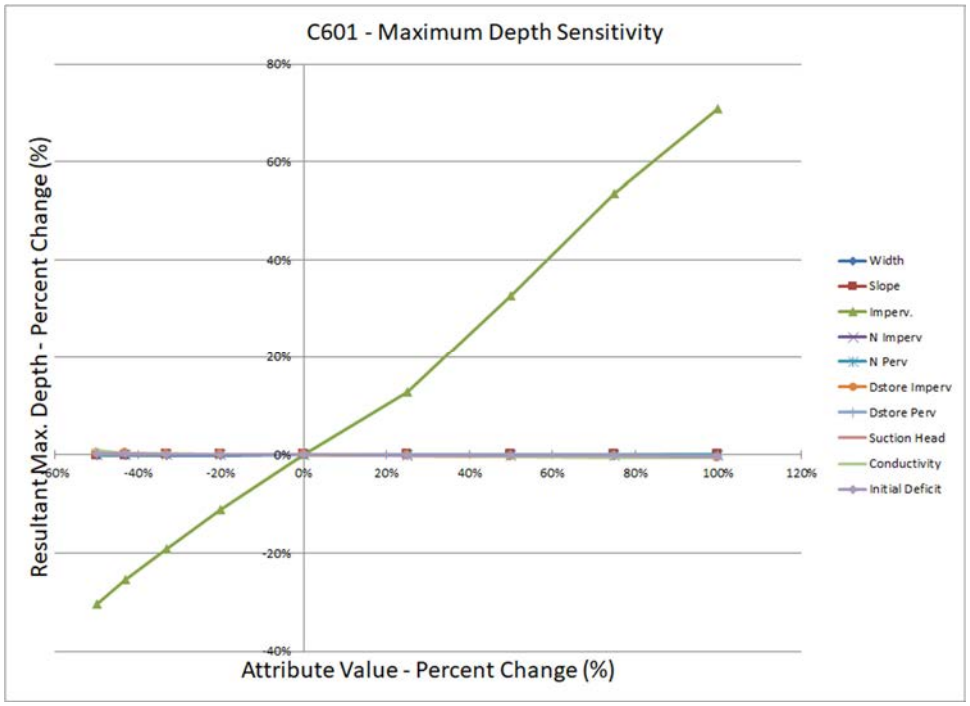


Figure C20 - Peak depth sensitivity at Wilket Creek (C601- Ex_DesignEvents.inp)

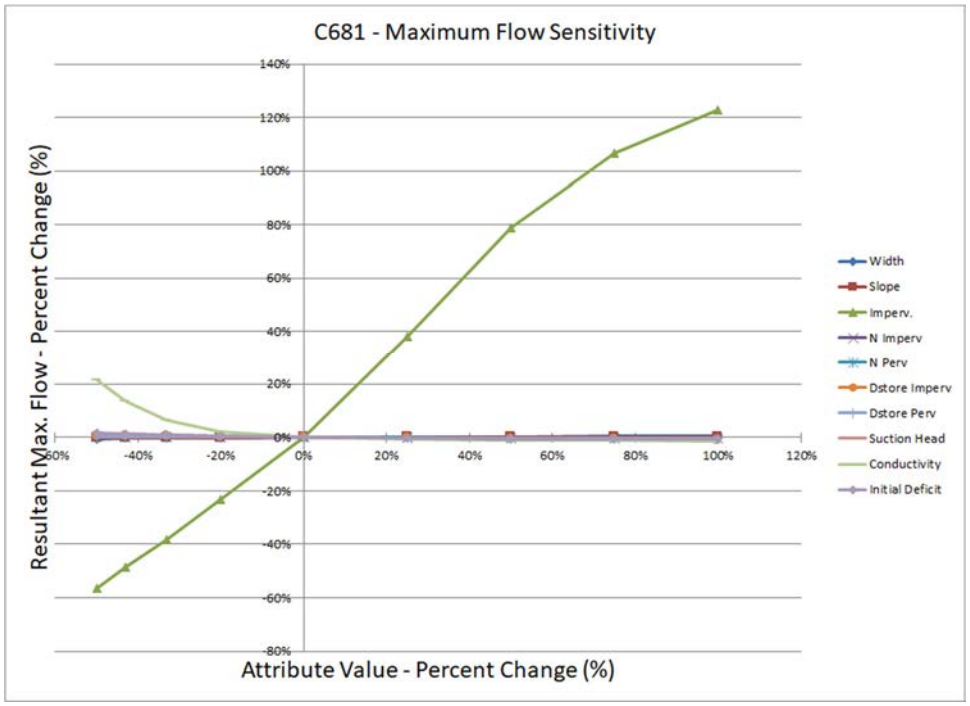


Figure C21 - Peak depth sensitivity at Taylor Creek South (C681- Ex_DesignEvents.inp)

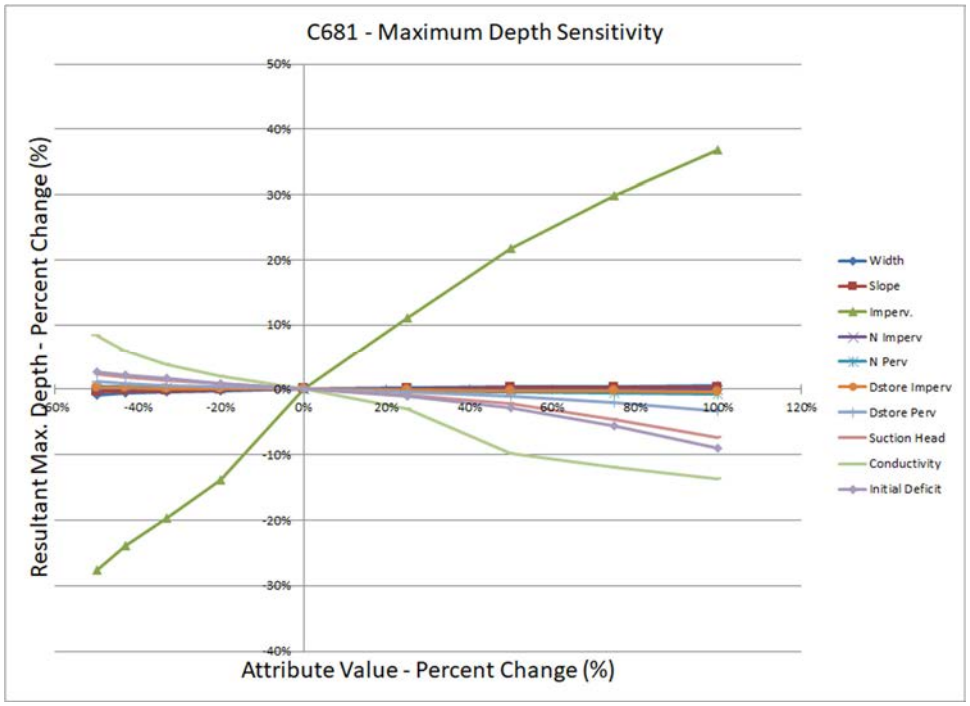


Figure C22 - Peak depth sensitivity at Taylor Creek South (C681- Ex_DesignEvents.inp)

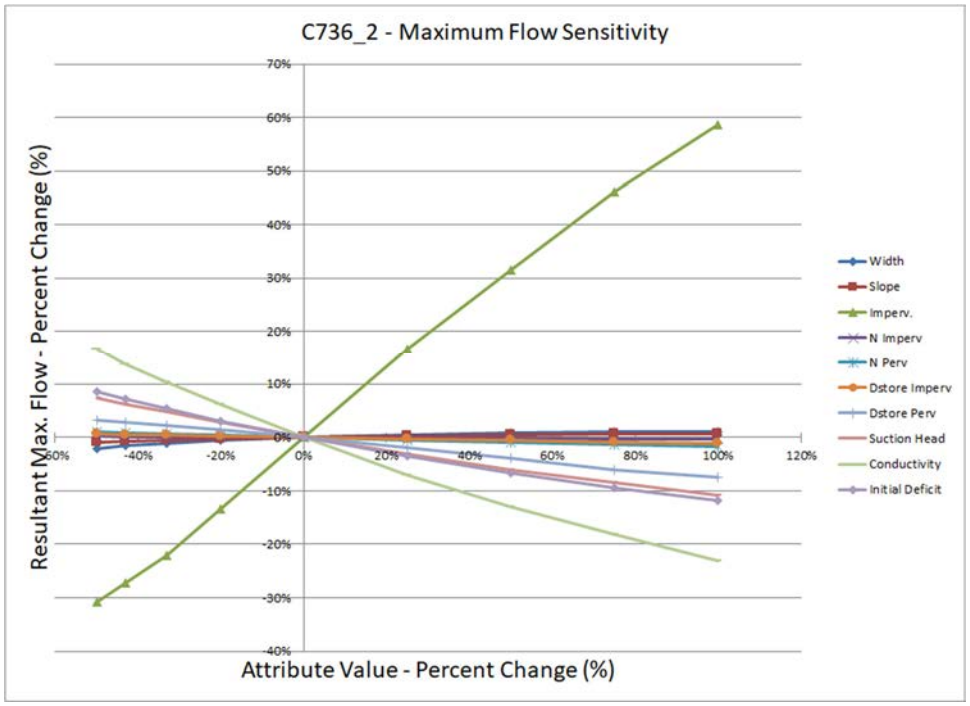


Figure C23 - Peak flow sensitivity at Don @ Dundas (C736_2- Ex_DesignEvents.inp)

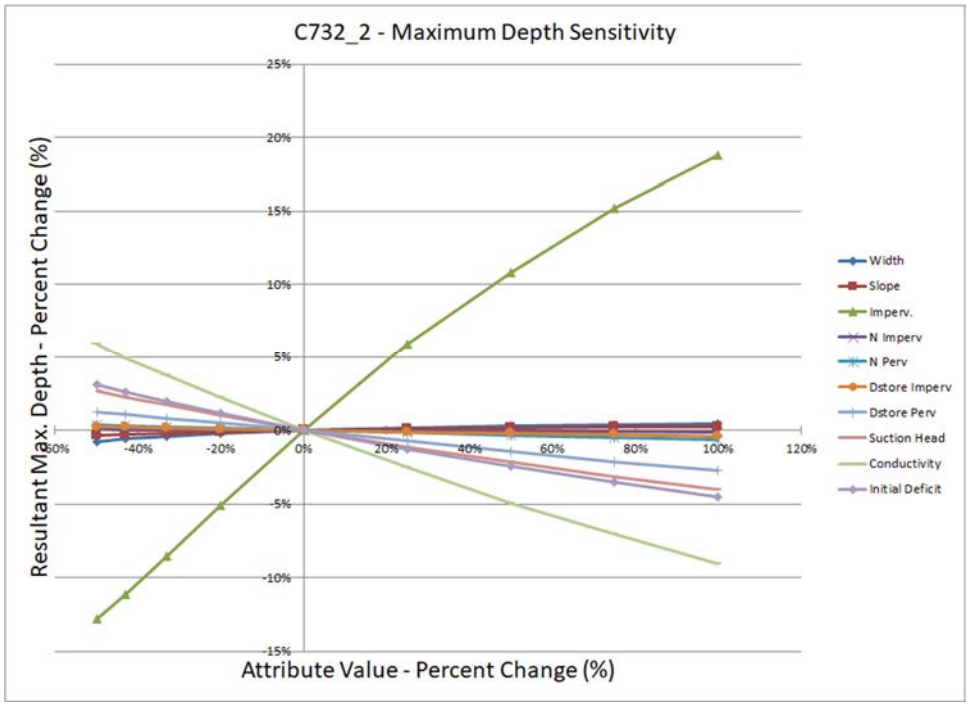


Figure C24 - Peak depth sensitivity at Don @ Dundas (C736_2- Ex_DesignEvents.inp)

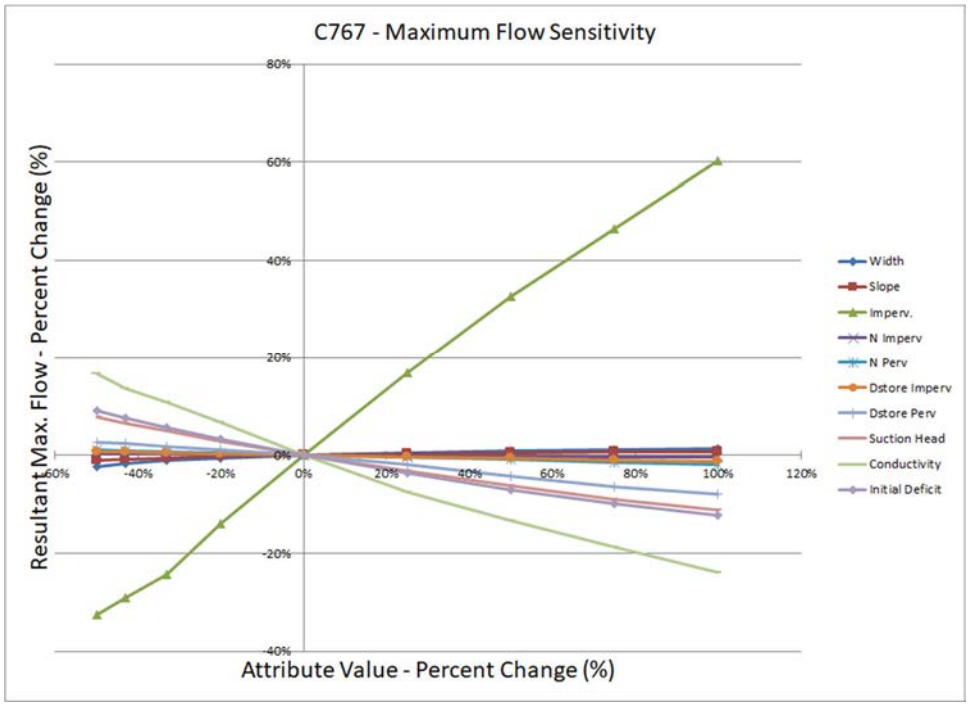


Figure C25 - Peak flow sensitivity at Don @ Todmorden (C767- Ex_DesignEvents.inp)

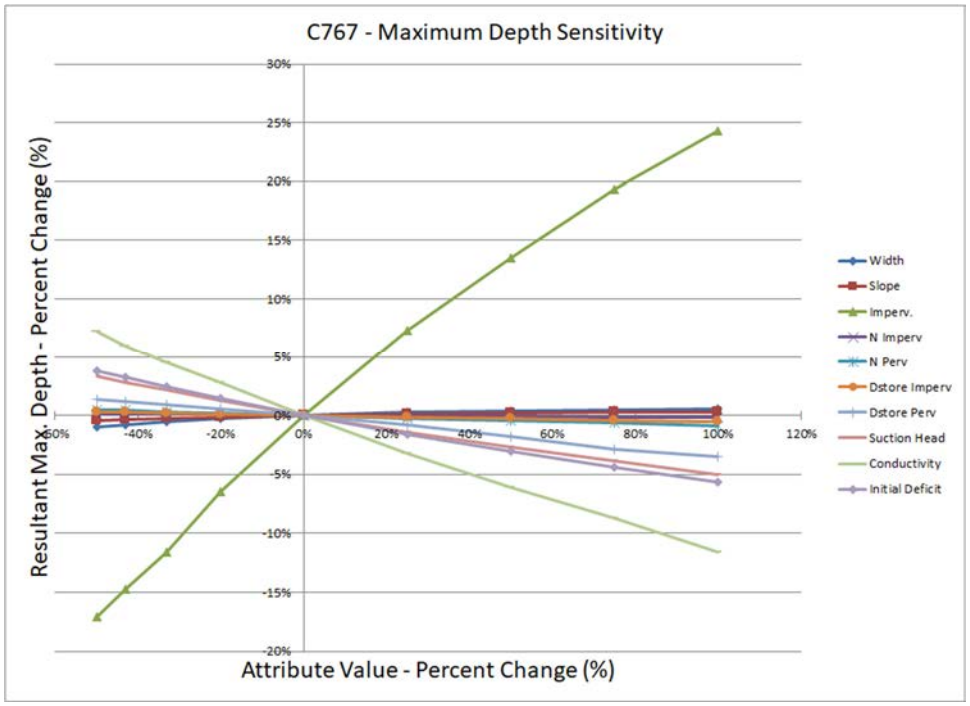


Figure C26 - Peak depth sensitivity at Don @ Todmorden (C767- Ex_DesignEvents.inp)

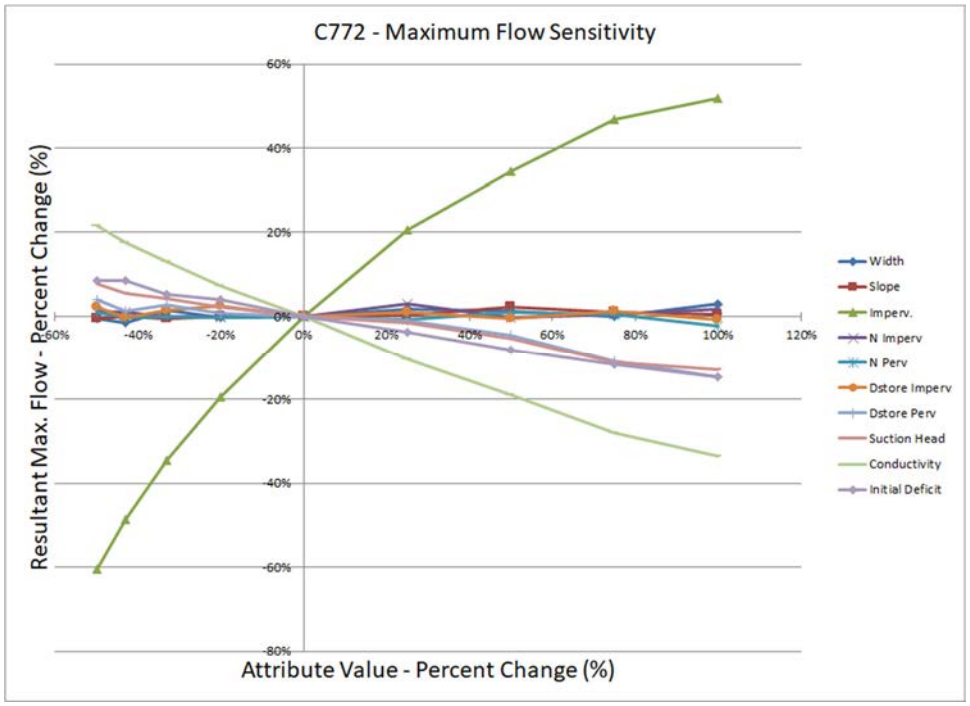


Figure C27 - Peak flow sensitivity at Don @ Todmorden (C767- Ex_DesignEvents.inp)

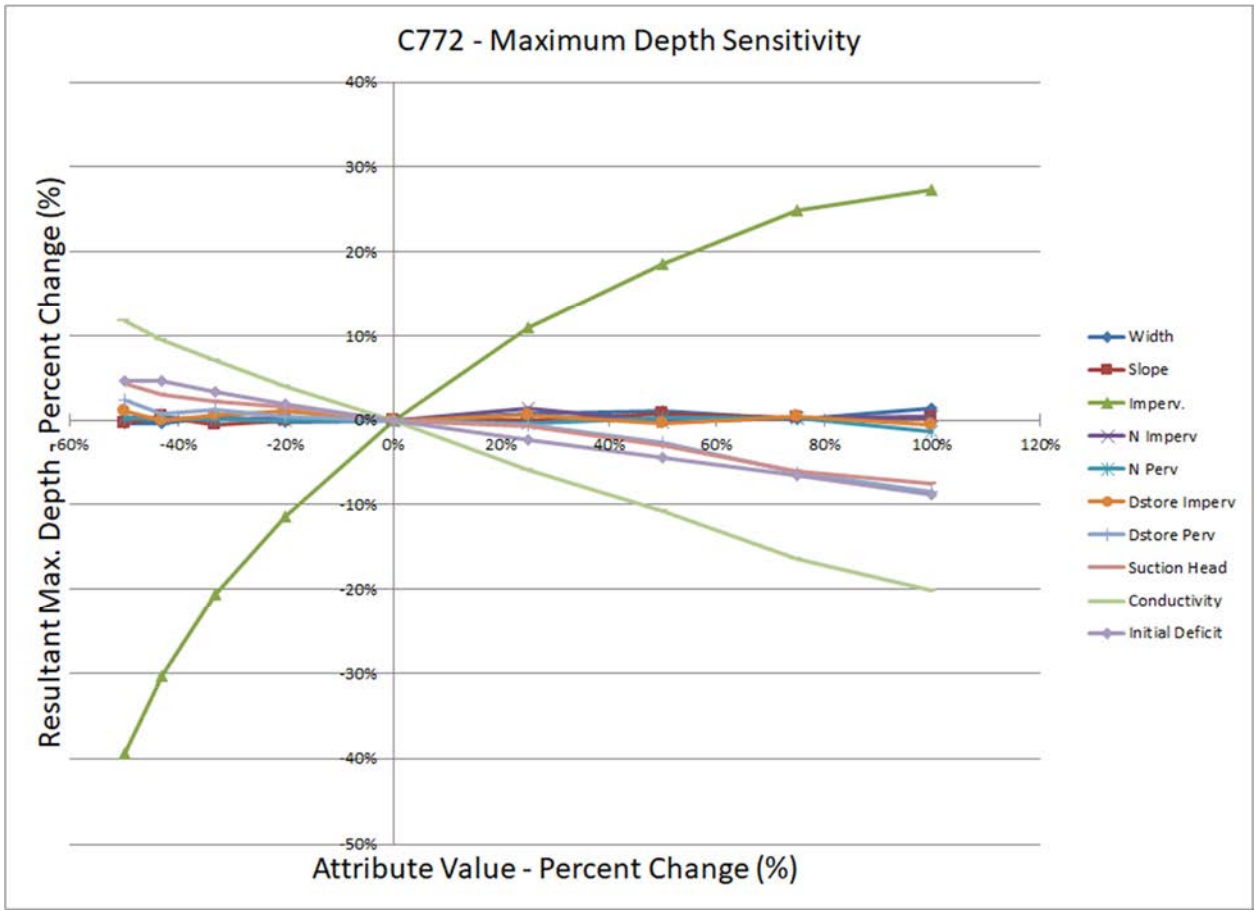


Figure C28 - Peak depth sensitivity at Don @ Todmorden (C767- Ex_DesignEvents.inp)

Sensitivity Analysis Plots for Scenario Calib_20120725

Figure C29 to Figure C56 shows sensitivity plots for each of the hydrology parameter tested using the Ex_DesignEvents.inp scenario.

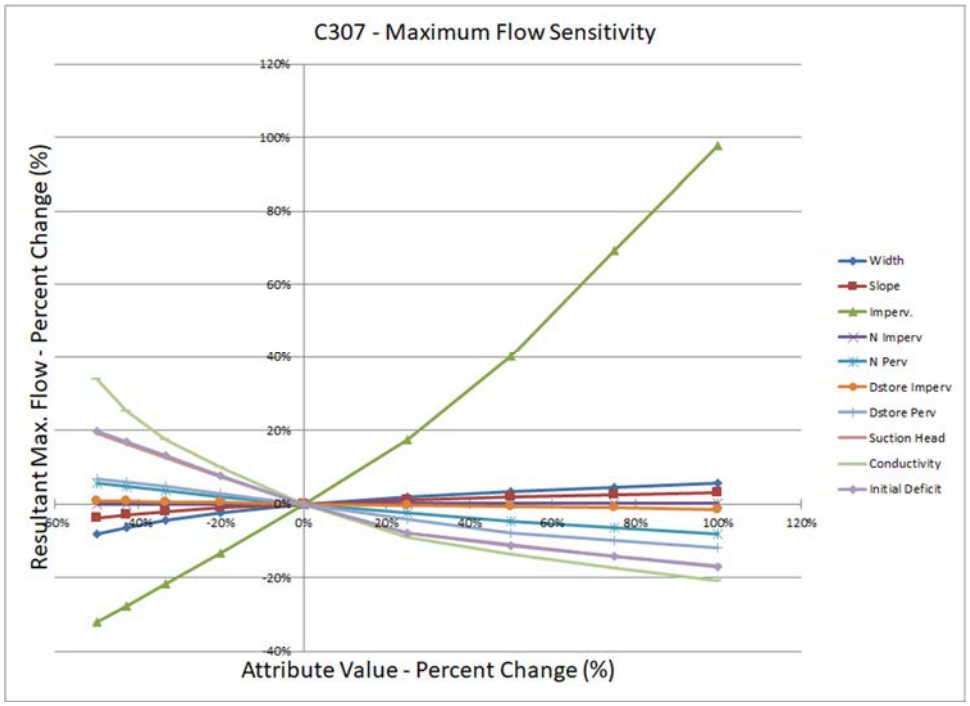


Figure C29 - Peak flow sensitivity at Don River East Branch near Thornhill (C307 - Calib_20120725)

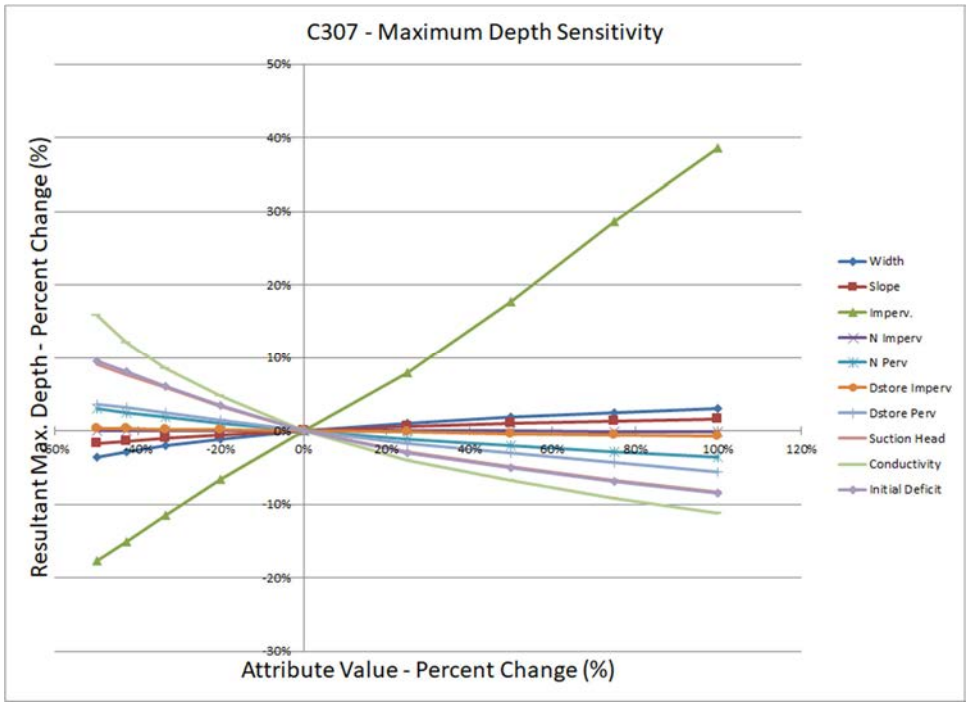


Figure C30 - Peak depth sensitivity at Don River East Branch near Thornhill (C307- Calib_20120725)

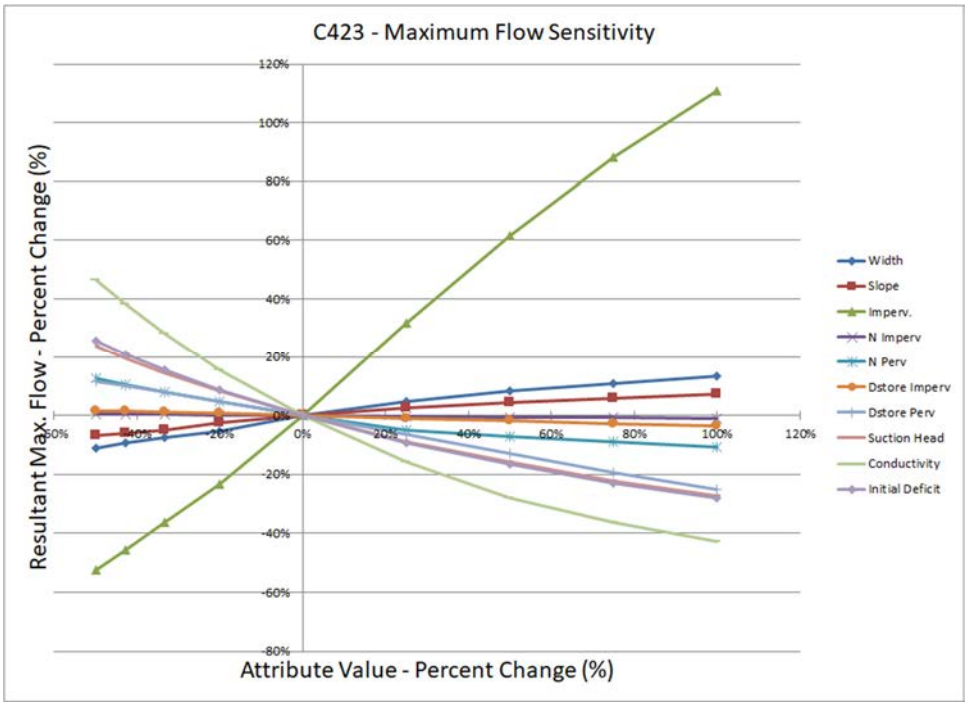


Figure C31 - Peak flow sensitivity at East Don @ Cummer (C423- Calib_20120725)

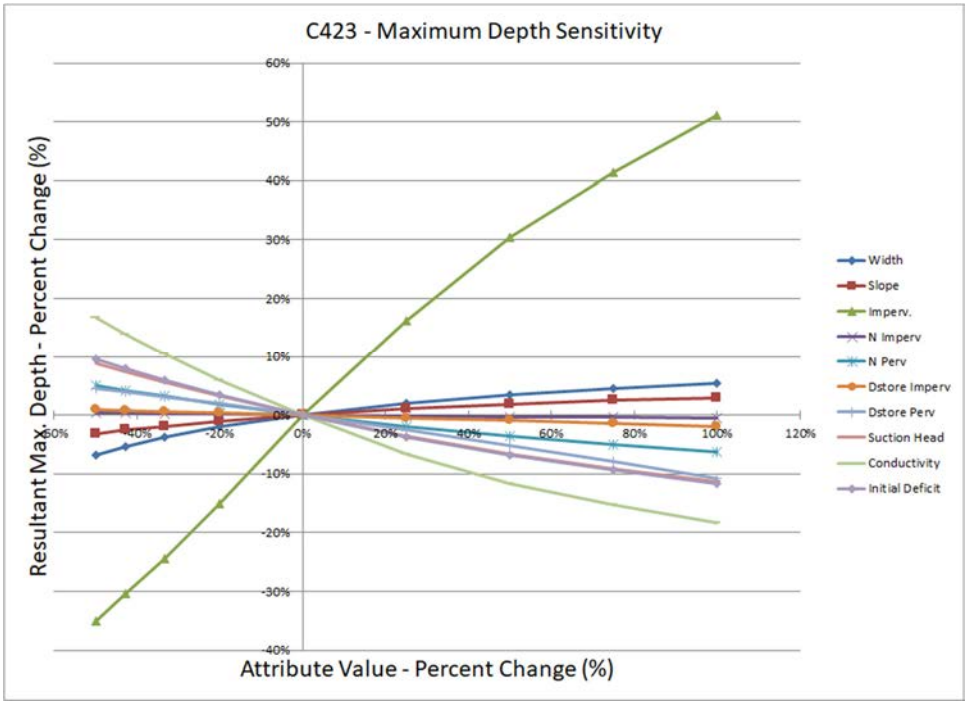


Figure C32 - Peak depth sensitivity at East Don @ Cummer (C423- Calib_20120725)

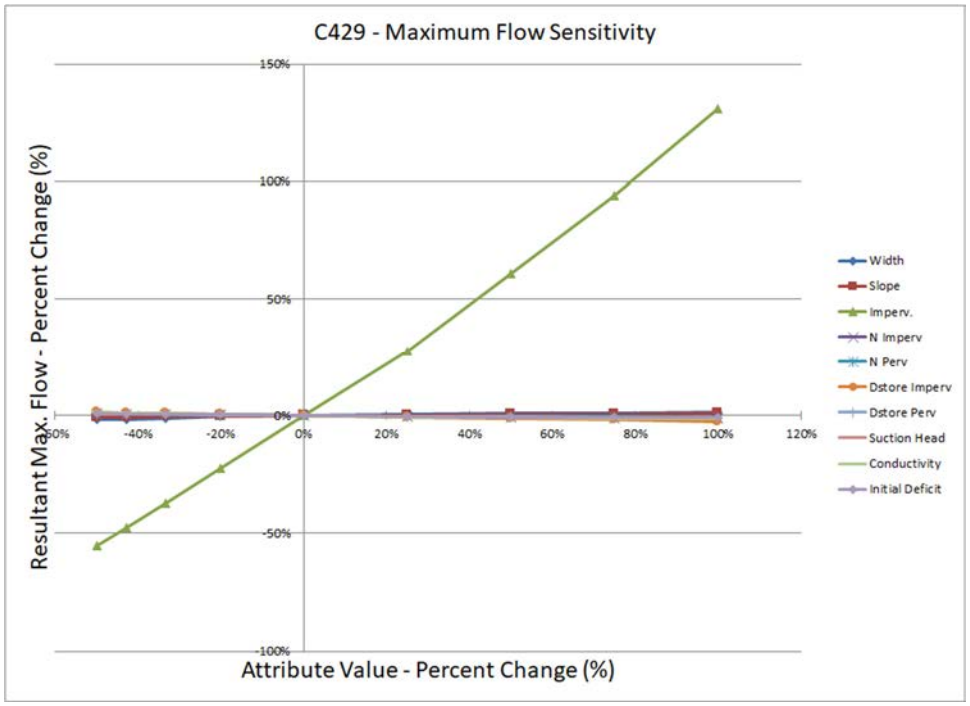


Figure C33 - Peak flow sensitivity at German Mills @ Cummer (C429- Calib_20120725)

