CITY OF VANCOUVER

City of Vancouver

InfoWorks ICM Modelling Standards & Guidelines

Version 1.0 – November 2023

DISCLAIMER

This standard is intended to provide modelling standards and protocols for the City of Vancouver ("City") staff and consultants, using the InfoWorks ICM modelling software. The City has adopted this modelling software for city-wide sewer and drainage modelling. The City's hydrologic and hydraulic model will be used in achieving multiple medium- and long-term goals, such as sewer capital project selection, growth, and development planning, CSO mitigation, and climate change adaptation.

This standard focuses on detailed processes and procedures of developing sewer and drainage models specific to the City. Careful consideration must be given to ensure that the approach, methodology, and specifications described in this standard are valid for other applications. The City makes no guarantees with respect to the correctness and applicability of its content, completeness, reliability, accuracy, timeliness, or errors and omissions. The users shall determine the applicability of this modelling standard for their intent and particular circumstances at their own discretion. The entire risk as to the results and performance of using this standard is assumed by the user, and the City shall have no liability for reliance placed upon the content of this standard.

Any quotations, reproduction, and reference of this standard, whether directly or implied, must be properly acknowledged.

City of Vancouver, Integrated Sewer and Drainage Planning

November, 2023

Table of Contents

VERSION CONTROL

This standard is a living document that will evolve over time to keep up with advances and lessons learned in the industry. Users are advised to obtain the most up-to-date version from the City or follow the direction upon award of a modelling assignment.

Version	Date	Description	InfoWorks ICM Version
1	November, 2023	Original Version	2024.01 version 26.1.12 (64 bit) April 2023

ABBREVIATIONS

CB	Catch basin
CSO	Combined Sewer Overflow
DS	Downstream
DWF	Dry Weather Flow
FM	Flow Monitor
GI	Green Infrastructure
GRI	Green Rainwater Infrastructure
GWI	Groundwater infiltration
HGL	Hydraulic Grade Line
I/I	Inflow and Infiltration
MH	Manhole
PS	Pumping Station
RFP	Request for Proposal
RG	Rain Gauge
RTC	Real Time Control
SSO	Sanitary Sewer Overflow
SWM	Storm Water Management
US	Upstream
WaPUG	Wastewater Planning User Group now known as CIWEM Urban Drainage Group
WWF	Wet Weather Flow
WWTP	Wastewater Treatment Plant

GLOSSARY OF COMMON TERMS

Calibration	Process of adjusting model parameters to make a model fit with measured conditions (usually measured flows).
Combined Sewer Overflow (CSO)	A discharge to the environment from a combined sewerage system that usually occurs as a result of a precipitation event (rainfall and/or snowmelt) when the capacity of the interceptor sewer at a regulator or treatment plant is exceeded. The discharge consists of wastewater and stormwater.
Combined Sewer System	A wastewater collection system designed to convey both sanitary wastewater and stormwater to a wastewater treatment plant.
Design Storm	A rainfall hyetograph of a specific duration whose total depth corresponds to a particular storm return period or recurrence interval, usually selected from the City of Vancouver's Design Guidelines and construction standards.
Dry Weather Flow (DWF)	Sewage flow resulting from both sanitary wastewater (residential, industrial, commercial, institutional) and groundwater infiltration from foundation drains or cracks that occur during periods absent of rainfall or snowmelt.
Green Rainwater Infrastructure (GRI)	A suite of rainwater management tools that use both engineered and nature-based solutions to protect, restore, and mimic the natural water cycle.
Groundwater Infiltration (GWI)	Groundwater flow entering the sewer system through cracks in pipes and manholes. Groundwater Infiltration is a component of Infiltration and Inflow (I/I). It is dependent on groundwater levels and tends to be continuous when present.
Inflow and Infiltration (I/I)	The components of sanitary flow that originate from non-sewage sources including groundwater or stormwater that enters from deficiencies in the pipe network (cracks, loose joints, leaky manholes), connections from private property (downspouts, foundation drains, other drains), and/or cross- connections from the storm drainage system.
Inflow Event	An inflow event is an InfoWorks ICM database item that can be made up of one or more inflow profiles that share the same timesteps, each representing a series of time-varying inflow hydrographs applicable to a particular node or link.
Level Event	A level event is an InfoWorks ICM database item that can be made up of one or more level hydrographs that share the same timesteps, each representing a series of time-varying water levels applicable to a particular outfall node.
Link	A link represents the physical connection between two nodes. Examples of a link include a conduit representing a closed pipe or

	an open channel, a control representing a weir, pump or other ancillary flow control device, a bridge, a channel, or a river reach.
Node	A point object in a modelled drainage system that receives runoff and other inflows, that connects links together, or that discharges water out of the system. Nodes can be manholes, junctions, storage units or outfalls.
Rainfall Event	A rainfall event is an InfoWorks ICM database item that can be made up of one or more rainfall profiles that share the same timesteps, each representing a rainfall hyetograph that can be associated with a particular geographic location (e.g., rain gauge).
Sanitary Sewer Overflow (SSO)	A raw sewage discharge to the environment from a sanitary sewerage system that usually occurs as a result of a precipitation event, or as a result of power/back-up power failure at a sanitary pump station, or other maintenance issue.
Scattergraph	A scattergraph has points that show the relationship between two sets of data. E.g., observed depth and velocity plotted together could be used to assess the consistency of the observed flow data.
Separated Sewer System	Two distinct collection systems designed to convey sanitary flow independently from stormwater flow.
Storm Outfall	The discharge point of a stormwater collection system, typically to a surface drainage feature, watercourse, or water body such as a stormwater management pond.
Subcatchment	A subcatchment is a drainage area that shares a common outlet.
Urban Drainage System	Characterized by roadways with curb and gutter, primarily utilizing catch basins to collect stormwater runoff to an underground sewerage system that typically conveys flow by gravity to a receiving watercourse or waterbody.
User Defined Number	In InfoWorks ICM, the User Number fields 1 to 10 in any object attribute table (e.g., node, conduit, subcatchment, etc.) can be used to store additional information in number format that is not stored in the object's other InfoWorks ICM data fields. The attribute or column name of any User Number field can be re-named and changed for the current network.
User Defined Text	In InfoWorks ICM, the User Text fields 1 to 10 in any object attribute table (e.g., node, conduit, subcatchment, etc.) can be used to store additional information in text format that is not stored in the object's other InfoWorks ICM data fields. The attribute or column name of any User Text field can be re-named and changed for the current network.
Validation	Process to identify and resolve simulation run errors and model instabilities to an acceptable degree, and to verify all

	assumptions made in the model development and calibration phases.
Wastewater Event	A wastewater event is an InfoWorks ICM database item that can be made up of one or more wastewater profiles, each containing a per capita flow rate and a set of 24-hour domestic wastewater diurnal patterns.
Wet Weather Flow (WWF)	The combination of dry weather flow and precipitation-derived (rainfall and/or snowmelt) inflow and infiltration, and stormwater runoff that enter the wastewater collection system.

1 Introduction

Since 2017, the City of Vancouver ("City") started using PCSWMM as the modelling software for sewer and drainage modelling. Many sewer and drainage engineers and planners in the City are using sewer and drainage models for hydrologic analysis and 1D hydraulic analysis of sewer systems for development planning and sewer capacity analysis.

In January 2019, the Utility Modelling and Data Management branch was formed, now reorganized, and renamed to the Integrated Sewer and Drainage Planning branch, and one of its mandates is to develop sewer drainage models that span the City. The City's models are intended for sewer capital project selection, growth and development planning, rainwater management, operation, and maintenance, as well as to achieve long-term goals including CSO mitigation and climate change adaptation. Therefore, the City's current and future modelling needs have expanded to include integrated 1D-2D, green rainwater infrastructure, stormwater quality, and live modelling.

InfoWorks ICM supports a wide range of system analysis, capital planning and design, and growth planning. It also supports 1D-2D, green rainwater infrastructure, water quality, and live modelling. To meet is needs, the City has selected InfoWorks ICM as the platform to develop city-wide sewer and drainage models to meet the expanded modelling needs of the City.

With InfoWorks ICM set as the modelling software for City's sewer and drainage model, this model standard was developed to ensure a consistent modelling approach and to provide a standardized model build process using InfoWorks ICM. To ensure that the previous PCSWMM models can be incorporated into the city-wide InfoWorks ICM platform, the standard includes a chapter for model conversion from PCSWMM to InfoWorks and vice versa.

1.1 Purpose and Intent of Standards

This standard provides a model development approach using InfoWorks ICM including a detailed methodology. It sets out firm guidance on development and validation of sewer models for the City and shall be followed by City staff and consultants for InfoWorks ICM modelling assignments.

Models can be used to analyze sewer systems during planning and design phases, including operational components. Various model uses include:

- Planning models:
    - Capital planning for growth.
    - Development review.
    - Current system performance assessment.
    - Level of service and/or risk assessment.
    - I/I analysis and reduction planning.
    - CSO analysis and mitigation planning.
    - Stormwater quality modelling.
- Design models: preliminary and detailed design models to support design and construction projects.
- Operational models: sewerage system analysis, system optimization, operational and maintenance strategies, and day to day operations support.

This standard focusses mainly on the use of models in the planning phase; however, guidance contained herein will be useful for all phases.

1.2 Overview and Summary of Chapters

The following is an overview of the chapters in this document:

Chapter 1 Introduction	Provides the purpose of this standard, a summary of its contents by chapters, and an overview on the City's sewer and drainage system.
Chapter 2 Set-up and Configuration	Provides guidance on creating a new model, managing modelling files and model setup, and defining naming conventions for model objects.
Chapter 3 Data Collection and Gap Analysis	Outlines the modelling datasets and provides a method to resolve data gaps.
Chapter 4 Model Development	Provides guidance on model documentation and setup, the process of model development including the hydraulic, hydrologic, and sanitary model, and the approach to green infrastructure modelling.
Chapter 5 Model Calibration	Provides guidance on model calibration to observed flow data including recommended calibration parameters and model calibration targets.
Chapter 6 1D-2D Integrated Modelling	Outlines the steps to develop 2D overland flow models and integrated 1D-2D models using InfoWorks ICM.
Chapter 7 Stormwater Quality Modelling	Provides an overview of recommended approaches to model stormwater quality.
Chapter 8 Performance Criteria	Provides a set of criteria for assessing the performance of the existing sewer system.
Chapter 9 Model Checks and Validation	Provides a list of model checks to validate models and to troubleshoot and resolve model instabilities.
Chapter 10 Model Conversion	Provides guidance on converting PCSWMM models into InfoWorks ICM models and vice versa.
Chapter 11 Live Modelling	Provides an overview of data requirements and system management for live modelling and guidance on when to use live modelling.

1.3 Overview of Sewer System

The City's sewer and drainage system consists of 2140 km of pipes and 25 pump stations, servicing an area of approximately 11,670 ha. The system delivers sanitary sewer predominantly to Metro Vancouver's Iona Island Wastewater Treatment Plant, with a small portion of the south-east catchments to Metro Vancouver's Annacis Island Wastewater Treatment Plant. Stormwater is conveyed within the combined sewage system or via separated system to outfalls along the City's waterfront to the Fraser River, False Creek, English Bay, Burrard Inlet, and the Salish Sea. A small catchment exits the City through Still Creek past Boundary Road into Burnaby into Burnaby Lake.

Much of the City's sewer and drainage system was designed and built in the 1900s and during major densification in the 1960s as a combined system. The combined sewer system collects sanitary sewage and stormwater in a single sewer system. The City has been working since the 1970s to convert the combined sewer system to a separated sewer system where stormwater and sanitary sewage are conveyed in two dedicated pipes.

Several challenges have been encountered with the current system of combined and separated pipes. A significant challenge is with the combined sewer overflows (CSOs), which occur when the combined sewer system does not have sufficient capacity and overflows through outfalls to receiving waterbodies. Beyond CSOs, a significant number of pipes are reaching the end of their life cycle and need to be replaced. The City's sewer system is further strained by population growth and changing climate conditions.

The City is working toward the Province of British Columbia's environmental goal to eliminate sewage overflows by 2050. To meet this requirement, the City is implementing sewer separation and separating sewer at a target rate of 1% replacement per year and constructing green rainwater infrastructure.

2 InfoWorks ICM Configuration

This chapter provides an outline of InfoWorks ICM model and database configuration and management practices, and standard model configuration procedures. The modeling procedures include how to configure InfoWorks ICM model groups for new City models, provide a standardized City Model Template Database, cover model scenario management, and outline City naming conventions for model networks and elements.

2.1 Model Database Management

InfoWorks ICM is designed as a workgroup system where multiple users that are assigned to a particular workgroup can work concurrently in a centralized master database hosted by a workgroup data server. A master database can hold multiple different model networks. However, in a standalone database configuration, the master database is hosted on a local machine which does not permit concurrent use. Figure 2-1 shows the typical configurations of a workgroup and a standalone database.

A standalone database is intended for standalone use only and could be used when only one user would be working on the database at the same time. A workgroup configuration, however, is preferred for collaborative projects with two or more users. Additionally, a workgroup configuration has a conflict resolution mechanism that can resolve concurrent changes to the same model database.

When building a model in either the workgroup or a standalone environment, some model data is stored on the user's local machine, e.g., changes by a user to the model network that have not been committed to the master database. Note that a workgroup master database shall be stored and managed on a dedicated server that is separate from users' local machines. This is critical to ensure performance and reliability of the workgroup database.

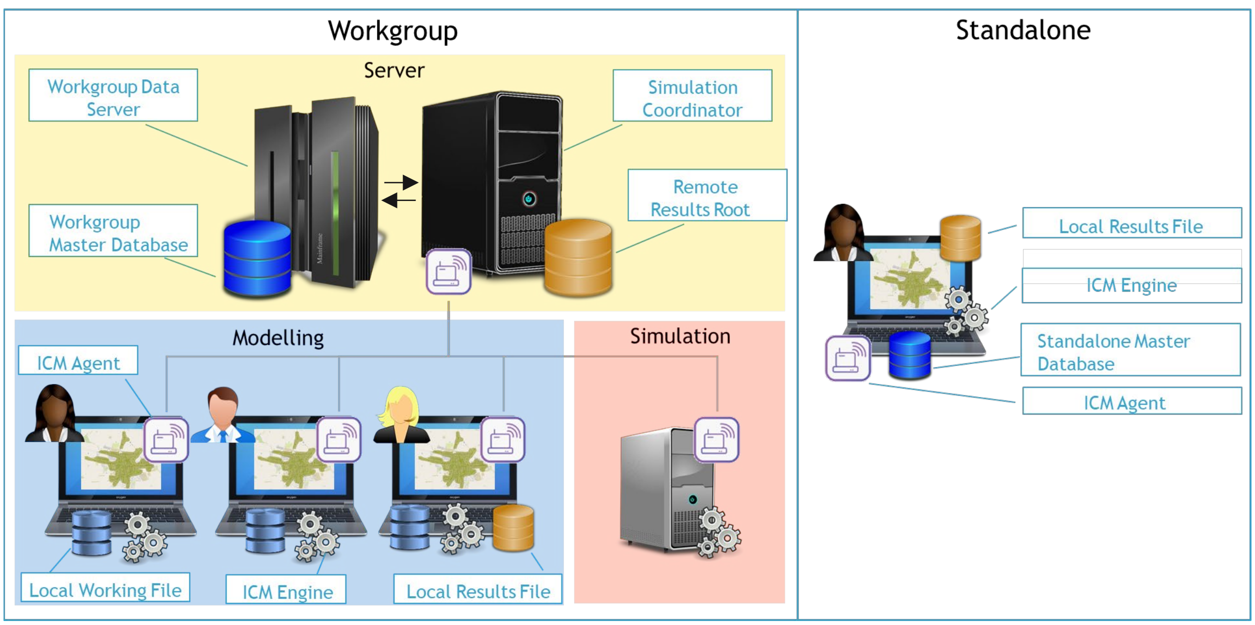


Figure 2-1 Workgroup versus Standalone Operation of InfoWorks ICM

For Consultants, multiple master databases are usually created for different projects and for different clients. Each master database would likely have a unique workgroup with an assigned team of modellers.

For the City, InfoWorks is configured to only have one master database where all City models will be created and maintained. In this configuration, the master database only has one workgroup to which the appropriate City modellers will be assigned. Within this InfoWorks ICM configuration, the City has a staging and production environment. The staging environment is for InfoWorks ICM maintenance and testing of software updates by City IT staff. The production environment shall be used to develop models by City staff. Therefore, all appropriate City modellers will be set up with the production environment by City IT staff when InfoWorks ICM is installed.

The staging and production environment configurations are shown on Figure 2-2 below.

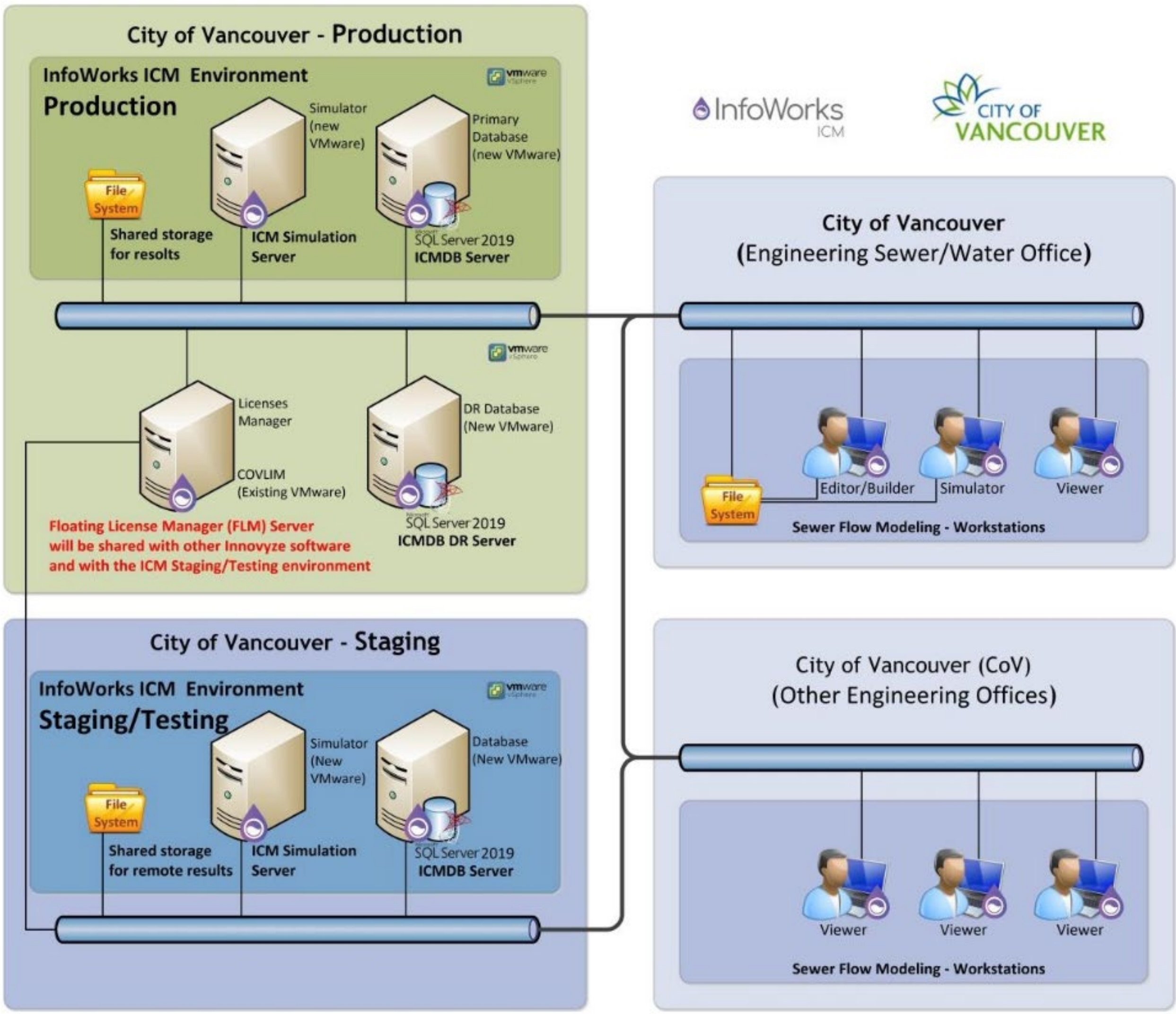


Figure 2-2 City of Vancouver InfoWorks ICM Environment

The direct transfer of data between two master databases is possible only if they are saved on the same machine or network. To transfer data between different two local machines or networks (such as between City and Consultants), transportable databases must be created.

A master database provides a flexible hierarchy for managing model data and results. The top level of this master database structure is the master group. Details of model group hierarchy and management is discussed in Section 2.4.

2.2 Software Version

InfoWorks ICM is periodically updated by Innovyze. Since 2021, a major version was released every year with several sub-versions during the year. At the time this standard was prepared, the latest version of InfoWorks ICM is 2021.9. InfoWorks ICM is not backward compatible, meaning that an older version of the software cannot open a model database created in a newer version. Additionally, InfoWorks ICM does not allow a model database to be down saved to a previous software version. The City's IT staff will update the software version of InfoWorks ICM annually. As a result, the City's master model database will automatically also be updated.

For a new modelling assignment by a consultant, the version currently used by the City shall also be used by the consultant. There may be exceptions to this requirement; therefore, the consultant shall discuss versioning with the City's project manager at the start of a new modelling assignment. Note that if a modelling assignment spans over several years, the consultant's InfoWorks ICM version shall follow the City's software updates.

2.3 Coordinate System

The coordinate system used by the City is "UTM Zone 10 (NAD 83) [EPSG 26910]" and all InfoWorks ICM models shall be configured and delivered in this coordinate system. To define the coordinate system in InfoWorks ICM, click Set Coordinate System as shown in Figure 2-3 below.

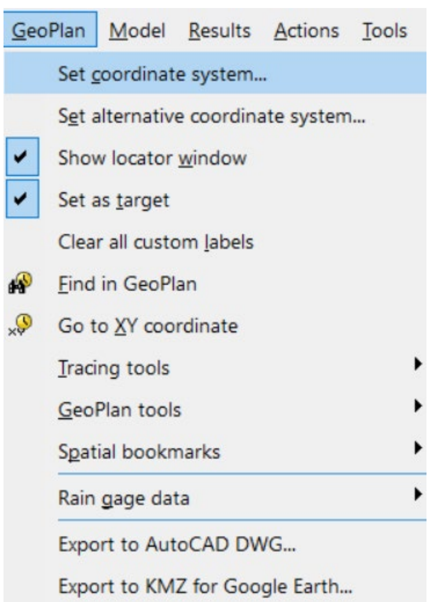


Figure 2-3 GeoPlan Menu to Set Coordinate System

Subsequently, set the coordinate system in the Select Coordinate System window shown below in Figure 2-4.

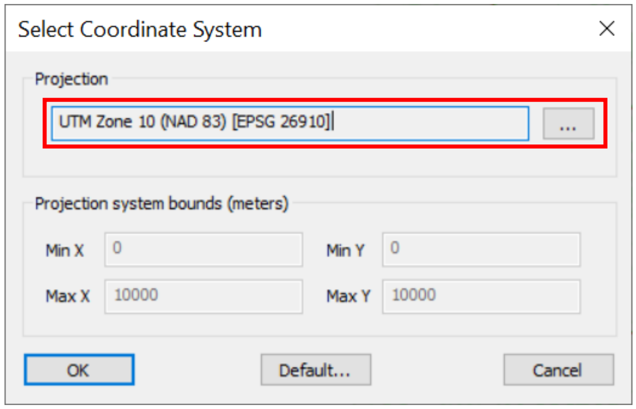


Figure 2-4 Select Coordinate System

Note that the Model Template Database to be used for new models has been configured to the correct coordinate system.

2.4 Model Group Hierarchy

The data and results of a model are stored in a master database where the top level of a master database hierarchical structure is a master group. The master group is a collection of individual model groups, which include model networks, and all supporting model groups. These supporting groups, such as the rainfall group, wastewater group, inflow group, and level group, are used in the simulation and analysis of the collection system.

A master group hierarchy structure shall be configured for each modelling assignment and the naming convention presented in Section 2.7 shall be adopted for all model components. As part of this modelling standards, a Model Template Database is provided that includes a master group hierarchy structure. This model template shall be used when creating a new model. Any changes to or deviations from the model template must be agreed upon with the City.

Figure 2-5 shows the master group hierarchy as provided in the Model Template Database. The Model Template Database has various master groups  for different phases of a modelling assignment. Each master group contains a model network with model data specifically relevant to the study phase. Some model data such as rainfall, GIS layer lists, SQLs, GeoPlan themes, and ground model are common items to all the study phases. These items shall be maintained outside the master groups and directly under the master database to avoid unnecessary duplication and references. A table with definitions of standard database groups and subcomponents within each model group is provided in Appendix 2A.

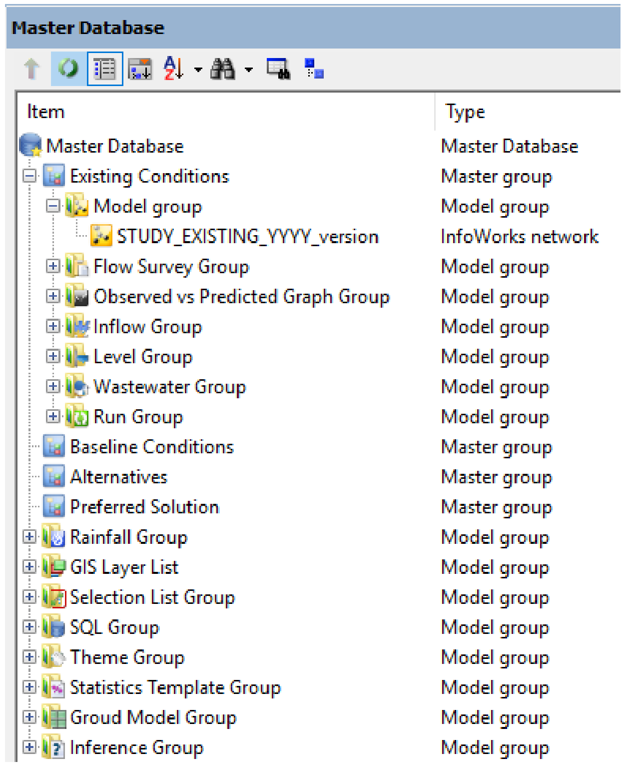


Figure 2-5 Master Group Hierarchy Template

All changes or additions to the model groups configuration or naming shall be documented using the description field in the network properties to assist future users.

2.5 Scenario Management

Scenarios are variations of a particular model that represent different configurations of the sewer system to be analyzed. At a minimum, a model network has a base scenario. Each additional scenario is created as a child of the base scenario and remains dynamically linked to the components of the model network within the base scenario. Any changes made to base scenario are automatically migrated to all child scenarios.

The scenario manager, in conjunction with a number of model networks and run files/groups, shall be utilized when modelling the sewer system at different timeframes, e.g., existing condition model versus future condition model and for studies that involve developing alternative solutions.

Scenario management for City InfoWorks ICM models shall follow a three-pronged approach using:

1. Scenario manager
    - Use to model land use conditions and “soft” hydraulic model parameter changes.
    - Scenarios for existing or future land use or soft changes of hydraulic parameters such as pipe shape, material, length, and roughness or similar changes to nodes or subcatchments. However, sewer infrastructure changes such as network connectivity, alignment, and sewer separation should be reflected in new model networks.
    - Each scenario shall be named in accordance with Table 2-1.

Table 2-1 Model Scenario Naming Convention Template

Land Use	Scenario Name	Description
N/A	Base	This Base scenario cannot be renamed.
Existing	Existing_YYYY	Scenario(s) for existing land use.
Future	Future_YYYY	Scenario(s) for future land use.

Where:

- YYYY – year of land use that the scenario represents.
- E.g., Existing_2021 is a scenario modelling the existing 2021 land use, and Future_2041 is a scenario modelling the future 2041 land use.

1. Model networks
   - Use to model different networks.
   - Create new model networks under the same or a different Model Group as needed.
   - Use whenever model network changes to nodes, links, and subcatchments are needed and to represent alternative solutions.

Each model network name (not the scenario name) shall be named in accordance with Table 2-2 in Section 2.6.

2. Run files
   - A run file contains the configuration of a particular model simulation to be executed.
   - Inputs to a run file include model networks, rainfall events, inflow and level files to set boundary conditions, and others.
   - Controls in a run file include dynamic wave, reporting, and timestep parameters.

The purpose of each scenario and model network shall be documented in the appropriate notes fields in addition to any changes made to each run file/group.

2.6 Model Network Naming

A model network naming convention shall be followed as per Table 2-2 below. Each model network name shall include the year and the model version number in order to track changes to the model. Table 2-2 Model Network Naming Convention Template

Study / Planning Models	Model Network Name	Description
Existing Conditions	StudyName_Ex_YYYY_vX	Existing
Baseline Conditions	StudyName_Base_YYYY_vX	Baseline
Alternative 1	StudyName_Alt1_YYYY_vX	Alternative 1
Alternative 2	StudyName_Alt2_YYYY_vX	Alternative 2
Preferred Solution	StudyName_PrefSol_YYYY_vX	Preferred Solution
Design Models		
Baseline Model	DesignName_Base_YYYY_vX	Baseline
Preliminary Design	DesignName_PrelDes_YYYY_vX	Preliminary Design
Final Design	DesignName_FinalDes_YYYY_vX	Final Design

Where:

- YYYY – year that the network represents/solution model design horizon.
- v (version) – number sequence with relevant updates during the year.

- E.g. StudyName_Ex_2021_vX – version up by whole number increments (v1, v2, etc.).

2.7 Model Elements Naming

An InfoWorks ICM model network represents a sewer system for a specific area. The model network consists of different model objects such as nodes, links, and subcatchments.

- Nodes represent a physical structure such as a manhole, storage structure, or outfall.
- Links represent the connection between two nodes such as a sewer pipe or an open channel. They also represent flow control structures such as orifices, gates, pumps, and weirs.
- Subcatchments represent the physical area from which the drainage system collects flow.

Dummy nodes, links, and subcatchments can be added to the model that do not represent normal assets but that are required for special situations. An example would be a dummy node to represent a change in gradient part way along a sewer.

Standard naming conventions shall be used for InfoWorks ICM model objects such as nodes, links, and subcatchments to reduce uncertainty in interpretation by future users and ensure consistency across models. Naming conventions are defined in Section 2.7.1 through Section 2.7.4.

2.7.1 Nodes

The purpose of this naming convention is to ensure all node IDs are unique across each InfoWorks ICM model. This approach prevents errors that arise from duplicate dummy node IDs within the same model or when merging multiple models.

Table 2-3 Naming Convention for Nodes

Description	Node Type	Node ID – Naming Convention	Node Object ID
Nodes that represent physical structures in the existing sewer system. Additional codes can be added as required.	Manhole	"MH" + FACILITYID	MH1407959
	Fitting	"FT" + COV_SOURCE	FT8462894
	Catch basin	"CB" + FACILITYID	CB3400078
	Pumping station	"PS" + FACILITYID	PS3400078
	Wet well	"WW"+FACILTYID	WW1408565
	Detention tank	"DT" + FACILITYID	DT1408565
	Start of forcemain	"FM" + FACILITYID	FM1407959
	Outfall	If City outfall GIS asset data is available, the Node Object ID naming convention shall be "OF" + the unique ID (FACILITY or COV_SOURCE or other); else use the method below: "OF" + last 4 digits of the Y-coordinate (e.g. 5454472) and last 4 digits of the X-coordinate (e.g. 495684)	OF44725684
Dummy Nodes to represent change in gradient part way along a sewer, missing manholes/fittings, dual manholes, etc.	Dummy nodes	"D" + last 4 digits of the Y-coordinate (e.g. 5454473) and last 4 digits of the X-coordinate (e.g. 495685)	D44735685

2.7.2 Links

When links are imported into the model, InfoWorks ICM automatically defines the Link ID using the upstream Node ID plus a numeric Link suffix that starts with "1". Note that InfoWorks ICM will only assign a numeric suffix in the case of a Link ID. If multiple links leave a common node, each subsequent Link Suffix is increased by 1, e.g., "upstream node ID.1", "upstream node ID.2", etc.

The Link naming conventions shown in Table 2-4 shall be followed to distinguish links such as flow control, overland flow, and dummy links from links representing sewers. Note that links that do not represent sewer pipes such as flow controls, streams, and dummy links will also be appended automatically by InfoWorks ICM with a numeric suffix upon import. These non-sewer type links shall be renamed from a numeric to an alphabetic suffix after import as per Table 2-4.

Table 2-4 Naming Convention for Links

Description	Link Type	Link Suffix Naming Convention	Upstream Node ID	Conduit Object ID
Physical structures in the existing sewer system.	Gravity sewers	Numeric starting from 1	MH1407959	MH1407959.1
	Pump	Numeric starting from 1	PS1407988	PS1407988.1
	Weir	Alphabetic starting from W	DT1407959 FACILITYID	DT1407959.W FACILITYID.W
	Orifice Flow control	Alphabetic starting from O	DT1407959 or MH1407959	DT1407959.O or MH1407959.O
Overland flow links	Flow paths above ground (e.g. roads/ditches)	Alphabetic starting from G	MH1407959	MH1407959.G
Dummy links	Dummy links	Alphabetic D	D44735685	D44735685.D

2.7.3 Subcatchments

Subcatchment IDs shall be defined using the Node ID of the node to which they drain with a prefix indicating the type of subcatchment.

Table 2-5 Naming Convention for Subcatchments

Description	Subcatchment ID Naming Convention*	Subcatchment Object ID
Storm subcatchments	"STM_" + Node ID	STM_ MH1407959
Sanitary subcatchment - existing flow and WWF	"SAN_" + Node ID	SAN_ MH1407955
Sanitary subcatchment - future flow	"FUT_" + Node ID	FUT_ MH1407955
Subcatchment representing external areas.	"EXT_" + Node ID	EXT_MH411008

* Where multiple subcatchments drain to the same node, a "_#" suffix shall be added, increasing numerically from 1; e.g. STM_MH1407959_1 and STM_ MH1407959_2.

2.7.4 New Nodes and Links

In some modelling assignments, new nodes and links will need to be added to the model, e.g. for a proposed new sewer system for a subdivision development. These new nodes and links may not have City Asset IDs yet. If design or as-built drawings are available, the naming convention provided in Table 2-6 should be adopted for these new nodes and links.

Node IDs for new or relocated MH structures shall use the drawing reference ID and MH ID joined by an underscore. Link IDs for new links shall consist of a MH ID joined appended with a Link suffix containing an alphabetic character starting with an "A". For multiple conduits with a common upstream node, each subsequent Link suffix shall be increased from A to B, to C, etc.

If design or as-built drawings are not available for a newly proposed sewer system, a suitable naming convention shall be developed in discussion with City staff.

Once constructed, the new sewer system will be added to the City's sewer asset database including Asset IDs. Subsequently, the nodes and links in the model shall be updated with these new Asset IDs and shall conform to the naming conventions used for existing nodes and links. This will involve updating various model object fields including Node IDs, Link IDs, Node and Link Asset IDs, User Defined Text/Number, etc.

Table 2-6 Naming Convention for New Nodes and Links

Description	Naming Convention	Model ID
Node - proposed new MH or relocated MH	Drawing number_Drawing version ID_MH ID	DB3973C_B_S06
Node - proposed new MH or relocated MH (no drawing and/or drawing number available)	"P" + last 4 digits of the Y-coordinate (e.g. 5454472) and last 4 digits of the X-coordinate (e.g. 4955684)	P44725684
Node - proposed new MH or relocated MH (for future alternative scenario models where a design has not been completed and drawings have not been created)	"F" + last 4 digits of the Y-coordinate (e.g. 5454471) and last 4 digits of the X-coordinate (e.g. 4955681)	P44715681
Link - proposed new sewer pipe	MH ID + link suffix starting from A	DB3973C_B_S06.A

3 Data Collection and Gap Analysis

This chapter sets out requirements for data collection and provides a methodology for data gap analysis. The guidance herein is intended to help the modeller ensure that collected data is adequate and appropriate to produce a robust and useful model.

The modeller shall complete the Data Collection and Gap Analysis phase as shown on Figure 3-1 and as outlined in this chapter, prior to commencing the Model Development phase. As part of the gap analysis, summary reports to document data gaps and resulting limitations to the model shall be prepared and reviewed, as outlined in Section 3.2.3 Data Gaps Identification.

Note that Figure 3-1 provides solid guidance but is not exhaustive; therefore, the modeler shall identify and add any project specific data requirements at the appropriate stage.

See Chapter 4 and Appendix 4B for the Model Development phase.

The following provides an overview of this chapter:

- Section 3.1 Data Collection – provides an overview with important details of data to collect for model development including their location on City servers and data available from open data sources. The data overview includes base, sewer, operations, and maintenance, and supporting data. Additionally, this section provides guidance on optional field investigations to fill critical data gaps and rainfall and flow monitoring data collection.
- Section 3.2 Data Gap Analysis – provides a methodology to identify, summarize, review, fill model data gaps, and rectify erroneous data. A detailed data rectification and gap filling methodology for Node-Link connectivity, using powerful InfoWorks ICM tools, is covered in Appendix 4B Section 2 as part of the Model Development phase.

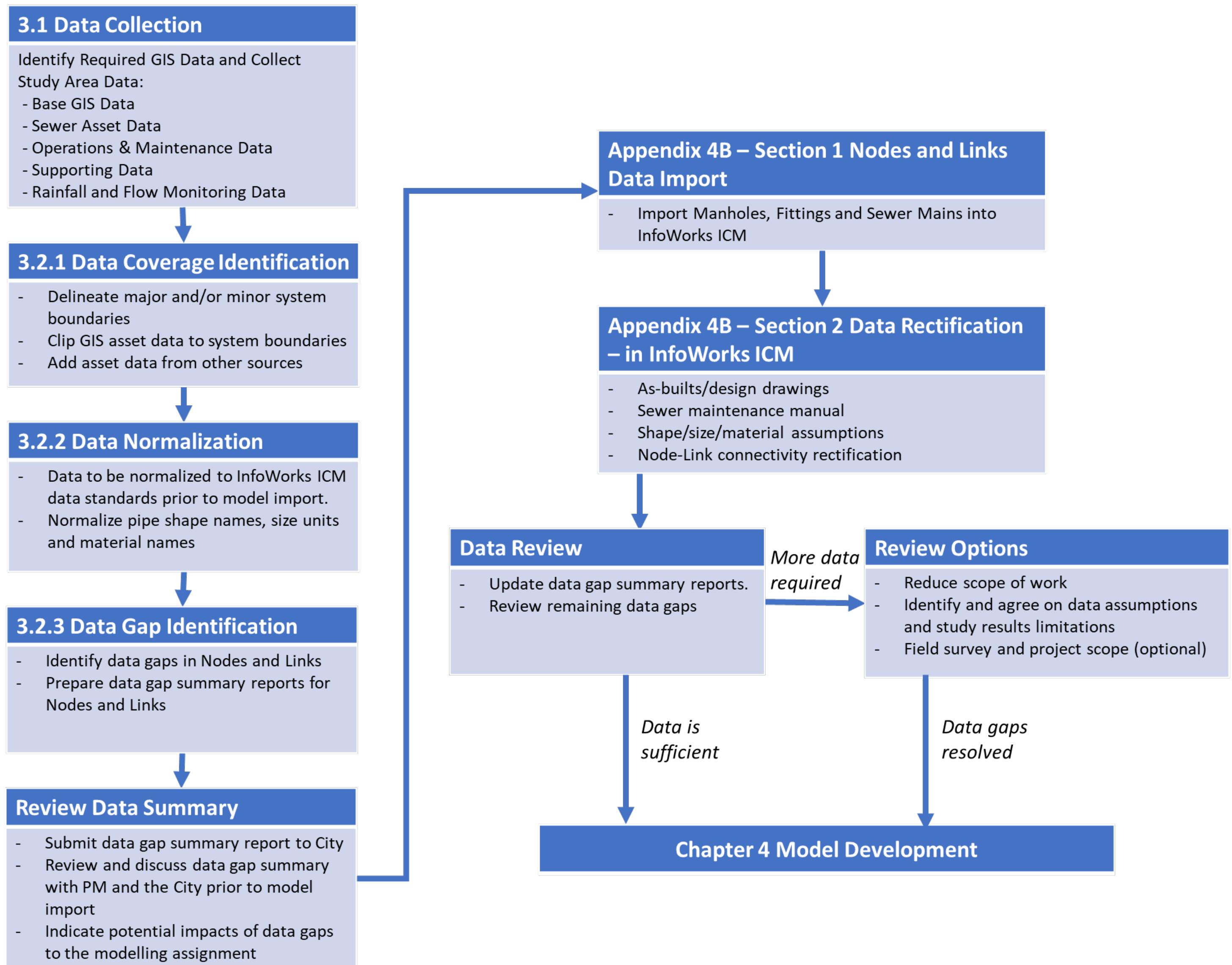


Figure 3-1 Recommended Data Collection and Gap Analysis Process

3.1 Data Collection

The purpose of the Data Collection phase is to determine if suitable data is available for model development and calibration and to identify if any additional information is required. Details of desktop data available from the City are provided in this chapter and include base, sewer asset, operations and maintenance, supporting, and rainfall and flow monitoring data.

All data relevant to the modelling study shall be collected by the modeller. The quality and accuracy of collected data for use in the study must be confirmed by the modeller. The Data Collection Checklist provided in Appendix 3A shall be used to document the source and condition of the collected data.

The recommended steps to complete the Data Collection phase are as follows:

1. Collect or request from the City all relevant desktop data – refer to sections below for details.
2. Delineate the major and/or minor system boundaries within the study area and clip required data for model development – refer to 3.2.1 Data Coverage Identification for guidance.
3. Review required model components within the study area boundary and identify and request additional data if missing, e.g., detailed information to model flow controls, pump stations, etc.
4. Complete the Data Collection Checklist in Appendix 3A and submit to the City project manager for review and approval.
5. Start Data Gap Analysis – refer to Section 3.2 Data Gap Analysis for a detailed methodology.
6. If survey is required to fill critical model data gaps – refer to Section 3.1.7 Field Investigation Data (optional) for guidance.

The following sections provide details about data collection required for model development.

3.1.1 Base Data

GIS data for the study area are available from the City's Open Data Portal, and upon request, from the City's database. Table 3-1 provides the location and details of the City's Base GIS data. The data source links in Table 3-1 are from May 2023 when this guideline was prepared. Note that it is the modeller's responsibility to obtain the latest available data for the modelling assignment.

Table 3-1 Base GIS Data

Category	Dataset	Purpose	Source	Notes
General Mapping	1. Property parcel	Define subcatchment boundaries.	W:\Tier1\2D\SHP\PROPERTYPARCEL Shapefile Name: PROPERTYPARCEL.shp	The property parcel layer defines property boundaries and is updated frequently.
	2. Parcel2Main Database	Assign storm and sanitary catchments to manholes.	To be requested from the ISDP GIS team pending approval.	The Parcel2Main layer contains information to help assign parcel catchments to the appropriate manhole in the model. Each parcel has been populated with the sewer main ID and the upstream manhole ID where a service lateral connects the parcel to a pipe. See Appendix 2B Data Catalog for relevant attribute data fields in the Parcel2Main database including definitions.
	3. Zoning district	Allocate runoff models.	W:\Tier1\2D\SHP\ZONINGDISTRICT Shapefile Name: ZONINGDISTRICT.shp	This data consisting of zoning polygons throughout the City. The city is divided into many development zones, with each zone further broken down into districts. The Zoning Development Bylaw describes each district and its list of permitted uses and regulation.
	4. Property addresses	Define population.	Open Data Portal: Property Addresses	The property addresses dataset contains street addresses that corresponds to parcel polygons.
	5. Ortho photos	Understand study area and flood flow paths.	Y:\ORTHO	Ortho photos are updated every year. The modeller shall be aware of the year of data and use the most recent data for existing conditions.
	6. Streets	Define overland flood flow paths.	Open Data Portal: Public Streets, Lanes, Non-City Streets	These datasets describe the streets in Vancouver and includes the street centerline and street names.
	7. Building footprint	Identify properties at risk of flooding.	Open Data Portal: Building footprints 2009	This data is from 2009. At the time of preparation of this document this data was not slated to be updated. The building footprint data may therefore be out dated and not be suitable for use in all areas of the City. The modeller should confirm suitability prior to use.
Population and Developments	8. Population (census and projection)	Define sanitary flows.	H:\UMDM\Reference\200 GIS\Databases\City-Wide\CityWidePopReview.gdb	Parcel-based population and/or equivalent population estimates based on 2016 Census.
	9. Development Activities	Understand current level of development activities (for reference only)	Open Data Portal: City Projects Package - Site	New and proposed developments may involve changes to site servicing and drainage to the sewer system. If details are required, the City has a Floor Space Ratio (FSR) database that can be used to help determine sanitary loading available at: I:\Engineering\City Hall\SEWER_DESIGN\REZONES\Background and Templates\Resources\Master FSR Database.xlsx
Topography	10. Contours	Define flood flow paths and allocate rain gauge data.	W:\Tier1\2D\SHP\Contours	The elevation contours shall be considered as approximate, and the modeller shall be aware of the year of the data.
	11. 2018 LiDAR – Complete Data Set	Define detailed definition of 2D overland flow.	Open Data Portal – LAS files: LiDAR 2018 LAS file format: H:\UMDM\Reference\200 GIS\FullCity\LiDAR 2018\lasv1.2 LiDAR Data Report: H:\UMDM\Reference\200 GIS\FullCity\LiDAR 2018 Filename: 2018 LiDAR Collection Report - City of Vancouver.PDF	The LiDAR in LAS file format shows the elevations as originally recorded including buildings and trees. The LAS files are gridded and contain the following point classifications: 1. Unclassified, 2. Bare-earth, 3. Low vegetation height (< 2m), 5. High vegetation height (> 2m) 6. Buildings, 7. Noise, 9. Water. The LAS files can be processed with appropriate software to create a Digital Elevation Model (DEM) for any of these categories.
	12. 2018 LiDAR – Bare Earth DEM		Bare Earth DEM – ASCII file format: H:\UMDM\Reference\200 GIS\FullCity\LiDAR 2018\DEM	Also known as a Digital Ground Model (DGM) or Digital Terrain model (DTM). A Digital Elevation Model (DEM) in ASCII file format that has been post processed to contain only the bare ground levels by removing buildings, trees etc. and interpolating the ground in the removed sections. The Bare Earth DEM data is useful to infer ground elevations and slopes.
Hydrology	13. Soil map	Define runoff model.	H:\UMDM\Reference\200 GIS\Soil Shapefile Name: COVSoil.shp	The soil map divides the spoils in the City into three distinct soil groups based on the infiltration potential.
	14. Impervious and Paved areas	Define runoff model.	H:\UMDM\Reference\200 GIS\Databases\City-Wide\UMDM.gdb Feature Class Name: Impervious_area Feature Class Name: Paved_Areas	These datasets are maintained by the saying ISDP branch (formerly UMDM branch). The Paved Areas layer is a single polygon representing the right-of-way area. The Impervious Area layer contains the paved area as well as parcel polygons with a breakdown of each parcel into road, building, other and natural areas, and a total impervious area field (TIA_AREA).
	15. Watercourses and floodplains	Define downstream boundary conditions.	To be requested and pending approval.	Still Creek, historic watercourses, and floodplain polygons for Fraser River and False Creek.
	16. Flow monitor / Rain Gauge locations 17. Flow monitor catchments	Understanding of calibration components.	To be requested from the Flow Metro Van trunk sewer books team pending approval.	GIS layers showing locations of rain gauges and active and historic flow monitors with corresponding catchments. The catchment layer is a work in progress and not all catchments have been delineated yet.
Trunk sewers	18. Major Sewer Catchments / Subcatchments	Define downstream boundary conditions.	H:\UMDM\Reference\200 GIS\Databases\City-Wide\UMDM.gdb Feature Class Name: MajorCatchments H:\UMDM\Reference\200 GIS\MetroVan\Sewersheds Shapefile Name: VSA_Sub_R1.shp	This data contains major catchment areas based on drainage areas contributing to trunk sewers.
	19. Metro Vancouver Trunk Sewers	Define downstream boundary conditions.	W:\Tier1\2D\SHP\ssTrunkMain Shapefile Name: ssTrunkMain.shp – additionally: Metro Vancouver trunk sewer books available upon request.	This data contains trunk sewer mains and provides the effluent type and size of the trunk sewer mains. The Metro Vancouver sewer books contain plan and profile record drawings with inverts.

3.1.2 Sewer Asset Data

The City maintains a digital inventory of the physical storm, sanitary and combined sewer system assets including locations of flow controls in a GIS. Additionally, the City owns and operates 24 sanitary pump stations and one storm pump station. This sewer asset data is continuously updated by the City as many sewer main separation, pump station upgrades and decommissions, and renewal projects are in progress. Therefore, the modeller shall ensure that the latest data is collected for a new modelling assignment.

The City's Sewers and Drainage Design (SDD) branch Maintenance Manual, discussed in Section 3.1.3, shall be reviewed to obtain detailed information to model flow controls. Additional drawing review, operator interview, and optional field investigation may be required to supplement missing or uncertain information.

Appendix 3B GIS Data Catalog provides an overview of GIS sewer asset data including descriptions of pertinent attribute data fields. Table 3-2 below shows the available sewer asset data to be collected and how to obtain more detailed information for pump stations and flow controls.

Additionally, the following data sources may be consulted:

- Tracker, SIS, and POSSE – City databases
- Wye sheets – City record drawings
- Metro Vancouver Sewer Books – plan/profile record drawings available upon request
- Metro Vancouver drawing requests - https://apps.metrovancouver.org/flore

Table 3-2 Sewer Asset Data

Dataset	Purpose	Source	Notes
Sewers Mains	• Define sewer mains	W:\Tier1\2D\SHP\SWGRAVITYMAIN Shapefile Name: SWGRAVITYMAIN.shp	Storm, sanitary, and combined sewer mains, (including force mains) that contain reference to record drawing numbers where available.
Manholes	• Define manholes • Identify flow controls	W:\Tier1\2D\SHP\SWMANHOLE Shapefile Name: SWMANHOLE.shp	Manhole locations. Locate flow control manholes from attribute field MHTYPE – see Section 3.1.3 Special Structures for additional instructions.
Fittings	• Define connections • Identify fittings located at the ends of sewer mains instead of manhole structures	W:\Tier1\2D\SHP\SSFITTING Shapefile Name: SSFITTING.shp	Some ends of sewer mains do not have a manhole node in the SWMANHOLE layer. Some of these end nodes may be fittings (wye, T-junctions, etc.) or valves and can be identified using these layers.
Valves	• Define valves	W:\Tier1\2D\SHP\COVSSVALVE Shapefile Name: COVSSVALVE.shp	
Outfalls	• Define outfall structures • Define boundary conditions	H:\UMDM\Projects\200 False Creek\206 CSO Monitoring\500 GIS\520 Analysis Shapefile Name: Outfalls.shp	Location of outfalls.
Pump Stations	• Define pumps stations	W:\Tier1\2D\SHP\COVSSPUMP	Location of pump stations. Detailed pump station data required for modelling shall be requested

Dataset	Purpose	Source	Notes
		Shapefile Name: COVSSPUMP.shp	from the SDD branch's pump station team. Data includes Pump Station Red Book record drawings, record/design drawings, Maintenance Manual, operational data (pump on/off elevations, SCADA, etc.), manufacturer's brochures, and product information sheets on pump capacities and characteristics.
Service Laterals	• Define subcatchment allocation	W:\Tier1\2D\SHP\SSSERVICELINE Shapefile Name: SSSERVICELINE.shp	These may not be explicitly modelled but may help assign catchment loading to the appropriate nodes.
Catch basins	• Identify flow exchange between overland flow and the sewer system	W:\Tier1\2D\SHP\SSINLET Shapefile Name: SSINLET.shp	
Catch basin Leads	• Identify catch basin connections to sewer mains	W:\Tier1\2D\SHP\ssCatchBasinLead Shapefile Name: ssCatchBasinLead.shp	

3.1.3 Special Structures

Special structures are located in sewer mains or manholes and consist of flow controls such as overflow structures, orifice chambers, flap gates, etc. A comprehensive description of special structures can be found in the SDD's Maintenance Manual. The modeller shall collect detailed information to model special structures, i.e., flow controls, from the sewer main and manhole GIS layers, the Maintenance Manual, and record drawings.

Note that flow controls may be present in the study area that are neither in the SWMANHOLE layer nor in the Maintenance Manual maps.

Flow controls can be located by reviewing the attribute fields MHTYPE, WEIR, WEIRELEVAT, FIRSTFLUSH, FFLUSHDIA, UNITDESCR, and LOCDESC in the SWMANHOLE layer. The "Separator, FirstFlush, and Overflow" entries in the MHTYPE attribute field indicate a flow control is present. Note that the MHTYPE data set is not complete and additional flow controls may be present but not listed. Some "STANDARD" entries in MHTYPE also have a weir elevation in the WEIRELEVAT attribute field indicating a weir is present; however, the weir elevation data provided is also not complete. Refer to the Maintenance Manual and record drawings for detailed information and configurations of these flow controls. Not all locations of flow controls can be found in the SWMANHOLE layer.

Therefore, the modeller shall also refer to the Maintenance Manual Maps for other potential flow control locations in the study area. Record/design drawings shall be reviewed to obtain flow control information that is not in the Maintenance Manual. Record drawing numbers can be found in the SWGRAVITYMAIN layer in the DRAWNUMBER, PP_NUMBER, REMARKS, and DESCRIPTN attribute fields. Copies of Metro Vancouver record drawings can be obtained from a hardcopy drawing book that the City owns, and are typically W, C, or SF numbered drawings. City record drawings are typically DB and PP (plan profile) numbered. PP are older and DB are newer drawings; therefore, some DB drawings may supersede older PP drawings.

Record drawings are located at:

- DB numbered - Y:\SEWER_DESIGN\PROJECTS\DB
- PP numbered - Y:\SEWER_DESIGN\PROJECTS\Plan Profiles

Plumbing plan of schools and parks:

- Y:\SEWER_DESIGN\PROJECTS\School Plumbing Plans
- I:\Park Board\Planning\SHARED

See Section 3.1.4 Operations and Maintenance Data for more information about the Maintenance Manual. Appendix 3B provides an overview of the sewer main and manhole asset data with descriptions of attribute fields.

3.1.4 Operations and Maintenance Data

The modeller shall request information from the City's Sewers and Drainage Design (SDD) branch of operational issues and performance failures relevant to sewers located within the study area such as work order logs and CCTV records. Please be aware that the GIS may not show sewer renewal projects that had been constructed recently or that are currently under construction. Therefore, the SDD branch shall be consulted for information on recent or planned sewer improvement projects.

The SDD branch has a Maintenance Manual that is used by City staff to perform maintenance on special structures. The modeller shall obtain detailed information of special structures, i.e., flow controls, from this Maintenance Manual. Overview maps of special structures in the manual can be used to determine their location. Once located, detailed information required for modelling can be obtained from diagrams in the manual showing the arrangement of the special structures.

Details on how to model special structures in InfoWorks ICM are provided in Section 4.3 and Appendix 4D Section 1.

Note that not all special structures in the City's sewer system are necessarily shown on the overview maps in the Maintenance Manual. Refer to Section 3.1.3 Special Structures for more detailed information on how to locate all special structures in the modelling study area.

Selected sections covered in the Maintenance Manual are briefly summarized in Table 3-3 below.

Table 3-3 Sewer and Drainage Design branch Maintenance Manual Sections on Special Structures

Maintenance Manual Section	Description
Section 1: Sewer Main Specials	This section covers special structures in sewer mains or in manholes attached to the sewer mains. They consist of backwater valves, siphons, overflow pipes, weir structures, overflow structures, orifice chambers, flap gates, tide gates, vortex manholes, Calco gates, storage basins, protective screens, sump manholes, Milwaukee gates, tide gate chambers, silt control chambers, oil separators, and energy dissipaters.
Section 2: Non Standard Manholes	These are manholes with an additional enclosed pipe running through them. They are built when clearance issues arise for the enclosed pipe to get over the sewer it must cross. These manholes do not fit into the regular Sewer Main Specials section because there are no working parts or pieces to these manholes other than they have pipes running through the manholes and are not used to separate or regulate flow.
Section 5: Pump Stations and Pump Station Overflows	This section covers special structures specific to pump stations such as valves around the pump station. This section excludes detailed information of the

Maintenance Manual Section	Description
	pump station itself. Full details related to pump stations can be found in the Pump Station Red Book and should be requested from the SDD's pump station team.
Section 6: Metro Intakes	This section covers special structures at connections to Metro Vancouver sewers. Metro intakes consists of sluice gates, gate valves, or weirs that are located where City of Vancouver sewers enter Metro Vancouver sewers, which in turn carry the sewage to the Iona or Annacis Island sewage treatment facilities.

3.1.5 Supporting Data

Supplemental background information includes:

- Previous studies and monitoring data from the City available from VanDocs/network drives.
- Monitoring data, reports, and record drawings from external agencies.
- Hydraulic models from previous studies including InfoWorks ICM and PCSWMM models.
- Record drawings: DB are older and PP numbered drawings are newer record drawings:
    - Y:\SEWER_DESIGN\PROJECTS\Plan Profiles
    - Y:\SEWER_DESIGN\PROJECTS\DB
- Design drawings such as sewer plan and profiles drawings.
- Geotechnical reports or data including the historic borehole database.
- Drain card information to determine foundation drain connection status.
- Van311 flood records

3.1.6 Rainfall and Flow Monitoring Data

Rainfall and flow data is required to calibrate and validate the sewer system model to ensure that it is robust and sufficiently accurate.

The data is required for two purposes:

1. Model calibration for typical rainfall events - Detailed flow and rainfall data should be collected at multiple flow monitoring and rain gauge locations. After analysis of flow and rain data (including widespread rain gauge-adjusted radar rainfall if obtained externally), dry weather flow time-series and typical rainfall events suitable for model calibration shall be selected.
2. Model validation for extreme rainfall events – Historical data of extreme rainfall events can be used to calibrate to observed flooding. A calibrated extreme rainfall event model could provide predictions of overland flood extent and the impact to sewer system operation.

Rainfall and monitoring information, as available, may include but is not limited to:

- Rain gauge locations GIS layer.
- Rain gauge depth time series.
- Rain gauge-adjusted radar rainfall data for calibration and verification events (only externally available; non-adjusted rain gauge radar rainfall data may not be used).
- Flow monitor locations GIS layer
- Flow monitoring depth, velocity, and flow time series.
- Flow monitoring documentation such as pipe ID, field notes, service area delineation, and additional reporting.

- Combined Sewer Overflow (CSO).
- Pump station SCADA records (available from SDD's Pump Station team).
- Flood extents during extreme events.
- Environment Canada tide level monitor data (https://www.tides.gc.ca)

The City uses FlowWorks, a web-based service that provides access to available flow, rain, and CSO monitoring data. Access to FlowWorks may be requested and modellers should contact the City's monitoring team to confirm data sources, data channels within FlowWorks, investigation information, monitoring configuration and data quality observations. Note that the City's monitoring team could be working to finalize data sets (rainfall, flow, etc.) that may not have been published to FlowWorks yet. Additionally, analyzed data sets may be available that are typically not published to FlowWorks. Data analysis could also be conducted by the monitoring team upon request.

3.1.7 Field Investigation Data (optional)

It is possible that data gaps required to build a robust model remain present after completion of data gap identification followed by data rectification and filling. In this case, the missing data should be carefully reviewed to determine if the model could still provide reasonable and justifiable results when using assumed data. The modeler shall discuss the pros and cons with the City and alternative solutions such as scope reduction to eliminate the required missing data should be considered.

Optional field investigation could be considered after exhausting all other options. Field investigation may consist of a visual inspection or survey of key sewer assets.

Note that a field survey would be considered an optional task and before undertaking any field work, the extent shall be confirmed and agreed upon with the City.

Upon completion of the field work, all surveyed data must be submitted to City in agreed upon formats.

3.2 Data Gap Analysis

A complete set of data is required for model development; therefore, after completion of the Data Collection phase, a data gap analysis shall be performed by the modeller. The gap analysis process provides a method to identify and fill data gaps. Subsequently, the condition and suitability of the data set for modelling shall be determined. The data to be analyzed shall be clipped to the study area as per Section 3.2.1 Data Coverage Identification.

Gap analysis shall be performed on this clipped data set and generally comprises of the following steps:

1. Data normalization.
2. Data gap identification.
3. Data Import into InfoWorks ICM
4. Data rectification and gap filling.

A high-level explanation of the gap filling process is provided in Section 3.2.4 Data Rectification and Gap Filling and a detailed methodology including Node-Link connectivity gap rectification is covered in Appendix 4B Section 2. After gap filling has been completed, any outstanding data should be reviewed. Options to complete missing data include, but are not limited to:

1. Identify and agree on data assumptions including corresponding study results limitations, if any.

2. Discuss the costs and benefits of conducting site investigations and surveys to fill critical data gaps to maintain project scope (optional).
3. Reduce scope of modelling analysis to appropriate level based on available data.

Figure 3-1 outlines the Data Gap Analysis phase along with the Data Collection phase.

3.2.1 Data Coverage Identification

Data coverage refers to the spatial extent of sewer assets to be modelled within the study area. The modeller shall define the spatial extent for each system to be modelled; the storm drainage system (minor and major), the sanitary collection system, and the combined system. This should be completed in GIS by delineating each system's boundary by considering the topography and all sewer assets that lie within the study area such as pipes, manholes, fittings, outfalls, pump stations, and special structures.

The boundary polygons should be used to clip the respective asset data to the study area for each system. The resulting clipped asset data should be named:

1. SWMANHOLE → clip_manholes
2. SSFITTINGS → clip_fittings
3. SWGRAVITYMAIN → clip_sewermains

If there are additional clipped data sets, the intent of the naming convention above should be followed for consistency.

Subsequently, the modeller shall conduct a cursory review of the clipped sewer asset data sets to identify if any obvious data is missing. If data is missing, a map showing the storm, sanitary, and combined system boundaries together with a detailed data request shall be submitted to the City. See Figure 3-2 for an example of data request map.

This clipped asset data shall be used in the data normalization and gap analysis process as outlined in the following sections. Following normalization and gap analysis, the clipped asset data should also be used to create the hydraulic model import layers as outlined in Appendix 4B.

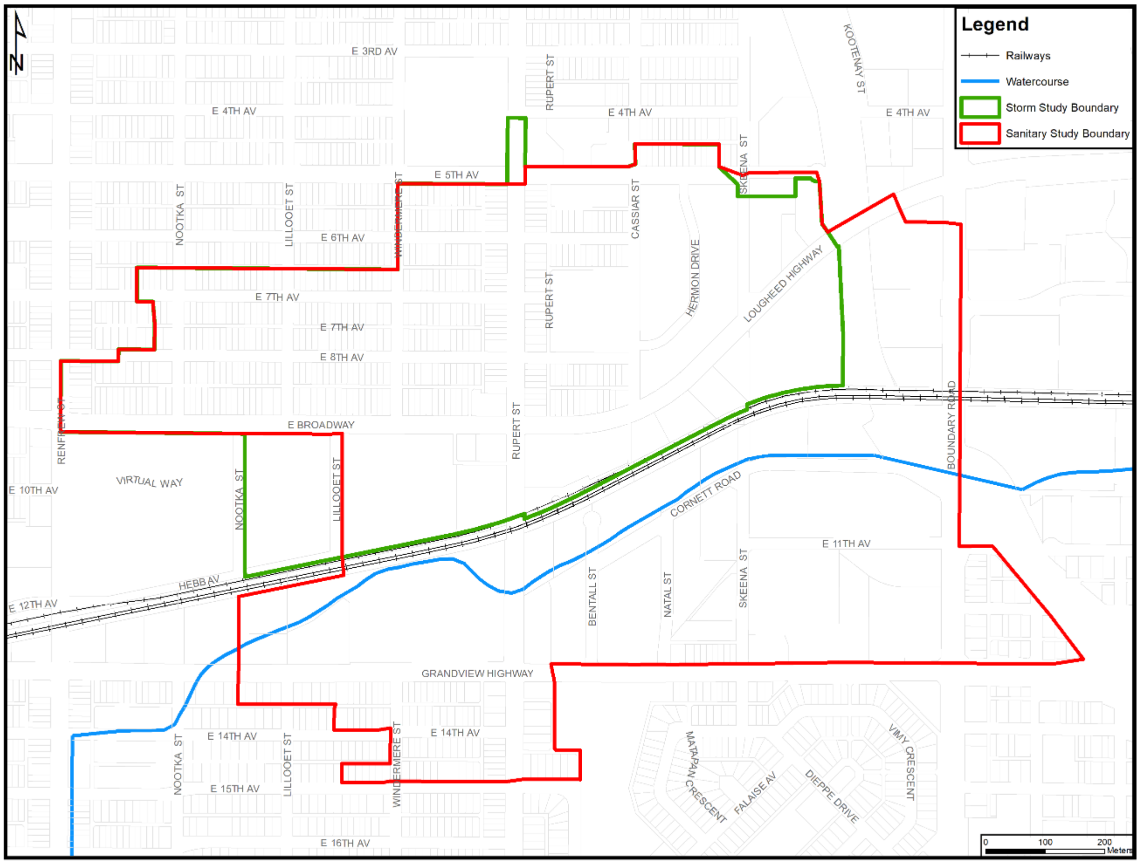


Figure 3-2 Defining Study Area Drainage Boundaries

3.2.2 Data Normalization

Data normalization is the process of transforming data into a standard form, e.g., standardization of units or text. InfoWorks ICM requires specific pipe length and size units and pipe shape text upon import of the pipe data into the model. Furthermore, pipe material should be normalized as the City's data set has over 30 pipe material types. Some material types can be grouped by common Manning's n values. Concrete and reinforced concrete, for example, can be grouped by the type Concrete since both have a Manning's n of 0.013. Appendix 3B provides a table containing Manning's n values to be assigned for different pipe materials.

Prior to starting data gap identification in Section 3.2.3, the modeller should normalize pipe length, size, shape, and material in the clipped model data sets clip_manholes, clip_fittings, and clip_sewermains using GIS. See Section 3.2.1 Data Coverage Identification on how to prepare the clipped model data sets.

See Table 3-4 and Table 3-5 below on how to normalize the data for pipes and fittings, respectively:

Table 3-4 Data Normalization Workflow for Pipe Length, Size, Shape, and Material

Pipe Data	City Data	Normalized	Recommended Workflow
Pipe Length	Metre [m]	Metre [m]	Confirm units are correct in the LENGTH, DIAMETER, and WIDTH_MM attribute fields in the clip_sewermains GIS layer.
Pipe Size	Millimetre [mm]	Millimetre [mm]	
Pipe Shape	• Round • Rectangle • Box • Oval • Horseshoe • BHS • ARCHE	• CIRC • RECT • RECT • OVAL • HORSESHOE • HORSESHOE • ARCH	• Create PIP_SHP attribute field in clip_sewermains GIS layer. • Sort MAINSHAPE alphabetically in the clip_sewermains GIS layer. • Populate PIP_SHP field with corresponding text as indicated in the "Normalized" column, e.g., Round becomes CIRC. • PIP_SHP attribute field shall be imported at the model development stage.

Pipe Material	Over 30 non-standard types in the MATERIAL field in the City's pipe GIS layer – see Appendix 3B for Pipe Material Manning's n and SWGRAVITYMAIN tables.		• Create PIP_MAT and MAT_ICM attribute field in clip_sewermains GIS layer.
			• Sort MATERIAL alphabetically in the clip_sewermains GIS layer.
			• Populate PIP_MAT field with full material name as mapped in the Pipe Material Manning's n and SWGRAVITYMAIN tables in Appendix 3B – create a lookup table in GIS from this table.
			• Populate MAT_ICM with "normalized material name for InfoWorks ICM" import from Appendix 3B (must be 5 characters or less). For MAT_ICM names use:
			  ○ CONC: concrete pipe
			  ○ PLAS: plastic pipe
			  ○ CLAY: vitrified clay pipe
			  ○ STEEL: smooth walled metal pipe
			  ○ CSP: corrugated steel pipe
			  ○ HDPE: high density polyethylene
			  ○ WOOD: wood stave
			  ○ BRICK: brick
			  ○ IRON: cast iron / ductile iron
			  ○ AC: asbestos cement
			  ○ UNKWN: unknown
			  ○ Other: other types of material
			• MAT_ICM attribute field shall be imported at the model development stage.

Table 3-5 Data Normalization Workflow for Effluent Type in Fittings

Fittings Data	City Data	Normalized	Recommended Workflow
Effluent Type	• ST • SAN • C	• Storm • Sanitary • Combined	• Create EFFL_TYPE attribute field in clip_fittings GIS layer. • Sort EFFLUENTTY alphabetically in the clip_fittings GIS layer. • Populate EFFL_TYPE field with corresponding text as indicated in the "Normalized" column, e.g., ST becomes Storm. • EFFL_TYPE attribute field shall be imported at the model development stage.

3.2.3 Data Gap Identification

After preparing the sewer asset data specific to the study area as discussed in Section 3.2.1 Data Coverage Identification, a gap analysis shall be conducted for the sewer mains and manholes. This involves identifying and summarizing missing or zero entries of critical data fields for model building, as well as checking for negative and extreme values for pipe and manhole attribute data. Critical pipe and manhole attribute data to be analyzed are shown in Table 3-6. Note that NodeLink- connectivity gap identification and rectification is excluded at this stage and is covered in Appendix 4B Section 2.

Gap identification analysis can be carried out in GIS or Excel. It is recommended to use an Excel template file provided with this document that includes macros to automate identification of zero and missing attribute data. The sewer and manhole GIS attribute tables should be copied into the appropriate tabs in the Excel file. Subsequently, data gap tables summarizing missing, and zero attribute data are generated after running the macro.

See Appendix 3C Gap Identification Template for the gap identification Excel template file including detailed instructions.

Additionally, the pipe attribute fields DOWNELEV, UPELEV, LENGTH, DIAMETER, and WIDTH_MM and manhole attribute field RIMELEV should be reviewed for extreme and negative values at this stage. Suspect records should be identified and tracked and shall be resolved at the data rectification and gap filling stage as outlined in Section 3.2.4 and Appendix 4B Section 2.

Ultimately, a summary table of the data gaps shall be completed by the modeller as shown in Table 3-6 and is provided in Appendix 3C Gap Identification Template.

The Data Gap Summary table shall be submitted, reviewed, and discussed with the project manager and the City prior to import into InfoWorks ICM and execution of the data rectification step. Potential impacts of data gaps to the modelling assignment shall be discussed and addressed, if possible. After completion of the data gap identification and model data import process, the modeller shall review missing and any suspect extreme value data and start the data rectification and gap filling process as covered in the following section.

Table 3-6 Data Gap Identification Summary Table

Asset Type	# of Records	Attribute	GIS Attribute Field	# of Missing Values	# of Zero Values	% Missing/Zero of Total	Extreme Value Asset ID
Sewer Mains (SWGRAVITYMAIN)		Upstream MH ID	FROMMH				
		Downstream MH ID	TOMH				
		Upstream Invert	UPELEV				
		Downstream Invert	DOWNELEV				
		Length	LENGTH				
		Diameter	DIAMETER				
		Width	WIDTH_MM				
		Pipe Shape	MAINSHAPE				

		Pipe Material	MATERIAL				
Manholes (SWMANHOLE)		Rim Elevation*	RIMELEV*				

* May contain rim elevations of "999" which indicate a sealed manhole type and is not a valid rim elevation.

3.2.4 Data Rectification and Gap Filling

The data rectification and gap filling process can be completed in GIS prior to import or in the model using InfoWorks ICM's built-in tools. Since these built-in tools have a wide range of functionality, it is recommended to import the sewer main and manhole asset data into InfoWorks ICM to review and fill the identified data gaps within the model environment. Additionally, InfoWorks ICM allows the modeller to track when and what type of assumed data is used in the model by using data flags as outlined in Section 4.1.2.

Therefore, a detailed methodology on how to rectify data and fill data gaps using InfoWorks ICM is provided in Appendix 4B Section 2. The methodology also includes a step-by-step process to check and resolve Node-Link connectivity issues.

Data shall be rectified, and gaps filled using data from sources in the order shown in Figure 3-3 below:

Order of Data Rectification and Gap Filling Sources

1. As-Built Drawings
   - The most preferred source for sewer asset data.
   - Includes the Sewers Design Branch – Maintenance Manual.
   - If multiple record drawings are available, use the most recent.
2. Field Investigation
   - Use this method if record drawings are available and data fill assumptions, scope reduction, and model results limitations due to data assumptions are not acceptable.
   - This method is subject to the City's approval.
3. Design Drawings
   - Use if record drawing is not available and Field Investigation is not required or possible.
   - If multiple design drawing, use the most recent.
4. Inference
   - Infer data if no drawings are available and Field Investigation is not required or possible.
   - The Inference approach is subject to approval by the City's senior engineer working on the project.
   - Use InfoWorks ICM Inference Tool to interpolate pipe size, shape, and inverts.
   - Populate manhole rim elevations from LiDAR.

Figure 3-3 Order of Data Rectification and Gap Filling Sources

4 Model Development

This chapter provides guidance on modelling the City's sewer system and green infrastructure. The approach to modelling overland flow is discussed in Chapter 6.

Model development of a combined storm and sanitary sewer system requires hydraulic, hydrologic, and sanitary model components. The hydraulic model represents the piped sewer system, and the model build approach is provided in Section 4.2. The hydrologic model consists of storm and sanitary subcatchments that generate flows in the storm, sanitary, and combined sewer system. Storm and sanitary flows serve as inputs to the hydraulic model where subsequently, the piped sewer system can be assessed. The hydrologic and sanitary model build approach and required subcatchment configuration is provided in Sections 4.7 and 4.8, respectively.

The sewer system hydraulics and hydrology are modelled using the following primary model elements:

- **Nodes**: representing entry points to the piped system such as manholes, pumping station wet wells, and storage tanks.
- **Links**: representing sewer mains, other pipes, and special structures such as weirs, orifices, siphons, channels, and sluice gates.
- **Subcatchments**: representing a sewershed or drainage area with soil and drainage characteristics including a land use category. Subcatchments generate hydraulic model flow (both storm and sanitary flows).
- **Ground model**: a digital surface created from ground elevation models used to route overland flood flows, commonly described as 2D modelling. Chapter 6 provides the 2D model build approach.

The following provides an overview of this chapter:

Section 4.1 – InfoWorks ICM Model Template Database

Introduces the Model Template Database to be used for creating City InfoWorks ICM models with customization details included in Appendix 4A – Model Template Database Configuration.

Section 4.2 – Hydraulic Model

Provides an overview of model hydraulics, a general hydraulic model build methodology, and presents the modelling approach for the following components:

- Nodes and links
- Minor losses
- Ditches, swales and watercourses

Details are included in Appendix 4B – Model Data Preparation and Import and Appendix 4C **–** SQL Queries.

Section 4.3 – Special Structures

Provides guidance on modelling the following types of special structures, with specific examples included in Appendix 4D.1 Special Structures:

- Weirs
- Orifices
- First flush separators
- Flag Gates
- Sluice Gates
- Pumps
- Siphons
- Culverts
- Outfalls

Further details on special structures parameters and model coefficients are included in Appendix 4D.2 WAPUG User Note 27 and Appendix 4D.3 WAPUG User Note 2.

Section 4.4 – Real Time Controls – Provides an approach to modelling real time controls.

Section 4.5 – Boundary Conditions

Provides an overview, a modelling approach, and guidance on how to establish inflow and level boundary conditions.

Section 4.6 – Green Infrastructure

Provides an overview of the City's green infrastructure types, performance targets, and the recommended modelling approach under two scenarios:

- Conceptual modelling of planned green infrastructure
- Detailed modelling of designed green infrastructure

Section 4.7 – Hydrologic Model

Provides an overview of runoff modelling and configuration of subcatchment hydrology including:

- Runoff routing model
- Runoff volume model
- Runoff surface configuration
- Land use configuration
- Subcatchment configuration for storm and combined sewer systems
- Design storms
- Historical rainfall events

Details are included in Appendix 4B – Model Data Preparation and Import.

Section 4.8 – Sanitary Model

Provides an overview of sanitary flow components and configuration of sanitary subcatchment including:

- Dry weather flow
- Wet weather flow
- Subcatchment configuration for sanitary sewer system

Details are included in Appendix 4B – Model Data Preparation and Import.

<u>Section 4.9 – Model Deliverables</u> – Provides a list of required model deliverables.

4.1 InfoWorks ICM Model Template Database

An InfoWorks ICM Model Template has been developed to ensure model consistency and to provide easy-of-use to all users. The Model Template is available in a Transportable Database (.icmt) file format. The Model Template shall be followed to create City InfoWorks ICM models. The following subsections summarize model documentation and data flagging practices that have been incorporated into the Model Template, with details provided in Appendix 4A.

4.1.1 Model Documentation

In InfoWorks ICM, all model objects such as nodes, links, and subcatchments have ten User Defined Number and ten User Defined Text fields. These user defined fields shall be used to track model data sources and to document model build assumptions and status.

A User Defined Text field named "Model Notes" has been created for each model object. InfoWorks ICM also has a built-in "Notes" field in each model object property table. However, the modeller shall first use the User Defined Text field "Model Notes" for short form notes. If the short form notes exceed the 100-character limit for the User Defined Text field, then the modeller shall additionally enter "see notes field" and enter the remaining long form notes into the built-in "Notes" field.

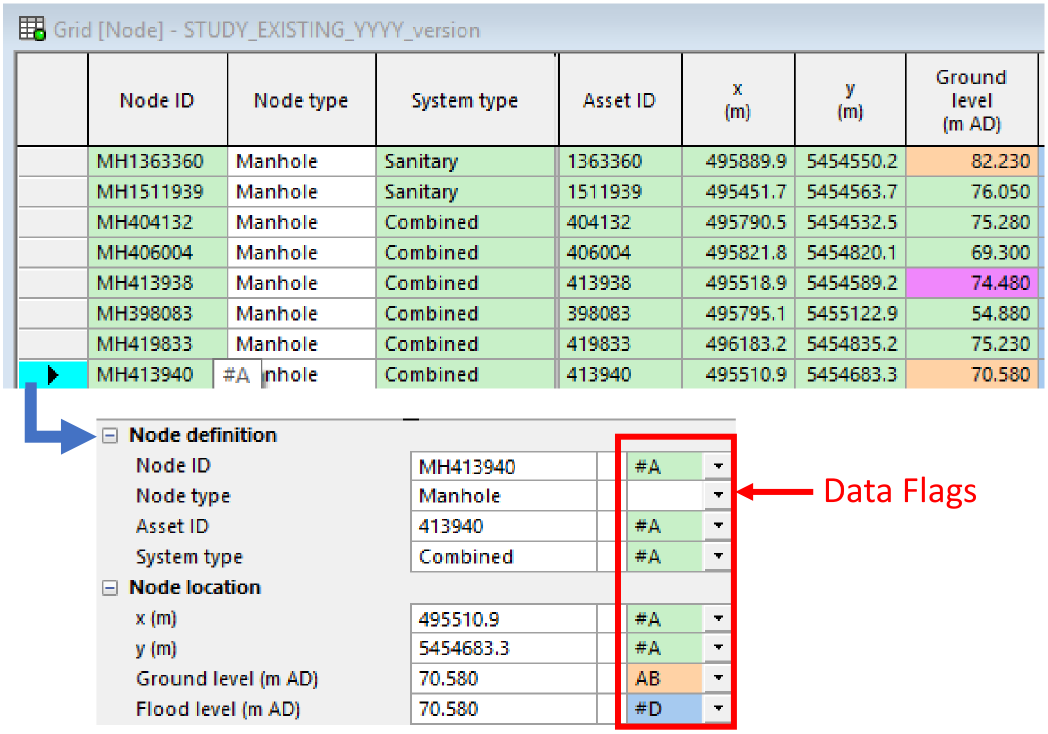
The user defined fields for each model element have been tabulated for reference and can be found in Tables 4A-2 to 4A-5 in Appendix 4A. At minimum, all fields indicated in the user defined tables shall be part of the base data structure for City models.

4.1.2 Data Flagging

Data flags are an important tool in InfoWorks ICM to record and track assumptions, data sources, and changes made during different modelling phases for all critical modelling fields. For all model objects including nodes, links, and subcatchments, each of their data fields can be flagged and each type of data flag is associated with a display colour. As shown in Figure 4-1, data flags can be viewed in grid windows by the data flag colour or in the property window of individual model objects.

A list of flags to be used for City models are provided in Table 4A-1 in Appendix 4A.

This list of data flags is also defined in the InfoWorks ICM Model Template Database that accompanies this guideline. Any addition to or deviation from the established list of data flags shall be discussed and agreed upon with the City.


Grid [Node] - STUDY_EXISTING_YYYY_version

	Node ID	Node type	System type	Asset ID	x (m)	y (m)	Ground level (m AD)
	MH1363360	Manhole	Sanitary	1363360	495889.9	5454550.2	82.230
	MH1511939	Manhole	Sanitary	1511939	495451.7	5454563.7	76.050
	MH404132	Manhole	Combined	404132	495790.5	5454532.5	75.280
	MH406004	Manhole	Combined	406004	495821.8	5454820.1	69.300
	MH413938	Manhole	Combined	413938	495518.9	5454589.2	74.480
	MH398083	Manhole	Combined	398083	495795.1	5455122.9	54.880
	MH419833	Manhole	Combined	419833	496183.2	5454835.2	75.230
	MH413940	#A nhole	Combined	413940	495510.9	5454683.3	70.580

Figure 4-1 Data Flag Display

4.2 Hydraulic Model

The hydraulic model consists of nodes and links that represent manholes and sewer mains in the City's sewer system. After completion of the Data Collection and Gap Analysis phase as outlined in Chapter 3, the hydraulic model build generally follows these steps:

1. Prepare sewer asset data and GIS import layers for manholes, fittings, and sewer mains.
2. Import sewer asset data into InfoWorks ICM.
3. Complete a data check and rectification process in InfoWorks ICM to resolve errors and data gaps.

Refer to Appendix 4B for a detailed data preparation methodology, import procedure, and data rectification procedure. City modelling staff shall follow all three steps; the data preparation methodology, import procedure, and data rectification process as outlined in Appendix 4B Section 2.

An external consultant may refer to the data preparation methodology, import procedure, and data rectification process in Appendix 3B as a guideline. However, the consultant shall ensure that the nodes and links are configured and populated according to Tables 4B-1, 4B-2, and 4B-3 in Appendix 4B and that the standards are adhered to as outlined in the sub-sections below.

See Table 3-2 and Appendix 3B for the base layer GIS data locations and attribute field definitions useful for nodes and links data preparation, respectively.

The following sub-sections outline standards for the configuration of nodes and links for City models.

4.2.1 Nodes and Links

A piped sewer system is represented by a network of nodes and links in the model. Each node or link has a set of properties including hydraulic parameters that define the model object. Figure 4-2 shows the InfoWorks ICM object properties window for nodes and links. Key node and link properties are covered in this section and details on all other properties can be found in the InfoWorks ICM Help module.

4.2.1.1 Nodes

Node elements shall be used to model manholes and some special structures. A manhole node has a shaft and chamber storage that represent a physical manhole or any other point where water can enter the sewer system.

A manhole requires the assignment of a flood type as indicated on the manhole property window shown on Figure 4-2. The flood type specifies how flooding is represented when the sewer system is overloaded. For the initial model build, the flood type “Stored” and “Sealed” shall be adopted for all manholes and fittings, respectively. Various flood types and key hydraulic parameters are described in Table 4-1 and may be used for nodes if more detailed manhole information is available.

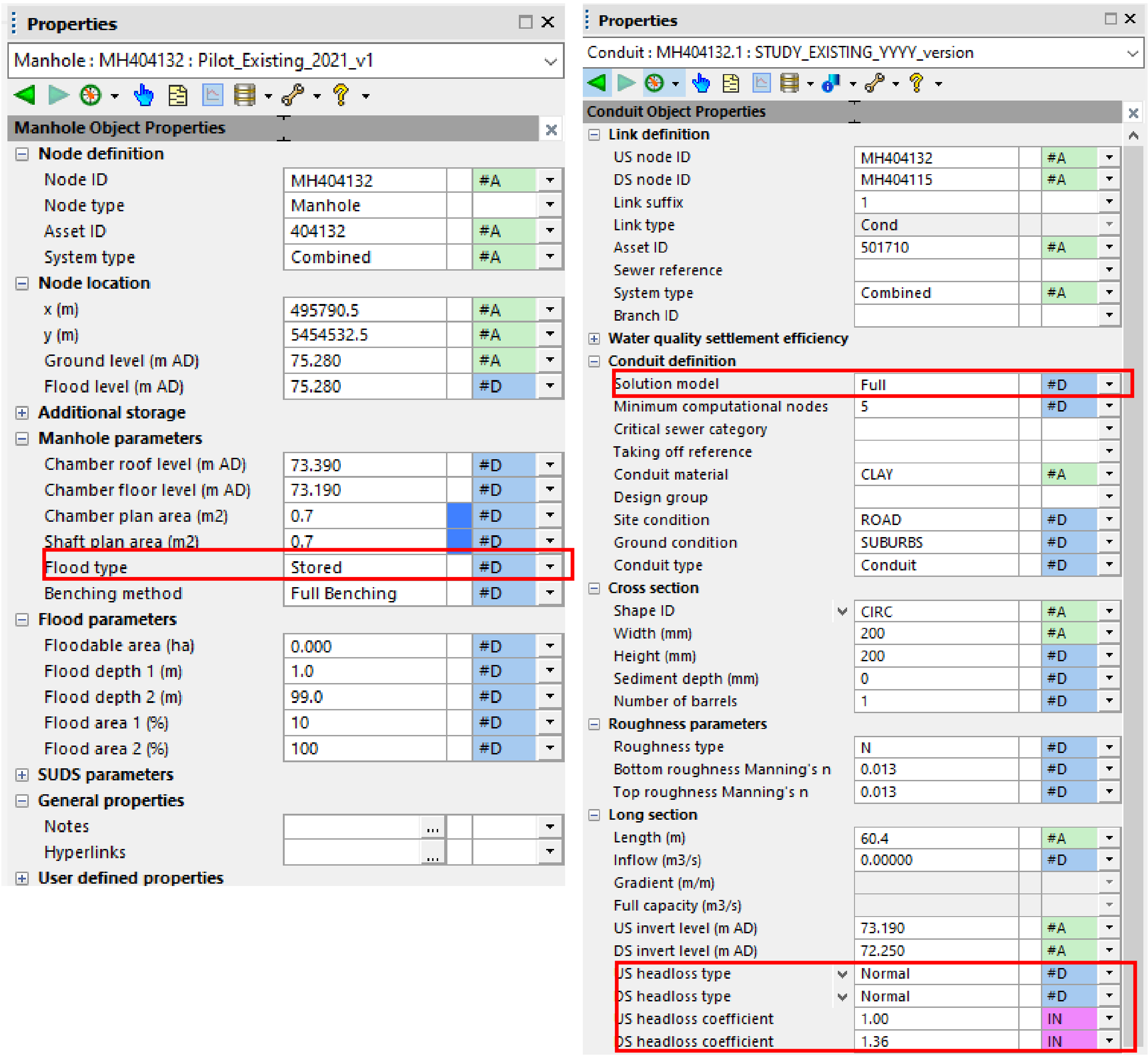


Figure 4-2 Object Properties Window for Manhole (left) and Conduit (right)

Table 4-1 Types of Nodes in InfoWorks ICM

Node Type	Flood Type	Key Hydraulic Parameters	Description	Recommended Use
Manhole	Sealed	Ground level	The water level can rise indefinitely without any flooding occurring at that manhole (i.e., no water exits the manhole). When the sewers surcharge, the MH operates under pressurized condition irrespective of the flood type as sealed or gully at a manhole. The main difference in a sealed versus other flood types is that flow does not exit the manhole.	To represent connection nodes and blind connections on all sewer systems. A blind connection is a connection without a manhole structure.

