SECTION III:
WATERSHED TECHNICAL ANALYSIS

A. Watershed Modeling

An initial step this study of the Trout Creek watershed was the selection of a stormwater simulation model to be used in the analysis. To provide a reasonable estimate of existing flows within the watershed to serve as a baseline for the study of stormwater management and to effectively evaluate the hydrologic response of the watershed to various changes in stormwater management it was necessary to select a model which:

- Modeled design storms of various durations and frequencies to produce routed hydrographs which could be combined
- Was adaptable to the size of subwatersheds in this study
- Could evaluate specific physical characteristics of the rainfall-runoff process
- Did not require an excessive amount of input data yet yielded reliable results

The model selected for use in this study was the U. S. Army Corps of Engineers, Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) for the following reasons:

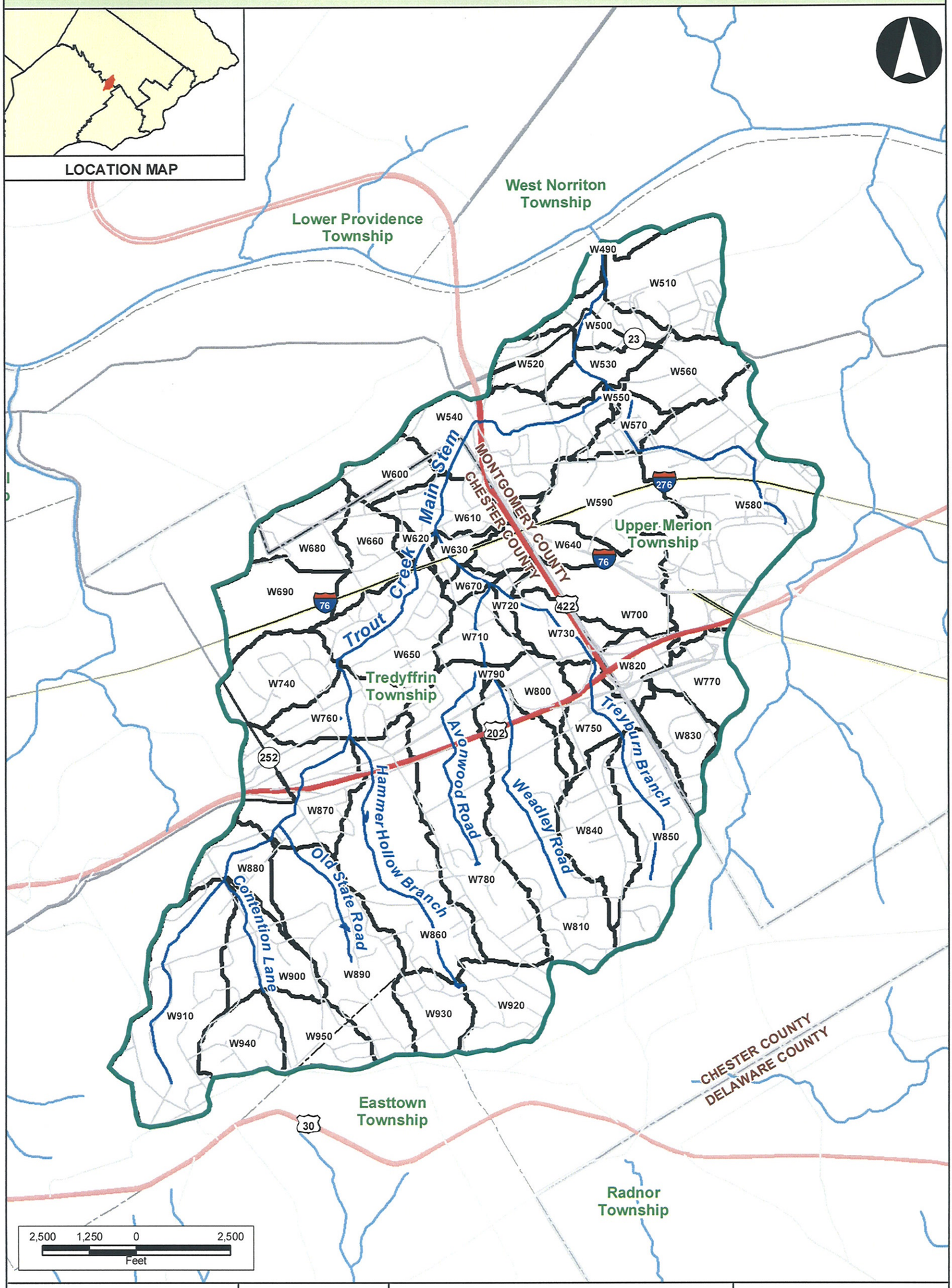
- It had been developed at the Hydrologic Engineering Center specifically for the analysis of the timing of surface flow contributions to peak rates at various locations in a watershed
- Although originally developed as an urban runoff simulation model, data requirements make it easily adaptable to a rural situation
- Input parameters provide a flexible calibration process
- It has the ability to analyze reservoir or detention basin routing effects
- It is accepted by the Pennsylvania Department of Environmental Protection

