Detroit Water and Sewerage Department

Wastewater Master Plan

DWSD Project No. CS-1314

Data Update and Model Display Tools

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Data Updates and Model Display Tools

1. Introduction

The Wastewater Master Plan (WWMP) called for an update of the Greater Detroit Regional Sewer System (GDRSS) Model and corresponding SWMM model display tools. A number of updates have been incorporated into the WWMP version of the GDRSS Model. This memo summarizes these updates. Also described is a model display tool called Mike SWMM that was selected for interfacing with the WWMP Model. Mike SWMM allows easy access to the model input data and provide a comprehensive viewing of model output data.

2. WWMP Updates to the GDRSS Model

Based on the evaluation of the GDRSS Model and the various related components, a number of updates for enhancing the model capabilities for used in the WWMP project have been implemented. The GDRSS Model is focused on wet weather related issues, in particular Combined Sewer Overflows (CSOs). For the WWMP, the model was extended to better address system capacity for future needs and demands over the next 50 years. How wet weather is handled in the system is still critical, but in addition, the transport capacity needs of the customers throughout the system were evaluated. The following updates and improvements to the WWMP version of the GDRSS Model have been included to better meet these needs:

- The model was extended to include DWSD owned transport system components that are not included in the GDRSS Model. In particular, this update included the interceptors in Macomb County up to the location of the billing meters. This extension enabled review of the transport needs where demands are continuing to increase due to growth and SSO issues.

- The model was extended to include the major DWSD pumping stations in Macomb County. These are the Clintondale and Garfield pumping stations. This extension allowed a more detailed evaluation of energy and service impacts of replacing these stations with gravity sewers. During the course of this project, the Garfield pump station was replaced with a gravity sewer. The model has been updated accordingly.

- The model was expanded to include the interceptors in the Clinton-Oakland Sanitary District. These interceptors are not DWSD owned; however, this district is also under growth pressure. Inclusion of these interceptors improved the level of consistency in the representation of the regional system, especially with respect to travel time and attenuation of flows in the system. A SWMM TRANSPORT model had already been developed for the system by the district. This existing model was obtained and incorporated into the GDRSS framework.

- The spatial resolution of model tributary area was increased by delineating additional subareas to include at a minimum one subarea per DWSD billing meter. This work applied in particular to Macomb County and Clinton-Oakland district with the extension of the interceptors in the model.

- The GDRSS Phase IV flow metering was used to obtain estimates of RDI/I parameters for the new subareas in Macomb County. The flow data as available was used to confirm earlier estimates of these flows and to improve spatial resolution of the wet weather response in these areas. Data for other separated communities was also used as available to improve model results, in particular, for SSO case studies.

- The model's representation of suburban connections to the DWSD system was reviewed and updated or extended to better represent connection hydraulics. This allowed review of peak discharge rates relative to contract capacities.

- The model was updated to include facilities that have recently been built and are not currently represented in the model. Facilities that were reviewed and/or added to the model included storage basins, in-system storage devices, pump stations, screening and disinfection facilities, and other structures that could impact capacity analysis.

- The DWFs as determined from the metering program conducted by DWSD over the last several years (CS-1249 Phase IV and Amendment 4) were incorporated into the model to improve the accuracy and spatial distribution of DWFs throughout the system.

- The projected changes to the DWFs due to projected changes in population and service area through the year 2050 have been developed and was incorporated into the model for analysis. These projections were developed for each decade through 2050.

- The model was updated to the current version of SWMM to handle issues relative to real time control and other operational controls. This allowed use of levels to control dewatering of screening and disinfection facilities, for example.

These updates and improvements are further documented in the WWMP Technical Memorandum *Greater Detroit Regional Sewer System Model Setup and Analyses.* In addition to these improvements, model development and use has been coordinated with other ongoing DWSD projects, in particular, the CS-1281 Long-Term CSO Control Plan project. WWMP updates and refinements to the GDRSS Model should be provided to the GDRSS modeling team at the conclusion of this project.