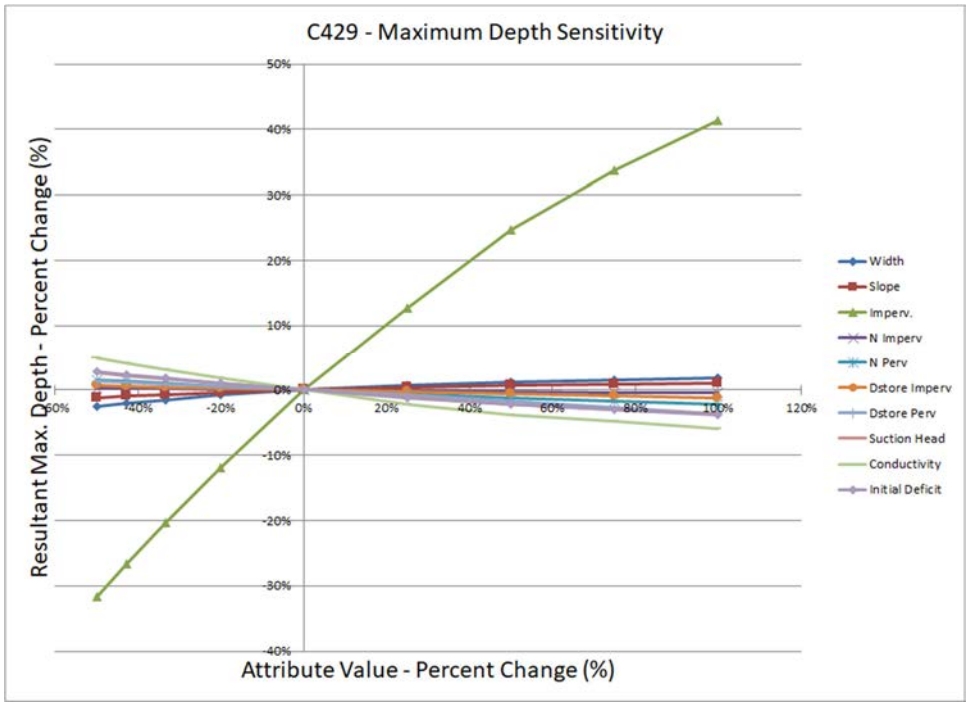


Figure C34 - Peak depth sensitivity at German Mills @ Cummer (C429- Calib_20120725)

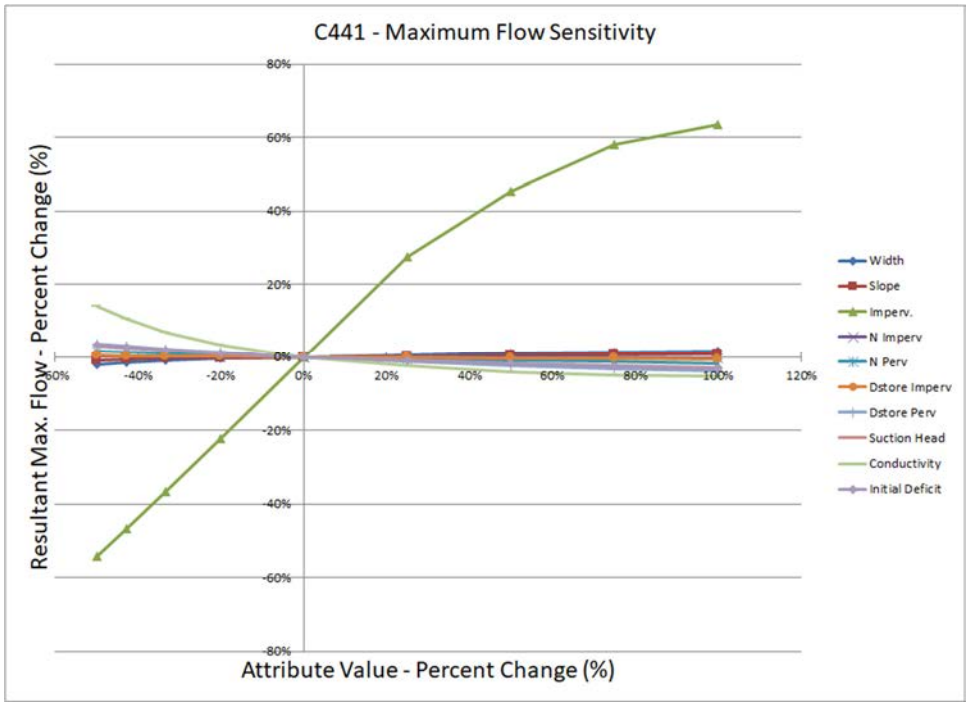


Figure C35 - Peak flow sensitivity at Don @ Glenshield (C441- Calib_20120725)

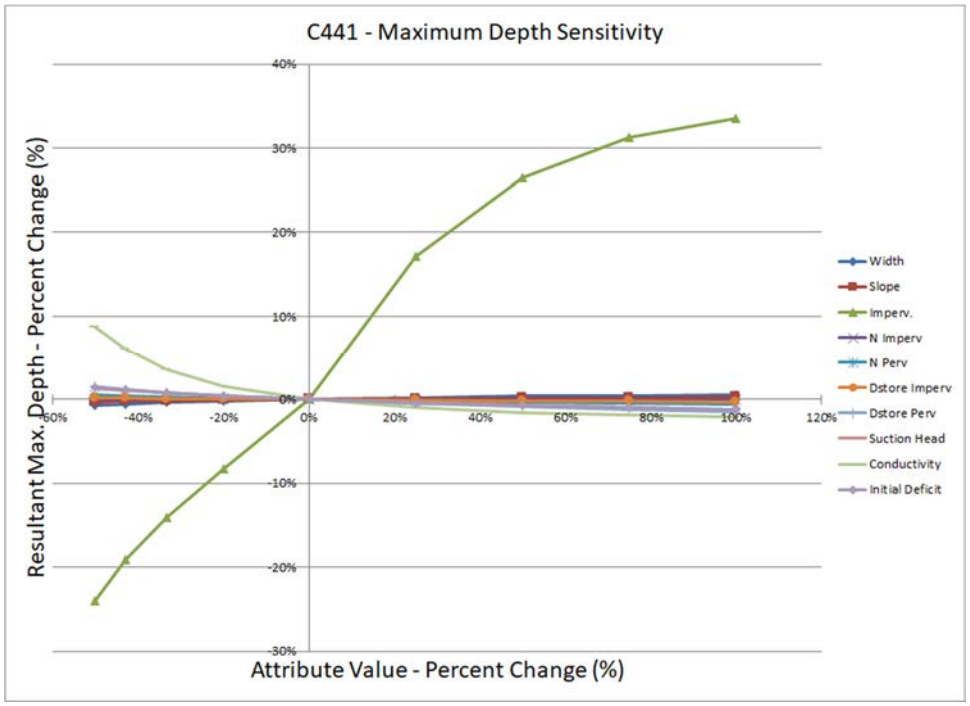


Figure C36 - Peak depth sensitivity at Don @ Glenshield (C441- Calib_20120725)

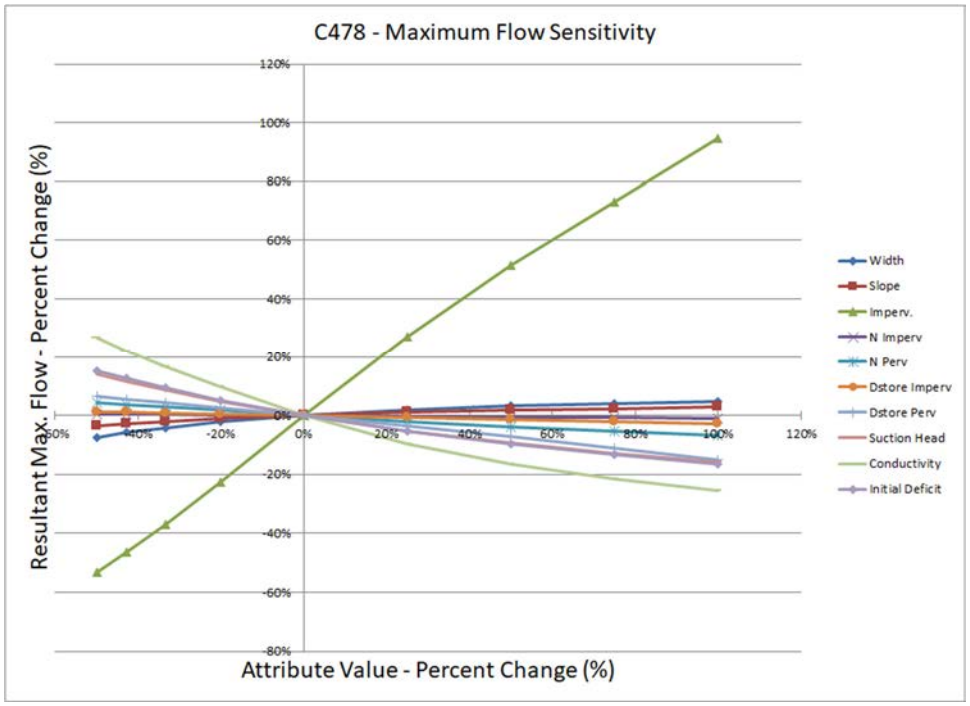


Figure C37 - Peak flow sensitivity at Little Don River near Lansing (C478- Calib_20120725)

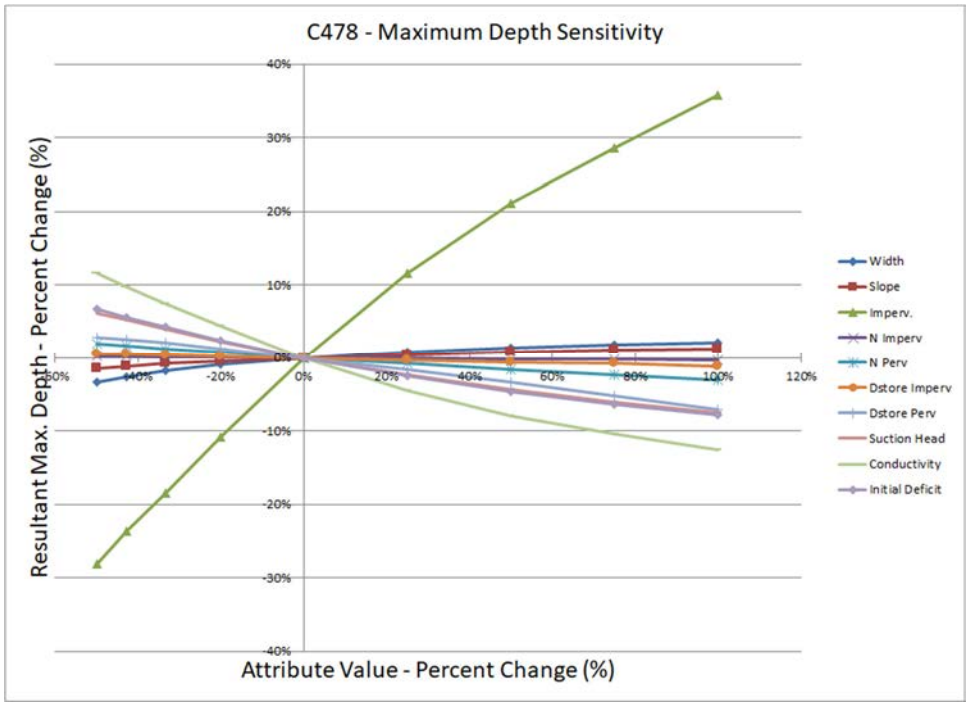


Figure C38 - Peak depth sensitivity at Little Don River near Lansing (C478- Calib_20120725)

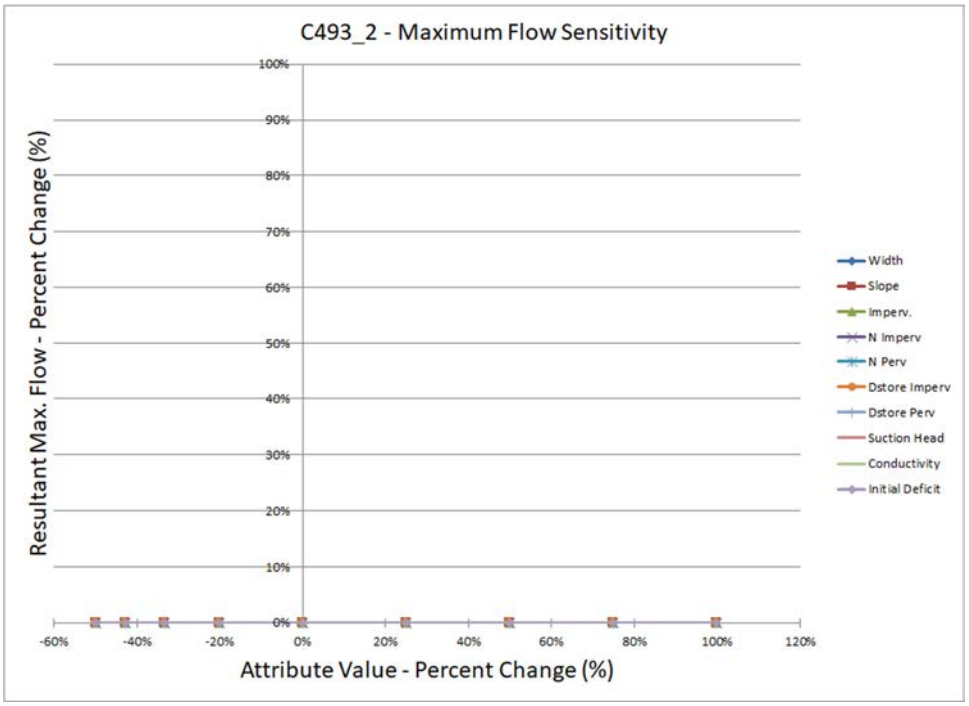


Figure C39 - Peak flow sensitivity at G. Ross Lord Dam (C493_2- Calib_20120725)

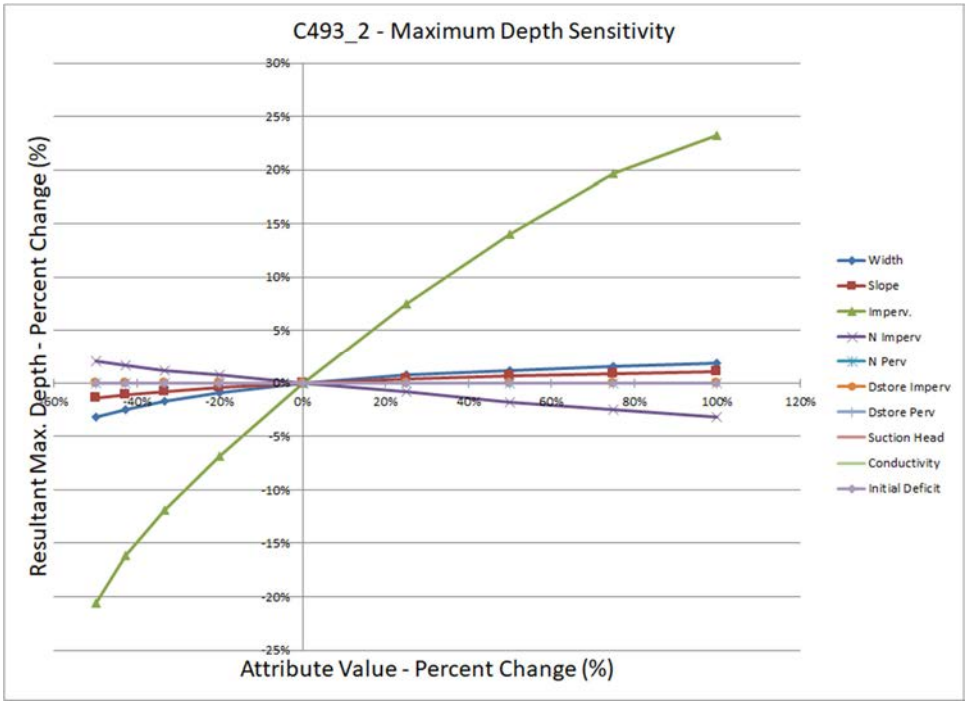


Figure C40 - Peak depth sensitivity at G. Ross Lord Dam (C493_2- Calib_20120725)

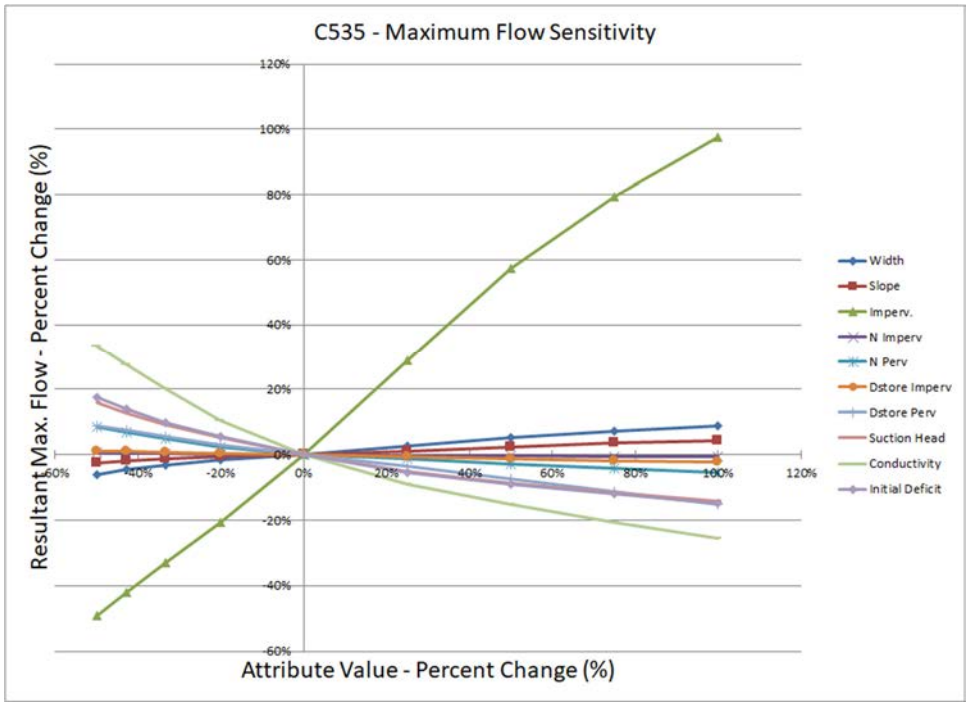


Figure C41 - Peak flow sensitivity at East Don @ York Mills (C535- Calib_20120725)

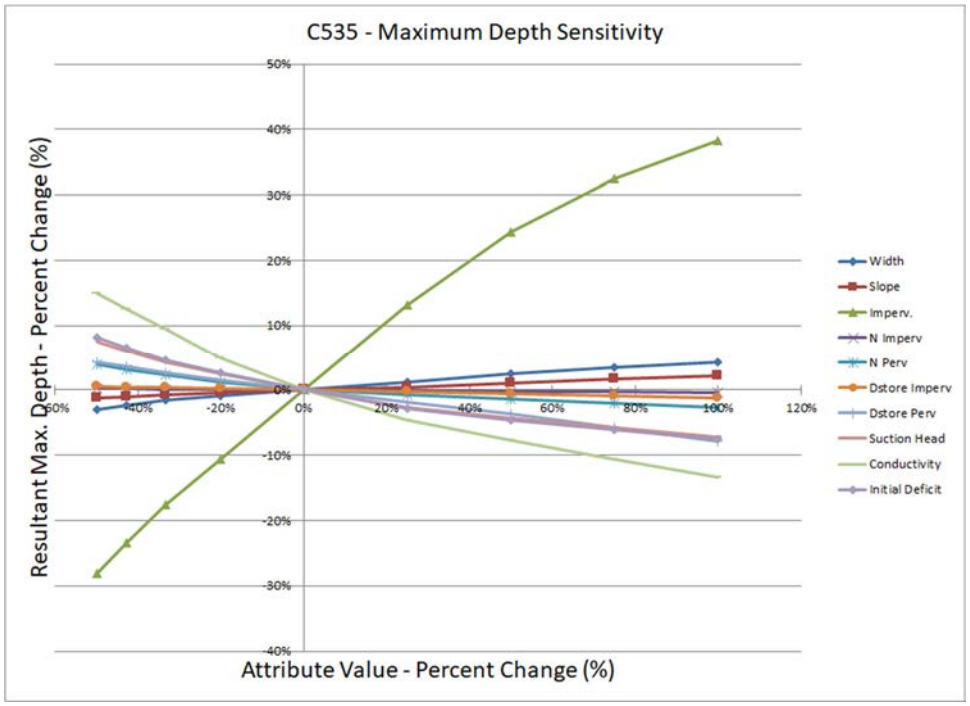


Figure C42 - Peak depth sensitivity at East Don @ York Mills (C535- Calib_20120725)

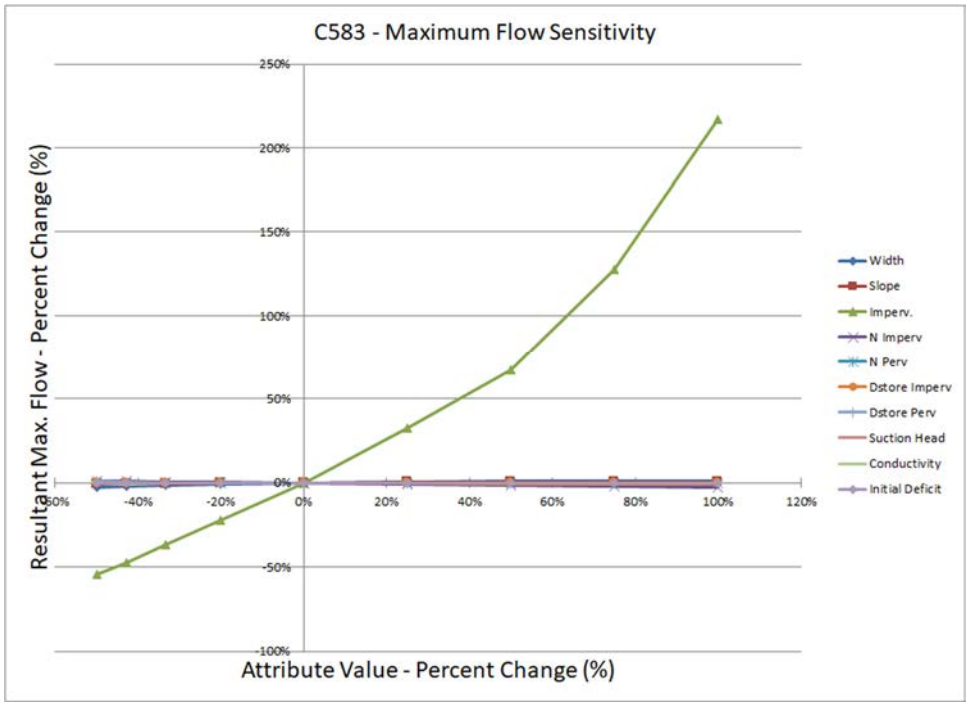


Figure C43 - Peak flow sensitivity at Don @ Knightswood (C583- Calib_20120725)

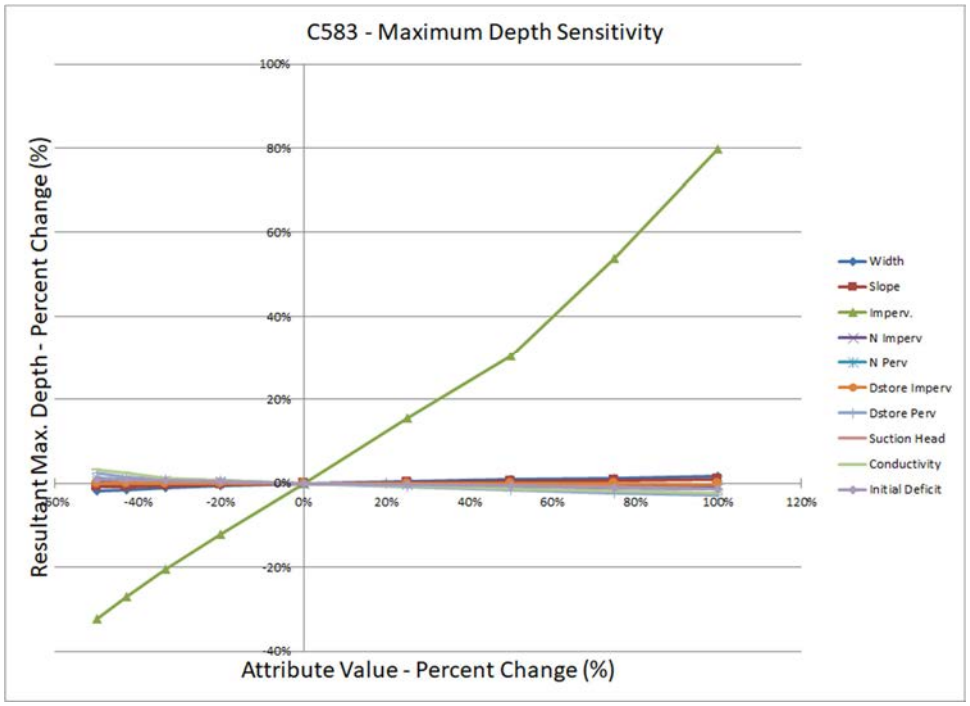


Figure C44 - Peak depth sensitivity at Don @ Knightswood (C583- Calib_20120725)

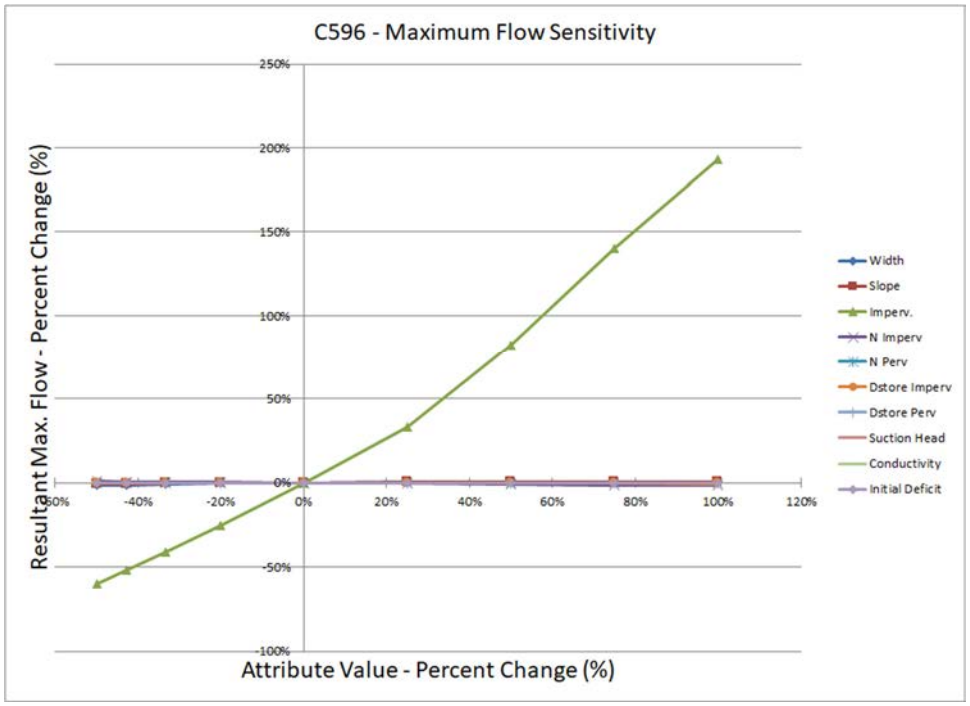


Figure C45 - Peak flow sensitivity at Taylor Creek North (C596- Calib_20120725)

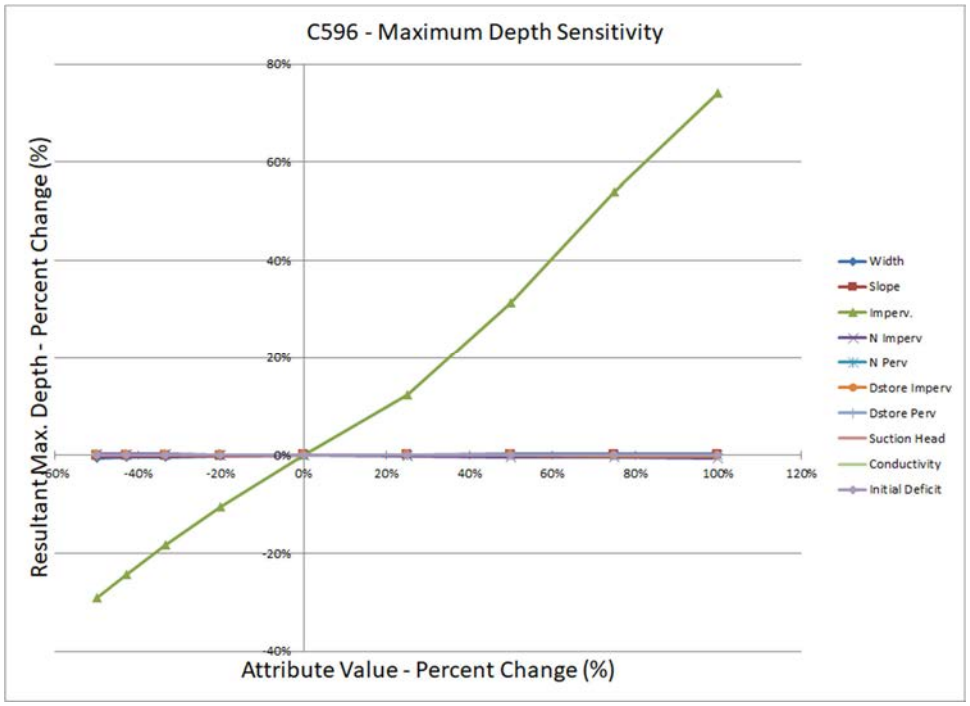


Figure C46 - Peak depth sensitivity at Taylor Creek North (C596- Calib_20120725)

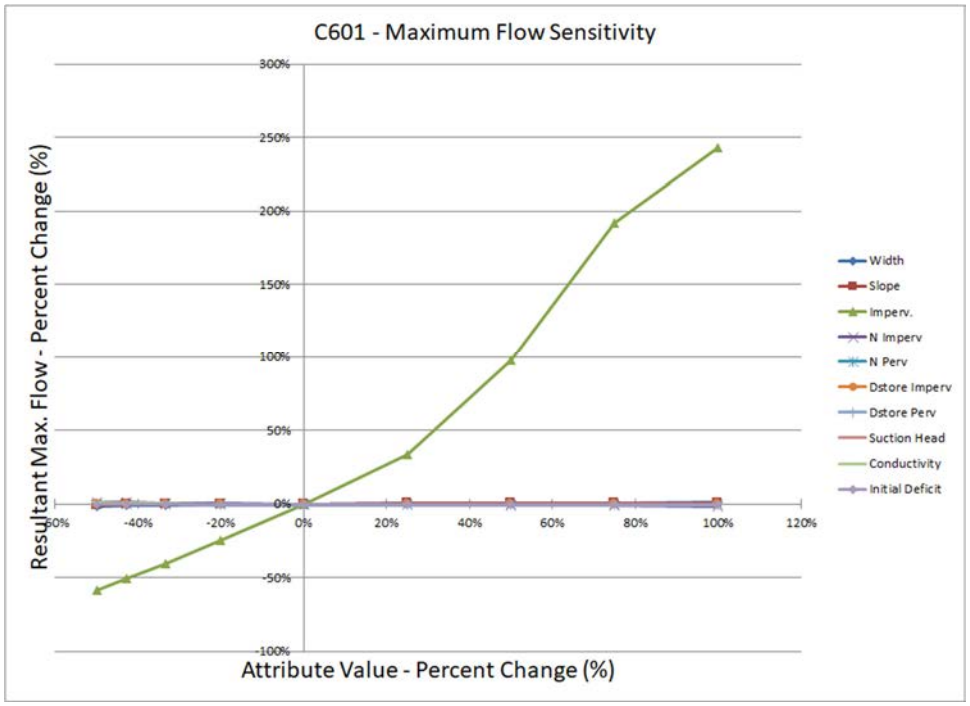


Figure C47 - Peak flow sensitivity at Wilket Creek (C601- Calib_20120725)

