Sanitary Sewer Design Using EPA Storm Water Management Model (SWMM)

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ABSTRACT: Traditional sanitary sewer design uses detailed design tables that contain all the necessary information to complete the design. An alternative approach is to use modeling software, such as the EPA SWMM model. This paper details the application of the EPA SWMM model to design the sanitary sewer system of a proposed 62 lot development. Typically SWMM is thought of almost exclusively as a storm water system analysis tool, but this application shows how it can also be used for sanitary sewer analysis and design. The paper details how the SWMM model parameters were set to handle infiltration and inflow as well as base residential sanitary flows. Comput Appl Eng Educ 18: 203–212, 2010; Published online in Wiley InterScience (www.interscience.wiley.com); DOI 10.1002/cae.20124

Keywords: SWMM; sanitary sewer; hydraulic model

INTRODUCTION

One of the cornerstone topics in Civil Engineering hydraulic design is the design of sanitary sewer systems. Traditionally these designs are done by constructing detailed tables that contain all the necessary information to complete the design [1–4]. An example of such tables is shown in Figure 1. Note that the tables in Figure 1 contains only the information required to design a sewer for three blocks on one street, Wayne Road. While such tables can be constructed using Excel, they represent a tedious procedure that is prone to errors. These design tables are very time consuming to produce and become very unwieldy when used to design even moderate size systems.

An alternative approach is to use hydraulic modeling software. An example of such hydraulic modeling software is the EPA Storm Water Management Model (SWMM). Typically SWMM is used for designing storm water systems [5]. It can also be used for sanitary sewer modeling if the user adjusts the model parameters accordingly. This article details an application of SWMM to design a sanitary sewer system for a development that was constructed in Cass County, Missouri.

SWMM MODEL OVERVIEW

SWMM was developed by the EPA and is free, public domain software. SWMM is a dynamic rainfall-runoff

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Location					Basic Data			Domestic Flow						Infiltration/Inflow			
1	2		3		4	5	6	7	8	9	10	11	12	13	14	15	16
Street	From	MH	To	MH	L (ft)	Area (ac)	Cumm. Area (ac)	Pop. Density (pers/ac)	Cumm. Pop.	Avg Unit Flow (gal/capita /day)	Cumm Avg Flow (cfs)	Peaking Factor	Cumm. Peak Flow (cfs)	Avg Infilt. (gal/ac/day)	Cumm. Avg Infilt (cfs)	Peaking Factor	Cumm. Peak I/I (cfs)
Wayne	James	78	Prince	79	740	19.17	19.17	30	575.21	110	0.10	4.5	0.44	1400	0.04	1.8	0.07
Wayne	Prince	79	Blane	80	830	16.51	35.68	25	987.97	110	0.17	4.5	0.76	1400	0.08	1.8	0.14
Wayne	Blane	80	Linden	122	1215	12.78	48.47	30	1371.44	110	0.23	4.5	1.05	1400	0.11	1.8	0.19

Location					Design Flows		Sewer Design								
							Ground Elevation (ft)							Invert Elevation (ft)	
1	2		3		17	18	19	20	21	22	23	24	25	26	27
Street	From	MH	To	MH	Cumm. Avg Flow (cfs)	Cumm. Peak Flow (cfs)	Upper MH	Lower MH	Drop (ft)	Slope	Pipe Dia. (in)	Capacity (cfs)	Full Velocity (ft/s)	Upper MH	Lower MH
Wayne	James	78	Prince	79	0.14	0.52	115	102	13	0.0176	8	1.61	4.60	108.33	95.33
Wayne	Prince	79	Blane	80	0.25	0.90	102	99	3	0.0036	10	1.32	2.42	95.17	92.17
Wayne	Blane	80	Linden	122	0.34	1.24	99	92	7	0.0068	10	1.67	3.06	92.17	85.17

Figure 1 Example of sewer design tables.

simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas [5]. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps. SWMM was first developed in 1971 and has undergone several major upgrades since then. It continues to be widely used throughout the world for planning, analysis and design related to storm water runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well. The latest version of SWMM (SWMM 5.0) features a graphical interface.

EXAMPLE APPLICATION

The example that was used in class was based on a development that was built in the Town of Raymore, in Cass County, Missouri. The development consisted of 62 lots varying in size from 1/8th of an acre to $\frac{1}{2}$ an acre, plus a swimming pool and several roads, as shown in Figure 2.

