JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 11 2003

MODELING OF URBAN WATERSHEDS USING BASINS AND HSPF

Scott A. Lowe Lawler, Matusky & Skelly Engineers LLP
Rob Doscher Westchester County Department of Planning
Westchester County, New York

The U.S. Environmental Protection Agency's BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) software was used to create a HSPF (Hydrologic Simulation Program - FORTRAN) watershed model of the Mamaroneck River, located in lower Westchester County, New York. This is a small urban watershed just north of New York City. The model was successfully calibrated and verified using 20 years of flow data. Land use, river reach and topographic data supplied with BASINS were compared to local county data and some discrepancies were noted, particularly with the reach data. Three versions of the model were developed: single segment, three segment and six segment. It was found that there was little gain in using the multi-segment models over the single segment. The calibrated parameters values from the single segment were found to provide an excellent starting point for calibrating the multi-segment models. The parameter values used were compared against those used in a large number of previous HSPF studies and found to be close to the median value in most cases.

INTRODUCTION

The Mamaroneck River is located in lower Westchester County, New York (Figure 1) and drains into Long Island Sound (Figure 2). Part of the ongoing investigation into water quality problems in Long Island Sound has involved focusing on nutrient loads delivered to the Sound by small coastal watersheds such as Mamaroneck River (Westchester County, 1997, 1998, 2001). To simulate the nutrient loads generated by the Mamaroneck River, a model of the watershed was developed using the U.S. Environmental Protection Agency's HSPF (Hydrologic Simulation Program - FORTRAN) within the EPA's BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) Version 2.0 software. This paper details the application of HSPF and BASINS to model the Mamaroneck River watershed. The specific issues addressed in this paper follow.

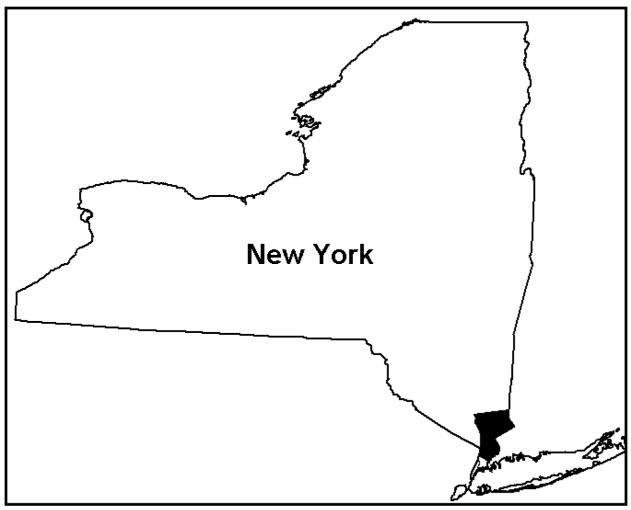

Figure 1. Location of Westchester County in New York State.

Figure 2. Location of Mamaroneck River Watershed.

1. How does the data supplied with BASINS compare with local county data? The data compared include land use, reach files and topography.

2. How applicable is BASINS and HSPF to a small urban watershed? That is, is it a suitable tool or should an alternative like SWMM be used?

3. Can a suitable HSPF calibration and verification be achieved by using a single reach model?

4. Do the results change significantly if 3 reaches or 6 reaches are used?

5. What results are obtained if the default values for HSPF given in BASINS are used?

6. How do the HSPF parameter values compare to those used in other studies?

BASINS OVERVIEW

The BASINS software package was first introduced by the EPA in the late 1990's for use by regional, state and local agencies in performing watershed and water quality based studies (EPA, 1998). The EPA's stated objectives in developing BASINS were:

a) To facilitate examination of environmental information;

b) To support analysis of environmental systems;

c) Provide a framework for examining management alternatives; and

d) To provide a mechanism to calculate Total Maximum Daily Loads (TMDLs).

BASINS operates through a geographic information system (GIS) framework. Within this framework there are a suite of six interrelated components:

1) national databases with tools to extract the data;

2) assessment tools to examine the data at different levels and scales;

3) data organization tools that include the ability to delineate watersheds;

4) reporting tools that allow compilation and output of watershed information on selected watersheds;

5) stream based water quality models – QUAL2E and TOXIROUTE; and

6) a watershed model - Non Point Source Model (NPSM).

The NPSM model is really a graphical interface to HSPF (Hydrologic Simulation Program – FORTRAN) Version 11.0 (Bicknell et al., 1996). In this paper BASINS Version 2.0 is used.

CASE STUDY: MAMARONECK RIVER WATERSHED

The Mamaroneck River is located in lower Westchester County, New York, as shown in Figure 3. The river drains directly into Long Island Sound and is approximately 11 miles long. The Sheldrake River is the major tributary that joins the Mamaroneck River approximately half a mile before it enters Mamaroneck Harbor. The area of the watershed is reported by the Westchester County Department of Planning (Westchester County, 2001) to be 14717 acres. The delineated watershed in BASINS totaled 15148 acres. The topology of the Mamaroneck River watershed is fairly flat with occasional rolling hills. The bottom of the watershed is at sea level and the maximum elevation is 135 m. The mean elevation is 60.5 m.

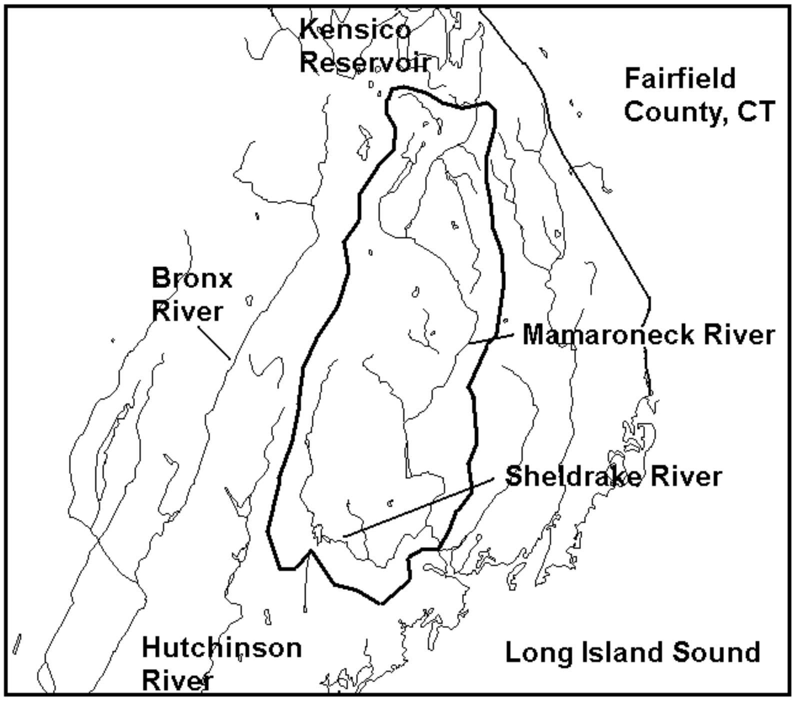

Figure 3. Delineation of Mamaroneck River watershed using Reach File 3 data.