3. Model Display Tools

One of the updates external to the model itself has been the tool used to interface with the model. There are three primary model display tools available for the EPA SWMM program:

1. Model Turbo View – EXTRAN (MTVE)
2. PCSWMM
3. MIKE SWMM

MTVE has been used extensively in the development and review of the GDRSS Model. In spite of its extensive capabilities, it runs in DOS and is limited more to review of model output than to building model data sets. Both PCSWMM and MIKE SWMM operate within windows and both include building model data set capabilities. Use of both of these programs revealed that either program would be a viable candidate for use with the WWMP Model. MIKE SWMM was selected, however, due to its availability to CDM at no cost and as it works most closely with the SWMM files in their native format. It allows easy access to the model input data and provides a comprehensive viewing of the model output data. It will provide DWSD the sewer network update functions and the WWMP Model display tools needed for use of the model.

3.1 Model Building – MIKE SWMM

The Mike SWMM user interface has been designed for maximum flexibility and ease of use. Network data can be digitized and viewed with background images directly in the main graphical horizontal view window. Editors, or views, of the same information are dynamically linked, so that changes introduced through one editor are automatically and instantly updated in the other views.

Mike SWMM allows for the viewing of input data for the GDRSS Model. RUNOFF input files, EXTRAN input files, and TRANSPORT input files can be loaded into Mike SWMM. Figure 1 is the Macomb Sewer District shown in Mike SWMM. Profiles can also be created in Mike SWMM. Figure 2 is a profile of the Oakland Arm and Corridor Interceptor, created in Mike SWMM.

