



Improving SWMM Modeling with GIS Tools

Rusty Jones (TUFLOW)

Matt Anderson (Inundar)



Disclaimer

Some graphics are based on models provided by others

The use of these graphics does not imply endorsement by those who provided them

Improving SWMM Modeling with GIS Tools

Today's Webinar

EPA SWMM Background and History

SWMM GIS Tools

Leveraging the GIS tools in TUFLOW-SWMM models

Improving SWMM Modeling with GIS Tools

EPA SWMM Background and History

Improving SWMM Modeling with GIS Tools

EPA SWMM Beginning

1969

Fed. Water Pollution Control Administration
Approved Grants to form a Joint Venture between
Metcalf & Eddy & University of Florida



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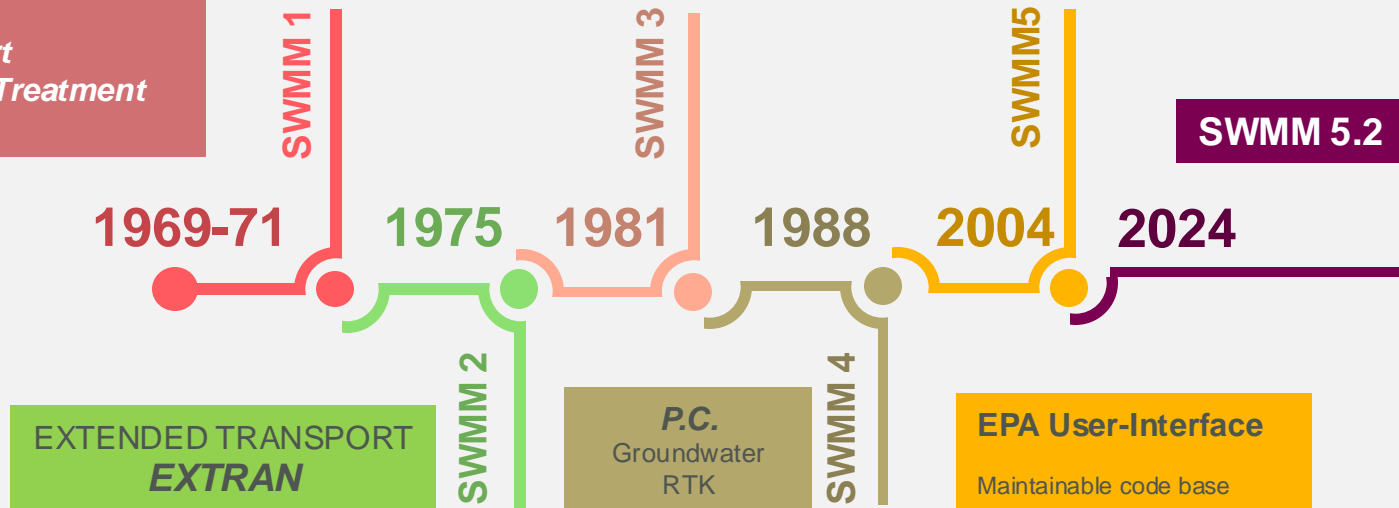
Improving SWMM Modeling with GIS Tools

EPA SWMM History

Blocks:

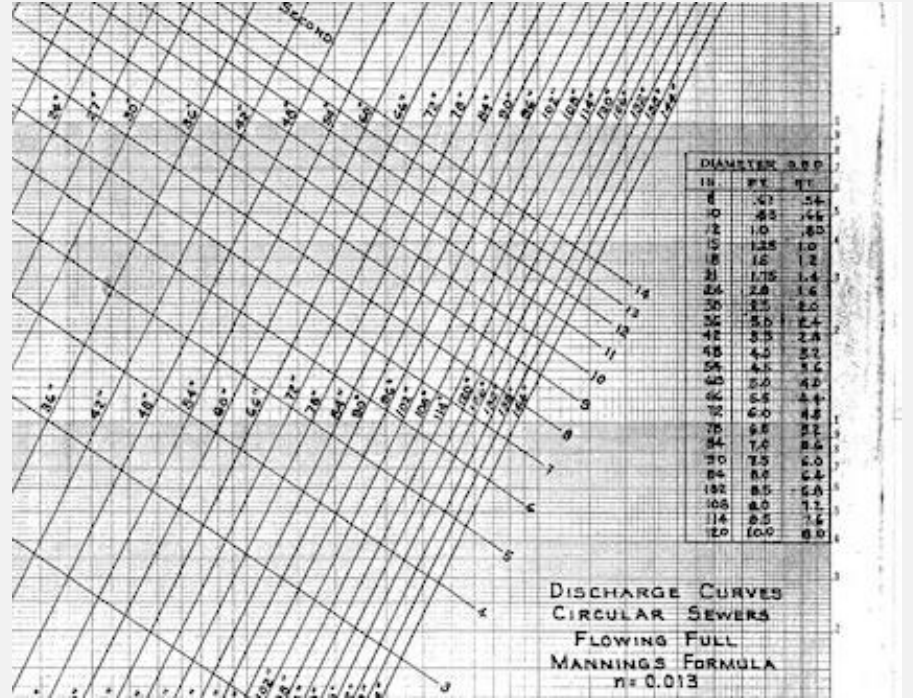
1. *Runoff*
2. *Transport*
3. *Storage/Treatment*
4. *Receive*

- Water Quality
- Open Channels



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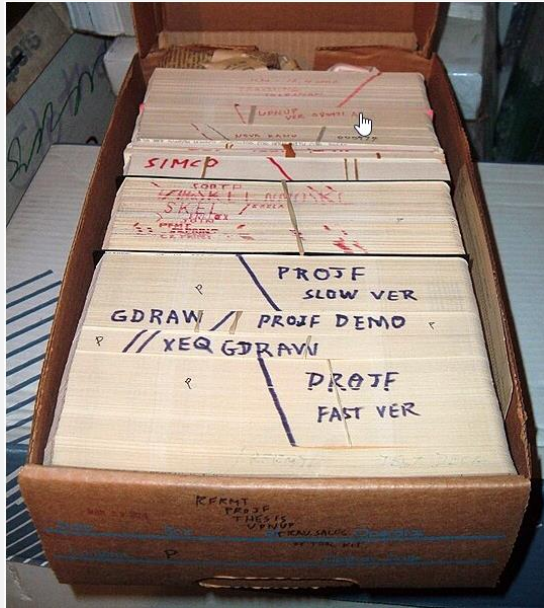
Advancing Technology