Node Type	Flood Type	Key Hydraulic Parameters	Description	Recommended Use
	Gully	• Ground level • Floodable area and flood depth • No. of gullies • Head discharge table (based on type of catch basin)	The flood water on the catchment surface is retained in the surface storage defined by the flood parameters (including floodable area and flood depths). The surface storage discharge to the manhole according to the specified head discharge table.	To represent flow interaction, via catch basins, between 1-D overland and the sewer network at storm and fully combined manholes.
	Stored	• Ground level • Floodable area and flood depth	Similar to a gully manhole, but the surface storage discharges to the manhole as the water level in the system drops and there is no constraint on the discharge.	To represent surface storage when the catch basins are not modelled using the gully flood type.
	Lost	• Ground level	Flood water is lost from the system.	To be used only if flood waters will not be returning to the manhole and the overland system is not modelled.
	2D	Ground level	The discharge between surface storage (on the 2D mesh) and manhole is calculated using standard weir equations, where the weir width is taken as the circumference of the manhole.	To be used for interaction of 1D network with 2D mesh.
	Gully 2D	• Ground level • No. of gullies • Head discharge table (based on type of catch basin)	The discharge between surface storage (on the 2D mesh) and manhole is defined by a Head Discharge Table.	To be used for interaction of 1D network with 2D mesh.
	Inlet	• Ground level • Inlet input type and Inlet type	The discharge between surface storage and manhole is defined by user defined inlet parameters. See Inlet Nodes in InfoWorks ICM Help for further details.	Not recommended to be used as this is intended for detailed modelling of drain inlets located in roadside gutters.
	Inlet 2D	• Ground level • Inlet input type and Inlet type	The discharge between surface storage (on the 2D mesh) and manhole is defined by user defined inlet parameters. See Inlet Nodes in InfoWorks ICM Help for further details.	Not recommended to be used as this is intended for detailed modelling of drain inlets located in roadside gutters.
Storage	N/A	• Ground level • Storage array	The storage node allows custom storage shape using a storage array consist of level and plan area pairs.	To be used for storage facilities.
Pond	N/A	• Ground level • Storage array	Pond node also supports infiltration to the ground from the sides and the base of the pond.	To be used for storage facilities with infiltration.
Break	N/A	Ground level	The break node can be used to model a change in gradient in a conduit. No storage at the node.	To be used only on forcemains to where there a change in gradient. See Section 4.3.6 for details on when forcemains shall be used.
Outfall	N/A	Ground level	This is where flow leaves the modelled system. No storage at the node.	To represent storm and CSO outfalls to a watercourse or node where flows leave the modelled system such as boundaries to outside of modelled areas, and discharge to a WWTP.

Node Type	Flood Type	Key Hydraulic Parameters	Description	Recommended Use
				InfoWorks ICM will apply free discharge for the outfall unless a water level is specified. See Section 4.5.2 on setting boundary condition for the outfalls.

4.2.1.2 Links

Link elements shall be used for modelling sewer pipes and some special structures. A key hydraulic parameter for links is the solution model and is shown on the link property window in Figure 4-2. The description and recommended use cases for the solution model link parameter are provided in Table 4-2 below.

Table 4-2 Key Conduit Hydraulic Properties

Conduit Type	Solution Model	Hydraulic Parameters	Recommended Use
Conduit	Full	Shape, width and height, roughness based on material, upstream and downstream inverts, upstream and downstream headlosses.	All sewers.
	Forcemain	Shape, width and height, roughness based on material, upstream and downstream inverts, upstream and downstream headlosses.	Represent forcemains and shall be used with pumps with defined head-discharge curve. See Section 4.3.6 for more details.

4.2.2 Minor Losses

In InfoWorks ICM, minor losses are represented by a headloss type and coefficients at the upstream and downstream end of the pipe, as shown on the link property window on Figure 4-2. For new City models, the headloss type shall initially be set to “Normal”. InfoWorks calculates the headloss using a built-in head loss curve.

By default, the headloss coefficients will be set to 1.0 by InfoWorks ICM when a new model link is created. However, the headloss coefficients shall be updated according to the angle of approach of the pipes connected to the manhole as shown on Figure 4-3 and Table 4-3 below.

The headloss coefficients can be calculated and populated automatically using the InfoWorks ICM Inference tool. Detailed instructions on how to calculate and populate headloss coefficients are provided at Step 7 of Section 2 Data Rectification Process in Appendix 4B.

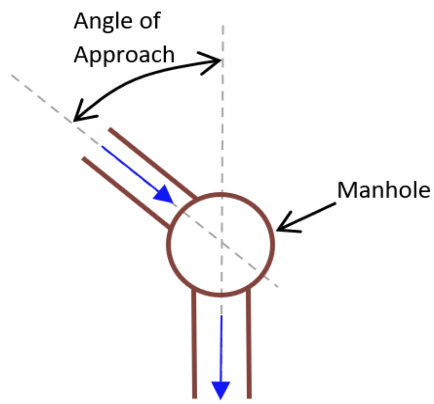


Figure 4-3 Angle of Approach for Sewer Pipes

Table 4-3 InfoWorks ICM Headloss Coefficients Based on Angle of Approach

Angle of Approach (Degrees)	Headloss Coefficient
30	3.3
60	6.0
90	6.6
> 90	8.0

Note that the headloss type is dependent on the physical conditions present at each end of the pipe. The headloss type “Normal” assumes sewer pipes that are connected to well-constructed manholes. Further, if the downstream pipe is sufficiently lower so that the upstream pipe is effectively hydraulically independent, the downstream pipe then acts similar to a free outfall. In this case, the modeller shall choose the headloss type of “None” at the appropriate location.

If sufficient detailed information is available about the condition of the pipe at the connections, the modeller may use engineering judgment to locally use a different headloss type. The built-in headloss types that may be selected for City model in InfoWorks ICM including their use case are:

1. NORMAL - headloss is calculated using a built-in headloss curve. Appropriate for well-constructed manholes on pipe systems, or for small open channel systems.
2. HIGH - headloss is calculated using a built-in headloss curve. Appropriate for badly connected manholes that are benched only to half pipe height.
3. FIXED - headloss is calculated using a built-in headloss curve. Appropriate for situations when there is a known headloss, such as entry into a reservoir or an open channel with bends.
4. User defined - select a user defined Headloss Curve ID. We do not recommend to use this type of headloss at the planning stage.
5. NONE - no headloss. Appropriate for free outfall type of conditions.

For more details on head loss types, coefficients, and equations refer to InfoWorks ICM Help.

4.2.3 Watercourses, Ditches, and Swales

4.2.3.1 Watercourses

The need for watercourse modelling and the level of detail required depend on the model objectives and should be assessed on a case-by-case basis by the modeller using engineering judgement. Depending on the level of detail required to achieve the study objectives, watercourses may be incorporated into the model as follows:

1. Model the entire watercourse of the watershed using survey, flow, and level data to the appropriate level of detail.
2. Model inflow or level boundary conditions where the watercourse connects to the sewer system instead of modelling the entire watercourse in detail. The inflow or level may be obtained from existing watercourse models such as HEC-RAS, flow or level monitoring stations or inferred from a floodplain map. Refer to Section 4.5 on setting model boundary conditions.
3. In absence of survey, inflow, and level data, the channel slope and cross section dimensions including roughness values may be estimated as follows:
    - Collect and review previous watercourse studies, background reports, DEMs, and orthographic photos.
    - Estimate cross section dimensions and channel roughness values from the collected data. Review the long profile on a DEM in GIS or CAD and estimate average channel slopes in between vertical grade break locations.
    - Optionally, if more detailed is required, conduct a field review of the watercourse to visually estimate average cross sections and roughness values including a photo survey and hand sketches at key locations.
    - Create nodes at grade breaks along the watercourse. The spacing between two nodes shall be between 3 to 100 m, as required. Note that not each vertical grade break needs to be modelled; the modeller shall attempt to use an average channel slope to minimize the number of nodes required while reasonably representing the channel slope.
    - Create the estimated cross sections shapes in the model as user defined shapes including the estimated roughness values. User defined cross section shapes can accessed from the channel property window: Channel definition -> Shape ID -> Insert New Channel shape Object. Create a new cross section by opening the Channel profile editor. Note that a channel cross section can be created using the Channel profile editor and not a channel profile as the name indicates.
    - Create channels links in the model between the grade break nodes and assign the estimated cross section shapes to the channels at the appropriate locations.

4.2.3.2 Ditches and Swales

A simple approach to model ditches and swales is to use conduit objects with custom defined shapes that represent the ditch or swale cross-section. The system type shall be set to “overland”. The cross-section of the conduit representing the ditch or swale can be defined from survey data or estimated using available DEM data and orthographic photos; a typical or average cross-section along the flow path can be used.

4.3 Special Structures

The following sub-sections provide guidance on how to configure different types of special structures in the model and what parameters are required. As mentioned in Section 3.1.3, the modeller shall obtain information about special structures from the Sewer Maintenance Manual, record drawings, and site photographs, if available. Supplementary information may be obtained from field investigation if warranted.

4.3.1 Weirs

As part of the sewer system, a weir is often used as an overflow structure to separate dry weather flow from wet weather flow and to control overflows to the environment.

The configuration and hydraulic parameters of the weir depends on the type of weir. There are three general types:

- High side weir – where the weir crest is parallel to the flow but the weir crest is above or close to the soffit of the pipe. This is the most common type of weir in the sewer system.
- Low side weir – where the weir crest is parallel to the flow and below the soffit of the pipe. This type of weir is very complex to model and advice from an experienced modeller is strongly recommended. The WaPUG User Note 27 Section 4 in Appendix 4D.2 Section 2 provides more explanations.
- Transverse weir – where the weir is across the flow. This type of weir is rare and requires additional considerations to determine the discharge coefficients, as discussed in Appendix 4D.1 Section 2.

4.3.1.1 Planning Model

At the planning stage, it is sufficient to model a weir using a weir link which represents a standard thin plate weir in InfoWorks ICM. Table 4-4 provides the hydraulic parameters for defining a weir link, including the crest level, width, and discharge coefficients.

Table 4-4 Parameters for Weir Definition in InfoWorks ICM

Weir Definition Fields	Description	Recommended Value
Crest (m AD)	The level at which the weir first comes into operation.	N/A
Width (m)	The width of the rectangular weir.	N/A
Discharge Coefficient	The coefficient for the weir flow equations.	0.85, a default value in InfoWorks ICM which corresponds to a weir as wide as the flow channel.
Secondary discharge coefficient	This coefficient applies when the water level is above the roof, and the weir begins to function as an orifice.	The default value in InfoWorks ICM shall be set to the value of Discharge Coefficient (0.85).
Roof height (m)	The level at which the weir behaves as an orifice or gate. This is required for piped system.	N/A

4.3.1.2 Design Model

At the design stage, it is recommended to perform additional site visits and complete a Computational Fluid Dynamics (CFD) model to accurately represent complex overflow structures and refine the discharge coefficients based on the results of the CFD model. An example of how to model a weir in InfoWorks ICM is provided in Appendix 4D.1.

4.3.2 Orifices

Orifices are used to regulate the flow rate and allow storage to occur upstream of the orifice. An orifice control is typically implemented as either a throttle pipe or an orifice plate. A throttle pipe shall be as a regular conduit with the actual length and inverts. The modeller shall follow the same guidance provided in Section 4.2.1 for modelling a conduit. An orifice plate can be modelled using either a conduit or an orifice link in InfoWorks ICM as discussed below.

4.3.2.1 Planning Model

At the planning stage, an orifice, either a throttle pipe or an orifice plate, shall be modelled as a regular conduit with the actual length and inverts. The modeller shall follow the same guidance provided in Section 4.2.1 for modelling a conduit. When the orifice control is extremely short (<3 m), an assumed conduit length of 3 m shall be used in the model to ensure model stability.

4.3.2.2 Design Model

At the design stage, an orifice control implemented as a throttle pipe shall also be modelled as a regular conduit; however, a typical orifice control within a manhole chamber shall be modelled using an orifice link in InfoWorks ICM. At the design stage, an orifice plate shall be modelled as an orifice link, which is a link object with zero length since it better represents the hydraulics across the system using the orifice equation which maybe the intent of designing the orifice plate. An example is provided in Appendix 4D Section 1.2. Table 4-5 provides the hydraulic parameters for defining an orifice link, including invert level, diameter, and discharge coefficients. When an orifice link is created in InfoWorks ICM, it is created with a default value of 1 for the discharge coefficients, but the modeller shall refer to the section guidance below for advice on the choice of discharge coefficients.

Table 4-5 Parameters for Orifice Definition

Orifice Definition Fields	Description
Invert level (m AD)	The level at which the orifice first comes into operation.
Discharge Coefficient	The coefficient for the orifice flow equations. See equation below and Section 4 in Appendix 43B Section 3 WaPUG User Note 2 for guidance on this value.
Secondary discharge coefficient	This applies when the depth of water is less than the diameter of the orifice, and weir equations apply. Section 3 in Appendix 3B WaPUG User Note 27 provides guidance on this value. The recommend value is 0.856 as for a sharp-edged weir in accordance with the guidance for modelling weirs in Section 4.3.1.
Diameter (m)	Diameter of circular orifice, or the diameter of equivalent area for non-circular orifices.
Limiting discharge (m3/s)	The maximum discharge allowed through the orifice. If left as blank which is the default, it assumes no restriction on the discharge. This would normally only be used for a complex flow control device or real time control that had a defined limiting discharge.

The basic orifice coefficient depends on the relative size of the orifice and the pipe that it discharges into:

$$C_0 = \frac{1.41}{1.70 - (A_0 / A)}$$

Where:

A_0 = area of orifice opening

A = area of continuation pipe

If all incoming flow is directed towards the orifice and there is a significant approach velocity typically greater than 1 m/s, then this basic coefficient is modified for the velocity of approach by multiplying by the factor F, which is further discussed in Appendix 4D Section 3.

4.3.3 First Flush Separator

A first flush structure is a pipe that diverts the initial storm runoff and shall be modelled as a conduit. An example is provided in Appendix 4D.1 Section 1.3. To model a first flush, the modeller shall follow the same guidance provided in Section 4.2.1 for modelling a conduit. When the first flush is extremely short (<3 m), an assumed conduit length of 3 m shall be used in the model to ensure model stability.

4.3.4 Flap Gates

Flap gates and backflow prevention valves shall be modelled using a flap valve link. An example is provided in Appendix 4D.1 Section 1.4.

Table 4-6 provides the hydraulic parameters for defining a vertical sluice gate. A discharge coefficient of 1.0 shall be used unless there is specific information on the flow characteristics of the gate or valve.

Table 4-6 Parameters for Flap Gate Definition

Sluice Definition Fields	Description
Valve type	Circular or Rectangular
Invert level (m AD)	The level at which the flap valve comes into operation.
Discharge Coefficient	A value of 1.0 is recommended, which corresponds with the typical head loss of a standard cast iron flap valve.
Diameter (m)	Applies when the "Circular" valve type is used.
Height (m)	Applies when the "Rectangular" valve type is used.
Width (m)	Applies when the "Rectangular" valve type is used.

4.3.5 Sluice Gates

Sluice gates are used in the model to represent gates in the sewer systems. The standard option in InfoWorks ICM is a vertical sluice gate, which is suitable for modelling a gate with a fixed opening. An example of how to model a vertical sluice gate is provided in Appendix 4D.1 Section 1.5. A gate that is operating under manual or automatic controls shall be defined as a variable sluice gate, which is discussed in Section 4.4 Real Time Control.

Table 4-7 provides the hydraulic parameters for defining a vertical sluice gate. When the flow is at a depth lower than the gate opening height, the sluice gate operates as open channel flow; and when the flow is submerged, it acts as an orifice control. For each flow condition, the appropriate value for the discharge coefficient shall be defined as described in Table 4-7.

Table 4-7 Parameters for Sluice Gate Definition

Sluice Definition Fields	Description
Invert level (m AD)	The level at which the sluice gate comes into operation.
Width (m)	The width of the rectangular sluice gate.
Discharge Coefficient	The coefficient for the orifice flow equations when the gate is fully submerged and act similar to an orifice. A default value of 1.0 shall be used for typical overall velocity and contraction coefficient based on ICM help menu.
Secondary discharge coefficient	This applies when the depth of water is less than the opening of the gate, and it operates like a thin plate weir the width of the gate. A default value of 1.0 shall be used for a typical gate in sewer system based on ICM help menu, unless the bottom of gate opening is raised above the incoming invert and then the weir coefficient value of 0.85 provided in Section 4.3.1 shall be used.
Overgate discharge coefficient	This applies when the gate is overtopped. This is not applicable to piped system and therefore shall be left as default value of 1.0.
Opening height (m)	Vertical opening of the gate.
Gate depth (m)	Depth of gate which is the dimension from the bottom to the top of the gate. If not specified, the sluice will never overtop. This is not applicable to piped system and therefore shall be left blank.

4.3.6 Pumps

Pumps are modelled where non-gravity flow elements are required to convey flow from lower areas to higher areas such as a sanitary pumping station or a stormwater tank.

Pumps are modelled as links and require a wet well node or an underground storage facility node upstream of the pump link. Pumps are controlled by an on/off switch based on the water elevation in the upstream node.

The modeller has flexibility to simplify pump representation in the model based on the magnitude of the drainage area or flow contribution to the collection system. Based on how the pump is operated and how the water levels vary in the wet well, a pump shall be modelled using either a fixed discharge pump or a variable frequency drive (VFD) pump. Examples are provided in Appendix 4D.1 Section 1.6.

Table 4-8 Types of Pump Model

Type	Characteristics	Parameters
Fixed discharge	The discharge capacity does not vary with the head across the pump.	• Switch on/off level • Discharge rate
Variable Frequency Drive	The discharge capacity is defined as a curve against the head across the pump.	• Switch on/off level • Head-discharge table • Nominal speed • Minimum and maximum speed • Positive and negative change in speed

4.3.6.1 Variable Frequency Drive Pumps

Variable frequency drive pump shall be used where the static head across the pump varies significantly compared to the total static and dynamic head. This is likely required if the forcemain is short and there is a large range of water levels in the upstream wet well, or the downstream gravity sewer affects discharge from the forcemain due to surcharging and backwater. This type of pump shall also be used if two different pumping stations share a pumping main, as the capacity of each pumping station depends on whether the other is operating or not.

For a VFD pump, the downstream conduit representing the forcemain shall be included in the model and shall have the Solution Model parameter in the pump table in InfoWorks set to “ForceMain”, which assumes the pipe is always full even though the hydraulic grade line can drop below the pipe obvert. This assumption forces InfoWorks to model the pipe as a pressurized pipe regardless of the flow conditions and so negative hydraulic grade lines do not necessarily indicate erroneous results.

If the control is based on more than only the upstream water levels in wet well, real-time controls can be added to the variable frequency drive pump; these are discussed in Section 4.4 Real Time Controls.

4.3.6.2 Fixed Discharge Pumps

Fixed discharge pumps shall be used for all other pumps. It is not necessary to include the downstream conduit representing the forcemain in the model. The pump link can discharge directly to the receiving manhole. The pump capacity shall be defined based on field survey of its performance e.g. drawdown tests or rated capacity (i.e. an assessment of pump curves and system curves).

If more than one pump can run at the same time, then the capacity of the additional pumps is defined as the marginal increase in discharge provided by the additional pump rather than the total capacity of the pumps.

If the control is based on more than only the upstream water levels in wet well, real-time controls can be added to the fixed discharge pump; these are discussed in Section 3.4.10 Real Time Controls.

4.3.7 Inverted Siphon

An inverted siphon is used to convey flow in a gravity sewer system under a crossing such as a roadway, a watercourse, or a major utility. An inverted siphon can be composed of a single barrel or of multiple parallel barrels. For a multiple barrel siphon, the barrels could have different diameters and be situated at different elevations. Additionally, each barrel may have an inlet weir at different elevations so that low flows are only directed into one barrel and the others solely operate at high flows. Therefore, each barrel needs to be represented as a separate model object. An example of how to model an inverted siphon is provided in Appendix 4D.1 Section 1.7.

Each barrel shall be modelled using as series of conduit objects that defines the length, size, and inverts. The modeller shall follow the guidance provided in Section 4.2.1 for modelling a conduit.

An inverted siphon is likely to have deposits of sediment; therefore, it is recommended to model the sediment based on findings of CCTV or field survey.

4.3.8 Culverts

Major culverts are conveyance structures typically connecting two open channels at a bermed crossing under a road or railway. A culvert can also be a direct inlet to a piped sewer system. For sewer system modelling, it is usually not necessary to model a culvert using specific culvert model objects unless the structures are larger than approximately 3000 mm in diameter. A driveway culvert may be modelled using a conduit.

In InfoWorks ICM, three links are used to define a major culvert connecting two open channels: a culvert inlet, a conduit representing the culvert barrel itself, and a culvert outlet. A series of dummy nodes and links are required to define and connect these components and an example is provided in Appendix 4D.1 Section 1.8. If the culvert functions as an inlet to the sewer system, it will only require the culvert inlet and conduit object to be modelled.

Table 4-9 provides the hydraulic parameters for defining a culvert. The headloss of a culvert is captured through the culvert inlet and outlet. Note that the headloss type for the conduit representing the culvert shall be set to "None" to avoid double counting the headloss. Parameters for the inlet and outlet variables shall be defined based on the inlet and outlet configuration. The headloss through the culvert is either dominated by the inlet or outlet headlosses (inlet or outlet controlled). For major culverts, the modeller shall conduct appropriate culvert hydraulic analysis and consult Appendix 4D.1 Section 4 for recommended culvert headloss coefficients.

Note that engineering judgment should be applied on a case-by-case basis to assess if culverts smaller than 3000 mmm should be modelled in detail using the appropriate level of culvert hydraulic analysis.

Table 4-9 Parameters for Culvert Definition

Definition Fields with Parameters	Description
Culvert Inlet	
Invert level (m, AD)	Invert level at upstream of the culvert barrel.
K, M, c, Y	Constants in inlet control equations.
Inlet headloss coefficient (Ki)	Constant in headloss equations.
Conduit	
Shape ID, Width (mm) and Height (mm)	Shape and size of the culvert barrel.
Bottom and Top roughness Manning's n	Roughness value based on material of the culvert barrel.
US and DS invert level (m, AD)	Upstream and downstream inverts of the culvert barrel.
US and DS headloss type	Set to "NONE".
Culvert Outlet	
Invert level (m AD)	Invert level at downstream of the culvert barrel.
Inlet headloss coefficient (Ko)	Constant in headloss equations.

4.3.9 Outfalls

Outfalls are placed at locations where water is known to exit the system such as storm outfalls, CSO outfalls, boundaries to another model, and discharge locations to a wastewater treatment facility.

An outfall is modelled via a conduit and a node with type "Outfall". An example is provided in Appendix 4D.1 Section 1.9. InfoWorks ICM assumes free discharge from an outfall by default. Where this assumption is invalid, such as under partially submerged or fully submerged conditions, an appropriate fixed boundary condition or a level event must be created to simulate time-varying boundary condition.

Outfalls are also used at Metro Vancouver (MV) tie-in points where the City sewers discharge into MV trunks, or where hydraulic conditions in the pipes downstream of the assumed outfall are unlikely to influence the modelled sewer system. Additionally, an outfall may be used to limit the extent of the model boundary. In this case, a boundary condition can be set at the outfall to replicate the hydraulic conditions of the downstream system as opposed to extending the model boundary outside of the study area or a MV trunk.

Section 4.5.2 provides guidance on how to apply boundary conditions for outfalls.

4.4 Real Time Controls

Real Time Controls (RTCs) can be used to represent changes in the operation of pumps, weirs, or sluice gates according to the flow condition elsewhere in the sewer system. RTC shall only be used as required to improve simulation of special structures or more complex operational conditions. Table 4-10 lists the two types of flow control structures that shall be implemented with RTC in InfoWorks ICM.

Table 4-10 Real Time Control Structures and Corresponding Control Actions

Structure	Control Action
Variable frequency drive pump	On-off speed (rpm)
Variable sluice gate	Vertical opening (m from bottom up)

There are four components to an RTC set-up in InfoWorks ICM:

- **A regulator** - This is the gate or pump itself.
- **A range** - This is a measurement of the variable that needs to be controlled between the defining maximum and minimum permitted values. A Range returns a logical trigger: TRUE if the conditions are within a defined range or FALSE otherwise.
- **A rule** - This defines what to do if the measured value is outside the defined range. The preferred set-up is to trigger a PID controller. The PID controller uses Proportional, Integral and Differential (PID) equations to calculate the change necessary for the regulator. Table 4-11 lists the recommended coefficients for a PID controller.
- **A controller** - This defines how the control structure (the pump or gate) changes to achieve the required value for the control variable.

Table 4-11 PID Coefficients

PID Coefficient	Description
P	Use -1 when the control point is downstream of the Regulator and use +1 when the control point is upstream of the Regulator.
I	Use I = 0.
D	Use D = 0.

The modeller shall refer to the InfoWorks ICM Help manual and to a modeller with experience of RTC for more detailed information and various examples for RTCs. In general, the steps to configure RTCs in InfoWorks ICM are:

1. Open the RTC editor window from Windows > Grid window > RTC editor.
2. Insert a Regulator by right clicking any item in the RTC editor and selecting 'Insert Regulator'. A pop-up window will list all structures eligible for RTC, select the desired structure and click 'OK'. If the desired structure does not show up in this list, it means it is not set up for operation as a RTC structure.

3. Insert other components necessary for RTC of the defined Regulator, such as Range, Rule, Controller, by right clicking the Regulator and selecting 'Insert dependant' to choose the desired option.
4. For each component added for the RTC, configure the set-up, and click 'Update' button to apply the changes. InfoWorks ICM Help manual may be consulted for more information and explanation of each definition field.
5. After adding and configuring all components for the Regulator, click on the Regulator and read the Description field of the Regulator. This Description will summarize how the Regulator operate based on the defined Range, Rule, Controller, etc. The modeller shall review it carefully to ensure the set-up is appropriate.
6. Validate the RTC definitions. Right-click any item in the RTC window and select 'Full validation'. A pop-up window will list errors found for all items in the RTC Editor. InfoWorks ICM Help manual contains a topic call 'RTC Validation Messages' which provides explanations for any error found through RTC validation.
7. Review the simulation results to understand the RTC operation. The modeller shall open the simulation results in Geoplan and use Graph tool to visualize the behaviour at the RTC structures, and confirm the modelled behaviour is consistent with expectations.

4.5 Boundary Conditions

The conditions at the study area boundaries shall be established early in the project as they may significantly impact the results from the model. Sanitary, combined, and storm systems in a study area may interact with adjacent systems like local sewers, receiving trunks, interceptors, and receiving water bodies. To model these boundary conditions, they are represented as inflow or a water level.

Table 4-12 Types of Model Boundary Conditions

Boundary Condition	Description	Data Source
Inflow	Inflow from connected upstream sewer system	• Flow monitoring data • External area models
Level	Outfall to watercourses/oceans	• Water level data • Tide level data
	Discharge to sewer outside study area or Metro trunk sewer	• Flow monitoring data • External area models • Trunk sewer models

4.5.1 Inflow

A newly modelled sewer system may receive inflows from an upstream catchment outside of the study area. The inflow from the upstream catchment shall be simulated by attaching an inflow event containing the flow versus time series with reference to the appropriate inflow node. Figure 4-4 shows the inflow definition in InfoWorks ICM. Alternatively, it may be appropriate to incorporate a simple lumped area model for the external source of inflow into the ICM model.

To apply an inflow event during model simulation, the date and time of the inflow event must match the date and time of the simulation for it to be applied. Separate inflow events shall be created for different storm events and used in the model simulation correspondingly, e.g. DWF inflow for DWF simulation, 5-year inflow for 5-year design storm simulation. Similarly, separate inflow events shall be created for multiple scenarios if they will be under the influence of different sewer system conditions, such as existing versus future conditions.

To define inflow from historical events, the preferred data source is from historical flow monitoring data. For all other conditions, some form of model will be required to generate the inflows, such as another existing InfoWorks ICM model.

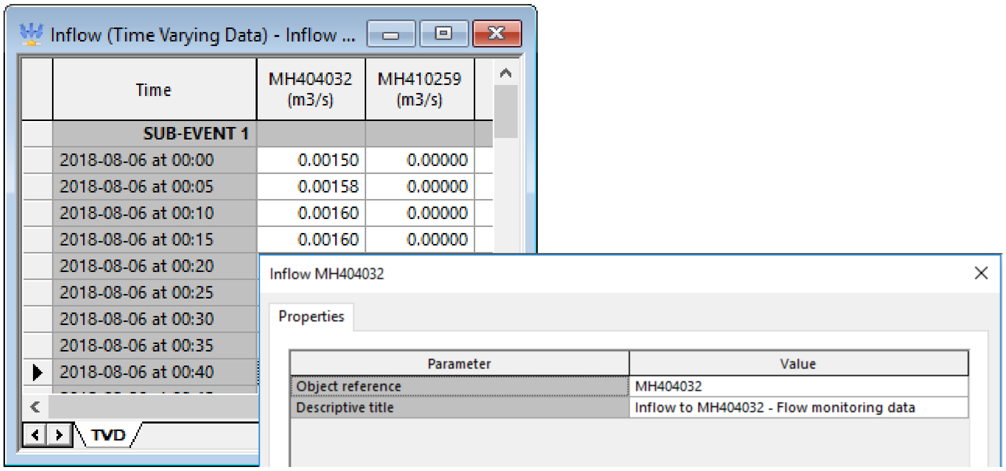


Figure 4-4 Inflow Hydrograph Editor

4.5.2 Level

Water level boundary conditions shall be applied where the HGL and flow rates in the sewer system can be impacted by fluctuating water levels at an outfall or a Metro Vancouver (MV) trunk connection.

Time varying water level data is needed to define the boundary conditions, which can be flow monitoring data, hydrometric data, or derived from other models. If water level data is available, a boundary condition containing a water level versus time series shall be assigned to the appropriate outfall or MV trunk connection node. Figure 4-5 below shows the level boundary condition definition in InfoWorks ICM.

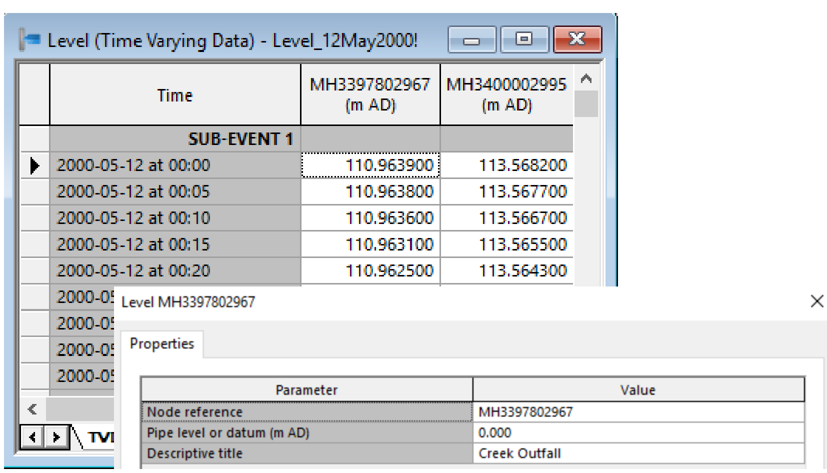


Figure 4-5 Level Hydrograph Editor

The date and time of the water level event must match the date and time of the simulation for it to be applied. Separate water level events shall be created for different storm events and used in the model simulation correspondingly, e.g., 5-year inflow for 5-year design storm simulation. Similarly, separate water level events shall be created for multiple scenarios if they will be under the influence of different sewer system conditions, such as existing versus future conditions.

If water level data is not available, the following boundary conditions shall be used:

1. Metro Vancouver trunks
   It would be ideal to obtain time varying water levels derived from the MV trunk sewer model to define level boundary conditions for City sewers that discharge into MV trunks. If hydraulic modelling results are not available from MV, assume fixed HGL boundary conditions equivalent to obvert of the trunk sewer at connections to MV trunk for up to a 5-year design storm. This assumes surcharging conditions in MV trunks. Beyond a 5-year design storm sensitivity tests shall be performed to achieve the overall goal of the project. For example, if the system is being designed for 25-year design storm, the outcome of the sensitivity tests based on cost benefit analysis may show that the sewer system can be designed for 25-year return based on a certain level in the trunk sewer.

2. Tidal boundary conditions
   The modeller shall refer to Appendix 4D.4 WaPUG user note No. 22 Section 2 for guidance on how to represent tidal levels. A diurnal tidal curve would be ideal to represent time varying tidal levels. It is recommended to review the latest published information on sea level rise and to perform a sensitivity analysis based on this a latest guidance, if applicable, to understand the impact on the sewer system.

3. Discharge to the Fraser River
   It would be ideal to obtain time varying water levels derived from hydrometric data, river floodplain studies, or existing river models to define level boundary conditions for City sewers that discharge into rivers. The modeller shall confirm the appropriate boundary level condition with City staff from the upcoming Fraser River Floodplain Flood & Drainage Options Study with estimated completion early 2024.

4. Discharge to Creeks
   It would be ideal to obtain time varying water levels derived from Hydrometric data, floodplain studies, or existing calibrated models to define level boundary conditions for City sewers that discharge into Creeks. The existing model should be calibrated / validated with the Creek's hydrometric data. If hydrometric data or hydraulic modelling results are not available, assume fixed HGL boundary conditions equivalent to the Creek's Bank Level at connections to the outlet pipe for up to a 5-year design storm. Beyond a 5-year design storm sensitivity tests shall be performed to achieve the overall goal of the project. For example, if the system is being designed for 25-year design storm, the outcome of the sensitivity tests based on cost benefit analysis may show that the sewer system can be designed for 25-year return based on a certain level of water in the Creek.

4.6 Green Infrastructure

Green Rainwater Infrastructure (GRI) systems can detain, infiltrate, and treat runoff from small and frequent rainfall events. The City requires the use of GRI systems to capture runoff in the public realm such as roads and sidewalks and in the private realm such as privately owned parcels including roofs and yards. The City's Integrated Rainwater Management Plan, 2016 sets performance targets for GRI systems for areas of the City where stormwater is piped directly to the sewer system, surface streams, and ocean outfalls.

The focus of the section is on the planning stage of public realm GRI systems on a watershed scale; such GRI system models typically evaluate:

- The existing condition with existing GRI systems
- The existing or future condition with proposed GRI systems

The following sub-sections outline a modelling approach in InfoWorks ICM for planning of public realm GRI systems and provide an overview of GRI systems, performance targets, and presents useful reference documentation.

4.6.1 GRI Systems

The City has a variety of GRI typologies that can rely solely on infiltration, or additionally, may also have an underdrain to convey flow back into the sewer system. These GRI typologies are referred to as full or partial infiltration GRI systems, respectively.

Table 4-13 below provides some examples of GRI typologies, though not exhaustive. For more in-depth information on GRI topologies, see the Green Infrastructure Design Guidance Manual (Draft) and Appendix B of the Rain City Strategy, 2019.

Table 4-13 Examples of Green Rainwater Infrastructure Typologies

GRI Typology	Description
Bioretention	Bioswales, rain gardens, and bioretention bulges/cells.
Rainwater Tree Trenches	Tree trenches are a series of tree pits connected in the subsurface by perforated pipes which receive stormwater from surface inlets.
Permeable Pavement	Includes porous asphalt, pervious concrete, permeable concrete unit pavers, and grid pavers that may be filled with gravel or vegetation.
Subsurface infiltration	Includes subsurface infiltration practices such as infiltration trenches, dry wells, soakways, chambers, arches, modular systems, and linear gravel filled trenches.
Absorbent landscapes	Natural or manmade landscapes that act like a sponge to soak up and slowly release rainfall.
Downspout disconnection	Rooftop disconnection is when roof drain pipes drain to pervious areas and lawns instead of directly into the drainage system.

4.6.2 Public Realm GRI Systems Performance Targets

As part of the Integrated Rainwater Management Plan, 2016 study, a quantitative assessment of historical rainfall patterns found that 70% of annual rainfall volumes are from light showers and are equivalent to the first 24 mm of rain in 24 hours. Furthermore, 90% of annual rainfall volumes are from light showers and rainstorms together and represent the first 48 mm of rain in 24 hours. Extreme rainstorms are only 10% of annual rainfall volumes and represent events exceeding 48 mm in 24 hours.

Table 4-14 presents the public realm performance targets summarized in Section 6.1.1 of the Rain City Strategy, 2019 report.

Table 4-14 Public Realm GRI Performance Targets

Target	Measure	Rainfall Depth
Runoff Volume	Capture (infiltrate, evapotranspirate, and/or reuse) 50% of the 6-month 24-hour storm event.	24 mm
Water Quality	Treat 100% (remove pollutants) of the 6-month 24-hour storm event.	48 mm

For guidance on private realm GRI performance targets see the City's Rainwater Management Bulletin, 2022.

4.6.3 Planning Stage Public Realm GRI Systems Modelling Approach

This section provides a public realm GRI systems modelling approach at the planning stage. Note that private realm GRI systems may need to be included in the public realm assessment. Therefore, a simplified method to model private realm GRI systems as part of a public realm model is also provided.

4.6.3.1 Public Realm Model

For public realm GRI systems at the planning stage, it is not recommended to represent each component of a GRI system in the model, as this requires too much detail. Therefore, approximating full infiltration GRI systems as an average across their catchments is generally deemed a more practical and appropriate modelling approach at the planning stage.

To achieve this, the catchment of a GRI system shall be represented by an impervious runoff surface where the infiltration rate and a storage depth are defined. A duplicate of the appropriate impervious runoff surface should be created and its Runoff Volume Type shall be set to ConstInf. In contrast to the Fixed runoff model that is used in the City's standard runoff surfaces, the ConstInf runoff model also has an "Infiltration loss coefficient" parameter which allows for a constant infiltration rate. In other respects, the ConstInf surface acts in the same way as a Fixed runoff surface. The storage capacity of the GRI system is represented by the "Initial loss value" parameter. The pervious runoff surface shall remain unchanged.

The Impervious-Pervious (IP) Ratio is a useful tool for preliminary GRI systems sizing. The IP ratio compares the contributing impervious catchment area to the pervious GRI system area. Refer to Chapter 5.7 of the GRI Design Guidance Manual (Draft) for the recommended maximum IP ratios for functional GRI systems sizing. The catchment area of the GRI system should be delineated and separately modelled if part of a larger catchment that is not intended to drain to the GRI system; the contributing area field in each catchment should be updated appropriately.

Note that the Runoff Routing Value, Initial Loss Value, and the Infiltration Loss Coefficient parameter values required to achieve the desired performance targets, will be different depending on the modelled GRI system type, IP ratio, GreenAmpt Conductivity, and design storm and duration. Therefore, these parameters shall be confirmed with the City's GII staff members for each GRI system and study area under assessment.

Recommended modelling parameters for the ConstInf surface are provided in Table 4-15 below.

Table 4-15 Runoff Surface Model Parameters for Public Realm GRI at the Planning Stage

Parameter	Description	Value
Runoff routing type	Specifies the runoff model to be used.	ConstInf
Runoff Routing Value	This value represents the Manning roughness of the surface.	0.018 for the impervious surface; however, this value shall be confirmed with the City's GII branch staff members for the each GRI system type, IP ratio, GreenAmpt Conductivity, and design storm and duration that is modelled since changes to peak flow are sensitive to this parameter.
Initial loss type	Specifies that the initial loss is an absolute value (m).	Abs
Initial loss value	Storage depth (m).	The target treatment depth – using the performance target values from Section 4.6.2 directly tend to overestimate the storage capacity of the modelled GRI system; therefore, the value shall be determined for each GRI system, IP ratio, GreenAmpt Conductivity, and design storm and duration that is modelled in consultation with the City's GII branch staff members.
Initial loss porosity	Proportion of storage that is open space and can hold water.	Use a value of 1.0.
Infiltration loss coefficient	Infiltration (mm/h).	Hydraulic conductivity values from in-situ soil testing are preferred. Since in-situ values are typically not available, the value for each GRI system, IP ratio, GreenAmpt Conductivity, and design storm and duration that is modelled shall be determined in consultation with the City's GII branch staff members. It not recommended to use the values in Table 4-14 of the Green-Ampt "conductivity" parameters based on the underlying soil, as they will likely provide unrealistic results.
Fixed runoff coefficient	The proportion of runoff that enters the drainage system.	Normally set to 1.0 – could be reduced if some or all of the overflow from a GRI system discharges directly to a watercourse.

Alternatively, GRI systems may also be modelled using the standard catchment and runoff surface configuration where the Runoff Routing Type is set to Fixed and the Initial Loss Value, i.e. storage depth, is set to an appropriate value to achieve the desired performance target. Note that directly using the performance targets values of 24 and 48 mm for the Initial Loss Value parameter would not result in realistic results. Using this approach, the value for the Initial Loss Value parameter shall be confirmed with the City's GII branch staff members for each GRI system, IP ratio, GreenAmpt Conductivity, and design storm and duration that is modelled.

4.6.3.2 Private Realm Contributions

At the planning stage, GRI systems for developments in the private realm may need to be modelled as part of a public realm GRI system assessment. Private developments are required to restrict post development future storm flows to the existing pre-development storm flows. To model this, rainfall profiles representing the existing and future rainfall events shall be defined as rainfall profile 1 and 2, respectively. Subsequently, rainfall profile 1 should be assigned to all redevelopment catchments and rainfall profile 2 to the remaining future condition catchments.

4.6.4 Design Stage Public Realm GRI Systems Modelling Approach

This Green Rainwater Infrastructure section is focused on public realm GRI systems modelling at the planning stage.

However, InfoWorks ICM does allow for detailed modelling of GRI systems, named SUDS (Sustainable Urban Drainage Systems) in InfoWorks ICM. SUDS Control Types can be used to model in detail various GRI systems and are located in the SUDS Control tab in the subcatchments grid window.

The parameters for each Control Type are available upon request from the City's Green Infrastructure Implementation (GII) branch. The detailed modelling approach using the SUDS Control Type follows a similar approach as GRI systems modelling in PCSWMM. The GII branch has extensive knowledge of modelling GRI systems in detail for design purposes using PCSWMM including modelling standards and parameters. Therefore, GII and ISDP staff should be consulted on the detailed design modelling approach of GRI systems in InfoWorks ICM.

Additionally, for guidance on design of public realm GRI systems, see the Green Infrastructure Design Guidance Manual (Draft), available upon request from the City's Green Infrastructure Implementation branch.

4.6.5 Reference Documents

Table 4-16 below provides useful reference documentation relating to GRI system modelling, design targets, and detailed design.

Table 4-16 GRI Reference Documentation

<table>
<tr><th>Document Name</th><th>Description</th></tr>
<tr><td>GI Modelling Guide, 2021</td><td>Request from the City's GII Branch.
Best practices for modelling GRI systems using SWMM software. This guide also includes guidance for assessing the performance of GRI assets relative to City of Vancouver performance targets.</td></tr>
<tr><td>Green Infrastructure Design Guidance Manual (Draft)</td><td>Request from the City's GII Branch.
Provides guidance on design of GRI systems.</td></tr>
<tr><td>COV Integrated Rainwater Management Plan Volume I, Vision, Principles and Actions, 2016</td><td rowspan="2">Stipulates rainwater management design targets and strategies for where stormwater is piped directly to the combined sewer system, ocean outfalls, and streams.</td></tr>
<tr><td>COV Integrated Rainwater Management Plan Volume II, Best Management Practices Toolkit, 2016</td></tr>
<tr><td>Rainwater Management Bulletin, 2022</td><td>Stipulates private realm GRI design targets.</td></tr>
<tr><td>Rain City Strategy, 2019</td><td>The strategy builds on the Integrated Rainwater Management Plan, 2019 and sets a vision for collective action around GRI implementation in the City.</td></tr>
</table>

Document Name	Description
MV Stormwater Source Control Guidelines, 2012	Provides guidance on how to design detailed GRI systems including descriptions, applications, design considerations, and sizing.

4.7 Hydrologic Model

This section discusses the runoff routing methodology and hydrologic parameters that shall be used for City models and describes how subcatchments, land use, and runoff surfaces can represent the Hydrologic model in InfoWorks ICM. Note that for City models, solely one land use has been defined in the land use module to link runoff surfaces to subcatchments, as per Section 4.7.4. Additionally, Section 4.7.5 outlines storm subcatchment configuration and Appendix 4B provides guidance on data preparation and a detailed methodology to import storm subcatchments into the model.

Guidance on how to configure sanitary subcatchments is provided in Section 4.8.3.

The hydrologic model in InfoWorks ICM follows a hierarchical structure with the subcatchments property tables at the highest level followed by the land use and runoff surface property tables as shown on Figure 4-6 below. Due to this structure, if any parameters are updated that are common to all three property tables, InfoWorks ICM will use the value in the table at the highest level.

The runoff models and runoff surfaces including their hydrologic parameters have been pre-configured and incorporated into the City's InfoWorks ICM Model Template Database that accompanies this document.

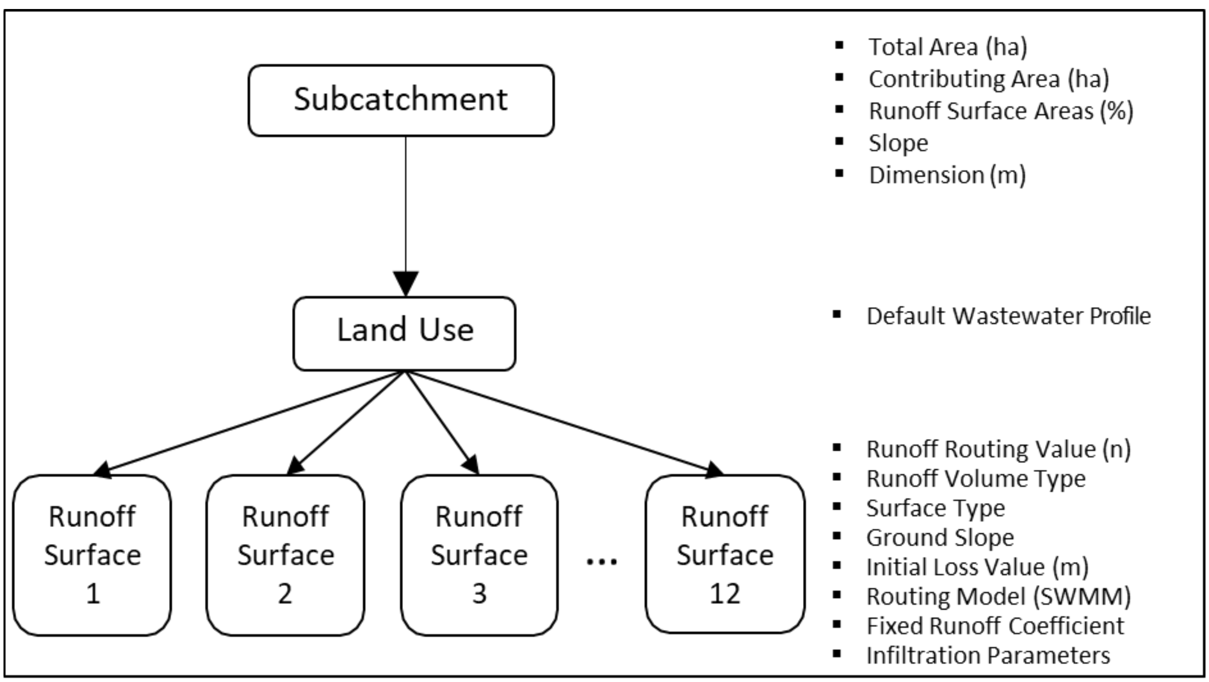


Figure 4-6 Hydrologic Model Structure

4.7.1 Runoff Routing Model

A Runoff Routing Model is used to generate surface runoff hydrographs from simulated rainfall. The most commonly used Runoff Routing Model in North America is the Stormwater Management Model (SWMM) and shall be used for City models. SWMM runoff routing incorporates a non-linear reservoir and the kinematic wave equation. Additionally, SWMM uses subcatchment width, Manning's n roughness values, and depression storage for impervious and pervious surfaces to calculate surface runoff, ultimately, providing stormwater inflows to the sewer system.

Section 4.7.3 provides the recommended SWMM Runoff Routing Model parameters that shall be used for City models.

4.7.2 Runoff Volume Model

The Runoff Volume Model is used in InfoWorks ICM to determine how much rainfall runs off the storm subcatchment into the sewer system after accounting for any initial losses. The Runoff Volume Model to be used is set in the Runoff Volume Type field in each runoff surface. For City models, the Runoff Volume Type shall be set to a Fixed Percentage Runoff for impervious runoff surfaces and the Green-Ampt infiltration method shall be set for pervious runoff surfaces.

Section 4.7.3 provides more details on runoff surfaces and the recommended SWMM Runoff Volume Type parameters that shall be used for City models.

4.7.3 Runoff Surfaces

InfoWorks ICM utilizes runoff surfaces to represent the hydrologic characteristics of impervious and pervious areas within each storm subcatchment. Table 4-17 presents the runoff surface categories that shall be used for City models.

Table 4-17 Standard Runoff Surface Categories

Category	Runoff Surface Type	Description
10	Impervious – general parcels	Parcels
11	Impervious – paved areas	Roads, sidewalks, parking lots, patios
12	Impervious – flat roofs	Flat roofs
13	Impervious – steep roofs	Steep roofs
50	Pervious – poor Infiltration	Pervious area with low infiltration potential
51	Pervious – low Infiltration	Pervious area with moderate infiltration potential
52	Pervious – moderate Infiltration	Pervious area with high infiltration potential

The percent impervious values for runoff surface 10 to 13 have been determined for each land use category and can be found in Section 4.7.4. Parcels and roads/sidewalks shall be represented in City models by impervious runoff surface 10 and 11, respectively, and only one of the pervious surfaces 50, 51, or 52 shall be used for each subcatchment.

Table 4-18 below shows the set of predetermined hydrologic parameters for each runoff surface such as initial loss values, runoff volume method, and routing method that shall be used for City models.

Table 4-18 Runoff Surface Configuration including Parameters

Parameter	Runoff Surface ID						
	10	11	12	13	50	51	52
Runoff Routing Type	Abs	Abs	Abs	Abs	Abs	Abs	Abs
Runoff Routing Value	0.018	0.018	0.015	0.015	0.410	0.410	0.410
Runoff Volume Type	Fixed	Fixed	Fixed	Fixed	GreenAmpt	GreenAmpt	GreenAmpt
Surface Type	Impervious	Impervious	Impervious	Impervious	Pervious	Pervious	Pervious
Ground Slope (m/m) [1]	0.01	0.01	0.01	0.33	0.01	0.01	0.01
Initial Loss Type	Abs	Abs	Abs	Abs	Abs	Abs	Abs
Initial Loss Value (m)	0.00125	0.00125	0	0	0.0025	0.0025	0.0025
Routing Model	SWMM	SWMM	SWMM	SWMM	SWMM	SWMM	SWMM
Fixed Runoff Coefficient	1.0	1.0	1.0	1.0			
Green-Ampt suction (mm)					292.2	166.8	61.3
Green-Ampt Conductivity (mm/h)					1.0	6.8	59.8
Green-Ampt deficit					0.092	0.171	0.312
Initial Loss Porosity [2]	1.0	1.0	1.0	1.0	1.0	1.0	1.0

1 Validation warnings will appear for some of these ground slope values, but no action is needed.

2 The initial loss porosity shall use different values when modelling green infrastructures. See Section 4.6 for guidance on this parameter for green infrastructures.

The runoff surfaces in Table 4-18 have been incorporated into the City's InfoWorks ICM Modelling Template that accompanies this document.

The hydrologic parameters are recommended industry values with the exception of the roof slopes which are City specific.

4.7.3.1 Initial Loss Values

The initial loss values are in line with the values in the City's PCSWMM Modelling Guide.

4.7.3.2 Green-Ampt

The Green-Ampt infiltration parameters in the City are divided into three distinct groups: poor, low, and moderate infiltration potential. Various soil types in the City were taken from the provincial BC Soils map and grouped into these three categories based on their infiltration potential. The Green-Ampt parameters were subsequently taken from the SWM manual and assigned to each group. These are default starting values and should be superseded with site specific geotechnical data if available.

4.7.3.3 Ground Slope

A fixed ground slope value of 1% shall be used for all subcatchment areas except steep roofs. This fixed ground slope assumption is used instead of the average ground slope from LiDAR since in reality most lots have been made relatively flat to build homes. Note that the ground slope values have a small impact on the runoff hydrograph.

4.7.3.4 Fixed Runoff Coefficient

The fixed runoff coefficient shall be set to 1.0, meaning all excess rainfall after the initial loss will contribute to runoff. A value of 1.0 is reasonable for non-extreme storm events below approximately the 5-year return period. However, a value of 1.0 has been shown to overestimate flows in the system under more extreme events. See Section 5.3.2 for how the fixed runoff parameter may be adjusted when calibrating the model under extreme events.

4.7.4 Land Use

The City has determined percent impervious values for land use types based on impervious values from calibrated City models. The percent impervious values for each land use type shown in Table 4-19 shall be used as initial values for new City models prior to calibration.

For City InfoWorks ICM models, four land use definitions shall be used in the land use module to link runoff surfaces to the subcatchments, as per Section 5 in Appendix 4A Model Template Database Configuration. These land use definition names in the land use module in InfoWorks ICM are:

- Poor infiltration potential
- Low infiltration potential
- Moderate infiltration potential
- Sanitary

The above land use definitions have been populated in the City's Model Template Database. Note that land use definitions of flow monitor IDs may be added to the land use module for model calibration purposes.

The land use types/zoning codes and the percent impervious values shall be populated in User Defined and Runoff Area (%) fields in the subcatchment object property table, respectively, as described in Section 4.7.5 and further guidance is provided in Appendix 4B Model Data Preparation and Import.

Table 4-19 Land Use Type and Corresponding Percent Impervious Values

Land Use Type	% Impervious	Recommended Zoning Code
Single Family Residential	55	RS, RT
Multi-Family Residential	70	FM, RM
Industrial	90	I, IC
Commercial	90	C, FC
Institutional	90	TBA
Parks	5	-
Historic Development	80	HA
Comprehensive Development	70	CD, CWD, DD, DEOD, FCCDD, BCPED
Roads and Paved Areas	80	-
Roofs	100	-

The land use types were developed by grouping parcels based on their zoning definition. Each zoning code contains many sub codes, e.g., C for commercial contains C1, C2, etc. It should be noted that the calibrated City models used to determine percent impervious values do not span the entire City. Subsequently, the land use types, and percent impervious values are not completely representative of all zoning categories in the City.

Therefore, the land use types, percent impervious values, and recommended zoning codes as shown in Table 4-19, will be refined as additional City models are calibrated using flow monitor data.

4.7.5 Storm Subcatchments

The following sub-sections outline standards for storm subcatchments configuration for City models. Refer to Appendix 4B for a detailed data preparation methodology and import procedure. City modelling staff shall follow both the data preparation methodology and import procedure.

An external consultant may refer to the data preparation methodology and import procedure in Appendix 4B as a guideline but shall adhere to naming conventions, model structure, and contents of model data fields as outlined in the appendix. The consultant shall also ensure that the subcatchments are configured and populated according to Table 4A-4 in Appendix 4A and the standards are adhered to as outlined below.

See Table 3-1 and Appendix 3B for the base GIS layer data locations and attribute field definitions useful for storm subcatchment data preparation, respectively.

Guidance on modelling sanitary subcatchments is provided in Section 4.8.

4.7.5.1 Parcel Main Layer

A city-wide Parcel2Main layer is available for all property parcels upon request from the City. The Parcel2Main layer is an unofficial GIS layer used by City staff to help develop internal models more efficiently. The layer contains additional attribute information that has been pre-processed by the City including zoning categories, pervious infiltration type based on City soil maps, and parcel service connections to sewer mains with corresponding upstream manhole IDs.

4.7.5.2 Parcel Storm Subcatchments

The storm and sanitary subcatchments shall be modelled as separate subcatchments for City models. The storm subcatchments shall consist of parcel and right-of-way subcatchments. Storm subcatchments shall not be used to model sanitary related items such as sanitary flows and rainfall-dependant inflow and infiltration; dedicated sanitary subcatchments shall be used. City GIS layers such as parcels, building footprints, right-of-way areas and soil mapping GIS layers shall be used to create the storm subcatchments.

However, in discussion with the City, the Parcel2Main layer may be used as the basis for the storm and sanitary subcatchments and storm modelling parameters. Note that all City pre-processed information in the Parcel2Main layer including the catchment outlet node IDs may not be blindly relied upon. The consultant/modeller is ultimately responsible for the accuracy of outlet node ID allocation, soil infiltration type, zoning codes, and land use for each subcatchment in the model when using pre-processed information contained in the Parcel2Main layer. Therefore, the consultant/modeller shall use the City's GIS layers to confirm the pre-processed information is accurate and appropriate.

If the consultant/modeller wishes to deviate from using the pre-processed information in the Parcel2Main layer such as the outlet node IDs for a parcel subcatchment, infiltration potential, land use type, zoning codes, etc., a summary Excel document with deviations from data in the Parcel2Main layer shall be submitted to the City for review and to provide the opportunity for the City to potentially update the Parcel2Main layer if justified.

City modelling staff shall use the Parcel2Main layer, and the information contained therein as the basis to create the storm subcatchments.

4.7.5.3 Right-of-Way Storm Subcatchments

The right-of-way subcatchments shall be based on the City's Paved Areas GIS layer within the UMDM.gbd database, representing the right-of way areas (ROW). The ROW areas complement the parcels by filling in the roads, sidewalks, and spaces between the parcels. This ROW layer shall be delineated into subcatchments based on topography. The ROW subcatchment outlet nodes shall be assigned to storm manholes on a pipe-by-pipe basis.

4.7.5.4 Building Roof Subcatchments

The City does not require building roofs to be modelled at present. However, if deemed appropriate for the model study, the City's building footprint layer shall be used to incorporate the roof areas in the storm subcatchments. The roofs can be modelled using a single or two-storm subcatchment method.

The single storm subcatchment has the roofs modelled within the parcel subcatchment but with the impervious and pervious runoff surface percentages adjusted so that the roof can be represented with roof runoff surface 12, 13, or in discussion with the City, an appropriate roof runoff surface for the study area.

Single subcatchment method:

1. The runoff surface percent of the roof, which equals the roof area to the total parcel area fraction, shall be modelled using a roof runoff surface.
2. The impervious runoff surface percent of the parcel shall be subtracted with the roof area to total parcel area fraction to obtain the new impervious runoff surface percent for the parcel.
3. The runoff surface percent for the pervious runoff surface remains the same.
4. The parcel subcatchment, which now also represents the roof, should be connected to one outlet node.

Figure 4-7 provides and an example of the single subcatchment storm approach.

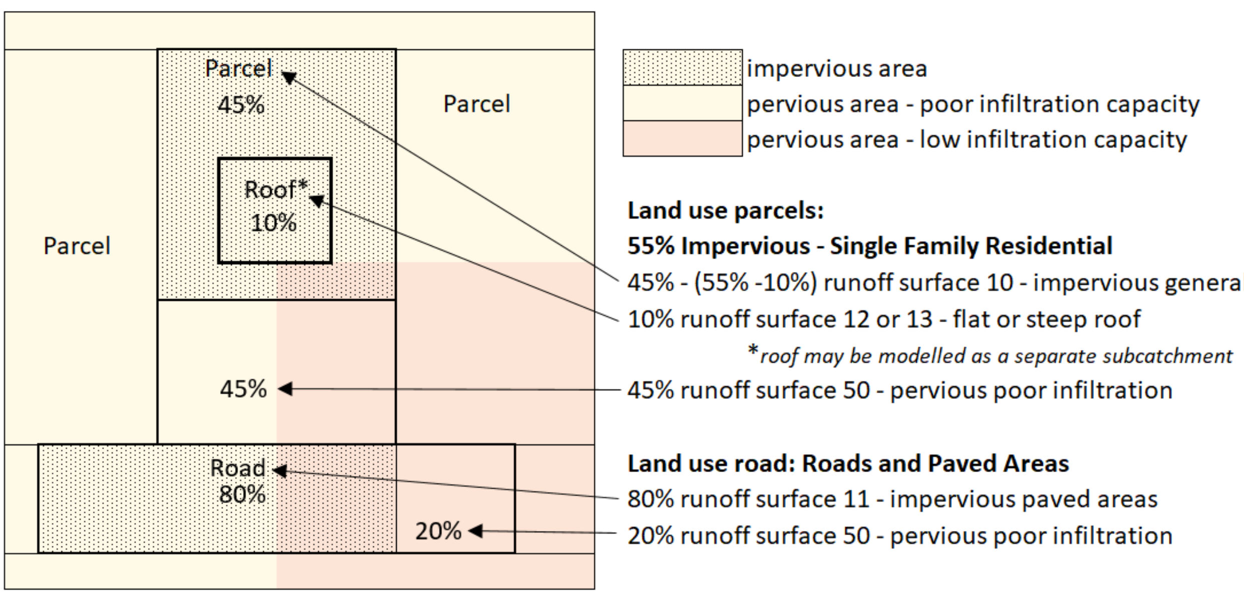


Figure 4-7 Storm Subcatchment Modelled with Roof – Single Subcatchment Approach

Two-storm subcatchment method:

The two-storm subcatchment method has the roofs modelled as separate subcatchments and requires the reconfiguration of the parcel subcatchments (total area, contributing area, and runoff surface percentage values) and the creation of separate roof subcatchments. Note that sufficiently detailed information is required such as accurate building polygons, ideally containing building and roof type definitions. Currently, flat and steep roof runoff surfaces have been defined in the City's standard runoff surfaces and if needed, more roof types could be added.

There are various use cases for this method, including but not limited to modelling detailed GRI systems (on-site rainwater collection systems, etc.), to assess the impact of disconnected roof leaders, and to enable a more refined control of the subcatchments' runoff response during model calibration.

The City is currently developing a standard methodology to modelling roof subcatchments separately, including subcatchment naming conventions, as part of the Trout Lake Assessment Model Development study. The exact model configuration, naming convention, and applicability of a two-subcatchment modelling approach to a new project shall be discussed and confirmed with the City prior to initiating model development. Note that a draft version of the two-subcatchment method may be available upon request from the City.

4.7.5.5 Subcatchment Property Table

The subcatchment property table in InfoWorks ICM contains various storm and sanitary parameters as shown in Figure 4-8.

Key fields to be populated in the storm subcatchments property tables are indicated in Figure 4-8 below. The black and green boxes are fields to be imported to define the storm subcatchments by following the methodology provided in Appendix 4B. The orange boxes indicate additional modelling options, and their purpose and usage can be found in the InfoWorks ICM help section. The red boxes indicate fields strictly used in the sanitary subcatchments. The remaining fields are parameters not used by the SWMM runoff routing model.

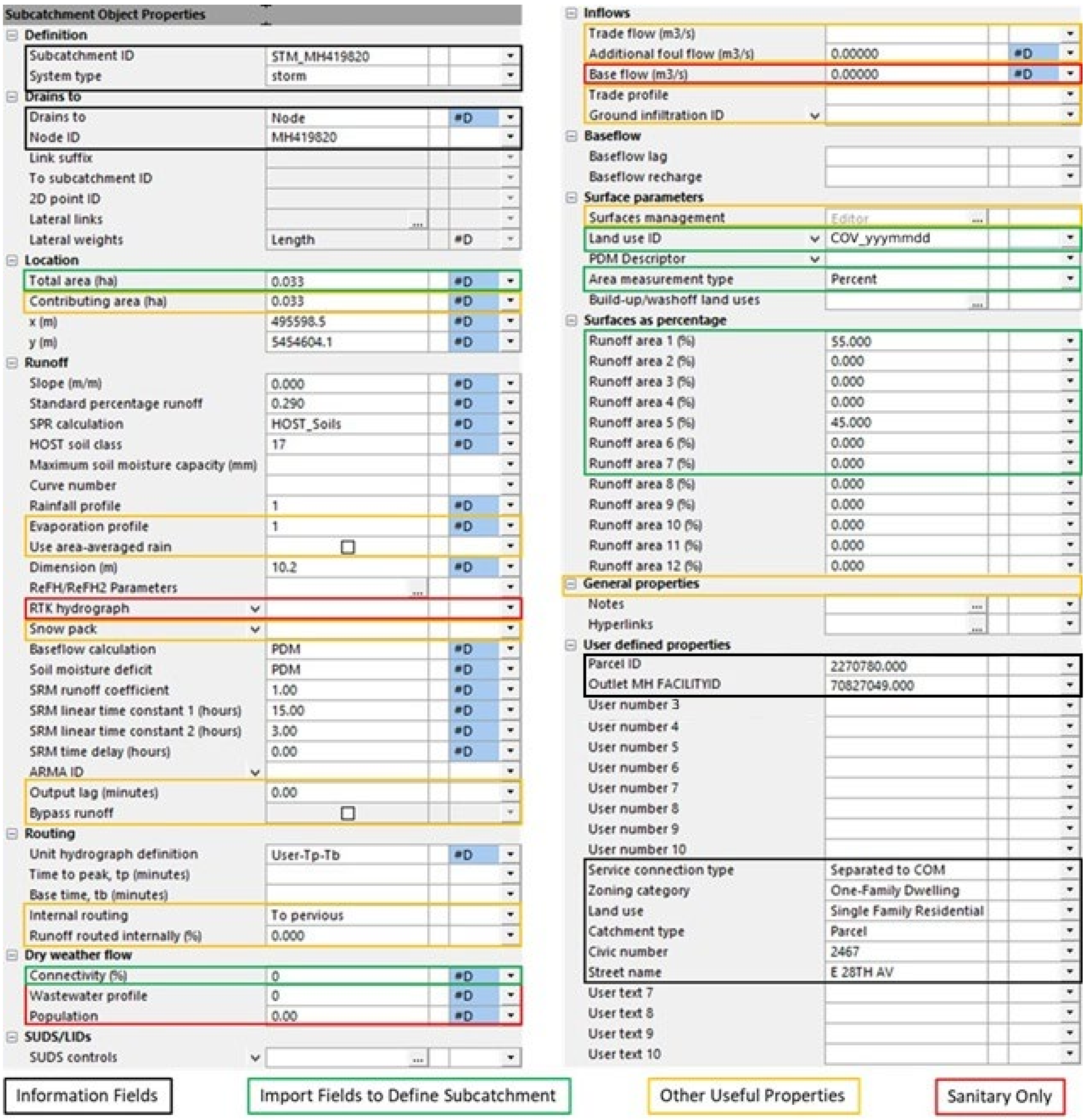


Figure 4-8 InfoWorks ICM Storm Subcatchment Object Property Table

4.7.5.6 Land Use Type

The land use type for a subcatchment can be identified based on the zoning codes as per Table 4-19. A methodology is presented in Table 4B-4 in Appendix 4B. Subsequently, land use type shall be imported into a User Defined field as indicated in Table 4B-5 in Appendix 4B.

Note that for City models, the Land use ID field in the subcatchment property table shall be populated with one of the City's standard land use definition. See Section 4.7.4 in this chapter and Section 5 in

Appendix 4A Model Template Database Configuration for further details on how the land use module shall be used for City models.

4.7.5.7 Runoff Area Percentages

Runoff area percentages for impervious and pervious runoff surfaces shall be imported into the Runoff area 1 to 4 (%) and the Runoff area 5 to 7 (%) fields in the storm subcatchments property table, respectively. Note that if the runoff area percentages fields are left blank, InfoWorks ICM will look to use default runoff area percentages in the Land use property table. Therefore, the runoff area percentage fields in the subcatchment tables must not be left blank; a zero value shall be populated for unused runoff surfaces.

Currently, the City is updating the Parcel2Main database with land use type, zoning category, and corresponding impervious and pervious runoff area percentages. In the interim, for new modelling studies, storm subcatchments shall be populated with impervious runoff area percent values by matching the appropriate land use to the corresponding zoning definition as presented in Table 4-19 for each parcel using GIS.

The appropriate Runoff area (%) field to populate the pervious percentage for each storm subcatchment can be determined from the Parcel2Main layer from the INFIL_POTE field or obtained manually from the soil map referenced in Table 3-1. Values of 0, 1, and 2 represent poor, low, and moderate infiltration potential per parcel in the INFIL_POTE field, respectively.

If other sources of soil type and infiltration parameters are suggested to be used by the consultant, they shall be discussed with the City for approval.

See Table 4B-4 in Appendix 4B for a methodology on how to calculate the impervious and pervious runoff area percentages and how to assign the values to the appropriate Runoff area (%) fields.

4.7.5.8 Internal Routing

The options for the Internal Routing field property are Direct, To Pervious, and To Impervious. The Direct option means that flows are routed directly to the assigned outlet node. When the To Pervious option is selected, the flow is first routed to the pervious area and then to the assigned outlet node. The Impervious option first routes flows to the impervious area and then to the assigned outlet node.

The Internal Routing field shall be set to "Direct" upon import for City Models. In discussion with the City, this could be set to the To Pervious or To Impervious option if detailed information about disconnected roof leaders are available and only if appropriate for the level of detail of the model study.

4.7.5.9 Rainfall Profile

The Rainfall Profile property shall be set to the default flag for all subcatchments. The modeller shall follow the guidance provided in Section 4.7.6 and 4.7.7 to model rainfall.

4.7.5.10 Dimension

The Dimension property is the subcatchment width. Its value is automatically calculated upon import of the subcatchment polygons by InfoWorks ICM. The dimension, or width, is calculated as the radius of a circle using the value in the Contributing Area field of the subcatchment. The Dimension property shall be set to the default flag to enable this feature.

4.7.5.11 Slope

For City models, the Ground slope (m/m) field for each runoff surface in the Runoff surfaces property table shall be used by InfoWorks ICM instead of the Slope (m/m) in the subcatchment property table. The Slope (m/m) property in all subcatchment object property tables shall be set to the default flag to enable this feature.

4.7.6 Design Storms

The rainfall IDF data and design storms are provided in City's Engineering Design Manual and shall be used in InfoWorks ICM to assess the City's sewer system. The design storms that are frequently used have been included in a Rainfall model group in the InfoWorks ICM Model Template Database. Note that the modeller shall confirm that the rainfall IDF data and design storms in InfoWorks ICM are the latest versions by consulting the City's Engineering Design Manual.

For each design storm, one rainfall event shall be created containing only one rainfall profile. To ensure that the design storm will be applied to all subcatchments, no boundary polygon will be defined in the Gauge data field of the rainfall event, as indicated on Figure 4-9, and additionally, the rainfall profile field in the subcatchment property table shall be set to the default flag. Note that historical rainfall events shall be set up differently, as discussed in Section 4.7.7.

A rainfall event has many tabs, as shown in Figure 4-9, but populating only the "Rainfall" tab is sufficient. The InfoWorks ICM Help shall be consulted before using rainfall event features provided in the other tabs.

InfoWorks ICM applies a moving average smoothing during model simulation by default. However, for design storms it is conventional to assume that they are spatially uniform across the study area. When using design storms, the modeller shall uncheck this option in the Run group for model simulations as indicated on Figure 4-10.

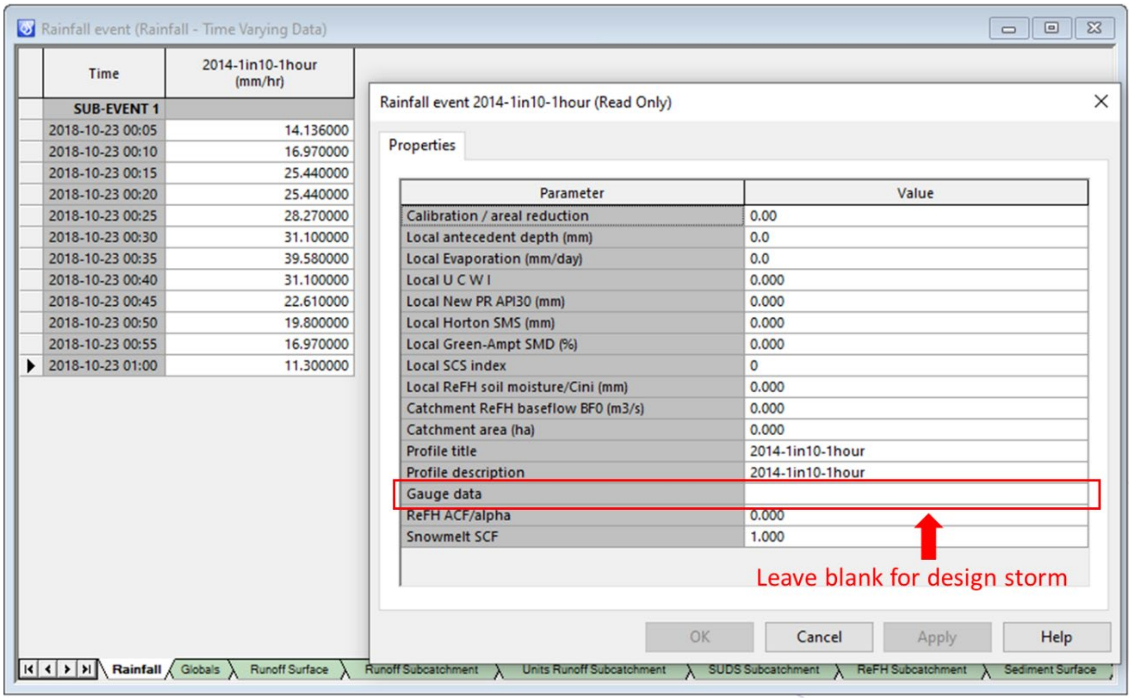


Figure 4-9 Design Storm Rainfall Event

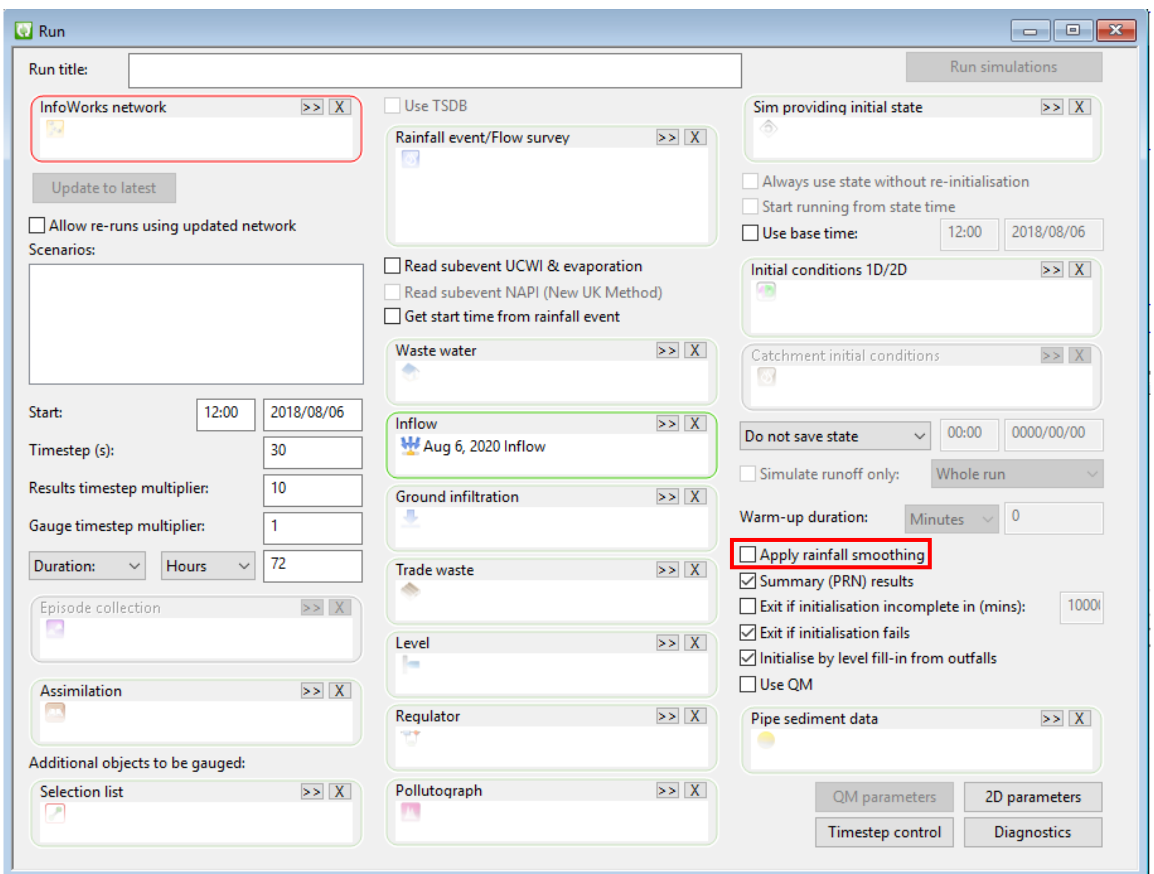


Figure 4-10 Rainfall Smoothing Option

4.7.7 Historical Rainfall

Observed historical rainfall events obtained from appropriate rain gauges shall be used to calibrate City models against flow monitoring data or historical flooding. A historical rainfall event can involve one or multiple rain gauges. Therefore, at least one rainfall profile shall be defined in one Rainfall Event to represent an observed historical event.

In addition, a historical Rainfall Event must have a defined boundary associated with each rainfall profile. Using the defined boundaries, InfoWorks ICM can automatically distribute the rainfall profiles to subcatchments during model simulation. Figure 4-11 shows the configuration of a Rainfall Event representing an observed historical rainfall event.

The rain gauge boundaries can be created using Thiessen Polygons in InfoWorks ICM or imported from a GIS layer, which is explained in InfoWorks ICM Help. Whenever applying a historical Rainfall Event, the modeller shall also double check that the boundaries have been defined correctly for the Rainfall Event. This can be done by dragging and dropping the Rainfall Event file into the GeoPlan window; all rain gauge boundaries should appear as blue outlines as shown on Figure 4-11.

Similarly, historical radar rainfall such as gauge adjusted radar rainfall (GARR) shall also follow the same modelling approach, by defining a rainfall profile and an associated boundary for each rain grid. When using radar or GARR data, the rainfall smoothing shall be turned off by unchecking the Apply rainfall smoothing check box in the Schedule Hydraulic Run view, shown on Figure 4-10.

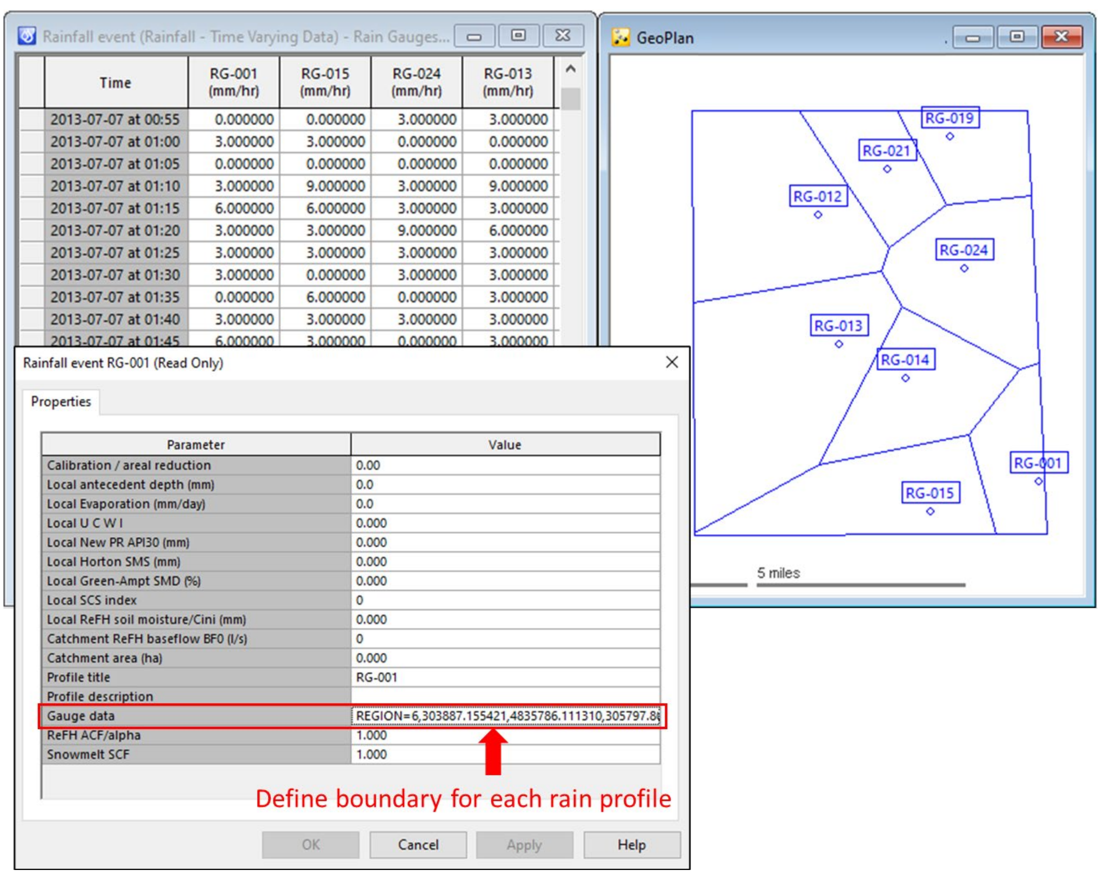


Figure 4-11 Historical Rainfall Event

4.8 Sanitary Model

The flow components of a sanitary system consist of dry weather flow (DWF) and rainfall-derived infiltration and inflow (RDII). The DWF component consists of the groundwater infiltration (GWI) and sanitary wastewater flow (SWF). Wet weather flow (WWF) is defined as the combination of DWF and RDII. Figure 4-12 shows the breakdown of flow components in a sanitary sewer system.

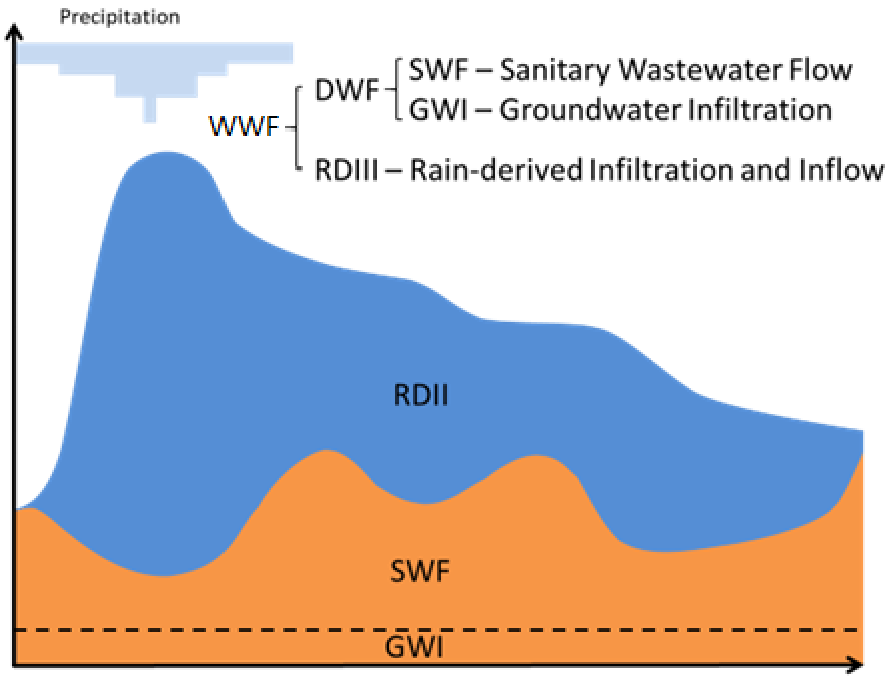


Figure 4-12 Components of Sanitary Flow

The following sections provide an overview of flow generation for DWF and WWF and detailed guidance on setting up sanitary subcatchments.

4.8.1 Dry Weather Flow

Dry weather flow (DWF) consists of groundwater infiltration (GWI) and sanitary wastewater flow (SWF). GWI enters the sewer from foundation drains or cracks that occur during periods absent of rainfall. SWF is sewage resulting from residential, industrial, commercial, and institutional areas.

4.8.1.1 Planning Models

For planning models, the DWF parameters shall be derived from flow monitoring data and population census information in the study area. If the study area was not monitored, then the per capita flow rates, GWI, and diurnal patterns derived from flow monitor data for other areas of the City, shall be reviewed and appropriate values selected. See Chapter 5 for guidance on how to determine DWF parameters from flow monitor data analysis.

The DWF shall be modelled using the Baseflow (m^3/s) (which represents GWI), Population, and Wastewater profile fields located in the subcatchment property table under the Dry weather flow heading, as shown on Figure 4-8.

A Wastewater event shall be created in InfoWorks ICM using the wastewater profile editor as shown on Figure 4-13; the red boxes indicate the fields to be populated at minimum. In the Wastewater event, the Per Capita Flow Rate field shall be populated and weekday and/or weekend diurnal patterns defined. The Title field in the Wastewater event shall contain the name of the flow monitor and the corresponding profile number shown in the Description field should be populated in the Wastewater profile field in the subcatchment property table.

