



# MIKE+

User Guide

SWMM





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# 1 General Settings

Set the model type for a MIKE+ project in the Model Type editor under the General Settings section. This section also contains the Description editor, wherein a free text note or description about the project may be added.

## 1.1 Model Type

The Model Type editor provides an at-a-glance view of which MIKE+ features and modules are active for a project. Active features and modules control the menus accessible from the Setup tree view.

MIKE+ supports modelling of the following system types:

- Rivers, collection system and overland flows
- SWMM5 collection system
- Water distribution

### 1.1.1 Features

The following features are activated for 'SWMM5 collection system' models:

- **Catchment.** Various hydrological processes that produce runoff from urban areas can be modelled by SWMM. These include:
  - Time-varying rainfall
  - Evaporation of standing surface water
  - Snow accumulation and melting
  - Rainfall interception in depression storage
  - Infiltration of rainfall into upper soil layers
  - Percolation of infiltrated water into groundwater layers
  - Interflow between groundwater and the conveyance system
  - Non-linear reservoir routing of overland flow
- **Collection System Network.** This feature allows for the hydrodynamic simulation of flows and water levels in the urban storm drainage and wastewater collection networks, thus providing an accurate information about the network functionality under a variety of boundary conditions. The model can be enhanced by the variety of real-time control functions.

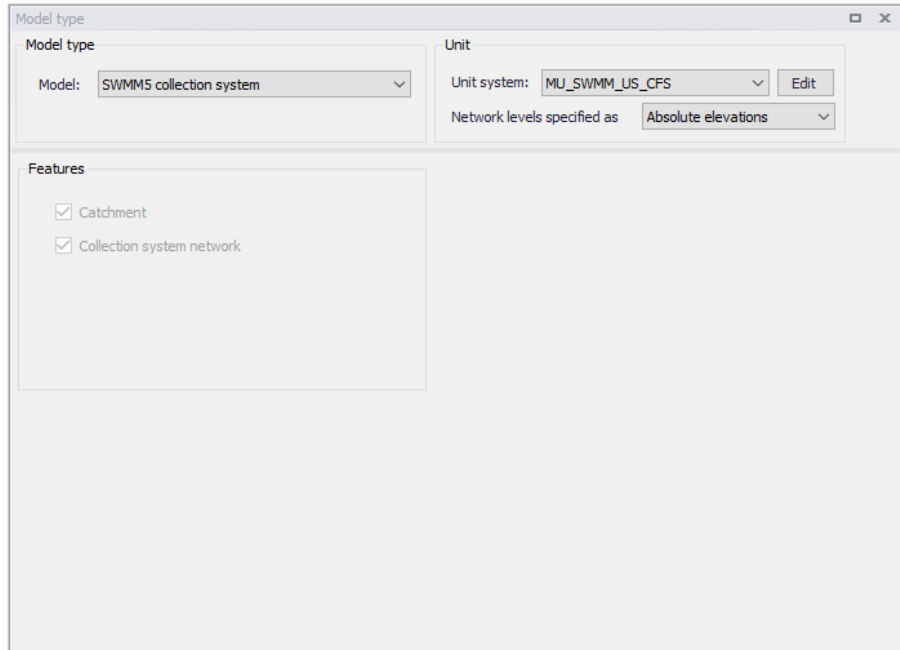


Figure 1.1 Editor for Model type, Unit, and Features selection

## 1.1.2 Unit

MIKE+ is fully flexible concerning the applied units for numeric attributes, number of decimals and default values for any attribute in the database. The system allows for a number of predefined unit environments. The unit environment is specified when the model is originally created but can be changed or modified at any stage. The units are automatically converted in the database. i.e. it is possible to change an existing database from one system to another.

The term "unit environment" is a pre-defined set of definitions for units, default values and display formats. The unit environment can be in SI units (International System of units) or US units (United States customary units).

For SWMM5 collection systems, there are six pre-defined unit environments within the SI and US unit groups which differ from each other by the applied units for flows and volumes.

Within the SI group, the following unit environments are available:

- MU\_SWMM\_SI\_CMS: SI environment, with flows in  $m^3/s$
- MU\_SWMM\_SI\_LPS: SI environment, with flows in L/s
- MU\_SWMM\_SI\_MLD: SI environment, with flows in MLD

Within the US group, the following unit environments are available:



- MU\_SWMM\_US\_CFS: US environment, with flows in cfs
- MU\_SWMM\_US\_GPM: US environment, with flows in gpm
- MU\_SWMM\_US\_MGD: US environment, with flows in MGD

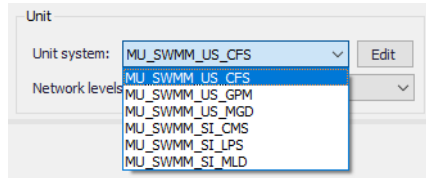


Figure 1.2 Selecting the unit environment for SWMM5 models

The unit environment will apply default units to all attributes (parameters) in the project. These units can then be customised with the Edit button.

The **Edit** button opens the Units Customisation dialog, which contains a first table to select units for given attribute types. The second table in the dialog is used to select the unit for specific attributes. Finally, the third tab in the dialog contains the units selection for real-time controls in collection system network simulations.

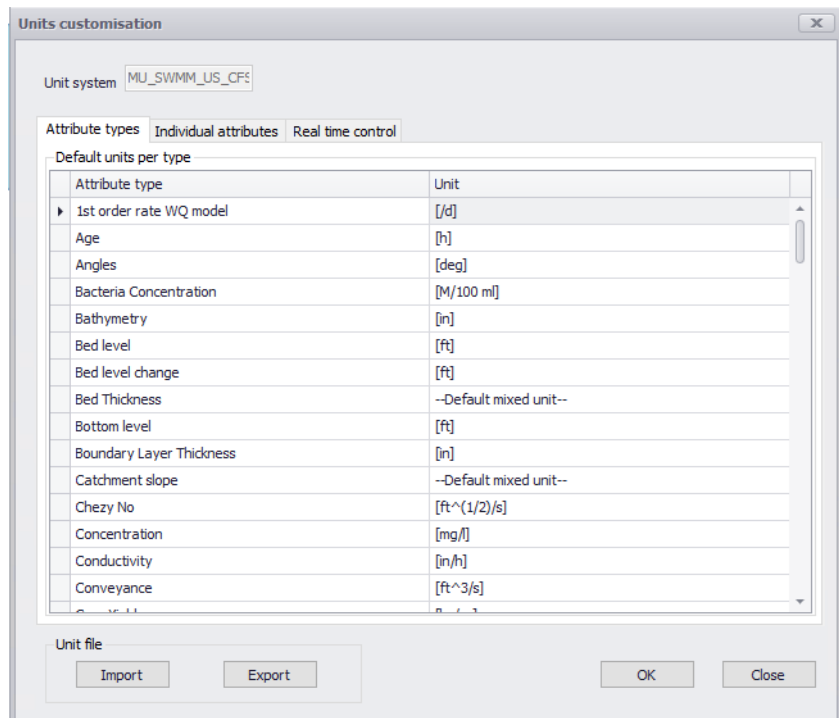


Figure 1.3 Units Customization dialog accessed via the Edit button



More information on customizing units are found in the MIKE+ Model Manager User Guide chapter on 'Units, Default Values and Numeric Formats.'

### 1.1.3 Network Levels Specification

One may specify how network level values shall be defined in the SWMM5 model via the Model Type editor under the Unit group.

For 'Network levels specified as', choose between the options:

- Absolute elevations
- Relative depths

This especially affects how level data are defined for Nodes and Conduits.

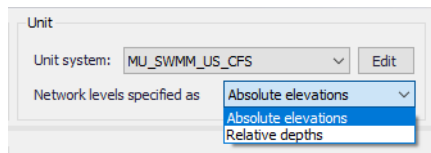


Figure 1.4 Options for definition of network levels

## 1.2 Description

The Description editor allows addition of information about the project and a free text description of the model. It may also be used as a model build log to make notes on updates and amendments to the model.

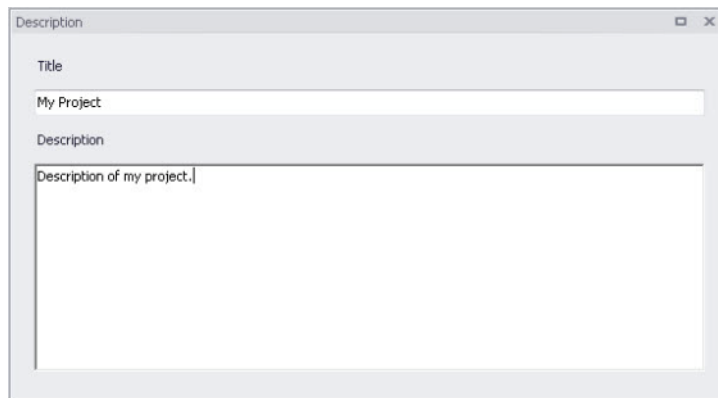


Figure 1.5 The Description editor



## 2 Map Configuration

The Map Configuration section contains information on the coordinate system used in the MIKE+ project and presents options for customising the background image.

### 2.1 Coordinate System

The Coordinate System editor (Figure 2.1) displays the Projection system used in the project.

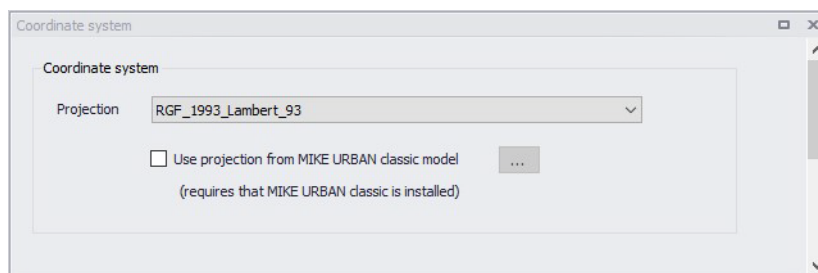


Figure 2.1 The Coordinate System editor showing information on the projection system used in the project

The Projection may be selected from the dropdown list, or by searching amongst the map projections available in MIKE+ via the <Browse...> option at the bottom of the list. This opens a window listing the available projections, where it is also possible to import new projections from a projection file (\*.prj file).

Alternatively, the map projection may be read from a MIKE URBAN classic file. If MIKE URBAN classic is installed on your computer, you can tick the corresponding option, select a MIKE URBAN classic file and the same projection will be used in MIKE+.

When changing the map projection, it is possible to reproject geographical data in the project, for example to convert the coordinates of the network and catchments data, or mesh arcs used for the creation of the 2D domain. Some data files used as input for the simulation however can not be reprojected; this is especially the case for an external 2D domain file (\*.MESH or \*.DFS2) or external 2D data file used to map input parameters (e.g. \*.DFSU or \*.DFS2 file used to map the 2D surface roughness).

The same options for selecting the Projection are also used in the 'New Module Setup' window when a new MIKE+ project is created (Figure 2.2).

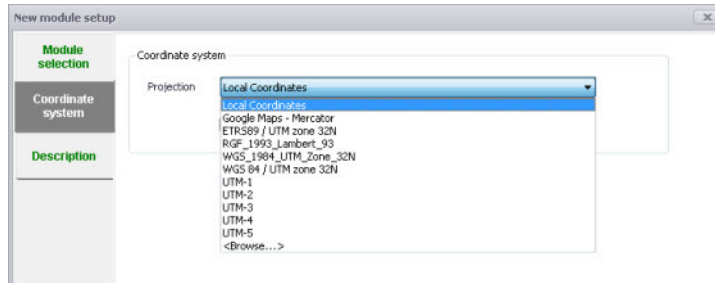


Figure 2.2 Specify the projection system for a new MIKE+ project on the New Module Setup dialog

## 2.2 Background Map

The Background Map editor allows the user to select a background image to show on the Map View in MIKE+ (Figure 2.3).

Activate a background map overlay by ticking the 'Visible' checkbox on the editor.

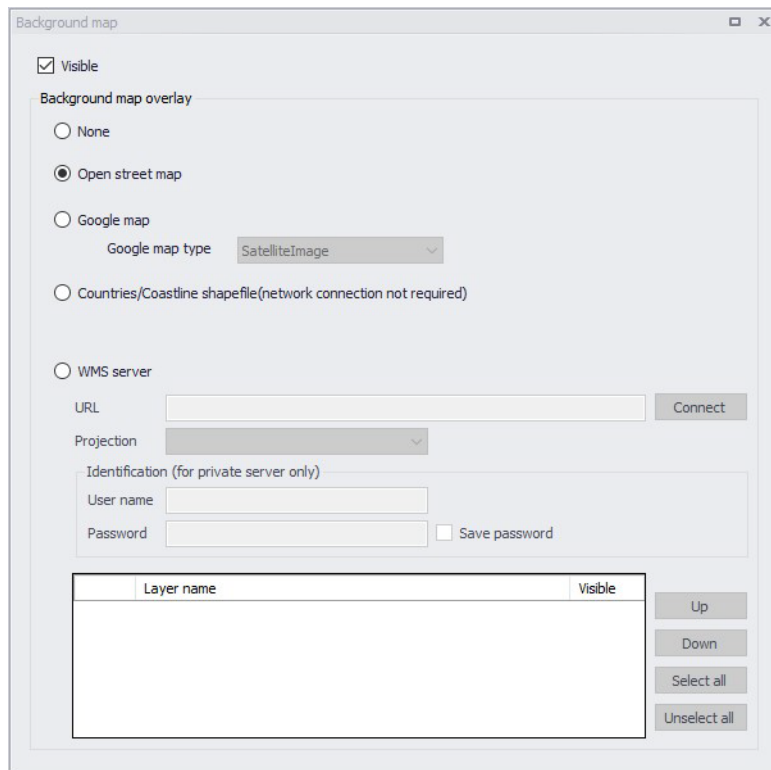


Figure 2.3 The Background Map editor



The following background map overlay options are available:

- **None**
- **Open Street Map**
- **Google Map.** Select the Google map type to display (i.e. Street map, Satellite image, Terrain, or Hybrid).
- **Countries/Coastline Shapefile.** Polygon feature showing coastlines and demarcating oceans and inland areas.
- **WMS server.** Background maps obtained from a remote server. Enter the URL of the server and click 'Connect'. If the server is a private server, you will need to supply the user name and password for authentication, and you may optionally tick 'Save password' in order not to enter it again the next time you open MIKE+. When the connection is established, the table will provide the list of layers available on the server, and it is possible to select which layers to display in MIKE+ using the 'Visible' box. Note that displaying layers from a WMS server requires that the MIKE+ project uses the same map projection as the WMS layers: if they differ, you will be asked to update the map projection in MIKE+. Also note that it is only possible to connect to WMS servers using projected map projections (geographical coordinate systems not supported).

An internet connection must be available for Open Street Map, Google Map and WMS server overlays (Figure 2.4).

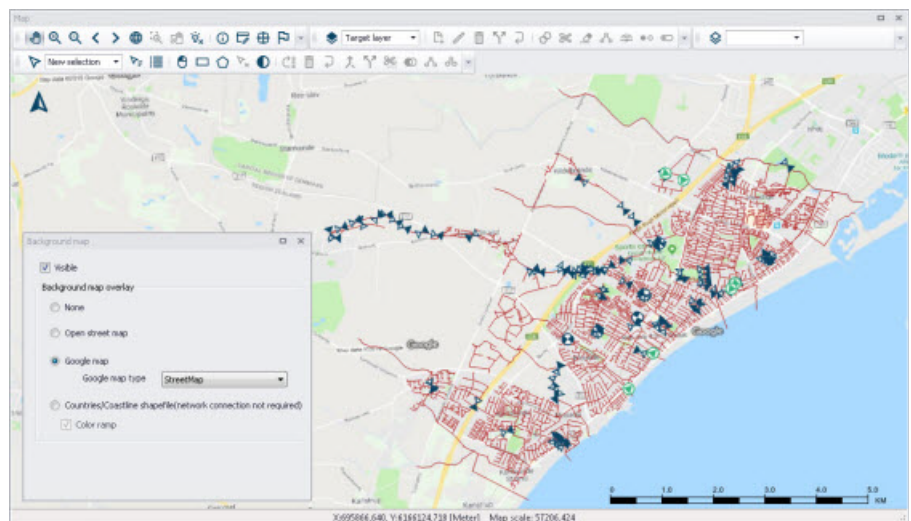


Figure 2.4 An example Google Map background for a project in MIKE+







## 3 Hydraulic Network Modelling with SWMM

SWMM allows for the hydrodynamic simulation of flows and water levels in urban storm drainage and wastewater collection networks, providing reliable information about the network functionality under a variety of boundary conditions. The hydrodynamic simulations can be extended with pollution and water quality simulations, and the model can also be enhanced by a variety of real-time control functions.

This chapter provides a comprehensive guide for the preparation of basic SWMM hydrodynamic simulation models.

The modelling process consists of the following distinct steps:

- Definition of network data
- Specification of boundary conditions
- Adjustment of computation parameters and running simulations
- Result analysis

Furthermore, an important part of successful modelling is model calibration and verification, which ensure that computed results fit well with observations.

### 3.1 Definition of a SWMM Network

A SWMM network within MIKE+ can be defined in one of the following ways. Please note that MIKE+ supports the EPA SWMM5 format. If you have a SWMM44 model, conversion tools are available on the US EPA website.

- Import of external data (e.g. GIS, \*.INP, MU \*.MDB or \*.GDB) into MIKE+ SWMM network.



When importing existing model setups into MIKE+, ensure that Unit Systems and elevation reference settings are consistent.

- Copying network data from MIKE+ CS network into MIKE+ SWMM network
- Graphical data digitalisation and manual data typing within MIKE+

The last option is frequently used in a combination with one of the previous options to build a well-defined SWMM network model.

The following paragraphs provide a comprehensive information on the SWMM network data model and the associated editors.

A SWMM network model consists of the following elements:

- Nodes



- Conduits
- Pumps
- Orifices
- Weirs
- Outlets

## 3.2 Nodes

SWMM network nodes are hydraulic elements such as Junctions, Outfalls, Storage Units and Flow Dividers.

- **Junctions** are conveyance system nodes where links join together. Physically, they can represent the confluence of natural surface channels, manholes in a sewer system, or pipe connection fittings. External inflows can enter the system at junctions. Excess water at a junction can become partially pressurized during surcharge events and can either be lost from the system or be allowed to pond atop the junction and subsequently drain back through it.
- **Outfalls** are defined as terminal nodes of the conveyance system and used to define final downstream boundaries under Dynamic Wave flow routing. For other types of flow routing, they behave as junctions. Only one link can be incident on an outfall node.
- **Storage Units** are defined as conveyance system nodes that provide storage volume. Physically, they could represent something as small as a catch basin or as large as a lake. They are allowed to have any shape as described by a function or table of surface area versus height.
- **Flow Dividers** are defined as conveyance system nodes used to split the total flow to two outflow conduits in a prescribed manner. Flow dividers are only active under Uniform or Kinematic Wave routing and are treated as simple junctions under Dynamic Wave routing.

The SWMM network Nodes editor organizes related input data into the following groups:

- **Identification.** General identification and location information for the node
- **Geometry.** Node type and basic geometric information
- **Storage Unit.** Further specifications for storage unit nodes
- **Outfall.** Further specifications for outfall nodes
- **Flow Divider.** Further specifications for flow dividers
- **Description.** Optional descriptive information for the node (Figure 3.3)



ID	X coordinate [ft]	Y coordinate [ft]	Node type	Invert level [ft]	Ground level [ft]	Max. depth [ft]
1	770061.770365656	3101444.41053473	Junction	118.1	130	11.9
2	772421.271455128	3102878.36091995	Junction	50.9	80	29.1
3	772225.730967088	3102135.3215009	Junction	78.7	100	21.3
4	772968.779699364	3100075.64108829	Junction	83.7	110	26.3
5	772525.560957179	3102930.51032759	Junction	49.2	80	30.8
6	772512.520112809	3098209.39171809	Junction	103.3	130	26.7
7	771378.399717681	3097870.45083642	Junction	108.3	140	31.7
8	771717.331286121	3099423.8410137	Junction	98.4	130	31.6
9	773190.39023461	3103621.40965222	Junction	16.4	40	23.6
10	772590.739567654	3099332.59002771	Junction	85.3	130	44.7
11	772525.560957179	3098391.89136176	Junction	101.7	130	28.3

Figure 3.1 SWMM Nodes editor

### 3.2.1 Identification

Each node is geographically determined by 'x' and 'y' coordinates. The coordinates may be specified in any local coordinate system.

Figure 3.2 Nodes editor Identification groupbox



The Insert and Delete buttons allow addition and deletion of network elements directly in the editor, respectively.

Table 3.1 The edit fields in the Identification group and Description tab page (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in data structure
ID	A unique name for the node. Up to 40 characters (letters, numbers, blank spaces and underscore characters)	Yes	MUID
X	X-coordinate of the node position	Yes	GeomX
Y	Y-coordinate of the node position	Yes	GeomY
Description			
Description	Descriptive information related to the structure	No	Description
Data Source	Reference to an external data source from which the record was imported	No	DataSource
Asset ID	Id in the asset management system	No	AssetName
Status	Status from a user- specified list in the Status Codes editor	No	Element_S
Network Type	Type of network i.e Stormwater, Combined or separate. The list of network types can be extended by the user. Network type can be specified for each element.	No	NetTypeNo
Tag	Optional label used to categorize or classify the node.	No	Tag

Figure 3.3 Nodes editor Description tab page



### 3.2.2 Geometry

Define general node properties and geometries in the Geometry tab page of the editor.

The screenshot shows the 'Geometry' tab of the SWMM Nodes editor. The 'Node type' is set to 'Junction'. The 'Invert level' is 118.1 [ft], 'Initial depth' is 0 [ft], 'Ground level' is 130 [ft], 'Surch. depth' is 0 [ft], 'Max. depth' is 11.9 [ft], and 'Ponded area' is 0 [ft<sup>2</sup>].

Figure 3.4 The SWMM Nodes Geometry tab page

Table 3.2 The edit fields in the SWMM Nodes Geometry tab (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in data structure
Node type	Definition of node as either Junction, Storage Unit, Outfall or Flow Divider	Yes	TypeNo
Invert Level	Invert elevation of the node	Yes	Einv
Ground level	Ground level of the node	Yes If Network levels specified as Absolute elevations	GroundLevel
Max. Depth	Maximum depth of node (i.e. from invert to ground surface)	Yes If Network levels specified as Relative depths	Dmax
Initial Depth	Initial depth of water at the node at the start of the simulation	No	D0



Table 3.2 The edit fields in the SWMM Nodes Geometry tab (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in data structure
Surch. Depth	Additional depth of water beyond the maximum depth that is allowed before the junction floods. This parameter can be used to model Bolted/Sealed manholes	No	Dsur
Ponded Area	Area occupied by ponded water atop the junction after flooding occurs. If the Allow Ponding analysis option is turned on, a non-zero value of this parameter will allow ponded water to be stored and subsequently returned to the conveyance system when capacity exists. Default is allow ponding is not turned on.	No	Apond

### 3.2.3 Storage Unit

Define input parameters for storage units in the Storage Unit tab page of the Nodes editor.

Figure 3.5 The SWMM Nodes Storage Unit tab page

The Geometry Type defines how the geometry of storage unit is specified. The geometry of a Storage Unit can be defined by a Functional geometry or a tabular geometry description (i.e. From curve).

- **Functional.** This option uses the following function to define the geometry by computing for surface area from water depth:

$$\text{Area} = \text{Coefficient} (\text{Depth})^{\text{Exponent}} + \text{Constant} \tag{3.1}$$



- **From curve.** This option uses a storage area-depth table defined in the Curves and Relations editor to define the geometry of the storage unit.

As an example, a Storage Unit whose cross-sectional area remains constant with depth (e.g. a cylinder or cube) can be described by a FUNCTIONAL geometry type whose coefficient equals the cross-sectional area and whose exponent is 0.

Table 3.3 Edit fields in the SWMM Nodes Storage Unit tab page (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in data structure
Geometry Type	Definition of the type of geometry description of the Storage Unit (Functional or From curve)	Yes	GeomTypeNo
Coefficient	Coefficient for the Functional relationship between storage depth and surface area	Yes, if Functional is chosen	GeomCoeff
Exponent	Exponent for the Functional relationship between storage depth and surface area	Yes, if Functional is chosen	GeomExponent
Constant	Constant value for the Functional relationship between storage depth and surface area	Yes, if Functional is chosen	GeomConst
Evaporation	Fraction of potential evaporation realized	No	Fevap
Storage Geometry	ID of the tabular geometrical description. The geometry is specified relative to the invert level. This ensures reusability of the geometry for different Storage Units with different inverts	Yes if From Curve is chosen	GeomID



Table 3.3 Edit fields in the SWMM Nodes Storage Unit tab page (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in data structure
Include Infiltration checkbox	Option to apply optional Green-Ampt infiltration parameters so that the storage unit can serve as an infiltration basin	Yes	StorageInfiltrationNo
Suction Head	Average value of soil capillary suction along wetting front	Yes, if Infiltration is included	StorageSuctionHead
Conductivity	Soil saturated hydraulic conductivity	Yes, if Infiltration is included	StorageConductivity
Initial Deficit	Fraction of soil volume that is initially dry	Yes, if Infiltration is included	StorageInitialDeficit

### 3.2.4 Outfall

Definition of an outfall in an urban drainage network is optional for uniform flow (UF) and Kinematic Wave (KW) routing.

However, when applying Dynamic Wave routing, at least one outfall in the urban drainage system must be defined. It is possible to select between five types of outfalls:

- **Free Outfall.** Bases the outfall stage on the smaller of the critical and normal depths of flow in the connecting conduit.
- **Normal Depth.** Uses just the normal depth of flow.
- **Constant Stage.** Uses a constant water elevation at all times.
- **From Tide Curve.** Has outfall stage varying in a repeating fashion over a tidal period.
- **Time Series.** Allows variation of the outfall stage in a specified manner over time.





Figure 3.6 SWMM Nodes editor Outfall dialog

Table 3.4 Edit fields in the Nodes Outfall dialog (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in datastructure
Outfall Type	Type of outfall	Yes	FlapGate-TypeNo
Constant Stage	Fixed position of tide gate	Yes if Outfall is of type Constant Stage	FixedStage
Tidal Curve	Outfall stage as a function of hour of day over a complete tidal cycle. Curve is specified in Curves and Relations	Yes if Outfall is of type From Tide Curve	TideGateID
Time Series	Outfall stage variation over time.	Yes if Outfall is of type Time Series	TideGateTSID
Non Return Valve	Option for defining a non-return valve preventing back-water	No	FlapGateNo
Route To	Option for leading the outflow discharge to another sub-catchment	No	RouteTo

### 3.2.5 Flow Divider

Flow divider nodes can be one of the following types:

- **Overflow.** All flow above the non-diverted conduits full flow depth is diverted
- **Cutoff Flow.** All flow above the cutoff level is diverted.



- **From Curve.** A curve is supplied that specifies the amount of diverted flow to total flow.
- **Weir.** The diverted flow is linearly proportional to the total flow in excess of some minimum flow

Figure 3.7 SWMM Nodes editor Flow Divider dialog

Table 3.5 Edit fields in the Flow Divider dialog (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in datastructure
Divider Type	Type of Divider	Yes, if Junction Type is Flow Divider	DividerTypeNo
Divided To	The ID of the link that receives the diverted flow	Yes	LinkID
Cutoff Flow	Cutoff flow value used for a Cutoff Flow divider	Yes, if Divider Type is Cutoff Flow	CutoffFlow
Divider Curve	ID of diversion flow series for a From Curve divider	Yes, if Divider Type is From Curve	DivertedFlowID
Min. Flow	Minimum flow at which diversion begins for a Weir divider	Yes, if Divider Type is Weir	DivertedMin-Flow



Table 3.5 Edit fields in the Flow Divider dialog (mss\_Node)

Edit field	Description	Used or required by simulations	Field name in datastructure
Max. Depth	Maximum depth above invert at which proportional diversion continues for a Weir divider	Yes, if Divider Type is Weir	DivertedMax-Depth
Diversion Coeff	Coefficient which determines what fraction between the min. and max. flows the diverted flow will be given the fraction that current water depth is of the max. depth for a Weir divider	Yes, if Divider Type is Weir	DiversionCoeff

### 3.3 Conduits

Conduits are pipes or channels that move water from one node (Junctions, Storage Units, Flow Dividers and Outfalls) to another in the drainage system. Their cross-sectional shapes can be selected from a variety of standard open and closed geometries. Irregular natural cross-section shapes are also supported.

The Conduits editor organizes the related input data into the following groups:

- **Identification.** General identification and connectivity information
- **Geometry.** Basic geometric information for the conduit
- **Hydraulic Properties.** Cross section data for specially-shaped conduits
- **Hydraulic Loss.** Head loss characteristics
- **Miscellaneous.** Other conduit properties
- **Description.** Optional descriptive information about the conduit. Also includes option for adding images of the structure (Figure 3.10).



ID	From node	To node	Conduit shape	Length [ft]	Geometric length [ft]	Inlet i
10	GIS2527748	GIS2527741	CIRCULAR	32.75	37.8167265169741	
2	AEC6001004-Dummy	DMH_AEC6001004	Dummy_DMH_Inlet	CIRCULAR	25	5.73041596943535
3	AEC6001005-04	DMH_AEC6001005	DMH_AEC6001004	CIRCULAR	74	74.6827459262228
4	AEC6001006-05	DMH_AEC6001006	DMH_AEC6001005	CIRCULAR	144	147.466462988816
5	AEC6001008-131A	DMH_AEC6001008	DMH_AEC600131A	CIRCULAR	82	75.6292952044686
6	AEC6001047-46	DMH_AEC6001047	DMH_AEC6001046	CIRCULAR	179	179.169236673126
7	AEC6001048-47	DMH_AEC6001048	DMH_AEC6001047	CIRCULAR	249	253.479811634275
8	AEC6001049-48	DMH_AEC6001049	DMH_AEC6001048	CIRCULAR	190	193.070894501212

Figure 3.8 The SWMM network Conduits editor

### 3.3.1 Identification

Shows ID and connectivity information for conduits. Use the Insert and Delete buttons to add or remove items directly on the editor, respectively.

Identification

ID: GIS1001191

From node: GIS2000787

To node: CH0000001

Buttons: Insert, Delete

Figure 3.9 Conduits Identification group



Table 3.6 Edit fields in the Conduits editor Identification group and Description tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Unique conduit Id	Yes	MUID
From Node	Upstream node	Yes	FromNodeID
To Node	Downstream node	Yes	ToNodeID
Description			
Description	Descriptive information related to the structure	No	Description
Data Source	Reference to an external data source from which the record was imported	No	DataSource
Asset ID	Id in the asset management system	No	AssetName
Status	Status from a user- specified list in the Status Codes editor	No	Element_S
Network Type	Type of network i.e Stormwater, Combined or separate. The list of network types can be extended by the user. Network type can be specified for each element.	No	NetTypeNo
Tag	Optional label used to categorize or classify the conduit	No	Tag

Figure 3.10 Conduits Description tab page

### 3.3.2 Geometry

Specify basic conduit geometric information on the Geometry tab page.



Geometry	Hydraulic properties	Hydraulic loss	Miscellaneous	Description
Conduit shape	CUSTOM	<input checked="" type="checkbox"/> Is active		
Geom. depth	6.208 [ft]	Length	3411.04 [ft]	3411.03833161938 [ft]
Sediment depth	0 [ft]	Inlet invert elevation	11.08 [ft]	[ft]
Top width	[ft]	Outlet invert elevation	0 [ft]	[ft]
Bottom width	[ft]	Exponent	[ ]	Calculate
Bottom radius	[ft]	Triangle height	[ ]	
Left side slope	[%]	Right side slope	[%]	
Side walls	None	Barrels	1	

Figure 3.11 The Conduits editor Geometry tab page

Table 3.7 Edit fields in the Conduits editor Geometry tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
Conduit Shape	Conduit cross section shape	Yes	ShapeTypeNo
Is Active	Option to include or disregard the conduit in model simulations	Yes	Enabled
Max. Height	Maximum conduit depth	Yes for all shapes except IRREGULAR shape	Depth
Length	Length of conduit	Yes	Length
Inlet Invert Elevation/Offset	Elevation or depth of upstream end of conduit above the upstream node invert	Yes	InletInvert
Outlet Invert Elevation/Offset	Depth or elevation of downstream end of conduit above the downstream node invert	Yes	OutletInvert
Sediment Depth	Sediment depth in conduit	Yes, if CIRCULAR shape	SedimentDepth



Table 3.7 Edit fields in the Conduits editor Geometry tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
Top Width	Top width	Yes, if RECT_CLOSED, RECT_OPEN, TRAPEZOIDAL, TRIANGULAR, ARCH, PARABOLIC, POWER, RECT_TRIANGULAR, and RECT_ROUND shapes	TopWidth
Bottom Width	Bottom width	Yes, if MODBAS-KETHANDLE shape	BottomWidth
Bottom Radius	Conduit bottom radius	Yes, if RECT_ROUND shape	BottomRadius
Left Side Slope	Left side slope of trapezoid	Yes, if TRAPEZOIDAL shape	LeftSideSlope
Right Side Slope	Right side slope of trapezoid	Yes if TRAPEZOIDAL shape	RightSideSlope
Side Walls	Option for defining walls along the cross section	If Shape = RECT_OPEN	SidewallsNo
Exponent	Exponent in power function for describing the shape	Yes, if POWER	Exponent
Triangle Height	Height of triangular shape	Yes, if RECT_TRIANGULAR shape	TriangleHeight
Number of Barrels	A conduit can have a number of barrels, meaning that it consists of a multiple number of parallel pipes of equal size, slope and roughness. Default value is 1.	Yes	Barrels

Note that a DUMMY conduit shape is a connecting pipe without geometry.



### 3.3.3 Hydraulic Properties

Define cross sections for CUSTOM or IRREGULAR shape conduits on the Hydraulic Properties tab page.

The screenshot shows a software interface with five tabs: 'Geometry', 'Hydraulic properties', 'Hydraulic loss', 'Miscellaneous', and 'Description'. The 'Hydraulic properties' tab is active. It contains two input fields: 'Transect ID' with an empty text box and a dropdown arrow, and 'Shape ID' with the text 'JSI\_Horseshoe' and a dropdown arrow.

Figure 3.12 The Hydraulic Properties tab page

Table 3.8 Edit fields in the Conduits editor Hydraulic Properties tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
Transect ID	ID for the Transect describing conduit geometry expressed as station/elevation value pairs in the Transects editor	If Shape = IRREGULAR	TransectID
Shape ID	ID for the Shape describing conduit geometry expressed as depth/width values defined in the Curves and Relations editor	If Shape = CUSTOM	ShapeID

### 3.3.4 Hydraulic Loss

Define hydraulic loss parameters for conduits on the Hydraulic loss tab page of the Conduits editor.





Geometry	Hydraulic properties	Hydraulic loss	Miscellaneous	Description
<input type="radio"/> Use material Material ID <input type="text"/>		Average losscoeff <input type="text" value="2.7"/> Entry loss coeff <input type="text" value="0.5"/> Exit loss coeff <input type="text" value="1"/>		
<input checked="" type="radio"/> Use local parameters Manning roughness <input type="text" value="0.01"/> [s/m <sup>1/3</sup> ] H-W roughness <input type="text" value="110"/> D-W roughness <input type="text" value="0.005"/> [ft]				

Figure 3.13 The SWMM Conduits Hydraulic Loss tab page

Table 3.9 Edit fields in the Hydraulic Loss tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
Use Material	Option to use loss parameters from the Materials editor	Yes	FricNo = 1
Material ID	ID for the desired conduit material from the Materials editor	If FricNo = 1	MaterialID
Use Local Parameters	Option to use loss parameters defined on the tab page	Yes	FricNo = 2
Manning Roughness	Manning n value for the conduit	If FricNo = 1 and Conduit Shape <> FORCE MAIN	Roughness
H-W Roughness	Hazen-Williams coefficient for the conduit	If FricNo = 1 and Force Main Equation = Hazen-Williams	ForceMainRoughnessHW
D-W Roughness	Darcy-Weisbach coefficient for the conduit	If FricNo = 1 and Force Main Equation = Darcy-Weisbach	ForceMainRoughnessDW
Average Loss Coeff	Average loss coefficient (using average velocity in conduit)	No	AvgLossCoeff



Table 3.9 Edit fields in the Hydraulic Loss tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
Entry Loss Coeff	Entry Loss coefficient (using entrance velocity)	No	EntryLossCoeff
Exit Loss Coeff	Exit loss coefficient (using exit velocity)	No	ExitLossCoeff

Minor losses are only computed for the Darcy-Weisbach Dynamic wave routing option. The minor losses,  $H_L$ , are computed as:

$$H_L = K \frac{v^2}{2g} \tag{3.2}$$

Where  $K$  is the energy loss coefficient, and  $v$  the flow velocity.

### 3.3.5 Miscellaneous

Define other parameters for the conduit on the Miscellaneous tab page.

Figure 3.14 The SWMM Conduits Miscellaneous tab page

Table 3.10 Edit fields in the Miscellaneous tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
Flap Gate	Option for activating a flap gate preventing backwater flow	Yes	FlapGateNo
Initial Flow	Flow in conduit at start of simulation	Yes	InitialFlow



Table 3.10 Edit fields in the Miscellaneous tab page (mss\_Link)

Edit field	Description	Used or required by simulations	Field name in datastructure
Max Flow	Maximum flow allowed through conduit	Yes	MaxFlow
Culvert Code*	Culvert type code for inlet geometry if conduit is a culvert	No	CulvertCode
Seepage Rate	Seepage loss rate from the conduit	No	SeepageRate
* Refer to the EPA SWMM Help Culvert Code Numbers chapter for Culvert Codes.			

## 3.4 Pumps

Pumps are drainage system elements that lift water to higher elevations. The relation between a pump's flow rate and conditions at its end node is described by a pump curve. MIKE+ SWMM represents a pump as a link connecting two nodes, where the pump itself is placed at the upstream node.

The Pumps editor organizes the related input data into the following groups:

- **Identification.** General identification and connectivity information
- **Pump Properties.** Pump data
- **Description.** Optional descriptive information about the pump. Also includes an option for adding images of the structure.

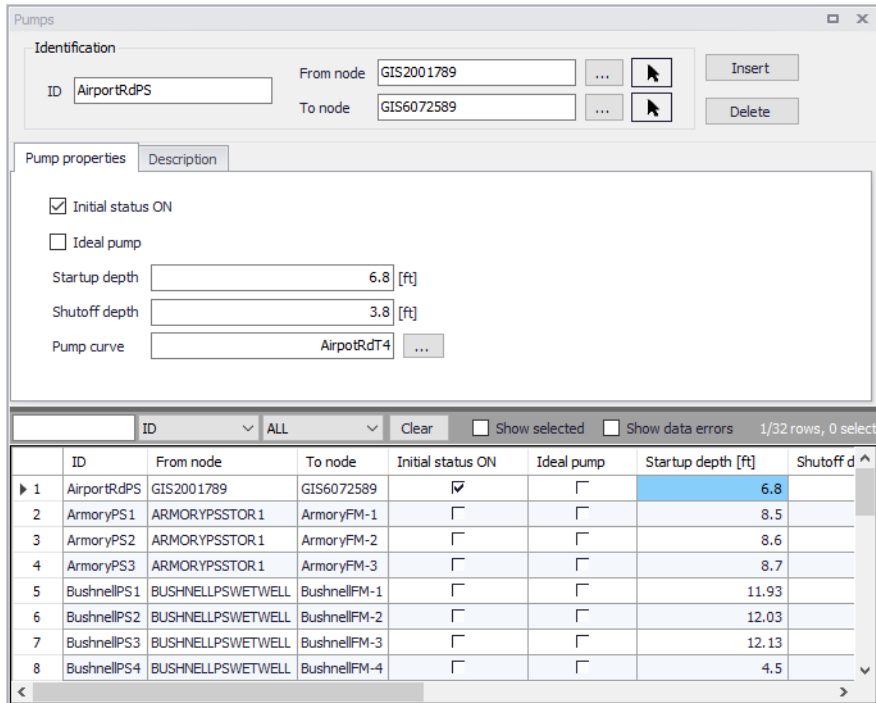


Figure 3.15 The SWMM Pumps editor

### 3.4.1 Identification

The identification groupbox holds information on the element ID and connectivity. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

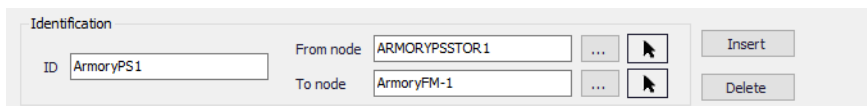


Figure 3.16 Pumps Identification groupbox

Table 3.11 Edit fields in the Pumps Identification groupbox and Description tab page (mss\_Pump)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Id of the Pump	Yes	MUID
From Node	Location of Pump	Yes	



Table 3.11 Edit fields in the Pumps Identification groupbox and Description tab page (mss\_Pump)

Edit field	Description	Used or required by simulations	Field name in datastructure
To Node	Receiving Node	Yes	
Description			
Description	Descriptive information related to the structure	No	Description
Data Source	Reference to an external data source from which the record was imported	No	DataSource
Asset ID	Id in the asset management system	No	AssetName
Status	Status from a user- specified list in the Status Codes editor	No	Element_S
Network Type	Type of network i.e Stormwater, Combined or separate. The list of network types can be extended by the user. Network type can be specified for each element.	No	NetTypeNo
Tag	Optional label used to categorize or classify the pump	No	Tag

The screenshot shows a software interface for editing pump properties. It features a tabbed window with 'Pump properties' and 'Description' tabs. The 'Description' tab is active, displaying several input fields: 'Description', 'Data source', 'Asset ID', 'Status' (a dropdown menu), 'Network type' (a dropdown menu), and 'Tag'. To the right of these fields is a button labeled 'Add picture'.

Figure 3.17 The Pumps Description tab page

### 3.4.2 Pump Properties

Define essential pump properties on the Pump Properties tab page.



Table 3.12 Edit fields in the Pump Properties tab page (mss\_Pump)

Edit field	Description	Used or required by simulations	Field name in datastructure
Initial Status ON	Option to set initial status as ON	No	InitialStatusNo
Ideal Pump	Option to define the pump as "ideal"	No	IdealPumpNo
Startup Depth	Depth at the inlet node at which the pump turns on	Yes	StartupDepth
Shutoff Depth	Depth at the inlet node at which the pump shuts off	Yes	ShutoffDepth
Pump Curve ID	Reference to a tabular Pump curve in Curves and Relations	Yes	PumpCurveID

An ideal pump will have a flow rate equal to the inflow rate at the inlet node (From Node), and thus does not require a pump curve. The ideal pump must be the only outflow link from the inlet node.

A pump curve must be defined for each pump. Pump curves are defined in the Curves and Relations editor. The following pump curves types are supported:

- **Pump Curve 1 (Volume-Flow)**. An off-line pump with a wet well where flow increases incrementally with wet well volume
- **Pump Curve 2 (Depth-Flow)**. An in-line pump where flow increases incrementally with node depth
- **Pump Curve 3 (Head-Flow)**. An in-line pump where flow varies continuously with head difference between the inlet and outlet nodes
- **Pump Curve 4 (Depth-Flow)**. A variable speed in-line pump where flow varies continuously with node depth

The on/off status of pumps may be controlled dynamically through user-defined control rules.

## 3.5 Orifices

Orifices are openings in a wall of a manhole junction or storage unit used to model outlet and diversion structures in drainage systems. Orifices belong to



the group of Link components connecting two nodes. An orifice can have either a circular or rectangular shape, be located either at the bottom or along the side of the upstream node, and have a flap gate to prevent backflow.

Orifices attached to storage units are active under all types of flow routing.

Those attached to other types of nodes are active only under Dynamic Wave flow routing; otherwise the flow through them is zero.

The flow through an orifice is computed based on the area of its opening, its discharge coefficient, and the head difference across the orifice. The area of an orifice's opening can be controlled dynamically through user-defined control rules.

The Orifices editor organizes the related input data into the following groups:

- **Identification.** General identification and connectivity information
- **Geometry.** Geometric data for an orifice
- **Hydraulic Properties.** Orifice hydraulic parameters
- **Description.** Optional descriptive information about the element. Also includes an option for adding images of the structure.

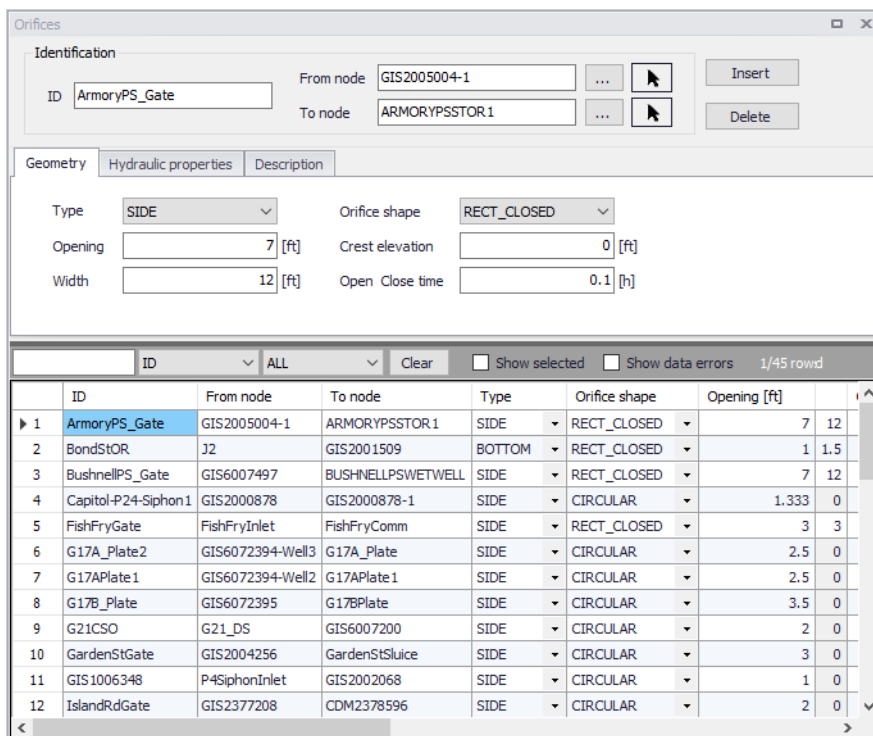


Figure 3.18 SWMM Orifices editor



### 3.5.1 Identification

The identification groupbox holds information on the element ID and connectivity. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

Figure 3.19 Orifices Identification groupbox

Table 3.13 Edit fields in the Orifices Identification groupbox and Description tab page (mss\_Orifice)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Id of the Orifice	Yes	MUID
From Node	Node location of orifice	Yes	FromNodeID
To Node	Downstream node	Yes	ToNodeID
Description			
Description	Descriptive information related to the structure	No	Description
Data Source	Reference to an external data source from which the record was imported	No	DataSource
Asset ID	Id in the asset management system	No	AssetName
Status	Status from a user- specified list in the Status Codes editor	No	Element_S
Network Type	Type of network i.e Stormwater, Combined or separate. The list of network types can be extended by the user. Network type can be specified for each element.	No	NetTypeNo
Tag	Optional label used to categorize or classify the orifice	No	Tag





Geometry	Hydraulic properties	Description
Description		
Description	Gate open ~half way observed in CCTV 2019; AI	
Data source	CCTV	
Asset ID	<input type="text"/>	
Status	1: Model <input type="button" value="Add picture"/>	
Network type	3: Combined	
Tag	<input type="text"/>	

Figure 3.20 Orifices Description tab page

### 3.5.2 Geometry

Specify geometric properties for orifices on the Geometry tab page.