Improving SWMM Modeling with GIS Tools

EPA SWMM Data

SWMM2.5 - 3



SWMM 2.5 and SWMM 3 punch cards box
LinkedIn – Robert Dickenson

```
4 # PLOT_ALL_NODES
5 # PLOT_ALL_CONDUITS
6 # SWMM5_CALIBRATION_FILE
7
8 # SWMM4
9
10 # EXTRAN
11
12 A1 'EXTRAN USER'S MANUAL EXAMPLE PROBLEM 1'
13 A1 'BASIC PIPE SYSTEM FROM FIGURE 3-1'
14
15 *
16 *
17 * B0 LINE IS COMPLETELY OPTIONAL
18 *
19 * ISOL = 0 --> USUAL EXPLICIT EXTRAN SOLUTION
20 * ISOL = 1 --> SEMI-IMPLICIT SOLUTION
21 * ISOL = 2 --> ITERATIVE EXTRAN SOLUTION
22 *
23 * NOTE: ISOL = 1 CAN ALSO BE INVOKED BY SETTING SURTOL < 0 AS EXPLAINED
24 * ON USER'S MANUAL PAGE 32.
25 *
26 * KSUPER = 0 --> ASSUME NORMAL FLOW WHENEVER WATER SURFACE
27 * SLOPE IS LESS THAN THE CONDUIT INVERT
28 * SLOPE. THIS IS THE USUAL (DEFAULT)
29 * EXTRAN ASSUMPTION FOR SUPERCRITICAL FLOW.
30 * KSUPER = 1 --> ASSUME NORMAL FLOW WHENEVER THE FROUDE
31 * FROUDE THAN OR EQUAL TO 1.0.
32 * THIS IS A MORE REALISTIC ASSUMPTION
33 * FOR SUPERCRITICAL FLOW.
34
35 * ISOL KSUPER
36 B0 1 0
37
38 * A LARGER TIME STEP IS USUALLY POSSIBLE USING ISOL = 1 OR 2, E.G.,
39 * NITCYC DELT TZERO NSTART INTER UNTER REDO
40 *B1 192 150.0 0.0 1 100 100 0
41
42 *
43 * HERE, CONTINUE THE EXTRAN INPUT SHOWN IN TABLE 3-1 OF USER'S MANUAL.
44 *
45 * NITCYC DELT TZERO NSTART INTER UNTER REDO
46 B1 1440 20.0 0.0 45 -1 1 0
47
48 * METRIC NEQUAL AMEN ITMAX SURTOL
49 B2 0 0 0.0 30 0.05
50
51 * NHPT NQPT NPLT LPLT NJSW
52 B3 6 6 6 6 3
```


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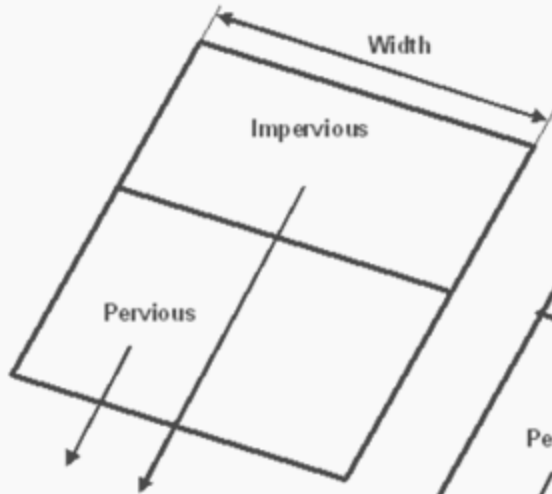
EPA SWMM User Interface

The screenshot displays the EPA SWMM 5.1 software interface. The window title is "SWMM 5.1 - DryPond_100yr24hr.inp". The menu bar includes File, Edit, View, Project, Report, Tools, Window, and Help. The toolbar contains various icons for file operations, navigation, and modeling. The interface is divided into several panes:

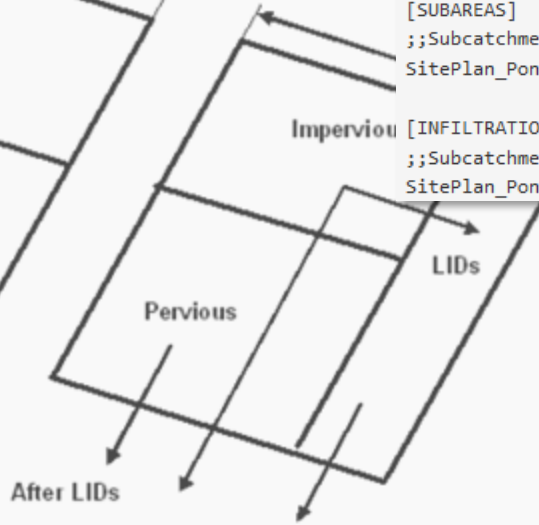
- Project Map:** A tree view on the left showing the project structure:
 - Title/Notes
 - Options
 - Climatology
 - Hydrology
 - Hydraulics
 - Quality
 - Curves
 - Time Series
 - Time Patterns
- Study Area Map:** A central map window showing a hatched polygon representing the study area. A dashed line indicates a flow path, and a black square marks a specific location. A legend in the bottom-left corner of the map pane reads: "Title/Notes: Illustration of a dry pond design in SWMM5." An arrow points from the legend to the corresponding feature on the map.
- Status Bar:** Located at the bottom, it displays: "Auto-Length: Off", "Offsets: Depth", "Flow Units: CFS", "Zoom Level: 100%", and "X,Y: 482708.857, 1312318.622 ft".

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EPA SWMM Background: Runoff



Before LIDs



After LIDs

[SUBCATCHMENTS]

;;Name	Raingage	Outlet	Total Area	Pcnt. Imperv	Width	Pcnt. Slope
SitePlan_Pond	100yr24hr_SCSType2-FL_11.4in	Storage	1.4741	58.078	142.693	0.5

[SUBAREAS]

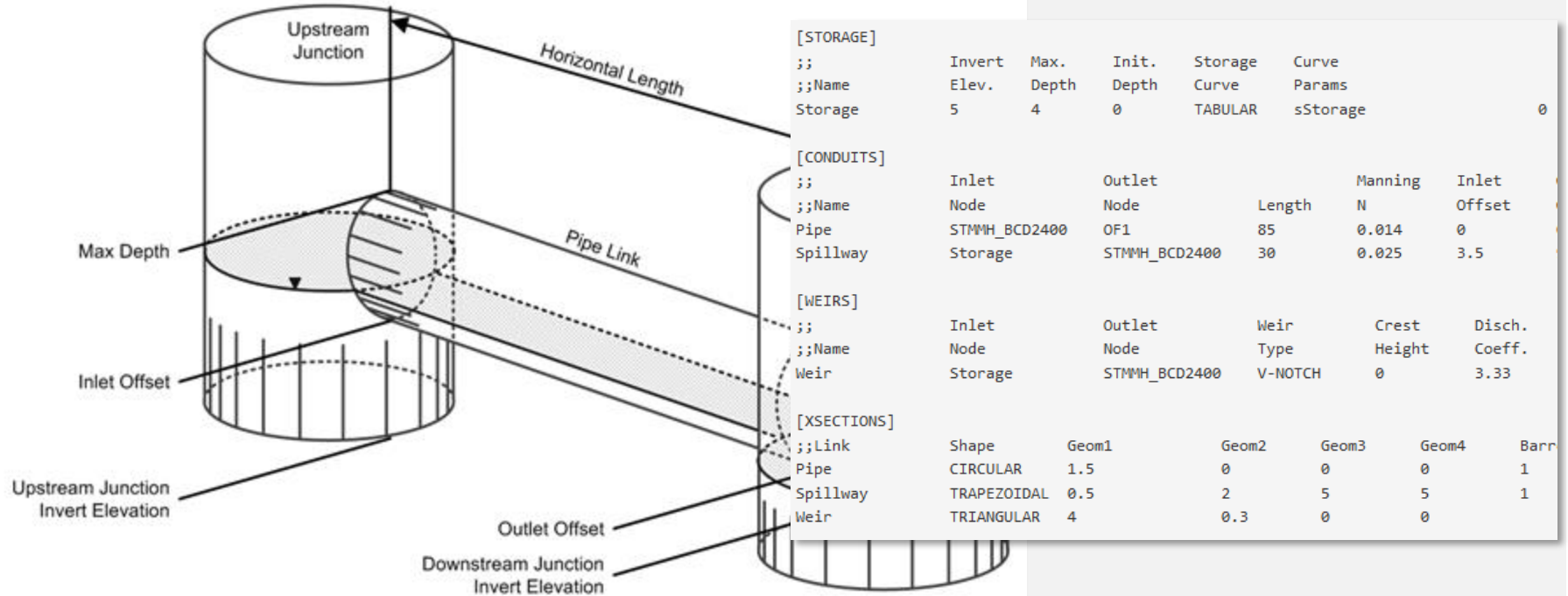
;;Subcatchment	N-Imperv	N-Perv	S-Imperv	S-Perv	PctZero	RouteTo	Pc
SitePlan_Pond	0.019	0.107	1.753	0.107	18.55	PERVIOUS	42

[INFILTRATION]

;;Subcatchment	Suction	HydCon	IMDmax
SitePlan_Pond	6.7	0.26	0.37

Improving SWMM Modeling with GIS Tools

EPA SWMM Background: Hydraulics



Improving SWMM Modeling with GIS Tools

SWMM GIS Tools

SWMM GIS Tools Motivation

TUFLOW Added SWMM as Alternative 1D Engine

ESTRY (TUFLOW 1D) has Rich GIS Integration

Desired Similar Functionality for SWMM users

Created Tools within TUFLOW QGIS Plugin



Model data courtesy of the City of San Antonio (no endorsement implied)

SWMM GIS Tools

Why Put SWMM Data in GIS?