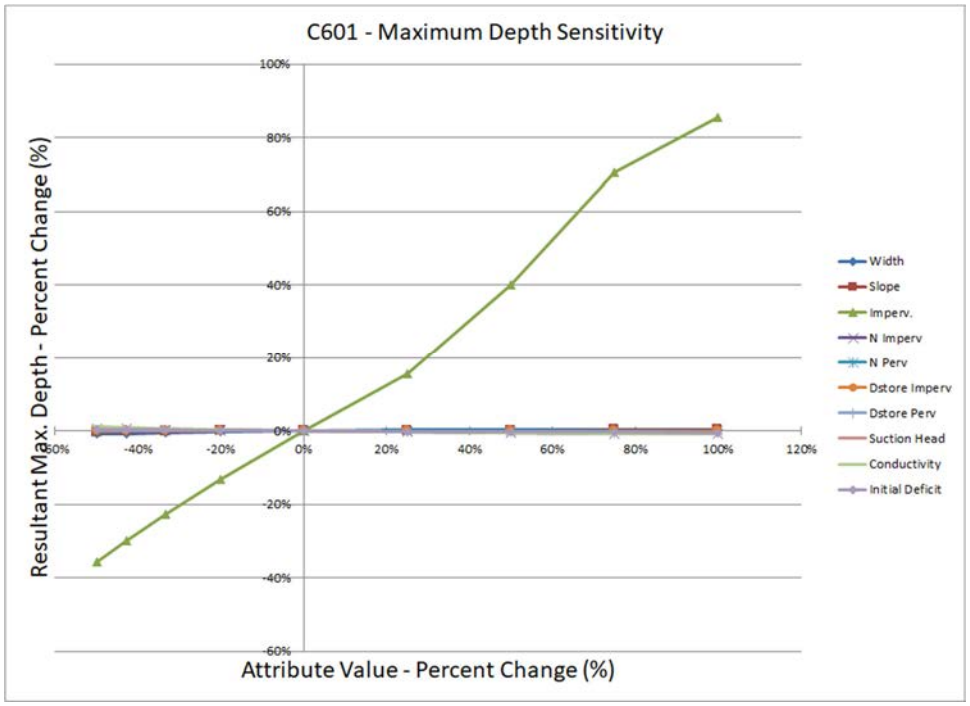


Figure C48 - Peak depth sensitivity at Wilket Creek (C601- Calib_20120725)

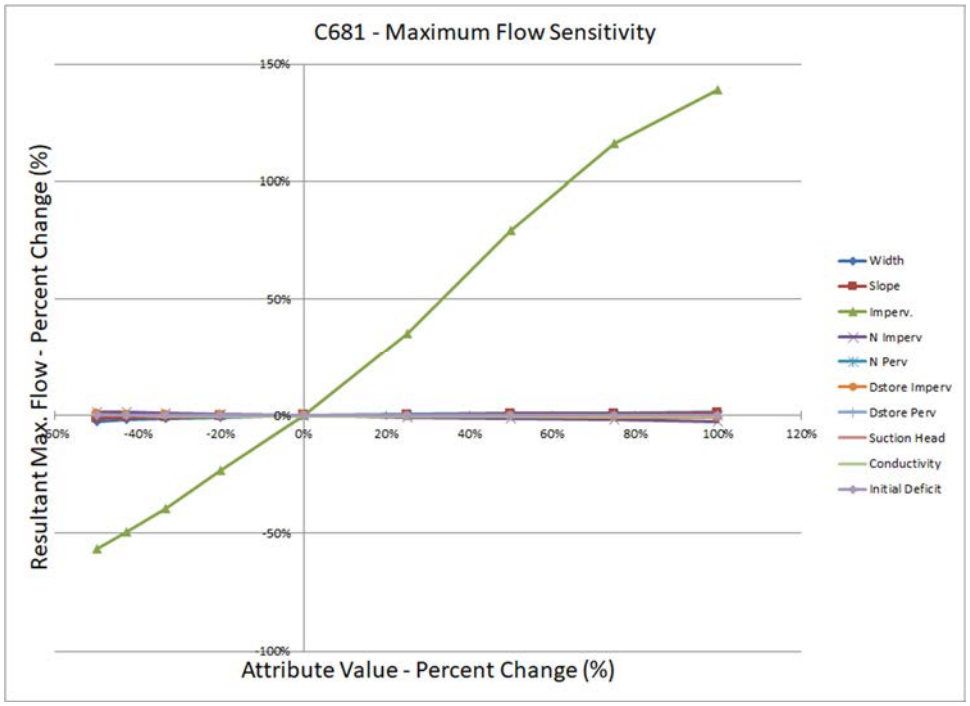


Figure C49 - Peak depth sensitivity at Taylor Creek South (C681- Calib_20120725)

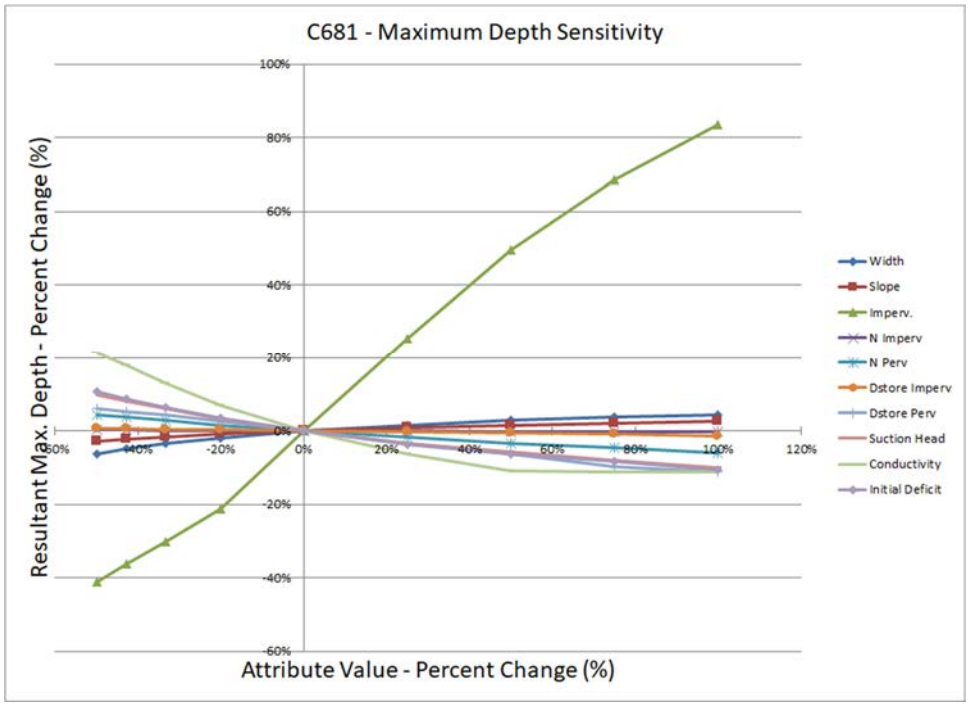


Figure C50 - Peak depth sensitivity at Taylor Creek South (C681- Calib_20120725)

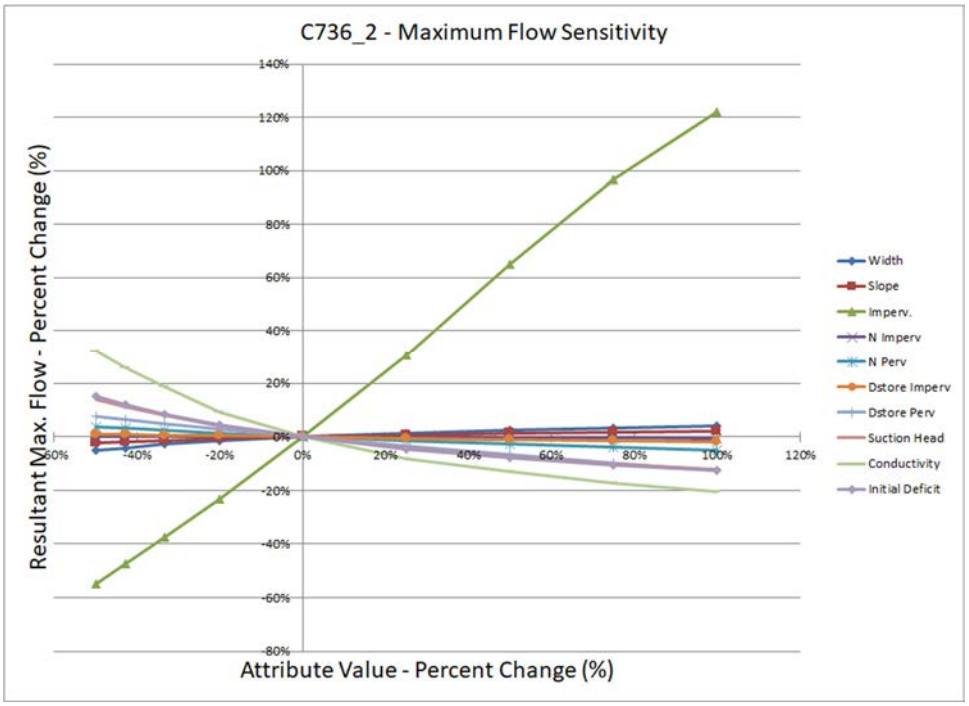


Figure C51 - Peak flow sensitivity at Don @ Dundas (C736_2- Calib_20120725)

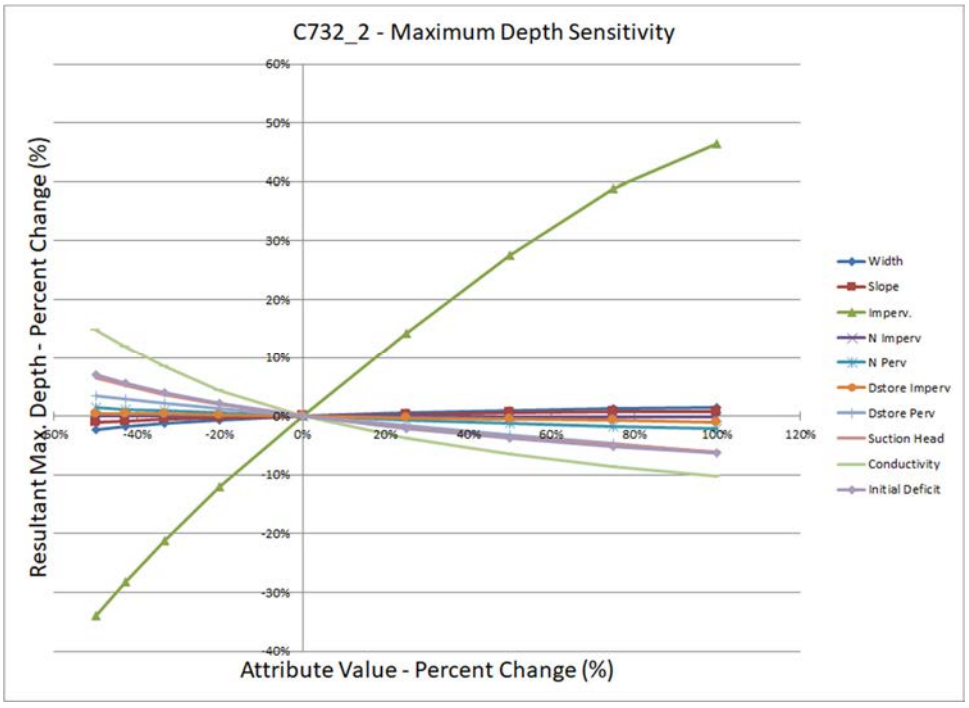


Figure C52 - Peak depth sensitivity at Don @ Dundas (C736_2- Calib_20120725)

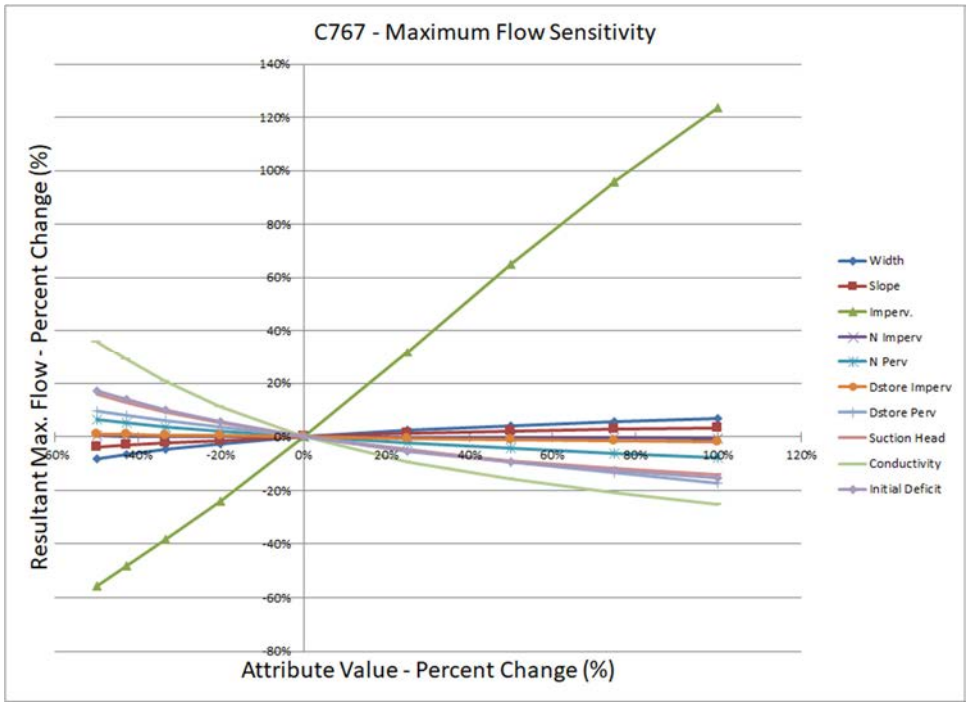


Figure C53 - Peak flow sensitivity at Don @ Todmorden (C767- Calib_20120725)

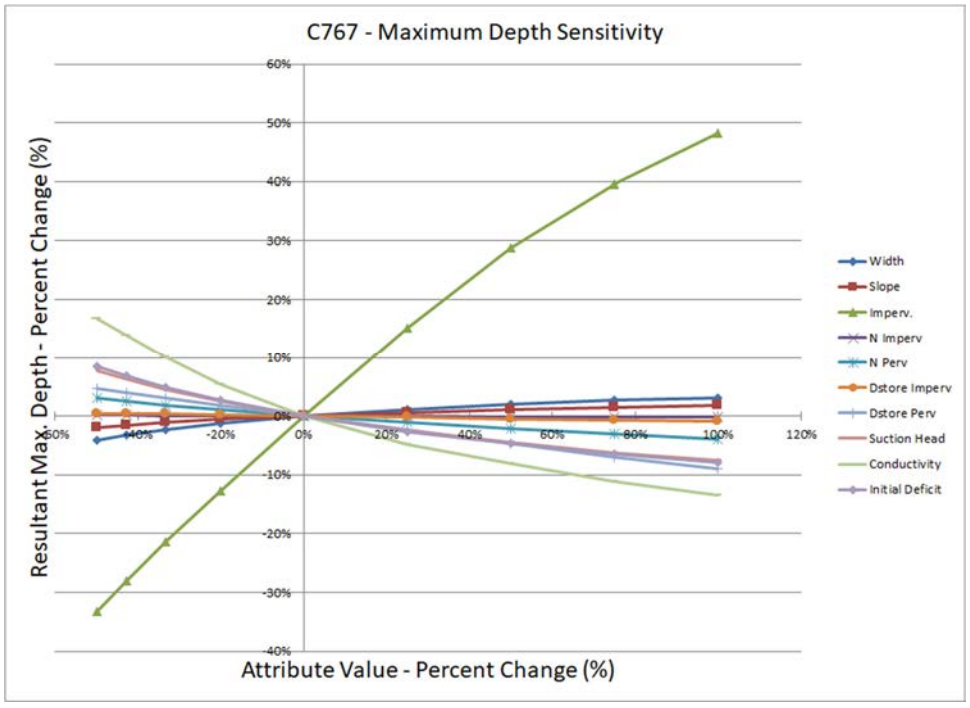


Figure C54 - Peak depth sensitivity at Don @ Todmorden (C767- Calib_20120725)

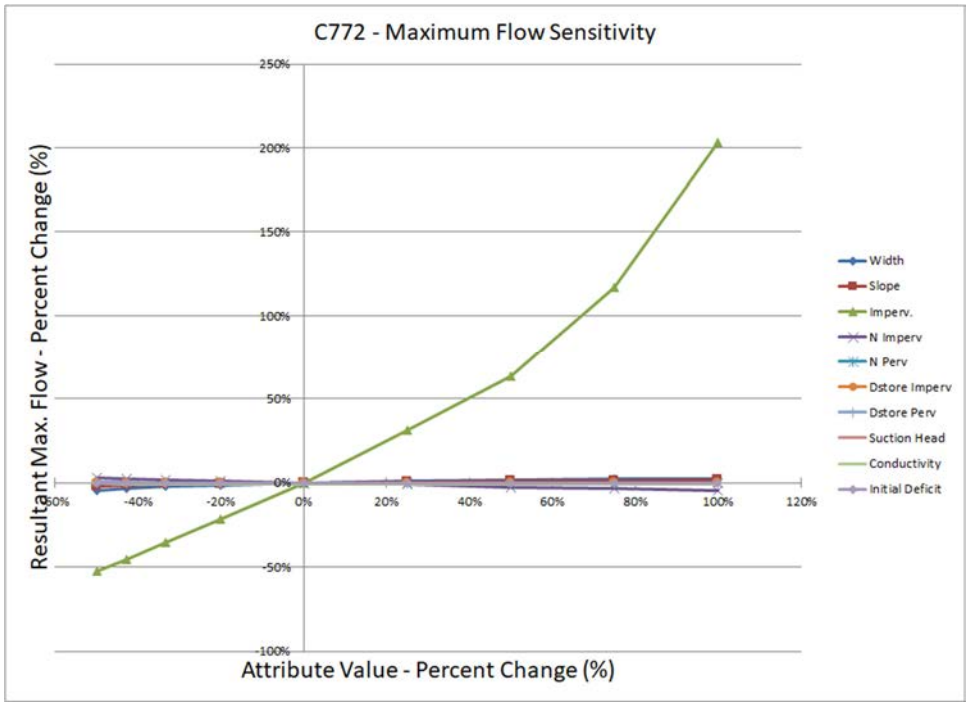


Figure C55 - Peak flow sensitivity at Don @ Todmorden (C767- Calib_20120725)

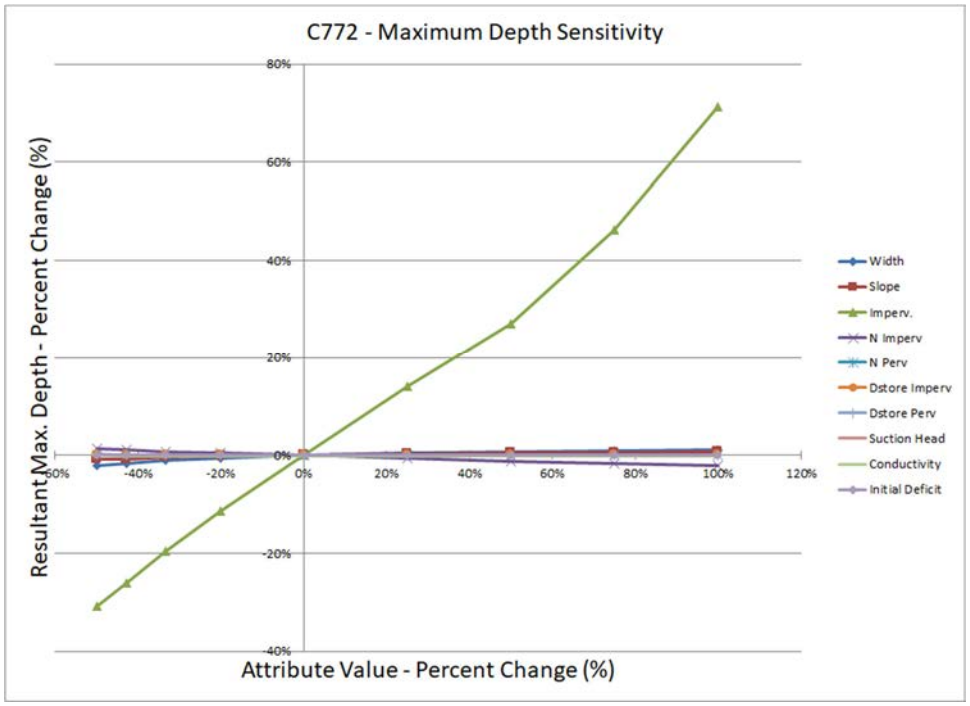


Figure C56 - Peak depth sensitivity at Don @ Todmorden (C767- Calib_20120725)

Sensitivity Analysis Plots for Scenario Calib_20130731

Figure C57 to Figure C86 shows sensitivity plots for each of the hydrology parameter tested using the Ex_DesignEvents.inp scenario.

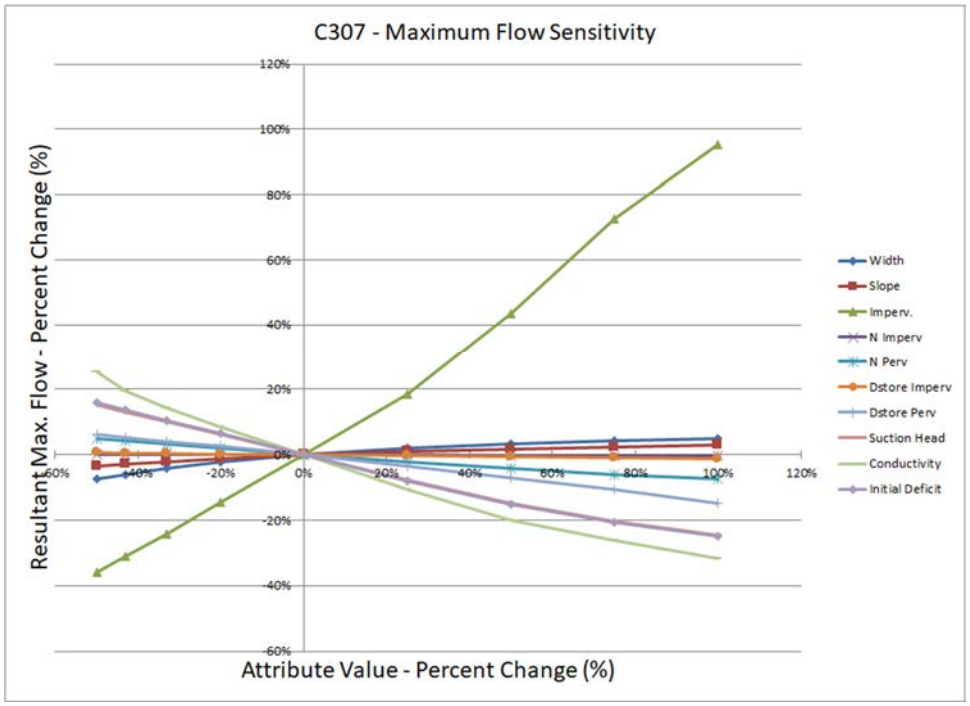


Figure C57 - Peak flow sensitivity at Don River East Branch near Thornhill (C307 - 20130731)

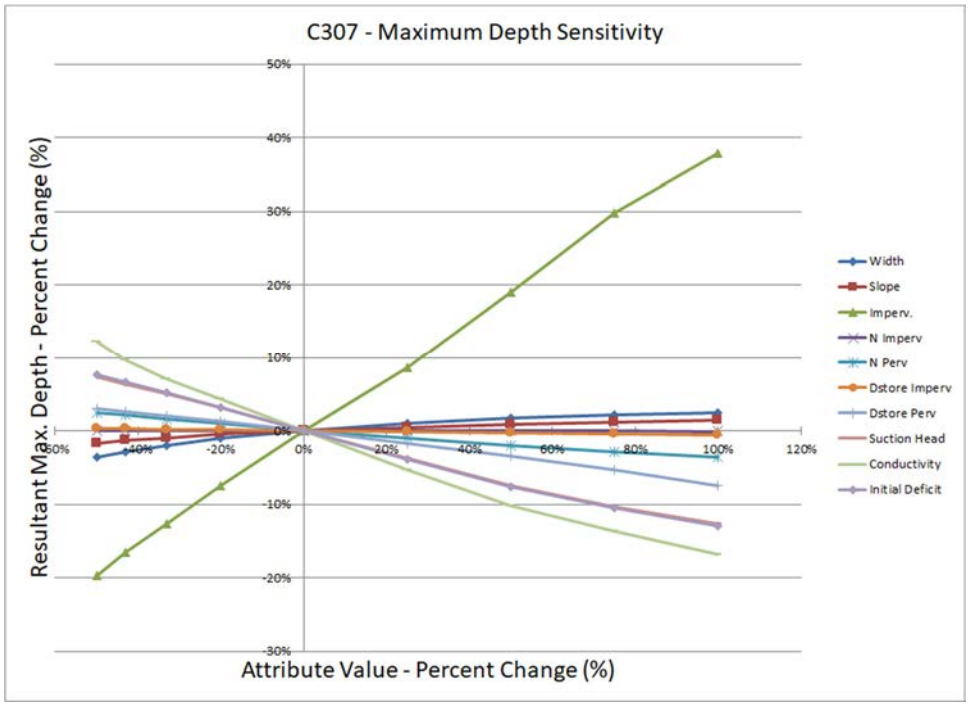


Figure C58 - Peak depth sensitivity at Don River East Branch near Thornhill (C307 - 20130731)

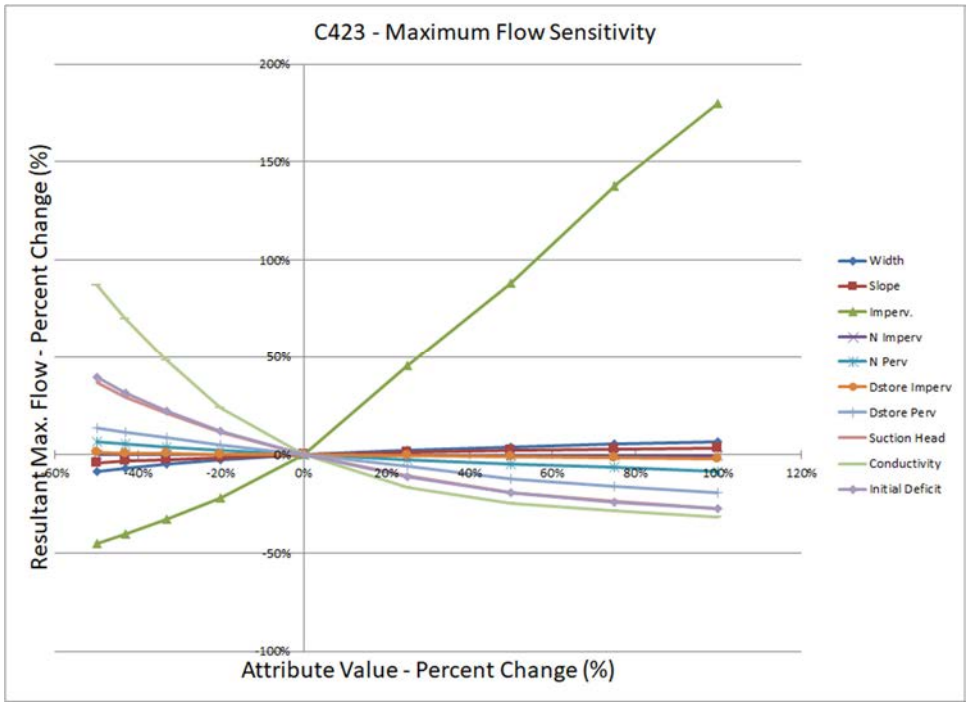


Figure C59 - Peak flow sensitivity at East Don @ Cummer (C423 - 20130731)

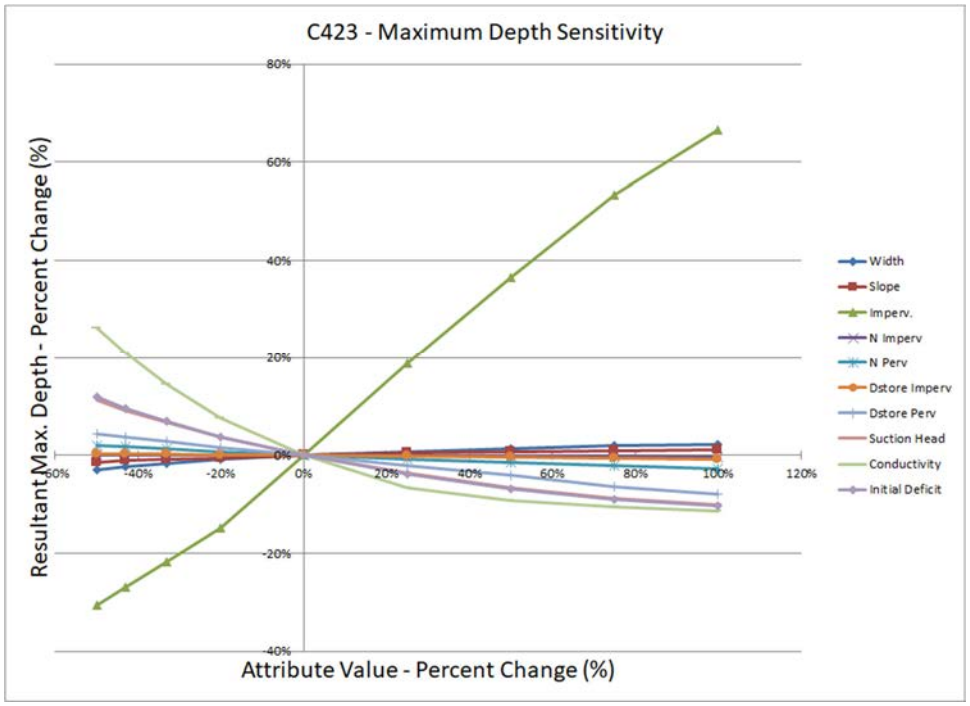


Figure C60 - Peak depth sensitivity at East Don @ Cummer (C423 - 20130731)

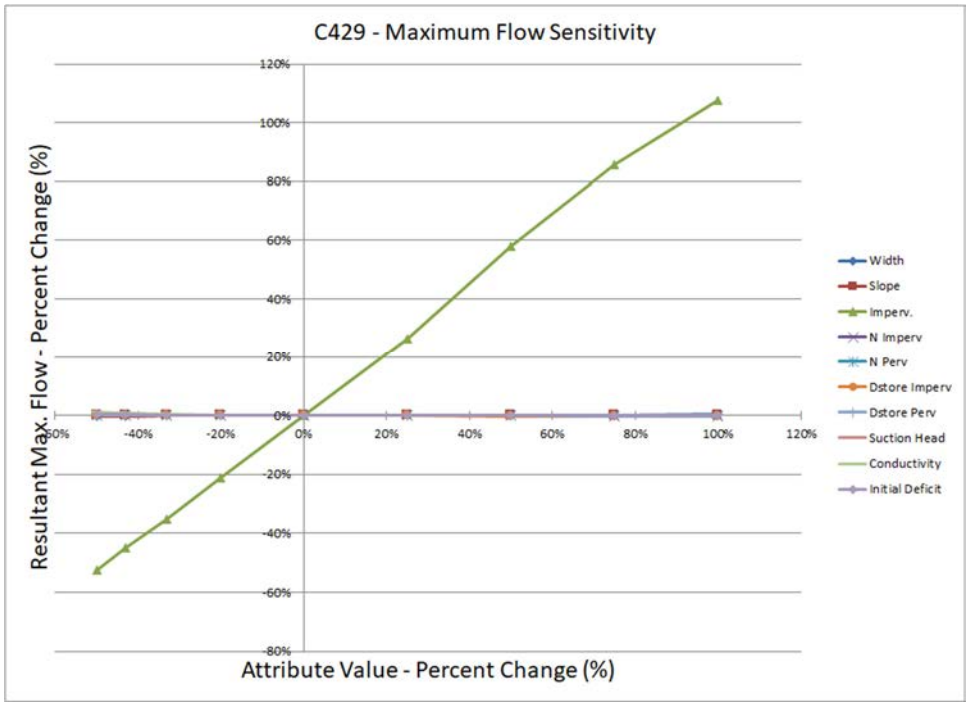


Figure C61 - Peak flow sensitivity at German Mills @ Cummer (C429 - 20130731)