Comparison of BASINS Supplied Data to Westchester County Data

Land Use

The land use distribution as supplied by BASINS and Westchester County (Westchester County, 1996) is shown in Table 1. Approximately 79% of the watershed is classified as urban with most of this being comprised of residential use. Another 19% of the watershed is classed as forest. The classification system used in BASINS and by Westchester County is not the same and Table 1 represents an attempt to match the county classifications with BASINS to make a comparison easier. The BASINS land use data is taken from U.S.Geological Survey (USGS) land use and land cover data from the mid 1970's to early 1980's (EPA, 1994). Overall the comparison shows a good match but this is very dependent on how the individual classifications are interpreted. For example "Residential Very Low Density" could well be split between residential and forest as these are homes on lots of several acres in size. "Private Recreation", which includes private golf courses, tennis clubs, swimming clubs and county clubs could also be split the same way. An interesting anomaly is the 163 acres of agricultural land identified in BASINS that actually turns out to be part of several golf courses. The actual land use distribution used in the models is given in Table 2. It should be noted that the BASINS manual states that "the data included within BASINS are intended to provide a starting point and data for those areas where limited site-specific information is available."

Reach Files

BASINS contains Reach File Version 1 (Rf1) and Reach File Version 3(Rf3) data compiled from EPA databases. This data contains information relating to stream and river reaches. Rf1 data is at a 1:500,000 scale and Rf3 data is at a 1:100,000 scale. There is no Rf1 data for the Mamaroneck River watershed. A comparison of Rf3 data and Westchester County data revealed some discrepancies near the headwaters of the Mamaroneck River. The differences are shown in

Table 1. Detailed Land Use Distribution for Mamaroneck River

BASINS		**Westchester County**	
Land Use Name and Code	**Area (acres)**	**Land Use Name and Code**	**Area (acres)**
Urban or Built-up Land			
RESIDENTIAL	7265	Residential High Density	186
		Residential Low Density	3931
		Residential Med. Density	706
		Residential Very Low Density	2486
		Private Recreation	1429
COMMERCIAL AND SERVICES	1211	Commercial	245
		Mixed Com. Res.	68
INDUSTRIAL	216	Manufacturing	77
TRANS, COMM, UTIL	724	Transportation Utility	657
MXD URBAN OR BUILT-UP	859	Office	775
OTHER URBAN OR BUILT-UP	1591	Institutional	1168
Subtotal	**11866**		**11728**
Agricultural Land			
CROPLAND AND PASTURE	163		0
Subtotal	**163**		0
Forest Land			
DECIDUOUS FOREST LAND	**3023**	Public Park Active	1362
		Public Park Passive	547
		Water Supply	79
		Undeveloped	884
Subtotal	3023		**2872**
Water			
LAKES	79	Water Body	117
BAYS AND ESTUARIES	2		
Subtotal	**81**		117
Barren Land			
TRANSITIONAL AREAS	15		0
Subtotal	**15**		0
Total	**15148**		**14717**

Table 2. Land Use Areas Used in Watershed Models

Land Use	**Segment Areas (Acres)**					
Single Reach						
Urban - pervious	7713					
Urban - impervious	4153					
Forest	3038					
Clear Rec.	163					
Three Reach Model	**Downstream Sheldrake**	**Sheldrake**	**Mamaroneck River**			
Urban - pervious	137	2184	5392			
Urban - impervious	137	1337	2679			
Forest	0	31	3007			
Clear Rec.	0	61	102			
Six Reach Model	**Downstream Sheldrake**	**Sheldrake**	**Upstream Sheldrake**	**Downstream Headwaters**	**West Branch**	**Headwaters**
Urban - pervious	137	2184	1270	2218	893	1011
Urban - impervious	137	1337	640	1098	450	491
Forest	0	31	537	565	227	1678
Clear Rec.	0	61	12	50	0	40

Figures 4a (Rf3 data) and Figure 4b (Westchester County data). The differences can be summarized as follows:

1. The headwater of the Mamaroneck River is not the overflow from the Kensico Reservoir. The Kensico Reservoir is part of the New York City drinking water system and was formed by damming the Bronx River (see Figure 4b). The headwaters of the Mamaroneck River are a series of small wetlands and ponds in Harrison, NY (Westchester County, 2001).

2. The upper west branch shown in Figure 4a should flow south to connect directly to the main branch of the Mamaroneck river rather than north as shown. This discrepancy can also be noted if the Rf3 data is overlaid on the DEM data, in which case the upper west branch can be seen to flow uphill.

Point Sources

One of the features of BASINS and the NPSM interface is the way that major point sources on the watershed are identified and made available to user as inputs for the watershed model. In this case this feature resulted in the erroneous headwater information, the Kensico Reservoir, being included it as a major point source for the Mamaroneck River. A flow of 40 cfs, approximately

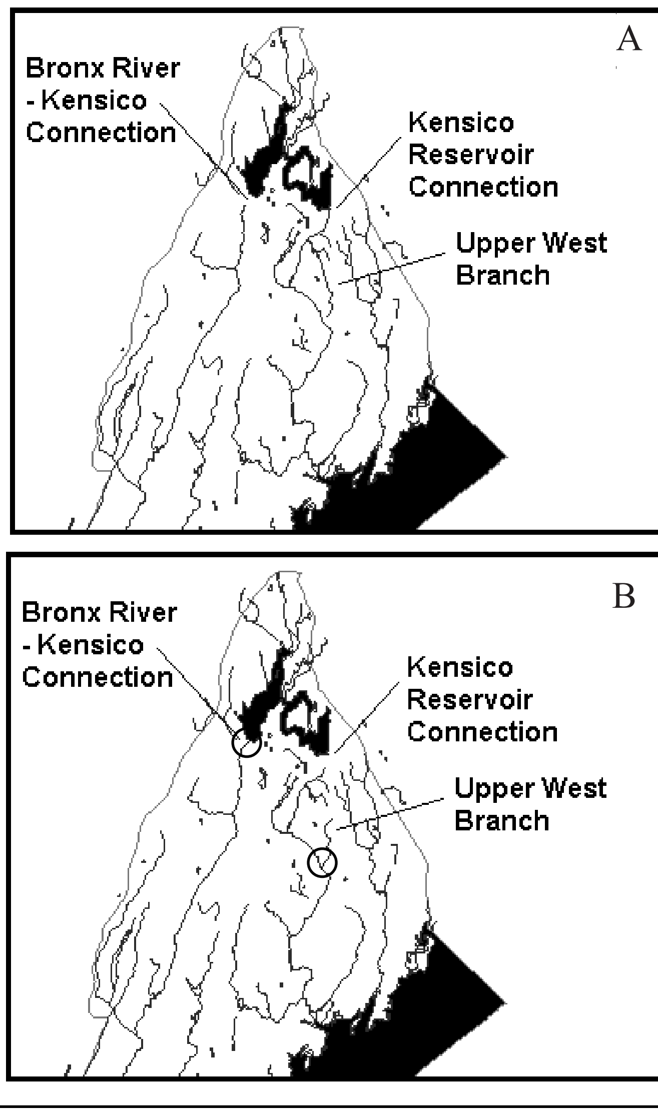

Figure 4. Original Reach File 3 data from BASINS (4a) and modified Reach File 3 data (4b).

the average flow in the Mamaroneck River, was attributed to the Kensico Reservoir. This source was manually excluded from the model input. There are no other major point sources for the Mamaroneck River.

