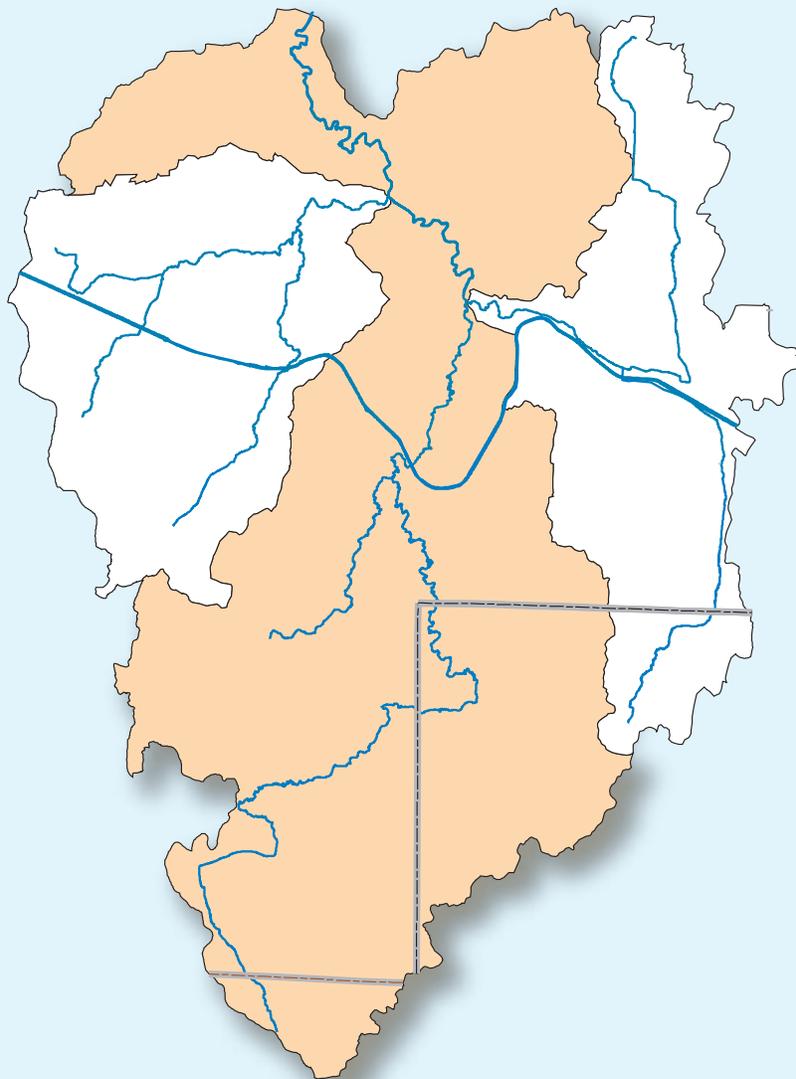




Simulating Land-Use Changes and Stormwater-Detention Basins and Evaluating their Effect on Peak Streamflows and Stream-Water Quality in Irondequoit Creek Basin, New York

A User's Manual for HSPF and GenScn

In cooperation with Irondequoit Creek Watershed Collaborative



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A User's Manual for HSPF and GenScn

By William F. Coon

U.S. GEOLOGICAL SURVEY

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In cooperation with Irondequoit Creek
Watershed Collaborative



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U.S. GEOLOGICAL SURVEY

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CONTENTS

- Abstract..... 1
- Introduction 1
- Overview 3
 - Data-Management System..... 3
 - Management of Flow Data 4
 - Management of Chemical-Load Data..... 4
 - HSPF and User-Control Input (UCI) File Modules..... 4
 - PERLND and IMPLND Modules..... 6
 - PERLNDs 6
 - IMPLNDs 6
 - RCHRES Module 8
 - EXT SOURCES and EXT TARGETS Modules 9
 - SCHEMATIC Module 9
 - FTABLE Module 9
- Simulating Land-use Changes and Stormwater-Detention Basins and Evaluating their Effect on Peak Stormflows and Stream-Water Quality 9
 - Effect of Simulated Changes on Peak Flows 11
 - Scenario 1—Simulation of Land-Use Changes 11
 - Scenario 2—Simulation of Stormflow-Detention Basins 14
 - Data Analysis 15
 - Practical Exercise..... 16
 - Effect of Simulated Changes on Stream-Water Quality 19
 - Model Revisions to Simulate Chemical Loads 19
 - Analysis of Chemical-Load Data 21
- References Cited..... 21
- Appendix
 - Subbasin and Stream-Reach (RCHRES) Correlation for HSPF Model of Irondequoit Creek Basin, Monroe and Ontario Counties, N.Y., with Corresponding Lot-size Code (AVGLOTSIZE) and Drainage Area..... 23

Figures

- 1. Location and principal geographic features of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y. 2
- 2. Data flow and connections between file system and computer programs to simulate and analyze output from model scenarios 3

Tables

- 1. Example of dataset-numbering (DSN) system used in Water Data Management (WDM) file for model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y. 5
- 2. Selected modules of HSPF (Hydrological Simulation Program—Fortran) used in model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y. 6
- 3. PERLNDs and IMPLNDs associated with hydrologic response units (HRUs) used in user control file for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y. 7
- 4. Subbasins with thin overburden underlain by fractured dolostone (PERLNDs 41 through 56) in Irondequoit Creek basin, Monroe and Ontario Counties, N.Y. 8
- 5. Percentages of residential or commercial areas assigned to pervious or impervious categories in user-control file for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y. 8

6. Calculation of acreage revisions for pervious and impervious land areas in user-control file of HSPF model for simulation of a hypothetical 100-acre residential-commercial development in Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.	14
7. Calculation of changes in acreages of pervious and impervious land areas for hypothetical development and for revision of HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.	17
8. Acreage revisions to PERLNDs and IMPLNDs in SCHEMATIC block of user-control file to simulate hypothetical development of subbasin T5 in sample problem	18
9. Peak flows associated with hypothetical land-use-change and detention-basin simulations developed in sample problem	18
10. Dataset-number (DSN) system for water-quality output used in WDM (Watershed Data-Management) file for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.	20

CONVERSION FACTORS

	Multiply	By	To obtain
	inch (in.)	25.4	millimeter
	foot (ft)	0.3048	meter
	mile (mi)	1.609	kilometer
	acre	0.4047	hectare
	square mile (mi ²)	2.59	square kilometer
	acre-foot	1,233.5	cubic meter

Simulating Land-Use Changes and Stormwater-Detention Basins and Evaluating their Effect on Peak Streamflows and Stream-Water Quality in Irondequoit Creek Basin, New York

A User's Manual for HSPF¹ and GenScn²

By William F. Coon

ABSTRACT

A computer model of hydrologic and water-quality processes of the Irondequoit Creek basin in Monroe and Ontario Counties, N.Y., was developed during 2000-02 to enable water-resources managers to simulate the effects of future development and stormwater-detention basins on peak flows and water quality of Irondequoit Creek and its tributaries. The model was developed with the program Hydrological Simulation Program-Fortran (HSPF) such that proposed or hypothetical land-use changes and instream stormwater-detention basins could be simulated, and their effects on peak flows and loads of total suspended solids, total phosphorus, ammonia-plus-organic nitrogen, and nitrate-plus-nitrite nitrogen could be analyzed, through an interactive computer program known as Generation and Analysis of Model Simulation Scenarios for Watersheds (GenScn). This report is a user's manual written to guide the Irondequoit Creek Watershed Collaborative in (1) the creation of land-use and flow-detention scenarios for simulation by the HSPF model, and (2) the use of GenScn to analyze the results of these simulations. These analyses can, in turn, aid the group in making basin-wide water-resources-management decisions.

¹HSPF, Hydrological Simulation Program-Fortran

²GenScn, Generation and Analysis of Model Simulation Scenarios for Watersheds

INTRODUCTION

Urbanization changes a drainage basin's response to precipitation by decreasing infiltration and increasing storm-runoff rates; this in turn increases runoff and peak streamflows. Increases in the deposition or application of chemicals on land surfaces are also associated with urbanization. These changes generate larger chemical loads that are transported more quickly to natural (stream channels) or man-made (ditches and culverts) drainage systems than occurred under pre-development conditions.

Urbanization of the Irondequoit Creek basin has resulted in hydrologic and water-quality changes, which have increased the difficulty of mitigating flooding and pollution problems. A computerized hydrologic model of the basin can simulate these changes and thereby help water-resources managers to (1) predict the effects of future development on peak flows and chemical loads, and (2) analyze the potential effects of instream stormwater-detention basins, as a step toward developing strategies to mitigate the adverse effects of urbanization.

During 2000-02, the U.S. Geological Survey (USGS), in cooperation with the Irondequoit Creek Watershed Collaborative (IWC), developed a computer model of the hydrologic and water-quality processes within the Irondequoit Creek basin in Monroe and Ontario Counties, N.Y. (fig. 1). The IWC members represent water-resources interests at municipal, town, and county levels. The model was developed through the program Hydrological Simulation Program-Fortran (HSPF), version 11 (Bicknell and others, 1997) such that proposed or hypothetical land-use changes and instream stormwater-detention basins could be simulated, and