Interchangeable – Easy to convert formats

Improved Mapping – Unlimited options

Easy to Post Online

Universal – Used by nearly all Engineers

Free (QGIS) and Paid Options (ArcGIS)

Scriptable



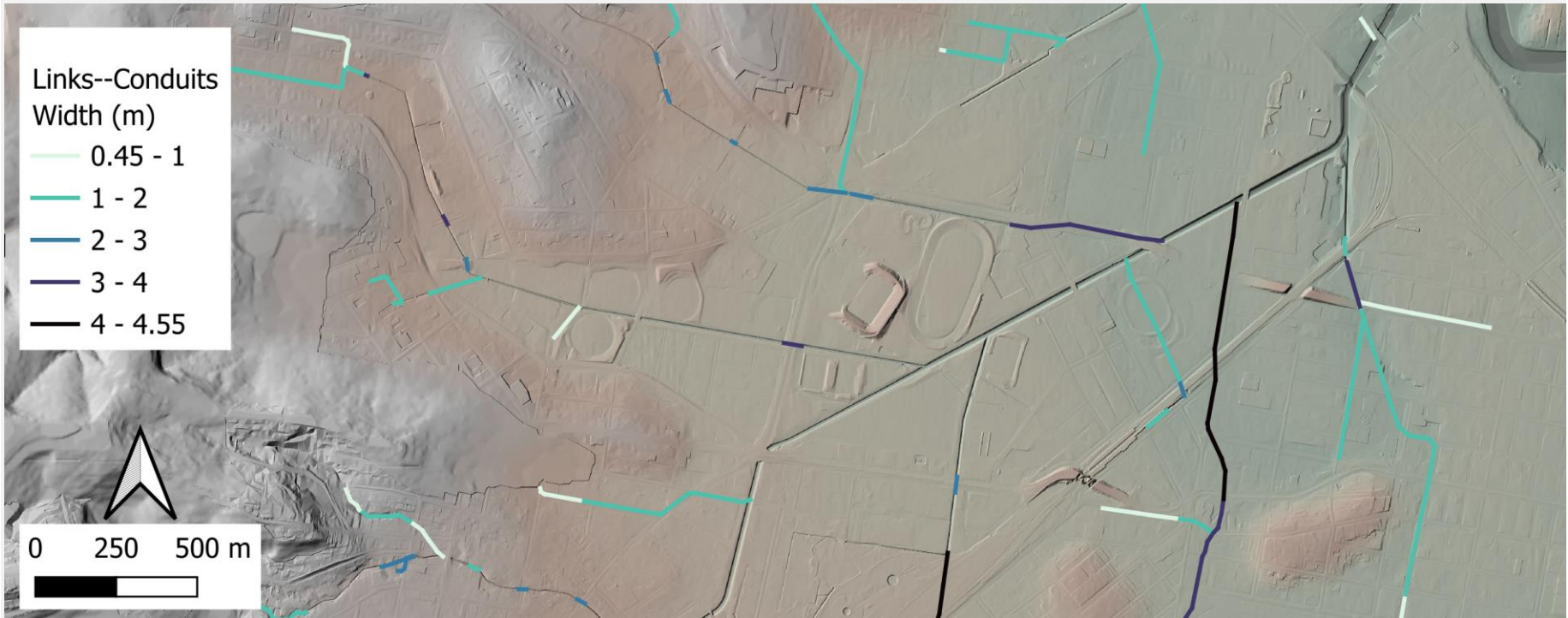
SWMM GIS Tools

GIS Symbology – The Sky is the Limit



SWMM GIS Tools

GIS Symbology – The Sky is the Limit



SWMM GIS Tools

GIS Symbology – The Sky is the Limit



SWMM GIS Tools

GIS Symbology – The Sky is the Limit



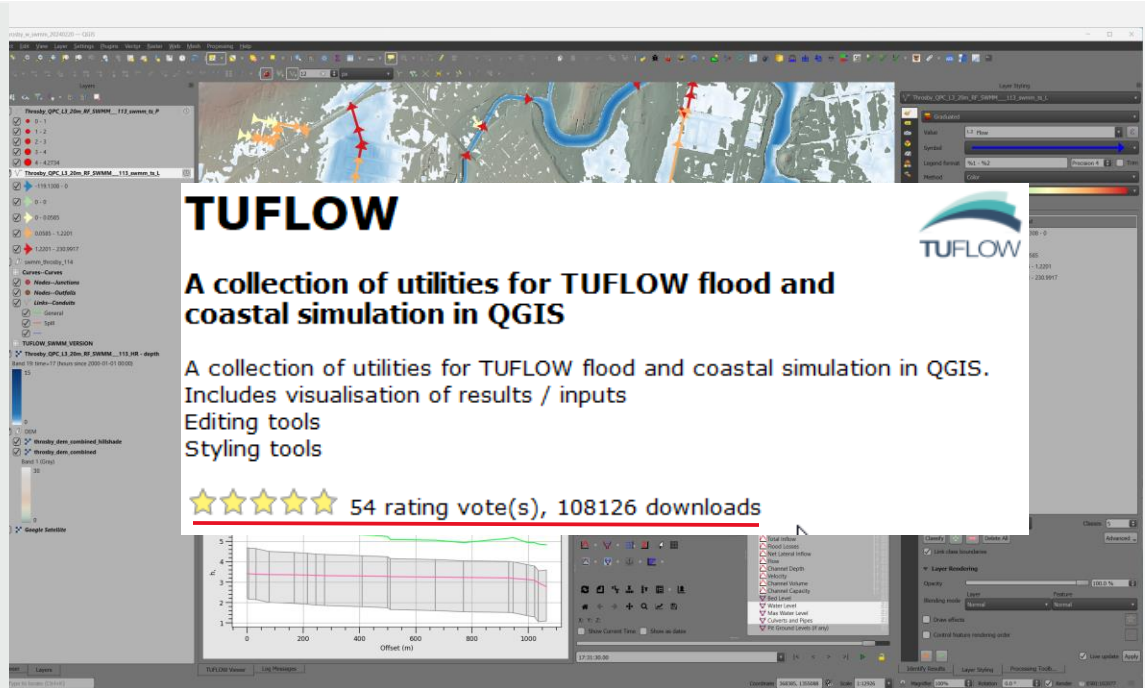
SWMM GIS Tools

TUFLOW QGIS Plugin Introduction

QGIS is Free and Open-source GIS Application

TUFLOW Plugin

- Free
- Downloaded from the plugin repository
- Tools for
 - TUFLOW 2D model data
 - TUFLOW 1D model data (ESTRY)
 - And now SWMM