DEM Data

The DEM data contained in BASINS is from the USGS at a resolution of 300m by 300m. This data was compared against Westchester County DEM data (30m by 30m resolution, Westchester County, 2001a) and USGS 7.5" topographic maps. The DEM data was consistent in terms of ranges of elevations, mean and median elevations. All values were within one percent of each other. The topographic maps were used to check the location of selected peaks and low points within the watershed and these were matched to the DEM data. Again good agreement was noted.

MODEL DEVELOPMENT

The Mamaroneck River watershed was delineated using the BASINS watershed delineation tool. The watershed was delineated using both Rf3 and DEM data supplied with BASINS but adjusted to account for the errors mentioned previously. A total of four land use types were used to represent the watershed – clear recreation, urban – pervious, urban - impervious and forest. These areas correspond to those listed in Table 2. The only allowance for impervious area is the urban-impervious class. This effectively splits the urban area into a pervious and impervious subclass. The urban area was estimated to vary between 32 – 50 % impervious (SCS, 1986).

Metereological Input and Model Timeframe

In order to run the Non Point Source Model (NPSM) within BASINS, a total of 16 meteorological parameters are required as input. The temporal resolution of each parameter is either 1 hour or 1 day. The meteorological parameters are listed in Table 3. The meteorological parameters reside in specially formatted files called Watershed Data Management (WDM) files. In BASINS each state has its own WDM file that contains complete meteorological data sets for selected locations (NOAA first order weather stations) throughout the state. This means that all the input data required to run the NPSM model already exist. This saves an enormous amount of time and problems by saving the user from actually having to create a WDM file.

The nearest meteorological station to Mamaroneck River reported in the BASINS WDM file was Central Park, New York City. This station is approximately 13 miles from the center of the Mamaroneck River watershed. The WDM data from this station start on January 1, 1970 and end

Table 3. Metereological Parameters Used in HSPF

Number	Parameter Name	Time Interval
1	Precipitation	Hourly
2	Evaporation	Hourly
3	Temperature	Hourly
4	Wind speed	Hourly
5	Dewpoint Temperature	Hourly
6	Cloud Cover	Hourly
7	Solar Radiation	Hourly
8	Potential Evapotranspiration	Hourly
9	Cloud Cover	Daily
10	Evaporation	Daily
11	Evapotranspiration	Daily
12	Dewpoint Temperature	Daily
13	Wind speed	Daily
14	Maximum Temperature	Daily
15	Minimum Temperature	Daily
16	Solar Radiation	Daily

on December 20, 1995. This means that the overlap between the data available to run the model and the USGS data with which to compare against (see below) is from January 1, 1970 until September 30, 1989. This 20 year period is the time frame that the model will be run over.

In order to check whether or not the precipitation reported at Central Park was representative of precipitation falling on the watershed, a comparison was made to data recorded at Westchester County Airport. The County Airport is located approximately 1 mile North East of the Mamaroneck River watershed. Monthly averages for a 30 year period, 1960-90 were compared and showed median differences of less than 5%. The annual averages differed by less than 2%. Based on this comparison, the data from Central Park supplied with BASINS was used to drive the model.

Flow Monitoring Data

Mamaroneck River daily flow was reported by the United States Geological Survey (USGS) from October 1954 through September 1989 (USGS, 2000). This data was used to calibrate the BASINS model. One feature of BASINS that is particularly useful is the ability to import downloaded USGS data files directly into the post-processing software to allow for immediate comparison to model output.

Land Use Changes 1970-1989

When running long term simulations there is the potential that land use on the watershed will change and have an impact on results. For an urban watershed like Mamaroneck River the concern is that forest land has been cleared and turned into residential developments. Discussion with the Westchester County Department of Planning confirmed that there had been some new developments near the headwaters of Mamaroneck River. Much of this development has taken place since 1989 and so would not affect the model. In the period between 1970 and 1989 it was estimated that total new development area was on the order of 150 acres of mainly low density residential use. Given the minimal impact this would have on the simulation results, a constant land use was used. The assumption of minimal residential development was also confirmed by checking population data for the period in question (Westchester County, 1998a). The data showed that the population on the watershed actually decreased slightly over the period 1970-89. Urban land use data from Westchester County in 1996 (see Table 1) also compared well to BASINS data from the mid 1970's, further indicating that minimal land use changes have occurred on this watershed.

Calibration and Results

In order to assess the effect of segmentation on model results, 3 different levels of segmentation were used. These were a single reach model, a three reach model and a six reach model.

Single Reach Model - calibrated

The single reach model uses one reach to represent the entire watershed. The reach length used here is 10.5 miles. The details of the land use and reach are given in Table 2 and Table 4, respectively.

The calibration of the NPSM model mainly involves adjusting the parameters associated with the pervious land segments in the model (Bergman and Donnangelo, 2000). A description of these parameters and those for the impervious segments is given in Table 5. Table 5 also includes a description of the parameters associated with the snow calculation which was used in the model. The model was calibrated using the first 10 years of data (1970-79) and then verified using the last 10 years (1980-89). The calibration sequence follows (AQUA TERRA, 1998).

Table 4. Reach Characteristics for Watershed Models

Model	Length (miles)	Elevation Difference (ft)	Mean Elevation (ft)	Slope
Single Reach	10.5	405	183	0.007
Three Reach				
Downstream Sheldrake	0.7	15	7.5	0.004
Sheldrake	6.5	268	177	0.008
Mamaroneck River	9.8	430	213	0.008
Six Reach				
Downstream Sheldrake	0.7	15	7.5	0.004
Sheldrake	6.5	268	177	0.008
Upstream Sheldrake	5.4	203	120	0.007
Downstream Headwaters	1.9	249	195	0.025
West Branch	4.6	266	189	0.011
Headwaters	2.5	315	305	0.024

