Getting Started with Storm and Sanitary Drainage Analysis using SWMM5 (Beta-E 01/23/04)

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This chapter comprises a step-by-step example for a simple storm drainage and sanitary sewer design (PAT Avenue), prepared by Robert Pitt and Alex Maestre, of the Department of Civil Engineering at the University of Alabama.

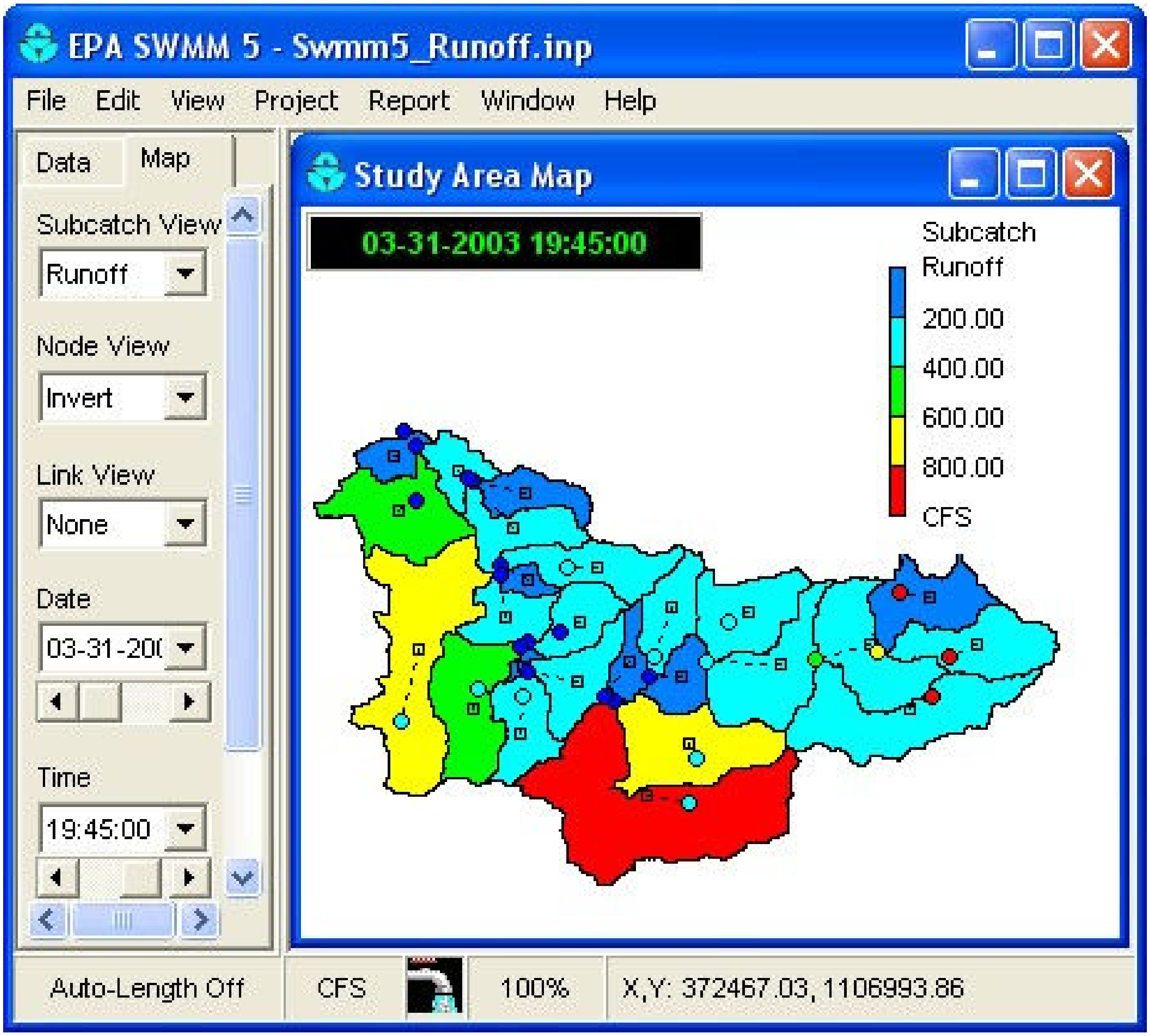
Introduction

The US EPA National Risk Management Laboratory and CDM Inc., are rewriting the Storm Water Management Model (SWMM) software. The original version of this software was developed between 1969-1971, with Metcalf and Eddy (M&E) of Palo Alto, CA, the main contractor to develop the different modules in the program. M&E subcontracted some of the modules to Water Resources Engineers of Walnut Creek, CA (WRE) and the University of Florida (UoF). WRE (now part of CDM), developed the original RUNOFF, RECEIV and GRAPH models. M&E developed the RUNOFF quality and STORAGe/Treatment routines. UoF developed the TRANSPORT module. In 1973, WRE developed the TRANS model that later in 1977 was modified to EXTRAN (Larry Roesner). Also in 1977, William James developed the minicomputer version known as FASTSWMM and SWESWMM. In 1984, Computational Hydraulics Institute (CHI), the company formed by William James, developed the first user-friendly microcomputer version known as PCSWMM. In 1988, version 4 of SWMM was released by EPA and included some of the enhancements developed by PCSWMM. Since that time, the UoF (Wayne Huber and Jim Heaney), University of Guelph (where William James taught) and Oregon State University (Wayne Huber) have been improving version 4, with the release of version 4.4gu in 1999 (James 2002).

SWMM5 was developed for many reasons: the previous versions were developed in DOS-based FORTRAN over more than a 30 year period with different levels of documentation. The development of the Windows environment and object oriented programming techniques improved programming capabilities and graphical user interfaces. One advantage of the new model is that only a single file is needed, and not multiple modules, for a single simulation. A single file can now be created that contains RUNOFF, TRANSPORT and/or EXTRANS at the same time. SWMM5 uses the same environment that EPANET uses, assigning the values to the objects used during the simulation. Other reasons for the new SWMM version are its ability to eventually develop routines for modeling stormwater control practices, to improve the routing procedures of water quality in the model, and to create the possibility to simulate Real Time Control by manipulating control structures (EPA 2002).

Starting SWMM5
The model can be downloaded by going to the EPA web site:

http://www.epa.gov/ednnrmrl/swmm/



Copy the program to your computer and follow the installation instructions. To start the program, go to the shortcut located on your desktop, or select *start/programs/SWMM5*.

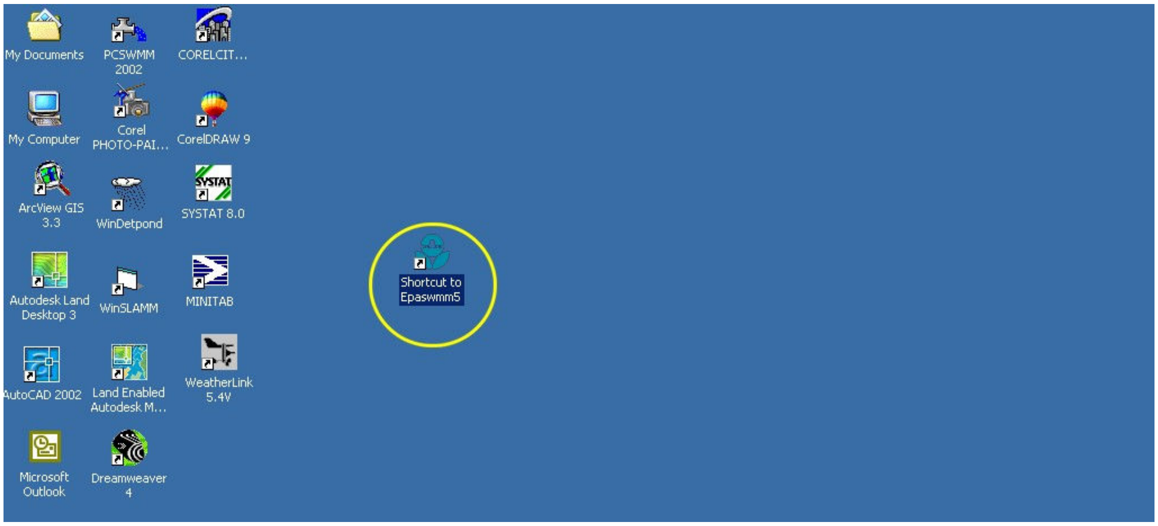


Figure 1

To start the program, go to the shortcut located on your desktop, or select *start/programs/SWMM5*. The SWMM 5 environment consists of seven areas: Main Menu, Main Toolbar, Drawing Element Toolbar, Data and Map Browser, SWMM controls, Properties, and the Drawing Area.

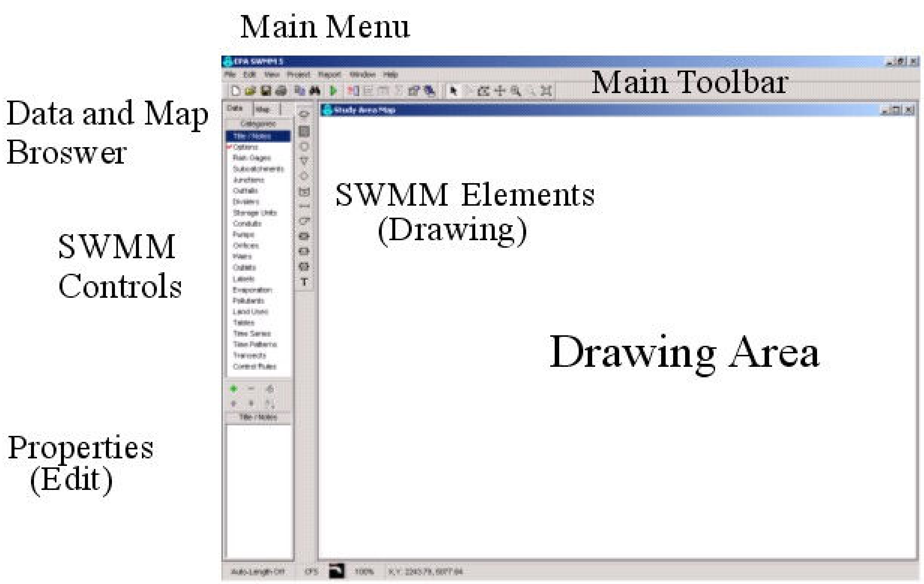


Figure 2. SWMM5 Environment

"Hello World" Pat Avenue Storm Drainage Design Example

Project Information

This is a very simple example intended to show the user how to access the main components of SWMM5 and to create and run a simple model. After going through this example, it should be much easier to follow more complex examples, or to enter site-specific information for a larger and more complex site.

Pat Avenue is located in Birmingham, AL. It consists of three subcatchments, three junctions (nodes) and two conduits (pipes) in a residential area. The water collected during a rainstorm is discharged to a main sewer trunk. Figure 3 shows the watershed delineation for Pat Avenue.

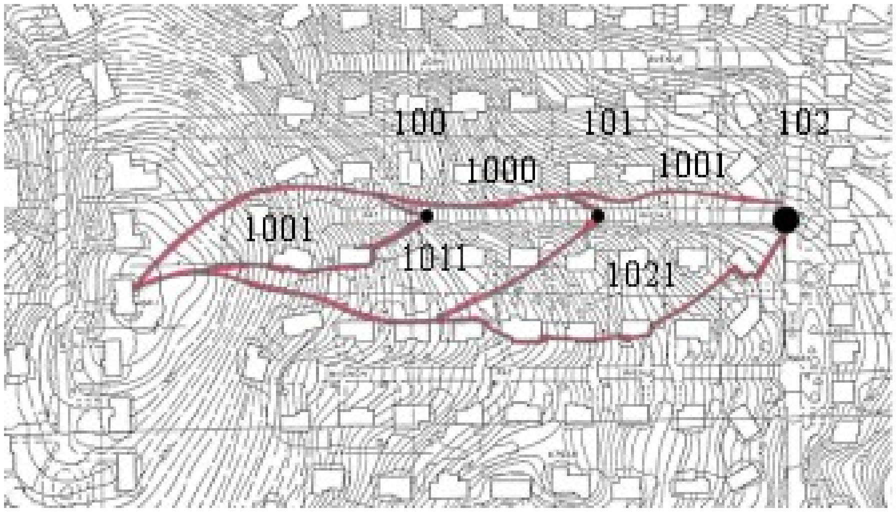


Figure 3. PAT Avenue subcatchments, joints and conduits (in this example, another link, 1003, was created to allow all subwatershed flows to be combined before the outfall junction, now 103).

The description of each subcatchment is shown in Table 1.

Table 1. Pat Avenue Subcatchment information:

SUBCATCHMENT	Area (Acres)	Width (ft)	Slope (ft/ft)	Percentage imperviousness	n Manning impervious	n Manning pervious
1001	1.067	98.3	0.084	54	0.040	0.410
1011	1.087	74.5	0.093	54	0.040	0.410
1021	1.431	109.0	0.072	54	0.040	0.410

SUBCATCHMENT	Horton maximum infiltration rate (in/hr)	Horton minimum infiltration rate (in/hr)	Horton decay coefficient (1/sec)	Horton recovery coefficient (fraction)	Maximum volume (inches)
1001	1	0.1	0.002	0.001	0*
1011	1	0.1	0.002	0.001	0
1021	1	0.1	0.002	0.001	0

* A zero value for maximum volume disables the maximum volume function

The three subcatchments are similar in all the parameters except area, slope and width. The width of the watershed can be calculated as the ratio of the area to the longest flow path in the watershed. This is a critical attribute that affects the watershed time of concentration. The infiltration parameters are the same for all three subcatchments. The junction properties are shown in Table 2.

Table2. Pat Avenue Junction Information:

JUNCTION	Invert Elevation (ft)	Maximum Depth (ft)	Initial Depth (ft)	Surcharge Depth (ft)	Ponded Area (ft^2)
100	791	10	0	0	0
101	769	10	0	0	0

102	753	10	0	0	0
103 (Outfall)	745	n/a	0	0	0

The invert elevation corresponds to the elevation of the corresponding junction. The maximum depth is the distance from the bottom of the junction to the ground surface. The surcharge depth is the additional water depth above the ground surface used to store water during surcharge conditions. The ponded area is the surface area of the water accumulated during the surcharge. The conduit information is shown in Table 3.

Table 3. Pat Avenue Conduit Information:

CONDUIT	Shape	Diameter (ft)	Length (ft)	n Manning	Inlet invert height offset (ft)
1000	Circular	1	300	0.013	0.5
1001	Circular	1	300	0.013	0.5
1003	Circular	1	100	0.013	0.5

CONDUIT	Outlet invert height offset (ft)	Initial flow (cfs)	Entry loss coefficient	Exit loss coefficient	Average loss coefficient
1000	0.5	0	0	0	0
1001	0.5	0	0	0	0
1003	0.5	0	0	0	0

There are two circular concrete pipes, each 1 ft in diameter (the minimum pipe diameter allowed by the local regulations). The length of each pipe is 300 ft. There is no initial flow in the pipe and entrance and exit losses are negligible. There is no flap (tidal) gate at the end on the pipe.

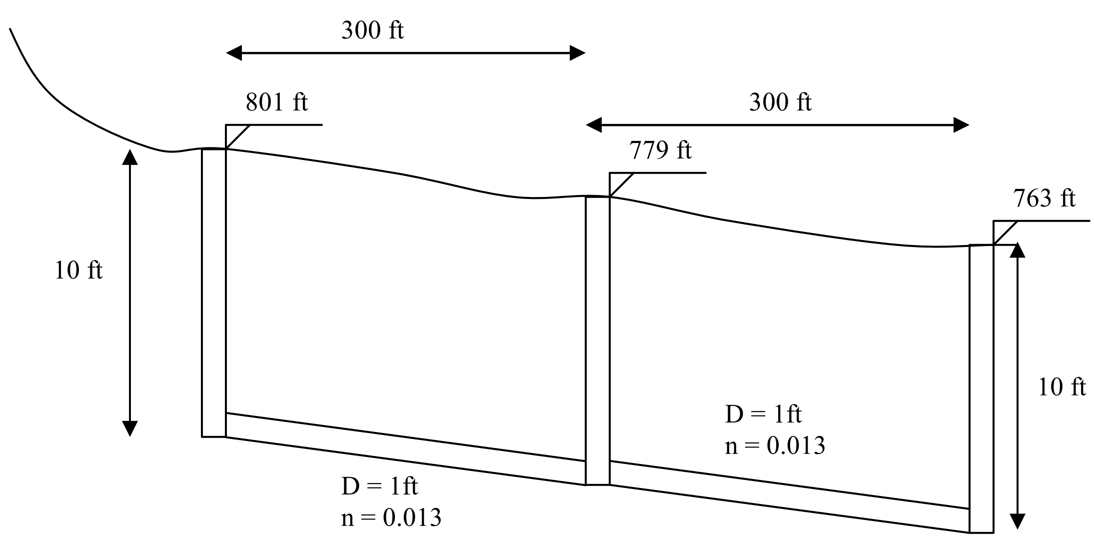
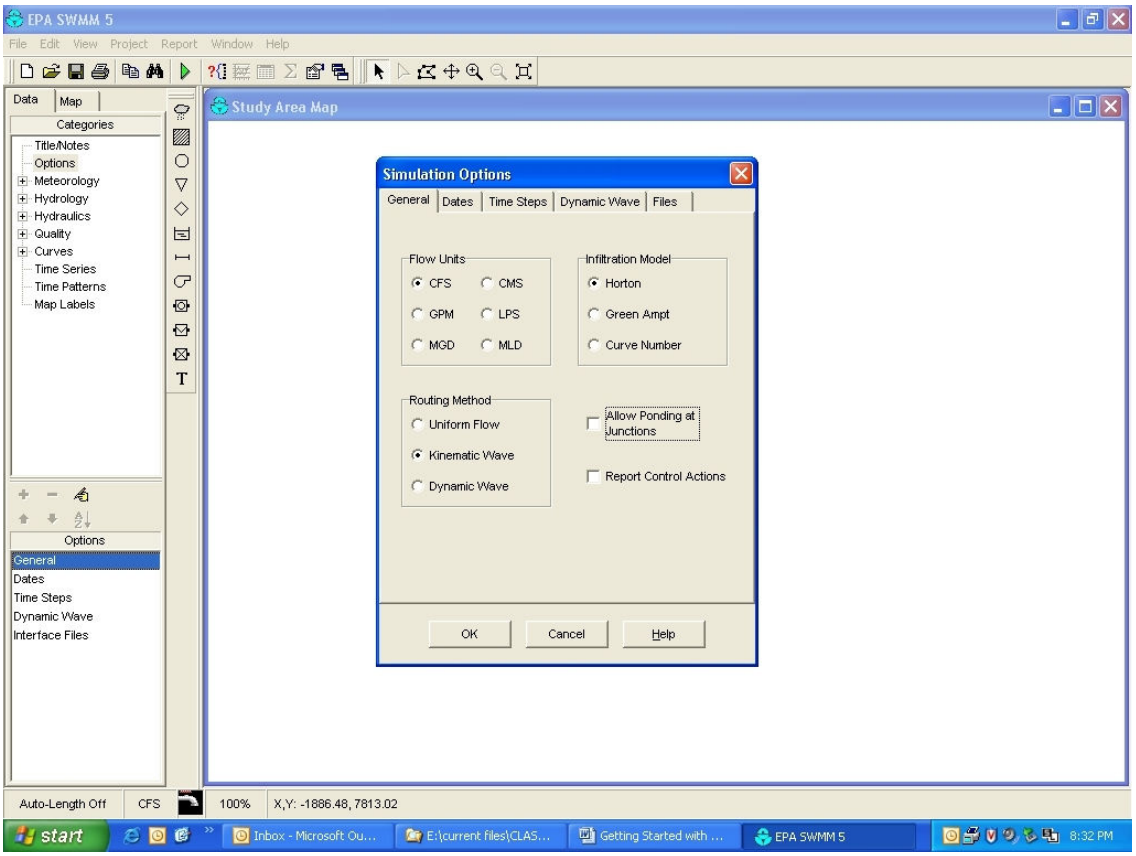


Figure 4. PAT Avenue's joints and conduits characteristics.

Creating a New Project

The first step is to name the project. Click on the data browser tab and select the *Title/Notes* option. In the properties area, a green plus sign will appear. Click on the green plus to add a title to the project. After assigning the title, you will be able to use the remaining options. The red minus sign will delete the object, and the yellow finger will edit the object. The remaining options will move up, move down or order the elements in the properties box.

Return to the data browser and click on the *options* category. The edit option will be active in the properties area. In order to display the properties, or click on the desired option. Double-click the *general* button to display the properties of the project. In the general tab, select the desired units. In this case they are in US. customary units. Select flow units in cubic feet per second (cfs). The infiltration model used is Horton, but the Green Ampt and NRCS Curve Number procedures are also available. The routing model used for this example is the kinematic wave option, a continuity equation for lateral flow in an unsteady channel. In the dynamic wave option (important for unsteady flows used for evaluating CSOs and SSOs, for example) all the Saint Venant equations are used. Chow (1988) presents a description of the two models in the distributed flow routing chapter.



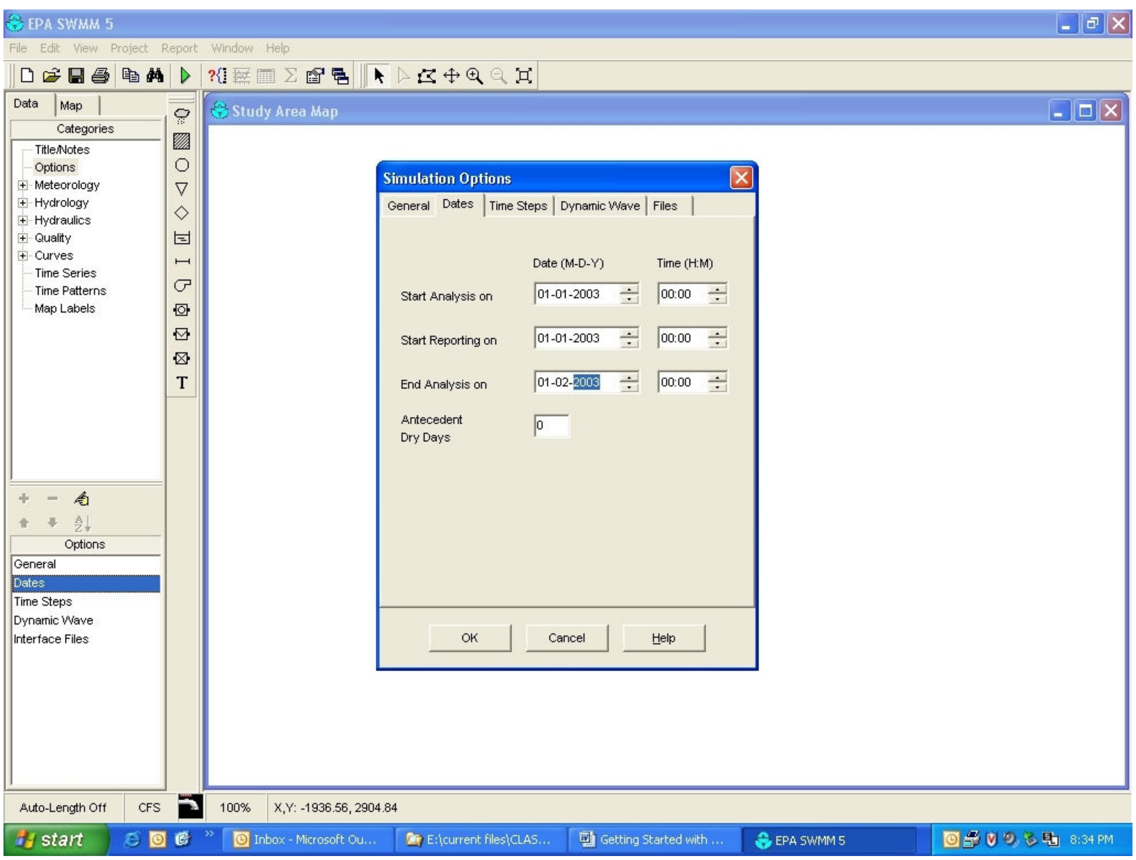
Continuity Equations:

Conservation Form	$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$
Nonconservation Form	$V\frac{\partial y}{\partial x} + y\frac{\partial V}{\partial x} + \frac{\partial y}{\partial t} = 0$