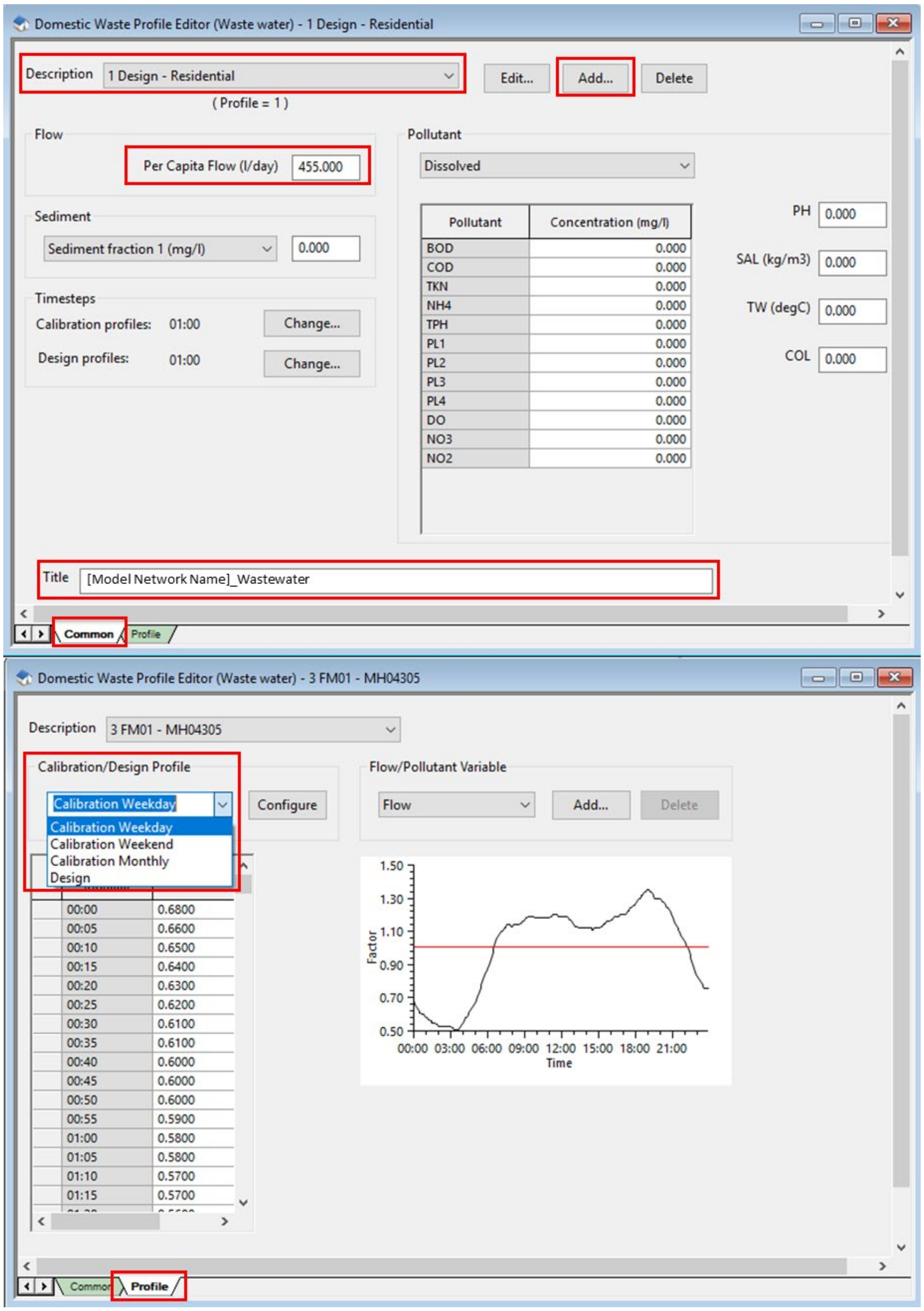


Figure 4-13 Wastewater Profile Editor in the Wastewater Event

Finally, the model uses the Population, Per Capita Flow Rate, and the diurnal pattern to calculate the SWF while running a constant GWI from the Baseflow (m^3/s) field.

See InfoWorks ICM help for details on the full functionality of the Wastewater event.

4.8.1.2 Design Models

InfoWorks ICM allows various approaches to model DWF. At present, DWF for design models shall be calculated per parcel and amalgamated and assigned on a pipe-by-pipe basis using the methodology outlined in Section 4.2.2 in the City's Engineering Design Manual.

The design model DWF method uses design per capita flow rates, population density, and maximum allowable Floor Space Ration (FSR). The FSR is defined as the area of floor space divided by the area of a parcel. An FSR database is available upon request to City.

Ultimately, the design model method consists of calculating sanitary design flows. These sanitary design flows consist of DWF including a peaking factor (defined as the Peak DWF) and an estimate for I/I, collectively referred to as WWF. The sanitary design flows are then to be populated in the Inflow (m^3/s) field of the appropriate pipes. Note that WWF for design models is integrated in this method.

4.8.2 Wet Weather Flow

Wet weather flow (WWF) for sanitary sewer systems is defined as the combination of dry weather flow (DWF) and rainfall-derived inflow and infiltration (RDII).

4.8.2.1 Planning Models

For planning models, if the study area has flow monitor data and model calibration is intended, the RDII may be determined, if possible, by the RTK method. Guidance on using the RTK method and model calibration is provided in Section 5.3.2. If flow monitor data shows that the RTK method is not a feasible option, the RDII could be assumed to enter the system through the storm runoff component of the model.

If the study is unmonitored, the design model method described in the Design Models section below shall be used to determine the WWF.

4.8.2.2 Design Models

At present, WWF for design models shall be calculated per parcel and amalgamated and assigned on a pipe-by-pipe basis using the methodology outlined in Section 4.2.2 in the City's Engineering Design Manual.

The design model method calculates Peak DWFs using the DWF and a peaking factor. Ultimately, sanitary design flows are determined and consist of the Peak DWF and an estimate for I/I. The sanitary design flows are then to be populated in the Inflow (m^3/s) field of the appropriate pipes. Note that WWF for design models is integrated in this method.

4.8.3 Sanitary Subcatchments

The following sub-sections outline standards for sanitary subcatchments configuration for City models. Refer to Appendix 4B for a detailed data preparation methodology and import procedure. City modelling staff shall follow both the data preparation methodology and import procedure.

An external consultant may refer to the data preparation methodology and import procedure in Appendix 4B as a guideline, but shall adhere to naming conventions, model structure, and contents of model data fields as outlined in the appendix. The consultant shall ensure that the subcatchments are configured and populated according to Table 4A-4 in Appendix 4A and the standards are adhered to as outlined below.

See Table 3-1 and Appendix 3B for the base GIS layer data locations and attribute field definitions useful for sanitary subcatchment data preparation, respectively.

4.8.3.1 Parcel Sanitary Subcatchments

For planning models, the sanitary and storm subcatchments shall be modelled separately. The sanitary subcatchments shall consist of parcel and shall be based on the City's GIS layers as outlined in the Parcel2Main Layer sub-section in Section 3.8.5. Sanitary right-of-way (ROW) subcatchments shall additionally be created and utilized if appropriate. If the sanitary ROW subcatchments are not required, they shall still be created for future models, but not used.

The DWF including the sanitary baseflow and GWI shall be represented by Connectivity (%), Wastewater profile, Population, and Baseflow (m^3/s) fields in the subcatchment property table. The RDII shall be represented by the RTK hydrograph, Rainfall profile and the Contributing area (ha) fields if flow monitor data is available and indicates the RTK method is appropriate. When a simulation is run, the RDII computation uses the applied rainfall event. Subsequently, the RTK hydrograph is applied to the sanitary subcatchment and multiplied by the subcatchment Contributing area field to give the resulting RDII into the subcatchment outlet node.

Both the DWF and WWF shall be modelled in the same sanitary subcatchment if RDII can be represented by the RTK method. If the RTK can not be used, the modeller shall use engineering judgement how best to represent the RDII; e.g. the RDII could assumed to be a component of the stormwater runoff in the hydrological model.

Note that the storm parameters Runoff area 1 to 12 (%) or Runoff area 1 to 12 (ha) in the sanitary subcatchment shall be set to 0 to prevent unintentional storm runoff generation.

4.8.3.2 Right-of-Way Sanitary Subcatchments

For planning models in a fully separated storm and sanitary system, the RDII shall be represented by the RTK method using the sanitary parcel and ROW subcatchments, if flow monitor data indicates RTK can be used. If RTK cannot be used, the sanitary ROW subcatchments shall still be created, but not utilized; they may be used in future versions of the model.

4.8.3.3 Design Model Sanitary Subcatchments

For design models, the design sanitary flow is calculated as per Section 4 Sanitary Sewer System in the City's Engineering Design Manual and entered as a constant flow in the Inflow (m^3/s) field in the sanitary conduits on a pipe-by-pipe basis. Therefore, design models may not need to use sanitary catchments.

4.8.3.4 Subcatchment Property Table

Key fields to be populated in the sanitary subcatchments property tables are indicated in Figure 4-8. The black, green, and red boxes are fields to be imported by the methodology in Appendix 4B Data

Preparation and Import. The fields with red boxes are strictly for sanitary subcatchments. The orange boxes indicate additional modelling options, and their purpose and usage can be found in the InfoWorks ICM help section. The remaining fields are parameters not used by the SWMM runoff routing model.

4.9 Model Deliverables

This section outlines the required model deliverables for external consultants to submit to the City.

4.9.1 Reports and Documentation

Technical reports are usually required for a modelling assignment to document findings of a modelling study. At a minimum, the following documentation shall be provided in one memo, if not already included in the reports:

- Purpose of model and year of the study
- Model data: including a list of sources and date (year) if obtained from existing data; if new data was collected for the model, all newly collected data shall also be submitted.
- Model assumptions
- Model updates: applicable if an existing model is provided for the study instead of building a new InfoWorks ICM model.
- Model scenarios: including a list of all model scenarios and their purposes
- Model calibration: including the data used for calibration, results of calibration (see requirements in Section 5.3.5, including Observed versus Predicted Graphs, calibration assessment table and statistical graphs), and a summary table of calibrated parameters.

4.9.2 GIS Data

An ESRI geodatabase shall be submitted to the City containing the following feature classes at a minimum:

- Boundary of modelled extent (polygon feature class)
- Boundary conditions (point feature class): include attribute fields for asset ID reference, type of boundary (inflow or level), if connection is to other City assets or MV assets, and the data/assumption for modelling the boundary conditions.
- Modelled manholes (point feature class)
- Modelled fittings (point feature class)
- Modelled sewer mains (line feature class)
- Modelled special structures (line feature class)

The feature classes for the modelled sewer assets can be created by exporting the InfoWorks ICM model. They can also contain key values from simulation results (e.g., freeboard and surcharge state) if requested by the City.

If additional data is collected for the modelling assignment, they shall also be returned in geodatabase format if possible. This could include address survey results, sewer asset survey results, rainfall, and flow monitoring locations, etc.

4.9.3 InfoWorks ICM Model

A model submission shall be included as part of the deliverables in the format of a transportable database (.icmt), accompanied by a Flags.csv file that include all data flags used in the model.

This transportable database shall contain:

- Model Group that collects all model networks
- Run Group that collects all simulation runs
- Rainfall Group that collects all rainfall events used in the simulation runs
- Wastewater Group that collects all wastewater events
- Level Group that collects all level events used in the simulation runs
- Inflow Group that collects all inflow events used in the simulation runs
- RTC Group (if applicable)
- Selection List Group (if applicable)
- SQL Group (if applicable)
- Graph Template Group (if applicable)
- Flow Survey Group (if applicable)
- Statistics Group (if applicable)
- Theme Group (if applicable)

Appendix 1A provides the configuration and definitions for each of these model groups.

To create a transportable database for model submission, copy and paste the Run files from the Master Database in InfoWorks ICM so all associated files needed to run the simulation will automatically be pasted to the Transportable Database.

To create the Flags.csv, open the user defined flag window and click "Export" to save a csv file.

5 Model Calibration

This section outlines the requirements and the process to conduct model calibration. The general process is to calibrate the model under dry weather flow conditions followed by wet weather flow calibration. Furthermore, this section provides the steps to complete rainfall and flow monitoring data analysis, guidance on assessing model calibration results, and recommended calibration targets.

The following provides and overview of this chapter:

- Rainfall and flow monitoring data analysis
- Dry weather flow calibration
- Wet weather flow calibration

5.1 Rainfall and Flow Monitoring Data Analysis

Rainfall and flow monitoring data analysis provides the basis for model calibration. The City's flow monitoring team typically conducts the rainfall and flow monitoring data analysis described in this section to identify quality issues and to determine the various flow components such as GWI, SWF, and RDII. If the analysis can not be completed by the City's flow monitoring team or a flow monitoring consultant, the modeller shall proceed with the analysis provided in this section.

Figure *5-1* outlines the analysis procedure.

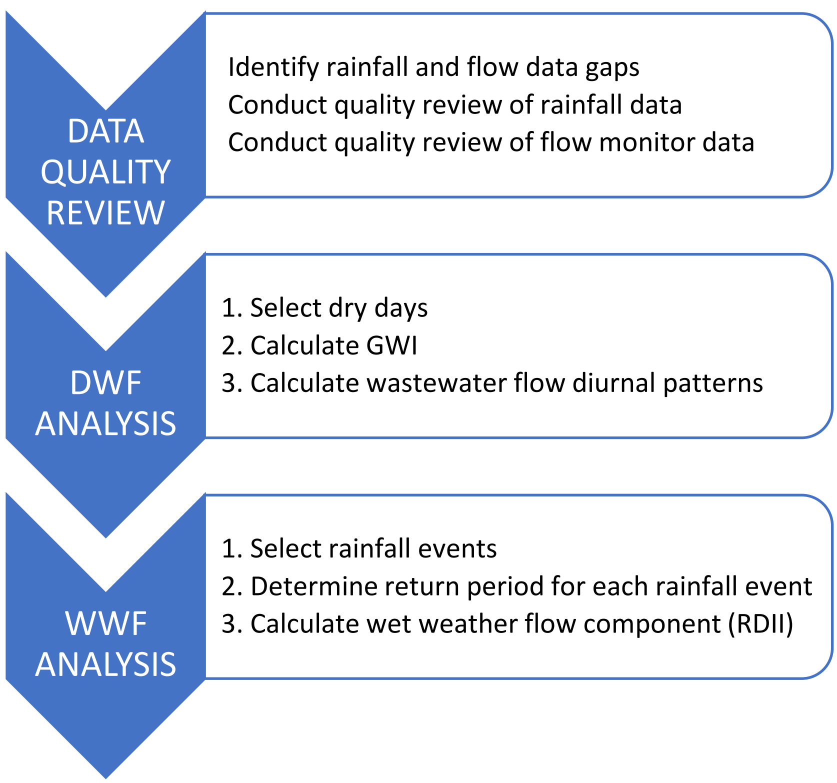


Figure 5-1 *Rainfall and Flow Monitoring Analysis Process*

5.1.1 Rainfall and Flow Data Quality Review

The quality of flow monitoring data is important to obtain useful information for model calibration. At minimum, the modeller shall review the data and identify data gaps in the rainfall and flow monitoring data.

For rainfall data, the modeller shall determine the coverage of each rain gauge and the spatial rainfall variation between rain gauges. A comparison among rain gauges shall be made by creating cumulative rainfall plots to determine rainfall differences. The modeller shall select the appropriate method to review how the rainfall is distributed across the study area such as the Thiessen Polygon method or using interpolation techniques like inverse distance weighting.

For flow monitoring data, the modeller shall use scattergraphs to inspect the data quality and infer information about equipment and/or system performance. Figure 5-2 provides an example of a scattergraph containing depth and velocity measurement for the entire flow data set independent of time.

The modeller shall evaluate a scattergraph for each flow monitor, if not available from City's flow monitoring team. These plots reveal the measured depth-velocity pattern and help identify outliers and data gaps. This graph can be overlaid with the depth-velocity relationship, iso-Froude curve, and iso-Q curves obtained using Manning's equation to evaluate flow conditions.

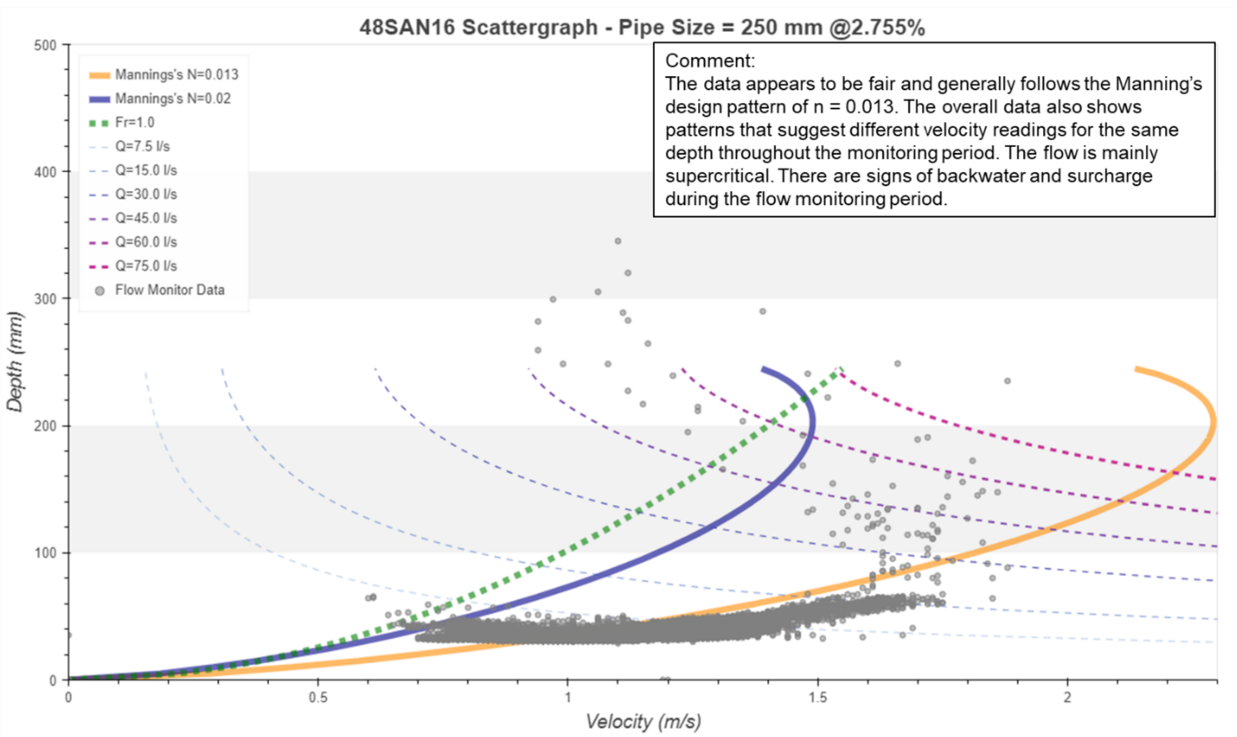


Figure 5-2 Scattergraph

5.1.2 DWF Analysis

The purpose of DWF analysis is to establish the DWF component consisting of groundwater infiltration (GWI) and sanitary wastewater flow (SWF) for each flow meter.

Step 1: Select dry days.

A dry day is defined as a day (24-hour period from 0:00 to 24:00) where at least the preceding 72 hours (three days) have less than 1 mm of rainfall according to the rain data. These dry days should be categorized as weekdays or weekend days. The selection of dry days shall attempt to include dry days from both the weekday and weekend of every month if possible.

Step 2: Calculate GWI.

The Stevens-Schutzbach method shall be used to calculate GWI, with Equation (1) *.

$$GWI = \frac{0.4\ (MDF)}{1 - 0.6 \times \left(\frac{MDF}{ADF}\right)^{0.07094 \times ADF^{0.7}}} \quad (1)$$

*Note: Modified from ADS (2007) to accommodate units in L/s

Where GWI is in L/s, MDF is the minimum daily flow in L/s, averaged over the selected dry days, ADF is average daily flow in L/s, averaged over the selected dry days. GWI should be reported in L/s/ha.

Step 3: Calculate the average wastewater flow and diurnal pattern for weekdays and weekends.

For all selected dry weekdays, subtract the GWI from the measured flow and obtain the sanitary wastewater flow. Plot the sanitary wastewater flow hydrograph for all dry weekdays on one graph and identify if any day is an outlier to be excluded. Outliers can include missing data or visible deviation from the average pattern after all dry days are plotted.

Repeat the same process for dry weekend days and obtain the weekend diurnal pattern.

5.1.3 WWF Analysis

After establishing the DWF component for each flow meter, the WWF analysis is conducted for each flow meter to isolate the rainfall-dependant inflow and infiltration (RDII) observed in the sewer system.

Step 1: Select rainfall events for analysis.

A rainfall event is defined as the period between DWF conditions and the return to DWF conditions after the rainfall. The inter-event time used, meaning the minimum time between two storm events, shall be 12 hours. All rainfall events with a cumulative depth of at least 15 mm over the duration of the storm shall be analyzed.

A modified scattergraph can be used to review the data quality and flow conditions for these rainfall events, as shown on Figure 5-3. This is useful to examine if any sewer surcharging or backwater conditions are present.

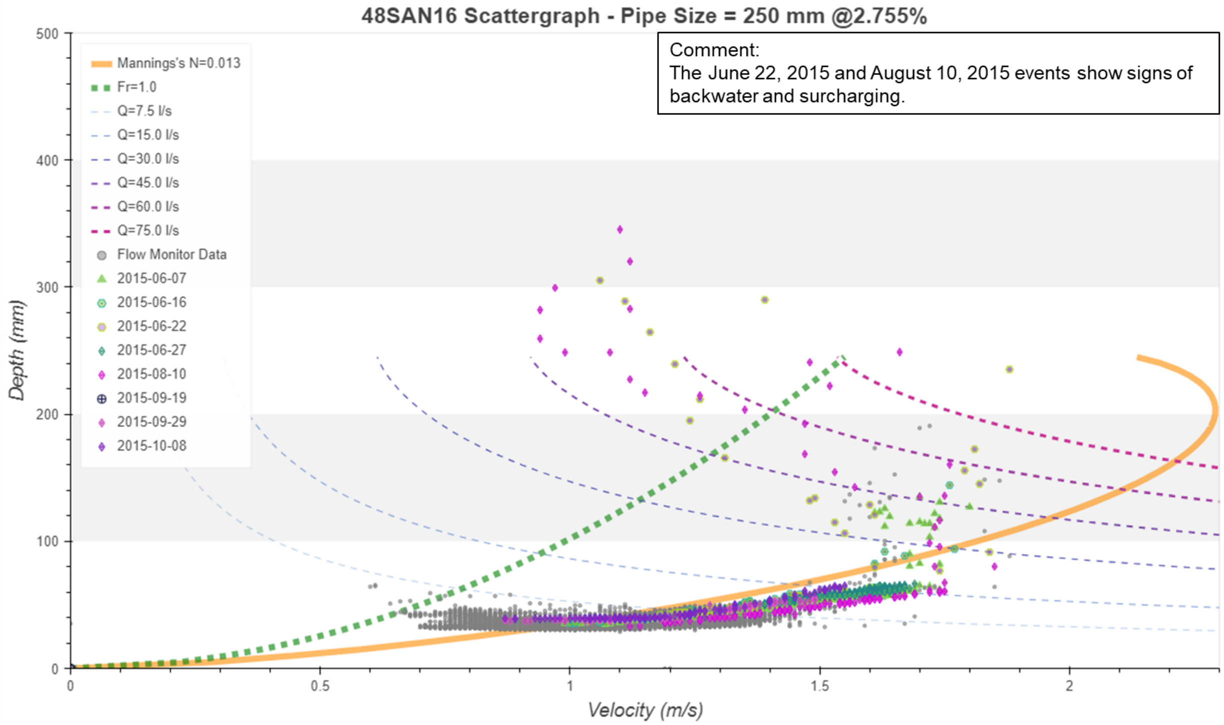


Figure 5-3 Modified Scattergraph

Step 2: Determine the return period of the rainfall events.

Plot the IDF curves of the rainfall events to be analyzed and overlay the City's IDF curves to determine the equivalent return period. The modeller shall refer to the Engineering Design Manual for the IDF equation coefficients.

Step 3: Calculate stormwater inflow or RDII.

For each rainfall event, the RDII hydrograph can be obtained by subtracting DWF from the observed flow hydrograph, starting from the beginning of rainfall until the observed flow recovers to DWF condition. If the resulting value is negative, a value of zero value shall be assigned instead. An adjustment value, or a multiplier of DWF, may be applied to compensate for the antecedent conditions and/or seasonal variability. Figure 5-4 provides a sample RDII plot that shows the result of RDII calculation.

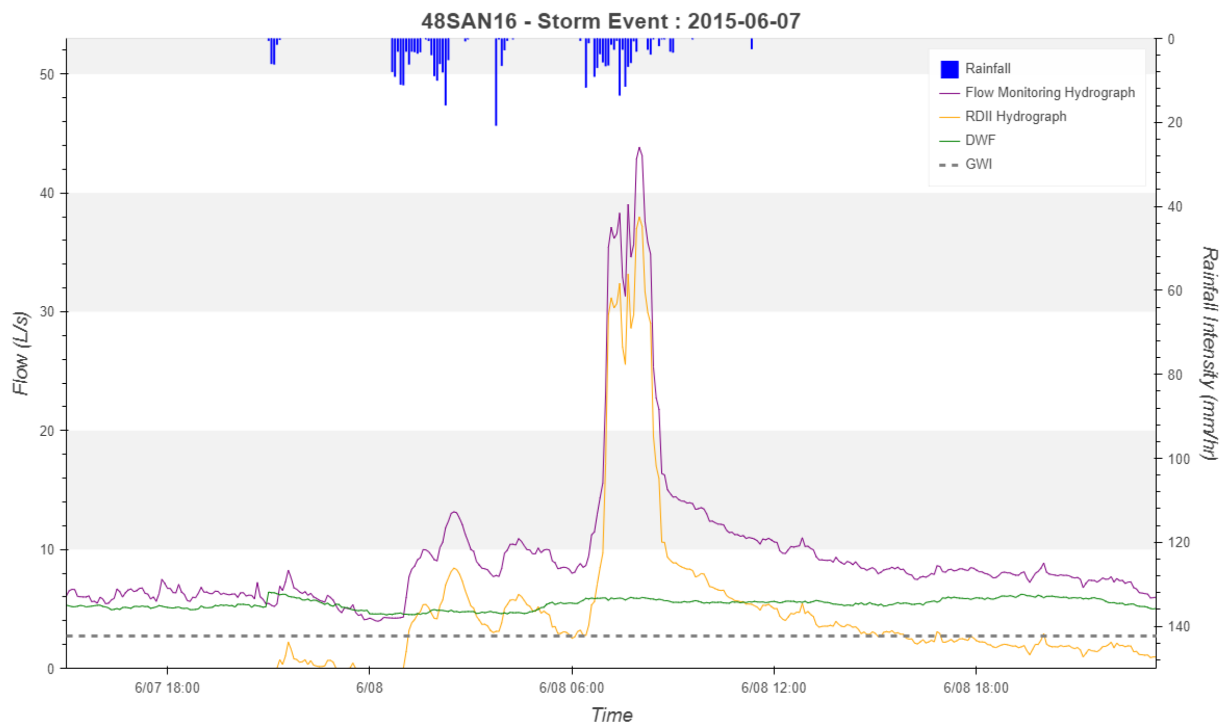


Figure 5-4 Sample RDII Plot

5.2 Dry Weather Flow Calibration

5.2.1 Selection of DWF Calibration Period

To conduct dry weather flow calibration, the modeller shall examine the flow monitoring data and select suitable dry weather period(s). Ideally, one period of the full week (seven days) or two periods of at least three days shall be used. The selected dry weather period(s) shall consist of both weekdays and weekend days, with total rainfall less than 1 mm during the period, and preferably with minimal antecedent moisture conditions.

The goal of dry weather flow calibration is to best represent the average dry weather flow throughout the flow monitoring period. The modeller shall select the most suitable calibration period to develop representative parameters given the nature of the study.

5.2.2 DWF Parameters

The DWF consists of GWI, diurnal patterns (weekday and weekend) for the wastewater, and a per capita wastewater generation rate. The GWI and diurnal patterns obtained from the DWF analysis step in Section 5.1.2 shall be applied in the model and the per capita wastewater generation rate shall be used as a calibration parameter.

The GWI obtained from flow monitoring analysis shall be distributed equally across the contributing sanitary subcatchments, by updating the “base flow” attribute in the subcatchment properties.

The wastewater diurnal patterns shall be entered in the Wastewater event. The modeller shall create one profile for each calibration area in the Wastewater event, and enter the diurnal patterns (weekday and weekend) for the profile, as shown on Figure 4-13 in Section 4.8.1.

With the GWI and diurnal patterns applied, the modeller shall adjust the per capita flow rates defined in the Wastewater event for dry weather flow calibration. Any additional adjustment to other DWF parameters (GWI and diurnal patterns) is subject to City's approval with justifications provided.

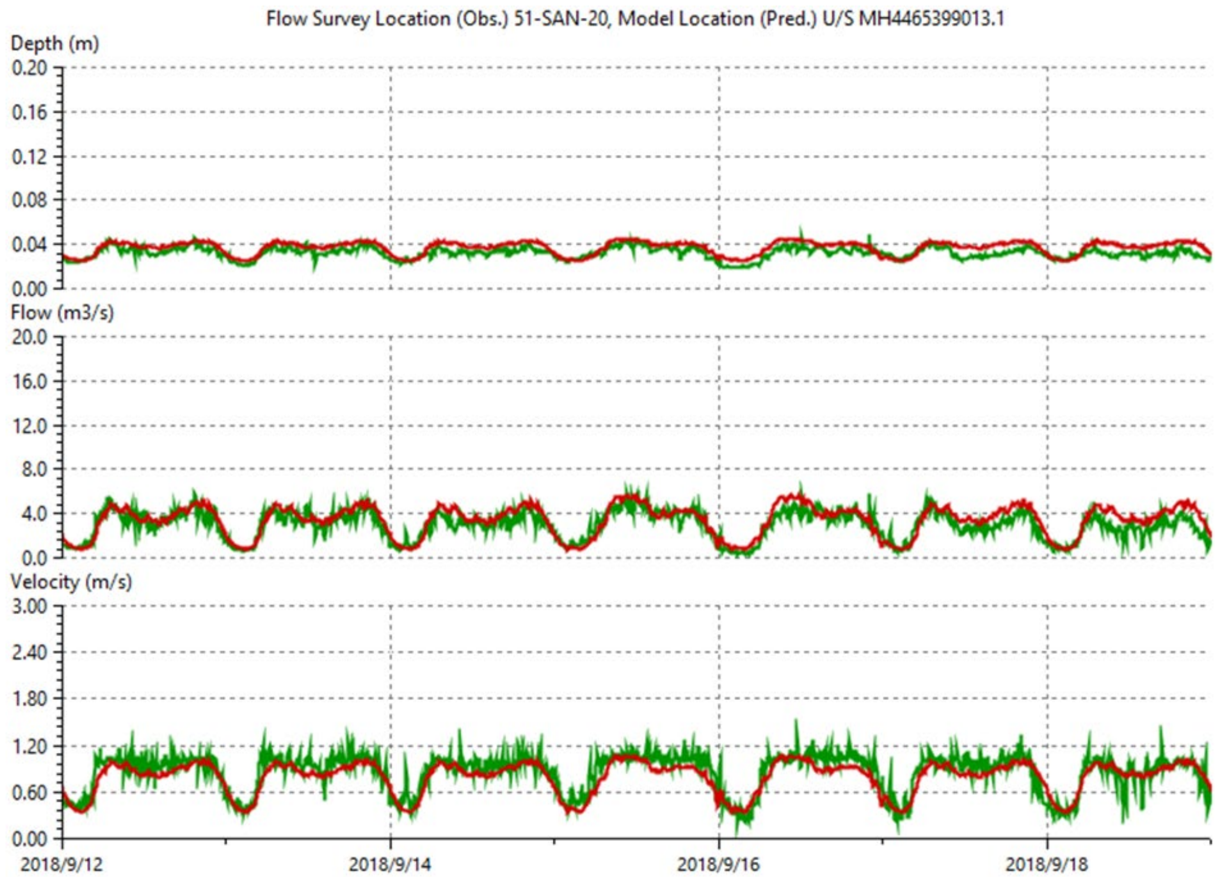
5.2.3 DWF Calibration Target

To compare the model simulation against the observed data for each monitor, the rainfall and flow monitoring data shall be imported into InfoWorks ICM as Flow Surveys. The Flow Survey and simulation results can then be inputted into an Observed versus Predicted Graph report, as shown in Figure 5-5.

The Observed versus Predicted Graph overlays the observed and modelled depth, flow and velocity hydrographs and generates a statistical table. The modeller shall use the Observed versus Predicted Graph and assess the DWF calibration as per criteria defined in Table 5-1.

Table 5-1 Sanitary Dry Weather Flow Calibration Criteria

Parameter	DWF Calibration Criteria
Shape	Good match
Time of peaks and troughs	± 0.5 hour
Peak depth	±10%
Peak flow	±10%
Flow volume	±10%
Per Capital Flow	100 - 450 Lpcd



	Depth		Flow			Velocity	
	Min (m)	Max (m)	Min (l/s)	Max (l/s)	Volume (m3)	Min (m/s)	Max (m/s)
Observed	0.019	0.050	0.320	6.060	1878.588	0.203	1.335
Modelled	0.025	0.045	0.773	5.684	2042.836	0.334	1.070

Figure 5-5 Observed vs. Predicted Graph Report

5.3 Wet Weather Flow Calibration

5.3.1 Selection of WWF Calibration Events

At least three rainfall events from all of the analyzed WWF events shall be selected for calibration. The key factors to consider when assessing the suitability of rainfall events for calibration are:

- There should have been adequate rain (>15 mm) to wet the catchment sufficiently so that runoff is generated.
- Avoid rain on snow events for calibration, unless any known issue or concern in the sewer system is being investigated for the event. In cases where a snow plus rain event is considered for further analysis, suitable information about the snowpack must be made available.
- There should be some variability of the duration and intensity of rainfall in the events selected so that the calibration results can be verified over as wide a range of rainfall as possible. The modeller can use findings from the modified scattergraph as mentioned in Section 5.1.1.

A useful technique to assist with selecting calibration events is the Flow versus Rainfall plot, which uses a linear regression line to assess the relationship between rainfall and the corresponding flow response.

Two common types of Flow versus Rainfall plot are the Flow volume versus Rainfall Depth and the Peak RDII versus Peak Rainfall Intensity, as shown on Figure 5-6.

All analyzed rainfall events shall be plotted using the Flow versus rainfall plots. Poor fit of any individual event indicates that the runoff response observed does not relate well to the rainfall data, possibly due to rainfall spatial variation, incorrect delineation of contributing areas and or impact from antecedent moisture conditions.

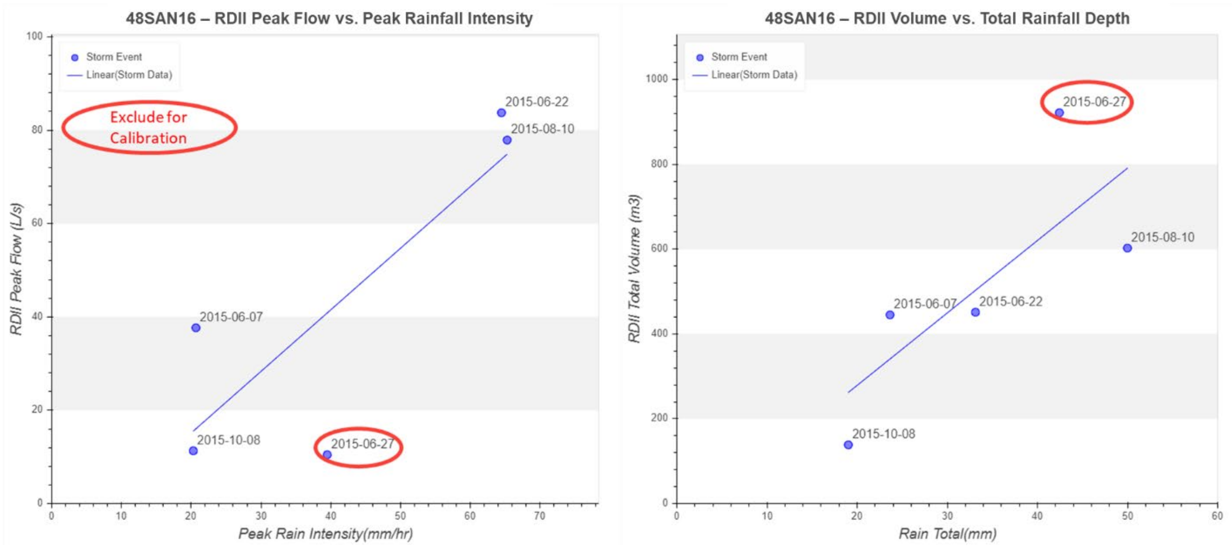


Figure 5-6 Flow versus Rainfall Plot

5.3.2 WWF Calibration Parameters

5.3.2.1 Storm/Combined Sewer System

The WWF parameters to be adjusted for storm and combined systems are the fixed runoff coefficients for impervious surfaces and the parameters of the Green Ampt model for the pervious surfaces. Justification shall be provided if the adjusted fixed runoff coefficients are outside the range provided in Table 5-2 and if any change to standard Green Ampt parameters.

The fixed runoff coefficient for impervious surfaces has a relatively large impact on the runoff hydrograph and has been set to a value of 1.0 for each runoff surface as indicated in Table 4-18 in Section 3.6.3. Meaning, all excess rainfall after the initial loss will contribute to runoff. However, a value of 1.0 has been shown to overestimate flows in the system for events at the 5-year return period or greater.

Therefore, adjustments to the fixed runoff coefficient parameter may be required during calibration. The value for the fixed runoff coefficient can be adjusted to 0.75 to 1 for general impervious parcel areas and 0.50 to 1 for roof areas where the overland flow path is along a grassed area, respectively. The fixed runoff coefficient for the ROW should remain 1.0.

Table 5-2 Storm/Combined Calibration Parameters

Parameter	Property of	Recommend Calibration Range	Note
Fixed Runoff Coefficient	Runoff Surfaces	0.75 to 1 for general impervious parcel areas 0.5 to 1 for roof areas (if modelled)	Primary calibration parameter
Runoff Routing Value	Runoff Surfaces	0.012 to 0.015	Not a sensitive parameter
Runoff Surface Area %	Subcatchments	N/A	Not recommended to change unless the time to peak or hydrograph shape cannot be matched within target range.
Dimension	Subcatchments	N/A	Not a sensitive parameter [1]
Slope	Subcatchments	N/A	Not a sensitive parameter [1]

1 These parameters are not sensitive as the subcatchments are modelled on a parcel basis.

5.3.2.2 Sanitary Sewer System

The preferred method to model and calibrate WWF in sanitary sewer system is the RTK method. The RTK method generates a linear response in flow with respect to rainfall. This means that for an event with twice as much rainfall, there will be twice as much RDII. However, it is important to understand that the relationship between rainfall and flow may not always be linear. The Flow versus Rainfall plot discussed in Section 5.3.1 can be used to determine whether the RTK model is appropriate. If the plot suggests an approximately linear relationship, then the RTK model is recommended.

If another approach is required, justification shall be submitted to City along with the Flow versus Rainfall plot for approval.

The RTK method, or the unit hydrograph method, calculates an RDII hydrograph for each subcatchment based on rainfall data, subcatchments contributing area, and the assigned RTK hydrograph. The RTK hydrograph, as shown on Figure 5-7, consists of three components of flow:

- Rapid inflow (short-term response) due to direct inflow from directly connected roof downspouts and perforated and leaky MH covers;
- Moderate infiltration (medium-term response) due to infiltration with a medium time response such as from foundation drains, cracks in pipes and MH chambers, and loose pipe joints; and
- Slow infiltration (long-term response) due to groundwater infiltration.

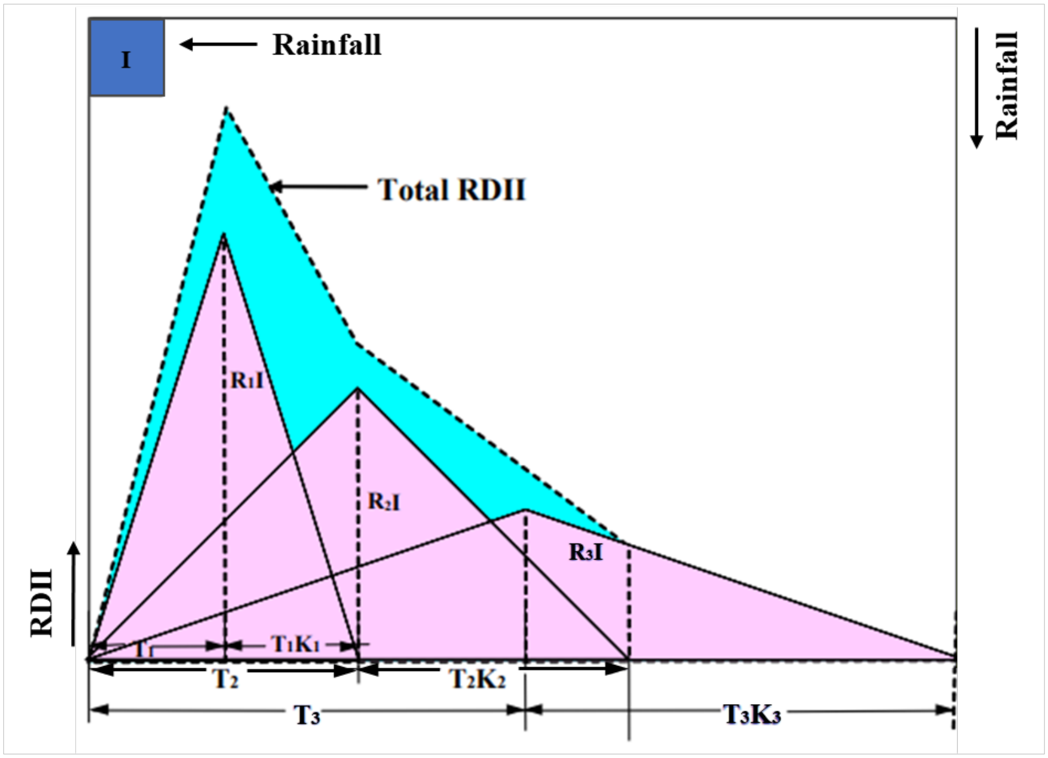


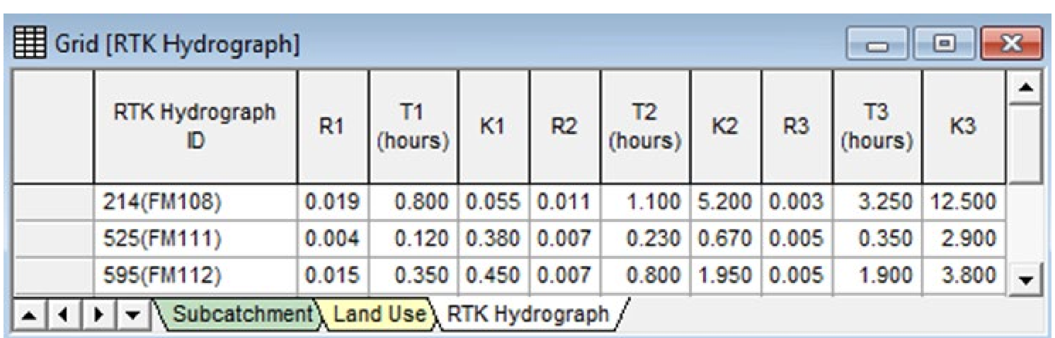
Figure 5-7 RTK Method

For each component, there are three parameters that describe the shape and volume of RDII:

- "R" is the fraction of precipitation that becomes direct inflow;
- "T" is the time to peak of the hydrograph; and
- "K" is the ratio of the recession time to time to peak.

For the separated sanitary system, the sum of R values is expected to be less than 4% unless significant deficiencies exist in the system or there are many direct connections from roof downspouts and foundation drains.

In InfoWorks ICM, the RTK hydrographs and associated RTK parameters can be accessed in the RTK Hydrograph tab in the Subcatchment Grid window, as shown in Figure 5-8.



	RTK Hydrograph ID	R1	T1 (hours)	K1	R2	T2 (hours)	K2	R3	T3 (hours)	K3
	214(FM108)	0.019	0.800	0.055	0.011	1.100	5.200	0.003	3.250	12.500
	525(FM111)	0.004	0.120	0.380	0.007	0.230	0.670	0.005	0.350	2.900
	595(FM112)	0.015	0.350	0.450	0.007	0.800	1.950	0.005	1.900	3.800

Figure 5-8 RTK Hydrograph Editor in Grid Window

For wet weather I/I into the sanitary-only system, the RTK parameters shall be adjusted to obtain a calibration of the selected events. Sanitary-only system exists in pockets across the City. It is not always apparent if the system is sanitary-only until flow monitoring data analysis has been completed for the area.

- The RTK parameters for the short duration response shall be adjusted first, then the medium duration, and then the long duration.
- Calibrated RTK parameters should have R1 > R2 > R3 and T1 > T2 > T3. There may be exceptions provided that there is evidence from flow monitoring data.

5.3.3 WWF Calibration Target

The modeller shall use the Observed versus Predicted Graph and assess the WWF calibration per criteria defined in Table 5-3. The WWF calibration criteria are adopted from the *Code of Practice for the Hydraulic Modelling of Urban Drainage Systems* by CIWEM (2017). The same criteria apply for all system types (storm, combined, and sanitary).

To document the WWF calibration results, the modeller shall prepare an assessment table and statistical graph for each flow monitor per the template provided in Appendix 5A.

Table 5-3 Wet Weather Flow Calibration Criteria

Parameter	WWF Calibration Criteria
Shape	Good match*
Time of peaks and troughs	± 0.5 hour
Peak depth	For unsurcharged sewers: greater of ±0.1m or ±10% For surcharged sewers: +0.5 m to -0.1 m
Peak flow	+25% to -15%
Flow volume (excluding poor data)	+20% to -10%

*A technique to evaluate the goodness of match for hydrograph shapes is the Nash-Sutcliffe Efficiency Coefficient (NSEC).

6 1D-2D Integrated Modelling

This chapter outlines when 2D modelling may be appropriate, the benefits and limitations of a 2D model, and provides a methodology to build a 2D model and how to integrate a 2D model into a 1D model. Subsequent sections outline the 2D model validation process and 2D model results analysis.

Note that the information and guidance in the following sections are not exhaustive and sound engineering judgement should be applied.

Section 6.1 provides an overview of different model types and outlines typical drivers to conduct a 1D-2D coupled model study. Additionally, the benefits and limitations of 1D, 2D, and 1D-2D coupled models for common flood cases are tabulated including the recommended model type and level of detail for each case.

Section 6.2 provides a schematic overview of primary components in the 2D and 1D-2D modelling process.

Section 6.3 outlines the required 2D model data and provides guidance on defining the 2D model extent and the level of detail for the 2D zones in the study area.

Section 6.4 outlines the data preparation and processing that are required prior to importing data into InfoWorks ICM.

Section 6.5 provides guidance on developing the 2D model. A methodology to prepare various 2D zones required to create a 2D mesh is provided in addition to the creation of the 2D mesh zone itself. Common 2D model development pitfalls and how to avoid them are highlighted as well. Additionally, this section provides guidance on creating roughness zones, infiltration zones and surfaces, and how to represent buildings, roads, and watercourses including features such as bridges and culverts. The representation of walls and linear structures, 1D model integration, and the application of boundary conditions are also covered in this section.

Section 6.6 outlines how to schedule a 2D model simulation and recommended checks to perform for model stability.

Section 6.7 outlines the data requirements for model validation.

Section 6.8 outlines how to review and analyze 2D model results.

6.1 Benefits and Limitations of 2D Modelling

The number of dimensions used in hydraulic model simulations will generally fall within one of the following categories, detailed in the CIWEM UDG Code of Practice:

- 1D – one dimension, e.g., a sewer and/or a watercourse model.
- 2D – two dimensions, e.g., a pluvial runoff, floodplain, and overland flow model.
- 1D-2D - a coupled one dimension and two-dimension model, e.g., with sewers and watercourses modelled in 1D but coupled with a 2D mesh to model overland flow and floodplain interaction.

Typical drivers to conduct a 1D-2D coupled model study versus modelling in 1D or 2D only:

- To establish whether overland flow is a contributory factor to network performance issues, i.e., flooding.
- Where it is known that significant overland flood water enters a different drainage system or a different part of the same drainage system.
- Where it is known that overland flood flows impact properties some distance from the source of the flooding.
- To understand if manhole flooding that is predicted from a 1D model could impact adjacent properties, i.e. to identify overland flood extents.
- To develop a solution that includes managing and attenuating overland flood flows.
- To represent an integrated Urban Drainage network that could include land drainage or urban watercourses.

Within the City's jurisdiction, 1D-2D coupled models can help identify and fully investigate both the root cause and impact of flooding. The existing inventory of the City's 1D models could be utilized to create 1D-2D coupled models. Note that adding a 2D mesh to a 1D model does increase complexity and may significantly increase simulation run times and produce large result files.

Table 6-1 provides a summary of common benefits and limitations, although not exhaustive, for 1D, 2D, and 1D-2D coupled models including the required level of model detail.

Table 6-1 Benefits and Limitations of 1D, 2D, and 1D-2D Models for Select Flood Cases

Flood Case	Description	Recommended Model Type	Recommended Level of Model Detail	Benefits	Limitations
Localized Sewer Flooding.	• Point source flooding where the sewer system is under capacity.	• 1D	• In areas with localized sewer flooding, develop a detailed sewer model with subcatchments smaller than 2 ha. • In the remaining areas where no flooding occurs, it is permissible to develop a skeletal sewer model that only includes the main sewer trunks and subcatchments greater than 2 ha.	• Prediction of pipe flows. • Representation of structures such as weirs, sluices, pumps, etc. • Representation of pipe surcharging, reverse flows, and backwater effects.	• Limited representation of surface flooding. • No representation of overland flow paths and flood water extents. • No interaction between above and below ground systems.
Flooding from overland runoff and watercourse flood flows.	• Overland flooding caused by runoff either directly from large permeable (e.g., Douglas Park, VanDusen Botanical Garden, etc.) or rural areas. • Overland flooding and ponding in urban areas from runoff due to catch basin inlet capacity limitations, usually during high intensity rainfall events from larger return period storms > approximately a 25-year return period, as opposed to flood water spilling from catch basins and manholes due to surcharging of the below ground piped sewer system. • Overland flooding from open channel watercourses with little known information.	• 2D	• 2D model (2D mesh) that covers the entire catchment area of the study area. • May require boundary conditions obtained from a hydrological assessment if the 2D mesh cannot cover the entire catchment of the study area. • Boundary conditions.	• No sewer record data required. • Representation of overland flows, sag locations, and flood water extents. • No detailed subcatchment delineation required. • Generally no detailed watercourse surveys required. • May help identify the 2D extents in a 1D2D model.	• No representation of pipe flows. • No representation of ancillary structures. • Detail of watercourse representation is limited by the accuracy of the LiDAR data. • Flood flows to inlet structures are not accounted for in the resulting flood water extents.

Flood Case	Description	Recommended Model Type	Recommended Level of Model Detail	Benefits	Limitations
Flooding from a drainage or river network.	• Flood water collects at a topographical low spot. • Known or suspected overland flow paths. • The flood water originates from the sewer system at locations such as catch basins, manholes, and sewer backup and/or overland flooding from watercourses such as rivers and streams. • Drainage flows into the sewer system via inlets (e.g., catch basins), are limited due to inlet capacity resulting in overland flood flows and ponding, usually seen during high intensity rainfall events > approximately a 10-year return period.	• 1D-2D Coupled	• Same as for 1D. • 2D in localized areas or entire catchment areas; to be determined based on model complexity and model run time constraints. • Mesh zones for properties. • Mesh zones for roads. • Representation of physical features in the 2D mesh such as walls, fences etc.	• Same as for 1D. • Allows representation of overland flow paths and sag locations. • Interaction between below and above ground systems. • Utilizes existing 1D drainage and river models. • Detailed open channel river sections can be included in the model as 1D sections.	• Longer run times. • Larger results files. • Needs LiDAR data and processing. • Increased model complexity and potential model instabilities that may require a greater level of effort, i.e., more time consuming.

6.2 2D Modelling Process with Optional 1D Integration

Figure 6-1 below shows a general approach to develop a 2D model with an option to integrate a 1D model.

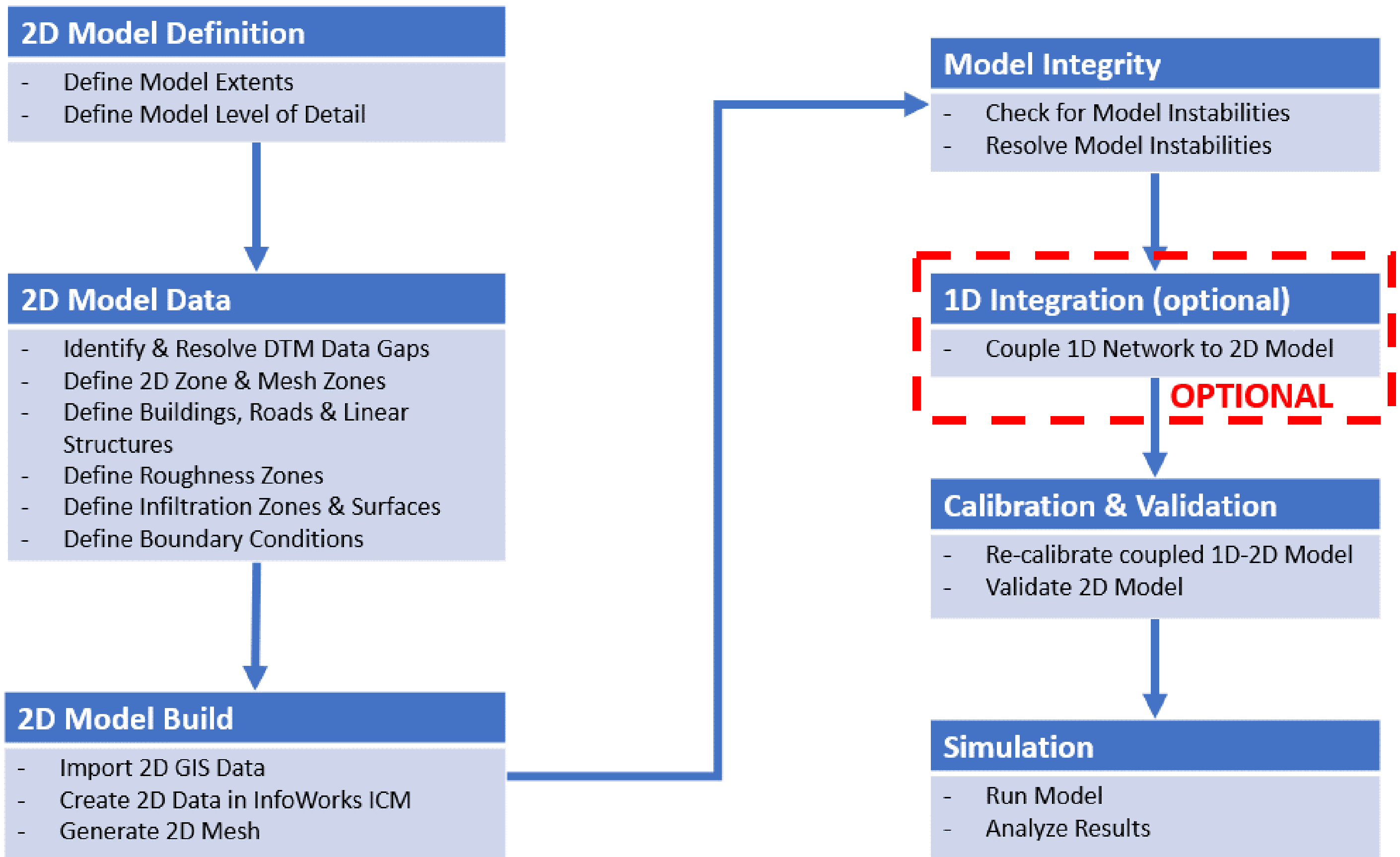


Figure 6-1 2D Modelling Process with Optional 1D Model Network Integration

6.3 2D Model Data Requirements

The data requirements of a 2D model depend on the purpose of the study and the risks to be assessed.

For example, to identify general overland flow paths, the catchment can be represented by a coarse 2D mesh without the inclusion of physical features such as roads, buildings, and walls. However, buildings, walls, and fences may need to be represented in the 2D mesh if a more detailed analysis is required since they can influence the flow direction of overland flood water.

The following section provides an overview of the digital terrain data, 2D model extent definition, and required level of detail of the 2D zones for a 2D model.

6.3.1 Digital Terrain Model

Digital Elevation Model (DEM) data are recorded with surveying techniques using satellites, manned aircraft, unmanned drones, or ground level equipment. The most common survey method is LiDAR (Light Detection and Ranging) from an aerial survey. The DEM contains data recorded from the surface scan usually also includes objects such as trees, buildings, structures, parked cars, and potentially smaller objects such as grass and plants. The DEM data is typically processed to remove those objects to represent the ground elevation known as the bare earth LiDAR or a Digital Terrain Model (DTM). A DTM is required for 2D modelling. Although detailed ground level survey can provide the greatest resolution and accuracy, LiDAR may be able to record elevations in locations where obstacles such as buildings and parked cars prevent survey crew access.

See to Section 6.4 for additional information on DTM data pre-processing and DTM validation.

6.3.2 2D Model Extent Definition

To determine the extent of the 2D model, it is necessary to identify the total catchment area contributing to flows in the study area. If the contributing catchment spans beyond the study area, it may not be practical to use a 2D mesh for the entire catchment area due to potentially long model run times. In this case, it is recommended to conduct a hydrological assessment of the catchment outside of the study area and determine the contributing inflows to the study area.

This can done by creating a 2D model of the entire catchment, simulating the model once with a long run time, and extracting level data or point source inflow data at the upstream study area boundary. Subsequently, a level or inflow file can be applied as a boundary condition to the 2D model that only covers the study area. Using the obtained boundary condition allows for various scenarios to be assessed without the longer run times.

The entire catchment can be modelled using a 2D mesh if model run times are not an issue.

Additionally, it is important to ensure that the 2D modelled area extends downstream far enough to capture all flood flows. Flood water may only run off the edge of the 2D mesh where the downstream boundary of study area is a watercourse or the ocean.

6.3.3 2D Zone Level of Detail

Consideration should be given to the detail within the area to be modelled in 2D.

The CIWEM UDG CoP defines four main area types with varying levels of detail and complexity in addition to the study area's primary 2D mesh zone:

- Coarse urban – containing a representation of a roads mesh zone and generally a single roughness. Depending on the resolution of the available DTM data it may be necessary to depress the road mesh by 0.15m to ensure representation of the road. Used to assess transfer of flood flows between systems and to identify those areas of the catchment where it is appropriate to undertake more detailed 2D modelling.
- Medium – containing a representation of buildings, roads and significant structures such as walls etc. Depending on the resolution of the available DTM data it may be necessary to depress the road mesh by 0.15m to ensure representation of the road. Used to assess individual parts of the model that are suspected to have interaction between drainage types or overland flow problems. This can help identify and scope areas requiring further investigations and surveys.
- Detailed – containing the same level of detail of the Medium but with the addition of road drainage gutters where present. Depending on the resolution of the available DTM data it may be necessary to depress the road mesh by 0.15m to ensure representation of the road. Used to assess known overland flooding problems that affect properties. 2D zones should be extended if there is a possibility of overland flows between zones as identified using a coarser 2D zone.
- Rural – containing varied roughness with no mesh zones or flood defence walls. Used to represent the floodplain of a watercourse where flooding impact on properties is minimal.

Depending on the study being undertaken it is anticipated that either Medium or Detailed Urban parameters will be required for studies in Vancouver.

Therefore, it will generally be necessary to include separate 2D mesh zones for roads and buildings are typically represented by voids in the 2D mesh. These can be generated from any background mapping, ensuring that these features are represented by closed polygons. Other catchment features that can affect overland flow paths such as walls, fences, hedges can be more difficult to obtain. Features close to roads can be determined by Google Street View but those not covered by the extents of Street View will generally need to be obtained by a site walk over.

Watercourses that flow across the modelled area may need to be included as a feature but could also be represented with a level or inflow file following a hydrological assessment, where they extend beyond the study boundary.

The details of these are contained in Table 6-2, (taken from CIWEM UDG Integrated Urban Drainage Modelling Guide V2.01, May 2021).

Table 6-2 2D Requirements and Parameters

2D Zone Type		Coarse-Urban	Medium-Urban	Detailed-Urban	Rural
Max Source Data grid resolution		2m	1m	1m	5m
Element	Max.	250m^2	100m^2	25m^2	250m^2
	Min.	75m^2	25m^2	25m^2	75m^2
Road Element	Max.	No	25m^2	No	No
	Min.		10m^2	2.5m^2	
Lower road areas		No	150mm	150mm	No
Buildings[1]		>100m^2 only	All buildings	All buildings	No
Walls, porous		No	Significant	All	No

2D Zone Type	Coarse-Urban	Medium-Urban	Detailed-Urban	Rural
Other Structures	No	Significant	All	Significant
Catch basins	No	Significant	All	No
Site Visit needed	No	Probably	Yes	No
Roughness zones min.	1	1	1	As required

Note: This table is reproduced from CIWEM UDG Integrated Urban Drainage Modelling Guide V2.01, May 2021.

1 Buildings are typically modelled as voids but where more detail is required, buildings may need to be represented using a 2D mesh – see Section 6.5.5 Infiltration Zones and Surfaces.

6.4 2D Model Data Preparation, Processing, and Import

6.4.1 DTM data pre-processing

It is important to carry out a check to make sure there are no data gaps in the DTM file prior to importing it. If the DTM contains gaps, the meshing will not be completed, giving this error: "*Meshing requires a height value to be specified at the following points*". In the absence of DTM data in a specific location, other available sources must be used to fill in the gaps (contour maps, publicly accessible lower resolution LiDAR, Synthetic Aperture Radar (SAR) data, etc.). The merging of different DTMs can be undertaken within a GIS by clipping the raster maps and merging.

Once this check is completed, the DTM can be imported to InfoWorks ICM. Refer to Section 6.4.3 2D Model Data Import for the DTM model import procedure.

6.4.2 2D Zone Definition

Before the 2D mesh can be created it is required to create a bounding polygon for the mesh. The bounding polygon is known as the 2D zone. The 2D zone can either be created within or imported into InfoWorks ICM. The 2D zone will define the extent of the mesh. A larger mesh size results in longer model run times and results files. Therefore, it is essential to delineate a 2D zone at the start of the study that is sufficient to meet the study's objectives, but with an acceptable model run time and result file size.

Once the 2D zone has been delineated, it is recommended that the mesh is generated using the default parameters detailed in Table 6-3 in Section 6.5.1. In a 2D model, a rainfall on mesh is simulation is run, without a 1D sewer model, to gain a clear understanding of overland flow paths and how natural ground features impact flow routes. Section 6.5 outlines how to prepare all model objects to perform a rainfall on mesh simulation.

Taken from the CIWEM IUD Modelling Guide Part B, the following checks are recommended to be performed at minimum when determining the extent of the 2D Zone:

- The extent of any existing 1D models which will be integrated is included.
- The study area or focus area is included.
- Catchment boundaries and topographical boundaries are included (which may be determined or influenced by the rainfall on mesh simulations).

As the study progresses it may be appropriate to review and update the 2D zone extent and the elements making up the 2D mesh. For example, if initial simulation results suggest the extent of the study area's catchment has been not been accurately represented. Iterations may involve altering the

2D zone extent and increasing or decreasing mesh element size depending on the level of detail required.

When creating a 2D zone it will be important to consider the granularity of the DTM data available, for examples a 2 m DTM grid may have sufficient resolution to model course-urban, rural areas, and watercourse floodplains; however, a 2 m grid is typically insufficient to model medium and detailed urban areas. If coarse resolution data is to be used medium-urban areas, the DTM should be modified by lowering road surfaces by 0.15 m (typical curb height) to provide channeling of the flows as the roads contained in the DTM will likely not be representative. Note also that buildings are typically modelled as voids, however, this may need to be reviewed where more detail is required, refer to Sections 6.5.3 and 6.5.5 for further building modelling guidance.

6.4.3 2D Model Data Import

A 2D model can account for different physical ground features in the 2D mesh. These ground features, such as roads and buildings, can either be digitized as polygons in InfoWorks ICM or obtained from existing GIS data and then imported into the model. The 2D zone polygon and the ground feature polygons that represent mesh zones in the model, can be imported using the Data Import Centre. To import the polygons select “Network” on the menu bar --> “Import” --> “Open Data Import Centre…”. If the 2D zone and mesh zone parameters have been prepopulated in the import file, the Data Import Centre allows those data fields from the import file to be mapped with the corresponding model objects.

It is also possible to import multiple polygons from one shapefile as a multi-part polygon. To import multi-part polygons select “Import multi-parts” in the Data Import Centre window, as shown in Figure 6-2.

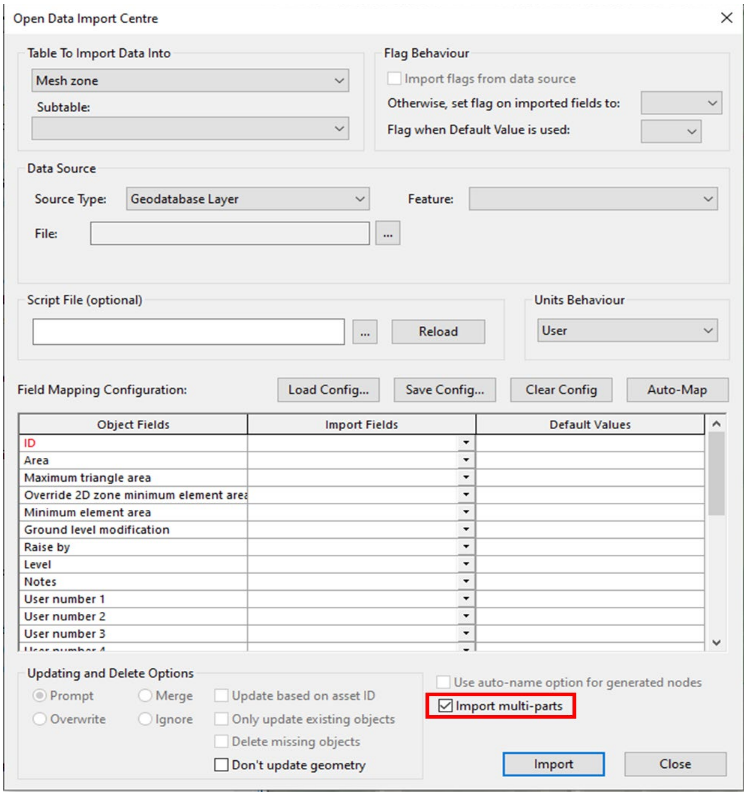


Figure 6-2 Data Import Centre - Import Multi-Parts Box

Subsequently, the Digital Terrain Model (DTM) should be imported as a ground model grid in ASCII grid format (*.asc) or Vertical Mapper (*.txt) as shown in Figure 6-3. To import a ground model from file, right click on the model group and select "Import InfoWorks" --> "Ground model grid" --> "from ground model grid files…".

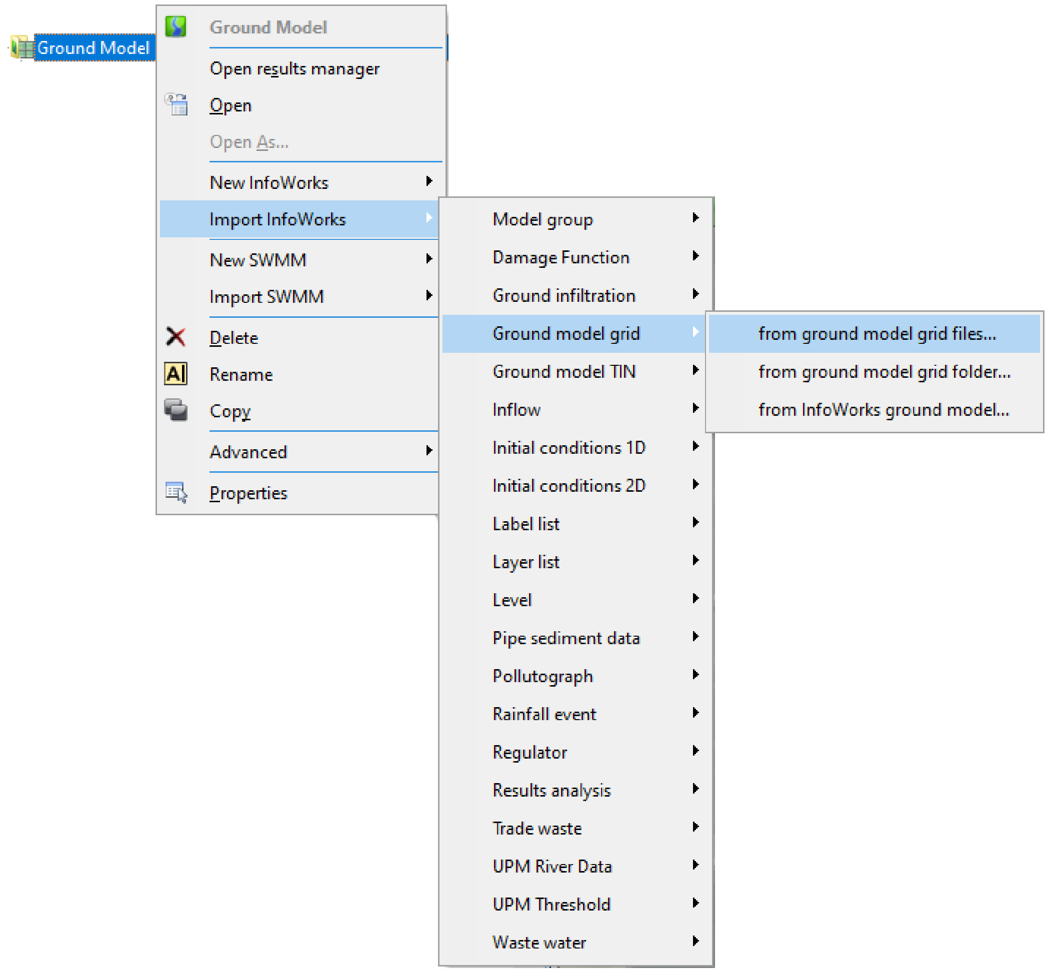


Figure 6-3 Importing DTM into InfoWorks ICM

The correct units shall be selected for ground elevation and using floating point for improved accuracy, as shown in Figure 6-4.

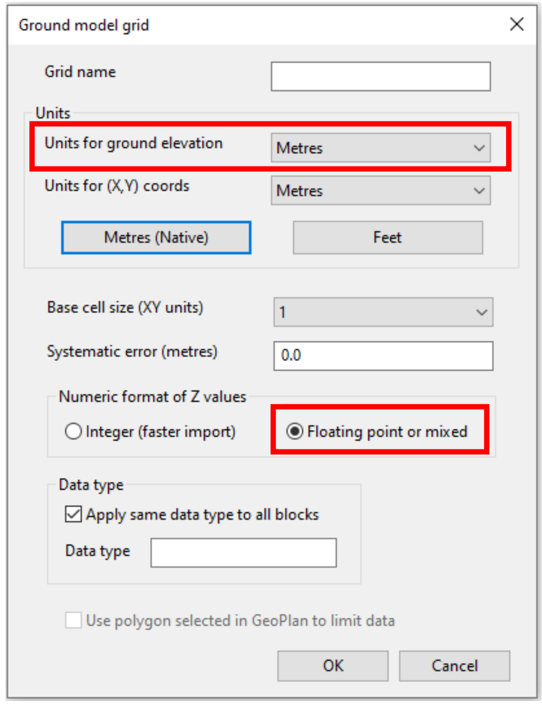


Figure 6-4 Ground Model Grid Import Window

6.4.4 DTM Validation

Once the DTM has been imported into InfoWorks ICM, it should be validated.

A typical "true to ground elevation" vertical tolerance of a DTM in a 1D2D model is approximately 0.18 m. Therefore, it is important to check if the DTM elevations match known (surveyed) elevations in the 1D model and to vertically adjust the DTM appropriately, also called "ground truthing". A comparison of DTM elevations to known ground elevations at the same locations in the model should be carried out, e.g. a comparison of DTM elevations to surveyed manhole rim elevations. If the DTM is found to have a vertical offset from known ground elevations within the 0.18 m tolerance, the entire DTM should be vertically adjusted as a whole to match known surveyed elevations.

Particular care needs to be taken when a model has been developed over a number of iterations as this can lead to the DTM being set at different benchmarks in the areas of the model that have been added.

6.5 2D Model Configuration

This section provides recommended parameters to build a 2D mesh, depending on the level of detail and accuracy required, and covers the primary components in a 2D model.

6.5.1 2D Zone

A 2D zone is used to define the extent of the 2D part of the model and acts as the bounding polygon where a 2D mesh is created. A 2D zone is required to generate a 2D mesh.

The extent of the 2D zone will be defined by the type and focus of the study. A small 2D Zone may be required if the flood mechanism is localized but could also be extended to cover the full catchment that contributes to the entire study area.

One or more 2D zones can be defined within a single 1D model network with different levels of detail and accuracy. Note that overland flow will be discontinuous between each 2D zone. If overland flow continuity is required, it is recommended to use mesh zones as outlined in Section 6.5.3 Mesh Zones.

A 2D zone is a polygon object that can be drawn in InfoWorks ICM by clicking the “New Object” button, as shown in Figure 6-5, and selecting “Polygon”. Once the polygon has been created, a new window named “New Polygon” will appear where the polygon type can be selected. In this instance “2D zone” should be selected, as shown in Figure 6-5. Alternatively, if the 2D zone is created in a GIS, a polygon shapefile can be imported using the Open Data Import Centre.

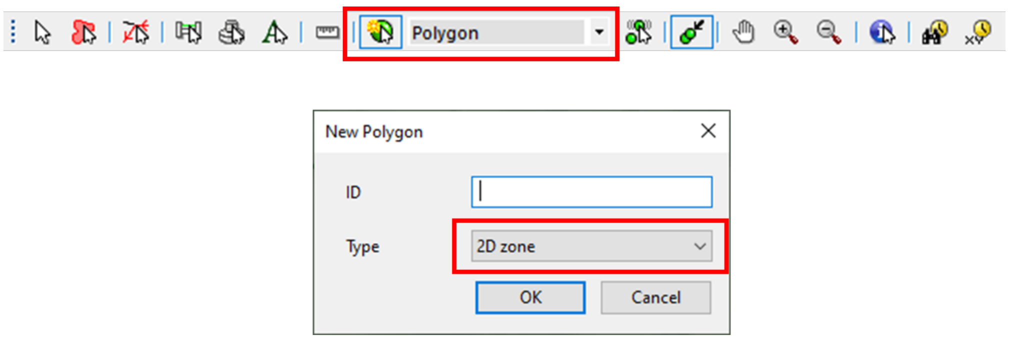


Figure 6-5 2D Zone Creation

Table 6-3 provides a set of default initial parameters that shall be applied to a 2D zone; however, the parameters should be carefully reviewed for each project, and if necessary, adjusted as appropriate.

To aid in model simulation stability, it is recommended that the ratio between the maximum triangle area and the minimum element area is 4:1. The proposed default initial values for the maximum and minimum triangle sizes may not be suitable for smaller 2D zones and may need to be decreased while maintaining the 4:1 ratio.

Further detail on the “boundary points” parameter is covered in Section 6.5.11 but “Dry” is deemed a reasonable initial parameter value that ensures flow can leave the mesh.

It is recommended that terrain-sensitive meshing is always enabled to ensure additional detail is added to the mesh at areas where the ground is steeper. If enabled, the maximum height variation value permitted within a single triangle will be adhere to during mesh generation. A height variation value of 0.3 m is a reasonable initial value, but this may be increased if the catchment is particularly steep. The same applies to minimum angle.

The value assigned to the roughness will be applied to the 2D zone unless superseded by a roughness zone. A value of 0.06 is an average roughness value and is suitable for general green spaces but it is recommended additional roughness zones are added to improve accuracy. Refer to Section 6.5.4 for more information about roughness zones.

If the infiltration parameter is left blank in the 2D zone, no infiltration will be simulated on the 2D mesh. However, an infiltration surface may be assigned to the 2D zone representing uniform infiltration across the entire 2D mesh. If soil infiltration information is available for various areas within the 2D zone, multiple infiltration zones can be created. Each infiltration zone can have a different infiltration surface assigned with distinct infiltration parameters. Refer to Section 6.5.5 on how to define infiltration surfaces and incorporate infiltration zones, if applicable.

Note that these parameters assume the presence of an existing 1D sewer model with connected subcatchments. Therefore, in a 1D-2D model, the "Apply rainfall etc." parameter should be set to "Outside Subcatchments". However, if no subcatchments from a 1D model are present, e.g., in a 2D only model, the "Apply rainfall etc." should be set to "everywhere".

Table 6-3 Default parameters for 2D Zone

Field	Default Parameters
ID	User Defined
Area	#D
Maximum triangle area (m²)	100
Minimum element area (m²)	25
Boundary points	Dry
Terrain-sensitive meshing	Enabled
Maximum height variation (m)	0.3
Minimum angle (degree)	15
Roughness (Manning's n)	0.06
Apply rainfall etc. directly to mesh elements	Enabled
Apply rainfall etc.	Outside Subcatchments (set to "Everywhere" in a 2D only model)
Rainfall profile	User Defined
Infiltration surface	User Defined
Turbulence model	Leave Blank
Rainfall percentage (%)	100

6.5.2 2D Mesh Creation

InfoWorks ICM uses a 2D mesh to represent the ground surface. This section describes how to create the base 2D mesh. The base 2D mesh can be further refined as described in subsequent sections. The initial mesh parameters are defined in the 2D zone. The 2D mesh is generated using a Digital Terrain Model (DTM) and other relevant input data polygons such as mesh, roughness, and infiltration zones. These zones are populated with values that characterize ground features within their polygons. When the 2D mesh is generated, these values are processed and assigned to each individual mesh element.

A DTM is required to create the 2D mesh. Refer to Section 6.4.3 for the DTM import procedure. Once the DTM has been imported into ICM, the mesh can be created by selecting the 2D zone, subsequently, navigate to "Model" in the menu bar and select "Meshing" --> "Mesh 2D Zones", as shown on Figure 6-6. Drag the DTM from the file tree into the "Ground Model" field and click "OK" to start the meshing.

If a river is present in the model, it is recommended that "lower 2D Mesh element ground levels higher than adjacent bank levels" box is ticked. This will help smooth the 1D-2D linear coupling between the riverbank and the adjacent mesh elements. If voids, e.g., buildings, have been prepared as a polygon layer, select the layer from the "Voids" section. Breaklines should be drawn as general lines and assigned a type; they can then be selected from the drop-down menu for "Polylines" located under the "Breaklines" menu item.

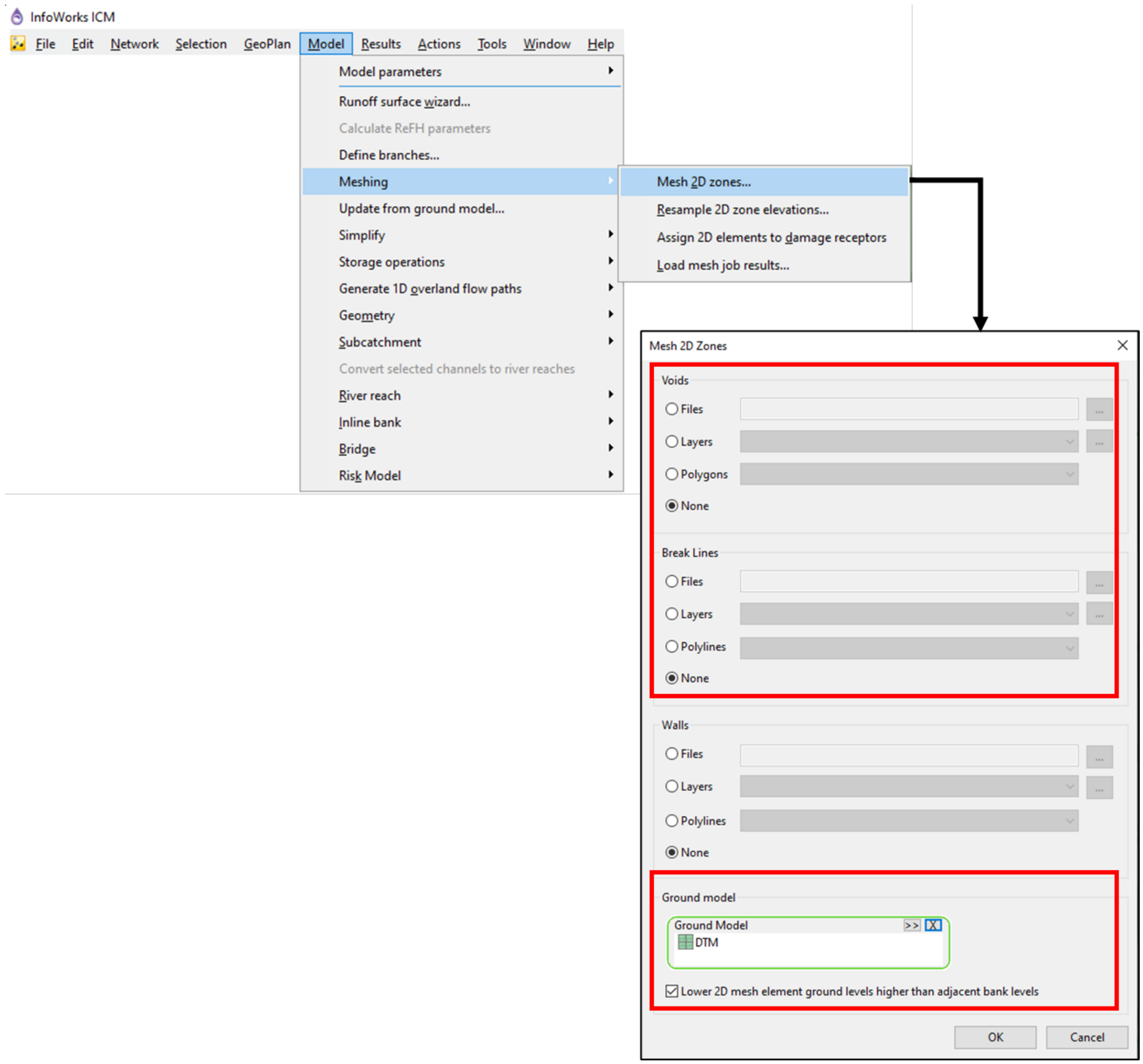


Figure 6-6 Creation of 2D Mesh

The length of time required to generate a 2D mesh will vary depending on the area and complexity of the mesh requirements. However, if mesh generation is taking longer than expected during the triangulation phase, it may be an indication that small triangles are being generated. Small triangle generation can occur in locations where there are slivers or gaps present between polygon features; refer to the example shown on Figure 6-7 below. If this occurs, action should be taken to identify and close the gaps. Guidance on how to resolve small silvers or gaps between polygons using ArcGIS can be found on desktop.arcgis.com and searching "Removing slivers or gaps between polygons".

Figure 6-7 Example of Excessive Triangulation of 2D Mesh

6.5.3 Mesh Zones

A Mesh Zone is an object used to divide a 2D Zone into regions of different resolution or to define zones in which ground level modification is required.

Mesh Zone objects with different resolution might help in two different ways:

1. Decrease the mesh elements size to increase the resolution of the 2D Zone to improve detailed modelling results in a localized area.
2. Increase the mesh elements size to decrease the resolution of the 2D Zone to reduce the number of mesh elements and computational efforts. This is recommended in non urbanized areas where high levels of resolution are not needed. Mesh Zones objects with ground level modification are used to represent a wide range of features, such as roads, channels, rivers, buildings, ponds, flood defenses or even to correct DTM anomalies.

To create a Mesh Zone object within InfoWorks ICM, a polygon object must be created first and then select the Mesh Zone option after digitizing it. These objects can also be imported from GIS (road polygons, etc) from the Open Data Import Centre.

Once the Mesh Zones have been created, the change in elevation should be applied. For example, when the purpose of the Mesh Zone is to lower the 2D Zone ground level, a negative number should be specified, e.g. -0.5m to represent a 0.5m deep channel that is not covered by the DTM.

The following example shows two different types of Mesh Zones – one to decrease the resolution of the 2D mesh to decrease the number of mesh elements, and another one to represent the roads.

Figure 6-8 Mesh Zones (in blue) to decrease the resolution of the 2D mesh and to represent roads

Once the Mesh Zones have been generated, a new meshing simulation will have to be run to incorporate all the changes (see Section 6.5.2). Refer to Sections 6.5.5 and 6.5.6 for more details on mesh zones and mesh zone parameters of buildings and roads.

6.5.4 Roughness Zone

Roughness zones can be used to represent areas where the Manning's roughness value differs from the default value specified in the 2D zone. Different Manning's n values can be assigned according to surface type. For example, the roughness across a heavily wooded area would be significantly different from an urban area.

A roughness zone is a polygon feature and can be created in the same way as a 2D zone as described in Section 6.5.1, but instead of "2D Zone" select "Roughness Zone" as the type in the drop-down menu. Alternatively, roughness zones can be imported using the Data Import Centre if these areas are available as a shapefile.

It is recommended that the roughness zones are only applied if accurate mapping data is available for the roughness types listed in Table 6-4. The default initial roughness parameters should be set to the values provided in Table 6-4.

To simplify the meshing process, ensure the "Exclude roughness zone boundary when creating 2D mesh" box is ticked in the roughness zone definition, as shown on Figure 6-9. However, note that selecting this option implies that the 2D mesh elements crossing the boundaries between 2D Roughness Zones will not have the roughness coefficient represented as neatly.

Table 6-4 Recommended Roughness Zone Parameters

Type	Default Roughness (Manning's n)
Buildings/Structures	0.5
Roads/Paved	0.025
Trees/Thick Vegetation	0.12
Fields/General Green Spaces	0.06

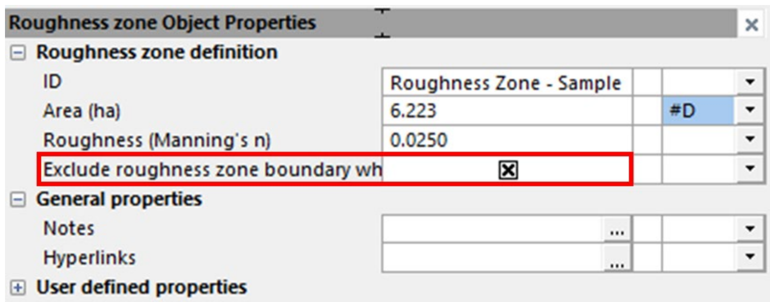


Figure 6-9 Roughness Zone Data Fields – Example

Update in InfoWorks ICM 2023: Previously, when two or more roughness zones that are located within the same 2D zone overlapped, the mesh could not be generated. A message would be included in the log indicating which zones intersected, and you would need to correct the overlapping geometry of the intersecting zones before the 2D zone could be meshed successfully. From ICM 2023 onwards, you can assign a priority value to roughness zones. If a zone overlaps another roughness zone, the overlapping part of the zone with the lowest priority value will have precedence over a zone with a higher priority value. However, the mesh generation process will still fail for overlapping roughness zones if:

- Priorities are not assigned.
- The same priority value is used as another roughness zone located in the same 2D zone.
- The classic method of mesh generation is used instead of clip meshing. Further information on clip meshing can be found on the InfoWorks ICM help menu.