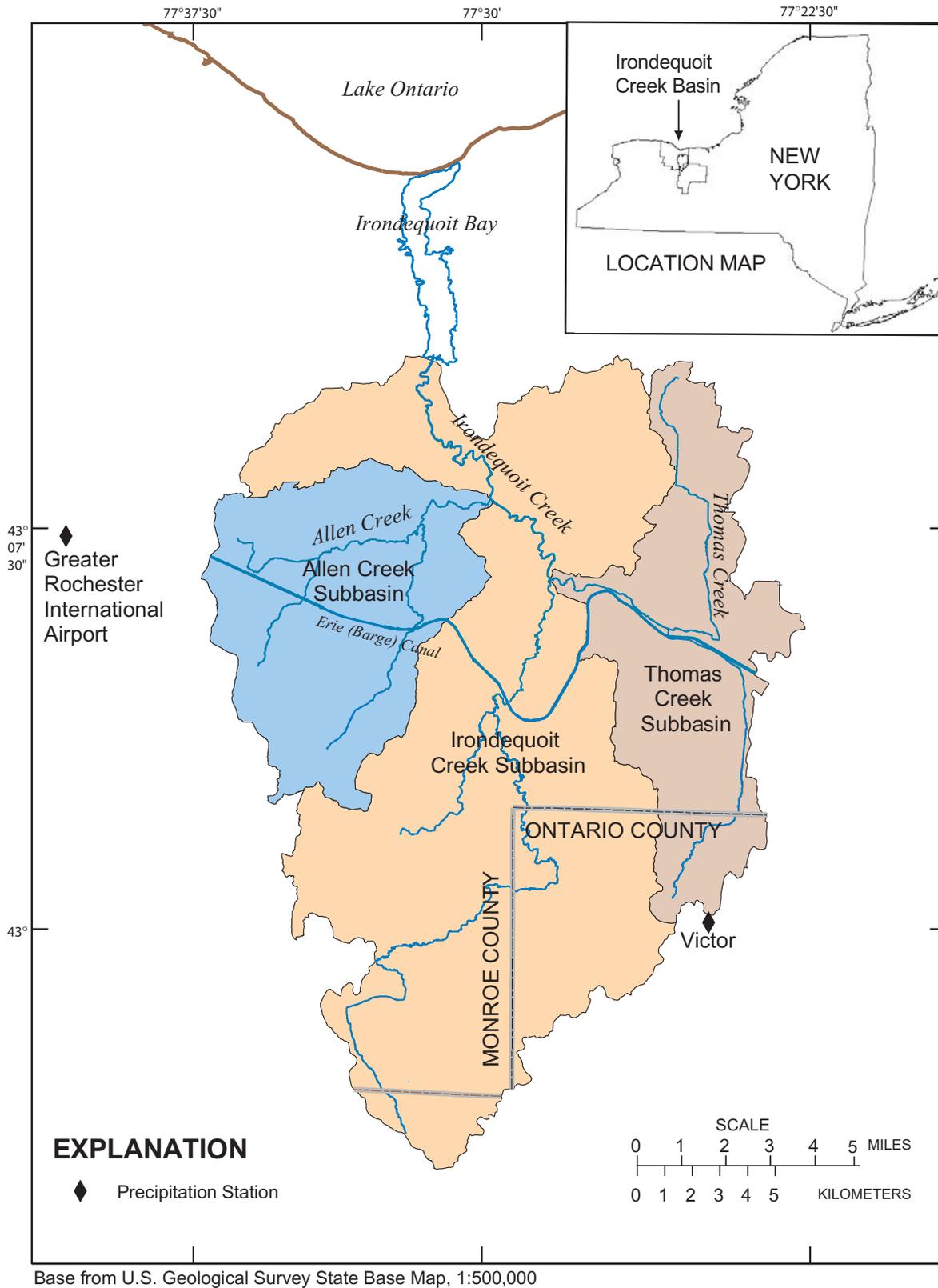


Figure 1. Location and principal geographic features of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

their effects on peak flows and water quality could be analyzed through an interactive computer program known as Generation and Analysis of Model Simulation Scenarios for Watersheds (GenScn), version 2.2 (Kittle and others, 1998).

This report is a user’s manual written specifically for the IWC to (1) provide background information on the two computer programs—HSPF and GenScn; (2) outline the steps for creating scenarios of land-use changes and flow-detention basins in the Irondequoit Creek basin and simulating these scenarios with the HSPF model; and (3) guide the use of GenScn to analyze the output from these scenarios. It includes a sample exercise to familiarize the user with these steps.

OVERVIEW

Time series of meteorological, hydrologic, and water-quality data are stored in data sets in a watershed-data-management (WDM) file. The input to HSPF is a user-control-input file (UCI) that contains instructions and parameter values that are required by HSPF for simulation of the hydrologic and water-quality processes of the basin. This file also identifies

the data sets in the WDM that are required for a given simulation, as well as the data sets in which time series of HSPF output will be stored. The output time series stored in the WDM can then be viewed, compared, and analyzed through GenScn. A diagram of this process is shown in figure 2.

Data-Management System

The HSPF data input and output time series are stored in a WDM file (*iron.wdm*). The input time series include hourly precipitation, air temperature, wind speed, and other meteorological data; water temperature; chemical loads from atmospheric deposition; inflow and chemical loads entering the Irondequoit Creek basin from siphoning and gate-leakage from the New York State Erie (Barge) Canal; and diversions to downstream golf courses. The output time series include hourly flows and monthly chemical loads at the downstream end of subbasins or channel reaches.

CAUTION: Never open a WDM file in a text editor—this could corrupt the file. Always use GenScn to view data sets stored in the WDM file.

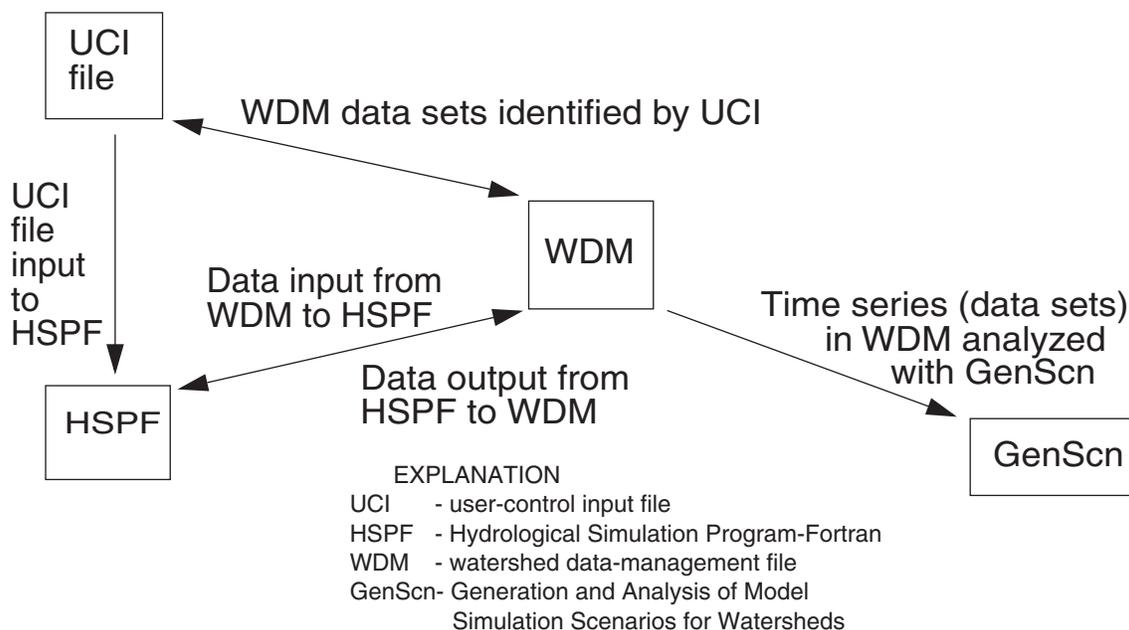


Figure 2. Data flow and connections between file system and computer programs to simulate and analyze output from model scenarios.

Management of Flow Data

Each channel reach (RCHRES) in the model has a unique identification number (see appendix) that is specified in the RCHRES module of the UCI file and is used to categorize data sets in the WDM. A data set number (DSN) in the WDM is in the form xxxn, where xxx is the RCHRES number, and n refers to a scenario type. In only two cases do the data set numbers not refer to a specific RCHRES, but to the confluence of two RCHRESs—these are the confluence of Irondequoit Creek with Thomas Creek (xxx = 465) and Irondequoit Creek with Allen Creek (xxx = 705). Flows recorded at a USGS streamflow-monitoring station are stored in DSN xxx0, where 0 (zero) refers to the OBSERVED scenario, and those generated by the model calibrated to observed flows are stored in DSN xxx1, where 1 refers to the BASE scenario. All flow data are stored as cubic feet per second. The UCI file for the base scenario is the starting point for creation of new scenarios and simulation of land-use changes and instream-detention basins. Whenever a new scenario is created, the user must decide (1) whether new data set numbers need to be identified in the EXT TARGETS module of the UCI file to receive the output time series generated by the scenario, and (2) whether the revised UCI file needs to be saved with a unique name. DSNs have been set up in the WDM to permit storage of simulated outflow records from two detention-basin scenarios and two land-use-change scenarios for each RCHRES. These files are numbered xxx2 and xxx3 for the detention-basin (DBASIN) scenarios, and xxx4 and xxx5 for the land-use-change (LANDUSE) scenarios. Examples of the flow-related DSNs and their associated scenarios for two RCHRESs are given in table 1.

Note that a change in discharge from a subbasin of interest (where the effects of a land-use change or a detention basin are being evaluated) might affect the output discharges from downstream RCHRESs. Therefore, the user should change the targeted DSNs of all RCHRESs for which outflow data are desired (for example, changing all DSNs to xxx3 for every RCHRES that might be affected by a detention-basin scenario); otherwise the downstream output discharges generated from a land-use-change or detention-basin scenario might inadvertently be associated with the BASE scenario (DSNs = xxx1) and compromise the analysis of future simulations that might be compared with BASE-scenario data. Whenever a new analysis is started, the user is advised to simulate the BASE

scenario to ensure that the data associated with that scenario are correctly stored in the WDM file. To accomplish this step, simply simulate the original UCI file (*copy_of_base.uci* copied and renamed *base.uci*), which has the BASE-scenario DSNs targeted.

Management of Chemical-Load Data

The observed chemical loads at a USGS water-quality monitoring station are stored in DSNs xx21, xx22, xx24, and xx25, respectively, where xx refers to the first two digits of the RCHRES number, and 21, 22, 24, and 25 refer to the OBSERVED monthly loads of total suspended solids (TSS), total phosphorus (TP), ammonia-plus-organic nitrogen (TKN), and nitrate-plus-nitrite nitrogen (NO_x), respectively (table 1). Daily loads of the same constituents that are generated by the model, which has been calibrated to observed loads (that is, the BASE scenario), are stored in DSNs xx31, xx32, xx34, and xx35, respectively (table 1). DSNs for output time series of chemical loads that are generated by land-use-change and detention-basin scenarios have not been set up in the WDM for each RCHRES as was done for simulated outflow records; rather, two sets of DSNs have been created to store loads from a user-specified RCHRES and allow comparison of the output from two scenarios. Although these data will be associated with a previously defined scenario, such as BASE, LANDUSE or DBASIN, they will be identified and retrieved in GenScn by the scenarios WQSCEN1 or WQSCEN2, as indicated in table 1.