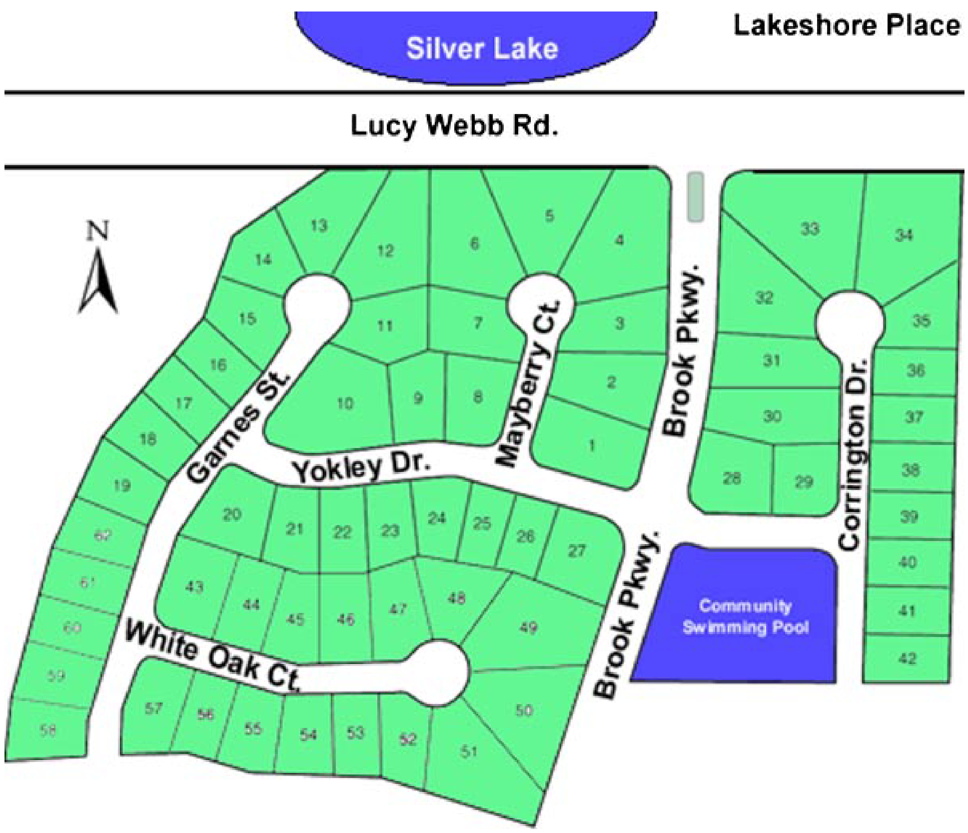


Figure 2 Site plan. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Contour maps based on elevation data given in Appendix 1 were constructed. Design requirements were adapted from those used by the City of Ann Arbor in Michigan [6] as they included detailed specifications on storm intensity and duration, inflow, and infiltration (I/I) requirements, and typical daily sanitary flow generation rates. These requirements are given in Appendix 2 and 3 and can be summarized as:

- Design dry weather flow = 300 gpd (Single family residence)
- Design dry weather flow = 20 gpd/capita (Swimming pool)
- Peak dry weather flow = 400% design flow
- Design storm = Type II SCS, 6 hr duration, 4″ total rainfall (see Appendix 4)
- I/I = 10% of rainfall enters sewers immediately
- Flow can not exceed 90% of pipe capacity.

Additional requirements that were to be met included:

- Only 1 connection to existing trunk main on Lucy Webb Road
- Minimum depth of cover in streets to be 6 ft
- Minimum depth of cover for lateral is 3 ft
- Minimize use of easements
- Minimum pipe size in streets is 8″
- Minimum lateral size is 6″

SWMM MODEL SET UP

The site plan was imported into SWMM and used as a background map, onto which the sewer network would be superimposed. This is shown in Figure 3. The various inputs that were required are detailed below.

Rainfall

As per the City requirements, a 6 hr storm that delivers 4″ of rain was constructed based on the SCS Type II rainfall distribution. This was set up as a time series in SWMM.