Table 5. Description of HSPF parameters

PERLND	Description
LZSN	Lower zone nominal soil moisture storage (Inches)
INFILT	Index to the filtration capacity of the soil (In/hr)
LSUR	Length of assumed overland flow plane (ft)
SLSUR	Slope of assumed overland flow plane
KVARY	Groundwater recession parameter
AGWRC	Base groundwater recession rate (1/d)
PETMAX	Air temp. at which evapotranspiration (ET) will start to be reduced due to low temp. (°F)
PETMIN	Air temp. at which evapotranspiration will be zero (°F)
INFEXP	Exponent in infiltration equation
INFILD	Ratio between max and mean infiltration capacity
DEEPFR	Fraction of groundwater lost to deep storage
BASETP	Fraction of ET which can be met from baseflow
AGWETP	Fraction of ET which can be met from groundwater
CEPSC	Interception storage capacity
UZSN	Upper zone nominal soil moisture storage (inches)
NSUR	Manning's n for overland flow plane
INTFW	Interflow inflow constant
IRC	Interflow recession constant (1/d)
LZETP	Lower zone ET constant
IMPLND	**Description**
LSUR	Length of assumed overland flow plane (ft)
SLSUR	Slope of assumed overland flow plane
NSUR	Manning's n for overland flow plane
PETMAX	Air temp. at which evapotranspiration (ET) will start to be reduced due to low temp.(°F)
PETMIN	Air temp. at which evapotranspiration will be zero (°F)
RETN	Retention storage capacity (inches)
SNOW	**Description**
SHADE	Fraction of land shaded from solar radiation
SNOWCF	Multiplying factor accounting for poor snow catch
COVIND	Maximum snow pack for full coverage
RDCSN	Density of snow relative to water
TSNOW	Air Temp. below which precip. will be snow (°F)
SNOEVP	Snow evaporation parameter
CCFACT	Snow condensation/convection melt parameter
MWATER	Max. water content of snow pack in depth water per water depth equivalent
MGMELT	Max rate of snowmelt by ground heat in depth of water equivalent per day (in/d)

1. Attempt to match the average flow of the model to the average flow of the data over the calibration period. This will ensure that the flow balance is correct.

2. Adjust the flow routing between surface runoff, interflow and baseflow so that the distribution of flow for the model agrees with the data. This is checked by plotting the flow probability distribution and checking the high flow and low flow statistics.

3. Adjust the hydrograph shape to better match the observed data.

A listing of the final values used is given in Table 6. In order to assess whether the calibrated parameter values were reasonable, Table 6 also shows the range and median values from 45 other HSPF applications retrieved from the HSPFParm database (EPA, 2000). In the case of monthly

Table 6. Parameter Values Used in Watershed Models

PERLND	**Single Reach - NPSM default**	**Single Reach calibrated**	**3 reach model calibrated**	**6 reach model calibrated**	**HSPF Parm range**	**HSPF Parm median**
LZSN	14.1	7	7	7	1.5-10.4	6.5
INFILT	0.16	0.15	0.15	0.15	0.01-0.52	0.04
LSUR	300	300	300	300	150 – 17225	300
SLSUR	0.007	0.007	0.004-0.008	0.004-0.025	0.0001–0.28	0.034
KVARY	0	0	0	0	0 – 4	0
AGWRC	0.98	0.98	0.9-0.98	0.9-0.98	0.3 – 0.997	0.975
PETMAX	40	40	40	40	35 – 45	40
PETMIN	35	35	35	35	32 – 36	35
INFEXP	2	2	2	2	1- 4	2
INFILD	2	2	2	2	1 –4	2
DEEPFR	0.1	0.25	0.25	0.25	0 – 0.5	0
BASETP	0.02	0.1	0.1	0.1	0 – 0.12	0.01
AGWETP	0	0.02	0.02	0.02	0 – 0.3	0
CEPSC * / **	0.1	0.02-0.1	0.02-0.1	0.02-0.1	0.01-0.55	0.06-0.098
UZSN */ **	1.128	0.5-1.5	0.5-1.5	0.5-1.5	0.05-1.6	0.35-0.42
NSUR */**	0.2	0.1-0.25	0.1-0.25	0.1-0.25	0.05-0.35	0.16-0.185
INTFW	0.75	2	2	2	0.4 – 8	1.7
IRC	0.5	0.6	0.6	0.6	0.1 – 0.9	0.75
LZETP */**	0.2-0.4	0.05-0.8	0.05-0.8	0.05-0.8	0.015-0.9	0.2-0.6
IMPLND						
LSUR	300	150	150	150	100-3000	160
SLSUR	0.035	0.01	0.01	0.01	0.001-0.19	0.02
NSUR	0.1	0.1	0.1	0.1	0.01-0.15	0.075
PETMAX	40	40	40	40	40	40
PETMIN	35	35	35	35	35	35
RETN *	0.065	0 – 0.1	0 – 0.1	0 – 0.1	0.036-0.35	0.049
SNOW						
SHADE **	0.3	0.5-0.6	0.5-0.6	0.5-0.6	0-0.98	0.564
SNOWCF	1.2	1.3	1.3	1.3	1-1.5	1.3
COVIND **	10	1.5-2.0	1.5-2.0	1.5-2.0	0.1-1	1
RDCSN	0.2	0.12	0.12	0.12	0.1-0.15	0.12
TSNOW	32	32	32	32	32	32
SNOEVP	0.1	0.05	0.05	0.05	0.05-0.1	0.05
CCFACT	1	1	1	1	0.01-1	1
MWATER	0.03	0.03	0.03	0.03	0.03-0.1	0.03
MGMELT	0.01	0.01	0.01	0.01	0.0001-0.01	0.01

* - varies by month

** - varies by land use

varying parameters the median for each month was calculated and the range of these median values is reported. The final parameter values adopted for this study all lie within the ranges reported by other studies shown in the table. Many of the values used are close to the median reported values from HSPFParm.

The calibration and verification results are presented in Table 7. The statistics presented are total runoff, lowest 50% runoff, highest 10% runoff and summer and winter runoff volumes. The final column in Table 7 is the mean of the (absolute) percent differences to allow a simple comparison to be made between different models. The flow distribution results for 1970-89 are