Table 3.14 Edit fields in the Orifices Geometry tab page (mss\_Orifice)

Edit field	Description	Used or required by simulations	Field name in datastructure
Type	Type of orifice: SIDE or BOTTOM	Yes	TypeNo
Orifice Shape	Shape of the orifice opening: CIRCULAR or RECT_CLOSED	Yes	ShapeTypeNo
Opening	Height/Diameter of orifice opening	Yes	Height
Width	Width of orifice when fully open	Yes, if Orifice shape is RECT_CLOSED	Width
Crest Height/Elevation	Offset height of orifice bottom from invert of upstream node	Yes (if Orifice Type is BOTTOM then Crest Height is set zero in SWMM engine)	CrestHeight
Open/Close Time	Time it takes to open or close a gated orifice in decimal hours	Yes	TimeToOpenClose

### 3.5.3 Hydraulic Properties

Define hydraulic flow properties for orifices on the Hydraulic Properties tab page of the editor.



Geometry Hydraulic properties Description

Flap gate

Discharge

Figure 3.21 Orifices Hydraulic Properties tab page

Table 3.15 Edit fields in the Hydraulic Properties tab page (mss\_Orifice)

Edit field	Description	Used or required by simulations	Field name in datastructure
Flap Gate checkbox	Option to add a flap gate preventing reverse flow through the orifice	No	FlapGateNo
Discharge Coeff	Orifice discharge coefficient. A typical value is 0.65.	Yes	DischargeCoeff

## 3.6 Weirs

Weirs, like orifices, are used to model outlet and diversion structures in a drainage system. Weirs are typically located in a chamber of a manhole, along the side of a channel, or along the top of a storage unit. MIKE+ SWMM represents a weir as a link connecting two nodes, where the weir itself is placed at the upstream node. A flap gate can be included to prevent backflow.

The Weir editor organizes the related input data into the following groups:

- **Identification.** General identification and connectivity information
- **Geometry.** Geometric data
- **Hydraulic Properties.** Hydraulic parameters
- **Description.** Optional descriptive information about the element. Also includes an option for adding images of the structure.



ID	From node	To node	Type	Coefficient	Opening [ft]	Length [ft]	Side slope
1	FishFryComm	FishFryWW	RoadWay		3.25	5	0
2	FishFryWeir	FishFryCommOut	TRANSVERSE		10	4	0
3	GIS1005778_2	J2	TRANSVERSE		1.5	4	0
4	JSI_ThrottleWr	GIS2000785	TRANSVERSE		7	6.5	0
5	OldS9_Tertiary	GIS2000409	TRANSVERSE		5	4	0
6	OldS9-Secondary	GIS2000409	TRANSVERSE		5	4	0
7	ORG23	GIS2004380	TRANSVERSE		3	2.61	0
8	ORG8I	GIS2002219	TRANSVERSE		1.25	4.25	0
9	P2Blockage	GIS2002104	TRANSVERSE		3.48	3.17	0
10	sLink_89	GIS2002191	SIDEFLOW		3.21	8	0
11	WEIRJuncPR	JuncPR	TRANSVERSE		23.04	60	0
12	WeirNBPR	NBPR4296	TRANSVERSE		35	76	0

Figure 3.22 The SWMM Weirs editor

### 3.6.1 Identification

The identification group box holds element ID and connectivity information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

Figure 3.23 Weirs Identification groupbox



Table 3.16 Edit fields in the Weirs Identification groupbox and Description tab page (mss\_Weir)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Id of the Weir	Yes	MUID
From Node	Node location of Weir	Yes	FromNodeID
To Node	Receiving Node	Yes	ToNodeID
Description			
Description	Descriptive information for the element	No	Description
Data Source	Reference to an external data source from which the record was imported	No	DataSource
Asset ID	Id in the asset management system	No	AssetName
Status	Status according to a user-specified list in the Status Code editor	No	Element_S
Network Type	Network type describes the type of network i.e Stormwater, Combined or separate. The list of network types can be extended by user. Network type can be specified for each hydraulic element.	No	NetTypeNo
Tag	Optional label used to categorize or classify the weir	No	Tag

Figure 3.24 Weirs Description tab page



### 3.6.2 Geometry

Specify weir geometric properties on the Geometry tab page.

Table 3.17 Edit fields in the Weirs Geometry tab page (mss\_Weir)

Edit field	Description	Used or required by simulations	Field name in datastructure
Type	Type of weir from a predefined list	Yes	TypeNo
Opening	Height of weir	Yes	Height
Crest Height/Elevation	Offset of weir crest above invert elevation of location node	Yes	CrestHeight
Length	Length of weir	Yes	Length
Side Slope	Side slope of weir	If Type = V-NOTCH or TRAPEZOIDAL	SideSlope

The following weir types are available, each with a slightly different formula for computing flow as a function of area, discharge coefficient and head difference across the weir:

- TRANSVERSE (rectangular shape)
- SIDEFLOW (rectangular shape)
- V-NOTCH (triangular shape)
- TRAPEZOIDAL
- Roadway

Weirs attached to storage units are active under all types of flow routing. Those attached to other types of nodes are active only under Dynamic Wave flow routing; otherwise the flow through them is zero.

The height of the weir crest above the inlet node invert can be controlled dynamically through user-defined control rules. This feature can be used to model RTC controlled Weirs and inflatable dams.

Roadway weir types model roadway overtopping using the FHWA HDS-5 (Hydraulic Design Series 5) method and would typically be used in parallel with culvert conduits.



### 3.6.3 Hydraulic Properties

Define weir hydraulic parameter values on the Hydraulic Properties tab page.

Figure 3.25 Weirs Hydraulic Properties tab page

Table 3.18 Edit fields in the Weirs Hydraulic Properties tab page (mss\_Weir)

Edit field	Description	Used or required by simulations	Field name in datastructure
Flap gate	Option to add a flap gate preventing backflow	No	FlapGateNo
Can surcharge	Option for allowing weir surcharge where upstream water level can go above height of opening	No	CanSurchargeNo
Discharge Coeff	Weir discharge coefficient	Yes	DischargeCoeff
No. End Contraction	Number of end contractions for Transverse and Trapezoidal weirs	Yes, if weir type is TRANSVERSE or TRAPEZOIDAL	NoEndContractions
End Coeff	Discharge coefficient for triangular ends of trapezoidal weir	Yes, if weir type is TRAPEZOIDAL	Cd2
Coefficient Curve	Optional weir curve that relates discharge coefficient to head	No Does not apply to ROADWAY weirs	CoeffCurveID



Table 3.18 Edit fields in the Weirs Hydraulic Properties tab page (mss\_Weir)

Edit field	Description	Used or required by simulations	Field name in datastructure
Road Surface	Type of road surface, PAVED or GRAVEL	Yes, if weir type is ROADWAY	RoadSurf
Road Width	Width of the road lanes and shoulders	Yes, if weir is ROADWAY	RoadWidth

### 3.7 Outlets

Outlets are flow control structures typically used to control outflows from storage units. They are used to model special flow-head relations that cannot be characterized by either orifices or weirs. MIKE+ SWMM represents an Outlet as a link connecting two nodes, where the outlet itself is placed at the upstream node.

Outlets attached to storage units are active under all types of flow routing. Those attached to other types of nodes are active only under Dynamic Wave flow routing; otherwise the flow through them is zero.

The Outlet editor organizes the related input data into the following groups:

- **Identification.** General identification and connectivity information
- **Hydraulic Properties.** Hydraulic and geometric parameters for the outlet
- **Description.** Optional descriptive information about the element. Also includes an option for adding images of the structure.

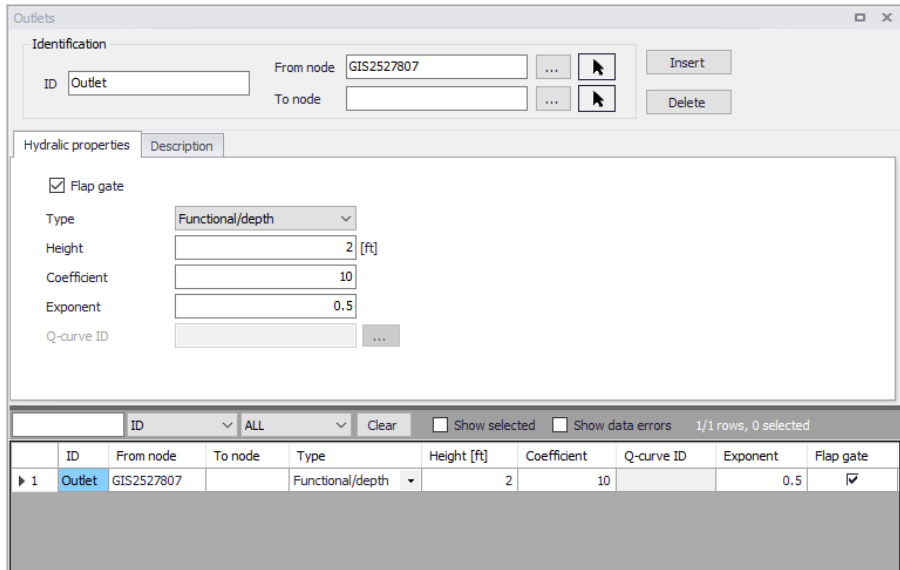


Figure 3.26 The SWMM Outlets editor

### 3.7.1 Identification

The identification group box holds element ID and connectivity information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

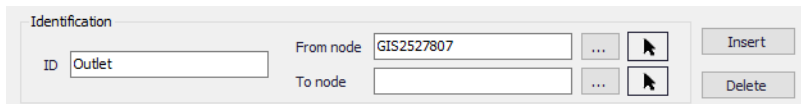


Figure 3.27 Outlets Identification groupbox

Table 3.19 Edit fields in the Outlets Identification groupbox and Description tab page (mss\_Outlet)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Id of the Outlet	Yes	MUID
Location	Node location of the outlet	Yes	FromNodeID
To	Receiving node	No	ToNodeID
Description			





Table 3.19 Edit fields in the Outlets Identification groupbox and Description tab page (mss\_Outlet)

Edit field	Description	Used or required by simulations	Field name in datastructure
Description	Descriptive information for the outlet	No	Description
Data Source	Reference to an external data source from which the record was imported	No	DataSource
Asset ID	Id in the asset database	No	AssetName
Status	Status according to user specified list in Status Codes editor	No	Element_S
Network Type	Network type describes the type of network i.e Stormwater, Combined or separate. The list of network types can be extended by user. Network type can be specified for each hydraulic element.	No	NetTypeNo
Tag	Optional label used to categorize or classify the outlet	No	Tag

The screenshot shows a software interface with two tabs: 'Hydraulic properties' and 'Description'. The 'Description' tab is active. The form contains the following fields and controls:

- Description: Text input field
- Data source: Text input field
- Asset ID: Text input field
- Status: Dropdown menu
- Network type: Dropdown menu
- Tag: Text input field
- Add picture: Button

Figure 3.28 Outlets Description tab page

### 3.7.2 Hydraulic Properties

Specify geometric and hydraulic parameters for outlets on the Geometry tab page.



Figure 3.29 Outlets editor Hydraulic Properties tab page

Table 3.20 Edit fields in the Outlets Hydraulic Properties tab page (mss\_Outlet)

Edit field	Description	Used or required by simulations	Field name in datastructure
Flap Gate	Option for adding a flap gate preventing backflows	Yes	FlapGateNo
Type	Outlet Type: Tabular/depth, Tabular/head, Functional/depth, Functional/head	Yes	TypeNo
Height	Minimum water depth at upstream node for outflow to occur	Yes	Height
Coefficient	Coefficient of power function that relates outflow to head across the outlet for a Functional outlet	Yes, if Outlet Type is Functional	Qcoeff
Exponent	Exponent of power function that relates outflow to head across the outlet fir a Functional outlet	Yes, if Outlet Type is Functional	Qexpon
Q-curve ID	ID of rating curve with outflow rate as a function of head across the outlet for a tabular outlet	Yes if Outlet Type is Tabular	QcurveID

Outlet types are based on how flow is computed as a function of freeboard depth or head across the outlet:

- **Tabular/depth.** Uses a tabulated curve of flow-freeboard depth values.
- **Tabular/head.** Uses a tabulated curve of flow-head difference values.



- **Functional/depth.** Uses a power function  $Q = \text{Coefficient}(y^{\text{Exponent}})$  where  $y$  is the freeboard depth above the outlet's opening.
- **Functional/head.** Uses a power function  $Q = \text{Coefficient}(y^{\text{Exponent}})$  where  $y$  is the head difference across the outlet.

An outlet can have a flap gate which restricts flow to only one direction and prevents backwater flow.

The flow through an outlet is determined by a user-supplied function or table of flow versus head difference across the outlet (Q-curve ID). This flow can be controlled dynamically through user-defined control rules.

### 3.8 Transects

Transects are geometric cross section data describing how bottom elevation varies with horizontal distance over the cross section of a natural channel or irregularly-shaped conduit. The figure below (Figure 3.30) displays an example of a transect for a natural channel.

MIKE+ offers a tool for automatically generating or editing transect data from survey points or DEM data. Access the Create and Update Transects tool from the Network Editing Tools toolbox on the CS Network menu ribbon (Figure 3.31).

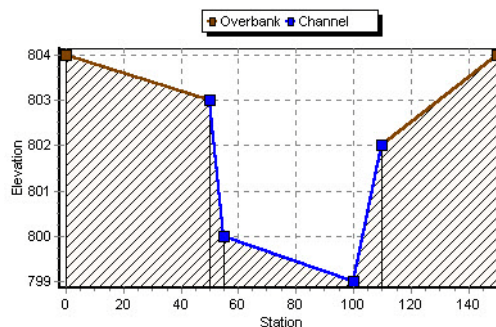


Figure 3.30 Definition of Transect data (Source: EPA SWMM Help Manual)

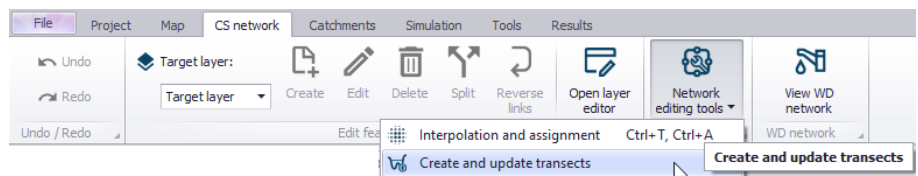


Figure 3.31 Access the Create and Update Transects tool from the CS Network menu ribbon.



Each transect has a unique ID. When a conduit has an IRREGULAR shape then a user-defined Transect must be set to define the cross-section shape for the conduit.

The SWMM engine converts these data into tables of area, top width, and hydraulic radius versus channel depth. In addition, as shown in the figure above, each Transect can have a left and right overbank section whose Manning roughness can be different from that of the main channel. This feature can provide more realistic estimates of channel conveyance under high flow conditions.

The Transects editor organizes the related input data into the following groups:

- **Identification.** General identification and description
- **Geometric & Hydraulic Properties.** Transect geometry and Manning  $n$  information

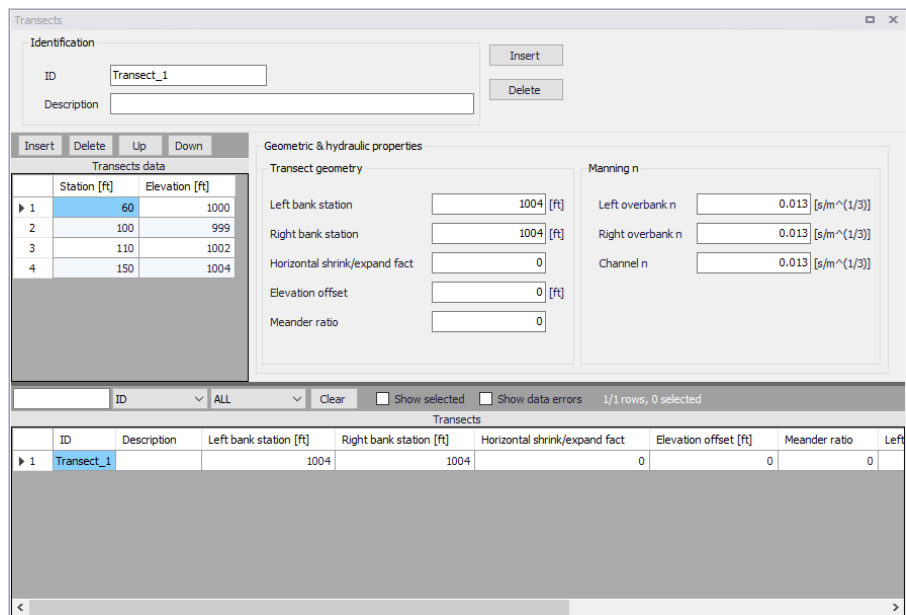


Figure 3.32 The SWMM Transects editor

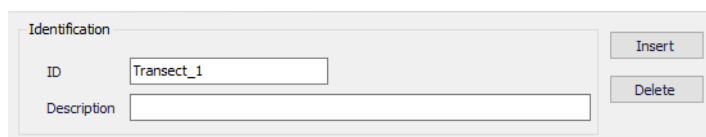


Figure 3.33 Transects Identification groupbox



Table 3.21 Edit fields in the Transects editor (mss\_Transect)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	ID of the transect	Yes	MUID
Description	Descriptive information on the transect	No	Description
<b>Transect Geometry</b>			
Left Bank Station	Left overbank station	Yes	Xleft
Right Bank Station	Right overbank station	Yes	Xright
Horizontal Shrink/Expand Factor	Horizontal shrink/expand factor by which the distance between each station is multiplied	Yes	Wfactor
Elevation Offset	Elevation offset	Yes	Eoffset
Meander Ratio	Meander ratio	Yes	LFactor
<b>Manning <i>n</i></b>			
Left Over-bank <i>n</i>	Manning <i>n</i> for left overbank	Yes	Nright
Right Over-bank <i>n</i>	Manning <i>n</i> for right overbank	Yes	Nleft
Channel <i>n</i>	Manning <i>n</i> for main channel	Yes	Nchannel

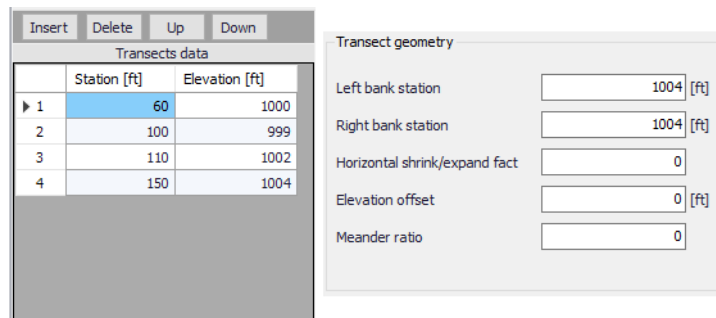


Figure 3.34 Transects geometry groupbox on the Transects editor

Specify station-elevation value pairs describing the transect in the Transects Data secondary table.



Table 3.22 Edit fields in the Transects Data secondary table

Edit field	Description	Used or required by simulations	Field name in datastructure
Station	Distance of cross section station from some fixed reference	Yes	Station
Elevation	Elevation of the channel bottom at a cross section station relative to some fixed relative reference	Yes	Elevation

## 3.9 Controls

Control rules are used to define how pumps and regulators are controlled based on simulation time or conditions at specific nodes and links.

The Controls editor organizes the related input data into the following groups:

- **Identification.** Identification and description
- **Control Rules.** Built from combinations of conditions and actions and are defined in the input box

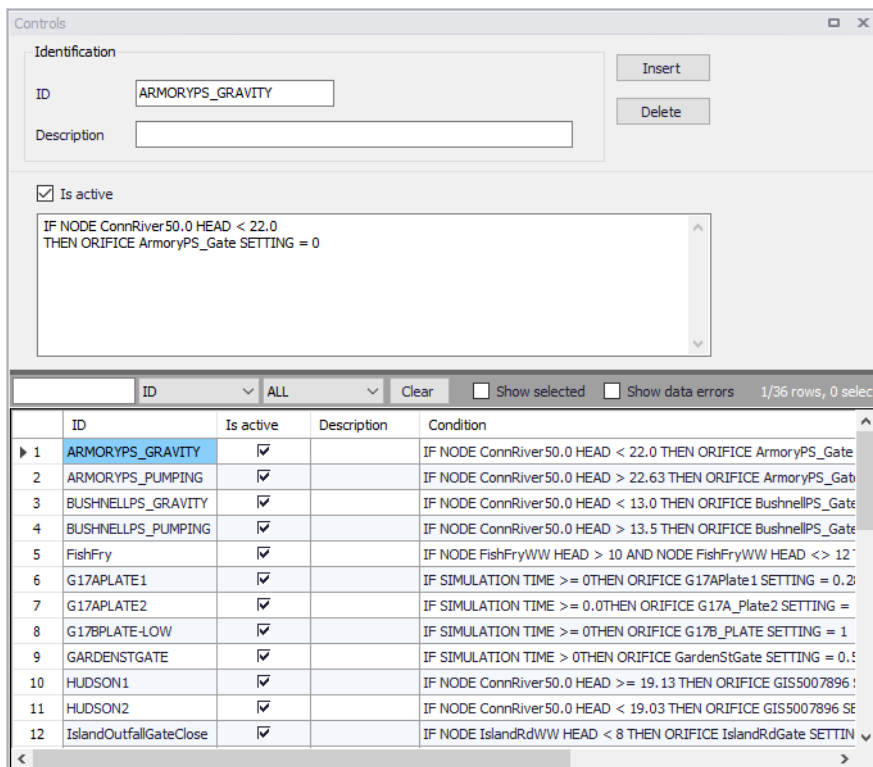


Figure 3.35 The SWMM Controls editor

Table 3.23 Edit fields in the SWMM Controls editor

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	ID of the specific rule	Yes	MUID
Description	User's descriptive information related to the node	No	Description
Is Active	Option for activating/deactivating a control rule during a simulation	Yes	Enabled

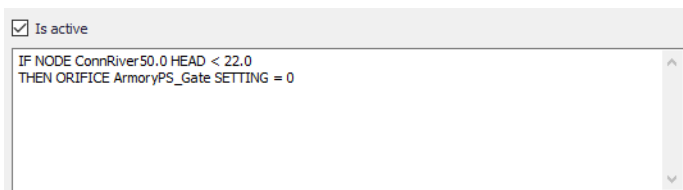


Figure 3.36 Control rules input box

Define control rules in the dialog dividing the lines into Conditions and Actions. Please note there can only be either a Condition or an Action in one line. Build control rules as combinations of conditions and actions using the following elements:

Table 3.24 Elements for building control rules

Elements	Description	Used or required by simulations
Operator	IF, AND, OR, THEN, ELSE	Yes
Object	Node, Link, Pump, Orifice, Weir or Simulation	Yes
Object ID	ID of the object	Yes
Attribute	Depth, Head, Inflow, Flow, Setting, Time, Date, Clocktime	Yes
Relation	=, <, >, <>, <=, >=	Yes
Value	Value	Yes

### 3.10 CS Network Tools

There are several tools available for facilitating edits to collection system network data. These tools are accessed via the CS Network menu ribbon.

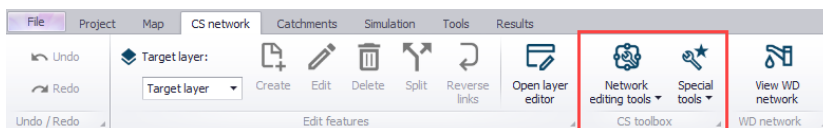


Figure 3.37 CS Network tools on the CS Network menu ribbon

The tools are grouped as:

- **Network Editing Tools.** Includes tools that assist in assigning or deriving model network data from various available data sources:
  - Interpolation and Assignment





- Create and Update Transects
- **Special Tools.** Offers the Spatial Processing tool, which may be used for performing various GIS processing operations on polygon and line features in the project.
  - Spatial Processing

### 3.10.1 Interpolation and Assignment

The Interpolation and Assignment tool helps assign values to any field in the MIKE+ database either by taking the attribute value directly from another feature/attribute or by interpolating between any number of other features.

Examples of the tasks that may be performed with this tool are:

- Assign ground elevation values from a raster layer representing the DEM to nodes
- Assign the diameter of manholes to be equal to the largest pipe entering the manhole
- Calculate missing values for manhole invert levels from a point theme using Inverse Distance weighted spatial interpolation
- Calculate pipe levels by interpolating values following the network (pipes)
- Assign a value to a construction year and or contractor based upon a polygon theme giving city areas

The source of the data (i.e. the features from where values are taken) may be any layer in the MIKE+ Map view, including layers that have been added as background layers. Any compatible data value can be assigned to almost any field in the database. This also means that it should be used with some care as it obviously can also make completely non-sense assignment if the wrong fields or names are specified.

The tool is accessed through the MIKE+ CS Network menu ribbon under Network Editing Tools.

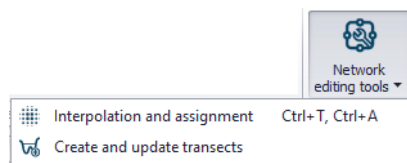


Figure 3.38 CS Network Editing Tools

The tool is used following the steps below:

- Target selection



- Assignment Method
- Assignment options (depending on the method chosen)
- Overall assignment
- Reporting

Each of the above steps are described in detail in the following sections.

## Target Selection

First, select the target layer and attribute for the assignment--i.e. the model element and property that shall be modified/defined. A target map layer (network component) must first be selected followed by a target attribute from the selected network component. For example, nodes layer, ground level attribute.

Once the empty fields are populated, MIKE+'s data validation functionality changes the "Target Selection" section of the workflow heading colour from red to green.

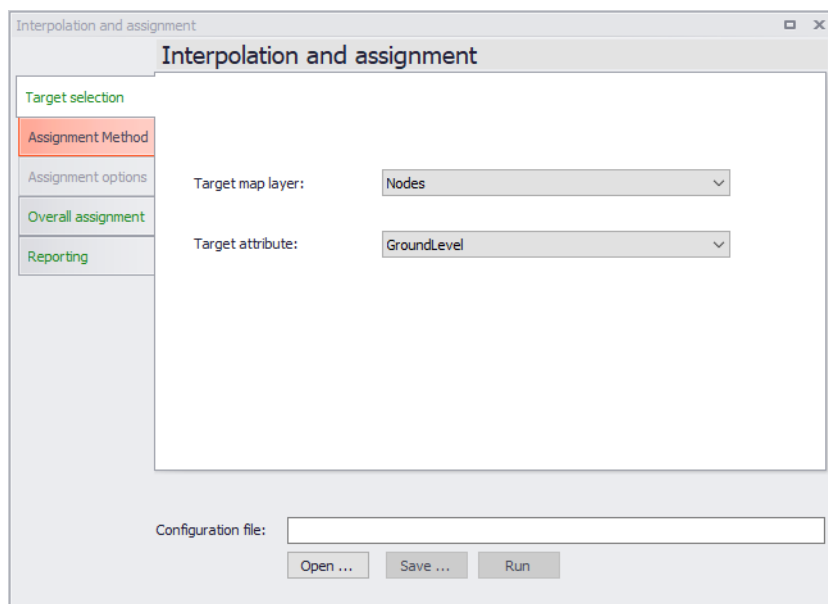


Figure 3.39 The Interpolation and Assignment tool Target Selection dialog

## Assignment Method

Then, define the method to use for assigning values to the target, and the data source.

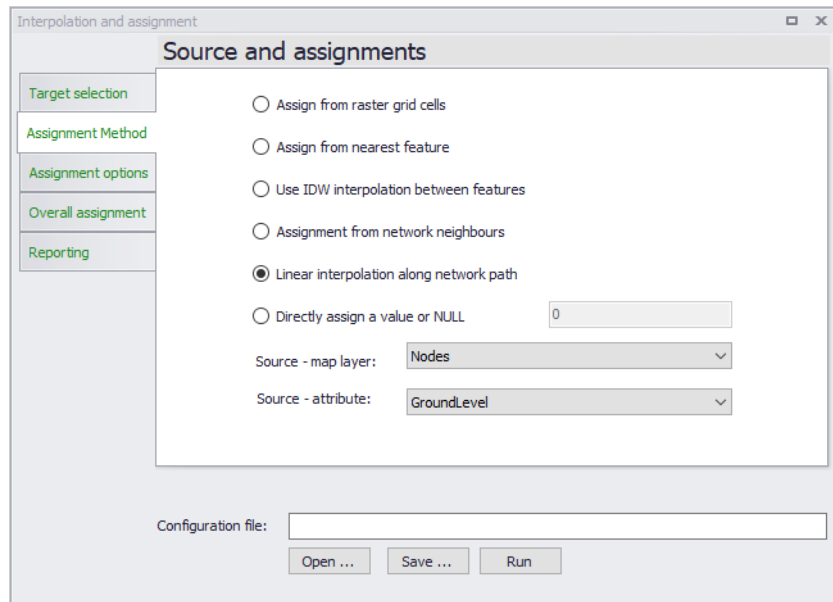


Figure 3.40 The Assignment Method dialog

The method selected will influence the valid choices for the data source. A number of methods exist:

- **Assign from Raster Grid Cells.** This will assign a value from the raster (DEM) cell located directly above the target data. For example, assign node ground levels based on levels in a raster. If the target is a polyline or polygon the tool will use the centroid position to determine the correct cell. No interpolation is done. The supported raster formats are \*.DFS2 files, ESRI text files (\*.TXT, \*.ASC), Arc/Info binary grids, GeoTIFF files (\*.TIF, \*.TIFF).
- **Assign from Nearest Feature.** The tool will locate the feature from the source layer that is closest to the feature in the target layer. If lines or polygons are used the centroid position is used for calculating distances.
- **Use IDW Interpolation Between Features.** This option will make an Inverse Distance Weighted (IDW) interpolation between features in the source layer to determine the value for each target feature. The IDW parameters are fixed to the following: max number of points is 12 and the max distance away from the target feature is 300 (map units).
- **Assignment from Network Neighbours.** This option will take the source value from a network neighbour to the feature being updated. This obviously requires both the target and the source to be included in the same network. For example, assign manhole diameters from other manhole diameters nearby. Assignment will only be done if the immediate neighbour has the requested value i.e. the network will not be traced.



- **Linear Interpolation Along Network Path.** This option will do a distance weighted interpolation along the path of the network. If the direct neighbours do not contain values (null) the network is traced until a value is reached or the number of 'hops' (number of network nodes traced though) exceed a given maximum.
- **Directly Assign a Value or NULL.** This option allows to assign a specific value or to delete the content of an attribute (by assigning the NULL value).

Depending on the choice of assignment method, the two selection boxes for the source data will be filled with layers/attributes compatible with the choice of method (i.e. only raster layers will be shown for raster assignment) or greyed out in the case of the last option.

## Assignment Options

When the assignment method is 'Assignment from network neighbours' or 'Linear interpolation along network path,' extra parameters need to be specified in the Assignment Options section.

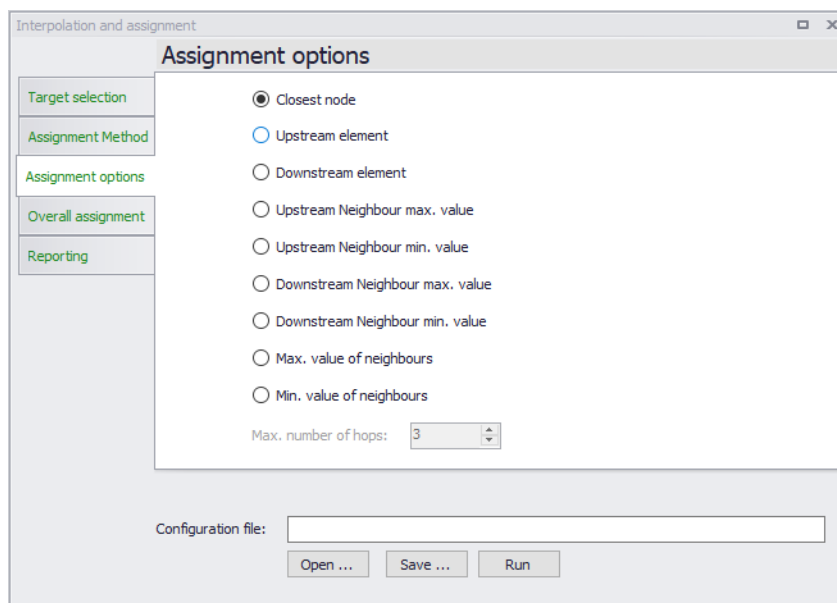


Figure 3.41 The Assignment Options dialog

For the 'Assignment from network neighbours' assignment method, the following assignment options are available:

- **Closest Node.** This will use the node that is closest to the one being assigned to. This option is only relevant if both target and source are nodes.



- **Upstream Element.** This option will assign from the upstream element (upstream/downstream is as defined by the GIS geometric network and may differ from the actual flow direction (which may not be constant)).
- **Downstream Element.** This option will assign from the downstream element (upstream/downstream is as defined by the GIS geometric network and may differ from the actual flow direction (which may not be constant)).
- **Upstream/Downstream Neighbour Max. Value.** These two options will scan the connected network neighbours upstream/downstream and use the maximum source value found as data source. Example: for assigning ground level and diameters.
- **Upstream/Downstream Neighbour Min. Value.** These two options will scan the connected network upstream/downstream neighbours and use the minimum source value found as data source. Example: for assigning invert levels.
- **Max. Value of Neighbours.** This option will scan the connected network neighbours and use the maximum source value found as data source. Example: for assigning ground level and diameters.
- **Min. Value of Neighbours.** This option will scan the connected network neighbours and use the minimum source value found as data source. Example: for assigning invert levels.

For the 'Linear interpolation along network path' option, only the maximum number of hops (i.e. number of elements away) need to be specified.

Max. number of hops:

This allows control of how many network 'hops' the interpolation will search for a value. The search continues until the max number is reached or a non-null value is found. When the value is set to 5 or higher it may cause instability (particularly in looped networks). A value of 0 means that only immediate neighbours are taken into consideration. Large values may be time consuming if a large number of features are selected for update.

## Overall Assignment

This step of the workflow controls which features are taken into account for the assignment operation.



Interpolation and assignment

### Overall assignment

Only assign value to missing (NULL) values

Value also considered missing:

Only assign values to selected record

Only assign if feature is inside the extent of the source layer  
(Only IDW and nearest feature assignment methods)

After assign change RECORD status to

After assign change ATTRIBUTE status to

Max. radius:

Max. no of features:

Configuration file:

Open ... Save ... Run

Figure 3.42 The Overall Assignment dialog

The following options are available:

- **Only assign value to missing (NULL) values.** Features that already have a value in the target field will not be updated. Removing this tick mark will overwrite any existing attribute values.
- **Only assign values to selected records.** Only records that are selected before the wizard was started are taken into consideration for updates.
- **Only assign to features inside the extent of the source layer.** This option prevents the tool from extrapolating outside the boundaries of the source layer when looking for the closest feature or when doing IDW interpolation.
- **After assign change RECORD status to.** This option changes the status of the modified records (e.g. nodes), by applying the predefined status selected from the list. This is the main status for the record (e.g. the nodes), which is typically found in the Description tab.
- **After assign change ATTRIBUTE status to.** This option changes the status of the modified attribute (e.g. ground level), by applying the predefined status selected from the list. Every record is defined with multiple attributes, and this option will change the status for the updated attribute only. Attribute status information (e.g. the node's ground level) is found in the **Property And Result Explorer** Status menu.

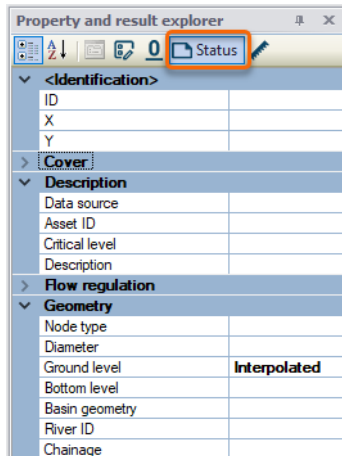


Figure 3.43 Element attribute status on the Property and Result Explorer

## Running the Tool and Reporting

Finally, update the model with the specified interpolation/assignment settings, click on the **Run** button. The Reporting tab page gives a summary of the features that have been updated.

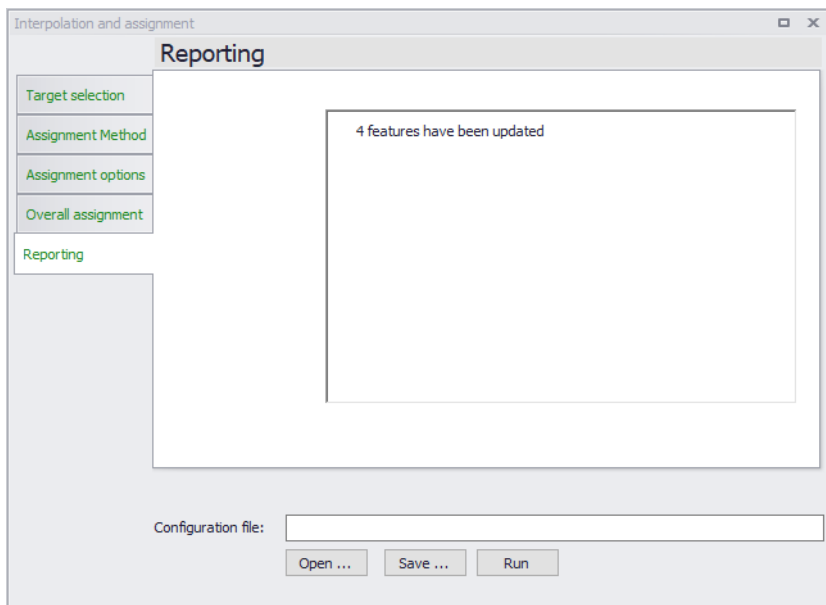


Figure 3.44 The Reporting dialog

Note that the features to be updated are selected on the Map before clicking on Run to make it easy to check that only the expected features are included.

This selection does not check for other constraints i.e. null values may still prevent some of the selected features from being updated.

## Configuration File

As with other MIKE+ tools, it is possible to save the tool setup configuration (Save button located near the bottom of the tool). A configuration file is created in \*.XML format, which can be reused later (Open button).

### 3.10.2 Create and Update Transects

The Create and Update Transects tool is used for deriving or updating transects data used for Conduits with Irregular cross sections. Transects data describe how bottom elevation varies with horizontal distance over the cross section. These are represented by Station-Elevation value pairs defined on the Transects editor in MIKE+.

Access the tool through the MIKE+ CS Network menu ribbon under Network Editing Tools.

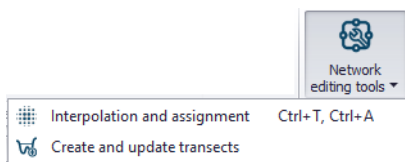


Figure 3.45 CS Network Editing Tools

Use the tool proceeding through each section of the dialog as follows:

- Method
- Survey Points Settings (depending on the method chosen)
- DEM Settings (depending on the method chosen)
- Input selection
- Reporting

Each of the above steps are described in the following sections.

## Method

Select the transect editing process to perform on the Method tab page of the dialog. The available operations are:

- **Create Transects from Survey Points.** Generate transects from survey points in \*.SHP or \*.XYZ file formats. This option activates the Survey Points Settings tab page, wherein one defines the file and the attribute from which elevation values are taken.





- **Create or Extend Transect from DEM.** Generate new or extend existing transects from a DEM raster. Transect data may be derived based on the locations of existing conduits or background features. This option activates the DEM Settings tab page on the dialog.
- **Create Transects from Survey Points and DEM.** Use both survey points data and a DEM to create or extend transect data. This option activates both the Survey Point Settings and the DEM Settings tab pages on the dialog.
- **Update Transects with DEM.** Option to make changes to existing Transects using a DEM raster, when, for example, new updated elevation data are available for the study area.

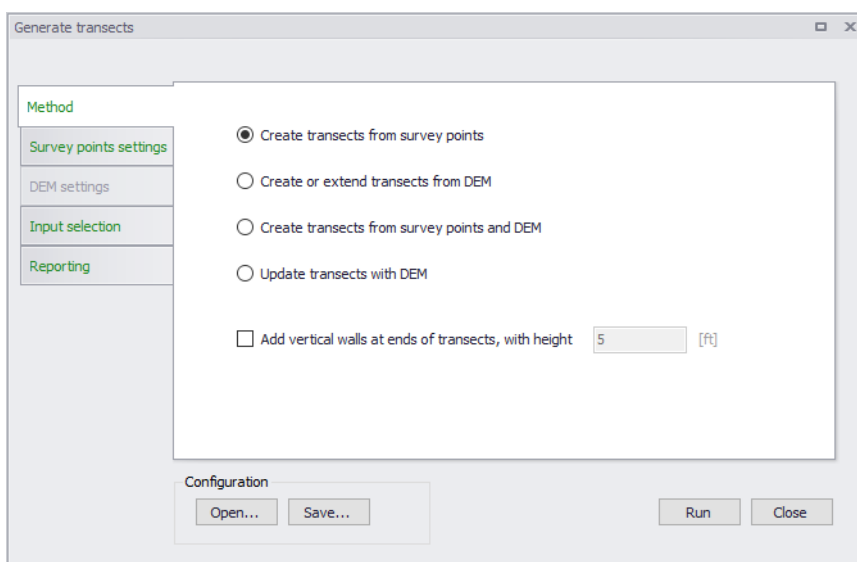


Figure 3.46 Method section on the Generate Transects dialog

There is also an option for adding vertical walls with a specified height to the ends of created/updated transects. Tick on the **'Add vertical walls at ends of transects'** option, and define the **height** of the vertical wall in the input box beside the option.

Add vertical walls at ends of transects, with height  [ft]

## Survey Points Settings

If the selected method from the previous tab page involves the use of survey points, the survey points data file and parameters related to how data from the file shall be interpreted by the tool are defined on the Survey Points Settings tab page.

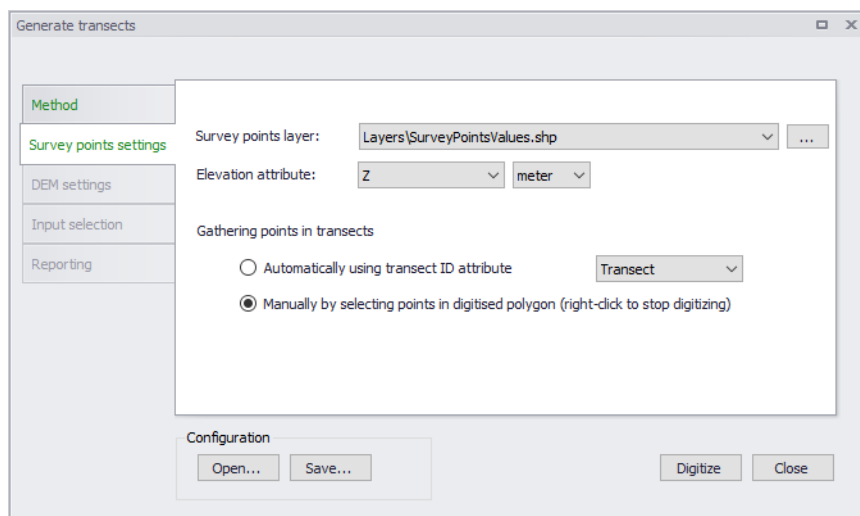


Figure 3.47 Survey Points Settings tab page on the Generate Transects dialog

Define the following on the page:

- **Survey Points Layer.** Choose or load the shape file or \*.XYZ file to use in the processing from the dropdown list or the ellipsis button, respectively.
- **Elevation Attribute.** Choose the item from the shape or \*.XYZ file to use as source of elevation values.
- **Gathering Points in Transects.** Set how values are obtained and saved as transect data:
  - **Automatically using Transect ID attribute.** Select the attribute in the file that connects the individual survey points to a specific transect. All survey points with the same ID field will be created as one transect.
  - **Manually by selecting points in digitised polygon.** Define a polygon on the Map covering survey points to be used for a transect. Click on the '**Digitize**' button at the bottom of the dialog to start defining the polygon feature on the Map. Right-click on the Map to end digitizing the polygon. This option creates one transect at a time.

The transect will be created as a straight line through the connected survey points using a least square fit. The individual survey points are projected orthogonal on to the transect line.

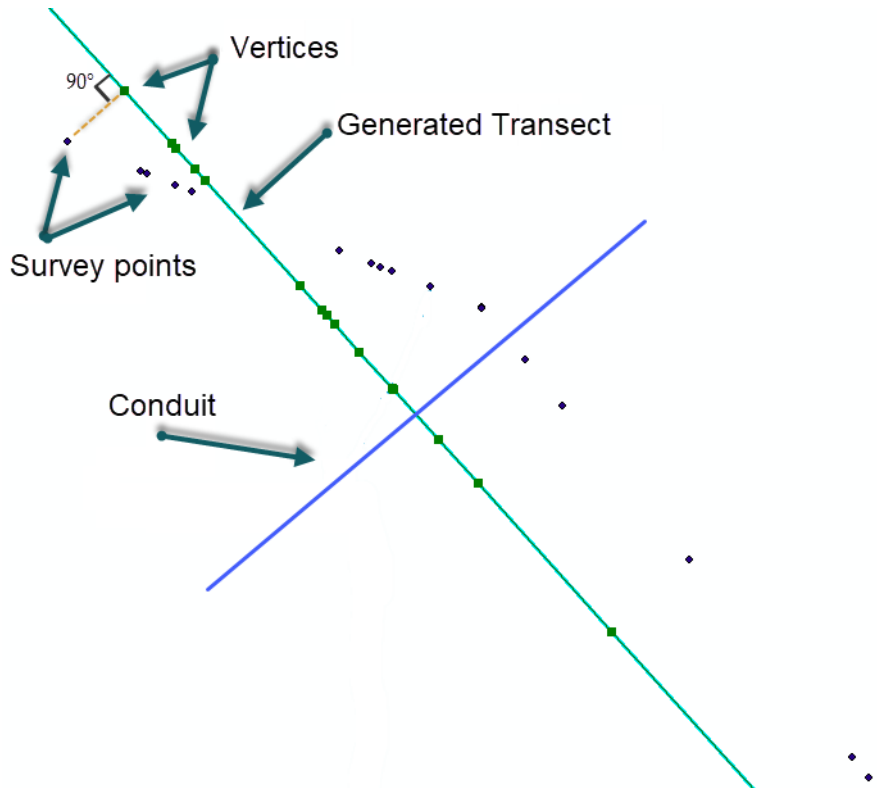


Figure 3.48 Survey points are projected onto the transect

## DEM Settings

If the selected transect creation method involves the use of DEM data, the DEM raster file and parameters related to how data from the file shall be used by the tool are defined on the DEM Settings tab page.



Figure 3.49 DEM Settings tab page on the Generate Transects dialog

## Elevation and Spacing

Define the following parameters under the Elevation and Spacing group:

- **DEM Layer.** Define or load the DEM raster layer to use for transects generation. These raster files may be in \*.TXT, \*.ASC, \*.DFS2, \*.TIF, or \*.TIFF formats.
- **Maximum Spacing Between Points.** The maximum spacing between transect points can be user-specified or assumed as half the cell size of the DEM.
  - **Half cell size from DEM.** Half the DEM grid size resolution.
  - **Custom Spacing.** Option to define a spacing for transect point values.
- **Maximum Number of Points.** Should the specified maximum spacing between points results in more than the allowed maximum points the spacing is increased to obtain the maximum number of points.



- **Use Bilinear Interpolation from 4 Closest Cells.** Option to use bilinear interpolation when extracting elevation values from DEM cells. If unchecked, the elevation along the transect will be the exact value from the DEM cells that are intersected, whereas if bilinear interpolation is used, elevation values will be the interpolated from the 4 closest neighbouring DEM grid cells.

### Transect Location

Define the following parameters under the Transect Location group:

- **Create One New Transect per Conduit.** Option to define one transect per conduit (as selected on the Input Selection tab page).
  - **Width.** Define the width of the transects to be generated.
- **Create New Location from Layer.** Use a shape file containing transect polylines at the requested locations along the irregular conduits in the model. Select the shape file to be used in the drop-down list of shape files.

Transects will only be generated where shape file features intersect with the selected conduits. The transect will be generated as a straight line from the first to the last point in the line shape.