Subcatchments and I/I Requirements

Each block of land, plus the pool, was defined as a subcatchment and its area calculated. The elevation

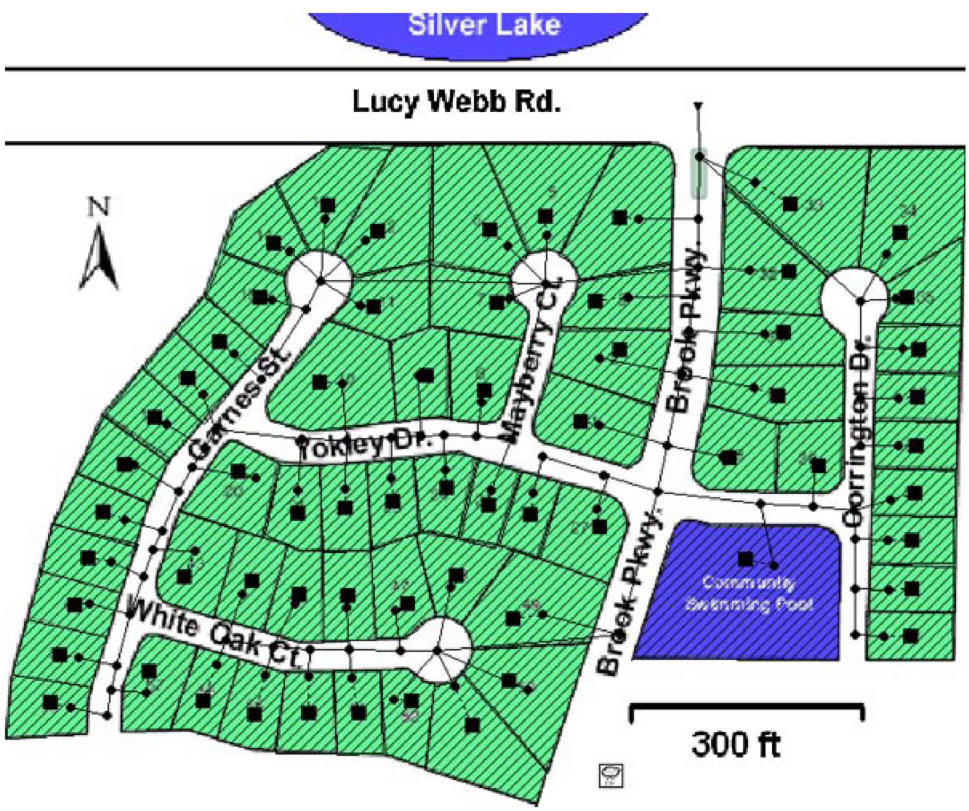


Figure 3 SWMM network. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

of the center of each block was computed and it was assumed that this elevation would represent the origin of each lateral connection, less the 3ft of cover that was required.

There were several possible ways to model the I/I requirements that 10% of the storm be allowed to enter the system immediately. The method used here was to let the 10% flow off the subcatchments and enter the junction where the laterals joined the main. This has the advantage of not forcing the I/I flow through the laterals, but instead having the flow first appear at a junction on the main. This is a realistic interpretation of what happens in reality, as manholes on the street are largely responsible for inflows in systems where roof leaders do not connect to the sanitary system.

This 10% storm runoff was achieved by setting the percent impervious of each block to 10% and forcing all of the impervious runoff to enter the system. To ensure that the runoff from the impervious area reached the system quickly, a width of 1000 ft was assigned to every subcatchment. This had the effect of reducing the effective length of the subcatchment, and therefore reduces the runoff travel time. The make sure that none of the storm was captured in depression storage, the depth of depression storage on the impervious area was set to zero.

On the other hand, none of the runoff from the pervious portion of subcatchment could be allowed to enter the system, otherwise more than the required 10% of the storm would be captured as I/I. To prevent this, the pervious area depression storage was set to a large value, 1000″. This value is large enough that any rainfall that lands on the pervious area is effectively held there in depression storage.

Junctions

The dry weather flow from the houses was input into the junction that acts as the start of the lateral connection. For each junction the invert elevation was set based on minimum cover requirements plus an additional foot to account for the pipe. The maximum depth was set as the difference between the invert and the ground elevation.

Conduits

It was assumed that PVC pipes would be used throughout the system and Manning's "n" was set to 0.01. The conduit type was circular (not "circular filled") and the depth is the pipe diameter.

Simulation Period

The model was run for 8hrs, beginning when the storm started and ending 2 hr after the storm finished. As the system is small no start time prior to the storm was necessary, especially as the crucial period occurs mid way through the design storm, 3 hr into the simulation.