HSPF and User-Control Input (UCI) File Modules

The user-control input (UCI) file is the text file of the user-developed model and is required by HSPF to simulate the hydrology and water-quality processes of the basin. The UCI file contains modules that control the simulation of specific processes within the model. These modules and their associated processes are listed in table 2 and described in the following paragraphs.

PERLND and IMPLND Modules

The Irondequoit Creek basin was divided into land segments, each of which was assumed to show consistent hydrologic and water-quality responses to precipitation, potential evapotranspiration, and other

Table 1. Example of data-set-numbering (DSN) system used in Water Data Management (WDM) file for model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

DSN for indicated reach	Scenario	Explanation
Simulation of Hydrologic Processes and Storage of Flow Data		
<i>RCHRES 50, Tributary of Irondequoit Creek in Subbasin T2</i>		
500	--	This site has no recorded or “observed” flow record; this DSN does not exist.
501	BASE	Simulated flow, calibrated to observed data.
502	DBASIN1	Two scenarios of flow generated from user-defined simulation of detention basin(s).
503	DBASIN2	
504	LANDUSE1	Two scenarios of flow generated from user-defined simulation of land-use change(s).
505	LANDUSE2	
521 - 525	--	This site has no computed or “observed” chemical-load records; these DSNs do not exist.
<i>U.S. Geological Survey streamflow-monitoring site, RCHRES 690, Allen Creek</i>		
6900	OBSERVED	Recorded or “observed” flow.
6901	BASE	Simulated flow, calibrated to observed data.
6902	DBASIN1	Two scenarios of flow generated from user-defined simulation of detention basin(s).
6903	DBASIN2	
6904	LANDUSE1	Two scenarios of flow generated from user-defined simulation of land-use change(s).
6905	LANDUSE2	
6921	OBSERVED	Computed or “observed” monthly loads of total suspended solids.
6922	OBSERVED	Computed or “observed” monthly loads of total phosphorus.
6924	OBSERVED	Computed or “observed” monthly loads of ammonia-plus-organic nitrogen.
6925	OBSERVED	Computed or “observed” monthly loads of nitrate-plus-nitrite nitrogen.
6931	BASE	Monthly loads of total suspended solids generated by the BASE scenario.
6932	BASE	Monthly loads of total phosphorus generated by the BASE scenario.
6934	BASE	Monthly loads of ammonia-plus-organic nitrogen generated by the BASE scenario.
6935	BASE	Monthly loads of nitrate-plus-nitrite nitrogen generated by the BASE scenario.
Simulation of Water-Quality Processes and Storage of Chemical-Load Data for User-Specified RCHRES		
9100	WQSCEN1	Daily loads of total suspended solids generated by user-defined scenario.
9101	WQSCEN1	Daily loads of total phosphorus generated by user-defined scenario.
9102	WQSCEN1	Daily loads of ammonia-plus-organic nitrogen generated by user-defined scenario.
9103	WQSCEN1	Daily loads of nitrate-plus-nitrite nitrogen generated by user-defined scenario.
9104	WQSCEN1	Daily loads of total nitrogen generated by user-defined scenario.
9110	WQSCEN2	Daily loads of total suspended solids generated by user-defined scenario.
9111	WQSCEN2	Daily loads of total phosphorus generated by user-defined scenario.
9112	WQSCEN2	Daily loads of ammonia-plus-organic nitrogen generated by user-defined scenario.
9113	WQSCEN2	Daily loads of nitrate-plus-nitrite nitrogen generated by user-defined scenario.
9114	WQSCEN2	Daily loads of total nitrogen generated by user-defined scenario.

Table 2. Selected modules of HSPF (Hydrological Simulation Program—Fortran) used in model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

[WDM, Water-Data-Management file.]

Abbreviation	Name	Purpose
PERLND	Pervious land segment	Simulates a pervious land area.
IMPLND	Impervious land segment	Simulates an impervious land area.
RCHRES	River reach or reservoir	Simulates a free-flowing reach or mixed reservoir (lake).
EXT SOURCES	External sources	Identifies the input time series (dataset numbers) from the WDM file that are required by HSPF.
EXT TARGETS	External targets	Identifies the dataset numbers in the WDM file that will receive output from HSPF.
SCHEMATIC	Schematic	Lists the connections between land segments (PERLNDs and IMPLNDs) and RCHRESs, and between RCHRESs.
FTABLE	Function table	A function table that relates stream-surface elevation (or depth), channel surface area and volume, and discharge for a given RCHRES.

meteorological factors. Each of these segments, also called hydrologic response units (HRUs), is simulated by HSPF as either a PERLND (pervious land area) or an IMPLND (impervious land area).

PERLNDs

PERLNDs as defined in the model reflect three hydrologic characteristics—land cover or land use, surface slope, and soil permeability. Land cover and land use categories are forest, agriculture, open and (or) grass, urban and (or) recreational grass (primarily golf courses and parks), wetland and water, residential, and commercial. The commercial category includes uses classified as commercial, industrial, transportation, and high-density residential. These seven land-cover and land-use categories were further divided into low- and high-slope areas (less than 6 percent and 6 percent or greater, respectively), and low- and high-permeability areas (infiltration rate in the B soil horizon of 2 in/h or less and greater than 2 in/h, respectively). Theoretically, this division of the basin would have resulted in 28 PERLNDs (7 land covers or land uses \times 2 slope classes \times 2 permeability classes). Some categories were combined, however, because they either represented less than 1 percent of the basin or were assumed to have a hydrologic response similar to that of another PERLND. Also, because PERLNDs are associated with a specific precipitation record, two sets of PERLNDs were created—one associated with the National Weather Service station at the Greater Rochester International

Airport; the other with the weather-observation station at Victor (fig. 1). The final PERLNDs used in the model are listed in table 3.

Preliminary calibration of the model indicated a substantial difference between the hydrologic response of the Allen Creek subbasin and that of the upper Irondequoit Creek subbasin—a difference that was poorly simulated by the original set of PERLNDs. This difference was attributed to large areas in the Allen Creek subbasin (and elsewhere in the northern half of the Irondequoit Creek watershed) in which thin soils are underlain by fractured dolostone; this condition affects the water-storage, interflow and ground-water-flow characteristics, and ground-water loss from the subbasin. Therefore, a duplicate set of PERLNDs was created for areas in which at least 50 percent of a subbasin contained less than 30 ft of overburden and was underlain by fractured dolostone, to permit simulation of flows in these “thin-soil” areas (table 3). The subbasins in this thin-soil category are listed in table 4.

IMPLNDs

A distinction was made between “effective” impervious areas—those that are hydraulically connected to the natural drainage system by means of ditches, culverts, and (or) a storm-sewer system—and “ineffective” impervious areas—those that are not hydraulically connected to the natural drainage system and drain to adjacent pervious areas. IMPLNDs 1, 2, and 3 represent three categories of effective

Table 3. PERLNDs and IMPLNDs associated with hydrologic response units (HRUs) used in user control file for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

[PERLND, pervious land segment; IMPLND, impervious land segment. Dash (--) indicates that the HRU did not require division according to this basin characteristic.]

Hydrologic response unit			Thick-soil ³ subbasin in indicated precipitation-record area		Thin-soil ³ subbasin
Land use / land cover	Slope ¹	Permeability ²	Victor	Rochester	
Undeveloped PERLNDs					
Forest	Low	Low	1	21	41
Forest	Low	High	2	22	42
Forest	High	Low	3	23	43
Forest	High	High	4	24	44
Agriculture	Low	Low	5	25	45
Agriculture	Low	High	6	26	46
Agriculture	High	--	7	27	47
Open and(or) grass	Low	Low	8	28	48
Open and(or) grass	Low	High	9	29	49
Open and(or) grass	High	Low	10	30	50
Open and(or) grass	High	High	11	31	51
Urban or recreational grass	--	--	12	32	52
Upland wetland and water	--	--	13	33	53
At-mouth wetland	--	--		38	
Developed PERLNDs					
Residential	Low	--	14	34	54
Residential	High	--	15	35	55
Commercial	--	--	16	36	56
IMPLNDs					
Residential	Low	--	1	21	21
Residential	High	--	2	22	22
Commercial	--	--	3	23	23

¹ Slope is average land-surface slope; low is less than 6 percent; high is 6 percent or greater.

² Permeability is average infiltration rate of the B soil horizon; low is 2 inches per hour or less; high is greater than 2 inches per hour.

³ Thin soil = less than 30 feet; thick soil = 30 feet or greater

impervious area in the basin—low-slope residential, high slope residential, and commercial, respectively. The National Land Cover Data (NLCD) that were initially used to classify the basin by land use and land cover contained only three categories for developed land and lacked the detail that was needed to quantify impervious area in the urbanized areas of the basin. The three NLCD categories for developed land were (1) low-intensity residential, defined as mostly single-family housing areas where constructed materials account for 30 to 80 percent of the total area; (2) high-intensity residential, defined as heavily built-up urban centers where people reside, and vegetation covers less

than 20 percent of the total area, and constructed materials cover 80 to 100 percent of the total area; and (3) commercial-industrial-transportation, defined as all highly developed lands not classified as high-intensity residential. County tax-parcel maps were used to estimate an average lot size for parcels that contained a “structure” in an effort to (1) improve the detail of the NLCD areas classified as residential, and (2) estimate the amount of impervious area in the developed areas of the basin. These parcels were identified by tax-parcel codes. Some parcels were classified as commercial (3.4 percent, which included apartment buildings), community and public services (0.56 percent), and industrial (manufacturing and processing, 0.36 percent), but most (95.6 percent) of the parcels were classified as residential. The combined acreage of these parcels was divided by the number of parcels to obtain an average lot size (AVGLOTSIZE), which was used as an

approximation of housing density and the degree of development within a given subbasin.

Any developed area in which the land surface has been covered to some extent by constructed materials (primarily buildings and pavement) generally contains some percentage of pervious land. Therefore, the areas classified by NLCD as developed were divided into pervious and effective-impervious areas. Ranges of AVGLOTSIZE values were grouped and related to estimated percentages of effective impervious area as defined in table 5. These percentages are based on impervious-area estimates from Alley and Veenhuis (1983), Natural Resources

Table 4. Subbasins with thin overburden¹ underlain by fractured dolostone (PERLNDs 41 through 56) in Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

[Locations can be seen in the map displayed during a GenScn session.]