Table 7. Results of Model Analysis

	Runoff (% Difference) – Inches										Mean % Difference
	Total		Lowest 50% flows		Highest 10% flows		Summer (June-Aug)		Winter (Dec-Feb)		
	1970-79	1980-89	1970-79	1980-89	1970-79	1980-89	1970-79	1980-89	1970-79	1980-89	
Observed	28	22.1	3.2	2.8	13.3	10.2	3.9	3.6	8.3	6.7	
Single Reach - NPSM defaults	32.1 (14.5)	26.2 (18.4)	5.7(74.6)	4.9(72.9)	15.3 (14.8)	12.0 (18.0)	5.9 (51.6)	6.3 (75.6)	8.4 (0.5)	5.9 (-11.1)	35.2
Single Reach - HSPFParm Median	35.0 (24.7)	28.2 (27.6)	3.9(19.8)	3.1(11.2)	19.7 (48.4)	15.6 (53.3)	5.8 (48.7)	6.0 (68.1)	9.9 (19.2)	7.2 (7.1)	32.8
Single Reach - calibrated	29.1 (3.8)	22.8 (3.1)	3.7(15.5)	2.9(1.5)	14.8 (11.6)	11.6 (13.9)	4.4 (13.7)	4.7 (31.2)	8.6 (3.8)	5.9 (-11.1)	10.9
3 Reach - uncalibrated	29.1 (3.7)	22.7 (2.9)	4.1(26.9)	3.213.5)	13.6 (1.9)	10.4 (2.7)	4.4 (13.4)	4.7 (31.2)	8.7 (4.0)	5.9 (-11.9)	11.2
3 Reach – calibrated	29.3 (4.3)	23 (4)	3.3(1.5)	2.5(-11.4)	14.1 (6.4)	10.9 (7.5)	4.2 (7.9)	4.5 (25.0)	8.9 (7.4)	6.2 (-7.3)	8.3
6 Reach - uncalibrated	29.6 (5.5)	23.2 (5)	4.4(36.3)	3.4(21.9)	13.5 (1.7)	10.5 (3.1)	4.7 (21.5)	5.0 (39.7)	8.6 (3.5)	5.8 (-12.6)	15.1
6 Reach – calibrated	29.8 (6.2)	23.5 (6.2)	3.6(10.6)	2.7(-3.2)	14.1 (6.3)	11.0 (8)	4.5 (15.6)	4.8 (33.4)	8.9 (7.1)	6.2 (-7.8)	10.4

shown in Figure 5. Two years selected at random are also shown, one during the calibration period (1974, Figure 6) and one for the verification period (1984, Figure 7). The results show that the single reach model can be successfully calibrated and verified for this watershed.

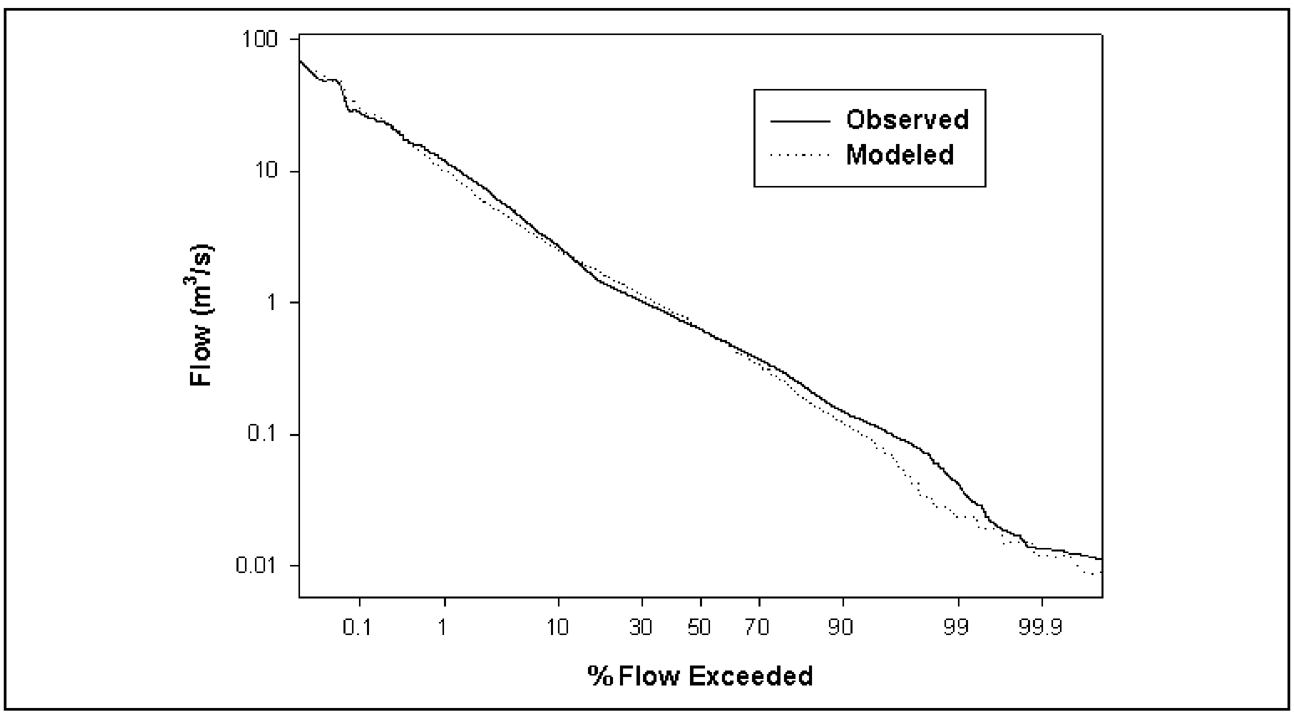

Figure 5. Log-normal flow distribution for single reach model 1970-1989.