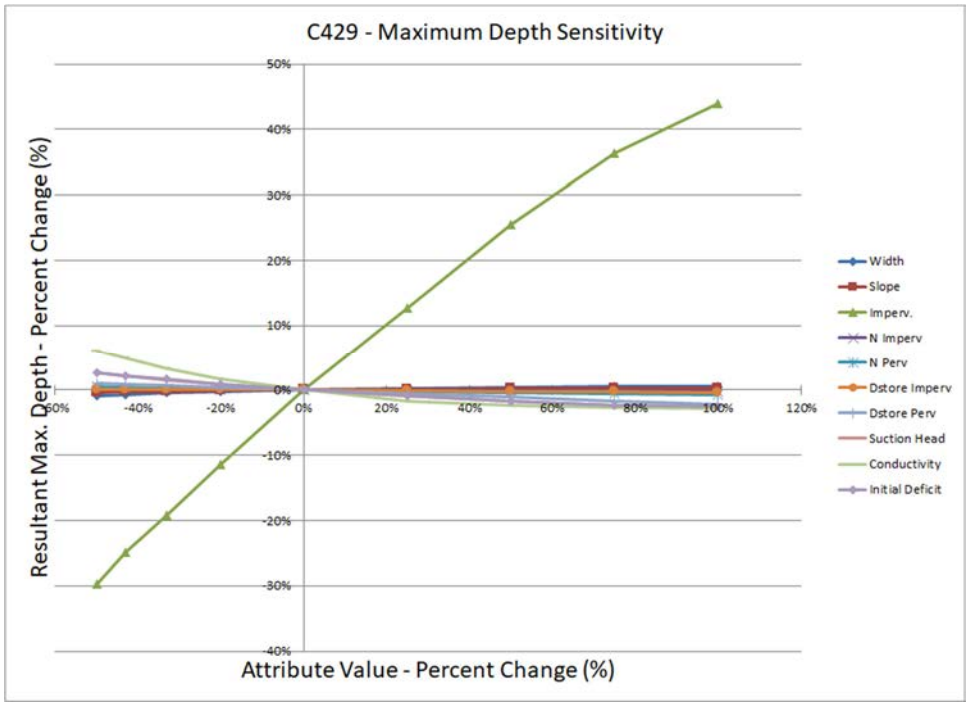


Figure C62 - Peak depth sensitivity at German Mills @ Cummer (C429 - 20130731)

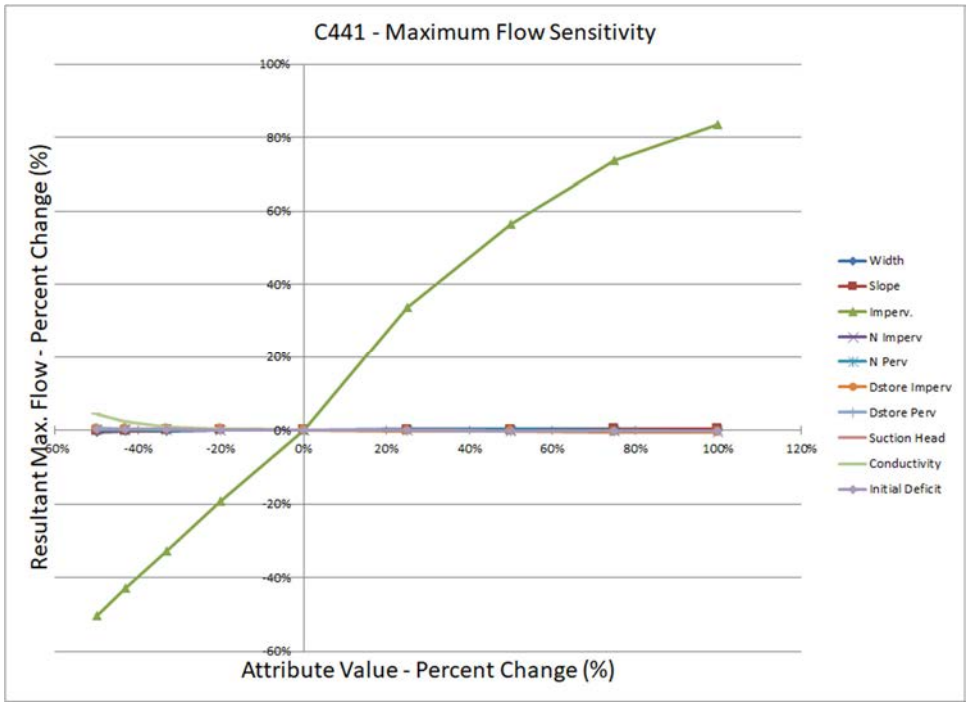


Figure C63 - Peak flow sensitivity at Don @ Glenshield (C441 - 20130731)

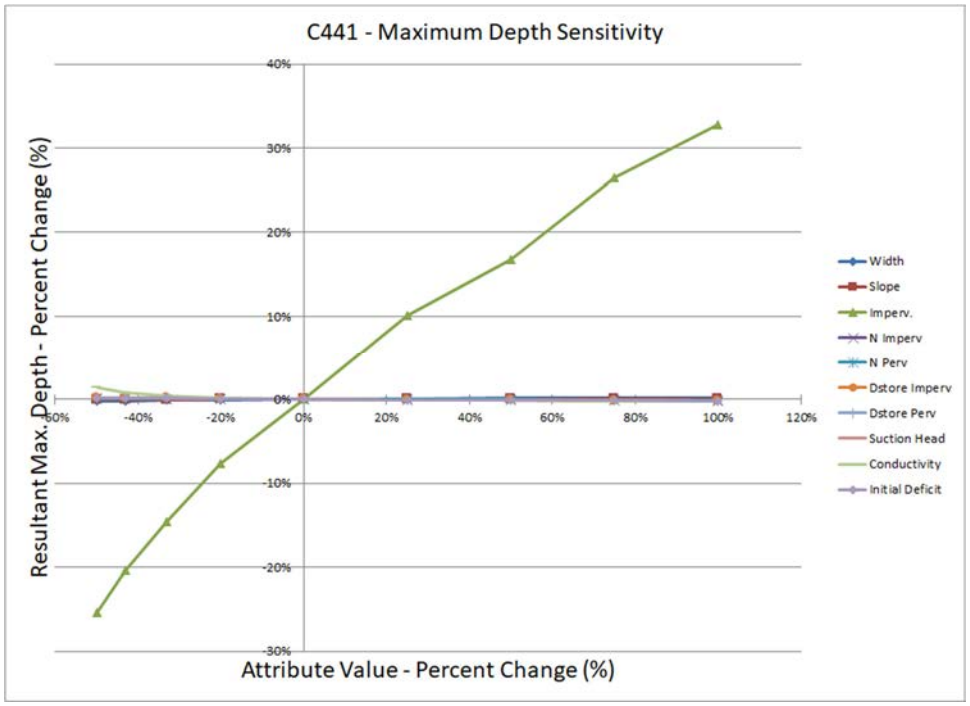


Figure C64 - Peak depth sensitivity at Don @ Glenshield (C441 - 20130731)

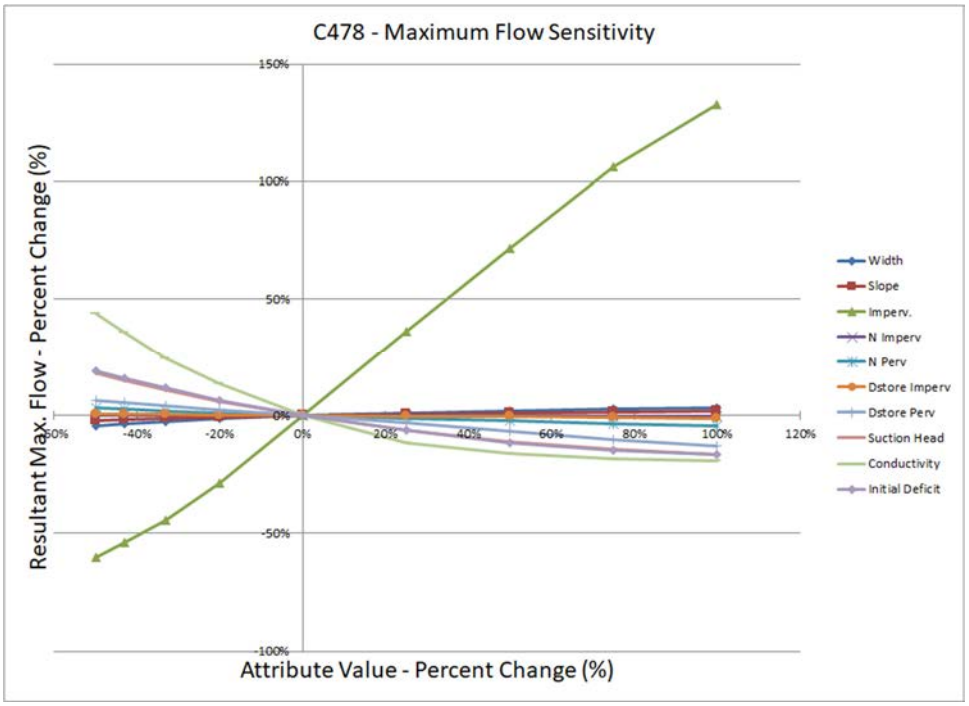


Figure C65 - Peak flow sensitivity at Little Don River near Lansing (C478 - 20130731)

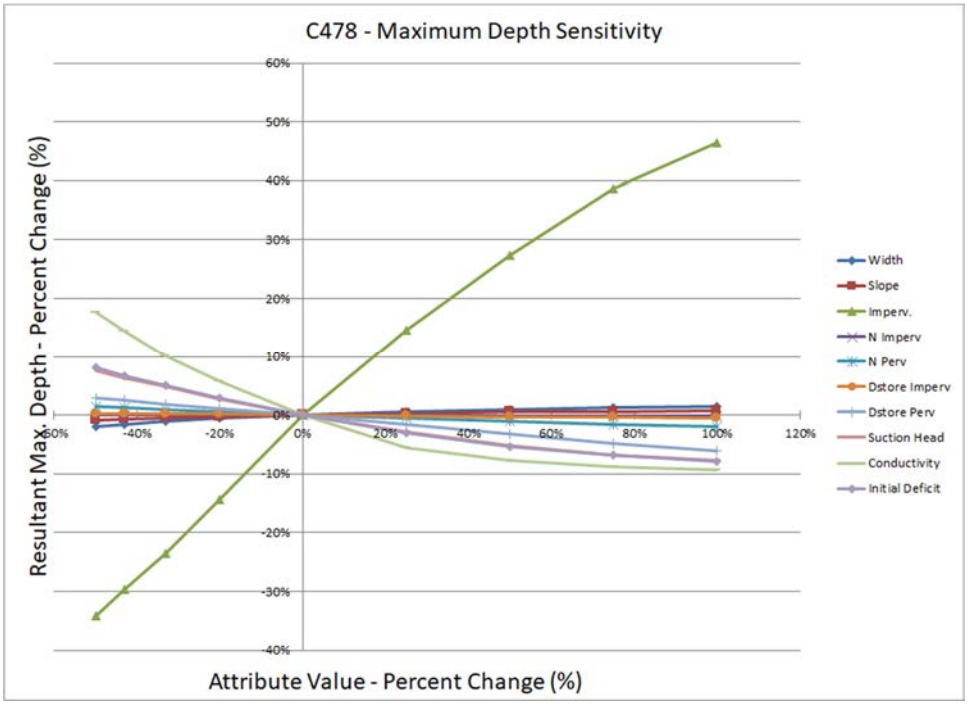


Figure C66 - Peak depth sensitivity at Little Don River near Lansing (C478 - 20130731)

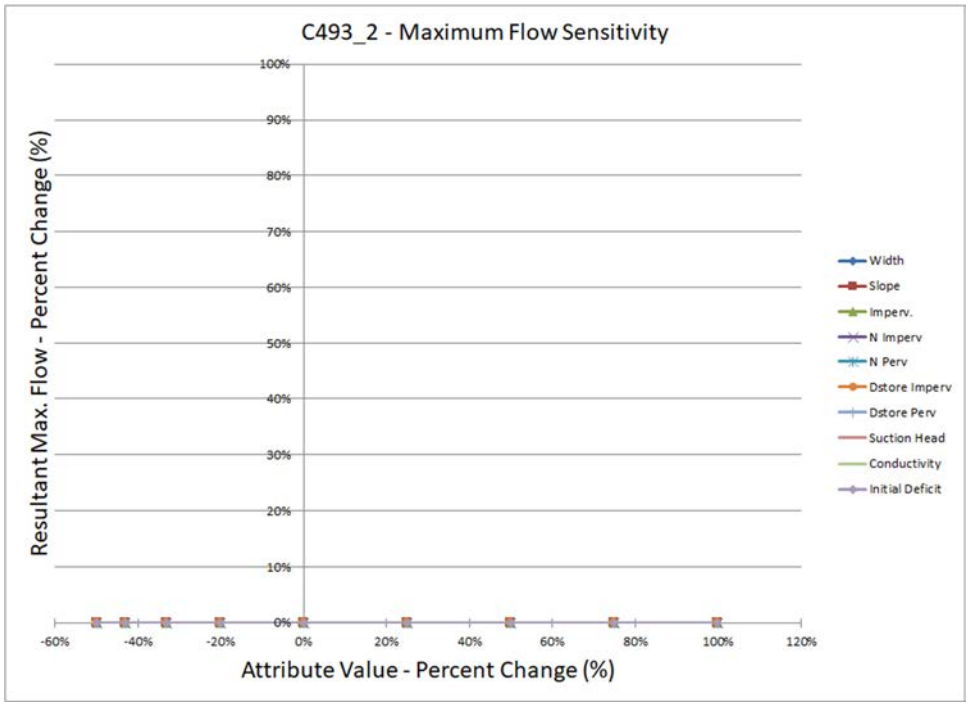


Figure C67 - Peak flow sensitivity at G. Ross Lord Dam (C493_2 - 20130731)

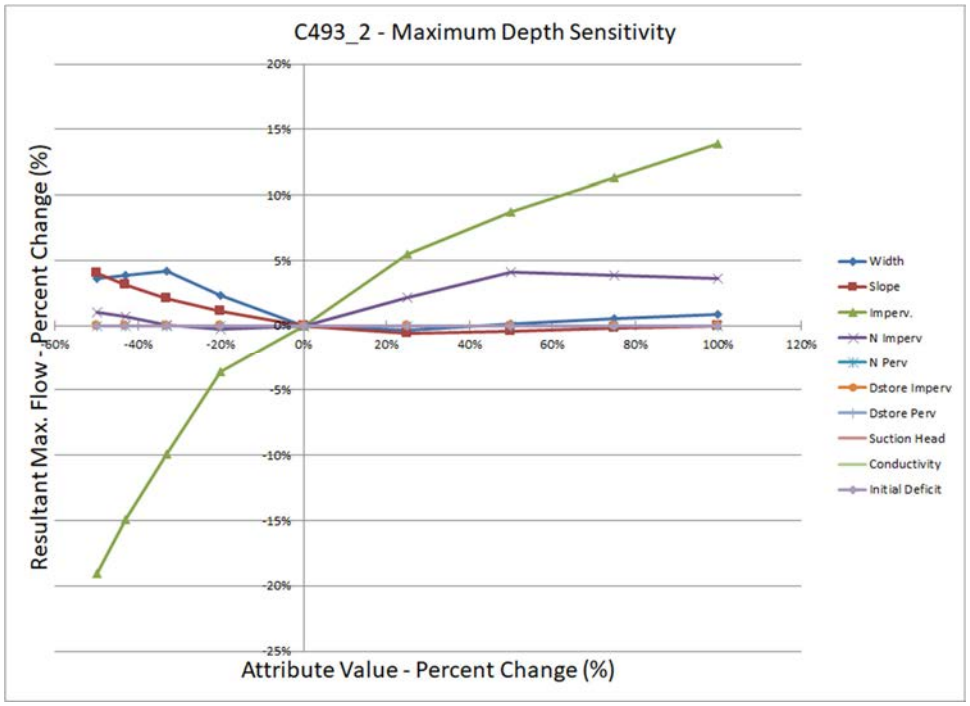


Figure C68 - Peak depth sensitivity at G. Ross Lord Dam (C493_2 - 20130731)

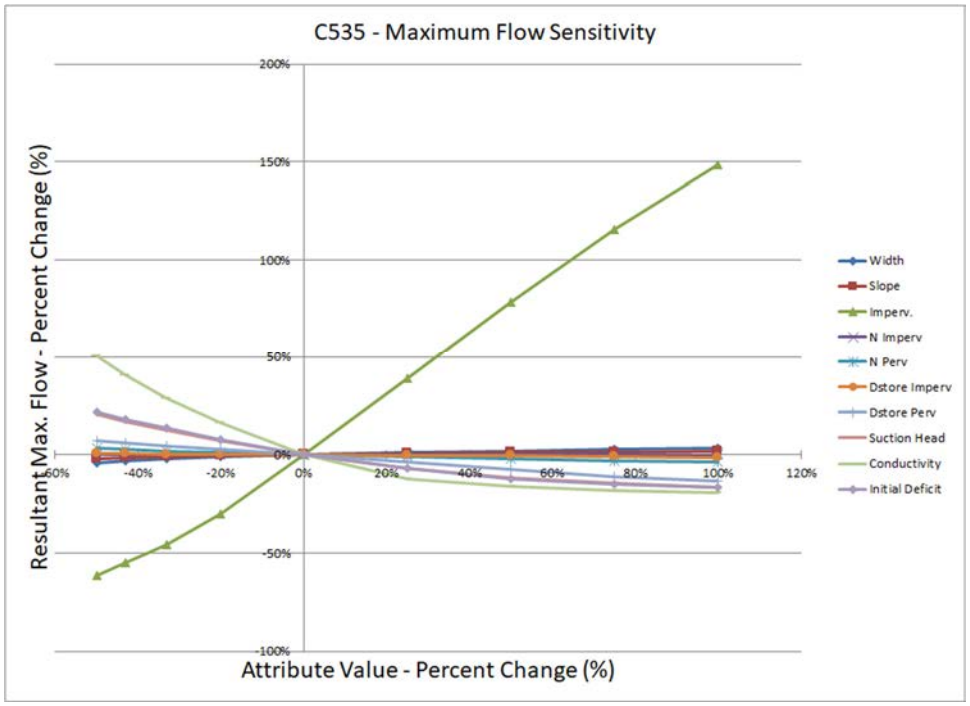


Figure C69 - Peak flow sensitivity at East Don @ York Mills (C535 - 20130731)

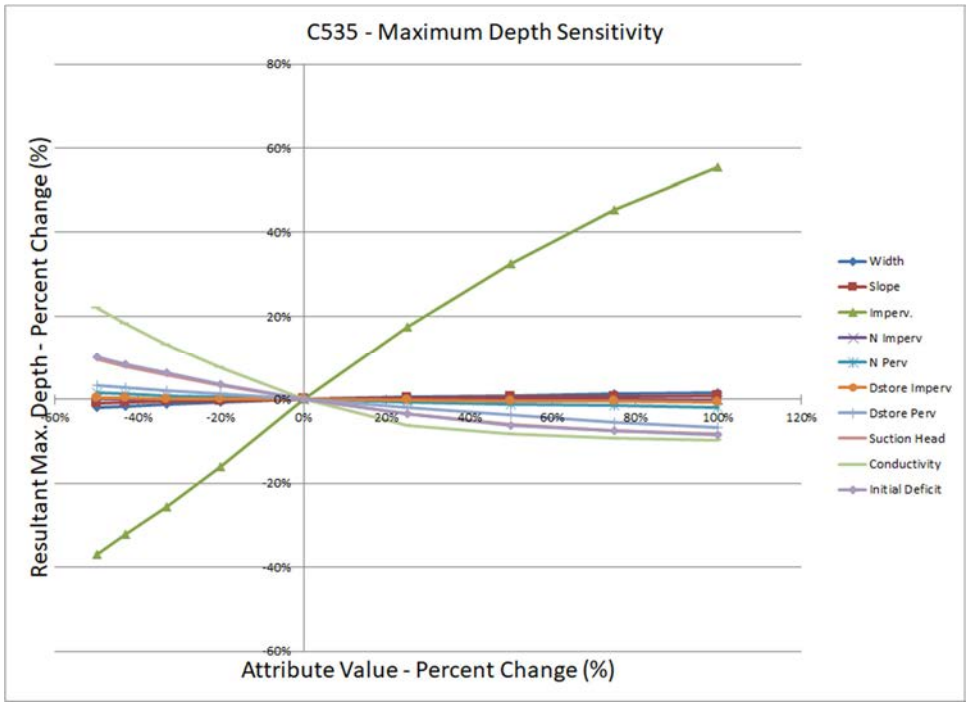


Figure C70 - Peak depth sensitivity at East Don @ York Mills (C535 - 20130731)

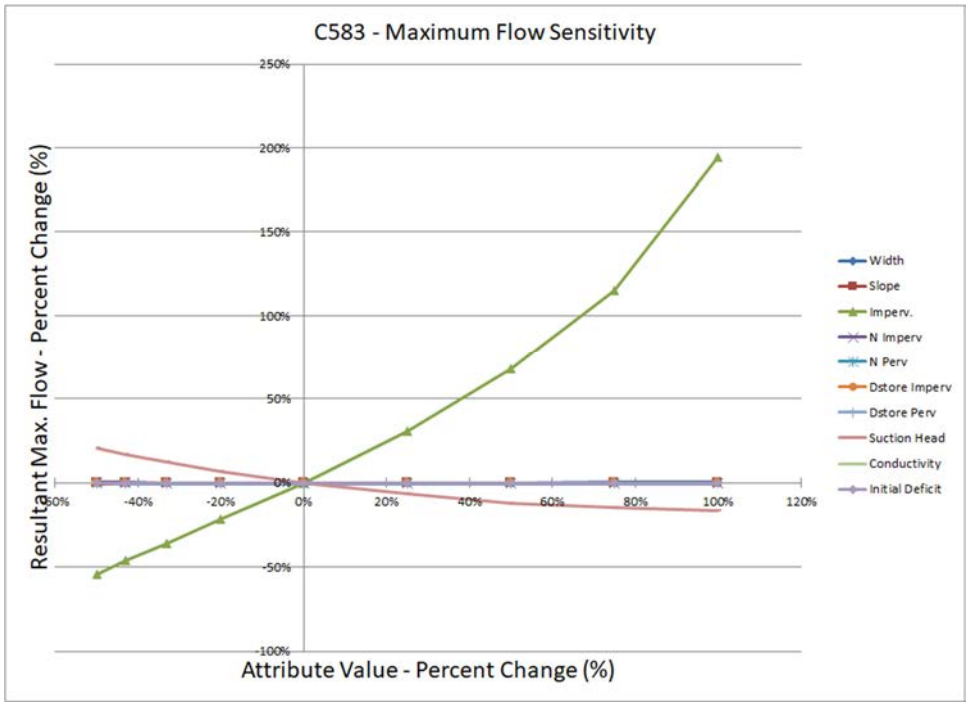


Figure C71 - Peak flow sensitivity at Don @ Knightswood (C583 - 20130731)

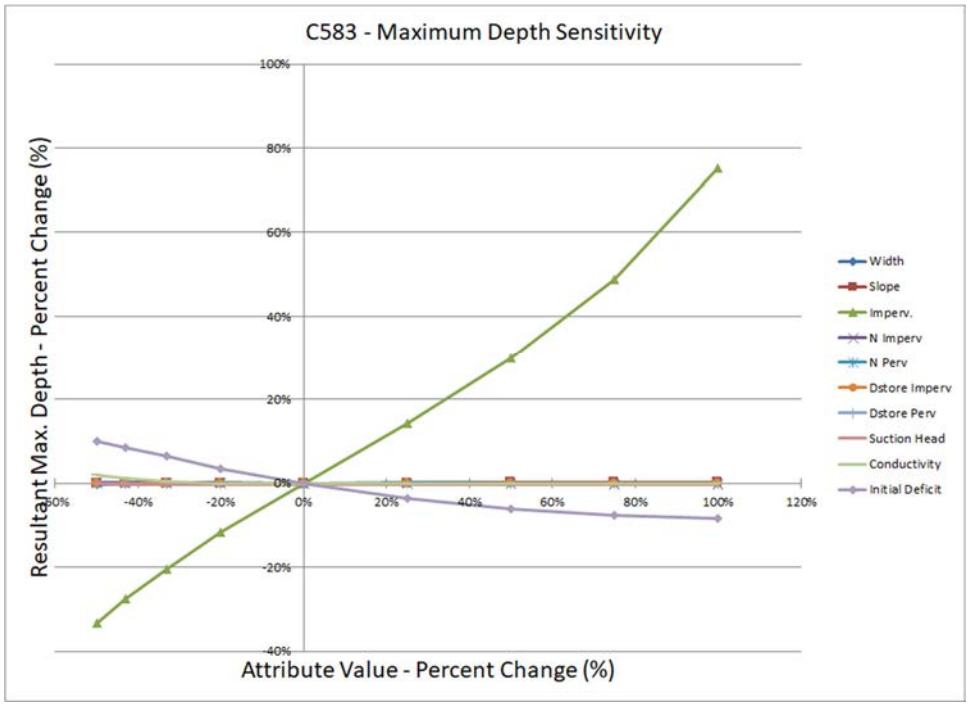


Figure C72 - Peak depth sensitivity at Don @ Knightswood (C583 - 20130731)

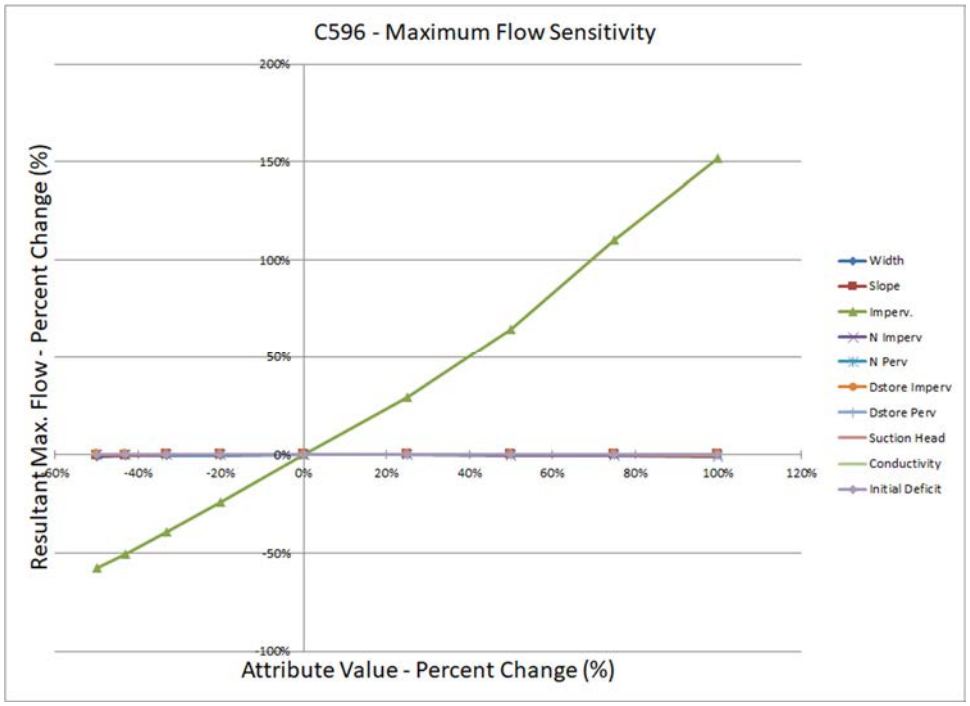


Figure C72 - Peak flow sensitivity at Taylor Creek North (C596 - 20130731)

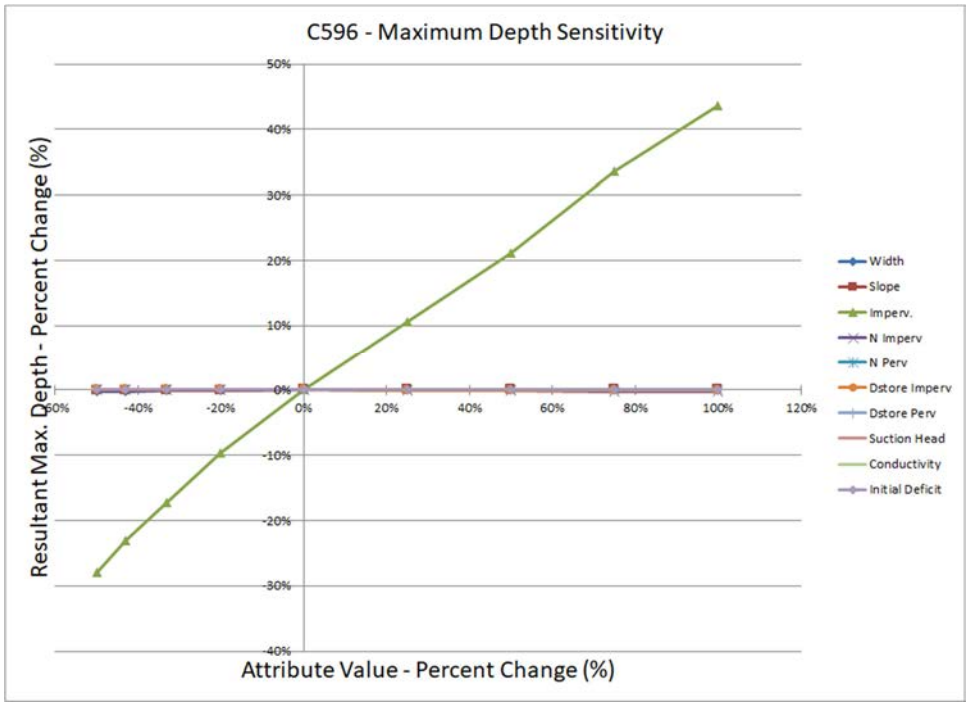


Figure C73 - Peak depth sensitivity at Taylor Creek North (C596 - 20130731)

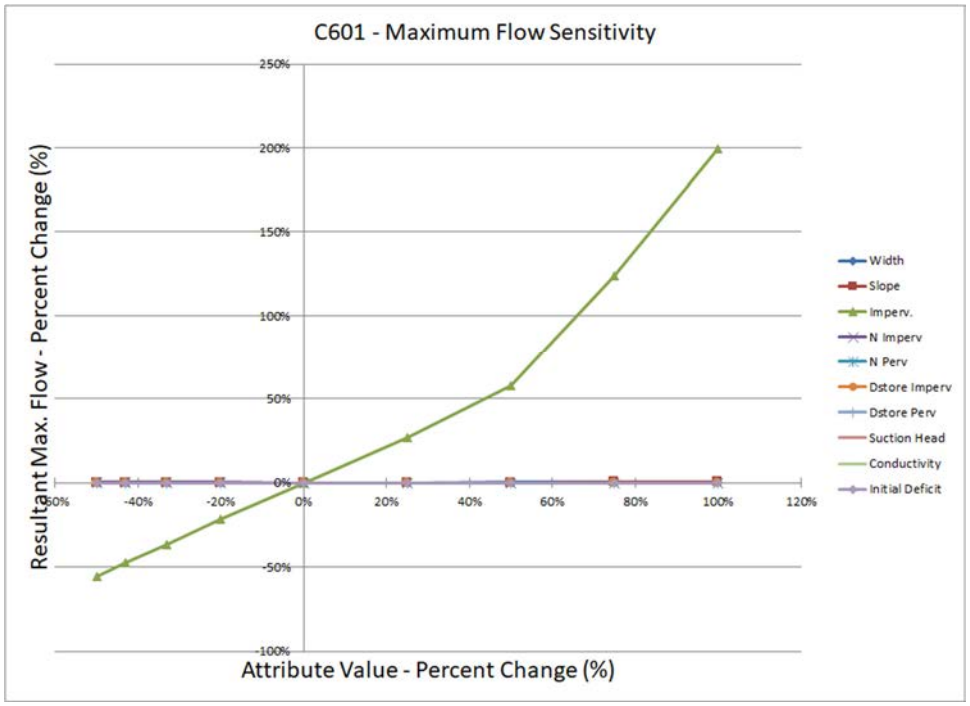


Figure C74 - Peak flow sensitivity at Wilket Creek (C601 - 20130731)

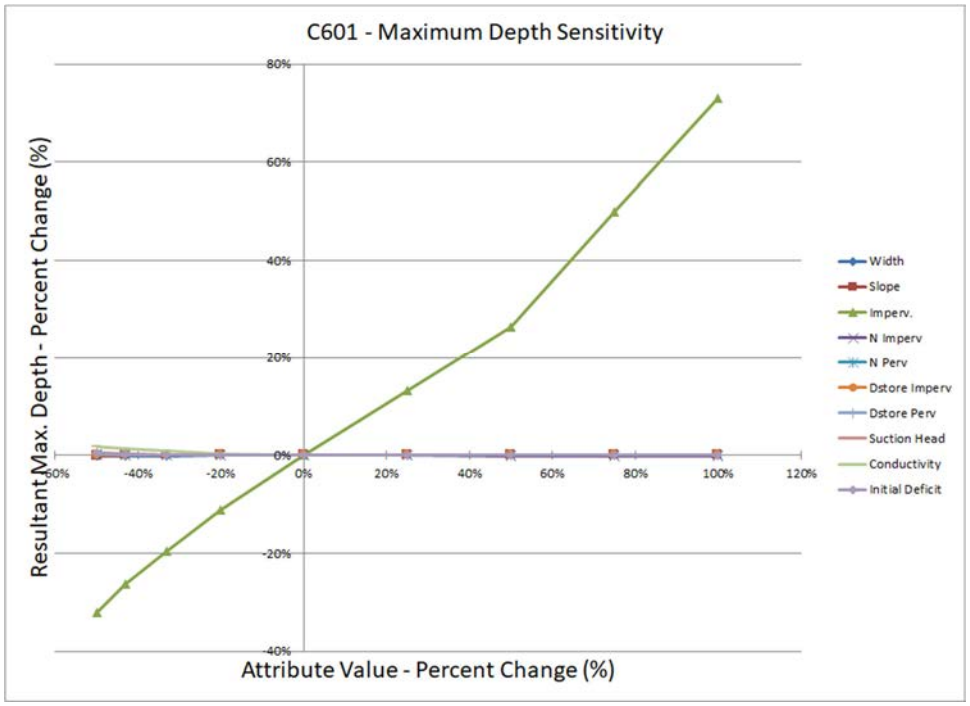


Figure C75 - Peak depth sensitivity at Wilket Creek (C601 - 20130731)

