Calgary

Prepared for: City of Calgary - Water Resources

Confederation Park Regional Drainage Study

Final Report

Associated Engineering

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Appendix C - Model Build

3 Model Build

3.1 OVERVIEW

Stormwater modelling was conducted for the N25 catchment to better understand regional drainage issues within the area. The model was developed with a high level of accuracy within the entire watershed; however, the focus of the modelling was on: the Upper and Lower Confederation Trunks; and the Confederation Valley. This modelling technique creates hydrographs which more accurately reflect upstream attenuation and time to peaks when compared to traditional lumped modelling techniques.

AE built a detailed stormwater model to understand the hydrologic and hydraulic regime of The Study area. The model was built within the PCSWMM modelling software using The City's GIS database and has a one dimensional minor and major system. Figures related to the model build are included within **Appendix A**.

3.2 HYDRAULIC MODELLING

The scope and accuracy of a hydraulic model is dependent on the model's dimensions and the amount of input data. A hydraulic model with extensive input data, detailed calibration and an advanced computational engine will yield very accurate results; however, it will not be suitable for all applications.

3.2.1 Model Dimensions

The model used for this study is a one-dimensional model. Details on model dimensions are provided below:

- One dimensional models are characterized by defined flow paths (i.e., major and minor system links). Flows are allowed to travel along defined paths, but not outside of those paths. One dimensional models have a simple degree of complexity and are suitable for modelling of large scale systems.
- Two dimensional models are characterized by a major system which is represented by a digital elevation model. Flows are allowed to travel horizontally in two directions within the major system and results accurately show inundation extents and flow paths. Two dimensional models have a high degree of complexity and are suitable for modelling of medium scale systems.
- Three dimensional models are characterized by flow in the horizontal and vertical planes. Flows are allowed to travel in any direction. Three dimensional models have a high degree of complexity and are suitable for modelling of small-scale systems.

3.2.2 Model Types

The model used for this study is a detailed model. Details on model types are provided below:

- Skeletal models are characterized by a simplified minor system. They are typically one dimensional and may not have a major system. The minor system in this type of model is comprised of only the largest diameter trunks. Skeletal models are suitable for evaluating a trunk system within a large area.
- Detailed models are characterized by a complete minor system. This includes all laterals in addition to the trunks. Service connections and catchbasin leads are typically excluded but can be added provided sufficient data is available.
- Semi-detailed models are somewhere in between skeletal models and detailed models. They are typically simplified based upon available data and modelling effort.

3.3 MODEL BUILD

The model used for this study is a concurrent, dual drainage model. Dual drainage models are characterized by having four distinct parts: catchments; a minor system, a major system, and a series of connections between the major and minor systems. Concurrent, dual drainage models are characterized by the ability to evaluate flow exchange between the major and minor systems during a single model run.

3.3.1 Catchments

Delineation

AE delineated catchment areas at a catchbasin level using The City's 1 m resolution LIDAR. Catchment areas within Nose Hill were split into steep and flat areas to isolate the plateau from the escarpment. This allowed for variation of hydrologic parameters and served to reduce runoff from the plateau during low intensity rainfall events. Refer to **Figure 3-1** for details.

Parameterization

Catchment parameters were determined with The City's GIS data. AE used the Green-Ampt formulas to determine infiltration. Catchment parameters are shown within **Table 3-1**.

Table 3-1
Catchment Parameters

Location	Soil	Suction Head (mm)	Conductivity (mm/hour)	Initial Deficit (%)	Impervious Depression Storage (mm)	Pervious Depression Storage (mm)
Nose Hill	Silt Loam	170	6.604	20	1.6	10
Park Spaces	Sandy Clay Loam	220	1.524	20	1.6	7.5
Other Areas	Sandy Clay Loam	220	1.524	20	1.6	2.5

The underlying soils within Calgary are predominantly silty/sandy clays. These soils are overlain with top soil which has a much higher infiltration capacity. For single event rainfall, AE neglected the deep infiltration capacity of the silty/sandy clays and assumed that infiltration is governed by the top soil. Geotechnical review of the catchment parameters has not been conducted.

3.3.2 Minor System

AE used The City's GIS data to create a detailed minor system. Refer to **Figure 3-2** for details. Included and excluded features are indicated below.

Included:

- Pipes greater than or equal to 300 mm
- Manholes
- Catchbasins
- Catchbasin Leads
- Major Building Services
- Private Pipes

Excluded:

- Perforated Pipe
- Weeping Tile

The City's GIS data is missing some of its tabular data on smaller diameter pipes and catchbasin leads. This is particularly true for private infrastructure. The missing data was supplemented as indicated within **Table 3-2**.

Table 3-2
Minor System Assumptions

Entity	Missing Data	Assumption
Pipes	Inverts	Missing inverts were interpolated between up and downstream nodes. Where there are multiple branches, precedence was given to the longest branch.
Pipes	Diameter	Missing diameters were assumed to be the smaller diameter of the up and downstream pipes.
Catchbasin Leads	Inverts	Missing upstream inverts were assumed to have an obvert 1.2 m below surface. Catchbasin leads were assumed to have a slope of 2% to determine the missing downstream invert. Where a 2% slope wasn't achievable, a minimum upstream cover of 0.6 m was assumed.
Manholes	Rims	Rim elevations were obtained from the DEM.

