The Kentucky Nutrient Model (KYNM)

Developed by the
Kentucky Water Resources Research Institute

Prepared for the
Kentucky Department of Environmental Protection (KYDEP)
Division of Water

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1.0 Introduction

Computational models for analyzing the hydrologic and water quality response of a watershed have been used for decades, beginning in the early 1960's with the development of the Stanford Watershed Model (SWM) by Crawford and Linsey (1966). By the 1970s, the SWM was refined by Hydrocomp which then produced the Hydrocomp Simulation Program (HSP). Following the passage of the Clean Water Act in 1972, EPA began to fund research in the development of more sophisticated models that also included water quality considerations. This effort resulted in the development of the Agricultural Runoff Management (ARM) model (Donigian and Davis, 1978) and the Nonpoint Source (NPS) model (Donigian and Crawford, 1976). In the late 1970's Hydrocomp received a grant from EPA to integrate HSP with ARM and NPS which resulted in the development the Hydrological Simulation Program - Fortran (HSPF). HSPF has seen extensive use and application in the development of Total Maximum Daily Loads (TMDLs) (Johanson, et al., 1980).

The 1970s produced several other continuous simulation models for use in analyzing water quality loads from stormwater runoff and Combined Sewer Overflow (CSO) discharges. Two of the more widely used models were the Stormwater Management Model (SWMM) developed by Metcalf and Eddy, et al. (1971); and the Storage, Treatment, Overflow, Runoff Model (STORM) developed by the US Army Corps of Engineers (1976). SWMM employs Green Ampt or Hortonian Infiltration methods along with a nonlinear storage method for generating stormwater runoff. Water quality simulation is handled using standard pollutant loading and wash-off functions. STORM uses National Resources Conservation Service (NRCS) hydrology and unit hydrograph methods for runoff generation along with build-up and wash-off formulations for water quality modeling.

With an increased emphasis on TMDLs in the 1990's, EPA sponsored the development of a comprehensive modeling system for use by the engineering and regulatory community. The final system was BASINS (Better Assessment Science Integrating Point and Nonpoint Sources), developed to integrate existing federal databases of hydrologic and water quality data into a Geographical Information System (GIS) based modeling environment (EPA, 1996). The original current version of BASINs incorporated three primary models: HSPF, QUAL2E (1985), and TOXIROUTE (GSC, 1993).

In 2005, Tetra Tech formally introduced the Loading Simulation Program in C++ (LSPC) for the simulation of watershed processes which include both point and nonpoint pollution. The system integrates GIS tools, data management capabilities, a postprocessor, and a dynamic watershed model within a common Windows environment (Shen et al., 2005). LSPC uses HSPF to model hydrology and water quality.

The Kentucky Nutrient Model (KYNM) was developed in 2014 to provide the Kentucky Division of Water (KYDOW) with a simplified tool for use in developing nutrient based TMDLs and in evaluating different nutrient management strategies. This report provides a brief overview of the KYNM along with a discussion of the validation of the model against observed hydrology and water quality data, and a comparison of the model results against the results obtained by the LSPC model developed by Tetra Tech for the Floyds Fork Watershed.

2.0 Tetra Tech Floyds Fork Watershed Model

In 2010, Tetra Tech was contracted by Region 4 EPA to develop an LSPC and Water Quality Analysis Simulation Program (WASP) model for the Floyds Fork watershed for the Kentucky Division of Water for developing a nutrient and organic enrichment TMDL. Tetra Tech produced an initial calibrated model of the watershed along with an accompanying report on December 30, 2011. Following an initial series of public presentations about the model by Region 4 and Tetra Tech in 2011, several stakeholders expressed concerns about some of the assumptions being made in the development of the model. This resulted in the formation of technical advisory committee in 2012 that included several subcommittees made up of interested stakeholders. Based on feedback received from the members of the technical advisory committee, the LSPC model went through several subsequent revisions, culminating in Revision 6 on May 14, 2013. A copy of the final report can be found at: http://water.ky.gov/watershed/pages/tac.aspx.

The LSPC model is a very complex continuous simulation model, that analyses rainfall, runoff, and water quality loadings using a daily time step for a multi-year simulation horizon. The model is capable of modeling both point and non-point sources of pollution. In applying the model to the Floyds Fork watershed, the watershed was ultimately subdivided into 202 sub-watersheds to provide appropriate hydrologic conductivity (see Figure 2.1). The locations of the major point sources in the basin are provided in Figure 2.2. The assumed flows and nutrient concentrations for these stations are shown in Table 2.1. The locations of the observed sanitary sewer overflows in the basin are shown in Figure 2.3.

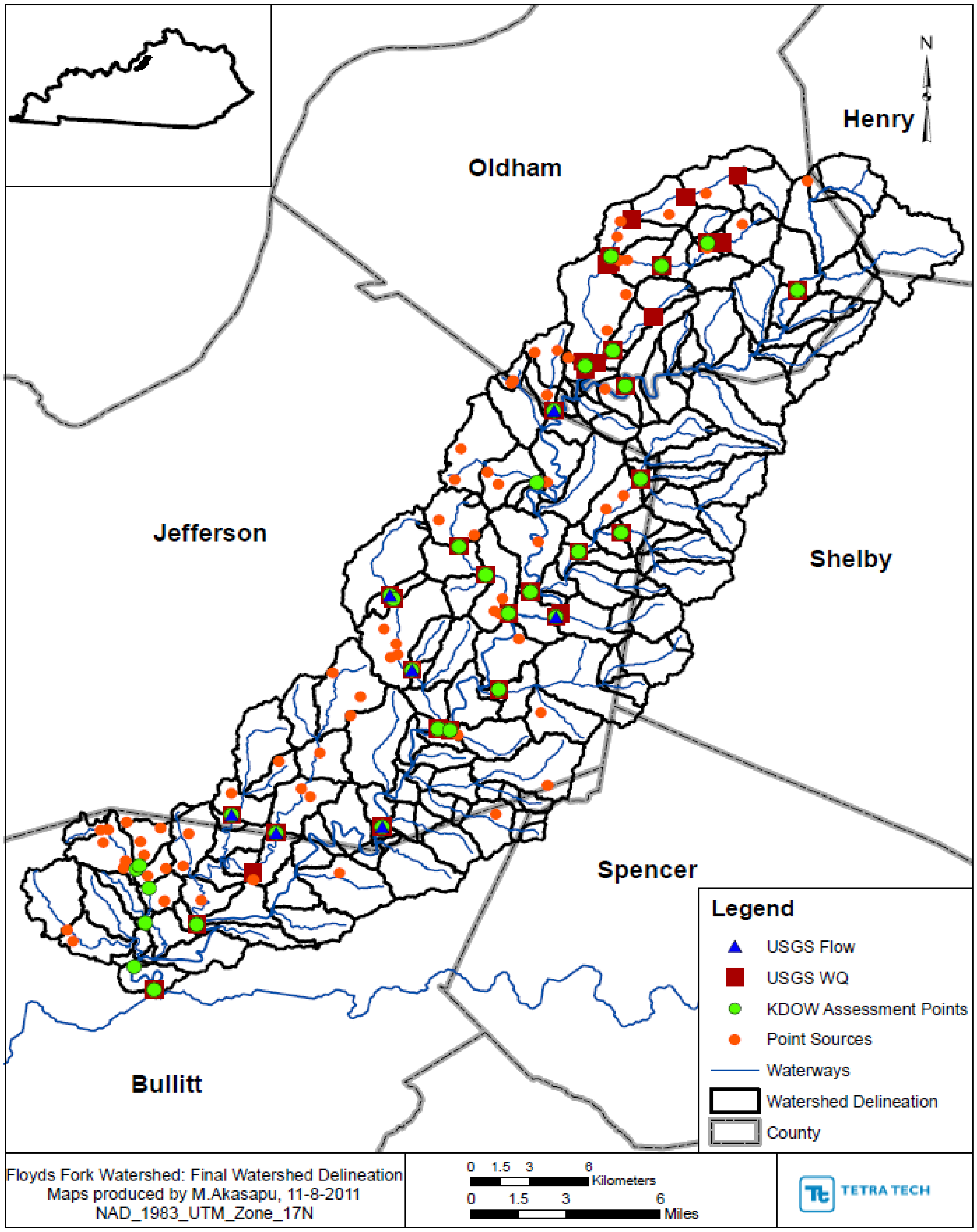
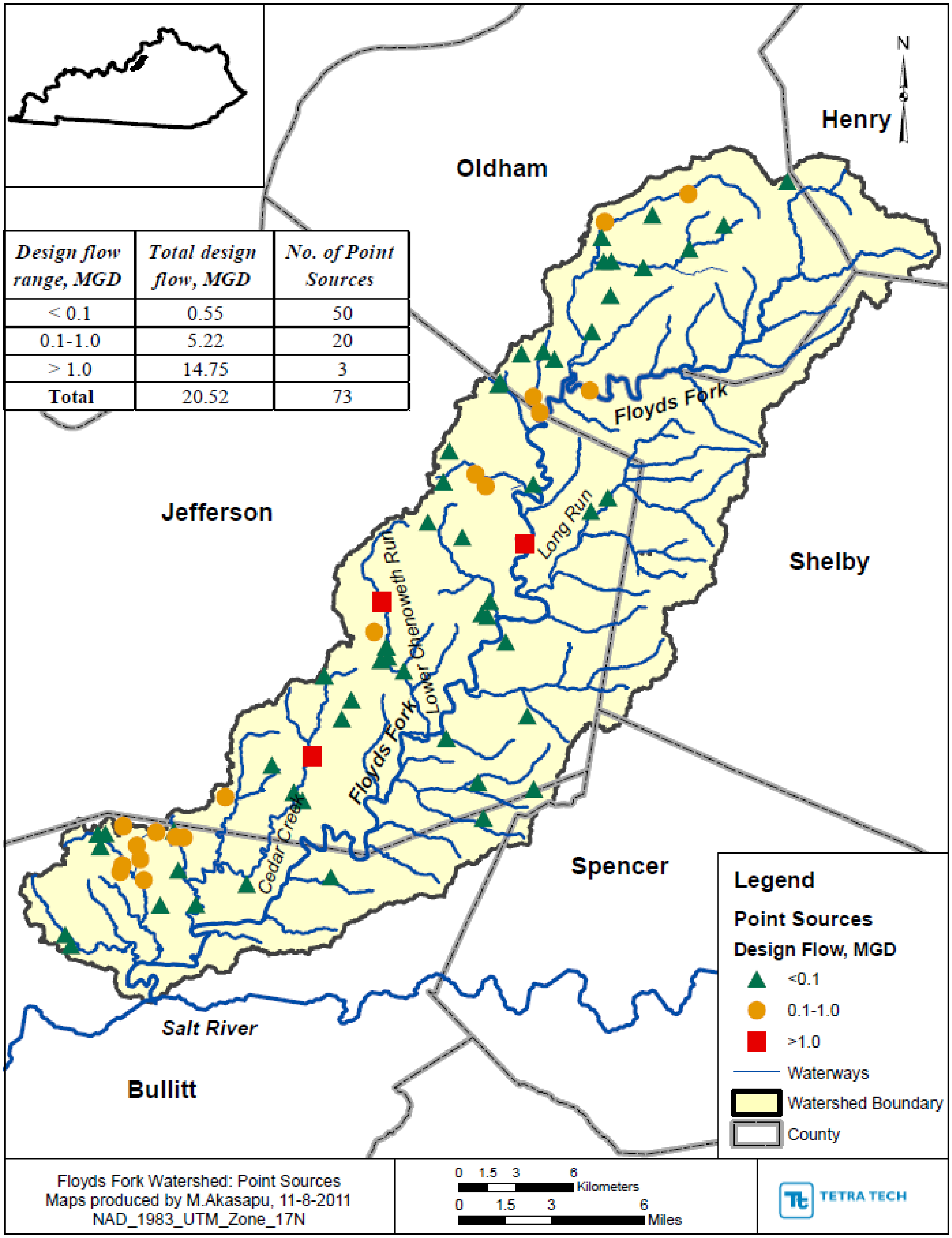


Figure 2.1 Sub-delineated Coverage for the Floyds Fork Watershed (Tetra Tech, 2013)



Design flow range, MGD	*Total design flow, MGD*	*No. of Point Sources*
< 0.1	0.55	50
0.1-1.0	5.22	20
> 1.0	14.75	3
Total	20.52	73

Figure 2.2 Permitted Discharges to the Floyds Fork Watershed (Tetra Tech, 2013)

Table 2.1 Assumed Flows and Nutrient Concentrations for Point Sources (Tetra Tech, 2013)

KPDES Permit #	Facility Name	Facility Type	Des Q (MGD)	Avg Q (MGD)	TN	TP
KY0020001	LaGrange STP	Municipal	0.775	0.833	Sum	DMR
KY0023078	Whispering Oaks	Private	0.125	0.056	Sum	DMR
KY0024724	Ashe Avenue STP	Subdivision	0.3	0.300	Sum	DMR
KY0025194	Jefferson WQTC MSD	Municipal	4	3.699	Calculated	DMR
KY0026972	Bates Elementary School	Schools	0.013	0.013	8	1.2
KY0029416	Mcneely Lake WQTC MSD	Subdivision	0.205	0.095	Sum	DMR
KY0029441	Green Valley Apartments	Private	0.03	0.034	Sum	2
KY0029459	Chenoweth Hills WQTC MSD	Subdivision	0.2	0.168	Calculated	DMR
KY0031712	Starview Estates WQTC MSD	Subdivision	0.1	0.101	Calculated	DMR
KY0031798	Cedar Lake Lodge Inc.	Private	0.02	0.014	Sum	DMR
KY0034151	Hillview Sewer System Plant 1	Subdivision	0.231	0.174	DMR	DMR
KY0034169	BCSD Hillview 2	Subdivision	0.317	0.338	Sum	DMR
KY0034177	BCSD Hillview 3	Subdivision	0.148	0.086	Sum	DMR
KY0034185	Pioneer Village Sewer Plant 1	Subdivision	0.31	0.215	Sum	1.2
KY0034801	BCSD Bullit Hills Subdivision	Subdivision	0.35	0.209	Sum	DMR
KY0036501	Berrytown WQTC MSd	Subdivision	0.075	0.077	Calculated	DMR
KY0038610	Hunters Hollow Subdivision	Subdivision	0.24	0.208	Sum	DMR
KY0039004	KJC Institute for Women	Private	0.125	0.053	Sum	DMR
KY0039870	Lakewood Valley STP	Subdivision	0.1	0.100	8	2.5
KY0040193	Overdale Elemenatry School	Schools	0.01	0.010	8	1.2
KY0042153	Cedar Ridge Camp Inc	Private	0.005	0.004	Sum	DMR
KY0042226	Chenoweth Run WQTC	Subdivision	0.47	0.408	Calculated	DMR
KY0044342	Lake of the Woods WQTC	Subdivision	0.044	0.035	Calculated	DMR
KY0054674	Lockwood Estates STP	Subdivision	0.045	0.046	Sum	DMR
KY0060577	Country Village STP	Subdivision	0.06	0.069	Sum	DMR
KY0069485	Friendship Manor	Private	0.017	0.003	Sum	DMR
KY0072168	Big Valley MHP	Private	0.07	0.009	Sum	4
KY0073059	Camp Shantituck Girl Scout Camp	Private	0.01	0.010	4	4
KY0076732	Centerfield Elementary School	Schools	0.01	0.010	8	1.2
KY0076741	Cherytree Apartments	Private	0.008	0.007	4	4
KY0077666	The Crossings Golf Club	Private	0.005	0.002	Sum	4
KY0077674	Lake Columbia	Subdivision	0.012	0.012	8	1.2
KY0086843	Middletown Industrial Park	Private	0.16	0.088	Sum	4
KY0090956	Persimmon Ridge Phase 14	Subdivision	0.142	0.075	Sum	DMR
KY0094307	BCSD Willabrook Sanitation	Subdivision	0.12	0.058	Sum	DMR
KY0098540	Cedar Creek WQTC MSD	Municipal	7.5	4.219	Calculated	DMR
KY0100994	Bullit County Board of Education	Schools	0.043	0.006	Sum	1.2
KY0101419	Kingswood	Subdivision	0.04	0.040	8	1.2
KY0101885	Riedling Building	Private	0.001	0.001	Sum	DMR
KY0102784	Floyds Fork WQTC MSD	Municipal	3.25	2.009	Calculated	DMR
KY0102873	Brooks Mobile Home RV Park	Private	0.015	0.004	Sum	DMR
KY0103110	Buckner STP	Municipal	0.135	0.143	Sum	DMR
KY0103900	Hillview STP	Municipal	0.15	0.009	Sum	DMR
KY0105384	Resident 1	Private	0.001	0.001	Sum	4
KYG400010	Resident 2	Private	0.001	0.001	4	4
KYG400028	Resident 3	Private	0.001	0.001	5	2
KYG400032	Resident 4	Private	0.001	0.001	4	4
KYG400082	Resident 5	Private	0.001	0.001	4	4
KYG400105	Resident 6	Private	0.001	0.001	4	4
KYG400112	Resident 7	Private	0.001	0.001	4	4
KYG400128	Resident 8	Private	0.001	0.001	4	4
KYG400137	Resident 9	Private	0.001	0.001	4	4
KYG400139	Resident 10	Private	0.001	0.001	4	4
KYG400147	Resident 11	Private	0.001	0.001	4	4
KYG400150	Resident 12	Private	0.001	0.001	4	4
KYG400153	Resident 13	Private	0.001	0.001	10	2
KYG400161	Resident 14	Private	0.001	0.001	4	4
KYG400166	Resident 15	Private	0.001	0.001	4	4
KYG400177	Resident 16	Private	0.001	0.001	4	4
KYG400189	Resident 17	Private	0.001	0.001	4	4
KYG400194	Resident 18	Private	0.001	0.001	5	2
KYG400235	Resident 19	Private	0.001	0.001	4	4
KYG400250	Resident 20	Private	0.001	0.001	4	4
KYG400251	Resident 21	Private	0.001	0.001	4	4
KYG400259	Resident 22	Private	0.001	0.001	10	2
KYG400289	Resident 23	Private	0.001	0.001	4	4
KYG400329	Resident 24	Private	0.001	0.001	4	4
KYG400403	Resident 25	Private	0.001	0.001	4	4
KYG400420	Resident 26	Private	0.001	0.001	4	4
KYG400613	Resident 27	Private	0.001	0.001	4	4
KYG401875	Resident 28	Private	0.001	0.001	4	4
KYG401905	Resident 29	Private	0.001	0.001	4	4
KYG402142	Resident 30	Private	0.001	0.001	10	2

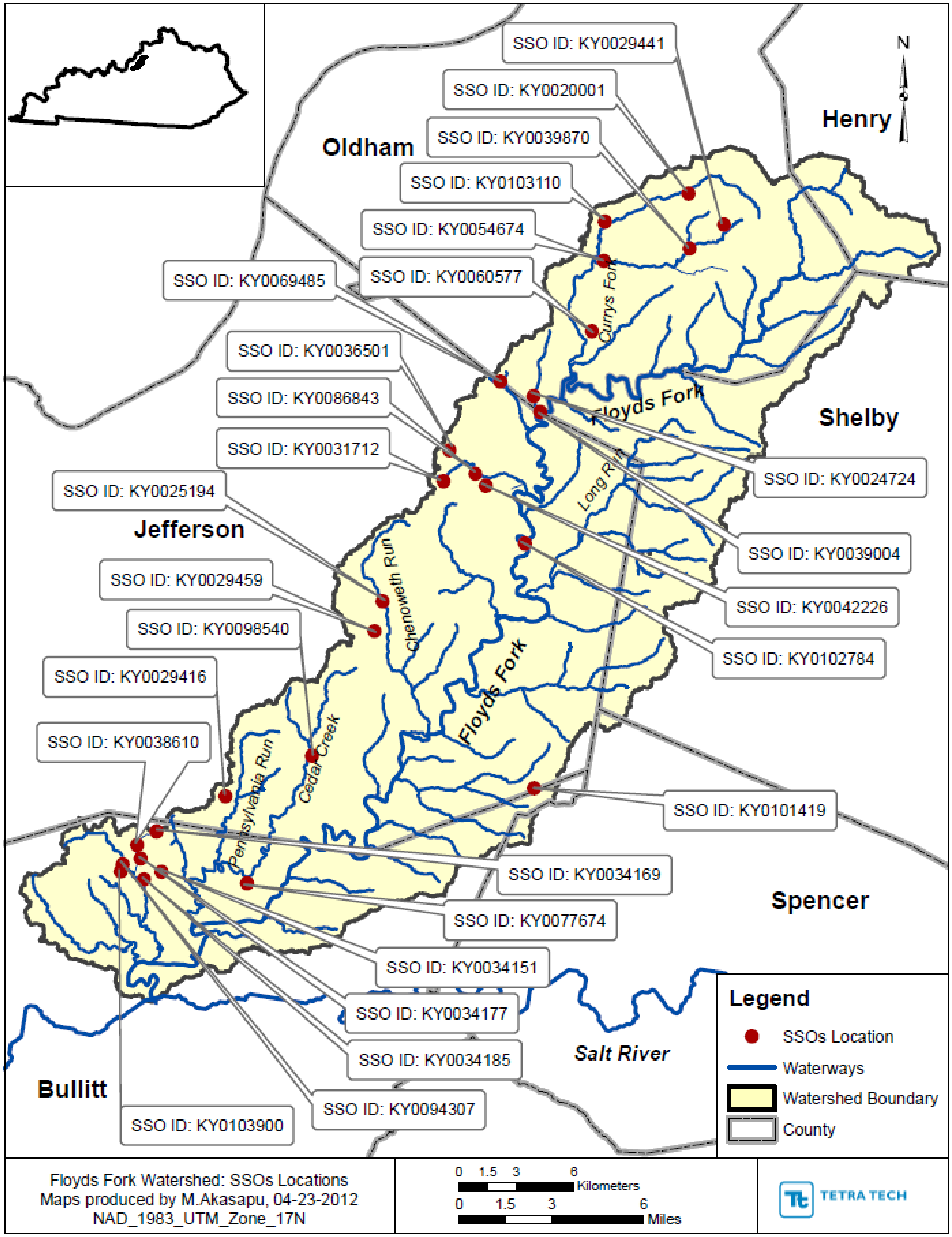


Figure 2.3 Identified Sanitary Sewer Overflows in the Floyds Fork Watershed (Tetra Tech, 2013)

The Floyds Fork LSCP model was calibrated and validated using data obtained from the USGS, the Kentucky Division of Water, and the Louisville Metropolitan Sewer District (MSD). The USGS gauging stations used in calibrating and validating the hydrologic parameters of the model are shown in Figure 2.4. The USGS and MSD water quality monitoring stations that were used in calibrating and validating the water quality parameters of the model are shown in Figures 2.5 and 2.6.

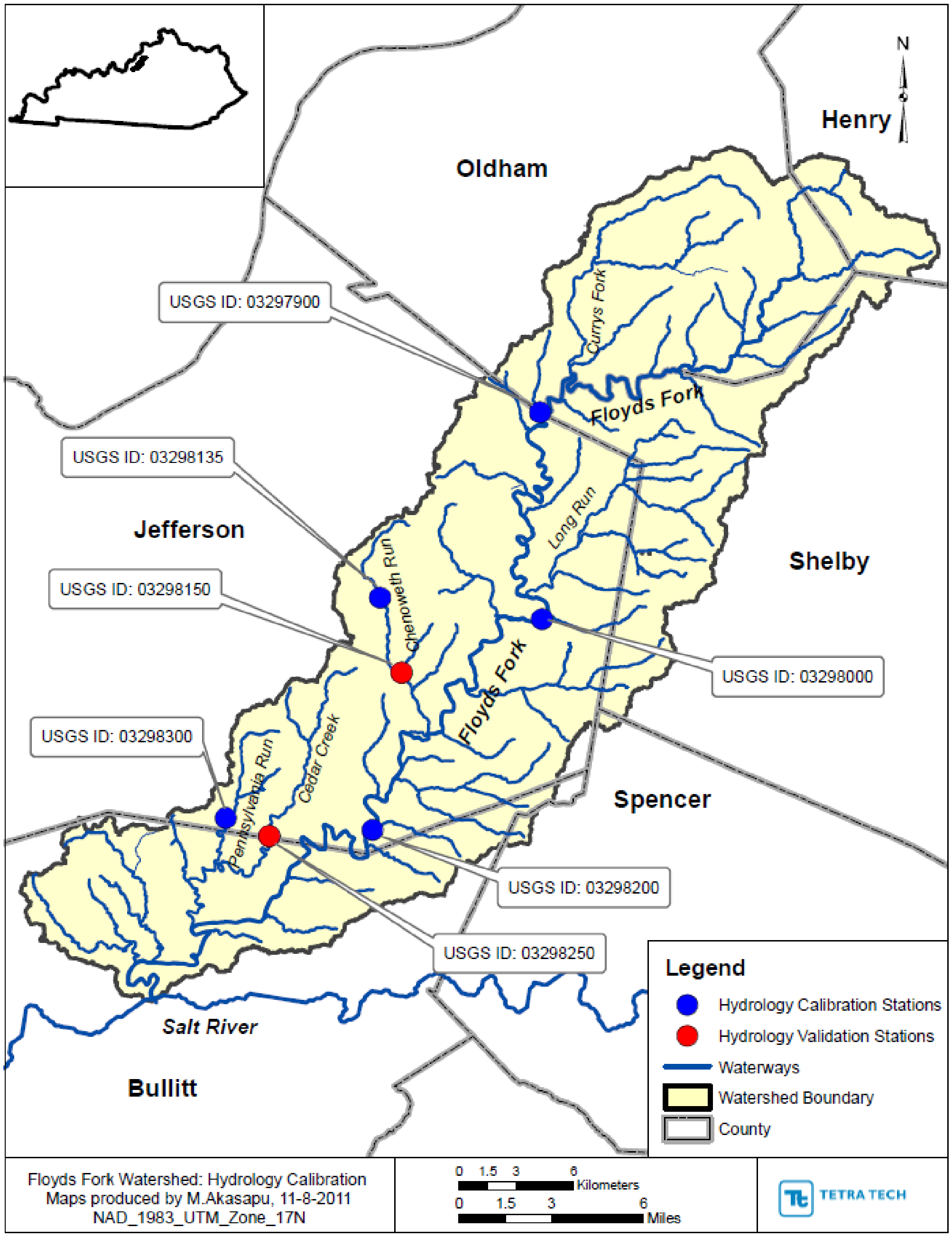


Figure 2.4 Calibration and Validation Stations used in LSPC Model (Tetra Tech, 2013)