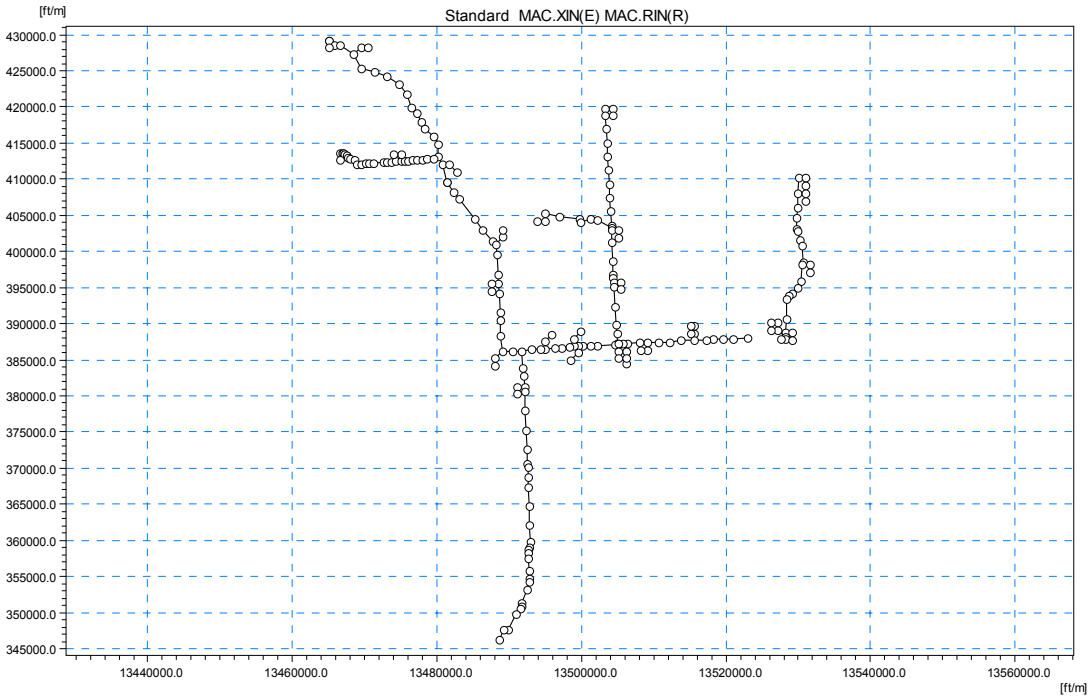

Figure 1. Macomb Sewer District in Mike SWMM

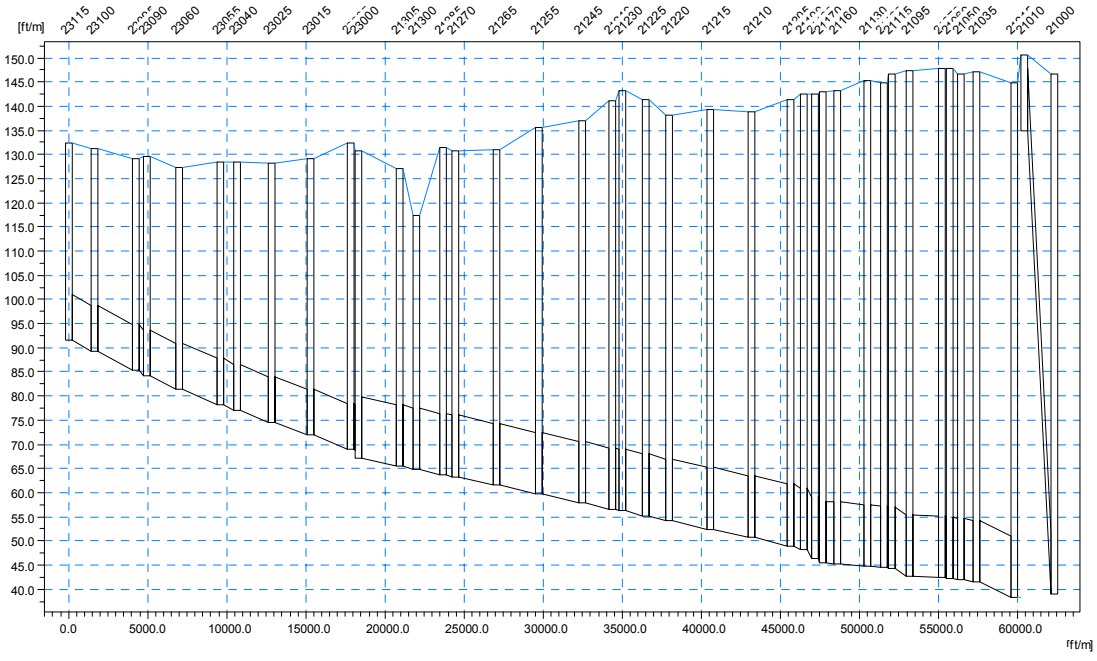

Figure 2. Profile of Oakland Arm and Corridor Interceptor in Mike

3.2 Model Results – MIKE View

Next to building model input, interpreting model results is the most time consuming process when analyzing networks. The result viewer for Mike SWMM is Mike View. From the experience of thousands of applications worldwide and the input of hundreds of users, Mike View has evolved to become the most versatile graphic user-interface for hydrologic and hydraulic analyses available today.

Mike View is also available as a stand-alone, multi-media reporting tool. This allows users to include digital versions of Mike SWMM simulation result files, together with Mike View, in conjunction with written reports and project documentation.

MIKE View capabilities include:

- Results can be viewed on user configurable plan drawings, longitudinal pipe sections and as time series in graphical and tabular views
- All results can be animated, and windows with different animations can be synchronized
- Multiple result files can be accessed and viewed simultaneously
- Flooding (water depths and pressure heights) can be shown and animated in the plan drawing
- DXF and BMP files (such as CAD drawings, ortho photos, and scanned maps) can be imported and used as background graphics
- Simulation results can be copied to spreadsheets and other applications for reporting
- Individual windows layouts or entire session layouts can be saved and reused

An example of a profile displaying the effects of a wet weather event in Mike View is provided in Figure 3. An example of flow vs. time for a particular conduit is provided in Figure 4.