Although other models, such as TR-20, may provide essentially the same results as the HEC-HMS, HMS's ability to compare subwatershed contributions in a peak flow presentation table make it specifically attractive for this study. The HEC-HMS Model generates runoff flows for selected subareas along the drainage course and compares subarea contributions to the total runoff. The model generates runoff quantities for a specified design storm based upon the physical characteristics of the subarea, and routes the runoff flow through the drainage system using variables that represent the hydraulic characteristics of the stream.

The amount of runoff generated from each subarea is a function of its slope, soil type or permeability, amount of development, and its vegetative cover. Composite runoff curve numbers were generated for the watershed by overlaying the land cover map with the subarea and hydrologic soil group maps. The generated curve numbers were then used for input into the computer model to simulate the amount of runoff generated for select return intervals. Map III-1 displays the subarea delineation for the Trout Creek watershed.

The hydrologic model developed for this project includes the entire Trout Creek Watershed. However, the primary area of interest for this study was the portion of the Trout Creek watershed within Tredyffrin Township and the small portion of the watershed within Easttown Township. As the main focus of this study is in the Tredyffrin Township portion of the watershed, special attention and most of the effort to develop the model was focused on that portion of the hydrologic model.

TREDYFFRIN TOWNSHIP
TROUT CREEK WATERSHED STUDY



Map III-1
SUBAREAS

Prepared For:
Tredyffrin Township
1100 Duportail Road
Berwyn, PA 19312
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Legend
- Watershed Boundary
- Subareas
- County Boundaries
- Municipal Boundaries
- Water Bodies
- Streams
- Interstates
- U.S. Highways
- PA State Routes
- Other Roads

NOTE:
Portions of this map were generated from existing data sources as listed below. These data are shown on the map for spatial reference only. These data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of these data and has corrected the data in locations where discrepancies were obvious, however, it was not a part of this plan to correct all of the mapping data.

DATA SOURCES:
Watershed Boundary - PADEP (Modified by BLE)
Streams - PADEP
Water Bodies - USFWS (Derived from NWI Wetlands)
Roads - PennDOT
County and Municipal Boundaries - PennDOT
Subareas - Delineated by Borton-Lawson

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PREPARED BY: SJD CHECKED BY: SAV
DATE: 9/18/2007 PROJECT #: 2007-2196-00

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The area of the watershed situated outside of Tredyffrin Township was incorporated into the project's hydrologic model so that the effects of management strategies applied in the Tredyffrin Township portion of the watershed could be evaluated, if desired, beyond the Township's corporate limits. As this required little additional effort to complete, the extension of the model to include the entire watershed was considered worthwhile.