MODEL RESULTS

One of the challenges of traditional design methods of sewer networks is the inherently static approach to a dynamic system. Sewer networks represent three dimensional, time variable systems. SWMM's output capabilities allow the user different options to view the system in multiple dimensions and time. This is one of the significant advantages of using SWMM, and directly impacts the users ability to see flaws in the design and make appropriate changes. An example of SWMM's output options include: color coded mapping of the system throughout a run; and the ability to plot hydraulic profiles along various sewer lines. Examples of these are detailed below.

A map of the system at peak flow is shown in Figure 4. In this figure the all three main components of the system are being tracked simultaneously: subcatchments, junctions and pipes. The user can change the legend to flag when critical design points occur. For this example the pipes would be set to turn red when their capacity reaches 90% (as per the design specifications) and the nodes would be set to turn red if they surcharge (overflow).

The route of flow that originates in Lot 58, and terminates at the connection to the existing trunk main in Lucy Webb Road (hereafter referred to as Route 1) is shown schematically in Figure 5. The corresponding SWMM generated hydraulic profile of Route 1 at peak flow is shown in Figure 6. In all of SWMM's output options the user has the ability to step through the model run in time, in effect creating an animation of the results.

An additional output feature of SWMM that is useful is the ability to look at a time series of flow at various points in the system. An example of this is shown in Figure 7. The nodes represent various manholes located along Route 1. This figure clearly demonstrates the peak flow timing within the system, as well as how the flow accumulates through the system.

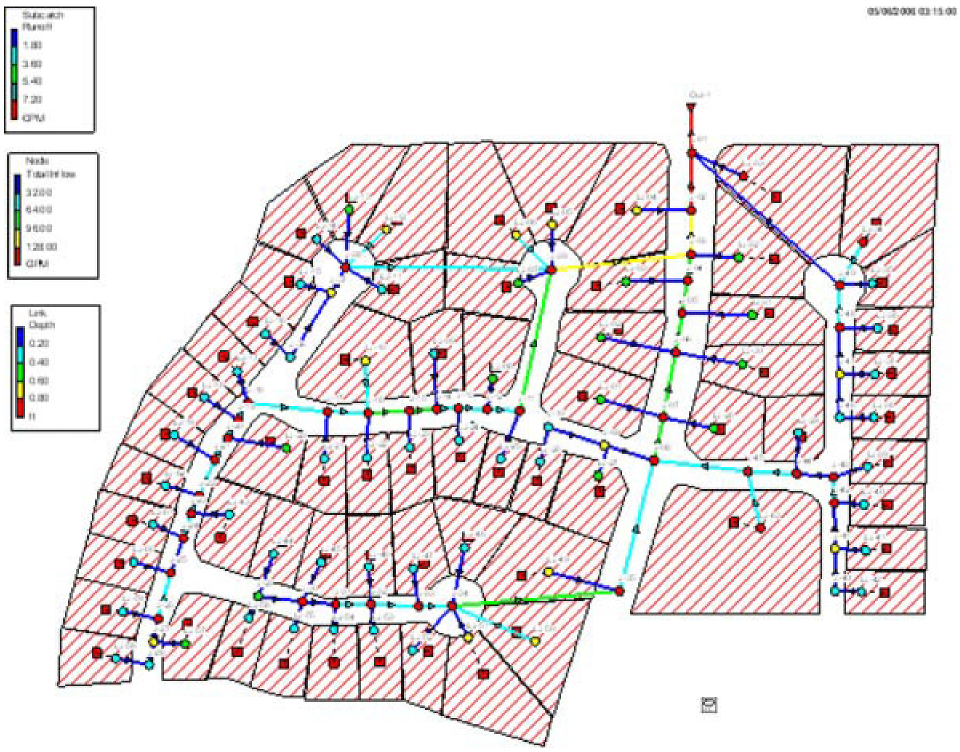


Figure 4 SWMM network at peak flow. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