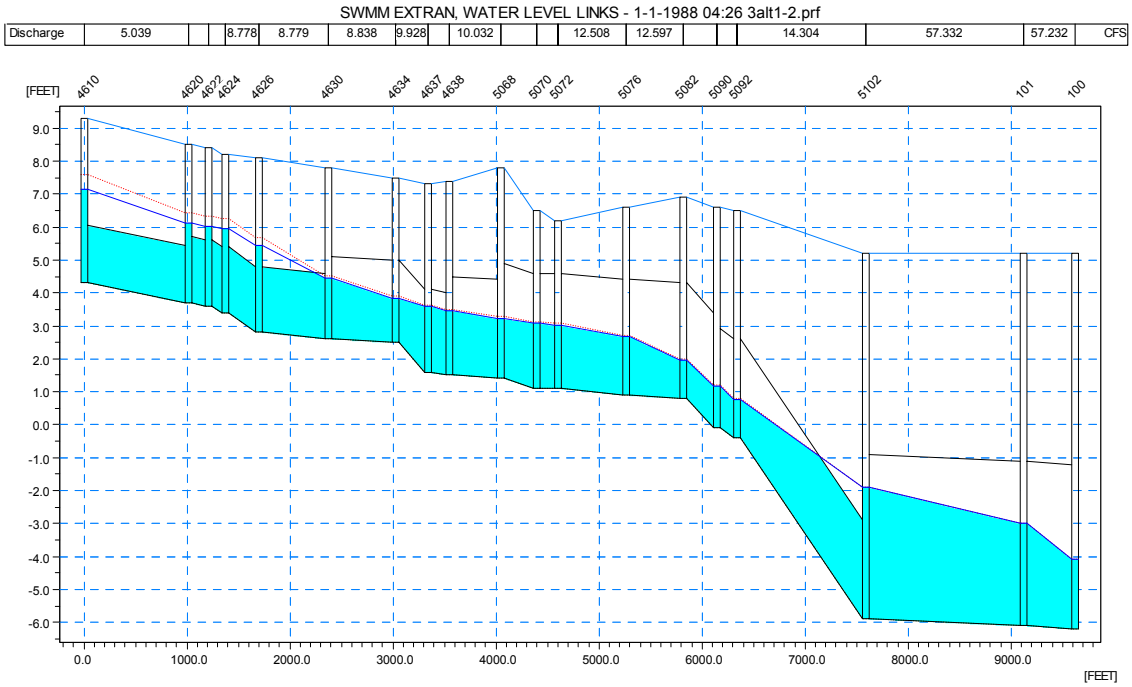

Figure 3. Wet Weather Event Profile in Mike View

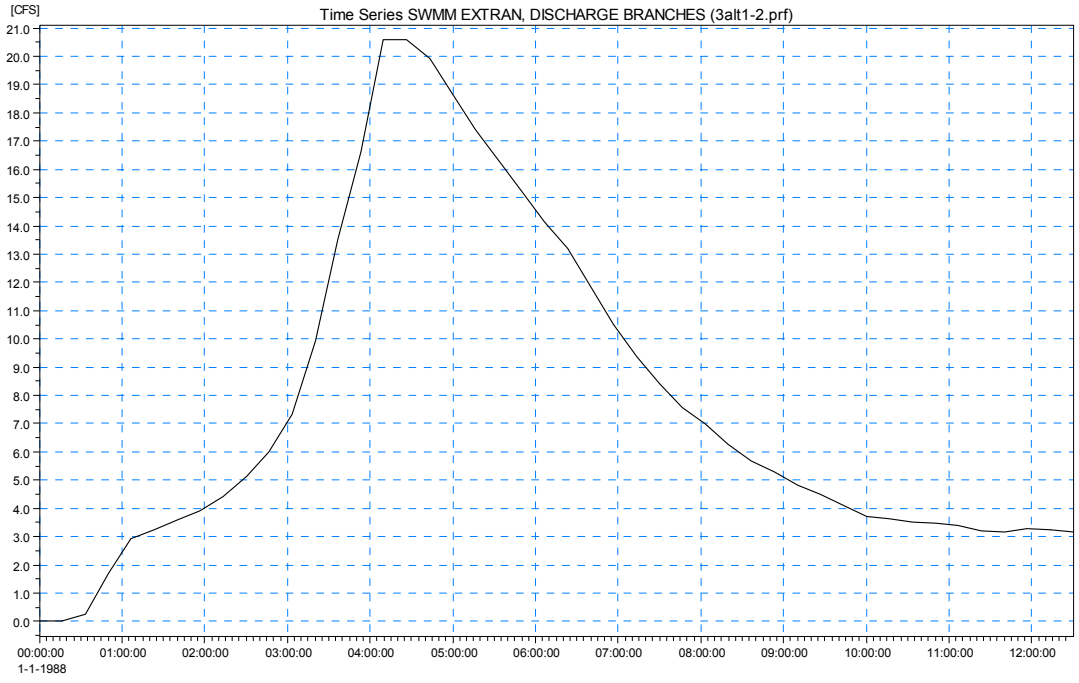

Figure 4. Flow Versus Time for a Particular Conduit in Mike View

3.3 GIS Integration – MOUSE GIS

MOUSE GIS is an ArcView based module for Mike SWMM users. Through MOUSE GIS, SWMM models can be integrated with GIS databases and with inventory and asset management systems.