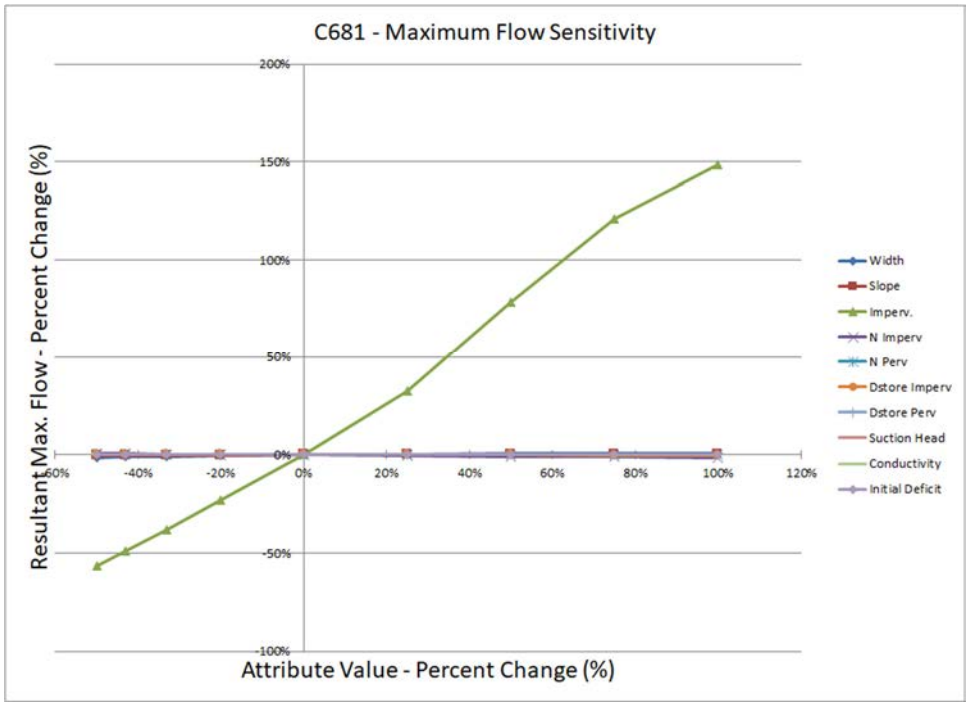


Figure C76 - Peak flow sensitivity at Taylor Creek South (C681 - 20130731)

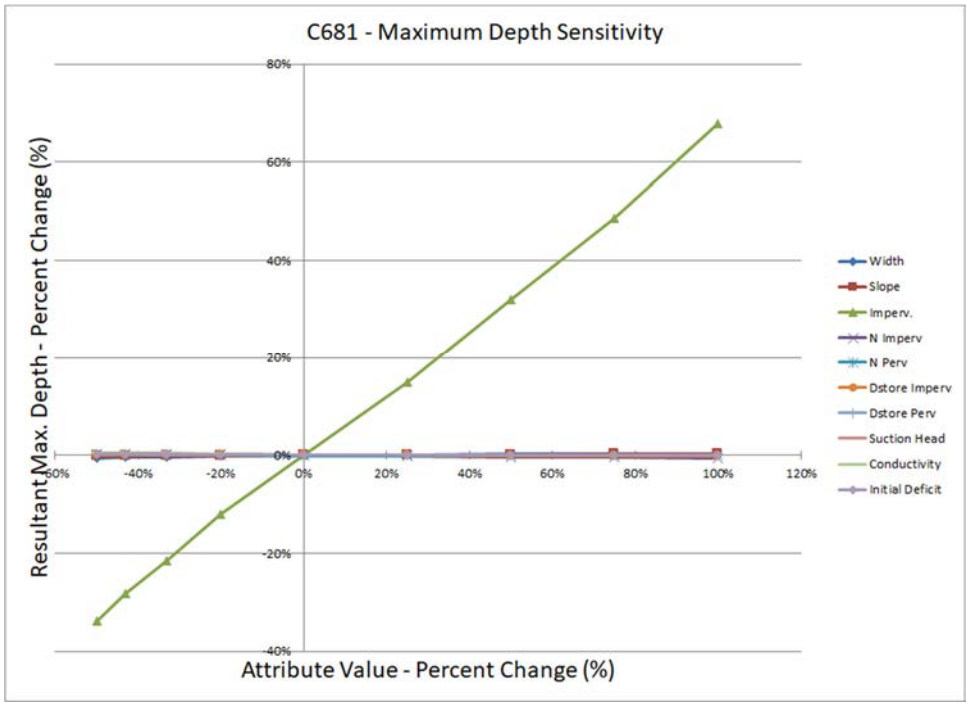


Figure C77 - Peak depth sensitivity at Taylor Creek South (C681 - 20130731)

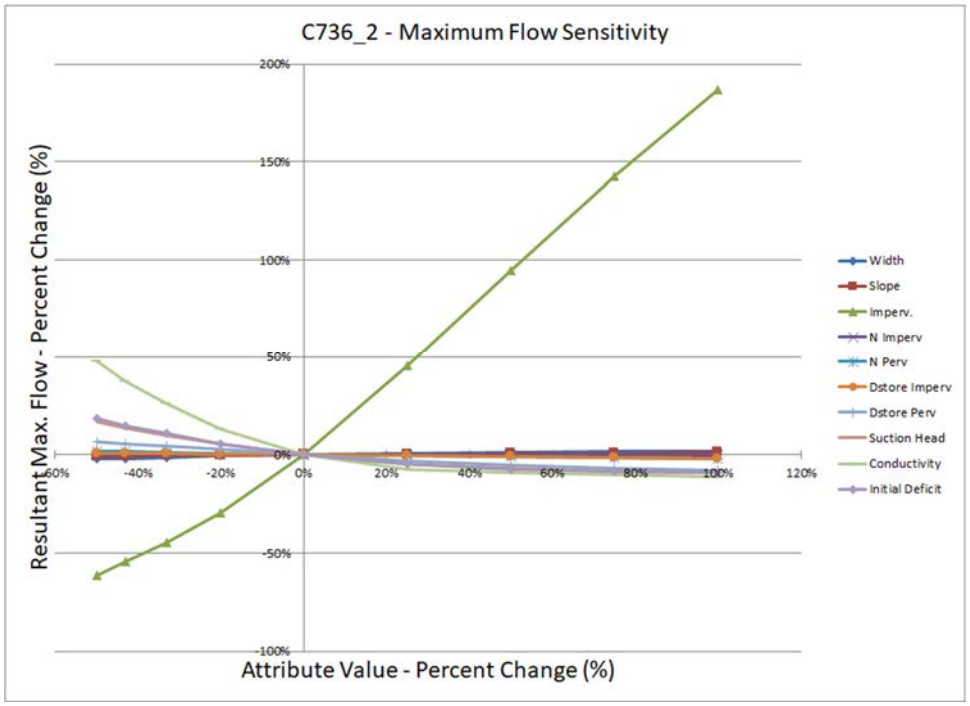


Figure C78 - Peak flow sensitivity at Don @ Dundas (C736_2 - 20130731)

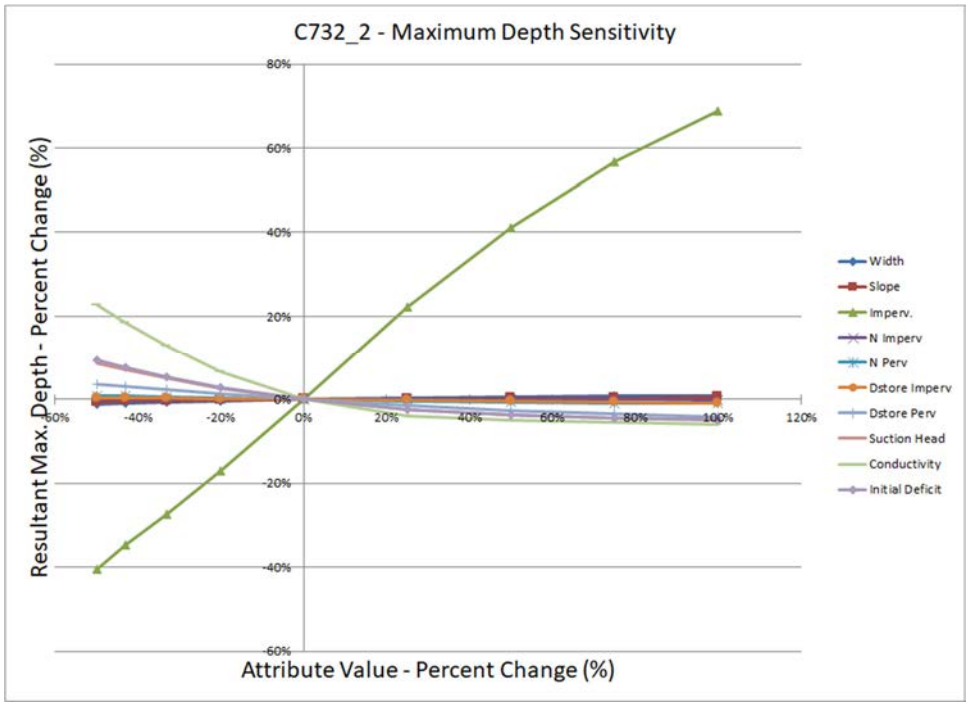


Figure C79 - Peak depth sensitivity at Don @ Dundas (C736_2 - 20130731)

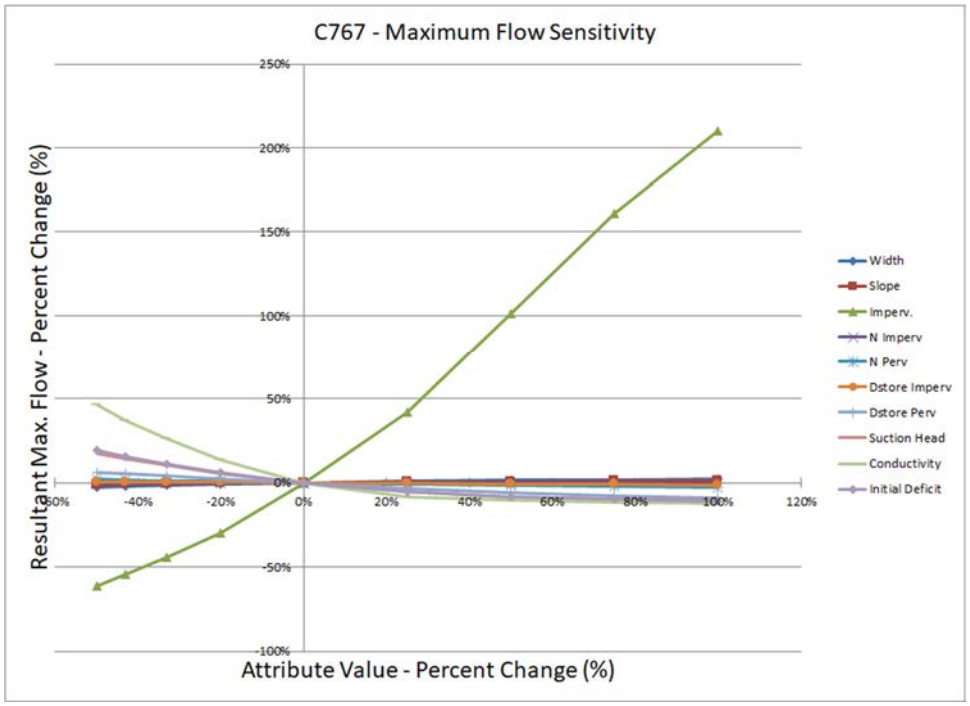


Figure C80 - Peak flow sensitivity at Don @ Todmorden (C767 - 20130731)

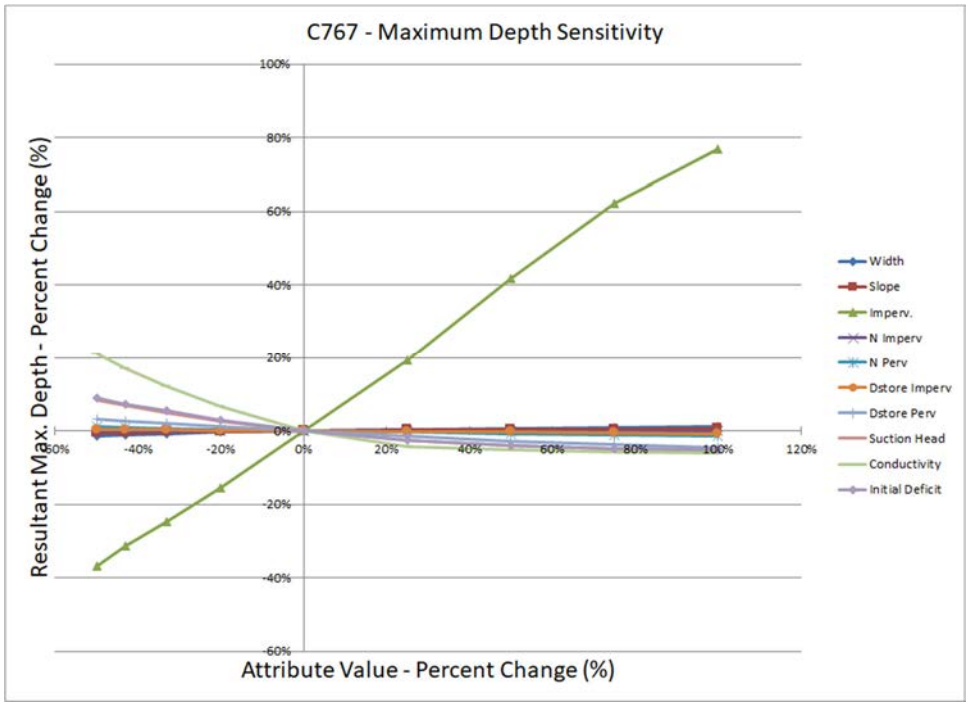


Figure C81 - Peak depth sensitivity at Don @ Todmorden (C767 - 20130731)

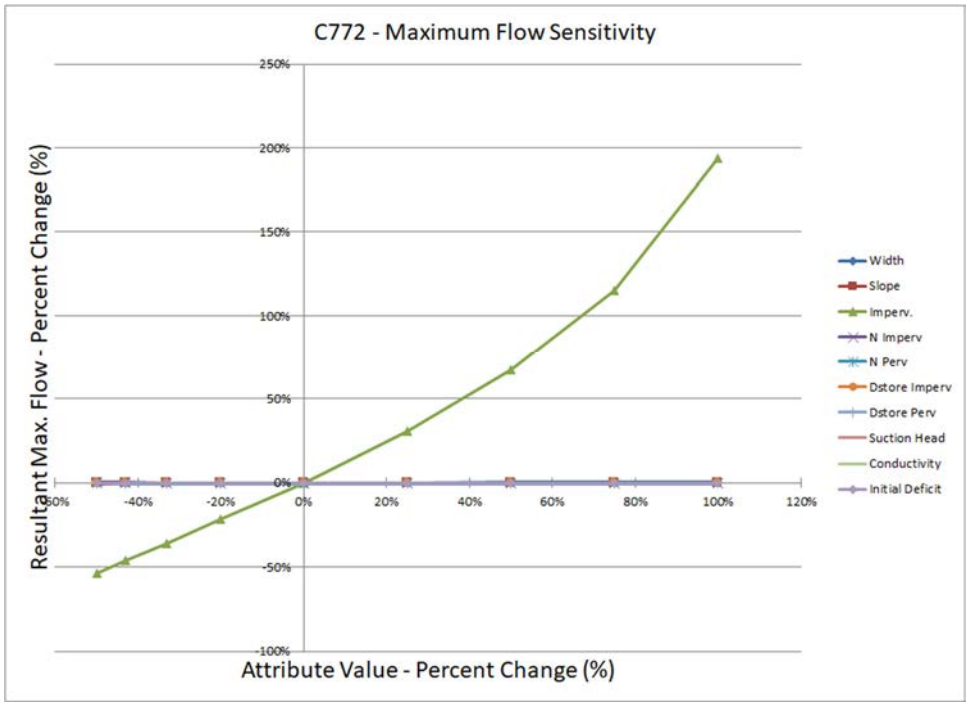


Figure C82 - Peak flow sensitivity at Don @ Todmorden (C767 - 20130731)

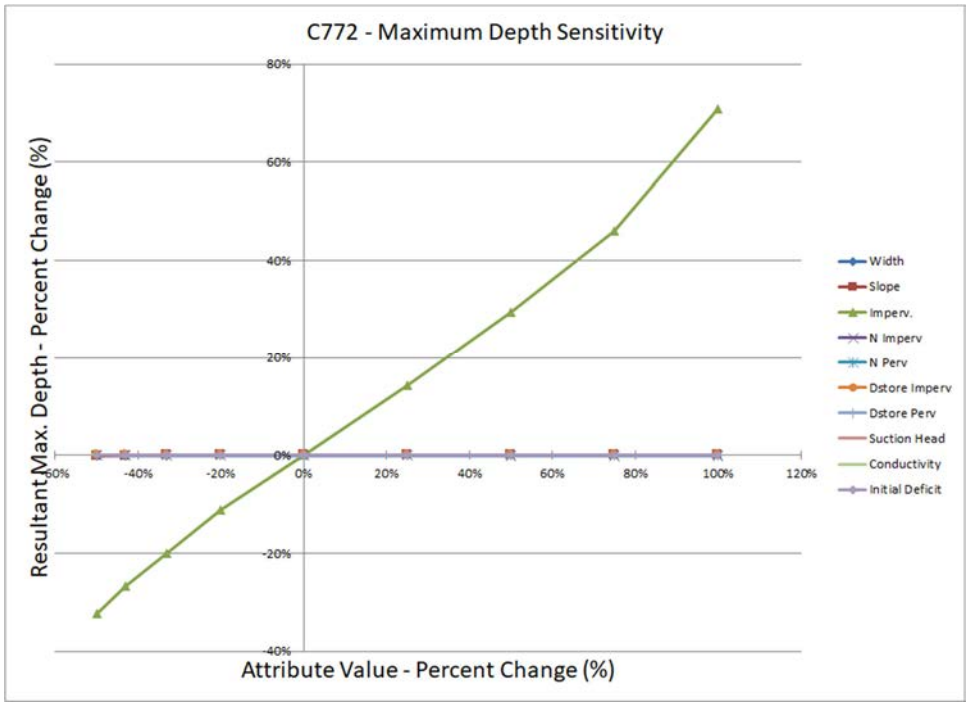


Figure C83 - Peak depth sensitivity at Don @ Todmorden (C767 - 20130731)

Appendix D – Rainfall Review

The following plots show the comparison of the rain gage data provided compared to the raw radar rainfall data downloaded from the KBUF station. In all instances the analysis was intended to check the timing of the peaks and not the volume. This was done to check if daylight savings was considered for the event rainfall.