B. Modeling Process

After delineating the Trout Creek watershed in the GIS, and checking the delineation by overlaying it on the USG.S topographic map, the watershed was divided into subwatersheds for modeling purposes. The main considerations in the subdivision process were watershed topography; location of obstructions, problem areas, and tributary confluences; as well as the grouping of portions of the watershed with similar hydrologic characteristics located in close proximity to each other. The input parameters required to create the subarea elements in the HEC-HMS hydrologic model include: slope, Soil Conservation Service (SCS) or Natural Resources Conservation Service (NRCS) curve numbers, lag, longest flow paths, and subarea centroids. In addition to the subarea characteristics, parameters are included in the hydrologic model, which define channel characteristics of the Trout Creek and its tributaries, such as, channel length, slope, and Muskingum routing. Each of these parameters were generated with GIS using data collected for this study and then exported to the Trout Creek watershed HEC-HMS model.

Points of interest area selected at important points in the watershed where quantification of the flow is of particular significance. The reason these points of interest are selected is to provide watershed-wide runoff control through effective control of runoff from individual subareas. Thus, control of stormwater runoff in the entire watershed can be achieved through stormwater management in each subbasin.

The modeling process addresses:

- Peak discharge values at various locations along the stream and its tributaries;
- Time to peak for the above discharges;
- Runoff contributions of individual subareas at selected downstream locations; and
- Overall watershed timing.

C. Calibration

In order to simulate storm flows for a watershed with confidence and reliability, the computer model requires calibration. The calibration process involves "fine tuning" the model to provide the most accurate representation of the real runoff and timing conditions of a watershed thus ensuring that the interaction of hydrographs from various subareas combine to achieve the target flows at the calibration points. Hydrographs are simply a plot of time versus flow in cubic feet per second. Calibration of a model involves the adjustment of input parameters (within acceptable value ranges) to reproduce the recorded or projected responses of a range of storm events.

When actual storm event data is available (i.e. stream flow and rain data), this information can be input into the model to produce simulated "hydrographs" and compared to observed hydrographs to calibrate the model. To simulate a specific event, antecedent moisture conditions and rainfall distribution must be duplicated in the model input. Adjustments to other parameters are made to

attempt to duplicate hydrograph shapes and peak flow rates at points in the watershed where flow measurements were recorded. The USGS manages many stream gages, which record flow over time, throughout the U.S. In order to utilize actual stream flow and rain data for calibration, sufficient data must be available. Rain gages must be in close proximity to the watershed so that actual rainfall conditions from these gages are representative of the actual rainfall that occurs over the watershed. Localized events, snowmelt, and unique conditions are typically not used for calibration due to their unique circumstances. Unfortunately, a USGS stream gage is not located within the Trout Creek watershed. However, a stream Gage was found within the adjoining Valley Creek watershed. It is located at the PA Turnpike Bridge near Valley Forge, PA and has a drainage area of approximately 21.0 square miles. The gage number and the period of record for the gage is indicated in Table III-1.

TABLE III-1
USGS Stream Gage Closest to the Trout Creek Watershed

USGS Gage No.:	Location	Period of Record
01473169	Valley Creek at PA Turnpike Bridge near Valley Forge, PA.	1982-current