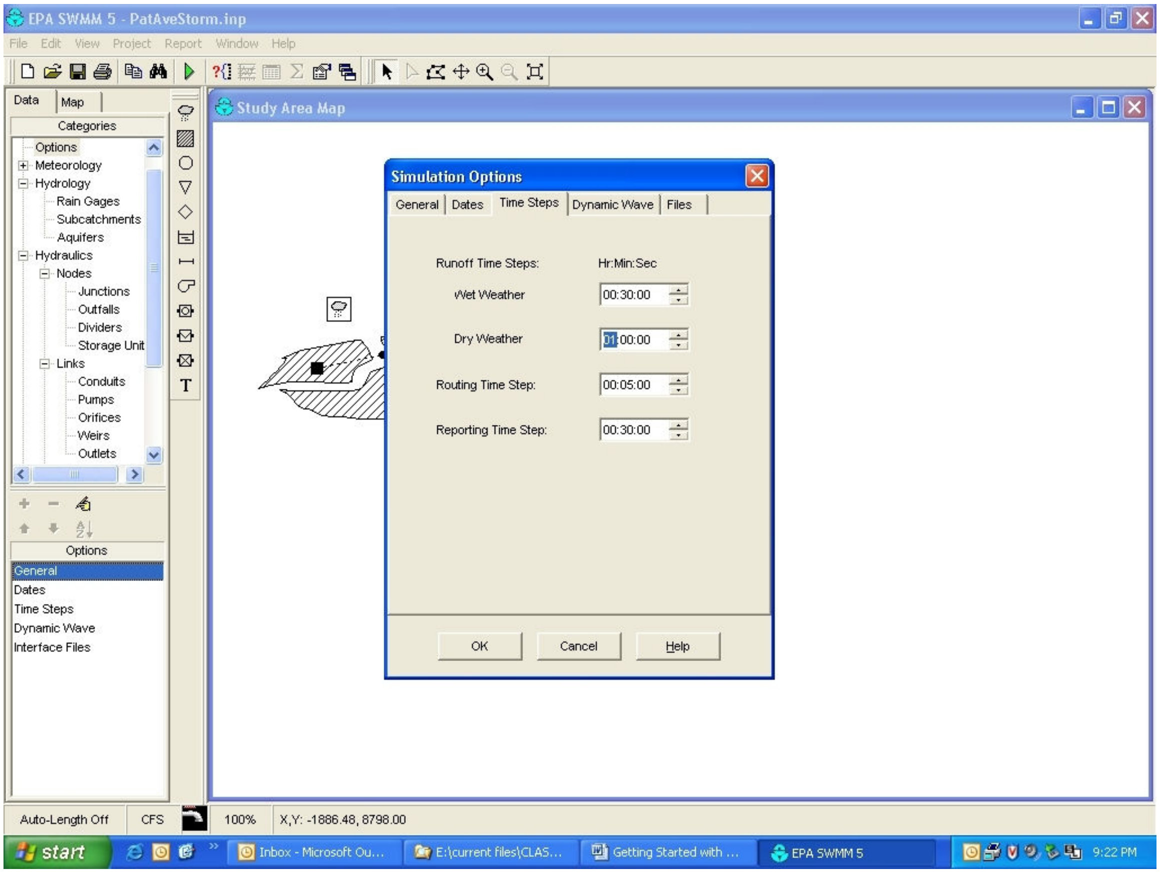
Momentum Equations:

Conservation Form	$\frac{1}{A}\frac{\partial Q}{\partial t} + \frac{1}{A}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$	
Nonconservation Form	$-g(S_o - S_f) = 0$	Kinematic Wave
	$g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$	Diffusion Wave
	$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$	Dynamic Wave

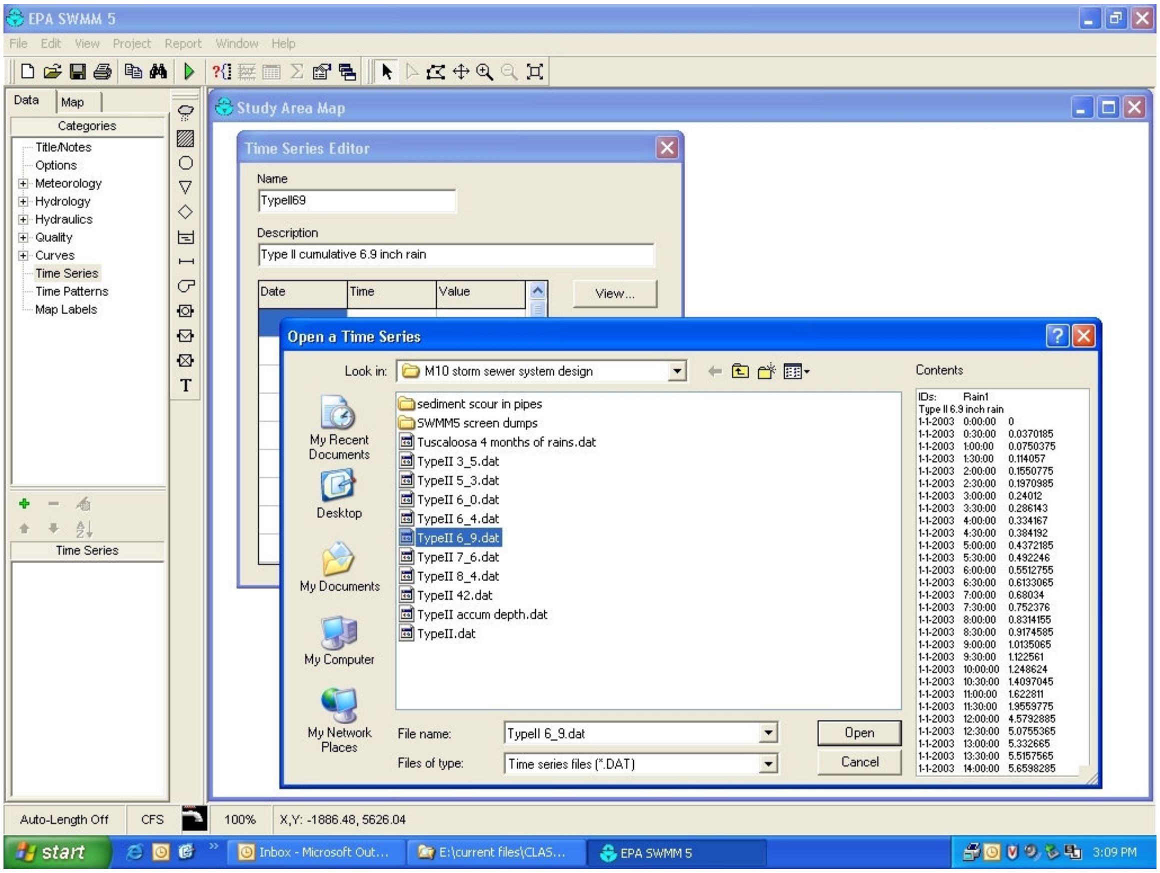
In this case, no ponding is allowed at the manholes. Uncheck this option in the general tab and click "OK". Now double-click the *dates* tab on the same window. Assume this simulation started on January 1, 2003 at 00:00 and had a 24 hour duration, in Birmingham Alabama. The analysis will end on January 2, 2003. The number of antecedent dry days is zero (it rained immediately before this simulated event). Click OK when finished.



Double-click on the *Time Steps* tab. Select the time steps according to the rain file. In this example, the rain file has data every 30 minutes. There are no dry weather processes simulated, but the default 1 hour time step needs to be selected. Select a 5-minute routing time step and a 30-minute reporting time step. The *dynamic wave* and *files* tabs are not used in this example. Click OK when finished.



Now you will import a time series with the precipitation for a 24-hour type II event, corresponding to Birmingham, AL. In the data browser, select the *Time Series* option and in the properties area add a new series by clicking on the green "+" key. In the name field, assign the name "TypeII69" without quotes or spaces. Now press the *load* button and select the TypeII 6_9.dat file. This is a type II rain distribution having a total of 6.9 inches in 24 hours, the "25-yr" reoccurrence event for Birmingham, AL. Click the *view* button to observe the 24-hour hyetograph. Close the window and click OK to accept the time series. It must be noted that this rain file only has data for 30-minute increments, likely too coarse for accurate analyses for small urban areas where the inlet times of concentrations may be about 5 minutes. A rain file having 5-minute time increments would therefore be more accurate and desirable. The example is an exercise in using the model and should not be taken as an absolute evaluation.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sediment scour in pipes
SWMM5 screen dumps
Tuscaloosa 4 months of rains.dat
TypeII 3_5.dat
TypeII 5_3.dat
TypeII 6_0.dat
TypeII 6_4.dat
TypeII 6_9.dat
TypeII 7_6.dat
TypeII 8_4.dat
TypeII 42.dat
TypeII accum depth.dat
TypeII.dat
My Recent Documents
Desktop
My Documents
My Computer
My Network Places
File name:
TypeII 6_9.dat
Files of type:
Time series files (*.DAT)
Open
Cancel
Contents
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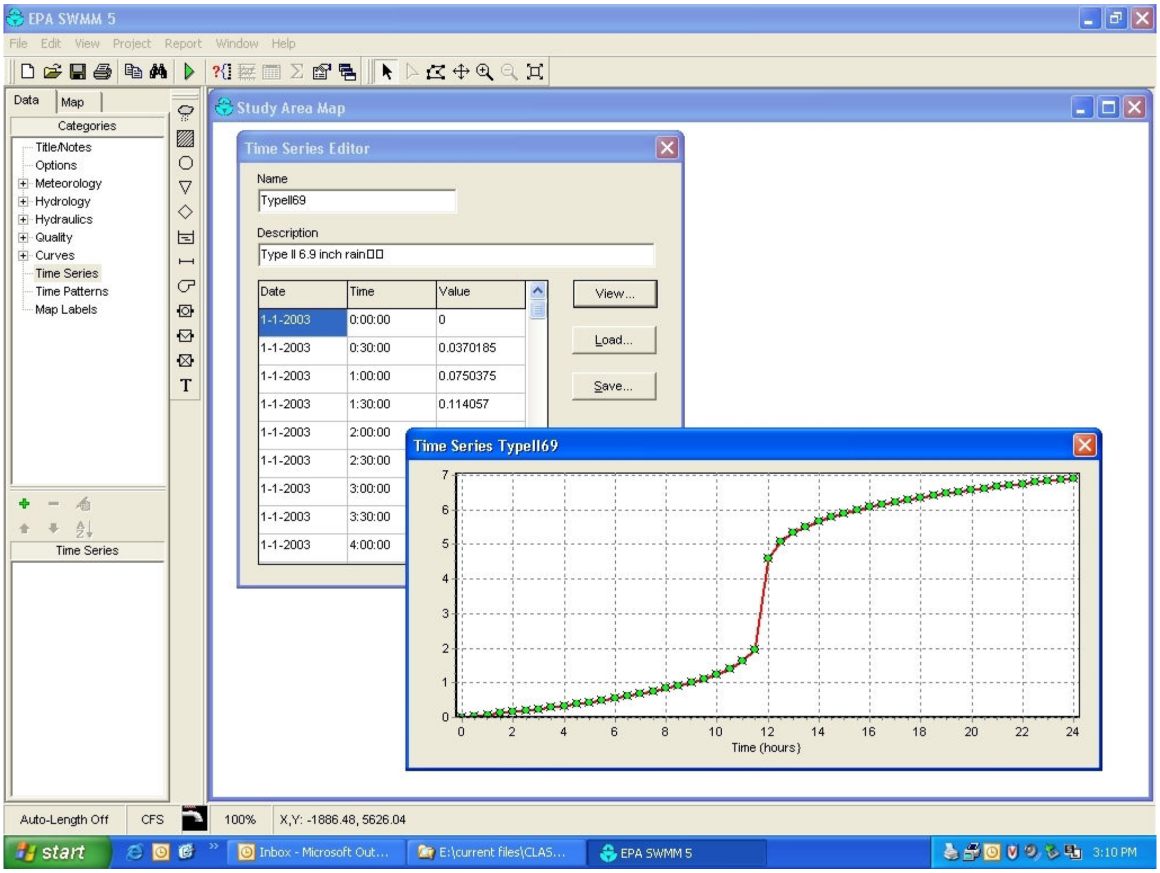
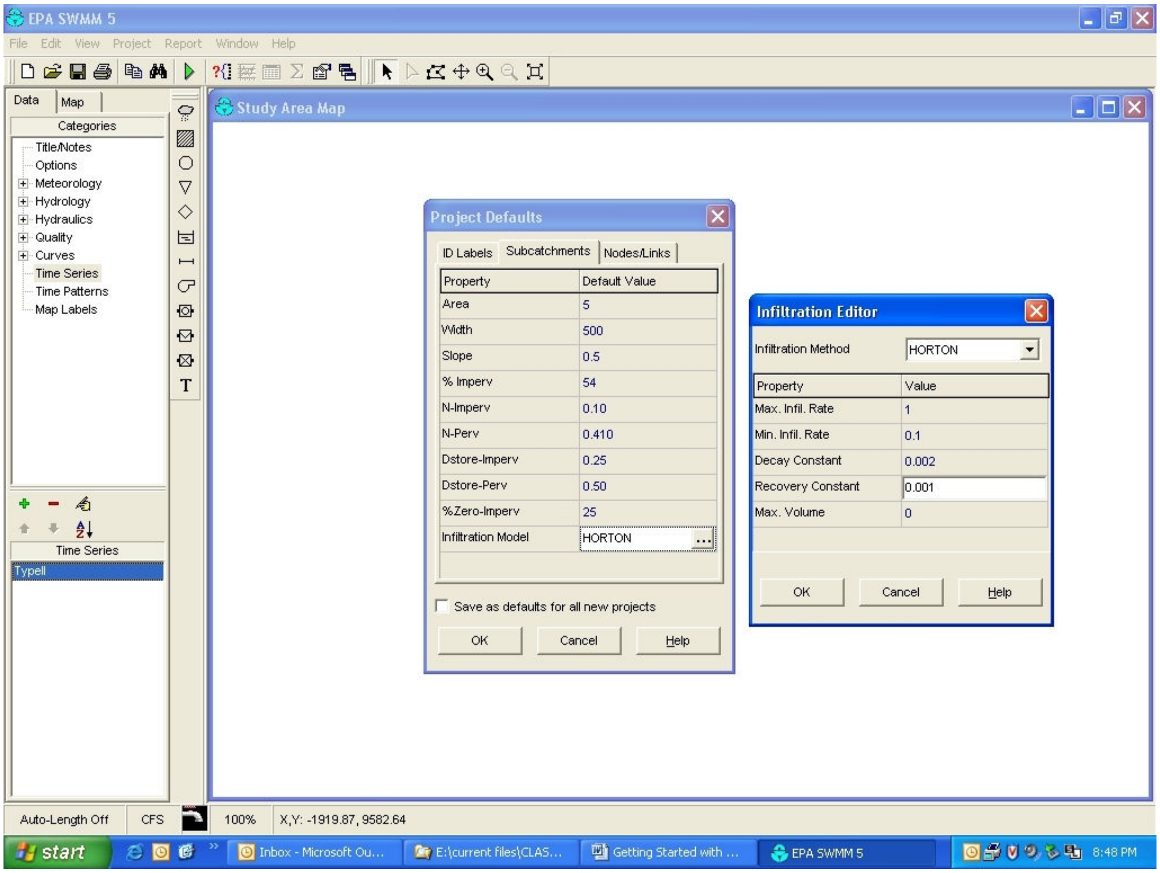
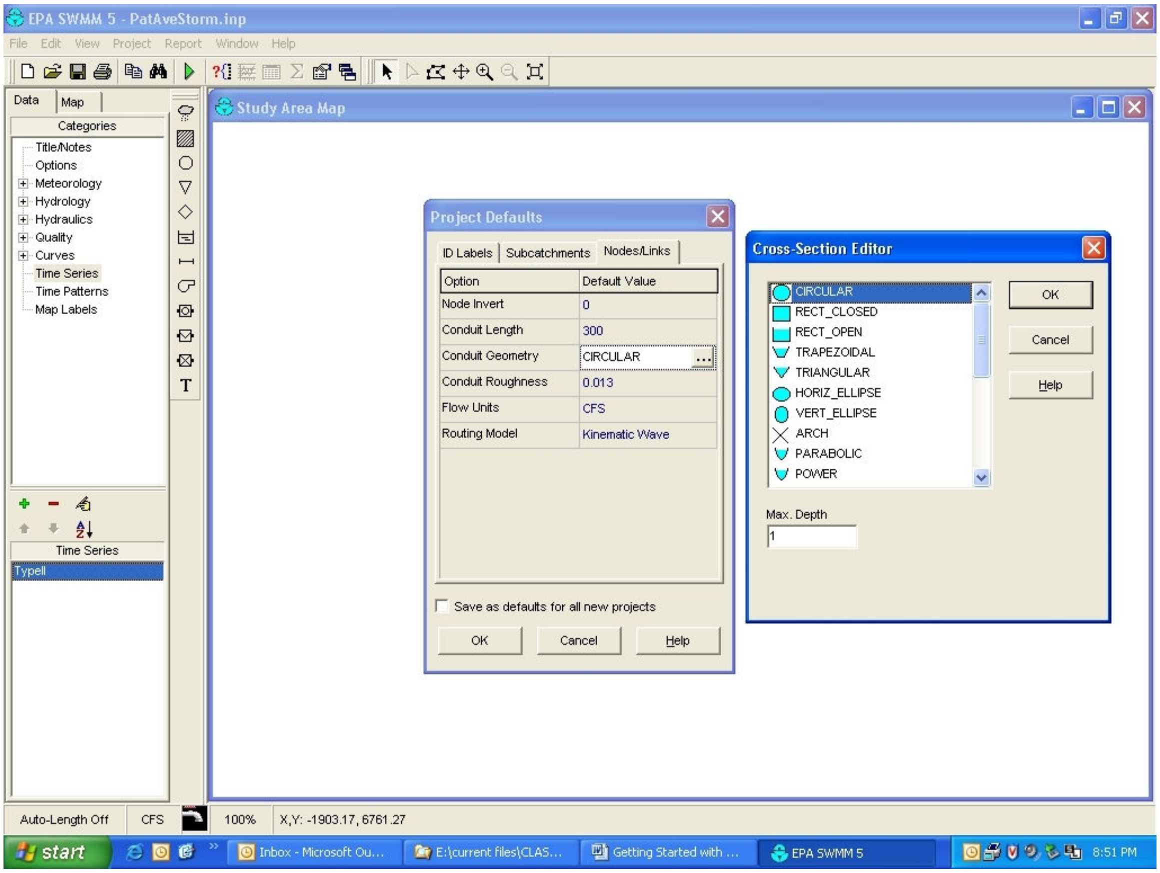


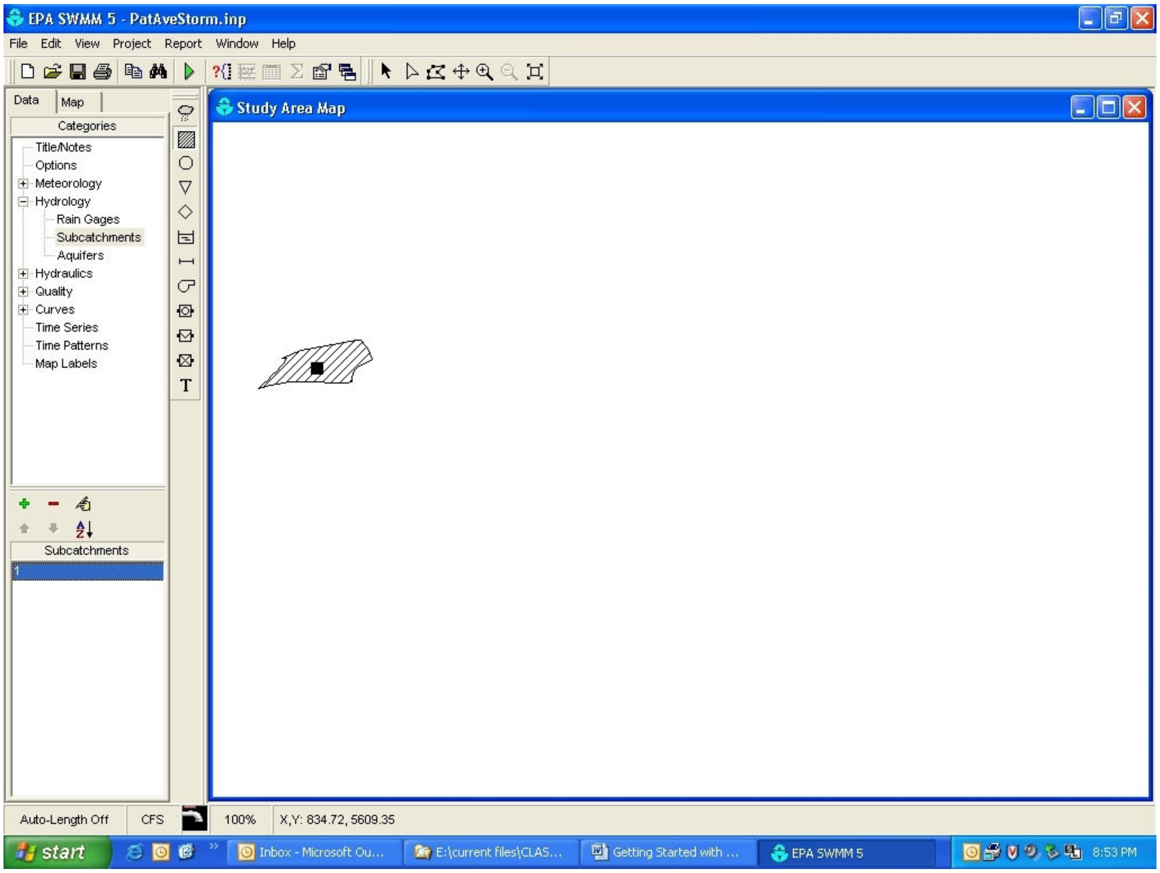
Now go to the main menu and select *project*, *defaults*. This option will create the default options for the subcatchments, conduits and junctions in the project. Click on the *subcatchments* tab. Assign 54 as the percentage imperviousness, the Manning's coefficient for pervious areas is 0.410 and for impervious areas is 0.040. Assign depression storage values for both pervious (0.50 inches) and impervious areas (0.25 inches; mostly flat roofs having large depression storage amounts). Use 25 as the percentage of zero imperviousness (to account for pitched roofs that have no depression storage). The infiltration method by default is the Horton equation. Select this method. Three dots will appear. Click on the three buttons. Assign the values indicated in Table 1. Click OK to accept.



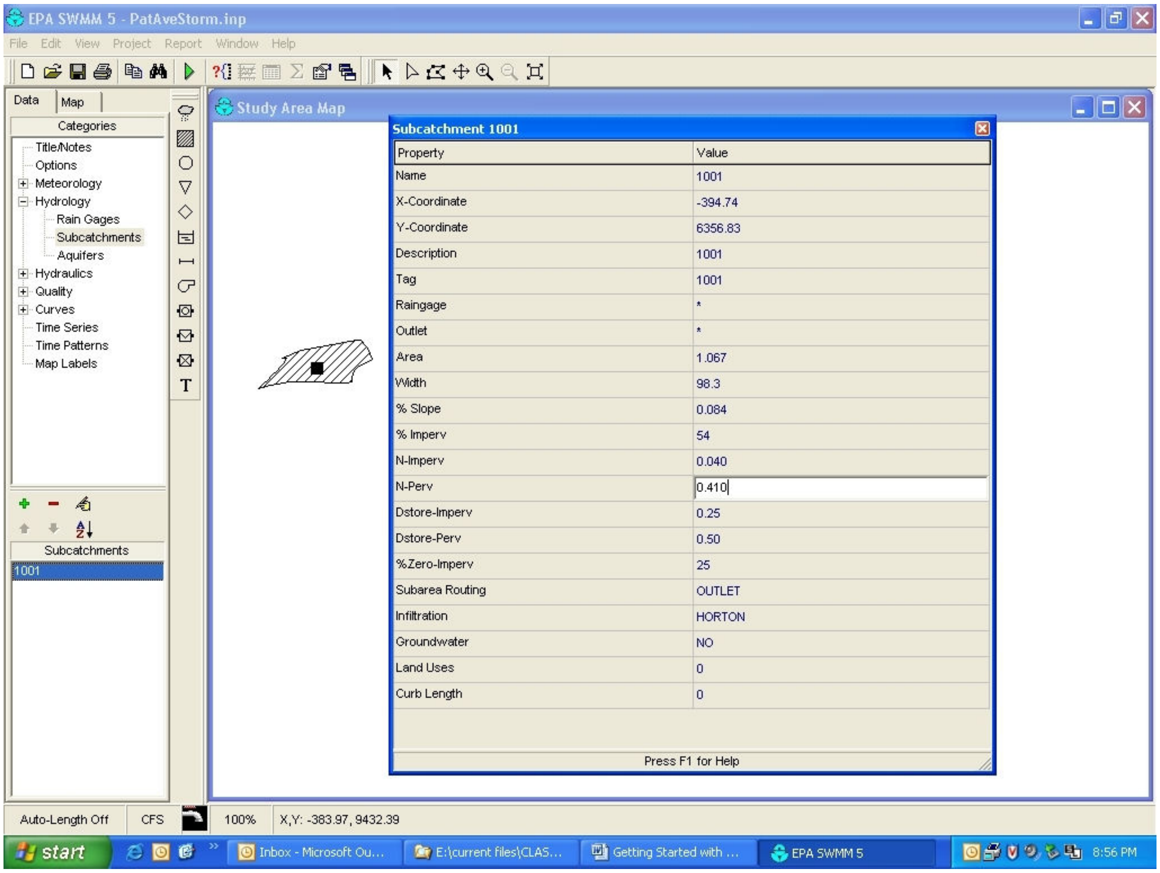
Select the *Nodes/Links* tab. Assign 300 as the length of each pipe. Select conduit geometry *circular*. Three dots will appear when you select this option. Click on the three dots to edit the pipe characteristics. Assign a maximum depth of 1. This will indicate that the pipe is 1 ft in diameter according to the units indicated in the *flow unit* field. The pipes are all reinforced concrete. Select a Manning's coefficient of 0.013 for concrete pipes. The flow units are in cubic feet per second and the routing system in this example is kinematic wave. Click OK to accept the default values. You can now start drawing the different elements for the project.