MOUSE GIS capabilities include:

- Import of sewer and drainage system data from a wide range of standard formats and automatic conversion to the non-proprietary SWMM formats
- Powerful network and catchment data simplification and management routines
- Presentation of simulation results
- Audit track facilities for quality checking of model building procedures

Mouse GIS has not been used at this point with the WWMP Model, but the capability is available. Another tool used to intergrate the model with GIS is SWMM TOOLS, which is discussed next.

3.4 GIS Integration – SWMMTools

SWMMTools is a group of open and extensible GIS scripts for SWMM developed within ArcView 3.X using ArcView's Avenue programming language. SWMMTools allows viewing of SWMM model input and output summary data within ArcView 3.X, allowing modelers to exploit GIS tools for analyzing model configurations and output. SWMMTools does not substitute for the commercial interfaces for SWMM, as none of the scripts permits viewing of conduit profiles, display of dynamic results, or editing of input data. The scripts are designed to facilitate modeling for engineers who have access to other SWMM visualization tools. However, provided they have access to ArcView 3.X, SWMMTools provides a basic GIS interface to SWMM for users who might otherwise only use the core SWMM program.

SWMMTools enables viewing of model input and output data by reading the respective model input/output files so as to build themes and populate the attribute tables with the associated data.

Functionality can be grouped into 3 areas based on the SWMM modules accessed plus a fourth area that contains routines to help build and update a model scenario.

3.4.1 EXTRAN Functionality

SWMMTools provides functionality to read both EXTRAN input and output files.

The **Read EXTRAN Input** option reads an EXTRAN input file and optionally, a .XYS or .COR coordinate file. Using the information read from the input file, SWMMTools creates two shapefiles, one for junctions and the other for conduits and other connection elements (orifices, weirs, pumps).

EXTRAN C1, F1, G1, and H1 data are read into the Conduits theme:

- PIPE- pipe name/number
- MHFROM - upstream manhole ID
- MHTO - downstream manhole ID
- PIPETYPE - EXTRAN pipe type for C1 conduits. 21 for orifices, 22 for weirs, 23 for pumps
- AREA - conduit area
- HEIGHT - conduit height or diameter
- WIDTH - conduit width
- LENGTH - conduit length
- ZP1 - upstream offset height or elevation
- ZP2 - downstream offset height or elevation
- MANNING - roughness coefficient
- WH - pipe dimensions in inches or millimeters, according to model units.

EXTRAN D1 junction data and I1/I2 outfall data are read into the following fields of the Manholes theme:

- JUNCTION- junction name
- RIM - ground elevation
- INVERT - invert elevation
- DWF - dry weather flow
- OUTFALL - a 0 for non-outfalls; the boundary condition number for outfalls
- OUTFALLS.DBF is created and used to populate the OUTFALL field in the Manholes theme.

The **Read EXTRAN OutPut** option extracts outflow, conduit and junction summary data from the EXTRAN output file. EXTRAN input themes must already have been created using the Read EXTRAN Input tool. Summary data are linked to existing manhole and conduit themes.

Table MANSUM.DBF is linked to an existing manhole theme. It contains the following fields:

- JUNCTION - junction name
- HMAX- maximum junction elevation

- PCTCHNG - junction average percent change
- SURCHARGE - feet/meters of surcharge at max elevation
- FREEBOARD - feet/meters max depth is below ground elevation
- SURCHMIN - length of surcharge (minutes)
- FLOODMIN - length of flooding (minutes)
- FLOOD_MG or FLOOD_M3 (depending on units used) - junction outflow (million gallons or cubic meters)

Flood_MG/Flood_M3 is read from the EXTRAN outflow summary.

The remaining fields are read from the EXTRAN JUNCTION summary.