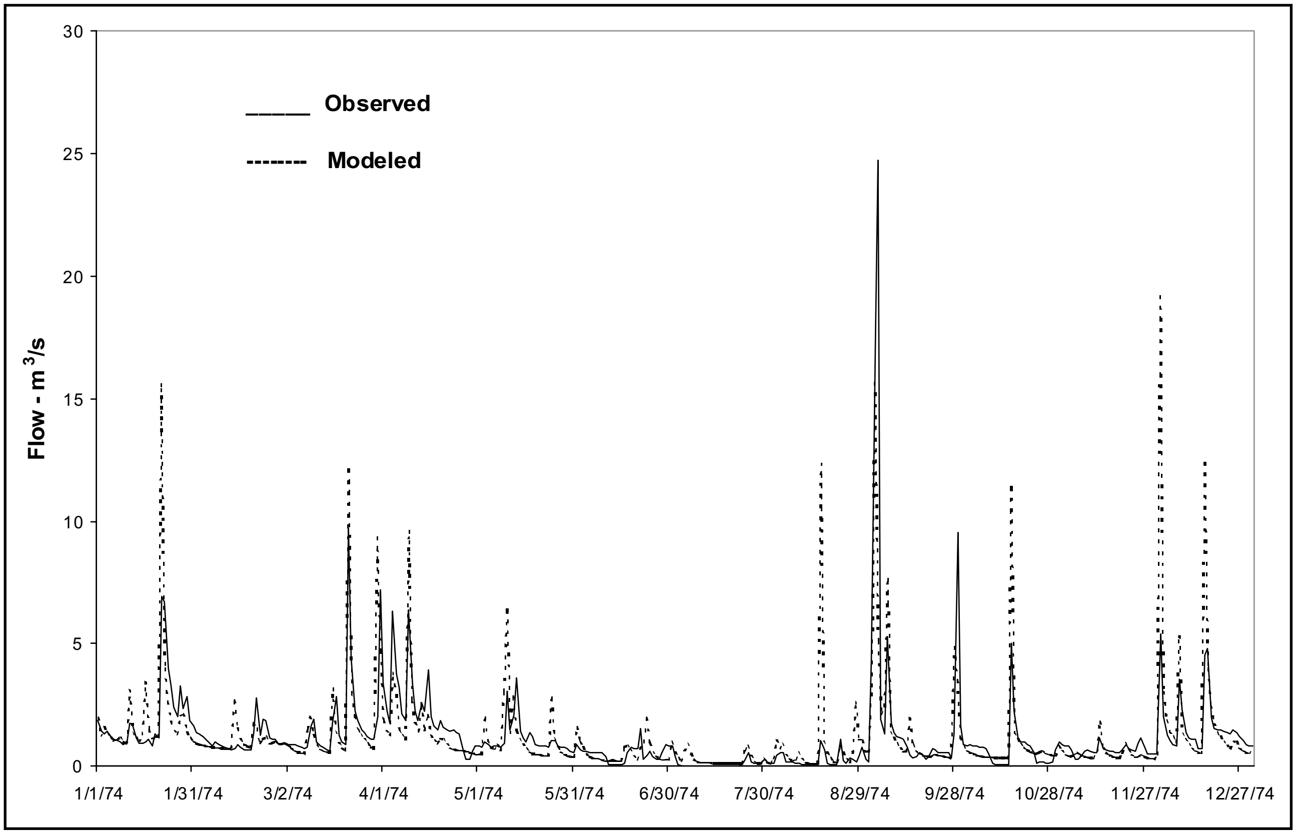

Figure 6. Modeled and observed flow for Mamaroneck River 1974.

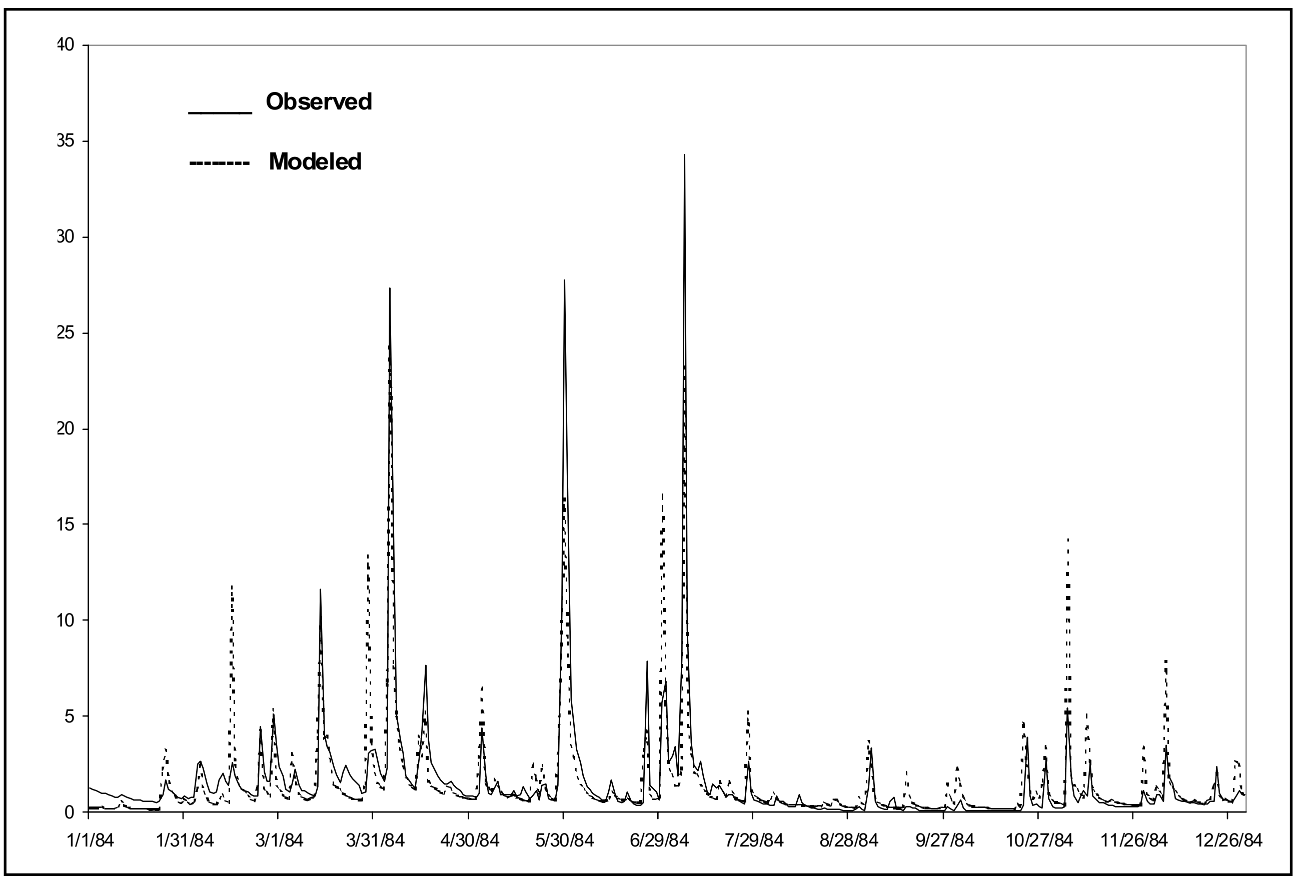

Figure 7. Modeled and observed flow for Mamaroneck River 1984.

Single Reach Model – using NPSM defaults

NPSM has default values for every parameter and a run was made to determine how well the model worked using this parameter set. The NPSM default parameters are given in Table 6. Note that the actual slope SLSUR was used. The results are shown in Table 7. As expected the results are substantially worse than the calibrated model with the mean percent difference over three times as much. The results are somewhat better for the high flows. This is largely due to the fact that the calibrated value of the infiltration rate (INFILT) was 0.15 in/hr and was almost exactly the same as the NPSM default value (0.16 in/hr). The low flows show large differences that can be attributed to many parameters but probably most reflect the fact that the annual water balance is in error.

Single Reach Model – using HSPFParm median values

It was noted previously that the calibrated single reach model has many parameter values that are close to the median values calculated using HSPFParm data. It is reasonable to assume that the HSPFParm median values from Table 7 would provide a good starting point from which to begin a HSPF calibration. With this in mind a model run was made using these median values. The results are shown in Table 7. Overall the mean percent difference is only slightly better than the NPSM default run (32.8% versus 35.2%). Interestingly the results for this run show poor agreement at the high flows and better agreement for low flows. These were the opposite findings from the NPSM default run. The poor high flow results come from the value of INFILT being 0.04 in/hr compared to 0.15 in/hr for the calibrated model. If this one change is made (INFILT = 0.15 in/hr) the results completely change, with the high flows matching considerably better than the low flows, similar to the NPSM run.