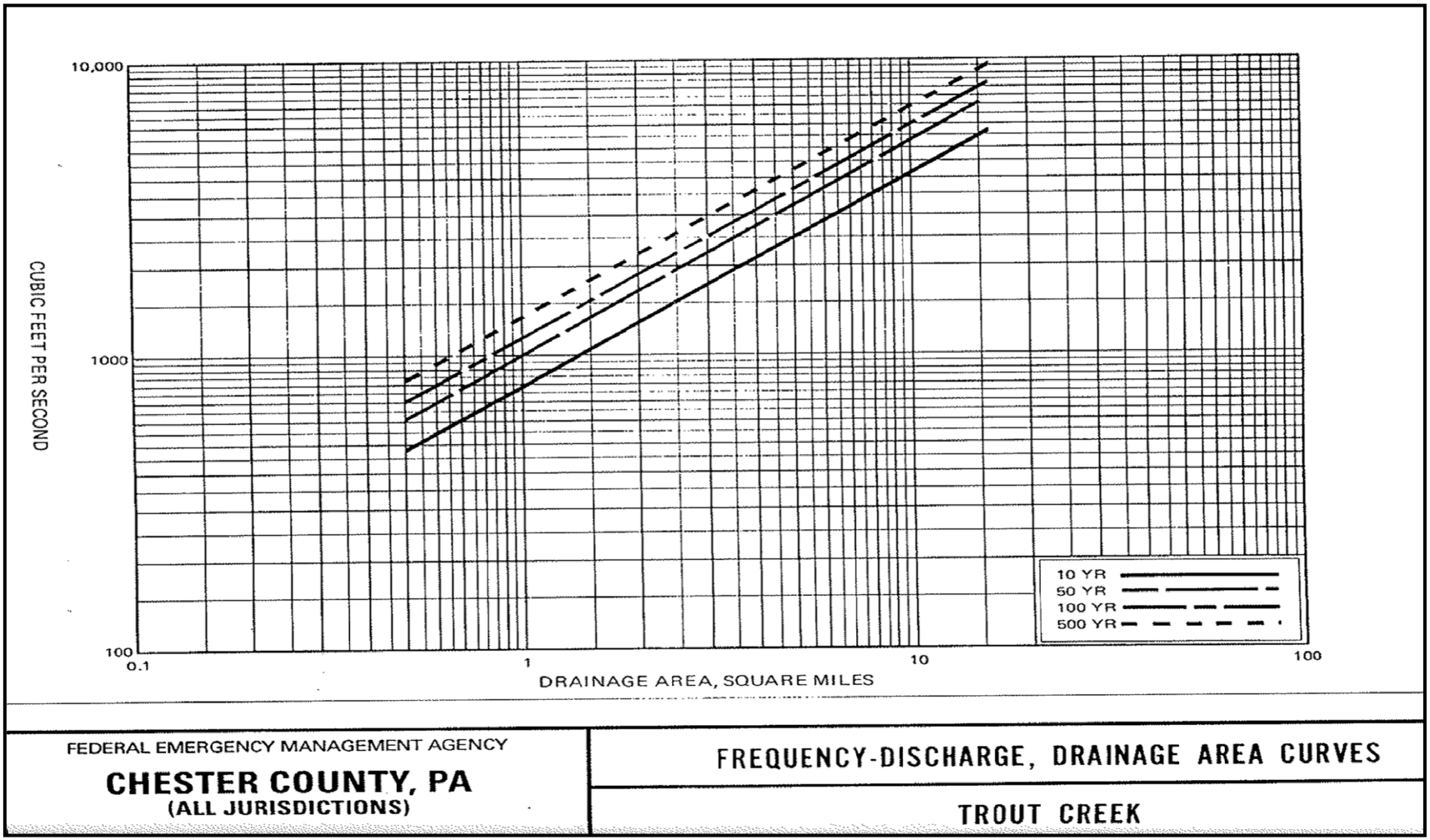
The observed hydrograph data from Valley Creek stream gage could not be used directly for the Trout Creek calibration. However, a statistical frequency analysis of the peak flows, (Log Pearson Type III) was performed on the Valley Creek gage data and transposed to the Trout Creek watershed. The results of this analysis after adjusting for differences between the drainage area for the Trout Creek watershed and the Valley Creek watershed are located in Table III-2.

TABLE III-2
Trout Creek Flows Determined from Transposition of the Valley Creek Stream Gage Flows

Drainage Area (sq. miles))	Peak Discharge (cfs)		
	10-Year	50-Year	100-Year
8.8	1,488	2,627	3,272

Since the ideal situation for calibration (stream flow data from the Trout Creek with at least ten years of flow data) was not attainable for the Trout Creek Watershed and the drainage area ratio between the Valley Creek stream gage and the Trout Creek watershed is somewhat large, another method of calibration was needed to use in conjunction with the transposition of stream gage data from the Valley Creek. Therefore, flow data contained in the Chester County Flood Insurance Study, dated March 17, 2002 was inspected for possible application in the calibration of the Trout Creek model. The FIS published by FEMA contains a Frequency-Discharge-Drainage Area Curve developed from regionalized frequency data based upon the statistical analysis of stream flow records from stream gages located in the area and operated by the USGS. A copy of the figure contained in the FIS is shown in Figure III-1. Although the curve extends up to 15 square miles the total drainage area of the Trout Creek watershed is 8.8 square miles. The reason the curve extends to a point larger than the size of the watershed is because the curves were developed from regionalized frequency curves based upon streamflow records from a group of gages located within the area. Therefore, even though the stream gages for surrounding watersheds may have had drainage areas significantly greater than the Trout Creek, the flow data from these gages was used to create FEMA's Frequency-