TUFLOW

A collection of utilities for TUFLOW flood and coastal simulation in QGIS

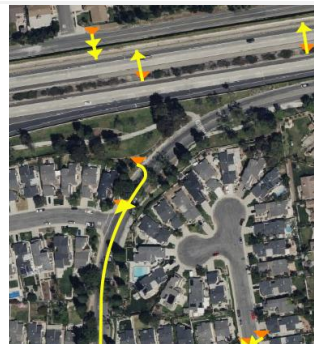
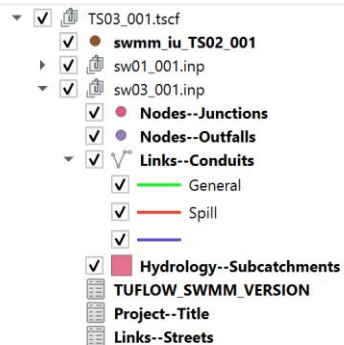
A collection of utilities for TUFLOW flood and coastal simulation in QGIS. Includes visualisation of results / inputs
Editing tools
Styling tools

★★★★★ 54 rating vote(s), 108126 downloads

SWMM GIS Tools

GeoPackage files

- SQLite database
- Open non-proprietary format
- Multiple layers within a single file (Functions as a geo-database)
- Interoperable
 - QGIS
 - ArcGIS
- Spatially Indexed – super fast
- Spatial and non-spatial data



fid	Name	Elev	Ymax	Y0	Ysur	Apond
1	1 Pit10	40.8	0	0	0	0
2	2 Pit11	40.6	0	0	0	0
3	3 Pit13	40	0	0	0	0
4	4 Pit15	41.4739	0	0	0	0
5	5 Pit17	41.81778	0	0	50	1
6	6 Pit18	41.91283	0	0	0	0
7	7 Pit19	42.19779	0	0	0	0
8	8 Pit2	41.96784	0	0	0	0
9	9 Pit3	41.84937	0	0	50	1
10	10 Pit4	41.95067	0	0	0	0
11	11 Pit5	42.4	0	0	0	0
12	12 Pit6	42.35	0	0	0	0
13	13 Pit7	41.65546	0	0	0	0
14	14 Pit9	41.30769	0	0	0	0


fid	Option	Value
1	1 FLOW_UNITS	CMS
2	2 INFILTRATION	GREEN_AMPT
3	3 FLOW_ROUTING	DYNWAVE
4	4 LINK_OFFSETS	DEPTH
5	5 FORCE_MAIN_E...	H-W
6	6 IGNORE_RAINF...	NO
7	7 IGNORE_SNOW...	YES
8	8 IGNORE GROU...	YES
9	9 IGNORE_RDII	YES
10	10 IGNORE_QUALI...	YES
11	11 ALLOW_PONDI...	YES
12	12 SKIP_STEADY_S...	YES
13	13 SYS_FLOW_TOL	1
14	14 LAT_FLOW_TOL	1
15	15 START_DATE	2020-01-01
16	16 START_TIME	00:00
17	17 END_DATE	2000-01-01
18	18 END_TIME	06:00
19	19 REPORT_START...	2000-01-01
20	20 REPORT_START...	00:00
21	21 SWEEP_START	01/01
22	22 SWEEP_END	01/01