Three Reach Model

Once the single reach model was calibrated and verified a three reach model was constructed. For this model the Sheldrake River represents a logical point to segment the watershed into 3 divisions:

1. Mamaroneck River downstream of confluence of Sheldrake River
2. Sheldrake River
3. Upper Mamaroneck River

The segmentation is shown in Figure 8. The corresponding land use and reach information is given in Tables 2 and 4, respectively. One of the useful features of the NPSM interface is the ability to add reaches graphically and built a stream network using a point and click approach. All the internal HSPF interconnectivity is automatically taken care of and built into the UCI (Users Control Input) file that actually runs HSPF.

Two runs were made. Firstly the parameter values obtained for the single reach calibration were used to determine how changing the segmentation affected the calibration. Then further adjustments were made to try to improve the calibration results. These values are shown in Table 6 and the results are indicated in Table 7.

Using the single reach values almost identical results are generated. The calculation is improved slightly by altering the active groundwater recession parameter, AGWRC, which was the only change made. Based on these results the three segment model does not perform noticeably better than the single segment model. To evaluate this further a six segment model was also constructed and is discussed below.

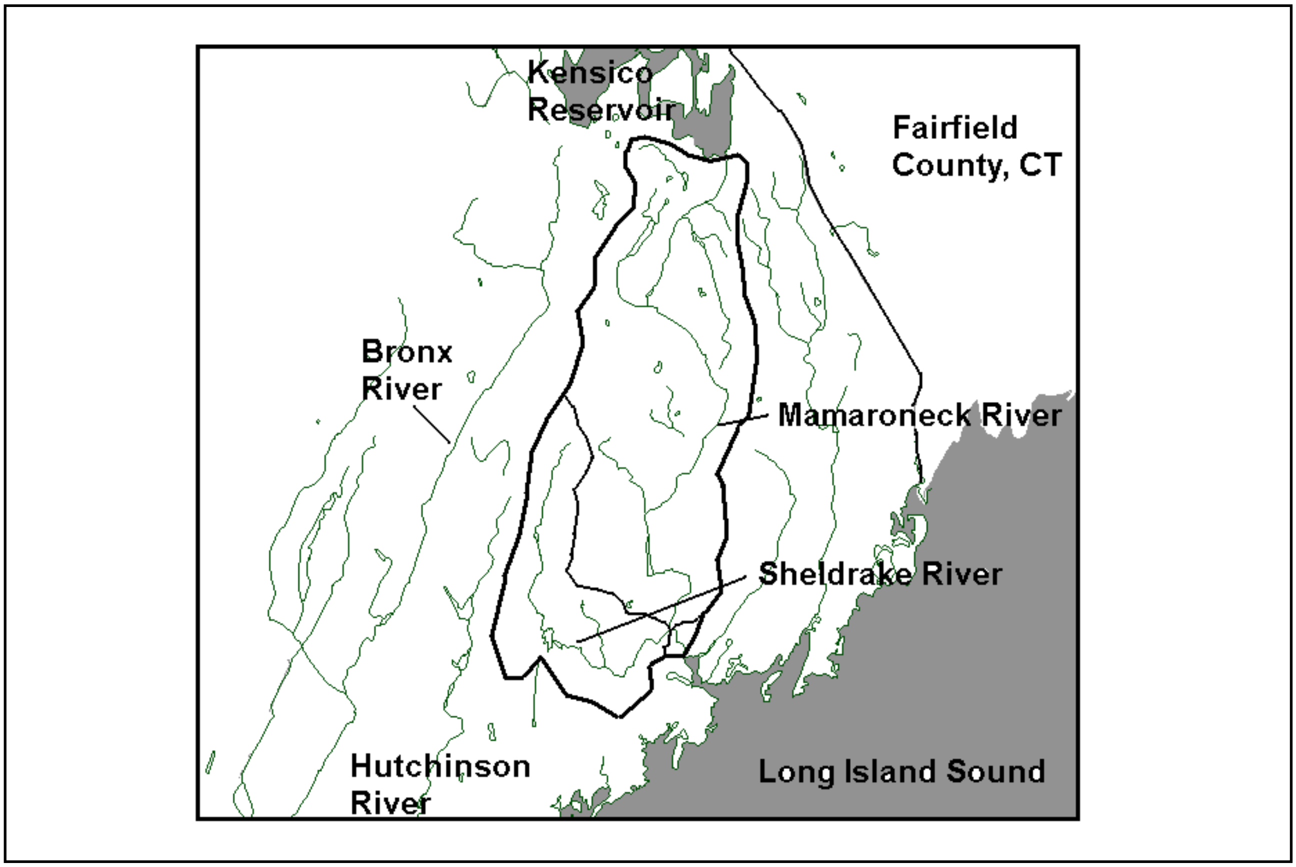

Figure 8. Segmentation for 3 reach model.