- **Assign ID from Attribute.** Automatically assign an ID to each generated transect by activating this option and selecting the shapefile attribute from the dropdown list.
- **Extend Existing with Fixed Width on Both Sides of Conduits.** Option to extend transect data a fixed distance on both sides of the conduits. Define the fixed width in the input box beside the option.
- **Extend Existing up to Alignment Lines.** Option to use defined alignment lines to extend existing transects data.
  - **Alignment Lines Layer.** Define/load the shapefile defining the alignment lines from the dropdown list or via the ellipsis button.
  - **Marker Attribute.** Shapefile attribute that contains the identifier corresponding to markers.
  - **Left Extent Marker Value.** The marker attribute value representing the left extent line.
  - **Right Extent Marker Value.** The marker attribute value representing the right extent line.
  - **Maximum Length to Extend per Side.** The length defines the maximum distance a transect can be extended. If an alignment line is not found within the given distance, the transect will not be updated.



- **Manually Digitize on Map (Right Click to Stop Digitizing).** Define the location of the transect to be generated directly on the Map (intersecting a conduit). Click on the 'Digitize' button at the bottom of the dialog to start defining the transect line feature on the Map. Right-click on the Map to end digitizing the line. This option creates one transect for one conduit at a time.

## Input Selection

Input Selection options control for which conduits transects are generated. These options are not available for settings involving manual digitization of transect locations on the Map, as this process creates one transect (for the intersected conduit) at a time.

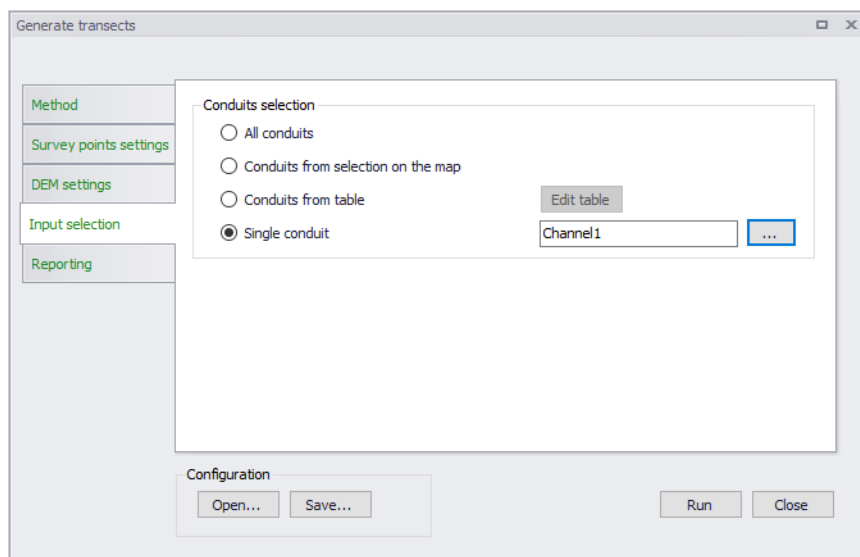


Figure 3.50 The Input Selection tab page on the Generate Transects dialog

Options available include:

- **All Conduits.** New transects are generated for all conduits.
- **Conduits from Selection on the Map.** New transects are generated only for conduits selected on the Map.
- **Conduits from Table.** The conduits for which new transects are generated are specified in a table. Click on the **Edit Table** button to access the Select Conduits dialog.

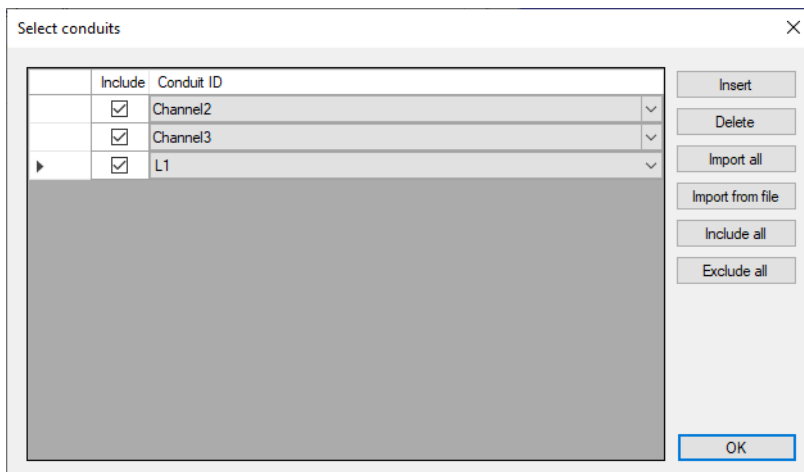


Figure 3.51 The Select Conduits dialog accessed via the Edit Table button

- **Single Conduit.** Select the conduit for which a transect will be created from the **ID Selector** list accessed via the ellipsis button.

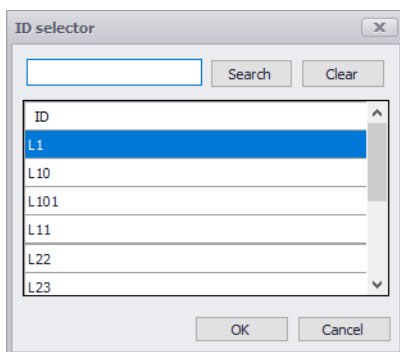


Figure 3.52 The ID Selector list

## Running the Tool and Reporting

For options not involving manual digitization of transect lines on the Map, manually run the tool via the **Run** button at the bottom of the dialog.

A status report of the operation is displayed on the Reporting tab page of the dialog. The report may then be saved in a \*.TXT file via the **Save Report** button. Use the **Clear Report** button to remove previous status reports displayed on the tab page ready for a new run of the tool.

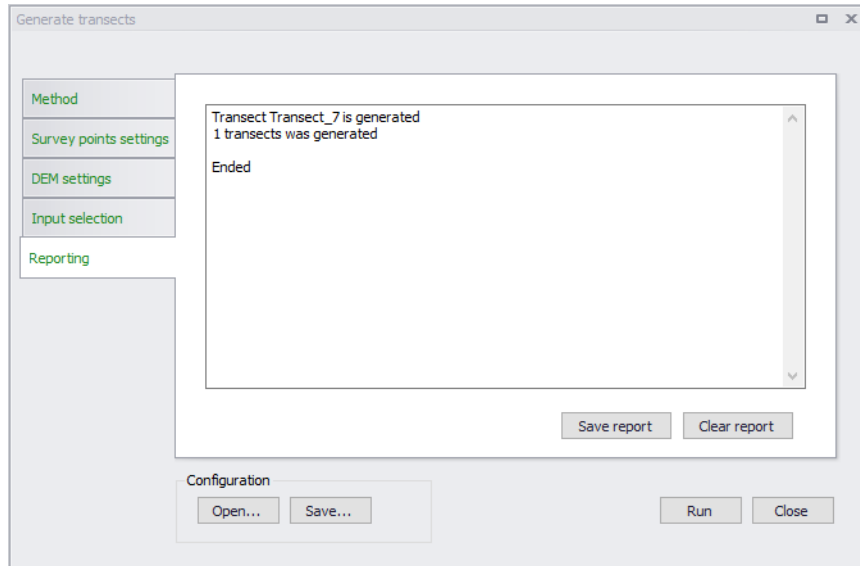
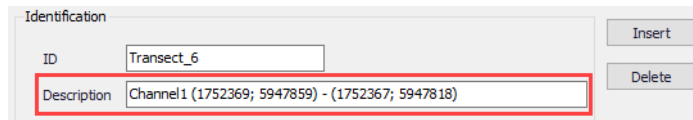


Figure 3.53 The Reporting tab page on the Generate Transects dialog



When a transect is created for a conduit, the conduit ID is indicated in the transect Description including the line coordinates for the transect.



If another transect is made for the same conduit, the Description for the previous transect is removed to avoid confusion about which conduit a transect is associated.

Also, when extending transects, left and right bank locations are updated (if they are initially different than 0).

## Configuration File

Save the tool setup configuration via the **Save** button located near the bottom of the tool dialog. An \*.XML configuration file is created, which may be reused later via the **Open** button.

### 3.10.3 Spatial Processing

The Spatial Processing tool may be used to perform various GIS processing operations on SWMM project line and polygon features. These layers are either model element layers or shapefile layers loaded into the project.

The tool is accessed via 'Special Tools' on the 'CS Network' menu ribbon.



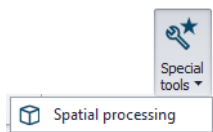


Figure 3.54 The Spatial Processing tool on the NS Network menu ribbon

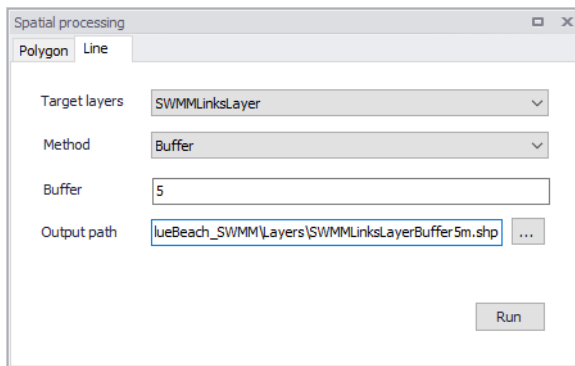


Figure 3.55 The Spatial Processing tool dialog

## Line

Operations such as Buffer and To Polygon may be performed for line layers. The analysis results are saved in a new shapefile and automatically loaded into the project as a new layer. It may also be imported as a model element feature.

- **Target Layers.** Line layer to be modified (i.e. to which the operation will be done).
- **Method.** Dropdown menu for selecting spatial operation to use:
  - **Buffer.** Creates buffer polygons around target layer features according to a buffer distance.
  - **To Polygon.** Converts the line features to polygons. Note that polyline features must be closed with overlapping start- and end-vertices to be converted to polygons.
- **Buffer.** Distance around the line features that will be buffered. If Method = Buffer.
- **Output Path.** Use the ellipsis button “...” to specify the path and file name for the resulting feature layer from the operation.
- **Run.** Button for executing the spatial processing.

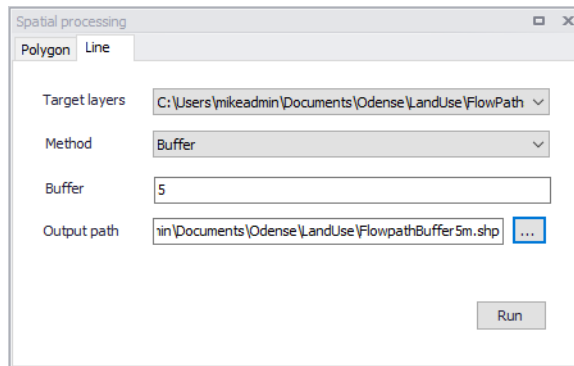


Figure 3.56 Spatial processing for lines

## Polygon

Operations such as Merge and Clip may be performed between various polygon layers. The analysis results are saved in a new shapefile and automatically loaded into the project as a new layer. It may also be imported as a model element feature.

Define the following parameters when using the tool for polygon features:

- **Target Layers.** Polygon feature to be modified (i.e. to which the operation will be done).
- **Reference Layers.** The second polygon layer used to modify the target layer.
- **Keep Properties.** Information on the feature attributes to keep for the resulting layer.
- **Method.** Dropdown menu for selecting spatial operation to use:
  - **Clip.** Extracts from target the areas intersecting the reference. Features in target not intersecting the reference are also kept.
  - **Erase.** Removes from target the areas intersecting the reference.
  - **Merge.** Features in both layers combined, where intersecting features are fused in new features.
  - **Join.** Extracts from target the areas intersecting the reference.
- **Output Path.** Use the ellipsis button “...” to specify the path and file name for the resulting feature layer from the operation.
- **Run.** Button for executing the spatial processing.

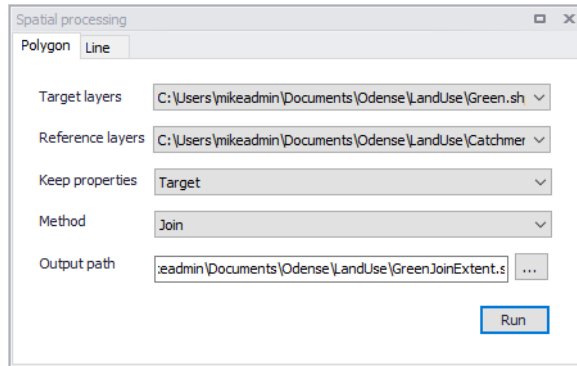


Figure 3.57 Spatial Processing dialog Polygon tab page





## 4 Rainfall-Runoff Modelling with SWMM

MIKE+ provides a versatile set of tools and computational models for modelling surface storm runoff and infiltration on urban and semi-rural catchments. The User can quickly prepare a precipitation-runoff model setup of desired level of detail (in terms of spatial discretization and input data) and use the computed runoff as a load to the collection network.

Various hydrological processes that produce runoff from urban areas can be modelled by SWMM. These include:

- Time-varying rainfall
- Evaporation of standing surface water
- Snow accumulation and melting
- Rainfall interception in depression storage
- Infiltration of rainfall into upper soil layers
- Percolation of infiltrated water into groundwater layers
- Interflow between groundwater and the conveyance system
- Nonlinear reservoir routing of overland flow

Spatial variability in these processes is achieved by dividing a study area into a smaller collection of homogeneous areas. In literature, different terms are used to describe the delineation of large study areas into smaller sub-areas each containing its own fraction of pervious and impervious areas.

The following terms for the delineation of areas are widely used in North America:

- Basin
- Sub-basin
- Watershed/Sewershed
- Catchment

Throughout this documentation the term *catchment* will be used as the term for the smallest hydrological unit of land.

Overland flow can be routed between catchments or to load points of a drainage conveyance system.

### 4.1 Catchments

Catchments are hydrological units of land whose topography cause surface runoff to drain to a single point. The user is responsible for the delineation of a watershed/sewershed into a compatible number of catchments, and for



identifying the outlet point of each catchment. Outlet points can be either nodes of the conveyance system or other catchments.

Catchments can be divided into pervious and impervious sub-areas. Surface runoff can infiltrate into the upper soil zone of the pervious sub-area, but not through the impervious sub-area. Impervious areas are themselves divided into two sub-areas - one that contains depression storage and another that does not. A portion of the runoff flow from one sub-area in a catchment can be routed to the other sub-area, or both sub-areas can drain to the catchment outlet.

For SWMM models, the Catchments editor organizes data into the following groups.

- Identification
- General Information
- SWMM Catchment Connections
- SWMM Hydrology & Hydraulic Properties
- SWMM Infiltration
- Description



**Note** that catchment data in the Catchment editor is shared by Network models in MIKE+ (i.e. MIKE 1D, SWMM, River).

	ID	X coordinate [ft]	Y coordinate [ft]	Catchment area [ac]	Geom area [ac]	Person Equi
▶ 1	4000_24_2_R1	1024697.71859456	854520.116536882	75.13961	75.4662449855498	
2	4000_24N	1017585.92078691	862376.385636987	858.6189	858.618821616116	
3	4000_24S	1019358.09098427	856711.683673189	899.167	899.167047372306	
4	4005_00N	1019063.46112977	823058.731076986	725	724.964664690252	
11	4401_03	992090.794201262	811188.161521463	1089	1210.51983241924	
12	4401_20	986807.184147837	819537.075484856	3193	3548.16340174502	

Figure 4.1 The Catchments editor for SWMM models



Catchments are featured as a data layer in MIKE+. They can be managed both graphically on the Map and through the Catchments editor.

The two modes complement each other, and efficient management of catchment data can be achieved through joint application of both modes.

The graphical mode (i.e. Edit Features functionality from the Catchments menu ribbon) allows digitisation of catchment extent by tools like Create, Edit, Delete, and Split. Descriptions of graphical catchment tools are found in the Model Manager User Guide.

The Catchments editor is used for:

- Editing catchment attributes. It is possible to insert catchments through the editor; these are given a schematised quadratic shape.
- Editing connections to model networks and hydrological data for Rainfall-Runoff models.
- Editing catchment hydrological model attributes. It is possible to edit catchment attributes in relation to various hydrological runoff models available in MIKE+.

### 4.1.1 Identification

The Catchments editor has a general Identification group containing information on catchment identifier and geographic location.

Identification	
ID	Catchment_6
X	1095418.71348999 [ft]
Y	907896.342153769 [ft]

Buttons: Insert, Delete

Figure 4.2 The Catchments editor Identification group



Table 4.1 Edit fields in the Catchments editor Identification group (msm\_Catchment)

Edit field	Description	Usage	Attribute Table Field
ID	Unique catchment identifier	Yes	MUID
X	X coordinate of the catchment geometry centroid	Yes	GeomCentroidX
Y	Y coordinate of the catchment geometry centroid	Yes	GeomCentroidY

Other catchment attributes related to hydrological modelling and connections to model networks are organized in tabs within the editor and are described in succeeding Sections.

#### 4.1.2 General

General catchment attributes related to hydrological model type and geometry are specified in the General tab page of the Catchments editor.

In MIKE+, the geographical extent of a catchment is determined by the catchment polygon perimeter. MIKE+ provides information on the total catchment area based on polygon geometry.

In some cases, the geographical boundaries of a catchment do not coincide with the actual drainage area. A catchment extent may be defined based on some administrative division, while the drainage network is present only in some parts of the catchment. In such cases, the User may specify the Catchment Area value, which overwrites the actual geometric area in all hydrological computations.



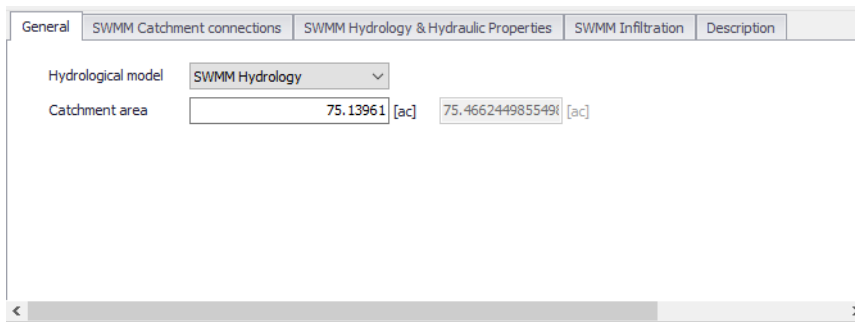


Figure 4.3 The Catchments editor General tab page

Table 4.2 Edit fields in the Catchments editor General tab page (msm\_Catchment)

Edit field	Description	Usage	Attribute Table Field
Hydrological Model	Hydrological runoff model to use for a catchment	Yes	HydrologicalModelNo
Catchment Area	The catchment area of relevance for the project ( $\leq$ Geom Area)	Optional	Area
(Derived Geometric Area)	Program-calculated geometric area of the catchment polygon	Calculated (read-only)	GeomArea

### 4.1.3 Catchment Connections

To transfer runoff generated on catchment surfaces into the collection network, the model must include information about the connection of the catchment outlet to the network.

For SWMM models, MIKE+ supports the connection of catchments to nodes as well as other catchments wherein runoff is routed from one area to another. One or multiple catchments can be connected to the same node.

Define catchment connections for SWMM models on the SWMM Catchment Connections tab page of the Catchments editor.

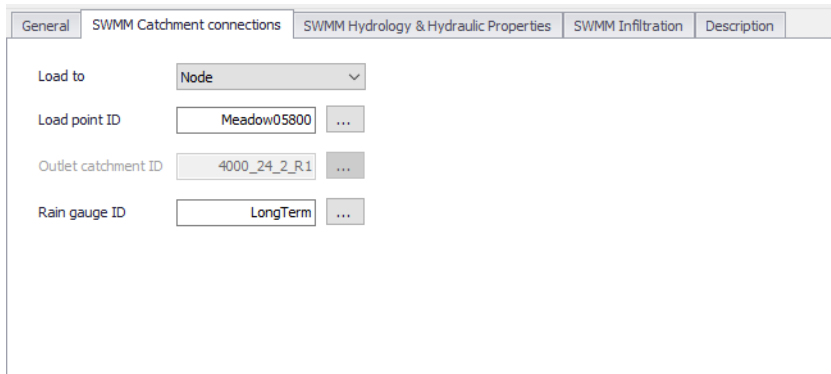


Figure 4.4 The SWMM Catchment Connections tab page in the Catchments editor

The definition and management of catchment connections is supported both through the editor and by a set of graphical catchment connection tools accessed via the Catchments menu ribbon.

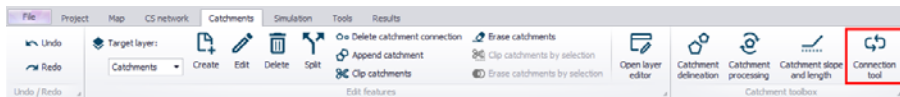


Figure 4.5 The Catchment Connection tool on the Catchments menu ribbon

Table 4.3 Edit fields in the Catchment Connections tab page (msm\_Catchment)

Edit field	Description	Usage	Attribute Table Field
Load to	Specifies the type of network element to which the catchment is connected. Options are: Node Catchment	Yes	SWMM_LoadToNo
Load Point ID	ID of Node that receives the catchment runoff	Yes If Load to = Node	SWMM_OutletNodeID
Outlet Catchment ID	ID of Catchment that receives the surface runoff	Yes If Load to = Catchment	SWMM_OutletCatchmentID
Raingage ID	Rain Gauge boundary setup ID associated with the catchment	Yes	SWMM_RaingaugeID



#### 4.1.4 Hydrology & Hydraulic Properties

The concept of the surface runoff used by SWMM is illustrated in the figure below. Each catchment surface is treated as a nonlinear reservoir. Inflow comes from precipitation and upstream catchments. There are several outflows, including infiltration, evaporation, and surface runoff.

The capacity of this "reservoir" is the maximum depression storage, which is the maximum surface storage provided by ponding, surface wetting, and interception.

Surface runoff per unit area,  $Q$ , occurs only when the depth of water in the "reservoir" exceeds the maximum depression storage,  $d_p$ , in which case the outflow is given by Manning's equation (Kinematic Wave).

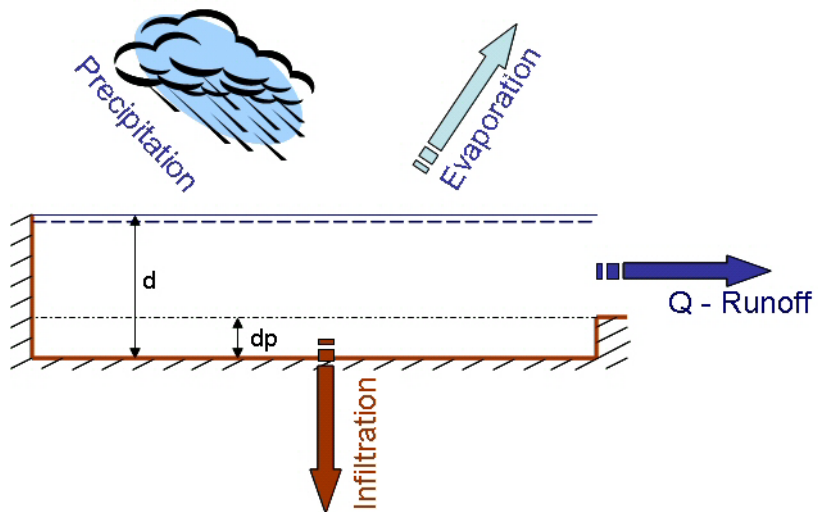


Figure 4.6 Nonlinear Reservoir Concept

Depth of water over the catchment is continuously updated with time by numerically solving a water balance equation over the catchment.

Define SWMM surface runoff computation data on the SWMM Hydrology & Hydraulic Properties tab page of the Catchments editor.



General	SWMM Catchment connections	SWMM Hydrology & Hydraulic Properties	SWMM Infiltration	Description	
Width	<input type="text" value="5"/>	[ft]	Imperv. d. storage	<input type="text" value="0.05"/>	[in]
Ground slope	<input type="text" value="0.1"/>	[%]	Perv. d. storage	<input type="text" value="0.2"/>	[in]
Imperviousness	<input type="text" value="23"/>	[%]	% DCIA w/o d. storage	<input type="text" value="25"/>	[0]
Impervious Manning	<input type="text" value="0.02"/>	[s/m <sup>1/3</sup> ]	Subarea routing	<input type="text" value="PERV"/>	
Pervious Manning	<input type="text" value="0.2"/>	[s/m <sup>1/3</sup> ]	Percent routed	<input type="text" value="65"/>	[%]
Snowpack ID	<input type="text" value="Snowpack"/>	<input type="button" value="..."/>	Curb length	<input type="text" value="0"/>	[ft]
N-perv Pattern	<input type="text"/>	<input type="button" value="..."/>	Infil Pattern	<input type="text"/>	<input type="button" value="..."/>
Dstore Pattern	<input type="text"/>	<input type="button" value="..."/>			

Figure 4.7 The SWMM Hydrology & Hydraulic Properties tab page of the Catchments editor

Table 4.4 Edit fields in the SWMM Hydrology & Hydraulic Properties tab page (msm\_Catchment)

Edit field	Description	Used or required by simulations	Field name in datastructure
Width	Width of catchment	Yes	SWMM_Width
Ground Slope	Ground slope of catchment in percentage	Yes	SWMM_Slope
Imperviousness	Impervious part of the catchment area in percentage	Yes	SWMM_Impervious
Impervious Manning	Manning number for the Impervious part of the area	Yes	SWMM_NImperv
Pervious Manning	Manning number for the Pervious part of the area	Yes	SWMM_NPerv
Imperv. d. Storage	Size of Impervious Depression Storage	Yes	SWM-M_DImperv
Perv. d. Storage	Size of Pervious Depression Storage	Yes	SWMM_DPerv
%DCIA w/o d. Storage	Percent of the impervious area with no depression storage	Yes	SWMM_ImpervPctZero
Subarea Routing	Choice of internal routing of runoff between pervious and impervious areas: IMPERV: runoff from pervious area flows to impervious area PERV: runoff from impervious flows to pervious area OUTLET: runoff from both areas flows directly to outlet	Yes	SWMM_RouteToNo



Table 4.4 Edit fields in the SWMM Hydrology & Hydraulic Properties tab page (msm\_Catchment)

Edit field	Description	Used or required by simulations	Field name in datastructure
Percent Routed	Percent of runoff routed between subareas	Yes	SWMM_PctRouted
Snowpack ID	Snowpack parameter set ID (if any) assigned to the catchment	Optional	SWMM_Snow-PackID
Curb Length	Total length of Curbs in the catchment. Only used when pollutant buildup is normalized to curb length	No	SWMM_CurbLength
N-perv Pattern	Operational monthly pattern that adjust pervious Manning n	Optional	SWMM_NPervPatternID
DStore Pattern	Optional monthly pattern that adjust depression storage	Optional	SWMM_DstorePatternID
Infil Pattern	Optional monthly pattern that adjust infiltration rate	Optional	SWMM_InfilPatternID

### 4.1.5 Infiltration

Infiltration is the process of rainfall penetrating the ground surface into the soil over the pervious areas of catchments. SWMM supports the following methods for modelling infiltration:

- **Horton Method.** This method is based on empirical observations showing that infiltration decreases exponentially from an initial maximum rate to some minimum rate over the course of a long rainfall event. Input parameters required by this method include the maximum and minimum infiltration rates, a decay coefficient that describes how fast the rate decreases over time, and a regeneration constant that describes the restoration of infiltration rate during dry periods.
- **Green-Ampt Method.** This method for modelling infiltration assumes that a sharp wetting front exists in the soil column, separating soil with some initial moisture content below from saturated soil above. The input parameters required are the initial moisture deficit of the soil, the soil's hydraulic conductivity, and the suction head at the wetting front.



- **Curve Number Method.** This approach is adopted from the NRCS (SCS) Curve Number method for estimating runoff. It assumes that the total infiltration capacity of a soil can be found from the soil's tabulated Curve Number. During a rain event this capacity is depleted as a function of cumulative rainfall and remaining capacity. The input parameters for this method are the curve number, the soil's hydraulic conductivity (used to estimate a minimum separation time for distinct rain events), and a regeneration constant that describes the restoration of infiltration capacity during dry periods.
- **Modified Horton Method.** A modified version of the Horton Method that uses the cumulative infiltration in excess of the minimum rate as its state variable (instead of time along the Horton curve), providing a more accurate infiltration estimate when low rainfall intensities occur. It uses the same input parameters as the traditional Horton Method.
- **Modified Green-Ampt Method.** This is a modified version of the original Green-Ampt procedure by not depleting moisture deficit in the top surface layer of soil during the initial periods of low rainfall as was done in the original method. This change can produce more realistic infiltration behavior for storms with long initial periods where the rainfall intensity is below the soil's saturated hydraulic conductivity.

Define SWMM Infiltration model parameters on the SWMM Infiltration tab page on the Catchments editor.

General	SWMM Catchment connections	SWMM Hydrology & Hydraulic Properties	SWMM Infiltration	Description	
<b>Horton</b>					
Max infiltration rate	<input type="text"/>	[in/h]	Decay rate	<input type="text" value="10"/> [%]	
Min infiltration rate	<input type="text"/>	[in/h]	DWF regeneration	<input type="text"/>	[d]
Max infiltration vol.	<input type="text" value="0"/>	[in]			
<b>Green Ampt</b>					
Soil capillary suction	<input type="text" value="6.57"/>	[in]	Conductivity	<input type="text" value="0.39"/> [in/h]	
Initial soil moisture	<input type="text" value="17"/>	[%]			
<b>Curve Number</b>					
Curve number	<input type="text"/>	[0]			
DWF regeneration	<input type="text"/>	[d]			

Figure 4.8 The SWMM Infiltration tab page

Only one of the above infiltration methods can be used in a simulation, which is defined in the Simulation Setup editor (Figure 4.9).

When running a simulation, defining infiltration parameters are mandatory only for the selected infiltration model; the other parameters may remain empty.

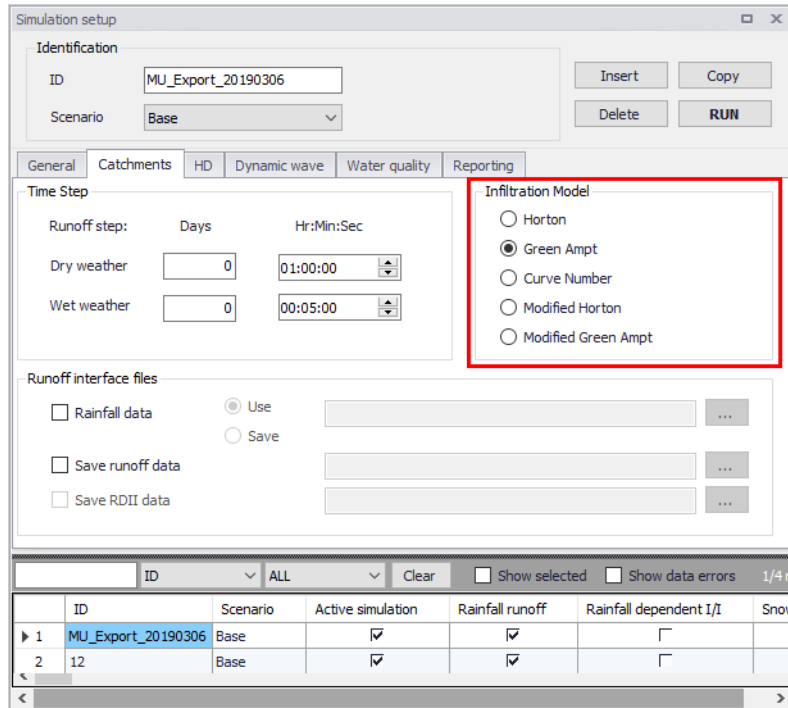


Figure 4.9 Infiltration method used in simulation as defined in the Simulation Setup editor

Table 4.5 Edit fields in the Infiltration tab page (msm\_Catchment)

Edit field	Description	Used or required by simulations	Field name in datastructure
Horton			
Max infiltration rate	Max Infiltration Rate	Yes	SWMM_MaxRate
Min infiltration rate	Min Infiltration Rate	Yes	SWMM_MinRate
Max infiltration vol.	Max Infiltration Volume	Yes	SWMM_MaxInFil
Decay rate	Decay Rate	Yes	SWMM_DecayRate
DWF regeneration	DWF regeneration factor	Yes	SWMM_HRegen
Green-Ampt			
Soil capillary suction	Soil Capillary Suction	Yes	SWMM_Suction



Table 4.5 Edit fields in the Infiltration tab page (msm\_Catchment)

Edit field	Description	Used or required by simulations	Field name in datastructure
Initial soil moisture	Initial saturated soil moisture	Yes	SWMM_InitDef
Conductivity	Soil saturated hydraulic conductivity	Yes	SWMM_Conduct
Curve Number			
Curve Number	Curve No	Yes	SWMM_RunoffCN
DWF regeneration	DWF regeneration factor	Yes	SWMM_CRegen

### 4.1.6 Description

The Catchments editor Description tab page allows the User to provide additional information for a catchment record.

The screenshot shows the 'Description' tab of the SWMM Catchment editor. The tabbed interface includes 'General', 'SWMM Catchment connections', 'SWMM Hydrology & Hydraulic Properties', 'SWMM Infiltration', and 'Description'. The 'Description' tab is active, displaying a form with the following fields: 'Description' (text input), 'Data source' (text input), 'Asset ID' (text input), 'Status' (dropdown menu), 'Network type' (dropdown menu, currently showing '2: Storm Water'), and 'Tag' (text input). An 'Add picture' button is located to the right of the form.

Figure 4.10 The Catchments editor Description tab page





Table 4.6 Edit fields in the Description tab page (msm\_Catchment)

Edit field	Description	Usage	Attribute Table Field
Description	Free text description related to the catchment	Optional	Description
Data source	Reference to an external data source (e.g. table ID) from where the record was taken	Optional	DataSource
Asset ID	Reference to an ID used in external data sources	Optional	AssetName
Status	Data status based on a user-specified list (Status Code editor)	Optional	Element_S
Network Type	Attributes the catchment to a certain type of network. Used in cases where different network types are in the same project.	Optional	NetTypeNo
Tag	Optional label to categorize/classify the catchment	Optional	SWMM_Tag
Add Picture button	Facility for defining an image file for the catchment record. Accepts .PNG, .JPG, and .BMP image files.	Optional	-

## 4.2 Aquifers

Aquifers are subsurface groundwater areas used to model the vertical movement of water infiltrating from the catchments above. They also permit the infiltration of groundwater into the conveyance system, or exfiltration of surface water from the conveyance system, depending on the hydraulic gradient. The same aquifer object can be shared by several catchments.

Aquifers are represented using two zones - an unsaturated zone and a saturated zone. Their behaviour is characterized using such parameters as soil



porosity, hydraulic conductivity, evapotranspiration depth, bottom elevation, and loss rate to deep groundwater. In addition, the initial water table elevation and initial moisture content of the unsaturated zone must be defined.

Define aquifers via the SWMM Aquifers editor in MIKE+. The editor organizes the aquifer data into the following groups:

- Identification
- Aquifer properties

Aquifers are connected to catchments and network nodes through the Groundwater editor (see Chapter 4.8. Groundwater)

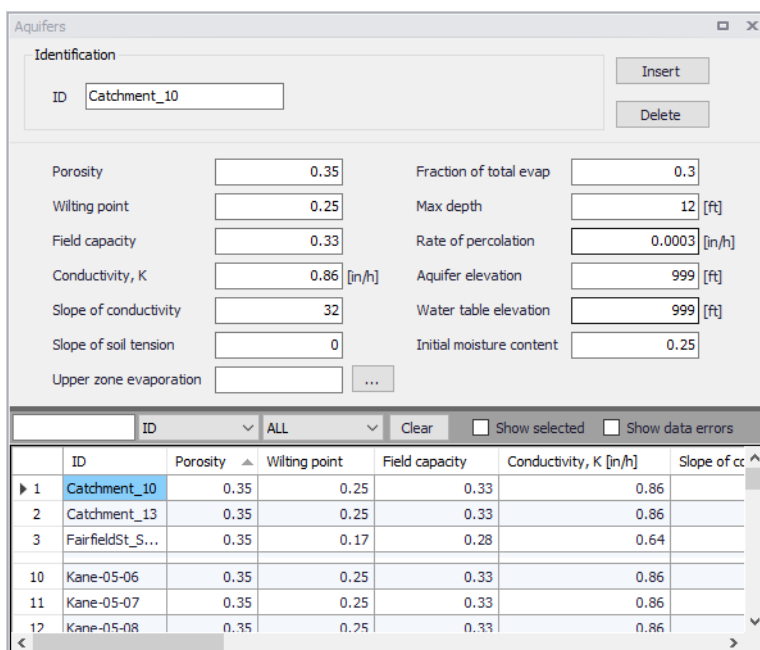


Figure 4.11 The Aquifers editor

Table 4.7 Edit fields in the Aquifers editor (mss\_Aquifer)

Edit field	Description	Used or required by simulations	Field name in datastructure
Porosity	Soil porosity (fraction)	Yes	Por
Wilting Point	Soil wilting point (fraction)	Yes	WP
Field Capacity	Soil field capacity (fraction)	Yes	FC



Table 4.7 Edit fields in the Aquifers editor (mss\_Aquifer)

Edit field	Description	Used or required by simulations	Field name in datastructure
Conductivity, K	Saturated hydraulic conductivity	Yes	K
Slope of Conductivity	Slope of hydraulic conductivity versus moisture content curve	Yes	Kslope
Slope of Soil Tension	Slope of soil tension versus moisture content curve	Yes	Yslope
Fraction of Total Evap	Fraction of total evaporation available for evapotranspiration	Yes	UEF
Max Depth	Maximum depth into lower saturated zone over which evapotranspiration can occur	Yes	LED
Rate of Percolation	Rate of percolation from saturated zone to deep groundwater when water table is at ground surface	Yes	GWR
Aquifer Elevation	Elevation of the bottom of the aquifer	Yes	BE
Water Table Elevation	Water table elevation at the start of simulation	Yes	WTE
UMC	Unsaturated zone moisture content at the start of simulation	Yes	UMC

## 4.3 Climatology

Climate-related variables used for computing runoff and snowmelt are defined in the Climatology editor.

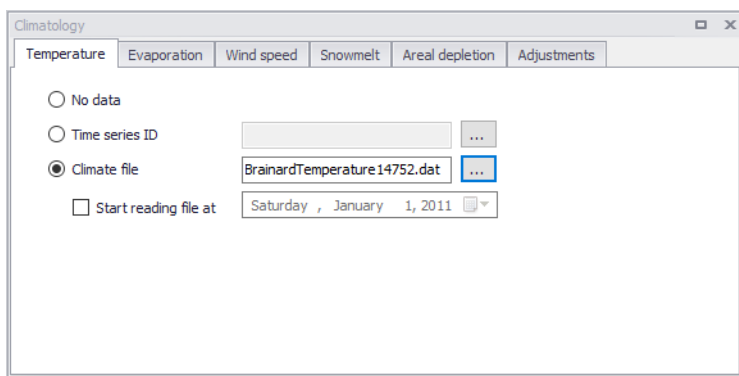


Figure 4.12 The Climatology editor for SWMM models

The editor organizes climatological data into the following groups:

- Temperature
- Evaporation
- Wind Speed
- Snowmelt
- Areal Depletion
- Adjustments

### 4.3.1 Temperature

Temperature data are used when simulating snowfall and snowmelt processes during runoff calculations. If these processes are not being simulated then no temperature data are needed.

Temperature data can be supplied from one of the following sources:

- A user-supplied time series of point values (values at intermediate times are found by interpolation)
- A NCDC 3200 or 3210 climatological file containing daily minimum and maximum values (SWMM fits a sinusoidal curve through these values depending on the day of the year).

For user-defined time series, temperatures are in degrees F for US units and degrees C for metric units. Note that the NCDC climatological file can also be used to define evaporation and wind speed data.



Figure 4.13 The SWMM Climatology Temperature tab page

Table 4.8 Edit fields in the Temperature tab page (mss\_Temperature)

Edit field	Description	Used or required by simulations	Field name in datastructure
	Radio button for temperature data type	Yes	TypeNo
No Data	No temperature data	Yes if TypeNo = 1	
Time Series ID	Temperature data read from time series defined in Time Series editor	Yes if TypeNo = 2	TimeSeriesID
Climate File	Temperature data read from NCDC *.DAT file	Yes if TypeNo = 3	FileName
Start Reading File at	Start date for reading from NCDC data file	Yes if TypeNo = 3	StartDate

### 4.3.2 Evaporation

Evaporation can occur for standing water on catchment surfaces, for subsurface water in groundwater aquifers, and from water held in storage units. Evaporation rates can be defined as:

- A single constant value
- A set of monthly average values
- User-supplied time series of daily values
- Daily values read from a NCDC climate file
- Values computed from the daily temperatures in the external climate file



If a NCDC file is used, then a set of monthly pan coefficients should also be supplied to convert the pan evaporation data to free water surface values.

Figure 4.14 The Climatology Evaporation tab page

Table 4.9 Edit fields in the Evaporation tab page (mss\_Evaporation)

Edit field	Description	Used or required by simulations	Field name in datastructure
	Radio button for evaporation data type	Yes	TypeNo
Constant Value	Evaporation is set to constant value TypeNo = 1	Yes if TypeNo = 1	ConstValue
Monthly Values TypeNo = 2			
Jan	Monthly evaporation value for January entered by user	Yes if TypeNo = 2	Value1
Feb	Monthly evaporation value for February entered by user	Yes if TypeNo = 2	Value2
Mar	Monthly evaporation value for March entered by user	Yes if TypeNo = 2	Value3
Apr	Monthly evaporation value for April entered by user	Yes if TypeNo = 2	Value4



Table 4.9 Edit fields in the Evaporation tab page (mss\_Evaporation)

Edit field	Description	Used or required by simulations	Field name in datastructure
May	Monthly evaporation value for May entered by user	Yes if TypeNo = 2	Value5
June	Monthly evaporation value for June entered by user	Yes if TypeNo = 2	Value6
July	Monthly evaporation value for July entered by user	Yes if TypeNo = 2	Value7
Aug	Monthly evaporation value for August entered by user	Yes if TypeNo = 2	Value8
Sept	Monthly evaporation value for September entered by user	Yes if TypeNo = 2	Value9
Oct	Monthly evaporation value for October entered by user	Yes if TypeNo = 2	Value10
Nov	Monthly evaporation value for November entered by user	Yes if TypeNo = 2	Value11
Dec	Monthly evaporation value for December entered by user	Yes if TypeNo = 2	Value12
Time Series ID	Evaporation data read from time series defined in Time Series editor	Yes if TypeNo = 3	TimeSeriesID
Directly from Climate File TypeNo = 4			
Jan	Evaporation data for January read from NCDC file	Yes if TypeNo = 4	Pan1
Feb	Evaporation data for February read from NCDC file	Yes if TypeNo = 4	Pan2
Mar	Evaporation data for March read from NCDC file	Yes if TypeNo = 4	Pan3
Apr	Evaporation data for April read from NCDC file	Yes if TypeNo = 4	Pan4
May	Evaporation data for May read from NCDC file	Yes if TypeNo = 4	Pan5
June	Evaporation data for June read from NCDC file	Yes if TypeNo = 4	Pan6
July	Evaporation data for July read from NCDC file	Yes if TypeNo = 4	Pan7
Aug	Evaporation data for August read from NCDC file	Yes if TypeNo = 4	Pan8
Sept	Evaporation data for September read from NCDC file	Yes if TypeNo = 4	Pan9



Table 4.9 Edit fields in the Evaporation tab page (mss\_Evaporation)

Edit field	Description	Used or required by simulations	Field name in datastructure
Oct	Evaporation data for October read from NCDC file	Yes if TypeNo = 4	Pan10
Nov	Evaporation data for November read from NCDC file	Yes if TypeNo = 4	Pan11
Dec	Evaporation data for December read from NCDC file	Yes if TypeNo = 4	Pan12
Computed from Temperatures in the Climate Files	Evaporation calculated based on temperature in the climate file	Yes if TypeNo = 5	
Evaporate Only During Dry Periods	Option for setting evaporation to occur only during dry periods	Yes	DryOnlyNo
Monthly Soil Recovery Pattern	Monthly infiltration recovery rate pattern defined in Time Patterns editor	Yes	SoilRecoveryPatternID

### 4.3.3 Wind Speed

Wind speed is an optional climatological variable that is only used for snow-melt calculations. Define either a set of monthly average speeds, or wind speed data from the same NCDC climatological file used for daily min/max temperatures.

Temperature Evaporation **Wind speed** Snowmelt Areal depletion Adjustments

No wind speed data  
 Monthly average wind speed  
 From climate file

Jan	Feb	Mar	Apr	May	Jun
8.3	8.8	9.3	9	8.1	7.2
[mi/h]					
Jul	Aug	Sep	Oct	Nov	Dec
6.6	6.3	6.7	7.3	7.9	8
[mi/h]					

Figure 4.15 The Climatology Wind Speed tab page





Table 4.10 Edit fields in the Wind Speed tab page (mss\_Temperature)

Edit field	Description	Used or required by simulations	Field name in datastructure
	Radio button for data type	Yes	WindSpeed-TypeNo
No Wind-Speed Data	No Windspeed data should be used	Yes if WindSpeed-TypeNo = 1	
Monthly Average Wind Speed WindSpeedTypeNo = 2			
Jan	Monthly evaporation value for January entered by user	Yes if WindSpeed-TypeNo = 2	Value1
Feb	Monthly evaporation value for February entered by user	Yes if WindSpeed-TypeNo = 2	Value2
Mar	Monthly evaporation value for March entered by user	Yes if WindSpeed-TypeNo = 22	Value3
Apr	Monthly evaporation value for April entered by user	Yes if WindSpeed-TypeNo = 2	Value4
May	Monthly evaporation value for May entered by user	Yes if WindSpeed-TypeNo = 2	Value5
June	Monthly evaporation value for June entered by user	Yes if WindSpeed-TypeNo = 2	Value6
July	Monthly evaporation value for July entered by user	Yes if WindSpeed-TypeNo = 2	Value7
Aug	Monthly evaporation value for August entered by user	Yes if WindSpeed-TypeNo = 2	Value8
Sept	Monthly evaporation value for September entered by user	Yes if WindSpeed-TypeNo = 2	Value9
Oct	Monthly evaporation value for October entered by user	Yes if WindSpeed-TypeNo = 2	Value10
Nov	Monthly evaporation value for November entered by user	Yes if WindSpeed-TypeNo = 2	Value11
Dec	Monthly evaporation value for December entered by user	Yes if WindSpeed-TypeNo = 2	Value12
From Climate File	WindSpeed data read from the NCDC data file which is specified on the Temperature tab page	Yes if WindSpeed-TypeNo = 3	

### 4.3.4 Snowmelt

Snowmelt parameters are climatological variables that apply across the entire model area when simulating snowfall and snowmelt. They include:



- The temperature at which precipitation falls as snow
- Heat exchange properties of the snow surface
- Study area elevation, latitude, and longitude correction

For additional information on Snowfall and Snowmelt processes please consult the section on Snowpacks.