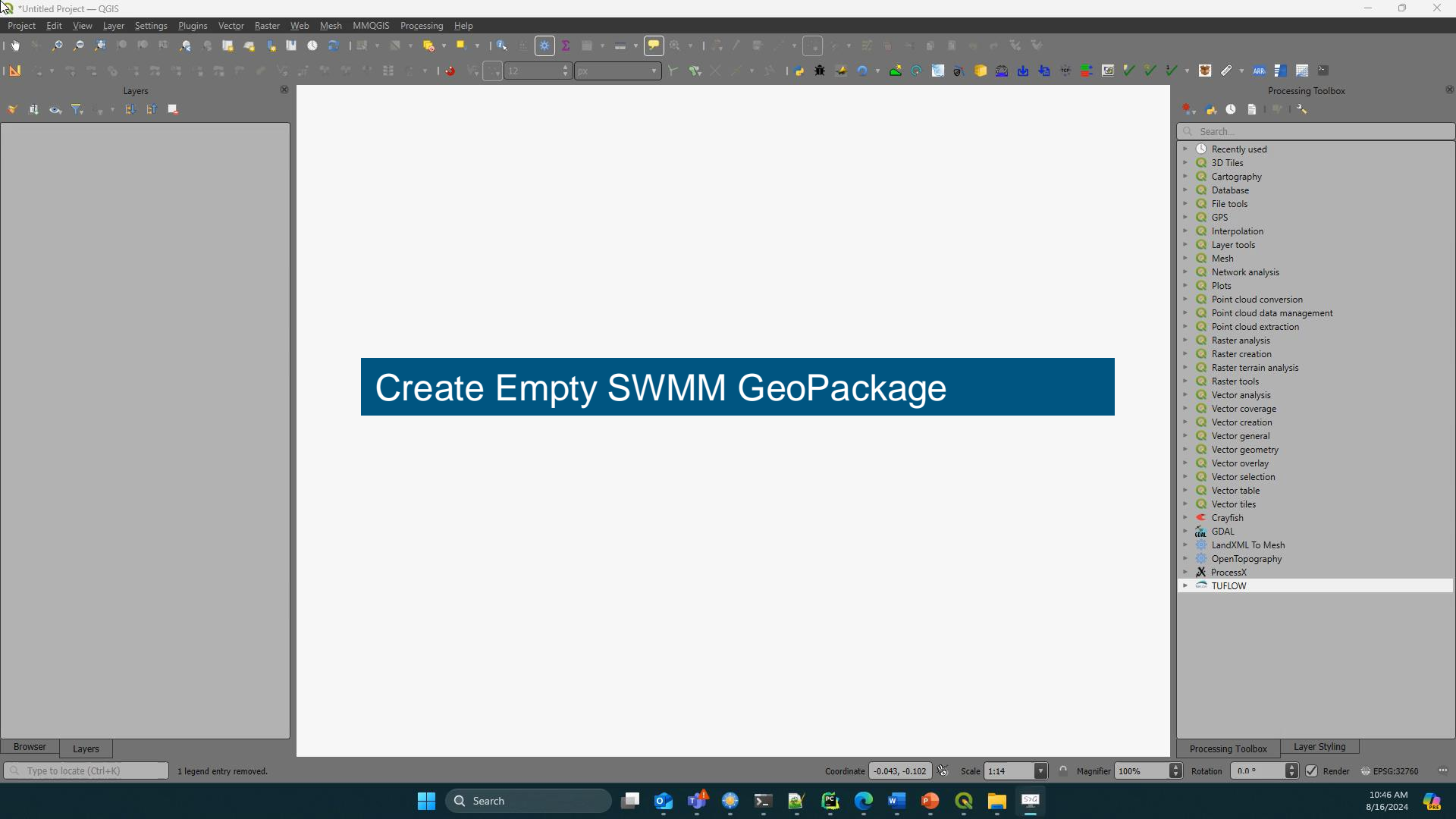


SWMM GIS Tools

TUFLOW Plugin - SWMM Tools

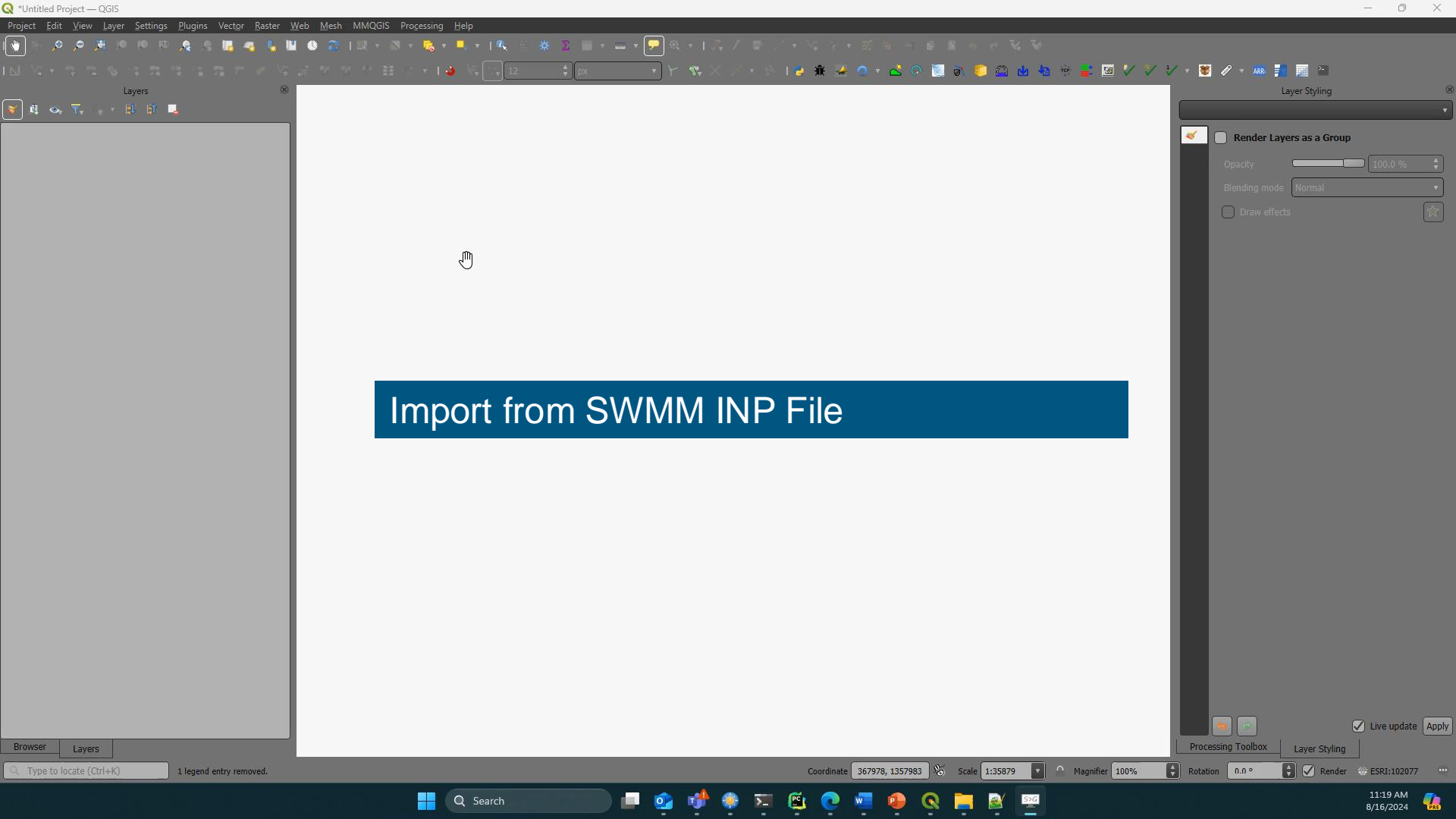
- **SWMM GeoPackage files**
 - Create/Add sections
 - Convert to and from EPA SWMM inp files
- **Integrity Tools**
- **Model Editing Tools**
- **Model Conversions (to SWMM)**
 - From ESTRY
 - From XPSWMM

- 
- TUFLOW
 - Convert TUFLOW Model GIS Format
 - Create TUFLOW Project (beta)
 - Custom TUFLOW Styling Functions
 - Import Empty (beta)
 - Package Model
 - TMO to Points
 - miTools
 - SWMM
 - BC - Convert Non-Outfall SX Connections to HX
 - BC - Create Channel Endpoint 1D/2D Connections
 - Conduits - Assign Losses
 - Conduits - Assign Node Fields
 - Convert - ESTRY Layers to SWMM
 - Convert - XPSWMM GIS Inlet Layers to SWMM
 - Convert - XPSWMM Hydrology (Beta)
 - Convert - XPSWMM Model from XPX (Beta)
 - GeoPackage - Add Sections
 - GeoPackage - Create
 - GeoPackage - Create from SWMM inp
 - GeoPackage - Write to SWMM Inp
 - Integrity - Make Object Names Unique
 - Junctions - Convert HX Nodes to Storage
 - Junctions - Downstream Junctions to Outfalls
 - Junctions - Set Attributes
 - Outfalls - Fix Multiply Connected Links
 - Scenarios - Extract from GPKG



Create Empty SWMM GeoPackage

- Processing Toolbox
- Search...
 - Recently used
 - 3D Tiles
 - Cartography
 - Database
 - File tools
 - GPS
 - Interpolation
 - Layer tools
 - Mesh
 - Network analysis
 - Plots
 - Point cloud conversion
 - Point cloud data management
 - Point cloud extraction
 - Raster analysis
 - Raster creation
 - Raster terrain analysis
 - Raster tools
 - Vector analysis
 - Vector coverage
 - Vector creation
 - Vector general
 - Vector geometry
 - Vector overlay
 - Vector selection
 - Vector table
 - Vector tiles
 - Crayfish
 - GDAL
 - LandXML To Mesh
 - OpenTopography
 - ProcessX
 - TUFLOW