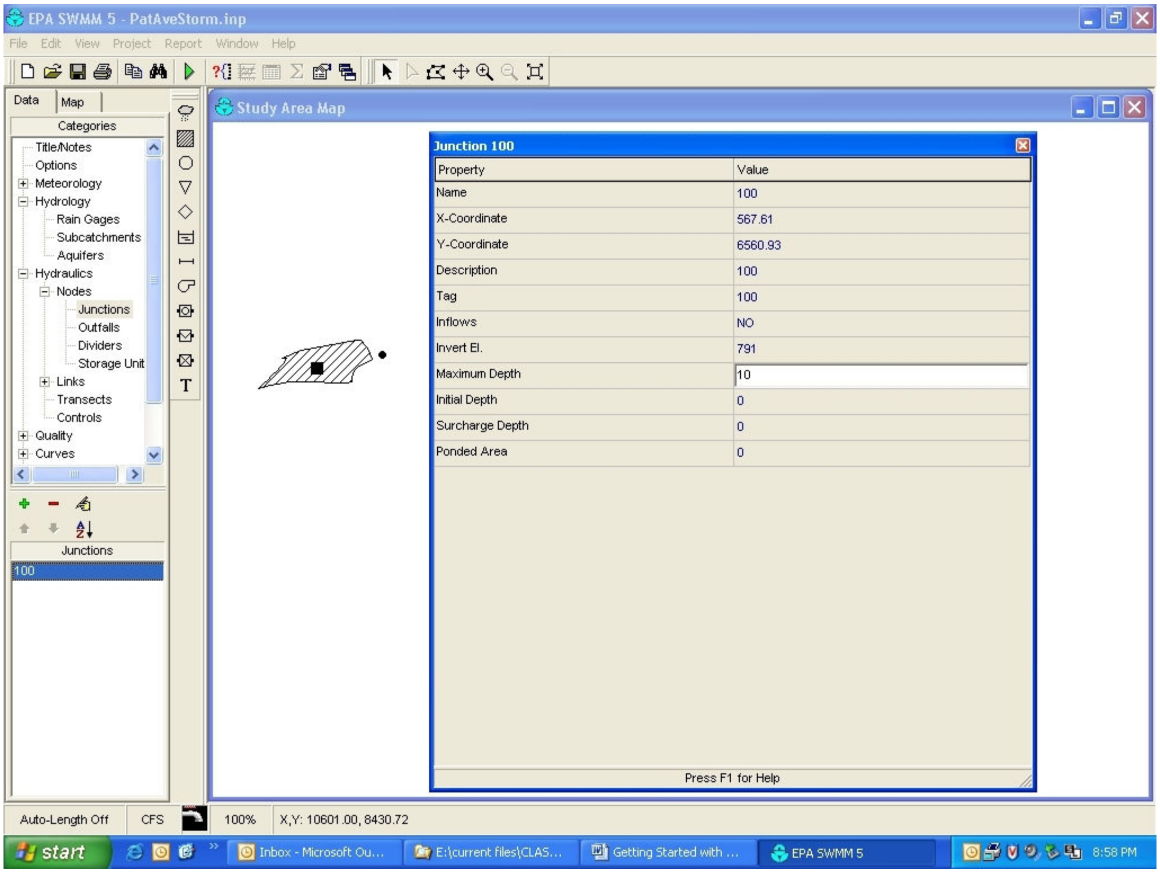
The second button in the SWMM elements is the subcatchment element. Click on it to start drawing the first watershed. A pencil will appear in the drawing area. Click the left mouse button and trace the watershed 1001 similar to that presented in Figure 3. Use the right mouse button to close the watershed drawing.



In the main toolbar, use the selector, the black arrow to select elements on the main toolbar. Now click on the blinking square inside the watershed. Assign the name, description and tag fields “1001”, without the quotes. Complete the area, width and slope information for this watershed from Table 1. Check that the infiltration information is correct and close the window.

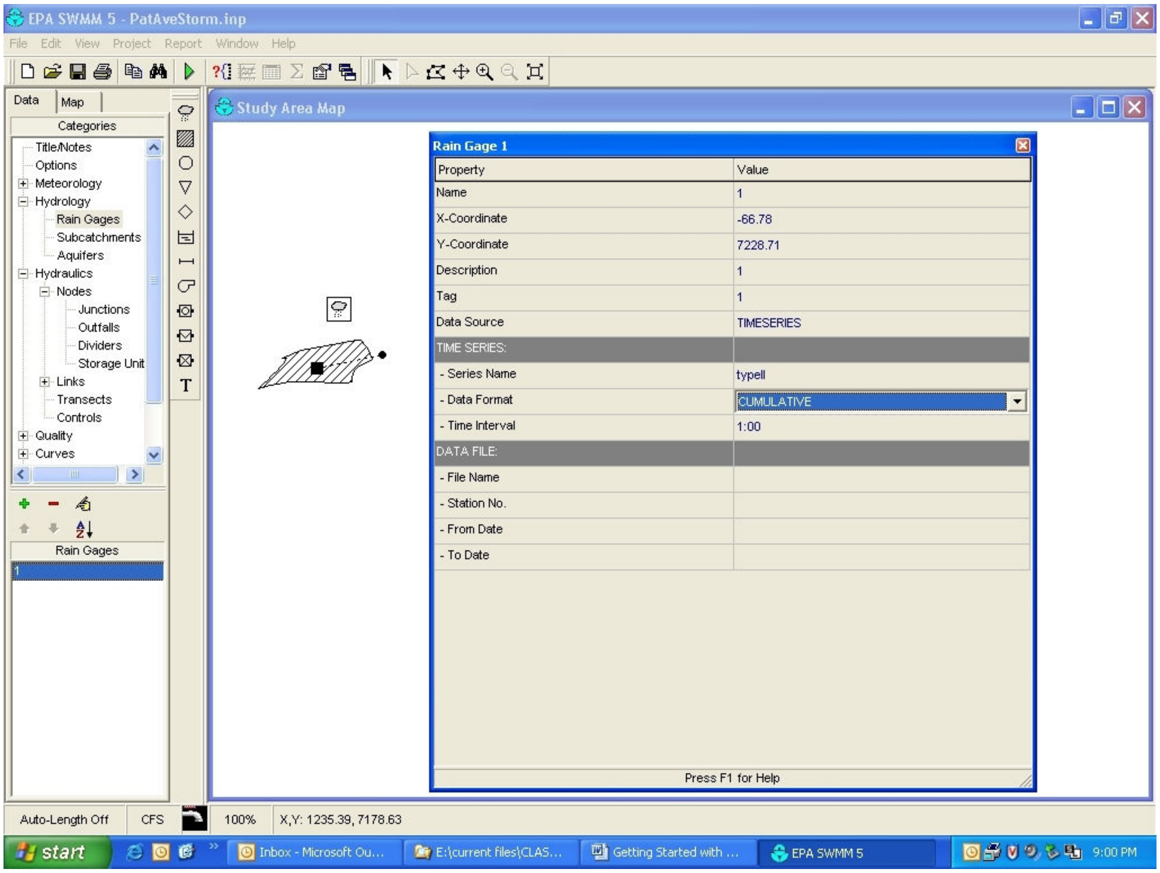


Select the *junction* button located below the *subcatchment* button. Locate the junction in the far East corner of the subcatchment 1001, outside the subcatchment. Use the selector to display the properties of the junction. Double click on the junction to display the properties. Assign “100” without quotes in the name, description and tag fields. There are no external or dry weather flow in this junction. The invert elevation of this junction is located 10 ft below the ground surface. Use 791 to assign the elevation of the junction and 10 as the maximum depth. Initial depth, surcharge depth and ponded area are zero in this case. Close the window.

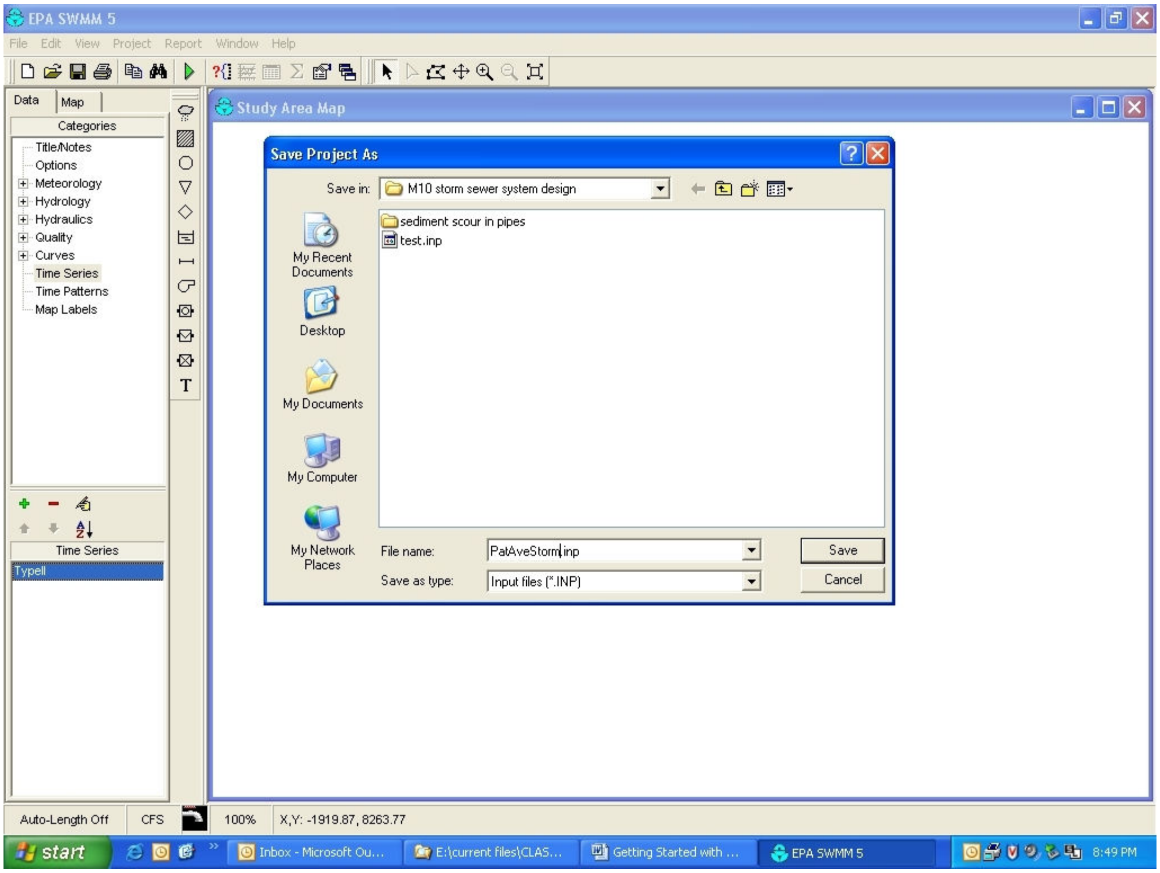


Double click again in the square located inside the subcatchment. Assign "100" without quotes to the field *outlet*. This will indicate that the water produced in this subcatchment will reach the first junction. Close the window. A dotted line will appear between the square and the junction.

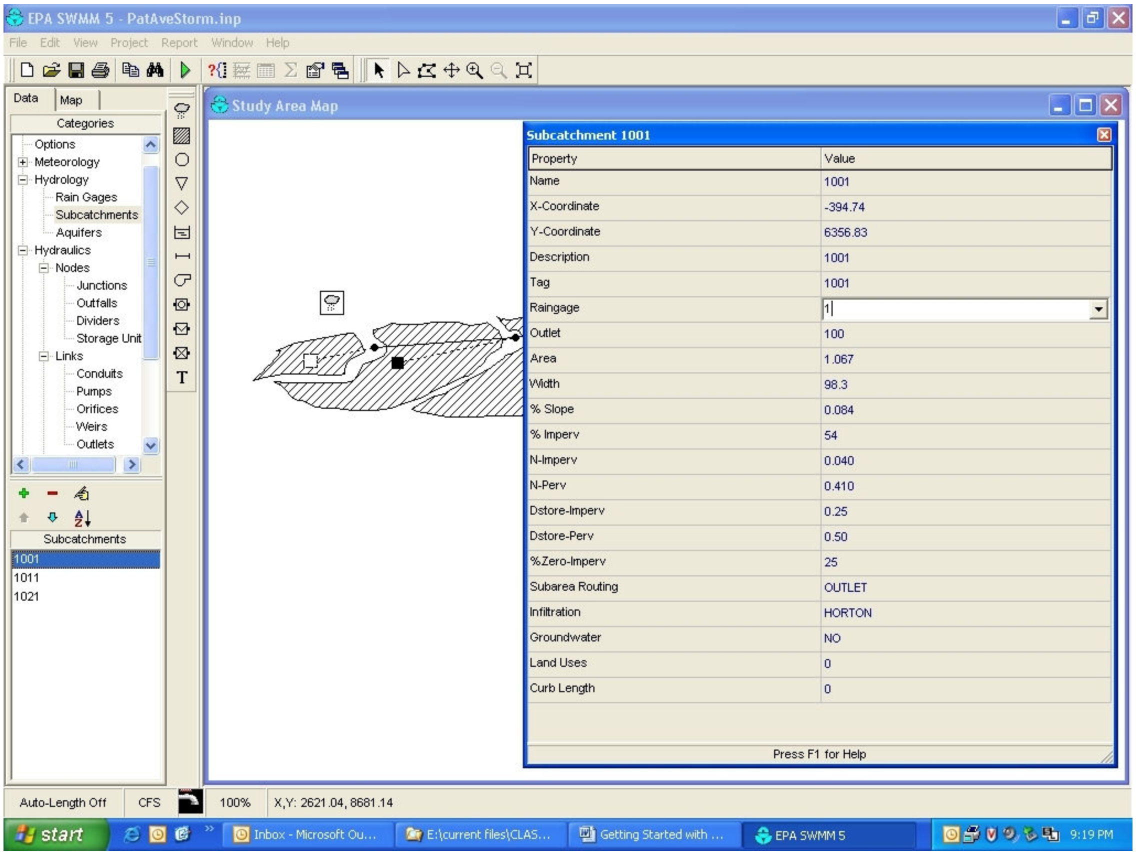
Now a raingage will be created. Click on the button located above the watershed button. It is similar to a cloud raining. Locate the raingage as shown below.



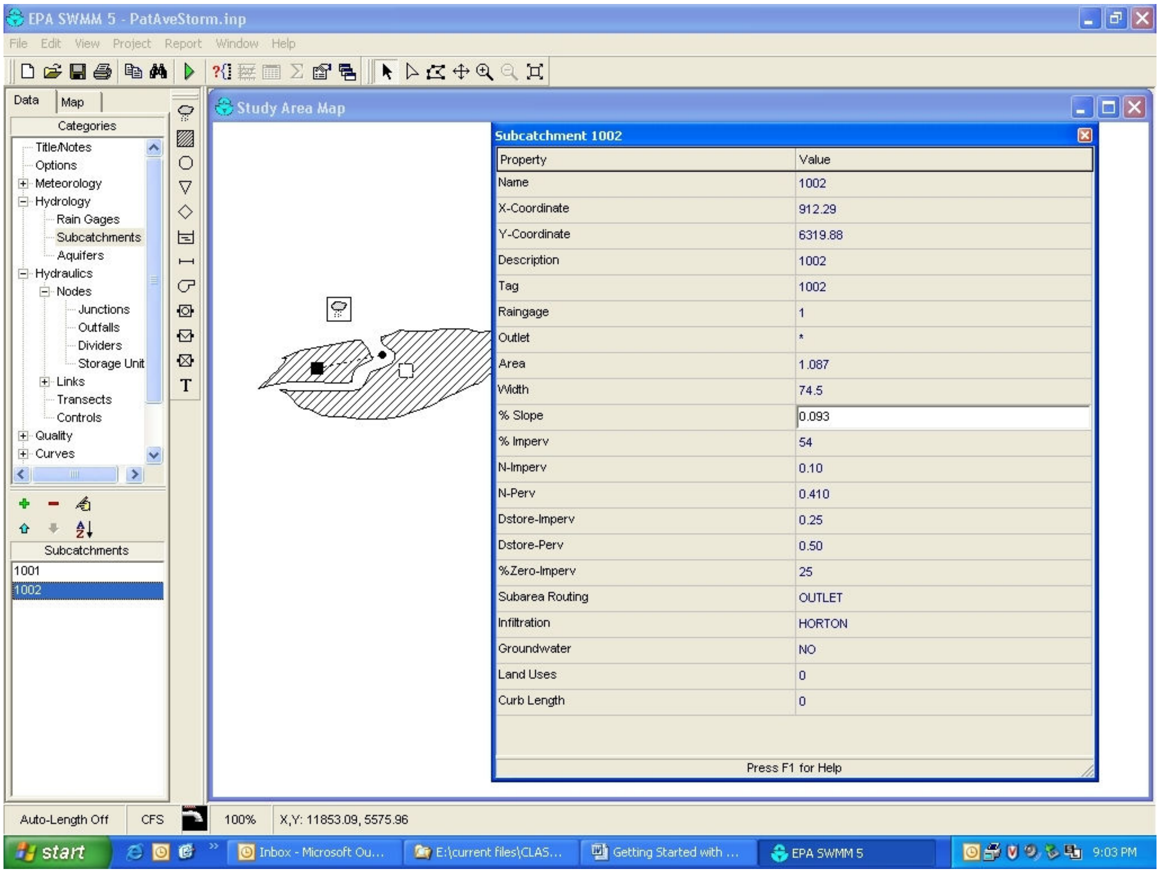
Use the selector from the main toolbar. Double click on the raingage to display its properties. Assign “1” without quotes to the name, description and tag fields. Click now on the series name. A drop-down menu will appear, select “Type II”. Close the window. Return to the subcatchment and edit the properties, including selecting “cumulative” as the data format (the rain is presented in this file as accumulative volumes). Click on the raingage field. A drop down menu will appear, select 1. Close the window. (Have you saved the project recently?)



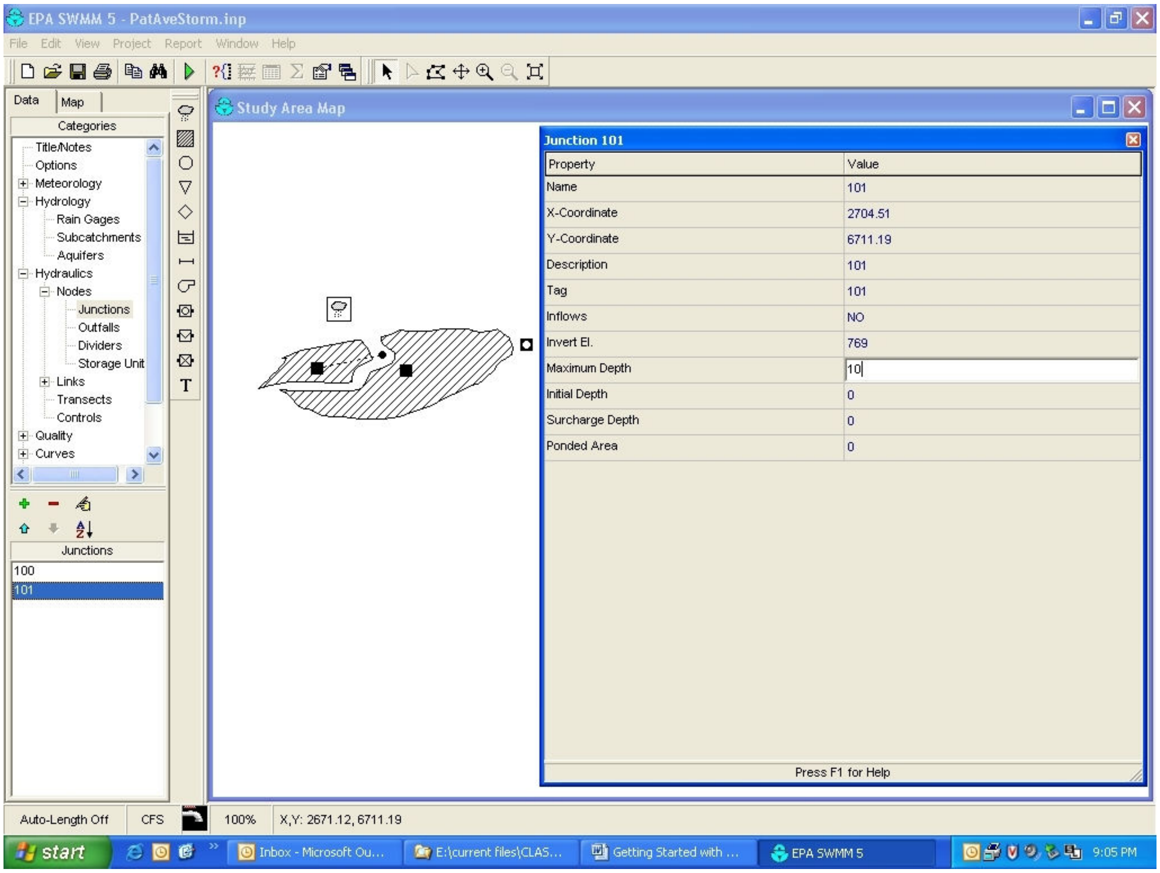
Go back to the subwatershed and make sure that the raingage 1 is selected



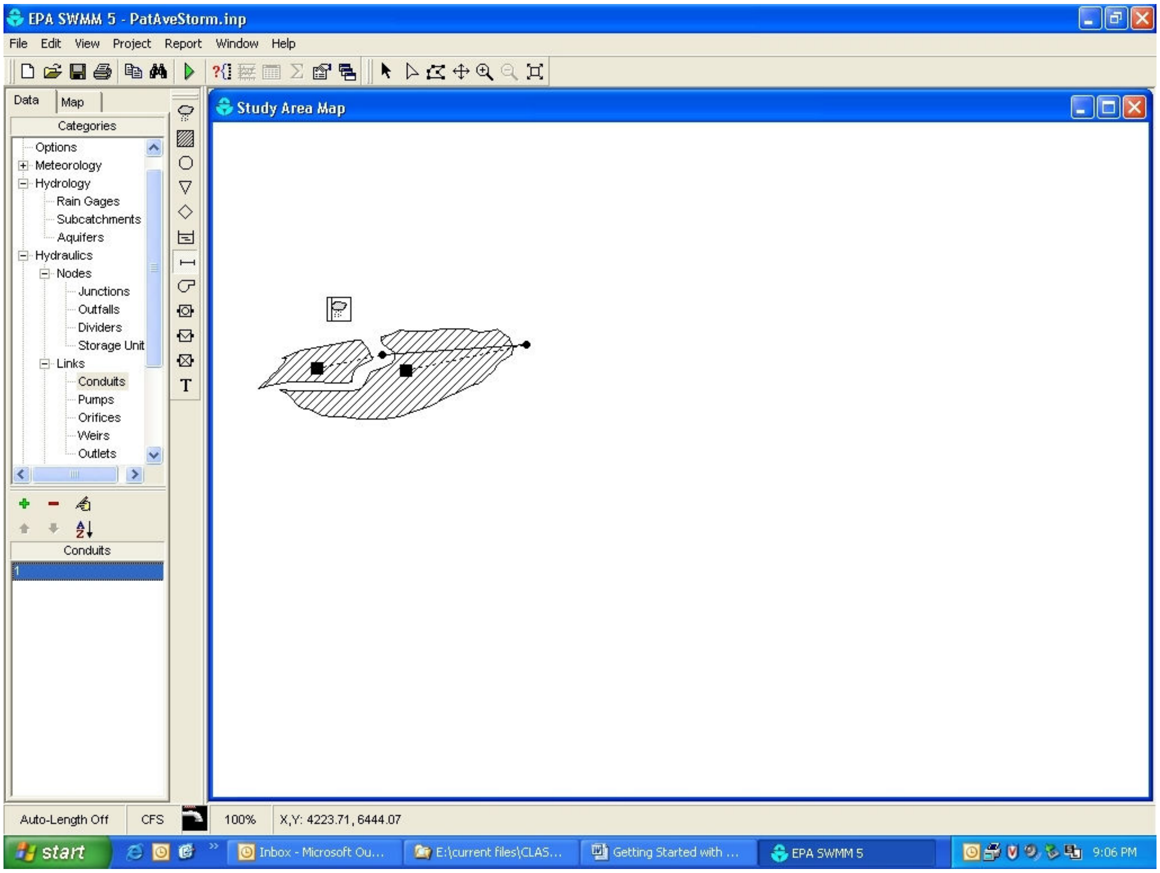
Now you have everything connected and can continue with the second subcatchment. It is recommended that you draw each element separately. Draw the second subcatchment a little displaced to the right without touching the previous watershed or the junction 100. The screen below shows the drawing area after drawing the second watershed. Complete the information using the information in Table 1. Also use the raingage 1 for this watershed. You will not be able to assign the outlet information at this moment.