Subbasin	Subbasin identifier
Allen Creek	AC2a, AC3, AC3a, AC4, AC5
Buckland Creek	BC1, BC2, BC3
East Branch Allen Creek	EB4, EB5, EB6
Thomas Creek	TC1, TC2
Irondequoit Creek tributaries	T11b, T12, T13a, T13b
City of Rochester	R1, R2

¹ Soil thickness less than 30 feet.

Conservation Service (1986), Dinicola (1990), Berris (1995), Zarriello (1999), Zarriello and Reis (2000), Lohani and others (2001), Prisloe and others (2000), and Center for Watershed Protection (2001). Depending on the type of development (residential or commercial-industrial-transportation), these percentages were used to estimate the acreage that would be simulated as effective impervious area. The remaining acreage, including that which was ineffective-impervious area, was assumed to be pervious land within the developed area. The residential areas were further divided on the basis of slope to provide three developed-land categories—low-slope residential, high-slope residential, and commercial (table 3). This method of impervious-area estimation results in a paired relation between PERLNDs and IMPLNDs such that, if PERLND 14 is found in a subbasin, then IMPLND 1

also should be present. Similarly, if PERLNDs 15 and 16 are present, then IMPLNDs 2 and 3, respectively, should also be found. This relation applies to PERLND 34 or 54 and IMPLND 21; PERLND 35 or 55 and IMPLND 22, and PERLND 36 or 56 and IMPLND 23. The only exceptions are where a given land-segment type contains less than 1 acre (the default minimum acreage used by HSPF). If an impervious area for a given developed category is less than 1 acre, the IMPLND acreage is added to its associated PERLND acreage. If the combined acreage of a given developed category is less than 1 acre, then the acreage is added to a hydrologically similar PERLND or IMPLND.

RCHRES Module

The overland and subsurface flow from the PERLNDs, and the overland flow from the IMPLNDs, are routed to the main surface-water channel (RCHRES) within that subbasin. Subbasins and RCHRESs are related as shown in the appendix. Subbasin identifiers consist of an alphanumeric code in which the letters are abbreviations for the main streams, such as Irondequoit Creek (IC), Thomas Creek (TC), and Allen Creek (AC), or a tributary (T), and the number, which increases downstream, refers to the subbasin sequence in the basin. RCHRES numbers generally increase in increments of 10 from the headwaters of Irondequoit Creek (RCHRES 10) to its mouth (RCHRES 800). The subbasin identifiers are for the benefit of the user and are not used by the

Table 5. Percentages of residential or commercial areas assigned to pervious or impervious categories in user-control file for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

[PERLND, pervious land area; IMPLND, impervious land area; <, less than; >, greater than. Land-use values are in percent. PERLND and IMPLND identifiers are given in table 3.]

Average residential lot (parcel) size in subbasin		Residential land use				Commercial land use	
		Low slope (< 6 percent)		High slope (≥ 6 percent)		PERLND 16, 36 or 56	IMPLND 3 or 23
Acres per parcel	Code	PERLND 14, 34 or 54	IMPLND 1 or 21	PERLND 15, 35 or 55	IMPLND 2 or 22		
> 1.5	1	100	0	100	0	100	0
0.751 to 1.5	2	95	5	95	5	60	40
0.55 to 0.75	3	86	14	86	14	14	86
0.21 to 0.54	4	80	20	80	20	14	86
< 0.21	5	52	48	52	48	14	86

model, whereas RCHRES numbers are used by the model to route water through the basin.

EXT SOURCES and EXT TARGETS Modules

The data set numbers included in the EXT SOURCES and EXT TARGETS modules of the UCI file refer to the data sets contained in the WDM file. The time-series data sets required by HSPF are input to the model through the EXT SOURCES module, and output is directed to desired storage data sets through the EXT TARGETS module. No user modifications to EXT SOURCES are required. Modifications to EXT TARGETS permit storage of output from user-defined simulations that reflect hypothetical land-use or flow-detention changes (scenarios) in the basin and comparison of simulated results with the calibrated BASE scenario. Flow time series at the downstream end of each RCHRES can be generated and stored in the preassigned DSNs (two for detention-basin scenarios and two for land-use-change scenarios) as described previously in the overview of the WDM system. An example of an EXT TARGETS command line is:

```
RCHRES 180 HYDR RO 11 1.0 WDM1 1801  
SIMQ 1 ENGL REPL
```

Here the number 1801 between WDM1 and SIMQ is the BASE scenario DSN for the discharge output time series at the downstream end of RCHRES 180 (Irondequoit Creek, subbasin IC6; see appendix). If the user wishes to store data for a simulation of a detention-basin scenario, the suffix “1” would be changed to either “2” or “3” (user’s choice; see table 1); if a land-use change is simulated, this suffix would be changed to either “4” or “5”.

SCHEMATIC Module

The SCHEMATIC module contains instructions that define the connections between land segments (PERLNDs and IMPLNDs) and RCHRESs, and between RCHRESs, as well as the acreages for the PERLNDs and IMPLNDs in a given subbasin. The connections are not modified by the user; rather, land-use changes are simulated by switching the types and quantities of pervious and impervious acreages.

FTABLE Module

The FTABLE module, which contains a function table for each RCHRES, relates surface-water elevation or depth in a RCHRES to water-surface area and volume in the channel and to discharge at the downstream end of the RCHRES. Flow detention can be simulated by increasing the storage volume or decreasing the discharge that is associated with a given depth (Donigian and others, 1997). The modifications can be hypothetical or based on a hydraulic analysis of a proposed flow-control structure. Discharges from a RCHRES are dependent on the volume of water in storage; that is, HSPF calculates a discharge on the basis of the volume of water that has entered the RCHRES from an upstream RCHRES and from adjacent PERLNDs and IMPLNDs during a given time step. Not being a hydraulic model, HSPF does not compute water-surface elevations or associated discharges; these are defined by the user in the Ftables of the UCI file.

SIMULATING LAND-USE CHANGES AND STORMWATER-DETENTION BASINS AND EVALUATING THEIR EFFECT ON PEAK STORMFLOWS AND STREAM-WATER QUALITY

The main objective in the development of the Irondequoit Creek basin model was to provide a tool that would enable water-resources managers to assess the effects that future development might have on peak stormflows and stream-water quality in the basin and to assess the effects that instream stormwater-detention basins might have on these flows and on chemical loads. Simulation of land-use changes and stormwater-detention basins entails the use of an interactive program, GenScn (GENeration and analysis of model simulation SCeNarios for watersheds; Kittle and others, 1998), which was designed to allow water-resources managers to create scenarios that reflect hypothetical or proposed changes in a basin and to view, analyze, and compare the output from two or more scenarios. This manual describes the system as adapted for HSPF, although other models can be adapted to use GenScn. First, a “base” scenario (*base.uci*), which represents stream discharges and water-quality characteristics that have been calibrated to observed or measured discharges and chemical concentrations or loads over several

years, is generated. A copy of the base scenario is then modified to reflect proposed changes in land use, land-use-management practices, or water-resources operations. The results from the revised scenario are then compared with those from the base scenario, and the changes are evaluated. A typical analysis might consist of simulating a proposed commercial development in an area that is currently forested or in an abandoned agricultural area. The results probably will indicate increased peak flows and decreased base flows in response to the increase in impervious area. A second modification could then be made to simulate the flow-attenuating effects of stormwater-detention basins or created wetlands to identify the point at which postdevelopment peak flows would approximate predevelopment flows. A similar analysis of pre- and postdevelopment chemical loads could be performed to assess initial changes in water quality and the probable effects of stormwater detention or of other strategies.

GenScn has the following computer-system requirements: 60 megabytes of free disk space for installation, and the following features to run the program: (1) Windows 9x or Windows NT 4.0 or higher; (2) 486 or greater processor, running at 50 megahertz or faster; (3) 16 megabytes of memory; (4) 60 megabytes of free disk space; and (5) display resolution of 1024 × 768. For optimal performance, the following are recommended: (1) Pentium processor running at 200 megahertz or faster; (2) 64 megabytes of memory; (3) 100 megabytes of free disk space; (4) display resolution of 1280 × 1024; and (5) color printer.

A project CD (compact disk), which contains the GenScn executable file, program support files, and WDM, UCI, and GenScn project files, was distributed to IWC members to use with this manual and is referred to in the following steps, which outline the GenScn installation procedures.

1. Download the file, GenScnWinHSPF2.2.exe, from the project CD or at <ftp://hspf.com/GenScn/> and install it in the main directory of the computer's hard drive (C:); this will establish the complete directory network for proper functioning of the programs. GenScn, version 2.2, is stored within this executable file and will be automatically installed at C:\BASINS\models\HSPF\bin\GenScn.exe if the installation is successfully completed.

2. Copy all other files, the folder "genscn," and its subfolder and files from the project CD to a directory of the user's choice. The "genscn" folder contains the WDM, UCI, and GenScn project files.
3. In an Explore window, right-click on each file and modify its Properties by removing "Read-Only" access to the files. This step can be performed on the "genscn" folder (rather than on individual files) and should remove "Read-Only" access to its files, subfolder, and all subfolder files at one time. Double-check the Properties of the files in the "genscn" subfolder to confirm that this step was successfully completed.
4. In C:\BASINS\models\HSPF\bin, rename the file *hspfmsg.wdm* as *hspfmsg.old.wdm*; then copy *hspfmsg.wdm* from the user's "genscn" directory to this directory.
5. Find and double-click the file *ATCoHSPFOutput.reg*. This step will update the user's registry (in the SYSTEM32 directory) and will correct a software problem that arises when water-quality processes are simulated by HSPF.
6. Create a shortcut for C:\BASINS\models\HSPF\bin\GenScn.exe. Then right-click on the shortcut icon, select Properties, and change the "Start-In" directory to the one that contains the "genscn" folder.

When a GenScn project is opened, six windows appear on the computer screen—Locations, Scenarios, Constituents, Time series, Dates, and Analysis. The "Locations" window displays various basin coverages that, with the click of the mouse, identify streamflow-monitoring sites, subbasin boundaries and identifiers, or hydrologic response units. This window can be toggled between a map display and a list of locations (that is, subbasins) by clicking on Locations/Change to List or /Change to Map. The "Scenarios" and "Constituents" windows list the available scenarios and data types, respectively, that are stored in the WDM. The "Time Series" and "Dates" windows are used to specify desired data sets and time periods for analysis, and the "Analysis" window is used to select the analytical procedure that is to be performed on these data sets.