6.5.5 Infiltration Zones and Surfaces

Infiltration can be modelled by assigning an infiltration surface to the entire 2D zone. However, if different infiltration parameters are known for multiple areas within the 2D zone, infiltration zones are required to represent these in the model. Each infiltration zone can be assigned a different infiltration surface that contains distinct infiltration parameters.

Up to a 25-return period, the infiltration potential of the study area should be investigated and assessed. If it is deemed appropriate to represent infiltration in the 2D model, ideally, infiltration parameters should be informed by site specific hydrogeological data. If these are not available, the Green Ampt infiltration parameters in Table 4-26 Runoff Surface Configuration in Chapter 4 for poor, low, and medium soil infiltration categories should be used as initial parameters as indicated on the City's soil GIS map. Note that the City's Model Template Database has these three infiltration surfaces prepopulated.

Typically in an urban setting, the amount of infiltration for return periods greater than 25 years is insignificant and may not need to be accounted for in the model.

An example of the Green Ampt infiltration surface parameters are shown on Figure 6-10.

Infiltration zones are polygon features and can be created in the same way as a 2D zone selecting "Infiltration Zone" in the drop-down box, alternatively, these can be imported using the Data Import Centre.

Similar to a roughness zone, ensuring "Exclude infiltration zone boundary when creating 2D mesh" is ticked for the infiltration zone definition will simplify the meshing process.

	ID	Infiltration type	Fixed runoff coefficient	Green-Ampt suction (mm)	Green-Ampt conductivity (mm/hr)	Green-Ampt deficit
	DEFAULT	Fixed	1.00000			
	Pervious area with poor infiltration potential	GreenAmpt		292.2	1.0	0.09
	Pervious area with low infiltration potential	GreenAmpt		166.8	6.8	0.17
	Pervious area with moderate infiltration potential	GreenAmpt		61.3	59.8	0.31
*						

Figure 6-10 Infiltration Surfaces - Example

Buildings are an obstruction to overland flow and can have a significant influence on flow routes within a catchment; therefore, it is important to represent buildings in the 2D mesh. Buildings can be modelled in two ways; as voids cut out of the 2D mesh or in detail, especially in locations where overland flow is known to pass through buildings.

Buildings are to be modelled as voids unless this higher level of detail is required. Voids in the 2D mesh are generated using polygons and define an area where flow cannot enter. Building polygons can be created using the polygon tool in ICM; however, it is recommended that the City's Building GIS layer is imported into the model using the Data Import Centre. All building polygons should be assigned a unique ID.

Prior to import, it should be confirmed that only buildings are present in the Building GIS layer. For example, structures that allow overland flow to pass through such as bridges, underpasses, and covered alleyways should be excluded from the Building GIS layer if present. Additionally, garages and other small outbuildings should be excluded to reduce unnecessary complexity in the 2D mesh.

Once the 2D mesh has been generated, it is recommended to simplify any over-detailed 2D meshing and protuberances that surrounds the building voids, as shown on Figure 6-11. The reduced complexity of the 2D mesh around the building voids improves simulation run times.

Simplification of building polygons can either be carried out in GIS software prior to importing into ICM or within ICM using the simplify geometry tool, as shown in Figure 6-12. The function of the tool is to reduce the number of vertices of selected objects by specifying a minimum segment length between vertices. Removal of vertices will alter the shape of the polygon so the minimal segment length applied needs to be considered and will vary between polygons.

Figure 6-11 Example of Mesh Before (left) and After (right) Simplification

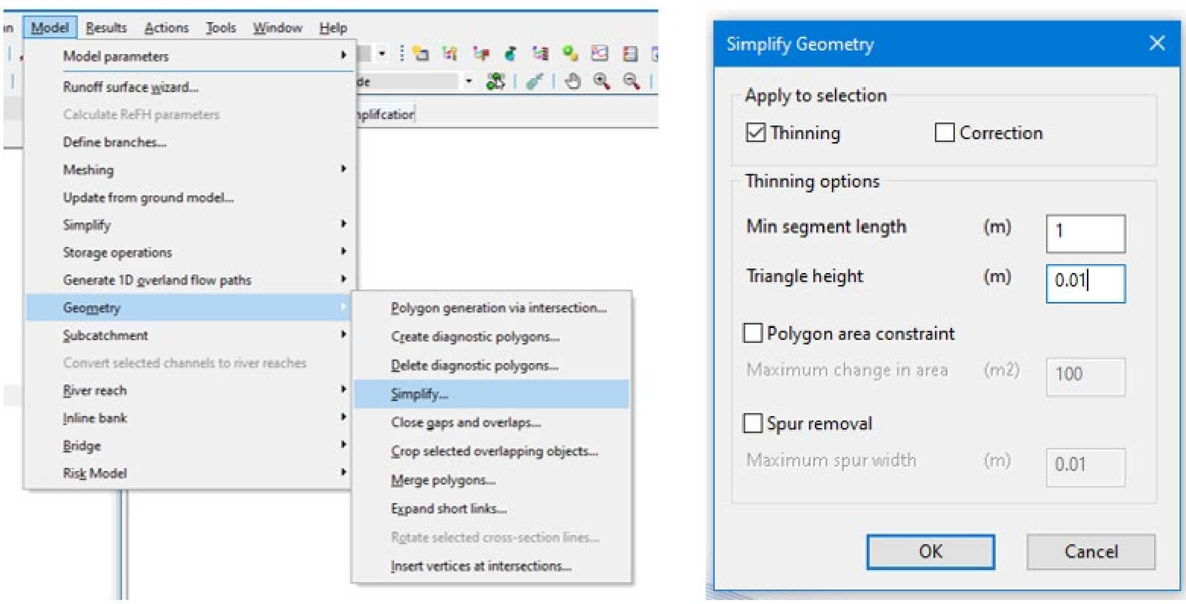


Figure 6-12 Simplify Geometry tool within ICM

If there are buildings that allow overland flow to pass through and are located in an area of interest, they can be represented in greater detail to provide more accurate flood extents and overland flow routes.

In this case, those buildings can be represented by building mesh zones where the ground level should be adjusted to the elevation where water spills into the building and flows through. These building mesh zones should be used with corresponding roughness zones. The building roughness zones should have a high Manning's n value to simulate the high level of difficulty for water to enter and flow through the buildings. Currently there is no industry standard Manning's n value to apply to buildings, however, 0.5 is widely recognized as good starting value.

6.5.6 Roads

Roads collect and route storm water when it rains; therefore, it is important to represent these accurately in a 2D model. Polygons defining roads should be imported as mesh zones into ICM using the Data Import Centre. Refer to Section 6.5.3 and Section 6.4.3 on how to create and import road mesh zones, respectively.

Note that after importing the road polygons, they should be assigned a unique ID.

To ensure roads and gutter flow paths are accurately represented, all road mesh zones shall be set to lower the default 2D mesh elevation by 0.15 m to account for the lower road pavement between curbs. Curbs are less likely to be present in rural areas; therefore, spot checks should be carried out in critical areas prior to depressing the road mesh.

As with the building polygons, once the road mesh zone polygons have been imported, it is recommended to simplify the polygons reducing complexity of detailed curves and refining the intersections; this will enable faster generation of the 2D mesh.

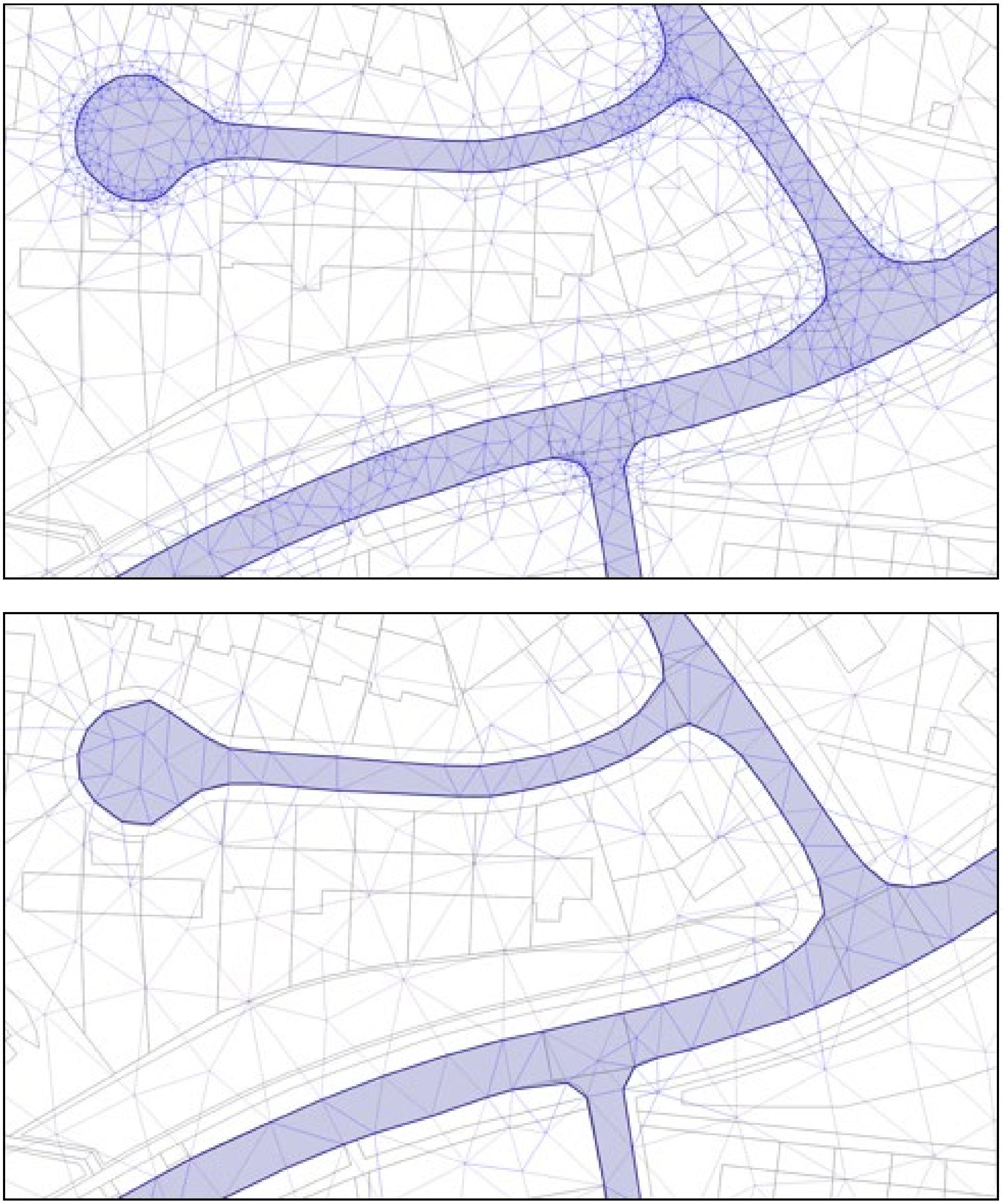


Figure 6-13 Example of Mesh Before (above) and After (below) Simplification

Table 6-5 provides default parameters to apply to the road mesh zones.

Table 6-5 Default parameters for Road Mesh Zones

Field	Default Parameters
ID	"Road_" + incrementing number
Area	#D
Maximum triangle area (m^2)	10
Override 2D zone minimum element area setting	Enabled
Minimum element area (m^2)	1
Ground level modification	Raise or Lower
Raise by (m)	-0.15

6.5.7 Watercourses

The City has two open channel watercourses, Still Creek and Musqueam Creek. The open channel watercourses can be modelled as a 1D river reach object coupled to a 2D mesh in a 1D-2D coupled model. Additionally, the watercourses could be modelled fully in 2D, where they are represented by a 2D mesh created using river mesh zones.

It is recommended to use a 1D-2D model to simulate the watercourses. If available, bathymetric surveyed cross-sections of the river channel should be used to build the river reach object as shown on Figure 6-14. This is also recommended for smaller watercourses where LiDAR resolution is low. The left/right banks and river reach boundaries are required model components to couple the river reach object to the 2D mesh. The 2D Zone ID needs to be added in the River Reach object properties (in the left and right banks drop down box) to fully couple the 1D-2D model.

The roughness coefficient values should be determined at the bed and bank levels. Note that by default, InfoWorks ICM will use the roughness from roughness zones that overlap the river reach object. In the absence of roughness zones, InfoWorks ICM will use the roughness from the river reach object cross-sections.

The left and right riverbanks need the "Discharge coefficients" and "Modular limits" parameters defined. Typical values for both parameters are 1.0 and 0.67, respectively.

While the 2D mesh is generated with the left and right riverbanks configured, the meshing engine will create a void-like object that will allow water to flow over the river banks in both directions.

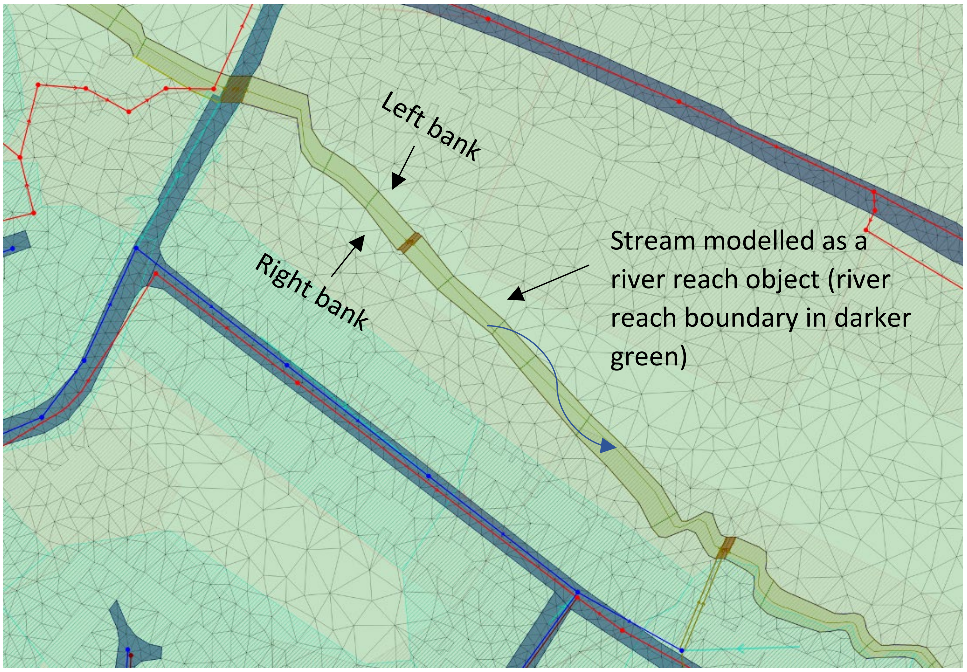


Figure 6-14 Modelling River using River Reach Objects

In channels where less detail is required, it is possible to run the 2D model using only the river channels selected from the DTM on the 2D mesh. This method relies on having an accurate DTM and is only recommended for flood prone areas where flood impacts are high. Small rivers may have erroneous LiDAR water levels within the channel that can cause back falls, that causes water to stop flowing and artificially pond due to a higher level in the mesh. These could be corrected by adding a mesh zone object onto the 2D mesh. A mesh zone object creates a zone which can be used to adjust the 2D mesh within, in this case to the level of the upstream datum smoothing out the back fall. A 2D mesh zone is also recommended to reduce the number of 2D elements.

6.5.8 Culverted watercourses

When a watercourse is conveyed through a culvert as shown in Figure 6-15, the culvert should be represented by modeling objects in the following sequence:

[River Reach or 2D Watercourse] -> Break Node (BN) -> Culvert Inlet -> BN -> Conduit -> BN -> Culvert Outlet -> [BN or Outfall or Outfall 2D] -> [River Reach or 2D Watercourse]

The culvert inlet object is used to represent inlet losses. The culvert object in InfoWorks ICM includes several empirical parameters that must be populated by the user depending on the culvert and headwall shapes. Guidance on the recommended values for the empirical variables can be found in Chapter 4 Section 4.3.8 Culverts.

Additionally, the typical culvert outlet loss value is 1.0 and is defined in the culvert outlet object.

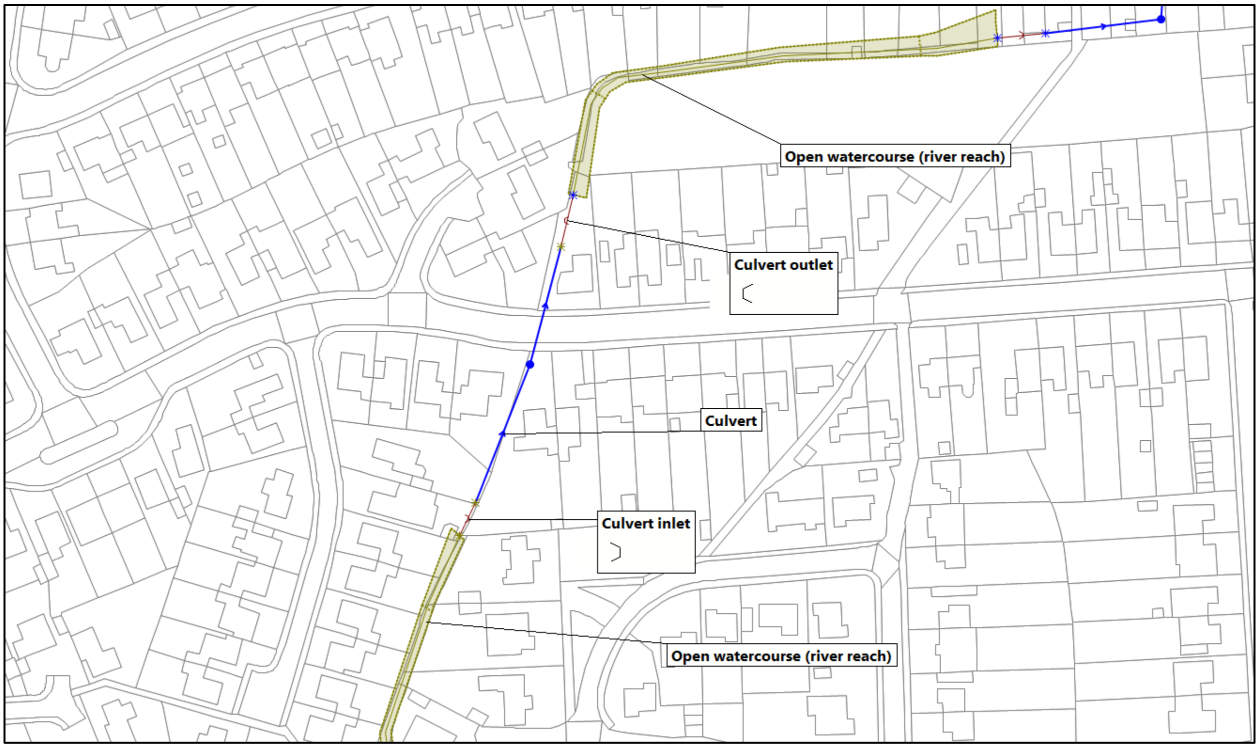


Figure 6-15 Modelling Sequence for a Culverted Watercourse

6.5.9 Bridges

A bridge is usually not required to be modelled in detail as a 1D bridge link object unless the modelling study requires a detailed analysis of the bridge hydraulics. Additionally, bridge link objects are known to cause stability issues; therefore, it is recommended to use a simpler 1D culvert object instead.

If the watercourse has been modelled in detail, then it may be necessary to represent the bridge structure as a bridge link. The detailed bridge information required will include information on decks, piers, openings, and upstream/downstream river cross sections. The bridge link object needs five different cross sections at the expansion and contraction reaches, upstream/downstream of the bridge, the bridge deck, and the bridge opening. Once these five bridge cross-sections have been configured, it is recommended to review the bridge shape using the 3D viewer tool as shown on Figure 6-16. A 1D culvert can also be used to represent a bridge even when detailed survey information for the bridge is available.

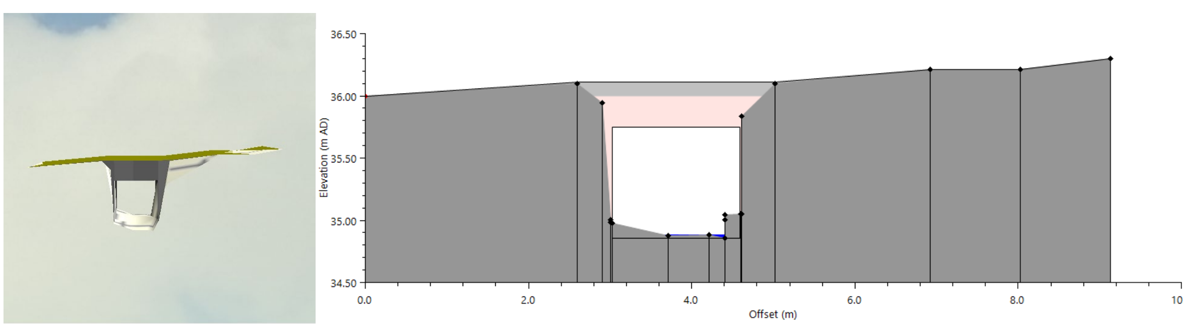


Figure 6-16 Example of 1D and 2D View of Bridge Sections

When a bridge is modelled in 2D and is fully represented by a 2D mesh, a bridge can also be modelled as a “Bridge Linear Structure (2D) object instead of a 1D culvert object. In this case, the five bridge cross-sections are not required because the elevations for the bridge linear structure will be taken from the DTM ground model. However, the bridge opening and deck thickness will still need to be defined.

6.5.10 Walls and Base Linear Structures (2D)

Linear features such as dikes, flood walls, boundary walls, and fences can play a significant role in directing overland flow paths. In some cases, a boundary wall can direct overland flow to properties causing flood damage. Walls may also significantly alter the direction of a flow path on a larger catchment wide scale. Figure 6-17 shows an example of how a wall can dramatically influence overland flow paths.

It is usually not necessary to model walls unless it is known that they have a strong influence on the overland flow path. Therefore, the modeller can use a rainfall on mesh simulation to determine if walls or other linear features will impact flow routes significantly. A rainfall on mesh simulation will show general overland flow paths and may provide insights on whether any walls or linear features that are not modelled could impact overland flow paths or cause property damage. Note that features like walls and fences are often not captured in the DTM ground model. Satellite imagery can be reviewed, or site visits can be conducted to identify these types of features, and subsequently, can be digitized and added to the model.

Linear features are usually modelled using either a “Porous Wall” or “Base Linear Structure (2D)” model object. A dike should be modelled using the base linear structure (2D) object where the structure type should be set to “Wall”. The “Crest level” parameter can be set to “infinite” to identify flood levels at storm scenarios of interest to the study.

Both model the porous and base linear structure 2D model objects can be created by clicking the drop-down for “New Object” in the toolbar and selecting “Line”. The base linear structure (2D) object has a wider range of parameters compared to a porous wall. However, using a porous wall object to represent a linear feature is usually sufficient as significantly more detailed information is required to represent a linear feature as a base linear structure 2D object. Note that setting the porosity parameter to a value of 0 in the porous wall object will represent the wall as an impermeable structure.

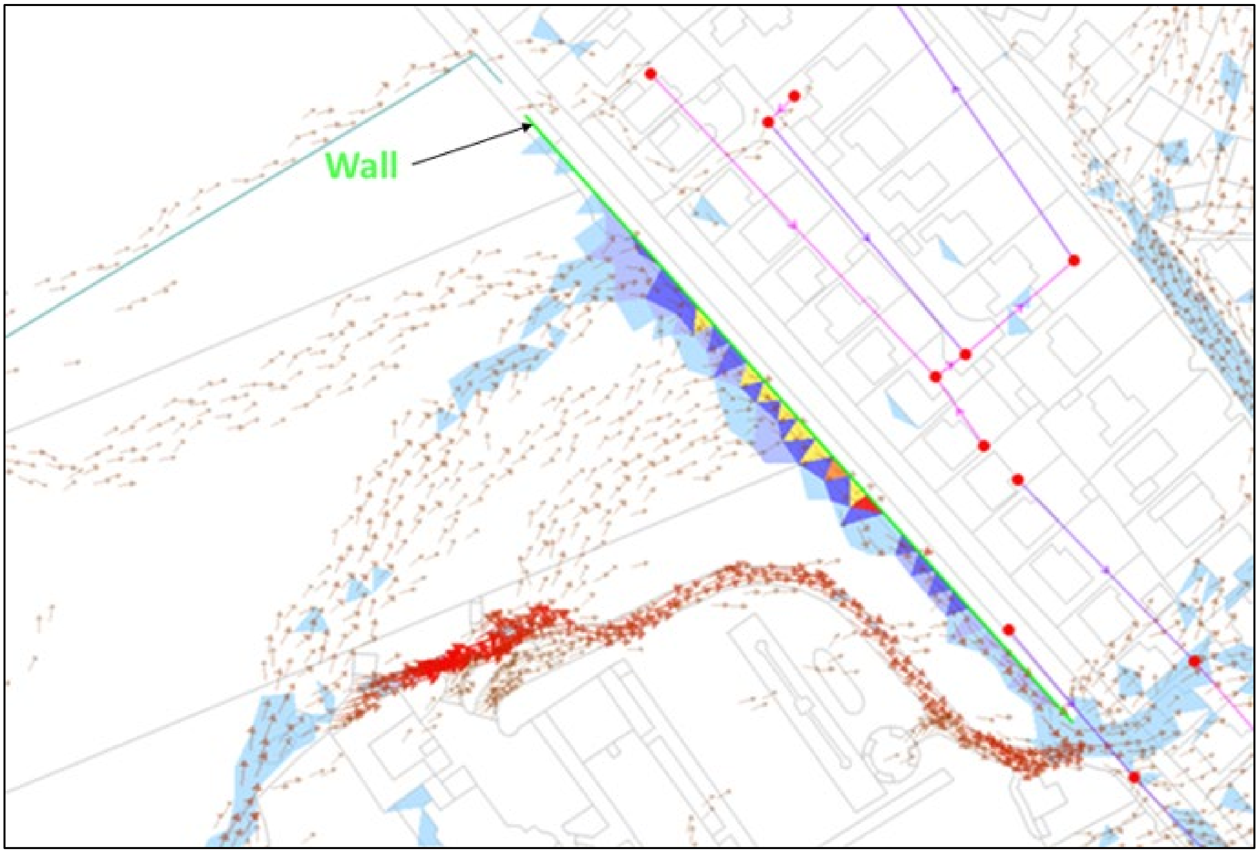


Figure 6-17 Example of Influence of Wall on Overland Flow Paths

6.5.11 Boundary Conditions

Boundary conditions define what happens to overland flow when it reaches the edge of a 2D zone. There are two types of boundary conditions; one is populated in the 2D zone object property table and applies to the entire boundary of the 2D Zone, the other is a boundary condition created as a separate 2D boundary model object using a line object. The 2D boundary object can be used to assign a boundary condition to a specific location along (the perimeter of) the 2D zone polygon to simulate a boundary condition that is different. The boundary condition assigned to the 2D boundary object will override the 2D zone boundary condition where they coincide.

Table 6-6 and Table 6-7 below provide the available boundary condition types for the "Boundary points" parameter in the 2D zone object and the "Boundary line type" parameter in the 2D boundary object, respectively.

Table 6-6 2D Zone Boundary Types Reproduced from the CIWEM UDG ICM CoP

Field	Description
Vertical Wall	The boundary of the 2D Zone is considered to be an impermeable infinitely high barrier. Water cannot flow out of, or into, the 2D Zone.
Critical Condition	If the level in the boundary element of the 2D Zone is above the boundary face level, flow out of the 2D Zone will be calculated using a broad crested weir equation without energy loss. If the level in the boundary element is below the boundary face level, the boundary is considered to be a vertical impervious wall. Water cannot flow into the 2D Zone.
Supercritical Condition	If the flow in the boundary element is supercritical (Froude > 1) and directed outside of the 2D Zone, then the flow at the boundary face will be considered supercritical and calculated using the boundary element depth and velocity, regardless of the boundary face level. If the conditions of the flow are not supercritical, or the flow is going into the 2D Zone, the boundary face will be considered as a vertical wall. This situation is useful in areas where the user knows that the flow is flowing out of the 2D Zone without any effects on the 2D Zone. Water cannot flow into the 2D Zone.
Dry	The boundary of the 2D Zone is considered to be surrounded by a bottomless pit. Water that reaches the edge of the 2D Zone will flow out of the zone and will be lost from the simulation. Water cannot flow into the 2D Zone.
Normal Condition	It is assumed that slope balances friction forces (normal flow). Depth and velocity are kept constant when water reaches the boundary, so water can flow out without losses.

Table 6-7 Additional 2D Boundary Types reproduced from the CIWEM UDG ICM CoP

Field	Description
Inflow	Inflow / Outflow to the 2D Zone at the boundary line is defined by a profile in an Inflow Event. The inflow is distributed evenly by length along the length of the boundary line.
Level	Depth of water at the boundary line is defined by a profile in a Level Event. If the level of water in the boundary is below the boundary element ground level, the water depth at the boundary is considered zero. Therefore, the boundary acts as a weir with crest level at the level of the boundary element.
Level & Head/discharge	Depth of water at the boundary line is defined by a profile in a Level Event. If the level of water in the boundary is below the boundary element ground level, the water depth at the boundary is considered zero. The flow at the boundary is calculated from the head-discharge relationship specified in the Head unit flow table. The head is calculated as the depth at the boundary minus the depth at the element(s) attached to a 2D boundary line. Positive and negative heads beyond specification in the head unit flow table are calculated using linear extrapolation.

A 2D boundary object is commonly used to represent a tidal influence along a 2D zone. Typically, a level file is assigned to the 2D boundary type to simulate the tide. Sometimes the level applied to the 2D boundary can be significantly higher than the 2D mesh elevations which without due consideration can cause model instabilities or provide unrealistic model results. An example of this could be where a 2D boundary level is set to a large height above the 2D mesh elevations and these are dry at the start of the simulation which can result in a large, and often unrealistic, rushing of flow onto the 2D mesh at the beginning of the simulation. Therefore, to mitigate this model instability, it is important to review and adjust the maximum tide elevations in the level file appropriately.

The “Initial Conditions 2D” model object can be used to assign initial hydraulic, infiltration, and water quality values to 2D mesh elements at the start of a 2D simulation which can be used to mitigate the scenario described above. The initial conditions 2D object is defined by a polygon and each 2D initial condition zone (2D IC Zone) can have different initial model conditions. Hydraulic values for initial level, depth, and velocity can be configured. Note that 2D IC zones override initial values set in the “Boundary points” parameter in the 2D zone and 2D boundary objects.

6.6 1D-2D Network Coupling

To couple a 1D network to a 2D model and enable flooding from a manhole onto the 2D surface, the flood type parameter in the manhole object should be set to “2D”, as shown in Figure *6-18*. A manhole with a flood type of 2D acts as a weir allowing two-directional flow of flood water from the manhole onto the mesh. The length of this weir is defined by the circumference of the manhole shaft. The discharge coefficient of this weir is defined by the flooding discharge coefficient, which can be specified by the user in the manhole object table. The default InfoWorks ICM flooding discharge coefficient value of 0.5 is adequate to be used as an initial parameter and may be adjusted as appropriate.

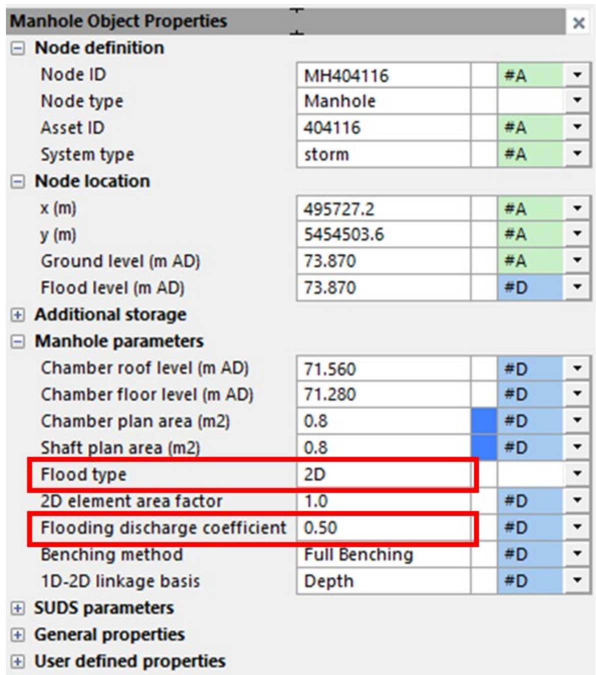


Figure 6-18 *Manhole Properties - Flood Type and Flooding discharge coefficient*

In general, manholes within a 2D zone should be modelled with the flood type parameter set to “2D”. However, a manhole may be assigned the flood type “Gully 2D” to represent the inflow characteristics of a catch basin. Gully 2D manholes require a head discharge rating curve to be applied to represent the flow attenuation effect of a catch basin inlet or from other flow limiting features.

In general, the 2D gully type should only be applied to manholes in a Detailed-Urban type model, as defined in Section 6.3.3, where there is a need to account for the inflow characteristics of catch basins. Note that the 2D gully flood type should be set to “stored” for sealed manholes, dummy modelling nodes, and manholes located within building voids.

It is important that the elevation of the 2D mesh above the manholes matches the manhole ground levels. If they do not match, water could spill onto the mesh before or after the water reaches the manhole ground level. It is recommended that a new scenario is created and ground levels of all manholes within the 2D Zone are inferred using the auto inference tool “NODE: Ground level from 2D mesh element” to ensure manhole ground levels and mesh elevation match for all nodes. Subsequently, it is recommended to investigate and resolve the manholes where the difference between the existing and inferred ground levels is greater than 150 mm. The invert elevations of all manholes, where the manhole ground levels were adjusted to match the mesh elevation, should also be reviewed and use engineering judgment to update the inverts if this generates negative gradients.

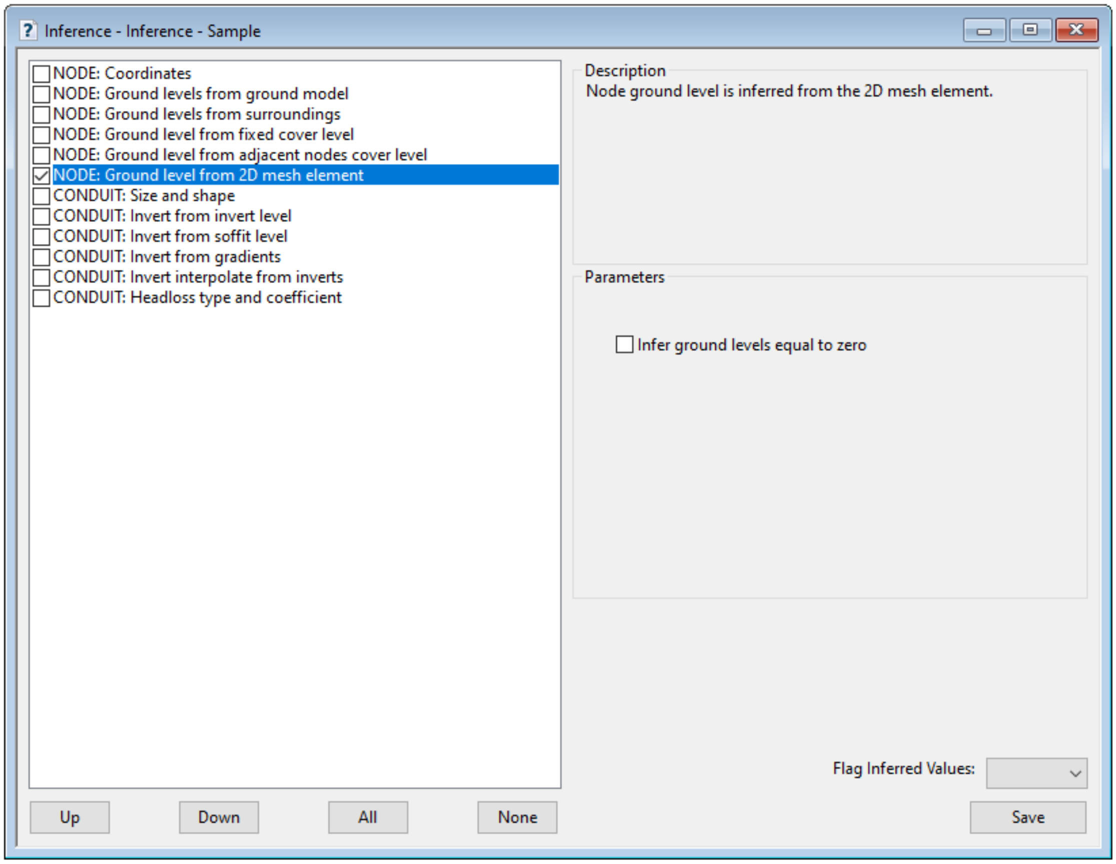


Figure 6-19 *Ground Level Inference Tool*

Where the 1D network discharges onto the 2D mesh as a culvert to a watercourse or an outfall to a waterbody, the node type in the manhole object table should be set to “Outfall 2D” to ensure water can flow onto the mesh. Additionally, the model requires the downstream invert elevation of the conduit connected to the outfall and the ground level of the outfall 2D to match the mesh element elevation at the point of discharge to the waterbody. Matching the elevations of the 1D and 2D elements will allow for bidirectional flow.

6.7 Model Simulation Configuration

A 2D simulation is scheduled using a “Run” group where a 2D or 1D-2D model network is attached and the 2D model parameters can be configured as shown on Figure 6-20. Note that configuring a 2D model should be an iterative process and it is recommended that the model is run regularly during model development so that issues can be resolved as they arise.

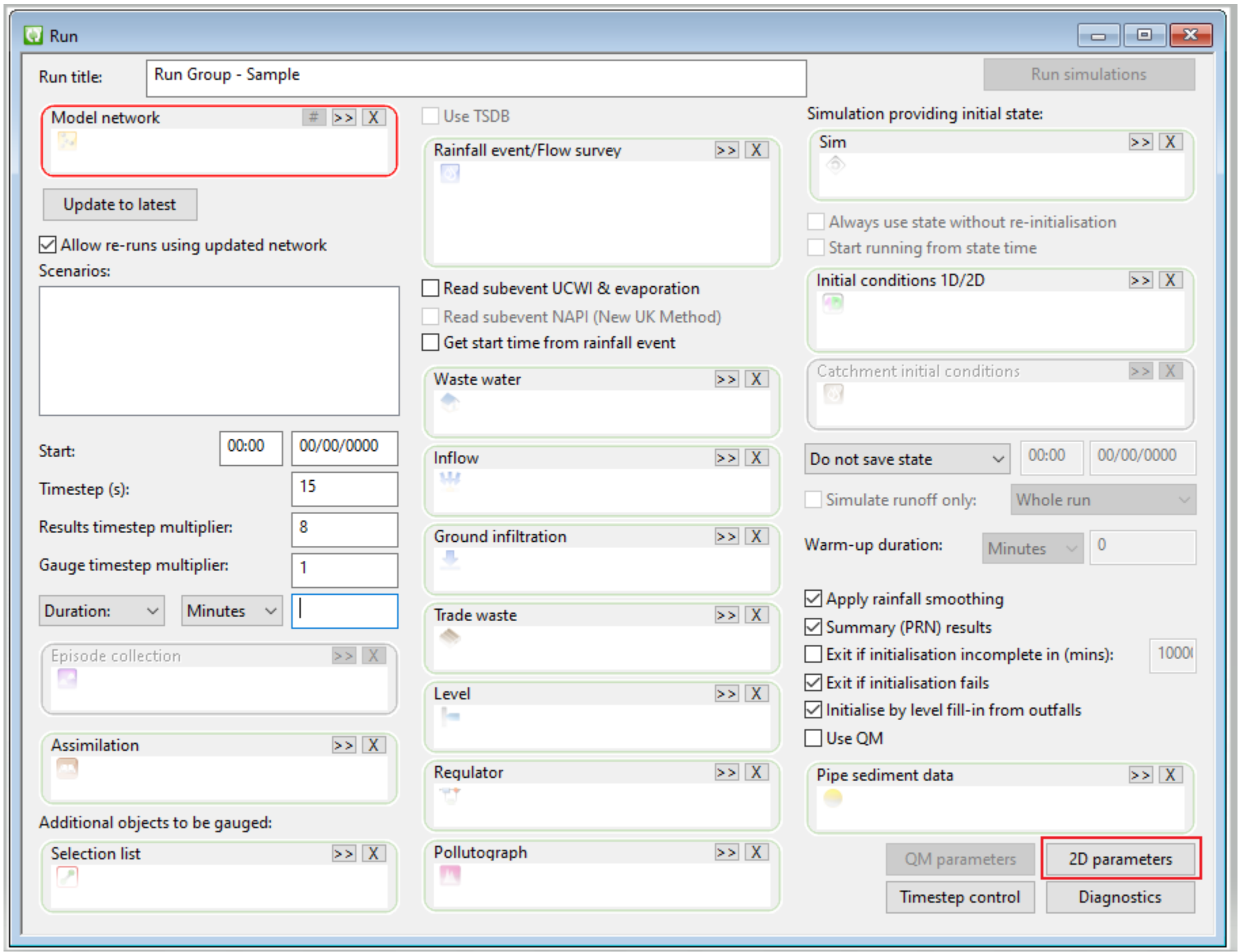


Figure 6-20 2D Parameters Option in Simulation Run Window

In the 2D parameters window, under the "General" tab, it is recommended that the "Adjust bank levels based on adjacent element ground levels" and "Link 1D and 2D calculations at minor timesteps" boxes are ticked to improve simulation stability as shown on Figure 6-21. The use of a GPU card can significantly reduce simulation duration. Therefore, if a GPU card is available, it is recommended that "If suitable card" is selected under the "GPU" tab, as shown on Figure 6-22.

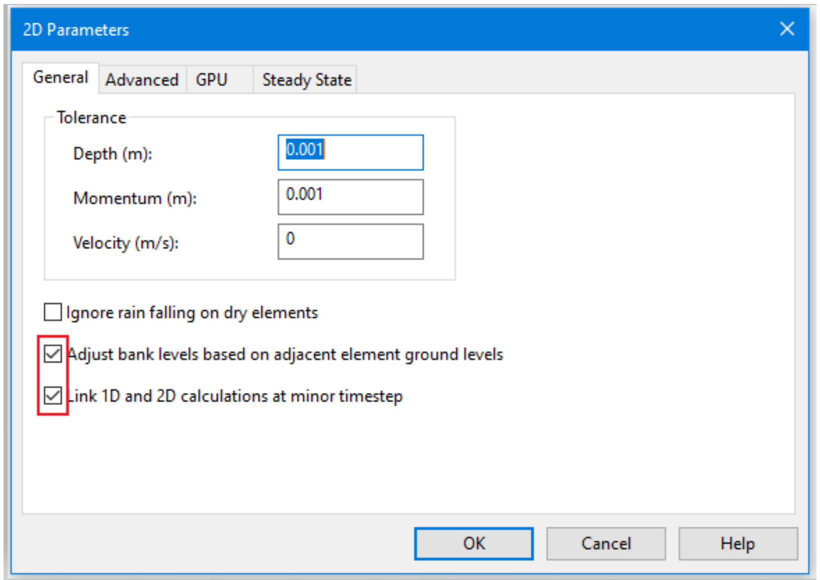


Figure 6-21 Simulation Run Window - 2D Parameters - General Tab

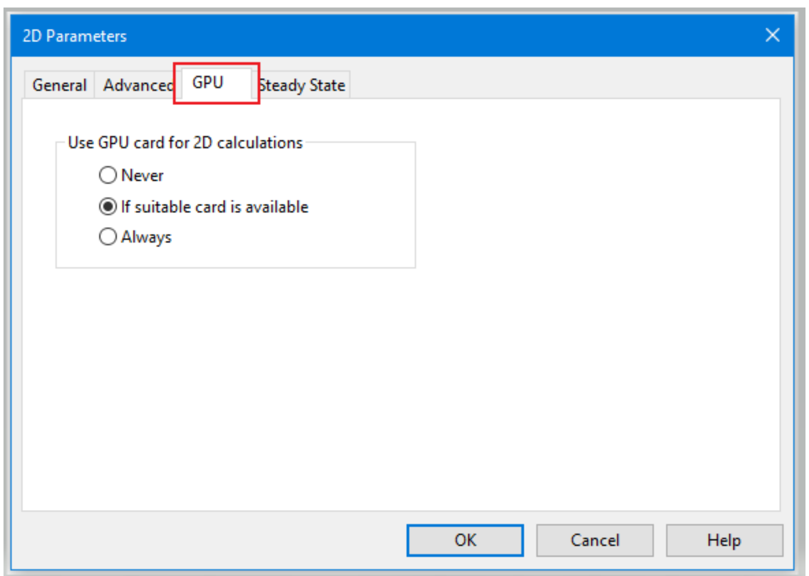


Figure 6-22 Simulation Run Window - 2D Parameters - GPU Tab

6.8 Model Instability Checks

The cause of most model instabilities can be identified and subsequently resolved by the following:

1) Reduce the simulation timestep – before making changes to the model to attempt to resolve an instability, it is recommend to first reduce the simulation timestep. A minimum timesteps of 1 or 2 seconds is acceptable for integrated catchment models.
2) Check the model for volume balance errors – 2D and 1D-2D coupled models should be checked for volume balance errors, especially when the model is unstable. Volume balance errors should be as close to 0% as possible and may not exceed 5%. A fully 2D model will only contain information about volume balance errors.

3) Check for model convergence errors for each timestep – the location and source of instabilities may be determined from reviewing the model convergence errors in a 1D-2D model for nodes and conduits at each timestep found in the "Timestep log" text file.
4) Group and merge small mesh elements – in the presence of a large number of small mesh elements, the model may become unstable and the model simulation and mesh generation run times may be extraordinary long. If during the mesh generation process, the job control window shows that a large number of mesh elements are being created, it is recommended to identify and reduce these small mesh elements. To identify small mesh elements these can be exported and examined externally using GIS, alternately, these can be identified within the model using the 2D mesh theme, see Figure 6-23. In this instance any mesh element with an area less than 1 m^2 will have a large red arrow associated with it and can then be investigated.

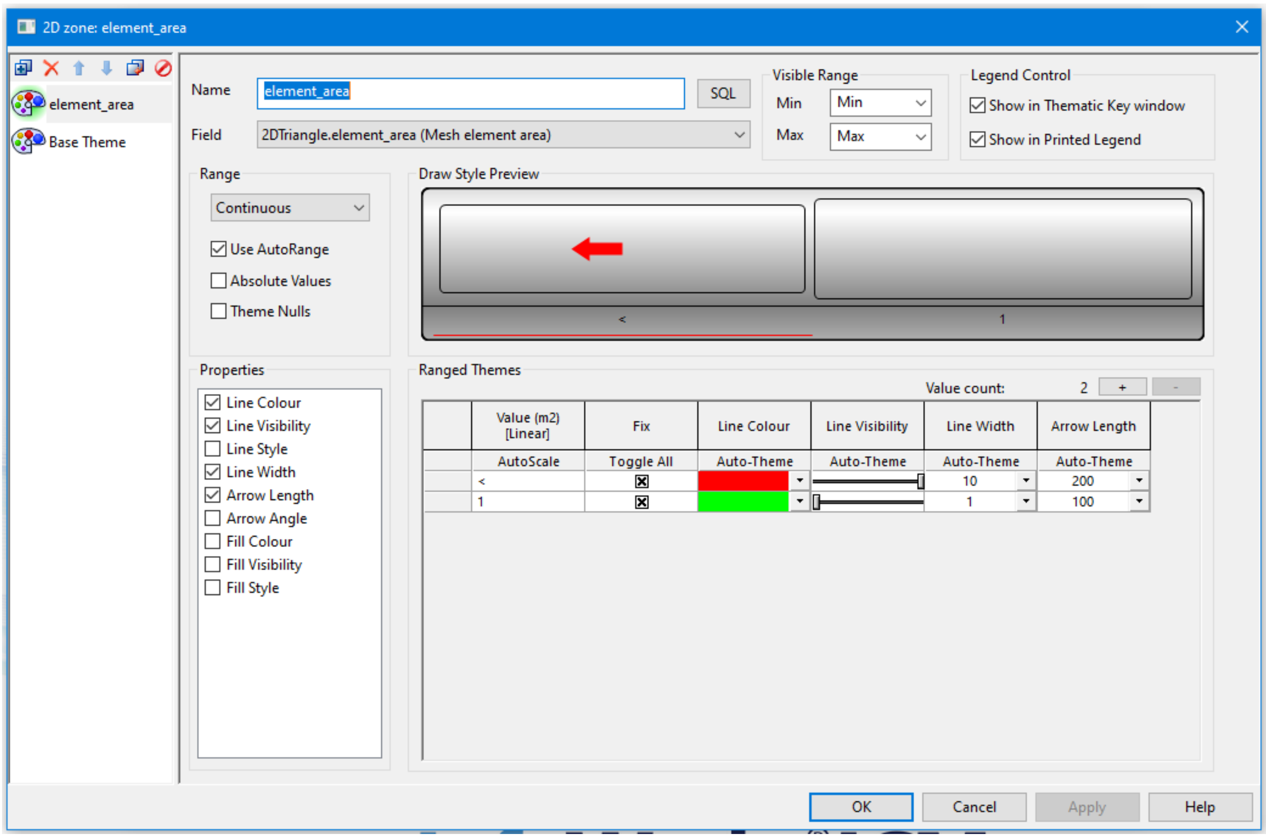


Figure 6-23 2D mesh theme – identify small elements

6.9 2D Model Validation

The overland flow paths and flood extent results from a 2D model need to be compared to known flood issues in order to validate that the 2D model is providing reasonable results. Therefore, information from historic flood events should be obtained from:

- City sewer flood records and the 311 calls database
- City fluvial flood records
- News reports
- Social Media

- Community flood action groups

Historic flood data that include flood extents, flow paths, and the date and time the flood occurred are ideal to attempt 2D model validation. The model should be run with the corresponding historic rainfall data and the simulated overland flood results should be compared to the historic flood data. If available, a minimum of two historic events shall be used to validate the 2D model.

If only an approximate rainfall return period of a historic flood event is known, a 2D model could still be validated to some degree. To attempt model validation in this case, a range of return period rainfall events, that are close in duration and magnitude to the historic flood rainfall event, should be simulated in the model. How well the 2D model represents reality, is indicated by how close the simulated return period rainfall event, that causes flooding in the model, is to the historic return period rainfall event.

Additionally, as a high level check, photographic evidence of a historic flood events could be used to make approximate estimations of observed flood depths. The estimated observed flood depth can be compared to simulated flood depths. Furthermore, simulated overland flow paths may be corroborated by flood affected residents or flood action group members.

6.10 Result Analysis

There are a number of different ways that the results from 2D simulations can be viewed and displayed.

6.10.1 View Results in ICM

To visualize the velocity and depth of flow including flow direction arrows, a Geoplan theme for the 2D zone should be defined, as shown on Figure 6-24.

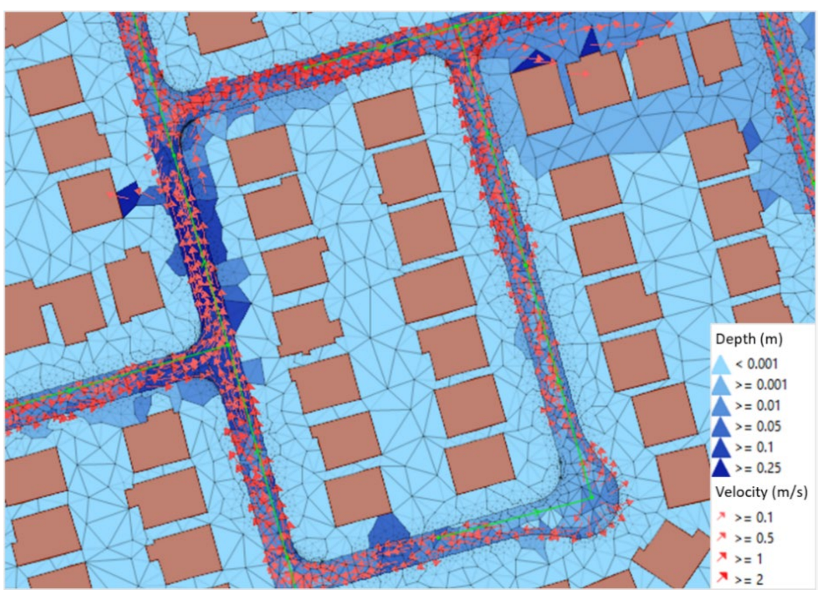


Figure 6-24 2D Results – Example

To create a new theme, open the "GeoPlan Properties and Themes" window and click "Edit" under the "Theme" column header, as shown on Figure 6-25.

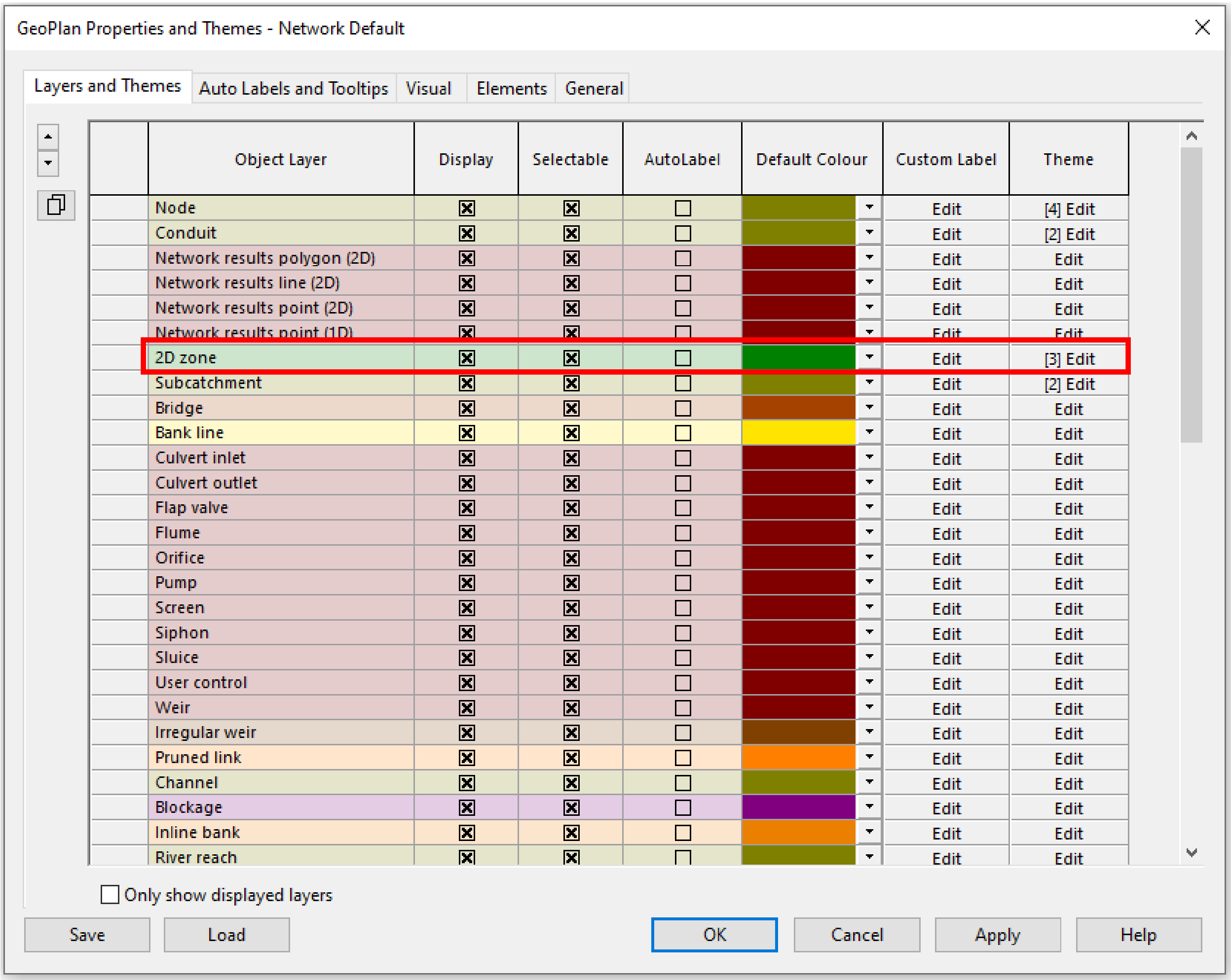


Figure 6-25 Geoplan Properties and Themes Window

In the theme window shown below on Figure 6-26, click “Add New” in the top left corner. This will create a new theme entry where 2D theme elements can be selected in the “Field” drop-down menu. The “Depth2d” and “Speed2d” attribute fields from the simulation results is required for visualizing flow depth and flow speed including flow direction arrows, respectively. It is recommend to create themes for the “Depth2d” and “Speed2d” simulation results with theme settings as shown on Figure 6-26 and Figure 6-27, respectively.

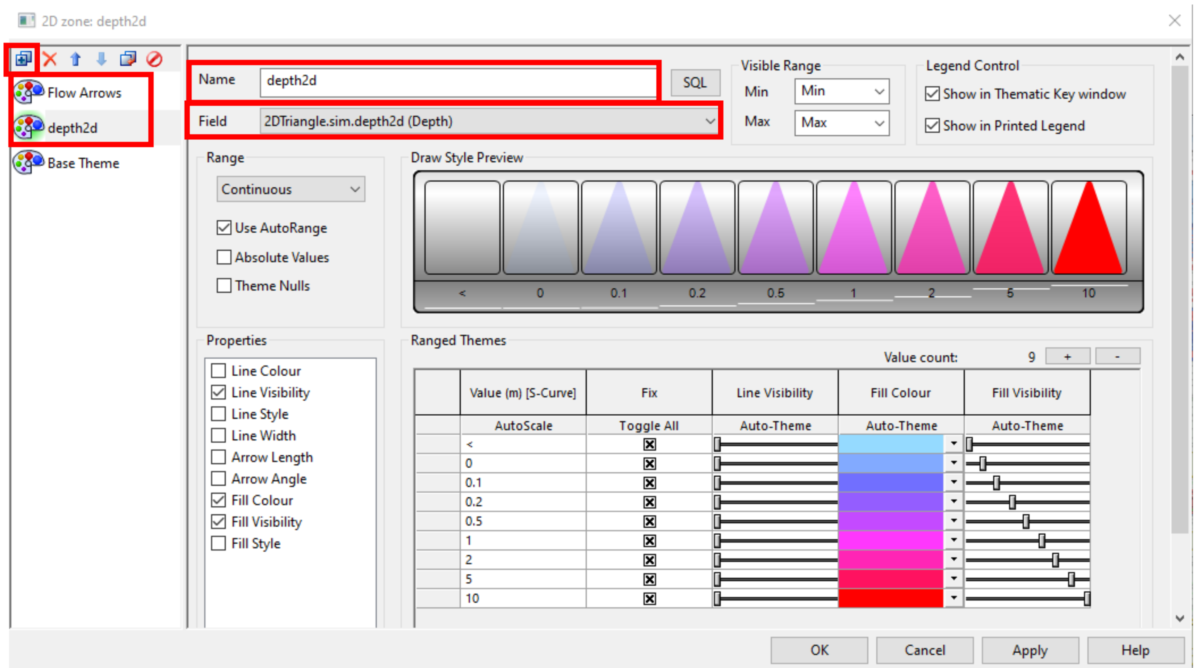


Figure 6-26 2D Zone Theme for Flow Depth - Depth2d

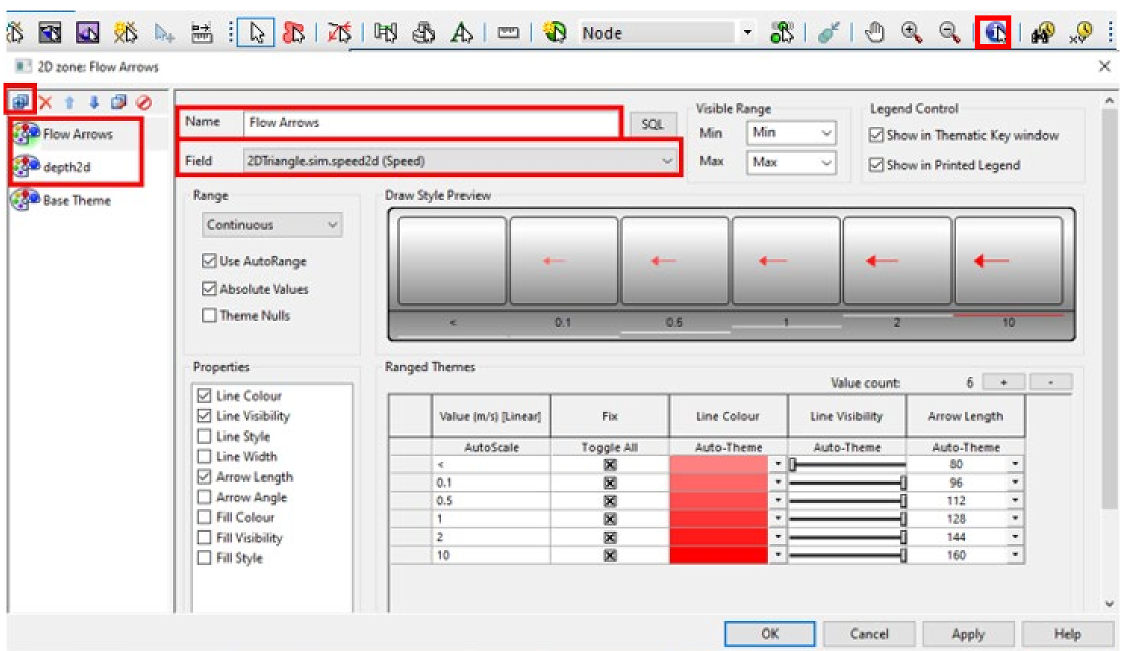


Figure 6-27 2D Zone Theme for Flow Speed and Direction - Speed2d

There are a number of options available to view 2D simulation results. Results for individual 2D mesh elements can be viewed by selecting any mesh element using the properties tool or double clicking on the mesh element. Selecting a mesh element with the properties tool opens the “2D Zone - Mesh Element” window. Within this window, a specific 2D element can be located using “Find in Geoplan” search function, as shown below on Figure 6-28.

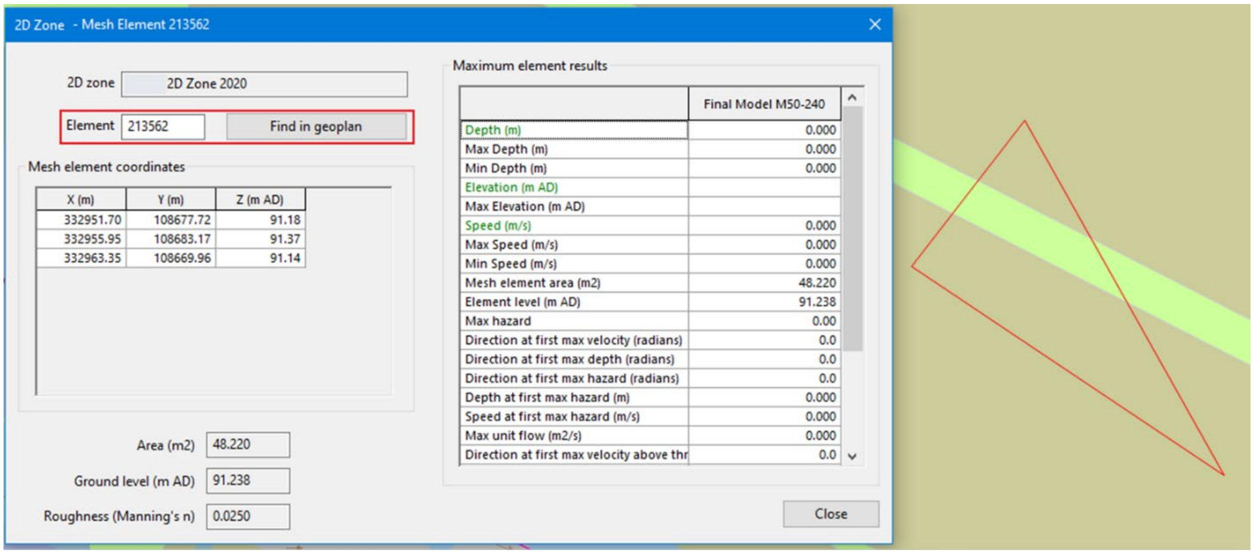


Figure 6-28 Mesh Element Window - Mesh Element Search

Multiple tools and methods are available to view 2D simulation results over a larger area than a single mesh element. The two primary methods use a line, polygon, or point object to view 2D results. The 2D results can be extracted using these objects in the Geoplan view of: 1) a specific model results file or 2) a model network.

In case 1, Geoplan view of “a specific model results file”, the model results can be viewed by creating a line, polygon, or point objects using the “New Object” tool and subsequently, the object types “Results section”, “Results polygon (2D)”, or “Results point (2D)” should be assigned, respectively. These objects are temporary, cannot be saved, and are removed from the model when the Geoplan of the results file is closed. Additionally, the 2D results that are shown by viewing them in case 1, are from flows that are summed across all the mesh elements they intersect without taking into account the direction of flow. Therefore, it is recommended to only use this method for a quick review of model results. Figure 6-29 shows an example where a result section (line object) is created to plot the depth time series.

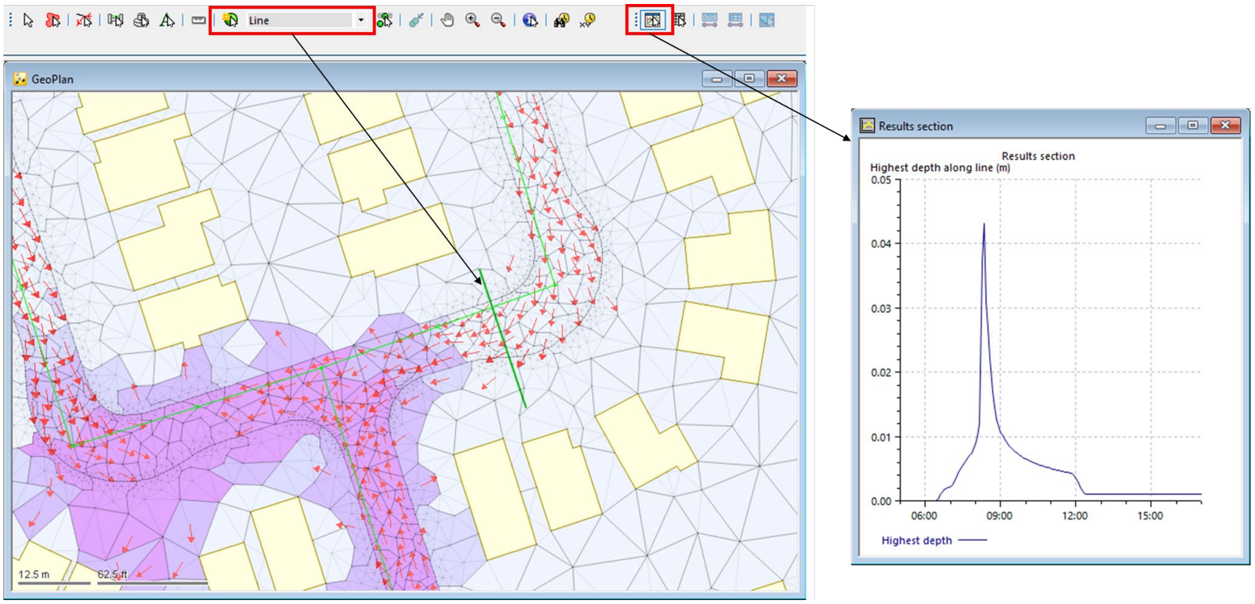


Figure 6-29 Results Section and Quick graph

In case 2, Geoplan view of "a model network", the line, polygon, and point object should be created in the model network, not in the results file view in the Geoplan. Additionally, the object types to be assigned are different; they are "Network Results Line (2D)", "Network Results Polygon (2D)" and "Network Results Point (2D)". These objects are incorporated as break lines within the mesh; they are saved to the model. The results they provide are more accurate because they record flow through the element faces that abut the line, polygon, or point object and take into account the direction of flow. Additionally, these objects can be imported or exported to different networks and scenarios. It is recommended to use this method for the primary analysis of model results as it is more accurate than in case 1.

6.10.2 Export Results to GIS

To export 2D results, select "Results" on the menu bar and select either "Export to GIS" or "Export maxima to GIS", as shown on Figure 6-30. "Export to GIS" provides options to specify a single timestep, start-end timestep (range), list from file (csv) or all timesteps. "Export maxima to GIS" will export the maximum results. Either selection provides various GIS file format export options.

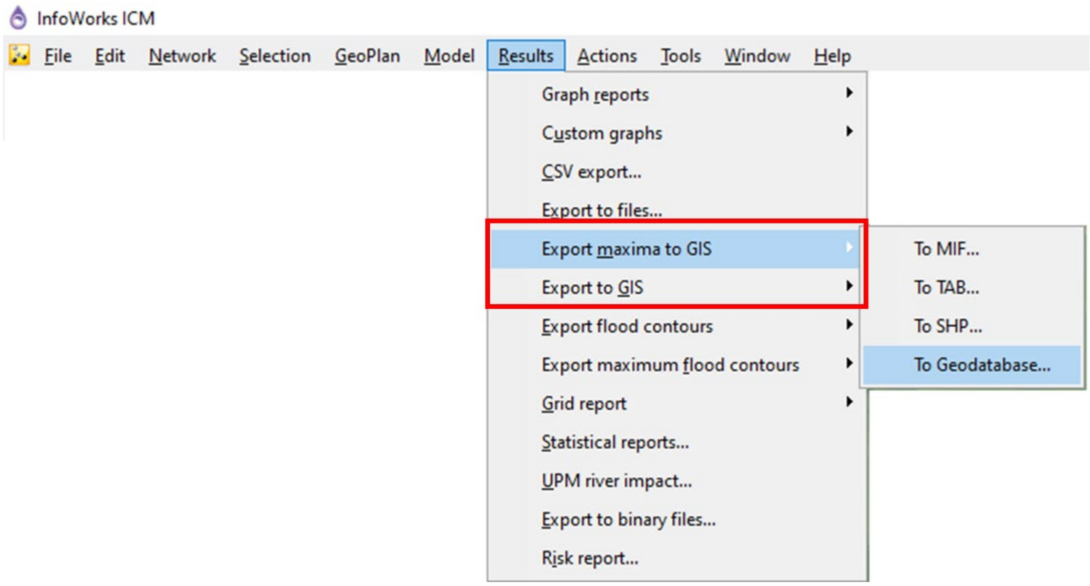


Figure 6-30 Exporting 2D Results

Once the GIS file format has been selected, the "Export maxima to SHP files…" window will appear. Any simulations that are to be exported should be dragged and dropped into this window. After selecting "OK", a "GIS Export…" window will appear; click the "Tables" button to select various items to be exported, as shown on Figure 6-31. The "2D Elements" option represents the 2D results. The "Do not export 2d results with depths below (m):" box can be ticked and a value can be entered to speed up export time.

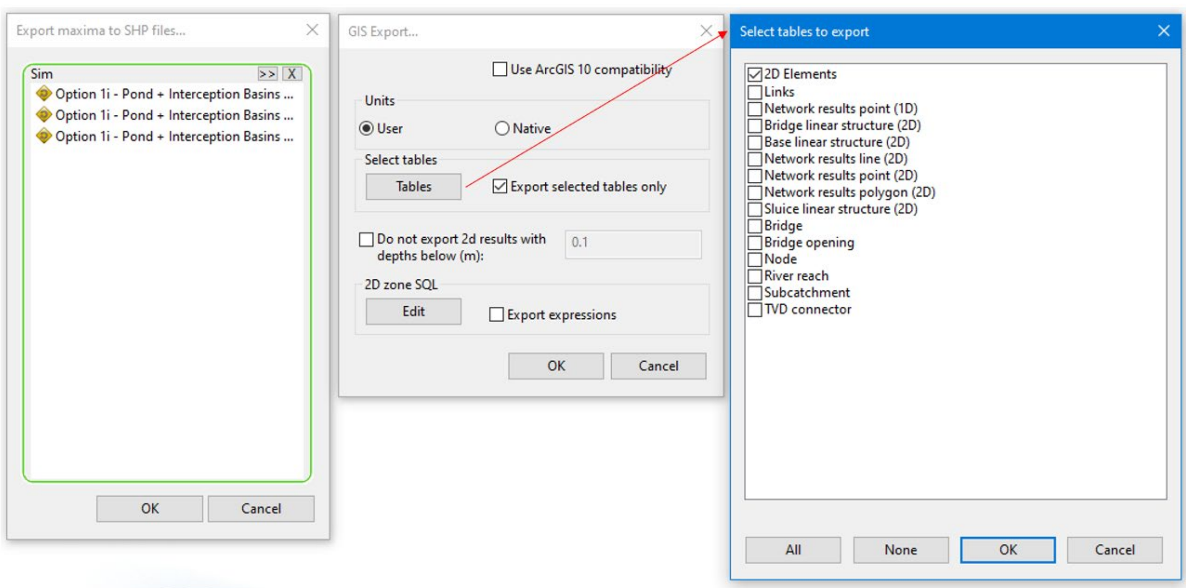


Figure 6-31 Exporting 2D Results - Continuation

7 Stormwater Quality Modelling

This chapter provides an approach for water quality modelling of sewage and in sewer to point of discharge at Combined Sewer Overflow (CSO) locations and compliance requirements for provincial standards. As the City continues to achieve its goal of sewer separation, it is envisioned to have a comprehensive approach to modelling water quality focused on separated sewer systems in future versions of this document. While high-level commentary is provided, future guidance will be required to the assessment and modelling of the impact of combined and stormwater discharges on receiving water bodies.

The addition of water quality to a hydraulically verified model is a more common approach than attempting both hydraulic and water quality modelling in parallel and the recommended approach. This has numerous practical advantages in considering less variables and enables other hydraulic catchment drivers, such as flooding/capacity and self-cleansing velocity etc., to be represented without the further complexity, potential instability, and simulation time of added water quality representation. Therefore, it is recommended that prior to the development of a water quality model that a model will have already been constructed, validated, and verified to meet the modelling standards in this document.

It is also recommended that a water quality model is produced and maintained as a separate tool. Its use and future model maintenance can then be reflected by specific drivers rather than any wider model use and update processes.

The following provides an overview of this chapter:

- Contaminants of Concern and Targets - establishes the pollutants of interest and categorizes them into three contaminant groups, bacterial, sanitary, and diffuse, for any given water quality study as it relates to loads transported by and discharges from CSOs. It details how these link to the development of the model, data collection processes, and demonstrates compliance with required standards in receiving watercourses and bodies.
- Stormwater Quality Modelling Approaches - discusses the two fundamental approaches to modelling the selected pollutants of concern. Each approach has benefits and challenges which are defined and explored to enable an informed decision at project scoping. This also links to the data collection and model upgrade requirements.
- Recommended Stormwater Modelling Approach - provides recommendations for initial in sewer and CSO water quality modelling based on a range of potential water quality outcomes.
- Data Requirements for Stormwater Quality Modelling - provides detail on the datasets to be collected to support the proposed approach for sewer and CSO water quality modelling. This provides a minimum level for the three contaminant groups to demonstrate compliance together with further enhancement options if required.

To develop a robust water quality impact assessment model a number of key decisions are required:

- Type of pollutants to be considered
- Standards to be achieved within the receiving water course/body
- Methodology to demonstrate compliance
- Data required for modelling

The following sections provides guidance on the sewer and CSO elements of each of these topics but further guidance is required for other point and diffuse sources of pollution and the assessment of the impact of all pollutants on receiving water bodies.

7.1 Contaminants of Concern and Targets

To define the contaminants of concern, first the water quality standard to be met including demonstration of compliance must be defined. Water quality standards and targets cover a broad range of potential parameters and contaminants as well as the concentration of these in absolute and time varying assessments.

The Sewer and Watercourse By-Law No. 8093 – TSS provide targets or standards of pH, temperature, and certain trace contaminants for assessing receiving water quality. Additionally, the British Columbia Approved Water Quality Guidelines can be considered formal targets if no alternative is present. The guidelines are used to protect water values including aquatic life, wildlife, drinking water sources, agriculture, and recreation, to inform water quality assessments, to support resource management decisions, to provide the basis for water quality objectives, to report on the state of water quality, and to promote water stewardship. Information on the British Columbia Approved Water Quality Guidelines can be found by performing a search on the government of BC website (www2.gov.bc.ca).

It is recommended that the City work with regulators to establish a formal set of quality derived targets aligned to all parties' aspirations for receiving water quality based on a combination of proposed use and desired aquatic life.

Metro Vancouver's Liquid Waste Management Plan (2011) and its ongoing update in 2021-24 identified numerous aspirations for improved receiving water quality from strategies to reduce spill frequency from sanitary overflows to the 1 in 5-yr return period. The document provides performance measures as part of its first goal to Protect Public Health and the Environment:

- compliance with parameters specified in the operating certificates for wastewater treatment plants
- discharges that do not meet provincial water quality guidelines
- number of sanitary sewer overflows— frequency, location and volume
- sanitary sewage volumes in combined sewer overflows
- beach closure days and locations
- watershed and stream health indicators as set out in the integrated stormwater management plan template

The derivation of Water Quality Guidelines (WQGs) is set out within British Columbia Policy and can readily be translated into a number of water quality standards but without clarity regarding which could be applied either individually or in combination, and the actual concentration or other standards to be achieved. As the City and Metro Vancouver have not decided on specific standards of contaminants of concern or priority targets, a more general approach to water quality modelling is required in the interim.

Therefore, this chapter provides guidance across the range of potential water quality modelling approaches based on existing standards and methods applied in other municipalities in Canada, and around the world.

To enable the potential sources of contaminants, their behaviour, impact, and assessment of impact to be considered it is best to consider these in the following three distinct groups:

- Bacterial contamination that affects public health by contact in recreation through swimming and water sports and the consumption of impacted shellfish. This sourced from both foul sewage and surface runoff within the urban area.
- Sanitary sewage contamination parameters such as BOD, ammonia and phosphorus that are predominantly derived from foul sewage, although with some contribution from urban runoff. These affect the aquatic ecology of the rivers and seas and can be characterised but change in concentration over time. Increasingly inert sanity sewage contamination including microplastics and medicinal residuals are also contaminants of concern.
- Diffuse contaminants such as Copper, Zinc, and hydrocarbons, but also micro plastics and other particulates, from urban runoff. These affect the aquatic ecology of the rivers and seas and can be characterised as unchanging other than by dilution.

Pollution from the urban environment is sourced from both the foul/combined sewerage system and the storm water network. Both sources of pollution require careful consideration and contribute to all 3 groups outlined above. In addition to the direct source of pollution the deposition and erosion of in-sewer sediments and can have a significant, and widely varying, impact on the concentrations all non-solute pollutants. Where required this can be replicated within the model, see Section 7.2, below.

The following sections set out the primary sources, behaviour (in terms of any change within and beyond the sewerage network), typical ranges of concentration and where appropriate typical per-capita loads, impacts of the contaminant on the receiving water course/environment and finally options for modelling and assessing impact with reference to standards applied in other jurisdictions.

7.1.1 Bacteria Contamination

7.1.1.1 Primary Sources

Bacteria pollution covers a wide range of bacteria species found in fecal material. It is most commonly measured and categorized in terms of two fecal indicator organisms Escherichia coli (E. coli /EC) and Intestinal enterococci (IE). These are commonly used as they are present within sewage and do not replicate outside of the host body. These bacteria are not unique to human waste and are found within any fecal matter with common sources in addition to foul sewage being livestock, wildlife (particularly birds) and therefore fecal matter in surface run off.

7.1.1.2 Behaviour

Bacteria pollution is inert and transported in suspension within the flow of sewage. Foul sewage contains bacteria predominantly from human excreta. Storm sewage, and run off directly to receiving water bodies, add surface deposits from animals and birds in urban and rural environments.

The decay of bacterial population results in their presence being transitory. This removes the potential for changing bacterial loads resulting from the deposition and resuspension of solids, although the concentration of foul sewage during a first foul flush (FFF) does occur but is commonly excluded for consideration, see concentration and loading below.

The rate of decay varies based on a number of factors. Principal to these is turbidity and the intensity of sunlight. Of the two indicator organisms IE has approximately double the half-life and as such is found for temporally longer and further from its source. This difference can help in the identification of potential sources and their relative distribution. Other factors which influence rates of decay include temperature and salinity, with lower temperatures and higher levels of salinity acting to decrease decay rates.

Decay within the sewer is limited due to a combination of the lack of light and oxygen, and the relatively low residence time within the piped network. Where the extent of network and its operational regime result in increased residence time, consideration should be given to the potential for greater decay and the resultant impact in terms of lower concentrations discharged.

7.1.1.3 Typical Ranges of Concentration and per Capita Loads

Bacterial Pollution is most commonly applied as a concentration at point of discharge. As outlined above, the assumption that this is a fixed value, based on the source of the sewage is practical, applied in most modelling studies, and recommended for the City.

Review of Canadian datasets has found sample data from sewer and receiving water body locations within and beyond the greater Vancouver area and these are in line with larger sampling dataset from the UK and elsewhere. It is always preferable to have specific local, or better still catchment specific, sample data; however, the cost, complexity, and practicality of sampling all potential sources make this unlikely for all but the most common of storm sewage and final effluent.

7.1.1.4 Impacts of the Contaminant on the Receiving Water Course/ Environment

Bacteria pollution has two primary impacts: Human Health: Shellfish as a food source.

Pathogenic Human Health impacts result directly in the risk of gastrointestinal infections from the ingestion of contaminated river and coastal water. The greater societal impact is in reduced access to amenity and the resultant commercial and reputation consequences for the areas impacted.

There is extensive academic and applied research into the relationship between bacteria pollution and the presence of bacteria at shellfish at levels which are dangerous for human consumption. In summary, the impact of the bacteria pollution results in shellfish being unsuitable for human consumption during and immediately after a period of overflow operation or other polluting discharge and for a prolonged period due to the build up of bacteria within the flesh of the shellfish.

7.1.1.5 Options for Modelling and Assessing Impact

Bacterial pollution can readily be modelled using fixed concentration and its variation is not greatly impacted by in sewer processes, although the first flow flush may be a factor.

Further details on the modelling for fixed concentrations are outlined in Section 7.2.

The impact of bacteria on amenity (Recreational Waters) and Shellfish have historically been assessed in terms of maximum spill frequency. This approach is overly simplistic with individual situations neither offering sufficient environmental protection nor allowing safe discharge.

It is now commonplace to utilize river and coastal models to represent the transportation of bacterial pollution from source to areas of impact. The detail of these types of modelling approaches are beyond the scope of this guidance but should be considered in the development of a detail water quality modelling approach for a bacterial contamination driver.

The representation of sewerage inputs to such a model require the addition of fixed concentrations of bacterial indicator species loads to the hydrograph of discharge from overflow, storm system and Wastewater Treatment Works. As detailed above, the application of these fixed loads can be from a number of sources and given the variability and uncertainty in the exact load, it is recommended that sensitivity analysis is applied to these concentrations as part of any modelling study in addition to any sensitivity to the flow derived from the sewerage model.

This approach does not require any additional sewerage modelling to be undertaken.

7.1.1.6 Types of Standards and Methodology for Assessment

Historically, European assessment of compliance with Recreational Water and Shellfish Standards were based on observed or model predicted overflow spill frequency rather than assessment of the impact of any discharge. More recently, Bacteria contaminants standards are measured in terms of the indicator organisms detailed and assessed in absolute number against a given standard in model predicted and observed sample data.

7.1.1.7 Approaches in Vancouver and Other Jurisdictions

The British Columbia Water Quality guidelines offer no standards for bacterial levels in fresh or marine waters. It is noted that Metro Vancouver has an ongoing program of bacterial contaminant sampling and utilizes the two common indicator organisms. This dataset can be used to refine typical/default concentrations, but consideration as to applicability of the samples in one subcatchment to another should be made with respect to details of any form of treatment, the dilution effect of storm water and/or infiltration, residence time, and decay of bacteria load.

Reference to Toronto and Region highlights their use of the International 'Blue Flag' Standard to classify their recreational beaches. Their approach is based on sampling rather than modelling and manages access to the beach based on observed EC concentrations with actions to address the breach of standards.

Internationally, the management of recreational coastal and inland recreational waters combines sampling and modelling to provide warning to beach users. The most advanced of these modelling approaches use a combination of predicted rainfall, sewerage network models, and coastal dispersion models to predict the impact of any storm discharge from network overflow. These predictions are linked to customer information advising against recreational use.

7.1.2 Sanitary Sewage Contamination

7.1.2.1 Primary Sources

Sanitary Sewage Contamination comes from foul sewage, with domestic and certain commercial processes being the source of individual contaminates and those which act as surrogates for deoxygenating impact. Domestic sources can be readily quantified based on the population in contributing subcatchments. Careful consideration should be given to other potential sources within the commercial and industrial trade contributions. Individual contaminants or a number of contaminants can be present in very high concentrations in waste streams such as dairy processes and food preparation.

7.1.2.2 Behaviour

The behaviour of individual contaminants varies. To provide a practical approach to considering this range is to consider those in solution, such as ammonia and a subset of Biological Oxygen Demand (BOD), and those in suspension such as the non-dissolvable elements BOD.

Those in solution remain within the flow from source to discharge. Their concentration varies based on the flow of sewage with diurnal variation and trade process variation in addition to the impact of storm response changes in sewer flows. Most of these contaminants, importantly including Ammonia and Phosphorus, do not change in property or concentration due chemical or other in sewer processes. The exception to this is solution BOD where any oxygen within the sewage will be consumed and the demand reduced. This change is usually small with BOD most commonly considered over 5 days, and residence time and the limited available dissolved oxygen in most sewage.

The contaminants in suspension are more complex. These can be deposited as sewer sediments, and similarly eroded, by the change in velocities associated with change in flow rates. As such the concentration of pollutants with sewer sediments is a function of that in suspension, the quantity resuspended by increased flow rates and the inter-event dry period during which disposition has occurred. This behaviour is further complicated by the residence time in sewer.