Temperature	Evaporation	Wind speed	Snowmelt	Areal depletion	Adjustments
Dividing temperature between snow and rain <input type="text" value="34"/> [deg F]					
ATI weight <input type="text" value="0.5"/>					
Negative melt ratio <input type="text" value="0.6"/>					
Elevation above MSL <input type="text" value="190"/> [ft]					
Latitude <input type="text" value="41.9"/> [degN50]					
Longitude correction <input type="text" value="-9"/> [min]					

Figure 4.16 The Snowmelt tab page on the Climatology editor

Table 4.11 Edit fields in the Snowmelt tab page (mss\_Temperature)

Edit field	Description	Used or required by simulations	Field name in datastructure
Dividing Temperature Between Snow and Rain (degrees F)	Temperature below which precipitation falls as snow	Yes	SnowTemp
ATI Weight	This parameter reflects to what degree heat transfer within a snowpack during non-melt periods is affected by prior air temperatures. Smaller values reflect a thicker surface layer of snow which result in reduced rates of heat transfer. Values must be between 0 and 1. The default value is 0.5.	Yes	Atiwt



Table 4.11 Edit fields in the Snowmelt tab page (mss\_Temperature)

Edit field	Description	Used or required by simulations	Field name in datastructure
Negative Melt Ratio	This is the ratio of the heat transfer coefficient of a snow-pack during non-melt conditions to the coefficient during melt conditions. It must be a number between 0 and 1. The default value is 0.6.	Yes	Rnm
Elevation Above MSL (feet)	Enter the average elevation above mean sea level for the study area, in feet or meters. This value is used to provide a more accurate estimate of atmospheric pressure. The default is 0.0, which results in a pressure of 29.9 inches Hg. The effect of wind on snowmelt rates during rainfall periods is greater at higher pressures, which occur at lower elevations.	Yes	Elev
Latitude (degrees North)	Enter the latitude, in degrees North, of the study area. This number is used when computing the hours of sunrise and sunset, which in turn are used to extend min/max daily temperatures into continuous values. The default is 50 degrees North.	Yes	Lat
Longitude Correction (minutes)	This is a correction, in minutes of time, between true solar time and the time on clocks. It depends on a location's longitude (q) and the standard meridian of its time zone (SM) through the expression $4(q - SM)$ . This correction is used to adjust the hours of sunrise and sunset when extending daily min/max temperatures into continuous values. The default value is 0	Yes	Dtlong



### 4.3.5 Areal Depletion

Areal Depletion refers to the tendency of snow to melt nonuniformly over the surface of a catchment. As the melting process proceeds, the area covered by snow is reduced. This behaviour can be described by an *Areal Depletion Curve*. It plots the fraction of total area that remains snow covered against the ratio of the actual snow depth to the depth at which there is 100% snow cover. A typical ADC for a natural area is shown below.

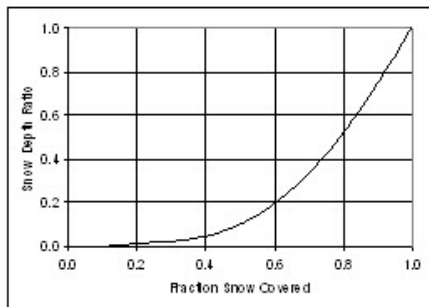


Figure 4.17 Example Areal Depletion Curve

Two such curves can be supplied; one for impervious areas and another for pervious areas.

Temperature	Evaporation	Wind speed	Snowmelt	Areal depletion	Adjustments
Fraction of area covered by snow					
Depth ratio	Impervious		Pervious		
0.0	<input type="text" value="0.1"/>	<input type="text" value="0.1"/>	<input type="text" value="0.1"/>	<input type="text" value="0.1"/>	
0.1	<input type="text" value="0.35"/>	<input type="text" value="0.35"/>	<input type="text" value="0.35"/>	<input type="text" value="0.35"/>	
0.2	<input type="text" value="0.53"/>	<input type="text" value="0.53"/>	<input type="text" value="0.53"/>	<input type="text" value="0.53"/>	
0.3	<input type="text" value="0.66"/>	<input type="text" value="0.66"/>	<input type="text" value="0.66"/>	<input type="text" value="0.66"/>	
0.4	<input type="text" value="0.75"/>	<input type="text" value="0.75"/>	<input type="text" value="0.75"/>	<input type="text" value="0.75"/>	
0.5	<input type="text" value="0.82"/>	<input type="text" value="0.82"/>	<input type="text" value="0.82"/>	<input type="text" value="0.82"/>	
0.6	<input type="text" value="0.87"/>	<input type="text" value="0.87"/>	<input type="text" value="0.87"/>	<input type="text" value="0.87"/>	
0.7	<input type="text" value="0.92"/>	<input type="text" value="0.92"/>	<input type="text" value="0.92"/>	<input type="text" value="0.92"/>	
0.8	<input type="text" value="0.95"/>	<input type="text" value="0.95"/>	<input type="text" value="0.95"/>	<input type="text" value="0.95"/>	
0.9	<input type="text" value="0.98"/>	<input type="text" value="0.98"/>	<input type="text" value="0.98"/>	<input type="text" value="0.98"/>	

Figure 4.18 The SWMM Areal Depletion tab page



Table 4.12 Edit fields in the Areal Depletion tab page (mss\_Temperature)

Edit field	Description	Used or required by simulations	Field name in datastructure
Impervious			
0.0	Fraction of impervious area covered by snow at interval [0.0-0.1]	Yes	AdclmPerv0
0.1	Fraction of impervious area covered by snow at interval ]0.1-0.2]	Yes	AdclmPerv1
0.2	Fraction of impervious area covered by snow at interval ]0.2-0.3]	Yes	AdclmPerv2
0.3	Fraction of impervious area covered by snow at interval ]0.3-0.4]	Yes	AdclmPerv3
0.4	Fraction of impervious area covered by snow at interval ]0.4-0.5]	Yes	AdclmPerv4
0.5	Fraction of impervious area covered by snow at interval ]0.5-0.6]	Yes	AdclmPerv5
0.6	Fraction of impervious area covered by snow at interval ]0.6-0.7]	Yes	AdclmPerv6
0.7	Fraction of impervious area covered by snow at interval ]0.7-0.8]	Yes	AdclmPerv7
0.8	Fraction of impervious area covered by snow at interval ]0.8-0.9]	Yes	AdclmPerv8
0.9	Fraction of impervious area covered by snow at interval ]0.9-1.0]	Yes	AdclmPerv9
Pervious			
0.0	Fraction of pervious area covered by snow at interval [0.0-0.1]	Yes	AdcPerv0
0.1	Fraction of pervious area covered by snow at interval ]0.1-0.2]	Yes	AdcPerv1



Table 4.12 Edit fields in the Areal Depletion tab page (mss\_Temperature)

Edit field	Description	Used or required by simulations	Field name in datastructure
0.2	Fraction of pervious area covered by snow at interval ]0.2-0.3]	Yes	AdcPerv2
0.3	Fraction of pervious area covered by snow at interval ]0.3-0.4]	Yes	AdcPerv3
0.4	Fraction of pervious area covered by snow at interval ]0.4-0.5]	Yes	AdcPerv4
0.5	Fraction of pervious area covered by snow at interval ]0.5-0.6]	Yes	AdcPerv5
0.6	Fraction of pervious area covered by snow at interval ]0.6-0.7]	Yes	AdcPerv6
0.7	Fraction of pervious area covered by snow at interval ]0.7-0.8]	Yes	AdcPerv7
0.8	Fraction of pervious area covered by snow at interval ]0.8-0.9]	Yes	AdcPerv8
0.9	Fraction of pervious area covered by snow at interval ]0.9-1.0]	Yes	AdcPerv9

### 4.3.6 Adjustments

Climate Adjustments are optional modifications applied to the temperature, evaporation rate, rainfall intensity, and hydraulic conductivity that SWMM would otherwise use at each time step of a simulation. Separate sets of adjustments that vary periodically by month of the year can be assigned to these variables.

Adjustments to the hydraulic conductivity are used in computing rainfall infiltration on all pervious land surfaces, including those in all LID units, and exfiltration from all storage nodes and conduits.

These can reflect the increase of hydraulic conductivity with increasing temperature or the effect that seasonal changes in land surface conditions, such as frozen ground, can have on infiltration capacity.

They can be overridden for individual catchments (and their LID units) by assigning a monthly infiltration adjustment Time Pattern to a catchment.



Monthly adjustment time patterns for depression storage and pervious surface roughness coefficient (Manning n) can also be specified for individual catchments (see Chapter 4.1.4 SWMM Hydrology & Hydraulic Properties).

Temperature	Evaporation	Wind speed	Snowmelt	Areal depletion	Adjustments
Month	Temp	Evap	Rain	Cond	
January	32 [deg F]	0 [in/d]	1	1	
February	32 [deg F]	0 [in/d]	1	1	
March	32 [deg F]	0 [in/d]	1	1	
April	32 [deg F]	0 [in/d]	1	1	
May	32 [deg F]	0 [in/d]	1	1	
June	32 [deg F]	0 [in/d]	1	1	
July	32 [deg F]	0 [in/d]	1	1	
August	32 [deg F]	0 [in/d]	1	1	
September	32 [deg F]	0 [in/d]	1	1	
October	32 [deg F]	0 [in/d]	1	1	
November	32 [deg F]	0 [in/d]	1	1	
December	32 [deg F]	0 [in/d]	1	1	
Temp - Temperature adjustment (+ -)		Rain - Rainfall multiplier			
Evap - Evaporation adjustment (+ -)		Cond - Soil conductivity multiplier			

Figure 4.19 The SWMM Climatology Adjustments tab page

Table 4.13 Edit fields in the Adjustments tab page (mss\_Adjustment.Default\_Adjustment)

Edit field	Description	Used or required by simulations	Field name in datastructure
Temp	Temperature adjustment (+-) for the months January-December	Yes	Temp01-Temp12
Evap	Evaporation adjustment (+-) for the months January-December	Yes	Evap01-Evap12



Table 4.13 Edit fields in the Adjustments tab page (mss\_Adjustment.Default\_Adjustment)

Edit field	Description	Used or required by simulations	Field name in datastructure
Rain	Rainfall multiplier for the months January-December	Yes	Rain01-Rain12
Cond	Soild conductivity multiplier for the months January-December	Yes	Con01-Con12

## 4.4 RDII

For SWMM models, Rainfall Dependent Inflow/Infiltration (RDII) are storm-water flows that enter sanitary or combined sewers due to inflow from direct connections of downspouts, sump pumps, foundation drains, etc. as well as infiltration of subsurface water through cracked pipes, leaky joints, poor man-hole connections, etc.

### 4.4.1 RDII Hydrographs

RDII for SWMM models can be computed for a given rainfall record based on a set of triangular unit hydrographs (UH) that determine a short-term, intermediate-term, and long-term inflow response for each interval of rainfall. Each unit hydrograph is defined by three parameters:

- **R.** The fraction of rainfall volume that enters the sewer system
- **T.** The time from the onset of rainfall to the peak of the UH in hour
- **K.** The ratio of time to recession of the UH to the time to peak



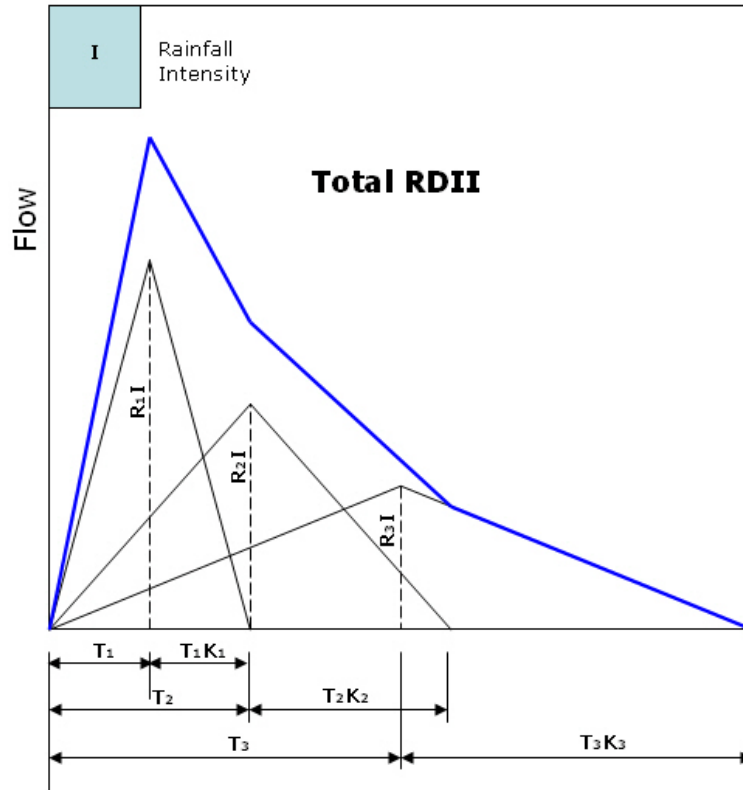


Figure 4.20 RTK concept for unit hydrographs

A SWMM RDII Hydrograph can contain up to 12 sets of unit hydrographs (one for each month of the year), and each set may consist of up to 3 individual hydrographs (for short-term, intermediate-term, and long-term responses, respectively).

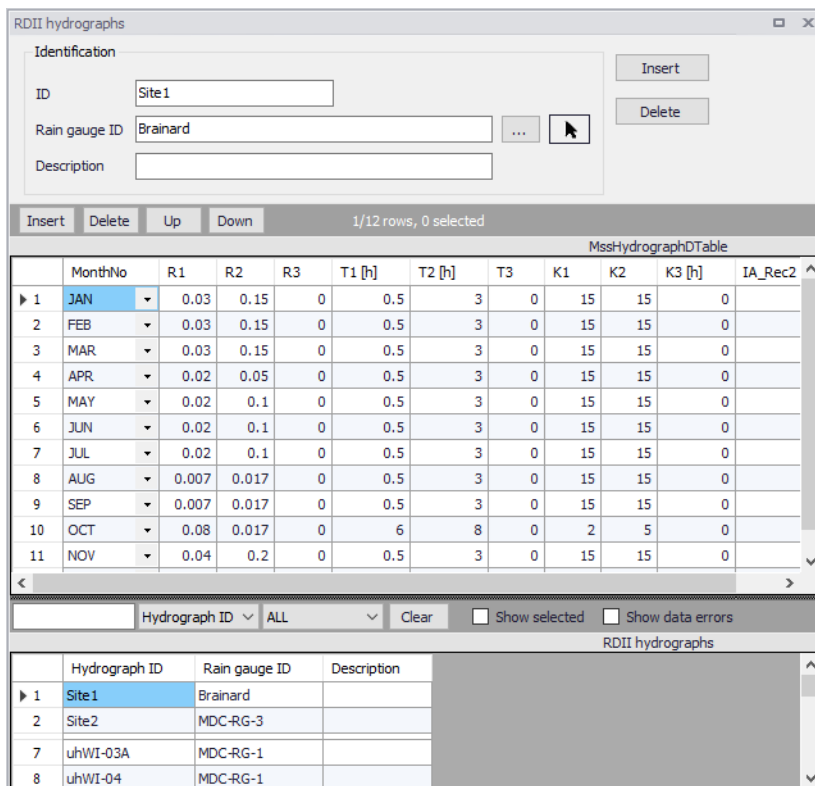


Figure 4.21 The SWMM RDII Hydrographs Editor

The SWMM RDII Hydrographs Editor organizes the related input data for the RDII Unit Hydrograph approach into following groups:

- Identification
- Tabular Data

### Identification



Figure 4.22 RDII Hydrographs Identification group



Table 4.14 Edit fields in the RDII Hydrographs Identification group (mss\_Hydrograph)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	RDII Hydrograph ID	Yes	MUID
Raingauge ID	ID of the associated Rain-gauge	Yes	RaingageID
Description	User descriptive text	No	Description

## Tabular Data

Define hydrograph characteristics in the secondary table on the RDII Hydrographs editor. Use the Insert and Delete buttons to add or remove records from the table, respectively. The Up and Down buttons may be used to reorder the table entries.

Insert		Delete		Up		Down		12/12 rows, 0 selected									
MssHydrographDTable																	
	MonthNo	R1	R2	R3	T1 [h]	T2 [h]	T3	K1	K2	K3 [h]	IA_Max1 [n]	IA_Rec1					
1	JAN	0.03	0.15	0	0.5	3	0	15	15	0	0						
2	FEB	0.03	0.15	0	0.5	3	0	15	15	0	0						
3	MAR	0.03	0.15	0	0.5	3	0	15	15	0	0						
4	APR	0.02	0.05	0	0.5	3	0	15	15	0	0						
5	MAY	0.02	0.1	0	0.5	3	0	15	15	0	0						
6	JUN	0.02	0.1	0	0.5	3	0	15	15	0	0						
7	JUL	0.02	0.1	0	0.5	3	0	15	15	0	0						
8	AUG	0.007	0.017	0	0.5	3	0	15	15	0	0						
9	SEP	0.007	0.017	0	0.5	3	0	15	15	0	0						
10	OCT	0.08	0.017	0	6	8	0	2	5	0	0						
11	NOV	0.04	0.2	0	0.5	3	0	15	15	0	0						
▶12	DEC	0.03	0.15	0	0.5	3	0	15	15	0	0						

Figure 4.23 Define RDII hydrograph characteristics in the secondary table on the editor



Table 4.15 Edit fields in the hydrographs data table (mss\_Hydrograph)

Edit field	Description	Used or required by simulations	Field name in datastructure
MonthNo	Individual Months or all months	Yes	MonthNo
R1	The fraction of rainfall volume that enters the sewer system	Yes	R1
T1	The time from the onset of rainfall to the peak of the UH in hour	Yes	T1
K1	The ratio of time to recession of the UH to the time to peak	Yes	K1
R2	The fraction of rainfall volume that enters the sewer system	Yes	R2
T2	The time from the onset of rainfall to the peak of the UH in hour	Yes	T2
K2	The ratio of time to recession of the UH to the time to peak	Yes	K2
R3	The fraction of rainfall volume that enters the sewer system	Yes	R3
T3	The time from the onset of rainfall to the peak of the UH in hour	Yes	T3
K3	The ratio of time to recession of the UH to the time to peak	Yes	K3
IA_Max1	Short term maximum depth	Yes	IA_Max1
IA_Rec1	Short term recovery rate	Yes	IA_Rec1
IA_Init1	Short term initial depth	Yes	IA_Init1
IA_Max2	Medium term maximum depth	Yes	IA_Max2
IA_Rec2	Medium term recovery rate	Yes	IA_Rec2
IA_Init2	Medium term initial depth	Yes	IA_Init2
IA_Max3	Long term maximum depth	Yes	IA_Max3
IA_Rec3	Long term recovery rate	Yes	IA_Rec3
IA_Init3	Long term initial depth	Yes	IA_Init3

#### 4.4.2 RDII

After defining the RDII Hydrographs, connect them to a node of the conveyance system and the sewershed area that contributes to RDII flow.



This is done via the SWMM RDII editor which organizes the related data into following groups:

- Identification
- Contributing RDII area

	ID	Node ID	Hydrograph ID	Sewershed area [ac]	Description
▶ 1	6711	GIS2003755	uhWI-02	0.775	
2	1	CDM2378553	uhWI-04	13.209	
3	10	GIS2075013	Site2	3.7	
4	100	GIS2076177	Site7	29.4	
11	107	GIS2076925	Site1	9.27	
12	108	GIS2076927	Site1	2.7	
13	109	GIS2076929	Site1	10.8	

Figure 4.24 The SWMM RDII editor

## Identification

The Identification groupbox holds information on the RDII setup ID, connectivity, and Description.

Figure 4.25 The RDII editor Identification group



Table 4.16 Edit fields in the SWMM RDII editor Identification group (mss\_RDII)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	RDII setup ID	Yes	MUID
Node ID	ID of Node which receives RDII	Yes	NodeID
Hydrograph ID	ID of Hydrograph defined in the RDII Hydrographs editor	Yes	HydrographID
Description	User-defined descriptive text	No	Description

## Contributing RDII Data

Define the size of the sewershed area contributing to RDII flows in the Contributing RDII Data groupbox.

Contributing RDII data

Sewershed area  [ac]

Figure 4.26 The RDII editor Contributing RDII Data group

Table 4.17 Edit fields in the Contributing RDII Data group (mss\_RDII)

Edit field	Description	Used or required by simulations	Field name in datastructure
Sewershed area	Area that contributes to RDII inflow	Yes	SewerArea

## 4.5 Snowpacks

The snowmelt routine is part of the runoff modelling process. It updates the state of the snowpacks associated with each catchment by accounting for snow accumulation, snow redistribution by areal depletion and removal operations, and snowmelt via heat budget accounting. Any snowmelt coming off the pack is treated as an additional rainfall input into the runoff process.

At each runoff timestep the following computations are made:



1. Air temperature and melt coefficients are updated according to the calendar date.
2. Any precipitation that falls as snow is added to the snowpack.
3. Any excess snow depth on the plowable area of the pack is redistributed according to the removal parameters established for the pack.
4. Areal coverages of snow on the impervious and pervious areas of the pack are reduced according to the Areal Depletion Curves defined for the study area.
5. The amount of snow in the pack that melts to liquid water is found using:
  - a heat budget equation for periods with rainfall, where melt rate increases with increasing air temperature, wind speed, and rainfall intensity
  - a degree-day equation for periods with no rainfall, where melt rate equals the product of a melt coefficient and the difference between the air temperature and the pack's base melt temperature.
6. If no melting occurs, the pack temperature is adjusted up or down based on the product of the difference between current and past air temperatures and an adjusted melt coefficient. If melting occurs, the temperature of the pack is increased by the equivalent heat content of the melted snow, up to the base melt temperature. Any remaining melt liquid beyond this is available to runoff from the pack.
7. The available snowmelt is then reduced by the amount of free water holding capacity remaining in the pack. The remaining melt is treated the same as a direct rainfall input onto the catchment.

The SWMM Snowpacks editor and the Climatology editor (Climatology (p. 91)) contains the above information required for characterizing the modeling of the snowfall and snowmelt processes. The Snowpacks editor organizes the data into following groups:

- Identification
- Snowpack Data

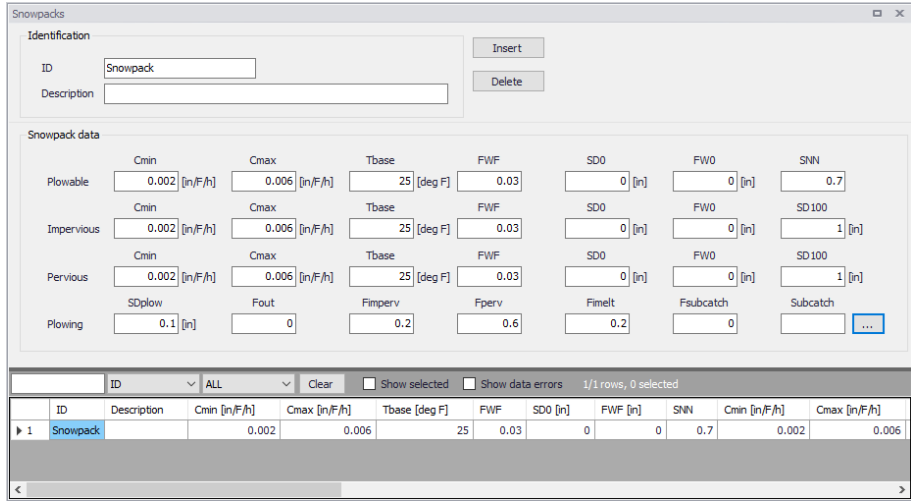


Figure 4.27 The SWMM Snowpacks editor

## Identification

The Identification groupbox holds parameter set ID and optional descriptive information. Use the Insert or Delete buttons to add or remove records from the editor, respectively

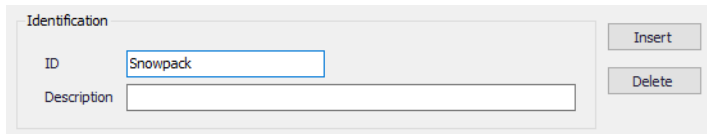


Figure 4.28 The Snowpacks editor Identification group

Table 4.18 Edit fields in the Snowpacks editor Identification group (mss\_Snow-Pack)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Snowpack parameter set ID	Yes	MUID
Description	User-defined description for snowpack data	No	Description





## Snowpack Data

Snowpack data characterize the buildup, removal, and melting of snow over Plowable, Impervious, and Pervious areas within a catchment. A set of snow removal parameters may also be defined for the Plowable area.

- **Plowable.** A user-defined fraction of the total impervious area representing such areas as streets and parking lots where plowing and snow removal can be done.
- **Impervious.** Covers the remaining impervious area of a catchment.
- **Pervious.** The entire pervious area of a catchment.
- **Plowing.** These parameters consist of the depth at which snow removal begins and the fractions of snow moved onto other areas.

The screenshot shows a 'Snowpack data' form with the following values:

- Plowable:** Cmin: 0.002 [in/F/h], Cmax: 0.006 [in/F/h], Tbase: 25 [deg F], FWF: 0.03, SD0: 0 [in], FW0: 0 [in], SNIN: 0.7
- Impervious:** Cmin: 0.002 [in/F/h], Cmax: 0.006 [in/F/h], Tbase: 25 [deg F], FWF: 0.03, SD0: 0 [in], FW0: 0 [in], SD100: 1 [in]
- Pervious:** Cmin: 0.002 [in/F/h], Cmax: 0.006 [in/F/h], Tbase: 25 [deg F], FWF: 0.03, SD0: 0 [in], FW0: 0 [in], SD100: 1 [in]
- Plowing:** SDplow: 0.1 [in], Fout: 0, Fimperv: 0.2, Fperv: 0.6, Fimelt: 0.2, Fsubcatch: 0, Subcatch: [empty]

Figure 4.29 Snowpack Data group

Table 4.19 Edit fields in the Snowpack Data group (mss\_SnowPack)

Edit field	Description	Used or required by simulations	Field name in datastructure
Plowable			
Cmin	Minimum melt coefficient	Yes	Cmin1
Cmax	Maximum melt coefficient	Yes	Cmax1
Tbase	Snowmelt base temperature	Yes	Tbase1
FWF	Ratio of free water-holding capacity of snow depth	Yes	Fwf1
SD0	Initial snow depth	Yes	Sd01
FW0	Initial free water in snowpack	Yes	Fw01



Table 4.19 Edit fields in the Snowpack Data group (mss\_SnowPack)

Edit field	Description	Used or required by simulations	Field name in datastructure
SNN	Fraction of impervious area with depression storage that can be plowed	Yes	Snn0
Impervious			
Cmin	Minimum melt coefficient	Yes	Cmin1
Cmax	Maximum melt coefficient	Yes	Cmax1
Tbase	Snowmelt base temperature	Yes	Tbase1
FWF	Ratio of free water-holding capacity of snow depth	Yes	Fwf1
SD0	Initial snow depth	Yes	Sd01
FW0	Initial free water in snowpack	Yes	Fw01
SD100	Snow depth above which there is 100% cover	Yes	SD1002
Pervious			
Cmin	Minimum melt coefficient	Yes	Cmin1
Cmax	Maximum melt coefficient	Yes	Cmax1
Tbase	Snowmelt base temperature	Yes	Tbase1
FWF	Ratio of free water-holding capacity of snow depth	Yes	Fwf1
SD0	Initial snow depth	Yes	Sd01
FW0	Initial free water in snowpack	Yes	Fw01
SD100	Snow depth above which there is 100% cover	Yes	SD1003
Plowing			
SDplow	Depth of snow on plowable area at which redistribution through plowing occurs	Yes	SDplow



Table 4.19 Edit fields in the Snowpack Data group (mss\_SnowPack)

Edit field	Description	Used or required by simulations	Field name in datastructure
Fout	Fraction of excess snow on plowable area transferred out of watershed	Yes	Fout
Fimperv	Fraction of excess snow on plowable area transferred to impervious area by plowing	Yes	Fimperv
Fperv	Fraction of excess snow on plowable area transferred to pervious area by plowing	Yes	Fperv
Fimelt	Fraction of excess snow on plowable area converted into immediate melt	Yes	Fimelt
Fsubcatch	Fraction of excess snow on plowable area transferred to pervious area in another catchment	Yes	Fsubcatch
Subcatch	ID of catchment receiving the Fsubcatch fraction of transferred snow	Yes	SubcatchID

- **Cmin.** Minimum melt coefficient.
- **Cmax.** Maximum melt coefficient.

The minimum and maximum snowmelt coefficients are used to estimate a melt coefficient that varies by day of the year. The latter is used in the following degree-day equation to compute the melt rate for any particular day.  $\text{Melt Rate} = (\text{Melt Coefficient}) * (\text{Air Temperature} - \text{Base Temperature})$ .

- **Tbase.** Snowmelt base temperature. Temperature at which snow begins to melt.
- **FWF.** Ratio of free water-holding capacity of snow depth. Fraction of snowpack depth which must fill with melted snow before liquid runoff from the pack begins.
- **SD0.** Initial snow depth. Depth of snow at the start of the simulation.



- **FW0**. Initial free water on the snowpack. Depth of melted water held within the pack at the start of the simulation. This number should be at or below the product of SD0 and FWF.
- **SD100**. Snow depth above which there is 100% cover. The depth of snow beyond which the entire area remains completely covered and is not subject to any areal depletion effect.
- **SNN**. Fraction of impervious area that is plowable.
- **SDplow**. Depth of snow on plowable area at which redistribution through plowing occurs. Depth which must be reached before any snow removal begins.
- **Fout**. Fraction of excess snow on plowable area transferred out of watershed. The fraction of snow depth that is removed from the system and does not become runoff.
- **Fimperv**. Fraction of excess snow on plowable area transferred to impervious area by plowing. The fraction of snow depth that is added to snow accumulation on the pack's impervious area.
- **Fperv**. Fraction of excess snow on plowable area transferred to pervious area by plowing. The fraction of snow depth that is added to snow accumulation on the pack's pervious area.
- **Fimelt**. Fraction of excess snow on plowable area converted into immediate melt. The fraction of snow depth that becomes liquid water which runs onto any subcatchment associated with the snowpack.
- **Fsubcatch**. Fraction of excess snow on plowable area transferred to pervious area in another catchment. The fraction of snow depth which is added to the snow accumulation on some other subcatchment. Define the subcatchment under 'Subcatch'.

Catchments are assigned snowpack parameters through their Snowpack ID property in the SWMM Hydrology & Hydraulic Properties tab page of the Catchments editor.

## 4.6 LID

Low Impact Development (LID) represents an approach to land development (or redevelopment) that works with nature to manage stormwater as close to its source as possible. It is also known as Water-Sensitive Urban Design (WSUD). LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product.

The ability to assess the benefit of LID practices installed in urban catchments is required by water utilities and other stakeholders responsible for the urban drainage. An essential part of this requirement is the ability to model



the various LID practices in order to evaluate the effect of installing LID practices as parts of a stormwater drainage system.

MIKE+ offers 2 ways of modelling LID structures:

- Modelling of LIDs at screening level - catchment-based approach
- Detailed hydraulic modelling of individual LID structures - drainage network based approach

Only the catchment-based method is available for SWMM models, and is described in this chapter. These methods are based on research published by US EPA adapted to the MIKE+ modelling concept of urban hydrology.

A user-defined number of LID controls can be deployed and assessed for each individual catchment. This catchment-based approach is used to size the required infiltration or rainwater harvest by subtraction of flow from the calculated runoff within each catchment.

LIDs are low impact development structures designed to capture or reduce surface runoff from the collecting area by means of a combination of detention, infiltration and evapotranspiration. LID controls are conceptual objects that are not displayed on the map visualization of the urban catchment model. Once deployed, they are considered as properties of a given catchment. MIKE+ can model the following types of LIDs:

- Bioretention Cell
- Infiltration Trench
- Porous Pavement
- Rain Barrel
- Vegetative Swale
- Rain Garden
- Green Roof
- Rooftop Disconnection

Bioretention cells, infiltration trenches, and porous pavement systems can have optional underdrain systems in their gravel storage beds to convey storage runoff off the site rather than infiltrate it all. They can also have an impermeable liner that prevents infiltration into the native soil. Infiltration trenches and porous pavement systems can also be subject to a decrease in hydraulic conductivity over time due to clogging.

#### 4.6.1 Bioretention Cell

Bioretention Cells are terrain depressions that comprise of selected types of vegetation, resistant to the extended periods of high moisture and extreme levels of nutrient concentrations (Nitrogen and Phosphorus) found in storm-

water runoff, grown in an engineered soil mixture above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from the collecting area surrounding the cell. Rain gardens, street planters, and green roofs are all different types of bioretention cells.

The different structural layers of this feature are:

- Surface
- Soil
- Storage
- Drain (optional)

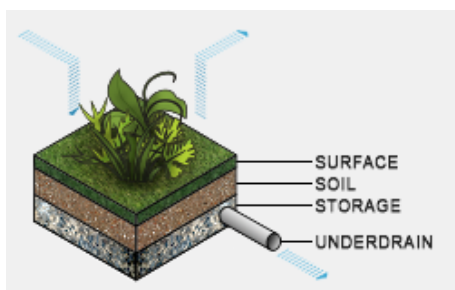


Figure 4.30 Bioretention cell structure layers

These are illustrated in Figure 4.30. There are one or several relevant hydrological processes associated with each layer.

In the surface occur surface storage, surface infiltration, the collecting area run-on, surface evaporation and overflow.

In the soil layer occur percolation (vertical water movement to the storage layer), evapotranspiration (loss due to the plant root action) and storage in the soil's voids.

In the storage layer, stormwater provided by the percolation through the soil layer is detained in the storage layer's voids. Infiltration (leakage) to the native soil through the storage bottom, controlled by the characteristics of the surrounding soil, restores the storage capacity.

An optional underdrain may be included to empty the storage. The underdrain is activated (with the specified capacity) when the water level in the storage reaches the offset level.



## 4.6.2 Infiltration Trench

Infiltration Trenches are storage cells filled with gravel that capture runoff from upstream impervious areas. They provide storage capacity and the possibility for captured runoff to infiltrate the soil underneath.

Figure 4.31 illustrates an infiltration trench structure showing the following components:

- Surface
- Storage
- Drain (optional)

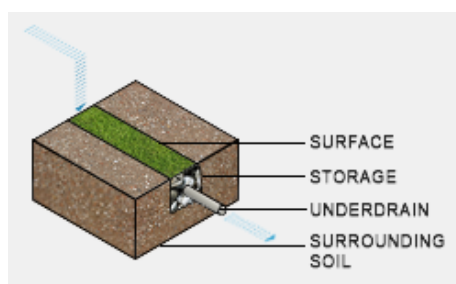


Figure 4.31 Infiltration trench structure layers

The processes simulated for the infiltration trench are similar as for bioretention cells, except for the missing soil layer; stormwater from the surface enters the storage directly, i.e. without detention in the soil layer.

## 4.6.3 Porous Pavement

Porous Pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix. Porous pavements are implemented in places where the surface has to provide a firm support for vehicle traffic, such as streets and parking lots.

Normally, all rainfall will immediately pass through the pavement into the gravel storage layer below where it can infiltrate at natural rates into the native soil.

Figure 4.32 shows a porous pavement structure, which has the following components:

- Surface
- Pavement material
- Soil (optional)



- Storage
- Drain (optional)

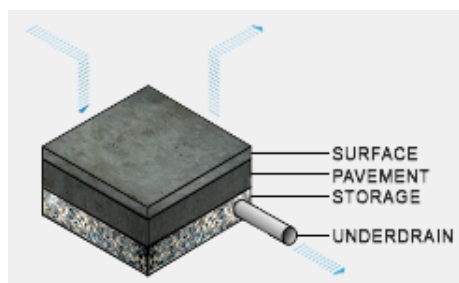


Figure 4.32 Porous Pavement structure layers

Essentially, the hydraulic functionality of porous pavements is similar to that of the bioretention cells, except that the soil layer (and vegetation) is replaced by some porous asphalt or concrete.

Some types of porous pavements may be subject to clogging by fine sediment particles, which reduces their infiltration capacity.

#### 4.6.4 Rain Barrel

Rain Barrels are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods.

A rain barrel includes:

- Storage
- Drain

The processes simulated include water detention in the storage, overflow and drainage (i.e. storage recovery). The action of the underdrain is timed; the time offset between the end of rain and the drain activation can be specified. This feature allows for the simulation of rainwater reuse for garden watering, which normally takes place several hours or days after the rain has stopped.

A conceptual sketch of a rain barrel is presented in Figure 4.33.



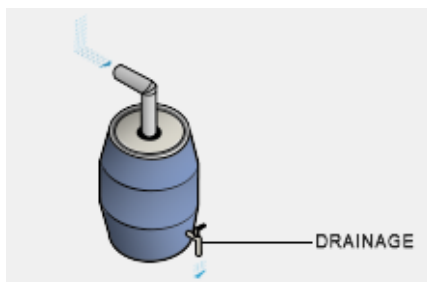


Figure 4.33 Rain Barrel

#### 4.6.5 Vegetative Swale

Vegetative Swales are waterways or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate to soil beneath it.

Vegetative swales are characterized by a surface and surrounding soil layer:

- Surface

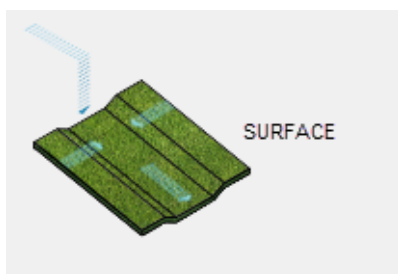


Figure 4.34 Vegetative Swale layer structure

#### 4.6.6 Rain Garden

A Rain Garden is a simplified form of bioretention cell, which takes advantage of rainfall and stormwater runoff in its design, simultaneously contributing to the reduction of runoff volume and pollutants released from the site. Typically, it is designed as a small garden with selected types of vegetation resistant to the extended periods of high moisture and extreme levels of nutrient concentrations (Nitrogen and Phosphorus) found in stormwater runoff.

The different layers comprising rain gardens are presented in Figure 4.35. These include:

- Surface
- Soil



Surface storage, surface infiltration, the collecting area run-on, surface evaporation, and overflow occur on the surface.

In the soil layer occur storage in the soil's voids, evapotranspiration (loss due to the plant root action) and infiltration (leakage) to the native surrounding soil through the bottom. The infiltration is controlled by the characteristics of the surrounding soil.

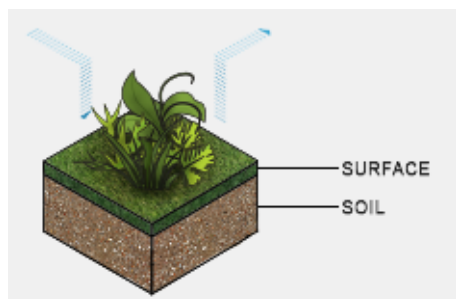


Figure 4.35 Rain Garden process layers

#### 4.6.7 Green Roof

Green Roofs are structural components that reduce the negative effects of urbanization on water quality and rainfall runoff by absorbing or detaining, and filtering runoff. They are built of a planted lightweight soil media and a drainage layer, and have the following components:

- Surface
- Soil
- Drainage Mat

Green Roofs may be designed with intensive or extensive vegetation cover. Intensive green roofs are heavy, with soil media layers larger than 15 cm. Extensive green roofs may include a soil layer as thin as 3 cm, affecting the choice of vegetative cover.

Green roofs are equipped with a drainage layer called a drainage mat placed beneath the soil media. The purpose of the drainage mat is to conduct the surplus water percolated through the soil layer from the roof to the drainage system.

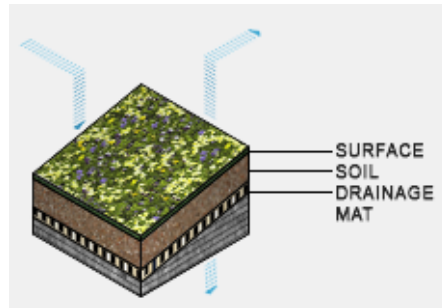


Figure 4.36 Green roof process layers

### 4.6.8 Rooftop Disconnection

Rooftop Disconnection involves the discharge from downspouts to pervious areas instead of directly into storm drains. It can also be used to model roofs directly connected to drains but that overflow onto pervious areas.

This LID solution has the following components:

- Surface
- Roof Drain

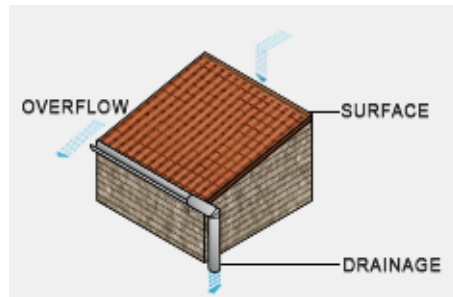


Figure 4.37 Rooftop Disconnection components

### 4.6.9 LID Properties Editor

The MIKE+ LID Properties editor organizes the data input for the different layers and functional elements of LID structures. The input data is organized into the following group and tabs:

- **Identification.** This group holds information on unique LID IDs. Each LID is generic and is specified per unit area. As such, it can be replicated and placed in any sub-catchment of the study area (i.e. deployed) with different actual sizes and in any number of instances.
- **General.** Tab page where LID type is defined.



- **LID components tabs.** Surface, Soil, Pavement, Storage, Drain, Drainage Mat, Roof Drain, and Pollutants Removal tabs. The properties of layers and functional elements constituting a LID type are entered in these tab pages.



Only the relevant data fields and tabs for a LID type are activated and available for data input.

And note that some components/functionalities are optional for some LID types.

## Identification

The identification group box displays element ID information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

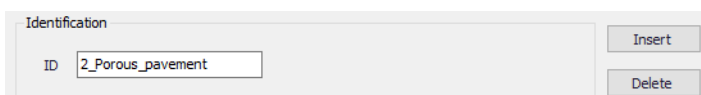


Figure 4.38 LID Properties Identification group

## General

Define LID type on the General tab page of the LID Properties editor.

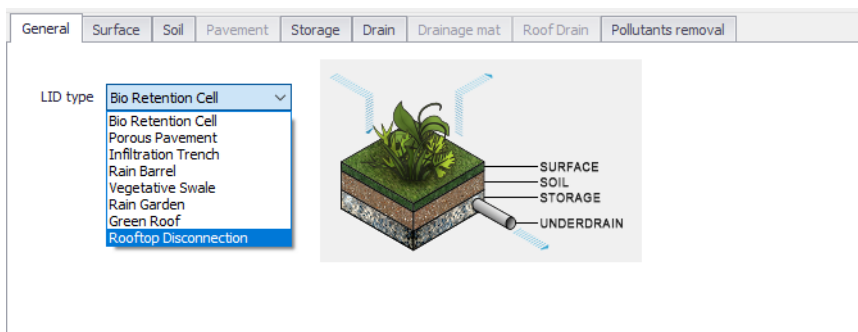


Figure 4.39 The General tab page of the LID Properties editor



Table 4.20 Edit fields in the LID Properties Identification group and General tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in data structure
ID	ID of the LID element	Yes	MUID
LID Type	Type of LID 1: Bio Retention Cell 2: Porous Pavement 3: Infiltration Trench 4: Rain Barrel 5: Vegetative Swale 6: Rain Garden 7: Green Roof 8: Rooftop Disconnection	Yes	LIDTypeNo

## Surface

A Surface component is used for the following LID structures:

- Bioretention Cell (LIDTypeNo = 1)
- Porous Pavement (LIDTypeNo = 2)
- Infiltration Trench (LIDTypeNo = 3)
- Vegetative Swale (LIDTypeNo = 5)
- Rain Garden (LIDTypeNo = 6)
- Green Roof (LIDTypeNo = 7)
- Rooftop Disconnection (LIDTypeNo = 8)

The screenshot shows the 'Surface' tab in the LID Properties editor. The 'Storage' sub-tab is active. The following parameters are visible:

- Storage depth: 200 [m]
- Swale side slope: 5 [0]
- Vegetative cover: 0.1
- Surface roughness: 10 [s/m<sup>1/3</sup>]
- Surface slope: 1 [%]

Figure 4.40 The LID Properties editor Surface tab page



Table 4.21 Edit fields in the LID Properties Surface tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Storage Depth	When confining walls or berms are present this is the maximum depth to which water can pond above the surface of the unit before overflow occurs (in inches or mm). For LIDs that experience overland flow it is the height of any surface depression storage. For swales, it is the height of its trapezoidal cross section.	Yes If LIDTypeNo <> 4	StorHt
Vegetative Volume	The fraction of the storage area above the surface that is filled with vegetation	Yes If LIDTypeNo <> 4 or 8	VegFrac
Surface Roughness	Manning's n for overland flow over the surface of porous pavement or a vegetative swale. See Table 4.29. Use 0 for other types of LIDs.	Yes If LIDTypeNo <> 4	Rough
Surface Slope	Slope of porous pavement surface or vegetative swale (percent). Use 0 for other types of LIDs	Yes If LIDTypeNo <> 4	Slope
Swale Side Slope	Slope (run over rise) of the side walls of a vegetative swale's cross section. This value is ignored for other types of LIDs	Yes If LIDTypeNo = 5	Xslope

## Soil

A Soil component is used for the following LID structures:



- Bioretention Cell (LIDTypeNo = 1)
- Rain Garden (LIDTypeNo = 6)
- Green Roof (LIDTypeNo = 7)
- Porous Pavement (LIDTypeNo = 2) (optional)

Figure 4.41 The LID Properties editor Soil tab page

Table 4.22 Edit fields in the LID Properties Soil tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Thickness	The thickness of the soil layer (inches or mm). Typical values range from 18 to 36 inches (450 to 900 mm) for rain gardens, street planters and other types of land-based bio-retention units, but only 3 to 6 inches (75 to 150 mm) for green roofs. Set Thickness = 0 when unused.	Yes If LIDTypeNo = 1, 6, 7, 2	SThick
Porosity	The volume of pore space relative to total volume of soil (as a fraction).	Yes If LIDTypeNo = 1, 6, 7, 2	Por



Table 4.22 Edit fields in the LID Properties Soil tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Field Capacity	Volume of pore water relative to total volume after the soil has been allowed to drain fully (as a fraction). Below this level, vertical drainage of water through the soil layer does not occur.	Yes If LIDTypeNo = 1, 6, 7, 2	FC
Wilting Point	Volume of pore water relative to total volume for a well dried soil where only bound water remains (as a fraction). The moisture content of the soil cannot fall below this limit.	Yes If LIDTypeNo = 1, 6, 7, 2	WP
Conductivity	Hydraulic conductivity for the fully saturated soil. This is equivalent to leakage capacity	Yes If LIDTypeNo = 1, 6, 7, 2	Ksat
Conductivity Slope	Slope of the curve of log (conductivity) versus soil moisture content (dimensionless). Typical values range from 5 for sands to 15 for silty clay	Yes If LIDTypeNo = 1, 6, 7, 2	Kcoeff
Suction Head	The average value of soil capillary suction along the wetting front. This is the same parameter as used in the Green-Ampt infiltration model	Yes If LIDTypeNo = 1, 6, 7, 2	Suct



Set Soil Thickness to 0 if it is unused for a LID.





## Pavement

A pavement component is used for Porous Pavements (LIDTypeNo = 2).