Figure III-1
FEMA FIS Frequency-Discharge, Drainage Area Curve



Discharge-Drainage Area Curve for the Trout Creek. A summary of the discharges obtained from the FEMA curve is shown in Table III-3.

Table III-3
Summary of Flows from the FEMA FIS Curve

Drainage Area (sq. miles)	Peak Discharge (cfs)		
	10 -Year	50 -Year	100 -Year
0.5	480	610	700
1.00	780	1,000	1,200
2.00	1,030	1,060	1,080
5.00	2,450	3,200	3,600
8.80	3,750	4,800	5,500

In addition to obtaining flows from the two aforementioned methods, the National Streamflow Statistics (NSS) program, developed by USGS, was accessed to obtain watershed characteristics for the Trout Creek watershed. These watershed characteristics were input into National Flood Frequency Program to obtain stream flows based upon the regression equations contained in USGS "Water-Resources Investigations Report 00-4189." Stream flows calculated from the WRIP-4189 regression equations, with both rural and urban equations are shown in Table III-4.

Table III-4
Flows from NFF Program

Drainage Area (sq. miles)	Peak Discharge (cfs)		
	10 -Year	50 -Year	100 -Year
Rural			
8.8	1,530	2,570	3,120
Urban			
8.8	1,670	2,620	3,160

Even though the rural and urban regression equations use different parameters to calculate the flows, the variations in flows between rural regression equation and the urban regression equation are relatively small. The rural regression equations uses the parameters of drainage area, flood region, percent urbanization, percent forest, percent underlain by carbonate rock and area controlled by swamps and lakes, while the urban equation uses the parameters of drainage area, channel slope, 2-year-2-hour rainfall intensity, basin storage, basin development and percent impervious surface. As the difference in flows between the rural equation and urban equation are relatively small it is believed that the diverse nature of the watershed, with significant commercial development at the bottom of the watershed and less intense rural development in the headwaters, makes both the rural and urban regression equations acceptable for calculating the flows in the watershed.

A side-by-side summary of the flows determined by all three methods is shown in Table III-5 along with a graphic representation of the results provided in Figure III-2. As can be seen, the flows vary somewhat from methodology to methodology, with the flow obtained from the FEMA Frequency-