Effect of Simulated Changes on Peak Flows

The steps required to simulate the effects of land-use changes and stormwater-detention basins, and to ana-

lyze the results, are given below. Implementing these instructions during an actual GenScn session should clarify the steps. Alternatively, pictures of the applicable GenScn screens referred to below can be viewed in the GenScn manual (Kittle and others, 1998). The first scenario entails simulation of land-use changes, and the second scenario entails simulation of stormflow detention. The files referred to below have been stored on the project CD.

Scenario 1—Simulation of Land-Use Changes

1. Begin GenScn by clicking on the shortcut icon that was created during the installation process and open the project station file (File/Open Project. Select *iron.sta*).
 2. After the project has loaded, note whether a map of the basin or a list of locations is shown in the “Locations” window. If a list of locations is displayed, click on “Locations/Change to Map”.
 3. Look at the legend below the map, which identifies the various attributes that should be displayed in the map. If a scroll bar is not shown along the right margin of the “Legend” box, click and hold the cursor (keep the left-mouse button depressed) on the top edge of the “Legend” box to make a double-headed arrow appear. Use this arrow to resize the “Legend” box slightly; this should reveal the scroll bar, which enables viewing of the HRUs, their names, and associated colors.
 4. Use the map tools at the top of the “Locations” window to zoom in on the area of interest. Roads, hydrology, and subbasin boundaries have been overlain on the HRU coverage to assist in locating a desired area. Use the “identify” (“i”) icon in the “Locations” toolbar to identify attributes within a selected coverage. First, select the desired coverage tab (for example, Subbasin or HRU) in the legend below the map, then select the “i” icon and hold the cursor over the area of interest. If the Subbasin tab was selected, the subbasin identifier will appear at the cursor location, and the name of that subbasin will appear at the top of the list in the subbasin-coverage legend. Record this subbasin identifier and the RCHRES number associated with the subbasin. (This information is also given in the appendix herein.) If the HRU tab is selected, position the cursor over the desired polygon in the HRU coverage. Several seconds will pass before the first HRU is identified, but subsequent identifi-
- cations will occur instantaneously. The selected HRU will turn yellow in the map, and its name will appear at the top of the list in the HRU-coverage legend.
5. Refer to table 3 to identify the HRUs by their possible PERLND numbers. Remember that a distinction has been made between PERLNDs based on the precipitation record that is associated with a given area, and between thin- and thick-soil PERLNDs for specific subbasins (table 4). At this point, and depending on the HRU type alone, the user will be left with three possible PERLND numbers and two possible IMPLND numbers from which to choose. The true PERLND or IMPLND number for the HRU of interest can be found in the SCHEMATIC module of the UCI file, which lists the PERLNDs and IMPLNDs within each subbasin. Locating and revising the SCHEMATIC module is discussed in step 10 below.
 6. Calculate the total acreage of the area, in which land use is to be changed, and estimate the percentage of the selected area occupied by each HRU (identified in step 4).
 7. Calculate the acreage changes that need to be input to the model. New development will require that a percentage of the area be treated as effective impervious area. From the proposed land-use change and housing density (as quantified by the average lot size; see table 5.), select and multiply the appropriate percentage of impervious area by the acreage of the area of development. Note the values; they will later be inserted in the UCI file as described in step 10 below.
 8. Modify the UCI file to simulate a new scenario. Open the file *base.uci*, which is the calibrated version of the model, in a text editor. The UCI file is a fixed-format file that requires data input in specific columns, therefore, a text editor that maintains column alignment is required. A *copy_of_base.uci* file has been stored in the genscn directory. This file should never be edited, but should be retained as a backup should the original UCI file become corrupted and unusable. CAUTION: Do not use the tab key while editing the *base.uci* file. It creates a hidden character that HSPF cannot interpret, and the job will not run. Instead, either position the cursor with the mouse or move along lines or columns in the file using the arrow keys or the space bar.

9. Decide whether water-quality or only hydrologic processes need to be simulated. The data sets in the WDM file that pertain to the different processes span different time periods; therefore the simulation period must be changed accordingly. Search for “GLOBAL” and select the line with a START date of 1991_9_1 and END date of 1998_9_30 to simulate hydrologic processes only, and select the line with the dates 1992_10_1 to 1998_9_30 to simulate water-quality processes. Line selection is accomplished by removing the three asterisks at the beginning of the desired line and adding three asterisks to the beginning of the undesired line. Three asterisks found anywhere in a line of the UCI file will “comment out” the line and cause HSPF to ignore it.

The simulation time for the hydrologic components of the model is faster if unnecessary water-quality modules are inactivated. Each of the three main modules (PERLND, IMPLND, and RCHRES) has an ACTIVITY block that identifies the sections of each module that are “active” during a given simulation. Search for “ACTIVITY” and select the appropriate line indicated to simulate hydrology alone or hydrology in conjunction with water-quality modules by removing the three asterisks at the end of the desired line, if they are present. Add three asterisks to the end of the undesired line. The first search will find the block associated with the PERLND module. Repeat this step to locate and revise the ACTIVITY blocks associated with the IMPLND and RCHRES modules. Following is an example of an ACTIVITY block that specifies simulation of hydrologic processes only. Note that HSPF will interpret only the first and fifth lines of this block; all other lines have been commented out.

10. Locate the SCHEMATIC module section of the *base.uci* file, and locate the desired subbasin by its identifier. Find and comment out the lines that need to be revised. For example, if the area of interest is in the Victor precipitation area and covered by “high-slope, low-permeability forest” and “low-slope, low-permeability open and (or) grass” HRUs, locate and insert three asterisks preceding the lines for PERLNDs 3 and 8. (See table 3.) One or more of the IMPLND (impervious land segment) HRUs might need to be treated similarly, depending on the proposed land-use change. Reproduce each “commented out” line below its original entry, being certain to maintain the original spacing and column alignment, and replace the original acreages by the revised acreages. Decrease the acreages associated with “nondeveloped” land uses (PERLND 1-13, 21-33, or 41-53; see table 3.), and increase the acreages for a “developed” land use (PERLNDs 14-16, 34-36, or 54-56 for pervious land in the developed area, and IMPLND 1-3 or 21-23 for effective impervious areas), by an equal amount. An example of simulating land-use changes is given below.

EXAMPLE: Assume that a 100-acre residential-commercial development is proposed for subbasin T8, a tributary to Irondequoit Creek in the town of Perinton. Note that subbasin T8 uses the Victor precipitation record and is not one of the thin-soil subbasins identified in step 5; therefore PERLNDs 1, 8, 14, and 16 are used in the SCHEMATIC module,

ACTIVITY															
*** <PLS > Active Sections (1 = Active, 0 = Inactive)															
*** ##	###	ATMP	SNOW	PWAT	SED	PST	PWG	PQAL	MSTL	PEST	NITR	PHOS	TRAC		
*** For simulation of hydrology only															
1	56	0	1	1	0	0	0	0	0	0	0	0	0	0	
*** For simulation of water-quality processes															
1	56	0	1	1	1	0	0	1	0	0	0	0	0	0	***

rather than PERLNDs 21, 28, 34, and 36 (for HRUs using the Rochester Airport precipitation record) or PERLNDs 41, 48, 54, and 56 (for thin-soil subbasins). Similarly, IMPLNDs 1, 2 and 3 are used to simulate the effective impervious land segments rather than IMPLNDs 21, 22, and 23. (See table 3.) The proposed development is in an area classified as forest and open/grass with poorly permeable soils on low slopes (PERLNDs 1 and 8, respectively, from table 3). The forested area covers about 20 percent of the proposed site, or 20 acres; the open-grass area covers the remainder of the site, or 80 acres. These percentages were estimated from the HRU map displayed in the “Locations” window of GenScn. Adjust the acreages listed in the SCHEMATIC module of the UCI file for subbasin T8 (91.90 for PERLND 1 and 186.69 for PERLND 8) by these amounts: the acreage assigned to PERLND 1 will be changed to 71.9 (91.90 minus 20 acres), and that for PERLND 8 will become 106.69 (186.69 minus 80 acres; table 6). Sixty acres of the proposed development will be used for single-family residences, and 40 acres will be used for a plaza of small retail services and office buildings. The 60 acres that are intended for residential development contain low-slope residential pervious land (PERLND 14) and low-slope residential impervious land (IMPLND 1). The corresponding acreages are computed from the percentages of pervious and impervious areas (table 5) that are estimated for these HRUs. The 40 acres intended for commercial development also contain two HRUs—commercial pervious land (PERLND 16) and commercial impervious land (IMPLND 3).

The calculations of impervious and developed pervious acreages are given in table 6.

a. Impervious-acreage calculation: Assume an average residential lot size of 1 acre. The percentages used to estimate the effective impervious area in the residential and commercial parts of the development (from the second row of table 5) will be 5 percent for low-slope residential (IMPLND 1) and 40 percent for commercial (IMPLND 3). Therefore, the effective impervious area in the residential part will be 3 acres (5 percent of 60 acres), and that in the commercial part will be 16 acres (40 percent of 40 acres). The effective impervious acreages in the SCHEMATIC module will therefore be increased to 3 acres for the low-slope residential HRU (IMPLND 1), and to 35.97 acres (19.97 + 16 acres) for the commercial HRU (IMPLND 3; table 6). Note that IMPLND 1 for low-slope residential use is not currently included in the SCHEMATIC module for subbasin T8

and must be added. To do this, copy any IMPLND line, correct the IMPLND number, and insert the correct acreage for this HRU. If a subbasin has no IMPLND HRUs, a PERLND line can be copied and inserted instead, but this requires two additional changes: (1) the word “PERLND” must be changed to “IMPLND,” and (2) the last number in the line must be changed from “1” to “2.” This number links the line in the SCHEMATIC module with instructions as to which hydrologic computations are applicable to this HRU. With experience, a user can type missing lines directly into the SCHEMATIC module as an alternative to copying and editing existing lines.

b. Pervious-acreage calculation: The pervious acreages in the residential and commercial parts of the development are the differences between the total area and the impervious area for a given land use as computed in step (a) above, or can be calculated with the percentages listed in table 5. These percentages, which are equal to 100 minus the effective-impervious-area percentage used in step (a) above, multiplied by the area assigned to a proposed land use (0.95 x 60 acres and 0.60 x 40 acres, respectively) will give the estimated pervious area associated with the residential and commercial parts. Therefore, 57 acres and 24 acres should be added to PERLNDs 14 and 16 to simulate this change in land use. (See table 6.)