General	Surface	Soil	Pavement	Storage	Drain	Drainage mat	Roof Drain	Pollutants removal
Thickness	<input type="text" value="100"/>	[in]	Clogging factor	<input type="text" value="0"/>				
Void ratio	<input type="text" value="0.15"/>		Regeneration interval	<input type="text" value="1"/>	[d]			
Impervious surface	<input type="text" value="0"/>	[0]	Regeneration fraction	<input type="text" value="0.5"/>	[0]			
Permeability	<input type="text" value="500"/>	[in/h]						

Figure 4.42 The LID Properties editor Pavement tab page

Table 4.23 Edit fields in the LID Properties Pavement tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in data-structure
Thickness	The thickness of the pavement layer (inches or mm). Typical values are 4 to 6 inches (100 to 150 mm)	Yes If LIDTypeNo = 2	PThick
Void Ratio	The ratio (expressed as a fraction) of the volume of the pores or interstices of a material to the total volume of the pavement. Typical values range from 0.11 to 0.17 for pavements Note that porosity = void ratio/(1 + void ratio).	Yes If LIDTypeNo =2	PVratio
Impervious Surface	Ratio of impervious paver material to total area for modular systems; 0 for continuous porous pavement systems	Yes If LIDTypeNo = 2	FracImp



Table 4.23 Edit fields in the LID Properties Pavement tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in data-structure
Permeability	Permeability of concrete or asphalt used in continuous systems or hydraulic conductivity of the fill material (gravel or sand) used in modular systems. Permeability of new porous concrete or asphalt is high (>2450 mm/h), but over time the fine particles in the runoff tend to clog the pavement, reducing the permeability of the structure.	Yes If LIDTypeNo = 2	Perm
Clogging Factor	Number of pavement layer void volumes of runoff treated it takes to completely clog the pavement. Use a value of 0 to ignore clogging. Clogging progressively reduces the pavement's permeability in direct proportion to the cumulative volume of runoff treated. Max. value = 1.	Yes If LIDTypeNo = 2	PVclog



Table 4.23 Edit fields in the LID Properties Pavement tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in data-structure
Regeneration Interval	The number of days that the pavement layer is allowed to clog before its permeability is restored. A value of 0 indicates that no permeability regeneration occurs.	Yes	PRegInterval
Regeneration Fraction	The fractional degree to which the pavement's permeability is restored when a regeneration interval is reached. A value of 0 means no restoration while a value of 1 indicates complete restoration to the original permeability value. Once a regeneration occurs the pavement begins to clog once again at a rate determined by the Clogging Factor.	Yes	PRegFraction

## Storage

A Storage component is used for the following LID structures:

- Bioretention Cell (LIDTypeNo = 1)
- Porous Pavement (LIDTypeNo = 2)
- Infiltration Trench (LIDTypeNo = 3)
- Rain Barrel (LIDTypeNo = 4)



General	Surface	Soil	Pavement	Storage	Drain	Drainage mat	Roof Drain	Pollutants removal
<p>Height <input type="text" value="500"/> [in]</p> <p>Void ratio <input type="text" value="0.4"/></p> <p>Conductivity <input type="text" value="12"/> [in/h]</p> <p>Clogging factor <input type="text" value="0"/></p>								

Figure 4.43 The LID Properties editor Storage tab page

Table 4.24 Edit fields in the LID Properties Storage tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Height	This is the height of a rain barrel or thickness of a gravel layer (inches or mm). Crushed stone and gravel layers are typically 6 to 18 inches (150 to 450 mm) thick while single family home rain barrels range in height from 24 to 36 inches (600 to 900 mm).	Yes If LIDTypeNo = 1,2,3,4	Height
Void Ratio	The volume of void space relative to the volume of solids in the layer. Typical values range from 0.5 to 0.75 for gravel beds. Note that porosity = void ratio / (1 + void ratio).	Yes If LIDTypeNo = 1,2,3	SVratio



Table 4.24 Edit fields in the LID Properties Storage tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Conductivity	The maximum rate at which water can flow out the bottom of the layer after it is first constructed (in/hr or mm/hr).	Yes If LIDTypeNo = 1, 2, 3	Filt
Clogging Factor	Total volume of treated runoff it takes to completely clog the bottom of the layer divided by the void volume of the layer	Yes If LIDTypeNo = 1,2,3	SVclog

## Drain

A Drain component is used for the following LID structures:

- Bioretention Cell (LIDTypeNo = 1) (optional)
- Porous Pavement (LIDTypeNo = 2) (optional)
- Infiltration Trench (LIDTypeNo = 3) (optional)
- Rain Barrel (LIDTypeNo = 4)

The screenshot shows the 'Drain' tab in the LID Properties editor. The 'Drain' tab is selected, and the following parameters are visible:

- Coefficient: 120 [in/h]
- Exponent: 1
- Offset height: 0 [in]
- Delay: 0 [h]
- Open level: 0 [in]
- Closed level: 0 [in]
- Control curve: [Dropdown arrow]

Figure 4.44 The LID Properties editor Drain tab page



Table 4.25 Edit fields in the LID Properties Drain tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Coefficient	Coefficient <i>C</i> that determines the rate of flow through the underdrain as a function of height of stored water above the drain height. If the layer has no drain then set <i>C</i> to 0.	Yes If LIDTypeNo = 1,2,3,4	Coeff
Exponent	Exponent <i>n</i> that determines the rate of flow through the underdrain as a function of height of stored water above the drain height. A typical value for <i>n</i> is 0.5 (making the drain act like an orifice).	Yes If LIDTypeNo = 1,2,3,4	Expon
Offset Height	Height of any underdrain piping above the bottom of a storage layer or rain barrel (inches or mm).	Yes If LIDTypeNo = 1,2,3,4	HOffset
Delay	The number of dry weather hours that must elapse before the drain line in a rain barrel is opened (the line is assumed to be closed once rainfall begins).	Yes If LIDTypeNo = 4	Delay



Table 4.25 Edit fields in the LID Properties Drain tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Open Level	The height in the drain's storage Layer that causes the drain to automatically open when the water level rises above it. Default is 0 which indicates disabled	No	OpenLev
Closed Level	The height in the drain's storage level that causes the drain to automatically close when the water level falls below it. Default is 0	No	ClosedLev
Control Curve	The name of an optional control curve that adjust the computed drain flow as function of the head of water above the drain. Leave blank if not applicable	No	ControlCurveID

The drain coefficient  $C$  and exponent  $n$  determines the rate of flow through a drain as a function of the height of stored water above the drain's offset.



Set the coefficient to 0 when a drain is not used.

The following equation is used to compute this flow rate per unit area of the LID unit:

$$q = Ch^n \quad (4.1)$$

where  $q$  is outflow (in/hr or mm/hr) and  $h$  is the height of saturated media above the drain (inches or mm).

Note that the units of  $C$  depend on the unit system being used as well as the value assigned to  $n$ .

## Drainage Mat

A Drainage Mat component is used for Green Roofs (LIDTypeNo = 7).



General	Surface	Soil	Pavement	Storage	Drain	<b>Drainage mat</b>	Roof Drain	Pollutants removal
Thickness		<input type="text" value="0.003"/>	[in]					
Void fraction		<input type="text" value="0.5"/>	[0]					
Roughness (Manning n)		<input type="text" value="0.1"/>	[s/m^(1/3)]					

Figure 4.45 The LID Properties editor Drainage Mat tab page

Table 4.26 Edit fields in the LID Properties Drainage Mat tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Thickness	The thickness of the mat or plate. It typically ranges between 25 to 50 mm	Yes If LIDTypeNo = 7	DMThick
Void Fraction	The ratio of void volume to total volume in the mat. It typically ranges from 0.5 to 0.6	Yes If LIDTypeNo = 7	DMVFractiomy
Roughness	Manning's <i>n</i> used to compute the horizontal flow rate of drained water through the mat. In absence of standard product specifications provided by manufacturers, the roughness must be estimated. One may use <i>n</i> values from 0.1 to 0.4 ( <i>M</i> = 2.5 - 10).	Yes If LIDTypeNo = 7	DMRough





## Roof Drain

Define Rooftop Disconnection (LIDTypeNo = 8) flow capacity on the Roof Drain tab page of the editor.

Flow capacity  [in/h]

Enter the maximum flow rate that the roof's drain system (gutters, downspouts and leaders) can handle before overflowing. Use 0 if not applicable.

Figure 4.46 The LID Properties Roof Drain tab page

Table 4.27 Edit fields in the Roof Drain tab page (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Flow Capacity	Maximum flowrate the roof gutters and downspouts can handle (in inches/hour or mm/hour) before overflowing.	Yes If LIDTypeNo = 8	RDFlowCap

## Pollutants Removal

The Pollutants Removal page of the LID Properties editor allows one to specify the degree to which pollutants are removed by a LID unit as seen by the flow leaving through its underdrain system. Hence, it only applies to LIDs with underdrain:

- Bioretention Cell (LIDTypeNo = 1)
- Porous Pavement (LIDTypeNo = 2)
- Infiltration Trench (LIDTypeNo = 3)
- Rain Barrel (LIDTypeNo = 4)

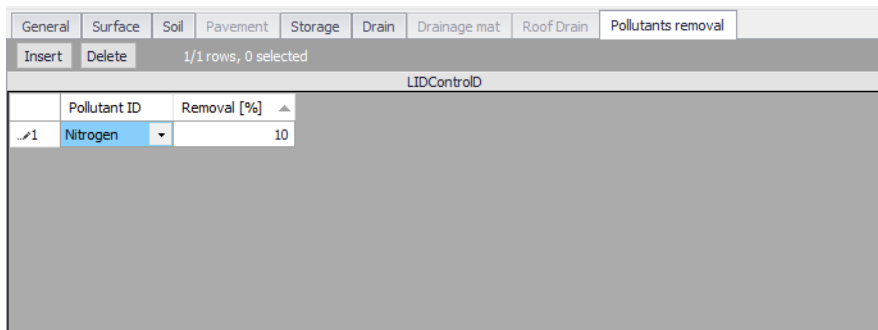


Figure 4.47 The Pollutants Removal tab page

Table 4.28 Edit fields in the Pollutants Removal tab page secondary table (mss\_LIDControl)

Edit field	Description	Used or required by simulations	Field name in datastructure
Pollutant ID	Pollutant treated by the LID (see Pollutants editor)	Yes If LIDTypeNo = 1,2,3,4	PollutantID
Removal [%]	Percent of pollutant removed by the LID	Yes If LIDTypeNo = 1,2,3,4	Removal

The page has a secondary table where entries are made for pollutant ID and the percent removal treated by the LID unit. The default status is blank interpreted as percent removal being 0.

The removals specified are applied to the LIDs underdrain when it sends flow onto either a subcatchment or into a conveyance system node. They do not apply to any surface flow that leaves the LID unit.

As an example (taken from EPA SWMM5.1 Help manual), if the runoff treated by the LID unit had a TSS concentration of 100 mg/L and a removal percentage of 90, then if 5 cfs flowed from its drain into a conveyance system node, the mass loading contribution to the node would be  $100 \times (100 - 90) \times 5 \times (28.3 \text{ L/ft}^3) = 1,415 \text{ mg/sec}$ .

If in addition the unit had a surface outflow of 1 cfs into the same node, the mass loading from this flow stream would be  $100 \times 1 \times 28.3 = 2,830 \text{ mg/sec}$ .



## Example Manning Coefficient and Soil Characteristics Values

Table 4.29 shows examples of Manning  $M$  and  $n$  values for different types of surfaces. Table 4.30 Table 4.31 show example hydraulic conductivity properties for various porous media.

Table 4.29 Example surface Manning  $M$  and  $n$  values for porous pavement or vegetative swale

Surface Type	Manning $M$	$n$
Smooth asphalt	91	0.011
Smooth concrete	83	0.012
Ordinary concrete lining	77	0.013
Good wood	71	0.014
Brick with cement mortar	71	0.014
Vitrified clay	67	0.015
Cast Iron	67	0.015
Corrugated metal pipes	42	0.024
Cement rubble surface	42	0.024
Fallow soils (no residue)	20	0.05
Cultivated soils		
Residue cover < 20%	17	0.06
Residue cover > 20%	6	0.17
Range (natural)	8	0.13
Grass		
Short, prairie	7	0.15
Dense	4	0.24
Bermuda grass	2	0.41
Woods		
Light underbrush	2.5	0.4
Dense underbrush	1.25	0.8
Source: McCuen, R. et al. (1996), Hydrology, FHWA-SA-96-067, Federal Highway Administration, Washington, DC.		



Table 4.30 Example hydraulic conductivity and porosity values for unconsolidated porous media

Material	Hydraulic Conductivity, $K$ (cm/s)	Porosity, $\eta$ (%)
Gravel	$10^{-1} - 10^2$	25 - 40
Sand	$10^{-5} - 1$	25 - 40
Silt	$10^{-7} - 10^{-3}$	35 - 50
Clay	$10^{-9} - 10^{-5}$	40 - 70

Source: Freeze, R.A., and Cherry, J.A., (1979), Groundwater, Prentice-Hall, Englewood Cliffs, NJ.

Table 4.31 Example soil characteristics values

Soil Texture Class	Hydraulic Conductivity, $K$ (in/hr)	Suction Head, $\Psi$ (in.)	Porosity, $\phi$ (fraction)	Field Capacity, FC (fraction)	Wilting Point, WP (fraction)
Sand	4.74	1.93	0.437	0.062	0.024
Loamy Sand	1.18	2.40	0.437	0.105	0.047
Sandy Loam	0.43	4.33	0.453	0.190	0.085
Loam	0.13	3.50	0.463	0.232	0.116
Silt Loam	0.26	6.69	0.501	0.284	0.135
Sandy Clay Loam	0.06	8.66	0.398	0.244	0.136
Clay Loam	0.04	8.27	0.464	0.310	0.187
Silty Clay Loam	0.04	10.63	0.471	0.342	0.210
Sandy Clay	0.02	9.45	0.430	0.321	0.221
Silty Clay	0.02	11.42	0.479	0.371	0.251
Clay	0.01	12.60	0.475	0.378	0.265

Source: Rawls, W.J. et al., (1983). J. Hyd. Engr., 109:1316.

## 4.7 LID Deployment

The LIDs are assigned to a catchment by means of the LID Deployment editor.



	ID	LID ID	Number of units	Area of unit [ft^2]	Overland flow width
1	Deployment_Bio_retention	1_Bio_retention_cell	1	100	
2	Deployment_rain_garden	6_Rain_garden	1	130	
3	Deployment_porous_pavement	2_Porous_pavement	1	1648	
4	Deployment_infiltration_trench	3_Infiltration_trench	1	54	
5	Deployment_Rain_barrels	4_Rain_barrel	17	2	

Figure 4.48 The LID Deployment editor

The input data is organized into the following groups:

- Identification
- Deployment Parameters

### Identification

Each LID is linked to a LID Deployment ID i.e. each deployment represents a LID deployed on a single catchment in a specified number of units.

Figure 4.49 The LID Deployment Identification group



Table 4.32 Edit fields in the Deployment Identification group (mss\_LIDusage)

Edit Field	Description	Used or required by simulations	Field name in data structure
ID	LID deployment ID	Yes	MUID
Catchment ID	ID of catchment in which the LID is deployed/located (see Catchments editor)	Yes	CatchID
LID ID	ID of LID to be deployed (see LID Properties editor)	Yes	LidID

## Deployment Parameters

It is possible to specify the size (i.e. area) of the individual LID structure, the size of the catchment's impervious area that is funnelled into it and the number of LID units of a certain type in a catchment. Furthermore, level of initial saturation and routing width for overland flow can be specified.

For each LID deployment, a result file can be generated containing time series of relevant variables (fluxes and storages). This result file is in the TXT time series format.

Figure 4.50 The LID Deployment Parameters group

Table 4.33 Edit fields in the LID Deployment Parameters group (mss\_LIDusage)

Edit Field	Description	Used or required by simulations	Field name in datastructure
Number of Units	Number of replicate LID units deployed within the catchment	Yes	ReplicateNumber
Area of Unit	The surface area devoted to each replicate LID unit (sq. ft or sq. m).	Yes	Area



Table 4.33 Edit fields in the LID Deployment Parameters group (mss\_LIDusage)

Edit Field	Description	Used or required by simulations	Field name in datastructure
Overland Flow Width	The width of the outflow face of each identical LID unit (in ft or m). This parameter only applies to LID processes such as Porous Pavement and Vegetative Swales that use overland flow to convey surface runoff off of the unit. (The other LID processes, such as Bio-Retention Cells and Infiltration Trenches simply spill any excess captured runoff over their berms.)	Yes	Width
Initial Saturation	For Bio-Retention Cells this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water	Yes	InitSat



Table 4.33 Edit fields in the LID Deployment Parameters group (mss\_LIDusage)

Edit Field	Description	Used or required by simulations	Field name in datastructure
Impervious Area	The percent of the impervious portion of the catchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire subcatchment then this field is ignored.	Yes	FromImp
Send Outflow to	Select whether to send the outflow from the LID onto the subcatchment's pervious area, or the subcatchment's outlet. An example of where this might apply is a rain barrel whose contents are used to irrigate a lawn area. This field is ignored if the LID takes up the entire subcatchment.	Yes	ToPervNo
Result File	Activate this option to generate a detailed result file for the LIDs	Yes	RptFileNo
(Filename input box)	The name of an optional TXT file where detailed time series results for the LIDs will be written	Yes	RptFileName

### LID Deployment Result File

A TXT result file may be generated for each deployed LID structure. The file includes time series of relevant variables for the LID structure in terms of inflow, flow between layers, storage levels in various layers and output from the structure to the native soil.





If the user does not activate this option, the only visible outputs from the runoff simulation including LIDs are the changed (reduced) runoff hydrographs, caused by infiltration loss and storage in the LID structure, and a LID Performance Summary in the simulation summary file.

The contents of the TXT file depend on the actual LID type. In Figure 4.51, an example file for porous pavement is presented. Columns contain time series values for processes in the porous pavement.



**Note:** The flow inside the LID structure and the drain flow are reported as intensities based on the LID area. In cases where the collecting area is bigger than the LID area, the reported intensities will not be comparable with rainfall and evapotranspiration intensities, which are given as model boundary conditions. In order to make the comparison possible, the reported flow intensities must be scaled down by the ratio between the LID area and the collecting area.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Date	Time	Elapsed Time Hours	Total Inflow In/hr	Total Evap In/hr	Surface Infil In/hr	Pavement Perc In/hr	Soil Perc In/hr	Storage Exfil In/hr	Surface Runoff In/hr	Drain Outflow In/hr	Surface Level Inches	Pavement Level Inches	Soil Moisture Content	Storage Level Inches
01/01/2010	00:10:00	0.167	0.000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:15:00	0.250	0.623	0.0000	0.623	0.623	0.000	0.623	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:20:00	0.333	0.623	0.0000	0.623	0.623	0.000	0.623	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:25:00	0.417	0.664	0.0000	0.664	0.664	0.000	0.664	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:30:00	0.500	0.664	0.0000	0.664	0.664	0.000	0.664	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:35:00	0.583	0.713	0.0000	0.713	0.713	0.000	0.713	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:40:00	0.667	0.713	0.0000	0.713	0.713	0.000	0.713	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:45:00	0.750	0.772	0.0000	0.772	0.772	0.000	0.772	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:50:00	0.833	0.772	0.0000	0.772	0.772	0.000	0.772	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	00:55:00	0.917	0.843	0.0000	0.843	0.843	0.000	0.843	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:00:00	1.000	0.843	0.0000	0.843	0.843	0.000	0.843	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:05:00	1.083	0.933	0.0000	0.933	0.933	0.000	0.933	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:10:00	1.167	0.933	0.0000	0.933	0.933	0.000	0.933	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:15:00	1.250	1.049	0.0000	1.049	1.049	0.000	1.049	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:20:00	1.333	1.049	0.0000	1.049	1.049	0.000	1.049	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:25:00	1.417	1.207	0.0000	1.207	1.207	0.000	1.207	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:30:00	1.500	1.207	0.0000	1.207	1.207	0.000	1.207	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:35:00	1.583	1.436	0.0000	1.436	1.436	0.000	1.436	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:40:00	1.667	1.436	0.0000	1.436	1.436	0.000	1.436	0.000	0.000	0.000	0.000	0.000	0.000
01/01/2010	01:45:00	1.750	1.807	0.0000	1.807	1.807	0.000	1.807	0.000	0.000	0.000	0.000	0.000	0.000

Figure 4.51 Example of a result report DFS0 file per deployment (a porous pavement control)

1. Date/Time. Calendar time for the simulated time steps
2. Elapsed Time [T]. Time elapsed relative to simulation start
3. Total Inflow [L/T]. Inflow to the LID unit given as a multiple of the rain intensity and the collecting area outside LID/LID area. It is the run-on from the collecting area outside the LID and rain on top of the LID unit. The run on represents the net rain on the impervious collecting area, i.e. with initial losses subtracted.
4. Total Evap [L/T]. Evaporation based on given Climatology parameter specified by the User valid for the catchment as well as for the LID unit.
5. Surface Infil [L/T]. Infiltration from the surface layer to the pavement layer.
6. Pavement Perc [L/T]. Flow from the pavement layer to the next layer i.e. storage layer or optional soil layer.
7. Soil Perc [L/T]. Flow from the optional soil layer to the storage layer.



8. Storage Exfil [L/T]. Infiltration from the storage layer to the surrounding soil.
9. Surface Runoff [L/T]. Represents overland flow for vegetative swales or overflow for other LIDs
10. Drain Outflow [L/T]. Water flow through the optional underdrain.
11. Surface Level [L]. accumulated water on the surface expressed as the water height on the surface. Maximum value is the specified surface storage depth/berm height.
12. Pavement Level [L]. Accumulated water depth in the pavement layer. Maximum value is the pavement thickness.
13. Soil Moisture Content []. Presented as a fraction relative to the total volume of the optional soil layer. Corresponds to the water that is held in the spaces between soil particles. Maximum soil moisture (i.e. full saturation) is equivalent to the specified soil porosity.
14. Storage Level [L]. Accumulated water in the storage layer expressed as the water height in the storage. Maximum value is the storage height.

## LID Performance Summary

The LID Performance Summary is provided as part of the overall simulation summary file. The summary reports the overall storage/loss depths and volume balance for each LID deployment (see example in Figure 4.52).

```

*****
LID Performance Summary
*****

```

Subcatchment	LID Control	Total Inflow in	Evap Loss in	Infil Loss in	Surface Outflow in	Drain Outflow in	Initial Storage in	Final Storage in	Continuity Error %
Urban_Catchment_1	4_Rain_barrel	8.32	0.00	0.00	0.00	0.00	0.00	8.20	1.43
Urban_Catchment_1	3_Infiltration_trench	8.32	0.00	0.00	8.32	0.00	0.00	0.00	0.00
Urban_Catchment_1	2_Porous_pavement	8.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban_Catchment_1	6_Rain_garden	8.32	0.00	0.00	0.00	0.00	85.00	93.21	0.11
Urban_Catchment_1	1_Bio_retention_cell	8.32	0.00	0.00	0.00	0.00	0.00	45.00	53.21

Figure 4.52 Example of a LID Performance Summary

## 4.8 Groundwater

A sketch of the two-zone groundwater model that is used in EPA SWMM is shown in Figure 4.53. The upper zone is unsaturated at a varying moisture content of  $q$ . The lower zone is saturated and therefore its moisture content is fixed at the soil porosity  $h$ . The fluxes shown in the figure, expressed as volume per unit area per unit time, consist of the following:

- $f_i$  infiltration from the surface
- $f_{EU}$  evapotranspiration from the upper zone which is a fixed fraction of the un-used surface evaporation



- $f_U$  percolation from the upper to lower zone which depends on the upper zone moisture content  $q$  and depth  $d_U$
- $f_{EL}$  evapotranspiration from the lower zone, which is a function of the depth of the upper zone  $d_U$
- $f_L$  percolation from the lower zone to deep groundwater which depends on the lower zone depth  $d_L$
- $f_G$  lateral groundwater interflow to the conveyance network which depends on the lower zone depth  $d_L$  as well as depths in the receiving channel or node.

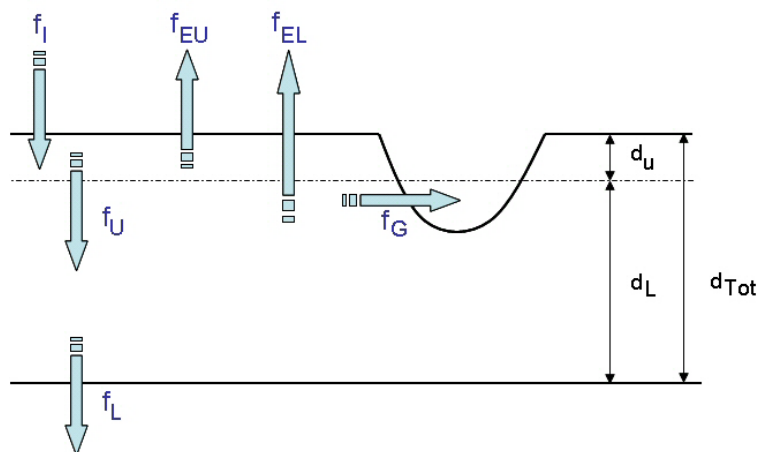


Figure 4.53 Groundwater Modelling Concept

After computing the water fluxes at a given point in time, a mass balance is written for the change in water volume stored in each zone so that a new water table depth and unsaturated zone moisture content can be computed for the next time step.

The SWMM Groundwater editor organizes the related input data for Groundwater into the following groups:

- Identification
- Groundwater Properties



**Groundwater editor - Identification**

ID: 37734      Aquifer ID: MDC\_485  
Catchment ID: MDC\_485      Node ID: GIS2003888  
Description: [Empty]

**Groundwater properties**

Catchment surface elev.: 21 [ft]      Surface water flow coefficient (A2): 0 [ft^2/s/ac]  
GW flow coefficient (A1): 0.0008 [ft^2/s/ac]      Surface water flow exponent (B2): 0  
GW flow exponent (B1): 2      GW interaction coefficient (A3): 0 [ft/s/ac]  
Surface water height (Hsw): 0 [ft]      Channel bottom height (Hcb): 11.4 [ft]  
Bottom elevation: 3.28084 [ft]      Water table elevation: 50.75459 [ft]  
Unsat. zone moisture: 0.33

Custom lateral flow equation      Edit...  
 Custom deep flow equation       $0*(Hgw-Hcb)^2+0.0001*Hgw/Hgs$       Edit...

ID	Catchment ID	Aquifer ID	Node ID	Catchment surface elev. [ft]	GW flow coefficient (A1) [ft^2/s/ac]	
1	37734	MDC_485	MDC_485	GIS2003888	21	0.0008
2	37735	MDC_1128	MDC_1128	GIS2003110	44	0.0008
3	37736	NNBI-07_16-C	NNBI-07_16-C	GIS2003105	51.81	0.0008
4	37737	NNBI-07_1-C	NNBI-07_1-C	GIS2002939	42.92	0.0004
5	37738	NNBI-07_2-C	NNBI-07_2-C	GIS2003106	52.57	0.0008
6	37739	NNBI-07_3-C	NNBI-07_3-C	GIS2003107	57.55	0.0008

Figure 4.54 The SWMM Groundwater editor

### Identification

The Identification groupbox of the Groundwater editor holds associated Catchment, Aquifer, and receiving Node information for the groundwater flow parameter set.

**Identification**

ID: 37734      Aquifer ID: MDC\_485  
Catchment ID: MDC\_485      Node ID: GIS2003888  
Description: [Empty]

Figure 4.55 The Groundwater Identification group



Table 4.34 Edit fields in the Groundwater Identification group (mss\_Groundwater)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Groundwater flow parameter set ID	Yes	MUID
Catchment ID	ID of catchment associated with the groundwater flow parameters	Yes	SubCatchID
Description	Optional descriptive information for groundwater flow parameters	No	Description
Aquifer ID	ID of Aquifer describing sub-surface soil properties, thickness, and initial conditions.	Yes	AquiferID
Node ID	ID of node receiving groundwater from the catchment	Yes	NodeID

## Groundwater Properties

Define groundwater flow properties on the Groundwater Properties groupbox of the Groundwater editor.

Groundwater properties

Catchment surface elev.	<input type="text" value="21"/>	[ft]	Surface water flow coefficient (A2)	<input type="text" value="0"/>	[ft <sup>2</sup> /s/ac]
GW flow coefficient (A1)	<input type="text" value="0.0008"/>	[ft <sup>2</sup> /s/ac]	Surface water flow exponent (B2)	<input type="text" value="0"/>	
GW flow exponent (B1)	<input type="text" value="2"/>		GW interaction coefficient (A3)	<input type="text" value="0"/>	[ft/s/ac]
Surface water height (Hsw)	<input type="text" value="0"/>	[ft]	Channel bottom height (Hcb)	<input type="text" value="11.4"/>	[ft]
Bottom elevation	<input type="text" value="3.28084"/>	[ft]	Water table elevation	<input type="text" value="50.75459"/>	[ft]
Unsat. zone moisture	<input type="text" value="0.33"/>				
<input type="checkbox"/> Custom lateral flow equation	<input type="text"/>		<input type="button" value="Edit..."/>		
<input checked="" type="checkbox"/> Custom deep flow equation	<input type="text" value="0*(Hgw+Hcb)^2+0.0001*Hgw/Hgs"/>		<input type="button" value="Edit..."/>		

Figure 4.56 The Groundwater Properties group



Table 4.35 Edit fields in the Groundwater Properties group (mss\_Groundwater)

<b>Edit field</b>	<b>Description</b>	<b>Used or required by simulations</b>	<b>Field name in datastructure</b>
Catchment Surface Elev.	Elevation of the catchment surface	Yes	SurfElev
GW Flow Coefficient (A1)	Groundwater flow coefficient A1 in the groundwater flow formula	Yes	A1
GW Flow Exponent (B1)	Groundwater flow exponent B1 in the groundwater flow formula	Yes	B1
Surface Water Flow Coefficient (A2)	Surface water flow coefficient A2 in the groundwater flow formula	Yes	A2
Surface Water Flow Exponent (B2)	Surface water flow exponent B2 in the groundwater flow formula	Yes	B2
GW Interaction Coefficient (A3)	Surface water - Groundwater interaction coefficient A3 in the groundwater flow formula	Yes	A3
Surface Water Height (Hsw)	Fixed level of surface water	Yes	Hsw
Channel Bottom Height (Hcb)	Level of receiving node invert	Yes	Hcb
Bottom Elevation	Elevation of the bottom of the aquifer below this particular catchment. Leave blank to use the value from the parent aquifer	Yes	BottomElev
Water Table Elevation	Initial water table elevation at the start of the simulation for this particular catchment. Leave blank to use the value from the parent aquifer.	Yes	WTElev
Unsat. Zone Moisture	Moisture content of the unsaturated upper zone above the water table for this particular catchment at the start of the simulation (volumetric fraction). Leave blank to use the value from the parent aquifer.	Yes	UZoneMoisture



Table 4.35 Edit fields in the Groundwater Properties group (mss\_Groundwater)

Edit field	Description	Used or required by simulations	Field name in datastructure
Custom Lateral Flow Equation	Option to use a user-defined groundwater flow equation for lateral groundwater flow (QL). The equation will be used in addition to the standard equation to compute groundwater outflow from the subcatchment.	No	Lateral-FlowEquation
Custom Deep Flow Equation	Option to use a user-defined groundwater flow equation for deep groundwater flow (QD). The equation will be used to replace the standard equation for deep groundwater flow.	No	DeepFlowEquation

## Custom Groundwater Flow Equations

Tick on the associated checkboxes to define and use custom groundwater flow equations.

Custom lateral flow equation

Custom deep flow equation

Figure 4.57 Define custom groundwater flow equations on the Groundwater editor

Click on the 'Edit' buttons to access the Custom Groundwater Flow Equation dialog, where one may define an equation in the input box.

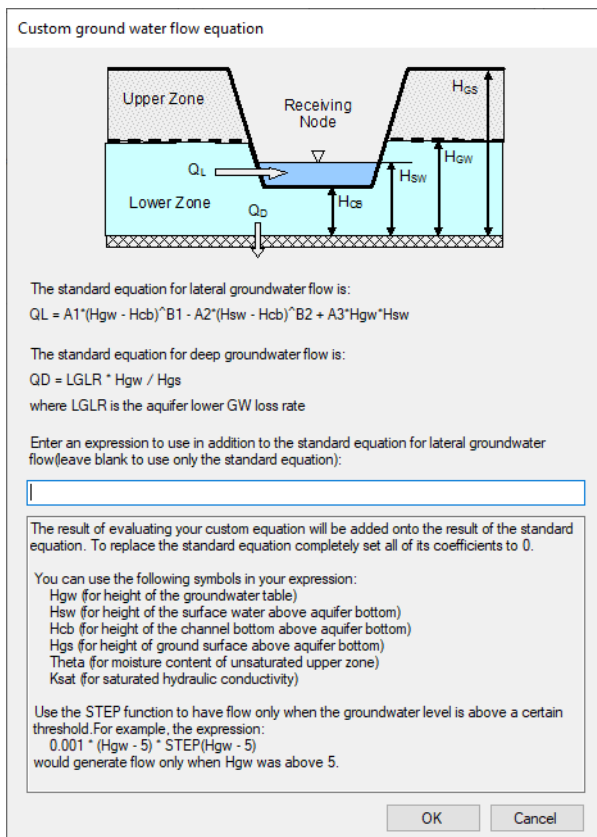


Figure 4.58 The Custom Groundwater Flow Equation dialog

## 4.9 Catchment Tools

The Catchment Toolbox is a collection of tools that makes delineation of catchments for stormwater networks easy and fast.

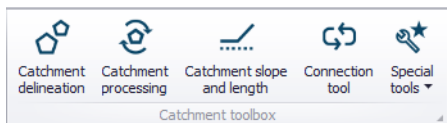


Figure 4.59 The Catchment Toolbox

The toolbox includes the following automated tools:

- Catchment Delineation.** Helps delineate catchment polygons in an automated and reproducible way. The catchments can be automatically created as Thiessen polygons derived from a layer of points or lines or as polygons derived from a digital elevation model (DEM).





- **Catchment Processing.** Automated way to calculate imperviousness and catchment widths for SWMM hydrological models - normally a very time consuming task with big risk of making errors and inconsistencies.
- **Catchment Slope and Length.** An automated way to calculate the slope and length of a catchment based on a DEM.
- **Connection Tool.** Automatically connects selected catchments to network elements based on a number of user-specified settings, e.g. to the nearest node. For those places where you want the catchments to be connected differently, the connections can be moved using graphical editing tools.
- **Special Tools.** An additional tool available for Catchments is **Spatial Processing**, wherein additional GIS operations such as Merge and Join could be performed with catchment layers and the results exported to a shapefile.

### 4.9.1 Catchment Delineation

The Catchment Delineation tool helps delineate catchment polygons in an automated and reproducible way. The catchments can be automatically created as Thiessen polygons derived from a layer of points or lines or as polygons derived from a digital elevation model (DEM).

The wizard guides you through the steps of the delineation process (Figure 4.60).

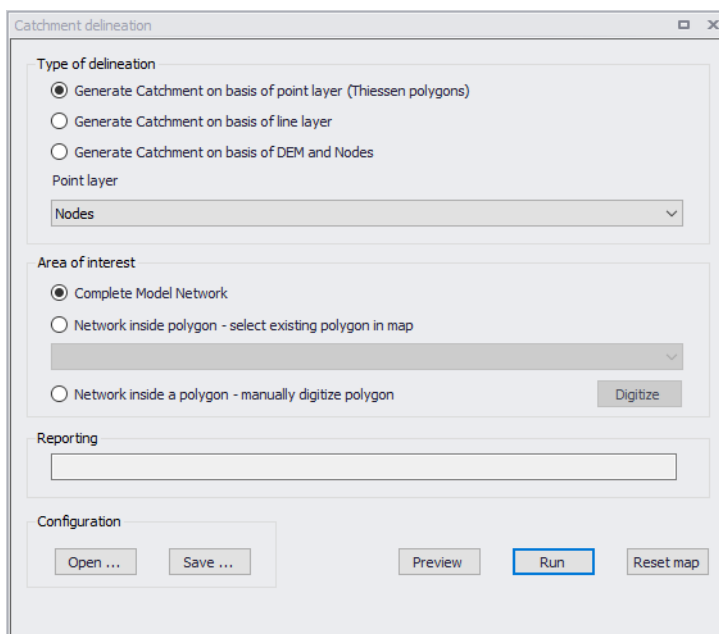


Figure 4.60 The Catchment Delineation wizard



## Type of Delineation

The first step in the use of the tool is selection of delineation type. The options available are:

- **Generate Catchment on Basis of Point Layer (Thiessen Polygons).** Based on Voronoi partitioning, which is a mathematical way of dividing spaces into a number of regions.
- **Generate Catchment on Basis of Line Layer.** Also based on Voronoi partitioning principles, but around line segments instead of points.
- **Generate Catchment on Basis of DEM and Nodes.** The catchments will describe the actual hydrological catchments around inlet nodes, defined based on the slopes on the DEM. This option requires pre-loading a valid DEM layer in the project. A valid DEM must be in \*.ASC or \*.DFS2 file format.

Depending on the delineation type, select the actual layer upon which the delineation shall be based. Available layers relevant to a delineation type are offered in the drop-down menu.

## Area of Interest

The next step is selection of the extent for the delineation. The options available are:

- **Complete Model Network.** Uses a default boundary defined by a rectangle covering the complete network (including a 30-m buffer zone). There is no additional dialog for this option.
- **Network Inside Polygon - Select Existing Polygon on Map.** Select an existing polygon from any polygon layer in the project. If this method is selected, the specific layer to be used is chosen from the dropdown menu and the specific feature selected on the map. See Figure 4.61.
- **Network Inside Polygon - Manually Digitize Polygon.** Manually digitize the boundary on the map. If this method is selected, use the **Digitize** button to draw the boundary directly on the map, ending the digitization with a double-click. See Figure 4.62.

Note that for DEM-based delineation, the delineation is performed according to the defined area of interest, but catchments covering the total extent of the input DEM will still be generated (See Figure 4.64).

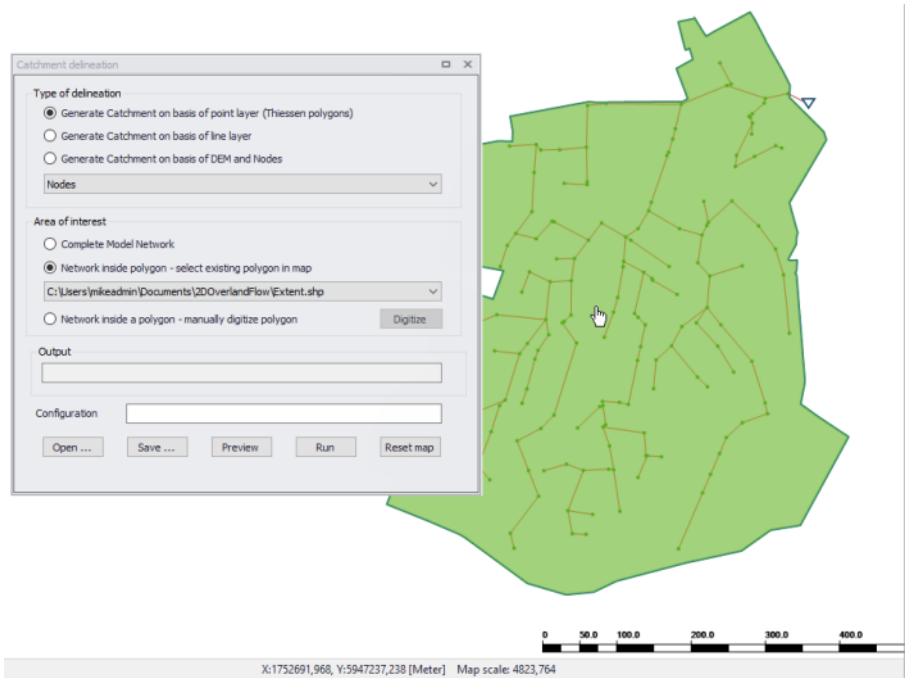


Figure 4.61 Selecting a polygon as a boundary for the delineation

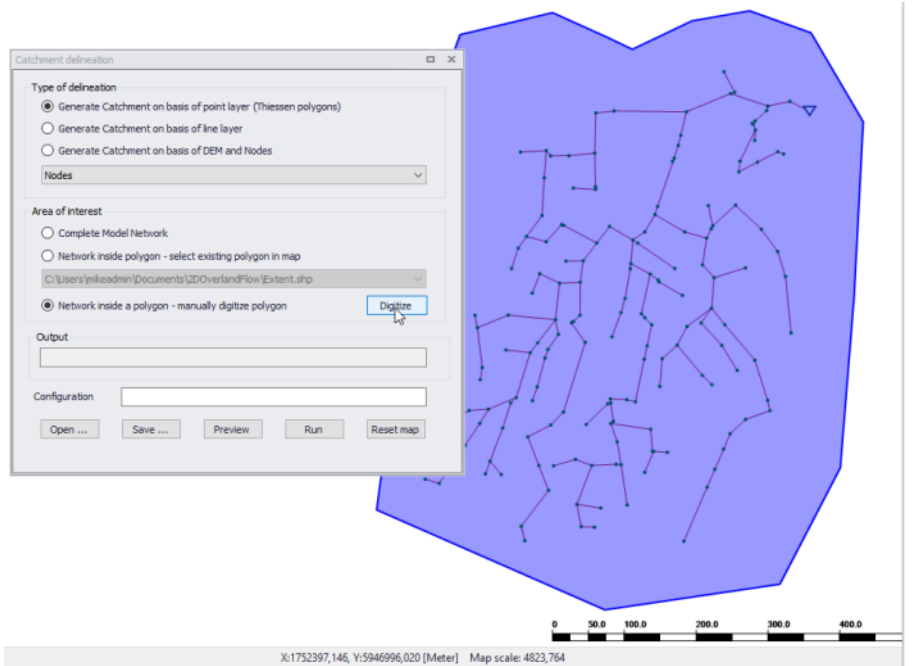


Figure 4.62 Digitizing the boundary on the Map via the 'Digitize' button



Click on the **'Run'** button to delineate the catchments according to the specified configuration.

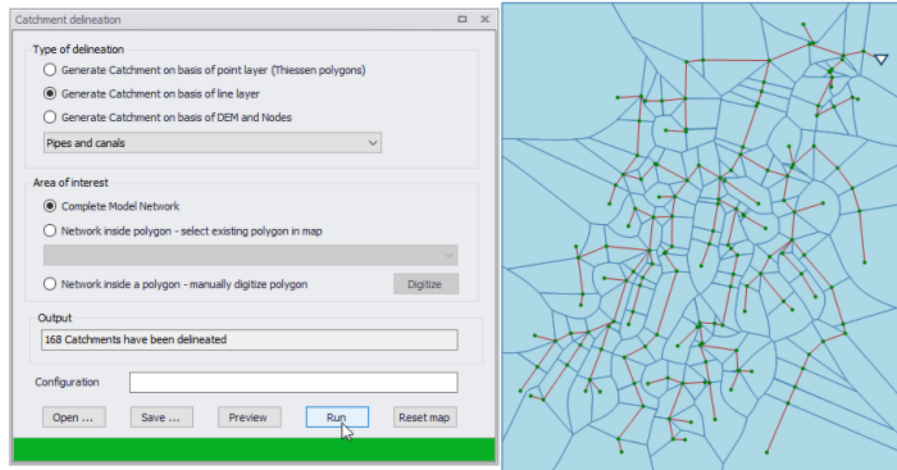


Figure 4.63 Click on the 'Run' button to perform catchment delineation

### Catchments Generated as Thiessen Polygons

When the catchments are created as Thiessen polygons (or Voronoi cells) you start out by specifying a selection of points or lines to use as an input layer. Typically either all manholes or all links.

The tool will proportionally divide and distribute a point coverage into the polygons known as Thiessen polygons. When a line layer is used as input, the points used are the midpoints of the lines. Each polygon contains only one input feature point. Each polygon has the unique property that any location within the polygon is closer to the polygon's point than to the point of any other polygon.

The Thiessen polygons (or Voronoi cells) are constructed as follows:

- All points are triangulated into a triangulated irregular network (TIN) that meets the Delaunay criterion.
- The perpendicular bisectors for each triangle edge are generated, forming the edges of the Thiessen polygons. The location at which the bisectors intersect determine the locations of the Thiessen polygon vertices.

The outside boundary of the Thiessen polygons needs to be specified. Either as a user specified polygon (created on the fly or loaded in as a layer) or as extent of the points used plus an additional area.

Please note that the underlying Delaunay triangulation method used works best with data in a projected coordinate system.



### Catchment Boundaries Based on a DEM

This method uses the geometrical network together with DEM data to delineate catchments.

To use this option, specify the DEM to use and the network inlets, which are the nodes where catchment runoff can enter the network. The tool will then use spatial analysis to pre-process the data and generate delineated catchments based on a DEM with sinks at node locations, and a flow direction grid following the terrain.

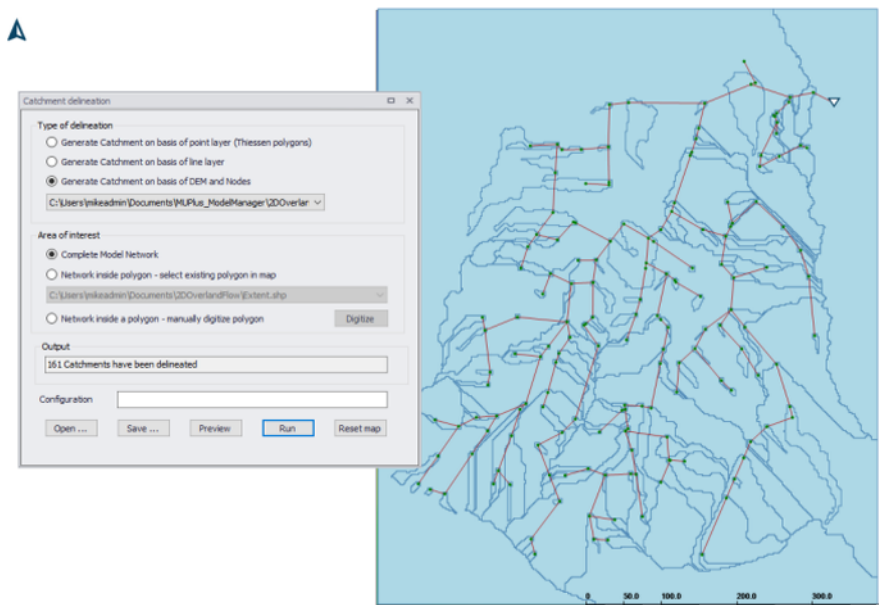
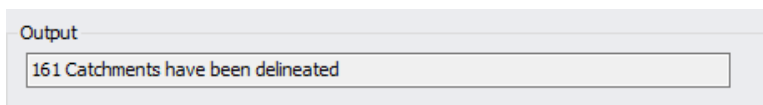


Figure 4.64 DEM-based catchment delineation. Note that catchment features will be generated covering the total extent of the input DEM by Default.

### Reporting

This section displays a summary of results from running the delineation tool. It starts off empty before the tool is run.



### Configuration

Displays the file name for a loaded/opened or saved delineation configuration \*.XML file. The path and file name for a new configuration may also be speci-



fied in the input box. Note that only specifying a file name will save the file in the user's Documents folder by Default.

#### 'Open...' button

Loads a previously-saved catchment delineation \*.XML configuration file.

#### 'Save...' button

Saves the current catchment delineation configuration into an \*.XML file.

#### 'Preview' button

Option for viewing preliminary results of a catchment delineation configuration.

#### 'Run' button

Executes the catchment delineation tool following the defined configuration.

#### 'Reset map' button

Resets the map view by removing highlights or preliminary delineation lines related to result previewing or extent digitization.

## 4.9.2 Catchment Processing

The Catchment Processing tool is an automated and reproducible way to calculate imperviousness and catchment width for SWMM hydrological models.

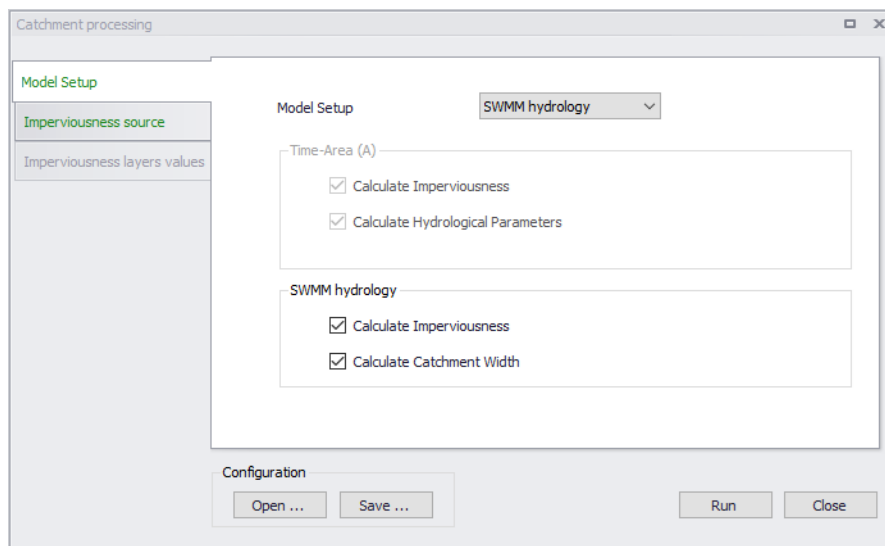


Figure 4.65 The start-up dialog of the Catchment Processing wizard



## Model Setup

The first step in catchment processing is selection of type of Model Setup for which parameters shall be calculated, and the parameters to calculate.