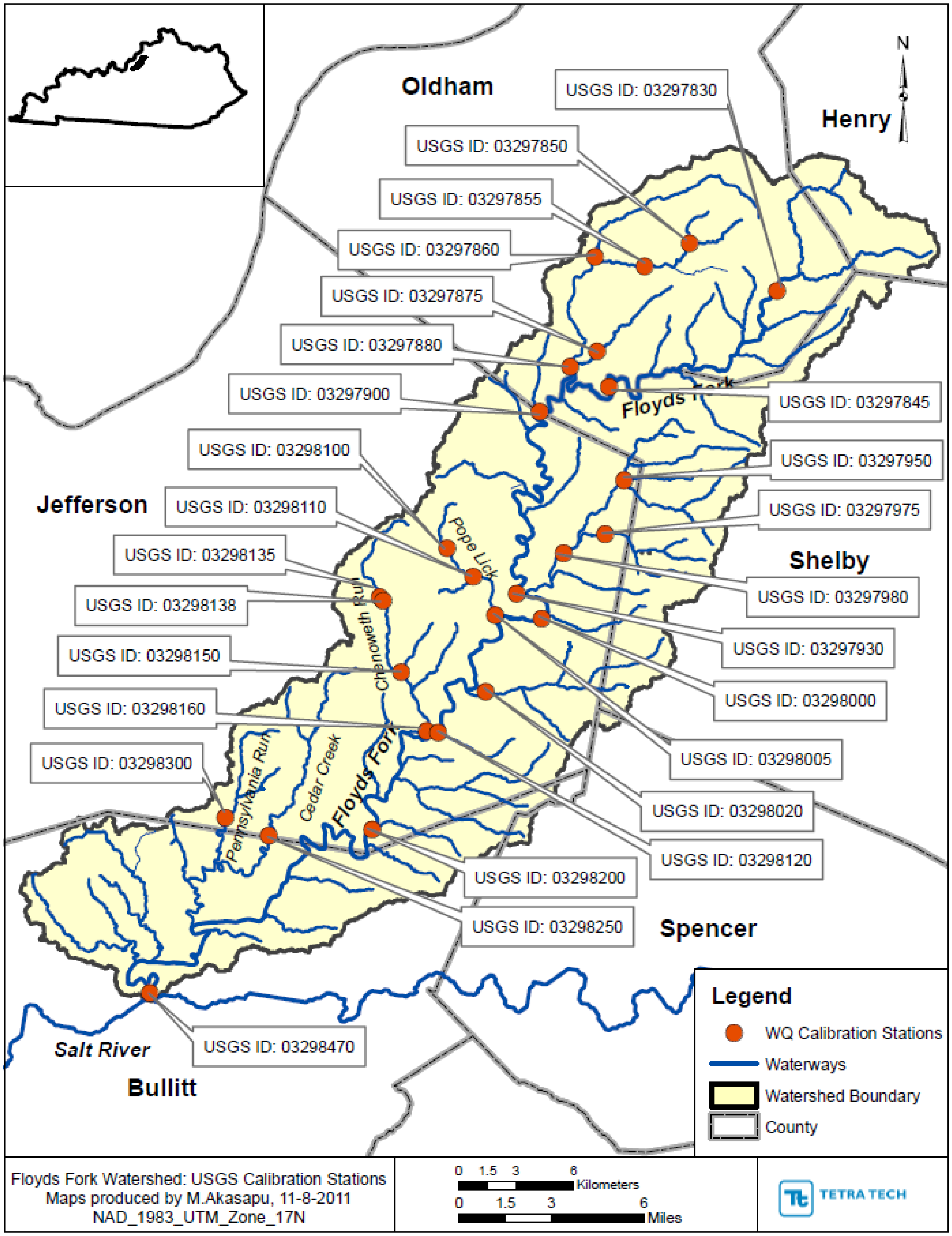


Figure 2.5 Water Quality Calibration Stations used in LSPC Model (Tetra Tech, 2013)

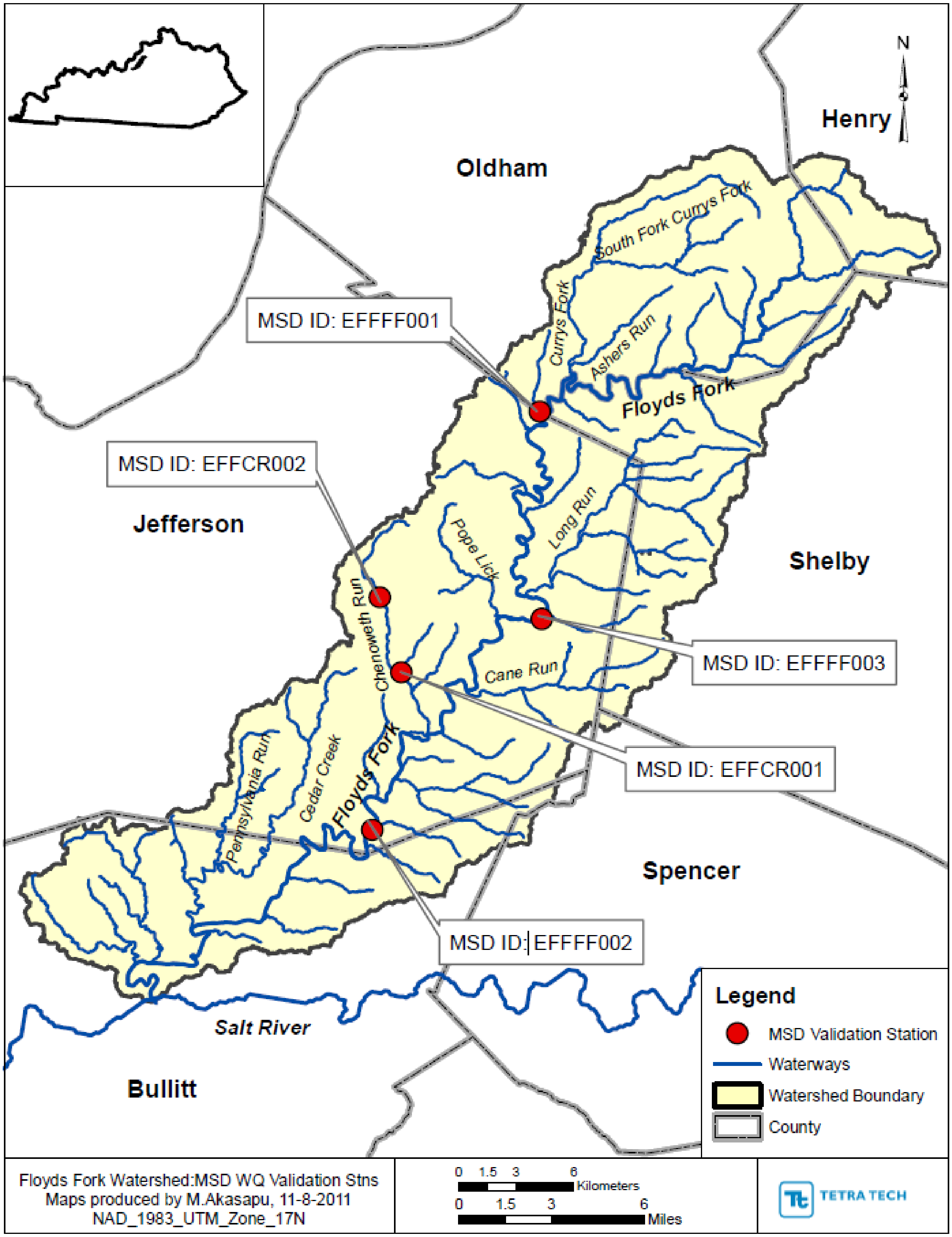


Figure 2.6 Water Quality Validation Stations used in LSPC Model (Tetra Tech, 2013)

3.0 Overview of the KWRRI Kentucky Nutrient Model

Faced with the challenge of using a very complex model like LSPC to develop a comprehensive nutrient and organic enrichment TMDL for the Floyds Fork watershed, and based on the feedback received from stakeholders during the model development process, the KDOW began to investigate potential ways to develop simpler screening tools that could be used to identify acceptable nutrient management strategies. This analysis ultimately resulted in two contracts with the Kentucky Water Resources Research Institute. The first contract was to identify and assess possible nutrient management strategies for the watershed as identified by the stakeholders themselves. This contract resulted in a three year study that produced a comprehensive report documenting 20 different potential BMPs for use in the Floyds Fork watershed (see www.uky.edu/WaterResources/FF). A second contract was initiated to investigate the development of a nutrient management tool for the Floyds Fork watershed. The original goal of this project was the development of a spreadsheet model that could be used to evaluate the relative trade-off between point and non-point source BMPs for the basin, taking into consideration the relative cost and effectiveness of different BMP technologies. The model was envisioned to be a lumped parameter model that would provide general estimates of total nitrogen and total phosphorus on an annual basis using annual load export coefficients for different landuses. The original vision was for this model to be used to screen potential management strategies that could then be tested in more detail using a comprehensive model such as LSPC.

Based on an initial review of the model, KDOW decided to investigate if the model could be modified and expanded to allow for its use in direct TMDL development for smaller watersheds that might not require the complexity of an LSPC model. This vision was consistent with the 2001 National Research Council review of the EPA TMDL program which concluded:

- "...the model selection criteria concerning cost, flexibility, adaptability, and ease of understanding all tend to favor simple models."
- "...USEPA should support research in the development of simpler models that can be fully parameterized from the available data."

As a consequence, the initial management model was modified to accommodate a daily time step along with NRCS runoff hydrology and an event mean coefficient based water quality model. Hydrologic and water quality transport was modeled using mass balance approaches along with linear reservoir models to accommodate temporal storage and simulate flow and mass attenuation. The model was ultimately expanded to include: 1) point source loads, including sanitary sewer overflows and septic systems, 2) non point source loads, including the ability to simulate multiple landuses, and 3) background loads, including groundwater, erosion, and air deposition. The final model was named the Kentucky Nutrient Model. Summaries of the model features and limitations are provided in Tables 3.1 and 3.2. Detailed instructions on how to build, calibrate, and apply the KYNM to a particular watershed are provided in the KMW user's manual.

The KYNM subdivides the hydrology and water quality of the watershed into three general categories: 1) point sources, 2) non-point sources, and 3) groundwater or baseflow sources. These are summarized in sections 3.2, 3.3, and 3.4 respectively.

Table 3.1 Summary of the features of the KYNM

Excel spreadsheet
Color coded sections to facilitate data entry and analysis
Lumped parameter model (watershed treated as one single unit)
MS4 and non-MS4 areas can be modeled separately
Daily time step
Year simulation period (although can be extended for multiple years)
Models point sources, non-point sources, and groundwater
Groundwater separation model for observed streamflow data
NRCS hydrology (accommodates varying soil moisture conditions)
Can accommodate multiple land use types (12)
Can accommodate multiple soil groups (4)
Event mean concentration water quality (variable EMCs based on antecedent rainfall)
Linear reservoir for time translation
Allows for sanitary sewer overflows (SSOs)
Allows for septic and failing septic system discharges
Allows for global adjustment factors for air deposition and erosion
Built in calibration statistics

Table 3.2 Limitations of the KYNM model

Lumped parameter model (may not be applicable for larger watersheds e.g. > 100 sqmi)
Does not consider spatial impacts of point sources within the watershed
Does not consider spatial/temporal impacts of landuse changes
Uses simplified NRCS hydrology
Uses simplified EMC water quality modeling
Does not explicitly model sinkholes, springs, water withdrawals (however these may all may be simulated via groundwater and SSO menus)

3.1 Watershed Delineation

The KYNM requires that the user delineate the watershed of interest so that the associated model input data can be located, synthesized, and input into the model. This can be done manually, using a topographic map, or digitally using GIS software such as ArcGIS or the USGS StreamStat program http://water.usgs.gov/osw/streamstats/kentucky.html. Once the watershed has been delineated, the user can determine the total watershed area as well as the dominant landuse and soil types within the watershed along with the location and magnitude of any point sources. Detailed instructions on how to perform these functions are provided in the KYNM User's Manual.

3.1 Modeling Rainfall and Streamflow Data

The KYNM requires daily point rainfall data and where available, daily streamflow data. These data are summarized below.

3.1.1 Rainfall Data

Daily rainfall data can be obtained from several websites as identified in Table 3.3. Instructions on how to access the data through the websites are provided in KYNM User's Manual.

Table 3.3 Sources of Point Rainfall Data

Site	Internet Link
NOAA	http://www.ncdc.noaa.gov/cdo-web/
UK Ag Weather Center	http://wwwagwx.ca.uky.edu/
USGS*	Ky.water.usgs.gov

* Note: Rainfall data collected at USGS streamflow stations. Precipitation data from these rain gauges are for informational purposes only. The data do not necessarily conform to the standards used by the National Weather Service.

Ideally, the point rainfall station should lie within the watershed, preferably at the center of the watershed. For larger watersheds it is preferable to use multiple stations and to obtain a weighted average daily rainfall using one of several potential methods such as the inverse distance weighted average method. Detailed instructions on how to apply this method to the rainfall data are provided in the KYMN User's Manual.

3.1.2 Streamflow Data

3.1.2.1 Gauged Watersheds

Daily streamflow data for gauged watershed in Kentucky can be obtained from the Kentucky U.S. Geological Science Center website: ky.water.usgs.gov. Details on how to access the data are provided in KYNM User's Manual. If the streamflow gauge is located upstream of the watershed outlet, an estimate of the discharge at the outlet can be obtained by simply multiplying the observed daily discharges by the ratio of the area upstream of the gauging station by the area of the total watershed (assuming the landuse and geology is fairly consistent). When the landuse is significantly different, the ratio may be modified by a weighting coefficient that takes the differences in to consideration. Detailed instructions on how to perform these calculations are provided in the KYNM User's Manual.

3.1.2.2 Ungauged Watersheds

If the watershed of interest does not have a gauge in the watershed, an estimate of the daily streamflow can be obtained using the daily discharges at a nearby station. Ideally the nearby station should be associated with a watershed whose area is within 50% of the total area of the ungauged watershed. Assuming the landuse and geology of the two watersheds are similar, a gross estimate of the daily discharge at the ungauged site can be obtained using the ratio of the watershed areas. A more accurate estimate of the daily streamflow can be obtained by developing a mathematical relationship or curve between the observed streamflow and the flows at the ungauged station (Chang and Ouarda, 2012).

3.2. Modeling Point Sources

Four different types of point sources may be modeled using KYNM. These include:

- Wastewater treatment facilities
- Sanitary sewer overflows
- Septic system discharges
- Springs

Each of these are briefly described in the following sections.

3.2.1 Wastewater Treatment Facilities

KYNM is configured to accommodate four types of wastewater treatment facilities. These include:

- Major Wastewater Treatment Facilities (> 1MGD)
- Minor Wastewater Treatment Facilities (< 1 MGD)
- Subdivisions and Schools
- Small Package Plants or Individual Residences

Each of these facilities can be modeled in the KYNM by the user specifying a flow and nutrient concentration for each point source. Three options are provided:

- Constant daily flow and concentration based on an annual average
- Constant monthly flow and concentration based on monthly averages
- Daily flows and concentrations

Where available, these data can be obtained from the EPA Discharge Monitoring Record (DMR) database (i.e. http://cfpub.epa.gov/dmr) or in some cases, directly from the utilities. In the absence of actual water quality data, the following concentrations may be assumed:

Table 3.4 Typical Effluent Concentrations for Point Sources

Facility	Typical Flow	TN (mg/L)	TP (mg/L)
Major Municipal	> 1 MGD	10	1.0
Minor Municipal	< 1 MGD	10	2.0
Subdivisions	< 0.4 MGD	10	2.0
Schools	<.04 MGD	10	2.0
Small Package Plants	< .1 MGD	20	4.0
Individual Residents	<.01 MGD	20	4.0

3.2.2 Sanitary Sewer Overflows

In addition to the normal loads from wastewater treatment facilities, additional loads to the stream may arise from the occurrence of sanitary sewer overflows (SSOs). Where available, flow data associated with SSOs can be obtained from the Kentucky Division of Water via Overflow Incident Reports. Sometimes this information may be obtained directly from the utility. KYNM provides an option for imputing the combined daily SSO discharges in a given watershed. The concentrations associated with these discharges may also be entered via an equation that allows for the concentrations to vary as a function of the SSO discharge. In the absence of data to support the development of such a relationship, the user may use the typical values provided in Table 3.5.

Table 3.5 Default Parameters for Sanitary Sewer Overflows (Tetra Tech, 2013)

Parameter	EMC (mg/L)
Total Nitrogen	40
Total Phosphorus	8

3.2.3 Septic System Flows

The KYNM also has an option for simulating point source loads from septic systems. Required input data includes: 1) the total number of households on septic systems, 2) the average number of persons per household (e.g. 2.8), 3) the amount of waste generated per person that is discharged to the septic system (e.g. 60 gal/day), and the average EMC for nitrogen and phosphorus. Typical EMC values are provided in Table 3.6.

Table 3.6 Default Parameters for Septic Systems (Tetra Tech, 2013)

Parameter	EMC (mg/L)
Total Nitrogen	.1263
Total Phosphorus	.1287

3.2.3.1 Average County Estimates of Number of Septic Systems

Most health departments will have some idea of the number of septic systems in their county. Alternatively, county estimates may be obtained from either US census data or from the Kentucky Infrastructure Authority (http://kia.ky.gov/).

The US Census Bureau determined the number of septic systems in each county as part of the 1990 census. Unfortunately, these data have not be collected in subsequent census. However, an estimate of the number of septic systems per county for later years can be obtained by multiplying by the ratio of the growth of population in each county.

A more accurate estimate of the number of septic systems per county may be obtained from the Kentucky Wastewater Management Report available on the Kentucky Infrastructure Authority website (KIA, 2014). This report provides the total number of households in a county, as well as the total number of households that are on public sewer. By subtracting the two numbers, an estimate of the number of septic systems may be obtained.

An average number per unit area can be obtained by dividing the total by the area of the county. Once this average number is obtained, the number of septic systems per watershed can be estimated by multiplying by the area of each watershed.

3.2.3.2 Normalized County Estimates of the Number of Septic Systems

A more accurate estimate of the number of septic systems per watershed can be obtained by subtracting the area associated with public sewers in a particular county from the total area of the county before determining the unit number per area as discussed above. The areas of public sewers in a county can be estimated from the maps in the Kentucky Wastewater Management Report (2014), or directly from the sewer line GIS shapefiles from the KIA Water Resource Information System (http://kia.ky.gov/wris/). In the later case, the shapefiles for all the sewer lines in a county can by overlaid onto a polygon of the county. A buffer can then be generated within ArcGIS around each of the lines (typically 300 to 500 feet). The total area of the buffered polygons can then be subtracted from the total area of the county to determine the normalized area of septic systems within the county. The total number of septic systems in the county can then be divided by this area to determine the number of septic systems per acre of the unsewered area of the county.

Once this number has been determined, the user can then overlay the buffered polygons of the sewer lines on top of the polygon boundary of the watershed. The user can then determine how many acres of the watershed are not covered by public sewers. Once this area is known, an estimate of the total number of septic systems within the watershed can be obtained by multiplying this number by the number of septic systems per acre.

3.2.4 Springs

If the watershed contains a significant spring, the user has the option to model the spring as a point source. Using the point source menus in KYNM, the user can give the spring either a constant flow or a time series flow from observed or synthesized data. The nutrient concentrations in the spring can likewise be set at constant values or estimated values as a function of some other parameter, e.g., the spring flow itself.

3.3 Non-Point Sources

3.3.1 Hydrology

The KYNM models stormwater runoff using standard NRCS hydrology theory (NRCS, 1997) for estimating the daily runoff of stormwater from different landuse-soil type combinations in response to a daily average rainfall depth. In this case, the watershed is divided into different polygons of common landuse and hydrologic soil type. Based on the landuse and soil type, a hydrologic runoff curve number is obtained for each polygon using Tables 3.8 - 3.10. For each day the runoff from that polygon is obtained using the NRSC runoff equation (see Figure 3.1). The daily runoff volumes from each polygon are then aggregated to determine the total daily runoff from the watershed. Timing effects on the runoff are modeled using a simple linear reservoir which is controlled by a single storage coefficient which can be adjusted during model calibration.

The model handles the influence of soil moisture on the runoff by adjusting the daily runoff curve number via an antecedent runoff condition which is based on the season and amount of rain in the last five days (see Table 3.7). The curve numbers provided in Tables 3.8 - 3.10 are based on an AMC condition of II. The equivalent curve number under AMC I and AMC II conditions, can be determined from equations 3.1 and 3.2 respectively:

$$CN(I) = 4.2*CN(II)/[10 - 0.058\ CN(II)] \qquad (3.1)$$

$$CN\ (III) = 23*CN(II)/[10+0.13*CN(II)] \qquad (3.2)$$

Table 3.7 Antecedent Runoff Conditions

C Condition	Dormant Season	Growing Season
I (dry)	Less than .5 inches of rainfall	Less than 1.4 inches of rainfall
II (average)	0.5 to 1.1 inches of rainfall	1.4 to 2.1 inches of rainfall
III (wet)	Greater than 1.1 inches of rainfall	Greater than 2.1 inches of rainfall

Table 3.8 Runoff Curve Numbers for Agricultural Areas (NRSC, 1997)

Cover description			CN for hydrologic soil group			
cover type	treatment [2/]	hydrologic condition [3/]	A	B	C	D
Fallow	Bare Soil	---	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C & T)	Poor	66	74	80	82
		Good	62	71	78	81
	C & T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C & T	Poor	61	72	79	82
		Good	59	70	78	81
	C & T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C & T	Poor	63	73	80	83
		Good	51	67	76	80

Table 3.9 Runoff Curve Numbers for Agricultural Areas (NRSC, 1997)

Cover description: cover type	treatment [2/]	hydrologic condition [3/]	CN for hydrologic soil group: A	B	C	D
Pasture, grassland, or range-continuous forage for grazing [4/]		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Meadow-continuous grass, protected from grazing and generally mowed for hay		Good	30	58	71	78
Brush-brush-forbs-grass mixture with brush the major element [5/]		Poor	48	67	77	83
		Fair	35	56	70	77
		Good	30 [6/]	48	65	73
Woods-grass combination (orchard or tree farm) [7/]		Poor	57	73	82	86
		Fair	43	65	76	82
		Good	32	58	72	79
Woods [8/]		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Farmstead--buildings, lanes, driveways, and surrounding lots		---	59	74	82	86
Roads (including right-of-way):						
Dirt		---	72	82	87	89
Gravel		---	76	85	89	91

1/ Average runoff condition, and I_a=0.2s.

2/ Crop residue cover applies only if residue is on at least 5 percent of the surface throughout the year.

3/ Hydrologic condition is based on combinations of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥20%), and (e) degree of surface toughness.
Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better then average infiltration and tend to decrease runoff.
For conservation tillage poor hydrologic condition, 5 to 20 percent of the surface is covered with residue (less than 750 pounds per acre for row crops or 300 pounds per acre for small grain).
For conservation tillage good hydrologic condition, more than 20 percent of the surface is covered with residue (greater than 750 pounds per acre for row crops or 300 pounds per acre for small grain).

4/ Poor: < 50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.

5/ Poor: < 50% ground cover.
Fair: 50 to 75% ground cover.
Good: > 75% ground cover.

6/ If actual curve number is less than 30, use CN = 30 for runoff computation.

7/ CNs shown were computed for areas with 50 percent woods and 50 percent grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

8/ Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed, but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 3.10 Runoff Curve Numbers for Urban Areas (NRSC, 1997)

Cover description cover type and hydrologic condition	Average percent impervious area[2/]	-- CN for hydrologic soil group -- A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3/]					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4/]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

1/ Average runoff condition, and $I_a = 0.2S$.

2/ The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

3/ CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space type.

4/ Composite CNs for natural desert landscaping should be computed using figures 9–3 or 9–4 based on the impervious area percentage (CN=98) and the pervious area CN. The pervious area CNs are assumed equivalent to desert shrub in poor hydrologic condition.

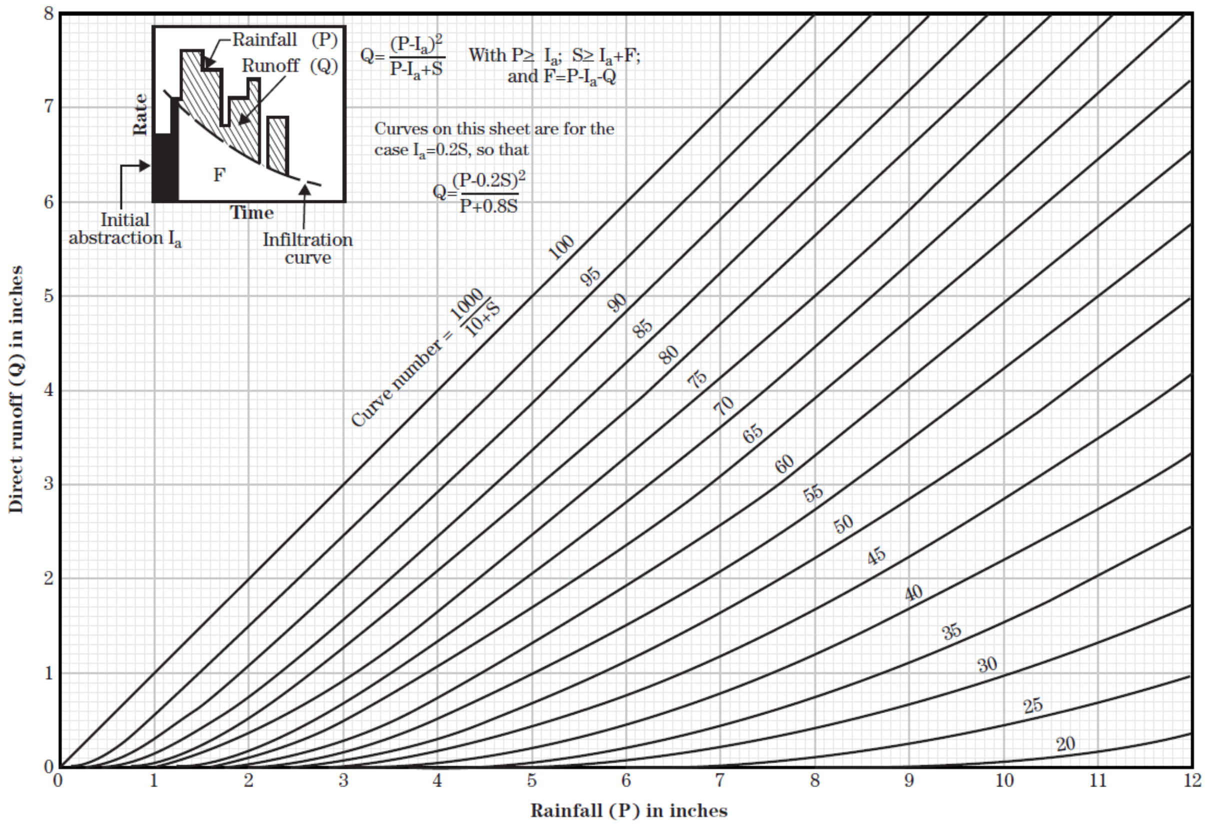


Figure 3.1 NRCS Hydrology Method (NRCS, 1997)

3.3.1.1 Landuse Data

The KYNM models the nonpoint source runoff and water quality using a concept of hydrologic response units. Hydrologic response units simply represent distinct combinations of different landuse and soil types within a watershed. As a result, the areas associated with each major landuse and the percentages of different soil types associated with the landuse must be input or entered into the KYNM. The areas of different landuses within a watershed can be determined using a GIS software package such as ArcGIS along with an associated landuse database. Potential sources of landuse data are provided in Table 3.11. Detailed instructions on how to use GIS to extract the landuse data is provided in the KYNM User's Manual.