The increased concentration of solute and in suspension pollutants in response to rainfall through this mobilization of sediments and flushing of the foul volume within the sewer prior to rainfall is commonly call the 'first foul flush (FFF)'. The significance of the FFF is a combination of catchment characteristics (gradient, extent of separation, etc.) and frequency of storm response.

7.1.2.3 Typical Ranges of Concentration and per Capita loads

The application of Sanitary Pollution is not straight forward and detailed below. Concentrations observed in sewage, particularly storm sewage can vary significantly due to a combination of catchment characteristics and dilution.

Therefore, it is more accurate to consider the concentration/load generated within the catchment from its population, traders, and surface wash off sources than simply discharged from overflows. Section 7.2 below discusses the options for representing the pollutant load generated but regardless of the degree of detail used the source and its load/concentration should be considered as a minimum as a mass balance between that generated, conveyed to treatment, and spilt to the environment.

Existing and proposed sewage sampling and analysis in the City and the wider Metro Vancouver area can provide greater understanding of the likely range of mean concentrations and the variation across the catchment which will relate to a combination of source load and dilution from water use and infiltration flows.

Academic literature identifies commercial sewage as being of similar pollutant characteristics to domestic sewage with a majority of the flow being associated with washing and toilet use.

The very wide range of potential load from industrial effluents require considerable thought if both flow and concentration result in a significant load. Consideration should be made to the trade effluent consent/permit levels and also those commonly used with reference to trade flow and water supply flow measurement and, if deemed sufficiently important, specific trade effluent sampling.

7.1.2.4 Impacts of the contaminant on the receiving water course/environment

The impact of these contaminants, whether in solution or suspension, is on the health of aquatic life within the water body. The oxygen demand of the pollution reduces the dissolved oxygen which is harmful to all aquatic life but particularly to larger species such as fish. Similarly, elevated ammonia concentrations in receiving waters have detrimental impact to aquatic life. For all sanitary contaminants, the receiving water body's ability to assimilate the discharge without detriment varies depending on the duration of an impact. To replicate this range of impact, standards are set as absolute levels (based on 99%ile level) for chronic impact and intermittent standards with a range of thresholds based on frequency and duration of exceedance, for immediate acute toxicity.

7.1.2.5 Options for modelling and assessing impact

The options for modelling depend on the type of impact being considered. In all cases it is recommended that the simplest approach is adopted for any study which achieves adequate representation of the contaminants of interest and their temporal and spatial variation. The following modelling approaches follow this concept from simplistic to complex:

- Fixed pollutant concentration applied to Hydrographs from sewer modelling is suitable where there is limited impact from changing pollutant concertation during an event. This would result in no representation of any FFF effects or the build up pollutants within sewer sediments but would be suitable for an ammonia and phosphorus sensitive catchment if in sewer concentration is not significant.
- Time varying pollutant concentrations applied to hydrographs from sewer modelling. Same as the above but representing the variation through a storm event without the complexity of running water quality within a sewerage model. This gives generic representation of FFF but does not represent the variation from a range of antecedent conditions without undertaking multiple scenarios and subsequent statistical analysis of the results.
- Full water quality representation within the sewerage network model including the development and conveyance of pollutants through the model. This provides both FFF representation and the variation of antecedence against observed of synthetic rainfall.

For each level, the concentrations applied should ideally be derived from local sample data but where this is not available can be based on documented values. There are numerous published sources of such data from Metro Vancouver and other Canadian municipalities and wider international studies and guidance.

7.1.2.6 Approaches in Vancouver and other jurisdictions

The assessment of the impact of sanitary contaminants on receiving water bodies is commonplace. Most approaches are based on the Urban Pollution Management methodology developed by the Foundation for Water Research in the UK in the late 1990's, with updates to maintain its relevance against the changes in legislation, substantial improvement in sampling, wastewater network modelling, and computational performance.

The overall aim of these studies is to define the problem to be addressed as:

- a potential environmental problem related to urban wet weather wastewater discharges to a specific set of receiving waters has been identified;
- a potential environmental problem in receiving waters has been identified, but its origin is not clear; and,
- significant changes are proposed to a sewerage network, including growth, and checks are required to ensure that the proposed changes do not lead to environmental deterioration in the receiving waters.

One or more of these potential problems should be identified and used to define a study specific scope which suitably address only the required driver(s) without unnecessary complexity or geographic extent.

This concept is particularly relevant to the City and their environmental regulator as the development of standards and demonstration of compliance and network upgrades to achieve compliance evolves.

The British Columbia (BC) Water Quality guidelines offer instantaneous and long-term average dissolved oxygen (DO) minimums for a range of aquatic life forms which would enable BOD/DO assessment to be made with impact models for receiving water bodies. Similar data is provided for Ammonia concentrations in fresh and saline waters with variation based on pH of the water and ambient temperature, again, this data can be used to develop standards and assess compliance with a suitable impact model. No data could be identified within the BC guidelines for phosphorous.

7.1.2.7 Other Considerations

Combined Sewer Overflows are not the only source of sanitary contamination in receiving water bodies. Surface wash off, whether directly to water course or via the surface water sewer, provides additional pollutant load, although generally at lower concentrations than combined sewage discharges.

The final effluent from Wastewater Treatment Works also provides a source of these pollutants. The magnitude depends on both the level of treatment (primary, secondary, or tertiary) and the extent and impact of changing hydraulic loading on these processes. Increased hydraulic loading on treatment processes reduces settling performance and biological removal efficiency and can, in extreme conditions, result in the wash out of solids.

These potential sources, and their relative and absolute impact, should be considered in the scoping of any study.

7.1.3 Diffuse Contamination

7.1.3.1 Primary Sources

The major sources of the wide range of contaminants categorized as diffuse pollution in the context of load from the sewerage network is surface deposits mobilized by rainfall runoff. The deposits are sourced from a wide variety of human activity. Significant in these are the particles from degradation of tyres, brakes and other consumable elements of motor vehicles, rubbish and general waste awaiting collection or simply dumped, and wash off from commercial and industrial processes, with numerous other minor sources.

7.1.3.2 Behaviour

The individual make up of these contaminants ranges from single metal elements such as Copper and Zinc through to complex compounds, plastics, and rubbers. What is common across all the contaminants within this grouping is that they are largely or completely inert, particularly in the context of residence time on the surface and within the sewerage network and receiving water body.

These contaminants exist in both solution and suspension once washed off the surface. As with other pollutants in suspension, the action of deposition and erosion in sewer occurs creating a build-up of these pollutants. However, given that these are sourced only during rainfall events, the extent of in sewer build up is relatively low and is commonly ignored.

For any individual specific contaminant of interest, consideration of the potential to be sourced from both diffuse surfaces and foul sources should be considered as this may have impact on the extent of any deposition between rainfall events.

7.1.3.3 Typical Ranges of Concentration

Given the wide range of potential contaminants in this category, it is not practical or desirable to provide typical values for each. Reference to published British Columbia data identifies nearly 50 individual contaminants of which the majority are from diffuse source.

Many contaminants have natural and manmade upland sources as well as those form human urban activity. For example, heavy metals can be generated from the weathering of rock formations and farming pesticide use. These sources are important when the impact is considered and also in comparison of model predicted and sample data in receiving water bodies.

Per capita load is not applicable to diffuse pollution.

7.1.3.4 Impacts of the contaminant on the receiving water body

There is range of impacts across the variety of contaminants, from fatal impacts on a wide range of aquatic life forms from large fish to algae, macrophytes, and invertebrates, and other impacts such as disruption to natural rates of growth and reproductive processes. In all cases, those of primary concern are direct impact of chronic and/or acute toxicity. The level of impact varies with contaminants but their inert nature results in the length, frequency, and concentration of exposure being primary factors.

The impact of individual contaminants can vary in solution and particulate forms and is further complicated by the formation of compounds from the individual elements. The pH, hardness, temperature, and other natural and human influenced variations in receiving water conditions can also influence the impact of contaminants.

In addition to direct toxicity effects on aquatic life, the build of contaminants within the food chain can result in levels harmful to humans in fish and sea food.

7.1.3.5 Options for modelling and assessing impact

The most simplistic approach is to consider the inert nature of diffuse contaminants in both sewer and receiving water body and that representation of in sewer and in receiving water body processes are not required. Once pollutant loads have been established, these can apply to overflow hydrographs. Combining this output from the sewer model with a receiving water body dispersion model, enables the concentration of each contaminant to be assessed.

This is true for some contaminants but the numerous potential factors impacting individual pollutants should be considered and, where necessary, represented with sufficient level of detail to suitably replicate the variation in potential impact.

Consideration should be made to the combined effect of multiple diffuse contaminants. For example, the toxicity of heavy metals to larger fish species is greater with multiple contaminants.

7.1.3.6 Approaches in Vancouver and other jurisdictions

The British Columbia Water Quality guidelines offer no standards for wide variety of diffuse contaminants. In most cases there is considerable scientific evidence supporting the data provided and differing standards for fresh and marine waters.

Reference to other provinces and international identifies numerous standards supported by sampling of local conditions and underlying science. These can all provide reference data for the creation of suitable local standards based on the levels identified in routine sampling and the observed impacts.

7.1.3.7 Other Considerations

More than any other form of pollution, diffuse contamination requires considerable thought in the selection of contaminants to consider based on the level and impact. The wide range of contaminants mean that traditional and advanced treatment processes have differing levels of benefit in reducing concentrations.

7.1.4 Recommended Pollutants and Potential Targets at CSOs

Sewage, including that discharged from CSOs during storm events, contains untreated domestic, industrial, and commercial wastes. Contaminants, as detailed above, include suspended solids (measured as total suspended solids (TSS)), biochemical oxygen demand (BOD), oils and grease, toxics, nutrients, floatables, pathogenic microorganisms, and other pollutants. CSOs often contribute to exceedances of water quality standards in receiving water bodies and can result in threats to public health, aquatic species, and aquatic habitat.

Combined sewer system quality modelling consists of predicting the quality of the combined sewage in the system, particularly at CSO outfalls. Water quality is measured in terms of critical parameters which serve as robust indicators to the broader spectrum of potential contaminants, such as bacterial counts and concentrations of BOD5, suspended solids, nutrients (Phosphorus and Nitrogen) and specific toxic contaminants.

Table 7-1 provides the water quality parameters recommended for modelling and analysis of water quality at CSOs.

Table 7-1 Recommended Pollutants and Potential Targets at CSOs

Parameter	Ontario[1 2]	USA[3 4 5 6]	British Columbia[7 8]	City of Vancouver [9]
Total Suspended Solids	25 mg/l	30 – 45 mg/l	45 mg/l	75 mg/l for storm 600 mg/L for sanitary
BOD_5	10 mg/l	30-45 mg/l	45 mg/l	BOD_5 target is determined for each discharge permit and billed accordingly
Total Phosphorus	0.020 mg/l	0.1 mg/l (3)	1 mg/l	-
Copper	0.5 mg/l	1.3 mg/l	0.5 mg/l	2.0 mg/L (for sanitary discharge only)
Ecoli	100 counts per 100 ml	400 counts per 100 ml	400 counts per 100 ml	-
Nitrogen as Total Ammonia	20 mg/l	2.2 mg/l	20.5 mg/l	-

7.1 Stormwater Quality Modelling Approaches

This section identifies the possible approaches to modelling the different contaminants and identifies the best approach for each contaminant based on the details outlined in Section 7.1 above.

There are two main approaches to applying water quality/contaminant determinants to a sewerage model:

- Constant concentration of contaminants in the discharge, applied as event mean concentrations to hydrographs from a hydraulic only model to generate time varying load.
- Dynamic representation of the pollutant(s) within the sewerage model including their development and subsequent pollutant transport from foul flow to discharge.

There is a common misconception within sewerage modelling communities that the development of dynamic contaminant models is complex, unstable, and unnecessary. While additional modelling is required to build and calibrate dynamic models, their benefits can significantly outweigh this additional effort due to the improved accuracy in certain situations which can either demonstrate compliance or improve confidence in the scale and performance of proposed network upgrades. As such, it is not desirable to have a single recommended approach for all situations and contaminants. The following sections offer a practical summary to the benefits and limitations of each approach.

---

[1] Water management: policies, guidelines, provincial water quality objectives | ontario.ca
[2] F-5-1 Determination Of Treatment Requirements For Municipal And Private Sewage Treatment Works | ontario.ca
[3] Chapter NR 217: Effluent Standards and Limitations for Phosphorus (epa.gov)
[4] Fact Sheet (epa.gov)
[5] Combined Sewer Overflows Guidance For Monitoring and Modeling (epa.gov)
[6] 2015_Copper.pdf (wqa.org)
[7] Municipal Wastewater Regulation (gov.bc.ca)
[8] bc_env_nitrate_waterqualityguideline_technical.pdf (gov.bc.ca)
[9] Sewer and Watercourse By-law 8093 (vancouver.ca)

7.1.5 Constant Concentration Approach

This approach is more straight forward and suitable where the contaminants are not impacted by the deposition and erosion of sewer sediments or in situations where the modelling is relatively high level with simplistic receiving water body impact assessment or modelling. This is commonly used in Bacteria contaminants and some diffuse continuants; it may also be suitable for sanitary contaminants, at least in the early stage of study or in the scoping of multiple catchments to assess risk.

7.1.6 Pollutant Transport Approach

This approach requires further actions within the sewerage model. Pollutant load is required to be generated and transported through the modelled network with significant variation in concentration of contaminants.

The additional modelling activity includes further inputs (load from runoff, foul domestic and commercial sewage and any pollutograph inputs) and additional computation at every node and timestep for water quality in addition to hydraulic simulation. To maintain a stable model, minor changes to the representation of the sewerage elements including fixed pumps in sewage pumping stations and removal of dry pipes are frequently required. This can have an impact on the model hydraulic verification which should be confirmed in parallel with any calibration of the model's water quality performance.

The key difference in this approach is the deposition and erosion of sewer sediment. This may require changes to the sediment represented for hydraulic purposes and will definitely require the consideration of initial conditions and the inter-event dry period between simulated storms.

7.1.7 Comparison of Constant Concentration and Pollutant Transport Approaches

Table 7-2 provides comparison of the two approaches for key considerations in the representation of CSO discharges for water quality assessment. In addition, it details the benefit and risk for each of the three contaminant groups.

Table 7-2 Comparison of Constant Concentration and Pollutant Transport Approaches

Parameter	Constant Concentration	Pollutant Transport
Program – time and cost	Faster – No additional modelling, limited further calculation, direct application to existing hydrographs	Slower – Additional modelling to set up and run WQ simulations. Further modelling inputs, calibration, and validation Export of pollutographs
Program - critical path	Simpler process – without additional model calibration etc. Therefore, program shorter and readily programmable	Complex additional modelling, has reputation for being problematic in numerous details, uncertain timescales for stable calibrated WQ models
Resource	Limited WQ understanding required, no further modelling skills	Specialist modelling skill set, limited resource, additional training and understanding of software required

Parameter	Constant Concentration	Pollutant Transport
Use of capture Water Quality data	Captured data used but simplified – either reduces cost/complexity of sampling or averages across multiple data points	Ability to match time varying observed datasets in great detail through calibration
Accuracy	Suitable for most/all contaminants but under and over represents detailed change in concentration through a CSO spill	Provides greater accuracy for contaminants which have an element within sewer sediments, particular when time series rainfall is used
Transparency	Simplistic – easy to convey, repeat and audit	More complex – can be perceived better but also more abstract and harder to pass audit etc.
Bacterial Contaminant Group	Suitable - bacterial load not influenced by sewer sediments	Not required
Sanitary Contaminant Group	Suitable – but careful consideration to proportion of BOD5 and other contaminants within mobilizable sedimentary load	Improved representation of sediments and therefore variation in load is catchment and time series rainfall specific
Diffuse Contaminant Group	Suitable – but careful consideration to proportion of contaminants with mobilizable sedimentary load	Improved representation of sediments and therefore variation in load is catchment and time series rainfall specific – less important than for sanitary sewers and diffuse load is rainfall drive rather than foul

7.2 Recommended Stormwater Modelling Approach

It is recommended that the City uses the fixed concentration in the representation of contaminants from CSOs. While this approach is not without limitations, particularly for contaminants present in foul flow and sewer sediments, this will enable the City to progress with initial water quality studies regardless of the specific contaminants and proposed standards. A constant concentration approach will be suitable for at least initial studies as compliance against all standards can be demonstrated in a cost-effective manner with reliable sewer water quality model.

The generation of fixed contaminant concentrations to be applied to CSO discharges is relatively straightforward. The data presented in Section 7.1, together with catchment specific datasets available and captured as set out in Section 7.4, provides a pollutant load for the catchment, or preferably the sub areas serviced by each CSO.

The following is an example of the proposed methodology for deriving load and subsequent concentration to be applied to the CSO spill hydrographs thus creating pollutographs for each contaminant specific to the CSO.

The annual runoff volume for each CSO, as predicted by the calibrated and validated hydraulic model in time series simulation, is combined with the Event Mean Concentration (EMC) for the pollutants of concern to quantify the annual total contaminant loading. An example calculation for the total loading of a single contributing CSO area is shown below. This example is completed with rounded values and will not match the total load as calculated for the analysis.

Example Total Load Calculation (kg):

$$TSS\ Load_{CSO\ 1} = \frac{\left(Runoff\ Volume_{CSO1}(m^3) * TSS\ EMC_{CSOA\ 1}({}^{mg}/_{L})\right)}{1000}$$

$$TSS\ Load_{CSO\ 1} = \frac{\left(40{,}887m^3 * 321\ {}^{mg}/_{L}\right)}{1000}$$

$$TSS\ Load_{CSO\ 1} = 13{,}140k$$

The development of catchment load, to derive the 'typical' concentration, rather than simply using typical values or those captured within a small sample set will reduce the risk of skewed data and provide a bespoke contaminant load/concentration for each CSO with observed and empirical evidence to support these values. Where necessary due to uncertainty in the dataset and/or compliance being achieved, sensitivity analysis to these applied concentrations should be undertaken.

It is further recommended that this approach is review periodically, at least every 5 years, to consider changes in modelling approaches, available data, and the standards to be complied with. Future upgrade to a pollutant transport approach, or more likely hybrid constant concentration and pollutant transport dependent on contaminant, will improve representation of the range of concentration discharged during a single event and particularly where multi -event time series rainfall is used. This may improve model prediction against observed datasets or to more accurately represent the benefit of capital and operational solutions to mitigate CSO impacts.

7.3 Data Requirements for Stormwater Quality Modelling

The collection of data for the representation of contaminants in sewer and in the discharge from CSOs is frequently complex in planning and execution and can be challenging and expensive. There is extensive published data from the Metro Vancouver area in British Columbia and more widely which provides both approaches to survey strategies and observed and typical ranges of key contaminants. In common with all other guidance, the detail of data requirements are dependent on the contaminants of interest as sampling and analysis process vary wildly between, for example, bacterial indicators such as E -Coli, aquatic life impacts for reduced dissolved oxygen represented by BOD5 and the impact of micro plastics in diffuse pollution.

The overall aim of any study is to supplement existing data, from historic catchment published sources in the case of the City and Metro Vancouver sampling and wider commercial and academic studies, with catchment specific datasets focused on assets of interest and where the available data is insufficient or unrepresentative due specific local conditions.

It is recommended that the City utilizes these published sources as a baseline for their modelling activities and subsequently supplement this with specific data from sampling of the spilt flow at individual CSO locations. This will provide a basis to start modelling water quality and assessing which CSOs are of particular interest based on typical loadings.

The selection of individual CSO to sample should be based on the outcome of this initial assessment in combination with catchment knowledge focused on key characteristics of the catchment upstream each CSO. Key characteristics should include knowledge of upstream wastewater flows and pollutant loads, sewer parameters of condition, gradient and infiltration/baseflow, and wider land use, but these will vary dependant on the contaminant of interest.

This will focus on published sources of typical standard parameters, where possible using Canadian sources but also publications from the USA and elsewhere. The section will also comment on the collection of site specific data to provide Event Mean Concentration values. This will draw on the experience of CSO monitoring by Metro Vancouver.

- Published data on bacterial loads.
- Published data on foul flow contaminants
- Published data on surface washoff of contaminants
- Costs and benefits of site specific data
- Outline guidance on collection of site specific data

This data will be used to supplement and support the initial and potentially wider scale use of existing standard data. The capture of data through the duration of a storm event, or better, a series of storm events, and its subsequent analysis requires careful planning and execution as multiple factors require consideration and a number of entities will be involved in the overall process.

7.3.1.1 Type and placing of equipment

Water quality data collection can be via auto-sampler or continuous on site data collection via water quality sonde. The selection of contaminant will be the primary influence of which measure as continuous data collection is not possible for many contaminants such as bacterial indicators, although surrogates can be used for other contaminants such as turbidity for suspended solids. In both cases, the sample required is of storm sewage spilt from a CSO. As such, the sample will be required from the intermittent flow and consideration should be given to the practicalities of collection from predominantly dry pipes, particularly with continuous on-site data collection.

7.3.1.2 Triggering sampling

The desire to capture spilt sewer requires a trigger based on in sewer observation (ideally) or rainfall observation or prediction, potentially linked to the hydraulic model. The process can be partially or entirely automated. The final decision on the laboratory analysis of any samples collected should be made based on the success the field activities, a suitable storm, successful deployment and operation of equipment, and laboratory availability to process samples. The cost of capture is commonly dwarfed by the cost of analysis so this decision is critical and requires sufficient evidence to support it which may include the need for study specific telemetered rainfall and flow measurement to confirm CSO operation.

7.3.1.3 Sampling Regimes

There is considerable published data on the benefit of differing sampling regimes from the single bulk 24hr Event Mean concentration sample to various composition samples which utilize the available 24 sample tubes in most commercial auto-samplers. It is recommended that while the City is using constant concentration in their studies, variation in concentration is still captured. It is proposed that in the initial deployment, samples are uniform across the duration of a storm and this may be revised to front end load the frequency once data is available. This will both provide the data to validate and enhance the application of event mean concentrations and enable the potential benefit of applying time varying or even pollutant transport loads to the modelling process dependent on outcome. This data will therefore support the cyclic modelling process review.

7.3.1.4 Security of equipment

Urban areas can be a challenge, the use of kiosks to house equipment, including telemetry, refrigeration, and power supplies should be considered for all sampling, as installations will be for a prolonged duration.

7.3.1.5 Combined outfalls

Sampling only the spill from a single CSO and exclude other CSO and storm assets which share discharge requires careful planning. The dilution effect of foul flow in the CSO of interest can easily be lost or shewed but other storm flows.

7.3.1.6 Sample storage and analysis

All samples degrade after capture. Dependent on the contaminant steps such as refrigeration and chemical stabilization can prolong the samples via life but consideration of access to laboratories for analysis is required throughout the duration of any sampling program.

7.3.1.7 Validation of auto-sampler data

Sewers and dry pipes are both hostile environments for sensitive monitoring equipment. It is common for continuous data capture to suffer from drift and other data issues. Frequency review of returned data, planned and reactive maintenance, and potentially laboratory analysis to confirm on site data capture should all be considered to support the success of any study.

8 Existing System Assessment Guidelines

8.1 Disclaimer and Usage

The City currently does not have formal assessment criteria. Any assessment metrics presented in this chapter are not official, formal, or binding and shall only be used with permission of City staff. Any model results obtained using these assessment metrics shall remain confidential.

The guidance provided in this chapter is solely intended to provide preliminary assessment metrics that could be used as a starting point to help gain a general understanding of the existing system performance. On a project-by-project basis, these assessment metrics shall be reviewed and discussed at the project initiation stage with the appropriate City staff to determine their applicability.

Subsequently, if needed and with confirmation of City staff, these assessment metrics shall be adjusted to better suit the project.

8.2 Background

This chapter contains existing system assessment metrics taken from draft assessment criteria developed specifically for the Cambie and Broadway Integrated Water Management Plans (IWMP).

The Cambie IWMP included the first internal discussions on acceptable surcharged hydraulic grade lines in the predominantly combined piped sewer system at 5- and 10-year 1-hour rainfall events. This was carried forward and refined in the Broadway IWMP to also consider specific aspects of separated sewers. The Broadway IWMP draft assessment criteria were also expanded to include overland flow, CSO, and stormwater quality.

Note that this chapter will solely present guidelines for assessment metrics for the piped system and overland flow taken from the Cambie and Broadway IWMPs draft assessment criteria. If required for the project, the assessment metrics for CSO and stormwater quality shall be confirmed with City staff.

8.3 Piped System

Table 8-1 below provides guidelines for assessment metrics for the existing piped sewer system.

Table 8-1 definitions:

- Separated sewer: Sewer intended to convey only stormwater or sanitary flows, but not both, either today or in a future state. A separated sewer may still be functionally combined today.
- Combined sewer: Sewer conveying both stormwater and sanitary flows (sewage) in the same pipe.
- Functionally combined: Refers to a sewer that is designated as "separated" but currently conveys combined flows.
- Surcharge: When the pipe is under a pressurized full flowing pipe condition. Defined as the ratio of the depth of pipe flow (d) to the diameter of the piper (D), so d/D => 1, but sometimes described by the ratio of the modelled pipe flow (q) to the design Manning's n pipe capacity (Q), so q/Q > 1, as appropriate for the analysis.

Table 8-1 Piped System Existing System Assessment

Assessment	Metric
DWF	
Sanitary or Combined (including separate "Storm" pipes that are functionally combined)	- No surcharging in DWF (including calibrated GWI). - Confirm no dry weather CSO/SSO or downstream pump station overflow/bypass. - Consider in the surcharging analysis any pipe storage occurring as a result of undersized pump stations.
WWF	
Combined (fully or functionally combined)	<u>WWF to be Assessed Based on 2018 IDF Curve for Existing</u> - Local pipes: 5- or 10-year events (depending on land use) - HGL at least 1.5m BGL*; surcharge permitted. - Trunks: 10-year events - HGL at least 1.5m below ground; surcharge permitted. <u>Flood Risk Matrix</u> (based on potential of basement flooding damage**) - High risk: HGL <= 1.5 m BGL - Moderate risk: HGL 1.5 - 2.5 m BGL - Low risk: HGL > 2.5 m BGL **Planning level studies may make blanket assumptions of basement levels (e.g. 1.5m below surface) and/or presence of backflow valves. Design work shall include refined evaluation of basement levels to confirm flood risk and HGL requirements shall be refined accordingly.
Storm (fully separated including all services)	<u>WWF to be Assessed Based on 2018 IDF Curve for Existing</u> - Local pipes: 5- or 10-year events (depending on land use) - HGL at least 1.5m BGL, especially if services are present; surcharge permitted. - Trunks: 10-year events - HGL at least 1.5m below ground; surcharge permitted. Note that pipe upgrade needs depend largely on overland flow route functionality/surface flood risk (see Section 8.4 - Overland Flow). Not all surcharge or flooding requires remediation, particularly for larger return periods. HGL < 1.5 m BGL with no flooding to ground may be permitted if no services at risk.
Sanitary (fully separated including most*** services) ***"most" requires definition/quantification in the future; generally implies all known services have been separated and the remaining are unknown/assumed based on high I/I in flow monitoring data.	Currently, The City does not have models in fully separated areas that would meet the WWF calibration requirements to analyze on this basis. In those cases, evaluate based on no surcharge during calibrated DWF + (design I/I or calibrated GWI). <u>Potential Future Assessment Metrics</u> - Desired: 100-year HGL at least 2.5m below ground. - Actual existing system metric may be reduced as appropriate for the system I/I (e.g.

	10-, 25-, or 50-year events, HGL at least 2.5m below ground). - I/I to be based on calibrated sanitary models and evaluated using a suitable historical flood event or longer duration design events (6 to 24 hours).

*BGL = below ground level

8.4 Overland Flow

Table 8-2 below provides guidelines for existing system assessment metrics for overland flow.

Table 8-2 Overland Flow Existing System Assessment

Assessment	Metric
Overland flow hazard (stability of persons in flowing flood waters)	<u>For 100-year and Lower Return Period Events</u> Depth vs. velocity curve below, for flowing water, must be met for safety; the ability for persons to not be swept away by flowing flood water and to remain stable. Water velocity (m/s) Permissible depth of water (m) 0.5 0.80 (not applicable to roadways) 1.0 0.32 2.0 0.21 3.0 0.09 If a more stringent assessment is appropriate, the roadway requirements for "depth of ponding at sags" shall additionally be applied (a max. 0.35m depth at 100-year rainfall event is required; see below "depth of ponding at sags" requirement below).
Depth of ponding at sags	<u>For 100-year and Lower Return Period Event</u> - Roadways: 0.35m depth of water or less, depending on adjacent building grades; min. 0.15m freeboard to building openings. - Outside of roadways and on private property: Assess based on risk of property damage or safety. Minimize flood flow and ponding on private property. Min. 0.15m freeboard to building openings; preferably 0.35m freeboard.
Roadway navigability	- 5- or 10-year events: 1 lane free on collectors/local roads, 1 lane free in either direction on arterial roads; max. 0.15m ponding depth at sags and inlets; no overtopping of curbs. - 100-year events: 0.35m max. depth of water at the deepest part of the road cross-section with the exception that the depth of flow at the crown of arterial roads are not to exceed 0.15m and a max. depth of water of 0.15m for local roads where reverse slope driveways are present. Regardless of these criteria, maintain a min. of 0.15m of freeboard to building openings; this may require restricting flow within the curb to protect adjacent zero lot line developments or depressed lots.

9 Model Validation

This chapter provides guidance on the process to identify and resolve simulation run errors and model instabilities to an acceptable degree, the model validation process. Hydraulic model components such as flow, depth, and HGL shall be checked for model instabilities and large HGL fluctuations.

Model validation should be performed after the model build is completed and the model network has been successfully validated.

9.1 Background Simulation Errors and Model Instabilities

To resolve simulation errors as outlined in Section 9.2, it is useful to understand the components of the simulation process. When a model run is executed, the process involves preprocessing, initialization, and finally, simulation. Preprocessing creates the required simulation input files and initialization provides an initial steady state for the simulation.

When attempting to identify and resolve model instabilities as presented in Section 9.3 and 9.4, it is useful to understand how the InfoWorks ICM simulation engine works.

The simulation engine solves for conduit flow and depth using the Saint-Venant equations of mass and momentum. By default, regularly spaced discrete computational points are added along all conduits. Each pair of adjacent points in a conduit is then linked by the discrete form of the Saint-Venant equations. These points are referred to as Computational Nodes.

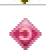
This method results in a large system of equations to be solved simultaneously for all conduits at each timestep. The solution of these calculations is computed using the iterative Newton-Raphson method. The timestep is automatically adjusted by progressively halving the timestep at each iteration until convergence of the Newton-Raphson method is reached, meaning that when an iteration fails to converge, it will halve the timestep and try again to iterate to converge.

9.2 Simulation Run Errors

As mentioned in Section 9.1, the simulation process involves pre-processing, initialization, and simulation. Simulation errors can arise during each stage.

The simulation icon indicates the status of the simulation and possible warnings and run errors. Table 9-1 shows simulation status icons and definitions.

Table 9-1 Types of Simulation Status

Simulation Icon	Status Description
	Results unavailable. Either the simulation has not been run, the results are not available locally or on the connected server, or the simulation results have been deleted.
	Simulation in progress. See Job Progress Window for current activity during the simulation run.
	Simulation failed. Check the simulation log for reported errors.
	Simulation completed successfully and full simulation results are available.
	Simulation completed with warnings. Check the simulation log for detailed warning messages.
	Simulation interrupted due to failure to meet convergence related to the 1D engine. Simulation results are available up to the point of failure.

9.2.1 Preprocessing Errors

Preprocessing errors are not common and help from Innovyze support shall be sought if preprocessing errors occur.

9.2.2 Initialization Failures

The model initialization stage attempts to achieve a steady state in the system to enable the model simulation to run. A steady state is achieved when convergence criteria defined by simulation parameters are met.

Initialization commonly fails due to flooding in the model. Flooding during initialization often occurs at very high flows or water levels resulting from an applied boundary condition. Flooding may also lead to long initialization times of more than ten minutes, or the initialization process may never end. It may be tempting to force stop the initialization process in order to start the model simulation. However, this is not recommended since it may prevent the modeller from noticing the excessive flooding issue during initialization.

Instead, if the initialization process takes more than ten minutes, it is recommended to check nodes that experience high flood volumes during initialization. The elapsed initialization time can be viewed in the Job Progress window, as shown on Figure 9-1. To check if any flooding occurs during initialization, use the Job Progress Window to force stop the initialization process after ten minutes; the results will be saved up to the stop point. Subsequently, review the node results grid to identify nodes with high flood volumes and confirm if the flooding appears realistic, as shown on Figure 9-2.

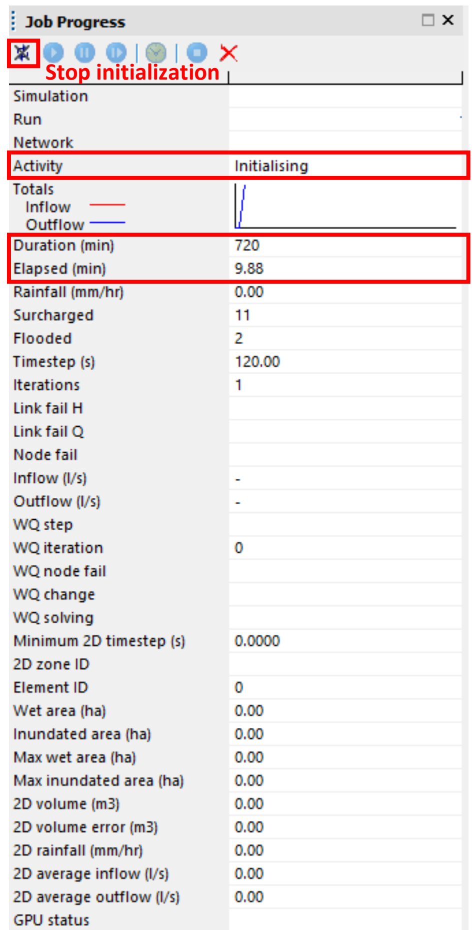


Figure 9-1 Job Progress Window

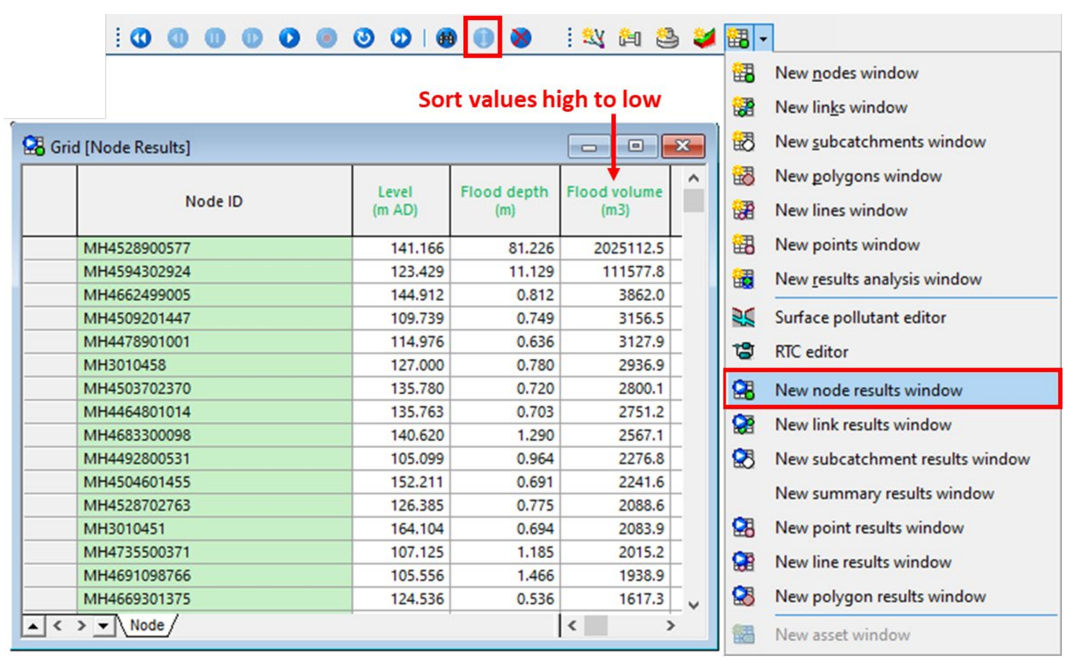


Figure 9-2 Flood Volume in Node Results Grid View

9.2.3 Simulation Run Failures

The most common errors that result in simulation run failures are due to solutions to hydraulic calculations not converging properly. Figure 9-3 shows the results log of a failed simulation run due to converge issues. The modeller shall investigate the nodes or links with convergence failures and attempt to resolve them by following the methods outlined in Section 9.3 and 9.4.

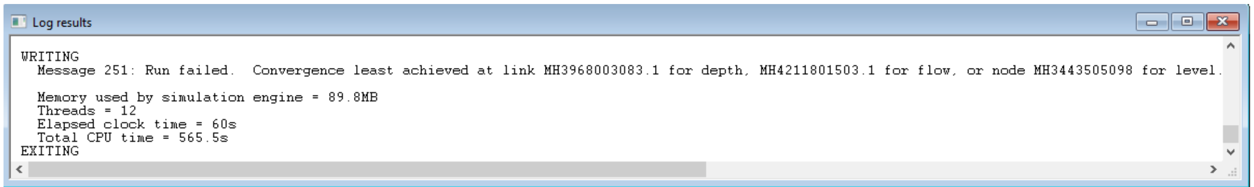


Figure 9-3 Timestep Log Convergence Failure Message

Sometimes a simulation run times are long but do not fail. A long run time indicates a large number of iterations were required to achieve convergence. Where convergence fail counts are greater than 1000, the modeller shall investigate and attempt to resolve these model instabilities as outlined in Section 9.3 and 9.4.

Another possible simulation error may be due to the file size of simulation results. When the simulation time is long or the model network is complex (1D-2D or 2D models), the results folder may not contain sufficient storage capacity to accommodate the simulation results files. In this case, the modeller shall delete any failed simulation results to free space so that the simulation can be re-run.

9.3 Model Instability Identification and Checks

Model instabilities result from hydraulic calculations performed by the simulation engine where the solution to the governing equations do not converge properly. See Section 9.1 for background on the InfoWorks ICM simulation engine.

Instabilities may lead to flow and depth estimates not representative of real hydraulic conditions in the sewer system and may skew critical model results. Therefore, model instabilities should be eliminated to an acceptable degree by performing the model checks as outlined in this Section.

The following subsections provide a methodology to identify model instabilities. See Section 9.4 for various methods to resolve model instabilities. Figure 9-4 show a summary of the model instability identification and resolution methods.

9.3 Model Instability Identification and Checks
- Node volume balance error - Conduit max velocity - Convergence failure log - Profile and hydrograph check

9.4 Model Instability Resolution	
Tier 1	**9.4.1 Troubleshoot Network Geometry** The most common causes of instability arise from network geometry. • Steep slopes • Very short/long conduit • Inappropriate headloss coefficients
Tier 2	**9.4.2 Timestep Selection** Decrease simulation timestep (default is 60s) progressively to: • 30s • 15s • 10s
Tier 3	**9.4.3 Minimal Computational Node** Increase conduit minimum computational nodes (default is 5) progressively to: • 10 • 20 • 40
Last Resort	**9.4.4 Simulation Parameters** Consult Innovyze support before modifying simulation parameters (generally not recommended)

Figure 9-4 Process for Resolving Model Instability

9.3.1 Node Volume Balance

It is recommended to start by checking volume balance errors in the node results grid window, as shown on Figure 9-5. A volume balance less than 5% is considered acceptable.

The grid results window provides time varying results for each node. Select "Show maxima" to show the maximum Flood volume (m^3) per node. The following SQL query can be used to select a list of nodes that exceed a 5% volume balance error:

abs(sim.volbal) > 0.05

Next, select "Group selections" to group all nodes selected by the query to the top of the list in the grid results window.

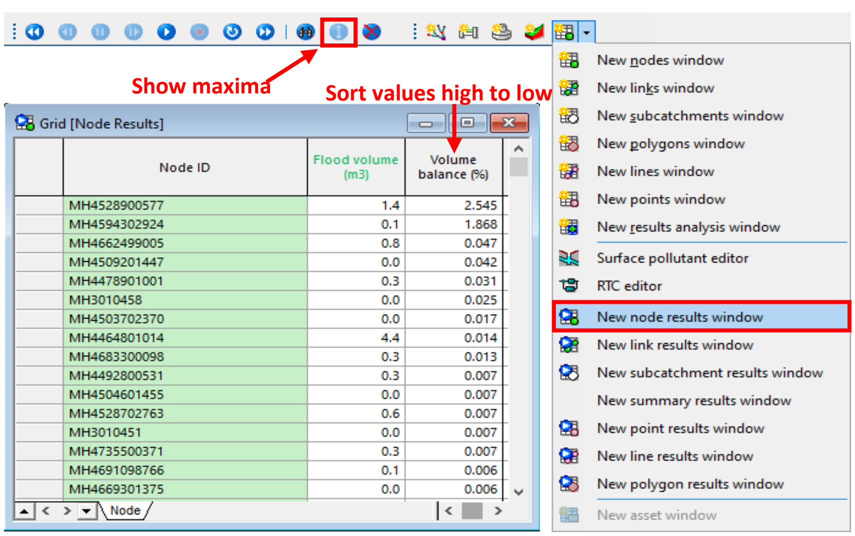
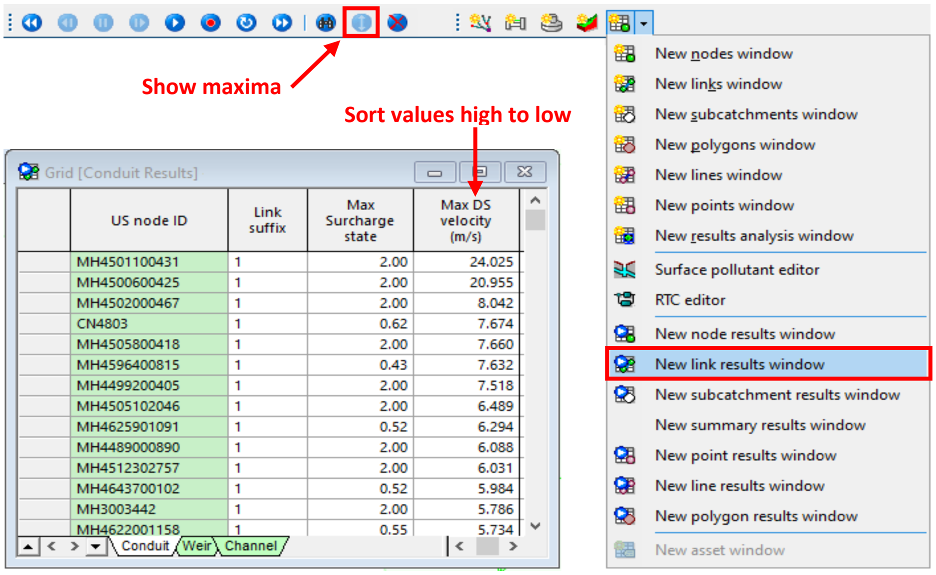


Figure 9-5 Node Results Grid Window

9.3.2 Conduit Max Velocity

In addition to node volume balance errors, conduits with high velocity can indicate model instabilities. The simulated maximum velocity of conduits can be reviewed in the link results grid window, as shown on Figure 9-6.



The following SQL query can be used to select conduits that exceed a maximum velocity of 6 m/s; the maximum velocity of 6 m/s is suitable for storm and combined sewers and can be changed to the required threshold by the modeller. Based on the City's engineering design manual, the maximum velocity must not exceed 3.5 m/s for sanitary sewers.

abs(sim.max_us_vel) > 6 or abs(sim.max_ds_vel) > 6

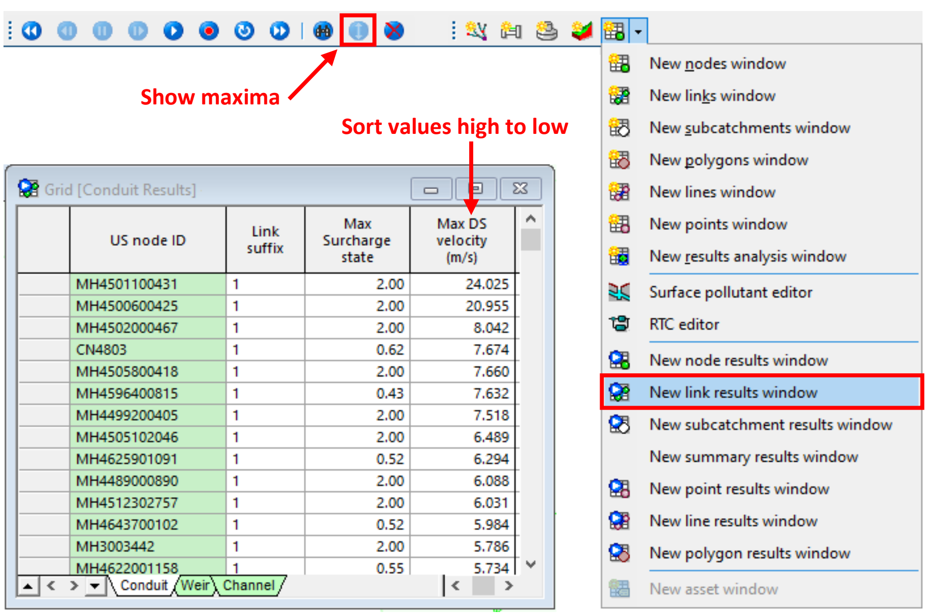


Figure 9-6 Link Results Grid Window

9.3.3 Convergence Failure Log

The simulation timestep log is a useful feature to summarize the convergence failure counts of individual nodes and links. To use this feature, prior to running the simulation, click the "Diagnostics" button at the bottom right of the Run window and in the resulting pop-up window, check the "Timestep Log" box as shown on Figure 9-7.

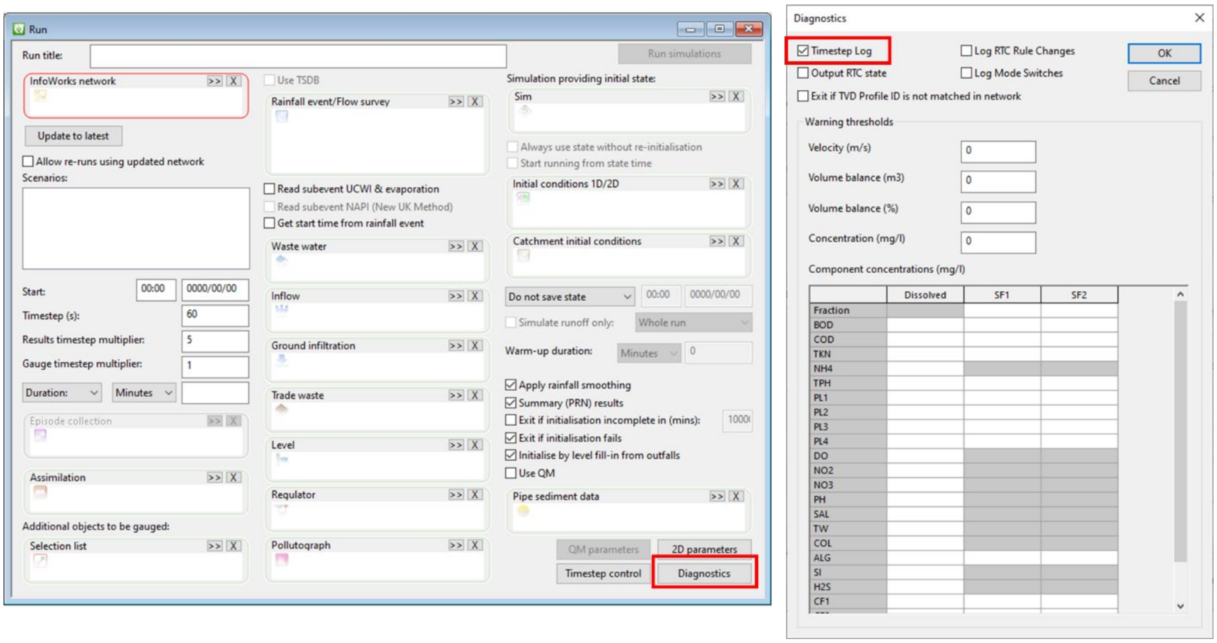


Figure 9-7 Enabling the Simulation Timestep Log

To view the convergence failure counts in a log results text file, right-click the simulation result under the Run group and select "Open As…", then select "Log results (text)" as shown on Figure 9-8.

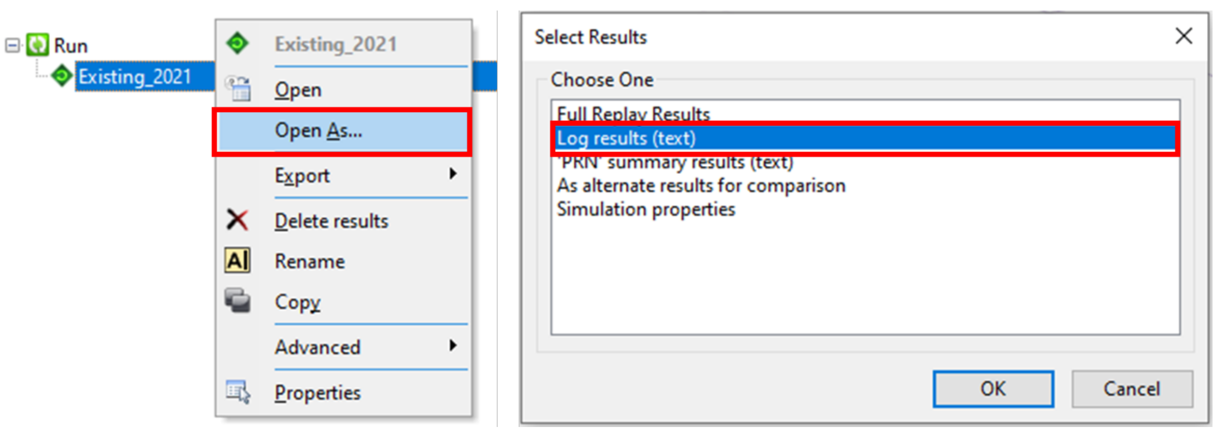


Figure 9-8 Opening the Convergence Failure Count Log Results Text File

Scroll to the text file section starting with "Link depth fail counts". Figure 9-9 below shows a log results text file with convergence failure counts. The log results text file will show three type of convergence failure counts: link depth fail, link flow fail, and node fail counts. Nodes or links with a failure count of 1000 or more are considered poor convergence and recommended to be checked. To create a list of model nodes and links to check, right-click in the log results window to export the entire log file to Excel or copy and paste a subset of convergence results of interest.

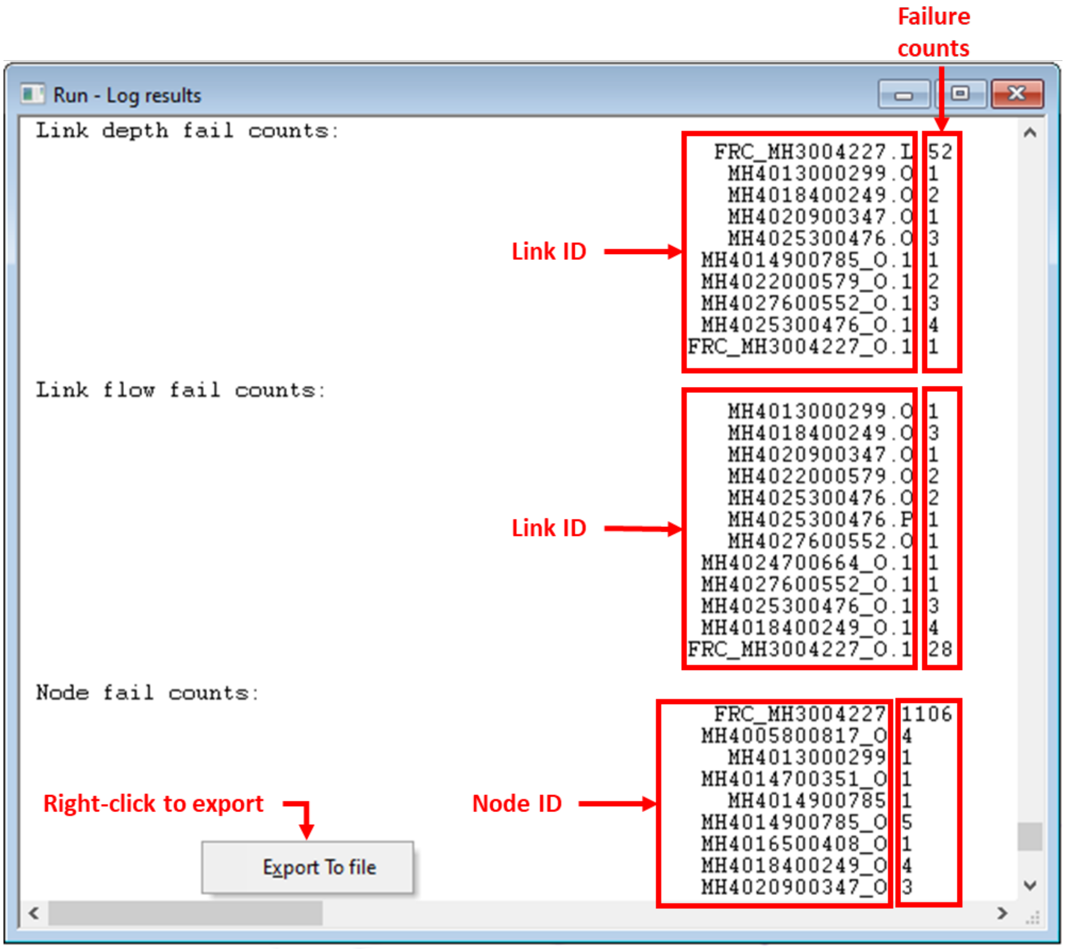
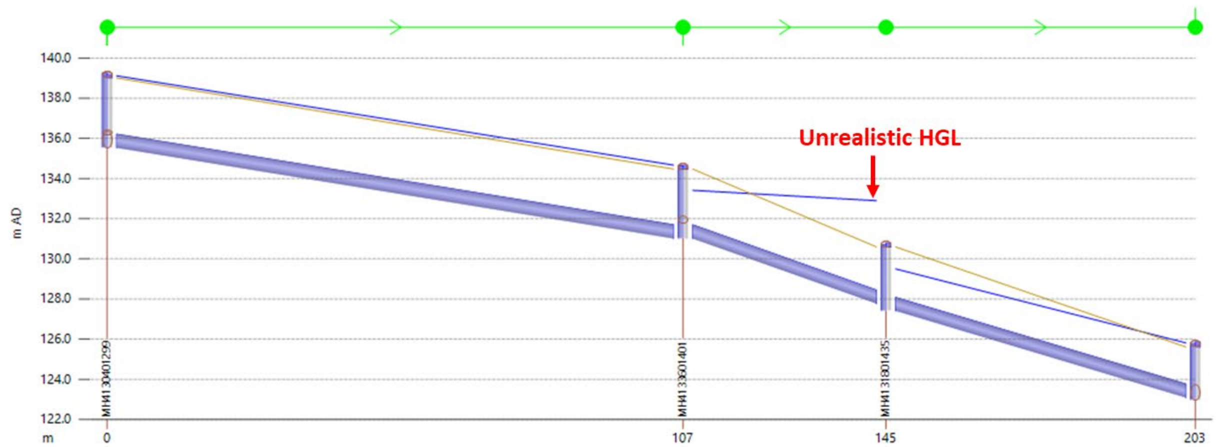


Figure 9-9 Log Results Text File with Node and Link Convergence Failure Counts

9.3.4 Profile and Hydrograph Check

Visual checks of the HGL profile and hydrographs are recommended. When reviewing simulation results using a profile view, any discontinuous HGLs shall be noted and investigated for model instability.

Figure 9-10 provides an example of an erroneous HGL in a profile view.



Link	MH4130401299.1	MH4133601401.1	MH4131801435.1
US node ID	MH4130401299	MH4133601401	MH4131801435
Link suffix	1	1	1
System type	storm	storm	storm
length (m)	107.4	37.8	57.7
Shape ID	CIRC	CIRC	CIRC
width (mm)	675	675	675
us inv (m AD)	135.535	131.021	127.403
ds inv (m AD)	131.021	127.766	123.090
grad (m/m)	0.04201	0.08606	0.07473
r.pfc (l/s)	1723	2466	2298
surc	2.00	2.00	2.00
DS flow (l/s)	2498.90	3115.64	4588.87
DS velocity (m/s)	29.789	7.751	13.779

Node	MH4130401299	MH4133601401	MH4131801435	MH4133501490
ground (m AD)	139.010	134.474	130.592	125.610
level (m AD)	139.255	134.636	130.685	125.773
expr:Freeboard	-0.245129	-0.162142	-0.093794	-0.163376

Figure 9-10 Conduit Profile View with Erroneous HGL

The Results toolbar, as shown on Figure 9-11 can be used to plot hydrographs: select the “Graph” tool to plot an individual object or make a selection and then select the “Graph selected objects” tool to plot hydrographs for multiple conduits at once. Any hydrographs showing negative or unreasonably large flow fluctuations, as shown on Figure 9-12, should be investigated for model instabilities.

Visual checks can be time consuming; therefore, it is recommended to start at critical locations such as outfalls, weirs, orifices, and pump stations. Other critical locations to review for model instabilities include nodes or links exceeding thresholds for volume balance, maximum velocity, or convergence fail count, as discussed in Sections 9.3.1 to 9.3.3. A selection list can be made for these critical locations to batch review profiles and hydrographs.

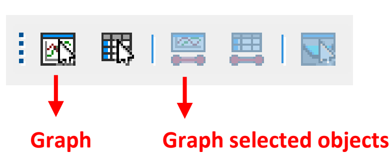


Figure 9-11 Results Toolbar

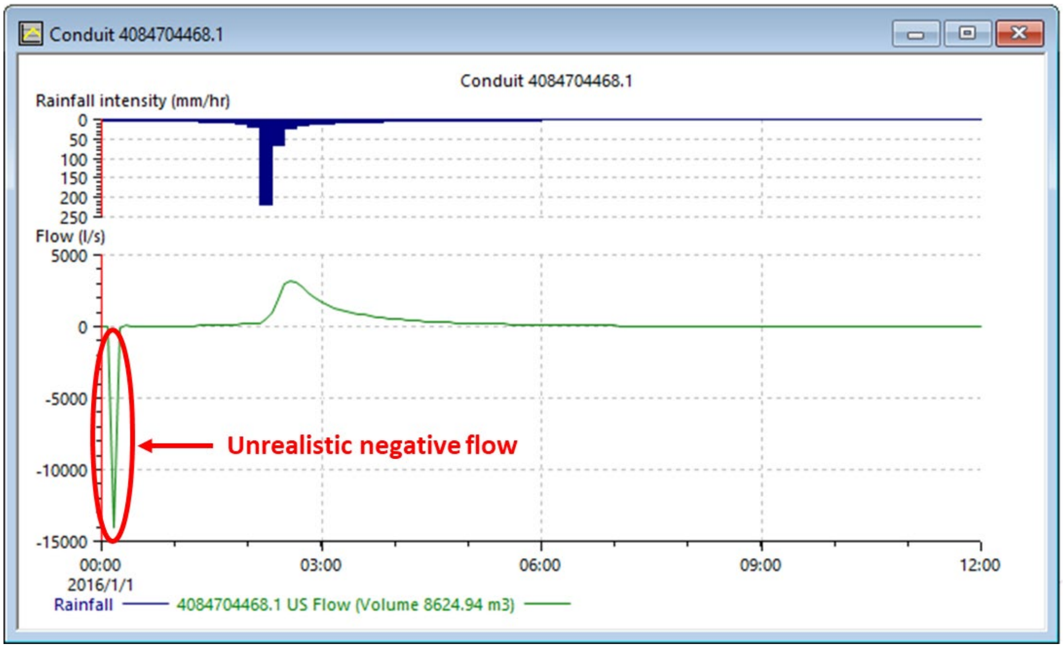


Figure 9-12 Hydrograph with Erroneous Flow

9.4 Model Instability Resolution

The following subsections provide methods to resolve model instabilities.

9.4.1 Troubleshooting Network Geometry

Model instabilities are commonly caused by poor network geometry; therefore, the network geometry should first be checked for the following issues:

- Steep slopes

  Conduits with a gradient greater than 10% *may* cause random convergence failures. If *steep slopes* are found to *be the* cause, removing the *conduit* headloss *may resolve convergence* failures.

- Short and long conduits

  Conduit lengths between 5 to 500 m are recommended. However, long conduits may cause convergence failures; therefore, they can be split into multiple conduits by adding dummy nodes. Alternatively, the minimum number of computational nodes may be increased, as described in Section 9.4.3. For short conduits that experience convergence failures, the run timestep may be decreased or the minimum number of computational nodes may be increased, as described in Sections 9.4.2 and 9.4.3, respectively.

- Inappropriate headloss coefficients

  When inferred upstream and downstream headloss coefficients are large, they may cause unrealistically fast oscillating water levels across conduits. In this case, the headloss coefficient may be reduced to a maximum value of 2.

9.4.2 Timestep Selection

A simulation timestep defines the maximum timestep at which the hydraulic calculations will be carried out. It is defined in the Schedule Hydraulic Run window, as shown in Figure 9-13. The default simulation timestep is 60 seconds. Decreasing the simulation timestep may reduce instances of model instabilities; however, the total duration of the simulation will usually increase.

Besides the timestep, the results timestep multiplier is another run parameter that can be adjusted. The results timestep multiplier changes how frequently the simulation results will be reported and works hand-in-hand with the timestep parameter. For example, a results timestep multiplier of 1 will report results at each timestep; however, a value of 5 would report a result every five timesteps. The default results timestep multiplier is set to 5 for a simulation timestep of 60 seconds. Note that the results timestep multiplier does not impact the simulation, it merely sets the result reporting frequency.

When refining the timestep to solve model instabilities, it is recommended to first change the timestep to 30 seconds with the result timestep multiplier set to 10. If smaller timesteps are needed, it is recommended to increment the timestep down to 20, 15, and 10 seconds with the result timestep multiplier modified to 15, 20, and 30, respectively. The timestep times the results multiplier is recommended to be 300s (5 minutes) for any changes to the timestep.

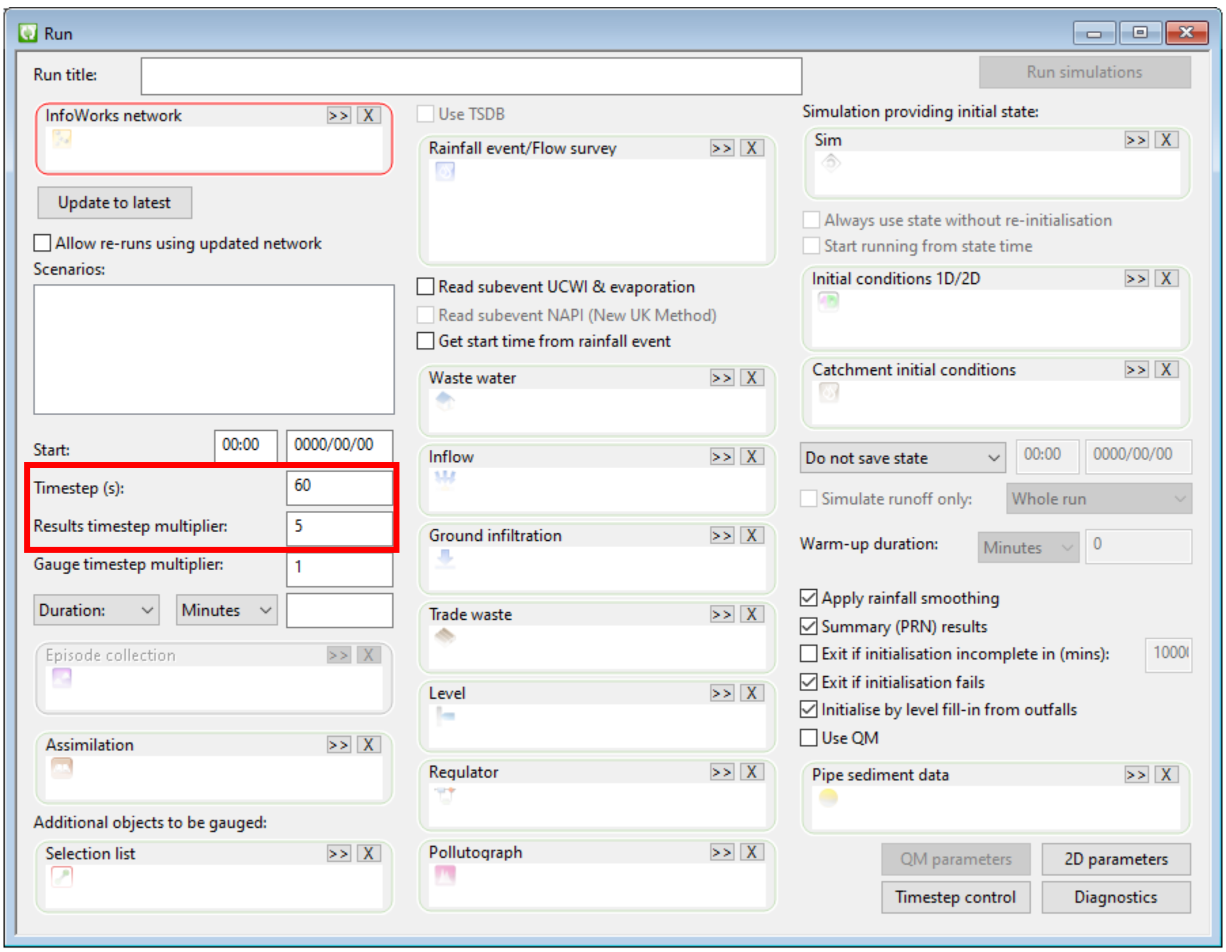


Figure 9-13 Timestep and Results Timestep Multiplier

9.4.3 Minimum Computational Node

All conduits have a minimum computational node attribute. The model performs hydraulic calculations at each computational node. By default, InfoWorks ICM allocates a minimum of five evenly spaced computational nodes for each conduit.

In the case of an unstable conduit, the minimum number of computational nodes of the conduit grid, including its up and downstream conduits, can be increased to 10, 15 and 20 in an attempt to resolve the instability. If this does not resolve the instability at the conduit, the methods outlined in the previous sections should be revisited.

The minimum computational nodes attribute can be adjusted in the conduit properties table by opening the New Links Window, as shown in Figure 9-14.

Site condition	Ground condition	Minimum computational nodes	Inflow (l/s)	Gradient (m/m)	Full capacity (l/s)	Is merged	Branch ID
ROAD	SUBURBS	5	0.00	0.00734	51	☐	
ROAD	SUBURBS	5	0.00	0.02216	49	☐	
ROAD	SUBURBS	5	0.00	0.02420	51	☐	
ROAD	SUBURBS	5	0.00	0.01145	35	☐	
ROAD	SUBURBS	5	0.00	0.00000	0	☐	
ROAD	SUBURBS	5	0.00	0.01145	103	☐	
ROAD	SUBURBS	5	0.00	0.02387	51	☐	
ROAD	SUBURBS	5	0.00	0.06749	85	☐	
ROAD	SUBURBS	5	0.00	0.02804	55	☐	
ROAD	SUBURBS	5	0.00	0.03289	60	☐	
ROAD	SUBURBS	5	0.00	0.01773	44	☐	
ROAD	SUBURBS	5	0.00	0.06561	84	☐	
ROAD	SUBURBS	5	0.00	0.07358	89	☐	
ROAD	SUBURBS	5	0.00	0.02245	49	☐	
ROAD	SUBURBS	5	0.00	0.00447	65	☐	
ROAD	SUBURBS	5	0.00	0.00000	0	☐	
ROAD	SUBURBS	5	0.00	0.01363	69	☐	
ROAD	SUBURBS	5	0.00	0.02219	49	☐	
ROAD	SUBURBS	5	0.00	0.00000	0	☐	
ROAD	SUBURBS	5	0.00	0.00000	0	☐	
ROAD	SUBURBS	5	0.00	0.00000	0	☐	
ROAD	SUBURBS	5	0.00	0.01970	83	☐	
ROAD	SUBURBS	5	0.00	0.01558	41	☐	
ROAD	SUBURBS	5	0.00	0.00852	397	☐	
ROAD	SUBURBS	5	0.00	0.02585	96	☐	
ROAD	SUBURBS	5	0.00	0.02569	53	☐	
ROAD	SUBURBS	5	0.00	0.01779	79	☐	
ROAD	SUBURBS	5	0.00	0.01145	103	☐	

Figure 9-14 Minimum Computational Nodes Attribute

9.4.4 Simulation Parameters

InfoWorks ICM contains a set of default simulation parameters that can be adjusted for each model network; they are not globally applied to all model networks. The parameters govern how the simulation engine performs hydraulic calculations. Note that these simulation parameters have been pre-configured by Innovyze for optimum simulation accuracy and performance.

Improperly adjusting the default parameters may enable the simulation engine to force the solution of the hydraulic calculations to converge without resolving the issues causing model instabilities. Forcing convergence may allow the simulation to complete; however, may provide erroneous model results. Therefore, it is not recommended to change these default simulation parameters to resolve model instabilities without properly understanding how they affect the hydraulic calculations and model results. However, if the modeller wishes to adjust the default simulation parameters, it is recommended to consult with Innovyze and to obtain confirmation that the adjustments are reasonable.

Figure 9-15 shows where to locate the simulation parameters of the current model network. Refer to InfoWorks ICM help for detailed information about each simulation parameter.

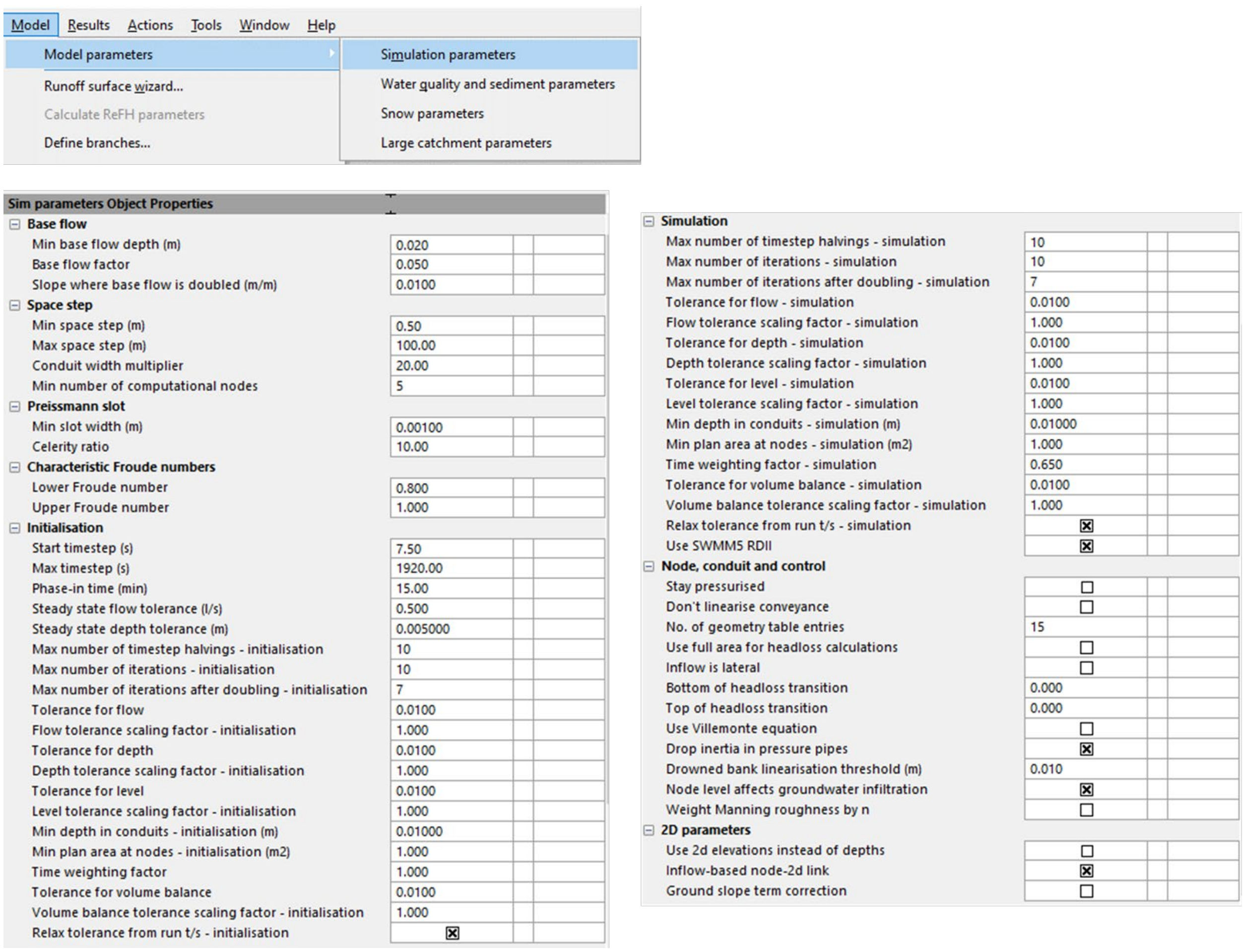


Figure 9-15 Simulation Parameters

10 Model Conversion

The City started using PCSWMM in 2017 and has developed PCSWMM models for the purpose of sewer system planning, design, and development reviews. In 2020, the City adopted InfoWorks ICM as the platform for modelling its sewer systems. The City intends to transfer portions of their PCSWMM models to InfoWorks ICM. However, there may be occasions when the City would have to provide parts of its models in PCSWMM format to developers and consultants that do not own an InfoWorks ICM licence.

This chapter is intended to provide a streamlined process for converting the City's PCSWMM models to InfoWorks ICM and vice versa, including methods to verify the model conversion. The methodology and guidance provided in this chapter are tailored to the City's PCSWMM model configuration procedures as per the City's PCSWMM Modelling Guideline provided in Appendix 10A.

An overview of the chapter structure is as follows:

- Model Conversion Overview – provides an overview of the model conversion process and compares the configuration of key modelling attributes in InfoWorks ICM versus in PCSWMM.
- Conversion from PCSWMM to InfoWorks ICM – provides a methodology for converting a PCSWMM model into an InfoWorks ICM model.
- Conversion from InfoWorks ICM to PCSWMM – provides a methodology for converting an InfoWorks ICM model into a PCSWMM model.

10.1 Model Conversion Overview

Converting a model from one software platform to another includes converting the model network and associated files needed to run a simulation. A model network primarily consists of nodes, conduits, and subcatchments. Other model data that needs to be converted are rainfall time series, wastewater patterns, and boundary conditions; these conversions can be completed using CSV files.

Table 10-1 provides a comparison of key attributes of model network elements in PCSWMM versus InfoWorks ICM. Additional notes for Table 10-1 are provided after the table.

Table 10-1 Comparison of PCSWMM and InfoWorks ICM Model Attributes

PCSWMM			InfoWorks ICM	
Model Object	**Attribute**	**Description**	**Corresponding Attribute in ICM**	**Attribute of**
Junction/Outfall	Name	Unique identifier of Node	Node ID	Node/Outfall
Junction/Outfall	Rim Elev.	Node ground elevation	Ground level	Node/Outfall
Junction/Outfall	EFFLUENT_T	Node system type (storm, sanitary or combined)	System type	Node/Outfall
Junction	Baseline	Groundwater infiltration (a component of dry weather flow)	Baseflow [1]	Subcatchment
Junction	Average value	Average value for base wastewater flow (a component of dry weather flow)	Population [1]	Subcatchment
Junction	Sewershed area	The area used in calculating RDII	Contributing area [1]	Subcatchment
Junction	Hydrograph	Unique identifier of a RTK hydrograph	RTK hydrograph [1]	Subcatchment
Conduit	Link ID	Unique identifier of conduit	US node ID and Link Suffix	Conduit
Conduit	Start node	Upstream node ID of conduit	US node ID	Conduit
Conduit	End node	Downstream node ID of conduit	DS node ID	Conduit
Conduit	EFFLUENT_T	Conduit system type (storm, sanitary or combined)	System type	Conduit
Conduit	Length	Length of conduit	Length	Conduit
Conduit	Shape	Shape of conduit	Shape ID	Conduit
Conduit	Conduit height	Height of conduit	Height	Conduit
Conduit	Conduit width	Width of conduit	Width	Conduit
Conduit	Upstream elevation	Upstream invert of conduit	US invert	Conduit
Conduit	Downstream elevation	Downstream invert of conduit	DS invert	Conduit
Conduit	Roughness	Manning's n roughness of conduit	Bottom and Top roughness	Conduit
Subcatchment	Name	Unique identifier of Subcatchment	Subcatchment ID	Subcatchment
Subcatchment	% Imperviousness	Percentage of subcatchment total area that is impervious	Runoff surface areas [2]	Subcatchment
Subcatchment	Routing	The method by which the subcatchment is to drain (Direct, To pervious, or To impervious)	Internal Routing	Subcatchment
Subcatchment	% routed	Percentage of runoff routed for selected routing method.	Runoff routed internally (%)	Subcatchment
Subcatchment	Impervious roughness	SWMM runoff routing value for impervious area	Runoff routing value [2]	Runoff surface

PCSWMM			InfoWorks ICM	
Model Object	**Attribute**	**Description**	**Corresponding Attribute in ICM**	**Attribute of**
Subcatchment	Impervious area storage	The depression storage of impervious area	Initial loss value [2]	Runoff surface
Subcatchment	Pervious roughness	SWMM runoff routing value for pervious area	Runoff routing value [2]	Runoff surface
Subcatchment	Pervious area storage	The depression storage of pervious area	Initial loss value [2]	Runoff surface
Subcatchment	Infiltration model	Infiltration model for pervious area (use Green-Ampt)	Runoff volume type [2]	Runoff surface
Subcatchment	Initial moisture deficit	A parameter for Green-Ampt infiltration	Green-Ampt deficit [2]	Runoff surface
Subcatchment	Average capillary suction	A parameter for Green-Ampt infiltration	Green-Ampt suction [2]	Runoff surface
Subcatchment	Saturated hydraulic conductivity	A parameter for Green-Ampt infiltration	Green-Ampt conductivity [2]	Runoff surface

Table 10-1 Notes

As indicated in Table 10-1, the major differences are as follows:

1. Sanitary dry weather flow and RTK hydrographs for generating RDII are modelled at Junctions in PCSWMM, whereas in InfoWorks ICM, these are attributes of subcatchments. In addition, the equivalent of average base wastewater flow in PCSWMM is subcatchment population multiplied by a per capita rate in InfoWorks ICM. The per capita rate in InfoWorks ICM is defined in a wastewater file outside the model network.
2. In PCSWMM, only one impervious and one pervious runoff surface is defined within each subcatchment; however, InfoWorks ICM has up to twelve (12) runoff surfaces (impervious or pervious) associated with each subcatchment. In addition, the runoff parameters in InfoWorks ICM are defined in runoff surfaces which are linked to subcatchments as described in Chapter 4 Section 4.7.

Sections 10.2 and 10.3 provide guidance on how to convert PCSWMM to InfoWorks ICM models while taking into account these differences.

10.2 Conversion from PCSWMM to InfoWorks ICM

This section provides a methodology to convert a PCSWMM model into an InfoWorks ICM model. For successful model conversion, the modeller shall familiarize themselves with the PCSWMM model and understand the key differences between PCSWMM and InfoWorks ICM described in Section 10.1. The modeller shall also be familiar with the City' PCSWMM Modelling Guide provided in Appendix 10A.

Figure 10-1 outlines the process for model conversion from PCSWMM to InfoWorks ICM. In general, the model conversion starts with configuring InfoWorks ICM and preparing inputs from PCSWMM, then importing PCSWMM model files into InfoWorks ICM, checking and updating the imported model, and lastly, validating the model conversion by comparing simulation results between the original and converted model. Sections 10.2.1 to 10.2.6 describes these steps in detail.

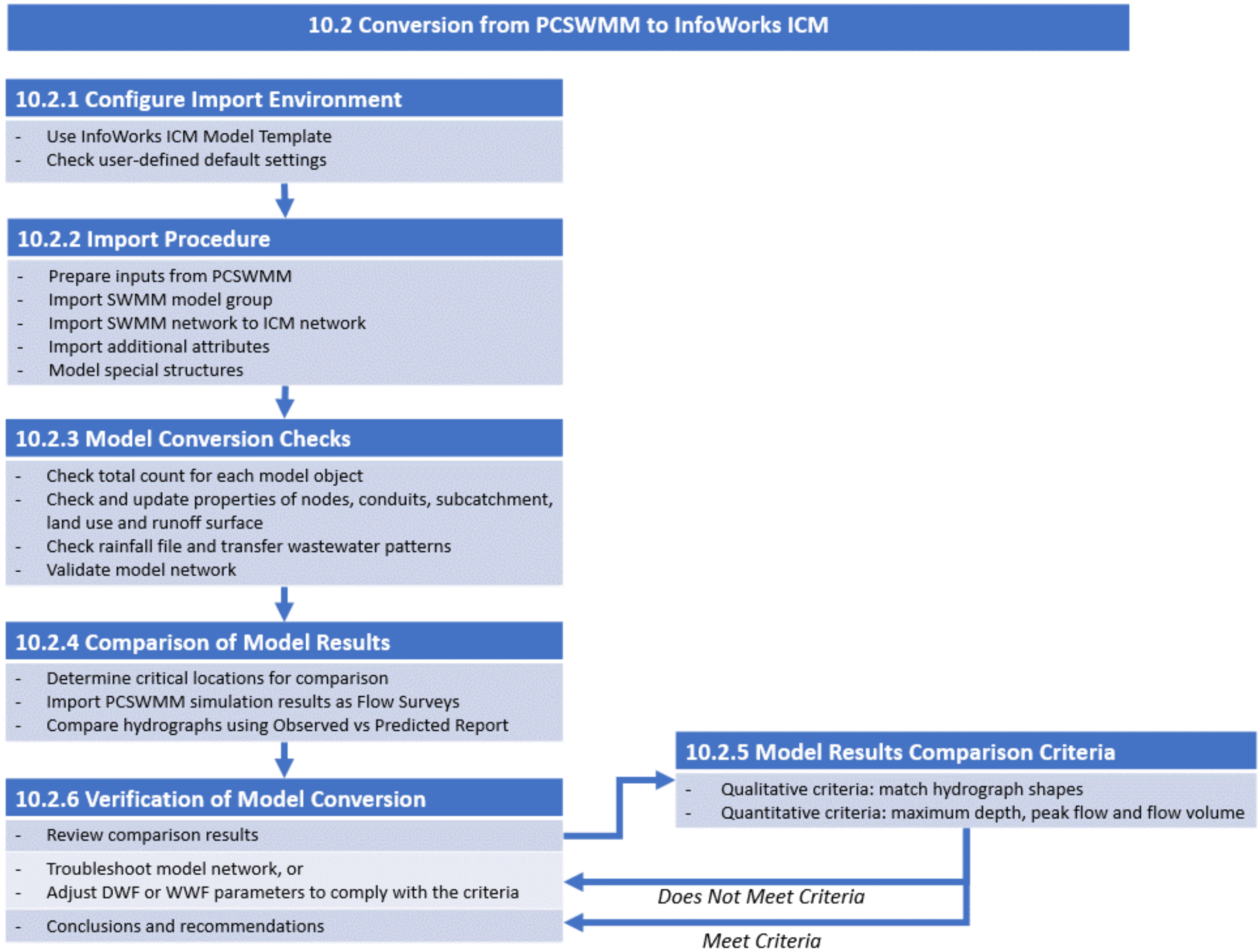


Figure 10-1 PCSWMM to InfoWorks ICM Model Conversion

10.2.1 Configure Import Environment

The InfoWorks ICM model environment needs to be configured before a model is imported. Specifically, the model units shall be set to International System of Units and the conduits roughness type to Manning's n. Note that the modeller shall use the InfoWorks ICM Model Template Database that is provided with this modelling standard where the units and Manning's n settings are preconfigured.

Prior to model import, the model units and Manning's n settings in the Model Template Database shall be confirmed.

Units can be accessed in the menu bar at Tool --> Options… and Manning's n at Network --> User Defined Default. The units for flow, depth, and velocity shall be set to m^3/s, m, and m/s, respectively. Manning's n shall be set to N.

10.2.2 Import Procedure

10.2.2.1 Prepare Inputs from PCSWMM

To prepare input files from PCSWMM, use the packaging function (File --> Package Project…) to export the PCSWMM project to a compressed PCSWMM package file (*.pcz) for ease of transfer. This package file shall be unzipped to obtain a plain text file (*.inp) which stores SWMM network data.

In addition, simulated hydrographs from the PCSWWM model are required in CSV file format for model results comparison which is further discussed in Section 10.2.4.

10.2.2.2 Import SWMM Model Group

The first step to import the PCSWMM model into InfoWorks ICM is to import it as a SWMM model group which preserves most of the data possible from the PCSWMM model. As shown on Figure 10-2, the modeller shall create a new Model Group and right-click to select the Import SWMM --> Model group --> from SWMM5 text file option. In the new pop-up window, select the SWMM5 text file (*.inp) to be imported and select "Open". This will import the SWMM network, rainfall, SWMM time patterns, etc. as shown on Figure 10-2.