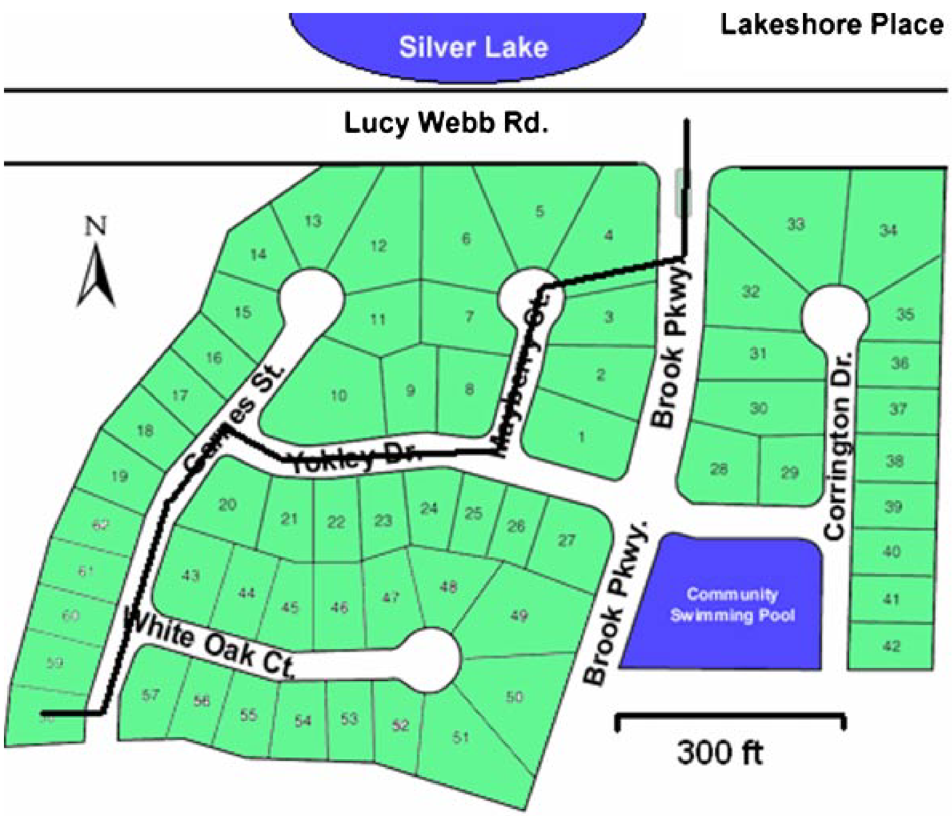


Figure 5 Flow route from Lot 58—Route 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

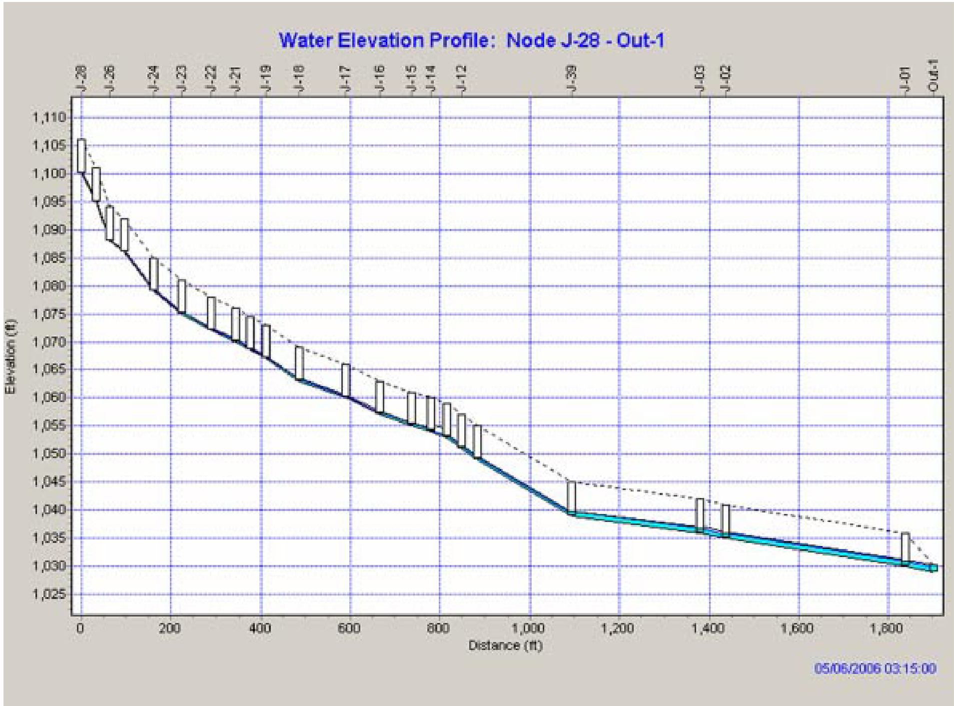


Figure 6 Hydraulic profile of Route 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