Manhole losses were approximated for each structure, taking into consideration:

- Pipe bends through the structure.
- The sizes of the structure and incoming / outgoing pipes.
- The drop across the structure.
- The presence of plunging flow, benching and multiple inlets.

3.3.3 Major System

Street Network

AE developed the major system model within the study area using information from The City's GIS database. Topographical high and low points on roadways were identified and incorporated into a set of nodes and links. The links represent flow on roadways within the dual drainage model and have a representative cross section to convey flow.

Storage within trap lows on the street network was modelled within the major system transects. This method captures storage on public right of ways but not private property. Not considering storage on private property increases the anticipated ponding depths on the street network. Considering storage on private property requires a two-dimensional, dual drainage model.

AE reviewed the street links and supplemented them where overland flow paths were identified to cross private property. Although many private property flow paths were identified, the modelled major system does not include all overland flow paths. This is a typical assumption for one dimensional dual drainage models. Refer to **Figure 3-3** for details on the major system.

AE modified the backlanes by increasing their elevations by 0.15 m. This increase in elevation takes into account the height of the curb which is missed because the streets are modelled based on their centrelines. Typically, this allows the backlanes to shed water onto the streets and prevents water from the streets rushing down backlanes where the depth is less than the height of the curb.

Confederation Creek

AE identified a flat Hydraulic Grade Line (HGL) through Confederation Creek when reviewing models created early in The Study. The flat HGL was due to severe capacity restrictions caused by the culverts at 14th Street NW, 10th Street NW and 30th Avenue NW. These early models used cross sections and creek centrelines to delineate the creek. This methodology assumed that storage volume was held in the cross section. The accuracy of the storage volume was dependent on the frequency of cross sections. However, increasing the number of cross sections reduced the model's routing stability. Flows oscillated severely between adjacent sections while the model attempted to distribute water.

Hence, AE and The City agreed to change the configuration of Confederation Creek in the model to a series of storage nodes. These storage nodes represent the entire trap low at their respective crossings. The benefits to this approach include: more accurate estimations of storage volumes and ponding depths; and reduced routing instability. However, the model inaccurately estimates the HGL within the creek because the storage nodes cannot have a spatially varying HGL. This limitation does not affect the results of the model because the areas upstream of the embankments predominantly function as storages during high intensity rainfall events. The City would have to re-evaluate this assumption if detailed results (i.e., channel velocities, impacts of bridges, detailed tailwater, etc.) are necessary within Confederation Creek.

3.3.4 Major / Minor Connections

Major to Minor Connections

Major to minor connections represent catchbasin grates. Each connection is assigned a rating curve representative of the grate type. Major to minor connections were modelled as one-way flow links.

The City separates catchbasins into two categories: flow-by and ponding. Ponding catchbasins are typically situated within trap lows and have a static pool of water on top of them. Flow-by catchbasins do not have a static pool above them and capture a percentage of the incoming flow. AE decided to model all catchbasins using rating curves for ponding catchbasins for the following reasons:

- Flow-by and ponding catchbasins are not separated within The City's GIS data.
- There is potential for flow-by catchbasins to function as ponding catchbasins during large storm events.
- PCSWMM does not allow flow separation by incoming flow within dynamic wave models. This can be mitigated by converting incoming flow to depth; however, depth is based upon incoming slope, cross section and manning's coefficients. As a result, dozens of capture depth curves would be required to accurately model flow-by catchbasins.

Modelling flow-by catchbasins as ponding catchbasins does not affect the results of the model within the extents of: the Upper and Lower Confederation Trunk; and the Confederation Valley. This is because flows are much higher in downstream reaches and there is significant attenuation within the system. The system should be further evaluated if results are necessary within local upstream areas of the model.

Minor to Major Connections

Minor to major connections (or surcharge conduits) represent the minor system surcharging to surface. These connections were modelled as 0.5 m, one-way flow, square conduits.

AE modelled a loss coefficient of 1 on the surcharge conduits. This loss coefficient forces the level of water in the minor system to be higher than the level of water in the major system. This assumption was made to model the difference in head observed from surcharging manholes.

3.4 MODEL HYDROLOGY

Storm events

Storm events for analytical purposes were selected from The City's "*Stormwater Management and Design Manual*" (City of Calgary, 2011). Refer to **Table 3-1**.

Climate Change

Given that the storm events presented in the 2011 Manual do not yet reflect climate change conditions, AE used the Western University's IDF_CC Tool (Western University Canada, 2018) to estimate the anticipated impacts of climate change.

The IDF_CC Tool uses data from 1947 to 2009 collected from 700 Environment and Climate Change Canada operated rain stations across Canada, as well as data generated from forward looking global climate models to generate IDF curve information based on historical data, as well as future climate conditions that can inform infrastructure decisions. The results are based on an ensemble of 24 Global Climate Models (GCMs), under different future emission scenarios known as Representative Concentration Pathways (RCPs).