Table 3.11 Potential Sources of Landuse Data

Landuse Data Source	Website Address
USDA Digital	www.datagateway.nrcs.usda.gov
KY Geoportal	www.kygeonet.ky.gov
KY Geological Survey	www.uky.edu/KGS

Most landuse datasets in the United States are based on something called the Anderson II landuse classification system (Anderson et al., 1976). This system assigns specific names and descriptions to the different types of landuses. The KYNM uses a smaller set of landuse categories to simplify the data processing and input process. The relationship between the Anderson II classification system and the landuse categories used in the KYNM is provided in Table 3.12.

Table 3.12 Landuse Category Map between Anderson II and KYNM

Anderson II Landuse		KYNM Landuse	notes
Barren Land		Barren Land	
Developed, Low Intensity		Residential	Since the Developed Low intensity areas most commonly include single-family housing units, the areas for failing septic systems were subtracted and the area left over was mapped to Residental. The KYNM assumes 6750 (sft) per failing septic system
		F. Septic Sys.	
Developed, Medium Intensity		Commerical	
Developed, High Intensity		Industrial	
Developed, Open Space		Parks	Since the Developed open space most commonly include large-lot single-family housing units, parks and golf courses, the areas for parks and golf courses were subtracted and the area left over was mapped to Residential.
		Golf Course	
		Residential	
Evergreen Forest		Forest	
Deciduous Forest		Forest	
Mixed Forest		Forest	
Shrub/Scrub		Forest	
Herbaceuous		Grassland	
Hay/Pasture		Pasture	
Cultivated Crops		Row Crops	
Open Water		Open Water	
Woody Wetlands		Wetlands	
Emergent Herbaceuous Wetlands		Wetlands	
		Other	Includes areas within a certain watershed that do not fit under the land use cateogries listed. The EMC and Curve numbers for this category can be user defined in the KYNM.

3.3.1.2 Soils Data

In addition to landuse data, the percentages of different hydrologic soil groups associated with a particular landuse must also be provided. These percentages can be determined using a GIS software package such as ArcGIS along with an associated soils database. Potential sources of soils data are provided in Table 3.13. Detailed instructions on how to use GIS to extract the soil data is provided in the KYNM User's Manual.

Table 3.13 Potential Sources of Soil Data

Data Source	Website Address
USDA Digital	www.datagateway.nrcs.usda.gov
USDA Maps	http://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=KY
Kentucky	www.kygeonet.ky.gov/kysoils/

In general, the spatial databases will provide polygons with an associated hydrologic soil group (e.g. A, B, C, D). However, in some cases, areas have been urbanized prior to the soil mapping. In this case the areas may be assigned a soil group of O for other. In some cases O soils will represent water features, as designated by Wxxx, while in other cases O soils may represent urban features, as designated by Uxxx. General guidelines for how to interpret the latter are provided in the KYNM User's Manual.

3.3.2 Water Quality

The water quality loads associated with the stormwater runoff are modeled using a simple event mean concentration (EMC) which is specified for each landuse. Once the runoff volume for each landuse is determined, the associated pollutant load is obtained by multiplying the runoff volume by the EMC. As with runoff, the EMC coefficients can also be adjusted based on the antecedent moisture conditions (the concentration following a series of storms can be modified to reflect a smaller EMC than that following an extended dry period). Timing effects of mass transport in the watershed can also be adjusted using a linear reservoir model.

An extensive review of the literature was performed to identify applicable EMC values for different landuses in Kentucky. Detailed summaries of the EMC data are provided in Appendix A. A summary of typical values for the landuses considered in the KYNM are provided in Table 3.14.

Table 3.14 Typical EMC Values for Landuses In Kentucky

Landuse	TN Median	TN Maximum	TN Minimum	TP Median	TP Maximum	TP Minimum
Urban	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)
Barren Land	1.32	1.35	1.29	0.58	0.95	0.21
Residential	2.51	3.76	1.25	0.56	0.81	0.30
Commerical	3.69	6.08	1.30	0.44	0.71	0.16
Industrial	1.78	2.90	0.66	0.31	0.41	0.20
Recreational	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)
Parks	1.36	1.51	1.20	0.19	0.26	0.12
Golf Course	3.61	6.12	1.10	0.55	1.07	0.03
Natural	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)
Forest	0.48	0.51	0.45	0.02	0.02	0.01
Grassland	1.63	2.80	0.45	0.08	0.15	0.01
Agricuture	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)	EMC (mg/L)
Pasture	3.35	5.09	1.60	0.61	0.97	0.00
Row Crops	7.57	13.89	1.25	0.03	1.99	0.06
Silvicuture	0.48	0.51	0.45	0.06	0.10	0.01

3.3.3 Failing Septic Systems

Failing septic systems are modeled in KYNM as a non-point source. The number of failing septic systems is determined by multiplying the total number of septic systems by the fraction of septic systems that are assumed to be failing. An estimate of this number can usually be obtained by contacting the local health department. In the absence of a number, a conservative value of 20% may be used.

The model assumes that each failing septic system field covers an average of 6,750 ft^2 (Inspectapedia 2009). The program determines a total contributing area from all failing septic systems by multiplying the number of failing septic systems by this unit area. The program determines the runoff from this area which is then used to determine the total failing septic system load to the stream. Daily failing septic system loading values were obtained from literature (USEPA, 2002) and are shown in Table 3.15.

Table 3.15 Default Parameters for Failing Septic System Loading Rates

Parameter	Loading Rates (lbs/ac/day)
Total Nitrogen	0.070
Total Phosphorus	0.009

In the model, the input loading rates (lbs/acre/day) are allowed to build up to a maximum of five days (assuming no rain). The amount of the total load that actually makes it to the stream is then calculated using a linear runoff relationship based on the amount of daily runoff. In determining the amount of runoff, the program assumes the septic system field would behave like a pasture landuse.

3.4 Background Sources

3.4.1 Groundwater Hydrology

The KYNM provides two basic options for simulating groundwater: 1) rainfall derived groundwater, and 2) streamflow derived groundwater.

3.4.1.1. Rainfall Derived Groundwater

Rainfall derived groundwater utilizes the input rainfall and NRSC hydrology to determine the daily infiltration from rainfall. These volumes are then routed through a groundwater reservoir that is modeled as linear reservoir with an associated groundwater storage coefficient K_g. Using a linear reservoir model the daily baseflow can be calculated using the following equation:

$$Q_t = Q_{t-1} + K_g * (I_{t-1} + I_t - 2 * I_{t-1}) \quad (3.3)$$

Where Q_t is the daily baseflow for day t (cuft), I_t is the daily infiltration for day t (cuft), and K_g is the groundwater storage coefficient.

The total volume of water input into the groundwater store can be controlled by a global runoff adjustment factor. The timing of the release of the water from the groundwater store is controlled by the storage coefficient. By adjusting both the global runoff factor and the groundwater storage coefficient, the user can then seek to match the observed groundwater recession trends in observed streamflow in the process of model calibration. When observed streamflow data are not available, the model can be used to predict the groundwater time series using the following default parameter values:

Table 3.16 Default Parameters for Groundwater Storage Coefficient

Watershed Area	Storage Coefficient Parameter
< 50 sqmi	0.3
50 sqmi < area < 100 sqmi	0.2
> 100 sqmi	0.1

3.4.1.2. Streamflow Derived Groundwater

If actual streamflow can be obtained for the watershed being modeled (or synthesized from a nearby gauging station) the groundwater time series can be disaggregated from the streamflow time series using one of two different separation models: a recursive filter model or a heuristic model. Each model contains two different parameters that can be adjusted so as to most closely match the predicted baseflow time series with the observed one.

3.4.1.2.1 Recursive Filter Method

The Recursive Filter Method is based on the work of Eckhardt (2005). The baseflow b_t for time step t is calculated from the following equations:

$$b_t = Min\ (b_t, Q_t) \quad (3.4)$$

$$b_t = \frac{(1 - BFI_{max}) * \alpha * b_{t-1} + (1 - \alpha) * BFI_{max} * Q_t}{1 - \alpha * BFI_{max}}$$

$$0 \le \alpha \le 1\ ;\ 0 \le BFI_{max} \le 1\ ;\ \alpha \text{ and } BFI_{max} \text{ are not both 1.}$$

where BFI max is the maximum value of long term ratio of base flow to total streamflow; α is the filter parameter; and Q_t is the total streamflow at the t time step (days). Typical values for BFI_{max} are:

Table 3.17 Default Parameters for BFI_{max} (Eckhardt, 2005)

Watershed Area	BFI_{max}
Perennial streams with porous aquifers	.8
Ephemeral streams with porous aquifers	.5
Perennials streams with rock aquifers	.25

Both parameters α and BFI_{max} jointly determine what fraction of the observed streamflow is attributed to baseflow. With a fixed BFI_{max}, lower values of α will attribute a larger proportion of the observed streamflow to baseflow; similarly with a fixed α, higher values of BFI_{max} will attribute a larger proportion of the observed streamflow to baseflow. However, BFI_{max} is the stronger of the two at assigning all of the observed streamflow to baseflow: if BFI_{max} is set equal to 1, the computed baseflow will exactly equal the observed streamflow regardless of the value of α (α and BFI max cannot both be set to 1 or we get division by zero). If α is set to 0, then the computed baseflow will equal the observed streamflow multiplied by BFI_{max}, leaving BFI_{max} to again assign the final proportion. The α parameter is the stronger of the two at the other extreme of the parameter values. If α is set to 1, then the computed baseflow is set equal to the previous time step baseflow, regardless of the value of BFI_{max}; because the minimum computed baseflow cannot be greater than the observed streamflow, this means that the computed baseflow will be numerically equal to the lowest previous observed streamflow. If BFI_{max} is set to 0, then the computed baseflow is equal to the previous time step baseflow multiplied by α, leaving α to assign the final proportion of the previous baseflow.

The parameter α will typically vary between 0.80 to 0.98. This value will normally be adjusted during model calibration so that the resulting surface water runoff will match the values predicted from the NRCS hydrology.

3.4.1.2.1 Heuristic Method

The Heuristic Method was developed by Ormsbee (2014) and also employs two model parameters: 1) the basin lag time L_t (days) and 2) the fraction of streamflow associated with the baseflow (%) B_f. The basin lag time can be related to the size of the watershed as shown in Table 3.18. B_f can be determined by selecting a value that most closely matches the behavior of the rising limb of the baseflow from the observed streamflow time series. A typical value for B_f is 0.3. This value will be higher for more impervious watersheds and lower for more rural or agricultural watersheds. An illustration of the method for L_t = 2 days and B_f = 0.3 is shown in Figure 3.2.

Table 3.18 Default Parameters for Basin Lag Time L_t (days)

Watershed Area	Basin Lag Time (days)
< 50 sqmi	1
50 sqmi < area < 100 sqmi	2
> 100 sqmi	3

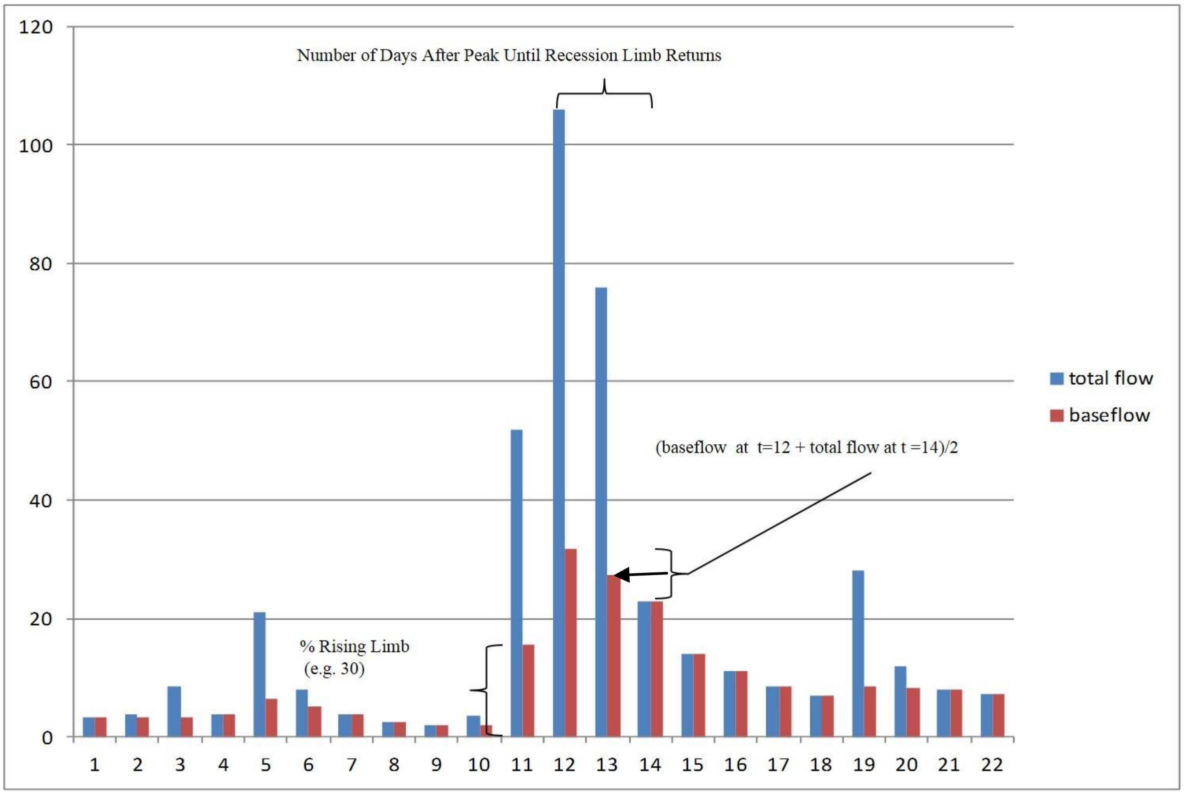


Figure 3.2 Illustration of Heuristic Method for L_t = 2 days and B_f = 0.3

3.4.2 Groundwater Quality

The water quality load associated with groundwater is obtaining by multiplying the daily groundwater flow by an associated event mean concentration. The event mean concentration is specified in the model via either a linear regression equation (Eq 3.6) or a inverse power function (Eq 3.7) that relates the baseflow to an associated EMC for total nitrogen and total phosphorus (See Figure 3.3)

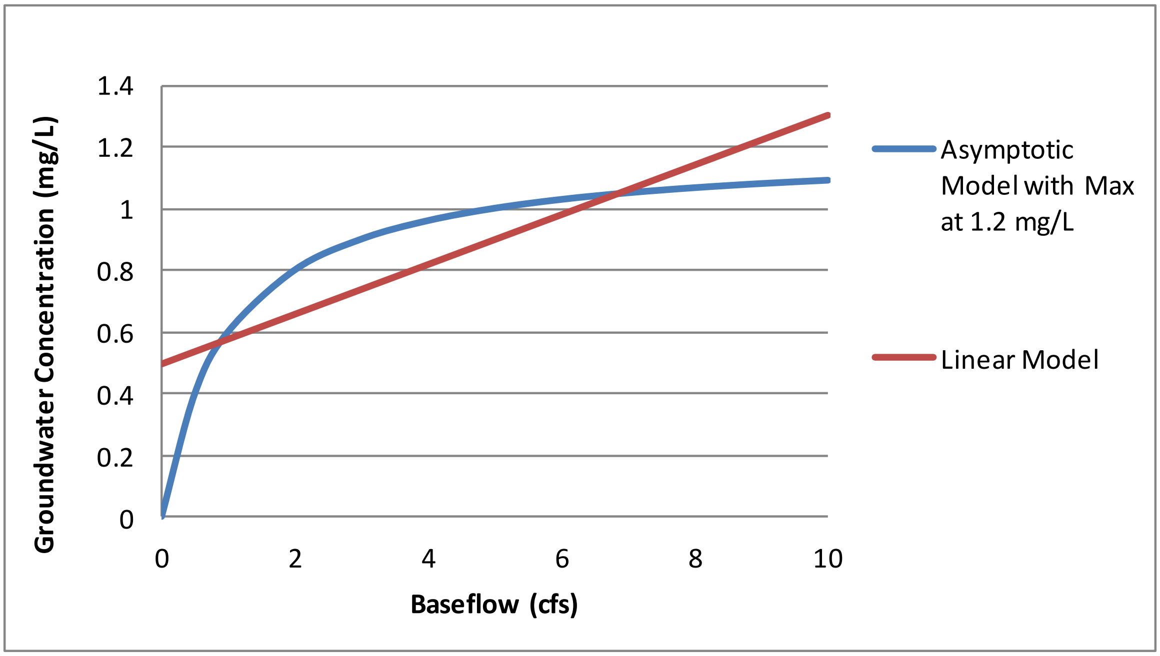


Figure 3.3 Groundwater Water Quality Functions.

The general form of the linear regression equation is:

$$EMC_{(N,P)} = \alpha_{g(N,P)} + \beta_{g(N,P)}\, b_t \qquad (3.6)$$

where α_g is the typical mean value and β_g is the slope of the relationship between the baseflow, b_t, and the event mean concentration for total nitrogen or total phosphorus $EMC_{(N,P)}$.

The general form of the inverse power function equation is:

$$EMC_{(N,P)} = MAX\{\beta_{g(N,P)}, ([- \alpha_{g(N,P)} /(b_t +1)] + \alpha_{g(N,P)}) \} \qquad (3.7)$$

where α_g is maximum expected value of $EMC_{(N,P)}$ which is approached asymptotically and β_g is the minimum value of the event mean concentration for total nitrogen or total phosphorus $EMC_{(N,P)}$.

When monitoring data are available, the user may plot the observed groundwater flow against the observed EMCs to determine the associated values of α_g and β_g. For the linear relationship, normally, the slope of the relationship will be negative, that is, the concentration will decrease as the groundwater flow increases. When such data are not available the user may use the typical values for α_g and β_g provided in Table 3.19, which can then be adjusted through model calibration.

Table 3.19 Default Parameters for α_g and β_g

Parameter	α_g	β_g linear	β_g power
Total Nitrogen (mg/L)	.5 < 1 < 1.5	-.001	0
Total Phosphorus (mg/L)	.05 < .1 < .15	-.001	0

3.4.3 Erosion

The model also has a provision for simulating potential nutrient loads associated with instream erosion. This is more likely to be important for phosphorus loads as opposed to nitrogen loads. Technically, these loads should be already reflected in the EMCs for the various landuses as modeled in the stormwater runoff, however the user may apply an additional load via this option if desired. The water quality load associated with erosion is obtained by multiplying the total daily streamflow by an associated event mean concentration. Similar to groundwater, the event mean concentration is specified in the model via a regression equation that relates the streamflow to an associated EMC for total nitrogen and total phosphorus. The general form of the equation is:

$$EMC_{(N,P)} = \alpha_{e(N,P)} + \beta_{e(N,P)} Q_t \qquad (3.8)$$

where α_e is the typical mean value and β_e is the slope of the relationship between the total streamflow and the event mean total nitrogen or total phosphorus concentration $EMC_{(N,P)}$. When monitoring data are available, the user may plot the observed streamflow against the observed EMCs to determine the associated values of α_e and β_e. When monitoring data are not available, these parameters can be obtained through model calibration. This feature of the model will normally be used to accommodate the mobilization of additional phosphorus in the stream.

3.4.4 Air Deposition

According to Mueller and Helsel (1996) "*The Earth's atmosphere is about 78 percent nitrogen and contains about three-fourths of the nitrogen available in the environment. Most of this nitrogen is in the form of elemental nitrogen gas, but compounds of nitrogen and oxygen also are present. Some of these compounds are produced by chemical reactions in the atmosphere, and a substantial amount are released into the atmosphere from the combustion of fossil fuel, such as coal and gasoline. Nitrogen compounds in the atmosphere undergo transformations that eventually leave the nitrogen in the form of nitrate. (This process also contributes to the formation of "acid rain.") Nitrate can dissolve in rainwater or snow and then can reach streams or ground water in runoff or seepage. More than 3.2 million tons of nitrogen are deposited in the United States each year from the atmosphere."*

The KYNM also has a provision for simulating potential nutrient loads associated with air deposition. This is more likely to be important for nitrogen loads as opposed to phosphorus loads. Technically, these loads should be already reflected in the EMCs for the various landuses as modeled in the stormwater runoff, however EMCs might not represent the amount of the air deposition that reaches the stream either by direct deposit or by groundwater. Typical observed loading values for the United States are illustrated in Figure 3.4. It should be emphasized that these values represent the amount of nitrogen deposited on the watershed and not necessarily the amount that reaches the stream. In the model, the input loading rates (lbs/acre/day) are allowed to build up to a maximum of five days without rain. The amount of the total load that actually makes it to the stream is then calculated using a linear runoff relationship based on the amount of daily runoff.

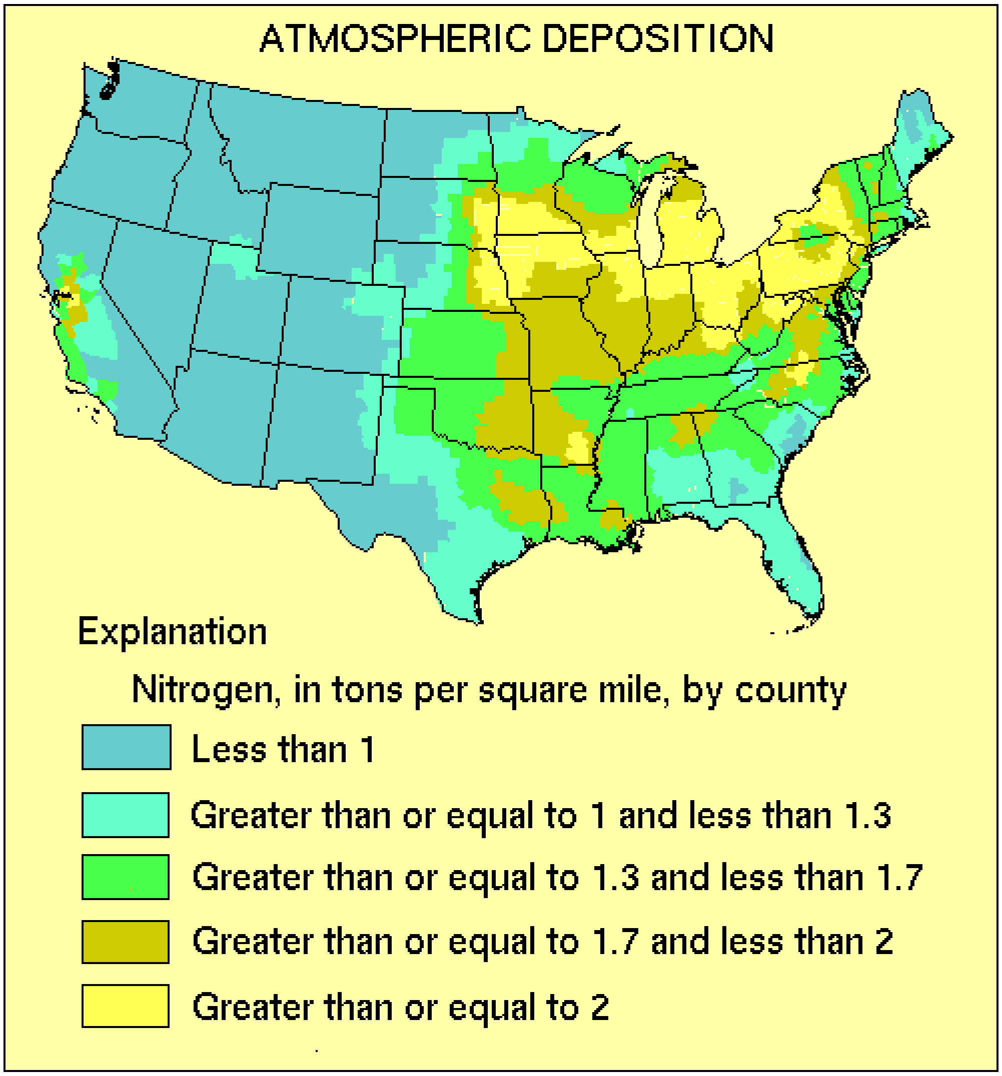


Figure 3.4 Average Air Deposition Loading Rates for Kentucky (Mueller and Helsel (1996)

4.0 Data Entry and Analysis Worksheet

Data for use in the KYNM are input via a simple spreadsheet worksheet. The calculations associated with the model are built into the spreadsheet and may be viewed by clicking on a particular cell. The worksheet has been organized into different sections as shown in Figure 4.1. Essentially, data are entered in the red shaded areas, while the calculations are performed in the blue shaded areas. The green shaded areas provide reference materials for the user.

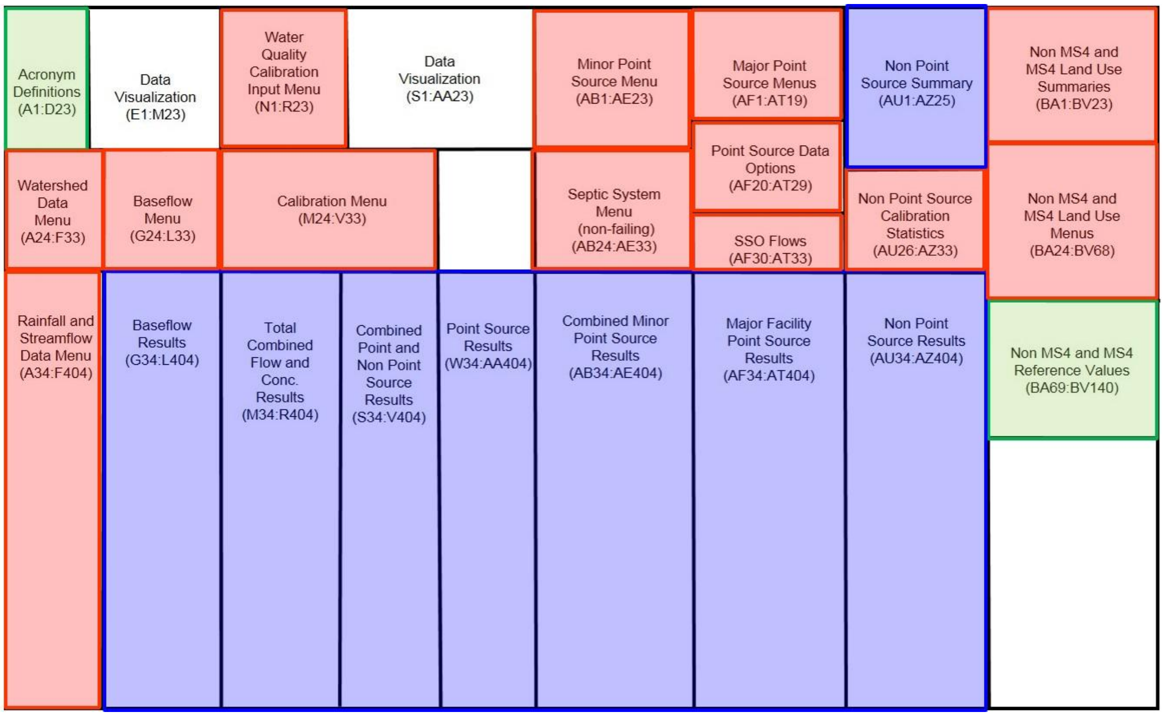


Figure 4.1 KYNM Organization

Detailed instructions on how to build, calibrate, and apply the KYNM to a particular watershed are provided in the KYNM user's manual.