As a check on the correctness of the calculations, refer to the “total” row of table 6: the acreage in column 2 should equal that in column 9, and the sum of the values in columns 6 and 8 should equal the value in column 3.

11. Locate the EXT TARGETS module in the UCI file. Find the RCHRES of interest in the “RCHRES Outflow” section of the module. Go along the line to the 3- or 4-digit number that identifies the target DSN in the WDM, and replace this number with one of the two DSNs that were assigned for land-use-change scenarios by changing the last digit to either “4” or “5,” which represent the LANDUSE1 and LANDUSE2 scenarios, respectively. Delete the three asterisks at the end of the line. If changes in flows in RCHRESs downstream from the RCHRES of interest are required, repeat these steps for each applicable RCHRES. The output in the new DSN can be compared with the base-scenario data or with data from a second scenario, which can

Table 6. Calculation of acreage revisions for pervious and impervious land areas in user-control file of HSPF model for simulation of a hypothetical 100-acre residential-commercial development in Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

[PERLND, pervious land area; IMPLND, impervious land area; Col., column. Values are in acres unless otherwise indicated.]

Land segment	Original total subbasin area	Area to be affected by development	Developed area classified as PERLND or IMPLND in col. 1	Estimated percent impervious area (from table 5, as decimal)	Impervious area (col. 4 x col. 5)	Estimated percent disturbed pervious area (from table 5, as decimal)	Estimated disturbed pervious area (col.4 x col.7)	Revised total area (col. 2 - col. 3 + col. 6 + col. 8)
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
PERLND 1	91.90	20						71.90
PERLND 8	186.69	80						106.69
PERLND 14	9.78	0	60			0.95	57	66.78
PERLND 16	30.00	0	40			.60	24	54.00
IMPLND 1	0	0	60	0.05	3			3.00
IMPLND 3	19.97	0	40	.40	16			35.97
Total ¹	338.34	100			19		81	338.34

¹Col. 2 - col. 3 + col. 6 + col. 8 should equal col. 9.

be created according to the directions in “Data-Management System” to target a second set of DSNs.

12. Save this edited UCI file with a name that matches a scenario and ends with “.uci”, such as *landuse1.uci* or *landuse2.uci*.
13. Simulate the scenario. In GenScn window, select “Analysis/HSPF.” Identify the UCI file and run the simulation. During the initial step of the simulation, HSPF checks the UCI file for any coding errors and automatically creates an output file, *base.ech*, each time a simulation is run. If the simulation fails to run, open *base.ech* in a text editor and search for lines of asterisks, which will bracket any error message. The message should identify the problem and lead the user to its correction. The *base.ech* file is overwritten each time a simulation is run.
14. Compare and analyze the output from the simulation as outlined in the section “Data Analysis”, further on.

Scenario 2—Simulation of Stormflow-Detention Basins

1. Review the steps for simulating land-use changes (Scenario 1 above). Steps 1-4, 8, and 9 are applicable to Scenario 2. After completing these six steps of Scenario 1, follow step 2 below.
2. Edit the UCI file, *base.uci*, or the previously created *landuse1.uci* or *landuse2.uci*. Locate the FTABLES module near the end of the file. Then locate the desired Ftable by subbasin identifier or RCHRES number, which is the same as the Ftable number for a given reach. Each Ftable lists four parameters—a reference depth (usually at the downstream end of the reach), water-surface area along the reach, volume of water stored in the channel along the reach, and the estimated discharge at the downstream end of the reach.
3. Ten detention basins—one actual and nine hypothetical—were identified as part of the Irondequoit Creek basin modeling project. The detention basin in RCHRES 640, subbasin EB3, is the Jefferson Road storm-water-management facility on East Branch Allen Creek in the Town of Pittsford. The Ftable for this RCHRES was developed to reflect observed storage volumes and discharges (Derek Anderson, ENSR International,

Rochester, N.Y., written commun., 2001), and the model was coded to automatically switch from pre-basin to post-basin discharges during August 1995, when the facility became operational (Martin Brewster, Town of Pittsford, oral commun., 2001). The nine hypothetical detention basins, which are associated with RCHRESs 110, 190, 260, 420, 470, 500, 540, 590, 640, and 740 (see appendix for their subbasin identifiers), are represented by a separate Ftable in the model. The user decides before a simulation run whether to use the primary Ftable, which simulates “natural conditions,” or the detention-basin Ftable. Each line of a detention-basin Ftable is preceded by three asterisks that cause it to be ignored by HSPF. Deactivate the primary Ftable by inserting three asterisks at the beginning of each line, and activate the detention-basin Ftable by deleting the three asterisks preceding each line of this table. The detention-basin Ftable reflects a 50-percent reduction in outflow, but the user can modify the Ftable as desired by adjusting the discharges or storage volumes to simulate other degrees of flow detention, as described in step 4.

4. Detention basins can be simulated in any other reach by (1) decreasing the outflow rates (in cubic feet per second) associated with the given storage volumes to simulate a flow-control structure across the channel, or (2) increasing the channel-storage volumes (in acre-feet) associated with the given discharges to simulate creation of one or more storage pools adjacent to the channel or upstream from the discharge point. These modifications could be hypothetical or based on computed outflows and storages from a field survey and design calculations for a proposed basin. To simulate a detention basin, copy and paste the current Ftable in the UCI file directly below itself to preserve the original version of the table. Then “comment out” the original table by placing three asterisks at the beginning of each line. Make revisions only to the copy of the Ftable.

As indicated above, the Ftable can be modified to reflect the combined storage of several detention basins within the area drained by a particular RCHRES. If storage-volume changes are made, the outflow rates of the Ftable (column 4) would be left “as is,” and the storage volumes (column 3) would be increased by an appropriate amount. If a flow-control structure is added, only the discharges

(column 4) would be revised. Column alignment of the values for each of the four parameters in an Ftable must be maintained when revisions are made; each field is 10 characters wide, and the values are right justified in their respective columns. Also, the third line of an Ftable (between the lines that begin with the words “ROW” and “DEPTH”) contains two numbers that refer to the number of data lines and columns in the Ftable. If the number of data lines in an Ftable is changed, the first number must be corrected to agree with this change; these numbers are right justified in their respective locations. The maximum permissible number of data lines in an Ftable is 25.

5. Locate the EXT TARGETS module in the UCI file and, as described in the instructions for simulating land-use changes, find the RCHRES of interest in the “RCHRES Outflow” section of the module. Go along the line to the 3- or 4-digit number that identifies the target DSN in the WDM. Replace this number with one of the two DSNs that were assigned for detention-basin scenarios by changing the last digit to either “2” or “3” (for DBASIN1 and DBASIN2 scenarios, respectively). Delete the three asterisks at the end of this line. Make similar changes on any lines that refer to downstream RCHRESs for which scenario outputs are also desired. The output in the new DSN can be compared with the base-scenario data, or with data from a second scenario. For the latter comparison, target a second set of DSNs as specified in the “Data-Management System” section.
6. Save this edited UCI file with a name that matches a scenario and ends with “.uci,” such as *dbasin1.uci* or *dbasin2.uci*.
7. Simulate the scenario. In GenScn window, select “Analysis/HSPF.” Identify the UCI file and run the simulation. During the initial step of the simulation, HSPF checks the UCI file for any coding errors and automatically creates an output file, *base.ech*, each time a simulation is run. If the simulation fails to run, open *base.ech* in a text editor and search error messages, bracketed by lines of asterisks, which should lead to correction of the problem. The *base.ech* file is overwritten each time a simulation is run.
8. Compare and analyze the output from the simulation as outlined in the following section.

Data Analysis

This section explains how to view and analyze the outflow records generated by the base scenario and compare them with those generated by a land-use-change scenario or a detention-basin scenario. Open GenScn and the *iron.sta* project, then specify the desired parameters in the six GenScn windows.

1. “Locations” window: select “Locations/Change to list” and select the desired subbasin(s).
2. “Scenarios” window: select the two scenarios with output to be compared, for example, BASE and LANDUSE1.
3. “Constituents” window: select “FLOW” to view and analyze the simulated flows.
4. “Time Series” window: add the selected time series (or records) to the list by using the “plus-sign” icon. Scan the DSN numbers to confirm that the selection process picked the desired records. Extraneous records can, but need not, be removed by highlighting them, and then using the “minus-sign” icon. Highlight the records to be compared. Several can be selected at a time by holding down the Control-key.
5. “Dates” window: Note the start and end dates that appear in the window. GenScn will automatically select the longest time period that is common to all the records in the “Time Series” window, but the user can manually change this time range if desired.
6. “Analysis” window: select any of the following:
 - a. the “red-bar” icon to generate graphs of the time series;
 - b. the “111-222” icon to list the values in the time series;
 - c. the “stopwatch” icon to perform flow-duration analysis; or
 - d. the “balance-scale” icon to perform statistical comparisons of the time series.

Practical Exercise

This exercise has been designed to enable the user to (1) assess the sensitivity of the Irondequoit Creek basin model to simulated changes in peak flows resulting from changes in land use and stormflow detention, and (2) provide practice in developing scenarios and using GenScn to analyze results. This exercise will quantify the magnitude of (1) development that would be needed to produce measurable differences in simulated peaks flows, and (2) stormflow detention that would be needed to

ensure that peak flows do not exceed their predevelopment rates.

SAMPLE PROBLEM: Assume that a hypothetical development is planned for subbasin T5, whose land segments cover 1,550 acres and drain to RCHRES 100, a tributary to RCHRES 110 (in subbasin IC3). About 20 percent of the area to be developed is “high-slope, high-permeability forested” area; the remaining 80 percent is “low-slope, high-permeability open-grass” area. Assume that all of the forested area will become part of the residential development, and that the rest of the residential area will encompass open-grass area. The forested and open-grass areas have different slope categories; therefore, their developed acreages will be applied to different PERLNDs and IMPLNDs. Select a percentage of the subbasin that is to be developed—between 2 and 10 percent, or 31 and 155 acres. The development will be 50 percent commercial and 50 percent residential, with an average lot size of 0.6 acres.