Select the junction button and draw the junction 101. This junction invert elevation is located at 769 ft and has a maximum depth of 10 ft. The 0.5 ft inlet and outlet invert offset depths account for the pipe elevation off the bottom of the junction itself. Close the window. Return to the subcatchment 1011 and update the outlet information. Assign to the outlet field “101” without the quotes.



To create the conduit between the junctions 100 and 101, select the seventh button in the SWMM elements toolbar. Click on the junction 100 and in the junction 101 to create the pipe. Use the selector. Double click on the conduit to display the properties. You can also click on the little yellow hand located on the properties window. Assign “1000” without the quotes to the name, description and tag field. Use Table 3 to complete the information of the conduit. Now create the last watershed using the watershed button and use the information from Table 1 to complete the required data.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Rain Gages
Subcatchments
Aquifers
Hydraulics
Nodes
Junctions
Outfalls
Dividers
Storage Unit
Links
Conduits
Pumps
Orifices
Weirs
Outlets
Conduits
1
Study Area Map
Auto-Length Off
CFS
100%
X,Y: 4223.71, 6444.07
start
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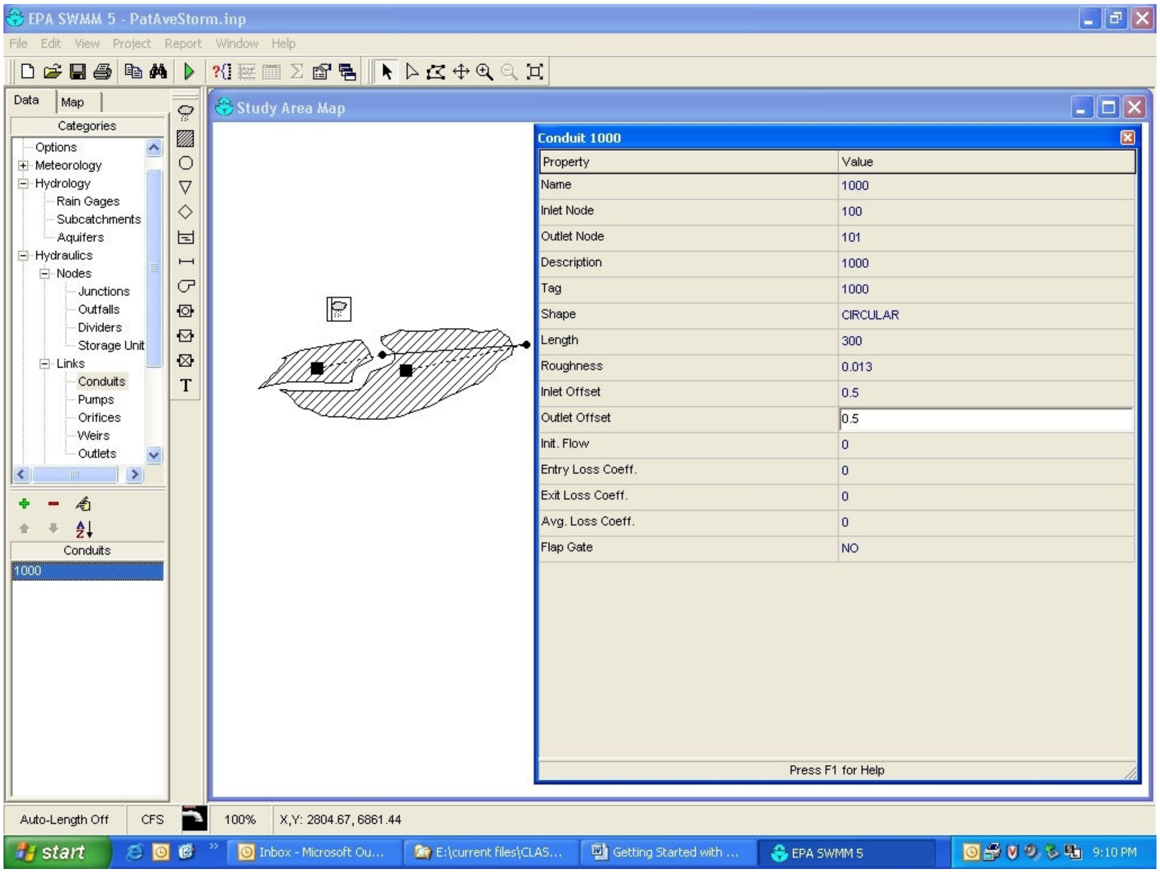
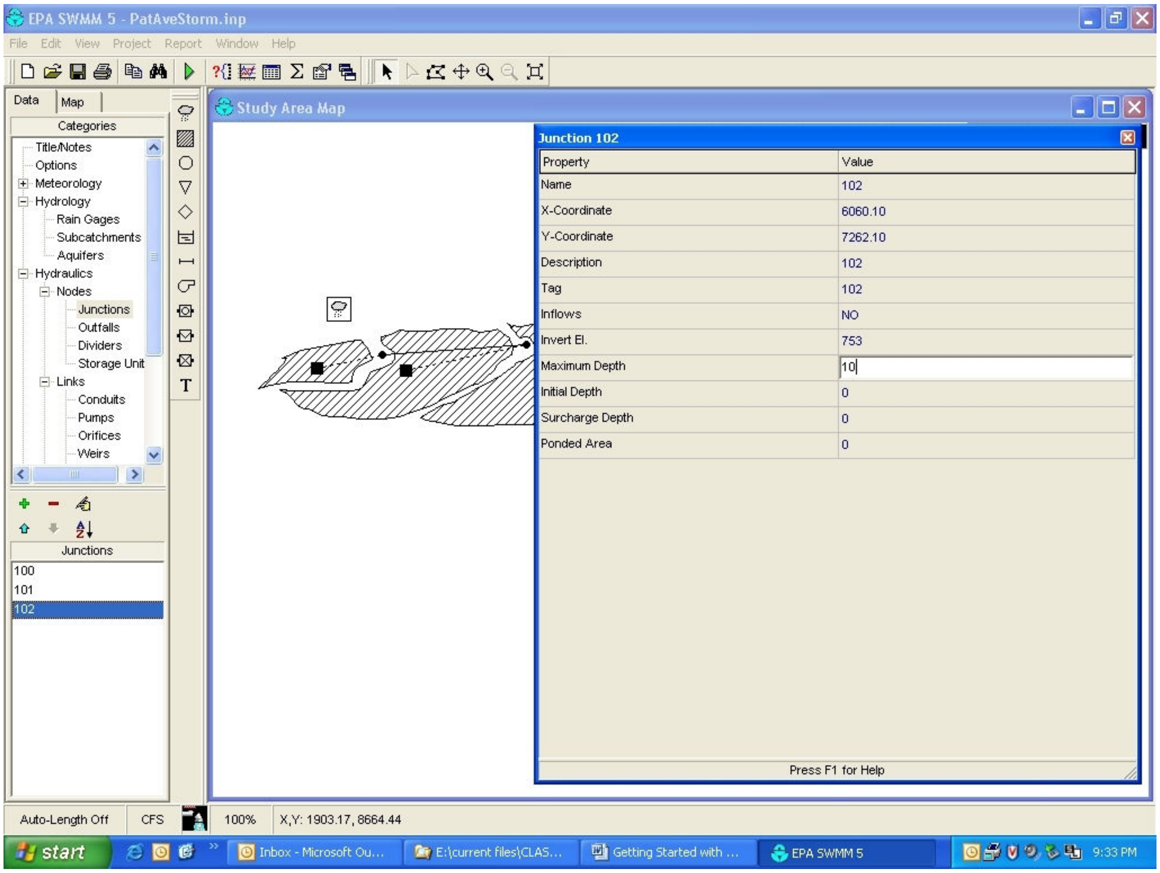


In this example, another pipe was used below the last subcatchment and before the outfall. A new junction was installed to allow all three subcatchment flows to join clearly before the outfall.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File Edit View Project Report Window Help
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Hydraulics
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Junctions
Outfalls
Dividers
Storage Unit
Links
Conduits
Pumps
Orifices
Weirs
Junctions
100
101
102
Study Area Map
Junction 102
Property
Value
Name
102
X-Coordinate
6060.10
Y-Coordinate
7262.10
Description
102
Tag
102
Inflows
NO
Invert El.
753
Maximum Depth
10
Initial Depth
0
Surcharge Depth
0
Ponded Area
0
Press F1 for Help
Auto-Length Off
CFS
100%
X,Y: 1903.17, 8664.44
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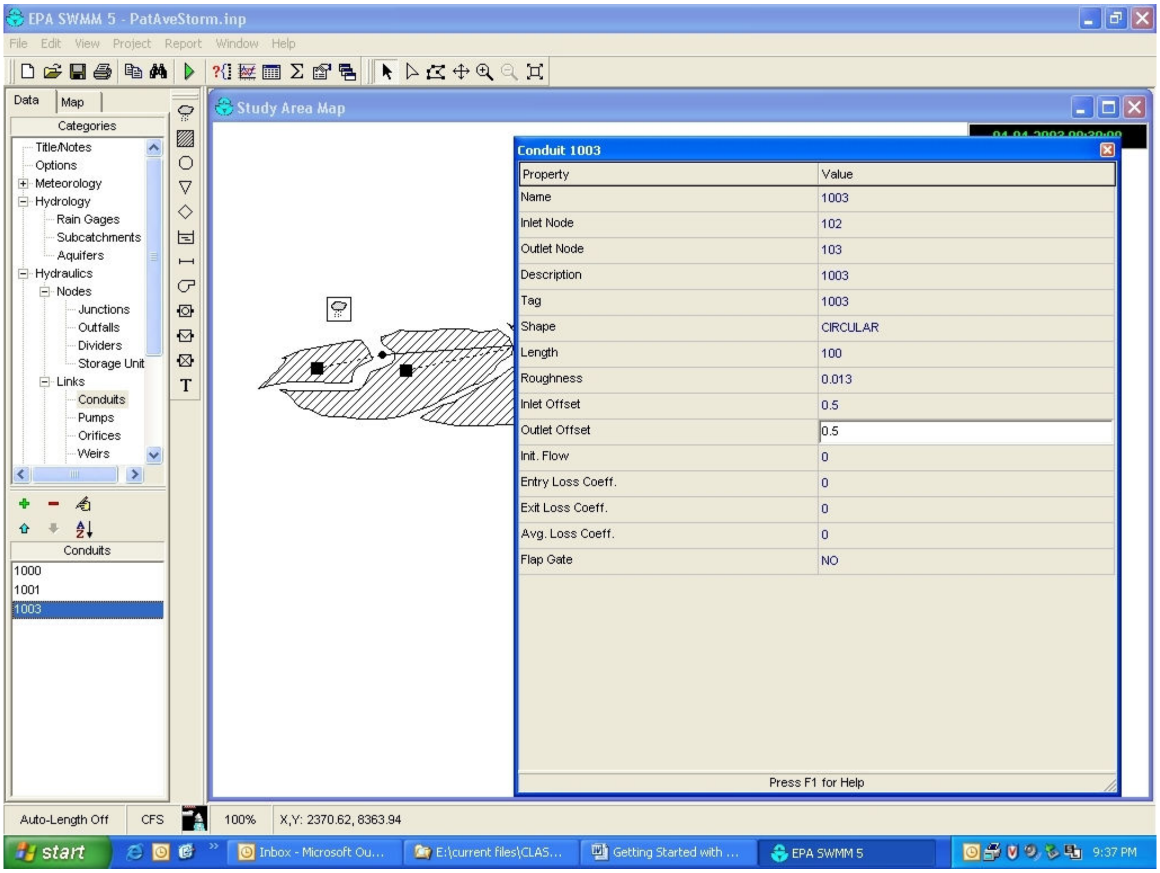
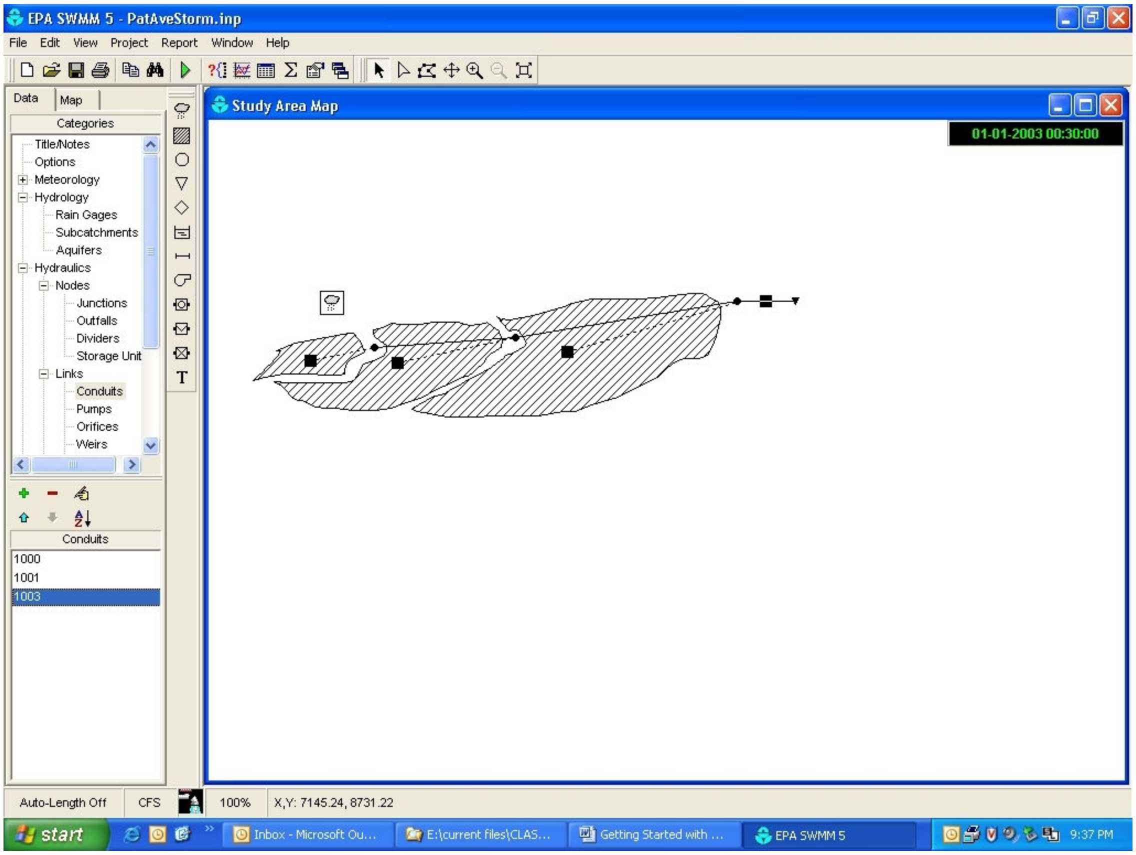
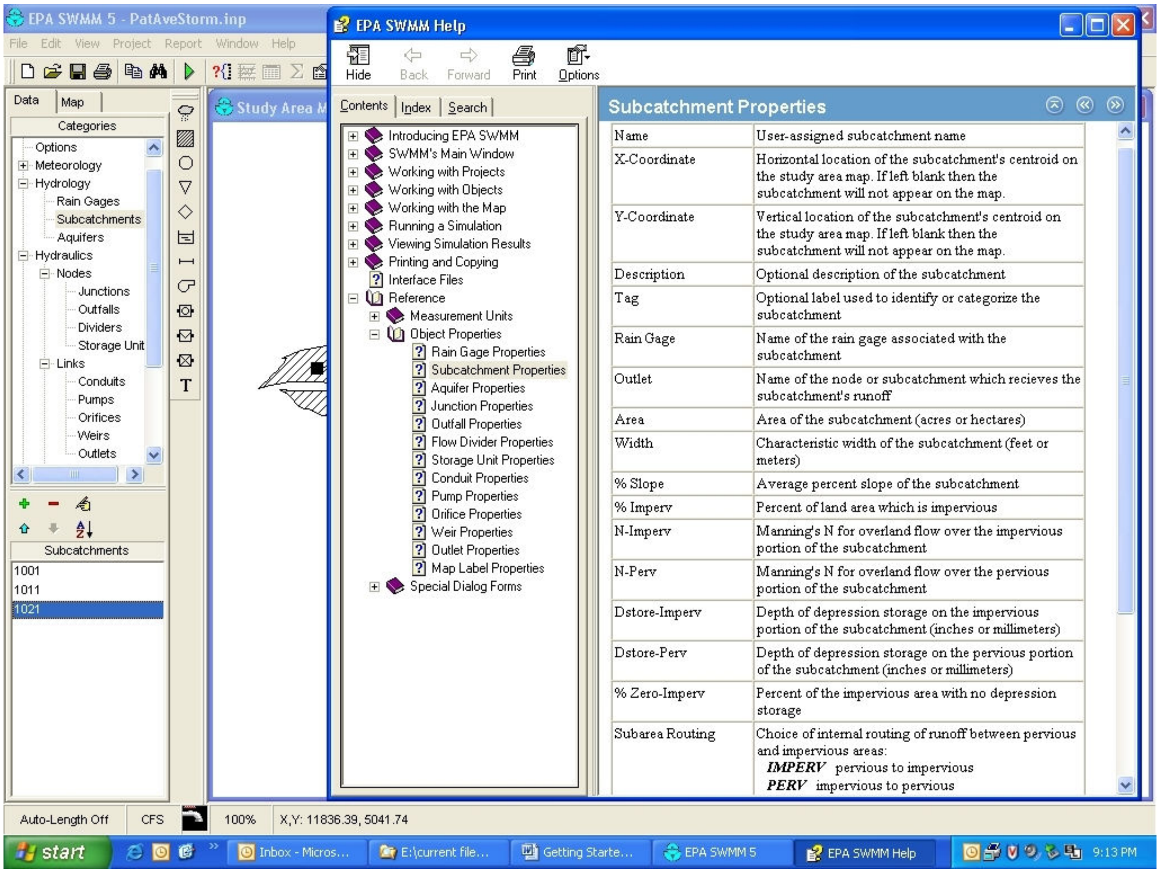


The last Junction will be modeled as an outfall. Select the fourth element on the SWMM elements toolbar. The outfall element is located below the junction element. Display its properties. Assign "103" without quotes in the name, description and tag fields. Assign an invert elevation of 745 ft. There is no tide gate. It is modeled as a free discharge. The last element is the pipe1003, create this element and update the information using Tables 1, 2 and 3.



The rain file used with the raingage is a type II cumulative distribution for a 6.9 inch rain, the “25-yr” recurrence storm for Birmingham. Different files are needed for each rain depth. A set of standard rain files are located on the class web site at: www.eng.ua.edu/~rpitt under classes. The files can be modified using Excel. The files are ascii format (*.txt). Make sure the format is correct. Some problems with Excel is that the SWMM data format MM-DD-YYYY is not available, and Excel “automatically” converts them to MM/DD/YYYY. The replace function does not work, as the format is set. If the “normal” format for the cell is used, the “negative” signs transform the values. In many cases, quotes are also placed on each line, further confusing SWMM. It is best to multiply the rain depths in Excel, and save as a text file. Then open the file in Notepad and then do a “replace all” command to change the date format. Finally, save the file before importing into SWMM. The same rain gage and rain event is used for each subcatchment in this example, but it is possible to have different rain gages to reflect varying rain conditions throughout an area.

At any time, it is possible to press the F1 key for context-sensitive help.



The details of the final SWMM5 file can be observed under *project/details* in the main menu. The following is the final entry file after adding all the data.

```
[TITLE]

[OPTIONS]
  FLOW_UNITS             CFS
  INFILTRATION           HORTON
  FLOW_ROUTING           KW
  START_DATE             01-01-2003
  START_TIME             00:00:00
  REPORT_START_DATE      01-01-2003
  REPORT_START_TIME      00:00:00
  END_DATE               01-02-2003
  END_TIME               00:00:00
  DRY_DAYS               0
  WET_STEP               00:30:00
  DRY_STEP               01:00:00
  ROUTING_STEP           00:05:00
  REPORT_STEP            00:30:00
  ALLOW_PONDING          NO
  DYNWAVE_METHOD         EULER
  COURANT_FACTOR         0.75
  NORMAL_FLOW_LIMITED    YES
  LENGTHEN_CONDUITS      NO

[RAINGAGES]
;                 Timeseries/  Source           Format/    RecdFreq/
;Name             File         Name             Station    RecdIntvl
;-----------------------------------------------------------------
 1                TIMESERIES   TypeII69         CUMULATIVE 0:30

[SUBCATCHMENTS]
;                                                   Total    Pcnt.             Pcnt.    Curb
;Name             Raingage         Outlet           Area     Imperv   Width    Slope    Length
;----------------------------------------------------------------------------------------------
 1001             1                100              1.067    54       98.3     0.084    0        ;1001
 1011             1                101              1.087    54       74.5     0.093    0        ;1011
 1021             1                102              1.431    54       109      0.072    0        ;1021
```