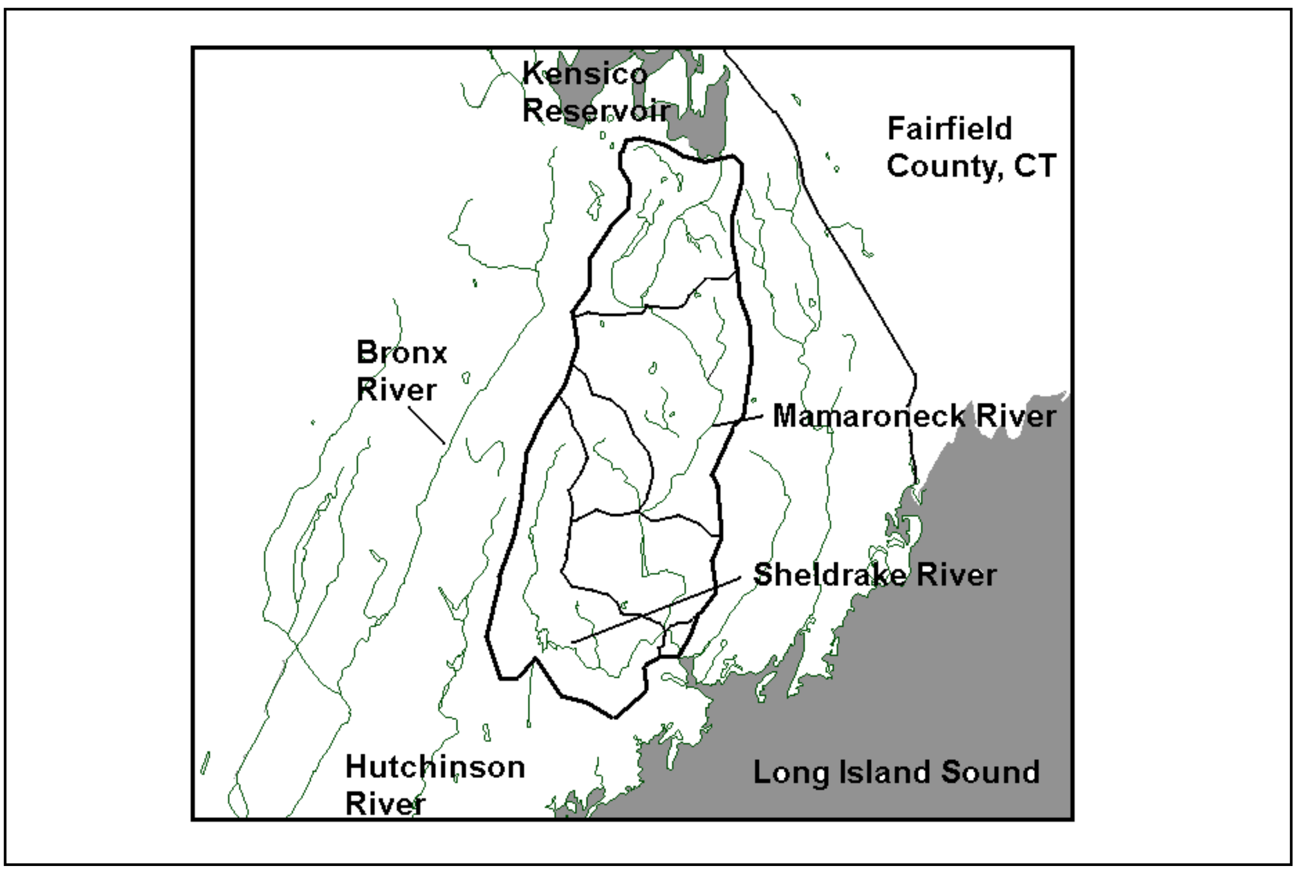

Figure 9. Segmentation for 6 reach model.

6 Reach Model

The six segment model subdivides the Upper Mamaroneck River segment of the three segment model into three segments itself. The segmentation is shown in Figure 9 with the land use and reach information given in Tables 2 and 4, respectively. The six reaches used are defined as:

1. Mamaroneck River downstream of confluence of Sheldrake River
2. Sheldrake River
3. Mamaroneck River immediately upstream of Sheldrake confluence
4. Mamaroneck River downstream of headwater reach
5. West Branch of Mamaroneck River
6. Headwaters of Mamaroneck River

As before the six reach model was run using the calibrated values from the single reach model. The model was then adjusted to improve the calibration. The final values used are given in Table 6 and the results are given in Table 7. As before the only value that was adjusted was the active groundwater recession parameter, AGWRC. The results show that the calibrated six reach model performed about as well as either the single or three reach models. The uncalibrated six reach model performed slightly worse than the uncalibrated three reach model.

The implication from the results for this watershed can be summarized as follows:

1. There were no real gains achieved from the finer resolution models over a single reach model.

2. The values used for the single reach model served as an excellent starting point for the other models.

CONCLUSIONS

This paper details the development of a watershed model of the Mamaroneck River in lower Westchester County, New York using the EPA’s BASINS software. The model was calibrated and verified using 20 years of measured USGS flow data. A comparison was made with the data supplied by BASINS and local county data and our conclusions follow.

1. In general the land use data from both sources agreed. This probably reflected the fact that the land use on the watershed has been established for several decades. One anomaly that was noticed was the inclusion of a small amount of agricultural land that turned out to be portions of local golf courses.

2. There was an error in the BASINS reach data that incorrectly identified the headwaters of the Mamaroneck River as the overflow from the Kensico Reservoir. The Kensico Reservoir actually forms the headwaters of the Bronx River. The error was compounded by the fact that the Kensico overflow was included as a major point source for the watershed and attributed a flow of 40 cfs, approximately the mean flow for the Mamaroneck River.

3. The topographic data showed good agreement between BASINS, the county and USGS topographic maps.

Three versions of the model were created: single segment, three segment and six segment. All three versions were successfully calibrated and verified. There was minimal improvement gained by using either the three or six segment model. In the case of the three and six segment models the parameters values used for the single segment model proved an excellent starting point for calibration. In fact only the value of the active groundwater recession parameter, AGWRC, was changed. A run of the single reach model was made using the default HSPF parameter values supplied with BASINS, as was a run using median values calculated from the HSPFParm database.

Both these runs produced poor results and the large impact the infiltration rate parameter, INFILT, had on the calculation was noted.

A comparison of the values used in all of the model runs was made to previously used values from a large number of studies. It was found that in general the parameter values used in this study were close to the median values reported from other studies, although the sensitive parameter INFILT was not. All the values used fell within the ranges of values from other studies.

The successful application of HSPF to this small urban watershed proves that it is an effective tool to analyze such a system. It should also be noted that using HSPF within BASINS via the NPSM interface was much more user friendly than using the stand alone version.

REFERENCES

AQUA TERRA; HSPF Training Workshop Handbook, AQUA TERRA Consultants, Mountain View, CA, 1998.

Bergman, M.J. and LJ. Donnangelo; Simulation of the Freshwater Discharges from Ungaged Areas to the Sebastian River, Florida, *Journal of the American Water Resources Association*, Vol. 36, No. 5, pp. 1121-1132, 2000.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, A.S. Donigian Jr and R.C. Johanson; Hydrological Simulation Program – FORTRAN, Users Manual for Release 11, USEPA Environmental Research Laboratory, Athens, GA, 1996.

EPA; 1:250,000 Scale Quadrangles of Landuse/Landcover GIRAS Spatial Data in the Conterminous United States, Environmental Protection Agency's (EPA) Office of Information Resources Management (OIRM), Washington, DC, 1994.

EPA; Better Assessment Science Integrating Point and Nonpoint Sources, BASINS Version 2.0 Users Manual, USEPA Office of Water, Washington, DC, 1998.

EPA; Beta Version of HSPFParm Software, 2000.

SCS (Soil Conservation Service); Urban Hydrology for Small Watersheds, Technical Release No. 55, Washington, DC, 1986.

USGS (United States Geological Survey); USGS website at http://water.usgs.gov, 2002.

Westchester County; Generalized Land Use Data, Westchester County Department of Planning, 1996.

Westchester County; A Management Plan for the Watersheds of Stephenson Brook, Burling Brook, Pine Brook and Larchmont Harbor, Westchester County Department of Planning, 1997.

Westchester County; A Management Plan for the Watersheds of Beaver Swamp Brook, Beaver Swamp Brook West, Blind Brook, Mamaroneck Harbor, Milton Harbor and Port Chester Harbor, Westchester County Department of Planning, 1998.

Westchester County; Westchester County Department of Planning Databook – 1998, Westchester County Department of Planning, 1998a.

Westchester County; Controlling Polluted Stormwater, A Management Plan for the Sheldrake and Mamaroneck Rivers and Mamaroneck Harbor, Westchester County Department of Planning, 2001.

Westchester County; http://giswww.westchestergov.com, 2001a.

ADDRESS FOR CORRESPONDENCE
Scott Lowe
Senior Project Manager
Lawler, Matusky & Skelly Engineers LLP
One Blue Hill Plaza
Pearl River, NY 10965

Email: SLowe@lmseng.com