AE applied RCP 8.5 given that "*The current global emissions trajectory is tracking higher than the worst-case scenario*" (APEGBC, 2016) and "*Generally, the most relevant scenario for infrastructure design and assessment is RCP 8.5*." (APEGBC, 2016). AE also applied a time horizon of 2075, and data from the Calgary International Airport's rainfall gauging station. The resultant IDF curves were used to generate the variation of the rainfall intensity with time. The 100-year storm event saw a 17 % increase in peak intensity and a 27 % increase in volume when compared to the storm events from The City's Stormwater Management and Design Manual. Refer to **Table 3-3**.

Table 3-3
Storm Event Information

Return Period	Existing Condition		Future Condition	
	Peak 5 min Interval Intensity (mm/hr)	Rainfall Depth (mm)	Peak 5 min Interval Intensity (mm/hr)	Rainfall Depth (mm)
2	58.2	21.4	71.8	25.6
5	86.7	29.8	103.5	36.9
10	105.8	35.4	125.5	44.2
25	130.9	42.7	154.4	53.4
50	148.8	48.0	175.7	60.9
100	166.7	53.3	196.8	68.0

Densification

AE used the 2076 population growth projections from The City's PlanIT study and correlated it to an increase in impervious area. On average the projected increase in population resulted in a 3% increase in imperviousness. The distribution of the change in densification reflects the presence of large tracts of open space within the catchment. Higher increases are evident in the southern extents of the catchment and along the future Green Line LRT corridor.

3.5 MODEL VERIFICATION

3.5.1 Radar Rainfall

AE verified the hydraulic model with two historical storms (June 2007 and August 2016). AE used The City's radar rainfall data to simulate the spatial variability of the storms. The total precipitation can be seen on **Figures 3-3** and **3-5**.

Verification

The June 2007 event caused flooding within the Queen's Park Cemetery and on 4th Street NW. Photos taken after the storm event indicate standing water within the cemetery. This correlates with model results which predict the hydraulic grade line within the Confederation Trunk to be above surface. The model also predicts large overland flows on 4th Street NW which were observed during the event.

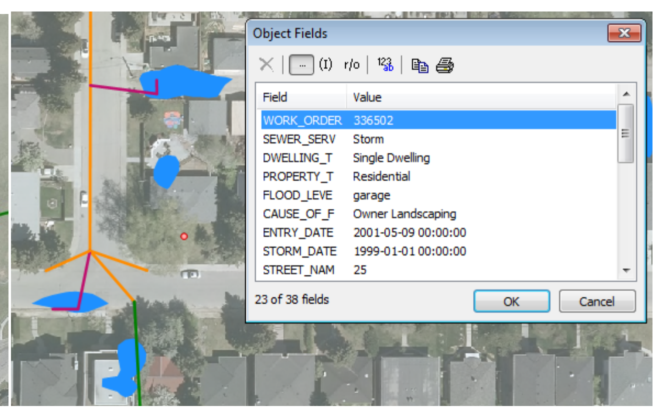
The City provided flow monitoring data for the August 2016 event. The intent was to verify the model by comparing predicted and actual flows. However, during the course of The Study, the flow monitoring data was found to have missing data. As a result, the August 2016 event was not used for model verification.

Given the uncertainty within the verification exercise AE made no adjustments to the hydraulic model.

3.5.2 Drainage Notifications

AE considered historical drainage notifications between 1973 and 2017 in an attempt to verify the model. Comparison of the model's results and drainage notifications suggested that the model's results were generally conforming with observed flooding. Refer to **Figure 3-6**.

-Numerous Notifications
-Trunk has between a 1:5 and 1:25-year LOS
-Large trap lows evident



-2001 notification of garage flooding
-Back lane service has a 1:5-year LOS
-Trap low evident in backlane

3.5.3 Verification by CHI

In February of 2018, The City commissioned Computational Hydraulics International (CHI) to undertake a third-party review of the PCSWMM model AE developed for this project. CHI was selected as they are the developers of the PCSWMM software. A summary of their results is as follows:

> *"Based on our review of the submitted materials, CHI believes that the Confederation Regional Drainage Study model developed by AE represents a high-quality effort, greatly exceeding our expectations for what we could consider a reasonable and acceptable application of the PCSWMM and the SWMM5 model for similarly scoped studies. That is, the correct practice and "science" of modeling has been demonstrated to our satisfaction.*
>
> *In our opinion, AE staff have exhibited exceptional skill, expertise, and judgment in developing the model, according to our understanding of the specific modeling objectives and having reviewed some of the base data with the model was built. Further, CHI confirms that:*
>
> - *The hydrologic and hydraulic representation is appropriate and input parameter values fall within the expected attribute ranges for the type of system modeled; and*
> - *The climate change/densification assumptions as well as alternatives to mitigate proposed conditions are appropriate.*
>
> *Based on our extensive review, CHI has not found anything to cause significant concern with the application of the model."* (Computational Hydraulics International, 2019).