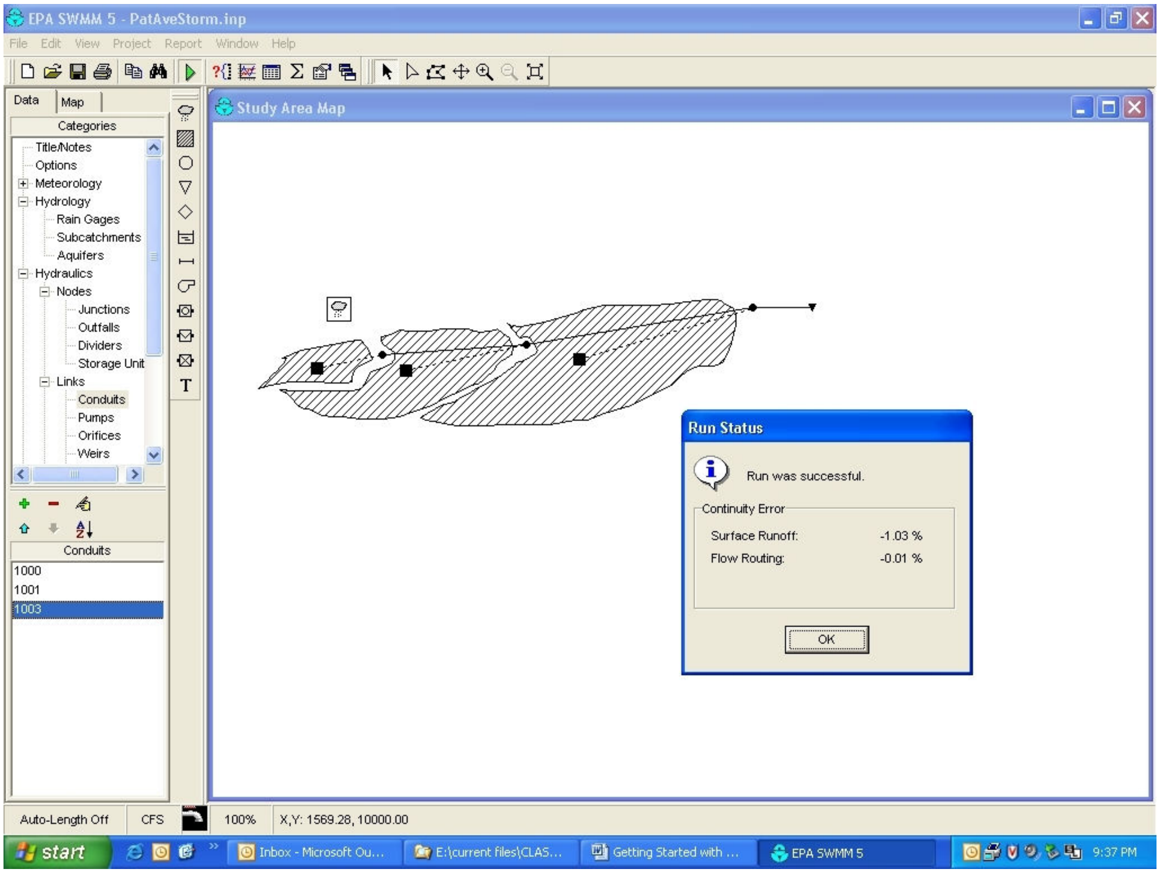
```
[SUBAREAS]
;Subcatchment     N-Imperv   N-Perv     S-Imperv   S-Perv     pctZERO    RouteTo
;-------------------------------------------------------------------------------
 1001             0.040      0.410      0.25       0.50       25         OUTLET
 1011             0.10       0.410      0.25       0.50       25         OUTLET
 1021             0.10       0.410      0.25       0.50       25         OUTLET

[INFILTRATION]
;Subcatchment     MaxRate    MinRate    Decay      Regen      MaxInfil
;---------------------------------------------------------------------
 1001             1          0.1        0.002      0.001      0
 1011             1          0.1        0.002      0.001      0
 1021             1          0.1        0.002      0.001      0

[JUNCTIONS]
;                 Invert     Max.       Init.      Surcharge  Ponded
;Name             Elev.      Depth      Depth      Depth      Area
;------------------------------------------------------------------------
 100              791        10         0          0          0          ;100
 101              769        10         0          0          0          ;101
 102              753        10         0          0          0          ;102

[OUTFALLS]
;                 Invert     Outfall      Stage/Table
;Name             Elev.      Type         Time Series
;------------------------------------------------------
 103              745        FREE       NO ;103

[CONDUITS]
;                 Inlet            Outlet                      Manning    Inlet      Outlet     Init.
;Name             Node             Node             Length     N          Height     Height     Flow
;---------------------------------------------------------------------------------------------------------------
 1000             100              101              300        0.013      0.5        0.5        0          ;1000
 1001             101              102              300        0.013      0.5        0.5        0          ;1001
 1003             102              103              100        0.013      0.5        0.5        0          ;1003

[XSECTIONS]
;Link             Type         Geom1      Geom2      Geom3      Geom4
;-------------------------------------------------------------------------
 1000             CIRCULAR     1          0          0          0
 1001             CIRCULAR     1          0          0          0
 1003             CIRCULAR     1          0          0          0

[INFLOWS]
;                                                   Concen   Conversion
;Node             Parameter        Time Series      /Mass    Factor
;--------------------------------------------------------------------

[DWF]
;                                  Average    Time
;Node             Parameter        Value      Patterns
;------------------------------------------------------

[RDII]
;Node             Unit Hydrograph  Sewer Area
;-------------------------------------------

[TIMESERIES]
;Name             Date       Time       Value
;------------------------------------------------

;Type II 6.9 inch rain
 TypeII69         1-1-2003   0:00:00    0
 TypeII69         1-1-2003   0:30:00    0.0370185
 TypeII69         1-1-2003   1:00:00    0.0750375
 TypeII69         1-1-2003   1:30:00    0.114057
 TypeII69         1-1-2003   2:00:00    0.1550775
 TypeII69         1-1-2003   2:30:00    0.1970985
 TypeII69         1-1-2003   3:00:00    0.24012
 TypeII69         1-1-2003   3:30:00    0.286143
 TypeII69         1-1-2003   4:00:00    0.334167
 TypeII69         1-1-2003   4:30:00    0.384192
 TypeII69         1-1-2003   5:00:00    0.4372185
 TypeII69         1-1-2003   5:30:00    0.492246
 TypeII69         1-1-2003   6:00:00    0.5512755
 TypeII69         1-1-2003   6:30:00    0.6133065
 TypeII69         1-1-2003   7:00:00    0.68034
 TypeII69         1-1-2003   7:30:00    0.752376
 TypeII69         1-1-2003   8:00:00    0.8314155
 TypeII69         1-1-2003   8:30:00    0.9174585
 TypeII69         1-1-2003   9:00:00    1.0135065
 TypeII69         1-1-2003   9:30:00    1.122561
 TypeII69         1-1-2003   10:00:00   1.248624
 TypeII69         1-1-2003   10:30:00   1.4097045
 TypeII69         1-1-2003   11:00:00   1.622811
 TypeII69         1-1-2003   11:30:00   1.9559775
 TypeII69         1-1-2003   12:00:00   4.5792885
 TypeII69         1-1-2003   12:30:00   5.0755365
```

```
 TypeII69         1-1-2003   13:00:00   5.332665
 TypeII69         1-1-2003   13:30:00   5.5157565
 TypeII69         1-1-2003   14:00:00   5.6598285
 TypeII69         1-1-2003   14:30:00   5.7858915
 TypeII69         1-1-2003   15:00:00   5.894946
 TypeII69         1-1-2003   15:30:00   5.9899935
 TypeII69         1-1-2003   16:00:00   6.0760365
 TypeII69         1-1-2003   16:30:00   6.1540755
 TypeII69         1-1-2003   17:00:00   6.2261115
 TypeII69         1-1-2003   17:30:00   6.2921445
 TypeII69         1-1-2003   18:00:00   6.355176
 TypeII69         1-1-2003   18:30:00   6.4142055
 TypeII69         1-1-2003   19:00:00   6.469233
 TypeII69         1-1-2003   19:30:00   6.521259
 TypeII69         1-1-2003   20:00:00   6.571284
 TypeII69         1-1-2003   20:30:00   6.619308
 TypeII69         1-1-2003   21:00:00   6.6643305
 TypeII69         1-1-2003   21:30:00   6.7083525
 TypeII69         1-1-2003   22:00:00   6.749373
 TypeII69         1-1-2003   22:30:00   6.7903935
 TypeII69         1-1-2003   23:00:00   6.829413
 TypeII69         1-1-2003   23:30:00   6.867432
 TypeII69         1-2-2003   0:00:00    6.9


[REPORT]
CONTROLS NO

[COORDINATES]
;Node             X-Coord          Y-Coord
 100              567.61           6560.93
 101              2704.51          6711.19
 102              6060.10          7262.10
 103              6944.91          7262.10

[VERTICES]
;Link             X-Coord          Y-Coord

[Polygons]
;Subcatchment     X-Coord          Y-Coord
 1001             -851.42          6510.85
 1001             -884.81          6444.07
 1001             -934.89          6393.99
 1001             -984.97          6327.21
 1001             -1068.45         6260.43
 1001             -1135.23         6176.96
 1001             -1202.00         6126.88
 1001             -1268.78         6060.10
 1001             -1202.00         6076.79
 1001             -1101.84         6110.18
 1001             -984.97          6126.88
 1001             -818.03          6160.27
 1001             -584.31          6160.27
 1001             -400.67          6160.27
 1001             -183.64          6143.57
 1001             50.08            6143.57
 1001             116.86           6160.27
 1001             116.86           6210.35
 1001             133.56           6293.82
 1001             183.64           6360.60
 1001             250.42           6410.68
 1001             400.67           6477.46
 1001             417.36           6494.16
 1001             383.97           6577.63
 1001             367.28           6627.71
 1001             333.89           6677.80
 1001             250.42           6777.96
 1001             183.64           6777.96
 1001             -267.11          6694.49
 1001             -634.39          6627.71
 1001             -918.20          6510.85
 1011             550.92           6777.96
 1011             567.61           6744.57
 1011             584.31           6711.19
 1011             651.09           6661.10
 1011             751.25           6594.32
 1011             751.25           6494.16
 1011             701.17           6427.38
 1011             667.78           6410.68
 1011             550.92           6360.60
 1011             450.75           6327.21
 1011             400.67           6310.52
 1011             383.97           6277.13
 1011             350.58           6227.05
 1011             317.20           6143.57
 1011             250.42           6060.10
 1011             133.56           6026.71
 1011             116.86           6026.71
```

1011	116.86	6026.71
1011	16.69	6026.71
1011	-150.25	6026.71
1011	-367.28	6026.71
1011	-534.22	6026.71
1011	-667.78	6026.71
1011	-801.34	6026.71
1011	-884.81	6043.41
1011	-951.59	6043.41
1011	-834.72	5976.63
1011	-767.95	5909.85
1011	-684.47	5809.68
1011	-601.00	5759.60
1011	-534.22	5759.60
1011	-517.53	5759.60
1011	-434.06	5709.52
1011	-317.20	5659.43
1011	-166.94	5642.74
1011	-33.39	5642.74
1011	116.86	5626.04
1011	233.72	5609.35
1011	450.75	5609.35
1011	584.31	5609.35
1011	818.03	5642.74
1011	1051.75	5726.21
1011	1302.17	5809.68
1011	1385.64	5859.77
1011	1602.67	5976.63
1011	1619.37	5976.63
1011	1769.62	6043.41
1011	1886.48	6110.18
1011	1986.64	6126.88
1011	2070.12	6193.66
1011	2136.89	6260.43
1011	2186.98	6293.82
1011	2237.06	6343.91
1011	2270.45	6410.68
1011	2320.53	6460.77
1011	2337.23	6477.46
1011	2387.31	6494.16
1011	2470.78	6560.93
1011	2487.48	6560.93
1011	2504.17	6661.10
1011	2487.48	6727.88
1011	2470.78	6761.27
1011	2454.09	6794.66
1011	2454.09	6811.35
1011	2353.92	6878.13
1011	2270.45	6944.91
1011	2253.76	6928.21
1011	2020.03	6894.82
1011	2003.34	6894.82
1011	1886.48	6928.21
1011	1836.39	6944.91
1011	1702.84	6944.91
1011	1452.42	6944.91
1011	1368.95	6928.21
1011	1268.78	6911.52
1011	1101.84	6911.52
1011	951.59	6911.52
1011	834.72	6928.21
1011	701.17	6861.44
1011	550.92	6828.05
1011	550.92	6811.35
1011	550.92	6811.35
1021	2487.48	6978.30
1021	2520.87	6994.99
1021	2570.95	6978.30
1021	2621.04	6978.30
1021	2704.51	6994.99
1021	2804.67	7011.69
1021	2971.62	7045.08
1021	3088.48	7078.46
1021	3439.07	7178.63
1021	3555.93	7228.71
1021	3856.43	7295.49
1021	4173.62	7295.49
1021	4307.18	7295.49
1021	4373.96	7295.49
1021	4574.29	7295.49
1021	4607.68	7295.49
1021	4791.32	7312.19
1021	4841.40	7312.19
1021	5075.13	7345.58
1021	5375.63	7378.96
1021	5509.18	7378.96
1021	5592.65	7362.27
1021	5626.04	7328.88

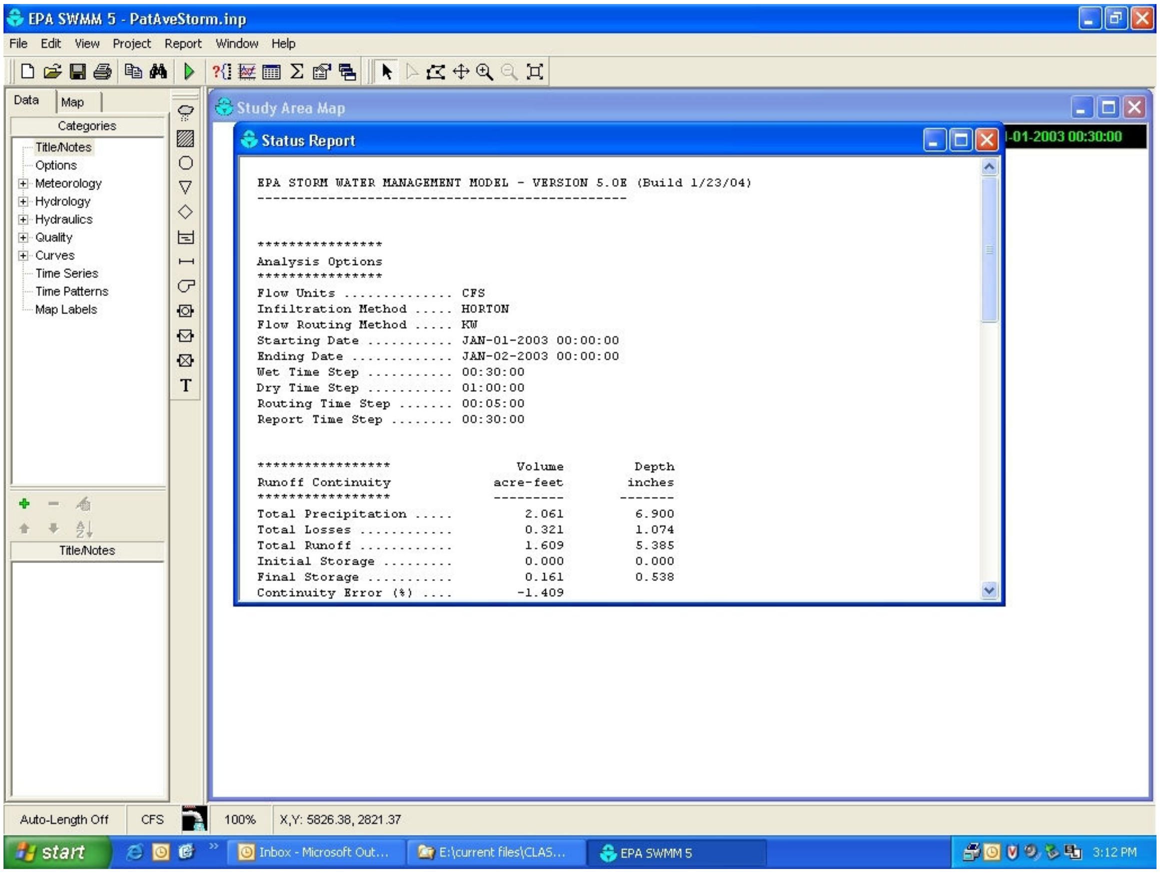
```
 1021            5776.29          7245.41
 1021            5809.68          7178.63
 1021            5809.68          7011.69
 1021            5792.99          6928.21
 1021            5742.90          6727.88
 1021            5709.52          6644.41
 1021            5626.04          6460.77
 1021            5575.96          6427.38
 1021            5475.79          6393.99
 1021            5375.63          6393.99
 1021            5275.46          6393.99
 1021            5208.68          6377.30
 1021            5158.60          6360.60
 1021            5075.13          6310.52
 1021            4974.96          6227.05
 1021            4858.10          6110.18
 1021            4824.71          6093.49
 1021            4257.10          5809.68
 1021            3856.43          5692.82
 1021            3606.01          5592.65
 1021            3422.37          5592.65
 1021            3055.09          5525.88
 1021            2938.23          5525.88
 1021            2704.51          5525.88
 1021            2353.92          5525.88
 1021            2120.20          5509.18
 1021            1752.92          5509.18
 1021            1669.45          5509.18
 1021            1218.70          5592.65
 1021            1135.23          5626.04
 1021            1135.23          5626.04
 1021            1151.92          5642.74
 1021            1235.39          5692.82
 1021            1335.56          5742.90
 1021            1402.34          5792.99
 1021            1485.81          5826.38
 1021            1636.06          5859.77
 1021            1719.53          5926.54
 1021            1869.78          5993.32
 1021            1953.26          6060.10
 1021            2136.89          6143.57
 1021            2337.23          6260.43
 1021            2420.70          6327.21
 1021            2520.87          6393.99
 1021            2554.26          6444.07
 1021            2621.04          6460.77
 1021            2704.51          6494.16
 1021            2838.06          6577.63
 1021            2871.45          6627.71
 1021            2821.37          6711.19
 1021            2754.59          6811.35
 1021            2687.81          6828.05
 1021            2604.34          6811.35
 1021            2420.70          7028.38

[SYMBOLS]
;Gage            X-Coord          Y-Coord
 1               -66.78           7228.71

[BACKDROP]
 DIMENSIONS      0.00             0.00             10000.00         10000.00
 UNITS           None
 FILE            ""
 OFFSET          0.00             0.00
 SCALING         0.00             0.00
```

Now you can run the model. In the main toolbar, click the seventh button from the left. The symbol is a green triangle like a play button. If the run was successful, a window will be displayed showing the successful run label.



Observing the Results

It is possible to observe the results under *report/status* in the main menu. An example of the results follows.




```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0E (Build 1/23/04)
 ----------------------------------------------


 ****************
 Analysis Options
 ****************
 Flow Units .............. CFS
 Infiltration Method ..... HORTON
 Flow Routing Method ..... KW
 Starting Date ........... JAN-01-2003 00:00:00
 Ending Date ............. JAN-02-2003 00:00:00
 Wet Time Step ........... 00:30:00
 Dry Time Step ........... 01:00:00
 Routing Time Step ....... 00:05:00
 Report Time Step ........ 00:30:00


 *****************                Volume         Depth
 Runoff Continuity              acre-feet        inches
 *****************              ---------       -------
 Total Precipitation .....          2.061         6.900
 Total Losses ............          0.321         1.074
 Total Runoff ............          1.609         5.385
 Initial Storage .........          0.000         0.000
 Final Storage ...........          0.161         0.538
 Continuity Error (%) ....         -1.409
```

Flow Transport Continuity	Volume acre-feet	Volume Mgallons
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	1.602	0.522
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	1.602	0.522
Initial Stored Volume ...	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	-0.003	

****
Node Depth Summary
****

Node	Average Depth Feet	Maximum Depth Feet	Time of Max Occurrence days hr:min	Average Depth Change	Total Minutes Flooded	Fraction Courant Critical
JUNCTION 100	0.58	0.92	0 12:30	0.0045	0	0.00
JUNCTION 101	0.63	1.16	0 12:30	0.0060	0	0.00
JUNCTION 102	0.65	1.30	0 12:30	0.0069	0	0.00
OUTFALL 103	0.00	0.00	0 00:00	0.0000	0	0.00

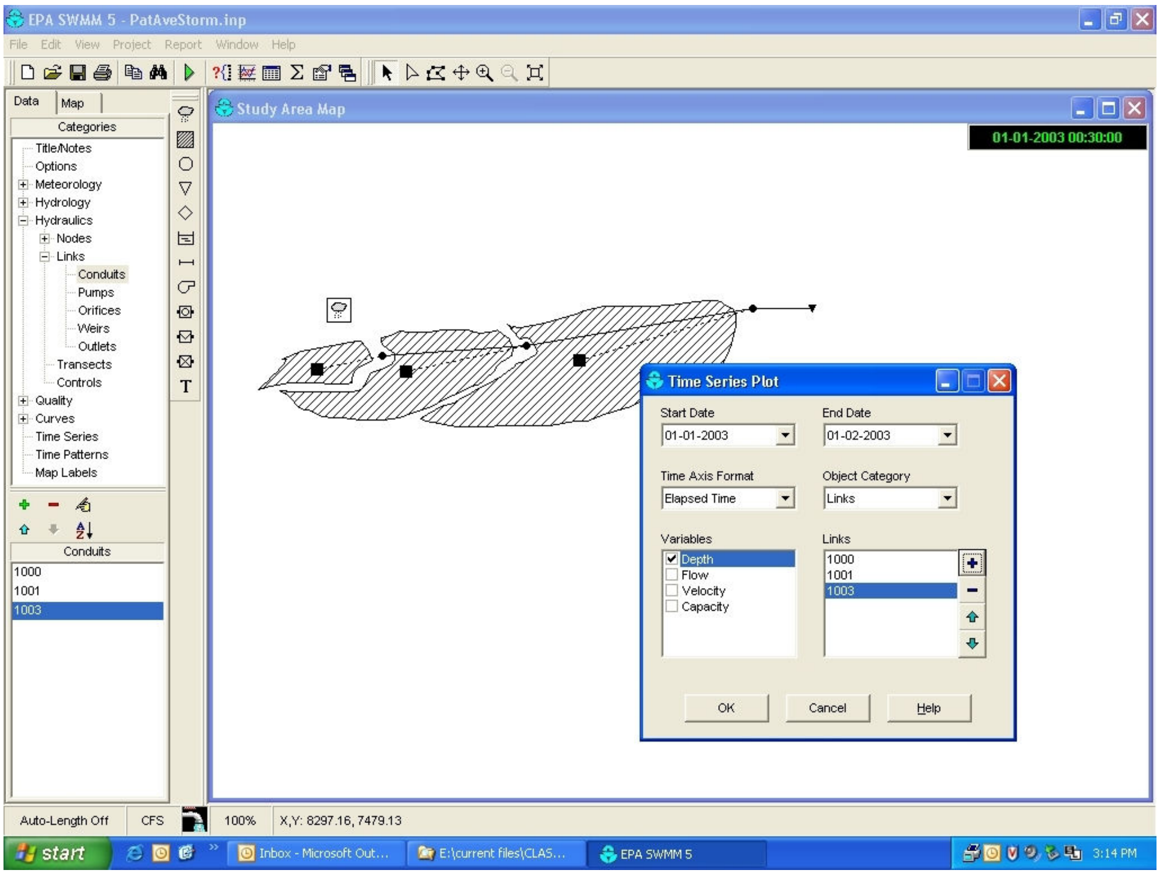
****
Conduit Flow Summary
****

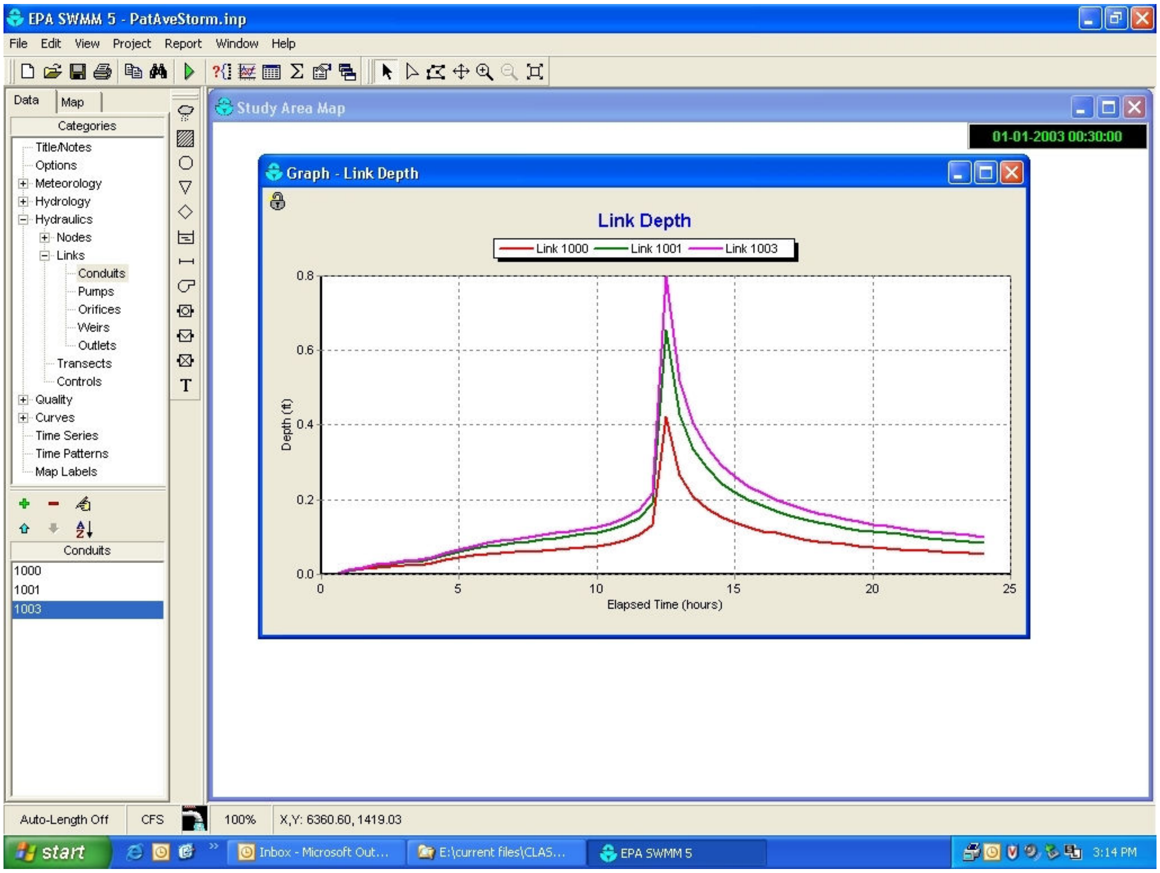
Conduit	Maximum Flow CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Time of Max Occurrence days hr:min	Maximum /Design Flow	Total Minutes Surcharged
1000	3.60e+00	0 12:30	11.38	0 12:30	0.37	0
1001	6.31e+00	0 12:30	11.55	0 12:30	0.77	0
1003	9.83e+00	0 12:30	14.61	0 12:30	0.98	0

Analysis begun: Wed Apr 28 15:12:02 2004

```
Analysis ended: Wed Apr 28 15:12:02 2004
```

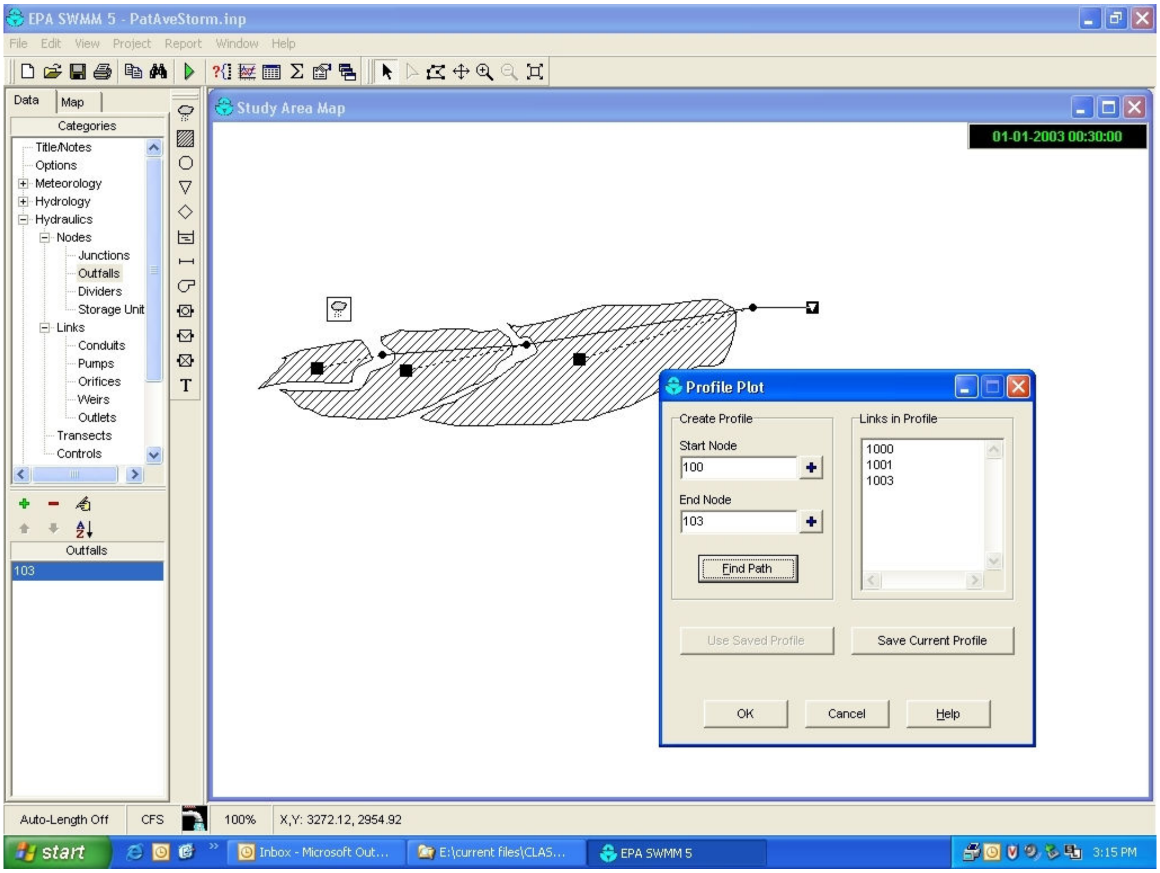
Click on the plot icon (the 9th from the left on the top tool bar) and select the type of graph and location where viewing is desired. The following example has “Links” and “Depth” selected in order to plot the depth of flow in the pipes to visually observe if any pipes surcharged. After these two selections are made, use the selection arrow tool to click on the links desired to be displayed, and click on the “+” icon in the selection box. Repeat for each link desired, the click OK for the plot.