Import from SWMM INP File

Render Layers as a Group

Opacity

Blending mode

Draw effects

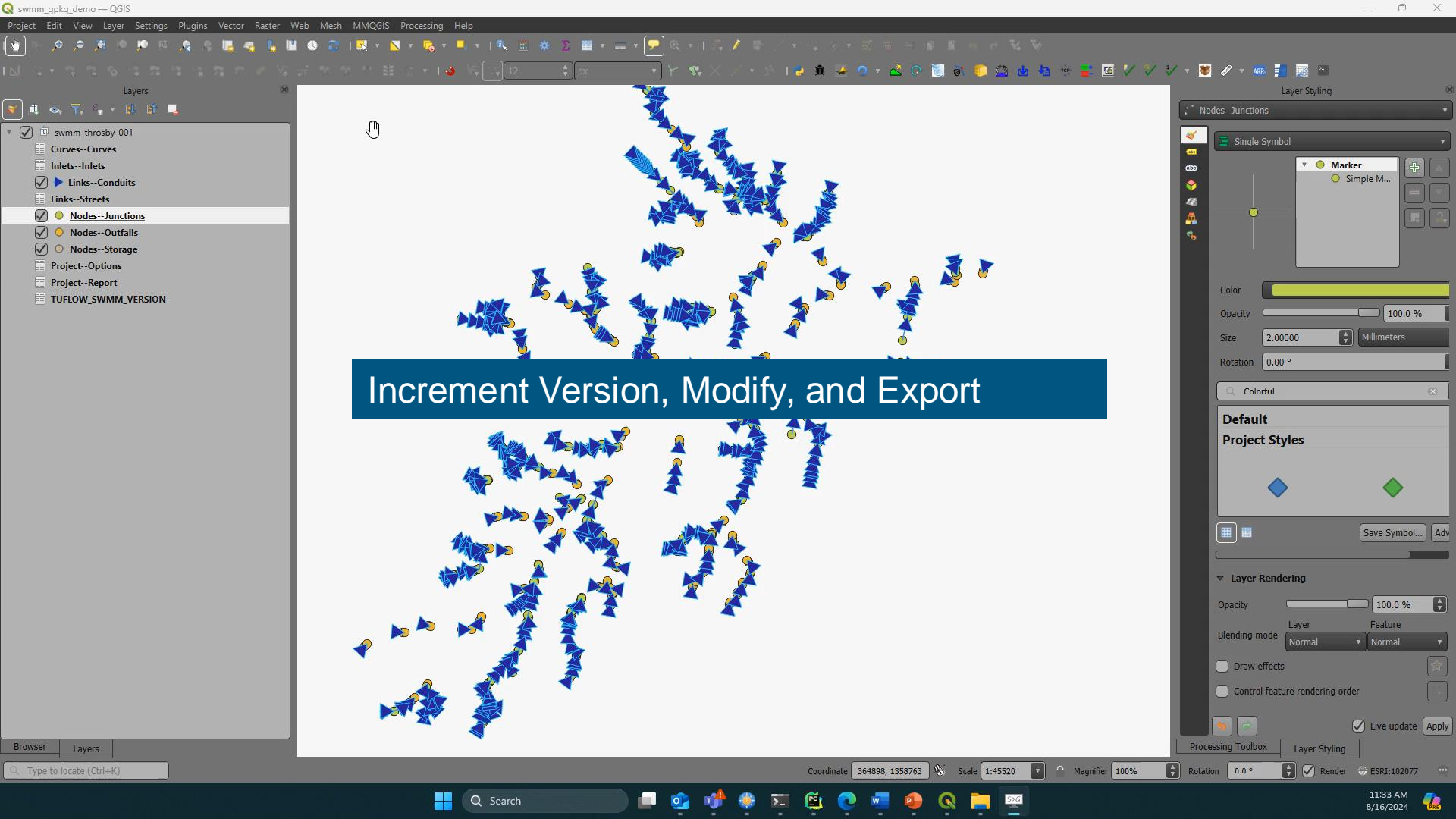
Live update

Coordinate: 367978, 1357983 Scale: 1:35879 Magnifier: 100%

Processing Toolbox Layer Styling

Rotation: 0.0° Render

11:19 AM 8/16/2024



Increment Version, Modify, and Export

Layer Styling

Nodes--Junctions

Single Symbol

Marker

Simple M...

Color

Opacity 100.0 %

Size 2,00000 Millimeters

Rotation 0,00 °

Default Project Styles

Layer Rendering

Opacity 100.0 %

Blending mode Normal Normal

Draw effects

Control feature rendering order

Live update Apply

Type to locate (Ctrl+K)

Coordinate 364898, 1358763 Scale 1:45520 Magnifier 100% Rotation 0.0 ° Render ESRI:102077

Improving SWMM Modeling with GIS Tools

1D Integrity Tools

Pipe Integrity Tool: Continuity Check

The screenshot displays the Pipe Integrity Tool software interface. The main window shows a topographic map with a complex network of blue pipes overlaid. The interface includes a toolbar at the top, a Layers panel on the left, and a right-hand panel for tool configuration.

Layers Panel:

- Smith_inlet_usage_sw024 -- inlet_usage
- Smith_sw024
- Curves--Curves
- Links--Conduits
 - CIRCULAR
 - RECT_CLOSED
- Inlets--Inlets
- Links--Streets
- Nodes--Junctions
- Nodes--Outfalls
- Project--Options
- Project--Report
- Topography

Right Panel (ID Integrity Tool):

- TUFLOW Documentation
- Input Network Lines
- Input Network Points
- Input Tables
- Input DEM

Navigation tabs: Snapping, Pipe Direction, **Continuity**, Flow Trace, Channel ID, Empty Geometry

Check entire network for downstream pipe continuity.

Documentation:
https://wiki.tuflow.com/index.php?title=ID_Integrity_Tool_-_Continuity

SWMM Link Offset Option: Depth

- Flow Area Check
 - % area decrease where there are multiple incoming pipes at the junction: 50%
- Invert Check
- Angle Check
 - Flag angles less than: 70 deg
- Ground Cover Check
 - Flag cover depths less than (map units are determined by the project projection): 0.0 map units

100% Finished Generating Long Plot Run

Coordinate 524260, 234168 Scale 1:16639 Magnifier 100% Rotation 0.0° Render EPSG:27700

Pipe Integrity Tool: Flow Trace

The screenshot displays the Pipe Integrity Tool interface. The main window shows a topographic map with a complex network of pipes overlaid in purple and blue, with arrows indicating flow direction. The interface includes a toolbar at the top, a Layers panel on the left, and a configuration panel on the right.

Layers Panel:

- Smith_inlet_usage_sw024 - inlet_usage
- Smith_sw024
- Curves--Curves
- Links--Conduits
 - CIRCULAR
 - RECT_CLOSED
- Inlets--Inlets
- Links--Streets
- Nodes--Junctions
- Nodes--Outfalls
- Project--Options
- Project--Report
- Topography

Configuration Panel (ID Integrity Tool):

- Input Network Lines**
- Input Network Points**
- Input Tables**
- Input DEM**
 - DEM: uFMSW_DTM_2m_001_trim
- Snapping: Pipe Direction Continuity Flow Trace Channel ID Empty Geometry
- Trace upstream network from selected pipe and perform continuity check of traced network.**
- Documentation: https://wiki.tuflow.com/index.php?title=ID_Integrity_Tool_-_Flow_Trace
- SWMM Link Offset Option: Depth
- Flow Area Check
 - % area decrease where there are multiple incoming pipes at the junction: 50%
- Invert Check
- Angle Check
 - Flag outflow angles less than: 70 deg
- Ground Cover Check
 - Flag cover depths less than (map units are determined by the project projection): 0.0 map units
- Generate Long Plots
- Use Previously Selected Channels

Status Bar: 100% Finished Generating Long Plot Run

Bottom Panel: Coordinate 522947, 234376 Scale 1:9741 Magnifier 100% Rotation 0.0° Render EPSG:27700

Improving SWMM Modeling with GIS Tools

SWMM coupled with TUFLOW

TUFLOW

Linkages to 1D Models

- 1990 ESTRY (TUFLOW 1D)
- 2006 XPSWMM
- 2006 FloodModeller (ISIS)
- 2012 12D Dynamic Drainage Analysis (SWMM)
- 2024 TUFLOW-SWMM



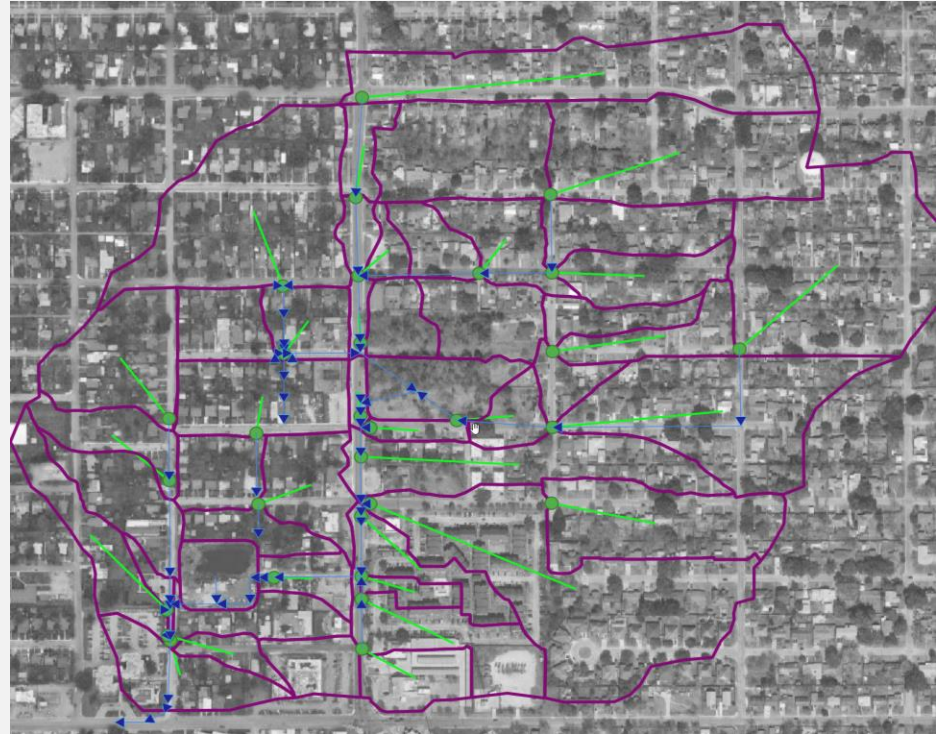
TUFLOW-SWMM

Introduction

Reasons we Added SWMM:

- Allow users to leverage existing models
- Many potential users familiar with SWMM
- SWMM embedded in many applications
- 3rd party editing and visualization tools exist

TUFLOW-SWMM uses EPA SWMM 5 inp files (can be generated from the GIS tools or separately)



Model data courtesy of the City of San Antonio (no endorsement implied)

TUFLOW-SWMM

Value Added Features

1. 1D/2D Models

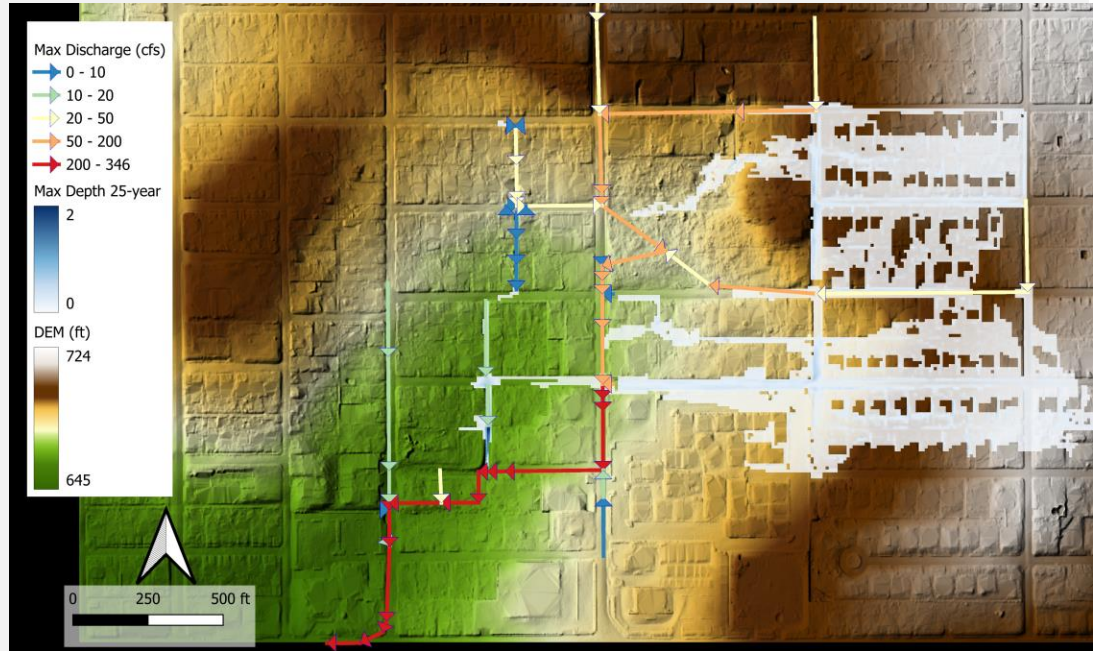
- a) 2D solver (GPU, SGS, Quadtree)
- b) HEC-22 inlets and direct 1D/2D connections
- c) Rain on grid or SWMM hydrology

2. Scenarios and Events

- a) Alternatives without duplicating input data
- b) Curves from bc database

3. GeoPackage Time-series Results

- a) Symbolize node and link results
- b) Time-series and profile

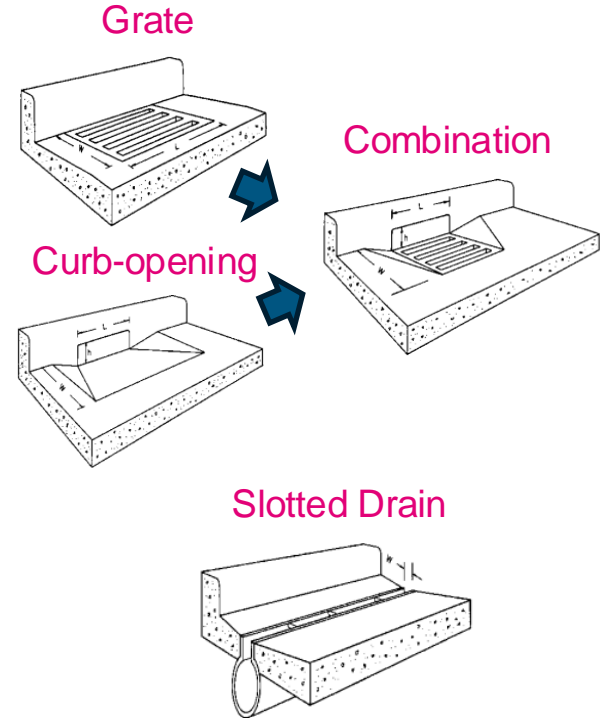


Model data courtesy of the City of San Antonio (no endorsement implied)

TUFLOW-SWMM – 1D/2D Modeling Stormwater Pipe Network Inlets

Based on Federal Highway Administration HEC 22 Urban Drainage Design Manual

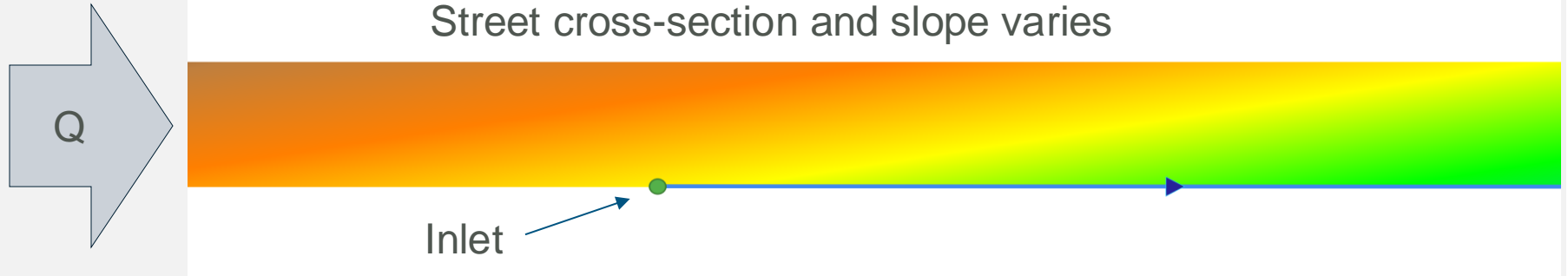
- Multiple inlet types including based upon custom curves
- On Sag inlets driven by WSE (from 2D model)
- On Grade inlets incorporate approach flows and velocities (from 2D)
- Uses modified EPA SWMM code to compute capture discharge