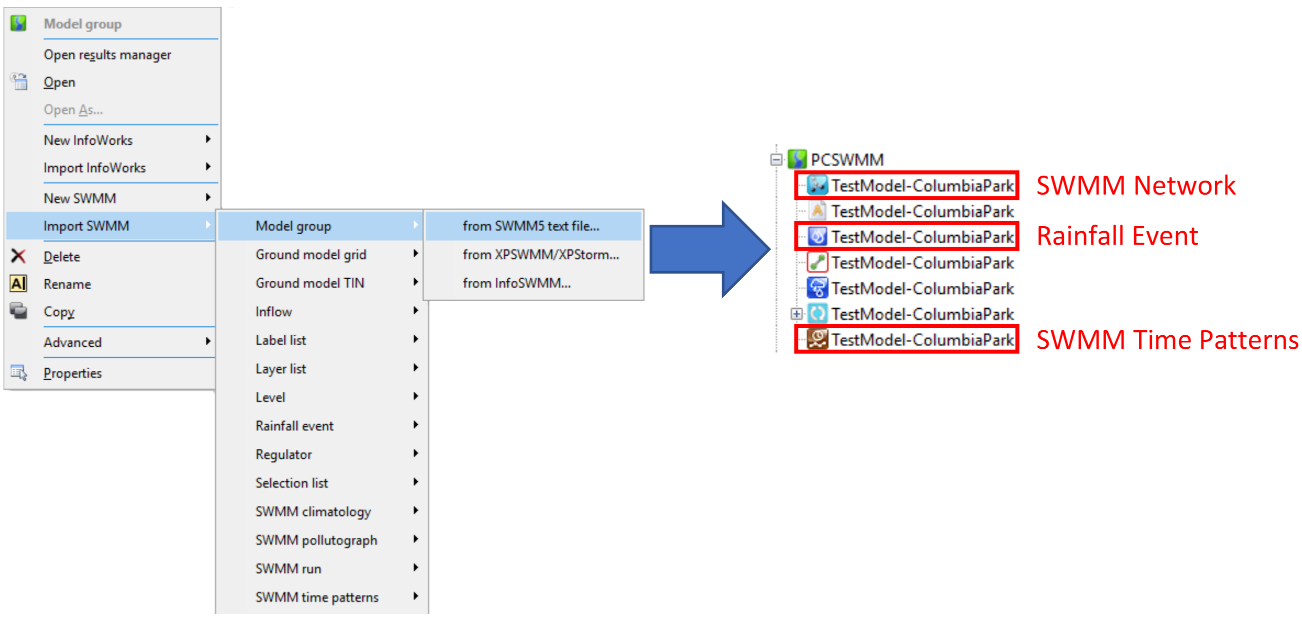


Figure 10-2 Import SWMM Model Group

10.2.2.3 Import SWMM Network to ICM Network

To import the SWMM model network into an InfoWorks ICM model network, from the menu bar navigate to Network --> Import --> Model --> from SWMM network, as shown in Figure 10-3. In the new pop-up window, select the SWMM network imported in the previous step and select "OK". Subsequently, the SWMM network will be imported as new InfoWorks ICM network.

The modeller shall review the imported InfoWorks ICM network by examining the property tables for nodes, conduits, and subcatchments and apply the text data flag "SWMM" to the imported attributes.

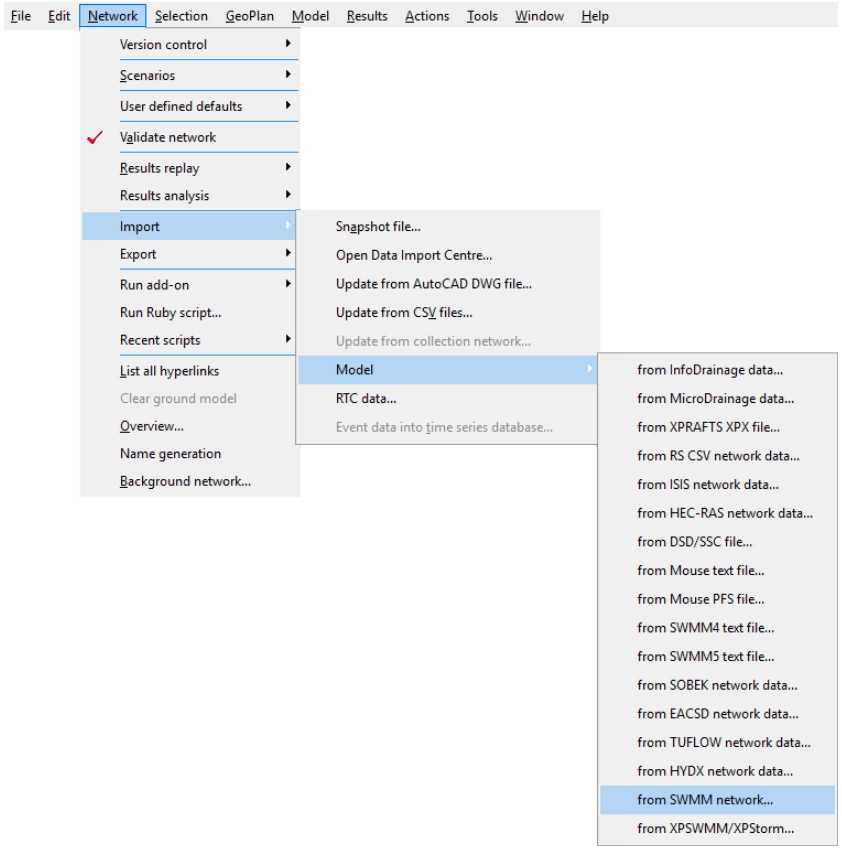


Figure 10-3 Import from SWMM Network

10.2.2.4 Import Additional Attributes

The steps described in the previous section will not import the "Tag" field in PCSWMM or any custom attribute field added through PCSWMM's restructure tool. Appendix 10A PCSWMM Modelling Guideline Sections 4.2, 4.3 and 5.1 explain the "Tag" and custom attribute fields used in the City's PCSWMM models. Therefore, an additional step is required to import these attribute fields, using the shapefiles from the PCSWMM model package, into the customizable user defined number and text fields in InfoWorks ICM. This can be completed by using the Data Import Centre in InfoWorks ICM, as described in Appendix 4B, and with the flag option set to "SWMM" to indicate the data source is from PCSWMM.

Furthermore, due to the differences in model parameters between PCSWMM and InfoWorks ICM as described in Section 10.1, the "Baseline", "Average value", "Time Pattern" and "Hydrograph " attributes for Junctions will not be imported into InfoWorks ICM. Therefore, these fields shall be also brought in as user number and user text fields via the Data Import Centre.

Table 10-2 summarizes the additional attributes to be imported for nodes, conduits, and subcatchments. Table 10-2 shows additional user number and user text fields to store data temporarily for use in the model conversion process and is based on the configuration of model attributes in the City's PCSWMM Modelling Guideline in Appendix 10A and the InfoWorks ICM model documentation requirements in Appendix 4A. Prior to importing these model attributes, the modeller shall update the heading of the user text and numbers according to Table 10-2. The corresponding import configuration files to import these fields via the Data Import Centre are provided with the InfoWorks ICM Model Template Database.

Table 10-2 Additional Attributes from PCSWMM Model

Model Object	Import Configuration File Name	PCSWMM Attribute	InfoWorks ICM Field
Node	PCSWMM_to_ICM_node_2023NOV.cfg	EFFLUENT_T	System type
		DEPTH	Depth of MH (m) (User Number 1)
		MANHOLE_TY	Structure Type (User text 2)
		LEGACY_ID	Legacy ID (User Text 3)
		BASEFLOW	User Number 8 *
		AVGVALUE	User Number 9 *
		SSAREA	User Number 10 *
		PATTERN1	User Text 9 *
		HYDROGRAPH	User Text 10 *
Conduit	PCSWMM_ to_ICM_conduit_2023NOV.cfg	EFFLUENT_T	System type
		TOTAL_SLOP	Pipe Slope (User Number 2)
		LEGACY_ID	Legacy ID (User Text 4)
		ID_MATERIA	Material (User Text 6)
Subcatchment	PCSWMM_to_ICM_sub _2023NOV.cfg	TAG	Zoning category (User Text 2)
		TOTAL_POP	Population

* These are not part of the InfoWorks ICM model documentation standards defined in Appendix 4A but are used here as fields for storing information for model conversion temporarily.

10.2.2.5 Model Special Structures

The configuration for special hydraulic structures such as pumps, weirs, orifices, and sluice gates are different in InfoWorks ICM than in PCSWMM. Therefore, the modeller shall add these to the InfoWorks ICM model network manually after importing the PCSWMM model network. The modeller shall follow Section 4.3 to model special structures.

10.2.3 Model Conversion Checks

The data imported from PCSWMM into InfoWorks ICM shall be checked and updated as needed. The following subsections provide the steps to check and update imported data including hydraulic and hydrologic components, rainfall time series, wastewater diurnal patterns, and boundary conditions.

10.2.3.1 Object Quantity Verfication

As a basic check, the modeller shall confirm the total number of nodes, conduits, and subcatchments imported into the InfoWorks ICM network to identify missing model objects or erroneous dummy objects that have been created by InfoWorks ICM upon import. Extra dummy objects may require clean-up.

10.2.3.2 Nodes

For all imported nodes, the data flags shall be set to the default flag “#D” for Chamber floor level, Chamber plan area and Shaft plan area attribute fields. Appendix 10B includes an SQL query that applies these changes. In addition, the node IDs shall be updated according to the naming convention defined in Section 2.7.1.

10.2.3.3 Conduits

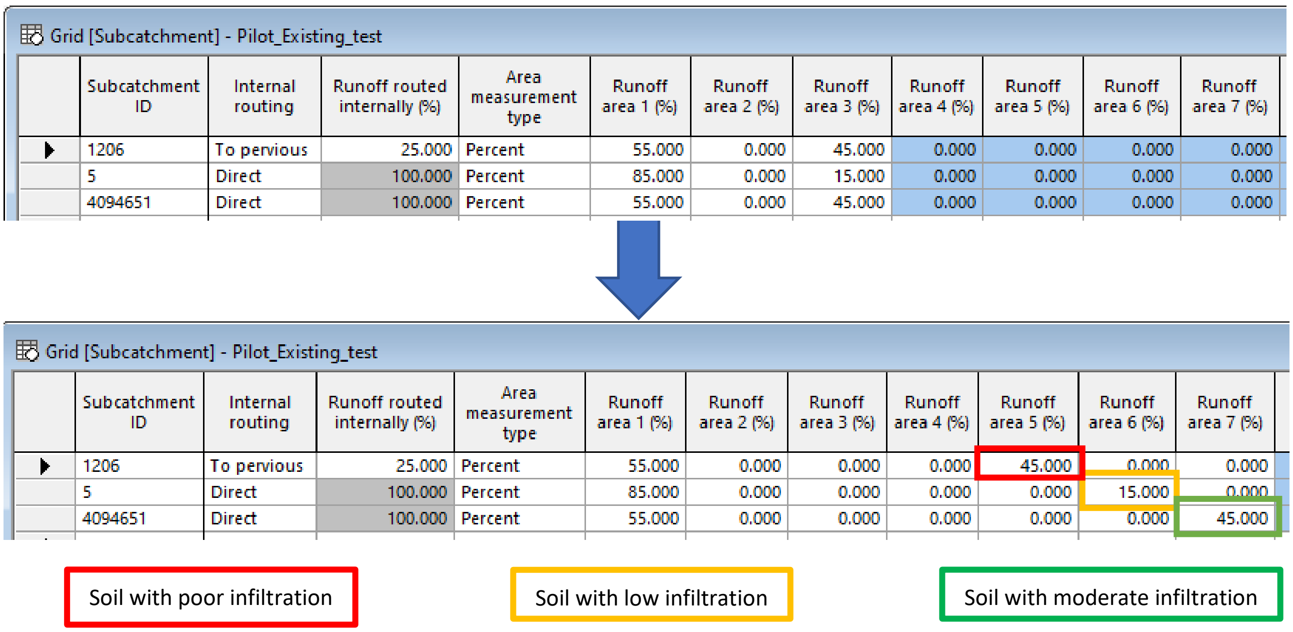
For all imported conduits, the headloss values imported from PCSWMM shall be cleared, and the headloss coefficients shall be updated using the Inference tool as discussed in Appendix 4B Section 2. In addition, the Manning's roughness values shall be updated as per Section 3.2.2 based on pipe material.

10.2.3.4 Subcatchments, Land Use, and Runoff Surfaces

For all imported subcatchments, the data flags shall be set to the default flag "#D" for the Slope, Dimension, and Rainfall profile attribute fields. Based on the location the subcatchment drains to, the System Type attribute field for all subcatchments shall also be updated. Appendix 10B includes an SQL query that applies these changes. In addition, the subcatchments IDs shall be updated according to the naming convention defined in Section 2.7.3.

The step in Section Import SWMM Network to ICM Network in Section 10.2.2 will assign the Impervious Area % data from PCSWMM to Runoff area 1 (%), a value of 0% to Runoff area 2 (%), and the Pervious Area % data from PCSWMM to Runoff area 3 (%) for each subcatchment, as shown in the top InfoWorks ICM Subcatchment window in Figure 10-4**.** Subsequently, the Runoff areas 5 to 7 (%) shall be used to represent the pervious areas based on the infiltration potential of the soil located in each subcatchment.

Therefore, after transferring runoff area percentages from PCSWMM to InfoWorks ICM, it will be necessary to update the subcatchment Runoff area (%) fields with the appropriate % area values in the Subcatchment window, as shown in Figure 10-4. The Pervious Area % in Runoff area 3 (%) shall be removed and distributed to Runoff areas 5 to 7 (%) based on the infiltration potential of the soil located in each subcatchment. The modeller shall follow the instructions in Section *Runoff Area Percentages* in Section 4.7.5 to populate the appropriate Runoff area (%) field. Note, that the modeller may populate the User Text 8 field with the Infiltration Potential from the City's GIS database as prescribed in Chapter 4 and Table 4A-4, and this field may be used to automate the distribution of Pervious Area % in Runoff area 3 (%) to Runoff areas 5 to 7 (%) using SQL query.



Grid [Subcatchment] - Pilot_Existing_test

Subcatchment ID	Internal routing	Runoff routed internally (%)	Area measurement type	Runoff area 1 (%)	Runoff area 2 (%)	Runoff area 3 (%)	Runoff area 4 (%)	Runoff area 5 (%)	Runoff area 6 (%)	Runoff area 7 (%)
1206	To pervious	25.000	Percent	55.000	0.000	45.000	0.000	0.000	0.000	0.000
5	Direct	100.000	Percent	85.000	0.000	15.000	0.000	0.000	0.000	0.000
4094651	Direct	100.000	Percent	55.000	0.000	45.000	0.000	0.000	0.000	0.000

Grid [Subcatchment] - Pilot_Existing_test

Subcatchment ID	Internal routing	Runoff routed internally (%)	Area measurement type	Runoff area 1 (%)	Runoff area 2 (%)	Runoff area 3 (%)	Runoff area 4 (%)	Runoff area 5 (%)	Runoff area 6 (%)	Runoff area 7 (%)
1206	To pervious	25.000	Percent	55.000	0.000	0.000	0.000	45.000	0.000	0.000
5	Direct	100.000	Percent	85.000	0.000	0.000	0.000	0.000	15.000	0.000
4094651	Direct	100.000	Percent	55.000	0.000	0.000	0.000	0.000	0.000	45.000

Figure 10-4 Convert Subcatchment Percentage Representations to Areas

The modeller shall also check land use and Runoff surface IDs. The import from SWMM5 function may create land use and Runoff surface IDs for each subcatchment imported so it is necessary to clean up the extra land use and Runoff surface IDs:

- If the PCSWMM model is set up with standard runoff parameters for GreenAmpt infiltration by soil type according to the City's PCSWMM Modelling Guideline Section 5.1, the standard InfoWorks ICM land use ID and runoff surface IDs already included in the InfoWorks ICM Model Template Database shall be used. The modeller shall assign the same standard InfoWorks ICM land use ID for all subcatchments according to Appendix 4A Section 5 and Section 4.7.4, and delete all extra land use and runoff surface IDs imported.
- If the PCSWMM model has been calibrated and the subcatchment runoff parameters have been adjusted, the modeller shall create new land use IDs and the associated runoff surfaces IDs for each calibrated area instead of using the single standard land use ID. The set-up for new land use and runoff surface shall be consistent with the standards for land use and Runoff surfaces defined in Section 4.7.3 and 4.7.4 but reflect the calibrated parameters.

Dry weather flow and RTK parameters are defined at Junctions in PCSWMM and need to be transferred over to properties of sanitary and combined subcatchments in InfoWorks ICM. Section 10.2.2 and Table 10-2 provide guidance on importing these parameters as user number and user text fields of nodes via Data Import Centre. The modeller shall utilize these fields and transfer them to properties of sanitary and combined subcatchments, by following these steps:

- In PCSWMM, it is not necessary to have sanitary subcatchments because the dry weather flow and wet weather I/I are applied directly to the Junctions. However, for planning models in InfoWorks ICM, the modeller needs to create sanitary subcatchments to generate the equivalent dry weather flow and wet weather I/I. The modeller shall follow guidance in Section

4.8.3 on sanitary subcatchment configuration and create sanitary subcatchments in the InfoWorks ICM network.

- Distribute the baseflow to the subcatchments: to equally distribute the baseflow from the PCSWMM model (Baseline L/s defined at Junctions) to the subcatchments draining to the node, set the Baseflow (m^3/s) field of each subcatchment = subcatchment contributing area * node User number 8 (Baseline L/s) * (1 m^3 / 1000 L) / sum (contributing area) of all subcatchment draining to the node. Appendix 10B includes an SQL query that performs this step.
- Transfer the wastewater profile ID to the subcatchments: follow instructions in the Wastewater Patterns section below to create a wastewater event and transform the SWMM time patterns to InfoWorks ICM wastewater event. Once the wastewater profiles have been created in the wastewater event, the node User text 9 (Time Pattern) shall be replaced with the numerical ID of the corresponding wastewater profile. To transfer the wastewater profile ID to subcatchments, set subcatchment wastewater profile = node User text 9. Appendix 10B includes an SQL query that performs this step.
- Calculate per capita flow rate: The "Average value (L/s)" defined at Junctions in PCSWWM represents the average wastewater flow. In InfoWorks ICM, it is generated from population defined at subcatchment level which is coupled with the per capita rate in the wastewater event. Therefore, the modeller shall calculate the per capital flow in L/cap/day = node User number 9 (Average value L/s) * (86400 s/day) / sum (subcatchment population), and input this per capital flow to the corresponding wastewater profile. Appendix 10B includes an SQL query that replaces the node User number 9 (Average value L/s) with equivalent per capita flow rate.
- Transfer the RTK hydrograph ID to the subcatchments: Where RTK hydrographs have been applied at Junctions in PCSWMM, the import from SWMM5 function will create extra dummy subcatchments that carry the sewershed area and RTK hydrographs from PCSWMM. They can be easily identified because the "Total area" field will be blank. The modeller shall delete these dummy subcatchment. For all remaining subcatchments, set the RTK hydrograph ID of subcatchments = node User text 10 (Hydrograph). Appendix 10B includes an SQL query that performs this step.

10.2.3.5 Rainfall

Following the import procedure described in Section 10.2.2, the data from PCSWMM will be imported as part of the SWMM model group and appear as a rainfall event file shown in Figure 10-2. The rainfall event can be directly used with InfoWorks ICM for model simulation; no further conversion is required.

10.2.3.6 Wastewater Patterns

Following the import procedure described in Section 10.2.2, a SWMM time pattern file will be imported as part of the SWMM model group. However, InfoWorks ICM cannot use a SWMM time pattern for model simulation; therefore, an equivalent wastewater event will need to be created in InfoWorks ICM.

The modeller shall create a new wastewater event and copy-paste the peaking factors from the SWMM time pattern file to the wastewater file. Each wastewater profile shall be assigned a numerical ID ranging from 1 to 999 including a description.

The different types of time patterns in PCSWMM include monthly, daily, hourly, and weekend. The monthly, hourly, and weekend time patterns shall be transferred to Calibration Monthly, Calibration

Weekday, and Calibration Weekend profiles, respectively. The daily time patterns has a series of seven multipliers for each day of the week; however, these can not be transferred because InfoWorks ICM does not have such an option. Therefore, as a conservative approach, it is recommended that the modeller shall apply the greatest daily multiplier to the per capita rate associated with the wastewater profile.

An example is provided in Figure 10-5 where a wastewater profile with ID 1 is created for the "CC-FM-Ash" flow monitor. The "CC-FM1-Ash Hourly" time pattern is copied over to the Calibration Weekday profile and the "CC-FM1-Ash Weekend" time pattern is copied over to the Calibration Weekend profile.

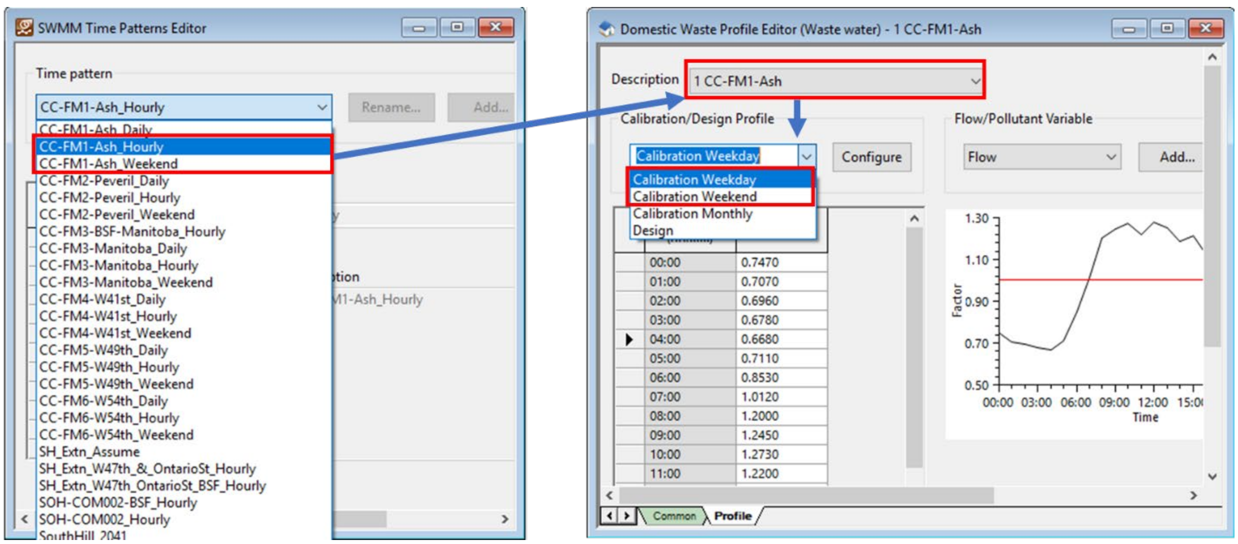


Figure 10-5 Convert SWMM Time Pattern to InfoWorks ICM Wastewater Profiles

10.2.3.7 Boundary Inflows and Levels

Direct inflows and levels at outfalls can be assigned using time series data in PCSWMM. The time inflow or level time series data in PCSWMM needs to be exported to a CSV file and imported into InfoWorks ICM.

Figure 10-6 shows the steps to import inflow or level data from CSV files. First, right-click on the model group and navigate to Import InfoWorks --> Inflow (or Level), and choose the "from generic csv file…" option. Select the CSV file in the pop-up window and the "Import Time Varying Data" window will appear. The "Import Time Varying Data" window will detect the data format and set the import region. The modeller shall review and adjust the settings in the "Import Time Varying Data" window and then click "OK". This will create an inflow (or level) file of the imported data. The imported inflow (or level) file shall be opened and compared with the data in the CSV file to confirm data import was successful.

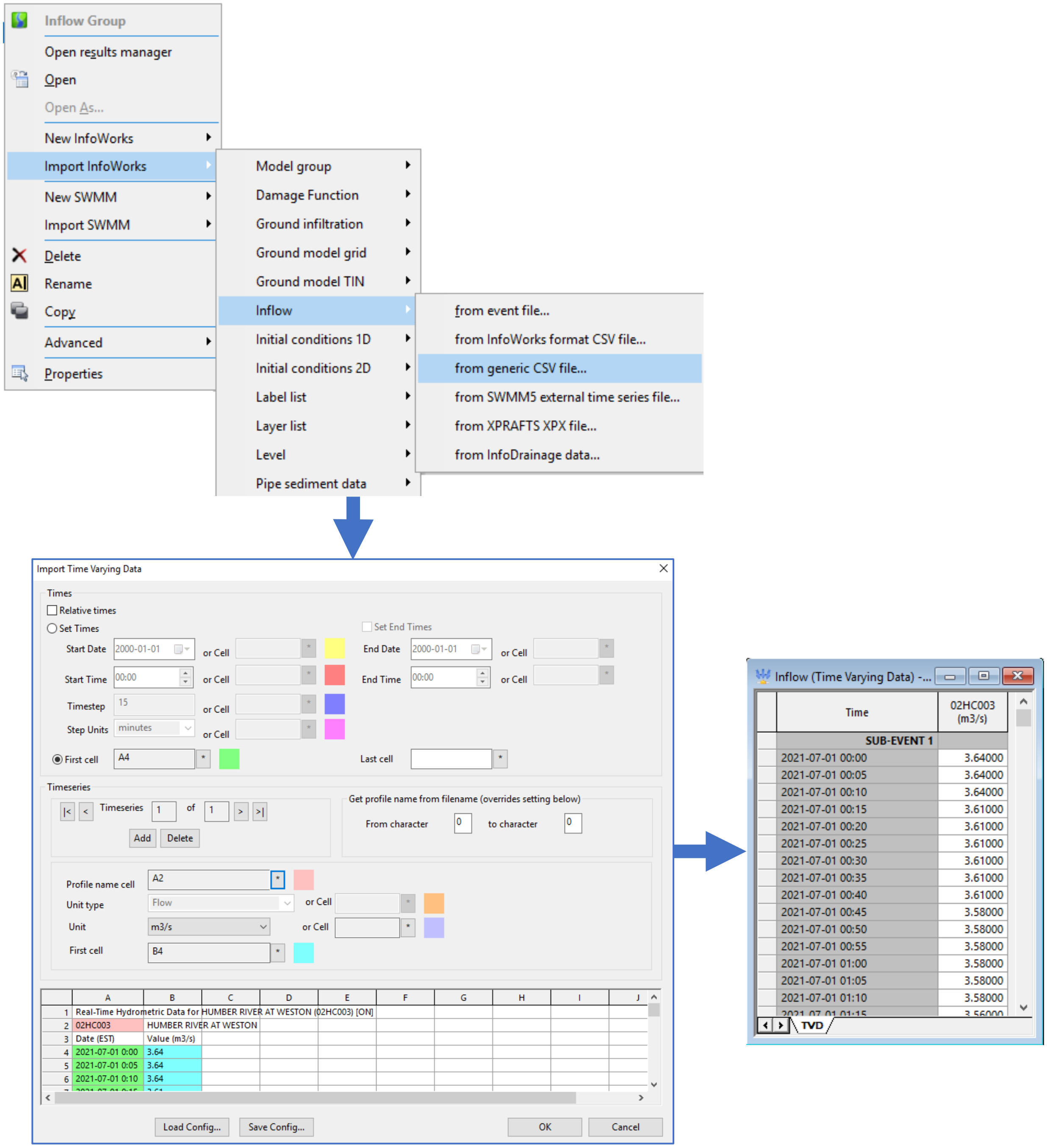


Figure 10-6 Import Inflow/Level from CSV Format Data

10.2.3.8 Model Network Connectivity

The modeller shall follow Step 1 through Step 4 in Section 2 Data Rectification Process of Appendix 4B to identify model connectivity issues or data errors in the converted model network.

Once validated, the converted model network can be saved and used for simulation. The InfoWorks ICM model simulation results shall be compared with the PCSWMM model, as outlined in the following section.

10.2.4 Comparison of Model Results

The final step of model conversion is to compare the InfoWorks ICM model simulation results to the PCSWMM model simulation results to confirm that the model conversion was successful. The modeller shall choose critical locations for comparison, including but not limited to:

- Flow monitoring locations, especially if calibrated in PCSWMM model;
- Upstream of a pumping station;
- Outfall to water bodies and connections to Metro Vancouver trunk sewers.

Both dry weather and wet weather flow comparisons shall be completed. For the dry weather comparison, if the PCSWMM model has been calibrated with a daily pattern, the weekday with the greatest daily multiplier shall be used for dry weather comparison (see Section ***Wastewater Patterns*** in Section 10.2.3); if the PCSWMM model has been calibrated without a daily pattern, the DWF calibration or verification period from the PCSWMM model shall be used; otherwise if the PCSWMM model was not calibrated, a full seven-day week period shall be used for dry weather comparison. For wet weather comparison, if the PCSWMM model has been calibrated, the calibration events shall be used for comparing model results; otherwise if the PCSWMM model was not calibrated, a 2-year design storm shall be used for wet weather comparison.

For the dry weather and wet weather comparison events, the simulated flow, depth, and velocity time series from the PCSWMM model shall be exported into CSV files. Note that the depth from the PCSWMM model results shall be calculated as the hydraulic grade line elevation minus the invert at a Junction.

The CSV files containing PCSWMM model results shall be imported into InfoWorks ICM as Flow Surveys. A Flow Survey, as introduced in Section 5.2.3, can be plotted in an Observed versus Predicted report. The modeller shall use the Observed versus Predicted report to compare simulation results of the PCSWMM model and the simulation results of the InfoWorks ICM model.

The criteria for comparing dry weather and wet weather results are provided in Section 10.2.5 and the process of verification is provided in Section 10.2.6.

10.2.5 Model Results Comparison Criteria

The modeller shall first compare and verify the dry weather flow results before proceeding with the comparison of wet weather flow. The Observed versus Predicted report shall be reviewed to compare hydrographs for each location selected for comparison.

Table 10-3 summarizes the criteria for dry weather flow comparison. The shape of the observed and predicted hydrographs are required to closely match. In addition, the flow and depth hydrographs shall meet the quantitative criteria in Table 10-3.

Once the dry weather flow is verified, the comparison shall also be completed for wet weather but according to the comparison criteria in Table 10-4. Section 10.2.6 provides guidance how to address when these comparison criteria are not met.

Table 10-3 Model Simulation Results Dry Weather Comparison Criteria

Parameter	Comparison Criteria
Shape	Good match
Time of peaks and troughs	± 15 minutes
Maximum depth	±5% if unsurcharged and ±10% if surcharged
Peak flow	±2%
Flow volume	±2%

Table 10-4 Model Simulation Results Wet Weather Comparison Criteria

Parameter	Comparison Criteria
Shape	Good match
Time of peaks and troughs	± 15 minutes
Maximum depth	±5% if unsurcharged and ±10% if surcharged
Peak flow	±5%
Flow volume	±5%

10.2.6 Verification of Model Conversion

The modeller shall document model conversion verification with the Observed versus Predicted report. If the criteria provided in Section 10.2.5 can be met for DWF and WWF, the model conversion is considered verified. If the criteria cannot be met, then additional troubleshooting or adjustment of model parameters may be necessary.

If the observed versus predicted plots do not match well, this indicates a discrepancy between the original and converted model networks. The modeller shall examine the model network upstream of the comparison location and troubleshoot in the converted model network prior to proceeding with modifying the runoff parameters.

If the observed versus predicted plots match well but the quantitative criteria are exceeded, the modeller shall adjust the following parameters in InfoWorks ICM:

- For dry weather flow, the per capita flow in the wastewater profile may be adjusted to meet the criteria.
- For wet weather flow, the impervious areas fixed runoff coefficient for storm and combined sewer system may be adjusted, or the RTK parameters in the case of a separated sanitary sewer system. The modifications are expected to be minor, typically between ±10% of the original values.

If the modeller is still not able to achieve the desired comparison criteria for DWF and WWF, a document with justification shall be completed. After converting and verifying the InfoWorks ICM model, the model shall further be updated to conform to the City's modelling standards as per Chapter 4.

10.3 Conversion from InfoWorks ICM to PCSWMM

This section provides a methodology to convert an InfoWorks ICM model to a PCSWMM model. For successful model conversion, the modeller shall familiarize themselves with the original InfoWorks ICM model and understand the key differences described in Section 10.1.

The City of Vancouver's PCSWMM Modelling Guide found in Appendix 10A shall be used in conjunction with this document, as it details City-specific standards for PCSWMM model configuration (e.g. simulation of pump stations, initial settings, etc).

Figure 10-7 outlines the process for model conversion from InfoWorks ICM to PCSWMM.

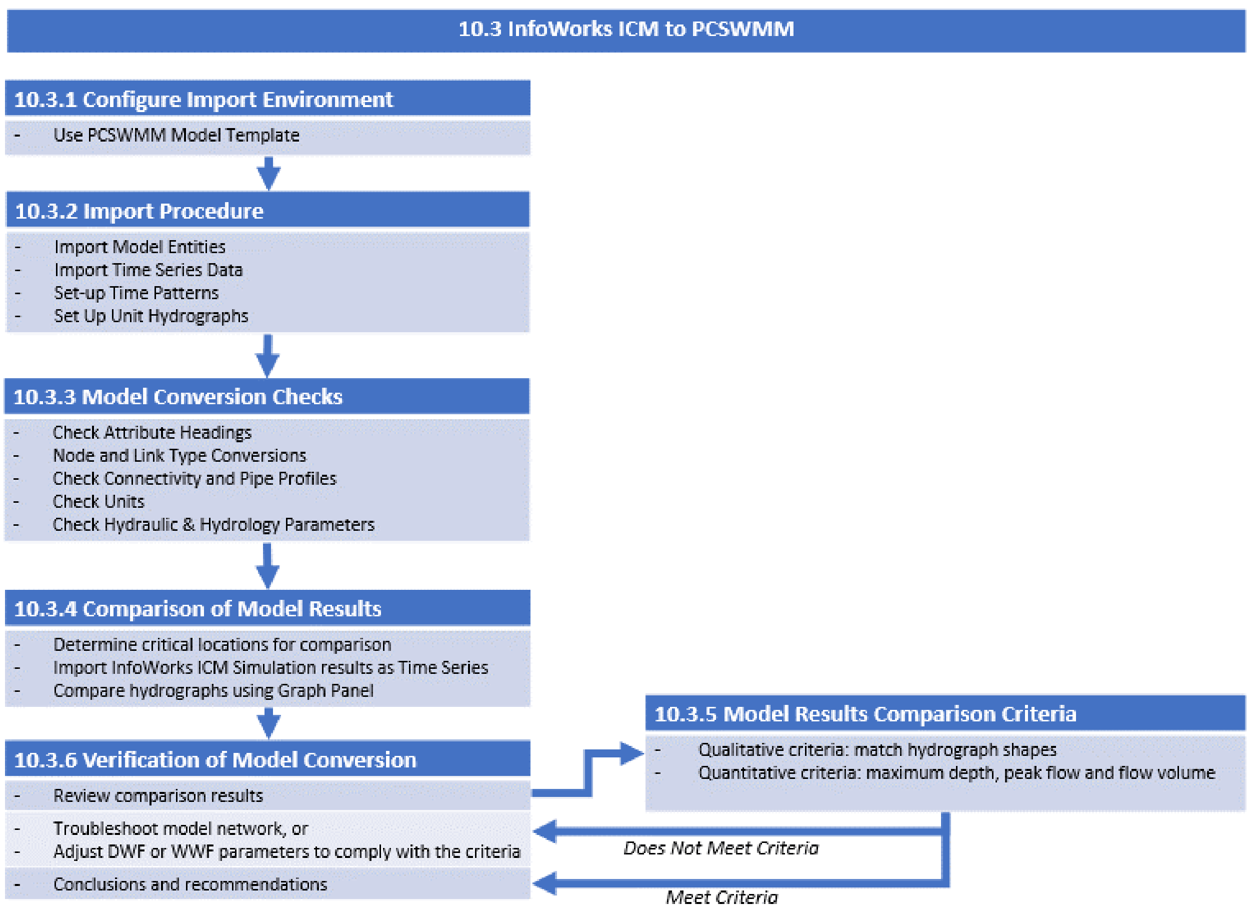


Figure 10-7 InfoWorks ICM to PCSWMM Model Conversion Process

10.3.1 Configure Import Environment

The modeller shall follow the City's PCSWMM Modelling Guide included in Appendix 10A and use the City's PCSWMM model template to configure a new PCSWMM model.

10.3.2 Import Procedure

An InfoWorks ICM network can be exported to a SWMM5 data format but PCSWMM recommends a GIS format (e.g. shapefiles) as the optimal choice for an intermediate format between the two modelling software.

The recommended approach for converting an InfoWorks ICM model to PCSWMM is to use shapefiles to transfer model network data, as detailed in the following subsections.

10.3.2.1 Prepare Inputs from InfoWorks ICM

The inputs required from the InfoWorks ICM model to be converted to PCSWMM include:

- Nodes, conduits, and subcatchments in shapefiles;
- Rainfall event file in CSV format;
- Boundary conditions (Inflow and Level event files) in CSV format; and
- Simulated hydrographs from the InfoWorks ICM model results in CSV format for model results comparison, which is further discussed in Section 10.3.4.

Nodes and conduits shall be exported from the InfoWorks ICM model to shapefiles using the Data Export Centre in InfoWorks ICM in a similar way to the Data Import Centre procedure in Appendix 4B.

For subcatchments, the InfoWorks ICM network shall be converted to a SWMM network first, then the subcatchments shall be exported from this SWMM network to a subcatchment shapefile. Converting an InfoWorks ICM network to a SWMM network will automatically extract the runoff parameters from the corresponding runoff surface IDs (e.g. Green Ampt infiltration). Note that this cannot be achieved by directly exporting the subcatchments to a shapefile from an InfoWorks ICM network.

To address the differences between the two modelling software highlighted in Section 10.1, configuration files are provided along with the City's InfoWorks ICM Model Template Database for exporting nodes, conduits, and subcatchments from InfoWorks ICM. These configuration files have been customized based on the required model attributes as per the City's PCSWMM Modelling Guide in Appendix 10A, including:

- ICM_to_PCSWMM_node_2023NOV.cfg
- ICM_to_PCSWMM_conduit_2023NOV.cfg
- ICM_to_PCSWMM_sub_2023NOV.cfg

10.3.2.2 Importing Model Objects

The nodes, conduits, and subcatchments shapefiles exported from InfoWorks ICM shall be imported into a PCSWMM model as per

Table 10-5 below. Note that additional processing of the shapefiles may be required and details are provided in Table 10-5.

Section 4.2 of the City's PCSWMM Modelling Guide in Appendix 10A details how to import the data from a shapefile and set up the attributes. The modeller shall follow the PCSWMM Modelling Guide and import the attributes accordingly.

Table 10-5 Model Object to Import to PCSWMM

Model Objects	Import Procedure
Junctions	All nodes exported to shapefile from InfoWorks ICM that have the "Node Type" field set to "Manhole" shall be imported into the Junctions layer in PCSWMM. However, before importing the shapefile to PCSWMM, a new field named "Average_WW_Flow" shall be created in the shapefile. This new "Average_WW_Flow" field shall be populated with a calculated average wastewater flow value. The "Average_WW_Flow" values shall be calculated by multiplying population with the corresponding per capital flow from the InfoWorks ICM Wastewater file using a VB Script in ArcPro's Field Calculator, as shown on Figure 10-8. The "Average_WW_Flow" values shall subsequently be imported to "Average value" field when importing to the Junctions layer in PCSWMM.
Outfall	All nodes with the Node Type set to "Outfall" exported from InfoWorks ICM shall be imported to the Outfalls layer in PCWMM.
Conduits	All conduits exported from InfoWorks ICM shall be imported to the Conduits layer in PCSWMM.
Subcatchments	Delete subcatchments in the InfoWorks ICM exported Subcatchments shapefile with Area of 0. These are the sanitary subcatchments that do not generate storm runoff but only generate dry weather flow and wet-weather I/I which are instead to be applied as inflows at Junctions in PCSWMM. The modeller shall follow the step described in Section ***Prepare Inputs from InfoWorks ICM*** in Section 10.3.2 and in the Junctions Row of this table to convert dry weather flow and wet-weather I/I to attributes of the Node shapefile. For the remaining subcatchments with Area > 0, import them into PCSWMM as a Subcatchments Layer.
Special Structures	The modeller shall verify if there are any special structures in the InfoWorks ICM model. The configuration for special hydraulic structures such as pumps, weirs, orifices, and sluice gates are different in InfoWorks ICM than in PCSWMM. Therefore, these shall be added and modelled separately in PCSWMM after importing the nodes, conduits, and subcatchments into PCSWMM. Refer to Section 4.3.for guidance on modelling special structures.

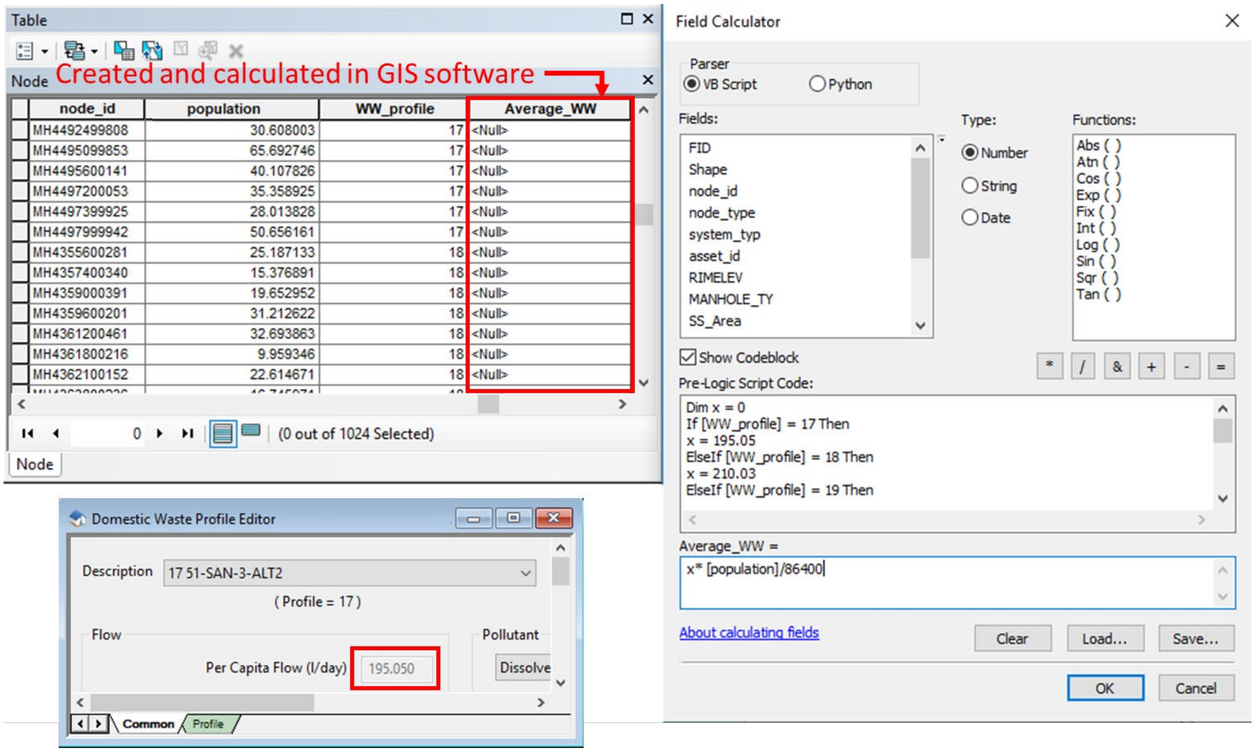


Figure 10-8 Calculate Average Wastewater Flow

10.3.2.3 Time Series Data

The following is a list of common table-based data (e.g. CSV format data) that can be imported into PCSWMM through the Time Series Manager:

- Flows (e.g. direct inflow values, measured flows, InfoWorks ICM simulated results)
- Rainfall Data
- Outfall Depths (boundary conditions)

The three steps below shall be followed to import time series data and assign them to the corresponding model object.

Step 1: Import CSV Data.

Tabular data can be imported via two methods:

- From the File Panel select Import --> Import Time Series; or,
- Copy the time series data and paste the data into the Graph Panel

Figure 10-9 shows where to access the Import Time Series window in the PCSWMM File Panel.

Figure 10-10 shows the Import Custom Time Series window in PCSWMM.

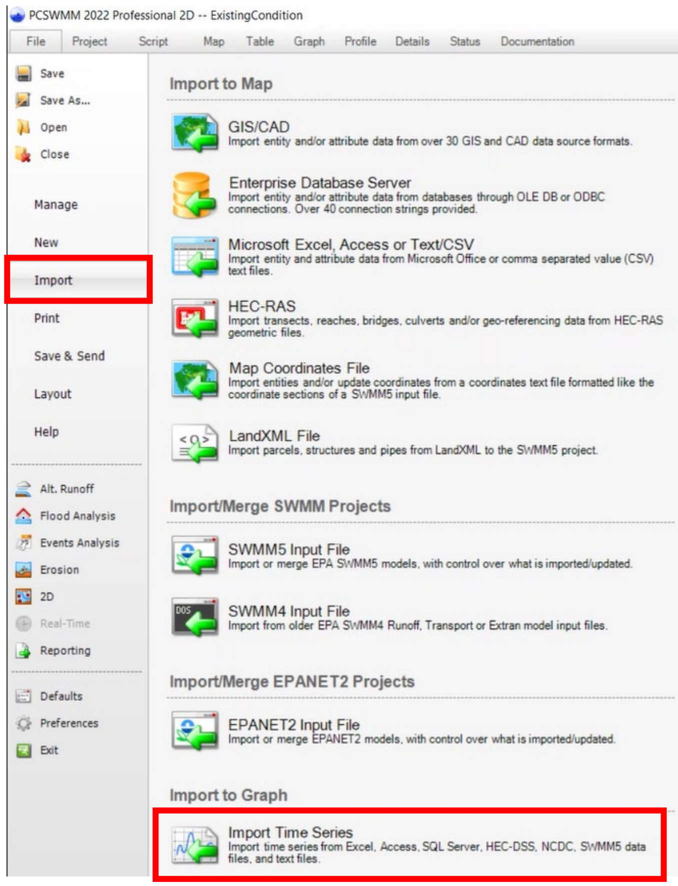


Figure 10-9 Location of Import Time Series Option

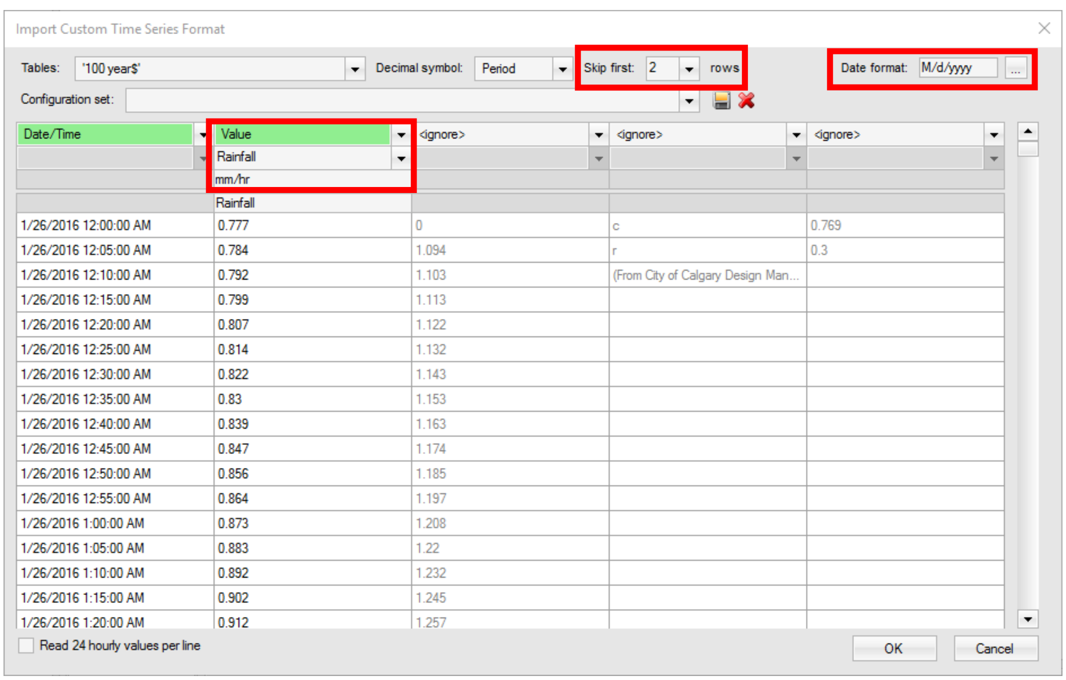


Figure 10-10 Import Time Series in PCSWMM

Key items to keep in mind during time series import:

- If the data table in the CSV file has headings, skip these rows by setting the "Skip first __ rows" box at the top of the window.
- If the data contains date and time data within the same cell, or delimiter, ensure the date format at the top right corner of the window is consistent with the input data. Alternatively, the date (day, month, year) and time data can each be input into separate columns.
- Ensure the appropriate Value and Units are selected in the dropdown menu of the Time Series Import.

Click 'OK' after the values and format have been set and the time series will be added into the Time Series Manager list under the Graph Panel. Right click on the time series in the Time Series Manager list to save the data as a Time Series File. A check to ensure the Time Series is saved properly is shown in Figure 10-11. When the Time Series icon is Red, it indicates that the data has not been saved.

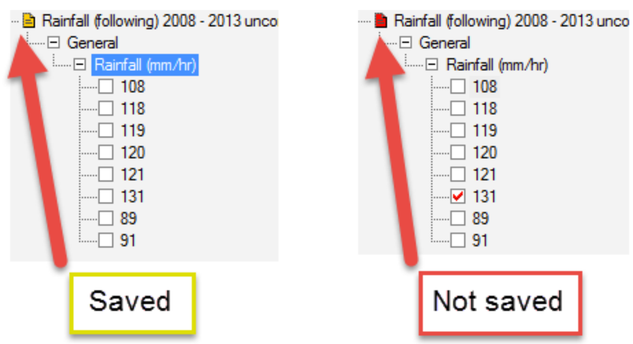


Figure 10-11 Saved Time Series Data

Step 2: Load Time Series into the Simulation Environment.

The saved Time Series files can be loaded into the model through the Time Series Editor in the Map Panel, as shown in Figure 10-12. Select "Use external data file named below …" to load the saved Time Series previously imported or copy and paste the time series data into the data table.

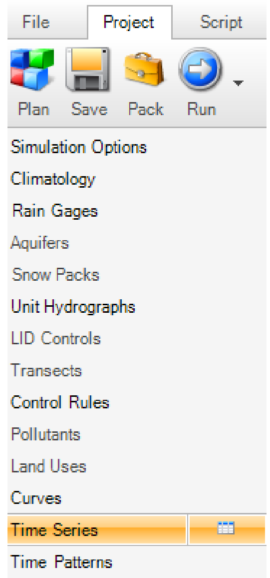


Figure 10-12 Add Time Series to Simulation Environment

Step 3: Assign Time Series to Model Object.

To assign a time series file to an Outfall, e.g. to represent a boundary level, select "Timeseries" as the Outfall Type in the Attributes table. Select "…" to bring up the Time Series window. Select the appropriate Time Series and "Assign to Outfall…".

To assign a time series to a Junction, e.g. direct inflow, select the Junction and click the "…" under Inflows --> Time Series in the Attribute Table. Select the appropriate Time Series and "Assign to Junction …".

Figure 10-13 shows the window where Time Series data are assigned to a junction.

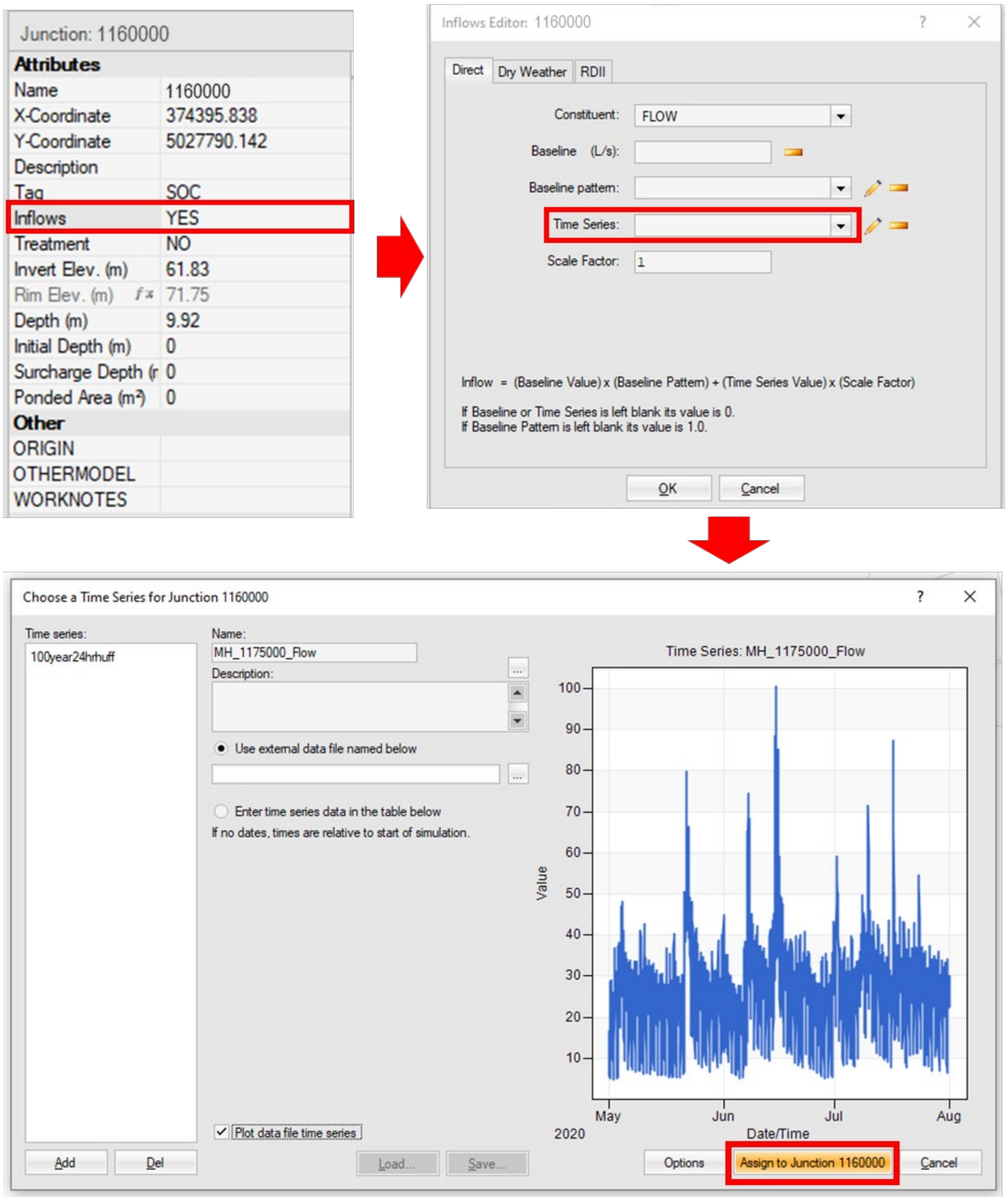


Figure 10-13 Assign Time Series to a Model Object

To assign a Time Series to a rain gage, select the Rain Gages Editor from the list of project editors under the Project Panel. Select "Add" to create a new rain gage and complete the following options. Figure 10-14 shows the window where Rainfall Time Series data can be assigned to a rain gage.

- Rain Format: units of the rain time series data
- Time Interval: the time interval of the rainfall data
- Data Source: Set to Time Series
- Series Name: Select "…" to load and assign a Rainfall Time Series

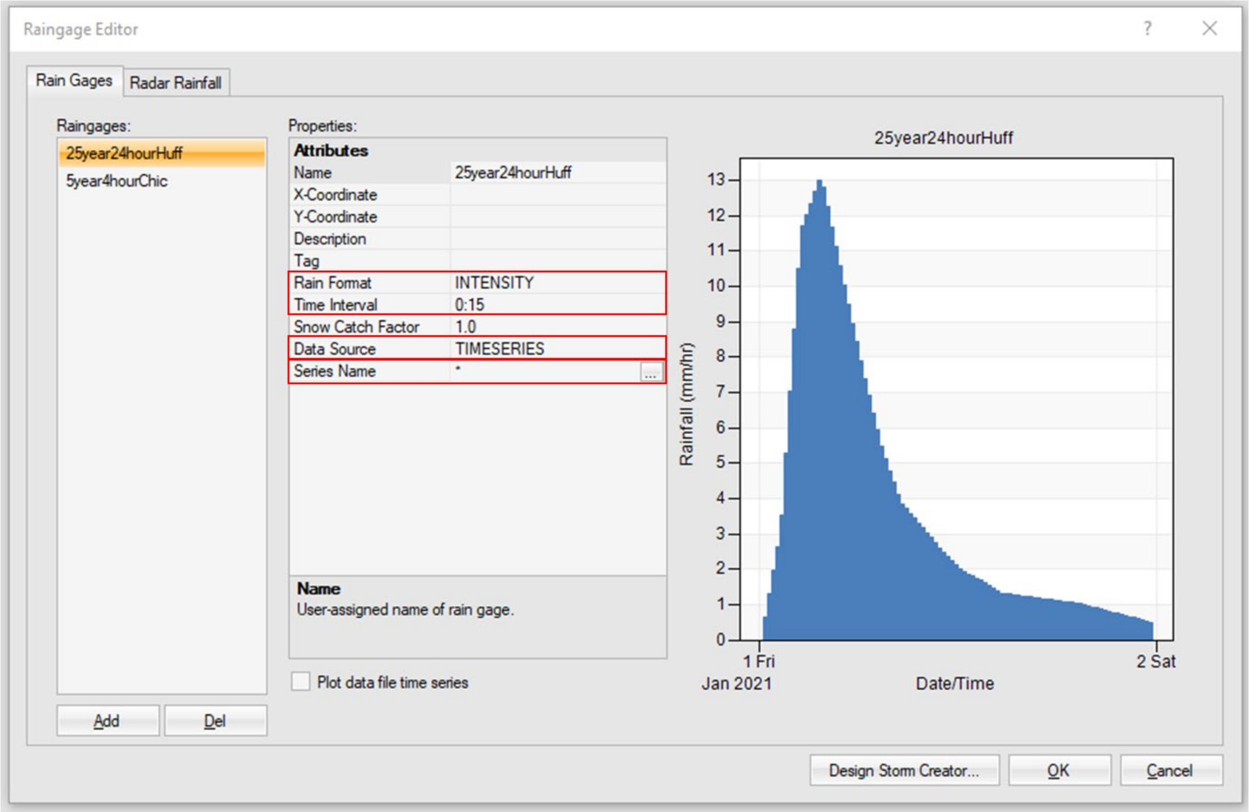


Figure 10-14 Assign Rain Gage

10.3.2.4 Time Patterns

Under the Project Panel, select the Time Patterns Editor and click "Add" to create a new time pattern and click "Type" to select the appropriate time step of the pattern, as shown on Figure 10-15. Paste the multiplier values into the table and click "OK". The modeller shall ensure that the naming convention of the time patterns correspond to the time patterns referenced in Junctions.

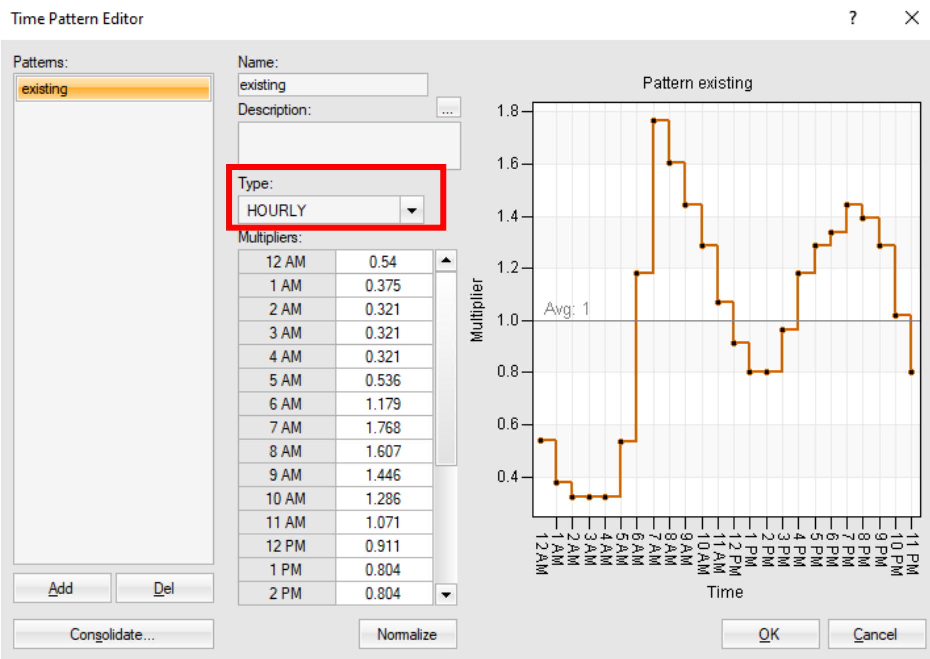


Figure 10-15 Add Time Patterns

10.3.2.5 Unit Hydrographs

Under the Project Panel, select the Unit Hydrographs Editor and click “Add” to create a new RTK Unit Hydrograph. Under the “Rain gage used:” select the applicable rain gage from the drop-down list and input the RTK values in the “Unit Hydrographs” table, as shown on Figure 10-16. The modeller shall ensure that the naming convention of the unit hydrographs correspond to the unit hydrographs referenced in Junctions.

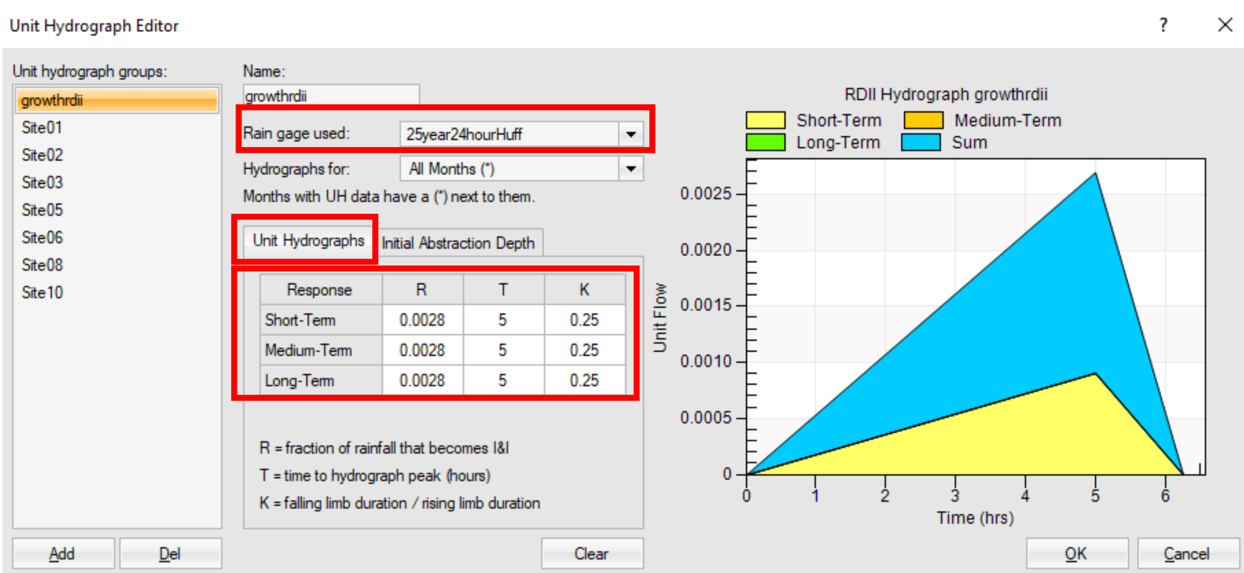


Figure 10-16 Add RTK Unit Hydrograph

10.3.3 Model Conversion Checks

The data imported from InfoWorks ICM into PCSWMM shall be checked and updated as needed. The following subsections provide a method to check and update imported data.

10.3.3.1 Attribute Headings

Some attributes within InfoWorks ICM may not be required in PCSWMM; however, the modeller may choose to import and store their data under a user defined attribute field. Note that PCSWMM attribute names are limited to 11 characters; therefore, attribute names imported from InfoWorks ICM with greater than 11 characters will be truncated upon import.

10.3.3.2 Node and Link Type Conversions

Using the Convert Tool, the type of node and link object can be converted. Nodes can be converted between Junction, Divider, Storage Unit, or Outfall as shown in Figure 10-17 below. Select and right-click the node and choose "Convert" from the drop-down menu, or select the node and choose "Convert" under the Menu option in the Attributes Panel.

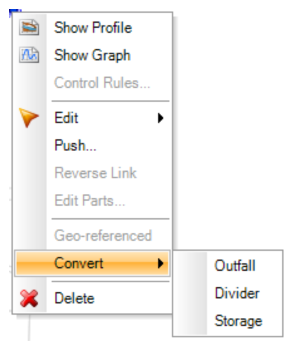


Figure 10-17 Convert Model Nodes

Links can be converted between Conduit, Weird, Pump, Orifice, or Outlet as shown in Figure 10-18 below.

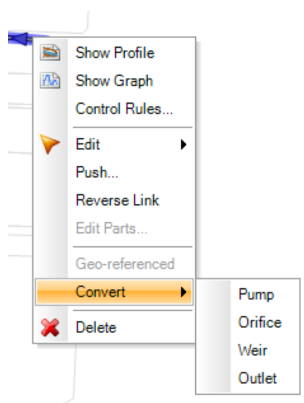


Figure 10-18 Convert Model Links

10.3.3.3 Connectivity and Pipe Profiles

Once the shapefiles have been imported into PCSWMM to build the model network, the network shall be reviewed for data gaps and checked for system connectivity. Sections 7.1 through 7.3 of the PCSWMM Modelling Guide in Appendix 10A details the processes and tools for checks and validations.

10.3.3.4 Units

The modeller shall check the units of imported attribute values into PCSWMM to ensure the correct units are used to represent the model object. For example, Subcatchment slopes in PCSWMM are represented as a percentage and not as a fraction. The Replace Tool in PCSWMM can be used to convert units, as described in Section 4.3 of the PCSWMM Modelling Guide in Appendix 10A.

Flow exported from InfoWorks ICM have units that have been set in InfoWorks ICM. Table 10-6 below summarizes the naming conventions differences for flow between InfoWorks ICM and PCSWMM.

Table 10-6 Unit Conversions between InfoWorks ICM and PCSWMM

InfoWorks ICM Flow Unit	SWMM5 Flow Unit
m^3/s	CMS
ft^3/s	CFS
L/s	LPS
MGD	MGD
US Gal/min	GPM

10.3.3.5 Hydraulic and Hydrologic Parameters

The imported hydraulic and hydrologic parameters in the PCSWMM model shall be verified for consistency with the hydraulic parameters in the InfoWorks ICM model. Additionally, the hydraulic and hydrologic parameter values in PCSWMM shall be checked for adherence to the City's standard values as outlined in Section 4 and Section 5 of the PCSWMM Modelling Guide in Appendix 10A, respectively.

10.3.4 Comparison of Model Results

The final step of model conversion is to compare model simulation results to verify that the converted model produces comparable results to the InfoWorks ICM model. The modeller shall select critical locations for comparison, including but not limited to:

- Flow monitoring locations, especially if calibrated in an InfoWorks ICM model;
- Upstream of a pumping station;
- Outfall to water bodies and connections to Metro Vancouver trunk sewers.

Both dry weather and wet weather comparisons shall be completed. If the InfoWorks ICM model was calibrated, the same period shall be used for dry weather comparison; otherwise if the InfoWorks ICM was not calibrated, a full seven-day week period shall be used for dry weather comparison. For the wet weather comparison, if the InfoWorks ICM model was calibrated, the same events shall be used for comparing model results; otherwise if the InfoWorks ICM was not calibrated, a 2-year design storm shall be used for wet weather comparison.

The simulated flow, depth, and velocity hydrographs from the InfoWorks ICM model shall be imported into PCSWMM as a Time Series as introduced in Section ***Time Series Data*** in Section 10.3.2. As a Time

Series, this data can be plotted in the Graph Panel to compare the PCSWMM simulation results to the InfoWorks simulation results.

The criteria for comparing dry weather and wet weather results are provided in Section 10.3.5 and the process of verification is provided in Section 10.3.6.

10.3.5 Model Results Comparison Criteria

The modeller shall first compare and verify the dry weather flow results before proceeding with the comparison of wet weather flow. The Time Series and Graph tools shall be used to review hydrographs for each location selected for comparison.

The modeller shall examine the simulation results between the original and converted model to ensure that the hydrographs closely follow each other and that the quantitative criteria in Table 10-7 and Table 10-8 for dry weather and wet weather are met. Section 10.3.6 provides guidance on addressing any non-compliances with this set of criteria.

Table 10-7 Model Simulation Results Dry Weather Comparison Criteria

Object Type – Parameter	Comparison Criteria
Conduit – Shape	Good match
Conduit – Time of peaks and troughs	± 5 minutes
Conduit – Peak flow	±4%
Conduit – Flow volume	±2%

Table 10-8 Model Simulation Results Wet Weather Comparison Criteria

Object Type – Parameter	Comparison Criteria
Conduit – Shape	Good match
Conduit – Time of peaks and troughs	± 15 minutes
Conduit – Peak flow	±5% if unsurcharged and ±10% if surcharged
Conduit – Flow volume	±5%

Additional parameters to be verified are outlined in Sections 7.4 and 7.5 of the PCSWMM Modelling Guide in Appendix 10A; it outlines processes and tools for checks and validations of the simulation run, e.g., total rainfall for subcatchments, and routing or runoff errors.

10.3.6 Verification of Model Conversion

The modeller shall document model conversion verification with the generated Time Series graphs and reports. If the criteria provided in Section 10.3.5 can be met for the converted PCSWMM model, the model conversion is considered verified. If the criteria cannot be met, then additional troubleshooting or model parameters adjustment may be necessary. Furthermore, the modeller shall document all adjustments made to achieve the criteria in Section 10.3.5.

If the hydrograph comparison do not suggest a good match, it indicates a discrepancy between the original and converted model networks. The modeller shall examine the model network upstream of the comparison location and troubleshoot the converted model network prior to proceeding with modifying the runoff parameters.

If the hydrograph comparison suggests a good match, but the quantitative criteria are exceeded, the modeller could make small adjustments to the parameters listed below in PCSWMM. Note that with properly converted and imported model objects and parameters, only minor adjustments are expected to be required. In the case where the dry weather and wet weather comparison criteria cannot be met, the modeller shall document a justification.

- For dry weather flow adjustments, the “Average value” field may be adjusted, using the Replace tool, to scale the ADWF from upstream sections.
- For wet weather flow adjustments in storm or combined sewer systems, the runoff coefficients may be adjusted. The modifications are expected to be minor, typically between ±10% of the original values.

For wet weather flow adjustments in separated sanitary sewer systems, the RTK parameters may be adjusted.

11 Live Modelling

Live modelling of urban drainage systems is a relatively new capability of InfoWorks ICM and it has not yet been widely used, although there has been more and more cases of successful implementation to provide flood warnings and optimize operations of the urban drainage system in real-time.

As the City's modelling strategy is evolving, it is intended to use the live modelling capability of InfoWorks ICM in the future. This Chapter sets foundations for the future implementation of live modelling using existing InfoWorks ICM models.

This chapter provides high-level guidance and recommendations for implementing a live model:

- Purpose and Benefits – provides an overview of the benefits of a live model.
- Live Modelling Requirements – explains the data and software requirements for implementing a live model.

11.1 Purpose and Benefits

A live model provides near real-time updates of the sewer system performance and forecasts of what will happen in the near future, based on past and current observations along with future rainfall predictions. It works in conjunction with real-time or forecast data and is set-up to automate the data ingestion, simulation, and analysis processes to modify operations for a desired outcome (e.g. optimize storage within collection system or at storage tanks).

Compared to planning models that are updated between master plans or study models that are updated as needed per project, a live model is updated constantly and allows managers and operators to utilize hydraulic modelling for real-time decision-making. It can offer various benefits for improving system operations by early identification of risks of flooding, blockages, and overflows, which provides knowledge and time for the City to take action to mitigate any impact and plan for operation and maintenance activities.

A live model can be used to achieve operations goals such as:

- reducing backups and street flooding
- reducing or eliminating combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs)
- managing/reducing energy consumption
- avoiding excessive sediment deposition in the sewers
- managing flows during a planned system disturbance (e.g., major construction) or during an unexpected system disturbance (e.g. major equipment failure or security related incidents)

Table 11-1 presents few case studies of live modelling applications.

Table 11-1 Case Studies of Live Modelling Applications

Case Study	Project Description	Alerts	Control Rules	Operator	Optimizer
Scottish Canals	Scottish Canals, Glasgow City Council, and Scottish Water looked for an innovative approach to address the historic surface water problems which prevented redevelopment of an area in the north of the city. A control system that uses remote sensor data and rainfall forecasts feeds into ICMLive was developed and applied. The system controls sluice gates to store up to 55,000 m^3 of runoff while the canal remains navigable; 110 hectares of land is now available for 3,000 new homes, shops, and business.	✓	✓	-	-
Anglian Water	The Southend final effluent conduits struggled to discharge into the long sea outfall at times of high tides and rainfall, and as a result, the flow escapes to overland, pollutes the beach, and potentially floods the road. Live modelling was used to predict when the flows in the final effluent will be large enough as well as high tide. This results in an email alert sent to the operations team who then dispatches on site to make the area safe. eto arrive at the TPS. This will allow for site teams to plan for temporary measures in order to cope with the increased flows.	✓	-	✓	-
Thames Water - Tideway Tunnel	Live modelling was used to forecast storm and sewer surges to ensure the safety of workers during the construction of the Thames Tideway Tunnel which has 40 connection points from the upper catchment. Depth loggers and model alerts were set up at each overflow to provide advanced warning of wet weather flow that is critical to the safety of construction crews.	✓	-	✓	-
Thames Water – Regatta London	There are 61 CSOs into the River Thames which cause pollution and safety hazards. With five-day forecast and by setting alert thresholds, live modelling was set up to forecast CSO spills.	✓	-		-

Figure 11-1 shows the concept of a live operational model using InfoWorks ICM.

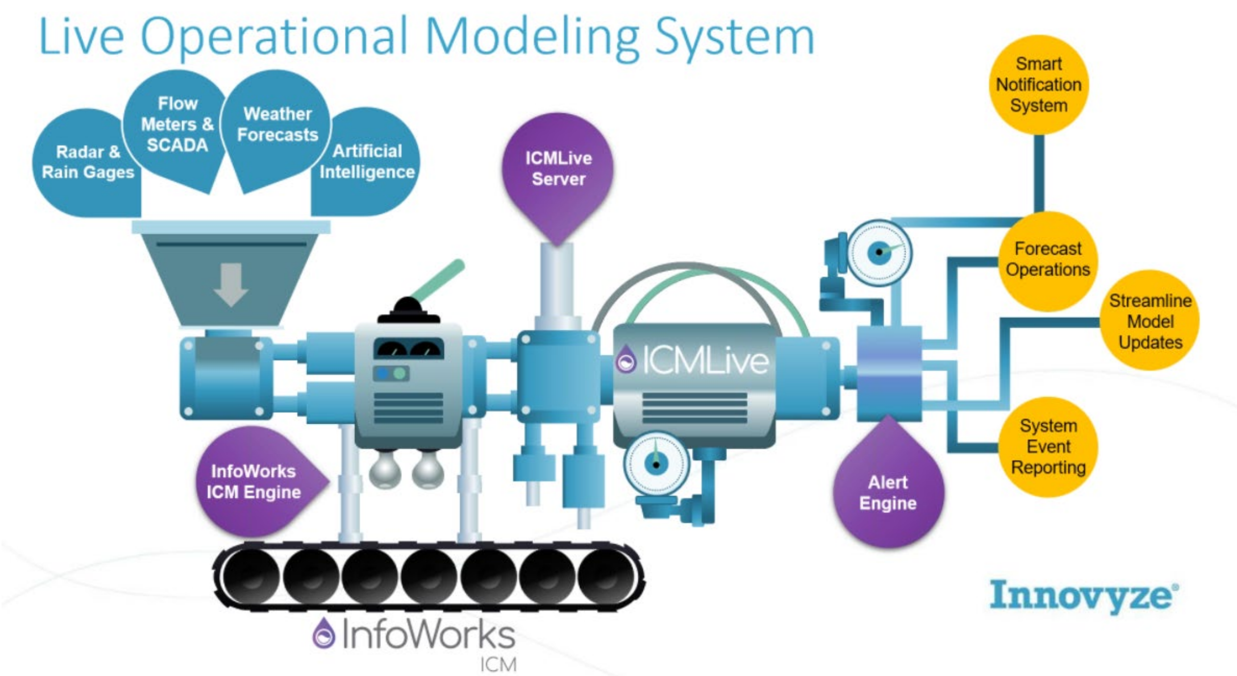


Figure 11-1 Schematic of a Live Operational Modelling System (Innovyze, 2021)

Depending on what the live is model is used for, it offers various benefits including:

1. Live and Forecast of System States
    - Alerts risks of surcharge, flooding, and overflows
    - Interrogate forecast conditions to support decision-making
2. Operational Management
    - Schedule pump operations
    - Evaluate and compare different control strategies
    - Optimize system storage
    - Continuous simulation
3. Maintenance Strategy
    - Improve understanding of system performance
    - Plan maintenance and repairs
    - Continuous improvement using data-driven decisions

11.2 Live Modelling Requirements

The live model will be driven by various input data that is ingested to perform modelling simulation, analyze system performance, and control system operations. Figure 11-2 shows an example of how a live modelling system is configured. The following subsections discuss the data and software required to support live modelling.

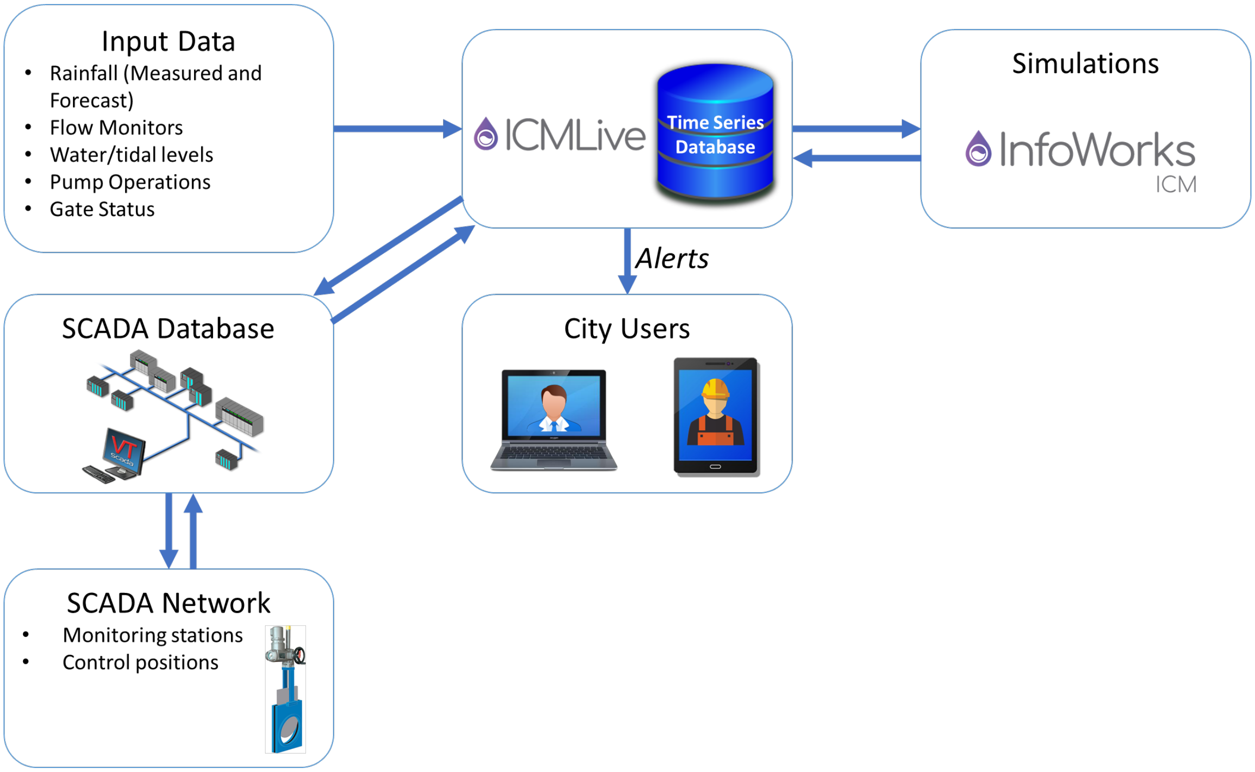


Figure 11-2 Living Modelling Configuration

11.2.1 Data Infrastructure Requirements

The input data required for live modelling will be collected using weather stations and flow monitors that may be maintained by different municipalities/agencies. The provision of monitors in the local sewer systems is an important component for the City to confirm model predictions and allow ongoing improvement in calibration. In addition, the live model can be used to control flows in the system by operating pumps and gates with additional infrastructure like SCADA systems. The following sections provides a brief overview of the data and infrastructure requirements.

11.2.1.1 Rainfall Monitoring and Forecasting

The live model requires rainfall data and also forecasting data depending on the proposed use of the model. The rainfall data will be fed into the live model for simulation, as shown on Figure 11-2. At a minimum, gauge adjusted radar rainfall (GARR) is required to provide a nowcast which is near real-time updates of the system, such that any incident occurrence can be quickly responded. However, rainfall forecasting in terms of radar data shall be used if it is necessary to provide some hours of advance warning of conditions for a large system like Vancouver, in order to take preventative actions such as emergency evacuation and preventing overflows.

11.2.1.2 Flow and Depth Monitoring

The provision of flow and depth monitors in the drainage system is an important system component to confirm the model predictions and allow ongoing improvement in calibration. Both permanent and temporary flow monitors can be used as data inputs. Permanent flow monitors with years of data will provide more reliability and confidence in the monitor measurements. Therefore, at critical locations such as CSO/SSO, it is recommended to establish permanent monitoring programs.

River hydrometric data and tidal level data, if available, can be useful to establish boundary conditions for the City's models, although the City's flow monitoring shall be primarily focused within the sewer network.

11.2.1.3 Other Data including SCADA

If the live model is to be used to control flows in the system by operating pumps and gates, then it will be necessary to have SCADA control capabilities at these facilities to allow real-time control (RTC) of the facilities in response to online measurements.

SCADA systems have become more and more prevalent in the wastewater industry for treatment plants and pump stations. The design and implementation of a SCADA system in detail would require a large document beyond the scope of this Modelling Standards. In short, to collect and manage monitoring data using a SCADA system, computers, data communication (wired or wireless), and GUIs are required components in addition to individual monitors and/or controllers. The City currently has SCADA systems for pump station and their components.

Operational information, if not already included in the SCADA data, such as manual gate operations, can also be taken into consideration of live modelling to conduit 'what-if' analysis.

11.2.2 Software Requirements

ICMLive is required to set up live modelling and operational modelling using an existing InfoWorks ICM model. The full functionality of ICMLive includes the following software programs:

- ICMLive Workgroup Data Server: this background process manages all interaction with the Workgroup database (network data, time series data etc).
- ICMLive Server: this is the background progress that is responsible for all automatic processes such as simulation scheduling and alert generation. It can be set up to send alerts via emails to desired recipients. It also communicates real-time system information to all connected Operator Clients.
- ICMLive Data Loader: this is the background process for processing any external data feeds (e.g. radar files) and adding the data into the Live system. It is an optional component and without it the simulations can be configured to process the external data feeds on a Just-In-Time basis.
- ICMLive Configuration Manager: this is an extension of InfoWorks ICM that enables the modellers to run and calibrate the network, create the ICMLive-specific objects which the Live system requires to operate, and deploy to the ICMLive Server.
- ICMLive Operator Client: this is the application that provides an interface for real-time monitoring of the current state of system, viewing simulation results and creating 'what-if' simulations.

Figure 11-3 shows a simple example of implementing ICMLive on multiple machines on the same organization network. In this example, several software components are installed on the server machine for efficiency, while the Configuration Manager and Operator Client can be installed across multiple machines (e.g. for modellers and operators).

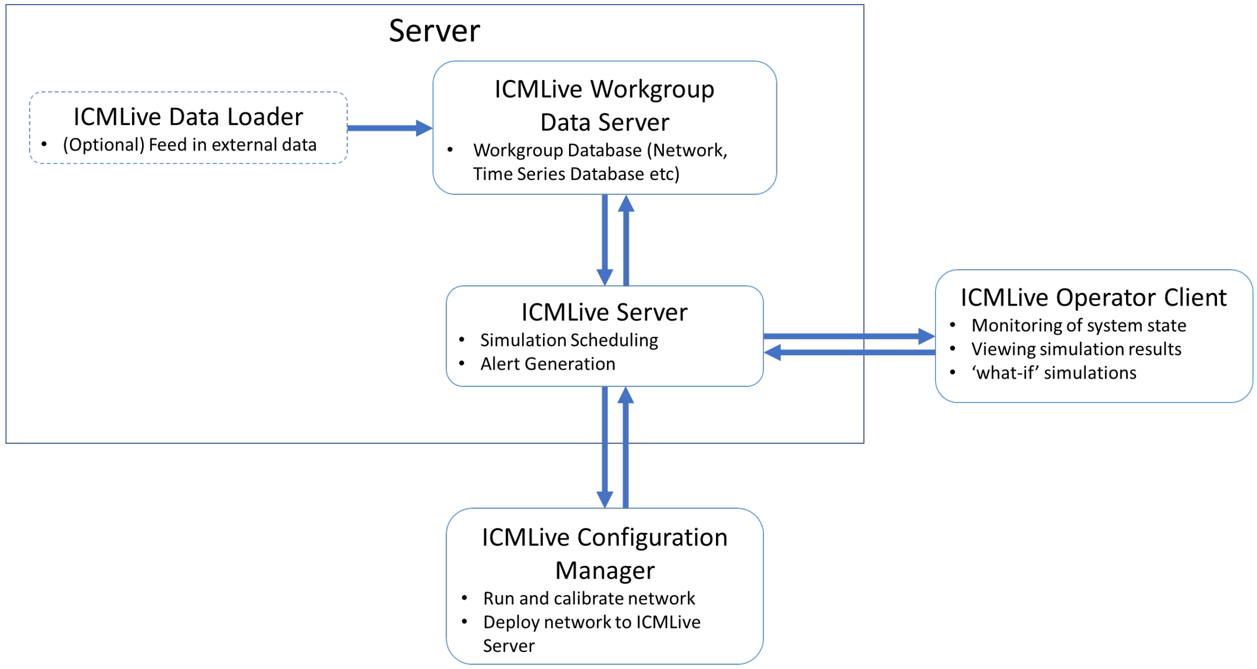


Figure 11-3 Implementation of ICMLive across Multiple Machines

Appendix 2A

InfoWorks ICM Model Groups

1 Model Groups

This Appendix provides descriptions for the individual model groups shown in Figure 2-4 in Section 2.4 and summarizes them in Table 2A-1. The Model Template Database provided along with this standard follows the same configuration shown in Table 2A-1. When new model data is added, the modeller shall follow this set-up and add data to the corresponding model group. Deviation from the set-up according to the template shall be discussed with and agreed by the City.