For SWMM models, the Model Setup is set to SWMM hydrology.

The wizard can be used for performing the following operations for SWMM hydrological models:

- **Calculate Imperviousness.** Use the tool to derive or set imperviousness values for catchment .

Calculating catchment imperviousness using the tool requires defining additional settings in the succeeding tab pages of the tool dialog.

- **Calculate Catchment Width.** Catchment width for SWMM catchments is computed as  $\text{Area} / \text{MaxLength}$ , where MaxLength is:
  - If the catchment is connected to a node, this is the distance from the connected node to the farthest point in the catchment.
  - If the catchment is connected to another catchment, the length is the maximum length across the catchment between two opposite points along the border.

Calculating only catchment width using the tool requires no further steps after selection of the option from the Model Setup tab page.

Note that when running the tool, processing is performed only for selected elements if selections are made prior to clicking on the Run button.

## Imperviousness Source

The Imperviousness Source tab page is active for when the tool is used for deriving or setting catchment imperviousness values.

The second step in the calculation of imperviousness is specification of the source of imperviousness values during processing.

Imperviousness for MIKE+ catchments can be calculated as a constant value or as a weighted average of imperviousness of multiple polygon layers. The layers should be pre-loaded in the project to be selectable in the wizard.

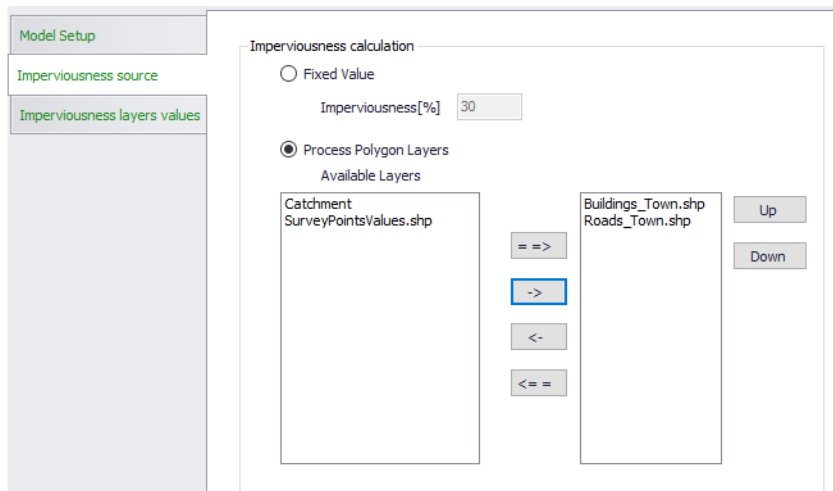


Figure 4.66 Polygon layer selection for calculation of imperviousness

## Imperviousness Layers Values

If polygon layers are to be used in deriving catchment imperviousness with the tool, the next step is specification of imperviousness values for the source polygon layers.

Please note that the list order of the layers is important. If some of the polygons are overlapping, the value from the uppermost overlapping layer (i.e. higher on the list) is prioritized.

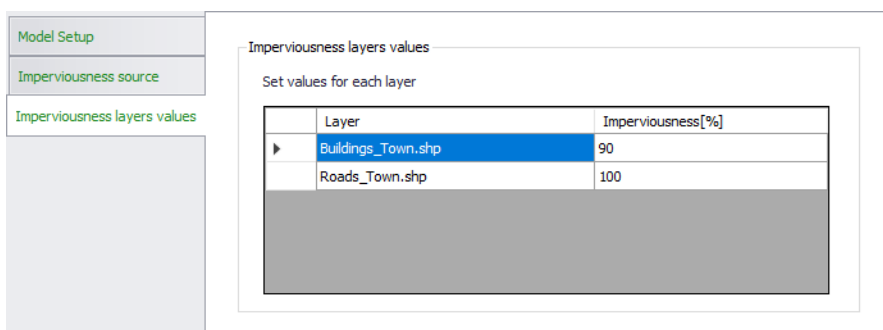


Figure 4.67 Specification of values for calculation of imperviousness

## Running the Tool

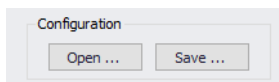
The final step is to execute the tool using the 'Run' button at the bottom of the wizard.





## Configuration

A section for saving or loading a Catchment Processing configuration \*.XML file. Use the **Save** button to save the current processing configuration into an \*.XML file. The **Open** button loads a previously-saved processing \*.XML configuration file.



### 4.9.3 Catchment Slope and Length

As part of hydrological modelling, the catchment slope and length must be estimated for some rainfall-runoff models.

Based on delineated catchments, a DEM, and lines for the flow path inside a catchment, the slope and length can be automatically estimated for each catchment using the Catchment Slope and Length tool.

#### Slope Line Layer

To calculate the slope and length, the typical flow path within the catchment must be digitized (i.e. the slope lines). These can be drawn from the load point or towards the load point but a consistent methodology should be used in a project. A multiple number of slope lines can be defined for each catchment. The slope lines must be a line feature in MIKE+ either from a background layer or an existing (unused) layer in the database.

The slope and length are calculated as an average slope and length of the lines that are completely contained within the catchment.

An example of slope lines are shown in Figure 4.68.

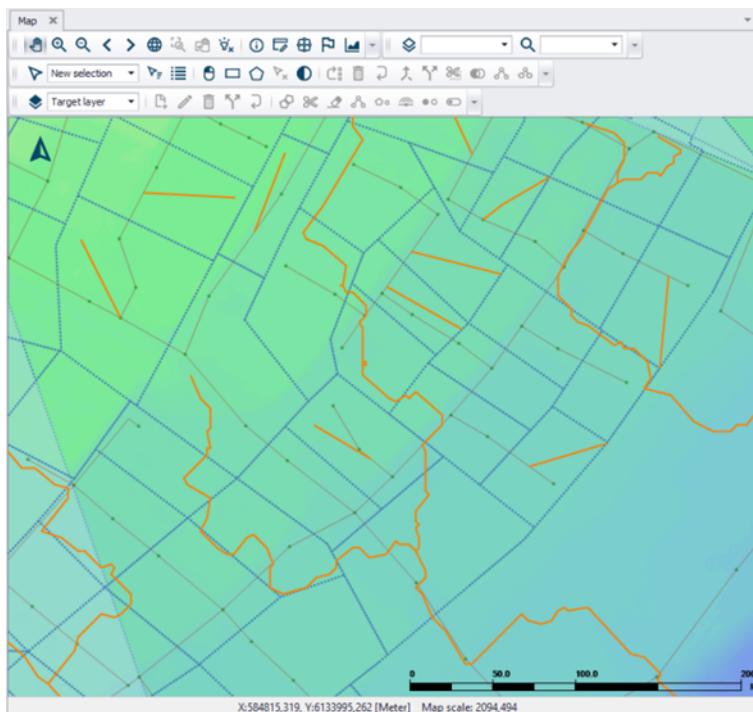


Figure 4.68 Example of slope lines (solid yellow lines) following surface flow paths overlaying catchments (broken blue lines) and the DEM (coloured surface), which are used in catchment length and slope derivation.

## Slope in Direction Towards

When the tool is opened, the slope line layer must be specified together with the direction the lines were digitized to obtain the correct sign for the slope.

## Minimum Slope

A minimum slope is also specified that will be assigned to all catchments with smaller slopes.

## DEM

Define the DEM layer based on which the slope and length derivation will be made. The DEM and slope line layers must be added as background layers in the MIKE+ project to be available in the tool, see Figure 4.69.

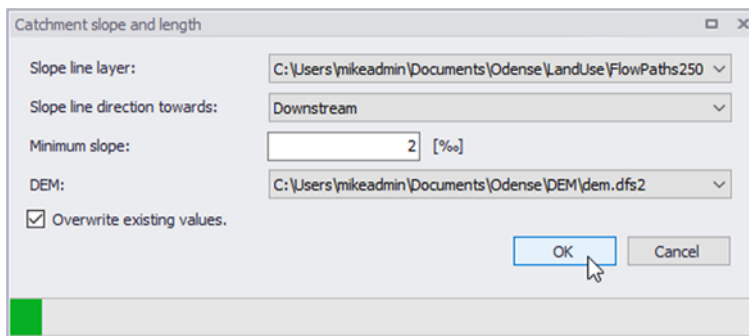


Figure 4.69 Catchment Slope and Length Tool

## Running the Tool

Click on the **OK** button to run the tool. The tool will calculate the length and slope for all selected catchments.

If no catchments are selected, the length and slope will be calculated for all catchments containing slope lines.

Activate the **Overwrite Existing Values** option if derived catchment slopes and lengths for selected catchments shall replace existing values, if any.

### 4.9.4 Connection Tool

The (catchment) Connection Tool is a generic wizard which can be used to connect catchments to the network.

The wizard automatically connects all selected catchments to nodes based on a number of principles, e.g. to the nearest node. For places where it is desired to connect catchments differently, the connections can be moved easily using graphical editing tools.

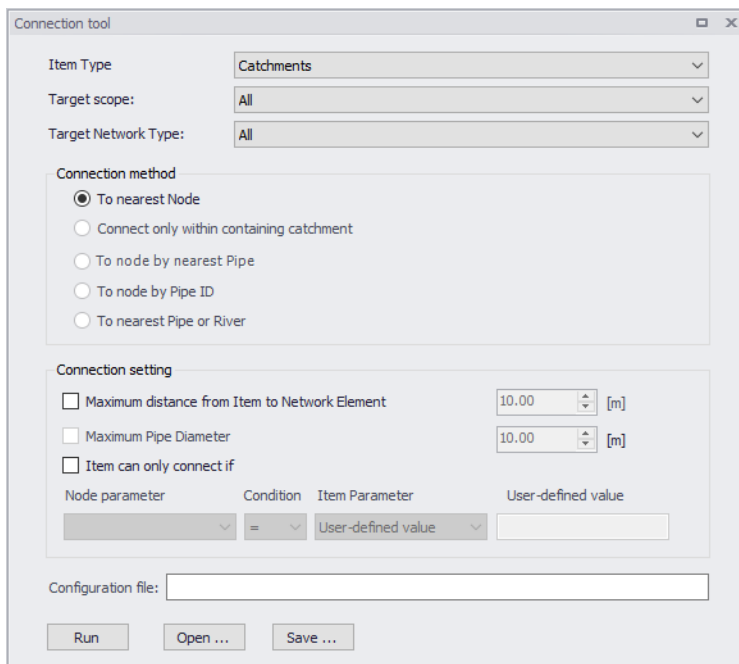


Figure 4.70 The (catchment) Connection Tool dialog

Use of the Connection Tool requires first defining the **Item Type** to be connected. I.e. Catchments for SWMM models.



The tool can only connect SWMM catchments to nodes and not to other catchments. If catchments shall be connected to other catchments for a SWMM model, this should be done manually through the Catchments editor SWMM Catchment Connections tab page.

Then, define the **Target Scope** or to which the items should be connected:

- **All.** All the appropriate model items.
- **Current Selection.** Only currently selected model items.

Define the **Target Network Type** to only consider target network element of certain Network Types in the processing. The target network type acts as a filter to select which items on the network may be connected. Note that catchments will not connect to nodes which have undefined Network Type when applying to a specific target network type (other than ALL). Therefore, the CS network type must be appropriately set for the network items before applying a specific target network type.

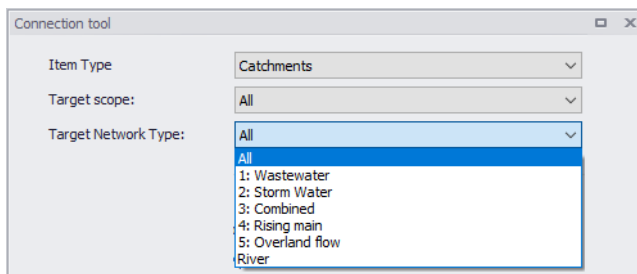


Figure 4.71 Selection of Network Type for target to which the items should be connected

## Connection Method

Define the Connection Method to use:

- **To Nearest Node.** Connect to node nearest the item location or centroid.
- **To Node by Nearest Pipe.** Connect to the nearest end node of the nearest pipe to an item location/centroid.

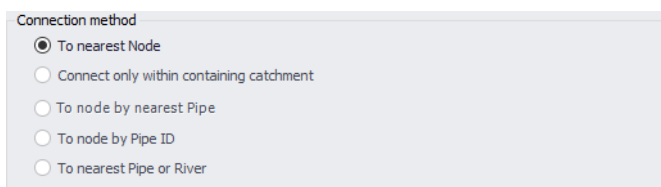


Figure 4.72 Selection of Connection Method

## Connection Settings

Connection Settings are optional and may be used to include extra criteria for connecting to the network.

- **Maximum Distance from Item to Network Element.** Maximum search distance to find nearest node element from the item location/centroid.
- **Maximum Pipe Diameter.** Maximum pipe diameter to involve in the search for nearest pipe element from the item location/centroid. E.g. for Method = To Node by Nearest Pipe.
- **Item Can Only Connect If.** Option for setting a user-defined condition in search for nearest node elements.
  - **Node Parameter.** Node parameter to use for additional filter criterion.
  - **Condition.** Mathematical condition for filter criterion.
  - **Item Parameter.** Item parameter to use for building the conditional statement for the filter criterion.



- **User-defined Value.** If a user-defined value instead of an item parameter value shall be used in building the condition. I.e. Item parameter = User-defined value.

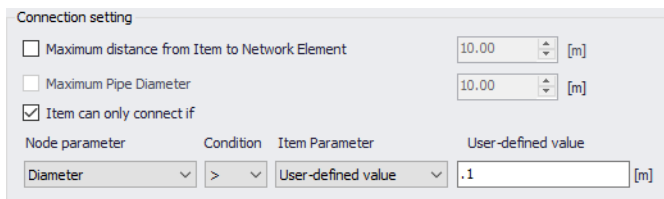


Figure 4.73 The Connection Tool Connection Settings section

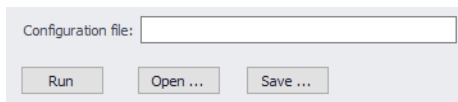
## Running the Tool

Finally, click on the **Run** button to run the Connection Tool.

## Configuration

The Configuration File input box shows the file name for a saved or loaded/opened connection configuration \*.XML file. The path and file name for a new configuration may also be specified in the input box. Note that only specifying a file name will save the file in the user's Documents folder by Default.

Use the **Save** button to save the current processing configuration into an \*.XML file. The **Open** button loads a previously-saved processing \*.XML configuration file.



### 4.9.5 Spatial Processing

The Catchment Toolbox also offers specialised tools for Spatial Processing. These are accessed via 'Special Tools' on the Catchments menu ribbon.

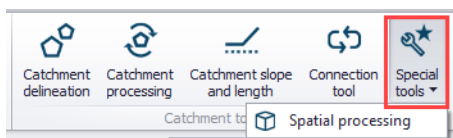


Figure 4.74 Spatial Processing tool for Catchments



Spatial analysis tools allow the user to perform several GIS-processing operations on various polygon and line layers available in the project. These layers are either model element layers, or shapefile layers loaded into the project.

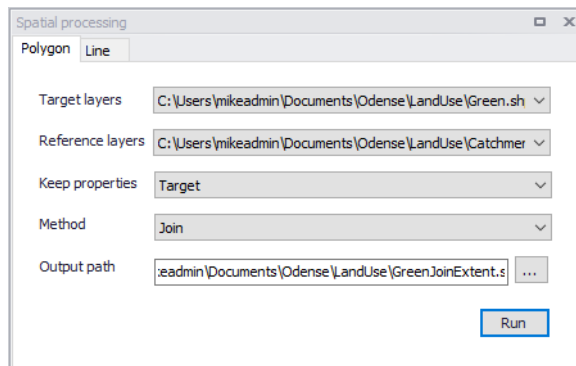


Figure 4.75 The Spatial Processing dialog

## Polygon

Operations such as Merge and Clip may be performed between various polygon layers. The analysis results are saved in a new shapefile and automatically loaded into the project as a new layer. It may also be imported as a model element feature.

Define the following parameters when using the tool for polygon features:

- **Target Layers.** Polygon feature to be modified (i.e. to which the operation will be done).
- **Reference Layers.** The second polygon layer used to modify the target layer.
- **Keep Properties.** Information on the feature attributes to keep for the resulting layer.
- **Method.** Dropdown menu for selecting spatial operation to use:
  - **Clip.** Extracts from target the areas intersecting the reference. Features in target not intersecting the reference are also kept.
  - **Erase.** Removes from target the areas intersecting the reference.
  - **Merge.** Features in both layers combined, where intersecting features are fused in new features.
  - **Join.** Extracts from target the areas intersecting the reference.
- **Output Path.** Use the ellipsis button “...” to specify the path and file name for the resulting feature layer from the operation.
- **Run.** Button for executing the spatial processing.



## Line

Operations such as Buffer and To Polygon may be performed for line layers. The analysis results are saved in a new shapefile and automatically loaded into the project as a new layer. It may also be imported as a model element feature.

- **Target Layers.** Line layer to be modified (i.e. to which the operation will be done).
- **Method.** Dropdown menu for selecting spatial operation to use:
  - **Buffer.** Creates buffer polygons around target layer features according to a buffer distance.
  - **To Polygon.** Converts the line features to polygons. Note that polyline features must be closed with overlapping start- and end-vertices to be converted to polygons.
- **Buffer.** Distance around the line features that will be buffered. If Method = Buffer.
- **Output Path.** Use the ellipsis button “...” to specify the path and file name for the resulting feature layer from the operation.
- **Run.** Button for executing the spatial processing.

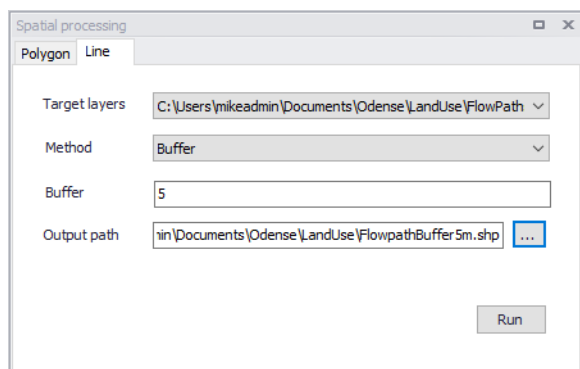


Figure 4.76 Spatial processing for lines





## 5 Boundary Conditions

A model boundary condition is defined as an external interference driving the behaviour of computed variables within the model domain.

Time series data representing rainfall, evaporation, water stages, and the like, are important drivers in model simulations. Boundary conditions describe the loading of these timeseries in the model.

### 5.1 Rain Gauges

Rain Gauges supply precipitation data for one or more catchments in a study area. The rainfall data can be either a user-defined time series (specified in Time Series editor as Type Rainfall) or come from an external file.

Several different popular rainfall file formats are supported, as well as a standard user-defined formats. These are:

- DSI-3240 and related formats which record hourly rainfall at U.S. National Weather Service (NWS) and Federal Aviation Agency stations, available online from the National Climatic Data Center (NCDC) at [www.ncdc.noaa.gov/oa/ncdc.html](http://www.ncdc.noaa.gov/oa/ncdc.html).
- DSI-3260 and related formats which record fifteen minute rainfall at NWS stations, also available online from NCDC.
- HLY03 and HLY21 formats for hourly rainfall at Canadian stations, available online from Environment Canada at [www.climate.weatheroffice.ec.gc.ca](http://www.climate.weatheroffice.ec.gc.ca).
- FIF21 format for fifteen minute rainfall at Canadian stations, also available online from Environment Canada.
- A standard user-prepared format where each line of the file contains the station ID, year, month, day, hour, minute, and non-zero precipitation reading, all separated by one or more spaces. An excerpt from the user-prepared format might look as follows:

```
STA01 2004 6 12 00 00 0.12
STA01 2004 6 12 01 00 0.04
STA01 2004 6 22 16 00 0.07
```

When a file is used as a source of rain gauge data, the user must supply the name of the file and the name of the recording station referenced in the file.

For the standard user-prepared format, the rainfall type (e.g., intensity or volume), recording time interval, and depth units must also be supplied as rain gauge properties.

For other file types these properties are defined by their respective file formats and are automatically recognized by SWMM.



The SWMM Rain Gauge editor organizes the related input data for the rainfall data into the following groups:

- **Identification.** General identification and location information.
- **Rain Gauge Properties.** Source data and data format information.

	ID	X coordinate [ft]	Y coordinate [ft]	Source data format	File	Station
1	Bradley	1018363.03684814	902541.555205181	FILE	CSO_1year_Oct1951.dat	1
2	MDC-RG-6	1015421.96895429	841019.870150092	FILE	CSO_1year_Oct1951.dat	1
3	MDC-RG-7	1016590.47129129	836879.235831226	FILE	CSO_1year_Oct1951.dat	1
4	Newington	1006118.2573537	816159.729426393	FILE	CSO_1year_Oct1951.dat	1
5	MDC-RG-5	1014148.60721567	846347.268622272	FILE	CSO_1year_Oct1951.dat	1
6	WestHartford	913217.576557224	800167.538445429	FILE	CSO_1year_Oct1951.dat	1
7	MDC-RG-4	1025546.38617578	831671.767469512	FILE	CSO_1year_Oct1951.dat	1
8	MDC-RG-2	1023819.10812406	850547.276595042	FILE	CSO_1year_Oct1951.dat	1

Figure 5.1 The SWMM Rain Gauge editor

## Identification

The identification group holds rain gauge ID and location information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.



Table 5.1 Edit fields in the Rain Gauge Identification group (mss\_Raingauge)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	ID of Rain gauge	Yes	MUID
X	X coordinate of rain gauge	Yes	GeomX
Y	Y coordinate of rain gauge	Yes	GeomY

## Rain Gauge Properties

Define the data source for rain gauges under the Rain Gauge Properties tab page of the editor.

Table 5.2 Edit fields in the Rain Gauge Properties tab page (mss\_Raingauge)

Edit field	Description	Used or required by simulations	Field name in datastructure
Source Data Format Radio buttons	Radio buttons for defining source data format: FILE TIMESERIES	Yes	TypeNo
FILE	Name of rainfall data file	Yes If TypeNo = 1	FileNameSeries
Station Name	Station ID in the data file	Yes If TypeNo = 1	StationNumber
Unit Type	Unit type (in or mm) Depth units (IN or MM) for rainfall values in user-prepared files (other standard file formats have fixed units depending on the format).	Yes If TypeNo = 1	UnitNo
TIME-SERIES	ID of Time Series item	Yes If TypeNo = 2	TimeSeriesID
Description	Optional rain gauge record description	No	Description
Format	Rainfall data value format: INTENSITY VOLUME CUMULATIVE	Yes If TypeNo = 2	FormNo



Table 5.2 Edit fields in the Rain Gauge Properties tab page (mss\_Raingauge)

Edit field	Description	Used or required by simulations	Field name in datastructure
Time Interval	Time interval between readings in the timeseries in decimal hours or hours:minutes format.	Yes If TypeNo = 2	TimeInterval
Snow Catch Deficiency Correction Factor, SCF	Snow catch deficiency correction factor that corrects readings for snowfall.	Yes	Scf

The following formats are supported when using TIMESERIES for rain gauge data:

- **INTENSITY.** Each value is an average rate (in/h or mm/h) over the recording interval.
- **VOLUME.** Each value is the volume of rain that fell over the recording interval (in or mm).
- **CUMULATIVE.** Each value represents the cumulative rainfall that has occurred since the start of the last series of non-zero values (in or mm).

## 5.2 Dry Weather Flow

Dry Weather Flows are continuous inflows that typically reflect the contribution from sanitary sewage in sewer systems or base flows in pipes and stream channels. They are represented by an average inflow rate that can be periodically adjusted on a monthly, daily, and hourly basis by applying Time Patterns multipliers to this average value.

The SWMM Dry Weather Flow editor organizes the related input data for each dry weather inflow into the following groups:

- **Identification.** The Identification group holds Dry Weather Flow setup ID and connectivity information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.
- **Flow Data.** Define flow values and associated patterns under the Flow Data group.
- **Pollutants.** Define pollutants attached to dry weather flow under the Pollutants group.

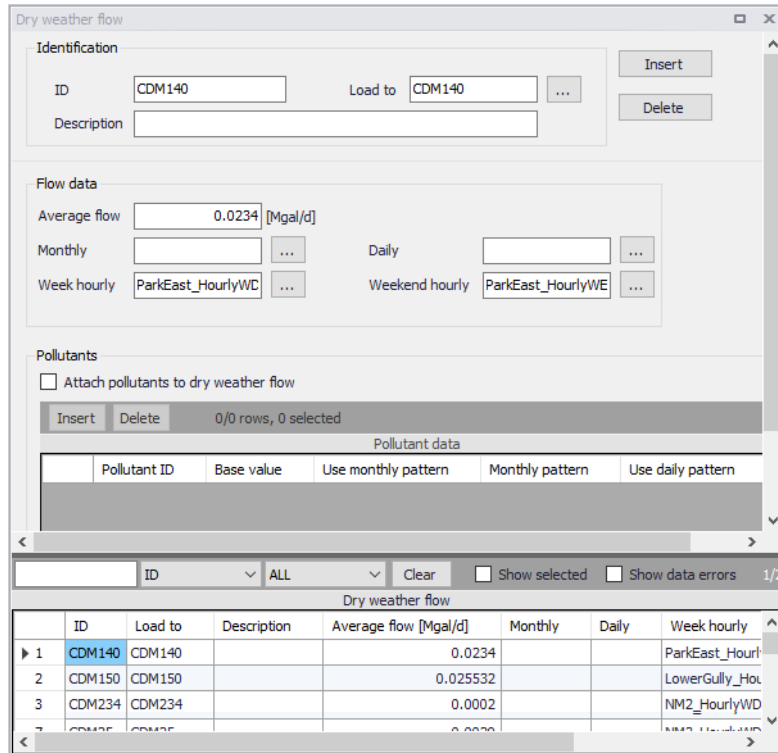


Figure 5.2 The SWMM Dry Weather Flow editor

### Identification and Flow Data

The Identification group holds Dry Weather Flow ID and connectivity information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

Define associated flow values and patterns for the DWF setup under the Flow Data group.

Table 5.3 Edit fields in the Dry Weather Flow editor (mss\_DWF)

Edit field	Description	Used or required by simulations	Field name in datastructure
Identification			
ID	ID Dry Weather Flow	Yes	MUID
Load To	ID of Node ID for DWF load	Yes	NodeID
Description	Optional description for the DWF setup	No	Description



Table 5.3 Edit fields in the Dry Weather Flow editor (mss\_DWF)

Edit field	Description	Used or required by simulations	Field name in datastructure
Flow Data			
Average Flow	Average DWF value	Yes	FlowValue
Monthly	Monthly Pattern ID	No	PatternMonthID
Daily	Daily Pattern ID	No	PatternWeekID
Week Hourly	Hourly Pattern ID for weekdays	No	PatternWeek-HourlyID
Weekend Hourly	Hourly Pattern ID for week-ends	No	PatternWeek-endHourlyID

## Pollutants

Define pollutants attached to dry weather flows under the Pollutants group. Tick on the 'Attach pollutants to dry weather flow' option to include pollutants in the DWF setup. Specify pollutant parameters in the secondary table.

Table 5.4 Edit fields in the Dry Weather Flow Pollutants Group (mss\_DWFD)

Edit field	Description	Used or required by simulations	Field name in datastructure
Attach Pollutants to Dry Weather Flow	Option to activate/define a DWF pollutant component for a simulation	Yes	PollutNo
Pollutant ID	ID of Pollutant	Yes If PollutNo = 1	PollutantID
Base Value	Base value of pollutant	Yes If PollutNo = 1	BValue
Use Monthly Pattern	Option to use a monthly pollutant pattern	Yes If PollutNo = 1	UseMonthlyPtn
Monthly	ID of Pattern of Monthly type	Yes If UseWeek-endPtn = 1	PatternMonthID



Table 5.4 Edit fields in the Dry Weather Flow Pollutants Group (mss\_DWFD)

Edit field	Description	Used or required by simulations	Field name in datastructure
Use Daily Pattern	Option to use a daily pollutant pattern	Yes If PollutNo = 1	UseDailyPtn
Daily	ID of Pattern of Daily type	Yes If UseDailyPtn = 1	PatternWeekID
Use hourly pattern	Option to use an hourly pollutant pattern	Yes If PollutNo = 1	UseHourlyPtn
Week hourly	ID of Pattern of Hourly type	Yes If UseHourlyPtn = 1	PatternWeek-HourlyID
Use Week-end Pattern	Option to use a different hourly pollutant pattern for weekends	Yes If PollutNo = 1	UseWeek-endPtn
Weekend hourly	ID of Pattern of Weekend type	Yes If UseWeek-endPtn = 1	PatternWeek-endHourlyID

## 5.3 Inflows

Direct Inflows are user-defined time series of inflows added directly into a node. They can be used for flow and water quality routing in the absence of runoff computations (as in a study area where no catchments are defined).

A pollutant component can only be defined as inflow to the system if it is attached to a flow component.

The CS SWMM Inflow editor organizes the related input data for each inflow into the following groups:

- **Identification.** General identification and connectivity information.
- **Time Series.** Associated time series item.
- **Base Flow.** Base flow value and associated variation pattern.
- **Pollutants.** Pollutant attached to the inflow.



Figure 5.3 The SWMM Inflows editor

## Identification, Time Series, and Base Flow

The Identification group holds inflow boundary ID and connectivity information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

Define a time series to describe the time varying inflow component under the Time Series group.

The Base Flow group is where the base flow component of the inflow is defined.

Table 5.5 Edit fields in the Inflows editor (mss\_Inflow)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Inflow boundary ID	Yes	MUID
Inflow To	ID of node where inflow is loaded	Yes	NodeID





Table 5.5 Edit fields in the Inflows editor (mss\_Inflow)

Edit field	Description	Used or required by simulations	Field name in datastructure
Description	Optional description for the inflow boundary	No	Description
Time Series ID	ID of flow time series describing time-varying inflows	Yes	FlowSeriesID
Scale Factor	Factor multiplied to time series values	Yes	ScaleFlowFactor
Base Flow	Constant base flow value. If left blank then no base inflow is assumed.	Yes	BaseFlowValue
Pattern ID	Optional time pattern with factors for adjusting base flows	Yes	BaselinePatternID

## Pollutants

Define pollutants attached to inflows under the Pollutants group. Tick on the 'Attach pollutants to inflow' option to include pollutants in the Inflow boundary setup. Specify pollutant parameters in the secondary table.

Table 5.6 Edit fields in the Inflows editor Pollutants group (mss\_InflowD)

Edit field	Description	Used or required by simulations	Field name in datastructure
Attach Pollutants to Inflow	Option to activate/define a inflow pollutant setup	Yes	PollutNo
Pollutant ID	ID of pollutant associated with the inflow boundary	Yes If PollutNo = 1	PollutantID
Format	Pollutant data Format: Mass Concentration	Yes If PollutNo = 1	FormatNo
Use Time Series	Option to use a time series to describe pollutant variation	Yes If PollutNo = 1	UseTimeSeries
Time Series ID	ID of pollutograph	Yes If UseTimeSeries = 1	PollutSeriesID
Scale Factor	Multiplier for adjusting time series values	Yes If UseTimeSeries = 1	ScalePollutValue



Table 5.6 Edit fields in the Inflows editor Pollutants group (mss\_InflowD)

<b>Edit field</b>	<b>Description</b>	<b>Used or required by simulations</b>	<b>Field name in datastructure</b>
Base Value	Pollutant base value	Yes If PollutNo = 1	BasePollutValue
Use Pattern	Option to use a time pattern to describe pollutant base value variation	Yes If PollutNo = 1	UsePattern
Base Pattern	Time pattern ID whose factors adjust base pollutant values	Yes If UsePattern = 1	BasePatternID
Unit Factor	A factor for converting the units of pollutant mass flow rate into concentration mass units per second	Yes If PollutNo = 1 and FormatNo = 2	ConvFactor



## 6 Tables

The SWMM Tables Section in MIKE+ holds data for the following tabular data types:

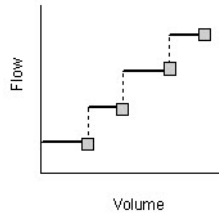
- Curves and Relations
- Materials

Tabular data are used to describe functional relationships between two quantities.

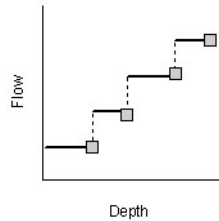
### 6.1 Curves and Relations

In the Curves and Relations editor, a number of tabular data used in other data dialogs are specified. The following curve types are available for SWMM models:

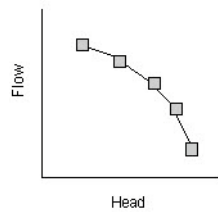
- **Storage.** Defines the geometry of a Storage Unit node by describing the variation of surface area as a function of water depth
- **Divider.** Defines how the diverted outflow from a Flow Divider node is related to the total inflow.
- **Tidal Curve.** Defines how the stage at an Outfall node varies by the hour of the day.
- **Rating.** Relates flow through an Outlet link to the head difference across the outlet
- **Control.** Sets how the control setting of a pump or flow regulator varies as a function of some control variable (such as water level at a particular node) as specified in control rule. Is also used to adjust the flow from an LID unit's underdrain based on head.
- **Shape.** Describes how the width of a customized cross-sectional shape varies with height for a Conduit link.
- **Weir.** Defines how a weir discharge coefficient varies with head.
- **Pump curve.** Relates flow through a pump to the depth or volume at the upstream node or to the head delivered by the pump. The following types of pump curves are available:
  - **Pump Curve 1 (Volume-Flow).** An off-line pump with a wet well where flow increases incrementally with wet well volume



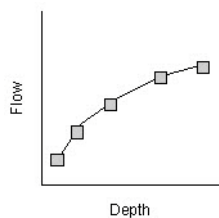
- **Pump Curve 2 (Depth-Flow).** An in-line pump where flow increases incrementally with inlet node depth



- **Pump Curve 3 (Head-Flow).** An in-line pump where flow varies continuously with head difference between the inlet and outlet nodes



- **Pump Curve 4 (Depth-Flow).** A variable speed in-line pump where flow varies continuously with node depth



The Tabular Data (Curves) editor organizes the related input data into the following groups:

- **Identification.** General identification and type information.
- **Curve Values.** Secondary table containing tabular data values.

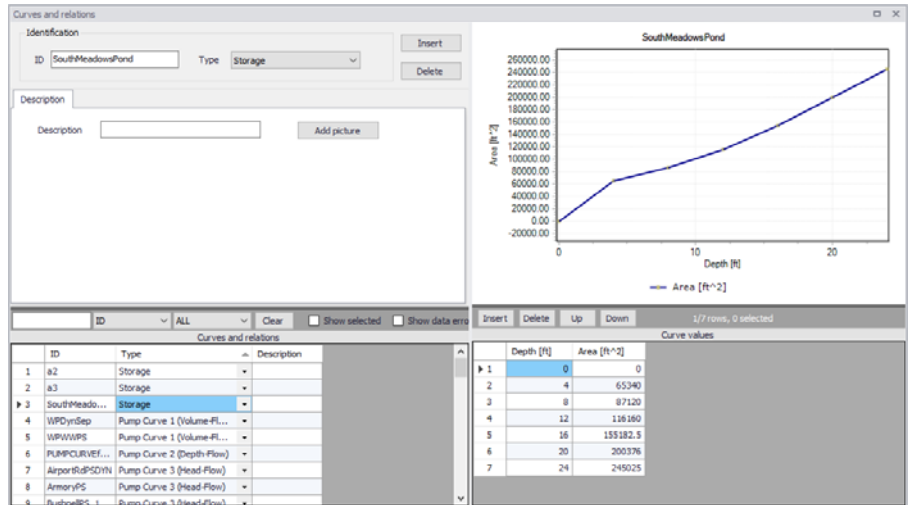


Figure 6.1 The SWMM Curves and Relations editor

## Identification

The identification groupbox holds curve ID and Type information.

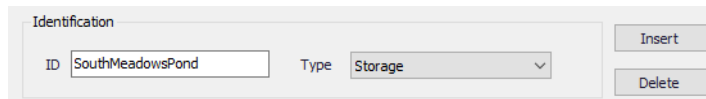


Figure 6.2 The Identification groupbox

Use the Insert or Delete buttons to add or remove records from the editor, respectively. Records are added to the primary table on the lower left corner of the editor.

The screenshot shows the primary table in the 'Curves and relations' editor. The table has columns 'ID', 'Type', and 'Description'. The table contains 11 rows of data, with the first row selected.

ID	Type	Description
1	Pump Curve 3 (Head-Flow)	
2	Pump Curve 4 (Depth-Flow)	
3	Pump Curve 3 (Head-Flow)	
4	Pump Curve 3 (Head-Flow)	
5	Pump Curve 3 (Head-Flow)	
6	Control	
7	Pump Curve 4 (Depth-Flow)	
8	Pump Curve 3 (Head-Flow)	
9	Pump Curve 4 (Depth-Flow)	
10	Pump Curve 3 (Head-Flow)	
11	Shape	

Figure 6.3 Primary table with the Curves and Relations list on the lower left side of the Curves and Relations editor



Table 6.1 Edit fields in the Curves and Relations Identification and Description groupbox

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Curve ID	Yes	MUID
Type	Type of curve	Yes	TypeNo
Description	User's descriptive information on the curve	No	Description

Add optional descriptive information for a curve on the Description tab page. An option for adding an images is also available.

The image shows a software interface window with a tab labeled "Description". Inside the window, there is a text input field with the label "Description" to its left. To the right of the input field is a button labeled "Add picture".

Figure 6.4 The Description tab page

## Curve Values

After inserting a new tabular data item, define the corresponding data values under the Curve Values table (i.e. secondary table to the right of primary table). Secondary table parameters/columns that should be filled vary depending on the curve and relation type.

A plot of the tabular data is also shown on the upper right corner of the editor.

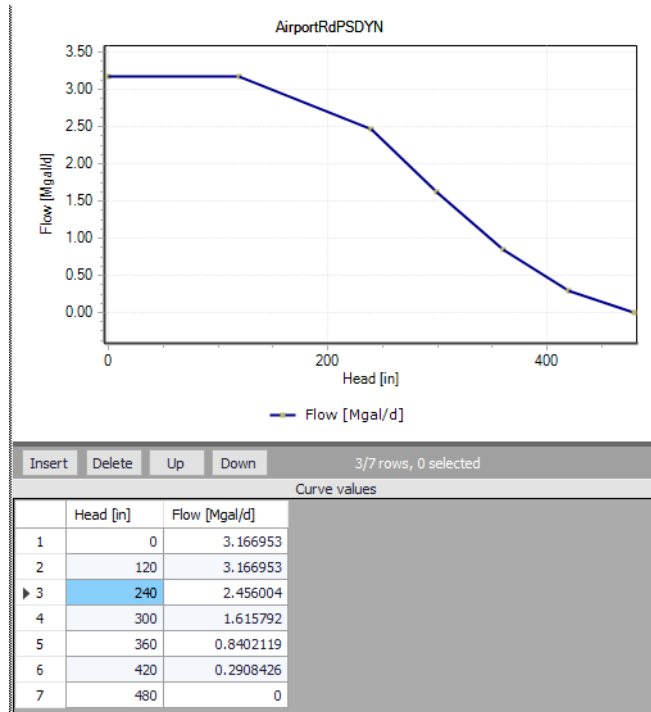


Figure 6.5 Secondary table containing Curves Values on the lower right side of the Curves and Relations editor. Also shown is the tabular data plot above the secondary Curve Values table.

Table 6.2 Edit fields in the Curve Values secondary table (mss\_Tab)

Edit field	Description	Used or required by simulations	Field name in datastructure
'Value1'	Value1, dependent on Type of curve (Depth, Inflow, Hour, Volume, Head)	Yes	Value1
'Value2'	Value2, dependent on Type of curve (Area, Outflow, Stage, Flow)	Yes	Value2

## 6.2 Materials

In MIKE+, a link may be characterised by material, which determines the Manning friction coefficient (Manning), the Colebrook-White coefficient (EQ Roughness), or Hazen-Williams coefficient (H-W Coefficient) for the conduit.



It is optional to use either the default roughness values for specific materials or local values.

Specification of the different kind of materials and roughness coefficients is done through the Materials editor.

ID	Manning (M) [m <sup>1/3</sup> /s]	EQ roughness [mft]	H-W coefficient	Description
1	77	3.28084	120	Cement Mortar
2	70	8.2021	110	Ceramics
3	75	4.92126	120	Concrete (Normal)
4	68	9.84252	100	Concrete (Rough)
5	85	1.64042	140	Concrete (Smooth)
6	70	8.2021	120	Iron (cast)
7	65	11.48294	100	Iron (wrought)
8	80	3.28084	140	Plastic
9	80	3.28084	130	Stone

Figure 6.6 Materials editor

MIKE+ has the following pre-defined Material types with friction loss properties:

- Cement Mortar
- Ceramics
- Concrete (Normal)
- Concrete (Rough)
- Concrete (Smooth)
- Iron (cast)
- Iron (wrought)
- Plastic
- Stone





Table 6.3 Edit fields in the Materials editor (ms\_Material)

<b>Edit field</b>	<b>Description</b>	<b>Used or required by simulations</b>	<b>Field name in datastructure</b>
ID	Material type ID	Yes	MUID
Manning	Manning roughness value	Yes If 'Manning Explicit' or 'Manning Implicit' is used	Manning
EQ Roughness	Equivalent roughness	Yes If 'Colebrook-White' formulation is used	EQRough
H-W Coefficient	Hazen-Williams roughness coefficient	Yes If 'Hazen-Williams' is used	HWCoef
Description	User's descriptive information on the material	Optional	Description





## 7 Time Series

Time series items are used to describe the variation of parameters over time.

### 7.1 Time Series

Time Series may be user specified or taken from external measured data of e.g. rainfall, evaporation, inflows to nodes of the drainage system, and water stage at outfall boundary nodes.

The following types of SWMM Time Series items may be defined in MIKE+:

- Rainfall
- Temperature
- Inflow hydrograph
- Evaporation
- Outfall stage
- Inflow pollutograph

Define Time Series items via the SWMM Time Series editor. The editor organizes time series data into the following groups:

- **Identification.** General identification and time series type information.
- **Time Series Format.** Set source of time series values.
- **Time Series Data Values.** Secondary table where values for internal time series are defined.

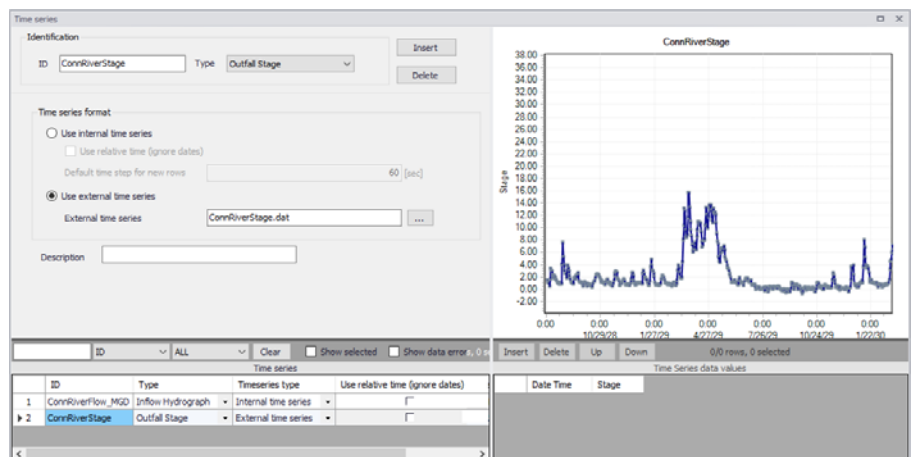


Figure 7.1 The SWMM Time Series editor



The time component of time series data may be defined as:

- Calendar date/time of day
- As elapsed hours since the start of the simulation (i.e. relative time)

For rainfall time series, it is only necessary to enter periods with non-zero rainfall amounts. SWMM interprets the rainfall value as a constant value lasting over the recording interval specified for the rain gage which utilizes the time series. For all other types of time series, SWMM uses interpolation to estimate values at times that fall in between the recorded values.

The SWMM engine supports the following external time series data formats:

- **Date / time / value format.** Dates are entered as month/day/year (e.g., 7/21/2004) and times in 24-hour military time format (e.g. 8:30 pm is 20:30). After the first date, additional dates need only be entered whenever a new day occurs.
- **Time / value format.** Times are entered as hours since simulation start. Time can either be decimal hours or military time since the start of a simulation (e.g., 2 days, 4 hours and 20 minutes can be entered as either 52.333 or 52:20).

Each entry is separated by one or more spaces or tab characters.

Table 7.1 Edit fields in the Time Series editor (mss\_Timeseries)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	ID of Time Series	Yes	MUID
Type	Type of Time Series: Rainfall (TypeNo = 1) Temperature (TypeNo = 2) Inflow Hydrograph (TypeNo = 3) Evaporation (TypeNo = 4) Outfall Stage (TypeNo = 5) Inflow Pollutograph (TypeNo = 6)	Yes	TypeNo
Use Internal Time Series radio button	Option to define time series values directly on the interface	Yes	TimeSeriesTypeNo = 1
Use Relative Time (Ignore Dates)	Option to define time series values with time axis relative to simulation start	Yes If TimeSeriesTypeNo = 1	UseRelativeTime



Table 7.1 Edit fields in the Time Series editor (mss\_Timeseries)

Edit field	Description	Used or required by simulations	Field name in datastructure
Default Time Step for new Rows	Time step between records when inserting time series values in the secondary table	Yes If TimeSeriesTypeNo = 1	m_GlobalParameter.SWMM.TimeSeries_DeltaT.ValueDouble
Use External Time Series radio button	Option to define time series values from an external file	Yes	TimeSeriesTypeNo = 2
External Time Series	Name and location of external time series file	Yes TimeSeriesTypeNo = 2	ExternalTimeSeriesFile
Description	Optional description for the time series item	No	Description

## 7.2 Time Patterns

Time Patterns are used to describe the cyclic behaviour of parameter values and time series. Time patterns may be of the following types:

- **Monthly.** Defines a multiplier for each month of the year.
- **Daily.** Defines a multiplier for each day of the week.
- **Hourly.** Defines a multiplier for each hour from 12 AM to 11 PM.
- **Weekend (Hourly).** Defines hourly multipliers for weekend days.

The SWMM Time Patterns editor organizes the related input data for time patterns into the following groups:

- **Identification.** General identification and pattern type information.
- **Pattern Data.** Pattern adjustment factors.



The screenshot shows the 'Time patterns' editor. The 'Identification' section has 'ID' set to 'dayWH1' and 'Type' set to 'Daily'. The 'Pattern Types' section has a grid of input fields for months (January to December), days of the week (Monday to Sunday), and weeks of the month (Week AM, Week PM, Weekend AM, Weekend PM). The table below shows a list of patterns:

ID	Type	Description	January	February	March	April	May	June	July	August	Sept
1	Hourly	CBB1_HourlyWD	1	1	1	1	1	1	1	1	1
2	Weekly	CBB1_HourlyWE	1	1	1	1	1	1	1	1	1
3	Daily	dayWH1	1	1	1	1	1	1	1	1	1
4	Daily	dayWH13	1	1	1	1	1	1	1	1	1
13	Daily	dayWI-08	1	1	1	1	1	1	1	1	1

Figure 7.2 The SWMM Time Patterns editor

## Identification

Table 7.2 Edit fields in the Time Patterns editor (mss\_Pattern)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Pattern ID	Yes	MUID
Type	Pattern type: Monthly Daily Hourly Weekend	Yes	TypeNo
Description	Optional description for the pattern	No	Description



## Pattern Data

Each pattern consists of a set of adjustment factors used as multipliers to a parameter base value (e.g. DWF, pollutants, catchment infiltration, etc.).