5.0 Model Verification

In order to assess the basic assumptions of the KYNM, the model was verified against the 2007-2008 water quantity and quality data that were used in the calibration and validation of the Tetra Tech LSPC model. The results of the KYNM were then also compared to the results of the LSPC model itself as well as annual load predictions using USGS regression equations.

For the purposes of model verification, seven different watershed models were created in the KYNM for both 2007 and 2008. The watersheds were suggested by the Kentucky Division of Water based on the following criteria: 1) the diversity of landuse, 2) the availability of a USGS gauging station within or nearby the watershed, and 3) the availability of a USGS water quality monitoring station. Each watershed can be identified by the USGS gauging station located at the outlet of the watershed (see Table 5.1). The seven watersheds are illustrated in Figures 5.1-5.3. The calibrated model parameters used for each model are summarized in Appendix B.

Table 5.1 Floyds Fork Subbasins used in the KYNM Verification

Watershed Name	Watershed Area (sqmi)	USGS Gaging Station
Ashers Run	3.27	03297875
Chenoweth Run	5.44	03298135
Chenoweth Run	11.61	03298150
Pennsylvania Run	6.96	03298300
Long Run	25.27	03297980
Currys Fork	28.48	03297880
Floyds Fork	213.98	03298200

Each model developed in KYNM was calibrated against rainfall, flowrate, and water quality data for 2007. The models were then validated against the same data for 2008.

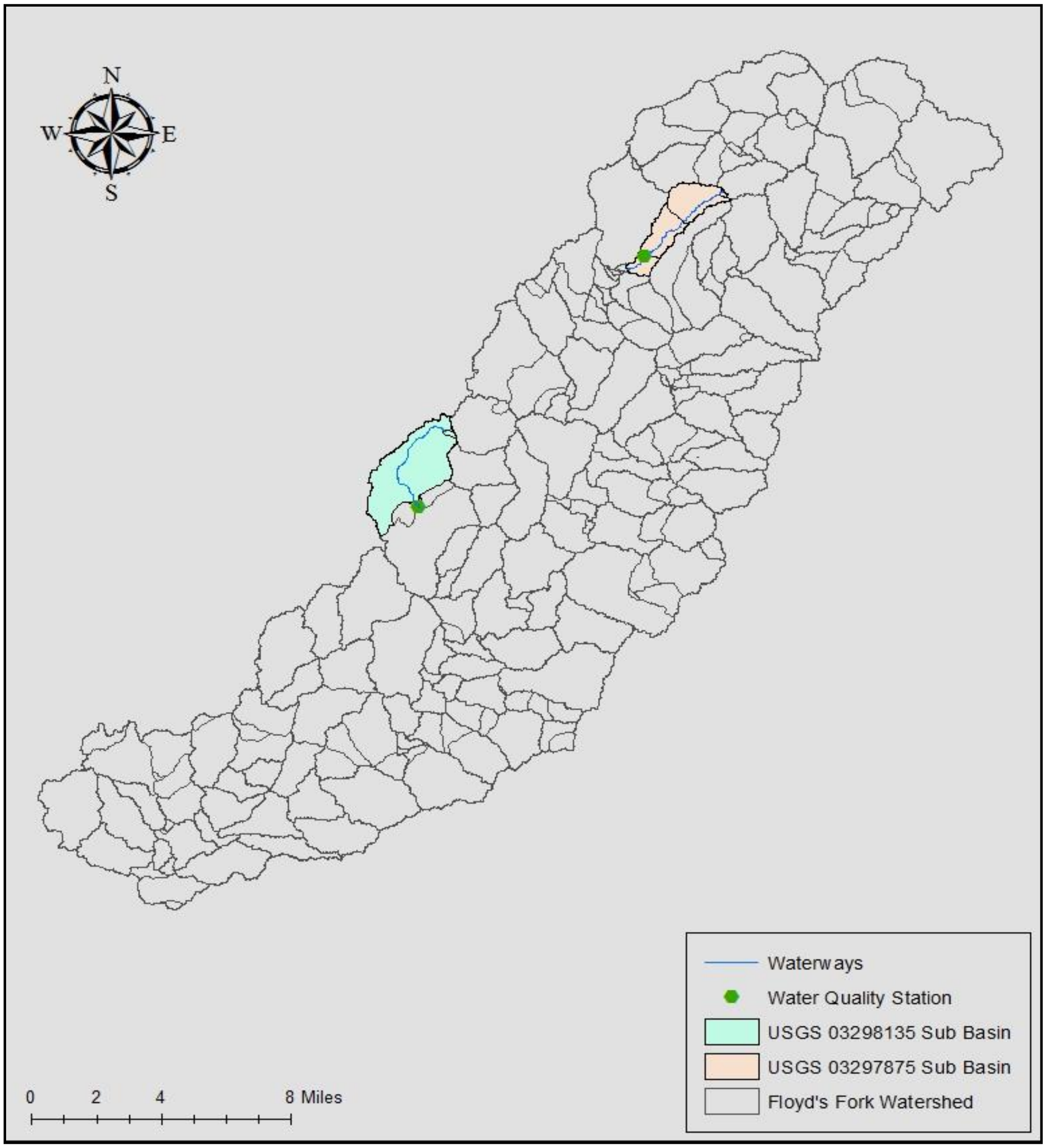


Figure 5.1 Ashers Run (03298175) and Chenoweth Run (03298135) Watersheds

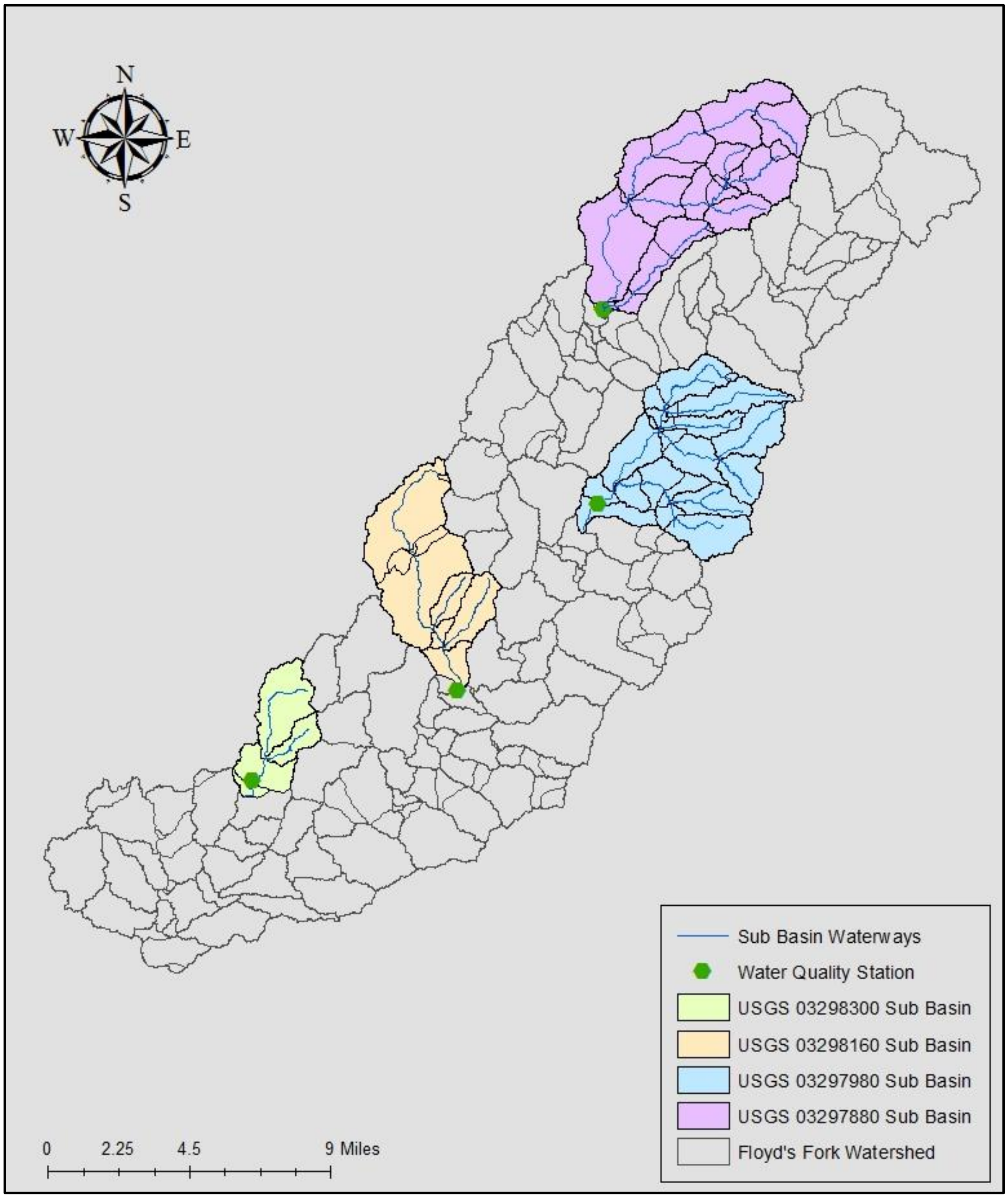


Figure 5.2 Currys Fork (03297880), Long Run (03297980), Chenoweth Run (03298160), and Pennsylvania Run (03298300) Watersheds

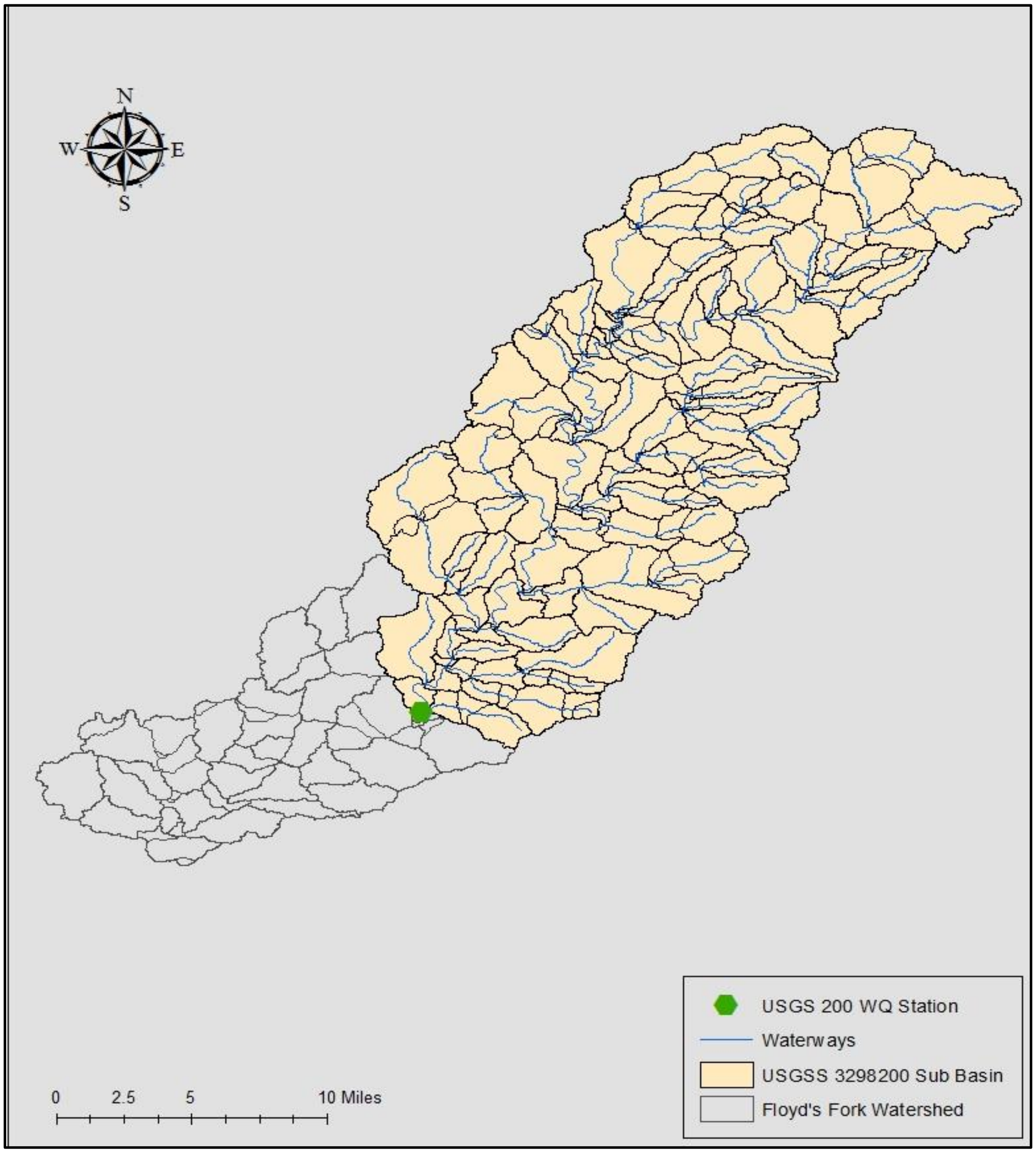


Figure 5.3 Upper Floyds Fork (03298200) Watershed

5.1 Hydrology Calibration and Validation

A qualitative evaluation of each model was obtained by comparing the observed and predicted daily streamflow and intermittent water quality data using daily histograms and scatter plots. These visual comparisons are provided in Appendix B. In addition, four statistics were used to guide the calibration. These statistics are defined below in Equations 5.1-5.4. The detailed results from this analysis are also provided for each watershed model in Appendix B. The Nash Sutcliffe Efficiency and Percent Bias were the two primary statistics used in the calibration and validation process. The calibration targets for these two statistics are summarized in Table 5.2. A summary of the calibration and validation results for each watershed for both 2007 and 2008 is provided in Table 5.3.

Table 5.2 Hydrologic Calibration Targets

Statistic	Acceptable Range	Very Good
Nash Sutcliffe Efficiency	>.50	> .75
Percent Bias	< 25%	< 10%

Based on the results provided in Table 5.3, it was concluded that the KYNM is able to adequately simulate the hydrologic response of the watersheds. In fact, in most cases the model performance was concluded to be excellent for model calibration, but perhaps more importantly for model validation. The one watershed that the model did not perform as well as the others was the upper Floyds Fork watershed, which was the largest watershed modeled. The lower performance of the model may reflect the inherent limitations in using a spatially lumped parameter model for such a large watershed, and the fact that the rainfall associated with such a large area is obviously not constant spatially or temporally. Nonetheless, the calibration statistics all fell within the acceptable range.

Equation 5.1 Nash Sutcliffe Efficiency

The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance (“noise”) compared to the measured data variance (“information”) (Nash and Sutcliffe, 1970). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line. NSE ranges from negative infinity to 1.0. A NSE of 0 indicates that the mean of the observed data is as good a predictor of the data as the model. A negative NSE predicts worse than the mean of the observed data. A perfect prediction results in a NSE of 1.0.

$$PBIAS = 1.0 - \frac{\sum_{i=1}^{N}\left(Y_{obs,i} - Y_{sim,i}\right)^2}{\sum_{i=1}^{N}(Y_{obs,i} - \bar{Y}_{obs})^2}$$

Where $Q_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Q_{sim,i}$ is the *i*th simulation for the constituent, $\bar{Y}_{obs}$ is the mean of observed data for the constituent being evaluate, and N is the total number of observations.

Equation 5.2 Percent Bias

Percent bias (PBIAS) measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Gupta et al., 1999). The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias (Gupta et al., 1999).

$$PBIAS = \frac{\sum_{i=1}^{N}\left(Y_{obs,i} - Y_{sim,i}\right) * 100}{\sum_{i=1}^{N}(Y_{obs,i})}$$

Where $Y_{i\ obs}$ is the *i*th observation for the constituent being evaluated, $Y_{i\ sim}$ is the *i*th simulated value for the constituent being evaluated, and n is the total number of observations.

Equation 5.3 Root Mean Squared Error (RMSE) and the RMSE Observations Standard Deviation Ratio (RSR)

RSR incorporates the benefits of error index statistics and includes a scaling/normalization factor, so that the resulting statistic and reported values can apply to various constituents. RSR varies from the optimal value of 0, which indicates zero RMSE or residual variation and therefore perfect model simulation, to a large positive value. The lower RSR, the lower the RMSE, and the better the model simulation performance.

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sqrt{\sum_{i=1}^{N}\left(Y_{obs,i} - Y_{sim,i}\right)^2}}{\sqrt{\sum_{i=1}^{N}\left(Y_{obs,i} - \bar{Y}_{obs}\right)^2}}$$

where $Y_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Y_{sim,i}$ is the *i*th simulated value for the constituent being evaluated, , $\bar{Y}_{obs}$ is the mean of observed data for the constituent being evaluated, and N is the total number of observations.

Equation 5.4 Coefficient of Determination

In statistics, the coefficient of determination, denoted R^2, indicates how well data fit a statistical model. It is a statistic used in the context of models whose main purpose is either the prediction of future outcomes or the testing of hypotheses, on the basis of other related information. It provides a measure of how well observed outcomes are replicated by the model, as the proportion of total variation of outcomes explained by the model.

$$R^2 = \left\{\frac{\sum_{i=1}^{N}\left(Y_{obs,i} - \bar{Y}_{obs}\right)\left(Y_{sim,i} - \bar{Y}_{sim}\right)}{\left[\sum_{i=1}^{N}\left(Y_{obs,i} - \bar{Y}_{obs}\right)\right]^{0.5}\left[\sum_{i=1}^{N}\left(Y_{sim,i} - \bar{Y}_{sim}\right)\right]^{0.5}}\right\}^2$$

Where $Y_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Y_{sim,i}$ is the *i*th simulation for the constituent, $\bar{Y}_{obs}$ is the mean of the observed data, $\bar{Y}_{sim}$ is the mean of the simulated data, and N is the total number of observations.

Table 5.3 Hydrology Calibration and Validation Results

Ashers Run Watershed					
Year	**NSE**	**% BIAS**	**RMSE**	**RSR**	**R2**
2007 Calibration	0.72	4.83	6.60	0.53	0.77
2008 Validation	0.92	6.71	5.88	0.29	0.93
Chenoweth Run at USGS 03298135					
Year	**NSE**	**% BIAS**	**RMSE**	**RSR**	**R2**
2007 Calibration	0.81	2.92	9.83	0.44	0.88
2008 Validation	0.93	4.15	8.52	0.27	0.95
Pennsylvania Run at USGS 03298300					
Year	**NSE**	**% BIAS**	**RMSE**	**RSR**	**R2**
2007 Calibration	0.82	5.00	9.30	0.43	0.86
2008 Validation	0.77	14.77	26.06	0.48	0.93
Chenoweth Run at USGS 03298150					
Year	**NSE**	**% BIAS**	**RMSE**	**RSR**	**R2**
2007 Calibration	0.82	0.18	22.87	0.42	0.85
2008 Validation	0.97	8.56	17.29	0.17	0.97
Long Run					
Year	**NSE**	**% BIAS**	**RMSE**	**RSR**	**R2**
2007 Calibration	0.82	14.48	34.88	0.42	0.83
2008 Validation	0.79	13.38	61.57	0.45	0.81
Currys Fork					
Year	**NSE**	**% BIAS**	**RMSE**	**RSR**	**R2**
2007 Calibration	0.90	7.71	33.12	0.31	0.91
2008 Validation	0.87	3.10	61.53	0.36	0.87
Lower Floyds Fork at USGS 03298200					
Year	**NSE**	**% BIAS**	**RMSE**	**RSR**	**R2**
2007 Calibration	0.74	1.98	367	0.51	0.83
2008 Validation	0.84	8.77	448	0.40	0.85

5.2 Water Quality Calibration and Validation

After the hydrology of the KYNM was verified, the water quality components of the model were verified. A qualitative evaluation of each water quality model can be performed by examining the associated scatter plots of observed versus predicted nutrient concentrations (See Appendix B).

In addition, five statistics were used in the KYNM to guide the calibration. These five statistics are defined below and are mostly different than those used to measure hydrology calibration due to differences in the nature of the data (e.g. the typically much smaller data set for water quality). Two of these statistics were primary guides with defined quantitative targets: the Relative Error and the Percent Bias (see Table 5.4). The detailed results from this analysis are also provided for each watershed model in Appendix B. A summary of the calibration and validation results for each watershed for both 2007 and 2008 is provided in Table 5.5.

Table 5.4 Water Quality Calibration Targets

Statistic	Acceptable Range	Very Good
Relative Error	< .45	< .3
Percent Bias	< 25%	< 10%

Equation 5.5 Relative Error

Relative error (RE) is the absolute error divided by the magnitude of the exact value. It is often used to compare approximations of numbers of widely differing size. There are two features of relative error that should be kept in mind. Firstly, relative error is undefined when the true value is zero as it appears in the denominator. Secondly, relative error only makes sense when measured on a ratio scale, (i.e. a scale which has a true meaningful zero), otherwise it would be sensitive to the measurement units (e.g. Celsius and Kelvin). A relative error of zero is ideal.

$$RE = \left[\frac{\sum_{i=1}^{N} |Y_{obs,i} - Y_{sim,i}|}{\sum_{i=1}^{N} (Y_{obs,i})}\right]$$

Where $Y_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Y_{sim,i}$ is the *i*th simulation for the constituent, N is the total number of observations.

Equation 5.6 Percent Bias

Percent bias (PBIAS) measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Gupta et al., 1999). The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias (Gupta et al., 1999).

$$PBIAS = \left[\frac{\sum_{i=1}^{N} (Y_{obs,i} - Y_{sim,i}) * 100}{\sum_{i=1}^{N} (Y_{obs,i})}\right]$$

Where $Y_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Y_{sim,i}$ is the *i*th simulation for the constituent, N is the total number of observations.

Equation 5.7 Mean Error (Signed)

Mean signed error (MSE) is a sample statistic that summarizes how well an estimator matches the quantity that it is supposed to estimate. It is one of a number of statistics that can be used to assess an estimation procedure. This error summarizes performance in ways that takes into account the direction of over- or under- prediction. MSE varies from a large positive to a large negative value. Note that a MSE of zero is ideal however a low MSE does not indicate a better model simulation performance since the MSE is a measure that places emphasis on the direction of error, and so there is a possibility that the average of the positive deviations are cancelling out that of the negative deviations.

$$MSE = \frac{\sum_{i=1}^{N}\left(Y_{obs,i} - Y_{sim,i}\right)}{N}$$

Where $Y_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Y_{sim,i}$ is the *i*th simulation for the constituent, N is the total number of observations.

Equation 5.8 Mean Absolute Error

Mean absolute error (MAE) is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. As the name suggests, the mean absolute error is an average of the absolute errors. Unlike the MSE, this error summarizes performance in ways that disregard the direction of over- or under- prediction; a measure that does not place emphasis on the direction of error. MAE varies from the optimal value of 0, which indicates zero residual variation and therefore perfect model simulation, to a large positive value. The lower the MAE the better the model simulation performance.

$$MAE = \frac{\sum_{i=1}^{N}\left|Y_{obs,i} - Y_{sim,i}\right|}{N}$$

Where $Y_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Y_{sim,i}$ is the *i*th simulation for the constituent, N is the total number of observations.

Equation 5.9 Root Mean Square Error (RMSE)

Root mean square error (RSME) represents the sample standard deviation of the differences between predicted values and observed values. It serves to aggregate the magnitudes of the errors in predictions for various times into a single measure of predictive power. RMSE is a good measure of accuracy, but only to compare forecasting errors of different models for a particular variable and not between variables, as it is scale-dependent. RSME varies from the optimal value of 0, which indicates zero residual variation and therefore perfect model simulation, to a large positive value. The lower the RMSE the better the model simulation performance.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} \left(Y_{obs,i} - Y_{sim,i}\right)^2}{N}}$$

Where $Y_{obs,i}$ is the *i*th observation for the constituent being evaluated, $Y_{sim,i}$ is the *i*th simulated value for the constituent being evaluated, and *N* is the total number of observations.

Table 5.5 Total Nitrogen Calibration and Validation Results

Ashers Run					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.186	12.797	0.177	0.256	0.348
2008 Validation	0.248	0.389	0.005	0.313	0.395
Chenoweth Run at USGS 03298135					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.223	7.279	0.062	0.19	0.267
2008 Validation	0.227	0.341	0.004	0.238	0.314
Pennsylvania Run at USGS 03298300					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.444	28.06	1.595	2.524	2.891
2008 Validation	0.798	-29.972	-0.745	1.986	2.25
Chenoweth Run at USGS 03298150					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.175	-0.335	-0.045	2.337	3.057
2008 Validation	0.189	0.516	0.061	2.211	2.875
Long Run					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.416	13.146	0.15	0.475	0.657
2008 Validation	0.378	-6.019	-0.052	0.328	0.443
Currys Fork					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.575	26.708	1.567	3.373	4.934
2008 Validation	0.59	28.943	1.764	3.599	5.092
Lower Floyds Fork at USGS 03298200					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.25	6.92	0.22	0.81	1.56
2008 Validation	0.40	39.11	1.49	1.54	2.05

Table 5.6 Total Phosphorus Calibration and Validation Results

Ashers Run					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.096	-3.868	-0.006	0.015	0.015
2008 Validation	0.274	21.485	0.024	0.03	0.04
Chenoweth Run at USGS 03298135					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.526	46.179	0.021	0.024	0.042
2008 Validation	0.377	-35.117	-0.008	0.008	0.01
Pennsylvania Run at USGS 03298300					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.283	12.562	0.11	0.247	0.303
2008 Validation	0.445	33.316	0.279	0.373	0.48
Chenoweth Run at USGS 03298150					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.279	4.319	0.028	0.178	0.247
2008 Validation	0.441	-30.023	-0.083	0.121	0.179
Long Run					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.55	11.652	0.022	0.106	0.186
2008 Validation	0.523	37.855	0.059	0.082	0.123
Currys Fork					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.541	-0.202	-0.001	0.357	0.457
2008 Validation	0.348	19.591	0.15	0.267	0.468
Lower Floyds Fork at USGS 03298200					
Year	**Relative Error**	**% BIAS**	**Mean Error**	**Absolute Mean Error**	**RMSE**
2007 Calibration	0.228	13.38	0.025	0.042	0.072
2008 Validation	0.445	8.71	0.010	0.049	0.057

The main WQ calibration and validation goal was to achieve a relative error less than 0.45 (USEPA 1990) and achieve scatter plots that were qualitatively balanced and demonstrated a modeling relationship. The other statistical parameters served as supplementary information. For total nitrogen, six out of seven of the watersheds met the relative error target for calibration, and five out of those six watersheds also met the relative error target for validation. For total phosphorus, six out of seven of the watersheds validated with relative errors less than 0.45; all relative errors for all sites and all years were not much above 0.45, with a highest relative error of only 0.55. Based on the results provided in Table 5.5 and Table 5.6 it was concluded that the KYNM is able to adequately simulate the water quality response of the watersheds. In some cases where the validation was not able to meet the relative error target, as in the case of Pennsylvania Run total nitrogen, a t-test reveals that there is a significant difference ($p = 0.0257 < 0.05$) between the total nitrogen water quality data in this basin between the years 2007 and 2008. When there is a factor causing a statistically significant difference in water quality between two years in a basin, it would not be expected for a model to predict a statistically similar results using the same input parameters and factors for both years as is done with calibration and validation.