Table 2A-1 Model Database Items Management

Group	Description	Purpose	File-Folder Configuration
Flow Survey	Recorded flow monitoring rainfall, flow, depth, and velocity data.	Use in calibration comparison plots of observed versus modelled data.	Flow Survey Group May 2018 to Oct 2018 Observed depth event Observed flow event Observed velocity event Rainfall event
Observed vs Predicted Graph	Graphs of model predicted results (or more commonly referred to as simulated results) at flow monitor locations.	Use to display model results against observed flow data.	Observed vs Predicted Graph Group DWF_July 14 to 20, 2018 WWF_Aug 6, 2018
Inflow	A time-varying flow data set applied to designated nodes or links.	Used in place of sewage inflow or runoff hydrograph, if data exist.	Inflow Group Inflow_2-year Design Storm Inflow_Aug 6, 2018
Level	Water level data applied to designated nodes.	Use to represent water levels or HGL at boundary condition nodes.	Level Group Level_2-year Design Storm Level_Aug 6, 2018
Wastewater	Source of diurnal patterns and per capita rates for sanitary dry weather flow.	Use to apply population derived diurnal patterns and per capita flow rates.	Wastewater Group Waste water
Rainfall	Collection of time-based rainfall hyetographs in mm/h.	Use to apply rainfall to model runs.	Rainfall Group Synthetic Design Storms 2-year Design Storm 5-year Design Storm 100-year Design Storm Historical Events
Run	Collection of run files, each containing a model simulation configuration, that are linked to respective model networks.	Use to manage simulation input and model results files. Use to add simulation inputs such as model networks, rainfall events, inflow and level files to set boundary conditions. Controls to be adjusted include dynamic wave, reporting, and timestep parameters. After a run file is executed, result files will be placed under each run.	Run Group STUDY_EXISTING_2019_v3_DWF_July 14-20, 2018 STUDY_EXISTING_2019_v3_WWF_Aug 6, 2018 STUDY_EXISTING_2019_v3_WWF_2-year Design Storm

Group	Description	Purpose	File-Folder Configuration
Layer List	Series of background GIS layer lists.	Background visualization of various GIS layers.	GIS Layer List Parcels Streets Watercourses Floodplain
Ground Model	Terrain 3-D grid surface elevation model.	Visualize surface topography and can be used to infer ground elevations.	Groud Model Group LiDAR_2013_1x1m
Inference	Infers data for conduit head losses, invert elevations, and node ground elevations.	Use to estimate values from adjacent asset data when no other data sources are available. Flag appropriately to indicate inferred data.	Inference Group Headloss Ground Level Pipe Inverts
Selection List	A saved selection of various model objects.	Allows the quick selection or de-selection of network objects. Particularly useful in defining long-section profiles.	Selection List Group Trunk Sewers Alternative 1
SQL	Selects and manipulates model objects according to defined criteria.	Use to create specific selection sets or to update object field data.	SQL Group SQL - Validation Missing Ground Level Orphan Node Gravity Sewer with Negative Slope Gravity Sewer with Extreme Slope SQL - Model Results Review Node Freeboard <1.8
Statistics Template	A saved selection of statistical analysis of model results.	Useful for continuous simulation results analysis such as identifying CSO spill frequency, duration, etc.	Statistics Template Group Statistics template
Theme	User defined plan view themes to visualize model object parameters and model results.	Powerful visualization tool for use in model building, alternative development, and model results review.	Theme Group Node - Freeboard Link - Surcharge State

Appendix 3A

Data Collection Checklist

1 Data Collection Checklist

The quality and accuracy of collected data must be confirmed and commented on in the checklist by the modeller. Additional data requests shall be identified and documented in the checklist.

The checklist shall be used to document, and track collected data sources and shall be submitted to the City for review and approval. It will serve as a record of data collection activities by the consultant or internal City modelling staff.

Note: The checklist included in this standard is for information only. Refer to the corresponding RFP for each project/study for the correct forms to be submitted to the City.

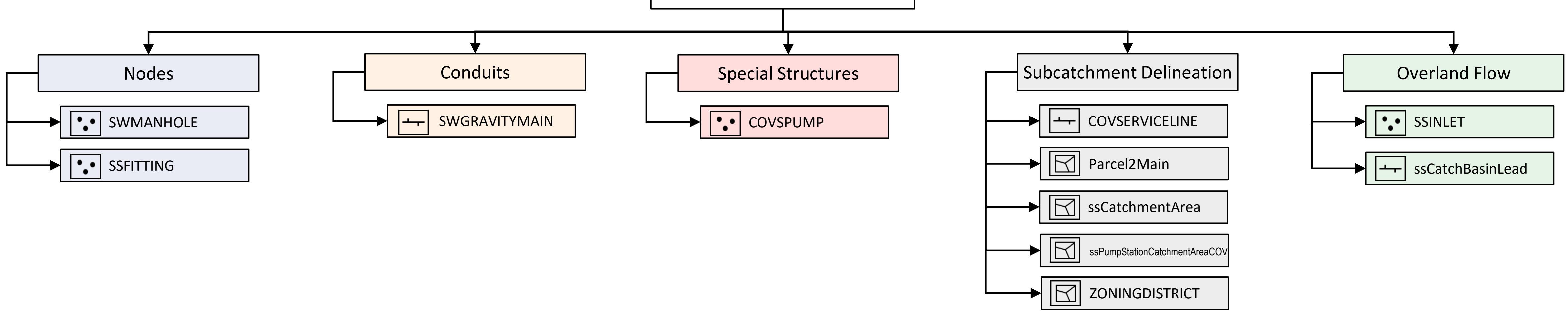
Data Collection Checklist			
Sec#	**Data**	**Received** (yyyy/mm/dd)	**Comments** (sufficient data / insufficient data / requires significant gap filling / requires some gap filling / requires additional data request / other comments)
2.1.1	**Base GIS Data**		
	• Property parcel	☐___/___/___	
	• Ortho photos	☐___/___/___	
	• Streets	☐___/___/___	
	• Building footprint	☐___/___/___	
	• Population (census and projection)	☐___/___/___	
	• LiDAR DEM or DTM	☐___/___/___	
	• Soil map	☐___/___/___	
	• Impervious surface area	☐___/___/___	
	• Zoning / Land Use	☐___/___/___	
	• Other (please specify in comments)	☐___/___/___	
2.1.2	**Sewer Asset Data**		
	• Maintenance Holes and fittings	☐___/___/___	
	• Sewers mains	☐___/___/___	
	• Service laterals	☐___/___/___	
	• Catch basins and catch basin leads	☐___/___/___	
	• Outfalls	☐___/___/___	
	• Pump stations	☐___/___/___	
	• Valves	☐___/___/___	
	• Weirs	☐___/___/___	
	• Separators	☐___/___/___``	
	• Other (please specify in comments)	☐___/___/___	
2.1.3	**Operation & Maintenance Data**		
	• Sewers Branch Maintenance Manual	☐___/___/___	
	• Historic work order logs	☐___/___/___	
	• CCTV records	☐___/___/___	
	• Pump station (SCADA) records	☐___/___/___	
	• Recent and planned sewer improvement works	☐___/___/___	
	Rainfall and Flow Monitoring Information		

Data Collection Checklist			
Sec#	**Data**	**Received** (yyyy/mm/dd)	**Comments** (sufficient data / insufficient data / requires significant gap filling / requires some gap filling / requires additional data request / other comments)
2.1.4	• Rain gauge locations	☐___/___/___	
	• Rain gauge data time series	☐___/___/___	
	• Flow monitor locations	☐___/___/___	
	• Flow Monitoring flow, depth and velocity time series (where available)	☐___/___/___	
2.1.5	**Other Supporting Data**		
	• Previous Studies (pdf or hard copy)	☐___/___/___	
	• InfoWorks ICM or PCSWMM Models related to the Assignment	☐___/___/___	
	• Geotechnical Reports	☐___/___/___	
	• Drain card information	☐___/___/___	
	• Other (please specify in comments)	☐___/___/___	

Appendix 3B

GIS Data Catalog

GIS Data Catalog



SWMANHOLE

Attributes for Modelling	Description
FACILITYID	Unique identifier
INSTALLDAT	Date the structure is installed
MHTYPE	Structure type
OWNEDBY	Ownership (37 is Metro, others are City)
WEIRELEVAT	Weir elevation
UNITDESCR	Notes about the manhole
EFLNTTYPE	Sewer system flow type (Storm/Combined/Sanitary)
FFLUSHDIA	First flush diameter
LEGACYID	Legacy ID before FACILITYID
RIMELEV	Ground Level
FIRSTFLUSH	Presence of first flush (Yes/No)
WEIR	Presence of weir (Yes/No)
LOCDESC	Location description
SERVSTATUS	Service status

SSFITTING

Attributes for Modelling	Description
TBFID	Unique identifier
INSTALLDAT	Date the structure is installed
FUNCTION_	Structure type
SERVICESTA	Service status
EFFLUENTTY	Sewer system flow type (ST/C/SAN)
OWNEDBY	Ownership

SWGRAVITYMAIN

Attributes for Modelling	Description
FACILITYID	Unique identifier
INSTALLDAT	Date the sewer main is installed
MAINSHAPE	Shape of sewer main
FROMMH	Upstream MH
TOMH	Downstream MH
OWNEDBY	Ownership
UPELEV	Upstream invert elevation
DOWNELEV	Downstream invert elevation
SLOPE	Slope pf sewer main
FLOWCAT	Flow category
WIDTH_MM	With of sewer main
DRAWNUMBER	Drawing number
PP_NUMBER	Plan and profile drawing number
LENGTH	Length of sewer main
LEGACY_ID	Legacy ID before FACILITYID
EFLNTTYPE	Sewer system flow type
DIAMETER	Diameter of sewer main
MATERIAL	Material of sewer main
DESCRIPTN	Notes about the sewer main
REMARKS	Notes about the sewer main

COVSSPUMP

Attributes for Modelling	Description
TBFID	Unique identifier
SERVICESTA	Service status
EFFLUENTTY	Sewer system flow type (ST/SAN)
FACILITYNA	Facility Name

Parcel2Main

Attributes for Modelling	Description
SL_Com_ID	ID of the sewermain that the Combined service is connected to, if any
SL_San_ID	ID of the sewermain that the Sanitary service is connected to, if any
SL_Storm_ID	ID of the sewermain that the Storm service is connected to, if any
Parcel_Service_Type	Service type of parcel
People_ per_Parcel	2016 Census population
JobsperParcel	2016 Census employment population
Zone_Base	Land use of parcel

COVSSSERVICELINE

Attributes for Modelling	Description
TBFID	Unique identifier
INSTALLDAT	Date the service line is installed
PIPESHAPE	Shape of service line
DIAMETERIN	Diameter of service line
SERVICESTA	Service status
PIPEUSE	Usage of service line
MATERIAL	Material of service line
EFFLUENTTY	Sewer system flow type (ST/C/SAN)

ZONINGDISTRICT

Attributes for Modelling	Description
ZONECLASS	Zoning district classification
ZONEDESC	Zoning district Description
ZONINGID	Unique identifier

SSINLET

Attributes for Modelling	Description
FACILITYID	Unique identifier
INSTALLDAT	Date the structure is installed
OWNEDBY	Ownership
SERVICESTA	Service status
NARRATIVE	Notes about the catchbasin
INLETTYPE	Catchbasin type

ssCatchBasinLead

Attributes for Modelling	Description
TBFID	Unique identifier
INSTALLDAT	Date the structure is installed
OWNEDBY	Ownership
SERVICE_ST	Service status
TB_LENGTH	Length of catchbasin lead
DIAMETER	Diameter of catchbasin lead
UP_INVERT	Upstream invert
DN_INVERT	Downstream invert
PP_NUMBER	Plan and profile drawing number
REMARKS	Notes about the catchbasin lead

SWMANHOLE - Coded Value Domain	
MHTYPE	
Code	**Description**
Chamber	Large chamber manhole
Cleanout	Cleanout small manhole
FirstFlush	Type of separator
GVS&DD	Owned and operated by Metro Vancouver
Lamphole	Small manhole to shine light in pipe to check for blockage
No	TBD
Observatio	Small manhole to visually inspect pipe but person cannot enter
Overflow	Type of separator
Separator	Type of separator
Silt Trap	Manhole with silt trap
STANDARD	Standard manhole (see standard specification drawings)
Sump	Manhole with sump
Type 1	Type of manhole chimney configuration (type 1 to 4 available)
Valve	TBD

SWMANHOLE - Coded Value Domain	
OWNEDBY	
Code	**Description**
37	Owned by City
0	Owned by Metro
17	Owned by Metro
20	Owned by Metro
34	Owned by Metro
35	Owned by Metro
36	Owned by Metro
38	Owned by Metro

SSFITTING - Coded Value Domain	
EFFLUENTTY	
Code	**Description**
ST	Storm
C	Combined
SAN	Sanitary

SSFITTING - Coded Value Domain	
FUNCTION_	
Code	**Description**
Air Vent	Air vent on pipe
Bend	Horizontal or vertical pipe direction change transition
Cap	Pipe end with cap
ChgGradeB	TBD
ChgGradeT	TBD
ChgMatl	Location of pipe material change
DummyNode	Not an actual fitting
Outfall	Outfall at end of pipe
Plug	Plug in a pipe to stop flow
Reducer	Transition for change of pipe size
Service	Access to pipe for service
ThrustBlk	Thrust block in pipe
Wye	Wye pipe transition

SWGRAVITYMAIN - Coded Value Domain		
MAINSHAPE		
Code	**Description**	**Normalized Name**
Round	Circular shape	CIRC
Box	Box shape	RECT
Rectangle	Rectangular shape	RECT
BHS	Basket-handle shape	HORSESHOE
Horseshoe	Horseshoe shape	HORSESHOE
Oval	Oval shape	OVAL
ARCHE	Arch shape	ARCH

SWGRAVITYMAIN - Coded Value Domain	
FLOWCAT	
Code	**Description**
Gravity	Gravity main
Forced	Forced main
Siphons	Siphons

SWGRAVITYMAIN - Coded Value Domain		
MATERIAL		
Code	**Description**	**Normalized Name**
MATERIAL	**PIP_MAT**	**MAT_ICM**
BR	Brick	BRICK
AC	Asbestos Cement	AC
CLAY	Clay	CLAY
VC	Vitrified Clay	CLAY
VIT	Vitrified Clay	CLAY
VTCLAY	Vitrified Clay	CLAY
VCP	Vitrified Clay	CLAY
BHS (boston horseshoe)	Concrete	CONC
BR/CON	Brick and Concrete	CONC
C	Concrete	CONC
CL3R.C (class3 reinforced concrete)	Concrete	CONC
CONC	Concrete	CONC
CPP	Cured in place pipe	CONC
MPC (meyer polymer concrete)	Concrete	CONC
RC	Reinforced Concrete	CONC
RC-BHS (reinforced concrete boston horseshoe)	Reinforced concrete	CONC
RC/VC	Reinforced Concrete and Vitrified Clay	CONC
CS	Corrugated Steel	CSP
HDPE	High Density Polyethylene	HDPE
HDPE3	High Density Polyethylene	HDPE
CI	Cast Iron	IRON
DI	Ductile Iron	IRON
DIP	Ductile Iron	IRON
3WR	Plastic	PLAS
FR (fibreglass reinforced)	Plastic	PLAS
FRP fFibreglass reinforced pipe)	Plastic	PLAS
PE (polyethylene)	Plastic	PLAS
POLY	Polyethylene	PLAS
PVC	Polyvinyl Chloride	PLAS
PVC-BB (blue brute)	Polyvinyl Chloride	PLAS
PVCP	Polyvinyl Chlordie	PLAS
SCLAIR	Plastic	PLAS
ULTRIB	Polyvinyl Chloride	PLAS
PRPVC	Polyvinyl Chloride	PLAS
ARMCO	Steel	STEEL
S	Steel	STEEL
ST	Steel	STEEL
STEEL	Steel	STEEL
STEEL	Steel	STEEL
SP	Steel Pipe	STEEL
SS	Steel	STEEL
n/a	Unknown	UNKWN
WS	Wood Stave	WOOD

Pipe Material Manning's n	
Normalized Name	**Manning's n**
MAT_ICM	**N_TOP / N_BOTTOM**
CONC	0.013
PLAS	0.013
CLAY	0.013
STEEL	0.013
CSP	0.024
HDPE	0.013
IRON	0.013
WOOD	0.013
BRICK	0.013
UNKWN	0.013
AC	0.013

ZONINGDISTRICT - Coded Value Domain		
ZONEDESC		
Code	**Description**	**Normalized Name**
BCPED	Comprehensive Development	Comprehensive Development
C	Commercial	Commercial
CD	Comprehensive Development	Comprehensive Development
CWD	Comprehensive Development	Comprehensive Development
DD	Comprehensive Development	Comprehensive Development
DEOD	Comprehensive Development	Comprehensive Development
FC	Commercial	Commercial
FCCDD	Comprehensive Development	Comprehensive Development
FM	Multiple Dwelling	Multi-Family Residential
FSHCA	Other	Comprehensive Development
HA	Historical Area	Historic Development
I	Industrial	Industrial
IC	Industrial	Industrial
M	Industrial	Industrial
MC	Industrial	Industrial
RM	Multiple Dwelling	Multi-Family Residential
RS	One-Family Dwelling	Single Family Residential
RT	Two-Family Dwelling	Single Family Residential
TBA	TBD	Institutional

Appendix 3C

Data Gap Identification

Refer to Excel Spreadsheet Entitled

"Appendix_3C_Gap_Identification_Template _2023NOV.xlsm"

Appendix 4A

InfoWorks ICM Model Template Database Configuration

APPENDIX 4A InfoWorks ICM Model Template Database Configuration

This Appendix contains the configuration of the City's Model Template Database and shall be used for all new City InfoWorks ICM models. The Model Template Database is pre-configured with City standard data flags, user defined fields, runoff surfaces, land use, and other City standard model configurations.

The Model Template is available in a Transportable Database (.icmt) file format and is accompanied by GIS data import configuration files (*.cfg) and data flag, runoff surface, and land use table CSV files.

File naming conventions for all modelling standards documents and files contain a suffix date.

When any updates are made to **either** the modelling standards, appendices, appendix Excel files, runoff surface/land use/data flag table CSV files, model configuration files, or the Model Template Database, so shall the suffix dates of all aforementioned documents and files be updated to reflect the same date; **future updates** should incorporate the format of "_yyyymmdd", e.g. "_20240501".

In other words, any update is considered a complete version update to the entire modelling standards package.

Note that a change log shall be maintained for each version update.

1 Data Flags

A list of flags to be used for City models has been provided in the table below. These data flags have been incorporated into the Model Template Database. A model_template_flags_2023NOV.csv table file has been prepared to easily make changes and future version updates to the Model Template by importing the table.

Table 4A-2 InfoWorks ICM Model Data Flagging Standard

Flag	Description	Color (RGB)
#A	Imported asset data from City's geodatabase. Used to represent fields that were brought in directly from the asset geodatabase.	Light green 200/240/200
#D	Model default. To indicate when a value is defined by a default or in the case of Length, is automatically calculated.	Light blue 166/202/240
#G	Data from Geoplan. Used when values are calculated within InfoWorks ICM based on background GIS layers (population, area take-off, etc.)	Jade Green 80/240/120
#I	Model import – imported from another InfoWorks ICM model	Sand 240/190/60
#V	CSV import – imported from an outside data source through CSV	Orange 255/128/0
A1	Alternative 1	Pink 255/128/128
A2	Alternative 2	Brown 199/87/50
AB	As-Built archived drawing source. Where a historic engineering drawing indicates the information is as-recorded or as-built.	Light Orange 255/210/165

Flag	Description	Color (RGB)
AD	As-Designed archived drawing source. Where historic engineering drawing is not labelled as as-recorded or as-built.	Light Purple 150/150/200
AS	Assumed data - no reference; dummy placeholder in non-critical areas	Red 255/50/50
CA	Parameter values adjusted during model calibration. This may apply to Manning's n and impervious surface adjustments, etc.	Yellow 255/255/0
CCTV	Data from CCTV surveys.	Light Grey 218/218/218
PS	Preferred solution	Green 115/255/115
FP	Future population	Purple 128/0/255
IN	Inferred or interpolated data	Magenta 240/135/252
MG	Based on modelling guidelines	Gold 255/177/100
OM	Operational data, e.g., SCADA	Olive Green 110/130/50
SWMM	Imported from PCSWMM model	Navy blue 26/92/192
RF	Roof - additions/modifications related to simulating roof runoff	Light Yellow 255/255/128
SD	Surveyed field data, includes geodetic, laser, tape	Turquoise 0/255/255

2 User Defined Fields

Below are the User Defined Fields required for each model object. The User Defined Fields in the tables below shall be part of the base data structure for City models. These fields have been incorporated into the Model Template Database.

Table 4A-3 User Defined Fields for Manholes and Fittings in Nodes

InfoWorks Object Field	Heading for User Defined Field	Data Source
User Number 1	Depth of MH (m)	SQL
User Number 2	No. of CBs Connected	Sewer Asset Data/Field Survey
User Number 3	Ownership MH (37 = City; others = Metro) [1]	Sewer Asset Data
User Text 1	Date of Construction [1]	Sewer Asset Data
User Text 2	Structure Type [1]	Sewer Asset Data
User Text 3	Legacy ID	Sewer Asset Data
User Text 4	Drawing Reference	Sewer Asset Data
User Text 5	Model Notes [2]	Modeller's input
User Text 6	Street Name	GIS/Modeller's input

InfoWorks Object Field	Heading for User Defined Field	Data Source
User Text 7	Solution Type [3]	Modeller's input
User Text 8	Project ID [3]	Modeller's input
User Text 9	Ownership (Fittings & Valves)	Sewer Asset Data

1. These fields are common to Manhole and Fitting GIS data.

2. InfoWorks ICM also has a "Notes" field as part of model object properties. However, the modeller shall use this User Text field to enter notes if needed for a specific model object. If the notes exceed the 100-character limit for a User Text field, then the modeller shall enter "See Notes field" in this User Text field and insert notes to the Notes field.

3. These fields may be applicable to design models only. The Solution Type field is reserved for documenting the purpose of solutions/designs for proposed sewer system, e.g., "new MH" or "new CBs" etc. The Project ID field is reserved for tracking the ID of one project or one assignment. A project or assignment is a combination of several solutions that need to be implemented together due to hydraulic connectivity or proximity in geographic locations.

Table 4A-4 User Defined Fields for Conduits in Links

InfoWorks Object Field	Heading for User Defined Field	Data Source
User Number 1	Pipe Length (m)	Sewer Asset Data
User Number 2	Pipe Slope	Sewer Asset Data
User Number 3	Ownership (37 = City; others = Metro)	Sewer Asset Data
User Text 1	Date of Construction	Sewer Asset Data
User Text 2	Flow Category	Sewer Asset Data
User Text 3	Legacy ID	Sewer Asset Data
User Text 4	Drawing Reference	Sewer Asset Data
User Text 5	Comment	Sewer Asset Data
User Text 6	Material	Sewer Asset Data
User Text 7	Model Notes [1]	Modeller's input
User Text 8	Street Name	GIS Layer/Modeller's input
User Text 9	Solution Type [2]	Modeller's input
User Text 10	Project ID [2]	Modeller's input

1. InfoWorks ICM also has a "Notes" field as part of model object properties. However, the modeller shall use this User Text field to enter notes if needed for a specific model object. If the notes exceed the 100-character limit for a User Text field, then the modeller shall enter "See Notes field" in this User Text field and insert notes to the Notes field.

2. These fields may be applicable to design models only. The Solution Type field is reserved for documenting the purpose of solutions/designs for proposed sewer system, e.g., "conveyance upgrade", "flow reversal" or "inline storage" etc. The Project ID field is reserved for tracking the ID of one project or one assignment. A project or assignment is a combination of several solutions that need to be implemented together due to hydraulic connectivity or proximity in geographic locations.

Table 4A-5 User Defined Fields for Subcatchments

InfoWorks Object Field	Heading for User Defined Field	Data Source
User Number 1	Parcel ID	Sewer Asset Data
User Number 2	Outlet MH FACILITYID	Sewer Asset Data
User Text 1	Service connection type	Parcel2Main Database/GIS Layer
User Text 2	Zoning category	Parcel2Main Database/GIS Layer
User Text 3	Land use	Parcel2Main Database/GIS Layer
User text 4	Catchment type	Parcel2Main Database
User text 5	Civic number	Parcel2Main Database/GIS Layer
User text 6	Street name	Parcel2Main Database/GIS Layer
User Text 7	Model Notes [1]	Modeller's input

InfoWorks Object Field	Heading for User Defined Field	Data Source
User Text 8	Infiltration Potential	INFIL_POTE

1. InfoWorks ICM also has a “Notes” field as part of model object properties. However, the modeller shall use this User Text field to enter notes if needed for a specific model object. If the notes exceed the 100-character limit for a User Text field, then the modeller shall enter “See Notes field” in this User Text field and insert notes to the Notes field.

Table 4A-6 summarizes a list of user defined fields to be populated for special structures modelled as links with the type: weir, orifice, flap, sluice, pump, culvert inlet, culvert outlet, and channel.

Table 4A-6 User Defined Fields for Special Structure Links

InfoWorks Object Field	Heading for User Defined Field	Data Source
User Number 1	Metro Trunk System (Yes =1; No =0)	SQL/ Modeller’s input
User Text 1	Asset ID	Sewer Asset Data
User Text 2	Facility Name	Sewer Asset Data / Modeller’s input
User Text 3	Drawing Reference	Sewer Asset Data / Modeller’s input
User Text 4	Maintenance Manual Reference	Modeller’s input
User Text 5	Model Notes [1]	Modeller’s input

1. InfoWorks ICM also has a “Notes” field as part of model object properties. However, the modeller shall use this User Text field to enter notes if needed for a specific model object. If the notes exceed the 100-character limit for a User Text field, then the modeller shall enter “See Notes field” in this User Text field and insert notes to the Notes field.

3 Import Configuration Files

A total of five import configuration files are provided with the InfoWorks ICM Model Template Database. These configuration files shall be used to map GIS import layer fields to InfoWorks ICM data fields during the import process using the Data Import Centre.

The modeller shall follow the instructions provided in Appendix 4B on how to load the configuration files into the Data Import Centre.

Configuration files:

1. clip_manholes_2023NOV.cfg
2. clip_fittings_2023NOV.cfg
3. clip_sewermains_2023NOV.cfg
4. stmCatch_2023NOV.cfg
5. sanCatch_2023NOV.cfg

Additionally, three PCSWMM to ICM import configuration files are provided with the InfoWorks ICM Model Template Database. These configuration files shall be used to import PCSWMM fields to InfoWorks ICM via the Data Import Centre to support the conversion of PCSWMM models into InfoWorks ICM. The modeller shall refer to Chapter 10 for more information and instruction regarding the PCSWMM conversion.

PCSWMM Configuration files:

1. PCSWMM_to_ICM_node_2023NOV.cfg
2. PCSWMM_ to_ICM_conduit_2023NOV.cfg
3. PCSWMM_to_ICM_sub _2023NOV.cfg

4 Runoff Surfaces Version Update Table

The standard runoff surfaces definitions may be subject for review and update if additional information provide a strong basis. Note that the standard runoff surfaces are not intended to be updated on a per project basis and modellers shall use the Model Template Database as provided without modification. Future Model Template Database version updates shall be reviewed and approved by the City.

The City's standard runoff surfaces as shown in Section 4.7.3 Table 4-26 have been incorporated into the Model Template Database. An icm_runoff_surfaces_2023NOV.csv table file has been prepared to easily make changes and future version updates to the Model Template Database by importing the table.

To import the runoff surfaces with the CSV file, use the Data Import Centre. In the Data Import Centre, click "Auto-Map" to map the CSV attribute fields with the InfoWorks ICM runoff surfaces fields and proceed with the import.

Table 4A-7 Runoff Surface Property Table

Runoff surface ID	Description	Runoff routing type	Runoff routing value	Runoff volume type	Surface type	Ground slope	Initial loss type	Initial loss value (m)	Routing model	Fixed runoff coefficient	Green-Ampt suction	Green-Ampt conductivity	Green-Ampt deficit	Initial Loss Porosity
10	Parcels	Abs	0.018	Fixed	Impervious	0.01	Abs	0.00125	SWMM	1				1.0
11	Roads, sidewalks, parking lots, patios	Abs	0.018	Fixed	Impervious	0.01	Abs	0.00125	SWMM	1				1.0
12	Flat roofs	Abs	0.015	Fixed	Impervious	0.01	Abs	0	SWMM	1				1.0
13	Steep roofs	Abs	0.015	Fixed	Impervious	0.33	Abs	0	SWMM	1				1.0
50	Pervious area with poor infiltration potential	Abs	0.41	GreenAmpt	Pervious	0.01	Abs	0.0025	SWMM		292.2	1	0.092	1.0
51	Pervious area with low infiltration potential	Abs	0.41	GreenAmpt	Pervious	0.01	Abs	0.0025	SWMM		166.8	6.8	0.171	1.0
52	Pervious area with moderate infiltration potential	Abs	0.41	GreenAmpt	Pervious	0.01	Abs	0.0025	SWMM		61.3	59.8	0.312	1.0

5 Land Use Version Update Table

The land use runoff definition may be subject for review and update if additional information provide a strong basis. Note that the City's standard land uses are not intended to be updated on a per project basis and modellers shall use the Model Template Database as provided without modification. Future Model Template Database version updates shall be reviewed and approved by the City.

An icm_land_use_COV_2023NOV.csv table file has been prepared to easily make changes and future version updates to the Model Template Database by importing the table.

The City's standard land use table as shown below in Table 4A-8 have been incorporated into the Model Template Database.

To import the runoff surfaces with the CSV file, use the Data Import Centre. In the Data Import Centre, click "Auto-Map" to map the CSV attribute fields with the InfoWorks ICM runoff surfaces fields and proceed with the import.

Table 4A-8 Land Use Property Table

Land use ID	Population density (person/ha)	Wastewater profile	Connectivity (%)	Pollution index	Description	Runoff surface 1	Runoff surface 2	Runoff surface 3	Runoff surface 4	Runoff surface 5	Runoff surface 6	Runoff surface 7
Poor infiltration potential	-	-	0	-	For storm subcatchments on soil with poor infiltration potential	10	11	12	13	50	-	-
Low infiltration potential	-	-	0	-	For storm subcatchments on soil with low infiltration potential	10	11	12	13	-	51	-
Moderate infiltration potential	-	-	0	-	For storm subcatchments on soil with moderate infiltration potential	10	11	12	13	-	-	52
Sanitary	-	-	100	-	For sanitary subcatchment, no runoff surface.	-	-	-	-	-	-	-

Appendix 4B

Model Data Preparation and Import

Appendix 4B Model Data Preparation and Import

This Appendix provides guidance and a methodology on how the nodes, links, and subcatchment data and the GIS import layers may be prepared.

An external consultant may refer to the data preparation methodology and import procedure in this appendix as a guideline but shall adhere to naming conventions, model structure, and contents of model data fields as outlined in this appendix.

City staff shall follow the methodology and approach outlined in this section to develop InfoWorks ICM models.

See Chapter 3 Table 3-1 for available base City GIS data sources and Appendix 3B for GIS layer attribute field definitions useful for nodes, links, and subcatchment data preparation.

Note that the City's parcels layer or the Parcel2Main GIS database layer can be used to create the subcatchments. See Chapter 4 Section 4.7.5 for detailed information about using the Parcel2Main database.

1 Hydraulic Model

After completion of the Data Collection and Gap Analysis phase as outlined in Chapter 3, the hydraulic model build may commence. The following sections provide guidance on nodes and links data preparation including a detailed methodology and a model import procedure.

1.1 Nodes and Links Data Preparation

1. Ensure Data Collection and Gap Analysis as outlined in Section 3.2 has been completed and collect the clip_manholes, clip_fittings, and clip_sewermains GIS import layers created during that process.

2. Clean up the clip_fittings layer to only contain the nodes required to supplement the missing nodes in the clip_manhole layer. The gap analysis using Appendix 3C Gap Identification Template will output a list of FROMMH and TOMH entries from the clip_sewermains that do not have matching values in the FACILITYID field of clip_manholes layer. Perform "Select by Attribute" using this list to select features from clip_fittings and delete all other unselected features that are not necessary for the model.
3. Ensure the sewer main and fitting GIS data is normalized in the clip_sewermains and clip_fittings layers and new attribute fields PIP_SHP, PIP_MAT, and MAT_ICM are created by following the steps outlined in Chapter 3 Section 3.2.2 Data Normalization.

4. Create RIMELEV attribute field in the clip_fittings layer. Bring in the LiDAR covering the study area, and transfer the surface elevations to the RIMELEV field for all fittings and any manholes that are missing rim elevations. Add an additional data flag field in both the clip_manhole and clip_fittings layers and populate with a flag for LiDAR transferred fields. This field shall be imported in the import procedure for the RIMELEV data field instead of using the #A data flag.

5. Create a Node_ID attribute field in the clip_manhole and clip_fittings layers and copy over the FACILITYID and COV_SOURCE values into the Node_ID field, then prepend them in the Node_ID

field with MH and FT or other codes according to Section 2.7 Model Elements Naming, respectively.

6. Create the following attribute fields in clip_sewermains:

   - N_TYPE = N (for all pipes)
   - N_TOP and N_BOTTOM – populate with Manning's n values according to the Pipe Material Manning's n and SWGRAVITYMAIN tables in Appendix 3B. Tabular Join the lookup table created during the data normalization process as outlined in Section 3.2.2 Data Normalization to populate the Manning's n values.
   - FROM_NODE and TO_NODE

     a. Join the attribute tables of the clip_manholes and clip_fittings layers into the clip_sewermains layer by matching the FACILITYID and COV_SOURCE fields present in the clip_manholes and clip_fitting layers to the "FROMMH" field in the clip_sewermains layer.

     b. Copy over the Node_ID field from the clip_manholes and clip_fittings layers to the "FROM_NODE" field in the clip_sewermains layer.

     c. Repeat the steps above but match the FACILITYID and COV_SOURCE fields to the "TOMH" field and copy over the Node_ID field to the "TO_NODE" field in the clip_sewermains layer.

7. The DIAMETER attribute field in the clip_sewermains layer shall be imported into the Width field of the Conduit property table in InfoWorks ICM for all conduit shapes. Conduit shapes different from circular require additional data that shall be updated manually in InfoWorks ICM according to Section 3.2.2 during the data rectification process. Conduit dimensions other than circular shall be confirmed from records as outlined in Figure 3-3 in Chapter 3.

1.2 Nodes and Links Data Import

Manholes and fittings are to be modelled as node objects and shall be imported first followed by sewer mains which are to be modelled as conduit objects.

(1) Manholes

The manhole data shall be obtained from the City's SWMANHOLE layer and the clip_manholes layer shall be imported into InfoWorks ICM.

Table 4B-9 summarizes the manhole attribute data fields to be imported into InfoWorks ICM.

Table 4B-9 Asset Data Import Field Mapping for Manholes

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
Node ID	-	Node_ID
System type	-	EFLNTTYPE
Asset ID	-	FACILITYID
Ground level	-	RIMELEV

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
User Number 3	Ownership MH (37 = City; others = Metro)	OWNEDBY
User Text 1	Date of Construction	INSTALLDAT
User Text 2	Structure Type	MHTYPE
User Text 3	Legacy ID	LEGACYID

(2) Fittings

The fittings data shall be obtained from the City's FITTINGS layer and the clip_fittings layer shall be imported into InfoWorks ICM.

To help resolve connectivity issues, fittings nodes shall only be imported if the upstream or downstream node of a sewer main is missing in the clip_manholes layer.

Note that the City's fittings and manhole GIS data are both imported into InfoWorks ICM as a Manhole model object. After importing the GIS fittings data, some User Defined fields in the Manhole property table in InfoWorks ICM will remain empty as the fittings GIS data only has three User Defined fields in common with the manhole GIS data.

Table 4B-10 summarizes the fittings attribute data fields to be imported into InfoWorks ICM.

Table 4B-10 Asset Data Import Field Mapping for Fittings

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
Node ID	-	Node_ID
System type	-	EFFL_TYPE
Asset ID	-	COV_SOURCE
Ground level	-	RIMELEV
User Text 1	Date of Construction	INSTALLDAT
User Text 2	Structure Type	FUNCTION_
User Text 9	Ownership (Fittings & Valves)	OWNEDBY

(3) Sewer mains

The sewer main data shall be obtained from the City's SWGRAVITYMAIN layer and the clip_sewermains layer shall be imported into InfoWorks ICM.

Table 4B-11 summarizes the data fields to be imported from asset data for sewer mains.

Table 4B-11 Asset Data Import Field Mapping for Sewer Mains

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
US node ID	-	FROM_NODE
DS node ID	-	TO_NODE
System type	-	EFLNTTYPE
Asset ID	-	FACILITYID
Length	-	LENGTH

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
Shape ID	-	PIP_SHP
Width	-	DIAMETER
US invert level	-	UPELEV
DS invert level	-	DOWNELEV
Conduit material	-	MAT_ICM
Roughness type	-	N_TYPE
Top roughness Manning's n	-	N_TOP
Bottom roughness Manning's n	-	N_BOTTOM
User Number 1	Pipe Length (m)	LENGTH
User Number 2	Pipe Slope	SLOPE
User Number 3	Ownership (37 = City; others = Metro)	OWNEDBY
User Text 1	Date of Construction	INSTALLDAT
User Text 2	Flow Category	FLOWCAT
User Text 3	Legacy ID	LEGACY_ID
User Text 4	Drawing Reference	PP_Number
User Text 5	Comment	DESCRIPTN
User Text 6	Material	PIP_MAT

Figure 4B-1 shows the import process using the Data Import Centre in InfoWorks ICM. To facilitate the data import process, configuration files that map the InfoWorks ICM data fields corresponding to the manholes, fittings, sewer mains, and storm/sanitary subcatchments attribute data fields are provided with the InfoWorks ICM Model Template Database. A list of the import configuration files and their names are provided in Appendix 4A Section 3.

To use the Data Import Centre, navigate to Network -> Import -> Open Data Import Centre, and follow the five steps labelled on Figure 4B-1:

1. Select object type: this would be "Node" when importing the manholes or fittings.
2. Set data flag to "#A": this will automatically flag the imported fields to "#A" which is the appropriate flag for imported sewer asset data (see Appendix 3A Section 1 for details on data flags).
3. Select data source: this would be the "clip_manholes" layer when importing manholes.
4. Set the configuration file: this would be the "clip_manholes.cfg" file when importing manholes.
5. Check the field mapping to ensure the mapped import fields correspond with the object fields, and click "Import".

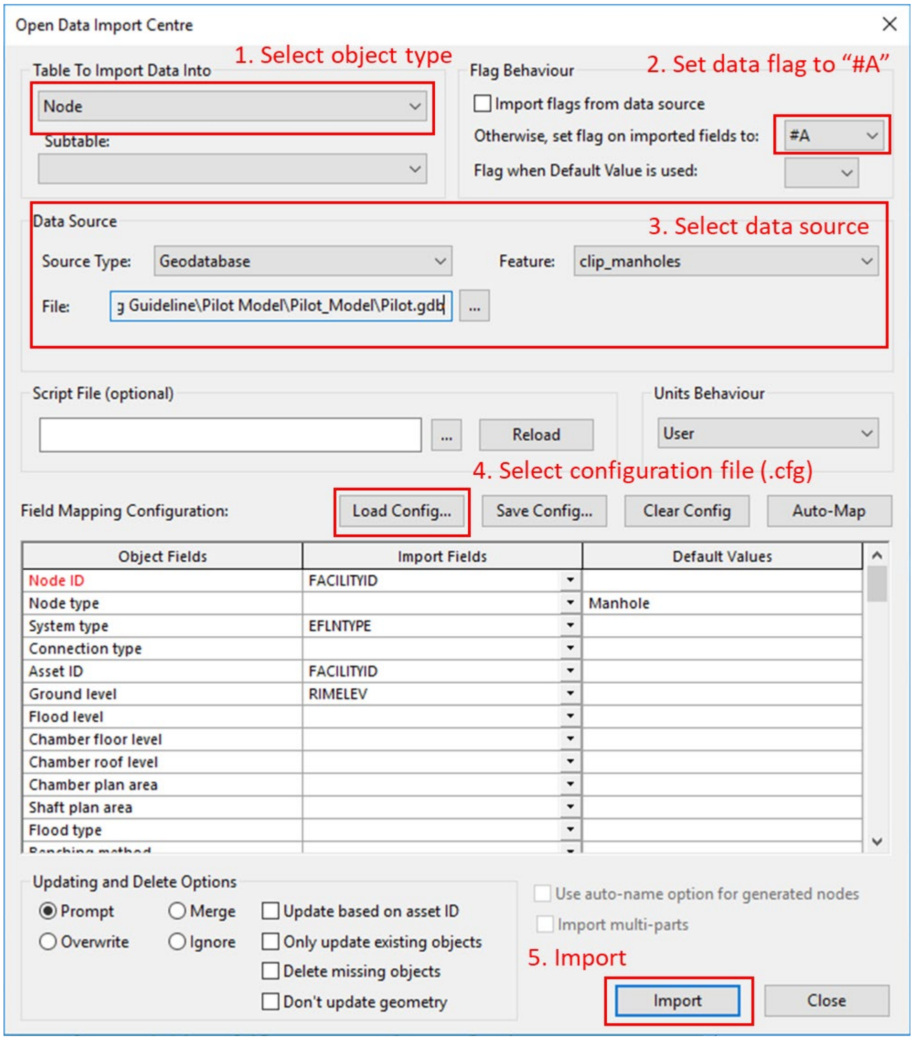


Figure 4B-1 Data Import Centre

2 Data Rectification Process

After importing sewer asset data into InfoWorks ICM, the procedure outlined in this section shall be followed to identify and resolve network errors as well as data errors. The modeller shall resolve any potential erroneous data with information obtained by following the approach outlined in Chapter 3 Section 3.2.4 and Figure 3-3.

SQL (Structured Query Language) queries, which are adopted by InfoWorks ICM for selecting and updating network objects using specified criteria, are recommended to be used during this process. A list of SQL queries are provided in Appendix 4C and they are also available in the City's Model Template Database file that accompanies this guideline.

During data gap filling and correcting data, the modeller shall enter data flags as prescribed in Appendix 4A Table 4A-1. Additionally, User Defined fields such as Model Notes and Drawing Reference shall be populated and updated throughout the data rectification process. Data flags should also be updated for model element data that were populated from SQL queries.

Step 1: Identify and resolve model connectivity errors and issues.

InfoWorks ICM provides built-in tools to identify isolated or disconnected networks, which is accessible by clicking GeoPlan – Tracing tools. The Connectivity tracing tool will generate a list of subnetworks and unconnected nodes and links, as shown on Figure 4B-2. In addition, other tracing tools including downstream trace, upstream trace, and pipe direction trace can help audit the network connectivity. The modeller shall review and confirm each subnetwork and resolve the connectivity issues before proceeding with next steps. The most common connectivity issues include:

- Orphan node: where a node is not connected to any link. Part 1 of Appendix 4C provides a SQL query for identifying orphan nodes.
- Orphan link: where a link is not connected to any node.
- Blind connection: where two or more links are connected without a node in between.

These connectivity issues can be resolved on a case-by-case basis, by correcting ID references, importing the missing node or link from sewer asset data or creating a node or link if it is not included in the sewer asset, reversing link direction, and deleting any node or link that is not part of the sewer system to be modelled. Note that the approach outlined in Section 3.2.4 and on Figure 3-3 shall be followed to obtain missing data.

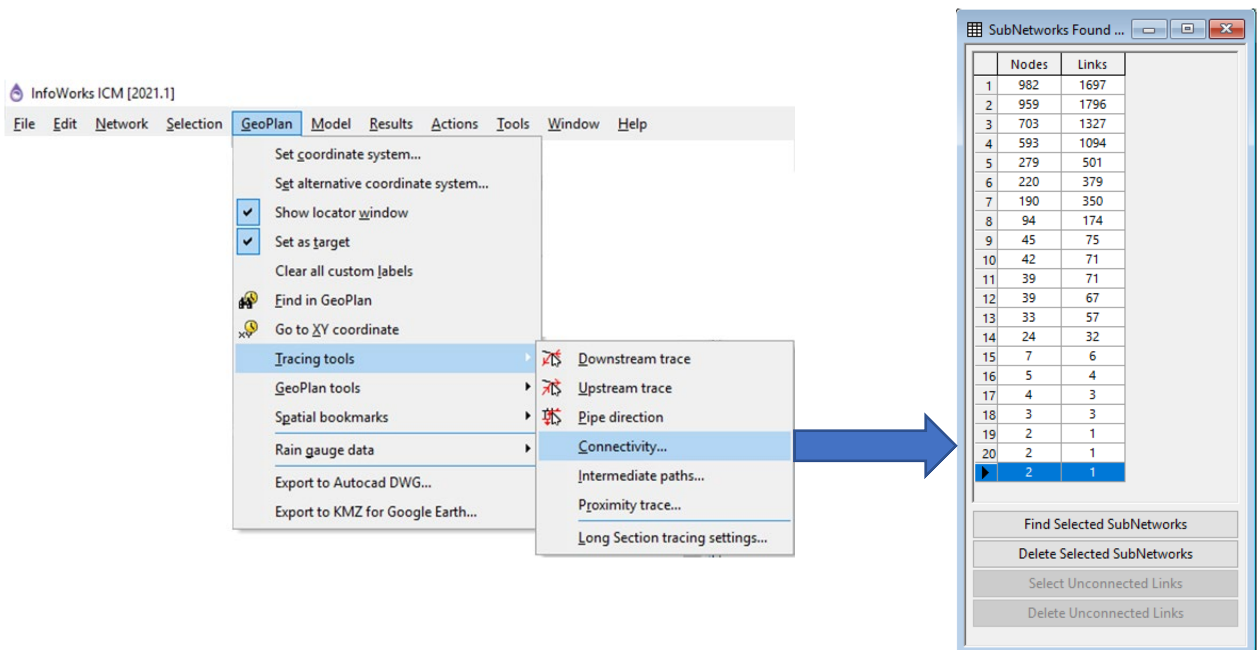


Figure 4B-2 Tracing Tools

Step 2: Conduct checks using SQL provided in part 2 of Appendix 4B to identify model objects with the following data gaps. The modeller shall follow the approach indicated on Figure 3-3 to obtain information to fill in these data gaps.

- Manhole ground elevation is missing or 0.
- Sewer invert is missing or 0.
- Sewer diameter is missing or 0.
- Sewer shape is missing.

- Sewer material is missing.

The quantity of these data gaps would have been identified if the modeller follows the method provided in Section 3.2.3 Data Gap Identification.

If no data can be found after following the approach outlined on Figure 3-3, the modeler may use the Inference tool in InfoWorks ICM. The Inference tool has built-in rules to infer missing data values for nodes and conduits based on information already available in the model. If inference will be used to fill in data gaps, the modeller shall apply the inference tool with appropriate rules selected. For example, infer ground elevation from ground model and interpolate sewer inverts based on inverts available from upstream and downstream links, as shown on Figure 4B-3. These two Inference tools are included in the sample ICM database file that accompanies this guideline. To use the Inference tool, select the model objects within missing data in Geoplan, and drag and drop the inference tool to the Geoplan.

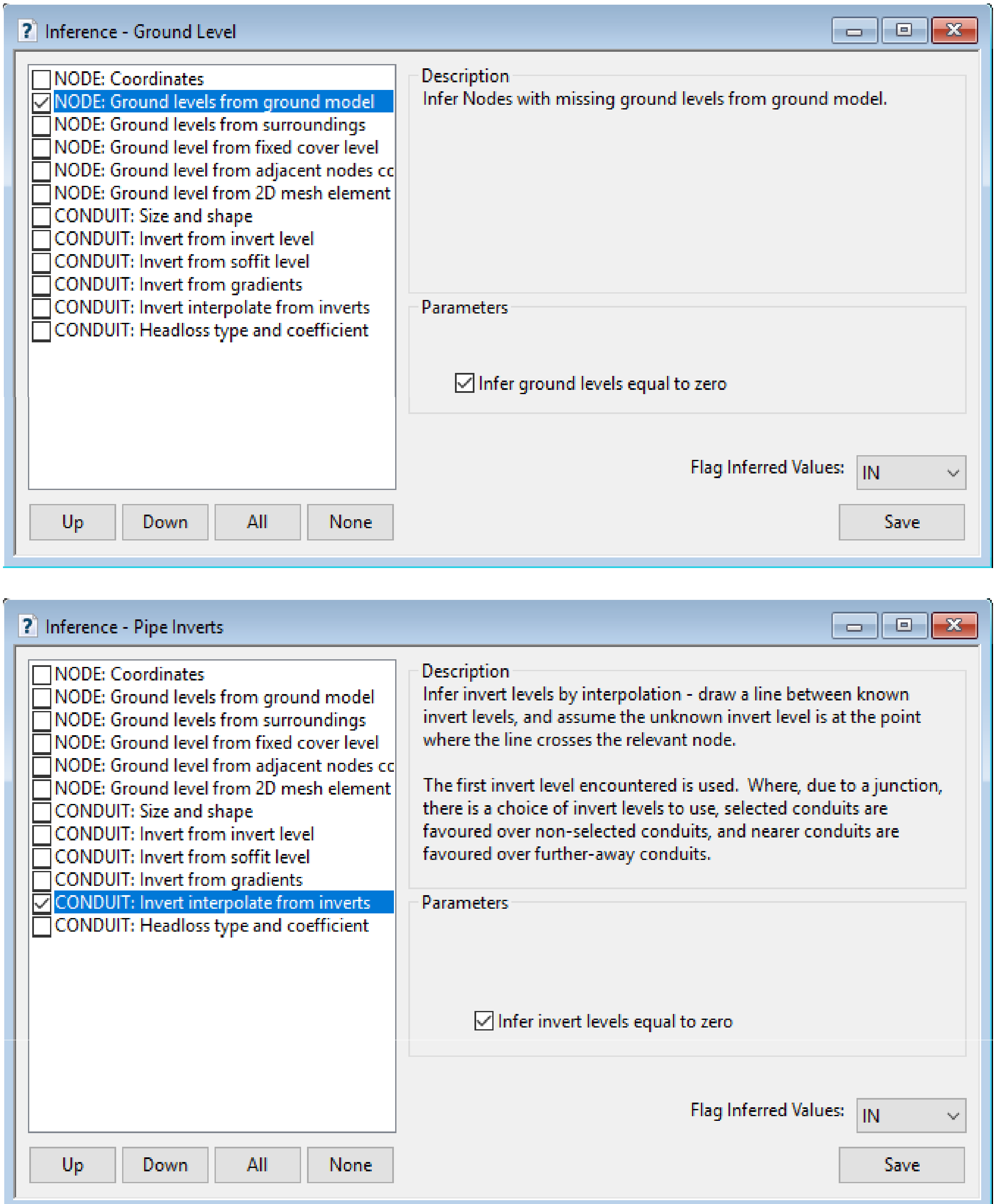


Figure 4B-3 Inference Tool

Step 3: Conduct checks using the SQL provided in part 3 of Appendix 4C to further identify suspicious and inconsistent data in the following list. The modeller shall review and confirm each location found, and resolve errors by obtaining information using the approach outlined in Section 3.2.3 and Figure 3-3.

- Sewer invert above ground
- Sewer obvert above ground

- Node backdrop: where downstream sewer invert is higher than upstream sewer invert. Overflow sewers are exceptions.
- Sewer with negative slope: forcemains and inverted siphons are exceptions.
- Sewer with flat slope
- Sewer with steep slope (>5%)
- Discontinuity in pipe size: where downstream sewer size is smaller than upstream sewer. Flow control orifice pipes downstream of storage units are exceptions.
- Bifurcation node: confirm these nodes are where flow bifurcates and add notes to User Text 4 Model Notes.
- Shallow sewers: update User Number 4 Shallow Sewer (Yes=1; No=0) accordingly.

Step 4: Validate the network using the built-in network validation tool in InfoWorks ICM and resolve any additional data errors. This tool is available by selecting Validate network from Network menu or clicking the validate button on the toolbar.

When a network is validated, a list of validation messages will appear in the Output Window. The three types of validation messages are: Error, Warning, and Information only. The modeller shall resolve all Error messages which indicate action is necessary and review the Warning messages to determine if any action is required. Information only messages do not require further action. The modeller may refer to the InfoWorks ICM Help for more details on each type of validation message, the cause, and the corresponding advice to resolve the error.

Step 5: Plot profiles of the network and visually examine each profile to ensure the data gap infilling is completed and data errors are properly rectified without causing further inconsistencies. The downstream trace and upstream trace tools introduced in Step 1 and the Long Section Pick tool available on the Geoplan toolbar can be used to generate the selection of the network for each possible profile route.

Step 6: Set roughness values for conduits with missing pipe material.

The roughness type of conduits shall be Manning's n. The roughness value shall be set based on the conduit material type as shown in the Pipe Material Manning's n and SWGRAVITYMAIN tables in Appendix 3B. For pipe materials not listed in the tables, or if the material is not known for the conduit, a value of 0.013 shall be adopted.

Step 7: Infer headloss coefficient values for conduits.

Headloss is used to define the energy lost due to pipe transitions at manholes or within a pipe, by appurtenances in the system, or inlet/outlet coverage. In InfoWorks ICM, when creating a new conduits, a default value of 1 is populated for the upstream and downstream headloss coefficient for each conduit. The inference tool as show in Figure 4B-4 shall be used to calculate headloss coefficients. This inference tool is calculates the headloss coefficient based on the angle of approach of the pipes connected to the same manhole and a built-in headloss curve which can be found in the InfoWorks ICM Help menu. To apply the inference, select the conduits to be applied to, clear off their upstream and downstream headloss coefficient values, and drag and drop the inference tool to the Geoplan.

One limitation of this inference tool, however, is that it will not calculate the headloss coefficient properly when the conduits connected to the same node have different shapes. In such cases, the tool will set the headloss type to "NONE" for the conduits. Therefore, the modeller may need to temporarily change the shape of all conduits to “CIRC”, apply the inference, and revert the shapes to original, in order to infer the headloss coefficients properly. The modeller shall review if any locations the headloss type is set to “NONE” after applying to inference tool.

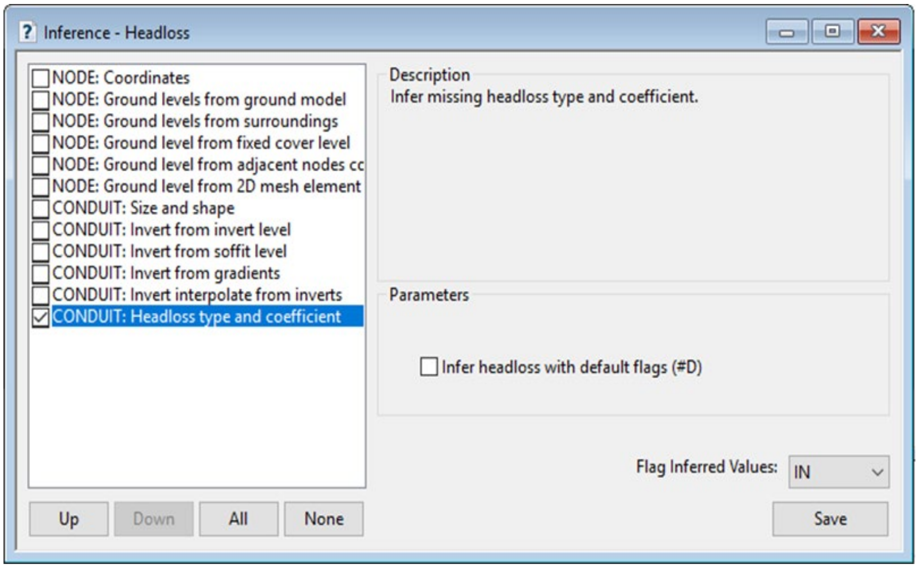


Figure 4B-4 Inference Tool for Headloss Coefficients

3 Hydrologic Model

The following sections provide guidance on storm subcatchment data preparation including a detailed methodology and a model import procedure. Storm subcatchments shall consist of parcel and right-of-way catchments.

3.1 Storm Subcatchment Data Preparation

1. Obtain the Parcel2Main layer and clip to study area polygon created earlier to clip the manhole and sewer main GIS layers in Chapter 3 Section 3.2.3 Data Coverage Identification.

2. Duplicate the clipped Parcel2Main layer and name it stmCatch.

3. Obtain the right-of-way (ROW) areas GIS layer called the Paved Areas layer within the UMDM.gbd database and clip to the study area using the study area polygon. Name clipped Paved Areas layer clip_ROW.

4. Delineate ROW subcatchments using clip_ROW layer – use the criteria outlined in the Right-of-Way Storm Subcatchments sub-section in Section 4.7.5 in Chapter 4. Populate the Node_ID field with the ROW outlet node IDs according to the naming conventions outlined in Chapter 2 Section 2.7 Model Elements Naming. Create an attribute field called INFIL_POTE in the clip_ROW layer. Perform a spatial join with the clip_ROW and the COVSoil layer. Copy over the values in the INFIL_POTE field in the COVSoil layer to the INFIL_POTE field in the clip_ROW layer. The values should be 0, 1, and 2 for poor, low, and moderate infiltration potential, respectively.

5. Copy the delineated clip_ROW subcatchments layer into the stmCatch layer including the outlet node ID field for the delineated ROW subcatchments.

6. Create a “Land Use Lookup Table” in GIS for Land use vs Zoning codes from Table 4-27 in Section 4.7.4 Land Use including a column with the percent impervious values.
7. Add new fields Area_ha, Drains_to, LandUse, and AreaM_Type and populate them as indicated in Table 4B-12 below.
8. Add all other attribute field names to the stmCatch layer as indicated in Table 4B-12, ***but do not populate them.***
9. Duplicate stmCatch and name it sanCatch. Clear all entries in the Node_ID field (being the storm outlet node IDs) from sanCatch. Delete the ImpPerc attribute field from sanCatch. Set sanCatch aside for data prep in Section 4 Sanitary Subcatchment Data Preparation and Import of this appendix.
10. Populate all the remaining attribute fields in the stmCatch layer as indicated in Table 4B-12 below.
11. Delete all non-required fields in stmCatch.
12. Start import procedure as outlined in the Storm Subcatchment Data Import section.

Table 4B-12 New Storm Subcatchment Asset Data Fields and Data Preparation Procedure

New Field Name	Populate Data Fields
Area_ha	Area in hectares
Drains_to	All subcatchments = "Node"
LandUse	Spatial Join with Zoning code layer, populate with Zoning Code, then a tabular join with the "Land Use Lookup Table ", then populate the LandUse field based on Zoning ID relation. Note that this procedure will populate the ROW records with erroneous land use data. To correct this, select all ROW records and populate the LandUse field with “Roads and Paved Areas” as per the land use type stated in Table 4-19 Land Use Type and Corresponding Percent Impervious Values in Chapter 4 of the Modelling Standards.
LandUseMod	SQL in GIS: LandUseMod = if INFIL_POTE = 0 (means poor soil infiltration), then LandUseMod = “Poor infiltration potential” else: LandUseMod = if INFIL_POTE = 1 (means low soil infiltration), then LandUseMod = “Low infiltration potential” else: LandUseMod = if INFIL_POTE = 2 (means moderate soil infiltration), then LandUseMod = “Moderate infiltration potential”
AreaM_Type	All subcatchments = "Percent".
*1. Before proceeding, create all subsequent attribute fields below, **but do not populate them.*** *2. Proceed to Step 9 in the methodology above.* *3. The sanCatch import layer will be further prepared in the Sanitary Subcatchment Data Preparation section.*	

New Field Name	Populate Data Fields
Node_ID	• Join the attribute tables of the clip_manholes and clip_fittings layers into the stmCatch layer by matching the FACILITYID and COV_SOURCE fields present in the clip_manholes and clip_fitting layers to the "STM_ALLOC_" field in the stmCatch layer. • Copy over the Node_ID field from the clip_manholes and clip_fittings layers to the stmCatch layer. The Node_ID field in the clip_manhole and clip_fittings layer should already have the FACILITYID and COV_SOURCE entries of the manholes and fittings prepended with "MH" and "FT", respectively, as outlined in Section 1.1 Nodes and Links Data Preparation of this appendix. • Maintain Tabular Join and go to stmCatchID method (1) to add catchment ID suffixes.
stmCatchID	(1) Using Parcel2Main Layer:* • Copy entries from the Node_ID field in the stmCatch layer to stmCatchID and prepended with "STM_". • Sort the Node_ID field and identify each group of subcatchments that drain to the same node i.e., that have the same Node_ID entry. • Append a "**_#**" suffix to the stmCatchID, increasing numerically from 1. For example, STM_ MH1407959**_1** and STM_ MH1407959**_2**, etc. for subcatchments with the same Node_ID entry. An Excel template file and python script for ArcPro is available upon request from the City that can generate the stmCatchID for each storm subcatchment. (2) Other methods: The consultant may use their own methods and expertise to determine the storm subcatchment outlet node IDs in discussion with the City. The storm subcatchment outlet node IDs shall be compared to the Parcel2Main outlet node IDs and a rationale shall be provided to the City where the outlet node IDs deviate.
Sys_Type	All subcatchments = "storm"
Catch_Type	"Parcel" for parcels and "ROW" for right-of-way area storm subcatchments.
ImpPerc	Table relation - populate Percent Impervious values based on "Land Use Lookup Table".
Conn_Perc	0 - if 0, InfoWorks ICM will direct 0% of the foul flow to the catchment. • When creating this field, set the data type to be "Long"
WWProfile	0 - if 0, InfoWorks ICM won't model foul flow to the catchment (see InfoWorks ICM help section).
Population	0 - if 0, InfoWorks ICM will calculate foul flow of 0.
Runoff Surface Percent Allocation – No Roofs Modelled Scenario	
RA1_Perc	SQL in GIS: RA1_Perc = if Catch_Type = "Parcel", then RA1_Perc = ImpPerc, else 0.
RA2_Perc	SQL in GIS: RA2_Perc = if Catch_Type = "ROW", then RA2_Perc = ImpPerc, else 0.
RA3_Perc	0 - unless roofs are modelled, see methodology in Building Roofs Subcatchments section.
RA4_Perc	0 - unless roofs are modelled, see methodology in Building Roofs Subcatchments section.
RA5_Perc	(1) Using Parcel2Main Layer:** SQL in GIS: RA5_Perc = if INFIL_POTE = 0 (means poor soil infiltration), then RA5_Perc = (100 - ImpPerc), else 0. (2) Using Soil Layer: Use GIS to determine the worst soil infiltration type, either poor, low, or moderate and populate RA5_Perc = (100 – ImpPerc) if worst soil infiltration type in subcatchment = poor.

New Field Name	Populate Data Fields
RA6_Perc	(1) Using Parcel2Main Layer:** SQL in GIS: RA6_Perc = if INFIL_POTE = 1 (means low soil infiltration), then RA6_Perc = (100 – ImpPerc), else 0. (2) Using Soil Layer: Use GIS to determine the worst soil infiltration type, either poor, low, or moderate and populate RA6_Perc = (100 - ImpPerc) if worst soil infiltration type in subcatchment = low.
RA7_Perc	(1) Using Parcel2Main Layer:** SQL in GIS: RA7_Perc = if INFIL_POTE = 2 (means moderate soil infiltration), then RA7_Perc = (100 – ImpPerc) (2) Using Soil GIS Layer: Use GIS to determine the worst soil infiltration type, either poor, low, or moderate and populate RA7_Perc = (100 - ImpPerc) if worst soil infiltration type in subcatchment = moderate.

**The Parcel2Main database has pre-processed the catchment outlet IDs and is populated for all parcels in the "STM_ALLOC_" attribute field.*
*** The Parcel2Main database has already processed the Soil GIS layer and the INFIL_POTE attribute field has been coded with 0 for poor, 1 for low, and 2 for moderate infiltration capacity.*

3.2 Storm Subcatchment Data Import

Table 4B-13 below shows the attribute data to be imported and the data fields they should be mapped to in InfoWorks ICM. The stmCatch GIS import layer prepared in the previous section should contain all the attribute data fields in Table 4B-13.

Table 4B-13 Asset Data Import Field Mapping for Parcels to Storm Subcatchments

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
Subcatchment ID	-	stmCatchID
System type	-	Sys_Type
Drain to	-	Drains_to
Node ID	-	Node_ID
Total area	-	Area_ha
Connectivity (%)	-	Conn_Perc
Wastewater profile	-	WWProfile
Population	-	Population
Area measurement type	-	AreaM_Type
Land use ID	-	LandUseMod
Runoff area 1 (%)	-	RA1_Perc
Runoff area 2 (%)	-	RA2_Perc
Runoff area 3 (%)	-	RA3_Perc
Runoff area 4 (%)	-	RA4_Perc
Runoff area 5 (%)	-	RA5_Perc
Runoff area 6 (%)	-	RA6_Perc
Runoff area 7 (%)	-	RA7_Perc
User number 1	Parcel ID	Parcel_ID

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
User number 2	Outlet MH FACILITYID	STM_ALLOC_
User text 1	Service connection type	Parcel_Ser
User text 2	Zoning category	Zone_Name_
User Text 3	Land use	LandUse
User text 4	Catchment type	Catch_Type
User text 5	Civic number	Civic_no
User text 6	Street name	Streetname
User text 8	Infiltration Potential	INFIL_POTE

The Data Import Centre in InfoWorks ICM, as shown in Figure 4B-1, shall be used to import the storm subcatchments using the stmCatch GIS layer. To facilitate the data import process, configuration files that map the InfoWorks ICM data fields corresponding to the storm subcatchments attribute data fields are provided with the InfoWorks ICM Model Template Database.

4 Sanitary Model

Storm and sanitary subcatchments shall be modelled as separate subcatchments for City models. The sanitary subcatchments shall represent the population-based wastewater flows, GWI and RDII in one subcatchment. Storm subcatchments shall consist of parcel and right-of-way catchments (ROW). ROW subcatchments in the sanCatch layer shall be used to simulate RDII into sanitary and combined pipes.

4.1 Sanitary Subcatchment Data Preparation

1. Locate the sanCatch layer created in Section 3.1 Storm Subcatchment Data Preparation of this appendix.
2. Re-purpose the ROW subcatchments in the sanCatch layer to be used as sanitary ROW subcatchments. Adjust the ROW subcatchments in the sanCatch layer such that they are delineated to combined and sanitary manhole locations if different from where the storm manholes are located.
3. Reassign the sanitary ROW subcatchment Node_IDs in the sanCatch layer to sanitary or combined manholes as appropriate.
4. Create new fields not yet present in the sanCatch layer and populate all attribute fields as indicated in Table 4B-14 below.

Table 4B-14 New Sanitary Subcatchment Asset Data Fields and Data Preparation Procedure

New Field Name	Populate Data Fields
Area_ha	Already populated in Section Storm Subcatchment Data Preparation.
Drains_to	Already populated in Section Storm Subcatchment Data Preparation.
LandUse	Already populated in Section Storm Subcatchment Data Preparation.
AreaM_Type	Already populated in Section Storm Subcatchment Data Preparation.
LandUseMod	"Sanitary" for all subcatchments

New Field Name	Populate Data Fields
Node_ID	• Join the attribute tables of the clip_manholes and clip_fittings layers into the sanCatch layer by matching the FACILITYID and COV_SOURCE fields present in the clip_manholes and clip_fitting layers to the "SAN_ALLOC_" field in the sanCatch layer. • Copy over the Node_ID field from the clip_manholes and clip_fittings layers to the sanCatch layer. The Node_ID field in the clip_manhole and clip_fittings layer should already have the FACILITYID and COV_SOURCE entries of the manholes and fittings prepended with "MH" and "FT", respectively, as outlined in Section 1.1 Nodes and Links Data Preparation of this appendix. • Maintain Tabular Join and go to sanCatchID method (1) to add catchment ID suffixes.
sanCatchID	(1) Using Parcel2Main Layer*: • Copy entries from the Node_ID field in the sanCatch layer to sanCatchID and prepended with "SAN_". • Sort the Node_ID field and identify each group of subcatchments that drain to the same node i.e., that have the same Node_ID entry. • Append a "_#" suffix to the sanCatchID, increasing numerically from 1. For example, SAN_ MH1407959_1 and SAN_ MH1407959_2, etc. for subcatchments with the same Node_ID entry. An Excel template file and python script for ArcPro is available upon request from the City that can generate the sanCatchID for each storm subcatchment. (2) Other Methods: The consultant may use their own methods and expertise to determine the sanitary subcatchment outlet node IDs in discussion with the City. The sanitary subcatchment outlet node IDs shall be compared to the Parcel2Main outlet node IDs and a rationale shall be provided to the City where the outlet node IDs deviate.
Sys_Type	"Sanitary" for all subcatchments.
Catch_Type	"Parcel" for parcels and "ROW" for right-of-way area sanitary subcatchments.
Conn_Perc	All subcatchment values = 100
WWProfile	Populate with wastewater profile ID. Each wastewater event can have several wastewater profiles.
Population	(1) For planning: Populate based on latest Census population data. (2) For design: Populate based on City design values.
RA1_Perc	0 - this will prevent rainfall from being modelled in the sanitary catchment.
RA2_Perc	0 - " "
RA3_Perc	0 - " "
RA4_Perc	0 - " "
RA5_Perc	0 - " "
RA6_Perc	0 - " "
RA7_Perc	0 - " "

**The Parcel2Main database has pre-processed the catchment outlet IDs and is populated for all parcels in the "SAN_ALLOC_" attribute field.*

5. OPTIONAL – This is not a required step. In discussion with the City, the following adjustments could be made to the Contributing area field.

    a. Create Contributing area attribute field in the sanCatch layer.

b. For residential areas, set the contributing area of the subcatchment equal to the area of the parcel.

c. For Industrial-Commercial-Institutional (ICI) areas, set the contributing area of the subcatchment equal to the area of the parcel if the parcel area is less than 1 ha. Where parcel areas are greater than 1 ha, set the contributing areas to 1.1*Area of the building footprint.

d. Only for those sewers running through open land without buildings, use a buffer-based subcatchment to account for I/I in the open spaces; in consultation with the City. In such areas, set the contributing area of the subcatchment equal to the footprint area of the sewer main. Adjust the Contributing area field for trunk sewers where no parcel are adjacent but have no service connections connected to the trunk sewer.

4.2 Sanitary Subcatchment Data Import

Table 4B-15 below shows the attribute data to be imported and the data fields they should be mapped to in InfoWorks ICM. The sanCatch GIS import layer prepared in the previous section should contain all the attribute data fields in Table 4B-15.

Table 4B-15 Asset Data Import Field Mapping for Parcels to Sanitary Subcatchments

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
Subcatchment ID	-	sanCatchID
System type	-	Sys_Type
Drain to	-	Drains_to
Node ID	-	Node_ID
Total area	-	Area_ha
Connectivity (%)	-	Conn_Perc
Wastewater profile	-	WWProfile
Population	-	Population
Area measurement type	-	AreaM_Type
Land use ID	-	LandUseMod
Runoff area 1 (%)	-	RA1_Perc
Runoff area 2 (%)	-	RA2_Perc
Runoff area 3 (%)	-	RA3_Perc
Runoff area 4 (%)	-	RA4_Perc
Runoff area 5 (%)	-	RA5_Perc
Runoff area 6 (%)	-	RA6_Perc
Runoff area 7 (%)	-	RA7_Perc
User number 1	Parcel ID	Parcel_ID
User number 2	Outlet MH FACILITYID	SAN_ALLOC_
User text 1	Service connection type	Parcel_Ser
User text 2	Zoning category	Zone_Name_
User text 3	Land use	LandUse

InfoWorks Object Field	Heading for User Defined Field	Asset Field Name
User text 4	Catchment type	Catch_Type
User text 5	Civic number	Civic_no
User text 6	Street name	Streetname
User text 8	Infiltration Potential	INFIL_POTE

The Data Import Centre in InfoWorks ICM, as shown in Figure 4B-1, shall be used to import the sanitary subcatchments using the stmCatch GIS layer. To facilitate the data import process, configuration files that map the InfoWorks ICM data fields corresponding to the sanitary subcatchments attribute data fields are provided with the InfoWorks ICM Model Template Database.

Appendix 4C

SQL Queries

Appendix 4C SQL Queries

This Appendix provides some examples of SQL queries that can be used to help identify sewer asset data gaps and inconsistencies. It is encouraged that the modeller develops and uses SQL to perform data analysis, including but not limited to the examples shown.

1 Check Connectivity

Orphan Node

The following SQL query selects all nodes that do not have any links connected to them.

Object: All nodes

SQL Code:

Count(us_links.*)= 0 and Count (ds_links.*)=0

2 Check Data Gaps

Node Missing Ground Level

The following SQL query selects all nodes where the ground level is missing or zero.

Object: All nodes

SQL Code:

ground_level = 0 or ground_level = ''

Link Missing Invert or Invert = 0

The following SQL query selects all links where either the downstream or upstream invert elevation is missing or zero.

Object: All links

SQL Code: ds_invert =0 or ds_invert = '' or us_invert = 0 or us_invert = ''

Link Missing Diameter

The following SQL query selects all links where the width is missing or 0.

Object: All links

SQL Code: conduit_width = '' or conduit_width = 0

Link Missing Shape

The following SQL query selects all links where the width is missing or 0.

Object: All links

SQL Code: shape = ''

Link Missing Material

The following SQL query selects all links where the material is missing.

Object: All links

SQL Code: conduit_material = ''

3 Check Data Errors

Node Backdrop

The following SQL query selects all nodes with backdrop.

Object: All Nodes

SQL Code:

ds_links.us_invert > us_links.ds_invert

Link with Negative Slope

The following SQL query selects all links with a negative slope.

Object: All links

SQL Code:

ds_invert > us_invert

Link with Flat Slope

The following SQL query selects all links with a flat slope.

Object: All links

SQL Code:

ds_invert = us_invert

Link with Steep Slope

The following SQL query selects all links with a slope greater than 0.05.

Object: All links

SQL Code:

((us_invert - ds_invert) / conduit_length)>0.05

Link Invert above Ground

The following SQL query selects all links where the invert is higher than the ground level.

Object: All links

SQL Code:

```
ds_invert> ds_node.ground_level  or us_invert>us_node.ground_level
```

Link Obvert above Ground

The following SQL query selects all links where the obvert is higher than the ground level.

Object: All links

SQL Code:

```
(ds_invert+conduit_height/1000)> ds_node.ground_level or
(us_invert+conduit_height/1000)>us_node.ground_level
```

Discontinuity in Pipe Size

This SQL query selects all nodes where maximum upstream conduit width is larger than maximum downstream conduit width.

Object: All Nodes

SQL Code:

```
max(us_links.conduit_width) >max(ds_links.conduit_width)
```

Bifurcation Node

The following SQL query select all nodes where flow bifurcates.

Object: All nodes

SQL Code:

```
count(ds_links.*)>1
```

Shallow Sewer

The following SQL query selects all link that are shallow, defined as link obvert less than 1.8m below the ground.

Object: All links

SQL Code:

(us_node.ground_level - (us_invert + conduit_height/1000))<1.8 or (ds_node.ground_level - (ds_invert + conduit_height/1000))<1.8)

Appendix 4D.1

Special Structures

Appendix 4D.1 Special Structures

This Appendix provides modelling examples for the special structures discussed in Chapter 4 and references for determining coefficient values for modelling the special structures.

4 Special Structures Modelling Examples

Modelling special structures is a process where each special structure needs to be manually created in the InfoWorks ICM model and data should be entered from engineering drawings, field survey data, O&M records, etc.

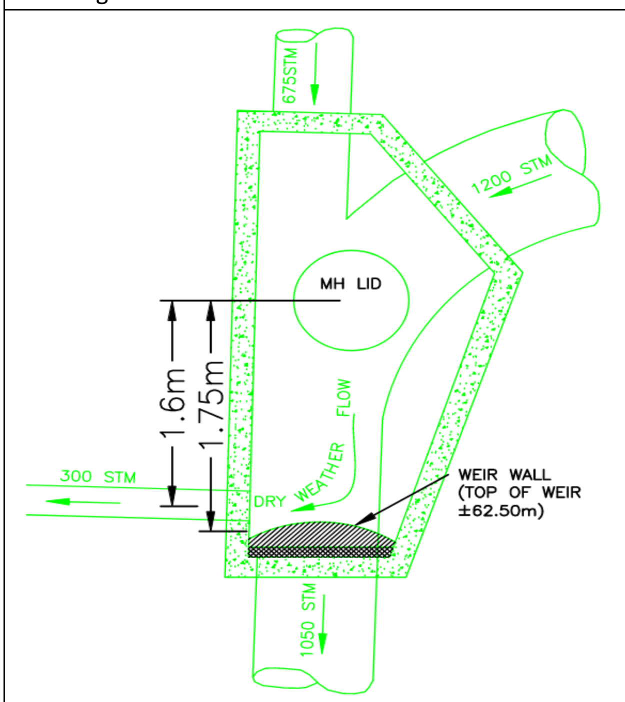
The following subsections provide a high-level overview of the recommended way to model each special structure. Additional details on the properties of each modelling object can be found in the InfoWorks Help manual.

4.1 Weirs

At the planning stage, a weir shall be modelled using the standard thin plate weir link in InfoWorks ICM.

Figure 4D-5 shows an example of modelling an overflow weir within a manhole. In this case, a dummy node is needed to connect the weir link with the rest of the sewer network. The key hydraulic parameters for the weir are shown on Figure 4D-6.

Drawing



Model

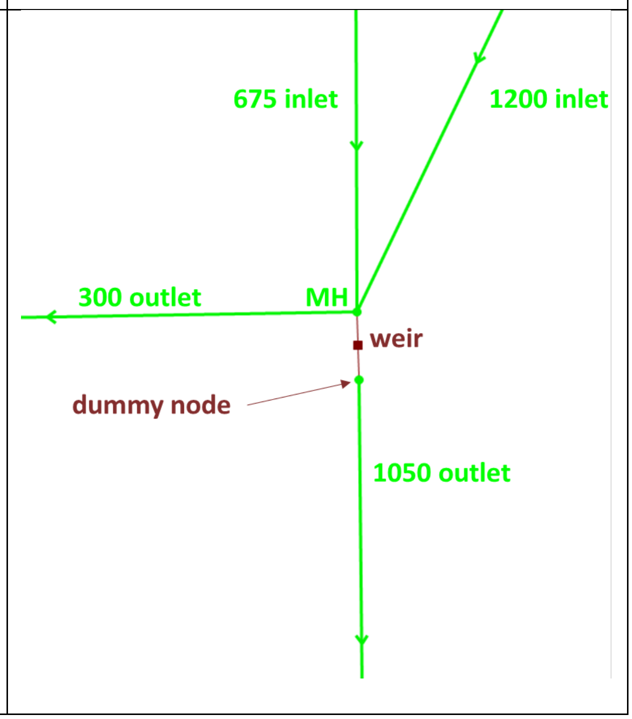


Figure 4D-5 Weir Example

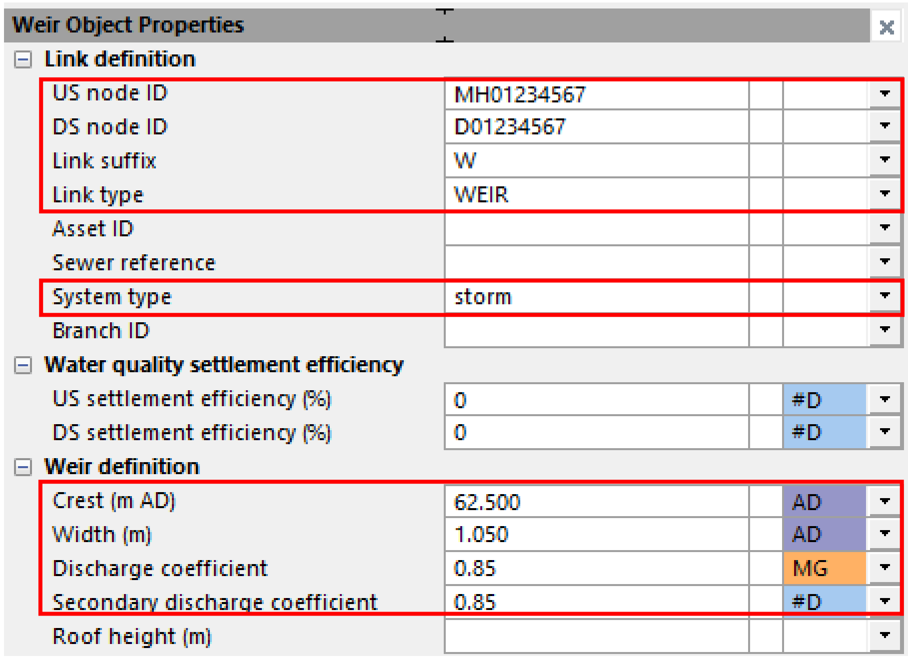


Figure 4D-6 Parameters for Standard Thin Plate Weir Definition

4.2 Orifices

At the planning stage, an orifice control shall be modelled as a regular conduit, whether it is implemented as a throttle pipe or through a reduced opening such as using an orifice plate. A minimum length of 3 m shall be used when the orifice control is modelled using a conduit to ensure model stability.

At the design stage, an orifice control implemented as a throttle pipe shall also be modelled as a regular conduit; however, a typical orifice control within a manhole chamber, as shown on Figure 4D-7, shall be modelled using an orifice link in InfoWorks ICM. A dummy node is usually needed to connect the orifice link with the downstream sewer network.

Figure 4D-8 shows the parameters required to define an orifice link. The discharge coefficient and second discharge coefficient values shall be calculated following the instructions provided in Section 4.3.2 under the Design Model subsection.

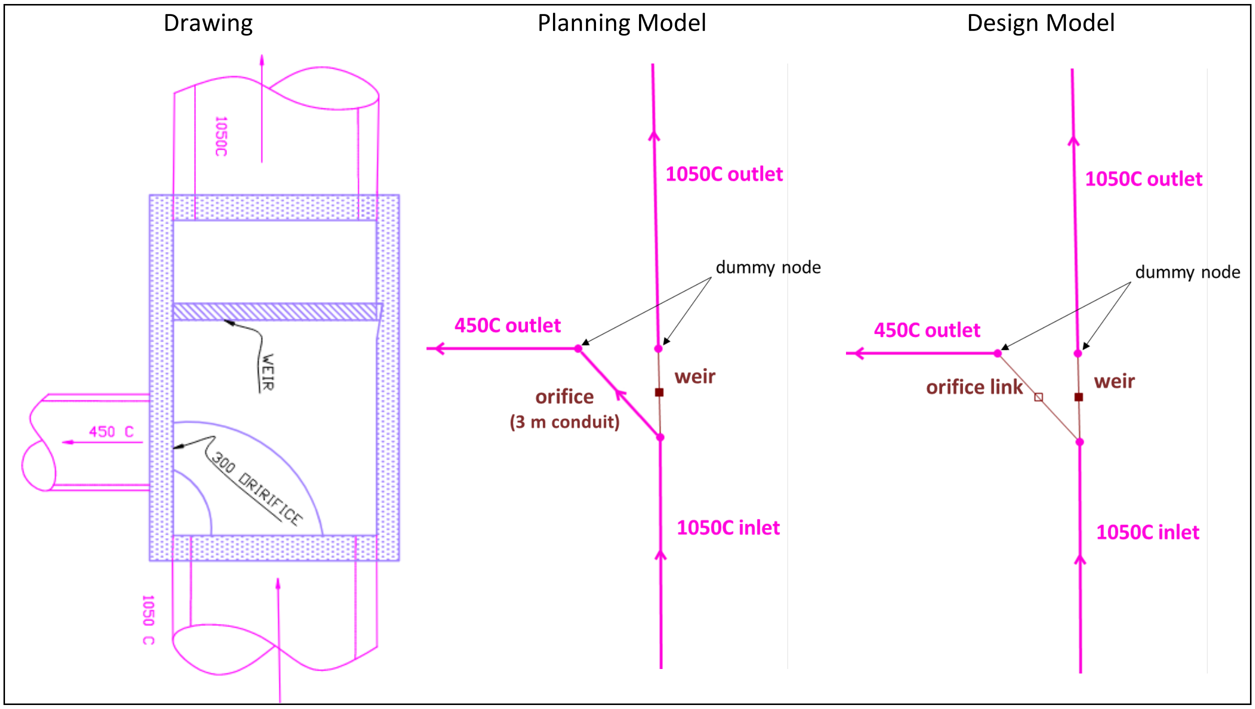
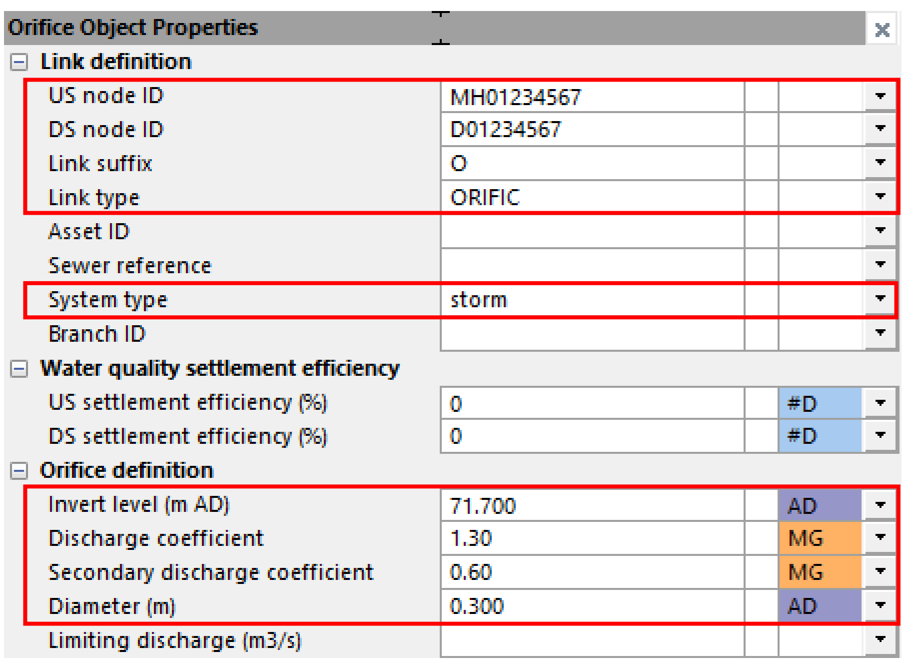


Figure 4D-7 Orifice Example



Orifice Object Properties		
Link definition		
US node ID	MH01234567	
DS node ID	D01234567	
Link suffix	O	
Link type	ORIFIC	
Asset ID		
Sewer reference		
System type	storm	
Branch ID		
Water quality settlement efficiency		
US settlement efficiency (%)	0	#D
DS settlement efficiency (%)	0	#D
Orifice definition		
Invert level (m AD)	71.700	AD
Discharge coefficient	1.30	MG
Secondary discharge coefficient	0.60	MG
Diameter (m)	0.300	AD
Limiting discharge (m3/s)		

Figure 4D-8 Parameters for Orifice Definition

4.3 First Flush Separator

A typical first flush separator, as shown on Figure 4D-9, shall be modelled with a regular conduit object. The length and inverts of the first flush pipe can be inferred using the upstream and downstream sewer network. A dummy node is usually needed to connect the first flush pipe with the downstream sewer network. Note that the minimum length of the first flush pipe shall be 3 m to avoid potential model instabilities.