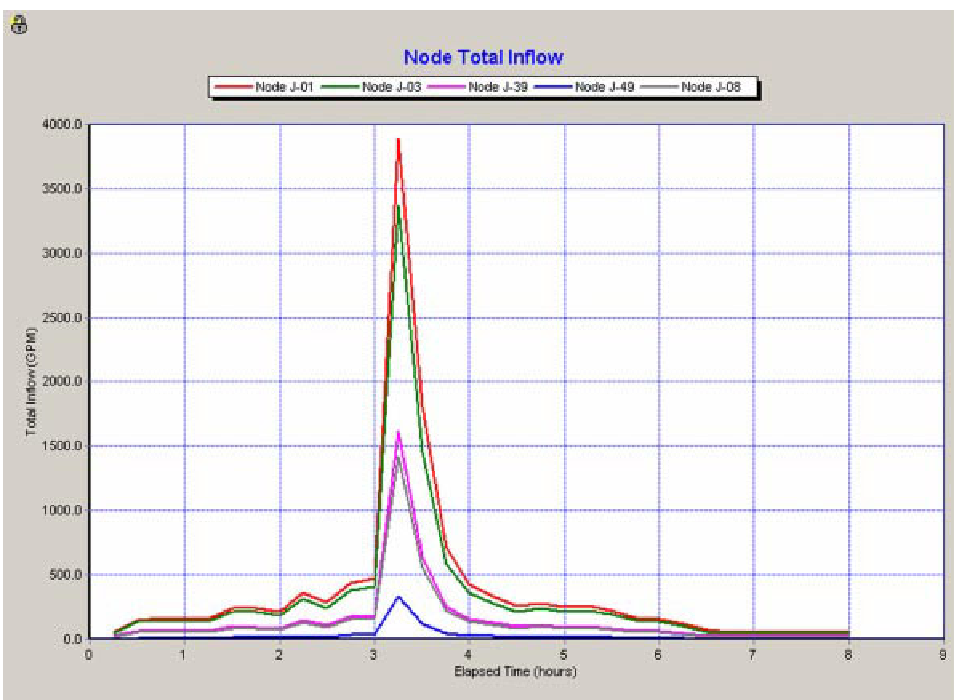


Figure 7 Time series of flow at various points along Route 1. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

CONCLUSIONS

Although primarily thought of as a storm water tool, the EPA Storm Water Management Model (SWMM) can be readily applied to the design of sanitary sewer systems if the appropriate parameters are set accordingly. In fact the use of SWMM is a much more practical way to approach a sanitary sewer design than the traditional tabular methods. As shown in the example documented in this paper, a SWMM sanitary sewer network is easy to set up and subsequently easy to modify as part of the design process. SWMM also comes with excellent post processing graphics that allows the user to view the system dynamically, both in plan and profile. Perhaps best of all is that SWMM is free, public domain software.

ACKNOWLEDGMENTS

The figures showing SWMM network and subsequent results were generated by Donald Dedrick, during the Hydraulic Design Course at Manhattan College in Spring 2006.

APPENDIX 1: SITE ELEVATION DATA

Reference Elevation Data (ft)

Silver Lake	1030.0
Lucy Webb at Brook Pkwy	1040.0
Brook Pkwy at South Pool	1060.0
SW Corner Lot 58	1120.0
SE Corner Lot 51	1070.0
SE Corner Lot 42	1080.0
NE Corner Lot 34	1050.0
NW Corner Lot 13	1050.0
NW Corner Lot 18	1080.0
SE Corner Lot 9	1060.0
SE Corner Lot 37	1065.0
NE Corner Lot 2	1050.0
NE Corner Lot 44	1085.0

APPENDIX 2: SEWER DESIGN REQUIREMENTS (BASED ON CITY OF ANN ARBOR, MI)

Table A. Design Dry Weather Flows

Type of facility or use	Design dry weather flow rate
Single family residence	300 gpd
Two family residence	600 gpd
Apartment to a single family unit (up to 400 sq. ft.)	150 gpd
Motels with kitchenettes, apartments, town houses, mobile homes, trailers, co-ops, etc. up to 600 sq. ft. of gross floor area	150 gpd/U
Motels with kitchenettes, apartments, town houses, mobile homes, trailers, co-ops, etc. with 601–1200 sq. ft. of gross floor area	225 gpd/U
Motels with kitchenettes, apartments, town houses, mobile homes, trailers, co-ops, etc with over 1200 sq. ft. of gross floor area	300 gpd/U
Motel unit less than 400 sq. ft.	100 gpd/U
Motel unit more than 400 sq. ft.	150 gpd/U
Hospital (without laundry)	150 gpd/bed
Hospital	300 gpd/bed
University housing, rooming houses, institutions	75 gpd/captia
Cafeteria (integral to an office or an industrial building)	2.5 gpd/capita
Non-medical office space	0.06 gpd/sq. ft. ground floor area
General industrial space	0.04 gpd/sq. ft. ground floor area
Medical arts (doctor, dentist, urgent care)	0.10 gpd/sq. ft. ground floor area
Auditorium/theater	5 gpd/seat
Bowling alley/tennis court	100 gpd/court-alley + food
Nursing home	150 gpd/bed
Church	1.5 gpd/captia
Restaurant (16 seat minimum or any size with dishwasher)	30 gpd/seat
Restaurant (fast food)	20 gpd/seat
Wet store—food processing	0.15 gpd/sq. ft. ground floor area
Wet store no food (barber shop, beauty salon, etc.)	0.10 gpd/sq. ft. ground floor area