Table 7.3 Edit fields in the Pattern Data group (mss\_Pattern)

Edit field	Description	Used or required by simulations	Field name in datastructure
Monthly			
Jan	Pattern value for January	Yes if Monthly	Mdr1
Feb	Pattern value for February	Yes if Monthly	Mdr2
Mar	Pattern value for March	Yes if Monthly	Mdr3
Apr	Pattern value for April	Yes if Monthly	Mdr4
May	Pattern value for May	Yes if Monthly	Mdr5
Jun	Pattern value for June	Yes if Monthly	Mdr6
Jul	Pattern value for July	Yes if Monthly	Mdr7
Aug	Pattern value for August	Yes if Monthly	Mdr8
Sep	Pattern value for September	Yes if Monthly	Mdr9
Oct	Pattern value for October	Yes if Monthly	Mdr10
Nov	Pattern value for November	Yes if Monthly	Mdr11
Dec	Pattern value for December	Yes if Monthly	Mdr12
Daily			
Mon	Pattern value for Monday	Yes if Daily	Day1
Tue	Pattern value for Tuesday	Yes if Daily	Day2
Wed	Pattern value for Wednesday	Yes if Daily	Day3



Table 7.3 Edit fields in the Pattern Data group (mss\_Pattern)

Edit field	Description	Used or required by simulations	Field name in datastructure
Thu	Pattern value for Thursday	Yes if Daily	Day4
Fri	Pattern value for Friday	Yes if Daily	Day5
Sat	Pattern value for Saturday	Yes if Daily	Day6
Sun	Pattern value for Sunday	Yes if Daily	Day7
Week AM			
12	Pattern value for 12AM week	Yes if Hourly	AM12
01	Pattern value for 01AM week	Yes if Hourly	AM1
02	Pattern value for 02AM week	Yes if Hourly	AM2
03	Pattern value for 03AM week	Yes if Hourly	AM3
04	Pattern value for 04AM week	Yes if Hourly	AM4
05	Pattern value for 05AM week	Yes if Hourly	AM5
06	Pattern value for 06AM week	Yes if Hourly	AM6
07	Pattern value for 07AM week	Yes if Hourly	AM7
08	Pattern value for 08AM week	Yes if Hourly	AM8
09	Pattern value for 09AM week	Yes if Hourly	AM9
10	Pattern value for 10AM week	Yes if Hourly	AM10
11	Pattern value for 11AM week	Yes if Hourly	AM11
Week PM			
12	Pattern value for 12PM week	Yes if Hourly	PM12
01	Pattern value for 01PM week	Yes if Hourly	PM1
02	Pattern value for 02PM week	Yes if Hourly	PM2





Table 7.3 Edit fields in the Pattern Data group (mss\_Pattern)

Edit field	Description	Used or required by simulations	Field name in datastructure
03	Pattern value for 03PM week	Yes if Hourly	PM3
04	Pattern value for 04PM week	Yes if Hourly	PM4
05	Pattern value for 05PM week	Yes if Hourly	PM5
06	Pattern value for 06PM week	Yes if Hourly	PM6
07	Pattern value for 07PM week	Yes if Hourly	PM7
08	Pattern value for 08PM week	Yes if Hourly	PM8
09	Pattern value for 09PM week	Yes if Hourly	PM9
10	Pattern value for 10PM week	Yes if Hourly	PM10
11	Pattern value for 11PM week	Yes if Hourly	PM11
Weekend AM			
12	Pattern value for 12AM week-end	Yes if Weekend	AMW12
01	Pattern value for 01AM week-end	Yes if Weekend	AMW1
02	Pattern value for 02AM week-end	Yes if Weekend	AMW2
03	Pattern value for 03AM week-end	Yes if Weekend	AMW3
04	Pattern value for 04AM week-end	Yes if Weekend	AMW4
05	Pattern value for 05AM week-end	Yes if Weekend	AMW5
06	Pattern value for 06AM week-end	Yes if Weekend	AMW6
07	Pattern value for 07AM week-end	Yes if Weekend	AMW7
08	Pattern value for 08AM week-end	Yes if Weekend	AMW8
09	Pattern value for 09AM week-end	Yes if Weekend	AMW9



Table 7.3 Edit fields in the Pattern Data group (mss\_Pattern)

Edit field	Description	Used or required by simulations	Field name in datastructure
10	Pattern value for 10AM week-end	Yes if Weekend	AMW10
11	Pattern value for 11AM week-end	Yes if Weekend	AMW11
Weekend PM			
12	Pattern value for 12PM week-end	Yes if Weekend	PMW12
01	Pattern value for 01PM week-end	Yes if Weekend	PMW1
02	Pattern value for 02PM week-end	Yes if Weekend	PMW2
03	Pattern value for 03PM week-end	Yes if Weekend	PMW3
04	Pattern value for 04PM week-end	Yes if Weekend	PMW4
05	Pattern value for 05PM week-end	Yes if Weekend	PMW5
06	Pattern value for 06PM week-end	Yes if Weekend	PMW6
07	Pattern value for 07PM week-end	Yes if Weekend	PMW7
08	Pattern value for 08PM week-end	Yes if Weekend	PMW8
09	Pattern value for 09PM week-end	Yes if Weekend	PMW9
10	Pattern value for 10PM week-end	Yes if Weekend	PMW10
11	Pattern value for 11PM week-end	Yes if Weekend	PMW11



## 8 Water Quality Modelling with SWMM

SWMM models in MIKE+ can model both the quantity and quality of runoff generated within catchments, as well as the flow rates, depths, and water quality in pipes and channels over a simulation period.

Water quality routing within conduits assumes that the conduit behaves as a continuously stirred tank reactor (CSTR). Although a plug flow reactor assumption might be more realistic, the differences will be small if the travel time through the conduit is on the same order as the routing time step. The concentration of a constituent exiting the conduit at the end of a time step is found by integrating the conservation of mass equation, using average values for quantities that might change over the time step such as flow rate and conduit volume.

Water quality modelling within storage unit nodes follows the same approach used for conduits. For other types of nodes that have no volume, the quality of water exiting the node is simply the mixture concentration of all water entering the node. The production and fate of pollutant loads associated with runoff is also modelled.

The following processes can be modelled for any number of user-defined water quality constituents:

- Dry-weather pollutant buildup over different land uses
- Pollutant washoff from each land use during storm events
- Direct contribution of rainfall deposition
- Reduction in dry-weather buildup due to street cleaning
- Reduction in washoff load due to BMPs
- Entry of dry weather sanitary flows and user-specified external inflows at any point in the conveyance system
- Routing of water quality constituents through the pipe/channel network
- Reduction in constituent concentration through treatment at junction nodes or in storage units

### 8.1 Pollutants

The generation, inflow, and fate of any number of user-specified pollutants can be modelled with SWMM models in MIKE+.

Define pollutants via the SWMM Pollutants editor. The editor organizes pollutant data into the following groups:

- **Identification.** General identification information.
- **General.** Tab page holding pollutant concentrations and characteristics.



- **Description.** Tab page for optional pollutant item description.

Figure 8.1 The SWMM Pollutants editor

## Identification

The Identification group holds pollutant item ID information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

Figure 8.2 The Pollutants editor Identification group

Table 8.1 Edit fields in the Pollutants Identification group and Description tab page (mss\_Pollutant)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Unique ID for pollutant component	Yes	MUID
Description	Optional description for the pollutant item	No	Description



Optional descriptive information about the pollutant item may be added via the Description tab page. The page also offers an option for adding images related to the item.

Figure 8.3 The Pollutants editor Description tab page

## General

Define pollutant properties on the General tab page of the Pollutants editor.

Figure 8.4 The Pollutants editor General tab page

Pollutants may be expressed in: milligrams/liter, micrograms/liter, or counts/liter

Co-pollutants can also be modelled, which are pollutants whose runoff concentrations contribute to the runoff concentrations of the active pollutant. For example, pollutant X can have a co-pollutant Y, meaning that the runoff concentration of X will have some fixed fraction of the runoff concentration of Y added to it.

The pollutant buildup and washoff on catchment areas are determined by the Land Uses assigned to those areas.



Table 8.2 Edit fields in the Pollutants General tab page (mss\_Pollutant)

Edit field	Description	Used or required by simulations	Field name in datastructure
Units	Dropdown menu for selecting units for pollutant item: mg/L µg/L #/L	Yes	TypeNo
Rain	Concentration of the pollutant in rain water	Yes	Crain
Groundwater	Concentration of the pollutant in groundwater	Yes	Cgw
Infiltration and Inflow Flows	Concentration of the pollutant in any infiltration or inflow	Yes	Cii
Dry Weather Flow	Concentration of the pollutant in DWF	Yes	Cdwf
Initial	Concentration of the pollutant throughout the network at the start of the simulation	Yes	Cinit
First Order Decay Coefficient	First order decay coefficient of the pollutant	Yes	Kdecay
Co-pollutant ID	ID of the co-pollutant whose runoff concentration contributes to the concentration of the current pollutant	Yes	CoPollut
Co-pollutant fraction	Fraction of co-pollutant's runoff concentration that contributes to the runoff concentration of the current pollutant	Yes	CoFract
Buildup during snowfall only	Option to allow buildup only when there is snow cover	Yes	SnowFlag

## 8.2 Land Uses

Land Uses are categories of activities or land surfaces that are assigned to catchment areas. Examples of land use activities are residential, commercial, industrial, and undeveloped. Land surface characteristics might include roof tops, lawns, paved roads, undisturbed soils, etc. Land uses are used solely to allow spatial variation in pollutant buildup and washoff rates.



There is complete freedom in defining land uses and assigning them to catchment areas. One approach is to assign a mix of land uses to each catchment, in which case all land uses in the catchment will have the same pervious/impervious characteristics. If this is not appropriate then it is possible to create catchments that have just a single land use classification along with a set of pervious/impervious characteristics reflecting the classification.

The following processes may be defined for each land use category:

- Pollutant Buildup
- Pollutant Washoff
- Street Sweeping

The SWMM Land Uses editor organizes the land use data into the following groups:

- **Identification.** Land use item identification information.
- **General.** Associated street sweeping parameters.
- **Buildup.** Pollutant buildup characteristics.
- **Washoff.** Pollutant washoff parameters.
- **Description.** Optional descriptive information for land use item.

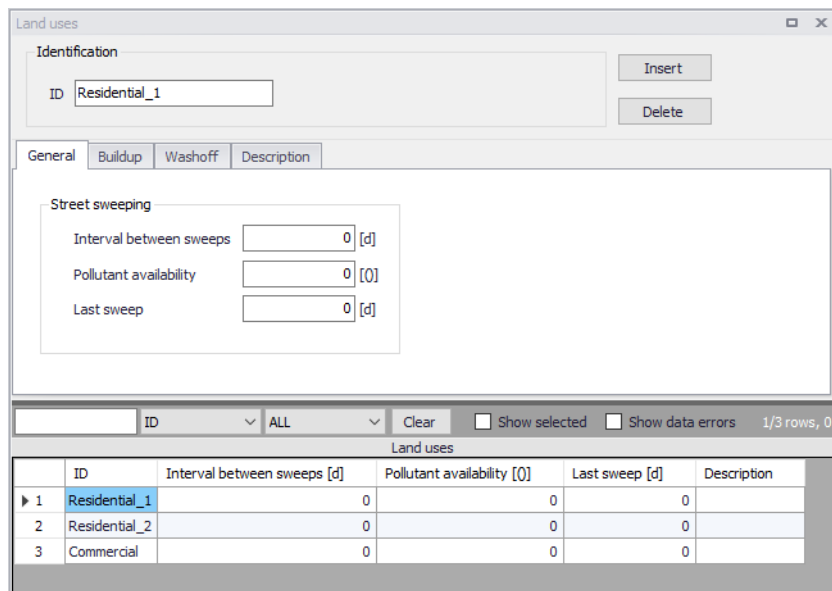


Figure 8.5 The SWMM Land Uses Editor



## Identification

The Identification group box holds land use item ID information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.

The screenshot shows a window titled 'Identification'. Inside, there is a text input field containing the word 'Commercial'. To the right of this field are two buttons: 'Insert' and 'Delete'.

Figure 8.6 The Land Uses editor Identification group

Table 8.3 Edit fields in the Land Use Identification group and Description tab page (mss\_Landuse)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Land use item ID	Yes	MUID
Description	Optional description for land use item	No	Description

Add optional descriptive information about land use items via the Description tab page of the editor. The page also includes an option for adding images of the land use item.

The screenshot shows a window with four tabs: 'General', 'Buildup', 'Washoff', and 'Description'. The 'Description' tab is active. It contains a text input field labeled 'Description' and a button labeled 'Add picture'.

Figure 8.7 The Land Uses editor Description tab page

## General

Define land use parameters related to Street Sweeping, which affects the buildup of pollutants in areas.





General
Buildup
Washoff
Description

Street sweeping

Interval between sweeps  [d]

Pollutant availability  [0]

Last sweep  [d]

Figure 8.8 The Land Uses General tab page

Table 8.4 Edit fields in the Land Uses General tab page (mss\_Landuse)

Edit field	Description	Used or required by simulations	Field name in datastructure
Interval Between Sweeps	Days between sweeping	Yes	SweepInterval
Pollutant Availability	Fraction of pollutant buildup available for removal by street sweeping	Yes	Availability
Last Sweep	Days since last sweeping at start of the simulation	Yes	LastSweep

## Buildup

Pollutant Buildup that accumulates over a category of Land Use is described by either a mass per unit of catchment area or per unit of curb length. The amount of buildup as a function of days of dry weather can be computed using one of the following functions:

### Power Function

Pollutant buildup (B) accumulates proportional to time (t) raised to some power, until a maximum limit is achieved:

$$B = \text{Min}(C_1, C_2 t^{C_3}) \tag{8.1}$$

where C1 = maximum buildup possible (mass per unit of area or curb length), C2 = buildup rate constant, and C3 = time exponent.



### Exponential Function

Buildup follows an exponential growth curve that approaches a maximum limit asymptotically:

$$B = C_1(1 - e^{-C_2t}) \quad (8.2)$$

where  $C_1$  = maximum buildup possible (mass per unit of area or curb length) and  $C_2$  = buildup rate constant (1/days).

### Saturation Function

Buildup begins at a linear rate which proceeds to decline constantly over time until a saturation value is reached:

$$B = \frac{C_1 t}{C_2 + t} \quad (8.3)$$

where  $C_1$  = maximum buildup possible (mass per unit area or curb length) and  $C_2$  = half-saturation constant (days to reach half of the maximum buildup).

Define pollutant buildup parameters for land uses on the Buildup tab page of the Land Uses editor. The list of pollutants for which to define parameters is based on pollutant items defined in the Pollutants editor. The following options are available for describing buildup processes for land uses:

- No Buildup
- Power
- Exponential
- Saturation
- Time Series. This option allows one to use a Time Series to describe the rate of buildup per day as a function of time. Define Time Series items in the Time Series editor with values expressed as mass per unit area (or curb length) per day.

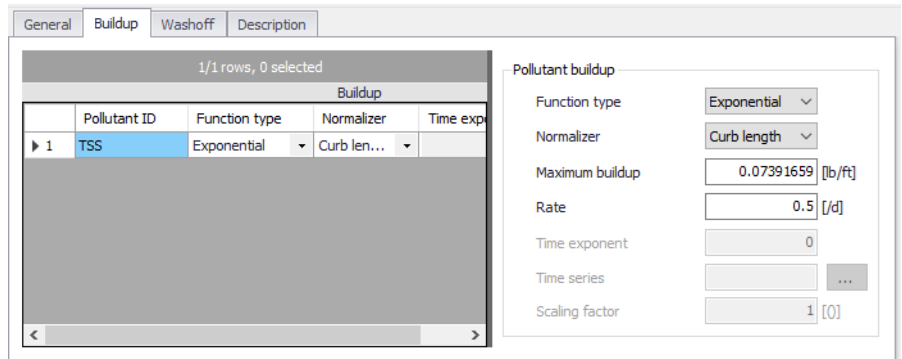


Figure 8.9 The Land Uses Buildup tab page

Table 8.5 Edit fields in the Land Uses Buildup tab page (mss\_Buildup)

Edit field	Description	Used or required by simulations	Field name in datastructure
Function Type	Choice of function tpe to use for Buildup computations: No Buildup Power Exponential Saturation Time Series	Yes	FuncTypeNo
Normalizer	Choice of normalizer to describe pollutant buildup in either mass per unit catchment area or mass per unit of curb length: Area Curb Length	Yes If Function <> No Buildup	NormalizerNo
Maximum Buildup	Coefficient C1 (Maximum buildup possible in mass per unit area or curb length)	Yes If Function <> No Buildup	C1
Rate	Buildup rate constant	Yes if Function is Power or Exponential	C2
Time Exponent	Time exponent in Power Function	Yes if Function is Power	C3
Half-Saturation Time	Half-saturation constant (days to reach half of the maximum buildup)	Yes if Function is Saturation	C3



Table 8.5 Edit fields in the Land Uses Buildup tab page (mss\_Buildup)

Edit field	Description	Used or required by simulations	Field name in datastructure
Time Series	Time series containing buildup rates. Define values in mass per unit area (or curb length) per day	Yes, if Function is external time series	ExternalTime-SeriesID
Scaling Factor	A scaling factor used to adjust buildup rates listed in the time series	Yes, if Function is external time series	C2_Scalingfactor

## Washoff

Pollutant Washoff from a given land use category during wet weather periods can be described in one of the following ways:

### Exponential Washoff

The washoff load ( $W$ ) in units of mass per hour is proportional to the product of runoff raised to some power and to the amount of buildup remaining:

$$W = C_1 q^{C_2} B \quad (8.4)$$

where  $C_1$  = washoff coefficient,  $C_2$  = washoff exponent,  $q$  = runoff rate per unit area (inches/hour or mm/hour), and  $B$  = pollutant buildup in mass (lbs or kg) per unit area or curb length. Washoff mass units are the same as used to express the pollutant's concentration (milligrams, micrograms, or counts).

### Rating Curve Washoff

The rate of washoff  $W$  in mass per second is proportional to the runoff rate raised to some power:

$$W = C_1 Q^{C_2} \quad (8.5)$$

where  $C_1$  = washoff coefficient,  $C_2$  = washoff exponent, and  $Q$  = runoff rate in user-specified flow units.

### Event Mean Concentration

This is a special case of Rating Curve Washoff where the exponent is 1.0 and the coefficient  $C_1$  represents the concentration of any and all runoff in mass per liter (the conversion between user-specified flow units used for runoff and liters is handled internally by SWMM).

Note that in each case, buildup is continuously depleted as washoff proceeds, and washoff stops when there is no more buildup available.



Washoff loads for a given pollutant and land use category can be reduced by a fixed percentage by specifying a BMP Removal Efficiency which reflects the effectiveness of any BMP controls associated with the land use.

Define pollutant washoff parameters for land uses on the Washoff tab page of the Land Uses editor. The list of pollutants for which to define parameters is based on items defined in the Pollutants editor. The following options are available for describing washoff processes for land uses:

- No Washoff
- Exponential
- Rating Curve
- Event Mean Concentration

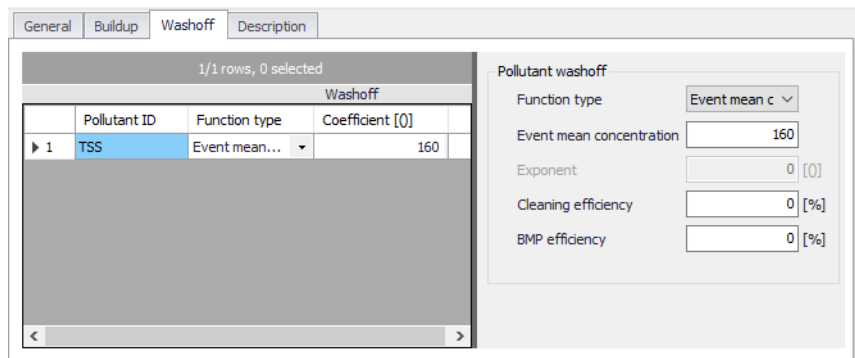


Figure 8.10 The Washoff tab page on the Land Uses editor

Table 8.6 Edit fields in the Washoff tab page (mss\_Washoff)

Edit field	Description	Used or required by simulations	Field name in datastructure
Function Type	Option for describing washoff process: No Washoff Exponential Rating Curve Event Mean Concentration	Yes	FuncTypeNo
Coefficient	Washoff coefficient	Yes If Function is Exponential or Rating Curve	C1



Table 8.6 Edit fields in the Washoff tab page (mss\_Washoff)

Edit field	Description	Used or required by simulations	Field name in datastructure
Exponent	Washoff exponent	Yes If Function is Exponential or Rating Curve	C2
Cleaning Efficiency	Street sweeping removal efficiency in percentage	Yes If Function <> No Washoff	SweepEfficiency
BMP Efficiency	Removal efficiency of BMP controls associated with land use expressed in percentage	Yes If Function <> No Washoff	BMPEfficiency
Event Mean Concentration	Washoff pollutant concentration in mass per liter	Yes If Function = Event Mean Concentration	C1

### 8.3 Initial Loading

Define initial pollutant quantities in catchments via the SWMM Initial Loading editor. The editor organizes data into the following groups:

- **Identification.** Initial load setup ID information.
- **Loading Properties.** Initial buildup data.

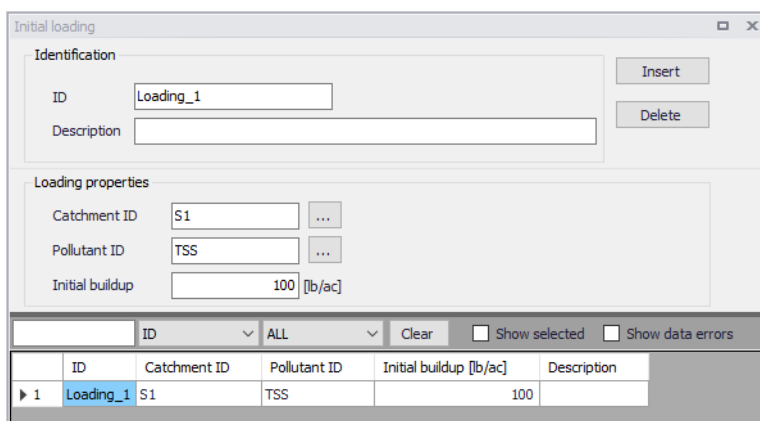


Figure 8.11 The SWMM Initial Loading editor



Table 8.7 Edit fields in the Initial Loading editor (mss\_Loading)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Initial loading setup ID	Yes	MUID
Description	Optional description of initial loading record	No	Description
Catchment ID	ID of catchment for which initial buildup is specified	Yes	CatchID
Pollutant ID	ID of pollutant	Yes	PollutantID
Initial Buildup	Amount of initial pollutant buildup	Yes	InitBuildUp

## 8.4 Coverage

Define Land Use cover percentages for Catchments on the SWMM Coverage editor. The editor organizes land use coverage data into following groups:

- **Identification.** Holds item ID information. Use the Insert or Delete buttons to add or remove records from the editor, respectively.
- **Connectivity.** Define the land use and catchment components for the coverage setup.
- **Landuse Coverage.** Specify the size covered by the land use in the catchment.

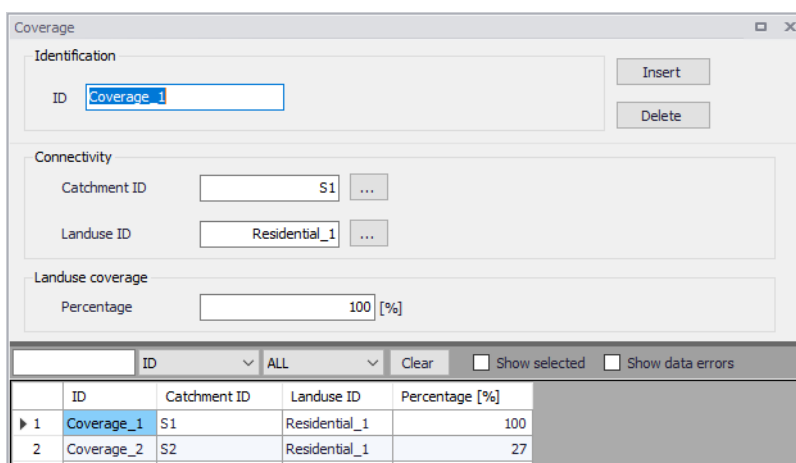


Figure 8.12 The SWMM Coverage editor



Table 8.8 Edit fields in the Coverage editor (mss\_Coverage)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	Coverage setup ID	Yes	MUID
Catchment ID	ID of Catchment	Yes	SubCatchID
Landuse ID	Landuse item ID (see Land Uses editor)	Yes	LandUseID
Percentage	Percentage of the catchment area covered by this type of land use	Yes	Percentage

## 8.5 Local Treatment

Removal of pollutants contained in the flow into a node can be modelled by assigning a set of treatment functions to the node. Treatment functions can be mathematical expression involving:

- Pollutant concentrations at the node inlet (use the pollutant name to represent a concentration)
- Removals of other pollutants (use R\_ prefixed to the pollutant name to represent removal)
- Process variables which include:
  - FLOW for flow rate into node (user's flow units)
  - DEPTH for water depth above node invert (ft or m)
  - AREA for node surface area (ft<sup>2</sup> or m<sup>2</sup>)
  - DT for routing time step (sec)
  - HRT for hydraulic residence time (hours)

The result of the treatment function can be either a concentration (C) or a fractional removal (R).

One may use the following math functions to build treatment expressions:

- abs(x) for absolute value of x
- sgn(x) which is +1 for x >= 0 or -1 otherwise
- step(x) which is 0 for x <= 0 and 1 otherwise
- sqrt(x) for the square root of x
- log(x) for logarithm base e of x
- log10(x) for logarithm base 10 of x
- exp(x) for e raised to the x power
- the standard trig functions (sin, cos, tan, and cot)
- the inverse trig functions (asin, acos, atan, and acot)





- the hyperbolic trig functions (sinh, cosh, tanh, and coth)
- standard operators +, -, \*, /, ^ (for exponentiation) and any level of nested parentheses

For example, a first-order decay expression for BOD exiting from a storage node might be:

$$C = BOD \cdot e^{-0,05 \cdot HRT} \tag{8.6}$$

while having the removal of some trace pollutant be proportional to the removal of total suspended solids (TSS) would be written as:

$$R = 0,75 \cdot R\_TSS \tag{8.7}$$

Define local treatment conditions on the SWMM Local Treatment editor. The editor organizes data into the following groups:

- **Identification.** General identification information.
- **Treatment Properties.** Local treatment parameters.

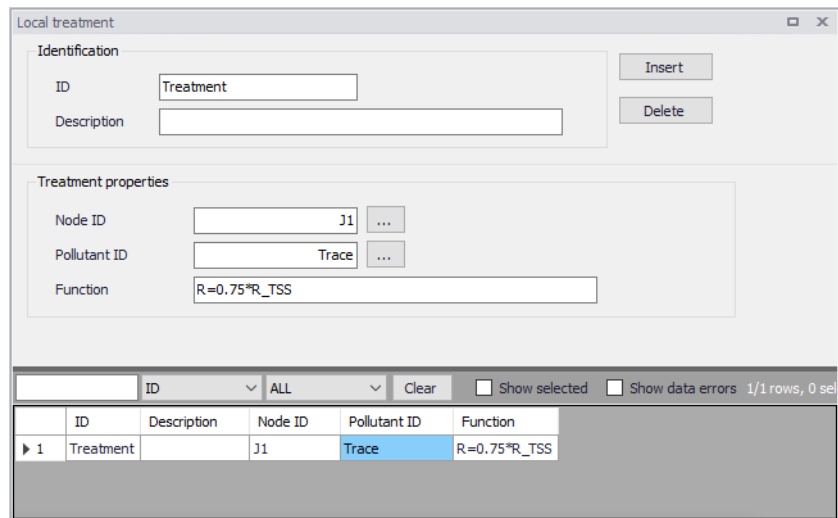


Figure 8.13 The SWMM Local Treatment editor



Table 8.9 Edit fields in the Local Treatment editor (mss\_LocalTreatment)

<b>Edit field</b>	<b>Description</b>	<b>Used or required by simulations</b>	<b>Field name in datastructure</b>
ID	Local treatment setup ID	Yes	MUID
Description	Optional description for Local Treatment item	No	Description
Node ID	ID of Node where local treatment is performed	Yes	NodeID
Pollutant ID	ID of locally treated pollutant	Yes	PollutantID
Function	Treatment expression in terms of pollutant concentration (C) or pollutant removal (R), and using other standard variables and functions	Yes	Function



## 9 Calibrations

Calibration involves reproducing the observed hydraulics and water quality behaviour of the system with the model. The process should include comparisons between model simulation results and field measurements for, but not limited to, the following:

- Flow
- Water level / Pressure / Hydraulic head
- Velocity
- Water mass balance
- Contaminant concentrations
- Contaminant migration rates
- Degradations rates

Usually, these comparisons are presented in maps, tables or plots. Calibration results must be evaluated by the modeller using engineering professional judgement, and there are no universally accepted 'goodness of fit' criteria that can be applied in all cases. However, it is important that the modeller makes every attempt to minimize the difference between model simulations and measured data.

Comparison plots of simulated and measured values may be set-up and evaluated in MIKE+. Statistical analysis may be performed to calculate goodness of fit measures. Calibration plots and statistics may be written to reports for documentation and further reporting.

### 9.1 Measurement Stations

Measurement stations representing locations of flow gauges, pressure meters, and the like may be defined in MIKE+.

One may graphically add a measurement station on the Map as well as via the Measurement Stations editor (Calibrations | Measurement Stations) (Figure 9.1).

ID	X coordinate [m]	Y coordinate [m]	Location type	Location ID	Chainage
1	708822,886005698	6165044,98065347	Nodes	Olsbaek_5225	Downstream
2	711477,237785518	6166506,63159307	Nodes	KystRenderen_960	Downstream

Figure 9.1 The Measurement Stations editor

The stations are added to the Map as a data layer providing the user an overview of monitoring locations in the model domain. Additional descriptive information about the station may also be provided on the editor.

Graphically add a measurement station on the Map using the 'Create' tool from the Edit Features toolbox on the CS Network menu ribbon, specifying 'Measurement stations' as the Target layer.

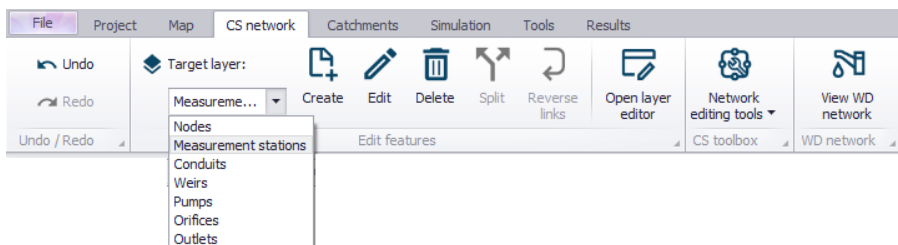


Figure 9.2 The Edit Features toolbox on the CS Network menu ribbon

Alternatively, use the layer editing tool from the Map toolbar. As with other feature layers, the 'Create', 'Edit', and 'Delete' tools are available for measurement stations.

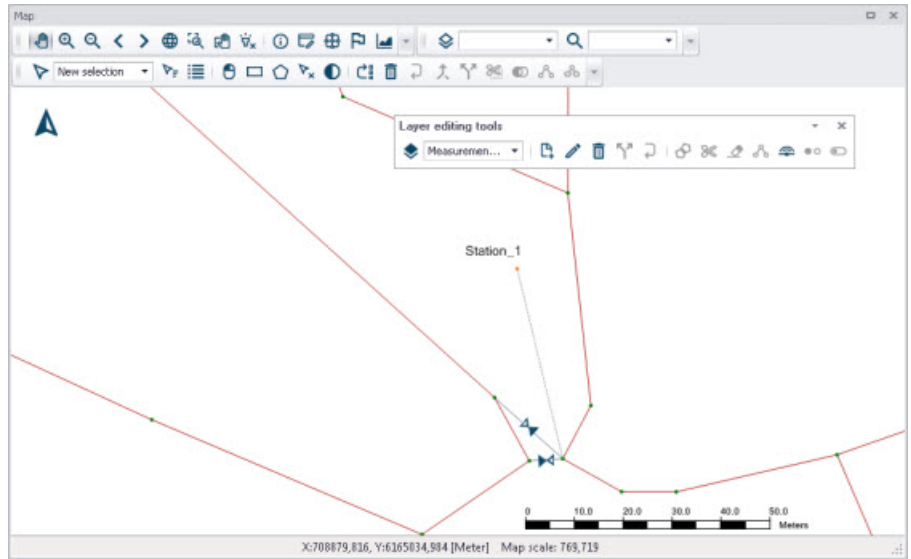


Figure 9.3 Graphically add or edit Measurement Stations on the Map using Layer Editing Tools. The example shows the creation of 'Station\_1' on the map.

The various parts of the Measurement Stations editor are described in succeeding sections.

### Identification

The Identification group box holds information on the measurement station ID and location. Use the 'Insert' button to add new measurement station records directly on the editor.



Figure 9.4 The Identification group box on the Measurement Stations editor

One may also graphically add a measurement station on the Map as previously mentioned.

### Model Connection

Measurement stations must be associated with elements of the model network to link the station with a model result item.

Associate measurement stations with specific model elements via the Model Connection tab page on the Measurement Stations editor (Figure 9.5).



Measurement stations

Identification

ID: Station\_2

X: 711477,237785518 [m]

Y: 6166506,63159307 [m]

Model connection | Measurements | Description

Model element type: Nodes

Model element ID: KystRender\_960

Chainage: Downstream

Figure 9.5 The Model Connection tab page on the Measurement Stations editor

### Model Element Type

Define the model element type to be associated with a measurement station by selecting an element type from the dropdown menu. SWMM model element types that may be linked to stations are:

- Nodes
- Conduits
- Orifices
- Pumps
- Weirs
- Outlets

### Model Element ID

Define the ID for the model element to associate with a station.

Use the ellipsis button to select the ID from a list.

Alternatively, use the cursor button to graphically select the element from the Map.

### Chainage

This option is not available/used for SWMM models as there is only one calculation point along SWMM conduits.

Note that connection lines between stations and the network are displayed on the Map after model connections are specified.

Also, on the Map View, the 'Connect station' tool from the 'Layer editing tools' toolbar may be used to connect stations to network elements. Activate the tool, click on a station feature to connect on the Map, and then select the network element to which to connect.

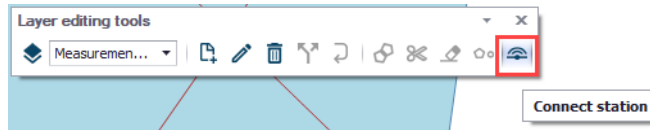


Figure 9.6 Layer editing tools on the Map

## Measurements

Define measured data time series at a station on the Measurements tab page of the editor (Figure 9.7).

Define external time series item(s) via the secondary table. Specify the time series file location under the 'File' column. A plot of the specified time series is shown to the right of the secondary table. Multiple measurement items and time series data may be defined for a station.

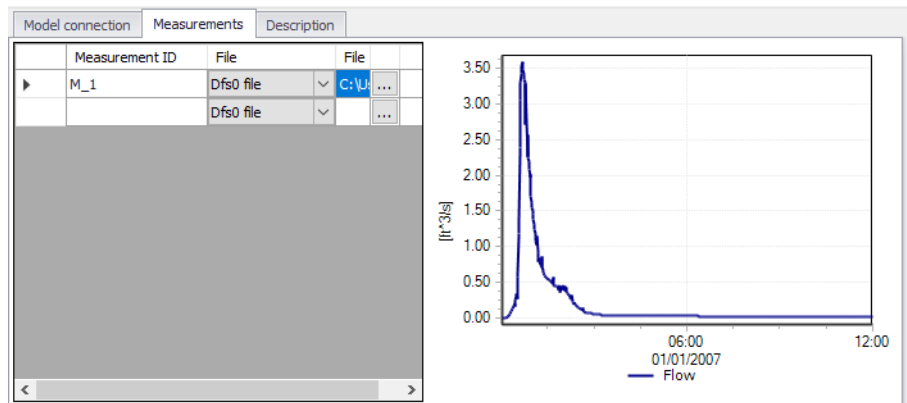


Figure 9.7 The Measurements tab page on the Measurement Stations editor

The Measurements secondary table has the following data columns:

### Measurement ID

The unique identifier for the measurement time series.

### File

Measurement time series data may be in \*.DAT or \*.DFS0 file formats.

### Item

The item to use from the time series file.

### Unit

Displays the units for the selected time series item.

### Start

Displays the start date and time for the time series.

## End

Displays the end date and time for the time series.

## Action (Edit)

Launches the Plots and Statistics editor wherein comparisons of the measured data with simulation results may be configured.

## Description

The Description tab allows the modeller to add descriptive information for the Measurement Station. An image may also be added using the 'Add picture' button.

Figure 9.8 The Description tab page on the Measurement Stations editor

Table 9.1 below shows an overview of the various parameters on the Measurement Stations editor.

Table 9.1 Edit fields in the Measurement Stations editor (m\_Station)

Edit field	Description	Used or required	Field name in data structure
ID	Station identified	Yes	MUID
X	X coordinate of the station	Yes	-
Y	Y coordinate of the station	Yes	-
Model Element Type	Type of connected model element	Yes	LocationType
Model Element ID	ID if connected model element	Yes	LocationID





Table 9.1 Edit fields in the Measurement Stations editor (m\_Station)

Edit field	Description	Used or required	Field name in data structure
Chainage	Model element grid point associated with measurements	Yes If Model Element Type = Conduits	Chainage
Description	Free text description of the measurement station	Optional	Description
Data Source	Source of data	Optional	DataSource
Asset ID	Station ID in asset database	Optional	AssetName
Status	Information on data status	Optional	Element_S
Network Type	Information on the type of network	Optional	NetTypeNo
Bottom Level	Bottom level at measurement point	Optional	BottomLevel
Model	Model group under which the station is categorised	Optional	SubModelNo

## 9.2 Plots and Statistics

The Plots and Statistics editor allows the user to make comparison plots of measured data and simulation results at measurement stations (Figure 9.9). Multiple plots and statistics setups may be created in a project.

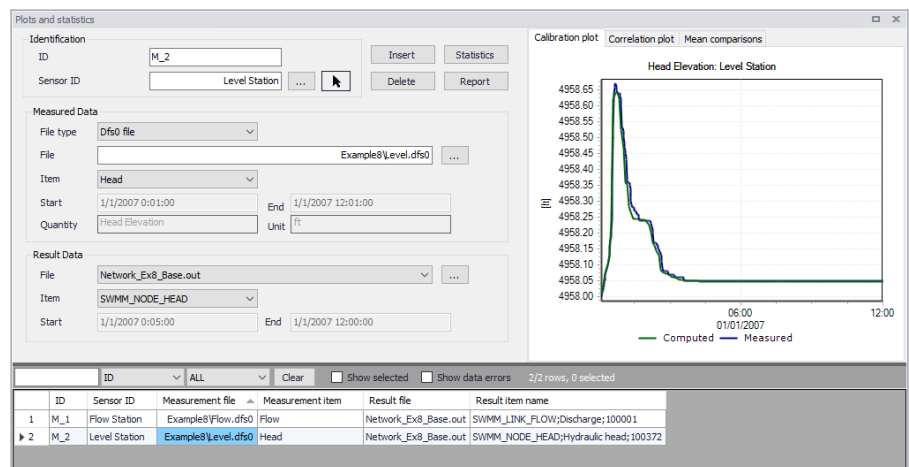


Figure 9.9 The Plots and Statistics editor

## Identification

The Identification group box contains ID and associated measurement station information for a plot and statistics setup item.

Identification

ID: M\_1

Sensor ID: Flow Station

Buttons: Insert, Statistics, Delete, Report

Figure 9.10 The Identification groupbox

The following button functionalities are available on the editor:

### Insert

Inserts a new Plot and Statistics item.

### Delete

Deletes the active Plot and Statistics item.

### Statistics

Displays various statistics parameter values, such as Mean error and RMS error, used for evaluating the comparison between simulated values and measurements.

	Measurement ID	Station ID	Number of observation	Observed mean value	Computed mean value	Mean error	RMS error
▶	M_1	Flow Station	715	0.1979536...	0.1632942...	0.0346594...	0.0048143...
	M_2	Level Station	715	4958.1035...	4958.0976...	0.0058600...	0.0006346...

Figure 9.11 Example Statistics for Plots and Statistics setup items generated from the editor

### Report

Option for exporting a report about the time series comparisons in various file formats.

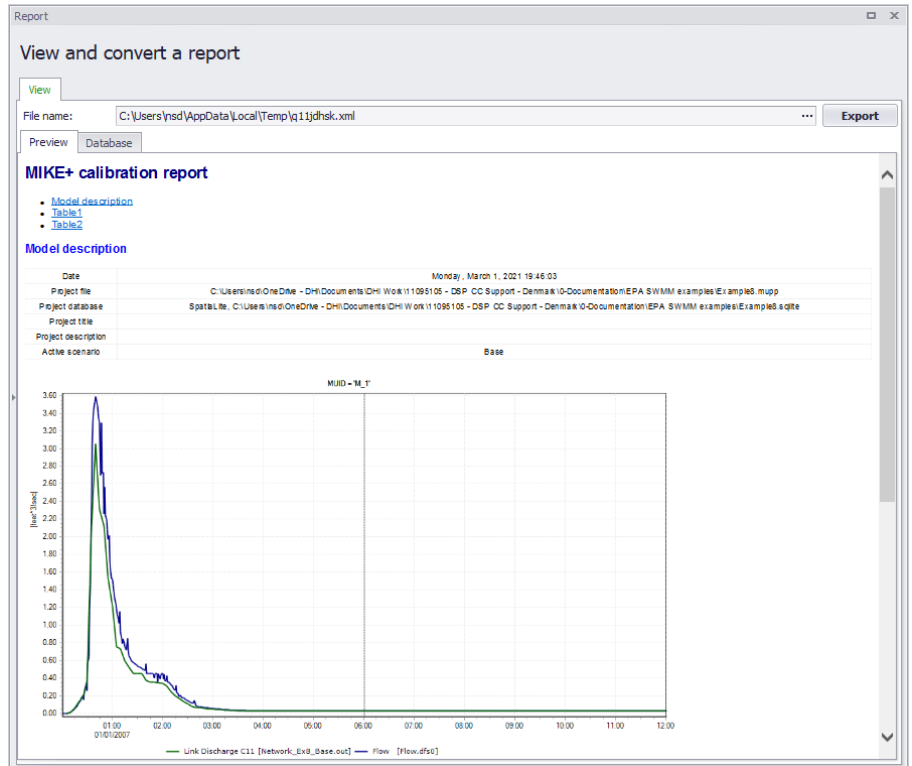


Figure 9.12 Example Report generated from the Plots and Statistics editor

## Measured and Result Data

Define the measured data item and model result item to compare for a Plot and Statistics setup.

**Measured Data**

File type: Dfs0 file

File: Example8\Flow.dfs0

Item: Flow

Start: 1/1/2007 0:01:00 End: 1/1/2007 12:01:00

Quantity: Discharge Unit: ft<sup>3</sup>/s

---

**Result Data**

File: Network\_Ex8\_Base.out

Item: SWMM\_LINK\_FLOW

Start: 1/1/2007 0:05:00 End: 1/1/2007 12:00:00

Figure 9.13 Define Measured Data and Result Data items for a plot and statistics setup on the editor



## Plots

Various plots comparing measured and model result data are presented on the right side of the editor.

### Calibration Plot

The Calibration Plot tab page shows a time series plot of measurements against simulation results.

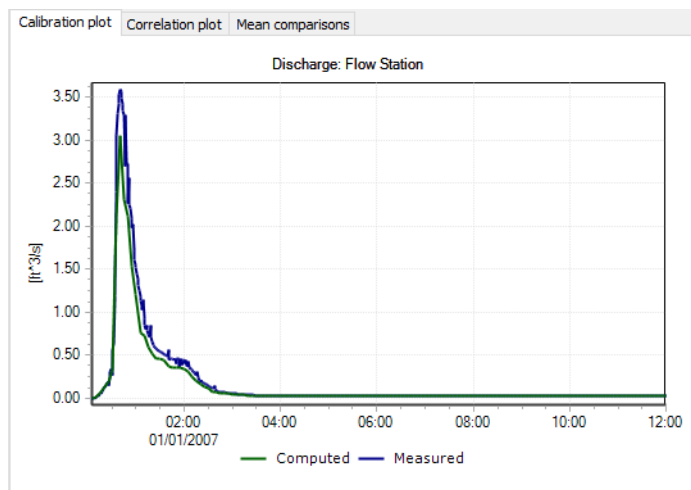


Figure 9.14 Example calibration plot

### Correlation Plot

The correlation plot shows the deviation of simulated results from observed data.

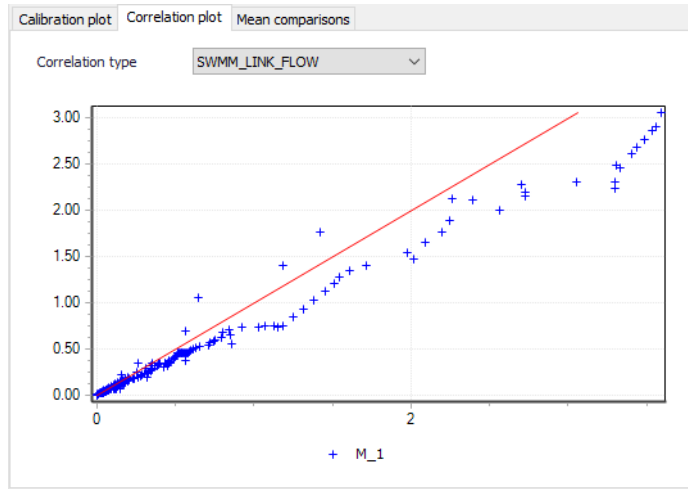


Figure 9.15 Example correlation plot

### Mean Comparisons

A bar chart plots mean measurement values against mean simulation result values for all Plots and Statistics setups on the Mean Comparisons tab page.

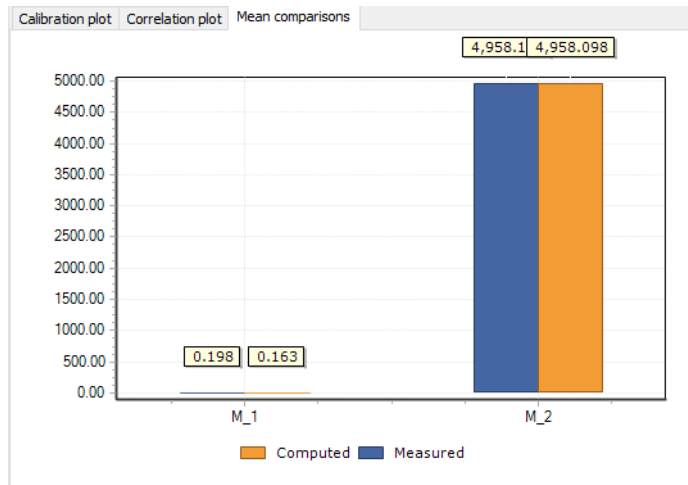


Figure 9.16 Example mean comparison plots



Table 9.2 Edit fields in the Plot and Statistics editor (m\_Measurement)

Edit field	Description	Used or required	Field name in data structure
ID	ID for the Plot and Statistics setup item	Yes	MUID
Sensor ID	The ID of the associated Measurement Station	Yes	MeasurementStationID
Measured Data			
File Type	Measurement time series data may be in .DAT or .DFS0 file formats.	Yes	-
File	External file name and path for measured time series linked to the measurement station	Yes	TSFileName
Item	Item to compare from the measured time series	Yes	TSItemName
Start	Auto filled with the time series file start time. Used to control the Start time for comparison	Yes	-
End	Auto filled with the time series file end time. Used to control the End time for comparison	Yes	-
Quantity	Displays item name for selected item from measurement time series	Yes	-
Unit	Displays units used for selected item from measurement time series	Yes	-
Result Data			
File	Result file name and path	Yes	ResFileName



Table 9.2 Edit fields in the Plot and Statistics editor (m\_Measurement)

<b>Edit field</b>	<b>Description</b>	<b>Used or required</b>	<b>Field name in data structure</b>
Item	The result file item being compared to measurements	Yes	ResItemName
Start	Displays simulated result time series start date and time	Yes	-
End	Displays simulated result time series end date and time	Yes	-







## 10 Scenarios

Water distribution and collection system models are commonly used for system performance analysis and planning studies. The complexity of the involved systems, the various uncertainties about future conditions, and usually huge costs associated with maintenance, rehabilitation, and development necessitate a thorough investigation of alternative system configurations in the search for a technically feasible, environmentally sound, and economically efficient solution.