EXTRAN Conduit Summary Statistics are read into table XCONSUM.DBF with the following fields:

- PIPE - conduit name
- QDES VDES - ratio of maximum to design flow
- QMAX - maximum computed flow (cfs or m3/s)
- VMAX - maximum computed velocity (ft/s or m/s)
- QMAX_QDES - ratio of maximum to design flow
- SLOPE - conduit slope (dimensionless)

XCONSUM is linked to the existing conduit theme. The fields are read from the EXTRAN output file.

Additional conduit summary data are read from the "Subcritical and Critical Flow Assumptions" table into XCONCRIT.DBF. The following fields are loaded into the XCONCRIT theme and linked to the existing conduit theme:

- PIPE - conduit name
- DRYMIN- length of dry flow (minutes)
- SUBCRITMIN - length of subcritical flow (minutes)
- UPCRITMIN - length of upstream critical flow (minutes)
- DNCRITMIN - length of downstream critical flow (minutes)
- QMEAN - mean flow (cfs or cms)
- PCTCHNG - average percent change
- TOTFLOW - total flow (cubic feet or cubic meters)

3.4.2 RUNOFF Functionality

The following functionality is provided by SWMMTools for interacting with the RUNOFF module.

The **Read RUNOFF Input** option converts RUNOFF G1 lines to one shapefile for "Gutters" (conduits) and one for Manhole/Inlet IDs ("RunoffMH"). H1 lines are read into CATCHMNT.DBF and optionally join data to existing catchment theme. If a catchment theme is supplied, the program creates a "Channels" theme that draws a line from each catchment centroid to its inlet manhole.

If a catchment theme is supplied, the user must specify which field contains catchment IDs. The catchment IDs in the catchment theme must match catchment names on RUNOFF H1 lines.

Pipe coordinates and inlet locations are read from either an .XYS file (N NodeID X Y) or from a standard coordinate file (NodeID X Y). MTVE-type files must have XYS extension. Standard coordinate files use default extension .COR, and cannot use XYS extension. Coordinates should be supplied for each inlet specified on the H1 lines and each MHTO specified on the G1 lines.

G1 data are saved into the following fields in GUTTERS.DBF:

- PIPE - Pipe name
- MHTO - Inlet ID
- PIPETYPE - Pipe type code (1=box; 2=circular, etc.)
- WIDTH - width (diameter for circular pipe)
- LENGTH - length
- SLOPE - conduit slope
- LSLOPE - left side slope
- RSLOPE - right side slope
- MANNING - Manning N
- HEIGHT - conduit height
- XFROM - upstream X ordinate
- YFROM - upstream Y ordinate
- WH - width×height

H1 data are saved into the following fields in CATCHMNT.DBF:

- RAINGAGE - Raingage ID
- CATCHMENT - Catchment ID (should match GIS theme ID)
- MHTO - Inlet
- CATCHWIDTH - Width
- CATCHAREA - Area
- DCIA - DCIA

- SLOPE - catchment slope
- IMPN - Impervious N
- PERVN - Pervious N
- IMPSTOR - Impervious depression storage
- PERVSTOR - Pervious depression storage
- INFINIT - Initial infiltration (Horton), capillary suction (G-A)
- INFFINAL - Minimum infiltration (Horton), hydraulic conductivity (G-A)
- DECAY - Decay (Horton), Initial moisture deficit (G-A)

-1 and -2 pipe and catchment IDs (default/ratio options) are read, but succeeding values do not incorporate the modified values

Read RUNOFF Input reads RUNOFF catchment and conduit data summaries from the RUNOFF output. RUNOFF input themes must have already been created using the Read RUNOFF Input tool.

Catchment data are saved in table CATSUM.DBF and linked to the existing catchment theme if available and if the catchment names in the theme match the names in RUNOFF output.

Summary statistics for subcatchments are saved into the following fields:

- CATCHMENT - subcatcment name or number
- MHTO - gutter or inlet number
- AREA - area (acres or hectares)
- DCIA - percent imperviousness
- TOTRAIN - total simulated rainfall (inches or millimeters)
- PERDEPTH - pervious runoff depth
- PERLOSS - pervious losses
- PERMAX - pervious area peak runoff
- IMPDEPTH - impervious area runoff depth
- IMPMAX - impervious area peak runoff
- TOTDEPTH - total subcatchment area runoff depth
- TOTMAX - total subcatchment area peak runoff rate
- TOTMAXUNIT - total subcatchment area peak unit runoff

Channel/Pipe summary information for the simulation is read into table RCONSUM.DBF. The user is prompted to link results to the existing "gutters" theme.