1. Following the steps listed for Scenario 1, calculate the acreage revisions in table 7 (as shown in table 6), and simulate these land-use changes. In completing table 7, obtain the original acreages from the SCHEMATIC module for subbasin T5, but only copy the acreages of HRUs that are affected by the proposed development (PERLNDs 4, 9, 14-16, and IMPLNDs 1-3). From the selected size of the development (2 to 10 percent of the 1,550-acre subbasin), compute the acreage of the development. Of the resulting acreage, 20 percent is assumed to be “high-slope, high-permeability, forest”; and 80 percent is “low-slope, high permeability, open and (or) grass.” Half of this computed acreage will be residential; the other half will be commercial. Because part of the land to be developed is high slope, “high-slope residential” pervious and impervious HRUs (PERLND 15 and IMPLND 2, respectively, from table 1) must be added to the SCHEMATIC module. A PERLND (no. 16) for pervious land in commercial areas is already included in subbasin T5’s SCHEMATIC module, but a corresponding IMPLND (no. 3) must be added. Follow instructions in the example for Scenario 1 to make these additions to the SCHEMATIC module. In the UCI file, target the WDM data sets xxx4 in the EXT TARGETS module for the first scenario, and save as *landuse1.uci*. If computed correctly, the revised acreages should agree with

Table 7. Calculation of changes in acreages of pervious and impervious land areas for hypothetical development and for revision of HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

[PERLND, pervious land area; IMPLND, impervious land area; Col., column. Values are in acres unless otherwise indicated.]

Land-segment number	Original total subbasin area	Area to be affected by development	Developed area classified as PERLND or IMPLND in col. 1	Estimated percent impervious area (from table 5, as decimal)	Impervious area (col.4 x col.5)	Estimated percent disturbed pervious area (from table 5, as decimal)	Estimated disturbed pervious area (col.4 x col.7)	Revised total area (col. 2 - col. 3 + col. 6 + col.8)
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9
Undeveloped PERLNDs (nos. 1-13, 21-33, or 41-53)								
Developed PERLNDs (nos.14-16, 34-36, or 54-56)								
IMPLNDs (nos. 1-3 or 21-23)								
Total ¹								

¹Col.2 - col. 3 + col. 6 + col. 8 should equal cl. 9.

- those listed in table 8 for the chosen development size.
2. Follow the steps in the section “Data Analysis” for analyzing data in GenScn, and plot the output for predevelopment (BASE scenario) and postdevelopment (LANDUSE1 scenario) conditions for RCHRES 100 and RCHRES 110.
 3. After simulating the land-use changes, follow the steps listed for Scenario 2 and simulate flow detention, first by decreasing the discharge rates and keeping storage volumes constant in the Ftable

for RCHRES 100; then by increasing the storage volumes and keeping the original discharge rates constant. In the UCI file, target the WDM data sets xxx2 in the EXT TARGETS module for the first scenario (discharge-rate modification) and save as *dbasin1.uci*, then target the WDM data sets xxx3 for the second scenario (storage-volume modification) and save as *dbasin2.uci*. Make adjustments in 10-percent increments until peak flows approximate predevelopment values for RCHRES 100 (plot LANDUSE1 and DBASIN1 or DBASIN2

Table 8. Acreage revisions to PERLNDs and IMPLNDs in SCHEMATIC block of user-control file to simulate hypothetical development of subbasin T5 in sample problem. [PERLND, pervious land area; IMPLND, impervious land area. Values are in acres unless otherwise indicated.]

Land segment	Original acreage	Revisions in acreages based on indicated development size, as percentage of total subbasin (total acres affected)				
	0% (0)	2% (31)	4% (62)	6% (93)	8% (124)	10% (155)
PERLND 4	112.38	106.18	99.98	93.78	87.58	81.38
PERLND 9	248.59	223.79	198.99	174.19	149.39	124.59
PERLND 14	17.22	25.22	33.22	41.22	49.22	57.21
PERLND 15	0.00	5.33	10.66	16.00	21.33	26.66
PERLND 16	27.80	29.97	32.14	34.31	36.48	38.65
IMPLND 1	0.00	1.3	2.60	3.90	5.21	6.51
IMPLND 2	0.00	0.87	1.74	2.60	3.47	4.34
IMPLND 3	0.00	13.33	26.66	39.99	53.32	66.65

Table 9. Peak flows associated with hypothetical land-use-change and detention-basin simulations developed in sample problem.

Storm dates	RCHRES 100			RHRES 110		
	Predevelopment peak flow (BASE scenario)	Postdevelopment peak flow (LANDUSE scenario)	Flow-detention peak flow (DBASIN scenario)	Predevelopment peak flow (BASE scenario)	Postdevelopment peak flow (LANDUSE scenario)	Flow-detention peak flow (DBASIN scenario)
Mar. 27, 1992						
Apr. 13, 1994						
Nov. 2, 1994						
Oct. 20, 1996						
Dec. 2, 1996						
Jul. 8, 1998						
Average						

data in GenScn). Adjustments to the closest 10-percent change in discharge rates or storage volumes are adequate for this exercise. If a 10-percent change in detention exceeds that which is necessary to mitigate the postdevelopment peak flows—that is, if flow detention results in peak flows that are lower than predevelopment flows, then select two percentages less than 10, simulate these flow-detention scenarios, and compare peak flows.

4. Follow the steps for analyzing data in GenScn and list the peak flows for the selected storms in table 9 under predevelopment (BASE scenario), postdevelopment (LANDUSE1 scenario), and flow-detention (DBASIN1 scenario) conditions for RCHRES 100 and RCHRES 110.
5. Complete the following statements.
 - a. The change in peak flows shown in table 9 resulted from development of _____ percent of the subbasin.
 - b. Conversion of high-slope forested area to high-slope residential area resulted in changing: _____ acres of PERLND 4 to _____ acres of PERLND 15 and _____ acres of IMPLND 2.
 - c. Conversion of low-slope open and (or) grass area to low-slope residential and commercial areas resulted in changing: _____ acres of PERLND 9 to _____ acres of PERLND 14 and _____ acres of IMPLND 1; and to _____ acres of PERLND 16 and _____ acres of IMPLND 3.
 - d. The proposed development caused an average increase in peak flows of about _____ percent in RCHRES 100 and _____ percent in RCHRES 110.
 - e. Reducing peak flows to predevelopment magnitudes required a _____ -percent decrease in RCHRES 100 outflow rates or _____ - percent increase in RCHRES 100 storage volume.

Effects of Simulated Changes on Stream-Water Quality

The second goal of the Irondequoit Creek model project was to provide a tool to assess the effects that future development might have on stream-water quality, and the extent to which instream stormflow-detention basins might mitigate these effects. Simulation of these scenarios requires repetition of the

steps listed for Scenario 1 and (or) Scenario 2, as well as completion of the additional steps listed in the following section.

The chemical loads computed from measured concentrations and observed discharges are referred to as OBSERVED loads, and those generated by the model (calibrated to observed loads) are referred to as BASE loads. Monthly OBSERVED and daily BASE loads are stored in the WDM only for USGS water-quality monitoring sites. The chemical-load data sets stored in the WDM file are numbered in the form xxnn, where xx is the RCHRES number divided by 10, and nn identifies the scenario and chemical constituent. For example, xx for RCHRES 690 is 69, and the nn values for the OBSERVED loads are 21 for total suspended solids (TSS), 22 for total phosphorus (TP), 24 for ammonia-plus-organic nitrogen (TKN), and 25 for nitrate-plus-nitrite nitrogen (NO_x) loads, respectively. The nn values for the corresponding BASE-scenario loads are 31, 32, 34, and 35, respectively (table 10). HSPF-generated loads that refer to a user-defined land-use-change or detention-basin scenario are stored in two WDM data sets, listed in table 10. These data sets have the “Location” of “USER” and scenarios of “WQSCEN1” or “WQSCEN2,” which must be selected in GenScn to identify the appropriate chemical-load data set to be analyzed. Loads of TSS, TP, TKN, NO_x, and total nitrogen (TN, the sum of TKN and NO_x) are simulated by the model.

Model Revisions to Simulate Chemical Loads

The HSPF-parameter values that simulate the processes that generate loads of water-quality constituents are associated with overland- and subsurface-flow processes of the PERLND module, the overland-flow processes of the IMPLND module, and the channel-flow processes of the RCHRES module. When PERLND and IMPLND acreages are modified as instructed in Scenario 1 (simulation of land-use changes), HSPF automatically simulates chemical loads resulting from these changes, and no adjustment of parameter values is required. Similarly, when RCHRES storage volumes or discharge rates from a stormwater-detention basin are modified as instructed in Scenario 2 (simulation of detention basins), HSPF will automatically simulate the changes in chemical loads that result from increased detention time and removal of particulate constituents. The user should be aware that peak-flow attenuation and water-

Table 10. Dataset-number (DSN) system for water-quality output used in WDM (Watershed Data Management) file for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y.

[xx refers to the first two digits of a RCHRES identification number. Dash (--) indicates no data set for this combination of constituent and scenario.

Constituent	USGS water-quality monitoring sites only		All user-developed water-quality scenarios	
	Observed	Base simulation	WQSCEN1	WQSCEN2
Total suspended solids	xx21	xx31	9100	9110
Total phosphorus	xx22	xx32	9101	9111
Ammonia-plus-organic nitrogen	xx24	xx34	9102	9112
Nitrate-plus-nitrite nitrogen	xx25	xx35	9103	9113
Total nitrogen	--	--	9104	9114

quality improvement often are incompatible functions for instream-detention basins and that water-quality effects will depend on the intended function and design of the basin. In addition to the possible modifications that could be made to a RCHRES Ftable to simulate a detention basin for peak-flow-attenuation purposes, the depth at which discharge from the basin occurs could be increased to simulate a permanent pool in the detention basin that theoretically would enhance the basin's water-quality-improvement function. This revision can be performed through the steps listed for Scenario 2 and, additionally, by setting the discharge outflow rate to zero up to the hypothetical sill of the permanent pool, then decreasing the outflow rates as depth increases. Except for this possible modification, the effects of land-use changes and (or) detention basins on water quality are simulated through the steps outlined for Scenarios 1 and (or) 2, respectively, followed by the steps listed below.