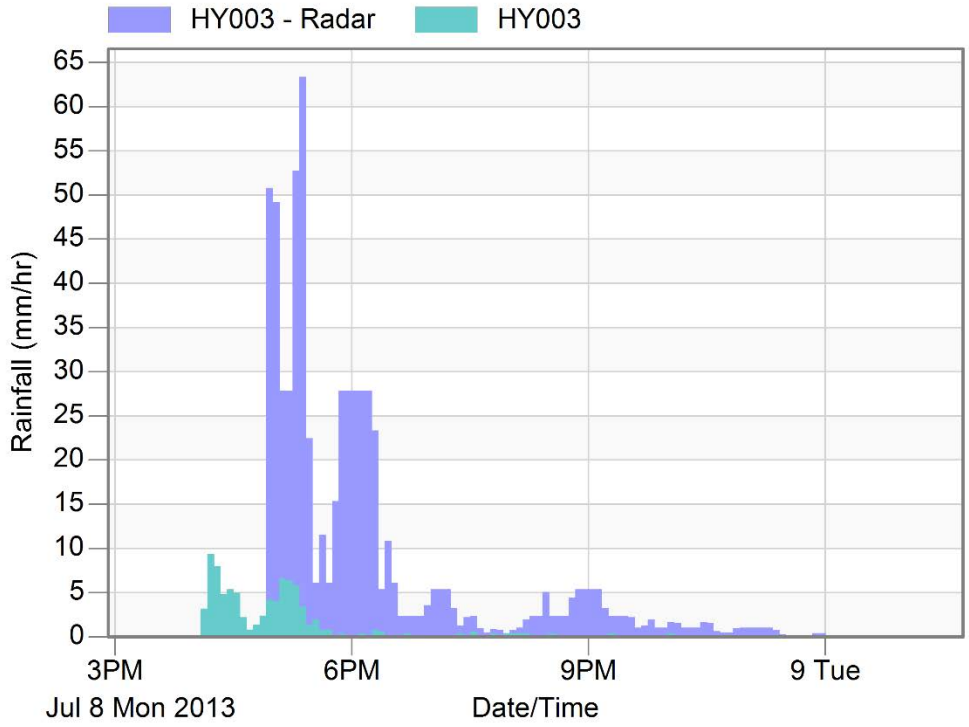


Figure D1 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY003

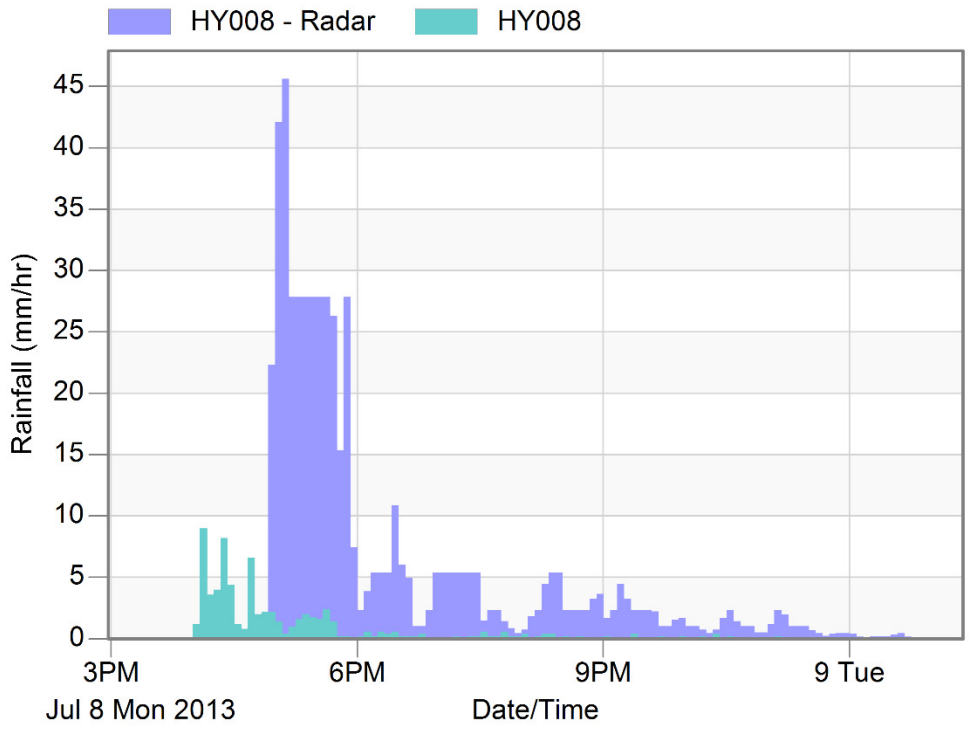


Figure D2 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY008

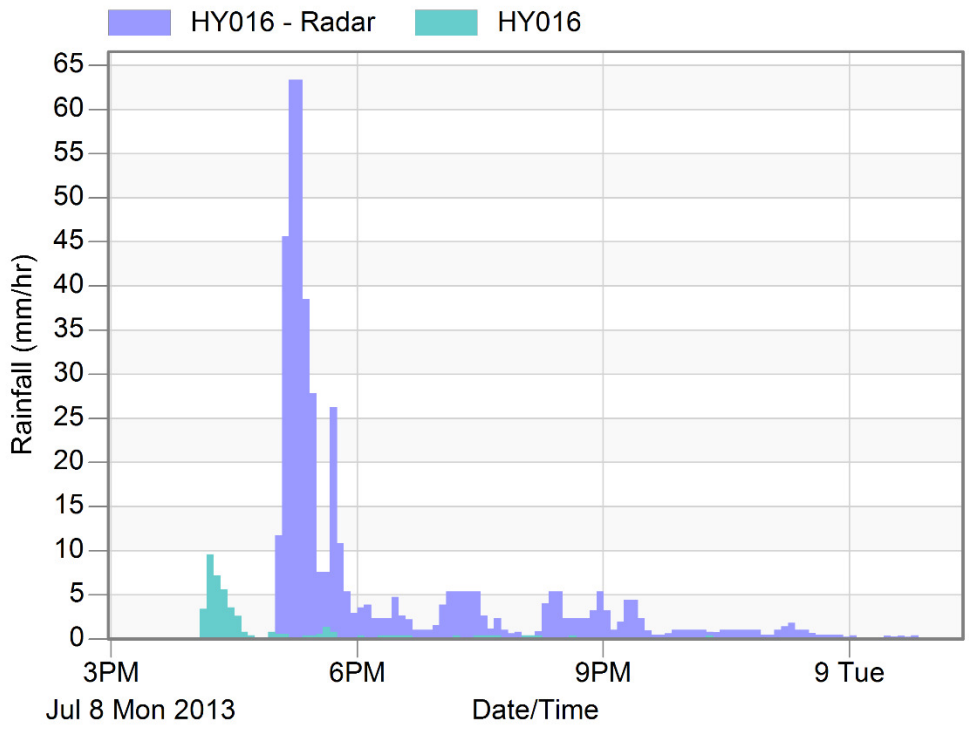


Figure D3 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY016

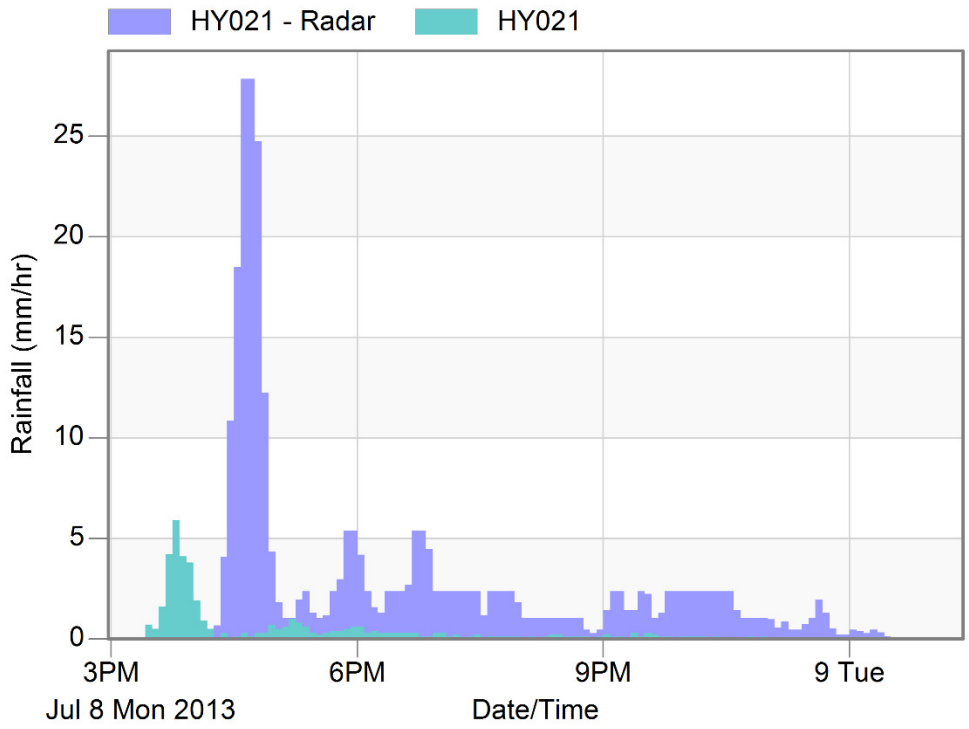


Figure D4 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY021

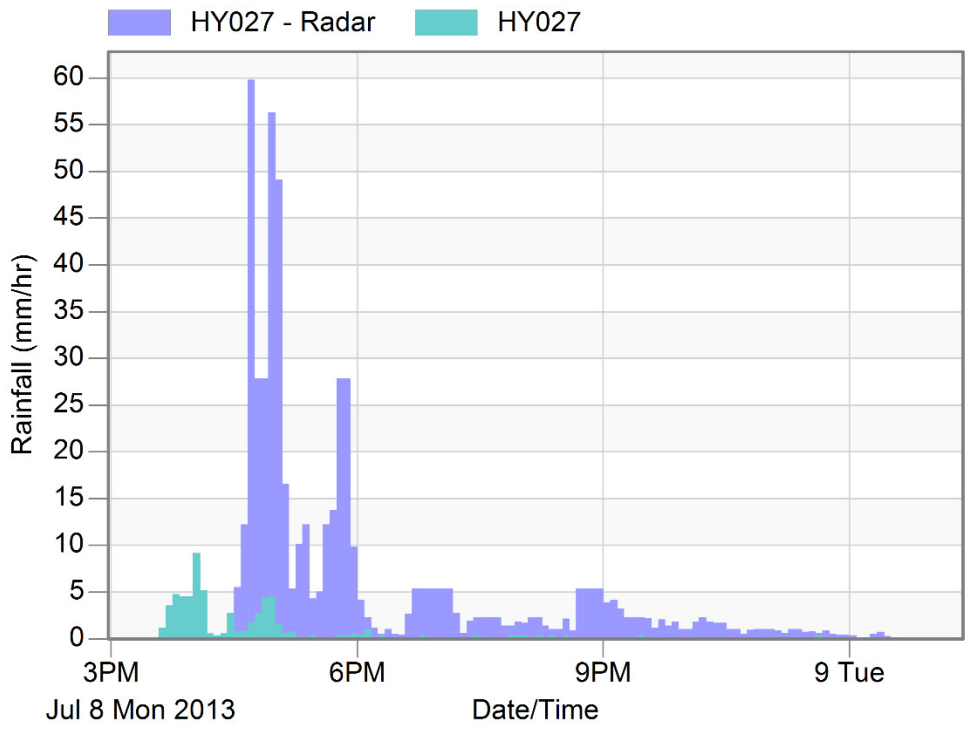


Figure D5 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY027

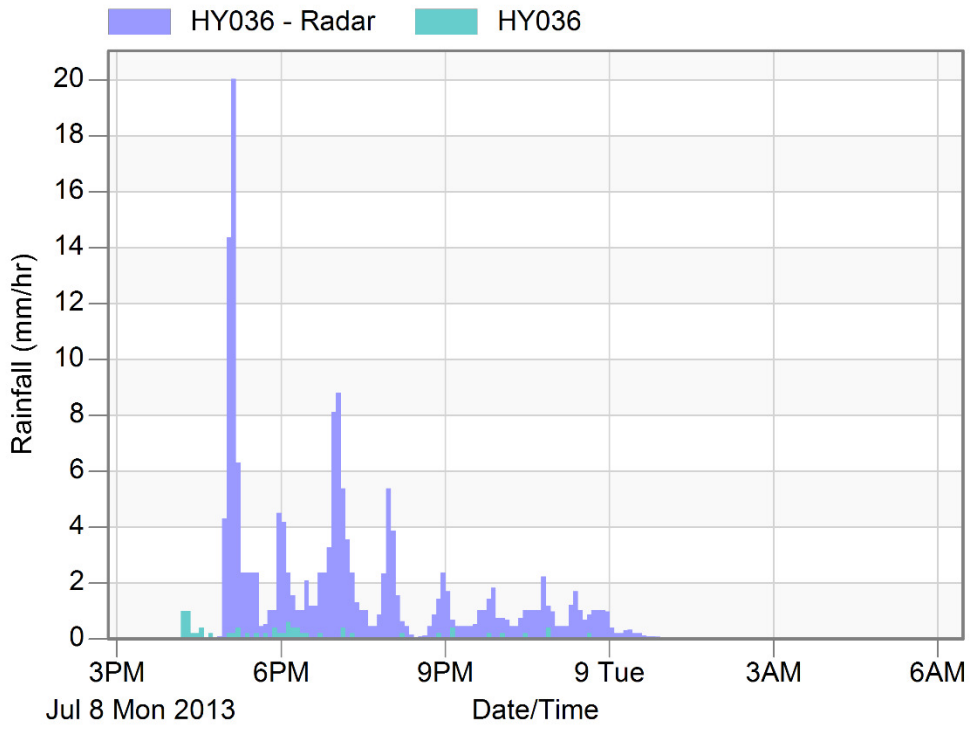


Figure D6 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY036

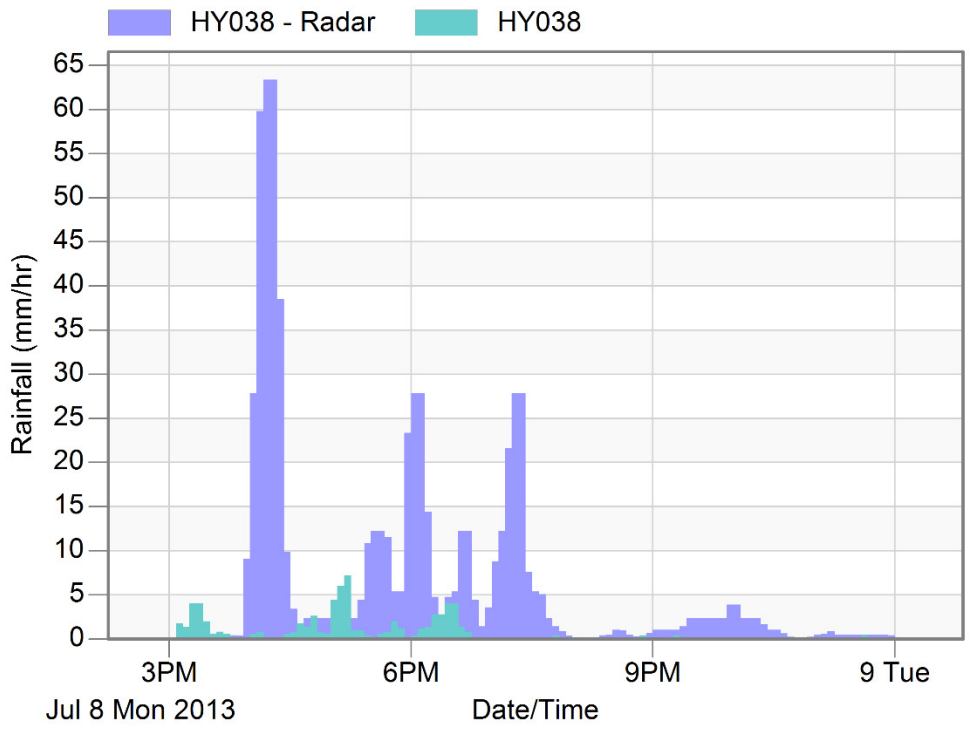


Figure D7 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY038

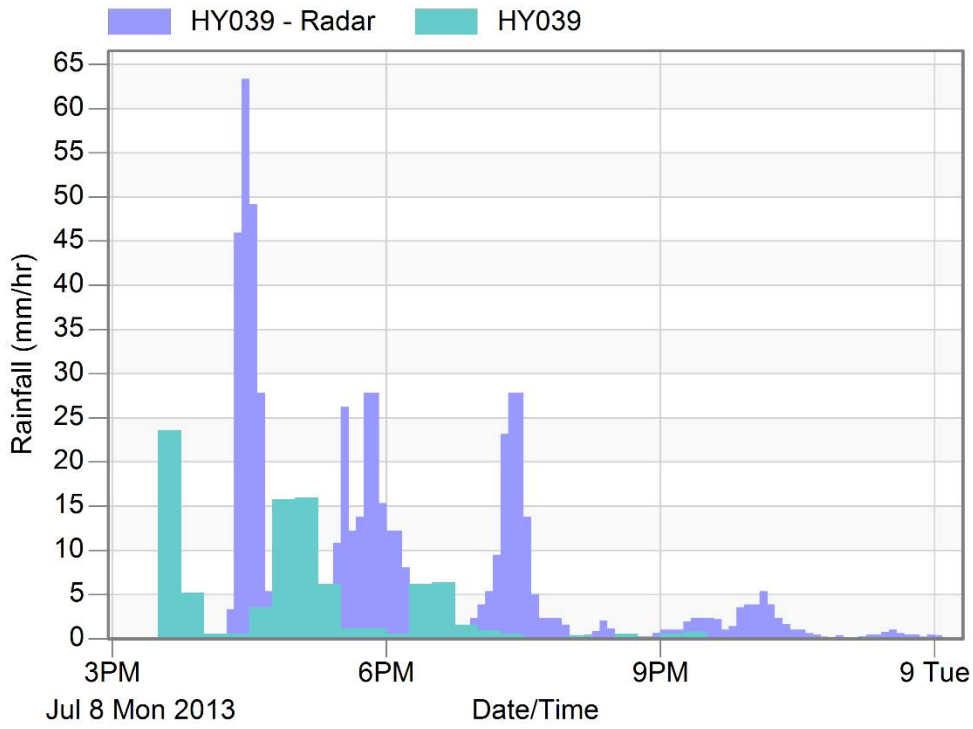


Figure D8 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY039

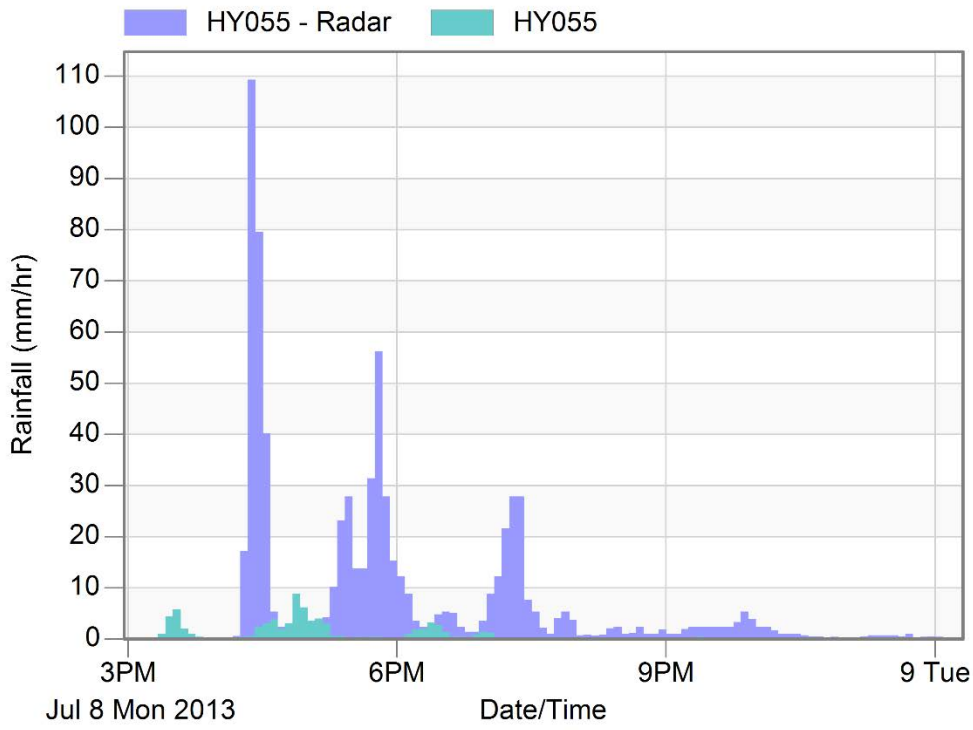


Figure D8 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY055

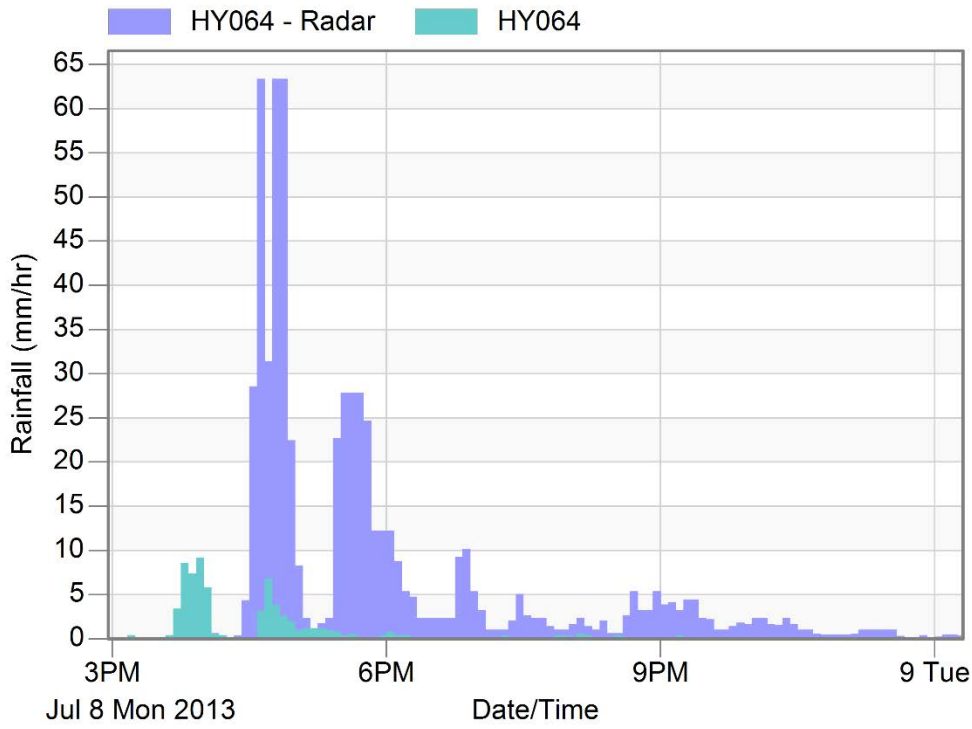


Figure D10 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY064

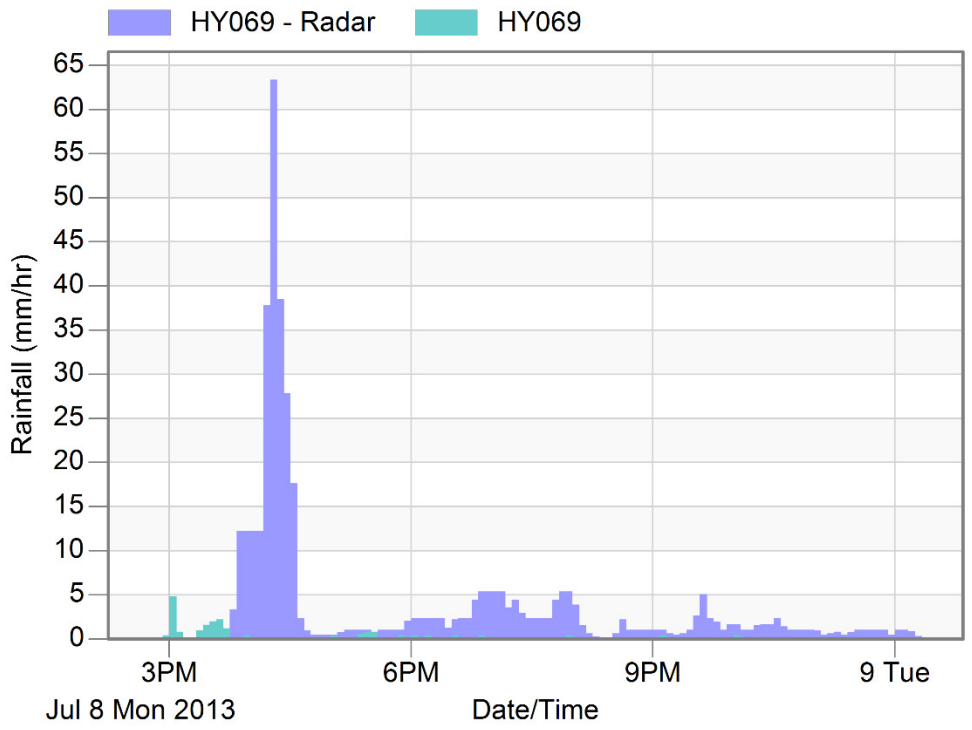


Figure D11 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY069

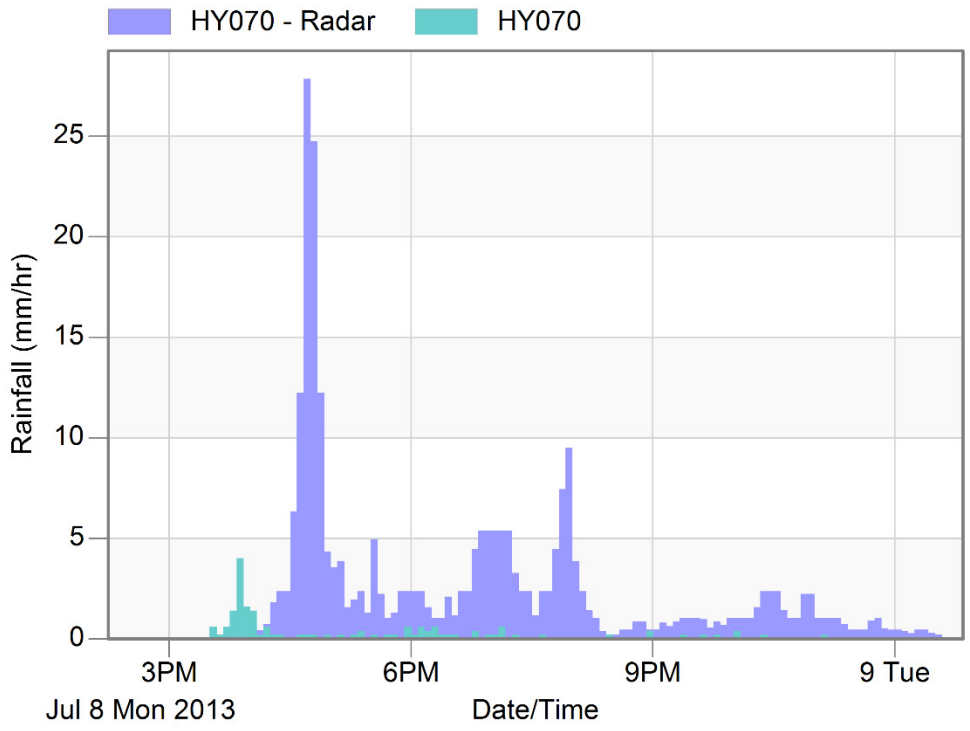


Figure D12 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for July 8th, 2013 at Gage HY070

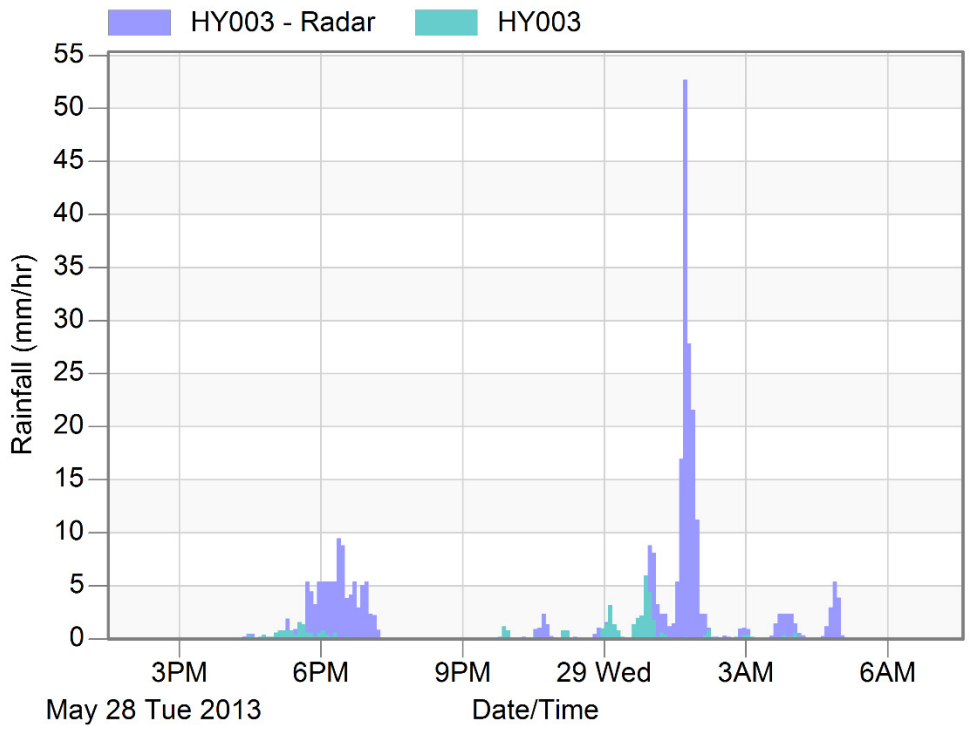


Figure D13 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for May 28th, 2013 at Gage HY003

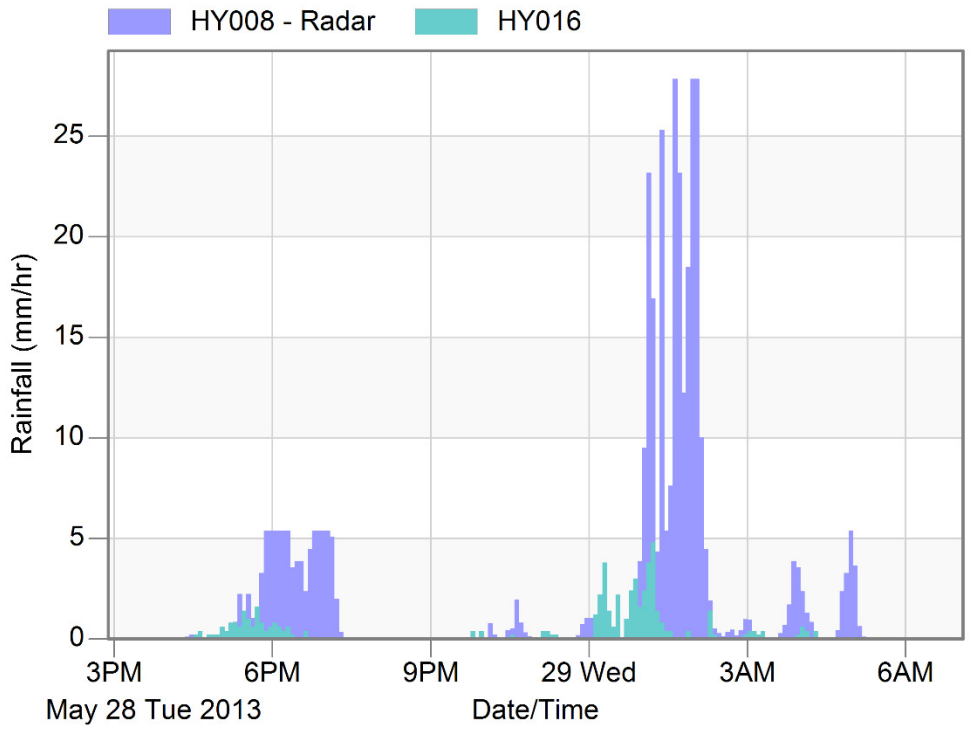


Figure D14 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for May 28th, 2013 at Gage HY016

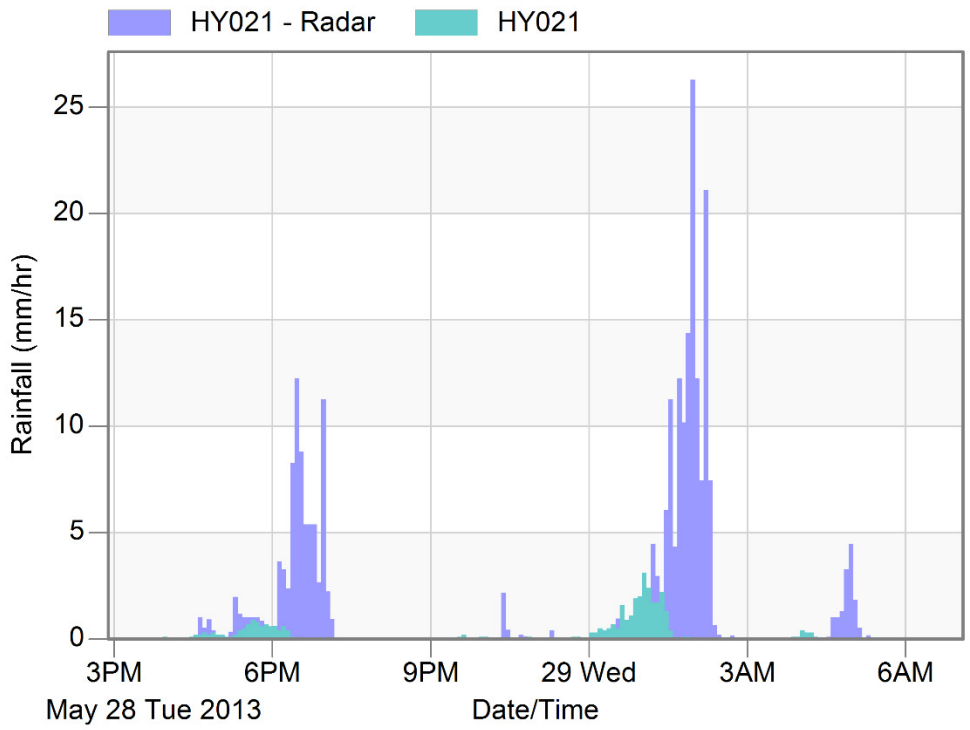


Figure D15- Observed Rain gage data vs. Radar Rainfall (not gage corrected) for May 28th, 2013 at Gage HY021

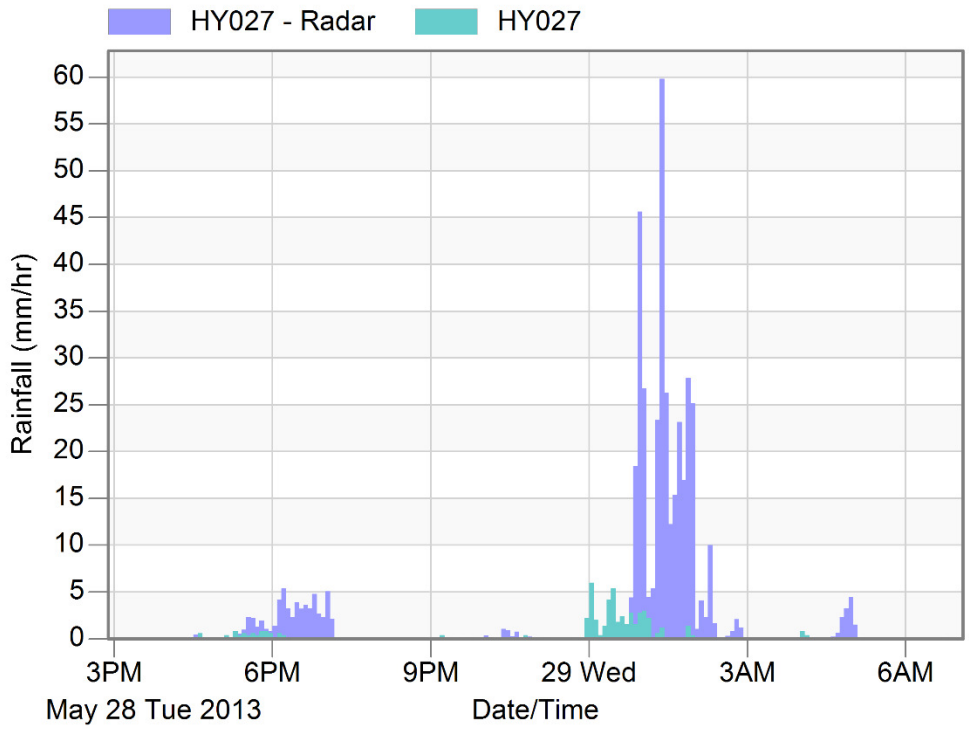


Figure D16 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for May 28th, 2013 at Gage HY027

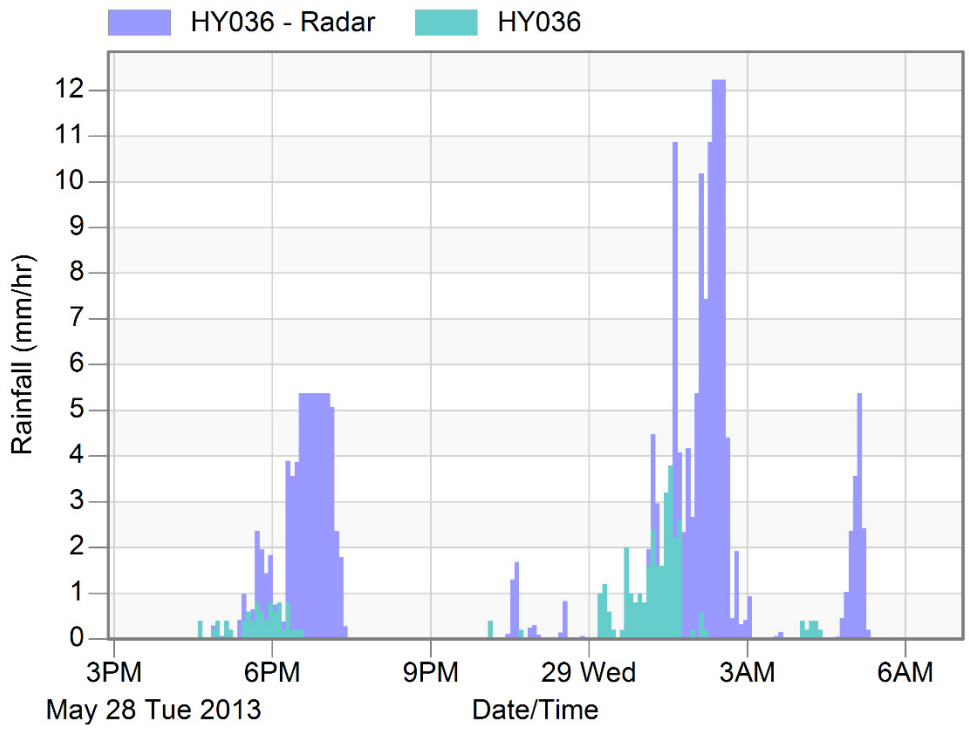


Figure D17 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for May 28th, 2013 at Gage HY036

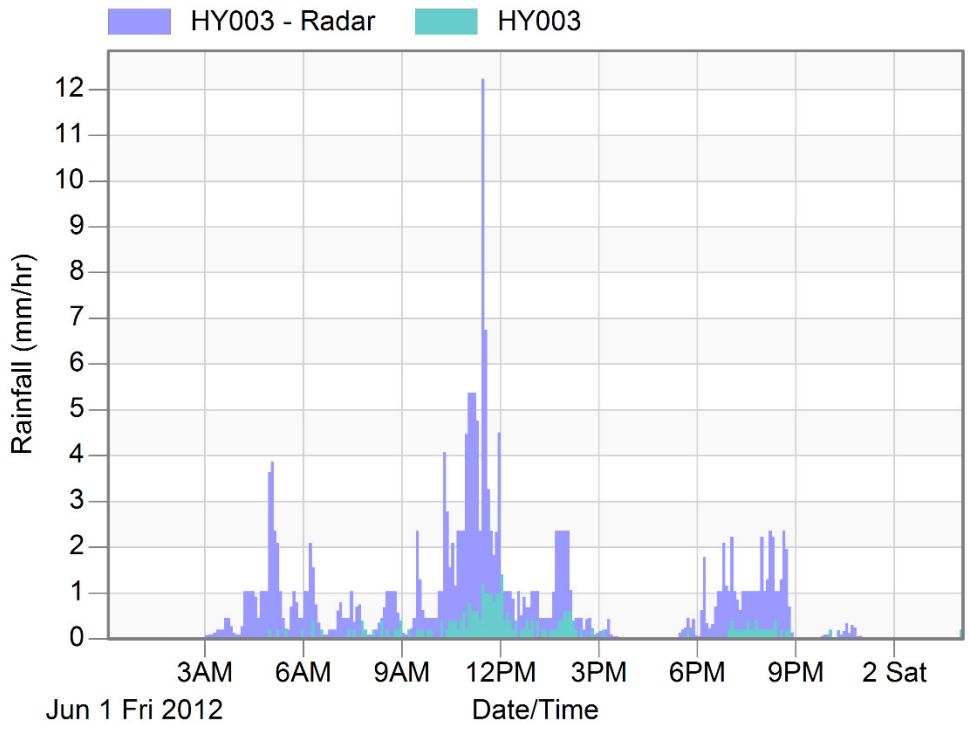


Figure D18 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for May 30th, 2013 at Gage HY003

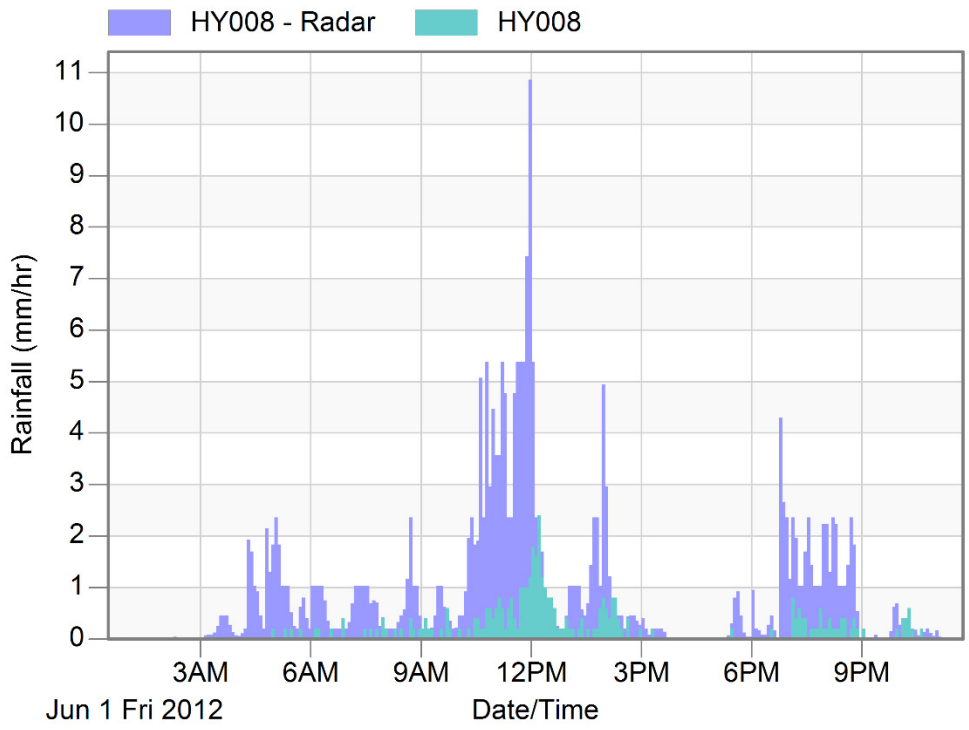


Figure D19 - Observed Rain gage data vs. Radar Rainfall (not gage corrected) for May 30th, 2013 at Gage HY008