After the water quality of the KYNM was verified using statistical measurements, the water quality of the model was then further verified in terms of annual loadings. This was done by comparing the performance of each basin model against the annual nutrient load prediction from the following four sources: 1) calibrated results from Tetra Tech LSPC Model, 2) stepwise forecast from existing data points, 3) interpolation forecast from existing data points, 4) annual load forecast from USGS regression equations. The latter equations were developed using data from 26 stations in Jefferson County, five of which were located in the Floyds Fork watershed (USGS, 1994). The exact form of the equations are given as:

$$NH_4 = 0.0006367 \times AR^{2.550} \times DA^{1.135} \times LUR^{0.8158}$$
$$NO_2 = 0.01077 \times AR^{2.621} \times DA^{1.043} \times LUC^{-0.2739}$$
$$NO_3 = 1.086 \times AR^{2.135} \times DA^{0.9300}$$
$$TP = 1.249 \times AR^{2.227} \times DA^{0.9008} \times IA^{-0.4846}$$

Where

NH_4 is annual load of total ammonia nitrogen in storm runoff, in pounds as N;
NO_2 is annual load of total nitrite nitrogen in storm runoff, in pounds as N;
NO_3 is annual load of total nitrate nitrogen in storm runoff, in pounds as N;
TP is annual load of total phosphorus in storm runoff, in pounds as P;
AR is total annual rainfall, in inches;
DA is drainage area, in square miles;
LUR is 1+ residential land use, in percentage of drainage area;
LUC is 1+ commercial land use, in percentage of drainage area;
IA is 1+ impervious area, in percentage of drainage area.

A summary of the performance of the KYNM for each of the seven watersheds as verified against these four statistics is provided in Table 5.7 for total nitrogen and Table 5.8 for total phosphorus. In general, the model tended to calibrate fairly well in comparison to the estimated annual loads. It should be pointed out, however, that the loads predicted using the USGS equations seemed to be somewhat more extreme than the other three estimates, especially for total phosphorus. In most cases the KYNM predicted values in-between the values predicted the LSPC model and those obtained using the stepwise and interpolation methods (see Figures 5.4.- 5.10 for total nitrogen and Figures 5.11 – 5.17 for total phosphorus). In general, the KYNM was able to predict the total annual nitrogen loads slightly better than the total annual phosphorus loads.

Table 5.7 Total Nitrogen Annual Load Calibration and Validation Results

Ashers Run										
Year	Analysis	KYNM	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	14765	8025	83.99	12740	15.89	13647	8.19	12456	18.54
2008	Validation	18339	9986	83.65	12910	42.05	17876	2.59	11979	53.09
Chenoweth Run at USGS 03298135										
Year	Analysis	KYNM	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	27071	16103	68.11	22076	22.63	18885	43.35	23263	16.37
2008	Validation	32602	19038	71.25	22374	45.71	40821	-20.13	36041	-9.54
Pennsylvania Run at USGS 03298300										
Year	Analysis	KYNM	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	29039	26585	9.23	27977	3.80	28722	1.10	30365	-4.37
2008	Validation	31198	31109	0.29	28622	9.00	52922	-41.05	42079	-25.86
Chenoweth Run at USGS 03298150										
Year	Analysis	KYNM	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	405429	146534	176.68	45231	796.35	454824	-10.86	495609	-18.20
2008	Validation	504538	260725	93.51	45843	1000.58	695282	-27.43	734674	-31.32
Long Run										
Year	Analysis	KYNM	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	51903	60368	-14.02	76221	-31.90	100921	-48.57	85712	-39.44
2008	Validation	71609	77990	-8.18	92780	-22.82	70865	1.05	48564	47.45
Currys Fork										
Year	Analysis	KYNM	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	166551	185405	-10.17	88013	89.23	195818	-14.95	189658	-12.18
2008	Validation	255309	189478	34.74	97761	161.16	266372	-4.15	243078	5.03
Lower Floyds Fork at USGS 03298200										
Year	Analysis	KYNM	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	1110174	642160	72.9	694103	59.9	1610815	-31.08	1396224	-20.49
2008	Validation	1616276	849716	90.2	703533	129.7	1846219	-12.45	1746585	-7.46

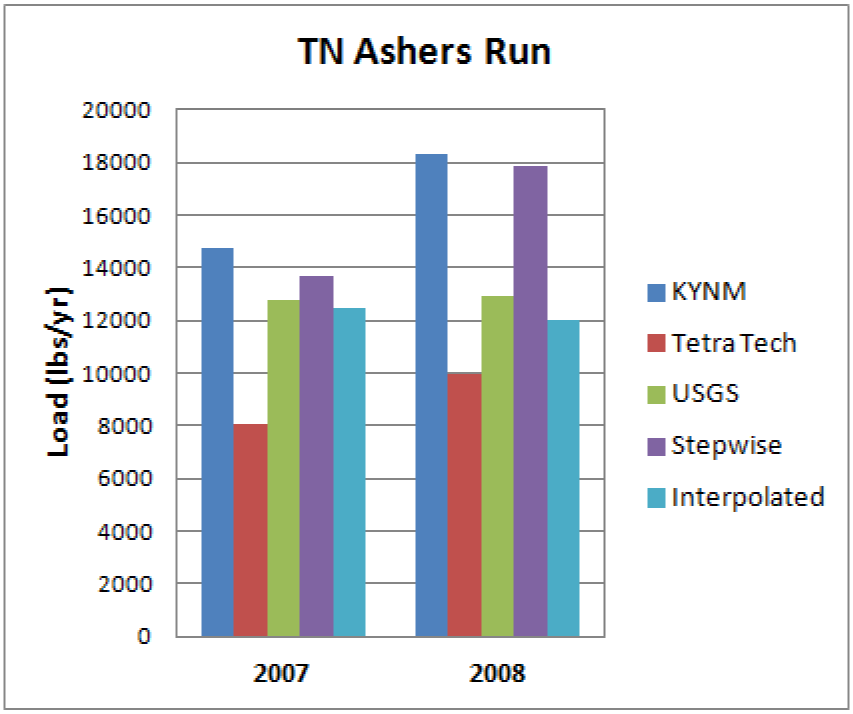


Figure 5.4 Comparison of Predicted and Estimated Annual Total Nitrogen Loads for Ashers Run

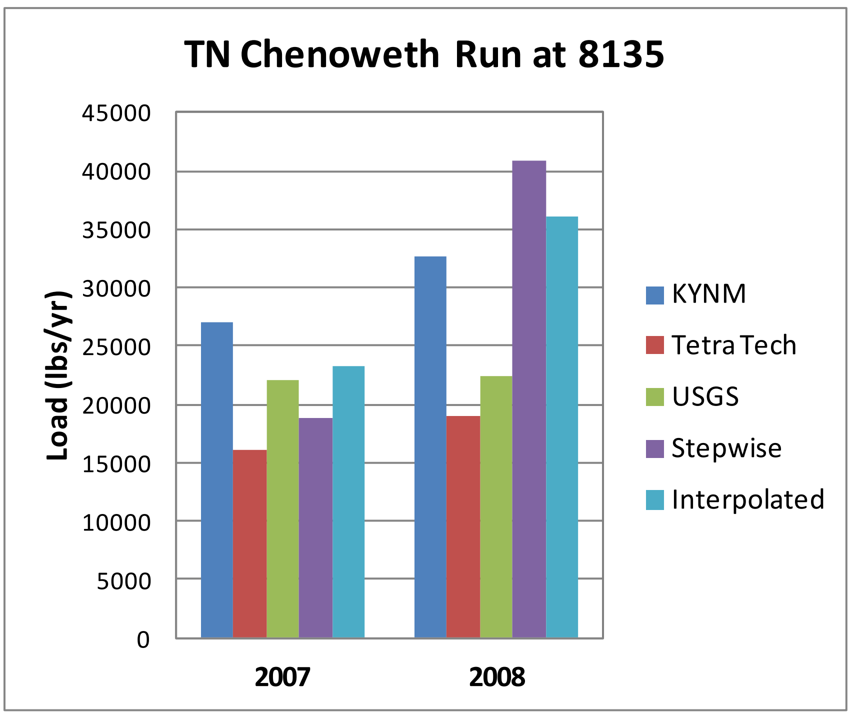


Figure 5.5 Comparison of Predicted and Estimated Annual Total Nitrogen Loads for Chenoweth Run at USGS 03298135

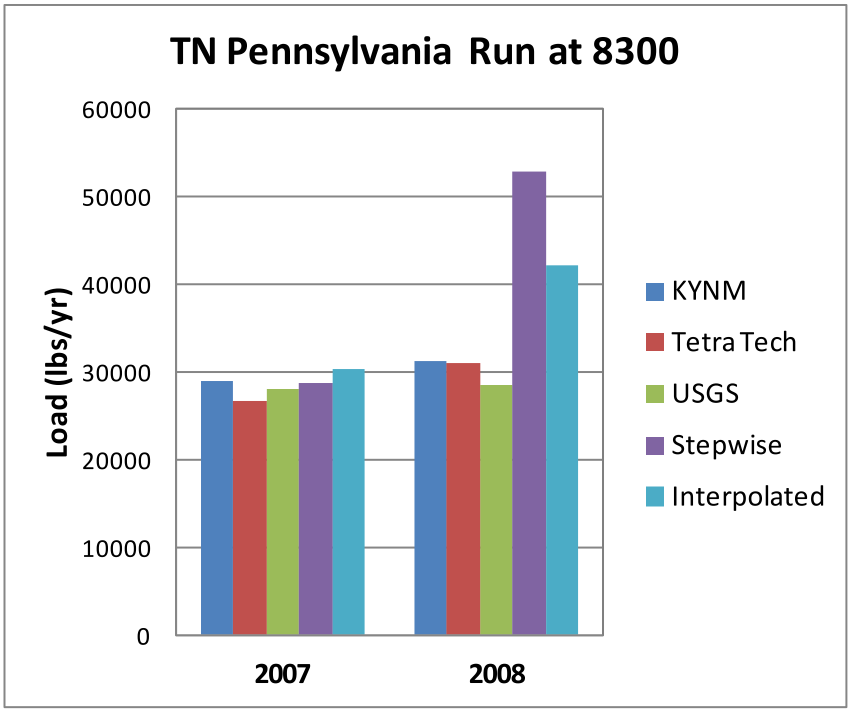


Figure 5.6 Comparison of Predicted and Estimated Annual Total Nitrogen Loads for Pennsylvania Run at USGS 03298300

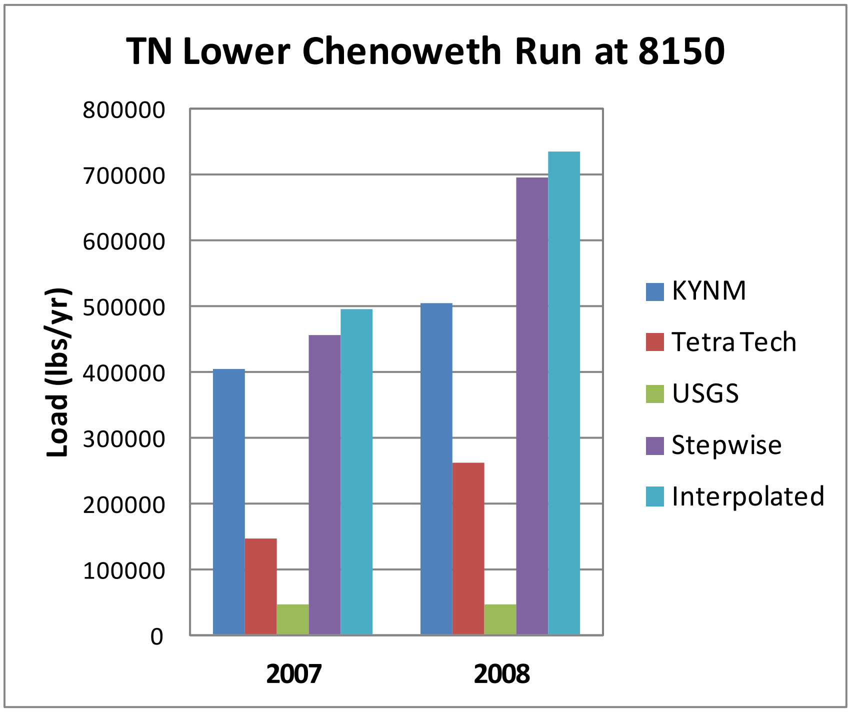


Figure 5.7 Comparison of Predicted and Estimated Annual Total Nitrogen Loads for Chenoweth Run at USGS 03298150

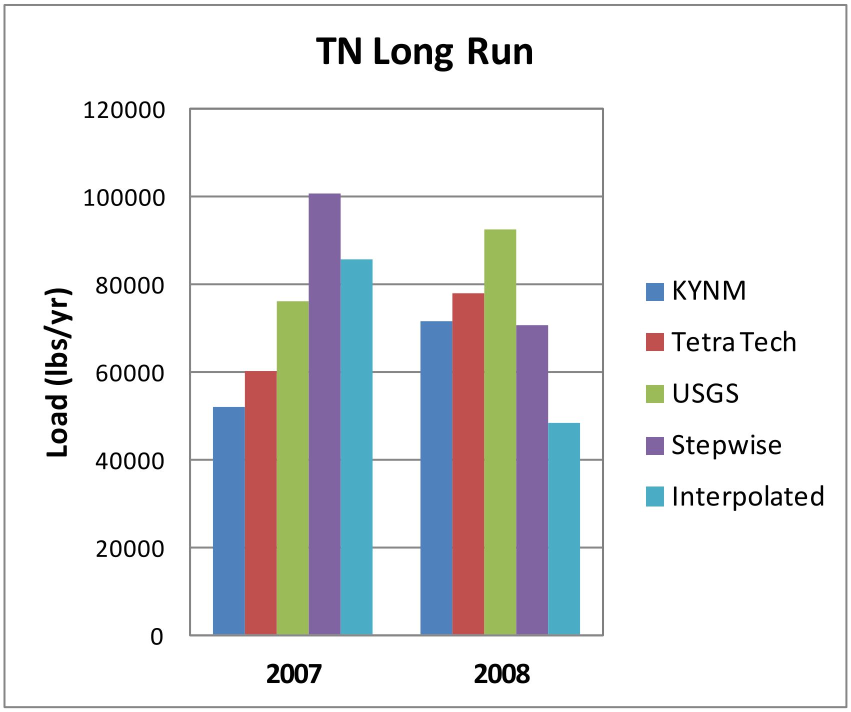


Figure 5.8 Comparison of Predicted and Estimated Annual Total Nitrogen Loads for Long Run

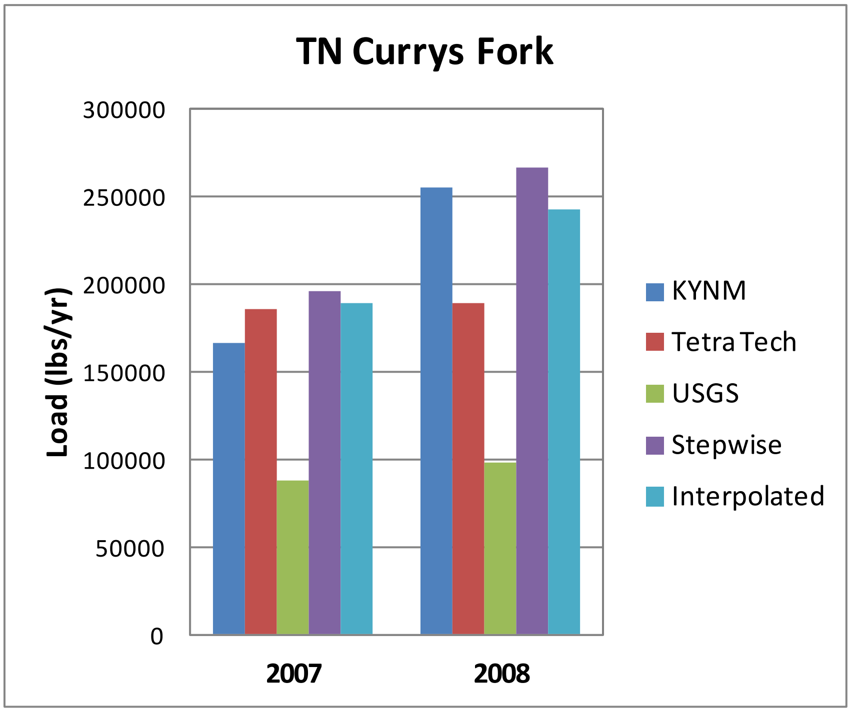


Figure 5.9 Comparison of Predicted and Estimated Annual Total Nitrogen Loads for Currys Fork

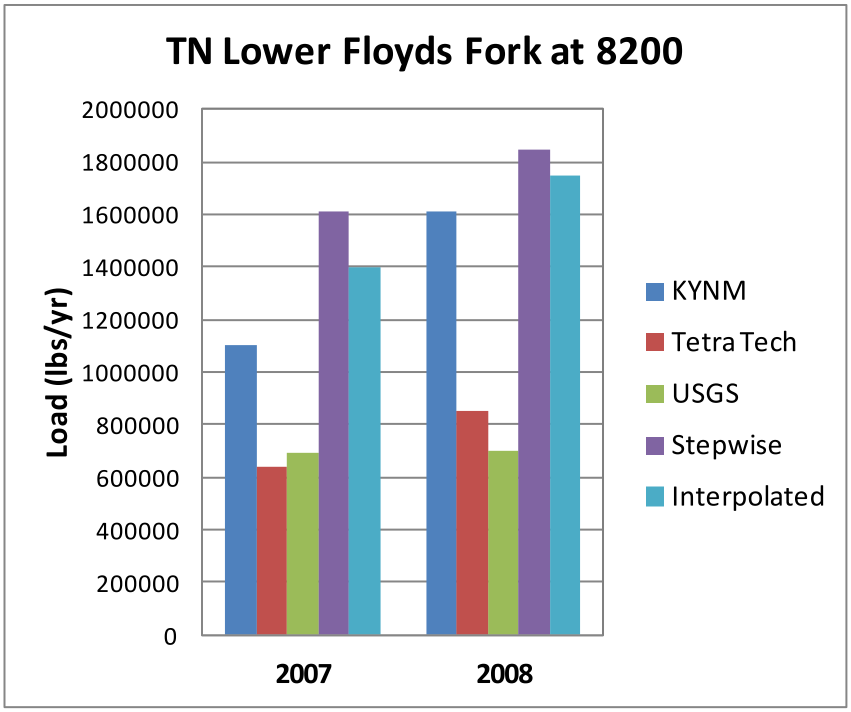


Figure 5.10 Comparison of Predicted and Estimated Annual Total Nitrogen Loads for Lower Floyds Fork at USGS 03298200

Table 5.8 below shows the annual load estimations for total phosphorus. Figures 5.11 through 5.17 show the same information, except that the annual load estimation from the USGS equation has been omitted due to its large relative magnitude over the other values skewing the scale of the charts.

Table 5.8 Total Phosphorus Annual Load Calibration and Validation Results

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
Ashers Run										
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	1247	649	92.14	29795	-95.81	1588	-21.47	1282	-2.73
2008	Validation	1490	770	93.51	30250	-95.07	1405	6.05	939	58.68
Chenoweth Run at USGS 03298135										
Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	804	878	-8.43	5978	-86.55	738	8.94	709	13.40
2008	Validation	964	983	-1.93	6060	-84.09	598	61.20	552	74.64
Pennsylvania Run at USGS 03298300										
Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	3813	2719	40.24	15378	-75.20	4209	-9.41	4042	-5.67
2008	Validation	3823	2493	53.35	15738	-75.71	3883	-1.55	3735	2.36
Chenoweth Run at USGS 03298150										
Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	13865	12167	13.96	15073	-8.01	24041	-42.33	24514	-43.44
2008	Validation	18418	17262	6.70	15281	20.53	16285	13.10	16079	14.55
Long Run										
Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	10129	7046	43.76	123714	-91.81	26736	-62.11	19036	-46.79
2008	Validation	17622	10226	72.33	151173	-88.34	11930	47.71	8066	118.47
Currys Fork										
Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	20045	15067	33.04	83930	-76.12	22031	-9.01	19421	3.21
2008	Validation	28983	16042	80.67	93530	-69.01	29270	-0.98	30963	-6.39
Lower Floyds Fork at USGS 03298200										
Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	78747	71056	10.82	507398	-84.48	125796	-37.40	109496	-28.08
2008	Validation	97649	99182	-1.55	514380	-81.02	72462	34.76	57689	69.27

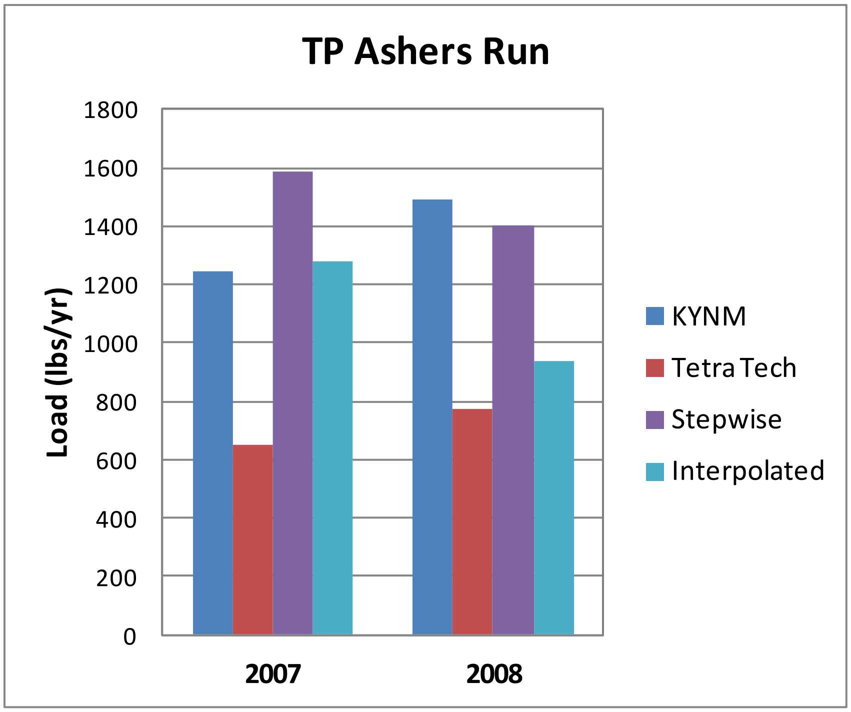


Figure 5.11 Comparison of Predicted and Estimated Annual Total Phosphorus Loads for Ashers Run

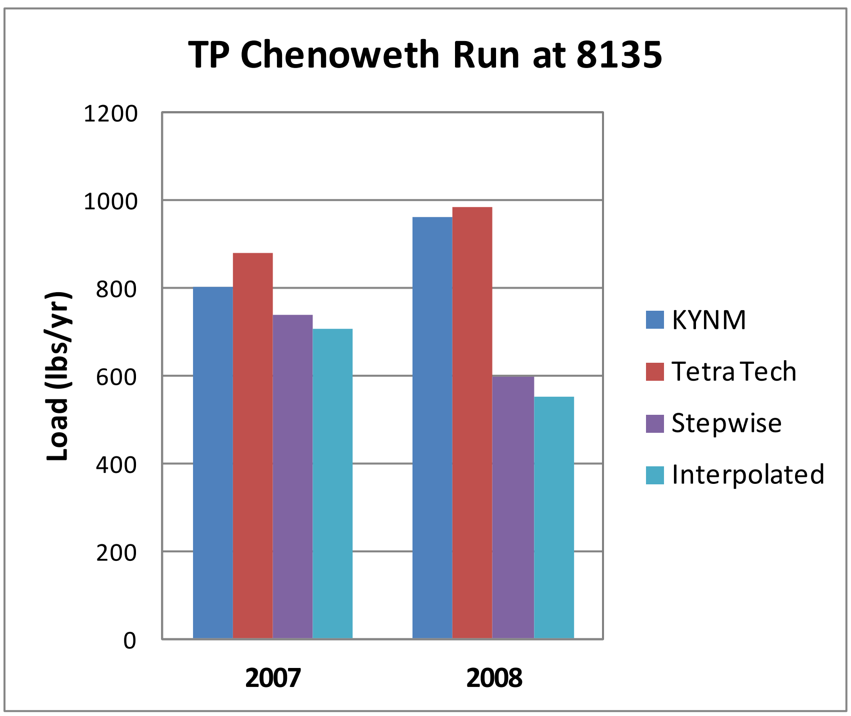


Figure 5.12 Comparison of Predicted and Estimated Annual Total Phosphorus Loads for Chenoweth Run at USGS 03298135

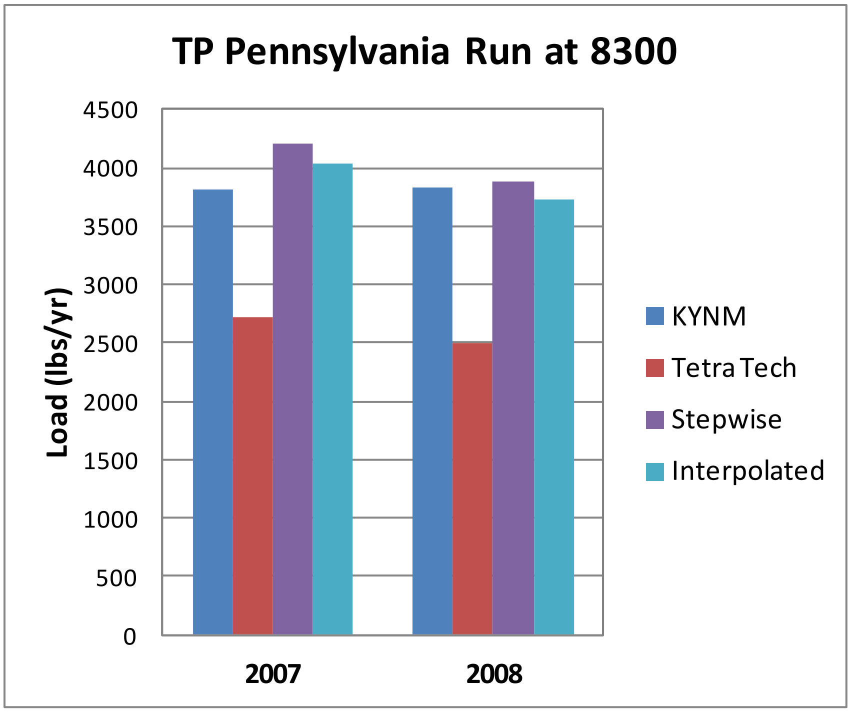


Figure 5.13 Comparison of Predicted and Estimated Annual Total Phosphorus Loads for Pennsylvania Run at USGS 03298300