These alternative configurations - scenarios - may differ by system physical layout, loading conditions, operational strategies, etc. Various projects, such as development of a Sewerage Master Plan, Wastewater Transportation Strategy, an Overflow Abatement Strategy, and the like, would typically result in a large number of scenarios, either representing alternative system configurations at a given time and/or representing the system at various development stages. Testing of each scenario against the prescribed legislation or the standards of service that the authorities provide requires a numerical model each.

These scenarios are always related to each other through the common origin ('Existing Case' or 'Base') and the differences typically involve only a part of the total data. Moreover, scenarios representing a development of the system through time are subject to the dependencies propagating along the time line.

Analysis of the scenarios as separate projects creates major inconveniences, such as:

- Large number of models, even when differences between them are minor
- Missing an efficient overview over the entire set of solutions
- Inability to maintain the existing dependencies between the individual scenarios automatically. Thus, the updating of the models with additional information requires editing of multiple files to change the same element, e.g. if a pipe diameter is found to have been incorrectly registered in the GIS database, it will have to be updated multiple times in each of the scenario project file
- Unable to easily visualise differences between scenarios

In other words, working with the scenarios as separate projects is inefficient and cumbersome.

Instead, the MIKE+ Scenario Manager provides an easy way of managing multiple scenarios within a single MIKE+ project (i.e. a single database).



## 10.1 What is Scenario Manager?

The MIKE+ Scenario Manager is accessed via the Scenarios sections on the Setup tree.

The Scenario Manager enables the definition, organisation, management and reporting of alternative model scenarios, such as:

- Augmentation of existing trunk sewer mains
- Increased wastewater loading from increased population
- Increased water demands from increased population
- Alternative design loads, e.g. rainfall-runoff of different return period
- Alternative/new alignment of water, sewer and storm mains
- Building of a new sewer trunk and water supply mains in order to cater for a new development area

all within the same MIKE+ project.

With the MIKE+ Scenario Manager, a user can work with an unlimited number of scenarios in a single MIKE+ project.

## 10.2 Design of the MIKE+ Scenario Manager

### 10.2.1 Data Groups, Alternatives, and Scenarios

The MIKE+ Scenario Manager is based on the concept of Data Groups, Alternatives and Scenarios.

In this context, a Data Group is a set of database tables comprising a model component. For example, all database tables containing collection system network data belong to the data group Network Data. Every database table relevant for the scenario manager is included in one of the Data Groups.

Each Data Group can appear in the MIKE+ project in any number of Alternatives. The initial alternative is named 'Base' by default. Any further alternatives are created upon user request and can have a user-specified name. The Alternatives for a certain data group are organised in a tree-like structure, where dependencies propagate along the branches - from the "parent" to all the "heirs" i.e. "child" alternatives.

A scenario contains a collection of one alternative from each Data Group. Individual alternatives are used as building blocks for constructing scenarios. For example, modelling a new development area could have new alternatives for Network, Loads and boundaries and Catchments and hydrology data groups, while the remaining data groups remain as the base case. A moderate number of data groups (6 for SWMM, 7 for CS, 5 for WD) allows for a manageable structure of scenarios while ensuring a high level of flexibility.

The initial 'Base' scenario consists of the 'Base' alternative of each data group. Any further scenarios are created upon user request and can have a



user-specified name. The scenarios can be organised in a tree-like structure of "parents" and "children". A new scenario is created in the Setup menu by right clicking on a scenario (e.g. Base) and selecting 'Create child scenario' from the context menu. Select the new scenario and tick on the relevant alternatives for the selected scenario.

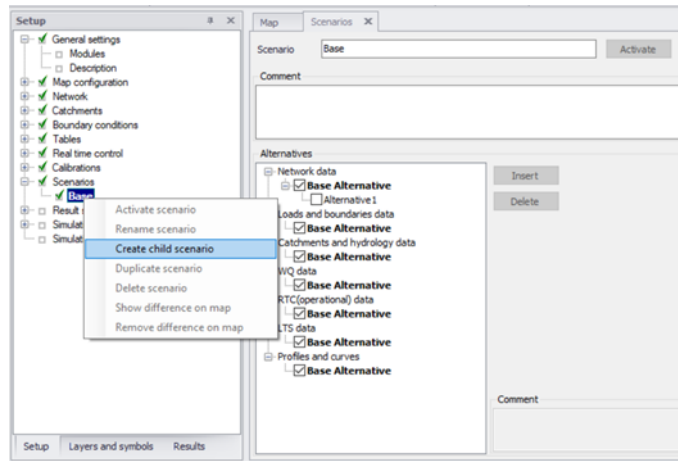


Figure 10.1 Create a new scenario by right clicking on an existing scenario (e.g. Base) and selecting 'Create child scenario'

Click on the Activate button to modify the database for this collection of alternatives.

## 10.2.2 Alternatives

As described in the previous section, alternatives represent components of scenarios. The various alternatives contain the actual data belonging to a certain data group. Each subsequent alternative only contains information on the differences relative to its immediate "parent", while the rest of the data is inherited from the "parent" through the principles of inheritance.

Grouping of various alternatives belonging to different data groups into scenarios is sometimes subject to limitations because the data groups have not been formed on the basis of data dependency but rather following the logical data grouping, recording differences according to hierarchy. E.g. An alternative of the Catchment connections CS data group, which specifies a catchment connection to node 'A', cannot be used with the alternative of the Network data data group where node 'A' has been renamed or deleted. Obviously, the catchment would remain disconnected. It is therefore prudent to plan the scenarios and alternatives before commencing a project, where possible.



## SWMM Network Alternatives

For SWMM Networks, the following data groups are available for creating scenarios:

- Network data
- RTC (operational) data
- Loads and boundaries data
- Profiles and Curves
- WQ data
- Catchments and hydrology data

## CS Network Alternatives

For CS Networks, the scenarios are composed of the following data groups:

- Network data
- Loads and boundaries data
- Catchments and hydrology data
- WQ data
- RTC (operational) data
- LTS data
- Profiles and Curves

## WD Network Alternatives

For Water Distribution Systems input data for scenarios are grouped in the following way:

- Network data
- Water demands
- Control data
- WQ data
- Patterns and Curves

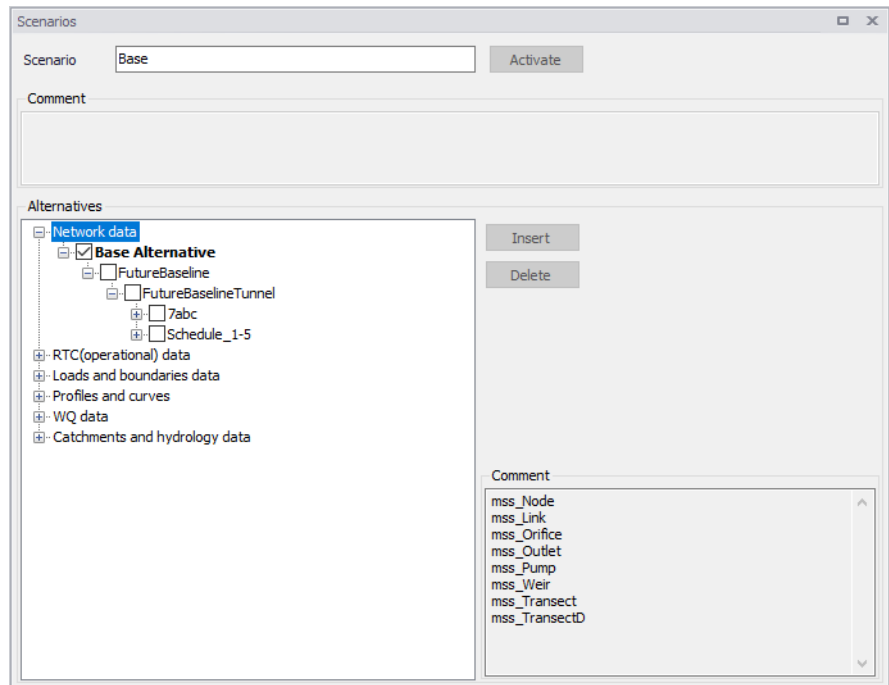


Figure 10.2 Click on a Data Group to see the relevant database tables on the bottom right of the screen. E.g. Network data for SWMM networks

Simply select an alternative and click on the button Insert in the scenario manager to create a new alternative that is a "child" of the alternative directly above it.

### 10.2.3 Base Data vs. Child Data

When the scenario manager is activated for the first time, the system automatically provides 'Base' alternatives for each data group. The 'Base' data contains the original model database and is the "trunk" for all the alternative branches.

A 'Base' alternative for any data group can be empty if no data are specified in any of the tables belonging to this data group. E.g. no operational data may be specified thus leaving the RTC (operational) data 'Base' alternative empty. So, although the RTC (operational) data is a part of the 'Base' scenario, it does not necessarily mean that any operational data are specified. It is possible to add a 'child' to the RTC (operational) data 'Base' alternative containing operational data and include this alternative in a new scenario. This way, the scenario containing operational data can be tested and the reports of the changes will reflect that the operational data have been changed in the 'child'.

There may be many reasons for adding child alternatives. E.g. it can be for testing the performance of the system if the diameters for certain pipes are



increased, testing the effects of population growth, or testing the effects of applying different real time control strategies.

After making a scenario active (click on the Activate button on the editor) all the alternatives that are a part of the scenario are automatically activated and the scenario may be edited. Changes made to the database will be recorded within the alternative for each data group as differences to the parent alternative. If a base alternative is active, the main database will be modified (not recorded as a difference).

## 10.2.4 Inheritance Principles

With the inheritance from 'parent' alternatives to 'child' alternatives, some considerations must be kept in mind.

- Making a change to an alternative will affect all descendent ('child') alternatives of that alternative. This means that it will impact all the scenarios where either the alternative or the children of that alternative are applied. The benefit of this feature is that it ensures that if one value needs updating it will be updated in all the scenarios where the alternative is applied (e.g. if a pipe diameter is found to have been incorrectly registered in the GIS data during the course of a project then the pipe diameter can be changed one place only, regardless of the number of scenarios and alternatives that reference to this alternative).
- The chain of inheritance for a certain data record stops where any change (or deletion) of that element has occurred in earlier work. E.g. if a bottom level of a node 'A' has been edited in a child alternative, a later update of the bottom level in the 'Base' will only propagate through the alternative tree until it reaches the alternative containing the first change.
- Adding an element (e.g. a node) in the 'parent' with an ID that already exists in one or more of its descendants ('children') will overwrite the content of the 'child' element
- If adding an element (e.g. pump) in the parent that cannot be added to all the children (because some parts may have been deleted/changed there), the element is added where possible and omitted elsewhere.

## 10.2.5 Data not Specific to any Alternative/Scenario

There are some data tables which are not included in the Scenario Manager.

These are typically tables containing data of general usability, i.e. data without a reference to the current network. For example, in MIKE+ CS these include cross sections, parameter sets, etc. These data should be understood as belonging to a general project database.



There are some single record tables containing various parameters (e.g. water quality parameters) that are not part of the Scenario Manager in order to allow the application of various parameters within the same project.

The data not included in the Scenario Manager can be accessed from any scenario regardless of the alternatives that make up that specific scenario.

Please note that the computed values are not part of Scenario Manager (all fields ending with \_C) and are not automatically re-computed after switching scenarios.

## 10.3 Managing Scenarios and Alternatives

The Scenario Manager involves:

- The Scenarios section in the Setup tree view
- The Alternatives section on the Scenarios editor

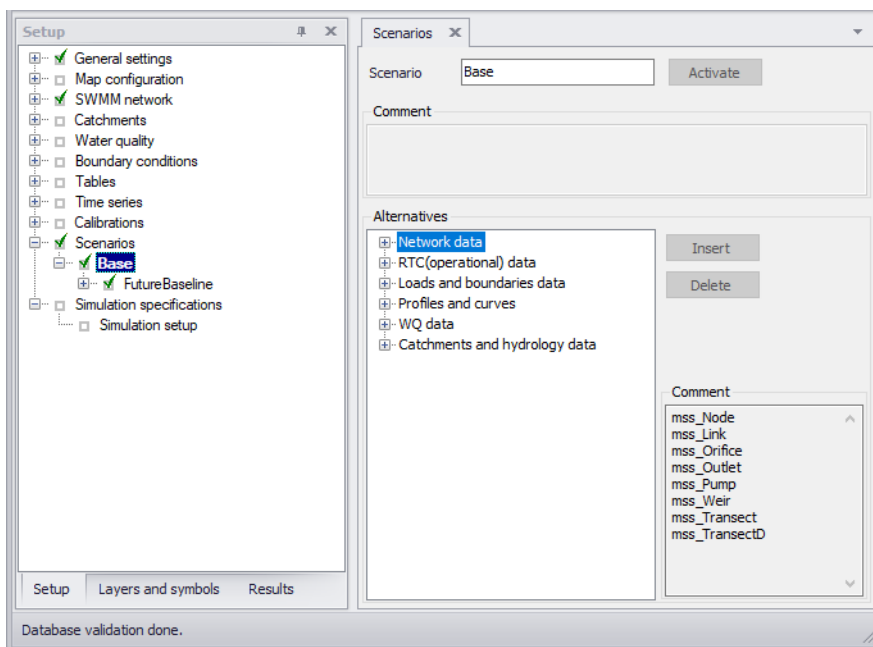


Figure 10.3 The Scenarios section in the Setup tree on the left panel and the Alternatives window on the Scenarios editor.

### 10.3.1 Scenarios

The scenarios section is used for creating, editing, and managing scenarios. There is one built-in scenario, i.e. the Base scenario, by default. The Base scenario cannot be edited nor deleted.

But an unlimited number of additional scenarios can be added.

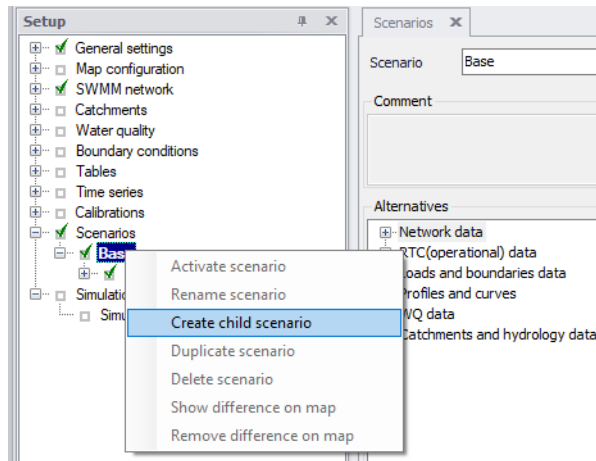


Figure 10.4 Scenario options are visible via the context menu

The context menu (i.e. right click) on a scenario offers various options for creating scenarios.

### Activate Scenario

The activate scenario option will load the scenario, i.e. the project data is manipulated so that all editors contain the appropriate data corresponding to the collated alternatives for the scenario. Depending on the size of the project this may take some time.

### Rename Scenario

The rename scenario button will make the scenario name active so it can be easily renamed.

### Create Child Scenario

The create child scenario option adds a scenario that is a child of the selected scenario (not to be confused with the active/current scenario), i.e. to begin with, the alternatives of a new scenario will be that of the selected scenario. A name for the new scenario is suggested by default. The name can be changed by using the rename scenario option.

### Duplicate Scenario

The duplicate scenario option will make a copy of the selected scenario. This means that all the alternatives that make up the original scenario will be transferred to also be applied to the new scenario. Once the new scenario has been made, the original and the duplicate scenario are edited independently of one another.





### Delete Scenario

The delete scenario option will remove the selected scenario. The Base scenario cannot be deleted. Note that deleting a scenario will not delete any data as the alternatives hold the data (the scenarios just refer to alternatives). The comments for the scenario being deleted, however, will also be deleted.

### Show Difference on Map

The show difference on map option is very useful to graphically display differences between scenarios. Differences are shown on the map view with a color code and will show differences between the activated scenario and the selected scenario.

## 10.3.2 Alternatives

Alternatives can be edited only once the corresponding scenario is activated.

Alternatives can, however, be added to the tree view in the manager regardless of the active scenario. When a scenario is loaded, the project data is manipulated so that all editors contain the appropriate data corresponding to the alternatives for the scenario.

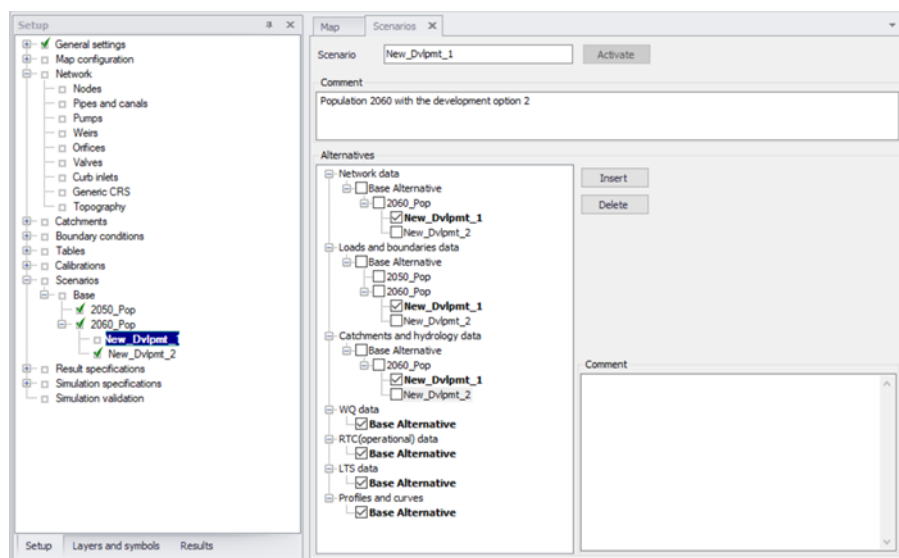


Figure 10.5 Selected scenario with corresponding alternatives ticked on and in bold.

The alternatives part of the dialog has two buttons: Insert and Delete on the right side.

The alternatives that correspond to the selected scenario are ticked in the alternatives tree. The alternatives available for editing in the MIKE+ tables are displayed in bold.



### Insert

The insert button adds an alternative that is a child of the selected alternative (not to be confused with the active/current alternative). A name for the new alternative is suggested per default. Rename an alternative by clicking on the alternative name.

### Delete

The delete button will remove the highlighted alternative. The alternatives must be deleted by starting at the end of the trees until the root is reached (the alternatives can only be deleted one by one starting from the latest child). The Base alternative cannot be deleted. Remember: Deleting an alternative will delete the changes made to that alternative.

## 10.3.3 Scenario Simulation

To run a simulation for a particular scenario, it is necessary to:

- Activate the relevant scenario. This is done by selecting the scenario in the Setup view, scenarios section, and then clicking the Activate button available in the Scenarios editor.
- Insert a new simulation. Define a new simulation setup via the Simulation Setup editor. Click on the Insert button to insert a new simulation setup item. The active scenario will automatically be the Scenario for the new simulation setup.
- Define the required fields for the simulation setup.
- Run the simulation. Once a simulation setup is created, it can be run for the Scenario, even when the active scenario is changed. i.e. when the simulation is run, MIKE+ will automatically activate the relevant scenario and run the model. In this way, multiple scenario simulations can be set up and run.

## 10.3.4 Example

To investigate how upsizing certain pipes and adding some real time control can affect the performance of the system, start by making two child alternatives: one for the network data (as the pipes are a part of this alternative) and one for the RTC (operational) data (as the real time control is a part of that alternative).

Then, create a scenario that applies the new network alternative and the new operational data alternative and then activate this scenario. Start editing the data in the MIKE+ tables (e.g. upsizing the pipes and adding real time control).

Once the data is edited, insert a new simulation to correspond to the active scenario. Run the model and compare the results to the original setup to see the effect of the changes.



You can also choose to make a new scenario that contains e.g. the network alternative (but not the operational data alternative), to see what change in performance the pipe upgrades alone will have.

### 10.3.5 Reporting Changes

When setting up multiple alternatives and scenarios, it is important to keep track of the changes that have been done. The Model and Result Report tool can be used to track and document changes made between scenarios.

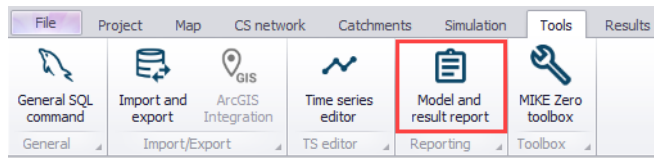


Figure 10.6 The Model and Result Report tool on the Tools menu ribbon

Access the Model and Result Report tool from the MIKE+ Tools menu ribbon.

On the Model and Result Report tool dialog, create a New template.

On the Content tab page of the dialog, select the items to be compared under the Scenario section. Click on Run to perform the comparison.

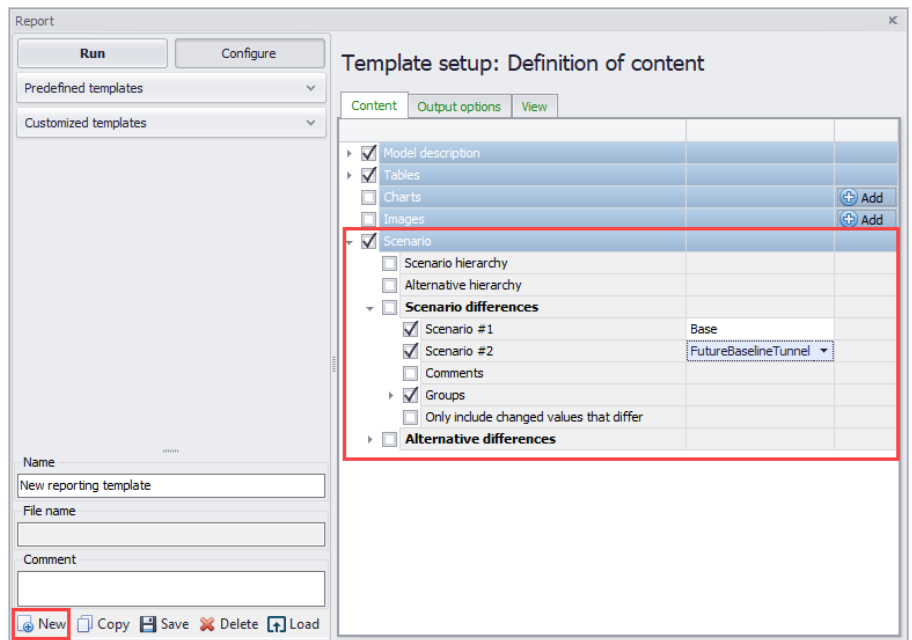


Figure 10.7 The Model and Result Reporting tool can be used to keep track of scenarios and alternatives.



All reports can be produced in color or in black/white. The reports are in XML format but can be imported into a Word document. (Refer to the MIKE+ Model Manager User Guide chapter on *Reports* for further details.)

The table can be exported to a variety of formats. E.g. Word, Excel, \*.PDF, \*.XML ,etc. The report style may be the default 'MURReport' format, or an imported style.

Within a report, color coding is used to signify the origin/status of the record:

- White: Original record, no changes
- Green: Record added
- Yellow: Record has been changed (updated)
- Red: Record has been deleted

### Scenario hierarchy

Will create a table with scenario IDs, active scenario, parent of the scenario and comments.

### Alternative hierarchy

Will create tables for each data group with alternative IDs, active alternative, the parent alternative, a comment, and the scenario to which the alternative is associated.

### Scenario differences

Scenarios #1 and #2 are compared to each other, selected from a drop-down list of all the scenarios in the model. Comments in the scenario specification can be included in the comparison as an option. To limit the comparison, specific data groups may be selected and whether or not to present a comparison of everything in a report or 'Only include changed values that differ' between scenarios.

### Alternative differences

When comparing two different alternatives, the data group to be compared must be chosen from a drop-down list of all data groups. Then two alternatives from within the specified data group can be selected to be compared to each other, selected from a drop-down list of all the alternatives within the data group. Comments in the alternative specification can be included in the comparison as an option and a choice can be made whether or not to present a comparison of everything in a report or 'Only include changed values that differ' between alternatives.

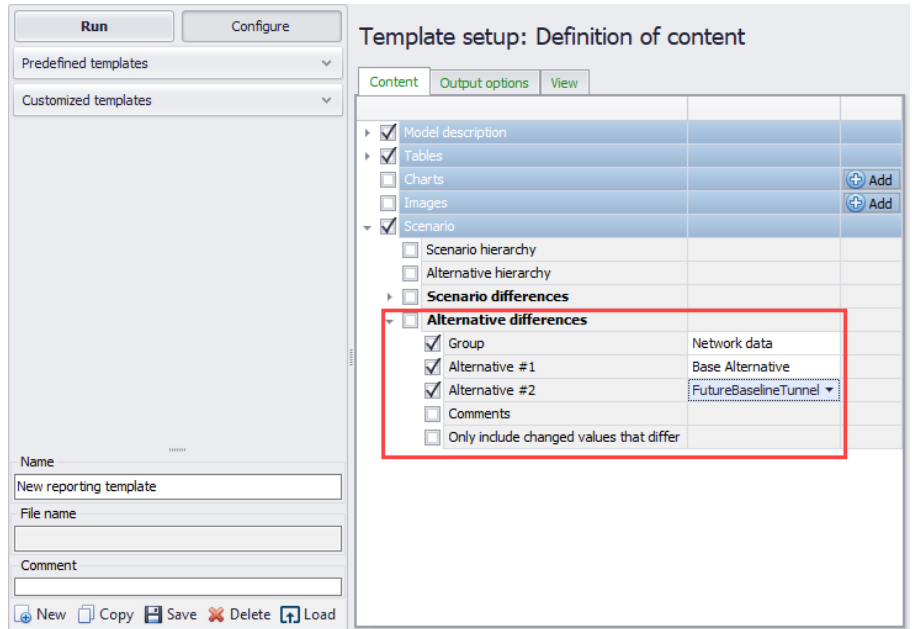


Figure 10.8 Reporting differences between Alternatives using the Model and Result Report tool

### 10.3.6 Show Differences on the Map

The 'Show difference on Map' option, accessed by right clicking on a Scenario ID in the Setup view is useful to graphically display the differences between two scenarios.

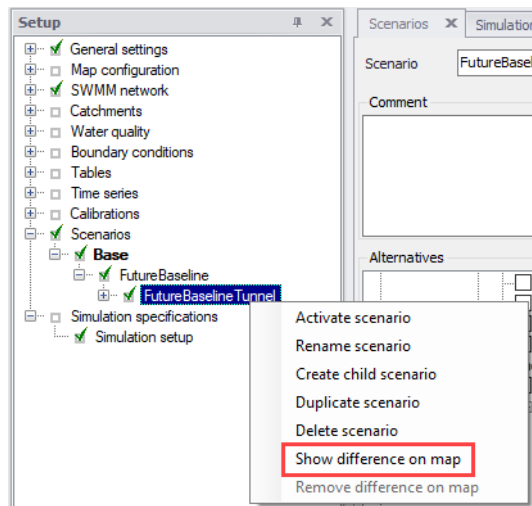


Figure 10.9 Option to show scenario differences on the Map

Color coding is used to signify the origin/status of the record:

- White: Original record, no changes
- Green: Record has been changed (updated)
- Yellow: Record added
- Red: Record has been deleted

The example below presents network differences between scenario '2060' (active scenario) and the 'Base' (font in light green).

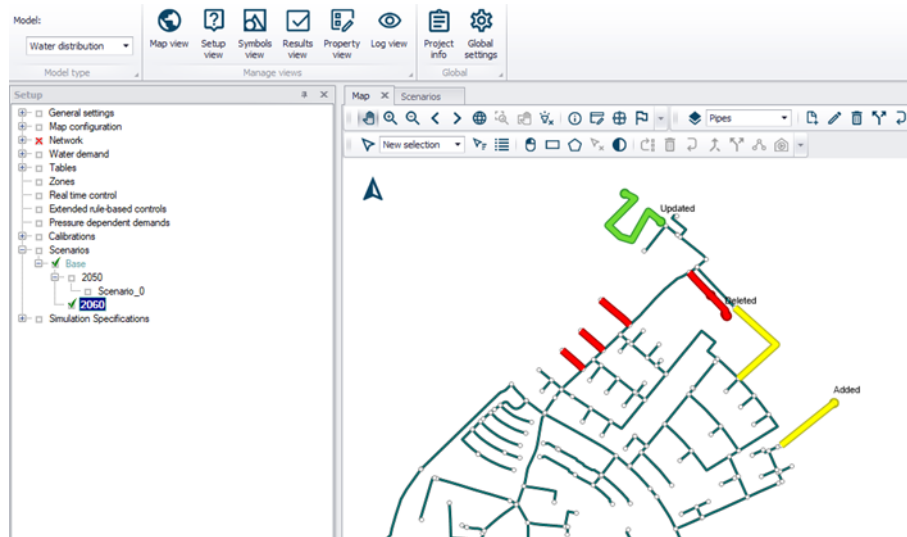
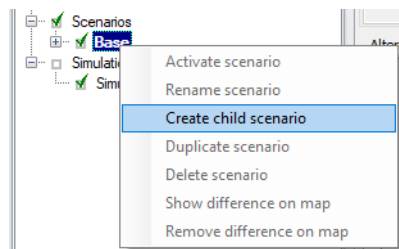


Figure 10.10 Graphical display presenting the differences between scenarios

## 10.4 Step-by-Step Guide to Creating Scenarios

1. Go to the Scenarios section on the Setup tree.
2. Create a child scenario by right clicking on an existing scenario and selecting the 'Create child scenario' option from the context menu.



3. On the Scenarios editor, select the alternative group to which to add an alternative and click on the 'Insert' button.





alternatives that relate to the active scenario are also displayed in bold in the list of alternatives.



7. Edit the model, making sure to edit only data from tables associated with the new activated alternatives.
8. Create a new simulation for the active scenario in the Simulation Setup editor.
9. Run the new scenario and compare results from other scenarios.





## 11 SWMM Simulation Specifications

SWMM model simulations are launched from the Simulation Setup editor, where combinations of different types of simulations may be defined.

The Simulation Setup editor has several tabs, which are relevant depending on the features and functionalities defined in the project:

- **General.** Includes general parameters, such as definition of the simulation period, selection of simulation types, and free text description of the simulation setup.
- **Catchments.** Includes parameters specific for Runoff simulation.
- **HD.** Includes parameters specific for HD simulation.
- **Dynamic Wave.** For defining parameters specific for Dynamic Wave flow routing computations.
- **Water Quality.** Includes parameters specific for water quality simulations.
- **Reporting.** Used for specifying results (output) to be generated by the simulation.

ID	Scenario	Active simulation	Rainfall runoff	Rainfall dependent I/I	Snow melt	Groundwater
1	Simulation 1	Base	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2	Sim 12	Base	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Figure 11.1 The SWMM Simulation Setup editor

The Identification group at the top and the scrollable grid table at the bottom of the editor are common across all tabs.



Table 11.1 Edit fields in the Simulation Setup Identification group (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
ID	User-specified ID of simulation. ID will be reflected in the name of result files	Yes	MUID
Scenario	Dropdown menu for selecting ID of related Scenario for the simulation	Yes	ScenarioName

The following buttons are also located at the top of the editor with the Identification group:

#### Insert

Inserts a new record in the Simulation Setup editor with a default unique MUID.

#### Copy

Duplicates an existing (currently active) simulation setup record.

#### Delete

Deletes a currently active simulation record.

#### RUN

Triggers export of the current simulation job and execution of the simulation.

## 11.1 General

The General tab page presents parameters relevant for the simulation setup. The following parameters are specified in the General tab:

- **Process Models.** Define the process models to be included in the simulation.
- **Simulation Period.** Period covered by the simulation.
- **Description.** Optional description for the simulation setup.

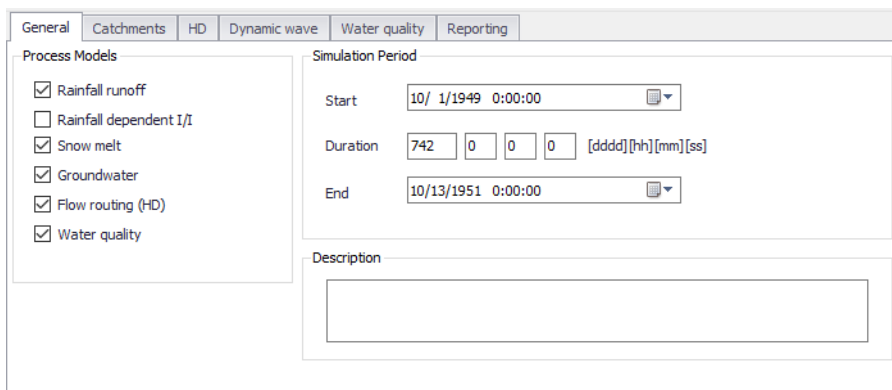


Figure 11.2 The SWMM Simulation Setup editor General tab

An overview of the editor fields and corresponding database attributes is provided in Table 11.2 below.

Table 11.2 Edit fields in the Simulation Setup General tab page (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
Rainfall Runoff	Surface runoff	Yes	UseRRNo
Rainfall Dependent I/I	Infiltration modelling	Yes	UseRDNo
Snowmelt	Snowmelt as part of surface runoff modelling	Yes	UseSMNo
Groundwater	Groundwater modelling	Yes	UseGWNo
Flow Routing (HD)	Network flow routing through conduits	Yes	UseFRNo
Water Quality	Water quality routing through conduits	Yes	UseWQNo
Start	Specifies start date and time for the simulation.	Yes	ComputationBegin



Table 11.2 Edit fields in the Simulation Setup General tab page (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
Duration	Displays the duration of the simulation in days, hours, minutes and seconds. Automatically adjusted based on Start and End time/date. May be edited, adjusting End date/time accordingly.	Yes	-
End	Specifies end date and time for the simulation. Adjusted automatically according to user's specification of duration.	Yes	ComputationEnd
Description	Free text description of the simulation setup	Optional	Description

## 11.2 Catchments

The following parameters can be specified on the Catchments tab page:

- **Runoff Time Step.** Runoff simulation time step.
- **Infiltration Model.** Infiltration method to use for the simulation.
- **Runoff Interface Files.** Options for specifying the use or saving of Interface Files for the simulation.



Figure 11.3 The SWMM Simulation Setup Catchments tab page

Table 11.3 Edit fields in the Simulation Setup Catchments tab page (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
Time Step			
Dry Weather Days Runoff Step	Time step length in days used for runoff computations (consisting essentially of pollutant buildup) during periods when there is no rainfall and no ponded water at junctions	Yes	RS_DryDay
Dry Weather Hr:Min:Sec Runoff Step	Time step length in hours/minutes/seconds during periods with no rainfall nor ponded water at junctions	Yes	RS_DryTime
Wet Weather Days Runoff Step	Time step length in days used to compute runoff from catchments during rainfall, or when ponded water still remains on the surface, or when LID controls are still infiltrating or evaporating runoff.	Yes	RS_WetDay



Table 11.3 Edit fields in the Simulation Setup Catchments tab page (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
Wet Weather Hr:Min:Sec Runoff Step	Time step length in hours/minutes/seconds used to compute runoff from catchments during rainfall, or when ponded water still remains on the surface, or when LID controls are still infiltrating or evaporating runoff.	Yes	RS_WetTime
<b>Infiltration Model</b>			
Horton	Horton infiltration method	No	InfiltrationModelNo
Green Ampt	Green-Ampt Infiltration method	No	InfiltrationModelNo
Curve Number	SCS Hydrology - or curve number method	No	InfiltrationModelNo
Modified Horton	Modified Horton infiltration method	No	InfiltrationModelNo
Modified Green Ampt	Modified Green-Ampt infiltration method	No	InfiltrationModelNo
<b>Runoff Interface Files</b>			
Rainfall Data	Option to use or save rainfall data file	No	RainfallFileNo
Use	Option to read information from already created rainfall data file	Yes If RainfallFileNo = 1	RainfallFileUseSaveNo = 1
Save	Option to a Rainfall data file	Yes If RainfallFileNo = 1	RainfallFileUseSaveNo = 2
(Rainfall data file input box)	Rainfall data file name	Yes If RainfallFileNo = 1	RainfallFileName
Save Runoff data	Option to save runoff data file	No	RunoffFileSaveNo
(Runoff data file input box)	Runoff data file name	Yes If RunoffFileSaveNo = 1	RunoffFileSaveName



Table 11.3 Edit fields in the Simulation Setup Catchments tab page (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
Save RDII Data	Option to save RDII data file	No	RDIIFileSaveNo
(RDII data file input box)	RDII data file name	Yes If RDIIFileSaveNo = 1	RDIIFileSaveName

## 11.3 HD

The HD tab page holds parameters related to hydrodynamic network computations. The parameters are organized into the following groups:

- **Routing Model Settings.** Parameters related to method for routing flows through the network.
- **Network Interface Files.** Options for specifying the use or saving of Interface Files for the network HD simulation.

The screenshot displays the 'HD' tab in the SWMM Simulation Setup editor. It features several configuration sections:

- Routing Model:** Radio buttons for 'Steady flow', 'Kinematic wave', and 'Dynamic wave' (selected).
- Steady Flow Periods:** A checkbox for 'Skip steady flow periods' and two input fields for 'System flow tolerance' and 'Lateral flow tolerance', both set to 5 [%].
- Time Step:** Input fields for 'Routing step' (15 [sec]) and 'Control rule step' (00:00:00).
- Routing Options:** A checked checkbox for 'Allow ponding' and an input field for 'Minimum conduit slope' (0 [%]).
- Network interface files:** A grid of checkboxes and file selection buttons for 'Save hotstart data', 'Use hotstart data', 'Use inflow data', 'Save outflow data', 'Use RDII data', and 'Use runoff data'.

Figure 11.4 The SWMM Simulation Setup editor HD tab page



Table 11.4 Edit fields in the Simulation Setup HD tab page (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
Routing Model	Choice of model to use for flow routing through the network: Steady Flow Kinematic Wave Dynamic Wave	Yes	RoutingModelNo
Routing Step	Flow routing time step	Yes	RoutingStep
Control Rule Step	Time step length used for evaluating control rules. A value of 0 means controls are evaluated every routing time step.	Yes If Controls are used	ControlRuleStep
Skip Steady Flow Periods	Option to make SWMM keep using the most recently computed conveyance system flows during identified steady flow periods instead of computing a new flow solution. Using this feature can help speed up simulation run times at the expense of accuracy.	Yes	SkipSteadyFlow-PeriodNo
System Flow Tolerance	Threshold for percent difference between total system inflow and total system outflow used to identify steady flow periods	Yes If SkipSteadyFlow-PeriodNo = 1	SysFlowTolerance





Table 11.4 Edit fields in the Simulation Setup HD tab page (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in datastructure
Lateral Flow Tolerance	Threshold for percent differences between the current lateral inflow and that from the previous time step for all points in the conveyance system used to identify steady flow periods	Yes If SkipSteadyFlow-PeriodNo = 1	LatFlowTolerance
Allow Ponding	Option to allow excess water to collect atop nodes and re-enter the network when hydraulic capacity is regained. The size of the surface area for ponding is a parameter for the junction	Yes	AllowPondingNo
Minimum Conduit Slope	The minimum value allowed for a conduit's slope (%)	Yes	MinConduitSlope
<b>Network Interface Files</b>			
Save Hotstart Data	Option to create a hotstart file from the simulation	No	HotstartFileSaveNo
Use Hotstart Data	Option to read information from an existing hotstart file	No	HotstartFileUseNo
Use Inflow Data	Option to read information from Inflow file	No	InflowFileUseNo
Save Outflow Data	Option to create Outflow interface file from the simulation	No	OutflowFileSaveNo
Use RDII Data	Option to read information from existing RDII interface file	No	RDIIFileUseNo
Use Runoff Data	Option to read information from existing Runoff interface file	No	RunoffFileUseNo



## 11.4 Dynamic Wave

Define parameters that control how the dynamic flow routing computations are made in the Dynamic Wave tab page of the Simulation editor. These parameters are only relevant if the Routing Model is set to Dynamic Wave on the HD tab page of the editor (see Chapter 11.3 HD (p. 247)).

The screenshot shows the 'Dynamic wave' tab in the SWMM Simulation Setup editor. The parameters are as follows:

- Inertial terms: Partial
- Normal flow criterion: Slope & Froude
- Force main equation: Hazen-Williams
- Surcharge method: Extran
- Use variable time steps adjusted by:  75 [%]
- Minimum variable time step: 0.5 [sec]
- Time step for conduit lengthening: 15 [sec]
- Minimum nodal surface area: 19.64 [ft<sup>2</sup>]
- Maximum trials per time step: 8
- Head convergence tolerance: 0.005 [ft]

Figure 11.5 The SWMM Simulation Setup editor Dynamic Wave tab page

Table 11.5 Edit fields in the Dynamic Wave tab page of the Simulation Setup editor (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in data structure
Inertial Terms	Indicates how the inertial terms in the St. Venant momentum equation will be handled: None Partial Full	Yes	InertialTermNo
Normal Flow Criterion	Basis used to determine when supercritical flow occurs in a conduit: Slope Froude Slope & Froude	Yes	NormalFlow-CritNo



Table 11.5 Edit fields in the Dynamic Wave tab page of the Simulation Setup editor (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in data structure
Force Main Equation	Equation for computing friction losses during pressurized flow for conduits that have a Circular Force Main cross section: Darcy-Weisbach Hazen-Williams	Yes	ForceMainEqNo
Surcharge Method	Method for handling surcharge conditions: Extran Slot	Yes	SurchargeMethodNo
Use Variable Time Steps Adjusted By	Option to use an internally computed variable time step at each routing time period. Define the adjustment factor in the input box beside the checkbox.	Yes	VarTSAdjustBy
Minimum Variable Time Step	The smallest time step allowed when variable time steps are used	Yes	MinVarTS
Time Step for Conduit Lengthening	Time step used to artificially lengthen conduits so that they meet the Courant stability criterion under full-flow conditions (i.e., the travel time of a wave will not be smaller than the specified conduit lengthening time step). As this value is decreased, fewer conduits will require lengthening. A value of 0 means that no conduits will be lengthened.	Yes	ConduitLenTS
Minimum Nodal Surface Area	Minimum surface area used at nodes when computing changes in water depth. If 0 is entered, then the default value of 12.566 ft <sup>2</sup> (i.e., the area of a 4-ft diameter manhole) is used	Yes	MinNodalSurfaceArea



Table 11.5 Edit fields in the Dynamic Wave tab page of the Simulation Setup editor (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in data structure
Maximum Trials per Time Step	Maximum number of trials that SWMM uses at each time step to reach convergence when updating hydraulic heads at the conveyance system's nodes. The default value is 8.	Yes	MaxTrialPerTS
Head Convergence Tolerance	When the difference in computed head at each node between successive trials is below this value the flow solution for the current time step is assumed to have converged. The default tolerance is 0.005 ft (0.0015 m).	Yes	HeadConvergenceTolerance

The available options for how inertial terms in the St. Venant momentum equation are handled are:

- **None.** Drops the inertial terms from the momentum equation, producing what is essentially a Diffusion Wave solution.
- **Partial.** Reduces the inertial terms as flow becomes critical and ignores them when flow is supercritical.
- **Full.** Maintains inertial terms at their full value under all conditions.

When setting how supercritical flow is identified in a conduit, the choices are:

- **Slope.** Water surface slope only (i.e. water surface slope > conduit slope)
- **Froude.** Froude number only (i.e., Froude number > 1.0)
- **Slope & Froude.** Both water surface slope and Froude number

Methods for handling surcharge conditions are:

- **Extran.** Uses a variation of the Surcharge Algorithm from previous versions of SWMM to update nodal heads when all connecting links become full.
- **Slot.** Uses a Preissmann Slot to add a small amount of virtual top surface width to full flowing pipes so that SWMM's normal procedure for updating nodal heads can continue to be used.

Further details on other parameters are also found in the EPA SWMM Help document.



## 11.5 Water Quality

The Water Quality tab page of the Simulation editor presents options for defining parameters related to pollutant buildup/washoff processes when simulating water quality.

Figure 11.6 The Water Quality tab page in the Simulation Setup editor

Table 11.6 Edit fields in the Water Quality tab page of the Simulation Setup editor (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in data structure
Start Sweeping On	Day of the year (day/month) when street sweeping operations begin	Yes	StartSweep
End Sweeping On	Day of the year (day/month) when street sweeping operations end	Yes	EndSweep
Antecedent Dry Days	The number of days with no rainfall prior to start of the simulation. Value used to compute an initial buildup of pollutant load on catchments	Yes	AntecedentDry-Day

## 11.6 Reporting

The Reporting tab page presents options for saving detailed time series results in individual subcatchments, nodes, and links. The dialog organizes information into the following groups:

- **Reporting Period.** For defining the period over which reporting of simulation results is done.
- **Summary Specification.** For defining items to be included in a simulation summary.



- **Subcatchments Detailed Report.** Option for generating detailed results for all/selected catchments.
- **Nodes Detailed Report.** Option for generating detailed results for all/selected nodes.
- **Links Detailed Report.** Option for generating detailed results for all/selected links.

Figure 11.7 The SWMM Simulation Setup Reporting tab page

### Reporting Period

Define the reporting frequency and period under the Reporting Period group.

Table 11.7 Edit fields in the Reporting Period group (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in data structure
Report Time Step	Report saving time step (in Days and Hr:Min;Sec)	Yes	Report_Time-step
Report Start Time	Date and time of day when reporting of simulation results commence	Yes	Report_Start-Time



## Summary Specification

Table 11.8 Edit fields in the Reporting tab page Summary Specification group (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in data structure
Input Summary	To include a summary of input data in the output report	No	ReportInputNo
Control Summary	To include a summary of the control data in the output report	No	ReportControlNo
Average Summary	To report the average of the results for all routing time steps in a reporting time step instead of the instantaneous results that occur at the end of the reporting time step	No	ReportAverageNo
Flow Statistics	Specifies whether or not summary flow statistics should be reported or not	No	FlowStatsNo
Control Actions	Specifies whether or not summary of control actions taken during simulation should be listed or not	No	ControlsNo
Continuity Check	Specifies whether or not summary of continuity checks should be reported or not	No	ContinuityNo

## Subcatchments Detailed Report

Table 11.9 Edit fields in the Reporting tab page Subcatchments Detailed Report group (mss\_Project)

Edit field	Description	Used or required by simulations	Field name in data structure
All, None, or List of Subcatchment	Options for which catchments detailed results are generated	Yes	SubCatchmentsNo
List of Subcatchments	Specify a catchment selection list	Yes If SubCatchmentsNo = 2	SubCatchmentsFileName



## Nodes Detailed Report

Table 11.10 Edit fields in the Reporting tab page Nodes Detailed Report group (mss\_Project)

<b>Edit field</b>	<b>Description</b>	<b>Used or required by simulations</b>	<b>Field name in data structure</b>
All, None, or List of Nodes	Options for which nodes detailed results are generated	Yes	NodesNo
List of Nodes	A nodes selection list is expected	Yes If NodesNo = 2	NodesFileName

## Links Detailed Report

Table 11.11 Edit fields in the Reporting tab page Links Detailed Report group (mss\_Project)

<b>Edit field</b>	<b>Description</b>	<b>Used or required by simulations</b>	<b>Field name in data structure</b>
All, None, or List of Links	Options for which links detailed results are generated	Yes	LinksNo
List of Links	Define a links selection	Yes If LinksNo = 2	LinksFileName





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