1. Open the base.uci file, or the previously created landuse.uci or dbasin.uci file, in a text editor. As was done before the previous simulations, search for the ACTIVITY blocks in the file and select the lines identified for simulating water-quality processes.
2. As in Scenarios 1 and 2, revise the DSNs to which the output from the water-quality simulations will be targeted. This is a two-step process. First, search for "NETWORK," then for "WQSCENARIO-1." Below this line are 13 lines, 10 of which begin with the word "RCHRES" followed by a RCHRES number. In each of these

lines, replace this number with the number of the RCHRES of interest, being careful to maintain column alignment and right-justification of the number. Delete the three asterisks on each of the "RCHRES" lines so that these lines can be interpreted by the program.

Second, search for the "EXT TARGETS" module, then for "WQSCENARIO-1". This line precedes two lines that begin with "RCHRES." As in the NETWORK module, change the RCHRES number in each of these lines to that of the reach of interest. Delete the three asterisks from each of the "RCHRES" lines as well as the following three "COPY" lines. Save the file with an appropriate name (for example, landuse1.uci or dbasin1.uci) that reflects the hydrologic revisions made in the earlier steps.

3. Run the simulation. View and analyze the output time series in GenScn as described in the next section, "Analysis of Chemical-Load Data."
4. Note that following the command lines identified in the NETWORK and EXT TARGETS modules is a second set of lines that can be modified to store chemical-load output from a second scenario, WQSCENARIO-2. If WQSCENARIO-2 pertains to a different RCHRES than identified in WQSCENARIO-1, simply follow the above directions and insert the desired RCHRES number in these lines. If the objective is to compare water-quality loads for a given RCHRES under differing land-use or detention-basin conditions, then
 - a) after the first scenario (for example, BASE) is simulated and output has been targeted to the DSNs

associated with WQSCENARIO-1, comment out the lines associated with this water-quality scenario in the NETWORK and EXT TARGETS blocks, and b) insert the same RCHRES number in the lines associated with WQSCENARIO-2 as was used for WQSCENARIO-1, remove the asterisks from these lines, and simulate the second scenario (for example, LANDUSE1 or DBASIN1).

Analysis of Chemical-Load Data

Chemical loads are simulated at the same time step as flows (hourly) but are stored in the WDM file as daily loads. The accuracy of daily loads likely is low because (1) estimates of instantaneous chemical loads based on automatically collected, hourly water samples that have been composited prior to analysis have a degree of uncertainty, and the period covered by these composite samples could span 3 to 4 days. (2) Discrete samples and their concentrations were not available for model calibration, and (3) concentrations of chemicals in composited samples, and daily loads based on these concentrations, were not used for calibration. The inherent uncertainty in computed chemical loads makes comparison of monthly, rather than daily, loads advisable.

Begin GenScn and open the project station file (File/Open Project. Select *iron.sta*); then specify the desired parameters in the six GenScn windows.

1. "Locations" window: select "Locations/Change to list" and select "USER."
2. "Scenarios" window: select either "WQSCEN1" and (or) "WQSCEN2."
3. "Constituents" window: select the desired chemical-load data set: TSS, TP, TKN, NOx, or TN.
4. "Time Series" window: add the selected time series (or records) to the list by clicking on the "plus-sign" icon. Highlight the records to be compared. Both can be selected at one time by holding down the Control-key.
5. "Dates" window: Select the desired time period for analysis. For analysis of monthly loads, locate "Time Step, Units" and click on the triangle at the right side of the lower box and select "Sum/Div." Then click on the triangle in the upper box and select "Month."
6. "Analysis" window: select either of the following:
 - a) the "red-bar" icon to generate graphs of the time series; or b) the "111-222" icon to list the values in the time series.

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Appendix. Subbasin and stream-reach (RCHRES) correlation for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y., with corresponding lot-size code (AVGLOTSIZE) and drainage area.

[Dash (--) indicates no RCHRES associated with this subbasin. Asterisk (*) indicates a subbasin or RCHRES for which a stormwater-detention basin has been included in the FTABLE module of the HSPF model. Locations can be seen in the map displayed during a GenScn session.]

Subbasin codes, in alphabetical order					RCHRES codes, in numerical order	
Subbasin	RCHRES	AVGLOTSIZE code	Drainage area		RCHRES	Subbasin
			Square miles	Acres		
Allen Creek						
AC1	520	4	2.100	1,343.95	--	CN1
AC2*	540	3	3.529	2,258.79	--	CN2
AC2a	530	3	1.180	755.51	--	CN3
AC3	550	3	0.677	433.06	--	CN4
AC3a	560	2	1.359	869.68	--	GWR1
AC4	580	4	0.911	583.11	--	GWR2
AC4a	570	3	0.780	499.09	10	IC1
AC5	690	4	1.458	933.08	20	T1a
AC6	700	3	0.636	406.72	30	T1
Buckland Creek						
BC1*	590	4	2.505	1,603.48	40	T2a
BC2	600	4	0.917	586.65	50	T2
BC3	610	3	0.498	318.52	60	IC2
Canal	900	--	--	--	70	T3c
CN1	--	3	3.276	2,096.51	75	T3b
CN2	--	4	2.242	1,435.16	80	T3a
CN3	--	3	0.874	559.41	90	T4
CN4	--	4	1.832	1,172.72	100	T5
East Branch Allen Creek						
EB1	620	1	2.598	1,662.89	*110	IC3
EB2	630	3	2.021	1,293.21	120	IC4
EB3*	640	4	0.587	375.65	130	T6b
EB4	660	3	0.557	356.44	140	T6a
EB4a	650	3	0.385	246.16	150	T6
EB4b	650	3	0.792	506.77	160	IC5
EB5	670	3	2.205	1,411.24	170	T7
EB6	680	3	0.879	562.79	180	IC6
Ground-water Recharge Area						
GWR1	--	2	0.390	249.50	*190	IC7
GWR2	--	2	0.530	339.51	200	T8
Irondequoit Creek						
IC1	10	1	3.539	2,265.13	210	IC8
IC2	60	1	0.808	517.10	220	IC9
IC3*	110	1	0.514	328.77	230	MC1
IC4	120	2	1.520	972.66	240	MC2
IC5	160	1	0.734	470.05	250	MC3
IC6	180	1	2.258	1,445.04	*260	IC10
IC7*	190	1	0.319	203.99	270	T9a
IC8	210	1	2.193	1,403.61	270	T9b
IC9	220	3	0.495	317.05	280	IC11
IC10*	260	3	0.852	545.55	290	T10b
IC11	280	3	1.335	854.33	290	T10a
IC12	300	4	1.951	1,248.64	300	IC12
IC13	310	4	1.326	848.92	310	IC13
IC14*	500	5	1.179	754.37	320	TC1
IC15	510	3	2.295	1,468.70	330	TC2
IC16*	740	3	0.926	592.70	340	TC3a

Appendix. Subbasin and stream- reach (RCHRES) correlation for HSPF model of Irondequoit Creek basin, Monroe and Ontario Counties, N.Y., with corresponding lot-size code (AVGLOTSIZE) and drainage area (continued)

Subbasin codes, in alphabetical order					RCHRES codes, in numerical order	
Subbasin	RCHRES	AVGLOTSIZE code	Drainage area		RCHRES	Subbasin
			Square miles	Acres		
IC17	750	4	1.542	986.66	350	TC3b
IC18	770	2	0.552	353.35	360	TC3
IC19	800	4	0.707	452.64	370	TC4
Mill Creek						
MC1	230	1	3.392	2,171.16	380	WB1
MC2	240	2	2.689	1,720.96	390	WB1a
MC3	250	4	1.252	801.52	400	WB2
City of Rochester						
R1	780	5	3.023	1,934.98	410	WB3a
R2	790	5	2.404	1,538.84	*420	WB3
Tributaries to Irondequoit Creek						
T1	30	1	2.319	1,484.43	430	WB4a
T1a	20	1	1.348	862.49	440	WB4
T2	50	1	1.950	1,248.16	450	TC5
T2a	40	1	1.896	1,213.36	460	TC6
T3a	80	1	1.831	1,171.67	*470	T11b
T3b	75	1	1.073	686.52	480	T11a
T3c	70	1	1.697	1,086.38	490	T12
T4	90	1	3.162	2,023.47	*500	IC14
T5	100	1	2.422	1,550.16	510	IC15
T6	150	1	3.482	2,228.16	520	AC1
T6a	140	1	3.448	2,206.78	530	AC2a
T6b	130	1	2.268	1,451.28	*540	AC2
T7	170	1	2.595	1,661.07	550	AC3
T8	200	2	2.106	1,347.93	560	AC3a
T9a	270	3	0.156	99.52	580	AC4
T9b	270	2	1.690	1,081.30	570	AC4a
T10a	290	3	0.622	398.19	*590	BC1
T10b	290	4	1.524	975.20	600	BC2
T11a	480	3	0.969	620.11	610	BC3
T11b*	470	3	2.024	1,295.43	620	EB1
T12	490	3	2.182	1,396.35	630	EB2
T13a	720	2	2.840	1,817.67	*640	EB3
T13b	710	1	2.670	1,708.99	650	EB4a
T14	730	3	1.296	829.23	650	EB4b
T15	760	4	1.540	985.32	660	EB4
Thomas Creek						
TC1	320	1	2.992	1,914.76	670	EB5
TC2	330	2	2.011	1,286.77	680	EB6
TC3	360	4	2.290	1,465.42	690	AC5
TC3a	340	3	1.658	1,061.36	700	AC6
TC3b	350	3	1.970	1,260.61	710	T13b
TC4	370	3	1.121	717.30	720	T13a
TC5	450	3	1.298	830.66	730	T14
TC6	460	3	0.230	147.15	*740	IC16
White Brook						
WB1	380	1	3.453	2,209.65	750	IC17
WB1a	390	1	1.555	995.39	760	T15
WB2	400	1	2.255	1,443.16	770	IC18
WB3*	420	2	0.559	357.69	780	R1
WB3a	410	2	4.110	2,630.44	790	R2
WB4	440	3	1.119	716.22	800	IC19
WB4a	430	3	1.296	829.64	900	Canal