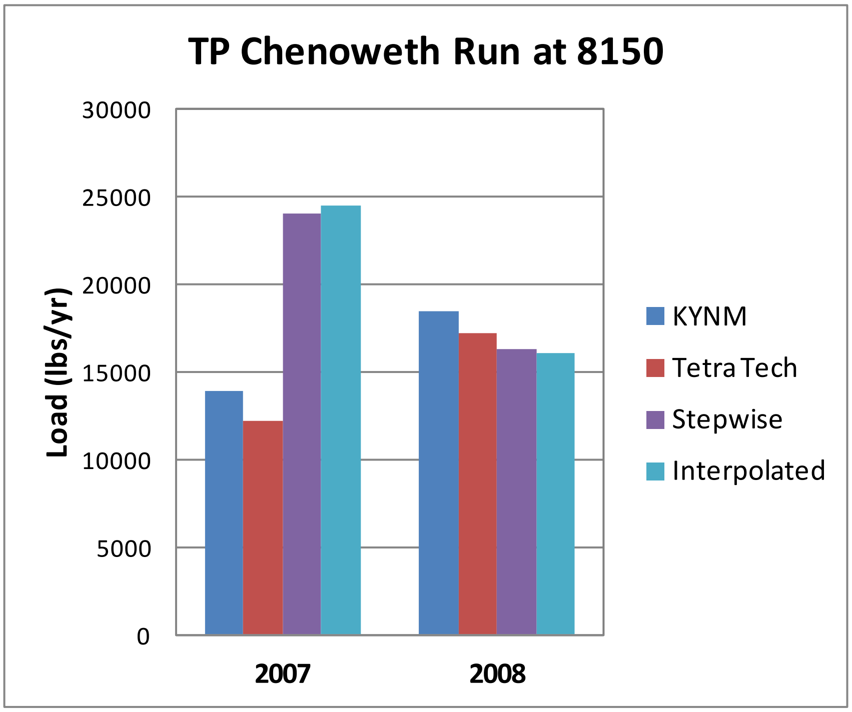


Figure 5.14 Comparison of Predicted and Estimated Annual Total Phosphorus Loads for Chenoweth Run at USGS 03298150

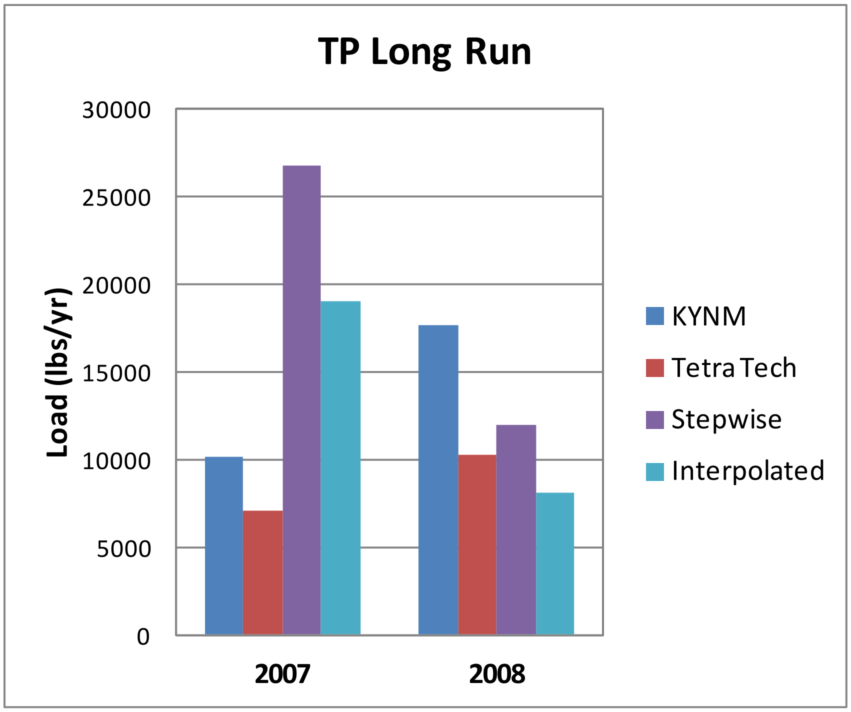


Figure 5.15 Comparison of Predicted and Estimated Annual Total Phosphorus Loads for Long Run

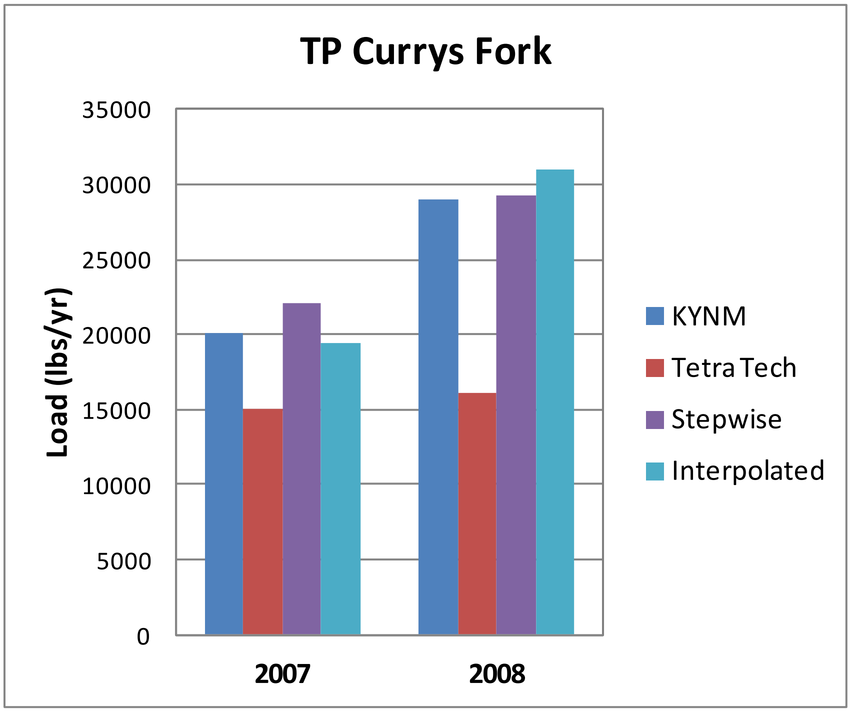


Figure 5.16 Comparison of Predicted and Estimated Annual Total Phosphorus Loads for Currys Fork

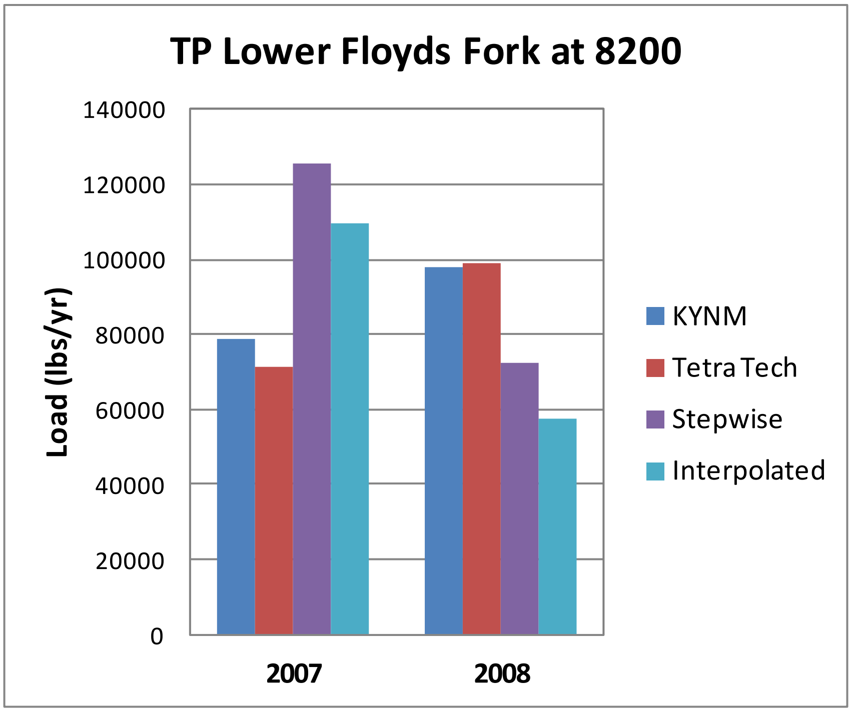


Figure 5.17 Comparison of Predicted and Estimated Annual Total Phosphorus Loads for Lower Floyds Fork at USGS 03298200

6.0 Model Development

Following the verification of the KYNM, 11additional watershed models were developed for use by the Kentucky Division of Water in the development of TMDLs for this watershed. The eleven watersheds are summarized in Table 6.1 and illustrated in Figures 6.1-6.3. The input parameters associated with these models are provided in Appendix C. The last watershed in the list, Upper Floyds Fork at USGS 03297900 was built using a segmental approach to demonstrate the adaptation of the KYNM to developing subwatersheds and incrementally combining them into a downstream result. The results from the Currys Fork model, the Upper Floyds Fork at Currys Fork model, and an incremental contribution model from Floyds Fork at Currys Fork down to USGS 03297900 were combined in a mass balance to yield the final results for Upper Floyds Fork at USGS 03297900.

Table 6.1 Additional Floyds Fork Subbasins Developed in KYNM

Watershed Name	Watershed Area (sqmi)	Impaired Mile Segments
Brooks Run	9.64	0.0-6.4
Cedar Creek	22.47	4.3-11.1
Chenoweth Run	16.72	0.0-9.2
Lower Floyds Fork at Bethel Branch	288.69	11.6-24.2
Middletown Chenoweth Run	7.46	0.0-2.5
North Currys Fork	10.14	0.0-6.0
Pennsylvania Run	8.42	0.0-3.3
South Currys Fork	9.33	0.0-6.1
South Long Run	7.64	0.0-3.35
Upper Floyds Fork at Currys Fork	28.63	48.0-61.9
Upper Floyds Fork at USGS 03297900	82.96	45.7-61.9

7.0 Summary and Conclusions

The Kentucky Nutrient Model (KYNM) has been developed to provide a tool for use in identifying the associated sources of nutrient loads in a watershed as well as providing a basis for identifying and evaluating potential management strategies. By developing the model in an Excel Spreadsheet environment, the user is provided with a platform that provides transparency to the underlying equations and calculations as well as a familiar platform for use in developing graphical representations for results presentation. The model has been calibrated and validated for a range of watershed types and conditions and thus should provide a reliable tool for use in nutrient management.

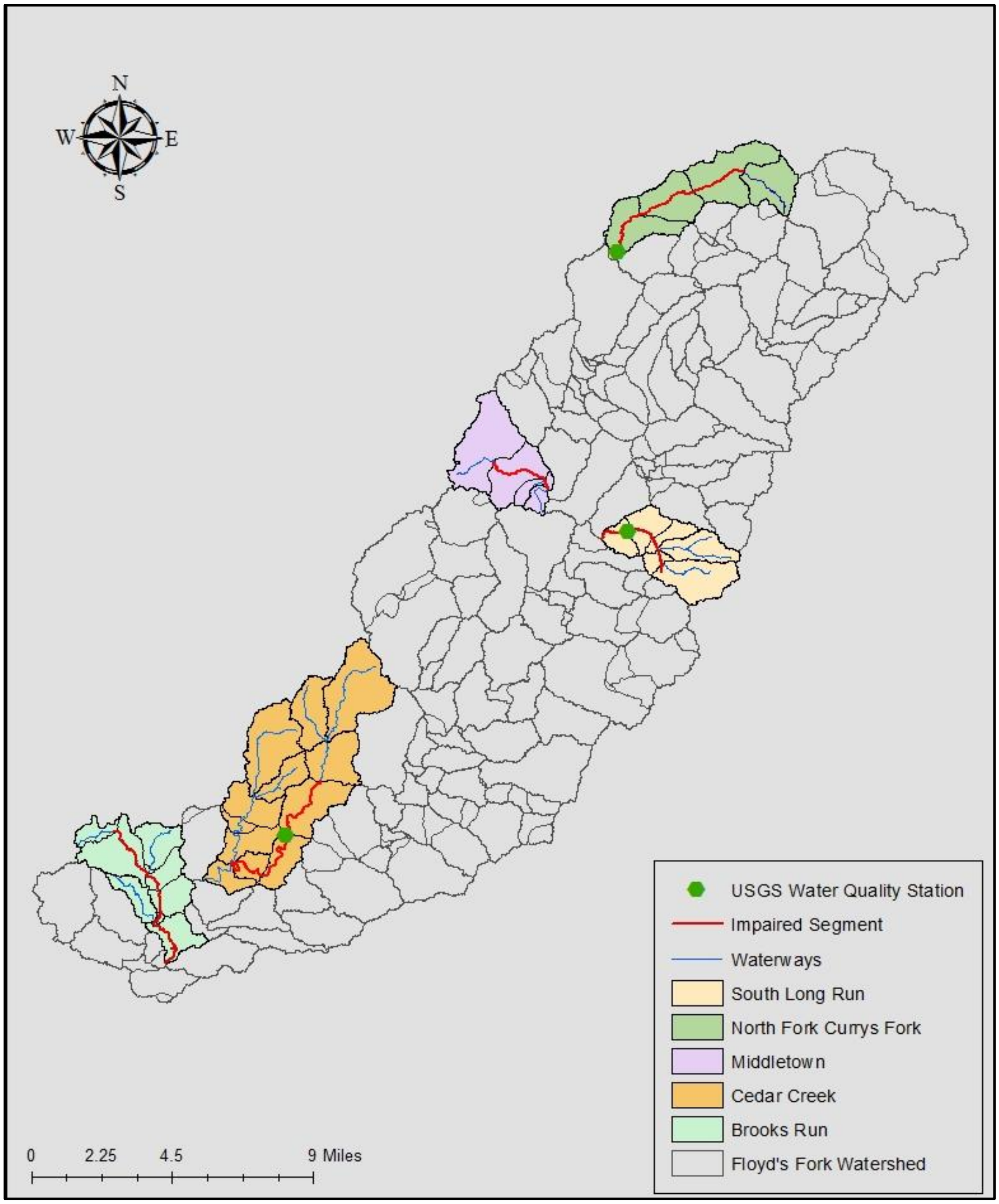


Figure 6.1 Impaired Floyds Fork Watershed Segments

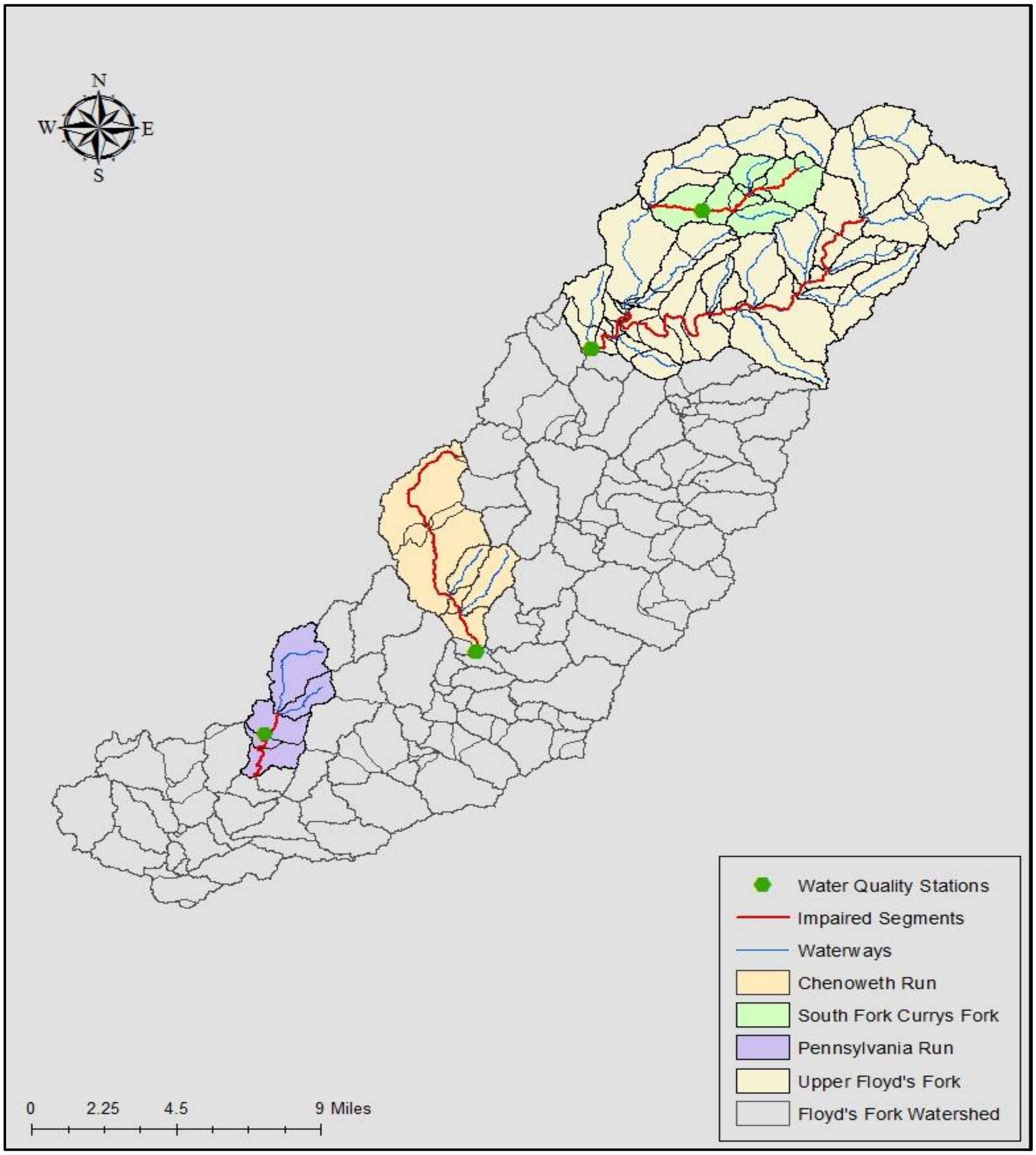


Figure 6.2 Impaired Floyds Fork Watershed Segments (cont)

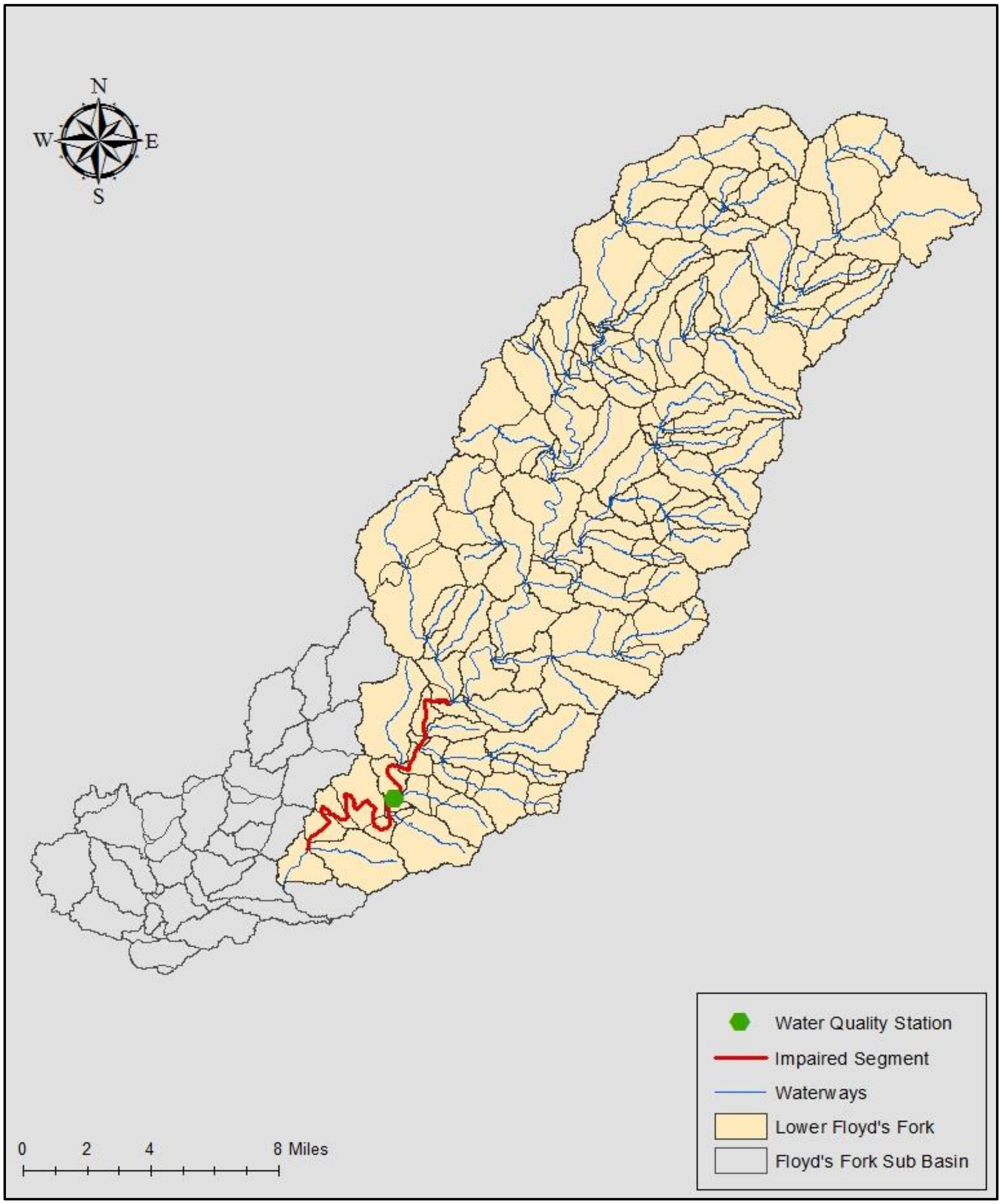


Figure 6.3 Impaired Floyds Fork Watershed Segments (cont)

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APPENDIX A: EMC DATABASE

A.1 EMCs for Barren Dirt and Roadways

Barren (Dirt)				
Reference	Location	TN (mg/L)	TP (mg/L)	Statistic
Line (02)	NC	1.35	0.21	Median
		1.29	0.43	Mean

Roadways				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
NSQD (04) Freeway	National	2.3	0.25	Median
NSQD (04) Freeway	Zone 2	2.4	0.95	Median
Steuer et al. (97)	Res Street	1.7	0.55	Median
Steuer et al. (97)	Urban Highway	3	0.32	Median

Line, D. E., White, N. M., Osmond, D. L., Jennings, G. D., & Mojonnier, C. B. (2002). Pollutant export from various land uses in the Upper Neuse River Basin. Water Environment Research, 74(1), 104.

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Steuer et al. (1997). Sources of contamination in an urban basin in Marquette, Michigan and analysis of concentrations, loads, and data quality. U.S. Geological survey, Water Resources Investigations Report: 97-4242.

A.2 EMCs for Residential

Residential				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
NURP (83)	National	2.64	0.33	Median
				Min
				Max
NSQD (04)	National	2	0.3	Median
				Min
				Max
NSQD (04)	Zone 2	1.8	0.43	Median
				Min
				Max
KY USGS (94)	Louisville	3.76	0.81	Median
		0.93	0.16	Min
		17.99	12.89	Max
NSQD (14)	Louisville	1.25	0.33	Median
		0.44	0.08	Min
		90.10	0.13	Max
NSQD (14)	Lexington	3.70	0.63	Median
		2.90	0.07	Min
		3.70	0.69	Max
NSQD (14)	Knoxville	1.50	0.34	Median
		0.30	0.03	Min
		7.50	1.78	Max

NURP. (1983). Tabels 3-4, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 54.

NSQD. (2004). Tables 3-10, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 60.

USGS. (1994). Water resources data KY: water year 1994.

NSQD. (2014). Data Retrieved from: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

A.3 EMCs for Commercial

Commercial				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
NURP (83)	National	1.75	0.20	Median
		2.20		Min
		2.20		Max
NSQD (04)	National	2.2	0.22	Median
				Min
				Max
NSQD (04)	Zone 2	2	0.37	Median
				Min
				Max
KY USGS (94)	Louisville	2.32	0.19	Median
		1.73	0.14	Min
		2.64	0.38	Max
NSQD (14)	Louisville	1.30	0.28	Median
		0.44	0.09	Min
		90.10	10.20	Max
NSQD (14)	Lexington	6.08	0.71	Median
		1.75	0.10	Min
		18.10	2.30	Max
NSQD (14)	Knoxville	1.50	0.16	Median
		0.50	0.01	Min
		20.20	1.83	Max

NURP. (1983). Tabels 3-4, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 54.

NSQD. (2004). Tables 3-10, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 60.

USGS. (1994). Water resources data KY: water year 1994.

NSQD. (2014). Data Retrieved from: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

A.4 EMCs for Industrial

Industrial				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
NURP (83)	National	2.10	0.26	Median
		1.44	0.23	Min
		2.10	0.26	Max
NSQD (04)	National	2.10	0.26	Median
				Min
				Max
NSQD (04)	Zone 2	1.8	0.26	Median
				Min
				Max
KY USGS (94)	Louisville	2.45	0.41	Median
		0.98	0.15	Min
		5.38	1.82	Max
NSQD (14)	Louisville	0.66	0.27	Median
		1.00	0.07	Min
		0.30	0.81	Max
NSQD (14)	Lexington	2.90	0.37	Median
		1.90	0.13	Min
		3.30	2.50	Max
NSQD (14)	Knoxville	1.30	0.20	Median
		0.28	0.02	Min
		16.70	0.97	Max

NURP. (1983). Tabels 3-4, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 54.

NSQD. (2004). Tables 3-10, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 60.

USGS. (1994). Water resources data KY: water year 1994.

NSQD. (2014). Data Retrieved from: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

A.5 EMCs for Parks

Parks				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
NURP (83)	National	1.51	0.12	Median
NSQD (04)	National	1.2	0.25	Median
NSQD (04)	Zone 2	1.2	0.26	Median

NURP. (1983). Tabels 3-4, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 54.

NSQD. (2004). Tables 3-10, 3-11 Retrieved from: Shaver , E., Horner, R., Skupien, J., May, C., & Ridley, G. (2007). Fundamentals of urban runoff management: technical and institutional issues (2nd ed.), pp. 60.

A.6 EMCs for Golf Courses

Golf Courses				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
Line et al (02)	N. Carolina	6.12	1.07	Median
King et al (11)	Minnesota	1.10	0.03	Median

Line, D. E., White, N. M., Osmond, D. L., Jennings, G. D., & Mojonnier, C. B. (2002). Pollutant export from various land uses in the Upper Neuse River Basin. Water Environment Research, 74(1), 104.