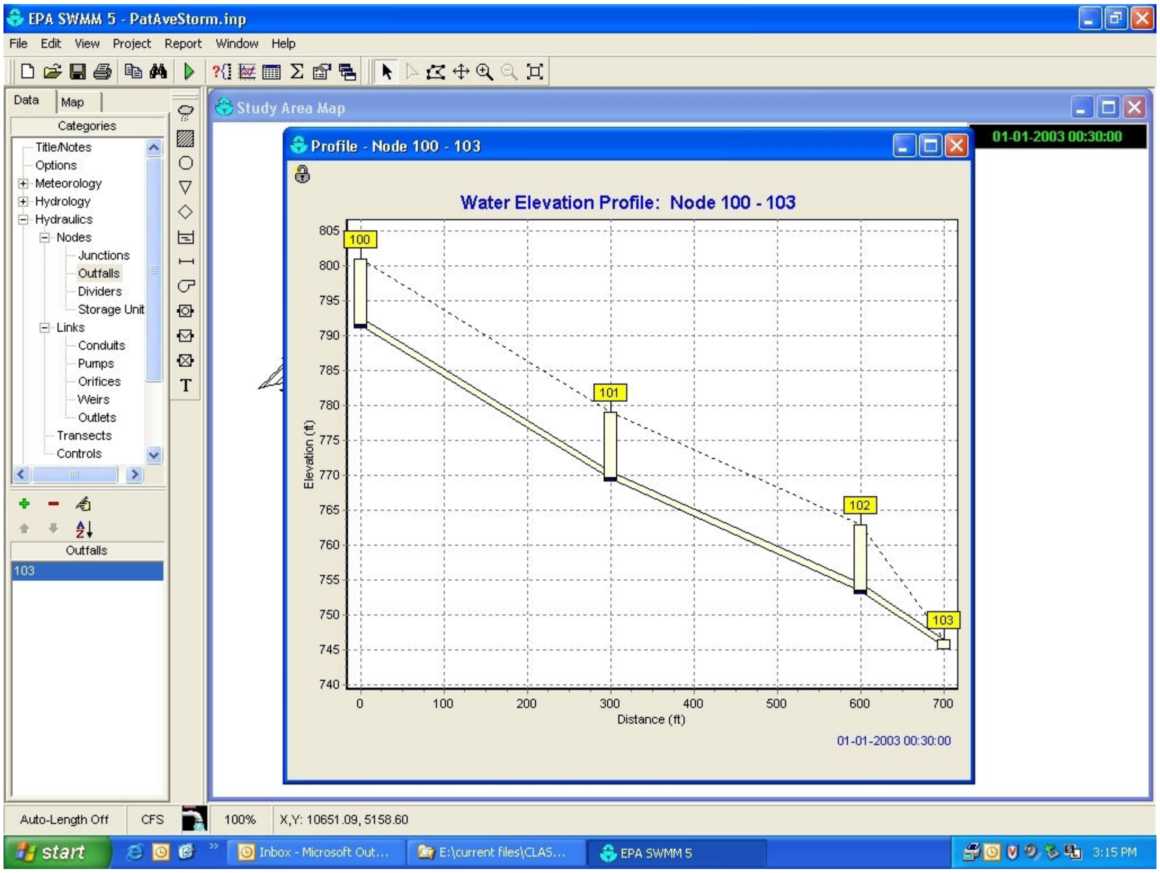




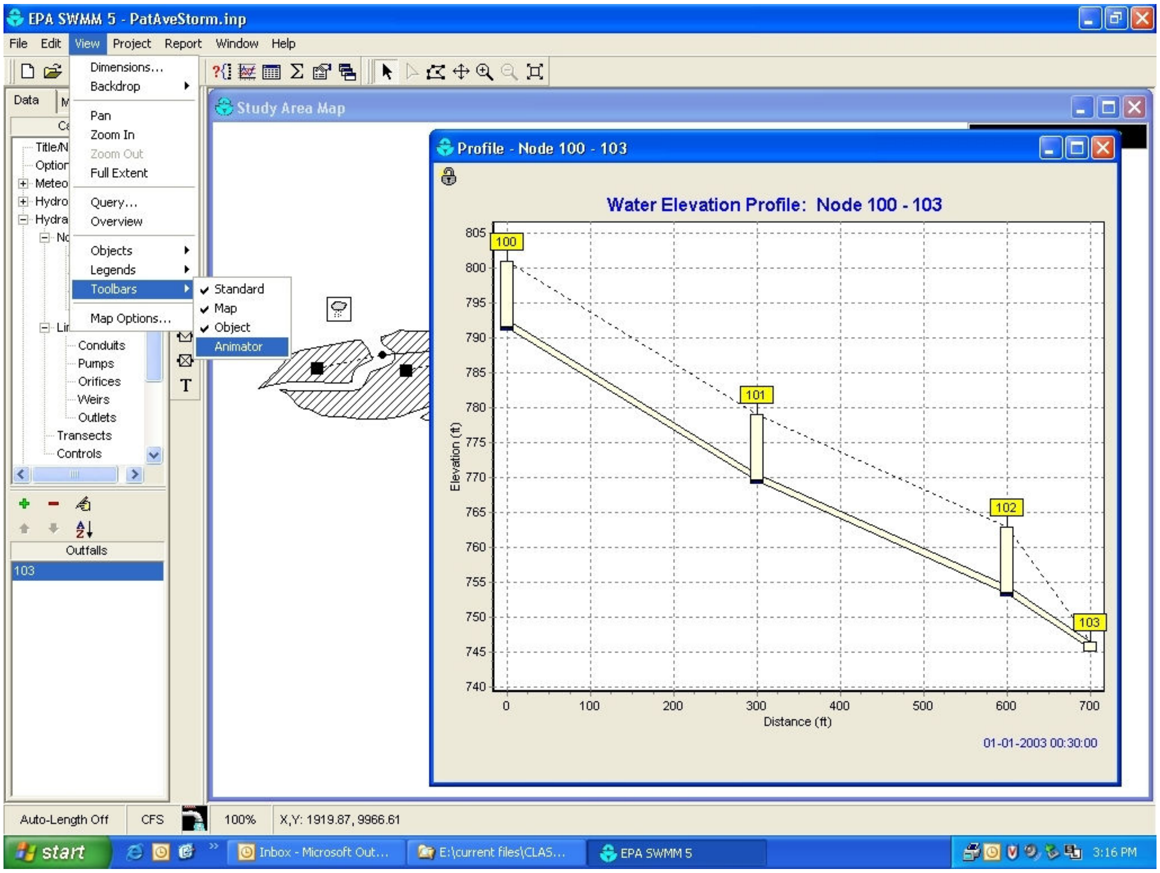
This plot shows that the most downstream pipe (link 1003) has the deepest flow and is at about 0.8 ft, less than then the 1 ft pipe diameter. Therefore, no surcharging occurs in these pipes. A similar plot can be created for the nodes which would be especially important if surcharging does occur to see how far the water rises in the manholes. Recall that the offset depth for the inlets and outlets for the nodes was 0.5 ft in this example, so the depth can be as great as 1.5 ft before surcharging occurs.

Another option is to show the results in a profile. In the main menu, select *Report/graph/profile*. The following figure shows the profile dialog box, with the start and end node selected. After they are selected, the “find path” button is clicked and the links in the profile are automatically displayed. The click OK to display the profile.

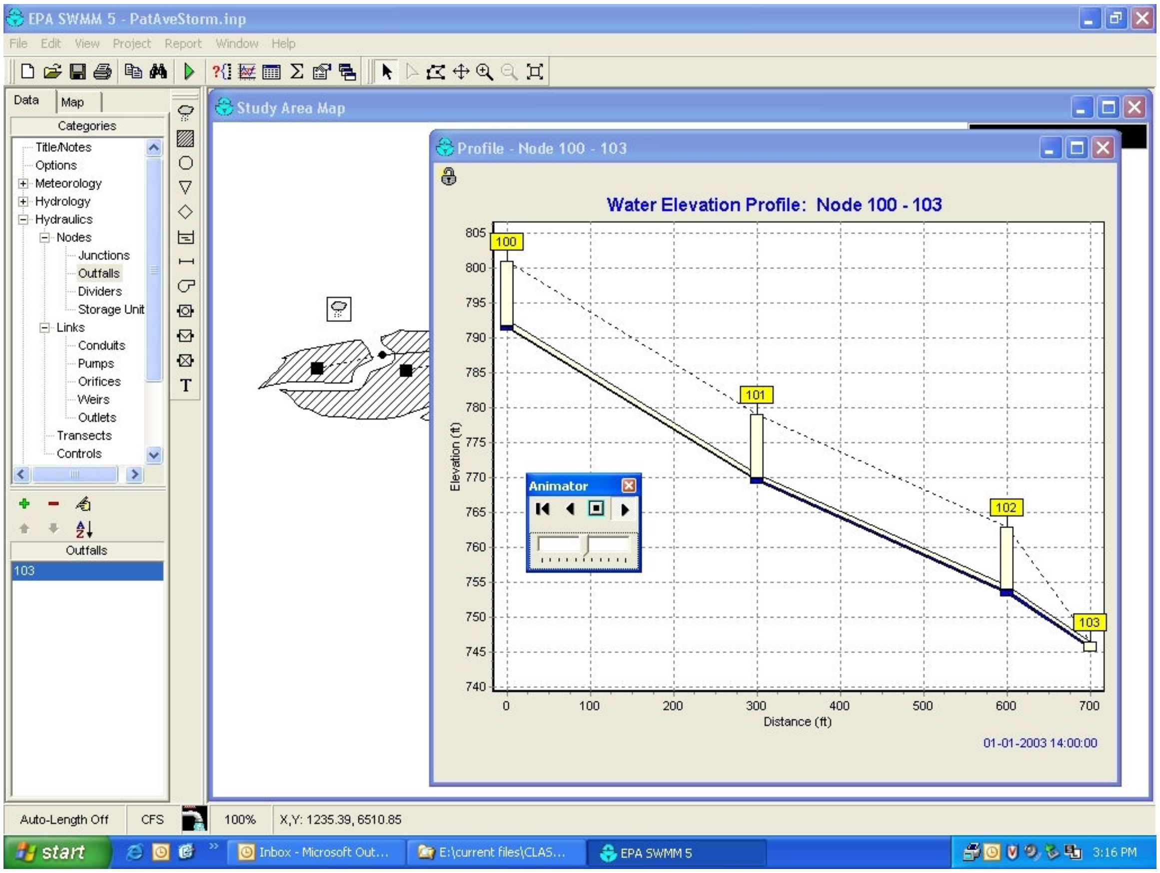

EPA SWMM 5 - PatAveStorm.inp
File Edit View Project Report Window Help
Data
Map
Categories
Title/Notes
Options
Meteorology
Hydrology
Hydraulics
Nodes
Junctions
Outfalls
Dividers
Storage Unit
Links
Conduits
Pumps
Orifices
Weirs
Outlets
Transects
Controls
Outfalls
103
Study Area Map
01-01-2003 00:30:00
Profile Plot
Create Profile
Start Node
100
End Node
103
Find Path
Links in Profile
1000
1001
1003
Use Saved Profile
Save Current Profile
OK
Cancel
Help
Auto-Length Off
CFS
100%
X,Y: 3272.12, 2954.92
start
Inbox - Microsoft Out...
E:\current files\CLAS...
EPA SWMM 5
3:15 PM



The animator option is used to display how the profile changes during the simulation. The static plot shows the depths at the designated time indicated in the lower right-hand corner of the figure. In the above case, water is shown for the 0.5 ft in the bottom of each node, but none in the pipe. In order to operate the animator, select the drop down "view/toolbars/animator" option, as indicated below.

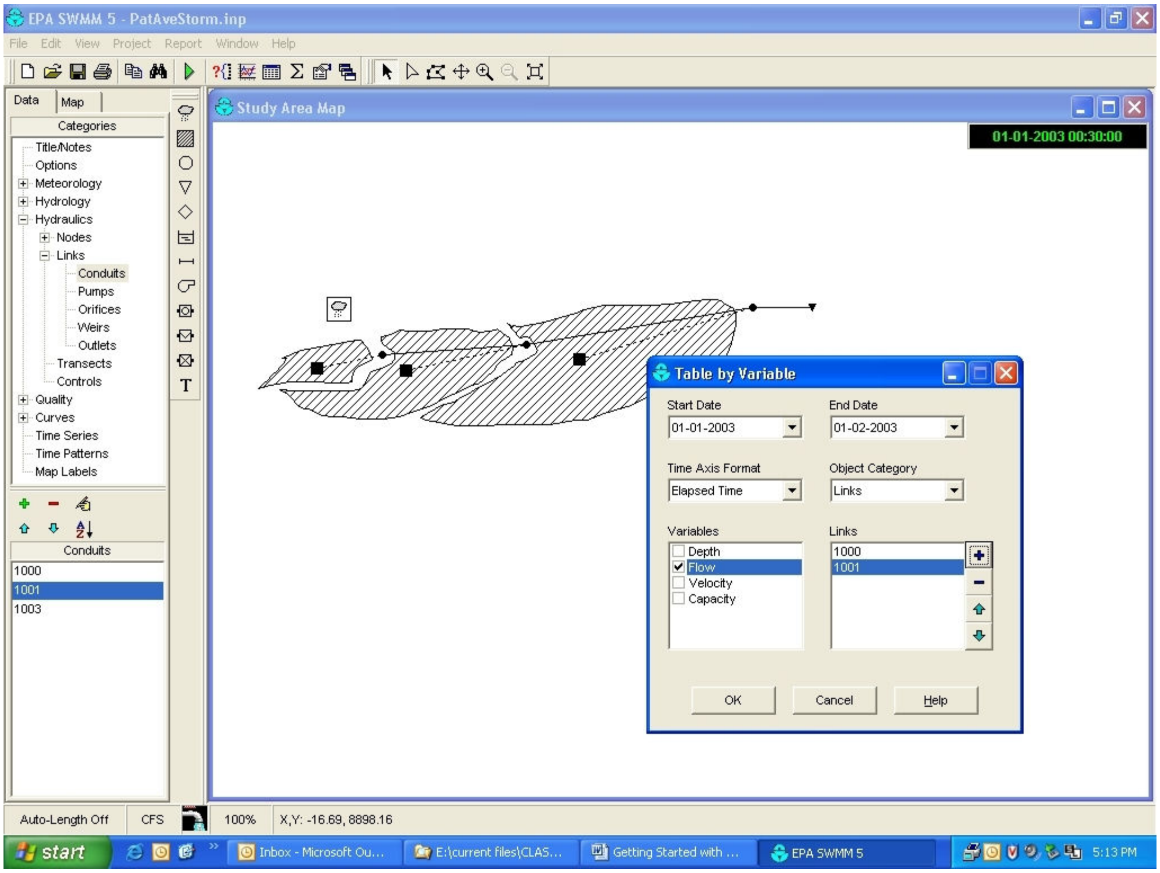


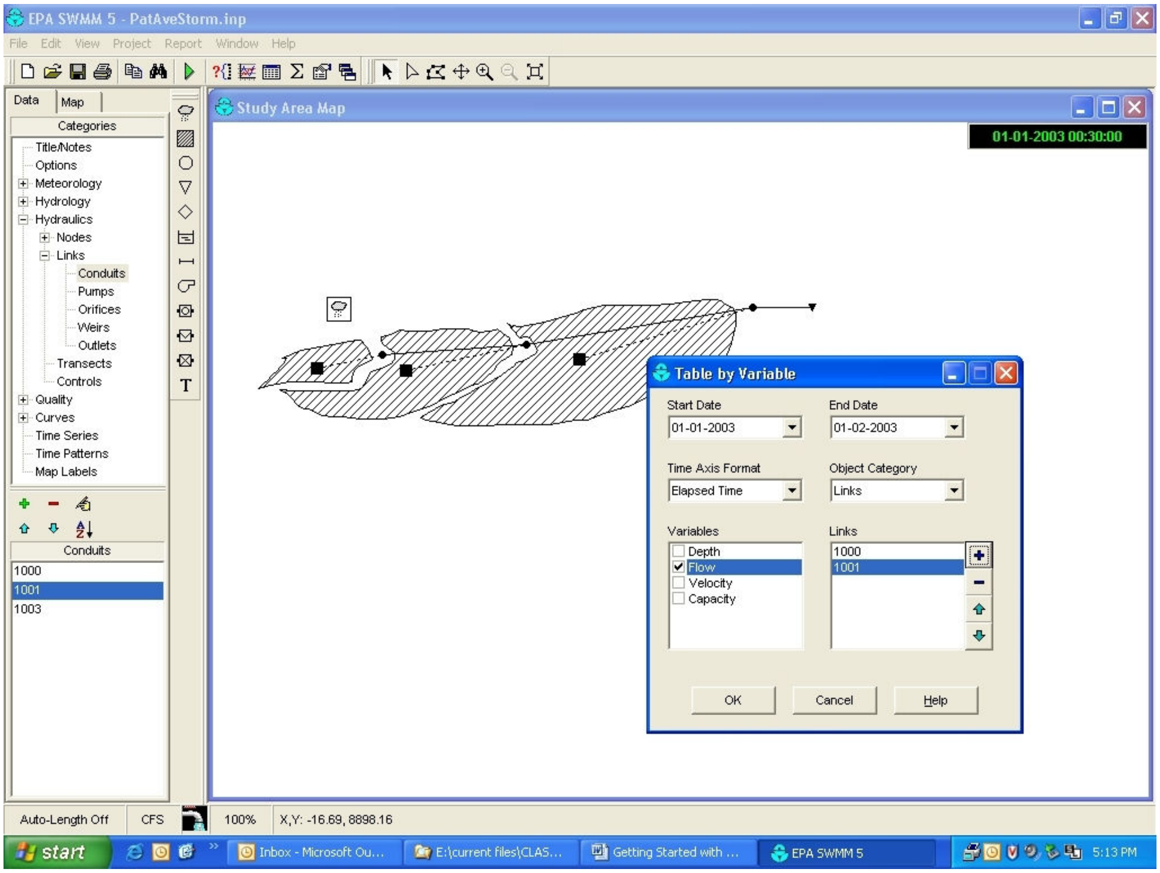
EPA SWMM 5 - PatAveStorm.inp
File Edit View Project Report Window Help
Dimensions...
Backdrop
Pan
Zoom In
Zoom Out
Full Extent
Query...
Overview
Objects
Legends
Toolbars
Map Options...
Standard
Map
Object
Animator
Study Area Map
Profile - Node 100 - 103
Water Elevation Profile: Node 100 - 103
Elevation (ft)
Distance (ft)
100
101
102
103
01-01-2003 00:30:00
Conduits
Pumps
Orifices
Weirs
Outlets
Transects
Controls
Outfalls
103
Auto-Length Off
CFS
100%
X,Y: 1919.87, 9966.61
start
Inbox - Microsoft Out...
E:\current files\CLAS...
EPA SWMM 5
3:16 PM



The lower bar in the animator increases or decreases the speed of the simulation. The left arrow rewinds the simulation and the right button plays it. The above figure shows the depth at 14:00, with water flowing through the system. It is difficult to see the water depth in the plotted pipes because of the thinness of the pipes. However, it is easy to see surcharging conditions during excessive rains.

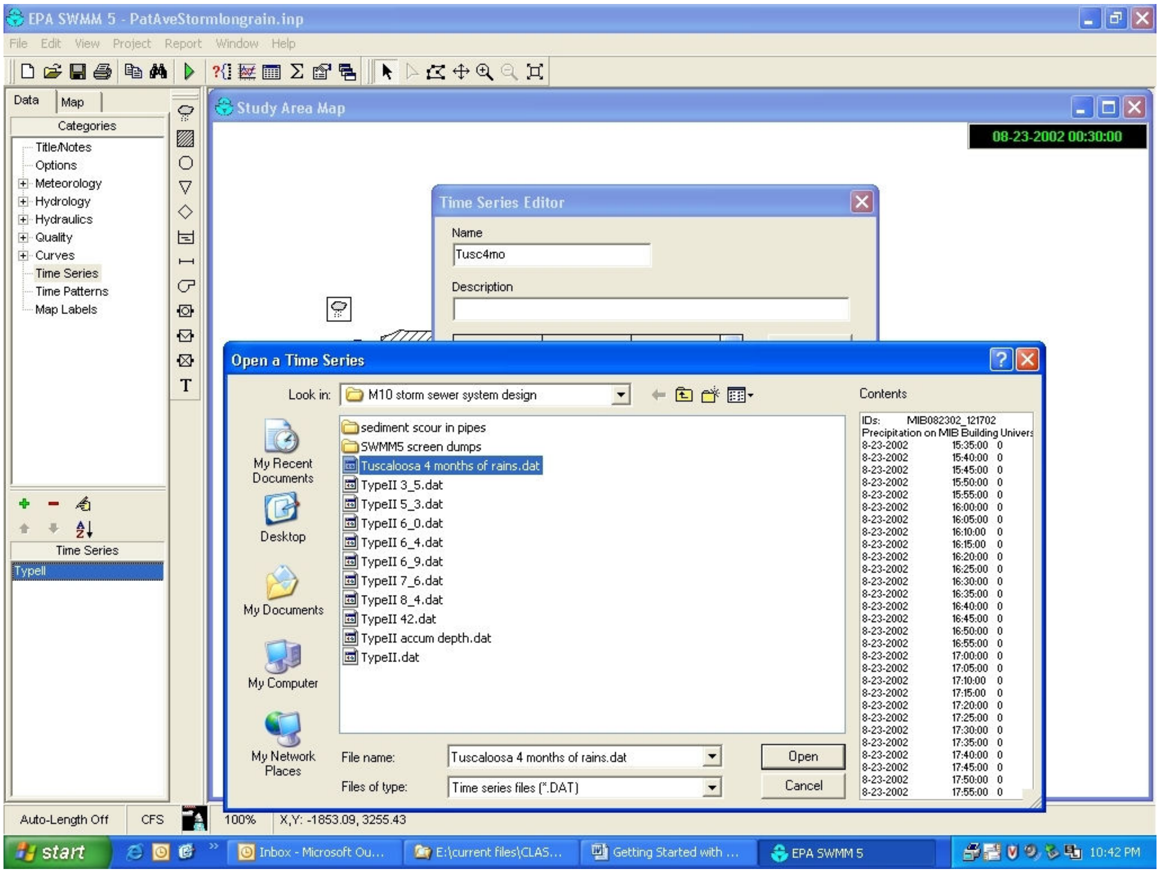
The results can be observed also in a table. Go to *Report/table/by variable* in the main menu. Select as object category: links and as variable: flow. On the map, click conduit 1000, now click the plus sign in the *table by variable* window. Now click on the conduit 1001 and click the plus sign to add it to the table. Click OK and the results will be displayed in a table.