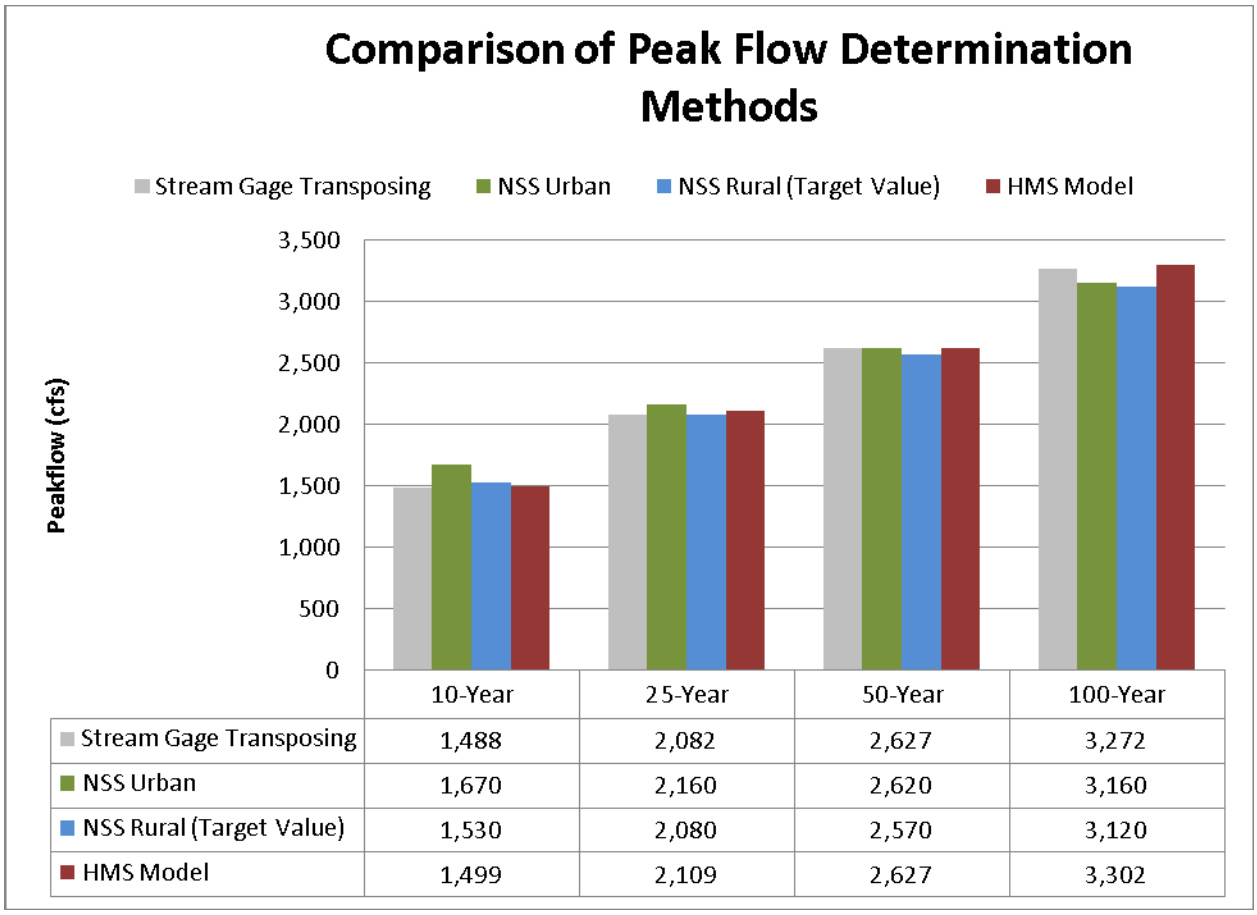
Table III-5
Comparison of Peak Flows Determined from Various Methods

	Peak Discharge (cfs)				
	Valley Stream Gage Transposition	**FEMA**	**NFF (Rural)**	**NFF (Urban)**	**HMS Model**
10-Year	1,488	3,750	1,530	1,670	1,499
50-Year	2,627	4,800	2,570	2,620	2,627
100-Year	3,272	5,500	3,120	3,160	3,302

Discharge-Drainage area curve substantially different from the remainder of the flows. There are several reasons to be skeptical of the higher FEMA flows. First, the FEMA flows used data from several gages dispersed throughout the region instead of data specific to the Trout Creek watershed or northeast Chester County alone. Some of these gages may be located in areas without carbonate geology and therefore would have higher runoff than areas such as the Trout Creek watershed which contains a large area with carbonate geology. Second, the FEMA data is based on Water Resource Council Bulletin 15, which was published in 1967. Since the issuance of this document the Water Resource Council has superseded Water Resource Bulletin 15 with other technical guidelines for evaluating surface water hydrology. Third, the data used to produce the FEMA flow values are based on a shorter period of record than the Valley Creek transposition and the regression equations developed in the NFF program. Fourth, both the transposed Valley Creek gage data and the NFF program use data and characteristics specific to Trout Creek and northeast Chester County, which are based on the latest hydrologic technical methods, and furthermore use a larger data set than what was used to develop the FEMA flows. As the flows computed based upon the regression equation contained in WRIP-4189 are reasonably close to the flows determined by the frequency analysis and transposition of the Valley Creek stream gage data, these flows developed from the regression equations were used to complete the calibration of the Trout Creek hydrologic model.