King, K. W., & Balogh, J. C. (2011). Stream water nutrient enrichment in a mixed-use watershed. Journal of Environmental Monitoring, 13(3), 728. doi: 10.1039/c0em00584c

A.7 EMCs for Forest

Forest				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
Reckhow (80)		0.51	0.01	Median
		0.15	0.02	Min
		0.89	0.00	Max
KY USGS (05)	Region IX	0.45	0.02	Median
		0.31	0.01	Min
		0.54	0.05	Max
KY USGS (05)	Region XI	0.45	0.01	Median
		0.31	0.01	Min
		1.30	0.10	Max

Reckhow, K. H., Beaulac, M. N., & Simpson, J. T. (1980). Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients, pp.91-104.

USGS (2005). Concentrations, and estimated loads and yields of total nitrogen and total phosphorous at selected water quality monitoring network stations in KY, 1979-2004.

A.8 EMCs for Grassland

Grassland				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
EPA (99)		2.80	0.15	Median
KY USGS (05)	Region IX	0.45	0.02	Median
		0.15	0.00	Min
		1.41	0.15	Max
KY USGS (05)	Region XI	0.45	0.01	Median
		0.15	0.00	Min
		1.41	0.15	Max

U .S. Environmental Protection Agency. (1999). Protocol for developing nutrient TMDLs. EPA 841-B-99-007. Office of Water (4503F). United States Environmental Protection Agency, Washington D.C., 58.

USGS (2005). Concentrations, and estimated loads and yields of total nitrogen and total phosphorous at selected water quality monitoring network stations in KY, 1979-2004.

A.9 EMCs for Pasture

Pasture				
Landuse	Source	TN (mg/L)	TP (mg/L)	Statistic
EPA (99)	Pasture	3.00	0.25	Median
Line e al (02)	N. Carolina	3.61	1.56	Median
KY USGS	Jefferson Co	4.08	0.37	Median
		0.55	0.01	Min
		13.16	3.57	Max
Reckhow (80)	Dairy Grazing	2.89	6.32	Median
		1.62	6.06	Min
		4.16	6.57	Max
	Continuous	5.09	0.97	Median
		4.06	0.75	Min
		6.26	3.33	Max
	Rotational	4.02	0.47	Median
		2.49	0.42	Min
		10.98	7.19	Max
KY USGS (05)	Region IX	1.60	0.21	Median
		1.10	0.05	Min
		3.80	0.39	Max

U .S. Environmental Protection Agency. (1999). Protocol for developing nutrient TMDLs. EPA 841-B-99-007. Office of Water (4503F). United States Environmental Protection Agency, Washington D.C., 58.

Line, D. E., White, N. M., Osmond, D. L., Jennings, G. D., & Mojonnier, C. B. (2002). Pollutant export from various land uses in the Upper Neuse River Basin. Water Environment Research, 74(1), 104.

USGS (2005). Concentrations, and estimated loads and yields of total nitrogen and total phosphorous at selected water quality monitoring network stations in KY, 1979-2004.

Reckhow, K. H., Beaulac, M. N., & Simpson, J. T. (1980). Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients, pp.91-104.

A.10 EMCs for Row Crops

Row Crops				
Landuse	Source	TN (mg/L)	TP (mg/L)	Statistic
Row Crops				
EPA (99)	Corn	2.60	0.26	Median
		0.50	0.20	Min
		4.50	0.50	Max
KY USGS	Jefferson Co	2.20	0.06	Median
		0.00	0.00	Min
		5.50	0.61	Max
Reckhow (80)	Corn	13.89	1.08	Median
	Contour	12.00	0.91	Min
		15.89	1.49	Max
	Corn	4.68	1.43	Median
	Continuous	1.80	0.56	Min
		21.92	4.71	Max
	SB/Corn	4.01	1.02	Median
		3.82	0.73	Min
		4.19	1.31	Max
	Wheat	7.77	1.99	Median
		6.72	1.87	Min
		8.82	2.11	Max
KY USGS (05)	Region IX	1.25	0.14	Median
		0.93	0.13	Min
		1.60	0.15	Max

U .S. Environmental Protection Agency. (1999). Protocol for developing nutrient TMDLs. EPA 841-B-99-007. Office of Water (4503F). United States Environmental Protection Agency, Washington D.C., 58.

USGS (2005). Concentrations, and estimated loads and yields of total nitrogen and total phosphorous at selected water quality monitoring network stations in KY, 1979-2004.

Reckhow, K. H., Beaulac, M. N., & Simpson, J. T. (1980). Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients, pp.91-104.

A.11 EMCs for Silviculture

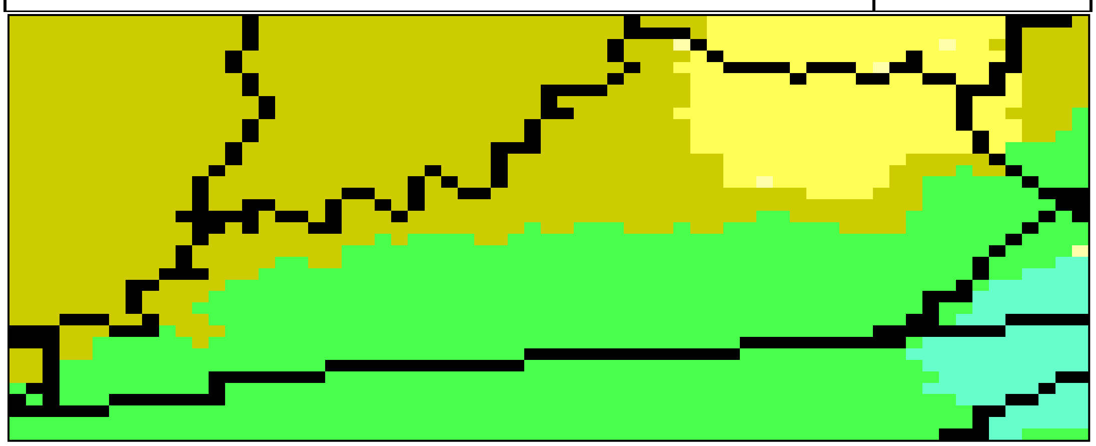
Silviculture				
Source	Location	TN (mg/L)	TP (mg/L)	Statistic
Reckhow (80)		0.51	0.01	Median
		0.15	0.02	Min
		0.89	0.00	Max
KY USGS (05)	Region IX	0.45	0.02	Median
		0.31	0.01	Min
		0.54	0.05	Max
KY USGS (05)	Region XI	0.45	0.01	Median
		0.31	0.01	Min
		1.30	0.10	Max

Reckhow, K. H., Beaulac, M. N., & Simpson, J. T. (1980). Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients, pp.91-104.

USGS (2005). Concentrations, and estimated loads and yields of total nitrogen and total phosphorous at selected water quality monitoring network stations in KY, 1979-2004.

A.12 EMCs for Air Deposition

Air Deposition				
Source	Location	TN	TP	Statistic
Forest				
		kg/hc/yr	kg/hc/yr	
Reckhow (80)		0.99	0.07	Min
		11.30	0.54	Max
		6.52	0.27	Median
		5.97	0.28	Mean
Rural				
		kg/hc/yr	kg/hc/yr	
Rechow (80)		10.49	0.13	Min
		38.00	0.97	Max
		13.13	0.28	Median
		20.98	0.45	Mean
Background				
		tn/sqmi/yr		
		2.00		Median
		1.70		Median
		1.30		Median
USGS Circular 1136				



Reckhow, K. H., Beaulac, M. N., & Simpson, J. T. (1980). Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients, pp.91-104.

Mueller, D. K., & Helsel, D. R. (1996). Nutrients in the nation's waters-Too much of a good thing?. M. A. Kidd (Ed.). US Government Printing Office. USGS Circular 1136. Retrieved from: http://pubs.usgs.gov/circ/circ1136/

APPENDIX B: MODEL CALIBRATION/VALIDATION RESULTS

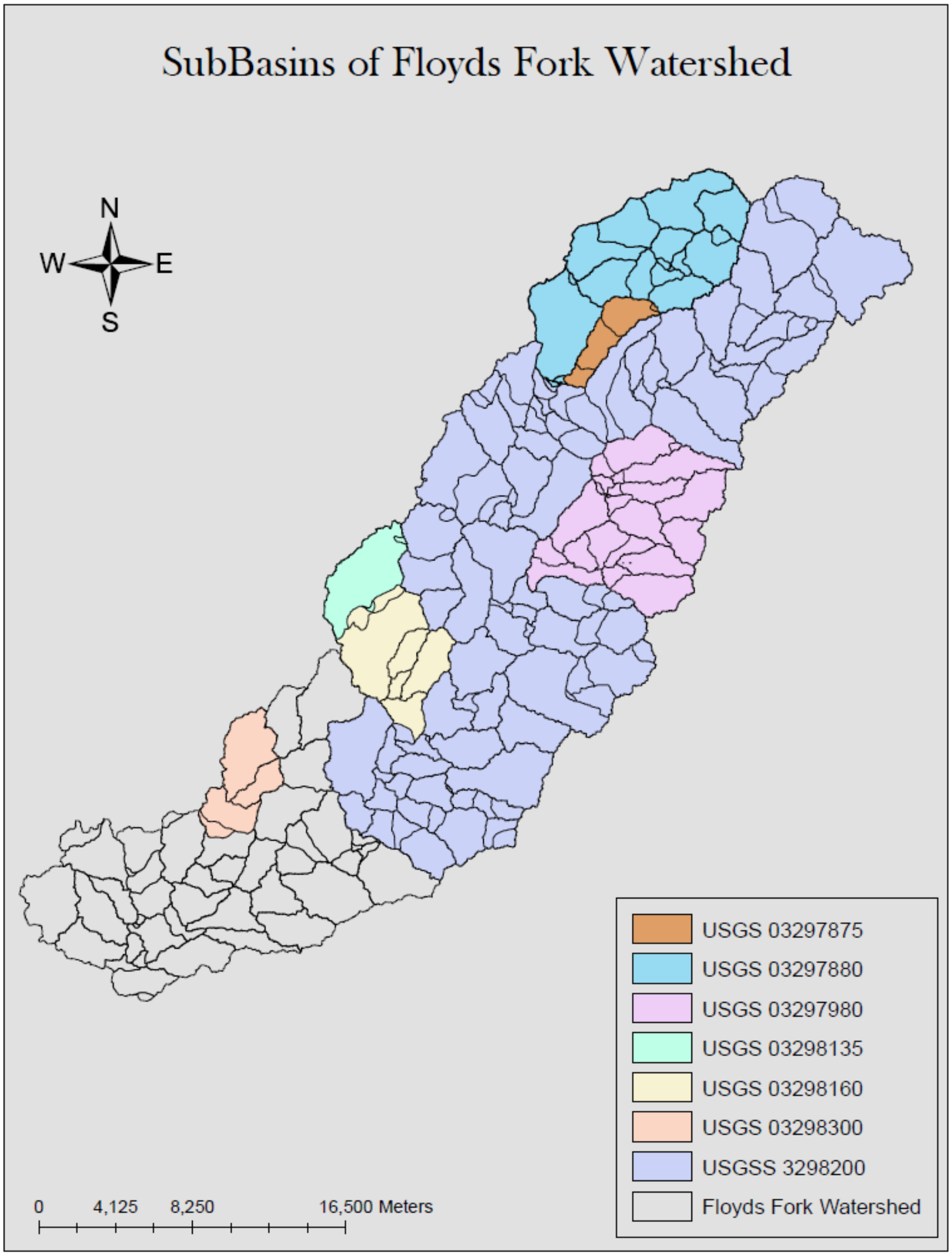


Figure B.1.1 Map of Subbasins of Floyds Fork Watershed

B.1 ASHERS RUN

B.1.1 Waterhed Characteristics:

Watershed Name: Ashers Run at Abott Lane

Watershed Area (sqmi): 3.27 sq mi (2,095 acres)

USGS Flow Station: None

USGS Water Quality Station: 03297875

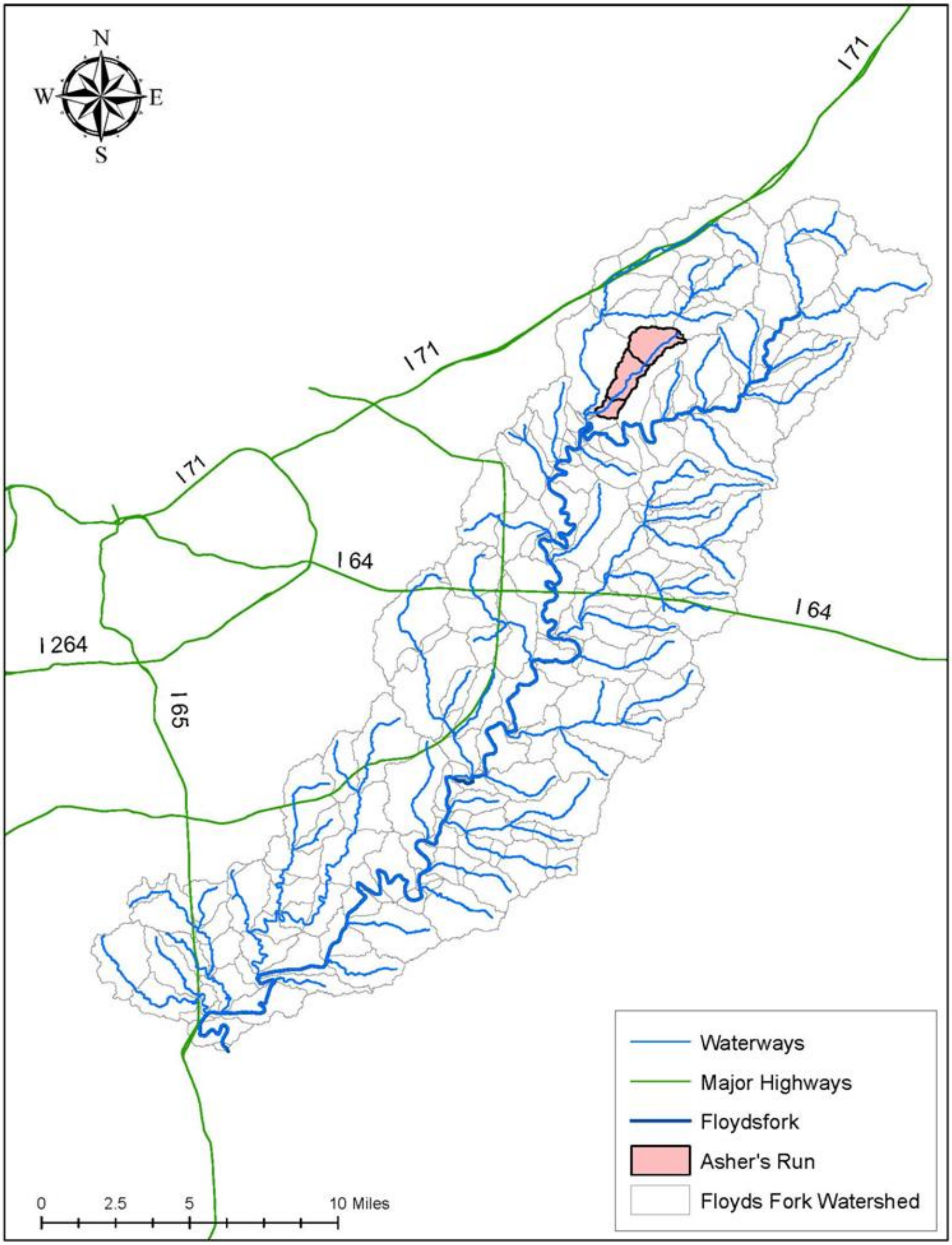


Figure B.1.2 Map of Ashers Run Watershed

Table B.1.1 Point Source Data for Ashers Run Watershed

# Households	168	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.028**	0.1263	0.1287

Table B.1.2 Non-Point Source Data for Ashers Run Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	(acres)		EMC (mg/L)	EMC (mg/L)
Barren Land	0.0	N/A	N/A	N/A
Residential	196.0	80	2.505	0.555
Commercial	3.3	94	3.69	0.435
Industrial	0.0	N/A	N/A	N/A
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	800.3	74	0.48	0.015
Grassland	12.9	77	1.625	0.08
Agriculture				
Pasture	997.2	77	3.345	0.61
Row Crops	63.1	84	7.57	1.025
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	7.0	0.01	0	0
Wetlands	8.7	0.01	0	0
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	6.5	80	0.18	0.02
	Total Area (ac)	Average CN	Tot Load (tons)	Tot Load (tons)
	2095	76	2.28	0.39

B.1.2 2007 Hydrology Calibration/2008 Validation:

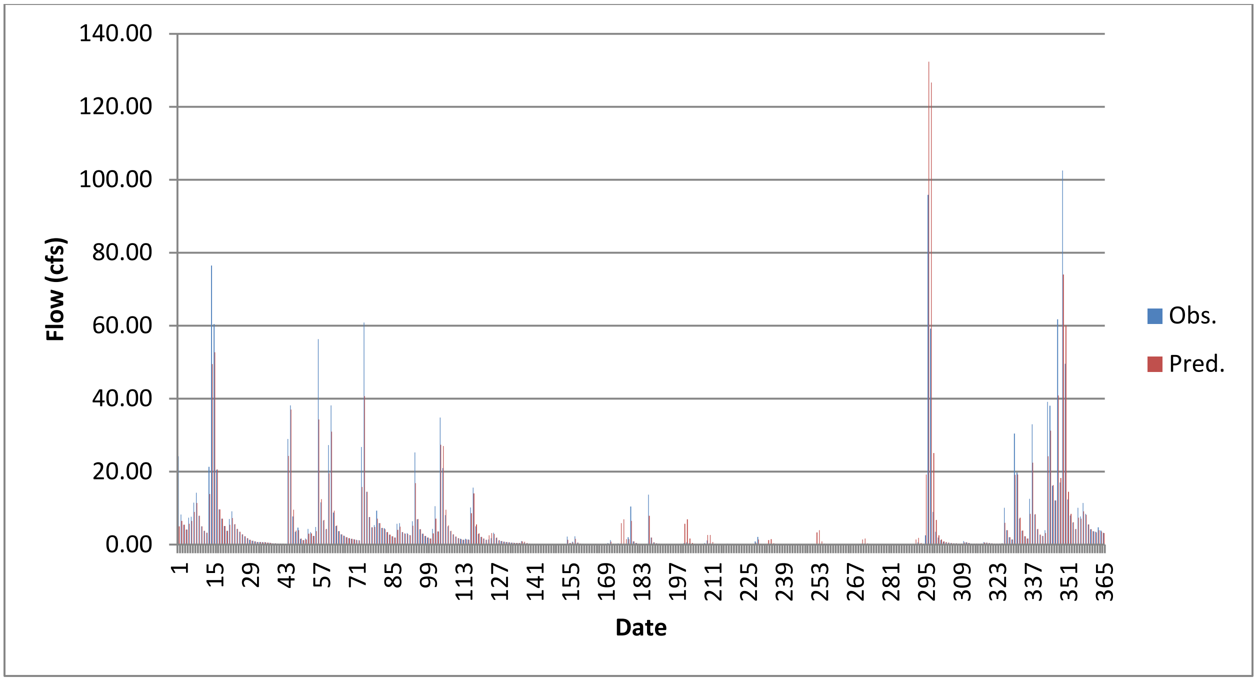


Figure B.1.3 Time Series Plot of 2007 Calibration

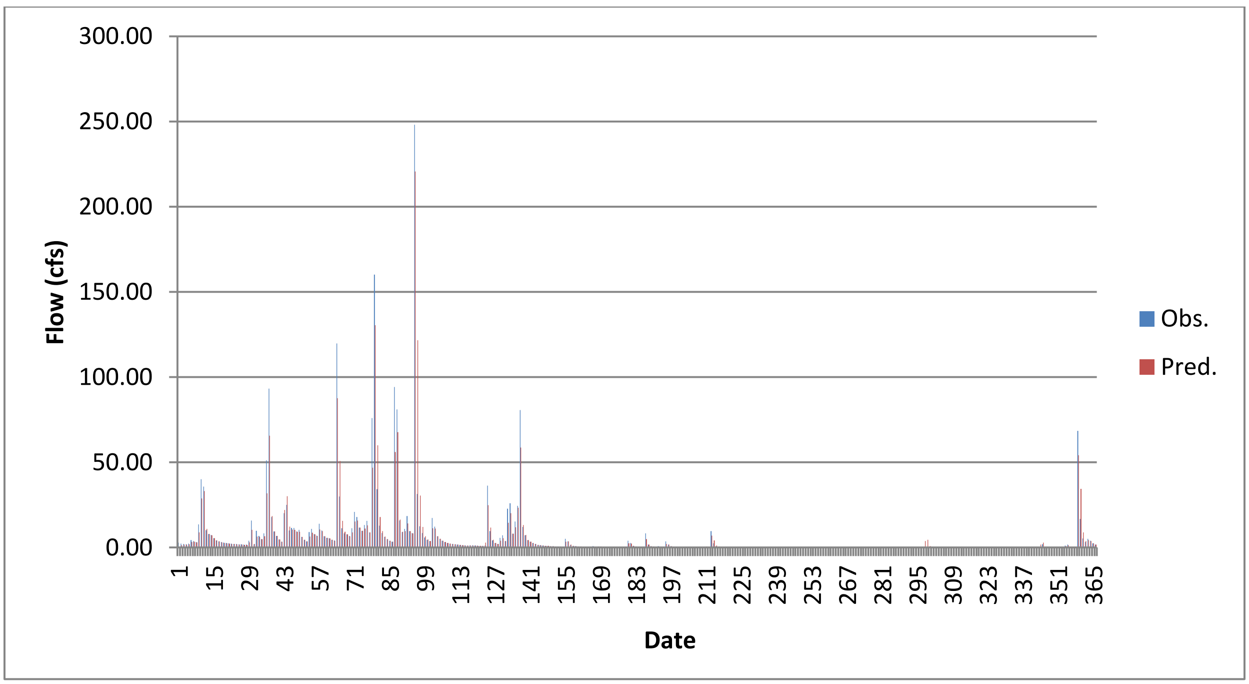


Figure B.1.4 Time Series Plot of 2008 Validation

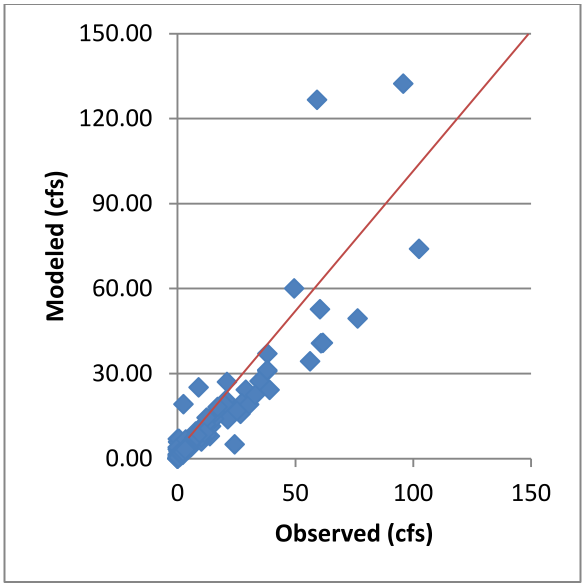


Figure B.1.5 Scatter Plot of 2007 Flow Calibration

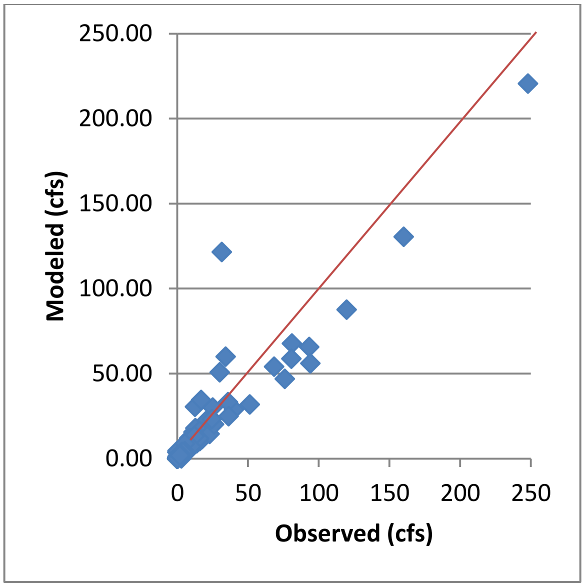


Figure B.1.6 Scatter Plot of 2008 Flow Validation

Table B.1.3 Flowrate Calibration/Validation Statistics

Year	R2	RMSE	RSR	% BIAS	NSE
2007 Calibration	0.77	6.60	0.53	4.83	0.72
2008 Validation	0.93	5.88	0.29	6.71	0.92

B.1.3 2007 Water Quality Calibration/2008 Validation (Total Nitrogen):

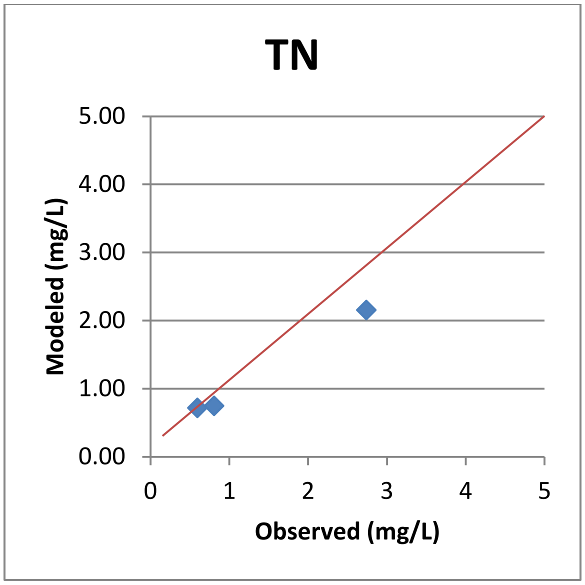


Figure B.1.7 Scatter Plot of 2007 TN Calibration

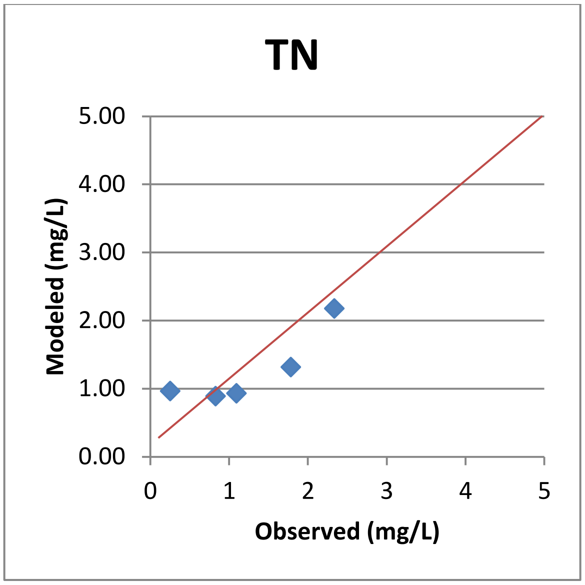


Figure B.1.8 Scatter Plot of 2008 TN Validation

Table B.1.4 Total Nitrogen Calibration/Validation Statistics for Ashers Run

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	14765	8025	83.99	12740	15.89	13647	8.19	12456	18.54
2008	Validation	18339	9986	83.65	12910	42.05	17876	2.59	11979	53.09