Inlet diagrams from HEC No 22, Third Edition

TUFLOW-SWMM

Inlet (1D/2D Connection) Benchmarking



Comparison	HEC-22	TUFLOW-SWMM
Example 4-1: Flow spread in gutter (m)	2.7	2.9
Example 4-8: Capture flow P-50 Grate (cms)	0.091	0.090
Example 4-9a1: Capture flow curb inlet (cms)	0.031	0.030
Example 4-10: Capture flow inlet (cms)	0.049	0.047

TUFLOW-SWMM

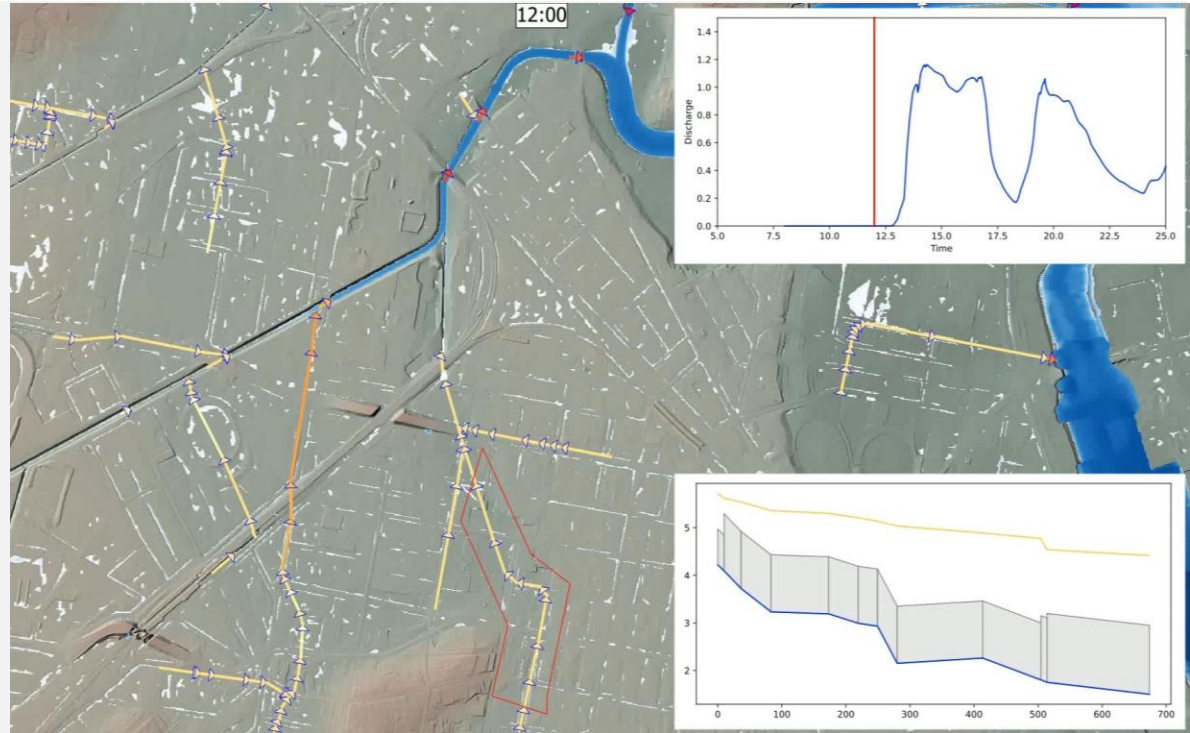
Result Viewing QGIS

2D (TUFLOW)

- Mesh or Raster coloring
- Time-series plots

1D (SWMM)

- GeoPackage based
- Channel and node results
- Dynamic color/size symbology base by result magnitude
- Time-series plots
- Section plots



TUFLOW-SWMM – 1D/2D Modeling Result Viewing using ArcGIS

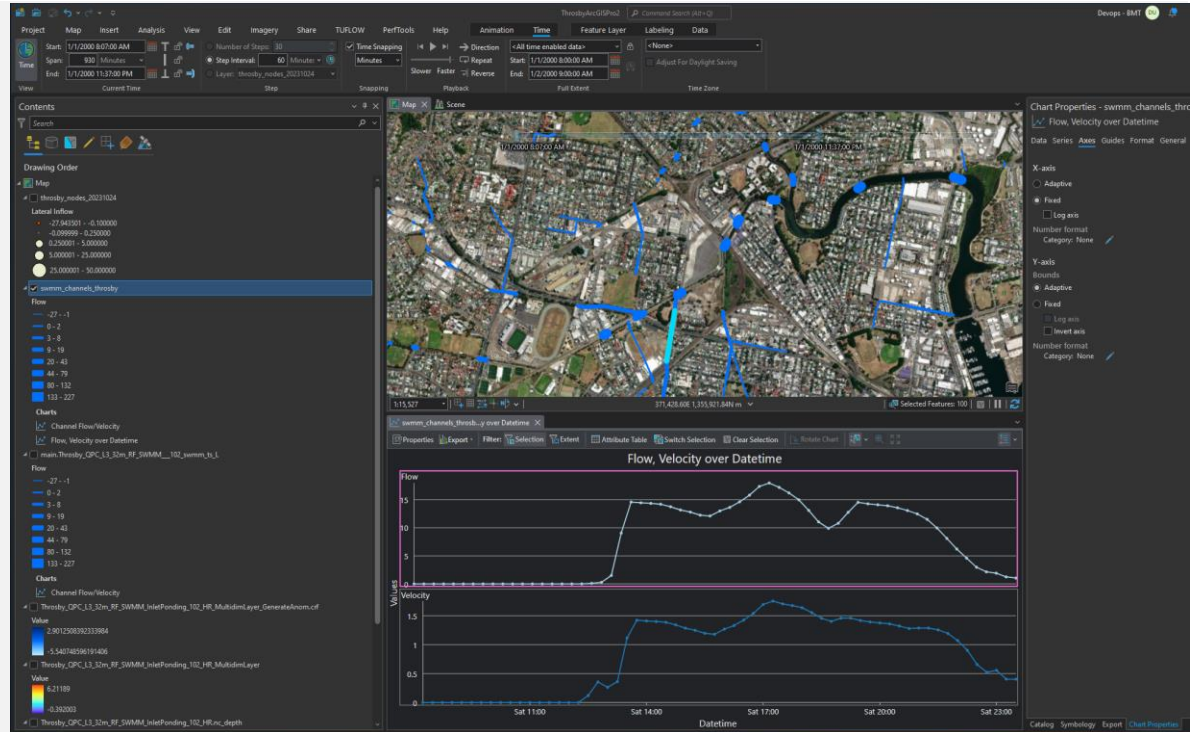
2D (TUFLOW)

- Contours
- Animations

1D (SWMM)

- GeoPackage based
- Channel and node results

Hint: Sometimes converting to ESRI formats reduces issues.



TUFLOW-SWMM

Learning Resources

Free Tutorials: https://wiki.tuflow.com/TUFLOW_SWMM_Tutorial_Introduction

1. 1D SWMM Culverts
2. 1D SWMM Pipe Network / 2D TUFLOW Direct Rainfall Hydrology
3. 1D SWMM Pipe Network / 1D SWMM Urban Hydrology
4. 1D SWMM Pipe Network / 1D SWMM Urban Hydrology: Executing multiple events from a single model
5. XPSWMM to TUFLOW SWMM - How to convert an XPSWMM model to TUFLOW SWMM

TUFLOW 2023 Release Notes <https://docs.tuflow.com/classic-hpc/release/latest>

Past TUFLOW webinars: <https://www.tuflow.com/library/webinars/>

Email support@tuflow.com or sales@tuflow.com: Let us know if you have questions or need help?