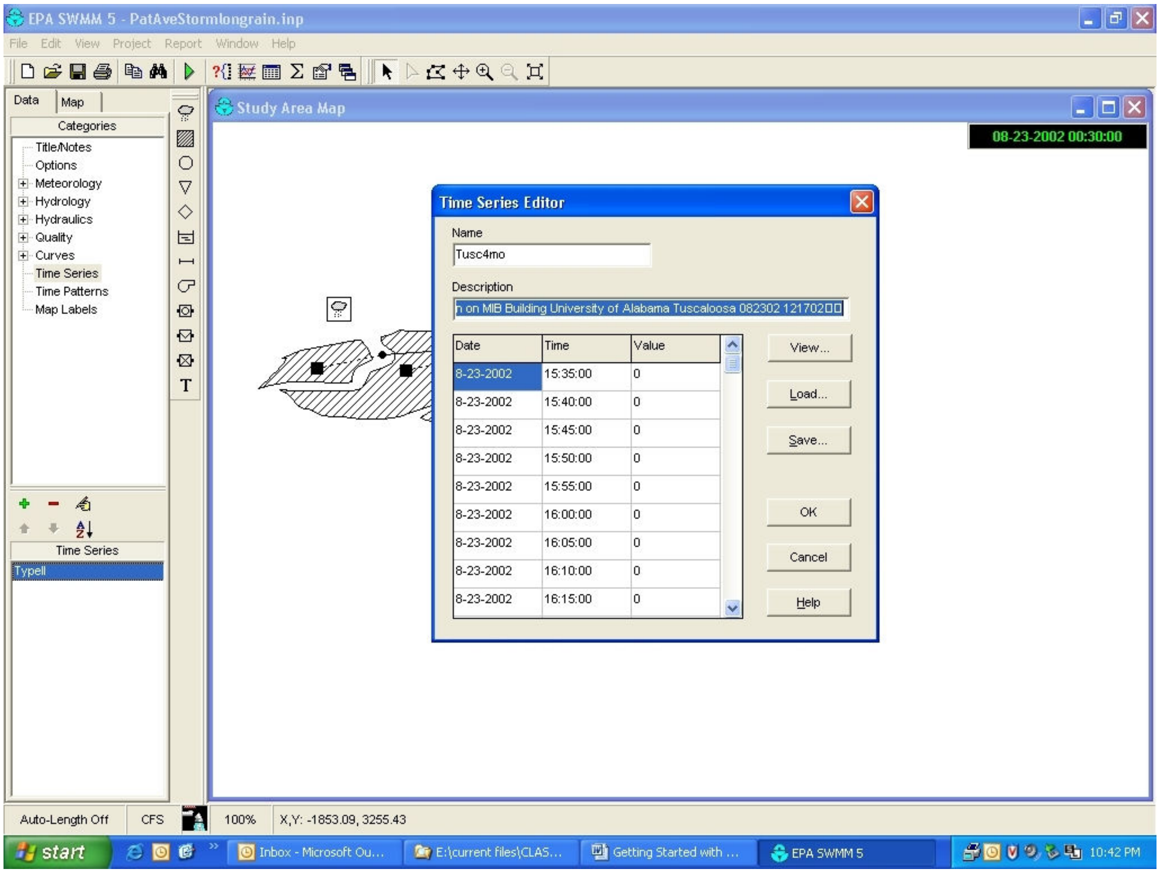

EPA SWMM 5 - PatAveStorm.inp
File Edit View Project Report Window Help
Data
Map
Categories
Title/Notes
Options
Meteorology
Hydrology
Hydraulics
Nodes
Links
Conduits
Pumps
Orifices
Weirs
Outlets
Transects
Controls
Quality
Curves
Time Series
Time Patterns
Map Labels
Conduits
1000
1001
1003
Study Area Map
01-01-2003 00:30:00
Table by Variable
Start Date
01-01-2003
End Date
01-02-2003
Time Axis Format
Elapsed Time
Object Category
Links
Variables
Depth
Flow
Velocity
Capacity
Links
1000
1001
OK
Cancel
Help
Auto-Length Off
CFS
100%
X,Y: -16.69, 8898.16
start
Inbox - Microsoft Ou...
E:\current files\CLAS...
Getting Started with ...
EPA SWMM 5
5:13 PM

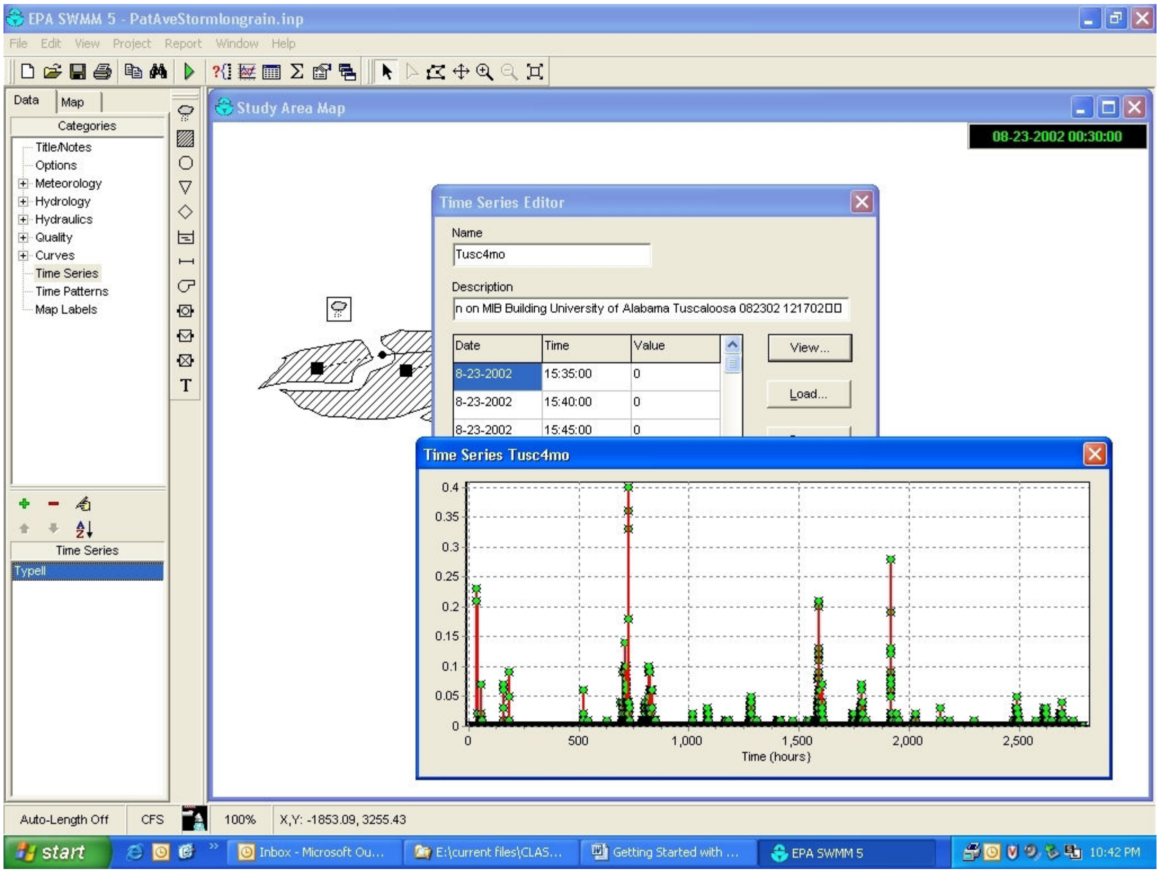


Long-term Continuous Simulation

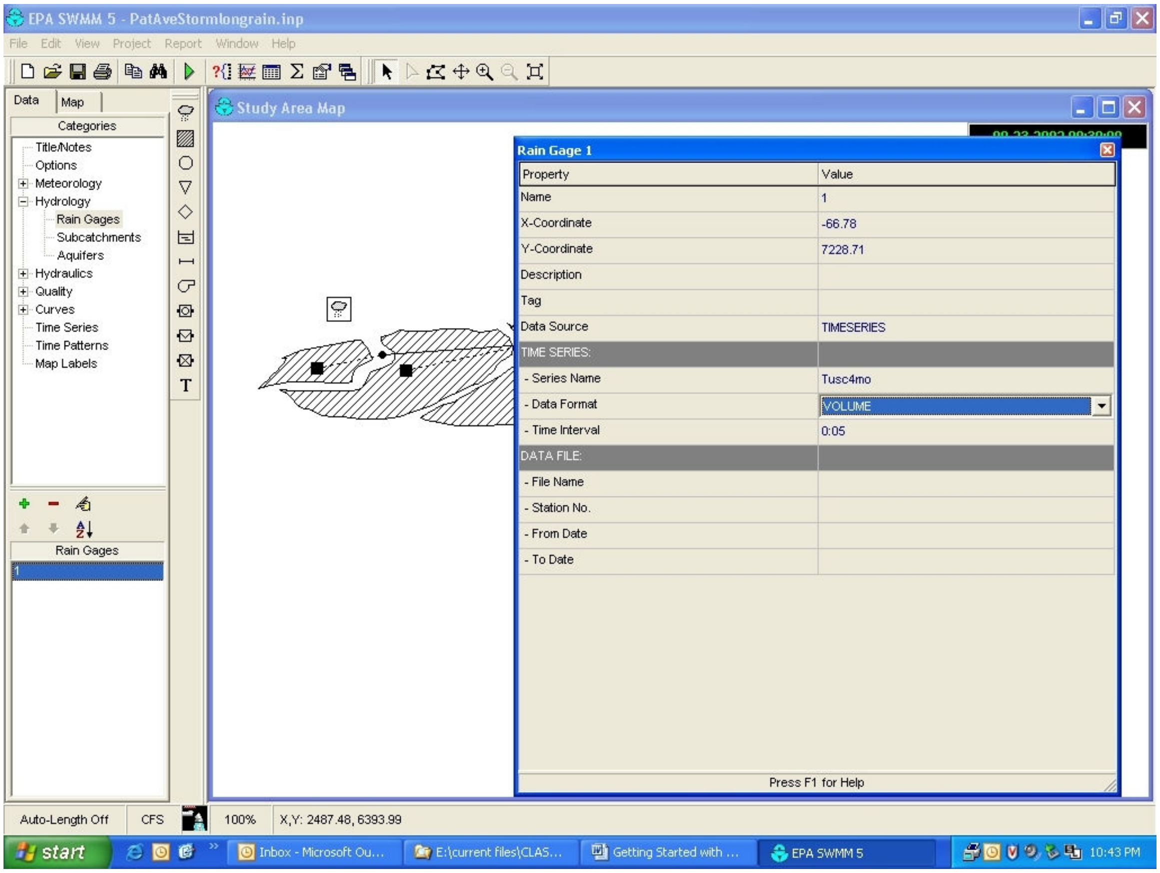
It is possible to use a variety of rain files with SWMM5. The following illustrates the use of a four month period of rains monitored at the University of Alabama for this site. The first step is to import the new rain file (4 months of 5 minute observations).


EPA SWMM 5 - PatAveStormlongrain.inp
File Edit View Project Report Window Help
Data
Map
Categories
Title/Notes
Options
Meteorology
Hydrology
Hydraulics
Quality
Curves
Time Series
Time Patterns
Map Labels
Time Series
TypeII
Study Area Map
08-23-2002 00:30:00
Time Series Editor
Name
Tusc4mo
Description
Open a Time Series
Look in:
M10 storm sewer system design
Contents
sediment scour in pipes
SWMM5 screen dumps
Tuscaloosa 4 months of rains.dat
TypeII 3_5.dat
TypeII 5_3.dat
TypeII 6_0.dat
TypeII 6_4.dat
TypeII 6_9.dat
TypeII 7_6.dat
TypeII 8_4.dat
TypeII 42.dat
TypeII accum depth.dat
TypeII.dat
My Recent Documents
Desktop
My Documents
My Computer
My Network Places
File name:
Tuscaloosa 4 months of rains.dat
Files of type:
Time series files (*.DAT)
Open
Cancel
Auto-Length Off
CFS
100%
X,Y: -1853.09, 3255.43

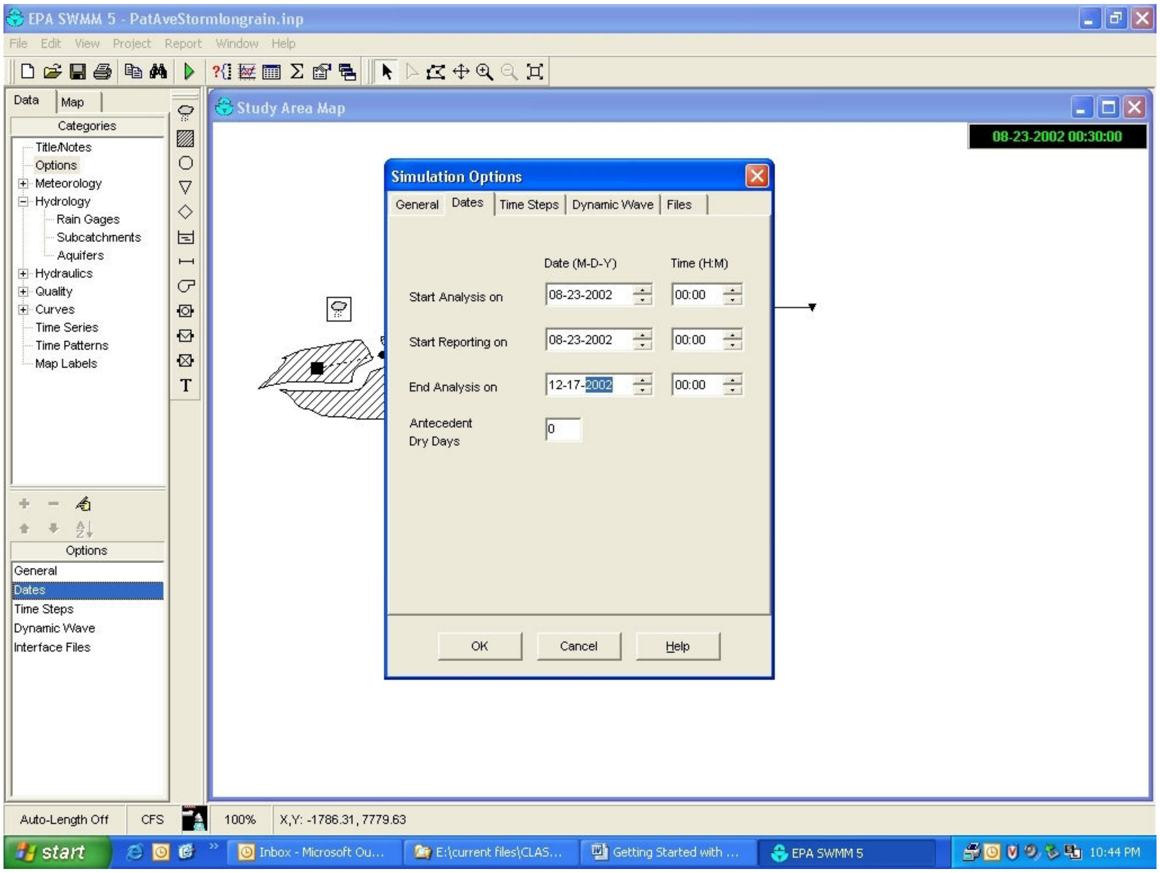

EPA SWMM 5 - PatAveStormlongrain.inp
File Edit View Project Report Window Help
Data
Map
Categories
Title/Notes
Options
Meteorology
Hydrology
Hydraulics
Quality
Curves
Time Series
Time Patterns
Map Labels
Time Series
TypeII
Study Area Map
08-23-2002 00:30:00
Time Series Editor
Name
Tusc4mo
Description
n on MIB Building University of Alabama Tuscaloosa 082302 121702
Date
Time
Value
8-23-2002
15:35:00
15:40:00
15:45:00
15:50:00
15:55:00
16:00:00
16:05:00
16:10:00
16:15:00
View...
Load...
Save...
OK
Cancel
Help
Auto-Length Off
CFS
100%
X,Y: -1853.09, 3255.43
start
Inbox - Microsoft Ou...
E:\current files\CLAS...
Getting Started with ...
EPA SWMM 5
10:42 PM



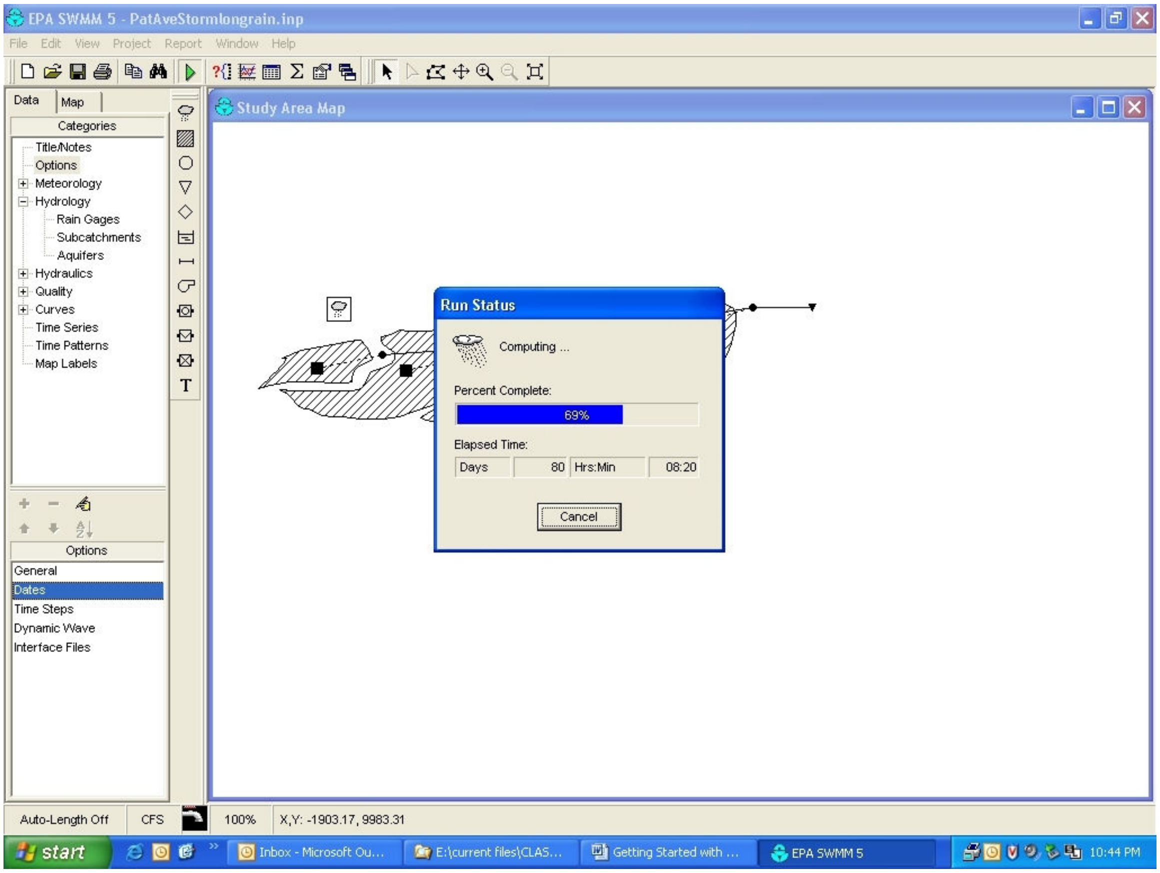
Next, the rain gage needs to be edited for the correct file name and file type. Again, this is a time series of volume data, collected at 5 minute intervals.



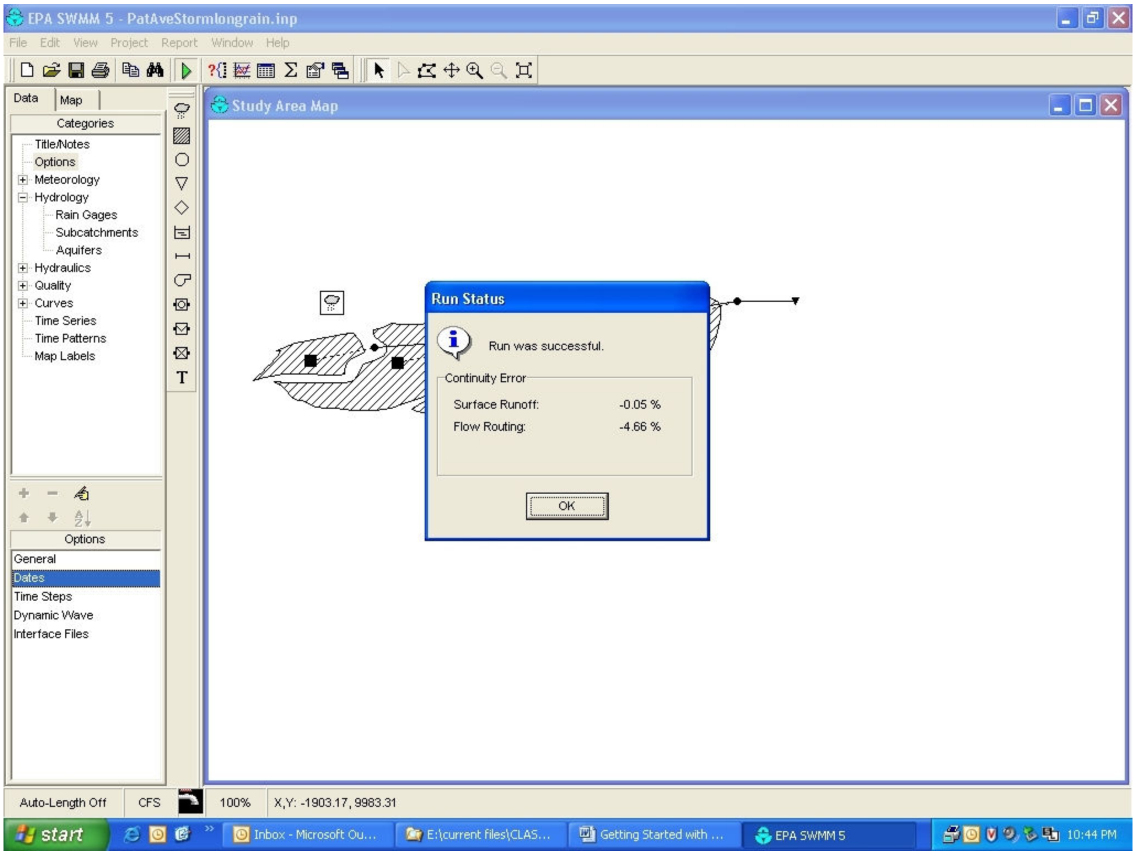
It is also necessary to edit the simulation options to reflect the new start and end dates for the simulation.



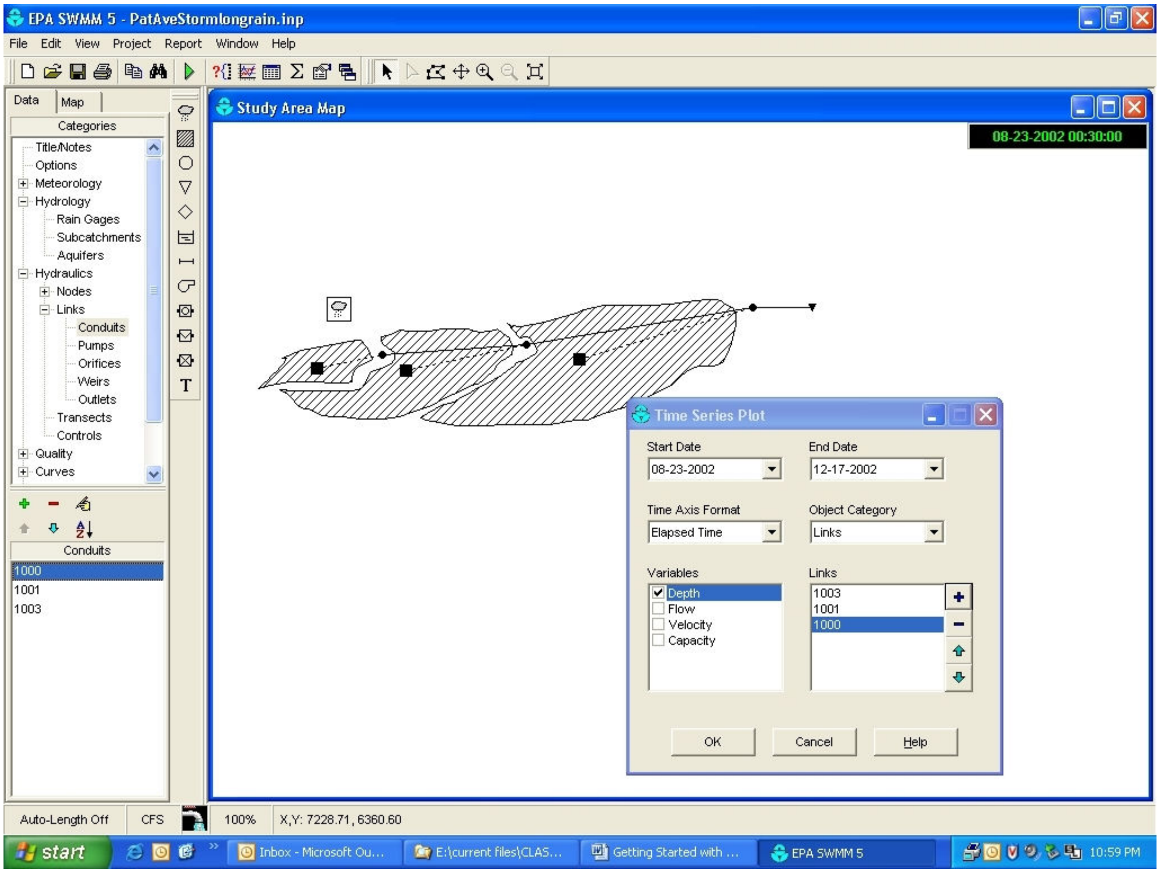
It takes appreciably longer to run this long simulation.