(*Continued*)

Table A. (*Continued*)

Type of facility or use	Design dry weather flow rate
Dry store (no process water discharge)	0.03 gpd/sq. ft. ground floor area
Catering hall	7.5 gpd/captia
Market	0.05 gpd/sq. ft. ground floor area
Bar, tavern, disco	15 gpd/occupant + food
Bath house	5 gpd/occupant + 5 gpd/shower
Swimming pool	20 gpd/capita
Service stations	300 gpd/double hose pump
Shopping centers	0.02 gpd/sq. ft. ground floor sales area
Warehouse	0.02 gpd/sq. ft. ground floor area
Laundry	425 gpd/machine
Schools, nursery, and elementary	10 gpd/student
Schools, high, and middle	20 gpd/student
Summer camps	160 gpd/bed
Spa, country club	0.30 gpd/sq. ft. ground floor area

Standards

Sanitary sewer connection for the proposed project will be allowed if only if all of the following three requirements are met:

1. Sanitary sewer trunks and laterals do not surcharge.
2. Total of existing dry weather peaks, wet weather flows, and the project's proposed peak dry weather flow is less than 90% of sewer pipe design capacity.
3. No historical reported backups for the sanitary sewer trunk system to which the proposed project will be connected. Sanitary sewer trunk system includes trunk sewer and flow contributing laterals.

Guidelines for Calculating Dry and Wet Weather Flows

Dry Weather Flow

- Use City of Ann Arbor Table B.1 to calculate design dry weather flows (see Appendix 3)
- Project's proposed peak dry weather flow is four times design dry weather flow.
- Existing flows are available from Field Services Division, Water Utilities Department.

Wet Weather Flow

- The rain storm to be used for analysis is four inches of rain in a 6-hr period (100-year event). Use SCS Type II Distribution at 15 min intervals (see Appendix 4)
- 6–10 percent of the rainfall enters the sanitary sewer instantaneously. Model scenario run using 10% level.

APPENDIX 3: CALCULATIONS FOR DESIGN DRY WEATHER FLOWS

Table B.1 Design Dry Weather Flows

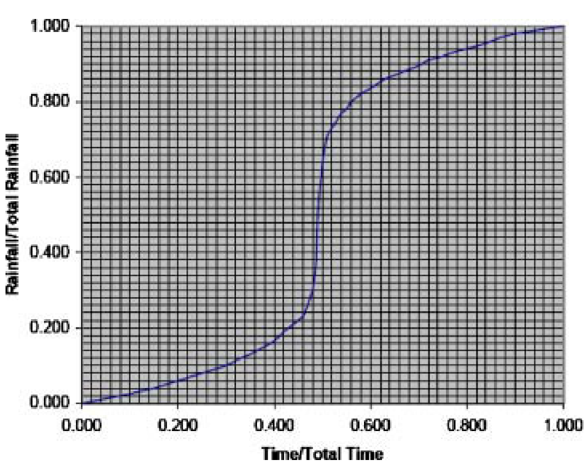
Type of facility or use	Design dry weather flow rate
Single family residence	300 gpd
Two family residence	600 gpd
Apartment to a single family unit (up to 400 sq. ft.)	150 gpd
Motels with kitchenettes, apartments, townhouses, mobile homes, trailers, co-ops, etc. up to 600 sq. ft. of gross floor area	150 gpd/U
Motels with kitchenettes, apartments, townhouses, mobile homes, trailers, co-ops, etc. up to 601–1200 sq. ft. of gross floor area	225 gpd/U
Motels with kitchenettes, apartments, townhouses, mobile homes, trailers, co-ops, etc. up to greater than 1200 sq. ft. of gross floor area	300 gpd/U
Motel unit less than 400 sq. ft.	100 gpd/U
Motel unit greater than 400 sq. ft.	150 gpd/U
Hospital (without laundry)	150 gpd/bed