Several potential calibration parameters are available to calibrate the hydrologic model within HEC-HMS. These include initial abstraction, surface roughness, subbasin time of concentration, runoff curve number, hydrograph routing velocity, and travel time. Prior to completing the calibration process several trial runs were initially made to complete a sensitivity analysis to determine the hydrologic response of the watershed model to each of these parameters. From these runs, it was determined that the initial rainfall abstraction and subbasin travel time, were the most sensitive parameters available to calibrate the model. Therefore, the values representing these calibration parameters could be modified, as needed, within an acceptable range of values for subbasins with similar land cover, hydrologic soil groups and slopes, to arrive at flow values that are reasonably close to the values calculated by the regression equations and the gage analysis.

Figure III-2
Graphical Comparison of Peak Flows Determined from Various Methods



In addition to the outlet of the watershed, two other calibration points were selected to further calibrate upstream portion of the model located in Tredyffrin Township. These additional calibration points are located downstream of the confluence of the Main Stem of the Trout Creek and the tributary east of the Gateway Shopping Center (HEC-HMS ID J150) and on the Main Stem of the Trout Creek in the vicinity of Richards Road (HEC-HMS ID J210).

Table III-6

Flows at Additional Calibration Points

	10-Year	**50-Year**	**100-Year**
Downstream of the Gateway Shopping Center (J150)			
NSS*	801	1,230	1,470
HEC_HMS	531	1,160	1,523
In the Vicinity of Richards Road (J210)			
NSS*	1,570	2,410	2,920
HEC-HMS	1,370	2,401	3,039
Outlet of Trout Creek to Schuylkill River (OutletWS)			
NSS*	1,670	2,620	3,160
HEC-HMS	1,499	2,627	3,302