The data are saved into the following fields:

- PIPE - channel name or number
- QFULL - full flow
- VFULL - full velocity
- DFULL - full depth
- QIMAX - maximum computed inflow
- QOMAX - maximum computed outflow
- DMAX - maximum computed depth
- VMAX - maximum computed velocity
- DATE - date of maximum flow
- HOUR - hour of maximum flow
- SURCHHRS - length of surcharge (hours)
- SURCHVOL - maximum surcharge volume

3.4.3 TRANSPORT Functionality

Read TRANSPORT Input reads E1 input data including conduits (Type 1-18) and junctions (Type 19-27) from the TRANSPORT Input file. The user is prompted to supply a .XYS or .COR format coordinate file.

The TRANSPORT network must have an established link-node layout, i.e. each conduit element must connect to a junction element

Null elements must be specified as zero-length strings, e.g. "". Non-zero length strings (e.g. " ") will cause an error

Read TRANSPORT Output reads summary data from the TRANSPORT output file. TRANSPORT input themes must have already been created using the **Read TRANSPORT Input** tool.

The TRANSPORT Conduit Surcharge Summary is read into TSURSUM.DBF with fields:

- PIPE - element number
- SURCHMIN- surcharge length (minutes)
- QFULL - Full flow
- QMAXTOQD - Peak flow ratio Qp:Qfull
- SURCHVOL - surcharge peak volume

The TRANSPORT Conduit Iteration Summary is read into TCONSUM.DBF with fields:

- PIPE - element number
- ITER - maximum number of iterations
- ITMAX - maximum number of iterations

- ERRMAX - maximum error
- QMAX - maximum flow
- SLOPECOND - conduit slope
- SLOPEMAX - maximum slope
- SLOPEMIN - minimum slope
- SLOPEAVG - mean slope
- FLOWTOTAL - total flow

3.4.4 Model Building Functionality

In addition to reading and writing input and output files from various SWMM modules, SWMMTools provides the user with several utilities to help build or update a model.

Land use data is frequently used to estimate effective percent imperviousness (DCIA) for a model. By unioning a land use theme with a catchment delineation theme, a theme that discretizes each land use group within each catchment can be produced. The utility, **Compute RUNOFF DCIA**, re-aggregates the land use - catchment theme and computes aggregate DCIA for each catchment . The user must supply a .DBF-format look-up table listing DCIA values for each land use type.

The **Update Basin Areas** utility primarily performs a housekeeping activity. While ArcView can compute the area of each catchment (polygon) within a polygon theme and store the values in a data table, it does not automatically update the data table as the theme is edited. The **Update Basin Areas** utility creates and/or updates either an Acres or Hectares field based on the appropriate project units. This script is derived in part from a sample script included in the ArcView sample files (calcapl.ave).

In addition to computing the area, the Update script estimates catchment width. Catchment width is a measure of the length of the main drainage channel in a catchment and the level of aggregation of the prototype drainage network. In many situations, this parameter is considered primarily a calibration parameter. The algorithm used computes the catchment width as 1.7 times the longer of the height or width of the catchment polygon. This approach is loosely based upon a methodology in the SWMM manual (Huber and Dickinson, 1988), which suggested an initial catchment width of 1.7 times the length of the main drainage channel. As ArcView only computes the axis lengths of a polygon along the X- and Y- axes, the polygon extent does not necessarily correspond with the length of the principal axis. However, the method yields a reasonable value for a typical model, and is intended as an initial estimate rather than a fixed specification. It could be easily modified to use the root mean square of the catchment's axis lengths or the catchment's perimeter.

4. Summary

The model has been updated with a number of changes and improvements in its representation of the greater Detroit regional sewer collections system. A model display tool, MIKE SWMM, has been utilized to provide a user interface with the

model input data and the model output results. SWMMTOOLS has been used to display the model in a GIS framework for additional capabilities for visual review of the model input and results spatially. These updates and model display tools will provide DWSD the sewer network display and update functions needed for use of the WWMP Model.

5. References

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