(*Continued*)

Table B.1 (*Continued*)

Type of facility or use	Design dry weather flow rate
Hospital	300 gpd/bed
University housing, rooming house, institutions	75 gpd/capita
Cafeteria (integral to an office or industrial building)	2.50 gpd/capita
Non-medical office space	0.06 gpd/sf
General industrial space	0.04 gpd/sf
Medical arts (doctor, dentist, urgent care)	0.10 gpd/sf
Auditorium/Theater	5 gpd/seat
Bowling alley, tennis court	100 gpd/crt—alley
Nursing home	150 gpd/bed
Church	1.50 gpd/capita
Restaurant (16 seat minimum or any size with dishwasher)	30 gpd/seat
Restaurant (fast food)	20 gpd/seat
Wet store-food processing	0.15 gpd/sf
Wet store no food (barber shop, beauty salon, etc.)	0.10 gpd/sf
Dry store (no process water discharge)	0.03 gpd/sf
Catering hall	7.50 gpd/capita
Market	0.05 gpd/sf
Bar, tavern, disco	15 gpd/occupant
Bath house	5 gpd/occupant + 5 gpd/shower
Swimming pool	20 gpd/capita
Service stations	300 gpd/double pump
Shopping centers	0.02 gpd/sf
Warehouse	0.02 gpd/sf gr. area
Laundry	425 gpd/machine
Schools, nursery, and elementary	10 gpd/student
Schools, high, and middle	20 gpd/student
Summer camps	160 gpd/bed
Spa, country club	0.30 gpd sf gr floor area

APPENDIX 4: SCS TYPE II STORM DISTRIBUTION



Time/ total time	Rainfall/ total rainfall	Time/ total time	Rainfall/ total rainfall
0.000	0.000	0.520	0.730
0.400	0.100	0.530	0.750
0.100	0.25	0.540	0.770
0.150	0.040	0.550	0.780
0.200	0.060	0.560	0.800
0.250	0.080	0.570	0.810
0.300	0.100	0.580	0.820
0.330	0.120	0.600	0.835
0.350	0.130	0.630	0.860
0.380	0.150	0.650	0.870
0.400	0.165	0.670	0.880
0.420	0.190	0.700	0.895
0.430	0.200	0.720	0.910
0.440	0.210	0.750	0.920
0.450	0.220	0.770	0.930
0.460	0.230	0.800	0.940
0.470	0.260	0.830	0.950
0.480	0.300	0.850	0.960
0.485	0.340	0.870	0.970
0.487	0.3700	0.900	0.980
0.490	0.500	0.950	0.990
0.500	0.640	1.000	1.000

REFERENCES

[1] American Society of Civil Engineers. Gravity sanitary sewer design and construction. ASCE manuals and reports on engineering practice, No. 60. ASCE, New York, 1982.

[2] R. K. Linsley, J. B. Franzini, D. L. Freyberg, and G. Tchobanoglous, Water resources engineering, 4th edition, McGraw-Hill, New York, 1992, pp 698−699.

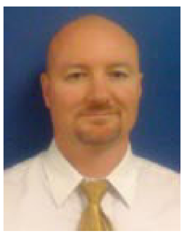
[3] D. Barnes, P. J. Bliss, B. W. Gould, and H. R. Vallentine, Water and wastewater engineering systems, Pitman Press, London, 1983, pp 73−74.

[4] D. A. Chin, Water-resources engineering, Prentice-Hall, Englewood Cliffs, New Jersey, 2000, pp 237−241.

[5] Environmental Proctection Agency, Storm Water Management Model—Users manual. Version 5.0. EPA water supply and water resources division. National Risk Management Research; Laboratory, Cincinnati, 2004.

[6] City of Ann Arbor, Sanitary SewerFlow Evaluation. Available from City of Ann Arbor, Michigan, website.

BIOGRAPHY



Scott Lowe is an Associate Professor in the Civil and Environmental Engineering Department at Manhattan College in Riverdale, New York. He has worked in the field of hydraulic engineering for many years and worked on projects throughout the US and overseas. The hydraulic design course featured in the paper also contains computer labs on water distribution system design using EPANET, river hydraulic analysis using HECRAS, and stormwater system design using HydroCAD.