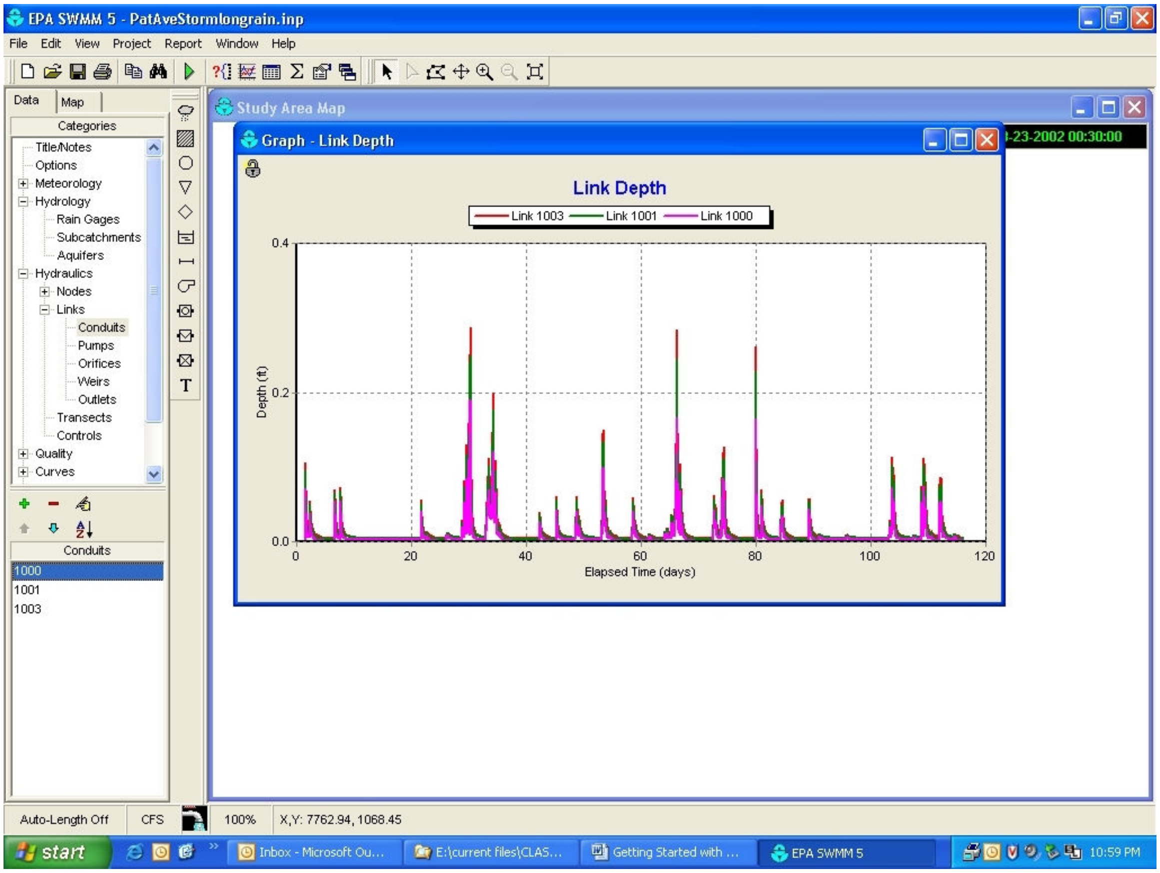


EPA SWMM 5 - PatAveStormlongrain.inp
File Edit View Project Report Window Help
Data
Map
Categories
Title/Notes
Options
Meteorology
Hydrology
Rain Gages
Subcatchments
Aquifers
Hydraulics
Quality
Curves
Time Series
Time Patterns
Map Labels
Options
General
Dates
Time Steps
Dynamic Wave
Interface Files
Study Area Map
Run Status
Computing ...
Percent Complete:
69%
Elapsed Time:
Days
80
Hrs:Min
08:20
Cancel
Auto-Length Off
CFS
100%
X,Y: -1903.17, 9983.31
start
Inbox - Microsoft Ou...
E:\current files\CLAS...
Getting Started with ...
EPA SWMM 5
10:44 PM



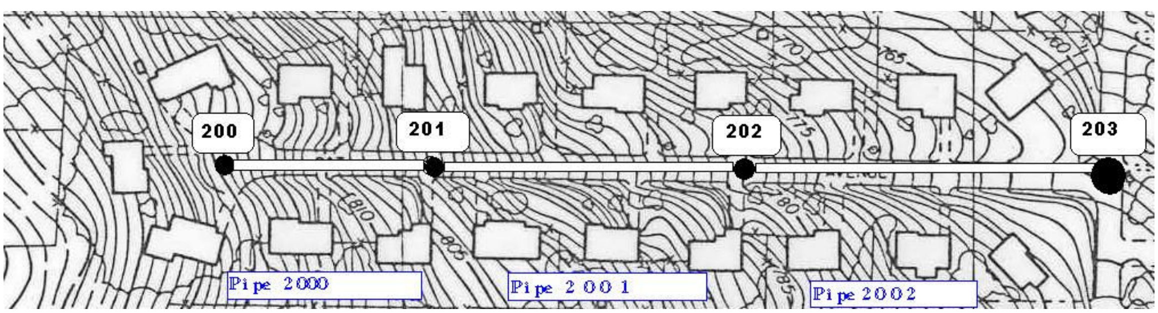
Again, the plotting options need to have the observation locations selected, but using the selector arrow in SWMM to click on the appropriate link, and then clicking on the "+" sign. Multiple elements of the same type can be selected for plotting together.


EPA SWMM 5 - PatAveStormlongrain.inp
File Edit View Project Report Window Help
Data Map
Categories
Title/Notes
Options
Meteorology
Hydrology
Rain Gages
Subcatchments
Aquifers
Hydraulics
Nodes
Links
Conduits
Pumps
Orifices
Weirs
Outlets
Transects
Controls
Quality
Curves
Conduits
1000
1001
1003
Study Area Map
08-23-2002 00:30:00
Time Series Plot
Start Date
08-23-2002
End Date
12-17-2002
Time Axis Format
Elapsed Time
Object Category
Links
Variables
Depth
Flow
Velocity
Capacity
Links
1003
1001
1000
OK
Cancel
Help
Auto-Length Off
CFS
100%
X,Y: 7228.71, 6360.60
start
Inbox - Microsoft Ou...
E:\current files\CLAS...
Getting Started with ...
EPA SWMM 5
10:59 PM



"Hello World" Pat Avenue Sanitary Drainage Design Example

It is easy to also design a sanitary drainage system using SWMM5. In this example, we will use the same location. The sanitary sewer is another pipe located on the other side of the road, 3 ft below the storm sewer pipe. Three pipes and three upper manholes are required in this design. Sewage discharges from the residents in the upper part of the street will be to pipe 2000. The following shows the location of the manholes and pipes in the design



The description of the sewage discharge and the subareas contribution is shown in Table 4.

Table 4. Sewage discharges and subareas

Junction (Node)	Area Served (ac)	# Apt. Buildings	Population (32 people / building)	Water Use (150 gal / day)	Daily Wastewater Flow (90% of water used)	Sewage (cfs)
200	0.98	3	96	14400	12960	0.020
201	1.63	5	160	24000	21600	0.033
202	2.18	6	192	28800	25920	0.040
203	2.00	4	128	19200	17280	0.027

For this example, it was assumed that the buildings shown on the map are actually apartment buildings (in order to produce a suitable flow in the upper reaches for this example). On the average, there are 32 people per building with an average per-capita consumption of 150 gal/day. About 90% of the water used is discharged to the sanitary system. The total average discharge in each pipe varies from 0.02 to 0.04 cfs. The information of each junction is shown in Table 5.

Table 5. Pat Avenue Junction Information (Sanitary Design):

JUNCTION	Invert Elevation (ft)	Maximum Depth (ft)	Initial Depth (ft)	Surcharge Depth (ft)	Ponded Area (ft²)
200	807	13	0	0	0
201	788	13	0	0	0
202	766	13	0	0	0
203 (Outfall)	750	n/a	0	0	0

The invert elevation corresponds to the elevation of the bottom of the manhole. The maximum depth is the distance from the bottom of the junction to the ground surface. The surcharge depth is the additional water depth above the ground surface used to store water during surcharge conditions. The ponded area is the surface area of the water accumulated during the surcharge. The information for each conduit (pipe) is shown in Table 6.

Table 6. Pat Avenue Conduit Information (Sanitary Design):

CONDUIT	Shape	Diameter (ft)	Length (ft)	n Manning	Inlet invert height offset (ft)
2000	Circular	1	200	0.013	0.5
2001	Circular	1	300	0.013	0.5
2002	Circular	1	300	0.013	0.5

CONDUIT	Outlet invert height offset (ft)	Initial flow (cfs)	Entry loss coefficient	Exit loss coefficient	Average loss coefficient
2000	0.5	0	0	0	0
2001	0.5	0	0	0	0
2002	0.5	0	0	0	0

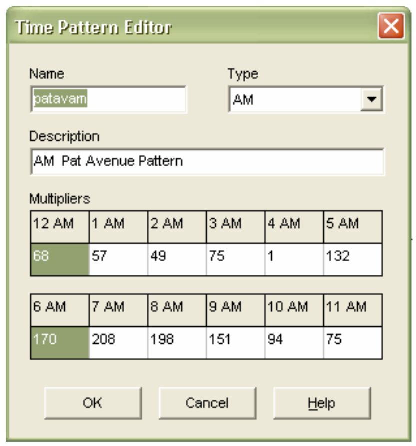
In this case, the fist pipe is shorter than the other pipes, but the initial diameter is the same at 1 ft. The main difference between the sanitary sewer design and the storm sewer design is that we don’t need to calculate the total runoff generated during the storm event (unless it was a combined sewer). In our simple example, the input to the modeled sanitary sewer is the sanitary sewage discharged by the apartment building residents.

Creating the Project

Open a new project. In the data browser tab select the *Title/Notes* option. Assign the title to the project. Return to the data browser and double click on the *options* category. As in the storm sewer example, select the flow units in csf, and the routing model as kinematic wave. Click on the *dates* tab. Assume this simulation started on January 1, 2003 at 00:00. The analysis will end on January 2, 2003 at 00:00. Report the whole simulation. Assume that the number of antecedent dry days was 10 (long dry period, having a minimal effect on inflow and infiltration).

Click on the *Time Steps* tab. In this example, the rain file will not be included, leave the default value or 30 minutes. The dry weather processes is simulated, use 1 hour time step in this case. Select a 5-minute routing time step and a 15-minute reporting time step. The *dynamic wave* and *Interface files* tabs are not used. Click *ok* to accept the values.

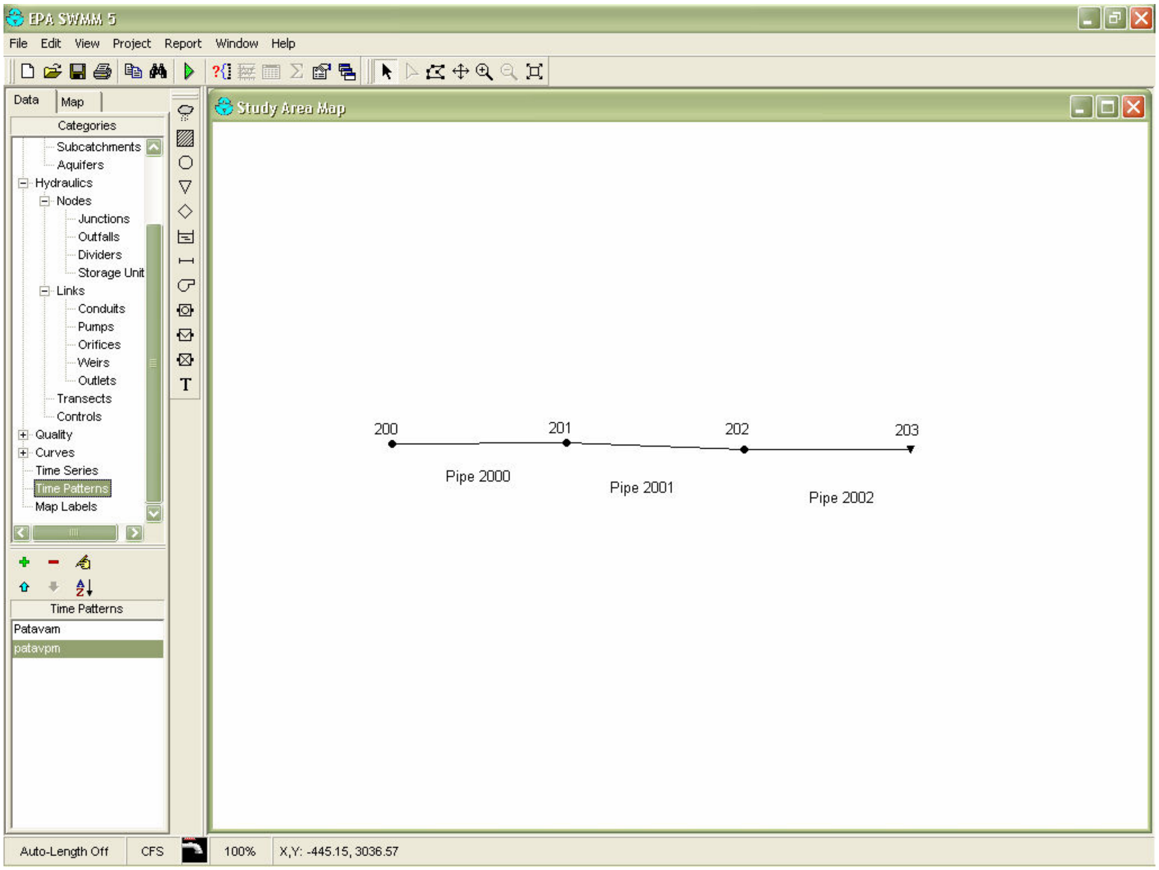
Now you will import a time series describing the sanitary sewage discharges in the study area. In the data browser, select the *Time Patterns* option and in the properties area add a new series. In the name field, assign the name "patavam" without quotes and spaces. Select type *AM*. Describe the time pattern, for example "AM Pat Avenue Pattern". The following figure shows the 12 percentages of the average flow used before noon: 68, 57, 49, 75, 100, 132, 170, 208, 198, 151, 94, and 75. Create a second pattern called "patavpm" for the PM part of the day. The percentages are: 79, 81, 91, 98, 100, 102, 83, 85, 87, 79, 70, and 72. These values are the percentages of the basic average hourly flow value produced by the residents.



Go to the main menu and select: *Project/defaults*. Click on the *Nodes/Links* tab. Assign 0 to the node invert and 300 ft to the conduit length. The pipes are circular with a roughness coefficient of 0.013. The flow units are in cfs and the routing model is kinematic wave. Click O.K. to accept the changes.

Now you can start to draw the pipes, nodes and outfall. Notice that in this case there are three pipes, three junctions and an outfall. Include all the required information using tables 4, 5 and 6. Start with the junctions and the outfall.

Double click on the first junction to display its properties. Rename the node as *200*. Click on *inflows*. A window will appear. Select the *Dry Weather* tab. Select constituent as *Flow*, the average values is shown in table 4. This flow is 0.020 cfs for the first junction. Assign the time patterns for the AM and PM part of the day. Click OK. Complete the required information for this node. Create the other two nodes and the outfall. Fill in the required information from tables 4, 5 and 6. The outfall is *free* (again, there is no a tide gate at the end). Use the T button in the drawing elements to add text labels to the map and identify each element. The following figure shows the final sketch for the layout for the sanitary sewer design.



Check in the main menu, project/details that the input file is complete, You can also open your input file with any word processor. In this moment you are ready to run the program. Compare your file with the following text file:

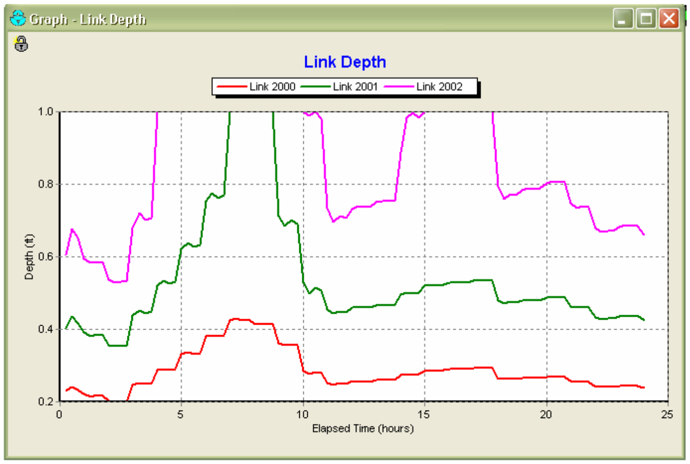
```
[TITLE]
Sanitary Sewer Design Example
Pat Avenue
Alex Maestre - University of Alabama

[OPTIONS]
  FLOW_UNITS            CFS
  INFILTRATION          HORTON
  FLOW_ROUTING          KW
  START_DATE            01-01-2003
  START_TIME            00:00:00
  REPORT_START_DATE     01-01-2003
  REPORT_START_TIME     00:00:00
  END_DATE              01-02-2003
  END_TIME              00:00:00
  DRY_DAYS              10
  WET_STEP              00:15:00
  DRY_STEP              01:00:00
  ROUTING_STEP          00:05:00
  REPORT_STEP           00:15:00
  ALLOW_PONDING         YES
  DYNWAVE_METHOD        EULER
  COURANT_FACTOR        0.75
  NORMAL_FLOW_LIMITED   YES
  LENGTHEN_CONDUITS     NO

[JUNCTIONS]
;                 Invert     Max.       Init.      Surcharge  Ponded
;Name             Elev.      Depth      Depth      Depth      Area
;-----------------------------------------------------------------------
 200              807        13         0          0          0
 201              788        13         0          0          0
 202              766        13         0          0          0
```

```
[OUTFALLS]
;               Invert     Outfall      Stage/Table
;Name           Elev.      Type         Time Series
;------------------------------------------------------
 203            750        FREE       NO

[CONDUITS]
;               Inlet           Outlet                      Manning    Inlet      Outlet     Init.
;Name           Node            Node            Length      N          Height     Height     Flow
;------------------------------------------------------------------------------------------------------------------
 2000           200             201             200         0.013      0.5        0.5        0
 2001           201             202             300         0.013      0.5        0.5        0
 2002           202             203             300         0.013      0.5        0.5        0

[XSECTIONS]
;Link           Type         Geom1      Geom2      Geom3      Geom4
;----------------------------------------------------------------------------
 2000           CIRCULAR     1          0          0          0
 2001           CIRCULAR     1          0          0          0
 2002           CIRCULAR     1          0          0          0

[INFLOWS]
;                                                   Concen   Conversion
;Node           Parameter        Time Series      /Mass    Factor
;-----------------------------------------------------------------------

[DWF]
;                                Average    Time
;Node           Parameter        Value      Patterns
;-------------------------------------------------------
 200            FLOW             0.020      "" "" "patavam" "patavpm" "" ""
 201            FLOW             0.033      "" "" "patavam" "patavpm" "" ""
 202            FLOW             0.040      "" "" "patavam" "patavpm" "" ""
 203            FLOW             0.027      "" "" "patavam" "patavpm" "" ""

[RDII]
;Node           Unit Hydrograph  Sewer Area
;---------------------------------------------

[PATTERNS]
;Name           Type       Multipliers
;---------------------------------------
;AM  Pat Avenue Pattern
 patavam        AM         68 57 49 75 100 132 170 208 198 151 94 75

;PM Pat Avenue Pattern
 patavpm        PM         79 81 91 98 100 102 83 85 87 79 70 72


[REPORT]
CONTROLS NO

[COORDINATES]
;Node           X-Coord          Y-Coord
 200            699.52           5516.69
 201            3688.39          5453.10
 202            6661.37          5373.61
 203            9157.39          5357.71

[VERTICES]
;Link           X-Coord          Y-Coord

[LABELS]
;X-Coord        Y-Coord          Label
 413.35         5898.25          "200"  ""  "Arial"  10  0  0
 3386.33        5771.07          "201"  ""  "Arial"  10  0  0
 6359.30        5691.57          "202"  ""  "Arial"  10  0  0
 8855.33        5675.68          "203"  ""  "Arial"  10  0  0
 1669.32        5214.63          "Pipe 2000"  ""  "Arial"  10  0  0
 4642.29        4960.25          "Pipe 2001"  ""  "Arial"  10  0  0
 7344.99        4912.56          "Pipe 2002"  ""  "Arial"  10  0  0

[BACKDROP]
 DIMENSIONS     0.00             0.00             10000.00         10000.00
 UNITS          None
 FILE           ""
 OFFSET         0.00             0.00
 SCALING        0.00             0.00
```

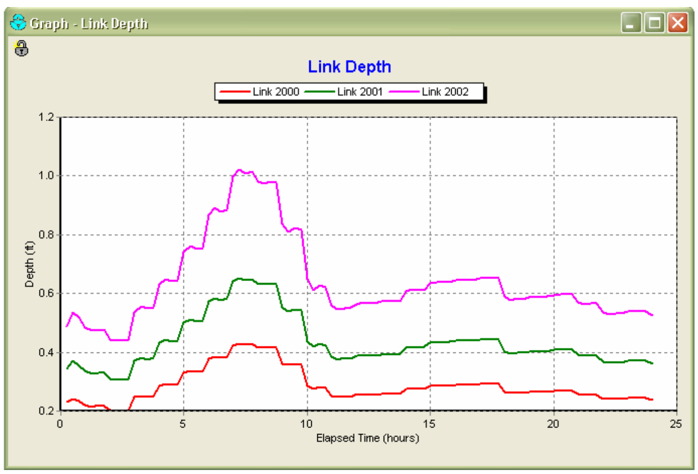
If everything looks fine, run the model. The results from the model should be similar to the following:

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0E (Build 1/23/04)
-----------------------------------------------

Sanitary Sewer Design Example
Pat Avenue
Alex Maestre - University of Alabama

****************
Analysis Options
****************
Flow Units ............. CFS
Flow Routing Method ..... KW
Starting Date ........... JAN-01-2003 00:00:00
Ending Date ............. JAN-02-2003 00:00:00
Routing Time Step ....... 00:05:00
Report Time Step ........ 00:15:00


*************************        Volume        Volume
Flow Transport Continuity     acre-feet      Mgallons
*************************     ---------     ---------
Dry Weather Inflow ......        23.869         7.778
Wet Weather Inflow ......         0.000         0.000
Groundwater Inflow ......         0.000         0.000
RDII Inflow .............         0.000         0.000
External Inflow .........         0.000         0.000
External Outflow ........        23.865         7.777
Initial Stored Volume ...         0.000         0.000
Final Stored Volume .....         0.007         0.002
Continuity Error (%) ....        -0.011


******************
Node Depth Summary
******************

---------------------------------------------------------------------------------------
                          Average   Maximum   Time of Max    Average     Total   Fraction
                            Depth     Depth    Occurrence      Depth   Minutes    Courant
Node                         Feet      Feet   days hr:min     Change   Flooded   Critical
---------------------------------------------------------------------------------------
JUNCTION  200                0.78      0.93      0  07:05     0.0063         0       0.00
JUNCTION  201                1.04      1.50      0  07:00     0.0128         0       0.00
JUNCTION  202                1.34      1.50      0  04:00     0.0145         0       0.00
OUTFALL   203                0.00      0.00      0  00:00     0.0000         0       0.00


********************
Conduit Flow Summary
********************

--------------------------------------------------------------------------------------
                  Maximum   Time of Max    Maximum   Time of Max   Maximum        Total
                     Flow    Occurrence   Velocity    Occurrence   /Design      Minutes
Conduit               CFS   days hr:min     ft/sec   days hr:min      Flow   Surcharged
--------------------------------------------------------------------------------------
2000             4.20e+00      0  07:05      13.04      0  07:05      0.38            0
2001             9.65e+00      0  07:00      13.97      0  06:05      1.00          120
2002             8.84e+00      0  10:40      11.94      0  20:05      1.07          560


Analysis begun: Sun Apr 25 20:12:34 2004
Analysis ended: Sun Apr 25 20:12:34 2004
```

The results show that the diameters of pipes 2001 and 2002 are not large enough to transport the flow (they surcharge). This pipes can be replaced by larger pipes (1.5 ft pipes will be used). The following figure shows the current results with pipes 1 ft in diameter.



The results after enlarging pipes 2001 and 2002 to the next largest commercial pipe size show that pipe 2002 only reaches 67% of the total capacity during the peak hour so the new design appears to be satisfactory. The following figure shows the flow depths at each node with pipes 2001 and 2002 enlarged to 2 ft in diameter.



References

http://www.epa.gov/ednnrmrl/swmm/beta_test.htm

US EPA, National Risk Management Research Laboratory, Office of Research and Development, (2002). *SWMM Redevelopment Project Plan*. Version 5. Water Supply and Water Resources Division.

James, W., W. Huber, R. Pitt, R. Dickinson, and R. James (2002). *Water Systems Models, Hydrology*. CHI, Guelph Ontario Canada. 347 pp.

Chow V., (1988). *Applied Hydrology*. McGraw Hill Book Co. – New York.