*NSS under urbanized condition

D. Model Results

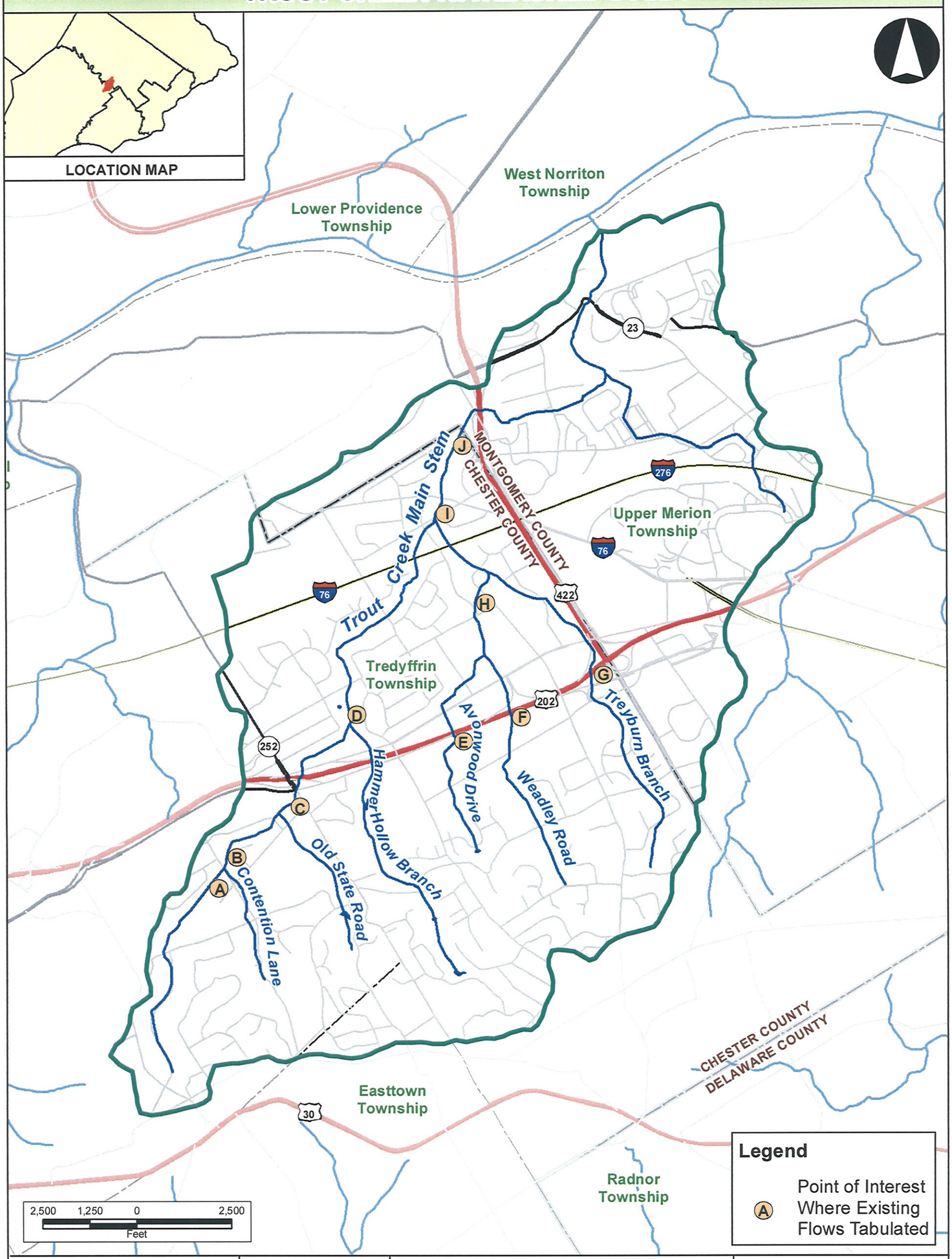
The benefit of the creating a watershed hydrologic model is that the flow from any single subarea or combination of subareas can easily be obtained for all storms and events in the model. Table III-7 contains flow data obtained from the hydrologic model for several key points dispersed throughout the Tredyffrin Township portion of the Trout Creek watershed. Generally the points of interest selected move from the western portion of the watershed to the eastern portion of the watershed, and then to the downstream sections of the watershed near the Township line. A Point of Interest Map shown in Map III-2 identifies the location of points of interest (P.O.I) shown in the table. The hydrologic model and the data it generates will be useful in evaluating stormwater management BMPs proposed for application in the watershed.

Table III-7

Trout Creek Watershed Hydrologic Model - Existing Condition Flows

P.O.I ID	Location	HMS ID	Branch	Flow (cfs)				
				2-Year	10-Year	25-Year	50-Year	100-Year
A	Old State Road	W910	Main Stem	14	103	176	237	317
B	Confluence of Tributaries North of Contention Lane	J140	Main Stem	35	247	419	555	735
C	Upstream of Route 202 Crossing (Western Most Crossing of Main Stem)	J145	Main Stem	48	339	576	774	1033
D	Confluence of Tributaries Downstream of Gateway Shopping Center	J150	Main Stem	143	531	871	1160	1523
E	Route. 202 Crossing of the Avonwood Branch	Userpoint2	Avonwood	11	72	120	156	204
F	Route 202 Crossing of the Weadley Branch	WeadleyBR	Weadley	21	110	176	226	294
G	Route 202 Crossing of Drummers Lane Tributary	Userpoint4	Drummers	70	142	221	302	406
H	Intersection of Walker and Glenhardie Roads (Downstream of the Richter Property)	RichterProp	Walker	189	408	528	612	735
H	Confluence of Tributaries Northeast of Old Eagle School Road and Walker Road Intersection	J188	Drummers	358	809	1070	1276	1568
I	Richards Road Culvert	J210	Main Stem	515	1370	1925	2401	3039
J	Township Line	J215	Main Stem	517	1385	1950	2434	3077

TREDYFFRIN TOWNSHIP
TROUT CREEK WATERSHED STUDY



Map III-2
POINT OF INTEREST MAP

Prepared For:
Tredyffrin Township
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Legend
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