Appendix E – Correspondence

Don River Hydrology Update 2017
Peer Review Comment Log

Suggested action item #	Comment	AECOM Response	CHI Response
1	Review HEC-RAS transects and compare with merged PCSWMM transects and ensure slopes in the merged sections have been preserved.	There are a total of approximately 3400 cross sections in the HEC-RAS models, while the PCSWMM model consists of 683 conduits with an average length of 342m, in the areas covered by the HEC-RAS models. The channel elevations in the PCSWMM model reaches at all the reach endpoints (including crossing locations) are consistent with the HEC-RAS elevations. Given the relatively short average reach length in the PCSWMM model relative to the size of the study area, any minor 'internal' slope inconsistencies within the reaches will not significantly effect the routing or lag in the overall model. We believe that adequate level of details has been built into the model for the purpose of the current study.	Satisfactory
2	Indicate in the report the locations where there was a bridge or culvert in the HEC-RAS model that was not included in the PCSWMM model. Evaluate their sensitivity and provide justification as to why these structures were not included in the model.	The structures have already been screened based on their sensitivy to introducing storage and attenuation. Hydraulic structures were included in the PCSWMM model based on their the hydraulic significance. The screening criteria includes: - Floodplain area/volume upstream of the structure - Difference in water surface elevation upstream and downstream of the structures The screening matrix was then reviewed by TRCA and TRCA suggested a number of additional hydraulic structures to be included in the model. The final list of structures included can be found in Appendix C of the report. Report has been revised to include additional commentary describing the hydraulic structure screening process.	Satisfactory
3	Assign urban and rural transects in downstream areas representative transects based on the DEM.	AECOM has reviewed the model to ensure the proper type (urban vs rural) transects are used in the model. We've now updated 63 transects based on cutting cross sections from the DEM. Each of these is actually a 'representative' cross section in the reach based on averaging of multiple sections along each reach.	Satisfactory
4	Confirm the loss coefficients assigned to the piped conduits and bridge shape curves are supposed to be 0. If so, explain why.	The draft model already had all the culvert entry and exit loss translated from HEC-RAS into PCSWMM. Losses for some of those piped section of the watercourse were taken from the hydraulics study reports provided by TRCA. The ones that were missing (and given values of zero) were the bridges openings. AECOM has updated these to use the same expansion/contraction coeffcents as HEC-RAS does associated with the bounding cross sections and transition to bridge structures. These are generally 0.3 and 0.5 in the HEC-RAS model.	Satisfactory
5	Edit lumped storage rating curves OL155 and OL95 to have a non-zero flow at depth zero.	These have been updated with the zero points	Satisfatory
6	Confirm jagged storage area/depth curves is representative of the total storage volume.	A number of the pond storage curves provided in the database are stage-storage as opposed to the stage-area format required by PCSWMM. Recognizing that at any given elevation the area equals the slope of the elevation-volume curve, the stage area curve was estimated by the following equation: A = (Vn+1 – Vn) / (Yn+1 – Yn) This resulting in jagged stage-area curves in some cases. The conversion is purely empirical and the resulting curves do not represent the physical geometry of the ponds. An alternative equation is average area * height: V n+1 = Vn + (An+1 + An) / 2 * (Yn+1 – Yn). AECOM tried this equation as well-- with this equation, all subsequent area will depend on A0. For quite a few ponds, we ended up having negative areas at We reached out to the SWMM community and Lew Rossman (the programmer of the SWMM engine) suggested using the equation we ended up using to convert the curves.	Satisfactory
7	Check that the rainfall time series and flow are timed correctly for 2013 (i.e. both not corrected for daylight savings time).	TRCA confirmed that both rainfall and flow time series were not corrected for daylight savings times. Time zone difference from Water Survey of Canada data has been corrected prior to calibration and verification. Calibration and verification events where rainfall and flow were plotted using different timeframes were evident as the model results are shifted bu one hour compared to the monitor flows; this did not affect the volumetric or peak flow calibration, and was accounted for when visually assessing the general goodness of fit of the shape of the response hydrograph	Satisfactory
8	Add a description of how G.Ross Lord Dam rating curves were developed in the report	The rating curves are taken from the dam Operations Manual. Will revise report, adding additional background information on the dam, and citing the operations manual as the source of the rating curves	Satisfactory
9	Provide justification as to why many areas marked as having primary clay soils have infiltration values represented of loam.	We have provided additional justification in the report. The infiltration values are calibrated from the volume of runoff measured at the flow gauges relative to the volume of rainfall. The infiltration values in disturbed / developed areas are different from those of native soils, potentially due to imported topsoil, lot grading and gardens, and recultivating of the surface. We used the calibrated infiltration values rather than those derived from soil mapping, since use of clay soil infiltration values produces model flow volumes that are far larger than measured flow volumes.	There is still some uncertainty whether the soil infiltration parameters used in few subcatchments are over estimated. However, we understand AECOM has explored several options (just short of field tests) to justify the values.
10	Provide justification as to why the infiltration parameters (specifically hydraulic conductivity and suction head) values are so varied across the watershed. For example, adjacent gauge watersheds HY068 and HY019 have hydraulic conductivity values of 40 mm/hr and 3.3 mm/hr respectively.	We have provided additional justification in the report. The justification is similar to as stated above. The parameters are calibrated based on gauged flows. The infiltration parameters are varied across the watershed because the actual runoff response is varied across the watershed.	Same response as above.
11	It is recommended to explore whether some of the higher hydraulic conductivity estimates are caused by potential under estimation of upstream storage (due to exclusion of limiting hydraulic structures) and rain gauge reporting time steps not matching flow monitoring data time step (Is there a correlation between 15-minute flow data from HY062, HY068, HY092 gauges and higher hydraulic conductivity values for their watersheds).	Issue 1: We are not excluding limiting hydraulic structures - all significant structures are included in the model. Issue 2: The concern is if increasing rainfall timestep (decreasing peak rainfall intensity) could potentially result in the calibration reducing the hydraulic conductivity. AECOM checked this by resampling the model at 15 minute time steps, which resulted in essentially no change in the modeled hydrograph. Our conclusion is that the model subcatchments are sufficiently large that they do not respond to rainfall durations as short as 5 minutes.	Same response as above.
12	As a good modelling practice use a DEM resampled to a coarser resolution (5-10 m) for subcatchment slope calculation.	Agree with the comment in theory. However, CHI's presentation suggests that changing the DEM resolution results in similar subcatchment slopes. Additionally, CHI's sensitivity analysis shows that catchment slope is not a sensitive parameter. Revising the model subcatchment slope will not appreciably change the model results, and represents considerable re-work- so we are not proposing to revise the catchment slope calculation with a coarser grid resolution	Satisfactory
13	Provide justification of large variation in percent routed among the different drainage areas	We have provided additional justification in the report. Similar to above, the parameter is calibrated based on gauged flows. The percent routed reflects a reduction of the total impervious area to an effective 'directly connected' impervious area. The directly connected impervious area essentially produces runoff for the entire storm volume, and the directly connected area is evident from the linear response (of runoff volume vs rainfall volume) for the storms used for calibration	Satisfactory
14	Provide an explanation for the development of a relationship between Antecedent Precipitation Index (API) and Initial Moisture Deficit (IMD) values as it was not used in the model. Ideally, the relationship could have been used in the verification runs. Instead, it seems the verification runs used IMD values similar to values for the remaining events as indicated in Table 6 of the consultant's report. Justification for the approach that is based on computed API for the verification events is requested.	The API and IMD relationship was developed as a result of the calibration and verification process – IMD was calibrated and then the relationship between API and IMD was developed based on the calibrated IMD values. The intention of the curve is for the future application of the model. AECOM will provide further explanation of the curve development in the report.	Satisfactory
15	It is recommended to include a reference in the report for the API equation on Page 21.	Will revise report. The equations should read $API_n = API_{n-1} \times 0.9992 + Rainfall_n$ and $API_n = API_{n-1} \times 0.8 + Rainfall_n$ These are the actual equations that were used. This equation is referenced in the SWMHYMO users manual (Aug 1999), where the"depletion coefficient" is identified as ranging from 0.8 to 0.95 / day	Satisfactory
16	Add additional clarification on the assigned IMD values representing the wet conditions.	We have provided additional clarification. See response to item 14 as well	Satisfactory

TRCA Memo - Progress update_with action items_Aug14_18.pdf

TRCA Memo – Don River Model Update – Status Report

August 14th, 2018

DRAFT

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Introduction

Based on our review of the submitted materials, CHI believes that the Don River Watershed model generally represents a good-quality effort, for what we could consider a reasonable and acceptable application of the PCSWMM and the SWMM5 model for similarly scoped studies.

The hydrologic and hydraulic representation is appropriate in general, and most input parameter values fall within the expected attribute ranges for the type of system modeled.

There were however several areas that CHI recommends are investigated further, these have been itemised below.

Initial peer review findings

The following section presents the initial findings of our review of the model, as stated on the tasks outlined in our proposal.

Confirm flow transition parameters are representative of the study area

- Alignment of the SWMM stream conduits developed using ArcHydro tools would not always match with the HEC-RAS river/reach segments. This required the consultant to import HEC-RAS cross-sections into the model and assign averaged transects
- Averaging HEC-RAS cross sections should provide realistic representation of volume and roughness characteristics of channel sections. However, by joining smaller HEC-RAS reach segments into longer SWMM conduits, local variation in channel slopes may potentially change the peak/timing of flow.
- It is recommended to check imported bridges/culverts with original HEC-RAS cross sections. Exclusion of some hydraulic components (culverts/bridges) included in the HEC-RAS models may alter the hydraulic routing in the Don River Model. Specially, if more flow constricting components were not modeled, it could result in increased downstream flow rates (for example, small culverts can reduce the peak flow by storing more flow volume in upstream channel segments).
- There are some conduits that are assigned urban transect (i.e., curb/gutter is represented). While it is suitable for more upstream areas where runoff is conveyed through road pavements, they should not be used for open watercourses that are prevalent in downstream reaches of the study area.
    - For example, some conduits within the southwest corner of the watershed (e.g. C728, C729, C722) carry more than 40 m3/s flow under 100-year design storm. This may not be realistic as flow at this stage should be conveyed through a more natural transect shape that provides greater flow attenuation than a typical road allowance with curb and gutter.
- Similarly, rural transects used in the model may be too simple as they do not represent varying wetted perimeter in the flow pathways under different flow ranges. Extracting flow pathway cross-sections from the DEM would be more appropriate as these will better define the flooplain portion of the channel. Derrick Creek is an example requiring more natural stream cross section.
- It is understood the conduits that run through David Balfour Park are buried pipes.

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Hydraulics in the model are represented with a high level of detail. Some observations that may require attention include:

- Piped systems and conduits represented with shape curves have not been assigned head loss coefficients, and we are concerned that energy losses might not be accurately represented particularly for shorter pipe lengths
- Initial water depth is not defined for the G. Ross Lord dam (calibration and verification events)
- Some of the junction invert elevations are based on the DEM elevation of the road pavement rather than the channel bottom (e.g. J852), which results in steeper slopes for downstream conduits.

Review the selected model procedures and methodologies

- The choice of measurement units was metric, and processes represented in the base model included rainfall/runoff (hydrology) and flow routing (hydraulics).
- The various simulation options were reviewed, and the following comments were noted, grouped by parameter type.

Infiltration Model

- The Modified Green-Ampt infiltration model was selected for computing infiltration in SWMM5. CHI agrees with the choice of this infiltration model, as it is the most physically-based model compared to the other options. Also, it is the most appropriate for handling variable water content conditions in the unsaturated soil zone.

Routing Method

- The Dynamic Wave option was selected with damped inertial terms in the solution of flow routing equations (i.e., “partial” damping). These are acceptable choices for the modeling objectives, and the other parameters selected for use with the dynamic wave solution are reasonable.

Reporting Time Step

- A reporting time step of five minutes was used. CHI believes the selected value is appropriate for the alternative scenarios evaluated considering five-minute time step used for the rain gauges. However, one consideration is the reporting time step used for calibration and verification events. In these cases, it is better if model reporting time step matches the flow monitoring time step.

Simulation Time Steps

- In SWMM5, there are three choices for computational time steps, two for hydrologic routing and one for hydraulic flow routing. In the Ex_DesignEvents.inp, both Wet and Dry hydrologic routing time steps were set to one minute. The wet time step is appropriate. Note that because the model is being run for a single event, as opposed to continuous simulation, the dry time step would likely not be used.
- The hydraulic flow routing time step was set to one second, which is appropriate for the dynamic wave solution. Depending on the time it takes to run the model (and the output file size), a smaller time step can be used, particularly if it is desired to reduce the overall continuity error.

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Parameter Defaults

- The SWMM5 defaults for the other simulation options are acceptable for the modeling objectives.

Associated Files

- In the Ex_DesignEvents model, there were no external files used by the base model; each time series dataset was directly included in the input file.
- For the calibration and verification scenarios, an external time series database file was read.

Validate subcatchment parameterization for appropriateness

- The subcatchment parameters are generally within an acceptable range for the modeling objectives.
- In total 52 subcatchments were flagged as potentially not representing the correct percent imperviousness, making up a total of 1755.93 ha, or 5% of the watershed area.
- Sensitive parameters in the model include: percent imperviousness, and the soil parameters representing saturated hydraulic Conductivity and Suction Head. Sample plots are shown below:

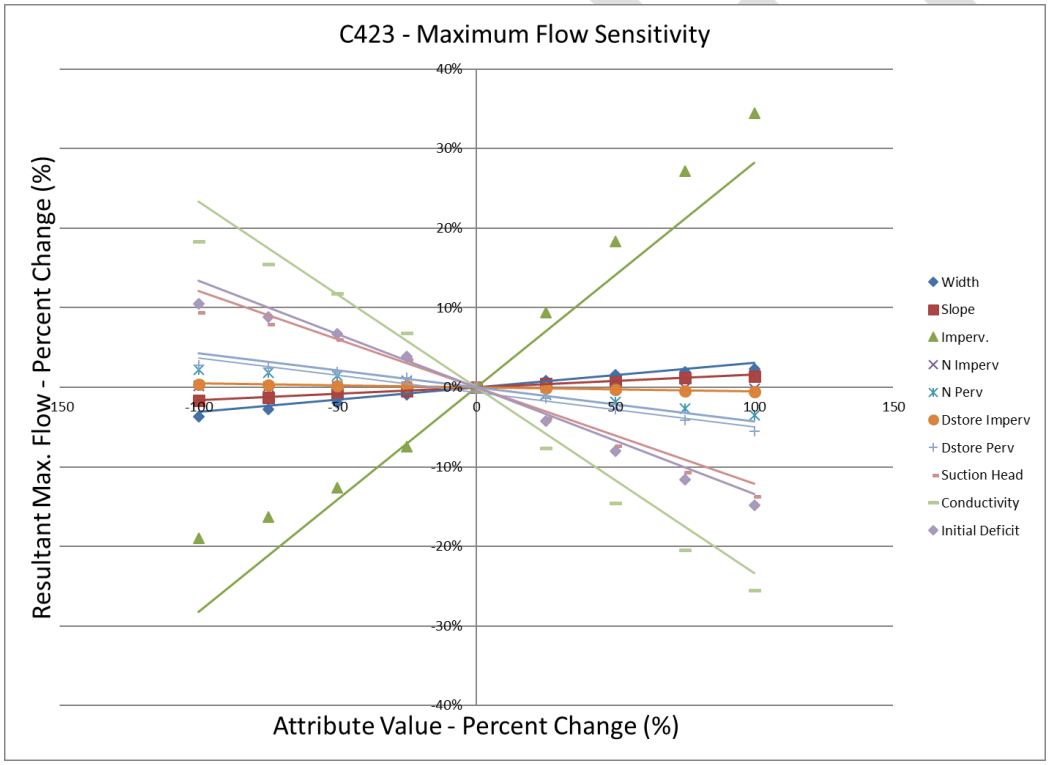


Figure 1 - Peak flow sensitivity at East Don @ Cummer (C423- Ex_DesignEvents.pcz)

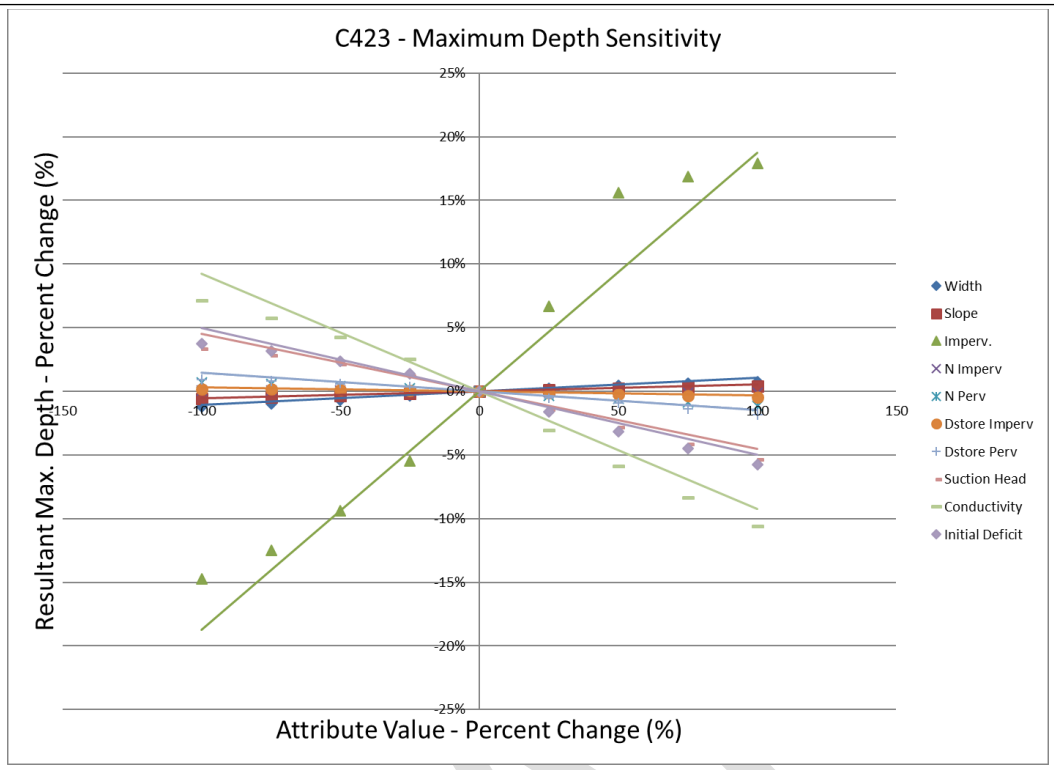


Figure 2 - Peak depth sensitivity at East Don @ Cummer (C423- Ex_DesignEvents.pcz)

- Less sensitive parameters include: depth of depression storage on pervious area (Dstore Perv.) and Manning's N for pervious area (N Perv.).
- Saturated hydraulic conductivity and Suction head values should be reviewed.
    - *Soils_omaf.SHP* map indicates that soils within the watershed are primarily clay and clay loam with some loam (i.e., the acceptable range for conductivity is 0.25 – 1.02 mm/hr)
    - Conductivity values in the original model ranges from 0.25 – 40 mm/hr with an average value of 10.4 mm/hr
    - While it is understood that surficial soils in urban areas can be highly disturbed and may contain imported soil, this large difference should be justified in the report.
- Suction head values should be reviewed.
    - Suction head values in the original model ranged from 88.9 – 320.04 mm with an average value of 101.55 mm
    - Re-estimated Suction head values ranged from 88.9 – 320.04 mm with an average value of 221.55 mm
- Subcatchment percent imperviousness estimates in the original Ex_DesignEvents.inp model are better than the values estimated based on land use for the majority of subcatchments.
- Two additional scenarios were created, and slope values were re-estimated using two coarser DEMs generated using the original DEM files provided. The two new DEMs were sampled at a 1 m and 2 m resolution. Generally, average subcatchment slope estimated from high resolution DEM tend to provide over-estimated values because of undulations at DEM cell level. A coarser DEM (5-10m) is more suitable to estimate hydrologically effective slope for subcatchments.

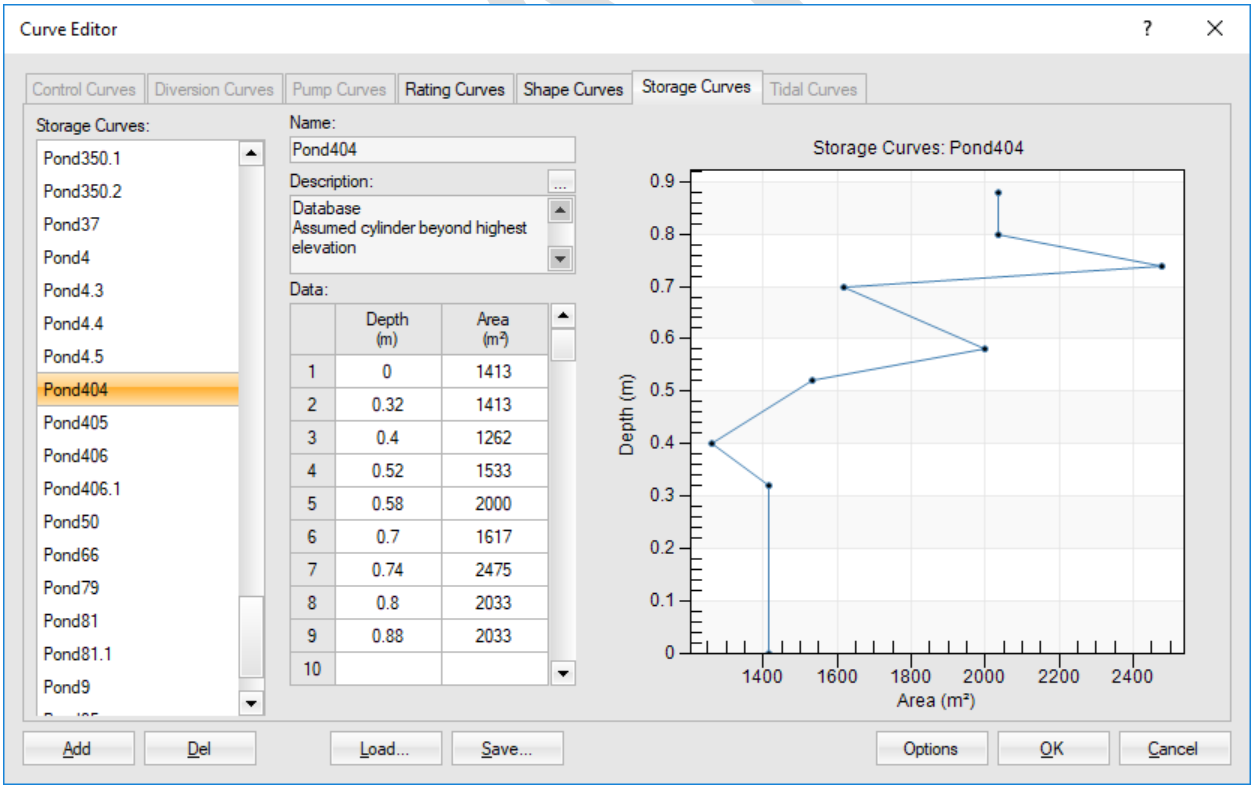
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Review the channel routing approach

- Subcatchments in the calibrated Don River model have a median flow length of 110 m (range 5 – 325 m) while the median area is 35 ha (range 0.1 – 200 ha).
- Although the highest values for subcatchment flow length and area are approximately 3 times the accepted values, the average value agrees with the accepted SWMM modelling criteria.

Assess the "lumped" SWM facilities in the model for consistency

- Storage outlet curves use a TABULAR/HEAD relationship, with the majority set up to represent the same invert elevations as the downstream junctions. This is a potential issue in cases when the downstream conduit has a higher water level, resulting in backwater effects.
- The impact of backwater effect will be more significant during conditions when downstream water levels are high.
- There are two rating curves (OL155 and OL95) with non-zero flow at depth zero, resulting in the outlet flows oscillating when the storage node is near empty.
- There are a few ponds with jagged storage area/depth curves.
- There are four ponds in the model representing lumped ponds and they are all in series (i.e., a composite model representation that reflects the cumulative storage area/depth curve of each pond, from upstream to downstream). There are no concerns regarding the representation of these ponds.



Review of the G. Ross Lord Dam representation

- The two spillway gates are closed in the non-regional event models (calibration/verification and analysis models) and removed in the regional event model.
- The rating curve was developed for the two low-level gates based on rate of rise and one gate opening and two gate opening tables (Tables A.2 and A.3 in the consultant's draft report Rpt_061418.pdf, June 2018) to regulate dam outflow. The lower level gates rating curve and spillway rating curve were not calibrated because the dam was closed during the calibration events. A description of how both rating curves were developed is needed in the consultant's report.

QA/QC for observed rainfall, flow and dam level data

- Spot checks using radar rainfall for several events indicate the rain gauge time series was not was not adjusted for daylight savings time in the 2013 rainfall timeseries, making the hyetographs off by one hour. Additional spot checks will be preformed to see if this is the case in other years.
- It is not known if the flow gauges accounted for the time change but it is advised it is checked.
- The one-hour shift may potentially change the hydraulic response time in the model.

Assessment of calibration/verification

- The model calibration has been undertaken considering multiple flow monitoring locations which contributes to better accuracy and lower uncertainty in model results.
- Discrete parameter values (instead of continuous values as used in SRTC tool) have been considered for calibration. This may be because the selected calibration events were far apart from each other and it was decided to estimate initial moisture deficit for each event separately.
- It is noted that the SRTC tool within PCSWMM can be used with all the events in a continuous simulation by consolidating events or by defining calibration events under simulation options (so that hydraulic routing is simulated only during defined events in order to reduce model run times). However, this approach requires a sufficient dry period prior to each event to use initial moisture deficit values that represent dry conditions. It is recommended a discussion about the calibration process should be added to the final report.
- Infiltration parameters as presented in Table 6 under section 3.5.1 of the consultant's report show calibrated values are different based on the gauge watersheds, instead of soil type. While it is understood that surficial soil conditions can be greatly affected in urban areas, some justification of calibrated values based on local soil types will increase the accuracy of model results. This is important considering the large variability in hydraulic conductivity among gauge watersheds. For example, adjacent gauge watersheds HY068 and HY019 have hydraulic conductivity values of 40 mm/hr and 3.3 mm/hr respectively.
- In addition to the reporting time step mentioned previously, it is more appropriate to use a rain gauge time step to match flow monitoring data time step. This would ensure simulation of flow response in the model similar to flow monitoring data. Flow estimation with five-minute rainfall data can provide larger five-minute peak flows (there would be some attenuation within the hydraulics) in comparison to 15-munite flow monitoring data. For example, flow timeseries data attached to the calibration/verification model scenario packaged files indicate flow data from HY019, HY062, HY068 and HY092 have 15-minute time step.

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Review and comment on the selection of parameters to be used for calibration

- From our sensitivity analysis it was determined that the infiltration parameters and percent imperviousness were sensitive parameters. While percent imperviousness is generally considered accurate when it is based on aerial images, the percentage of sub-area routing parameter is better quantified through calibration. The report should be updated to provide explanation as to why it was not included in the calibration.
- The flow length parameter was, in most cases, an insensitive parameter and the initial values already fall within an acceptable sheet flow length range.

Confirm assumptions made for subcatchments with sub-area routing

- The consultants modelling approach accounts for the value for the sub-area routing percentage comparing total rainfall volume and runoff volume for smaller events at each gauge location. This methodology provides different values for sub-area percent routed for drainage areas of each gauge location.
- While this is an acceptable creative approach for sub-area routing, it is interesting to evaluate whether assigning percent sub-area routed on a land use zoning basis is more accurate. Some justification of large variation in % routed among different drainage areas (in the range of 20-55%) based on distribution of different land uses would decrease the uncertainty of results.

Investigate the use of antecedent precipitation for Green-Ampt infiltration

- It is not clear in the draft report the purpose of the development of a relationship between Antecedent Precipitation Index (API) and Initial Moisture Deficit (IMD) values as it was not used in the model. Ideally, the relationship could have been used in the verification runs. Instead, it seems the verification runs used IMD values similar to values for the remaining events as indicated in Table 6 of the consultant's report. Justification for the approach that is based on computed API for the verification events is requested.
- It is recommended to include a reference in the report for the API equation on Page 21.
- Clarification on assigned IMD values based on the event API would add value to the final report. For example, Gauge HY062 watershed had highest API values for 2014-09-10 and 2015-06-27 events, but a lower IMD value representing wet conditions was assigned only for the 2013-07-08 event. Similarly, a lower IMD value was not assigned for the 2013-09-20 event for the Gauge 02HC056 watershed. Some discussion on this deviation would improve the report.
- Assigning IMD based on soil type would be more appropriate.

Suggested action items

- Review HEC-RAS transects and compare with merged PCSWMM transects and ensure slopes in the merged sections have been preserved;
- Indicate in the report the locations where there was a bridge or culvert in the HEC-RAS model that was not included in the PCSWMM model. Evaluate their sensitivity and provide justification as to why these structures were not included in the model;
- Assign urban and rural transects in downstream areas representative transects based on the DEM;

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- Confirm the loss coefficients assigned to the piped conduits and bridge shape curves are supposed to be 0. If so, explain why;
- Edit lumped storage rating curves OL155 and OL95 to have a non-zero flow at depth zero;
- Confirm jagged storage area/depth curves is representative of the total storage volume;
- Check that the rainfall time series and flow are timed correctly for 2013 (i.e. both not corrected for daylight savings time);
- Add a description of how G.Ross Lord Dam rating curves were developed in the report;
- Provide justification as to why many areas marked as having primary clay soils have infiltration values represented of loam;
- Provide justification as to why the infiltration parameters (specifically hydraulic conductivity and suction head) values are so varied across the watershed. For example, adjacent gauge watersheds HY068 and HY019 have hydraulic conductivity values of 40 mm/hr and 3.3 mm/hr respectively;
- It is recommended to explore whether some of the higher hydraulic conductivity estimates are caused by potential under estimation of upstream storage (due to exclusion of limiting hydraulic structures) and rain gauge reporting time steps not matching flow monitoring data time step (Is there a correlation between 15-minute flow data from HY062, HY068, HY092 gauges and higher hydraulic conductivity values for their watersheds);
- As a good modelling practice use a DEM resampled to a coarser resolution (5-10 m) for subcatchment slope calculation;
- Provide justification of large variation in percent routed among the different drainage areas;
- Provide an explanation for the development of a relationship between Antecedent Precipitation Index (API) and Initial Moisture Deficit (IMD) values as it was not used in the model. Ideally, the relationship could have been used in the verification runs. Instead, it seems the verification runs used IMD values similar to values for the remaining events as indicated in Table 6 of the consultant's report. Justification for the approach that is based on computed API for the verification events is requested;
- It is recommended to include a reference in the report for the API equation on Page 21;
- Add additional clarification on the assigned IMD values representing the wet conditions.

DRAFT

E-mail correspondence

Karen Finney

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: July 5, 2018 8:08 AM
To: Karen Finney
Cc: Wilfred Ho
Subject: BaseCamp

Hi Karen,

Can you please send me the list, and emails of CHI staff you would like included as part of the BaseCamp group for the Don Hydrology Peer Review.

Thanks,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
C: 416 991 3702
E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

Toronto and Region Conservation Authority (TRCA) | trca.ca

Karen Finney

From: Rhianydd Phillips (Basecamp) <notifications@basecamp.com>
Sent: July 6, 2018 8:46 AM
To: Karen Finney
Subject: You've been added to the Don River Hydrology Update Peer Review project on Basecamp



Rhianydd Phillips added you to this project on Basecamp.

Don River Hydrology Update Peer Review
Accept this invitation to get started

Hi there. We'll be using Basecamp to share ideas, gather feedback, and track progress during this project.

We're using Basecamp to collaborate. It's a website where we have discussions, share files and keep track of to-do lists.

If you're new to Basecamp, check out this 60 second video for tips to getting the most from Basecamp.

The other people added to this project are:
Moranne McDonnell, Nick Lorrain, Robert Chan, Wilfred Ho, hailiang@chiwater.com, and nandana@chiwater.com

You can also decline this invitation if you don't want to participate.

Karen Finney

From: Karen Finney
Sent: July 6, 2018 8:23 AM
To: Nick Lorrain
Cc: Wilfred Ho
Subject: RE: BaseCamp

Hi Nick,

The names and e-mails are as follows:

CHI Staff Name	e-mail
Karen Finney	karen@chiwater.com
Nandana Perera	nandana@chiwater.com
Hailiang Shen	hailiang@chiwater.com

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: July 5, 2018 8:08 AM
To: Karen Finney <karen@chiwater.com>
Cc: Wilfred Ho <who@trca.on.ca>
Subject: BaseCamp

Hi Karen,

Can you please send me the list, and emails of CHI staff you would like included as part of the BaseCamp group for the Don Hydrology Peer Review.

Thanks,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
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E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

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Karen Finney

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: July 13, 2018 9:51 AM
To: Karen Finney
Cc: Hailiang Shen; Nandana Perera; Wilfred Ho
Subject: Re: 2018 Don River Watershed Hydrology - Review Questions

Hi Karen,

We're pulling together a response with AECOM, I'll hopefully have something for you by the end of the day.

Regards,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
C: 416 991 3702
E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

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From: Karen Finney <karen@chiwater.com>
To: Nick Lorrain <nlorrain@trca.on.ca>, Wilfred Ho <who@trca.on.ca>,
Cc: Nandana Perera <nandana@chiwater.com>, Hailiang Shen <hailiang@chiwater.com>
Date: 11/07/2018 04:39 PM
Subject: 2018 Don River Watershed Hydrology - Review Questions

---

Hi Wilfred and Nick,

We had a few questions come up and wanted to ask before Wilfred leaves for the summer. The questions are as follows:

1. Can it be assumed we are reviewing only the existing model (as opposed to the future model)?
2. Could you provide the derivation of relationship between API and IMD and explanation of how this relationship is used?
3. Could you provide the methodology used for developing the lumped storage curves and lumped discharge curves?
4. In Background Data\From AECOM\DesignFlow20180424.xlsx, the peak flows with different return period AES storms are the same. Please provide the updated peak flows for AEC storms.
5. Could we get the 5-min historical (1940-2007) rainfall data used to develop the original IDF curve as well as the additional 15-min fata for 2008-2017 which was used to update the IDF curve?
6. For discussion: For evaluating unitary flow requirements for the watershed, we will use the same sub-basins for the areas north of Steeles Avenue as per the current guidelines. The evaluation will be based on peak flow results from the design storm scenarios under existing conditions. These will be compared with the current release rates developed from 2004 OTTHYMO model (it is noted that subcatchment parameters, i.e. imperviousness, may differ between the 2004 OTTHYMO model and the 2018 PCSWMM model).

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

Karen Finney

From: Karen Finney
Sent: July 16, 2018 9:38 AM
To: Nick Lorrain
Cc: Hailiang Shen; Nandana Perera; Wilfred Ho
Subject: RE: 2018 Don River Watershed Hydrology - Review Questions

Thank-you Nick. We will let you know if there are any follow-up questions.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: July 16, 2018 9:11 AM
To: Karen Finney <karen@chiwater.com>
Cc: Hailiang Shen <hailiang@chiwater.com>; Nandana Perera <nandana@chiwater.com>; Wilfred Ho <who@trca.on.ca>
Subject: Re: 2018 Don River Watershed Hydrology - Review Questions

Hi Karen,

Sorry for the delay, we're very busy right now... Please see the responses to the questions below in Red. I have also attached the output file and the data for the flood frequency analysis, as requested.

Please feel free to contact me should you have any further questions or concerns.