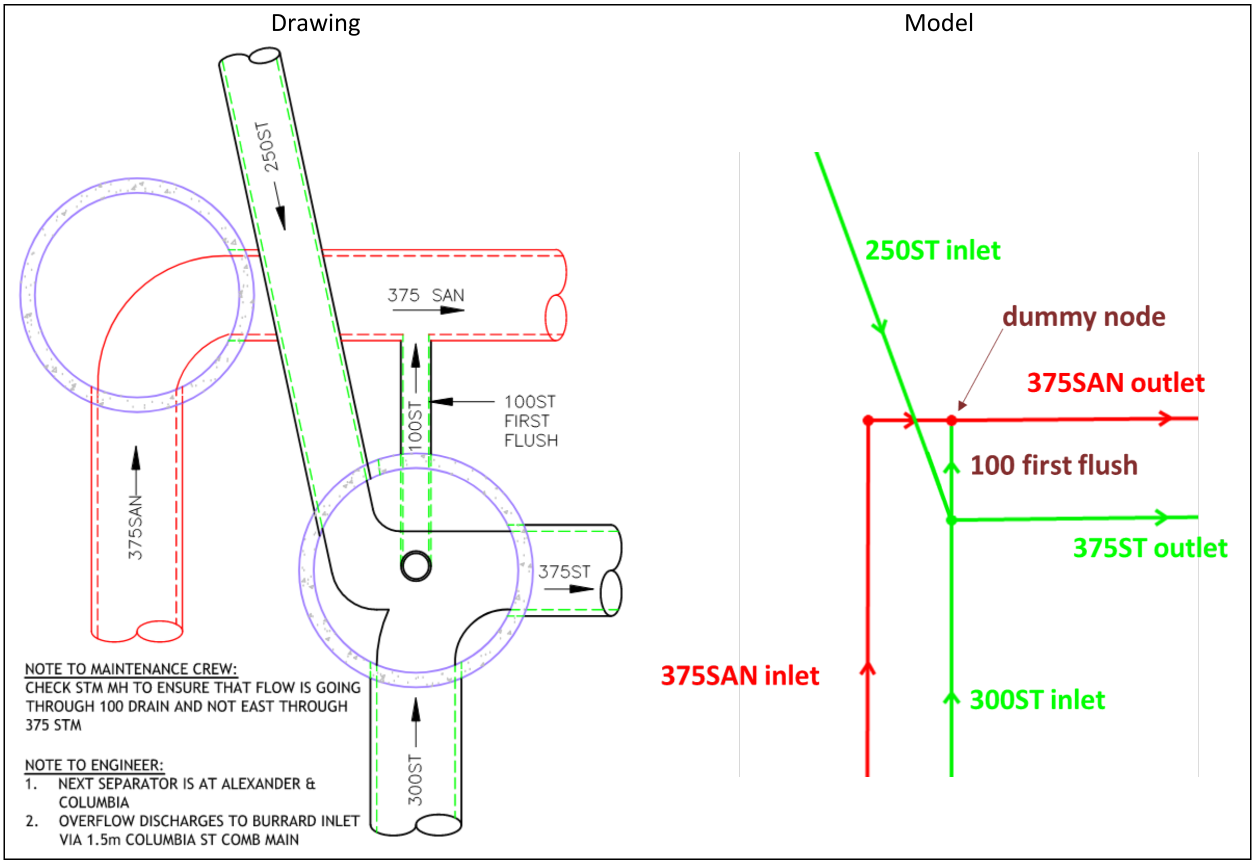


Figure 4D-9 First Flush Example

4.4 Flap Gates

Flap gates and backflow prevention valves shall be modelled using a flap valve link as shown on Figure 4D-10.

The definition of a flap valve includes its shape, size, and invert level. A value of 1.0 is recommended for the discharge coefficient. Figure 4D-10 shows the key parameters required to define a flap gate.

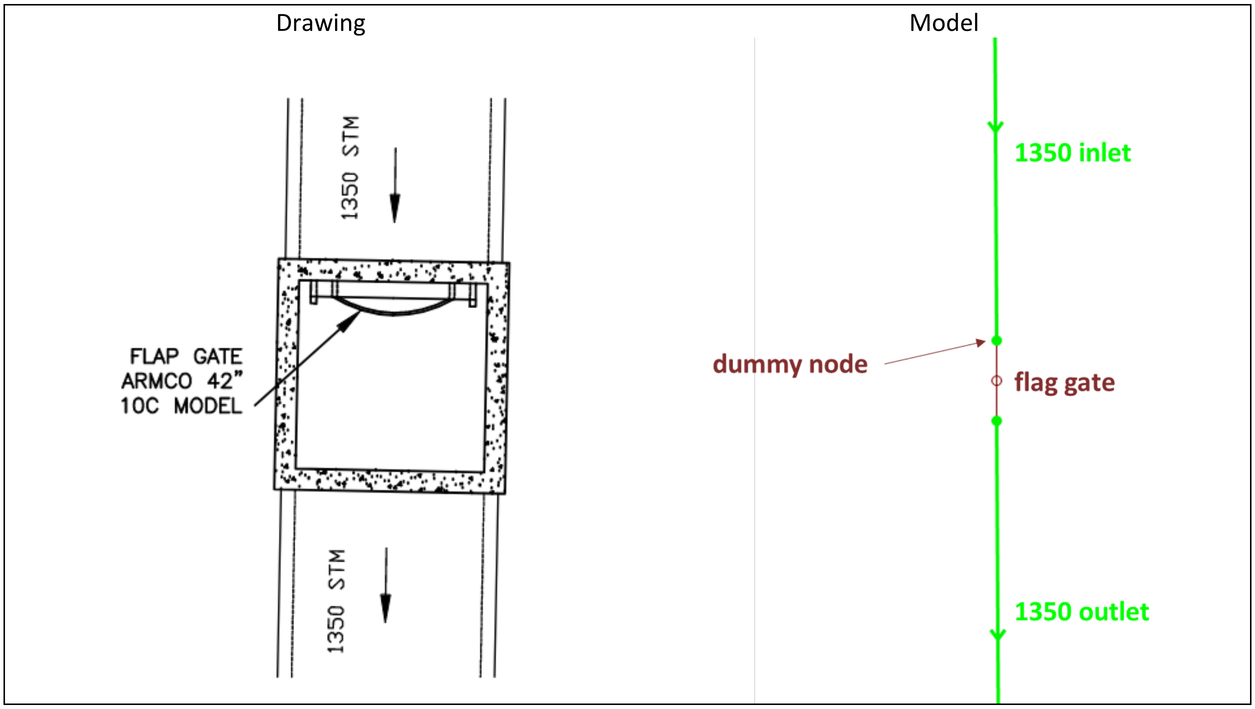
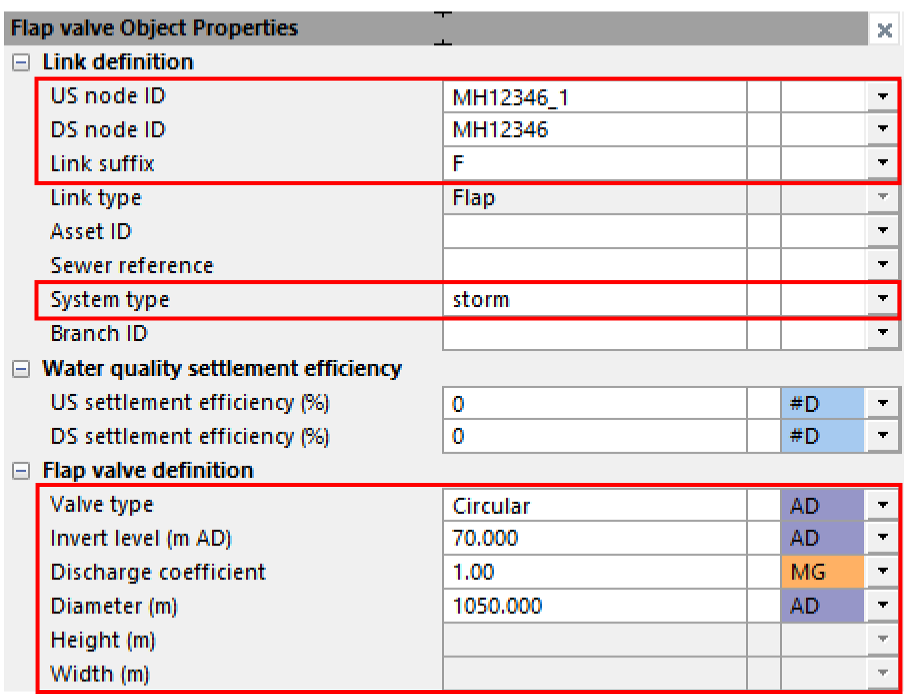


Figure 4D-10 Flap Gate Example



Flap valve Object Properties

Link definition		
US node ID	MH12346_1	
DS node ID	MH12346	
Link suffix	F	
Link type	Flap	
Asset ID		
Sewer reference		
System type	storm	
Branch ID		
Water quality settlement efficiency		
US settlement efficiency (%)	0	#D
DS settlement efficiency (%)	0	#D
Flap valve definition		
Valve type	Circular	AD
Invert level (m AD)	70.000	AD
Discharge coefficient	1.00	MG
Diameter (m)	1050.000	AD
Height (m)		
Width (m)		

Figure 4D-11 Parameters for Flap Gate Definition

4.5 Sluice Gate

A typical sluice gate, such as the example shown on Figure 4D-12, shall be modelled using a standard vertical sluice gate link in InfoWorks ICM. A dummy node is usually needed to connect the sluice gate with the downstream sewer network.

Figure 4D-12 shows the key parameters required to define a vertical sluice gate.

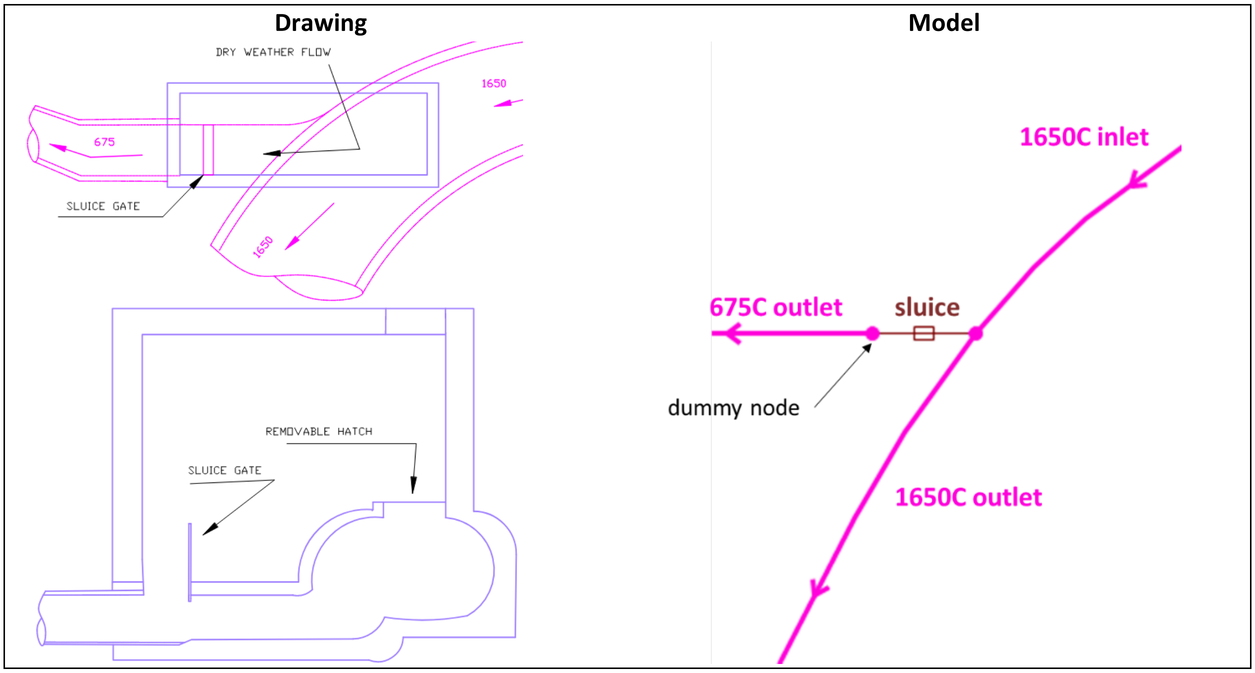
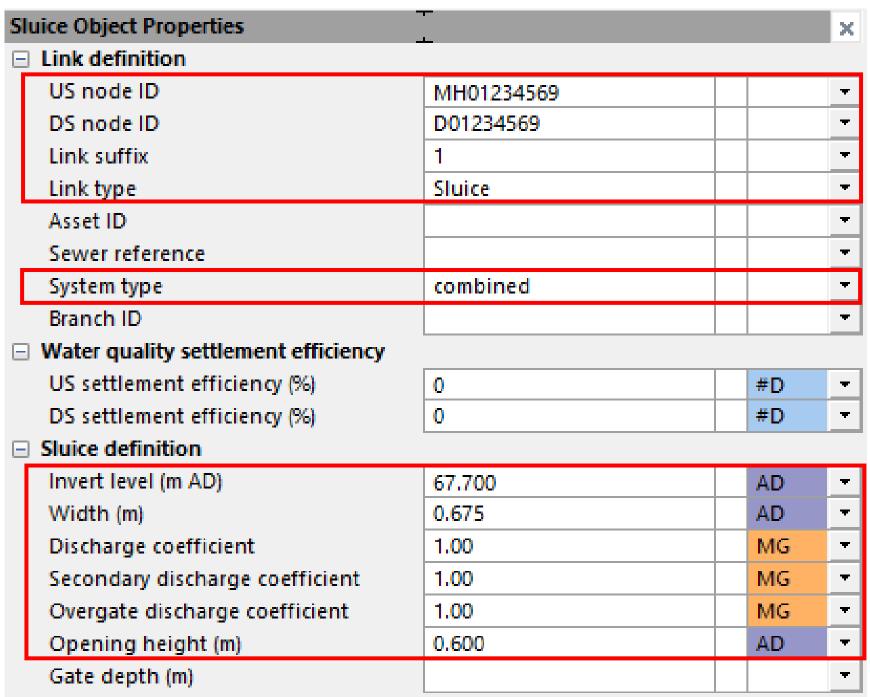


Figure 4D-12 Sluice Gate Example



Sluice Object Properties

Link definition		
US node ID	MH01234569	
DS node ID	D01234569	
Link suffix	1	
Link type	Sluice	
Asset ID		
Sewer reference		
System type	combined	
Branch ID		
Water quality settlement efficiency		
US settlement efficiency (%)	0	#D
DS settlement efficiency (%)	0	#D
Sluice definition		
Invert level (m AD)	67.700	AD
Width (m)	0.675	AD
Discharge coefficient	1.00	MG
Secondary discharge coefficient	1.00	MG
Overgate discharge coefficient	1.00	MG
Opening height (m)	0.600	AD
Gate depth (m)		

Figure 4D-13 Parameters for Vertical Sluice Gate Definition

4.6 Pumps

A typical sewer pump station is modelled in InfoWorks ICM using the following components:

- Inlet pipe: a conduit representing the gravity sewer main that discharges into the wet well.
- Wet well: a node should be created to represent the wet well of the pump station.
- Pumps: each pump is drawn as a link object from the wet well to the forcemain inlet node.
- Forcemain inlet: is a node that all pumps connect to and the forcemain starts at. This can be a regular manhole node, or a break node if the forcemain is modelled with solution type “ForceMain”. See Section 3.3.6 for details on when “ForceMain” shall be used.
- Forcemain: is modelled as a conduit with its solution type set to “Full” or “ForceMain”. See Section 3.3.6 for details on when “ForceMain” shall be used.

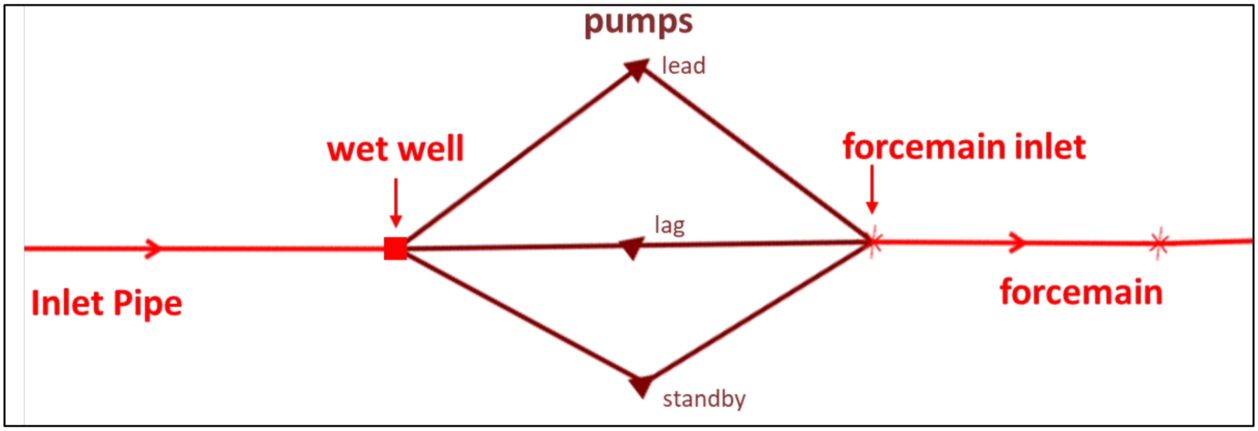


Figure 4D-14 Pump Example

A pump shall be modelled using either a fixed discharge pump or a variable frequency drive (VFD) pump, depending on the magnitude of the drainage area or flow contribution to the collection system. Pump station information shall be requested from the City’s pump station team to determine the type of pump to model in InfoWorks ICM. Key hydraulic pump parameters required to model a VDF pump and a fixed discharge pump are shown on Figure 4D-15 and Figure 4D-16, respectively.

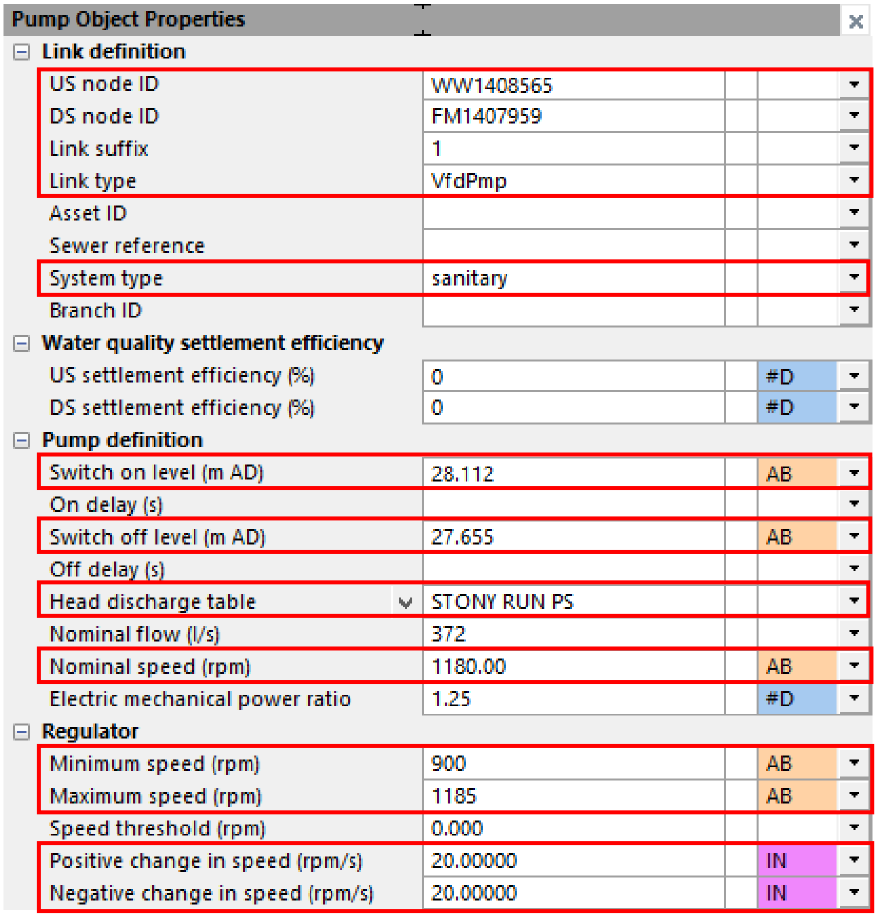


Figure 4D-15 Parameters for Variable Frequency Drive Pump Definition

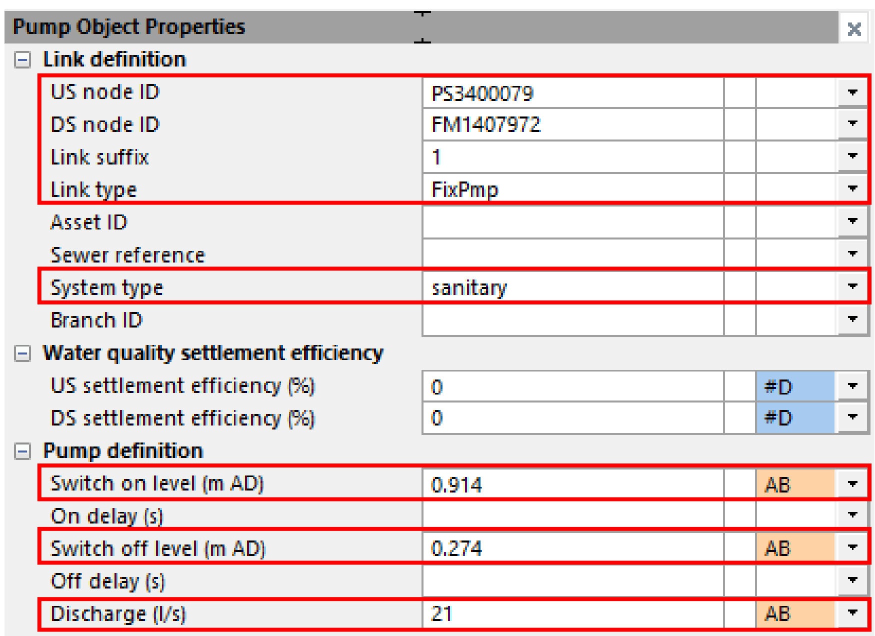


Figure 4D-16 Parameters for Fixed Discharge Pump Definition

4.7 Inverted Siphon

An inverted siphon can be modelled using a series of conduit objects as shown on Figure 4D-17 below. Dummy node(s) shall be created as needed to connect the series of conduits representing the inverted siphon structure.

An inverted siphon is likely to have deposits of sediment; therefore, it is recommended to apply a sediment depth based on findings of CCTV or field survey and a bottom roughness coefficient of 0.2 to 0.025 for the conduits representing the inverted siphon. Figure 4D-18 shows these two parameters in the conduit property table for defining sediment for inverted siphon.

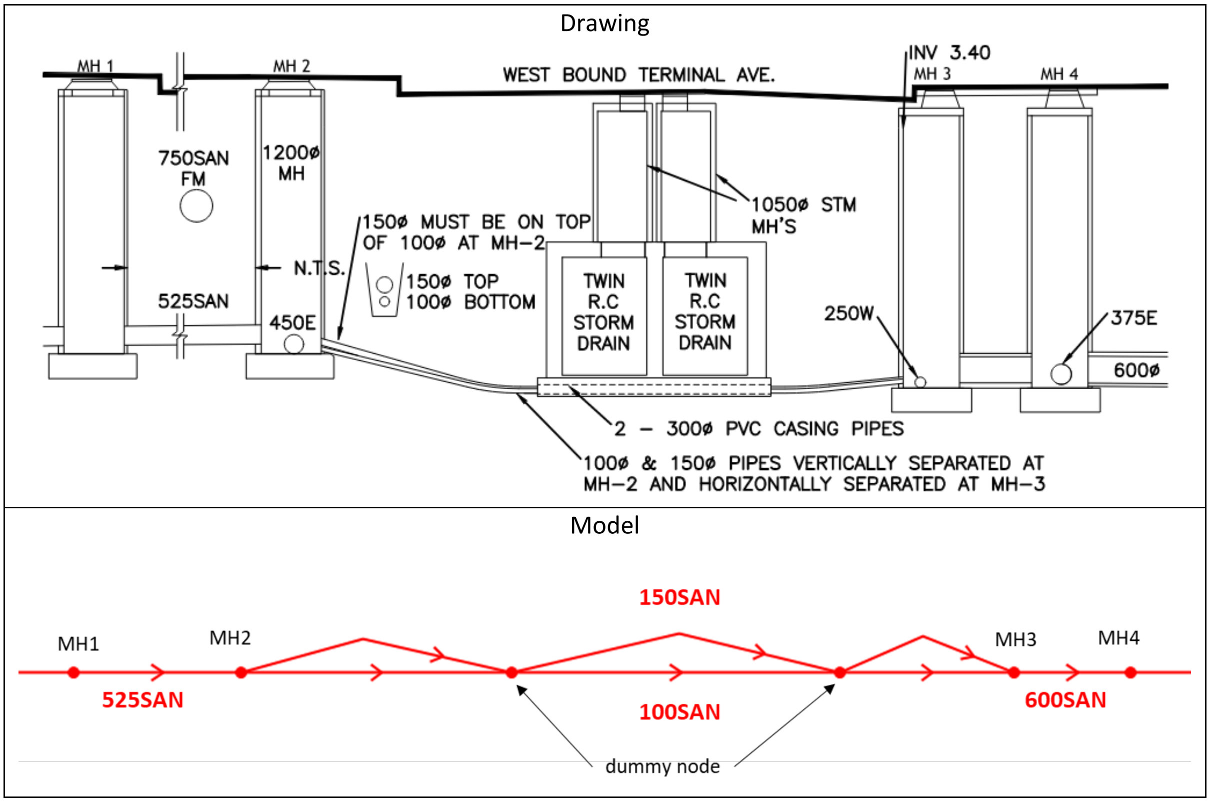


Figure 4D-17 Siphon Example

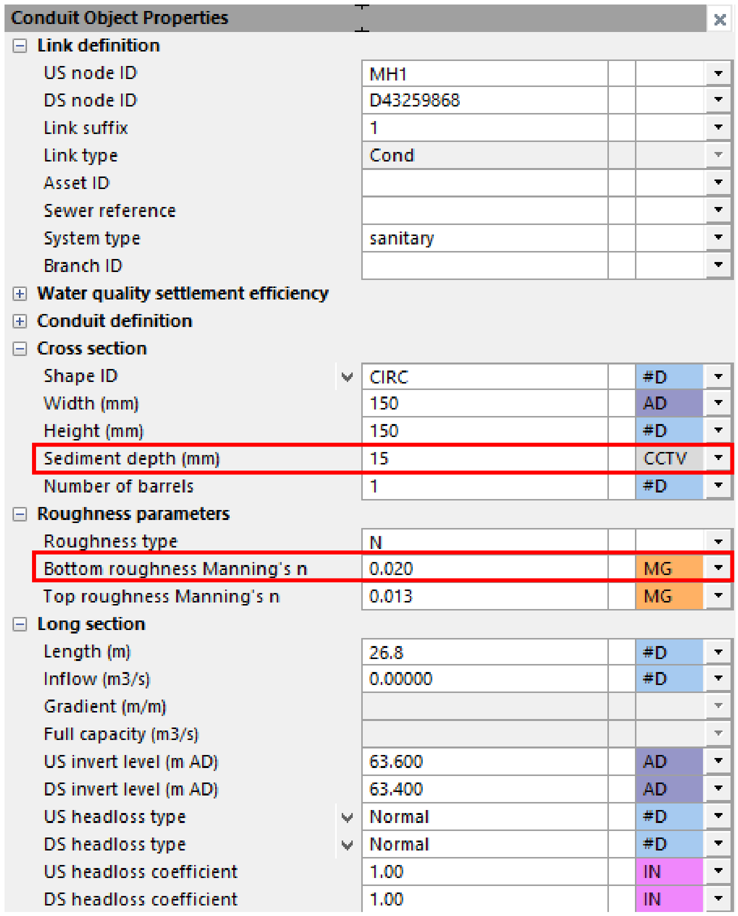


Figure 4D-18 Parameters for Defining Sediment in an Inverted Siphon

4.8 Culverts

A typical culvert with both an inlet and an outlet structure is modelled using a series of dummy nodes and links:

- A culvert inlet link: represents headlosses that occur at the inlet of the culvert. The headloss values depend on whether the culvert is operating under inlet or outlet controlled conditions.
- A conduit: represents the culvert barrel. Since the culvert inlet and outlet replace the usual headloss calculations, both the upstream and downstream headlosses in the conduit should be set to “None”.
- A culvert outlet link: represents headlosses that occur at the outlet of the culvert.

Figure 4D-19 shows an example of a culvert that is under a pedestrian bridge and connects to the open channel. Figure 4D-20 and Figure 4D-21 show that various parameters required for modelling a culvert inlet and a culvert outlet. Section 7 provides empirical values for these parameters, which depends on whether the culvert operate under inlet or outlet control, the culvert’s shape, material, and structure type.

Without much prior knowledge about the operation of the culvert, it is recommended to use an initial assumption that the culvert operates under inlet control to establish the modelling parameters as per the Innovyze help menu. However, the modeller shall confirm this assumption if this level of detail is required for the model.

Table 4D-1 and Table 4D-2 in Section 4 shows the recommended parameter values for modelling culverts under outlet control and inlet control, respectively, and can be used to add the outlet and inlet loss coefficients. These tables are adopted from Table 9.1 and 9.2 of Normann, Houghtalen, and Johnston, 2001. The default value for the outlet headloss coefficient and the inlet headloss coefficient is 1 and 0.5, respectively, in the InfoWorks ICM software.

If the culvert capacity is to be assessed and a potential culvert upgrade needs to be determined, it is recommended to use other software for culvert analysis and design with the modelled flow from InfoWorks ICM as input. The modeller is responsible to choose the appropriate methods for culvert analysis and design.

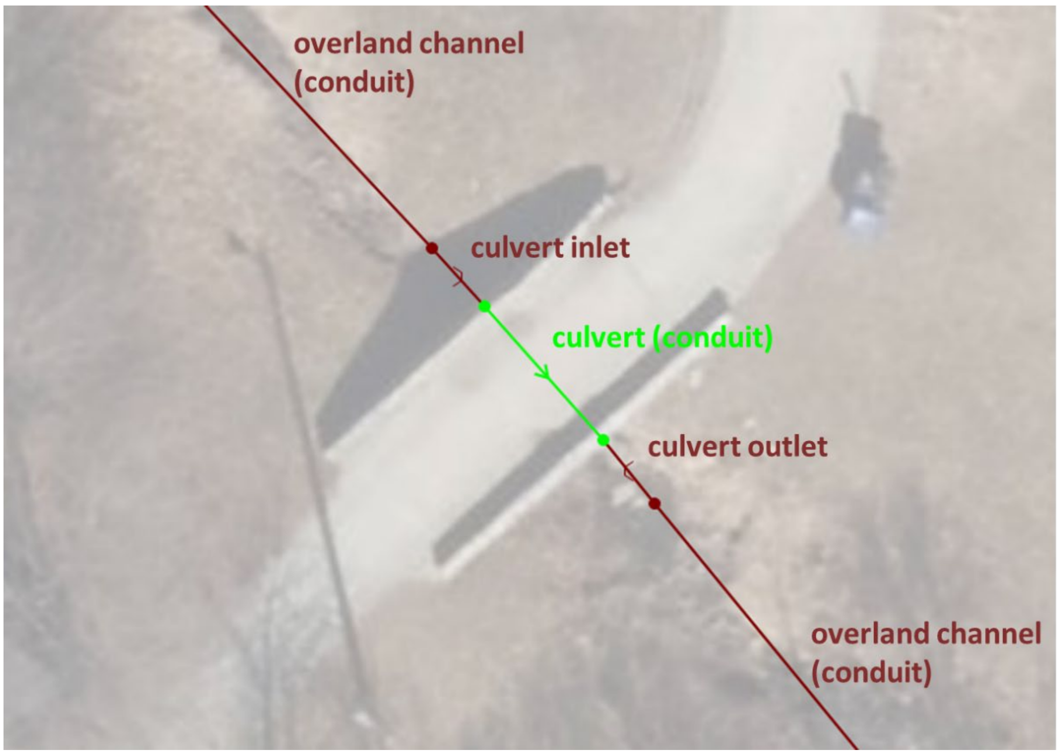


Figure 4D-19 Culvert Example

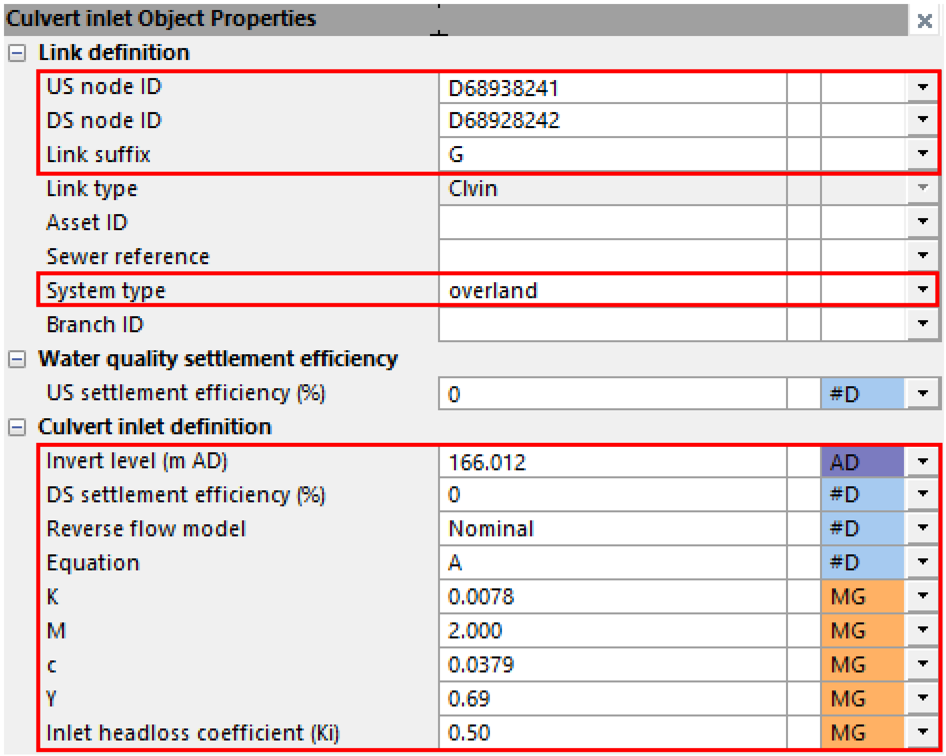


Figure 4D-20 Parameters for Culvert Inlet Definition

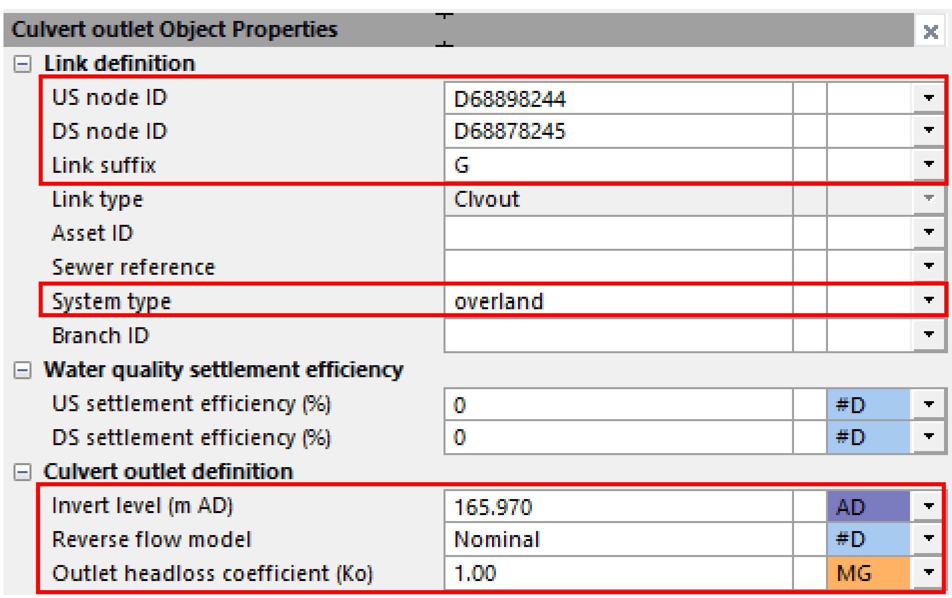


Figure 4D-21 Parameters for Culvert Outlet Definition

4.9 Outfalls

A simple outfall is modelled using an "Outfall" node and a conduit representing the outfall pipe, as shown on Figure 4D-22. The key parameters to define an outfall include:

- Node: the “Outfall” type shall be used and the key parameter is the ground elevation.
- Conduit: represents the outfall pipe and requires the definition of shape, width, height, and upstream and downstream inverts.

In addition to the physical outfall structures, an “Outfall” node shall also be used to model outflow to an external area or a receiving MV trunk, if not included in the modelling extent.

If outfall nodes experience backwater, it is critical to account for this in the outfall node boundary condition. See Section 3.5 for instructions on boundary conditions.

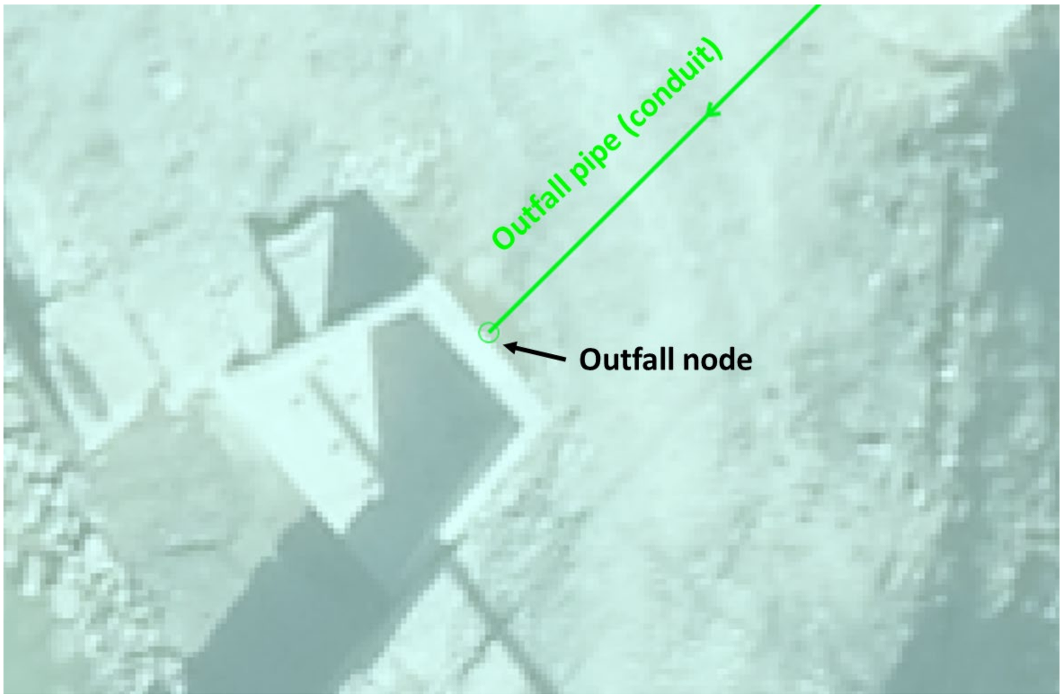


Figure 4D-22 Outfall Example

Outfall Object Properties		
Node definition		
Node ID	OF4333045	
Node type	Outfall	
Asset ID	4333045	#A
System type	storm	
Node location		
x (m)	301699.6	
y (m)	4843325.0	
Ground level (m AD)	124.840	AB
Flood level (m AD)	124.840	#D

Figure 4D-23 Parameters for Outfall Node Definition

5 Weir Coefficients

Section 4.3.1 in Chapter 4 and Section 4.1 in this Appendix provide guidance on modelling a common high sided weir. This section provides more guidance on modelling a transverse weir or low side weir.

A transverse weir has a weir crest that is placed perpendicular to the sewer flow. The WaPUG User Note 27 Section 3 in Appendix 4D.2 provides details regarding the discharge coefficient values for a transverse weir. In addition, the weir coefficient for a transverse weir should be multiplied by the factor F to allow for the velocity energy in the flow approaching the weir where:

$$F = \sqrt{\frac{1}{1 - r^2}}$$

And where:

$$r = \frac{H_w}{H_w + P}$$

H_w is the height of the water surface above the weir
P is the height of the weir crest above the chamber floor

Note that this factor shall be calculated for peak flow conditions.

Low sided weirs are very complex to model and advice from an experienced modeller is strongly recommended for these. The WaPUG User Note 27 Section 4 in Appendix 4D.2 provides details explaining the operations of a low sided weir with a method to model a low sided weir in Section 4.3 in Chapter 4 of the Modelling Standards.

6 Orifice Coefficients

Section 4.3.2 of Chapter 4 provides guidance on modelling an orifice control at the planning stage.

At the design stage, an orifice plate shall be modelled using an orifice link with proper definitions of discharge coefficients. The basic orifice coefficient depends on the relative size of the orifice and the pipe that it discharges into, as mentioned in Section 4.3.2 of Chapter 4.

If all incoming flow is directed towards the orifice and there is a significant approach velocity (the incoming velocity immediately upstream of the structure), then this basic coefficient is modified for the velocity of approach by multiplying by the factor F:

$$F = \sqrt{\frac{1}{1 - r^2}}$$

Where:

$r = A_0 / A_u$ and is no greater than 0.9
A_u = Cross section area of chamber upstream of the orifice

This factor F will increase the coefficient value to allow for the effects of the approach velocity. More information on orifice discharge coefficients is provided in WaPUG User Note 2 in Appendix 4D.3. However, note that a different version of the correction factor for approach velocity is given in the

WaPUG note that has a reduced range of applicability.

7 Culvert Parameters

The following Table 4D-16 and Table 4D-17 shows the recommended parameter values for modelling culverts under outlet control and inlet control, respectively. These tables are adopted from Table 9.1 and 9.2 of Normann, Houghtalen, and Johnston, 2001.

Table 4D-16 Entrance Loss Coefficients for Pipes and Culverts Operating Under Outlet Control

Structure Type and Entrance Condition	k_i
Concrete Pipe	
Projecting from fill, socket or groove end	0.2
Projecting from fill, square edge	0.5
Headwall or headwall and wingwalls	0.2
Socket or groove end	
Square edge	0.5
Rounded (radius = *D*/12)	0.2
Mitered to conform to fill slope	0.7
End section conforming to fill slope	0.5
Beveled edges (33.7° or 45° bevel)	0.2
Side- or slope-tapered inlet	0.2
Corrugated Metal Pipe or Pipe-Arch	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls (square edge)	0.5
Mitered to conform to fill slope	0.7
End section conforming to fill slope	0.5
Beveled edges (33.7° or 45° bevel)	0.2
Side- or slope-tapered inlet	0.2
Reinforced Concrete Box	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 sides	0.5
Rounded or beveled on 3 sides	0.2
Wingwalls at 30° to 75° from barrel	
Square-edged at crown	0.4
Side- or slope-tapered inlet	0.2

Table 4D-17 Entrance Loss Coefficients for Pipes and Culverts Operating Under Inlet Control

Constants for Inlet Control Equations						
Culvert Shape and/or Material	**Inlet Edge Description**	**Unsubmerged (Weir Flow)**			**Submerged (Orifice Flow)**	
		Equation	***K***	***M***	***c***	***Y***
Circular, concrete	Square edge with headwall	A	0.0098	2	0.0398	0.67
	Groove end with headwall		0.0018	2	0.0292	0.74
	Groove end projecting		0.0045	2	0.0317	0.69
Circular, CMP	Headwall	A	0.0078	2	0.0379	0.69
	Mitered to slope		0.021	1.33	0.0463	0.75
	Projecting°		0.034	1.5	0.0553	0.54
Circular	Beveled ring, 45 bevels	A	0.0018	2.5	0.03	0.74
	Beveled ring, 33.7° bevels		0.0018	2.5	0.0243	0.83
Rectangular box	30° to 75° wingwall flares	A	0.026	1	0.0347	0.81
	90° and 15° wingwall flares		0.061	0.75	0.04	0.8
	0° wingwall flares		0.061	0.75	0.0423	0.82
Rectangular box	45° wingwall flares, d = 0.043D	B	0.51	0.667	0.0309	0.8
	18° to 33.7° wingwall flares, d = 0.083D		0.486	0.667	0.0249	0.83
Rectangular box	90° headwall with ¾-in. chamfers	B	0.515	0.667	0.0375	0.79
	90° headwall with 45° bevels		0.495	0.667	0.0314	0.82
	90° headwall with 33.7° bevels		0.486	0.667	0.0252	0.865
Rectangular box	45° skewed headwall; ¾- in. chamfers	B	0.545	0.667	0.0505	0.73
	30° skewed headwall; ¾- in. chamfers		0.533	0.667	0.0425	0.705
	15° skewed headwall; ¾- in. chamfers		0.522	0.667	0.0402	0.68
	10-45° skewed headwall; 45° bevels		0.498	0.667	0.0327	0.75
Rectangular box	45° nonoffset wingwall flares	B	0.497	0.667	0.0339	0.803
with ¾-in. chamfers	18.4° nonoffset wingwall flares		0.493	0.667	0.0361	0.806
	18.4° nonoffset wingwall flares; 30° skewed barrel		0.495	0.667	0.0386	0.71
Rectangular box w/ top bevels	45° wingwall flares, offset	B	0.497	0.667	0.0302	0.835
	33.7° wingwall flares, offset		0.495	0.667	0.0252	0.881
	18.4° wingwall flares, offset		0.493	0.667	0.0227	0.887
Corrugated metal boxes	90° headwall	A	0.0083	2	0.0379	0.69
	Thick wall projecting		0.0145	1.75	0.0419	0.64
	Thin wall projecting		0.034	1.5	0.0496	0.57
Horizontal ellipse, concrete	Square edge w/ headwall	A	0.01	2	0.0398	0.67
	Groove end w/ headwall		0.0018	2.5	0.0292	0.74
	Groove end projecting		0.0045	2	0.0317	0.69
Vertical ellipse, concrete	Square edge w/ headwall	A	0.01	2	0.0398	0.67
	Groove end w/ headwall		0.0018	2.5	0.0292	0.74
	Groove end projecting		0.0095	2	0.0317	0.69

Constants for Inlet Control Equations						
Culvert Shape and/or Material	**Inlet Edge Description**	**Unsubmerged (Weir Flow)**			**Submerged (Orifice Flow)**	
		Equation	***K***	***M***	***c***	***Y***
Pipe arch, CM, 18-in. corner radius	90° headwall	A	0.0083	2	0.0379	0.69
	Mitered to slope		0.03	1	0.0463	0.75
	Projecting		0.034	1.5	0.0496	0.57
Pipe arch, CM, 18-in. corner radius	Projecting	A	0.03	1.5	0.0496	0.57
	No bevels		0.0088	2	0.0368	0.68
	33.7° bevels		0.003	2	0.0269	0.77
Pipe arch, CM, 31-in. corner radius	Projecting	A	0.03	1.5	0.0496	0.57
	No bevels		0.0088	2	0.0368	0.68
	33.7° bevels		0.003	2	0.0269	0.77
Arch, CM	90° headwall	A	0.0083	2	0.0379	0.69
	Mitered to slope		0.03	1	0.0463	0.75
	Thin wall projecting		0.034	1.5	0.0496	0.57

Appendix 4D.2

WaPUG User Note 27

MODELLING ANCILLARIES: WEIR COEFFICIENTS

David Balmforth, MWH

1. SCOPE

This user note gives advice on the choice of coefficient for overflow weirs and orifices when modelling storm sewage overflows and bifurcations.

2. BACKGROUND

Before modelling any ancillary the user must understand:

- the hydraulic performance of the prototype;
- the workings of the algorithm in the computer model.

A combined sewer overflow is typically represented as a small on-line tank with a horizontal base, horizontal weir, and horizontal water surface. Some software can also accommodate an overflow as a hole in the wall of a manhole chamber. In each case the flow in the chamber is assumed to be subcritical and the water level regulated by a throttle on the continuation pipe (WaPUG User Note No 2).

The discharge over the weir (Q_w) is determined by the head above the crest (H_w) using the equation:

$$Q_w = C_w L_w \sqrt{g h_w^n} \qquad (1)$$

where L_w length of weir (or weirs if more than one) (m)
g gravitational acceleration (9.81 m/s^2)
n index, normally 1.5
C_w weir coefficient

Alternatively the user can specify an orifice overflow, such that the discharge through the orifice overflow (Q,) is determined by the equation:

$$Q_0 = C_0 A_0 \sqrt{g H_0^n} \qquad (2)$$

where A_0 area of orifice (m^2)
H_0 head across the orifice (m)
n index, normally 0.5
C_0 orifice coefficient

The user also has the option to specify whether the overspill goes to waste, or to the head of a specified branch.

A bifurcation may be modelled as a special case of an overflow orifice, but with the crest level of the overflow placed a small vertical distance above the chamber floor (e.g. 100 mm).

3. TRANSVERSE WEIRS

3.1 Introduction

Five different flow cases can occur and it is important to establish which case is appropriate in each ancillary. Sometimes the flow case will change during the operation of an overflow and the flow case that occurs during a verification event may be different from that which occurs in a more extreme event (e.g. a design storm).

3.2 Case 1: Free discharge over a weir

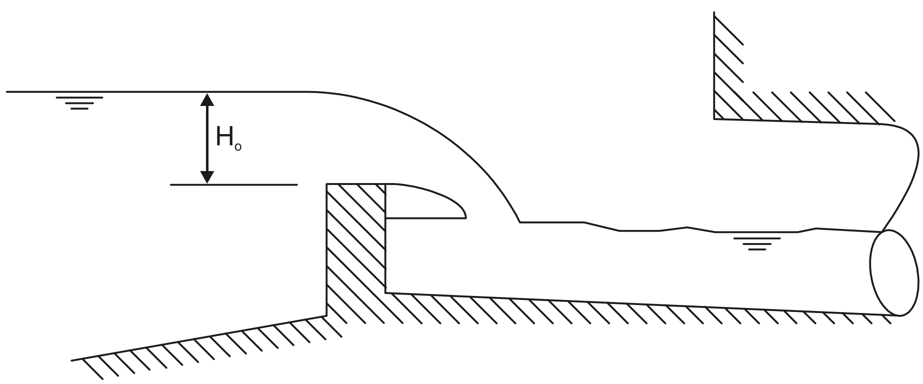


Figure 1a Free discharge over a weir

The discharge is solely dependent upon the head above the crest, and is calculated by Equation 1. The weir control should be selected and the weir coefficient C_w, depends on the geometry of the weir crest, and Table 1 gives suitable values.

Table 1 Values of C_w for Case 1 flow

Weir crest	C_w
Sharp edged	0.60
Square crest	0.70
Round crest	0.80

3.3 Case 2: Freely discharging orifice

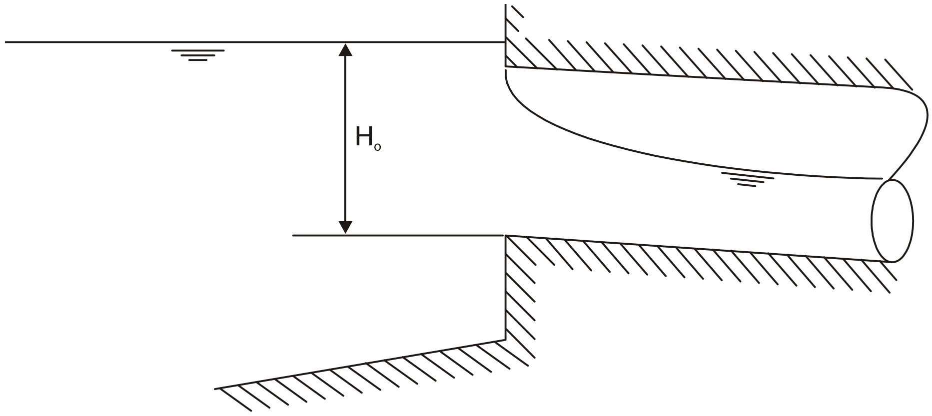


Figure 1b Freely discharging orifice

The discharge is unaffected by water levels in the overflow pipe. The upper surface of the jet springs free from the upper edge of the pipe entry, and is vented to the atmosphere. H_0 is defined as the head above the vertex of the overflow orifice, and Q_0 is calculated from Equation 2. The orifice control should be selected and C_0 given a value of 0.85.

3.4 Case 3: Drowned Overflow – overflow pipe not specified in the data file

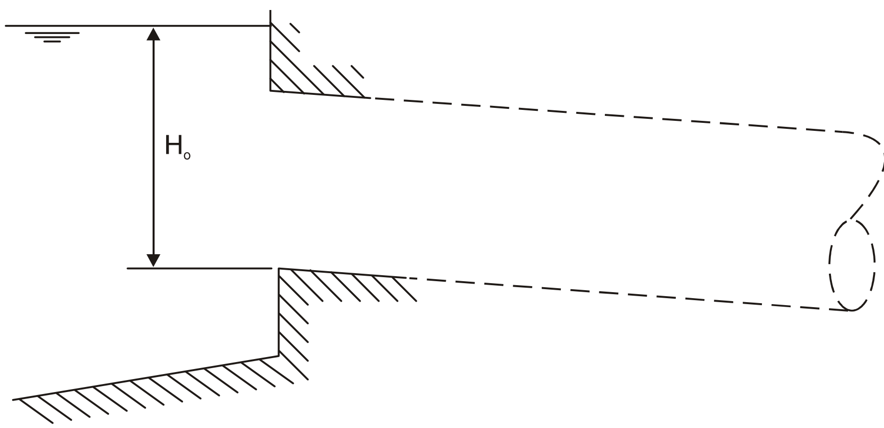


Figure 1c Drowned overflow with overflow pipe not included in model

In this case H_0 is taken as the head above the vertex of the overflow pipe, but energy losses in the overflow pipe (bends, flap valves etc.) can only be accounted for in the value C_0. In this case the orifice control should be selected and C_0 calculated from:

$$C_0 = \frac{2}{\sqrt{\sum K}} \qquad (3)$$

where ΣK is the sum of the loss factors for fittings in the overflow pipe.

Values of appropriate loss factors may be taken from Table 2 which is based on energy loss factors for fittings in water mains. Note that if Equation 3 gives a value in excess of 0.85 then 0.85 should be used.

Table 2 Energy loss factors for pipe fittings

Fitting	K
Sharp entry	0.5
Sharp exit	1.0
90^o bend	1.0
Empty silt trap	3.0
Flap valve	3.0 to 6.0

3.5 Case 4: Drowned orifice, overflow pipe specified in the data file

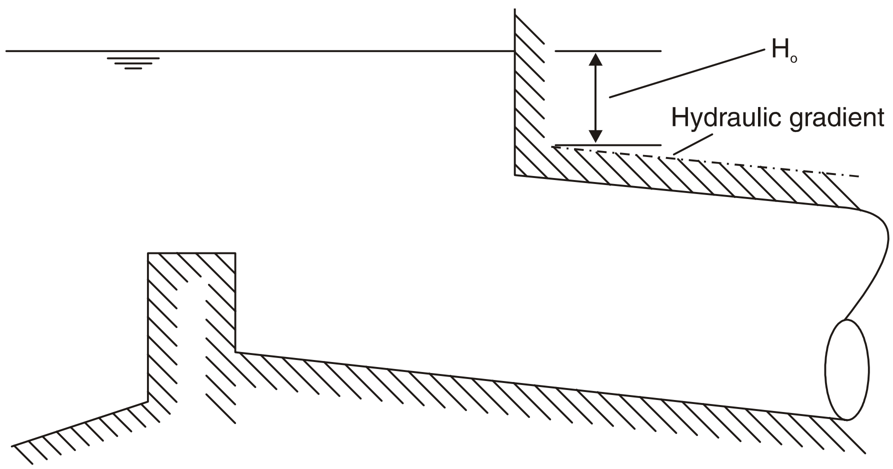


Figure 1d Drowned overflow with overflow pipe included in model

In recent software the overflow pipe is normally included as a second control pipe.

Where an orifice entry is assumed in place of the normal entry losses, the orifice equation 2 has to represent only the energy loss at entry, and C, should be specified as 2.0. In some early software (e.g. WASSP) H was taken as the head above the vertex until the overflow pipe surcharged. Thereafter the difference was used. The sudden change in H, when the pipe surcharged could lead to instabilities in computation if the vertex was low (as in a bifurcation). To overcome such problems overflow pipes were often oversized.

3.6 Case 5: Weir drowned by flow backing up from overflow pipe

This flow condition is quite common. Once the overflow operates and flow builds up in the overflow pipe the weir ceases to become the dominant control. The flow is effectively Case 3 or Case 4 and should be treated as such, but with the invert level of the overflow pipe reset to the weir crest level to give the correct overflow setting.

3.7 Allowance for velocity of approach

Allowance for the velocity energy in flow approaching a transverse weir may be made by multiplying the weir coefficient by a factor F, where

$$F = \frac{1 + \sqrt{1 - 2C_w^2 r^2}}{C_w^2 r^2} \qquad (5)$$

where $r = \dfrac{H_w}{H_w + P}$

P height of weir crest above the chamber floor

Similarly for an orifice overflow:

$$F = \frac{1}{\sqrt{1 - \frac{1}{2} C_0^2 r^2}} \qquad (6)$$

where $r = \dfrac{A_0}{A_u}$

A_u cross sectional area of flow approaching the orifice

These corrections should only be used where there is an appreciable velocity of flow directly approaching the overflow.

4. MODELLING SIDE WEIRS

4.1 Introduction

With side weirs the main issue that arises is the potential variation in water level along the length of the weir due to the reduction in flow in the channel. With low side weirs and where the incoming flow is supercritical there can also be a hydraulic jump in the channel leading to a large and unpredictable change in water level.

Low side weirs normally have a crest below the centre line level of the upstream sewer, and this flow type occurs when the energy at inlet exceeds twice the weir height.

$$d_1 + \frac{V_1^2}{2g} \geq 2C_1 \qquad (7)$$

where d_1 = depth at the upstream end of the weir

V_1 = velocity at the upstream end of the weir

C_1 = height of weir crest at the upstream end of the weir

Fraser (Ref 2) identified five possible flow types of side weir flow, as illustrated in Figure 2.

Type I Flow:

Occurs with low side weirs in mild sloping sewers. A mild sloping sewer is defined as a sewer where uniform flow is subcritical.

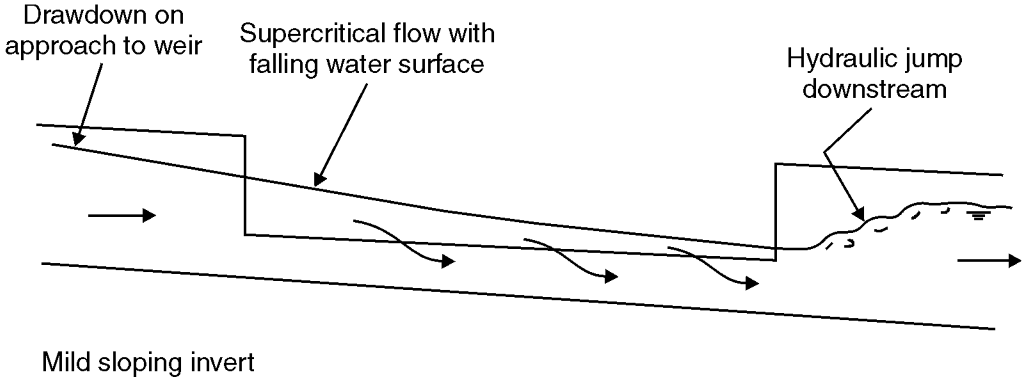


Figure 2a Low side weir

The head over the weir decreases along the length of the chamber and water levels (and hence weir discharge) are governed by conditions at inlet to the chamber, where the depth will be between 0.85 and 0.90 of the critical depth. When this flow type occurs, conditions in the downstream sewer have no influence on the weir discharge nor on the level of the hydraulic gradient in the upstream sewer. Flow in the chamber is supercritical.

Type II Flow:
Occurs with high weirs, which usually have their crest above the centreline level of the upstream sewer. Water levels in the chamber, and the weir discharge, are determined by the throttle at entry to the downstream sewer, and the discharge and level of the hydraulic gradient in that sewer. In this case the head on the weir increases along the length of the chamber. Flow in the chamber is subcritical.

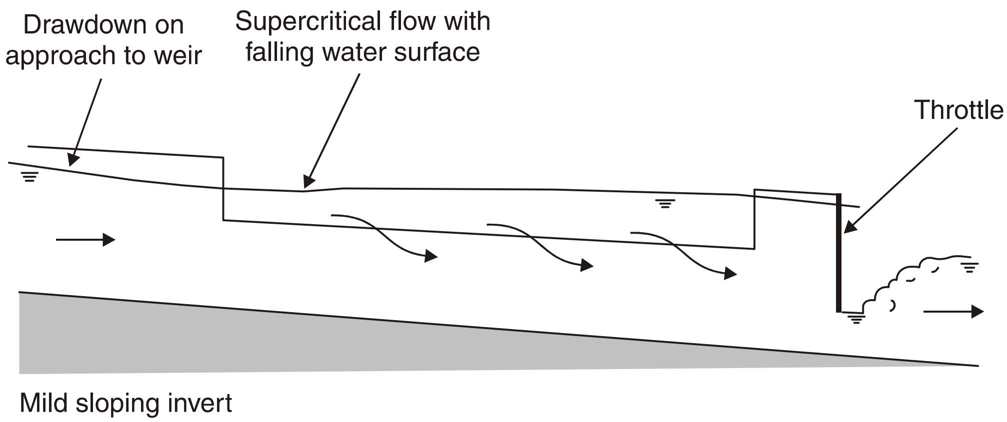


Figure 2b High side weir with throttle

Type III Flow:

Occurs in mild sloping sewers with low side weirs fitted with a throttle at the downstream end of the chamber, or with low side weirs where the downstream sewer is surcharged. Conditions in the downstream sewer influence the weir discharge but do not determine the water level in the upstream sewer. Flow in the chamber is a combination of Type I and II with a hydraulic jump forming.

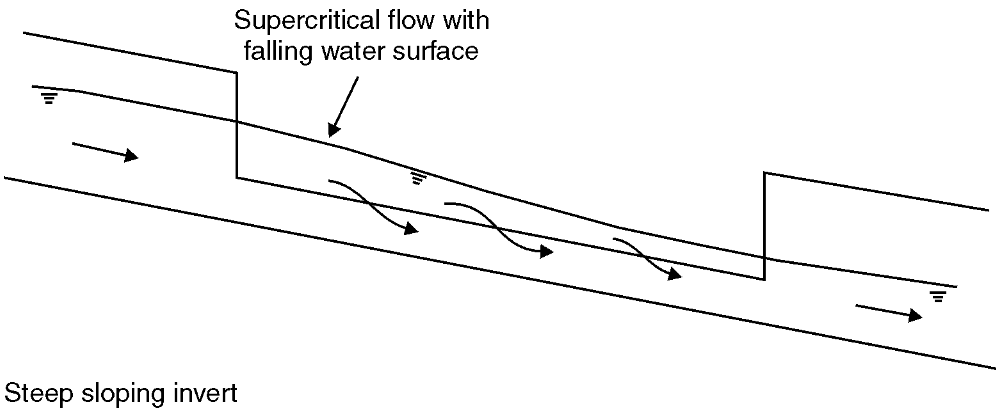


Figure 2c Low side weir on steep slope

Type IV Flow:

Occurs with low weirs in steep sewers. It is similar to Type I flow but the approaching flow is uniform and d_1 approximates to the depth of uniform flow in the upstream sewer.

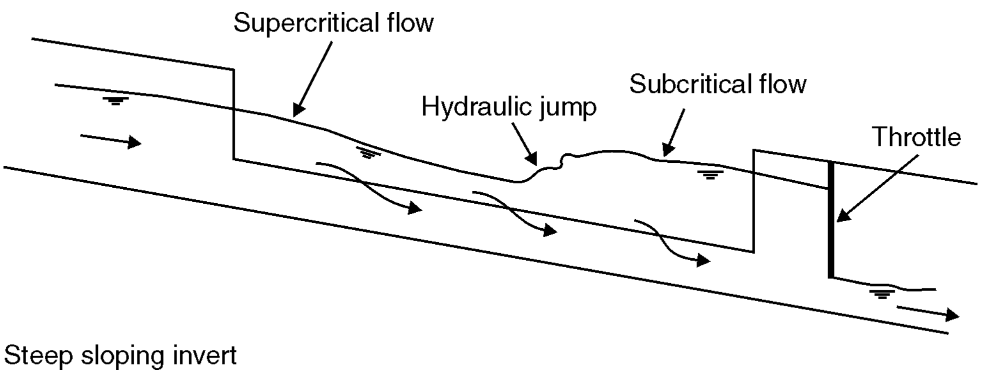


Figure 2d Low side weir with throttle, on steep slope

Type V Flow:

Occurs with low side weirs in steep sewers where the chamber has a throttle at outlet, or where the downstream sewer is surcharged. It is a combination of Types IV and II and is similar in character to Type III.

A number of alternative methods exist for analysing side weir flow and calculating weir discharges. Balmforth and Sarginson (Ref 1) have reviewed the various methods and explain how the discharge capacity of side weirs can be calculated.

4.2 Modelling requirements - High Side Weirs

Where the user is confident that the flow in the chamber is subcritical, the following approach is recommended.

Where there is a significant variation in the head above the crest of a weir, along its length, then an allowance for this should be made in the value of the weir coefficient C_w. For a particular head at the **downstream** end of the weir the discharge over the weir should be calculated (Ref 1) or measured in situ. Denoting this head by H_w, and the corresponding weir discharge Q_w, these values should be substituted into Equation 1 and the corresponding value of C_w calculated.

Where the flow in the chamber can be supercritical (i.e for low side weirs). The method below should be used.

4.3 Modelling requirements - Low Side Weirs

In models it is assumed that the flow in the chamber is governed by the continuation throttle and conditions in the downstream sewer. However, with low side weirs, water levels and weir discharges, are governed by conditions in the upstream sewer at entry to the chamber.

If the actual chamber dimensions and weir coefficients are used directly in the model then the model will over-predict the weir discharge and the water levels in the upstream sewer, as Figure 3 demonstrates.

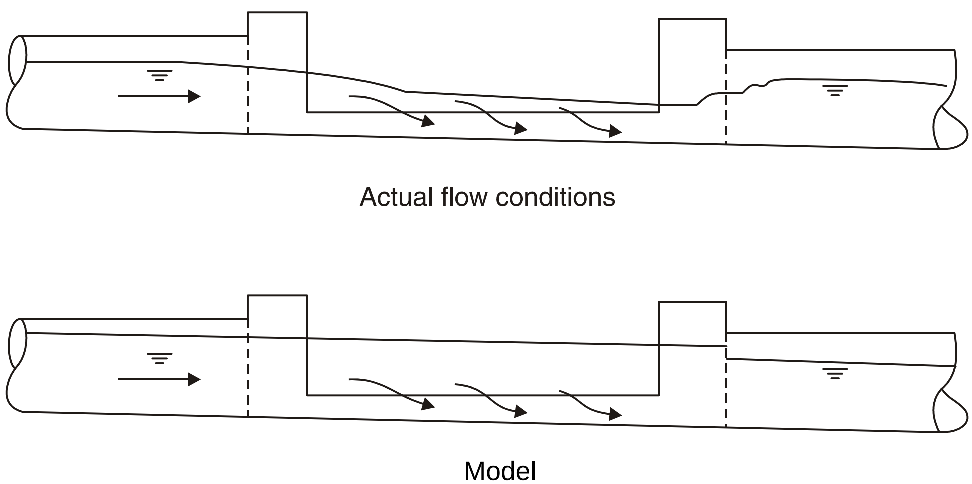


Figure 3

For a particular inflow, the correct weir discharge can be simulated simply by reducing the weir coefficient to give the desired result. However, the water level in the upstream sewer will be over-predicted and this can affect the discharge capability of the upstream system and flooding may be predicted where it does not occur in practice.

Over-prediction of upstream water levels can be avoided by artificially over-sizing the first sewer length immediately downstream of the chamber, and if necessary reducing its gradient to maintain the correct first spill value. For Type I and IV flows the procedure is best summarised as follows:

(i) using proportional depth-discharge calculations for the upstream and downstream sewers, determine the setting of the overflow;

(ii) upsize the downstream sewer. An increase to twice the actual diameter is normally sufficient, though both higher and lower multiples have proved necessary at times.

(iii) adjust the gradient of the oversize pipe to give the correct overflow setting by raising the downstream invert level (the ground level at this point may also have to be raised);

(iv) for the upstream sewer running approximately three-quarters full, calculate the weir discharge and continuation discharge using an established method of calculating side weir flow (Ref 1). Scumboards fitted to the weir reduce the discharge by 10-20%, and this should be allowed for in estimating the weir flow;

(v) using proportional depth discharge calculations, determine the depth of flow in the oversize downstream sewer at the calculated continuation discharge. Calculate the drop in the level of the hydraulic gradient at the throttle using the software's orifice equation. Add this drop to the depth in the oversize sewer to give the depth at the downstream end of the chamber;

(vi) the software typically assumes a horizontal water level and weir crest in the chamber, so that the downstream depth may now be used to determine the head on the weir and the water level in the upstream sewer. Use the former, together with the actual weir length and the calculated weir discharge, in the software's weir equation to obtain an equivalent weir coefficient for use in the model. This may be much smaller than traditional values;

(vii) review the calculated water level in the upstream sewer and if it is significantly higher or lower than that which actually occurs, after the diameter of the oversize downstream sewer and adjust the other parameters accordingly.

When test running the model, particular attention should be paid to the conditions adjacent to the low side weir overflow. In particular, the sewer immediately downstream of the oversize pipe surcharges to any extent then Type III or V flow conditions will probably occur in practice. In this case the downstream sewer should not be oversized.

For Type III and V flow the following procedure should be adopted:

(i) model the downstream sewer as built;

(ii) assume the hydraulic jump forms half way along the weir that the head along the downstream half of the weir is constant, and that the discharge over the upstream half of the weir is negligible;

(iii) model the weir as a transverse weir. Use the actual weir length. If there is only one side weir, take the transverse weir coefficient (reduced by 10-20% if a scumboard is fitted), and halve it. If there are two weirs, do not halve the coefficient.

With smaller side weir chambers in particular it is possible that the whole chamber becomes drowned so that the weir has little effect, and the weir discharge and continuation flow are determined by the size of their respective outlets. In this case it is better to model the chamber as a 'hole-in-manhole' overflow, but with the invert of the overflow orifice set level with the crest of the actual weir.

Note:
Adoption of the above procedures will greatly improve the simulation of the sewer system containing a number of low side weir overflows. During verification, it is permissible to make minor changes to the ancillary data provided they can be justified in the way the ancillary has been modelled, and not purely as a means of force fitting the data. Care should be taken to identify possible Type III and V flow conditions. This is particularly true when running a verified model with design storms where greater surcharging may cause the flow case to change from I to II or IV to V in practice. It may be necessary therefore to amend ancillary data between verification and running with design storms. Time-series rainfall should be in with the verification data however.

Often the data used to model low side weirs appears strange, bearing little resemblance to actual values. This is because the on-line tank model in the software behaves differently from the physical performance of low side weirs, and this has to be compensated for when specifying the ancillary data.

5. OTHER ALLOWANCES

5.1 Allowance for scumboards

Where fitted, scumboards tend to reduce the discharge capacity of weirs. They can have little or no effect, or where their supports are weak they can distort and press against the weir shutting off the flow almost completely. In most cases the vertical distance between the underside of the scumboard and the floor of the chamber will be much greater than the horizontal opening between the scumboard and the face of the weir. It is therefore the latter that usually determines how much the flow is restricted.

If the horizontal opening is greater than the maximum head on the weir then no allowance for the scumboard is needed. At other times a reduction in C, of 10% to 20% is recommended. Where ragging around scumboard supports is excessive a greater reduction should be made.

5.2 Allowance for screens

Screens fitted to the crest of the weirs also tend to reduce the discharge capacity. In this situation it is better to use an equivalent weir length, shorter than the actual weir length rather than adjusting the weir coefficient.

L_w = Actual weir length $\dfrac{h_b}{h_b + t_b}$

where h_b is the clear spacing between the bars (mm)
t_b the bar thickness (mm)

If the screens are not mechanically raked, a further allowance may be necessary for ragging. For widely spaced bars rags tend to accumulate around the bars, reducing the effective dimension h_b. For finer screens, rags will completely obstruct the openings between the bars immediately above the weir crest. The weir crest height should therefore be increased to allow for this.

6. REFERENCES

1. Balmforth D J and Sarginson E J; A comparison of methods of analysis of side weir flow, Chartered Municipal Engineer, Vol 105, No 10 pp 273-279, October 1978.

2. Fraser W, 'The Behaviour of Side Weirs in Prismatic Rectangular Channels', proceedings of the Institution of Civil Engineers, Vol 6, February 1957.

AMENDMENTS

Ver	Description	Date
1.	First Published	August 1993
2.	Revision incorporating material from user note 14	March 2009

Appendix 4D.3

WaPUG User Note 02

MODELLING ANCILLARIES: ORIFICE COEFFICIENTS

David J Balmforth, MWH

1. INTRODUCTION

The ability to model ancillaries is an important feature of sewerage network models. To obtain accurate representation in the hydraulic model it is important that, appropriate values are used for the various parameters. This User Note gives guidance on the modelling of the outlet throttle at entry to the continuation pipe in the on-line and off-line tanks.

2. TYPES OF THROTTLE

There are four types of throttle in common use:-

(i) Throttle Pipe (Figure 1). This is described in Section 3
(ii) Orifice Plate (Figure 2). This is described in Section 4
(iii) Adjustable Penstock
(iv) Vortex Regulator (e.g. Hydro-Brake®). This is described in WaPUG User Note No 1.

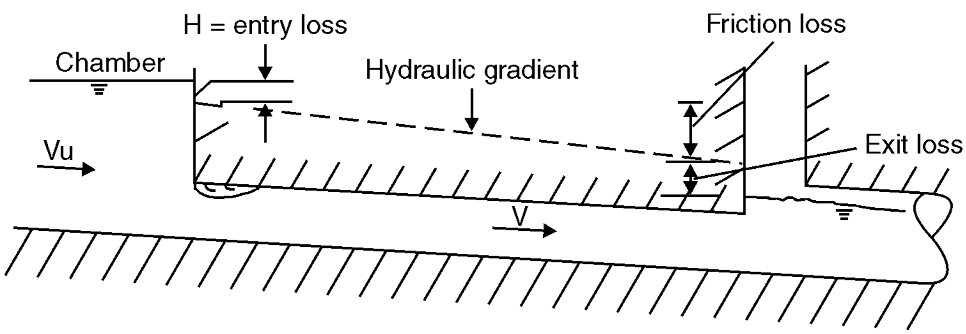


Figure 1 Longitudinal Section through Throttle Pipe

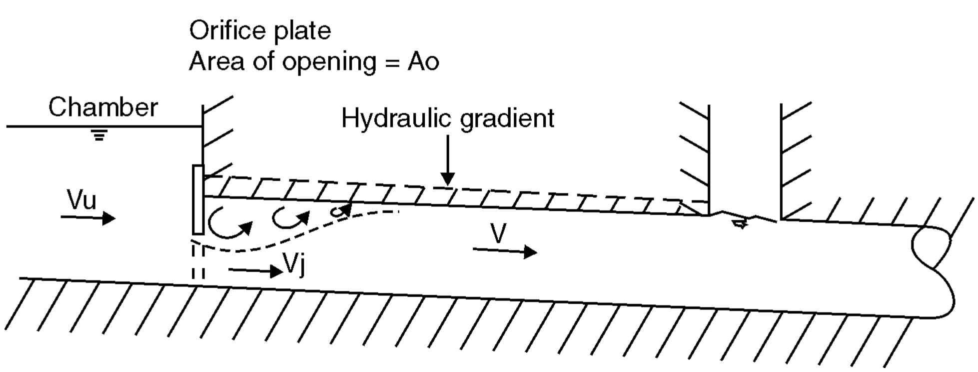


Figure 2 Longitudinal Section through Continuation Pipe with Orifice Plate Throttle

The adjustable penstock is effectively an orifice plate with a variable area of opening, and is modelled as an orifice. The same comments that apply to an orifice apply also to a penstock.

With older types of storm overflow structures, and with bifurcations, the continuation pipe may not have a specific throttle, the ongoing flow being limited solely by the capacity of the continuation sewer.

3. THROTTLE PIPES

3.1 General

Typically each pipe in the model is modelled separately by the program. At a particular discharge the program calculates friction losses from the Colebrook-White and Darcy equations (Ref 2) and entry and exit losses from K_1V^2 / 2g and K_2V^2 / 2g respectively (Figure 1). Standard values of K_1 and K_2 are typically built into the program but the user may be able to specify additional losses due to non-standard manholes.

3.2 Recent software

Recent software commonly includes a specific capability to model throttle pipes as a control link. In this case no special consideration is necessary.

3.3 Older software

Some older software (e.g. WASSP and WALLRUS), however, assumes that there is an orifice plate at the entry to the continuation pipe. The entry loss is not then calculated from K_1V^2 / 2g using standard (default) values, but by using an orifice discharge equation, as follows:

$$Q = C_0 A_0 (gH)^{0.5} \qquad (1)$$

where C_0 = orifice coefficient
A_0 = area of orifice opening (m^2)
H = head loss at entry to continuation pipe (m) (Figure 2)

Note that C_0 differs from the traditional coefficient of discharge C_d(C_0 – C_d $2^{0.5}$).

Rearranging equation (1) gives

$$H = \frac{Q^2}{gC_0^2A_0^2} \qquad (2)$$

The following points should be noted:-

(i) the programs assumed that the orifice is ‘drowned’ (Figure 2): a freely discharging orifice cannot be modelled;

(ii) if the continuation pipe does not have an orifice throttle at inlet (e.g. a throttle pipe) then the area and invert level of the orifice in the tank record should be left blank (default values taken from continuation pipe record).

(iii) for the conditions in (ii) above there is a fixed relationship between the orifice coefficient C_0 and the entry loss coefficient $K_1 (C_0 = (2/K_1)^{0.5})$.

4. VALUES OF THE ORIFICE COEFFICIENT

The performance of an ancillary in the hydraulic model is extremely sensitive to the value of the coefficient for the orifice on the continuation pipe. In the absence of field data the engineer should carefully consider the path the flow takes in entering the continuation pipe. Generally, the more the flow is directed into the continuation pipe, and the less the contraction of the jet, the smaller will be the losses and the larger the value of C_0.

The value of the coefficient C_0 for, a drowned orifice may be obtained from the following equation,

$$C_0 = \frac{1.41}{1.70 - \left(A_0 / A\right)} \qquad (3)$$

where A_0 = area of orifice (m^2)
A = area of continuation pipe (m^2)

Equation (3) assumes that the continuation pipe runs full. Comparison of values given by equation (3) with measured values obtained from a limited number of laboratory tests (Ref 3) shows that equation (3) generally predicts values to within 15% of the measured values.

5. ALLOWANCE FOR VELOCITY OF APPROACH

In most practical cases the velocity in the chamber of the ancillary will be so small that the velocity head $V_u^2/2g$ will be negligible when compared with the depth of flow. When this is not so the value of C_0 should be increased to allow for the effects of the ‘velocity of approach’.

The value of C_0 may be increased using the multiplying factor F obtained from the equation

$$F = \frac{1}{1 - 0.5C_0^2 r^2}$$

where $r = A_0/A_u$

A_0 = area of orifice (m^2)

A_u = cross-sectional area of flow in chamber (m^2) for value of C_0 r not greater than 1.2.

6. STABILITY PROBLEMS

In recent software stability problems are not normally encountered.

When large values of C_0 (say greater than 2.5) are specified when using older software (e.g. with WASSP and WALLRUS), instabilities can occur in the computations. These are caused by small changes in water level (and therefore H) resulting in large changes in the continuation flow Q_0. Heavily overloaded systems, and systems which have two or more ancillaries in close proximity, are prone to this problem. It manifests itself in oscillating flows in flow hydrographs, excessively large flooded volumes and/or an imbalance of flow volumes. To overcome the problem the value of C_0 should be progressively reduced until the instability disappears. In general the subsequent error in C_0 will not have such a serious influence on the results as the instability.

7. REFERENCES

1. Anon, 'Design and Analysis of Urban Storm Drainage, The Wallingford Procedure', Volume 2, 'Program User's Guide', DoE, STC Report No 29, September 1981.

2. Anon, Tables for the Hydraulic Design of Pipes and Sewers', 4th ed, Hydraulics Research Station Ltd, 1983.

3. Smith R K, 'The Design of Outlet Control Devices for Storm Water Overflows', Internal Report, Dept of Civil Engineering, Sheffield City Polytechnic, June 1979.

AMENDMENTS

Ver	Description	Date
1.	First Published	March 1986
2.	Revision	October 1996
3.	Editorial Amendments	March 2009

Appendix 4D.4

WaPUG User Note 22

SELECTION OF TIDE LEVELS

Martin P Osborne, Mouchel Group

1. INTRODUCTION

Many sewerage systems are affected by tide levels at the main outfall, or on overflows. This note considers the choice of tide levels for use with particular rainfall events for verification, analysis of flooding, and analysis of overflow spill.

2. REPRESENTATION OF TIDE LEVELS

The tide curve for a site is made up of many different components, both regular and irregular. The most important ones are:

Daily tidal cycle
The regular variation between high and low tide with a period between successive high tides of 12 hours 20 minutes.

Spring-neap cycle
The regular monthly variation between high spring and low neap tides.

There are other regular components with longer periods which have a small effect on the tide level. The regular components are independent of weather conditions, and therefore are independent of rainfall.

Surge
An irregular increase in tide level due to low atmospheric pressure or decrease due to high atmospheric pressure.

Wind set
An irregular increase in tide level due to onshore winds and decrease due to offshore winds.

Surge and wind set are particularly important on the west coast of the UK and they should be included in any analysis, elsewhere it may be possible to ignore them. The two irregular components may not be independent of rainfall. However the analysis of return periods is much easier if we assume that they are.

The two regular components can be used to define a curve of tide level against the proportion of time for which that level was exceeded. This curve would show a maximum level equal to the mean spring high water level and that this occurs once per month.

This analysis would not show extreme high tide levels above this level as they are due to the other tidal components.

If surge and wind set are important and tide level records are available then a similar level exceedance curve can be drawn from the measured tide levels. The surge and wind set will only affect the extreme ends of the curve.

3. REPRESENTATION OF RAINFALL

Rainfall return periods can be represented by the familiar depth-duration-frequency analysis. This shows the rainfall depth for a given duration increasing with return period, and the rainfall depth for a given return period increasing with duration. In order to completely represent a particular return period it is necessary to analyse a range of events of different durations.

4. JOINT PROBABILITIES

If we assume that the tide level and rainfall are independent then we can consider the probability of them happening together by combining the probabilities of each of them happening alone.

For example:

If the tide level exceeds 2.2 m for 10% of the time, it has a probability of 0.1. A storm with a return period of 5 years has a probability of occurrence in any year of 0.2. The probability of a 5 year storm coinciding with one of the tides greater than 2.2 m is given by:

$$0.1 \times 0.2 = 0.02 = \text{one in 50 years}$$

However a one in 50 year probability would also be given by a one in 50 year storm coinciding with any tide (i.e. all tides above spring low water level) or by tides which are only exceeded once in fifty years combined with no rainfall.

The one in 50 year situation is taken as the worst case of this family of situations which each have a calculated probability of one in 50 years.

5. SPATIAL VARIATION OF TIDE LEVEL

For many systems, it will be adequate to use the same tide level on all overflows and outfalls from the system. However local knowledge and tide records will be useful to determine whether there is a significant difference in tide levels between different parts of a large drainage system. This is particularly important in narrow inlets where there may be a difference in both time and level between different points.

6. VERIFICATION

To verify a model which is affected by a tide level it will be necessary to have records of the tide level at the outfall. This should be the level of the tide itself not the level which would be recorded by a flow monitor in the outfall pipe. The level recorded in the pipe will be higher due to the water flowing through it. This tide level should be used in the model as a level hydrograph giving the variation with time during the verification event. A timestep of one hour should be satisfactory for this level hydrograph.

7. ANALYSIS OF FLOODING

The analysis of system performance for flooding will use the techniques of joint probabilities set out above.

1. Draw up a tide level exceedence curve either from analysis of a tide record or by generating it from the mean spring and neap tide levels.
2. Decide on the required return period of flood risk.
3. Choose the storm return periods which will be used. These should range from 1:1 year to the required return period of risk.
4. For each storm calculate the probability for the tide level P.P = storm return period I required return period of risk.
5. Mark P on the tide level exceedence curve. The tide level which is required is the average of all tides above P. This can be approximated by the tide level for 0.5 x P.
6. Use a constant tide level equal to this value with storms of this return period and a range of durations.
7. Repeat from step 4 for each return period and then tabulate the worst flooding from the entire range of storms which have been analysed.

8. ANALYSIS OF OVERFLOW SPILL

The analysis of overflow spill volumes is normally done using a rainfall time-series. As the concern would probably be with pollution during the bathing season, the analysis may use only the parts of the time series which represent summer rainfall.

If the rainfall time series is intended to represent a typical year, it should be used with typical tide levels, i.e. mean sea level. It is therefore not necessary to carry out a seasonal analysis of tide levels to use only the summer events from the time series. Any seasonal change in mean sea level is small enough to be ignored.

Choice of storm duration
Systems which are affected by tide levels will be using storage in the system to attenuate the flows. The effective time of concentration of the systems and the critical storm duration will therefore be increased compared to a system which is not affected by tides. This causes two difficulties.

For large systems or those with a large amount of storage affected by the tide, the storm duration may become sufficiently long that it is not reasonable to use a fixed tide level as described above. A time varying tide level can be derived by drawing out a single tidal cycle as a sine curve using the fixed level calculated above as the peak level. The tide levels should then be read from this curve starting half of the storm duration before high tide. This requires a different level hydrograph for each storm duration and is therefore tedious, but may show significant savings for large systems.

The other problem with long duration storms is the effect of runoff from permeable areas in the wet conditions at the end of these storms. In particular the possible need to consider winter runoff conditions should be checked.

AMENDMENTS

Ver	Description	Date
1.	First Published	August 1991
2.	Revision	Oct 1996
3.	Editorial Amendments	March 2009

Appendix 5

Calibration Assessment

Refer to Excel Spreadsheet entitled

Appendix_5A_Calibration_Assessment_Template_2023NOV.xlsx”