Regards,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
C: 416 991 3702
E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

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From: Karen Finney <karen@chiwater.com>
To: Nick Lorrain <nlorrain@trca.on.ca>, Wilfred Ho <who@trca.on.ca>,
Cc: Nandana Perera <nandana@chiwater.com>, Hailiang Shen <hailiang@chiwater.com>
Date: 11/07/2018 04:39 PM
Subject: 2018 Don River Watershed Hydrology - Review Questions

Hi Wilfred and Nick,

We had a few questions come up and wanted to ask before Wilfred leaves for the summer. The questions are as follows:

1. Can it be assumed we are reviewing only the existing model (as opposed to the future model)?
Because of the entirely urbanised nature of the Don watershed there is one modelling scenario, which is existing conditions, which is essentially a full built out conditions for the Don.
2. Could you provide the derivation of relationship between API and IMD and explanation of how this relationship is used?
Please review seciton 2.7.3.2 and 2.7.3.3 of the Draft summary report. Information related to the how API was calculated and translated into IMD is provided. We acknowledge that further discussion related to the conversion of API to IMD is required, as such please review and advise if you have any further questions or a need for clarification.
3. Could you provide the methodology used for developing the lumped storage curves and lumped discharge curves?
Lumped storage is the sum of individual ponds storage. Lumped discharge is the discharge of the most downstream ponds of the group.
4. In Background Data\From AECOM\DesignFlow20180424.xlsx, the peak flows with different return period AES storms are the same. Please provide the updated peak flows for AEC storms.
Please see attached file DesignFlow20180424.xlsx
5. Could we get the 5-min historical (1940-2007) rainfall data used to develop the original IDF curve as well as the additional 15-min fata for 2008-2017 which was used to update the IDF curve?
Please see attached file 6158355_HYL01_262-270.xlsb, also the attached PDF is an excerpt from a presentation Wilfred put together related to the treatment of the data for the IDF update.
6. For discussion: For evaluating unitary flow requirements for the watershed, we will use the same sub-basins for the areas north of Steeles Avenue as per the current guidelines. The evaluation will be based on peak flow results from the design storm scenarios under existing conditions. These will be compared with the current release rates developed from 2004 OTTHYMO model (it is noted that subcatchment parameters, i.e. imperviousness, may differ between the 2004 OTTHYMO model and the 2018 PCSWMM model).
Understood, the intend of the evaluation is to further verify the appropriateness of the updated model, however we understand that due to the differences in modelling methodology and data sources there will be some differences. As noted in the start up meeting we need to define thresholds in which to evaluate the model performance against the previous update. Also, I'm not sure we should be very focused on ensuring consistency with the previous model...

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

Karen Finney

From: Robert Chan <rchan@trca.on.ca>
Sent: July 23, 2018 4:23 PM
To: Karen Finney
Subject: RE: Don Hydrology Peer Review Progress

Hi Karen,

I can't seem to find that file, maybe Wilfred didn't save it on our server. Can you upload it somewhere for me to download?

Thanks,
Robert Chan, M.Eng., P.Eng.
Project Engineer, Capital Projects
Engineering Services | Restoration & Infrastructure

T: 416.661.6600 ext. 5728
C: 647.891.6982
E: rchan@trca.on.ca
A: 101 Exchange Avenue, Vaughan, Ontario L4K 5R6

Toronto and Region Conservation Authority (TRCA) | trca.ca

From: Karen Finney <karen@chiwater.com>
To: Robert Chan <rchan@trca.on.ca>
Cc: Nandana Perera <nandana@chiwater.com>, Nick Lorrain <nlorrain@trca.on.ca>
Date: 07/23/2018 02:41 PM
Subject: RE: Don Hydrology Peer Review Progress

Hi Robert,

Thank-you for checking in. We are doing well and still scheduled to have preliminary comments by late July/early Aug.

One thing I wouldn't mind requesting is the TRCA gage data in Excel format for the events included in the calibration/validation. I have not been able to open the TRCA database file named: DonHydrology.mdf and am assuming this is where the TRCA gage data is stored.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
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From: Robert Chan <rchan@trca.on.ca>
Sent: July 23, 2018 2:35 PM
To: Karen Finney <karen@chiwater.com>

Cc: Nandana Perera <nandana@chiwater.com>; Nick Lorrain <nlorrain@trca.on.ca>
Subject: Don Hydrology Peer Review Progress

Hi Karen,

Just wanted to check in on the Don Hydrology Peer Review project. Do you guys need anything from TRCA or have any questions? Are we still on-track to get preliminary comments late July or early August?

Thanks,
Robert Chan, M.Eng., P.Eng.
Project Engineer, Capital Projects
Engineering Services | Restoration & Infrastructure

T: 416.661.6600 ext. 5728
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E: rchan@trca.on.ca
A: 101 Exchange Avenue, Vaughan, Ontario L4K 5R6

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Karen Finney

From: Robert Chan <rchan@trca.on.ca>
Sent: July 23, 2018 5:01 PM
To: Karen Finney
Subject: RE: Don Hydrology Peer Review Progress

Hi Karen,

Was there a database .bak file provided by any chance?

Robert Chan, M.Eng., P.Eng.
Project Engineer, Capital Projects
Engineering Services | Restoration & Infrastructure

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Date: 07/23/2018 04:32 PM
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Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Robert Chan <rchan@trca.on.ca>
Sent: July 23, 2018 2:35 PM
To: Karen Finney <karen@chiwater.com>
Cc: Nandana Perera <nandana@chiwater.com>; Nick Lorrain <nlorrain@trca.on.ca>
Subject: Don Hydrology Peer Review Progress

Hi Karen,

Just wanted to check in on the Don Hydrology Peer Review project. Do you guys need anything from TRCA or have any questions? Are we still on-track to get preliminary comments late July or early August?

Thanks,
Robert Chan, M.Eng., P.Eng.
Project Engineer, Capital Projects
Engineering Services | Restoration & Infrastructure

T: 416.661.6600 ext. 5728
C: 647.891.6982

E: rchan@trca.on.ca
A: 101 Exchange Avenue, Vaughan, Ontario L4K 5R6

Toronto and Region Conservation Authority (TRCA) | trca.ca

Karen Finney

From: Robert Chan <rchan@trca.on.ca>
Sent: July 23, 2018 5:31 PM
To: Karen Finney
Subject: RE: Don Hydrology Peer Review Progress

hi Karen,

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From: Karen Finney <karen@chiwater.com>
To: Robert Chan <rchan@trca.on.ca>
Date: 07/23/2018 04:32 PM
Subject: RE: Don Hydrology Peer Review Progress

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Date: 07/23/2018 02:41 PM
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Karen Finney

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: July 23, 2018 4:23 PM
To: Karen Finney
Cc: Nandana Perera; Robert Chan
Subject: RE: Don Hydrology Peer Review Progress

Hi Karen,

Can you please upload the file to Basecamp, and we can see if we can convert the data into excel. I can't seem to find all the background information on the server, so I'm thinking Wilfred forgot to upload all the data from his laptop onto our server.

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
C: 416 991 3702
E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

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Cc: Nandana Perera <nandana@chiwater.com>, Nick Lorrain <nlorrain@trca.on.ca>
Date: 23/07/2018 02:41 PM
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A: 101 Exchange Avenue, Vaughan, Ontario L4K 5R6

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Karen Finney

From: Karen Finney
Sent: July 24, 2018 4:15 PM
To: Robert Chan
Subject: RE: Don Hydrology Peer Review Progress

Hi Robert,

I can access the rainfall data now. Thank-you for your efforts!

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Robert Chan <rchan@trca.on.ca>
Sent: July 24, 2018 12:07 PM
To: Karen Finney <karen@chiwater.com>
Subject: RE: Don Hydrology Peer Review Progress

Hi Karen,

Try giving this file a try, I think it fixes the permission errors. The file was also created using a new version of SQL so that might be an issue for CHI as well.

https://torontoregion-my.sharepoint.com/:f:/g/personal/michael_ellis_trca_on_ca/ErVFIfRZwr5Ihw2zhFOsw0wBe8RaUnJeufmbJKLKp7jPag?e=udkMSC

Robert Chan, M.Eng., P.Eng.
Project Engineer, Capital Projects
Engineering Services | Restoration & Infrastructure

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A: 101 Exchange Avenue, Vaughan, Ontario L4K 5R6

Toronto and Region Conservation Authority (TRCA) | trca.ca

From: Karen Finney <karen@chiwater.com>
To: Robert Chan <rchan@trca.on.ca>
Date: 07/24/2018 08:45 AM
Subject: RE: Don Hydrology Peer Review Progress

Hi Robert,

We do use a SQL to handle databases. I have one of our programmers looking to see if there is anything he can do on his end.

As for your other question, there was no .bak file provided.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
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519.767.0197 ext. 1005 | www.chiwater.com

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Subject: Don Hydrology Peer Review Progress

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Karen Finney

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: August 1, 2018 12:30 PM
To: Karen Finney
Cc: Robert Chan
Subject: Re: TRCA Don River Model Review - Progress

Hi Karen,

I believe Friday will work best for us... around 10:30 in the am.

Can you please send out the invite.

Thanks,

Nick

Sent from my iPhone using IBM Verse

On Aug 1, 2018, 12:05:26 PM, karen@chiwater.com wrote:

From: karen@chiwater.com
To: nlorrain@trca.on.ca
Cc: rchan@trca.on.ca
Date: Aug 1, 2018, 12:05:26 PM
Subject: TRCA Don River Model Review - Progress

Hi Nick,

We are wrapping up our preliminary findings and will be sending you a point form summary on Friday for review.

Could we please schedule a meeting next week via WebEx to discuss? There are several people away on holidays for the long-weekend, so I was hoping we could meet next week either on August 8th or Friday August 10th, preferably in the afternoon.

Let me know what works best for you.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

Karen Finney

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: August 8, 2018 10:36 AM
To: Karen Finney
Cc: Wilfred Ho; Robert Chan
Subject: Re: Don River Watershed Model - Progress memo

Hi Karen,

Thanks for sending this over, we really appreciate how thorough the review has been. I'm hopping you will be able to include an additional section in the progress memo explicitly stating what model revisions CHI feels needs to be completed, and what components of the report needs to be updated with additional documentation. Alternatively maybe provide a recommendation after every subsection of the memo.....

I want to be able to provide AECOM with clear and concise direction as to what they need to do in order to address your comments.

Thanks,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

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From: Karen Finney <karen@chiwater.com>
To: Nick Lorrain <nlorrain@trca.on.ca>,
Cc: Wilfred Ho <who@trca.on.ca>, Robert Chan <rchan@trca.on.ca>
Date: 08/08/2018 09:23 AM
Subject: Don River Watershed Model - Progress memo

Hi Nick,

I hope you had a lovely long weekend.

Please see our progress memo attached. We will be discussing our findings further on Friday.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

[attachment "CHI Memo (10007756) (2018.08.08) - Progress update.pdf" deleted by Nick Lorrain/TRCA]

Karen Finney

From: Karen Finney
Sent: August 10, 2018 8:48 AM
To: Nick Lorrain
Cc: Wilfred Ho; Robert Chan
Subject: RE: Don River Watershed Model - Progress memo
Attachments: TRCA Memo - Progress update_with action items.pdf

Hi Nick,

Please find the updated memo document attached. The suggested action items are listed at the end of the document.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Karen Finney
Sent: August 8, 2018 11:15 AM
To: 'Nick Lorrain' <nlorrain@trca.on.ca>
Cc: Wilfred Ho <who@trca.on.ca>; Robert Chan <rchan@trca.on.ca>
Subject: RE: Don River Watershed Model - Progress memo

Hi Nick,

Not a problem, I can send you an updated document before our meeting on Friday.

Sincerely,

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[attachment "CHI Memo (10007756) (2018.08.08) - Progress update.pdf" deleted by Nick Lorrain/TRCA]

Karen Finney

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: August 14, 2018 8:59 AM
To: Nandana Perera
Cc: Hailiang Shen; Karen Finney; Robert Chan; Wilfred Ho
Subject: RE: Don River Watershed Model - Progress memo

Thanks Nandana,

This is very much appreciated!

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
C: 416 991 3702
E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

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From: Nandana Perera <nandana@chiwater.com>
To: Nick Lorrain <nlorrain@trca.on.ca>,
Cc: Robert Chan <rchan@trca.on.ca>, Wilfred Ho <who@trca.on.ca>, Karen Finney <karen@chiwater.com>, Hailiang Shen <hailiang@chiwater.com>
Date: 14/08/2018 08:56 AM
Subject: RE: Don River Watershed Model - Progress memo

Hi Nick,

Please find attached the updated memo.
One additional comment included here is to explore whether the flow monitoring data time step had an impact during model calibration (if the flow data from some gauges have 15-min time step that may not capture peak flow response based on 5-min rainfall data/reporting time step).

Please do not hesitate to contact if you have any questions or require further clarifications. Thank you.

Best regards,

Nandana Perera, Ph.D., P.Eng.
Computational Hydraulics Int. (CHI)
www.chiwater.com
1-519-767-0197 ext. #1008



From: Karen Finney
Sent: August 10, 2018 4:17 PM
To: Nick Lorrain <nlorrain@trca.on.ca>
Cc: Robert Chan <rchan@trca.on.ca>; Wilfred Ho <who@trca.on.ca>; Nandana Perera <nandana@chiwater.com>; Hailiang Shen <hailiang@chiwater.com>
Subject: RE: Don River Watershed Model - Progress memo

Hi Nick,

Please find a PDF of the PPT slides attached. It seems I spoke too soon when I said we would have the updated memo by the end of today as Nandana would like to do a few more tests before sending a recommendation.

Please expect to have the updated memo sometime Monday.

Hope everyone has a great weekend!

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: August 10, 2018 8:55 AM
To: Karen Finney <karen@chiwater.com>
Cc: Robert Chan <rchan@trca.on.ca>; Wilfred Ho <who@trca.on.ca>
Subject: RE: Don River Watershed Model - Progress memo

Thanks Karen,

This is great, we look forward to the conference call.

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
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[attachment "TRCA Memo - Progress update_with action items.pdf" deleted by Nick Lorrain/TRCA]

[attachment "TRCA Memo - Progress update_with action items_Aug14_18.pdf" deleted by Nick Lorrain/TRCA]

Karen Finney

From: Meghan Korman
Sent: August 20, 2018 10:01 AM
To: nlorrain@trca.on.ca
Cc: Karen Finney; Mike Gregory
Subject: E754 - Don River Review CHI invoice #25480
Attachments: CHI Invoice #25480.pdf

Good morning Nick,

Attached please find the invoice due on the work completed for the Don River Hydrology Review.

If you have any questions please contact Karen or Mike.

Regards,

Meghan Korman
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1001 | www.chiwater.com

Karen Finney

From: Karen Finney
Sent: September 26, 2018 10:09 AM
To: Hailiang Shen; Nandana Perera
Subject: Re: Don Hydrology Peer Review - September 24 Conference Call

Hi Hailiang,

That is great the conference call went well. I have been working on the report and will continue to when I have the opportunity to do so (airport and breaks).

Could you please be sure to edit the online report? That way we always have the latest version.

Cheers,

Karen Finney M.Sc. Eng. P.Eng.
Environmental & Water Resources Analyst

Computational Hydraulics International
www.chiwater.com

From: Hailiang Shen
Sent: September 26, 2018 8:56:59 AM
To: Wilfred Ho; Nandana Perera; Karen Finney
Cc: Nick Lorrain
Subject: RE: Don Hydrology Peer Review - September 24 Conference Call

Wilfred, we have gone through the stormwater ponds and selected five ponds with jagged curve for verification, see attachment.

The steps for our selection are:

- iterate each storage pond and check their storage curve for jags,
- for each curve, we check from depth 0 to maximum, after we found the first jag (Area[i+1] < Area[i]), we note the curve as jagged. There are a total of 49 jagged curves,
- for each jagged curve, we also grabbed the modeled average and max storage depth to review whether the jag may impact results,
- if a pond has avg or max depth within or greater than the first jagged depth range (Depth[i] to Depth[i+1]), we highlight it. If avg or max depth is below the jag depth range, the results will not be impacted by the jag.

We used model Ex_DesignEvents.pcz for this selection. Any questions, please let us know.

Thanks and have a good day.

Hailiang Shen, Ph.D., P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1015 | hailiang@chiwater.com | www.chiwater.com

From: Wilfred Ho <who@trca.on.ca>
Sent: September 24, 2018 10:54 AM

To: Nandana Perera <nandana@chiwater.com>; Hailiang Shen <hailiang@chiwater.com>; Brian Richert <Brian.Richert@aecom.com>; Olivia Chung <Olivia.Chung@aecom.com>
Cc: Nick Lorrain <nlorrain@trca.on.ca>
Subject: Don Hydrology Peer Review - September 24 Conference Call

Hello all,

Please find attached a spreadsheet summarizing action items from today's conference call:

If there are any significant changes from what was written, please let me know and I will update the document.

Cheers,

Wilfred Ho, B.E.S.
Analyst, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416.661.6600 ext. 5738
E: who@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

Toronto and Region Conservation Authority (TRCA) | trca.ca

Karen Finney

From: Hailiang Shen
Sent: September 28, 2018 9:09 AM
To: Nick Lorrain; Wilfred Ho
Cc: Karen Finney; Nandana Perera
Subject: Don Hydrology Peer Review - invoice for Work completed up to Sep 28, 2018
Attachments: CHI invoice 25825.pdf

Nick and Wilfred, please find our invoice in attachment. Any questions, please let us know.

Have a great weekend,

Hailiang

Hailiang Shen, Ph.D., P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1015 | hailiang@chiwater.com | www.chiwater.com

Karen Finney

From: Karen Finney
Sent: October 31, 2018 3:24 PM
To: 'Wilfred Ho'
Cc: Nandana Perera (nandana@chiwater.com); Hailiang Shen
Subject: RE: Don Hydrology Peer Review Status

Hi Wilfred,

Than-you for sending the worksheet. The CHI team met and discussed the AECOM responses and feel AECOM has addressed most of the comments satisfactorily, utilizing available data. We do have the following comments:

- Item 1: Are the graphs in the 'Test Runs' tab included in the *Don Hydrology Update Peer Review Comments – AECOM Response* testing the sensitivity of the HEC-RAS transects in the model?
- Item 9/10: We are still not convinced the soil characteristics would be more representative as a loam over a clay. There is still some uncertainty whether the soil infiltration values used in few subcatchments are over estimated.

To finalize our comments, could you send the following:

- Updated Excel file DesignFlow20180424.xlsx with the latest modeled flows. CHI will compare the modeled flows summarized in this file with the 2004 model.
- Updated models for calibration, verification, and design events including resampled 15 min rainfall data.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Wilfred Ho <who@trca.on.ca>
Sent: October 29, 2018 11:06 AM
To: Nandana Perera <nandana@chiwater.com>; Hailiang Shen <hailiang@chiwater.com>
Cc: Karen Finney <karen@chiwater.com>
Subject: Fw: Don Hydrology Peer Review Status

Hello folks,

Please find in the forwarded correspondence, AECOM's actions to CHI's recommendations.

Cheers,

Wilfred Ho, B.E.S.
Analyst, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416.661.6600 ext. 5738
E: who@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

Toronto and Region Conservation Authority (TRCA) | trca.ca
----- Forwarded by Wilfred Ho/TRCA on 10/29/2018 11:04 AM -----

From: "Richert, Brian" <Brian.Richert@aecom.com>
To: Wilfred Ho <who@trca.on.ca>, "Chung, Olivia" <Olivia.Chung@aecom.com>
Cc: Nick Lorrain <nlorrain@trca.on.ca>
Date: 10/23/2018 03:32 PM
Subject: RE: Don Hydrology Peer Review Status

Wilfred / Nick
The final responses to the CHI review comments are attached.
We have made any referenced model changes, and have re-run the design events in the updated model.
The report edits are made and the Appendices are compiled-- we can quickly compile the whole document once you want it resubmitted
Let me know if you want me to wait until CHI signs off on these responses, or if you want the final compiled report now
('Now' might mean Friday, since I'm out the office tomorrow)
Brian

Brian Richert, P. Eng
Senior Water Resources Engineer, Water, Ontario
D 519-963-5868 C 519-280-5797
Cisco 3225868
brian.richert@aecom.com

AECOM Canada Ltd.
410-250 York Street
London, ON N6A 6K2, Canada
T +1-519-673-0510
aecom.com

Karen Finney

From: Wilfred Ho <who@trca.on.ca>
Sent: November 14, 2018 9:30 AM
To: Nandana Perera
Cc: Nick Lorrain; Karen Finney; Hailiang Shen
Subject: RE: Don River Hydrology Update - Peer Review Status

Hello Nandana,

Do you need the table updated for all events or just the storms that will be used for regulatory (future conditions Regional) and design purposes (12-hr AES)?

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To: Nick Lorrain <nlorrain@trca.on.ca>, Karen Finney <karen@chiwater.com>
Cc: Wilfred Ho <who@trca.on.ca>, Hailiang Shen <hailiang@chiwater.com>
Date: 11/14/2018 08:28 AM
Subject: RE: Don River Hydrology Update - Peer Review Status

Hi Nick,

I am responding to your e-mail as Karen is currently attending the Latornell Symposium.
We are finalizing the report and updating some tables based on the revised model results. We are planning to send you the final version of the report early next week. AECOM has addressed CHI's comments satisfactorily and the updated spreadsheet with our responses is attached here.

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Best regards,

Nandana Perera, Ph.D., P.Eng.
Computational Hydraulics Int. (CHI)
www.chiwater.com
1-519-767-0197 ext. #1008

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: November 13, 2018 7:41 AM
To: Karen Finney <karen@chiwater.com>
Cc: Wilfred Ho <who@trca.on.ca>; Nandana Perera <nandana@chiwater.com>; Hailiang Shen <hailiang@chiwater.com>
Subject: Don River Hydrology Update - Peer Review Status

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Please contact me should you have any questions or concerns.

Regards,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
C: 416 991 3702
E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

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[attachment "Don Hydrology Update Peer Review Comments - AECOM Response- 10'23'18_CHI Response.xlsx" deleted by Wilfred Ho/TRCA]

Karen Finney

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: November 14, 2018 10:19 AM
To: Nandana Perera
Cc: Hailiang Shen; Karen Finney; Wilfred Ho
Subject: RE: Don River Hydrology Update - Peer Review Status

Hi Nandana,

Thanks for the clarification, this is an issue we are continually struggling with. Please ensure that in the final report, if you are making a statement like this, you provide a qualifier, stating that this is still the best practice and the model characterises watershed response in lieu of having a Hurricane Hazel type event.

We are being pushed for the final report, can you please complete and send it to us as soon as possible.

Thanks,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416 661 6600 ext. 5278
C: 416 991 3702
E: nlorrain@trca.on.ca
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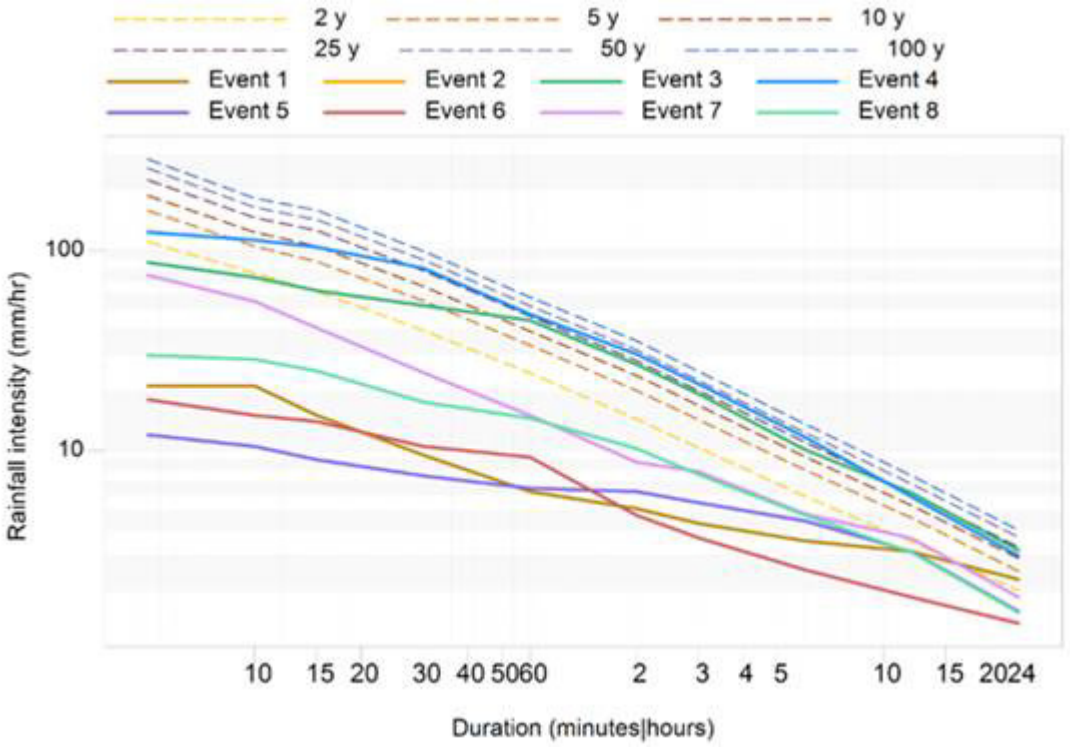
Toronto and Region Conservation Authority (TRCA) | trca.ca

From: Nandana Perera <nandana@chiwater.com>
To: Nick Lorrain <nlorrain@trca.on.ca>,
Cc: Hailiang Shen <hailiang@chiwater.com>, Karen Finney <karen@chiwater.com>, Wilfred Ho <who@trca.on.ca>
Date: 14/11/2018 10:11 AM
Subject: RE: Don River Hydrology Update - Peer Review Status

Hi Nick,

This is a challenge with model calibration with large storm events. It is not easy to find large historical storm events with reliable data for calibration (even if there are events, monitoring data may have some uncertainty due to malfunctioning of rain gauges/flow gauges, flows may be higher than the available gauge rating curve etc.) for extreme event evaluation. For example, the storm events used for calibration/verification for this model are less than 100 year return period. Therefore, when the model is used to simulate much larger events we are extrapolating the flow responses from a model calibrated for more frequent events, which involves some uncertainty. That is the reason I indicated that there is some uncertainty involved with simulations of the regional and 350-year storm.

Having said that, in practical terms, this meets or exceeds the current state of the practice. In many situations modellers do not have access to the extent of events that were available for this study. I am attaching the calibration/verification events in comparison to the IDF curve.



Hope this clarifies my comment. Please do not hesitate to contact us if you have any further questions. Thanks.

Best regards,

Nandana Perera, Ph.D., P.Eng.
Computational Hydraulics Int. (CHI)
www.chiwater.com
1-519-767-0197 ext. #1008

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: November 14, 2018 9:08 AM
To: Nandana Perera <nandana@chiwater.com>
Cc: Hailiang Shen <hailiang@chiwater.com>; Karen Finney <karen@chiwater.com>; Wilfred Ho <who@trca.on.ca>
Subject: RE: Don River Hydrology Update - Peer Review Status

Hi Nandana,

Thanks for the update. We will be sending over the excel sheet shortly. Can you please clarify your 2nd commend related to the 350 and Regional storm simulations. The entire exercise has been about the establishment of new Regional storms flows for floodplain mapping and flood remediation purposes, so I'm concerned with comments like "there is some uncertainty using the model for simulations of the regional of .50-year storm".

Regards,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

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From: Nandana Perera <nandana@chiwater.com>
To: Nick Lorrain <nlorrain@trca.on.ca>, Karen Finney <karen@chiwater.com>,
Cc: Wilfred Ho <who@trca.on.ca>, Hailiang Shen <hailiang@chiwater.com>
Date: 14/11/2018 08:28 AM
Subject: RE: Don River Hydrology Update - Peer Review Status

Hi Nick,

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We are finalizing the report and updating some tables based on the revised model results. We are planning to send you the final version of the report early next week. AECOM has addressed CHI's comments satisfactorily and the updated spreadsheet with our responses is attached here.

The current model has been calibrated with the largest storm events occurred during last 10 years. However, considering their event magnitudes within the watershed, there is some uncertainty using the model for simulation of regional or 350-year design storm.

As indicated in our previous e-mail, we would appreciate if you could send the updated Excel file: DesignFlow20180424.xlsx with the latest modeled flows (to revise the table in our report). Thank you.

Best regards,

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Subject: Don River Hydrology Update - Peer Review Status

Hi Karen,

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Please contact me should you have any questions or concerns.

Regards,

Nick

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Toronto and Region Conservation Authority (TRCA) | trca.ca

[attachment "Don Hydrology Update Peer Review Comments - AECOM Response- 10'23'18_CHI Response.xlsx" deleted by Nick Lorrain/TRCA]

Karen Finney

From: Nandana Perera
Sent: November 14, 2018 10:38 AM
To: Wilfred Ho
Cc: Nick Lorrain; Karen Finney; Hailiang Shen
Subject: RE: Don River Hydrology Update - Peer Review Status
Attachments: DesignFlow20180424.xlsx

Hi Wilfred,

We were thinking of including all the design storm scenarios. That data was included in the spreadsheet provided by AECOM (I am attaching the original spreadsheet). If you have received the updated spreadsheet you can send it. Otherwise please send the updated Appendix G: Design flow – existing in the report. What we require is the 2004 model flow and updated model flows with AES 12 hr storm. Thanks.

Best regards,

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Cc: Nick Lorrain <nlorrain@trca.on.ca>; Karen Finney <karen@chiwater.com>; Hailiang Shen <hailiang@chiwater.com>
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Hello Nandana,

Do you need the table updated for all events or just the storms that will be used for regulatory (future conditions Regional) and design purposes (12-hr AES)?

Wilfred Ho, B.E.S.
Analyst, Capital Projects
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Please contact me should you have any questions or concerns.

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Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

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E: nlorrain@trca.on.ca
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Toronto and Region Conservation Authority (TRCA) | trca.ca

[attachment "Don Hydrology Update Peer Review Comments - AECOM Response- 10'23'18_CHI Response.xlsx" deleted by Wilfred Ho/TRCA]

Karen Finney

From: Wilfred Ho <who@trca.on.ca>
Sent: November 14, 2018 11:39 AM
To: Nandana Perera
Cc: Hailiang Shen; Karen Finney; Nick Lorrain
Subject: RE: Don River Hydrology Update - Peer Review Status
Attachments: DesignFlow20181018.xlsx

Hello Nandana,

I've attached AECOM's updated table.

Hopefully, this helps with your reporting.

Take care,

Wilfred Ho, B.E.S.
Analyst, Capital Projects
Engineering Services | Restoration and Infrastructure

T: 416.661.6600 ext. 5738
E: who@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

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Regards,

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Senior Manager, Capital Projects
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[attachment "Don Hydrology Update Peer Review Comments - AECOM Response- 10'23'18_CHI Response.xlsx" deleted by Wilfred Ho/TRCA]

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Nick

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Senior Manager, Capital Projects
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[attachment "Don Hydrology Update Peer Review Comments - AECOM Response- 10'23'18_CHI Response.xlsx" deleted by Nick Lorrain/TRCA]

Karen Finney

From: Karen Finney
Sent: November 20, 2018 1:05 PM
To: 'Nick Lorrain'
Subject: RE: Don River Hydrology Review - Report

Of course, here is a link: http://www.chiwater.com/Files/Don%20River%20Model%20Hydrology%20Review%20-%20Report%202018.11.20%20(CHI).docx

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: November 20, 2018 12:09 PM
To: Karen Finney <karen@chiwater.com>
Subject: Re: Don River Hydrology Review - Report

Hi Karen,

Can you please send us a word version of the report, it would be easier for us to track changes and provide comments within word.

Thanks,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

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Cc: Wilfred Ho <who@trca.on.ca>, Nandana Perera <nandana@chiwater.com>, Hailiang Shen <hailiang@chiwater.com>
Date: 20/11/2018 11:59 AM
Subject: Don River Hydrology Review - Report

Hi Nick,

The final Don River Hydrology Review report can be downloaded via following link:
http://www.chiwater.com/Files/Don%20River%20Model%20Hydrology%20Review%20-%20Report%202018.11.18%20(CHI).pdf

Please let us know if you have any questions or concerns.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
Computational Hydraulics Int. (CHI)
519.767.0197 ext. 1005 | www.chiwater.com

Karen Finney

From: Karen Finney
Sent: November 21, 2018 11:15 AM
To: Nick Lorrain
Cc: Hailiang Shen; Nandana Perera; Wilfred Ho
Subject: RE: Don River Hydrology Review - Report

Thanks Nick. We aim to have the revised report finished by the end of the week.

Sincerely,

Karen Finney M.Sc. Eng. P.Eng.
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519.767.0197 ext. 1005 | www.chiwater.com

From: Nick Lorrain <nlorrain@trca.on.ca>
Sent: November 21, 2018 10:59 AM
To: Karen Finney <karen@chiwater.com>
Cc: Hailiang Shen <hailiang@chiwater.com>; Nandana Perera <nandana@chiwater.com>; Wilfred Ho <who@trca.on.ca>
Subject: Don River Hydrology Review - Report

Hi Karen,

Thanks for sending the draft report over for review. I have reviewed and redlined the document which I will be providing you via OneDrive shortly. Based on my review of the document I think a format change is required to fully explain the process and tie the review process off with AECOM's responses. The way the report is currently written would imply that CHI has provided comments, and has approved the model without a thorough response from AECOM.

I would like to see the following main components (or something similar) for the report:

- Define the peer review process
- Communicate CHI's initial peer review comments
- Communicate AECOM's response to the initial comments
- Communicate CHI's concurrence with AECOM's responce
- Conclusions and Recommendations

In addition we need to include a Appendix for correspondence, and include all correspondence to and from TRCA, CHI, and AECOM.

The report will eventually be provided to MNRF and we need to be very clear that CHI provided detailed comments to improve and validate the model and methodology used to develop Regional Flows, and AECOM has taken the comments, revised the model, and clearly defined the modelling approach.

Please give me a call if you have any questions or concerns.

Regards,

Nick

Nick Lorrain, C.E.T
Senior Manager, Capital Projects
Engineering Services | Restoration and Infrastructure

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C: 416 991 3702
E: nlorrain@trca.on.ca
A: 101 Exchange Avenue | Vaughan, Ontario L4K 5R6

Toronto and Region Conservation Authority (TRCA) | trca.ca

Karen Finney

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Follow Up Flag: Follow up
Flag Status: Flagged

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