B.1.4 2007 Water Quality Calibration/2008 Validation (Total Phoshporus):

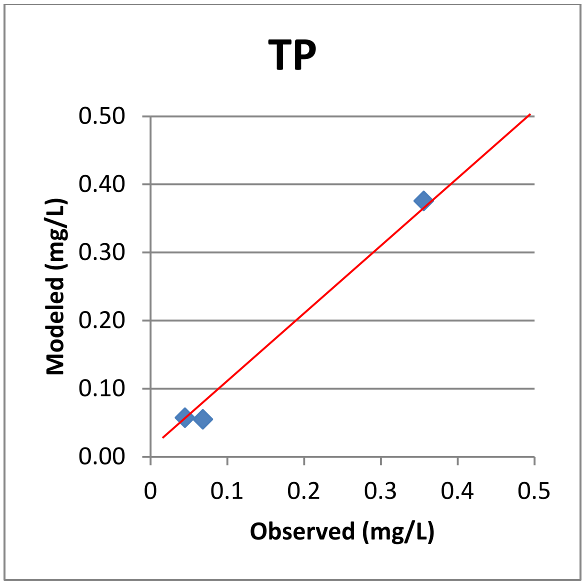


Figure B.1.9 Scatter Plot of 2007 TP Calibration

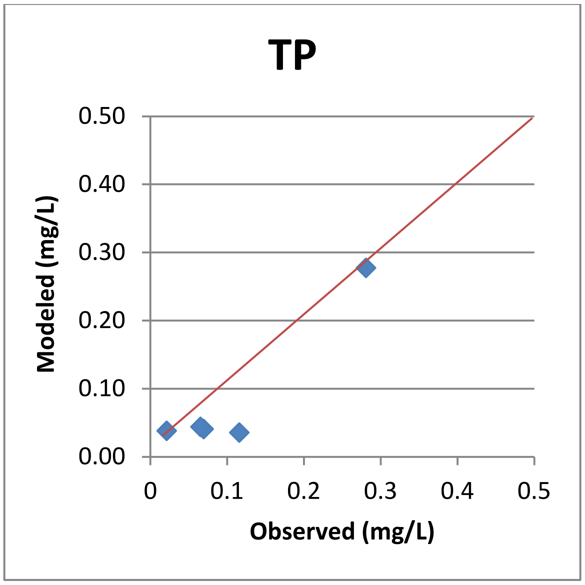


Figure B.1.10 Scatter Plot of 2008 TP Validation

Table B.1.5 Total Phosphorus Calibration/Validation Statistics for Ashers Run Watershed

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	1247	649	92.14	29795	-95.81	1588	-21.47	1282	-2.73
2008	Validation	1490	770	93.51	30250	-95.07	1405	6.05	939	58.68

B.2 CURRYS FORK

B.2.1 Watershed Characteristics:

Watershed Name: Currys Fork at KY 1408

Watershed Area: 28.48 sq. mi. (18,228 acres)

USGS Flow Gauge: None

USGS Water Quality Station: 03297880

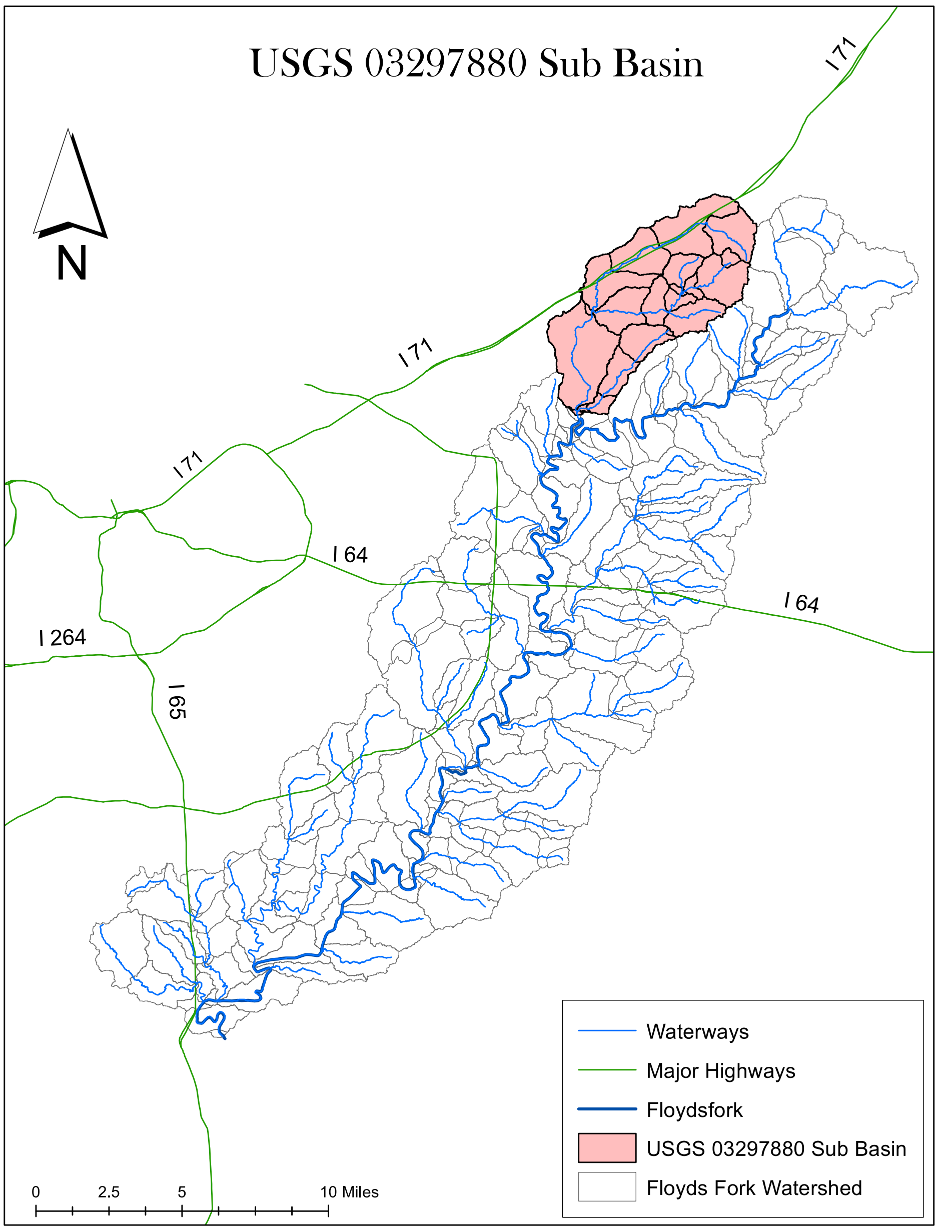


Figure B.2.1 Map of Currys Fork Watershed

Table B.2.1 Point Source Data for Currys Fork Watershed

Major Facility #2 Point Source Menu			
Name	LAGRANGE STP	**KPDES #**	KY0020001
	Discharge	TN EMC	TP EMC
Design (limits)	0.833	24.5	1.03
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.720	24.50	1.03
2	0.650	24.50	1.03
3	0.640	24.50	1.03
4	0.660	24.50	1.03
5	0.540	24.50	1.03
6	0.510	24.50	1.03
7	0.510	24.50	1.03
8	0.509	24.50	1.03
9	0.490	24.50	1.03
10	0.550	24.50	1.03
11	0.580	24.50	1.03
12	0.840	24.50	1.03

Table B.2.1 (Continued) Point Source Data for Currys Fork Watershed

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400289	0.001	20	4
KYG400147	0.001	20	4
KYG400112	0.001	20	4
KYG400105	0.001	20	4
Total	0.004	20	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0029441	0.027	9.000	1.200
KY0039870	0.068	9.000	2.517
KY0103110	0.164	9.000	1.200
KY0076732	0.010	9.000	1.200
KY0054674	0.042	9.000	1.200
KY0060577	0.054	9.000	1.200
Total	0.366	9	1.44
# Households	1484	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.249**	0.1263	0.1287

Table B.2.2 Non-Point Source Data for Currys Fork Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	(acres)		EMC (mg/L)	EMC (mg/L)
Barren Land	0.0	N/A	N/A	N/A
Residential	2674.3	80	2.505	0.555
Commercial	259.7	94	3.69	0.435
Industrial	99.8	91	1.78	0.305
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	8297.9	74	0.48	0.015
Grassland	357.5	77	1.625	0.08
Agriculture				
Pasture	5384.0	77	3.345	0.61
Row Crops	866.2	84	7.57	1.025
Silviculture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	142.4	0.01	0	0
Wetlands	89.1	0.01	0	0
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	57.5	80	0.18	0.02
	Total Area (ac)	Average CN	Tot Load (tons)	Tot Load (tons)
	18228	77	21.14	3.37

B.2.2 2007 Hydrology Calibration/2008 Validation:

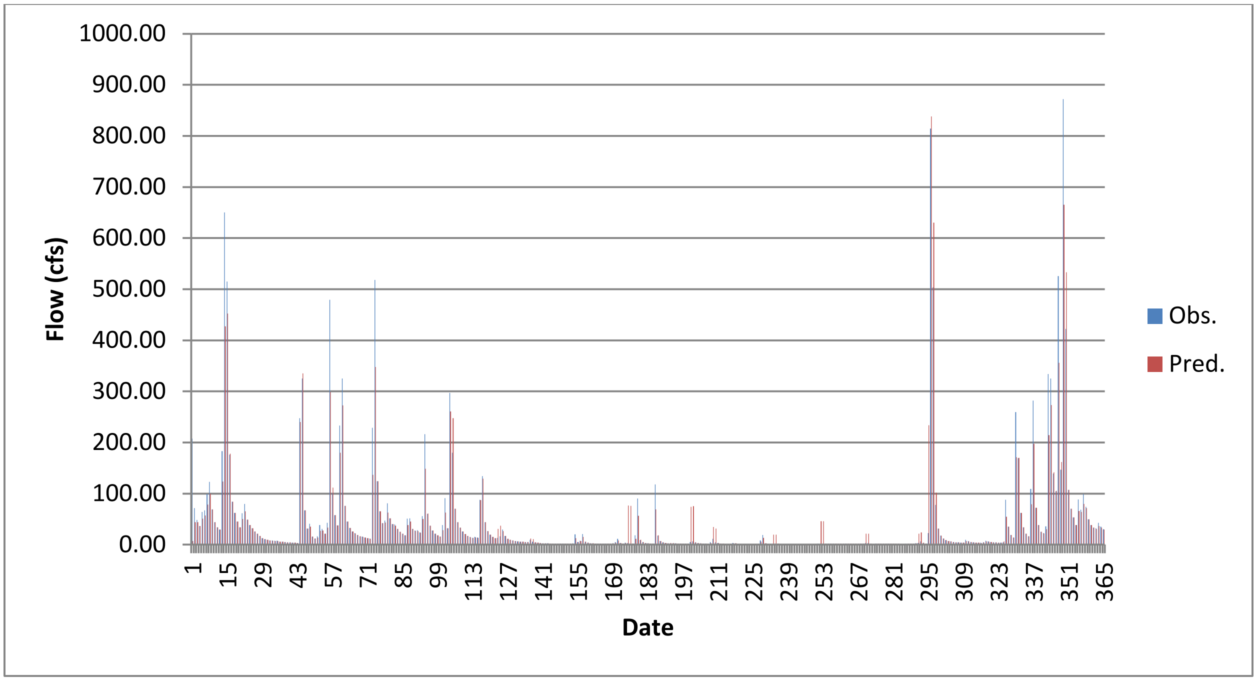


Figure B.2.2 Time Series Plot of 2007 Calibration

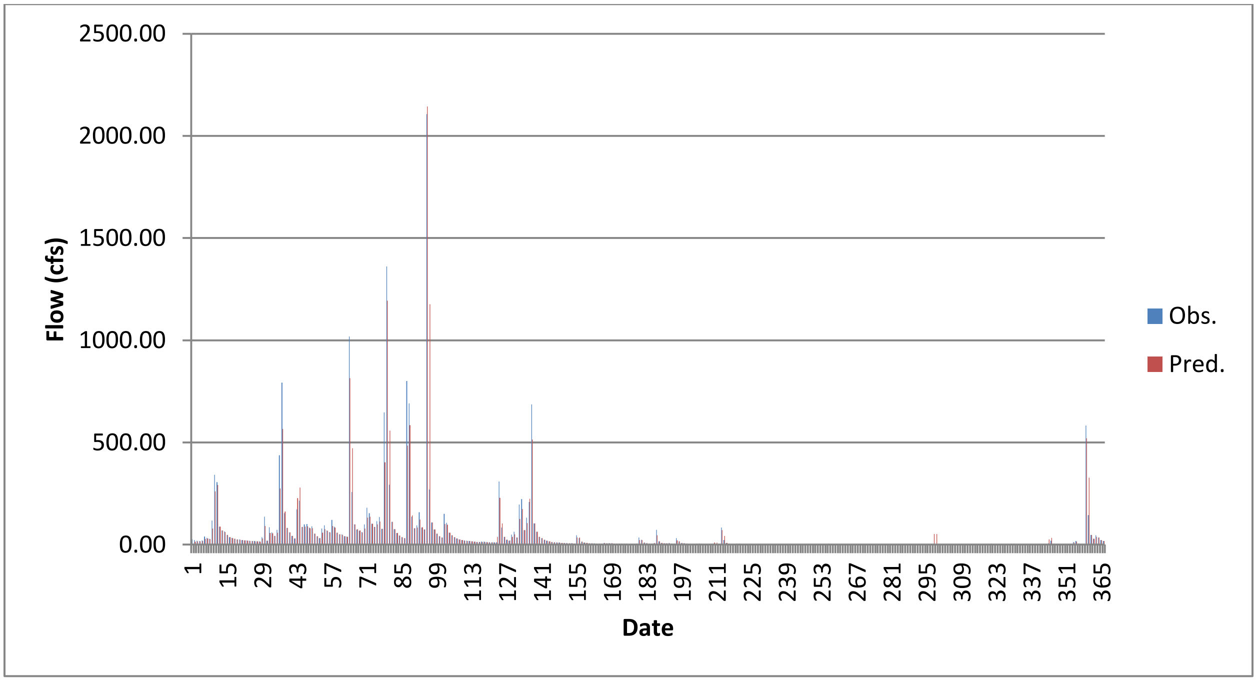


Figure B.2.3 Time Series Plot of 2008 Validation

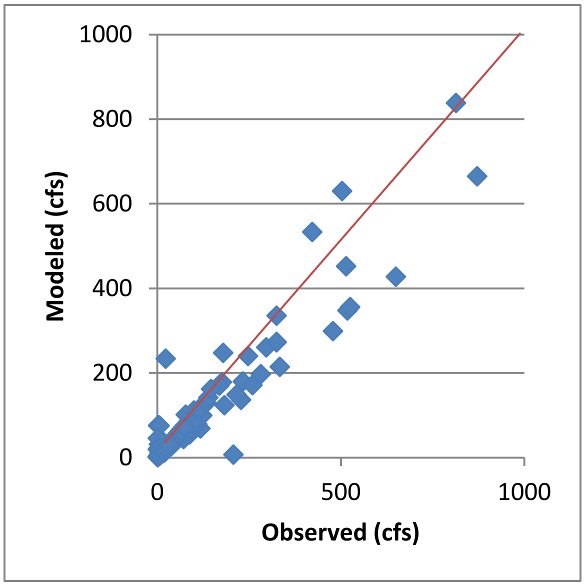


Figure B.2.4 Scatter Plot of 2007 Flow Calibration

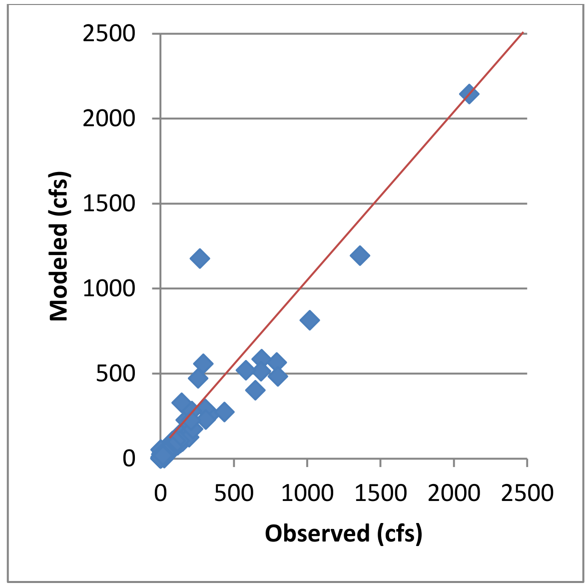


Figure B.2.5 Scatter Plot of 2008 Flow Validation

Table B.2.3 Flowrate Calibration/Validation Statistics for Currys Fork Watershed

Year	R2	RMSE	RSR	% BIAS	NSE
2007 Calibration	0.91	33.12	0.31	7.71	0.90
2008 Validation	0.87	61.53	0.36	3.10	0.87

B.2.3 2007 Water Quality Calibration/2008 Validation (Total Nitrogen):

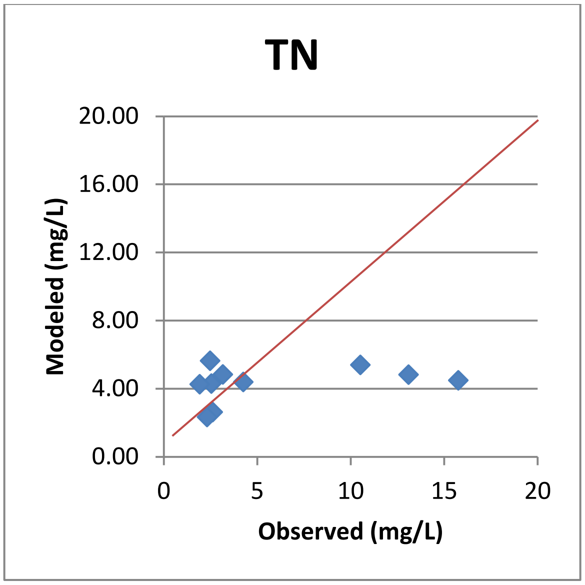


Figure B.2.6 Scatter Plot of 2007 TN Calibration

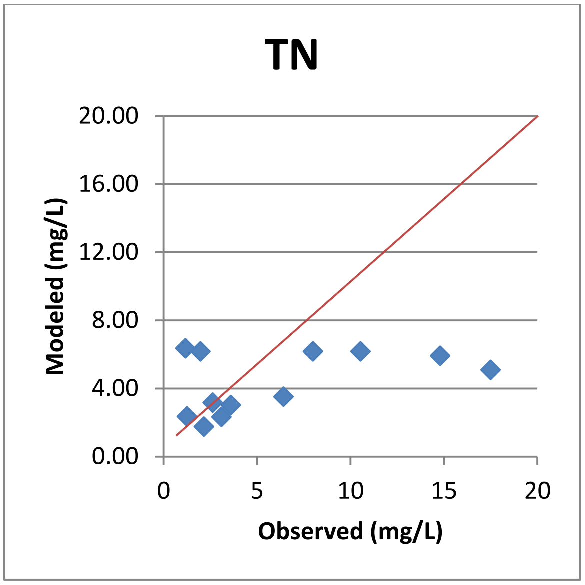


Figure B.2.7 Scatter Plot of 2008 TN Validation

Table B.2.4 Total Nitrogen Calibration/Validation Statistics for Currys Fork Watershed

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	166551	185405	-10.17	88013	89.23	195818	-14.95	189658	-12.18
2008	Validation	255309	189478	34.74	97761	161.16	266372	-4.15	243078	5.03

B.2.4 2007 Water Quality Calibration/2008 Validation (Total Phoshporus):

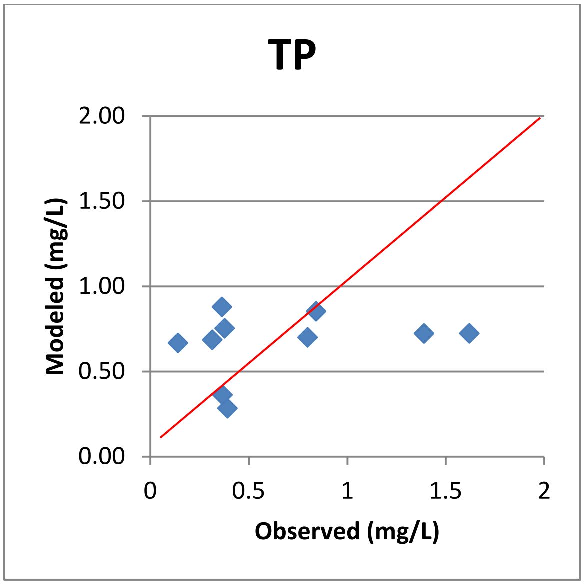


Figure B.2.8 Scatter Plot of 2007 TP Calibration

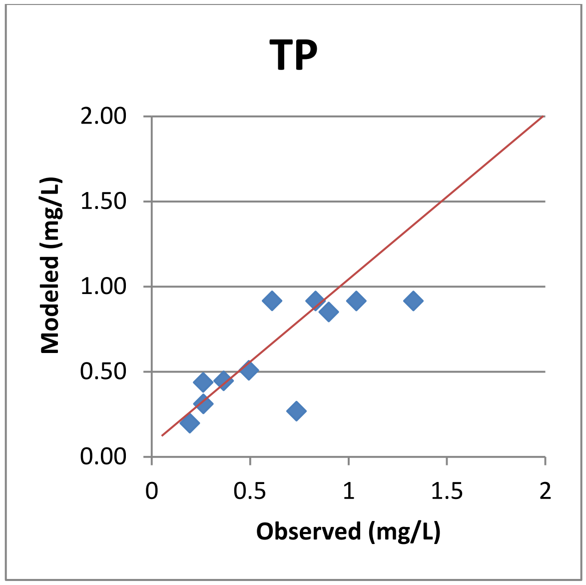


Figure B.2.9 Scatter Plot of 2008 TP Validation

Table B.2.5 Total Phoshporus Calibration/Validation Statistics for Currys Fork Watershed

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	20045	15067	33.03	83930	-76.12	22031	-9.01	19421	3.11
2008	Validation	28983	16042	80.67	93530	-69.01	29270	-0.98	30963	-6.39

B.3 LONG RUN

B.3.1 Watershed Characteristics:

Watershed Name: Long Run near Fisherville

Watershed Area: 25.27 sq mi (16,174 acres)

USGS Flow Station: None

USGS Water Quality Station: 03297980

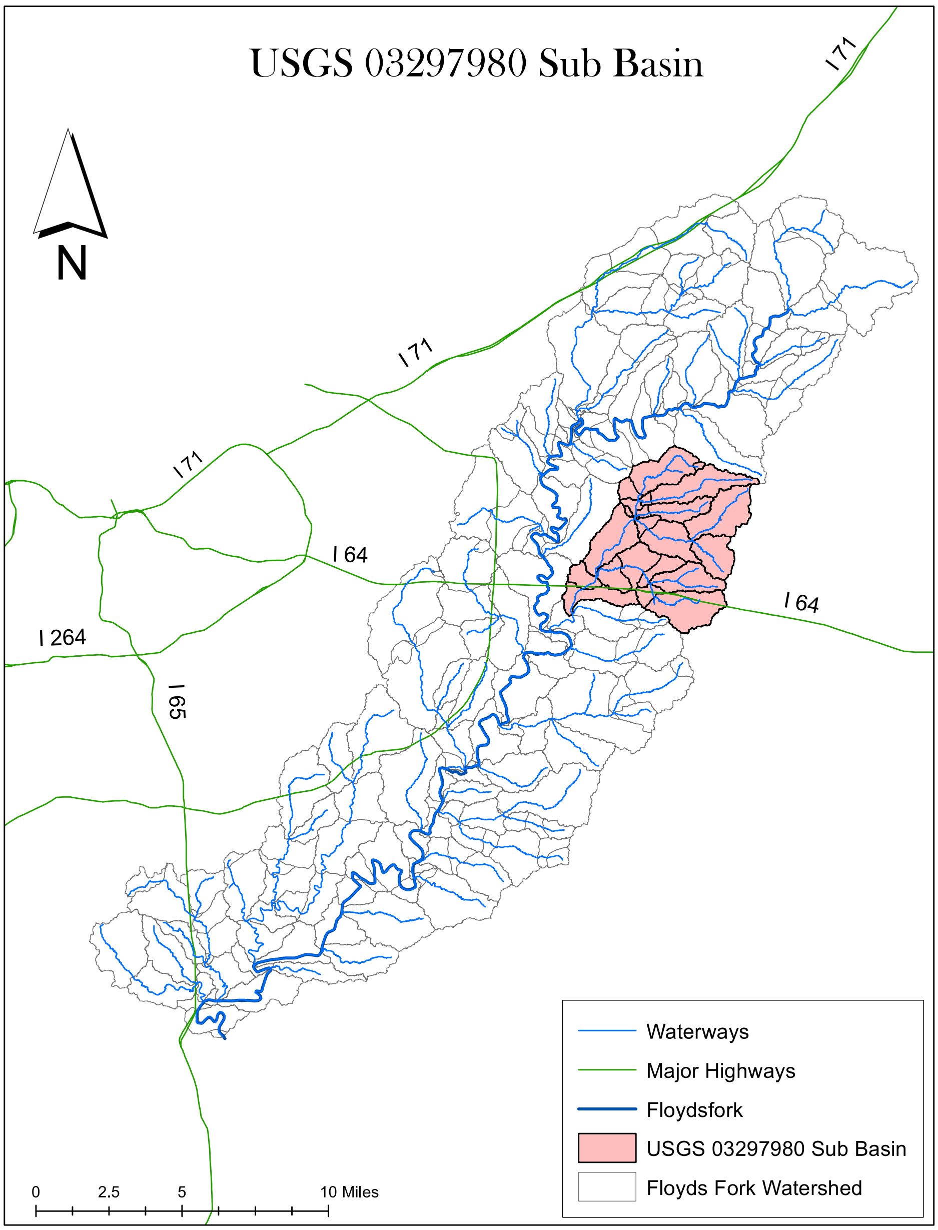


Figure B.3.1 Map of Long Run Watershed

Table B.3.1 Point Source Data for Long Run Watershed

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400128	0.001	20	4
KYG400250	0.001	20	4
Total	0.002	20	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
Total	0	0	0
# Households	947	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.159**	0.1263	0.1287

Table B.3.2 Non-Point Source Data for Long Run Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	(acres)		EMC (mg/L)	EMC (mg/L)
Barren Land	0.0	N/A	N/A	N/A
Residential	1274.4	83	1.25	0.555
Commercial	82.6	94	1.3	0.435
Industrial	1.1	91	0.66	0.305
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	6928.0	76	0.45	0.015
Grassland	973.9	74	0.45	0.08
Agriculture				
Pasture	6209.0	79	1.6	0.61
Row Crops	506.5	85	1.25	1.025
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	145.1	0.00	0	0
Wetlands	17.0	0.00	0	0
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	36.7	80	0.18	0.02
	Total Area (ac)	Average CN	Tot Load (tons)	Tot Load (tons)
	16174	78	5.76	2.07

B.3.2 2007 Hydrology Calibration/2008 Validation:

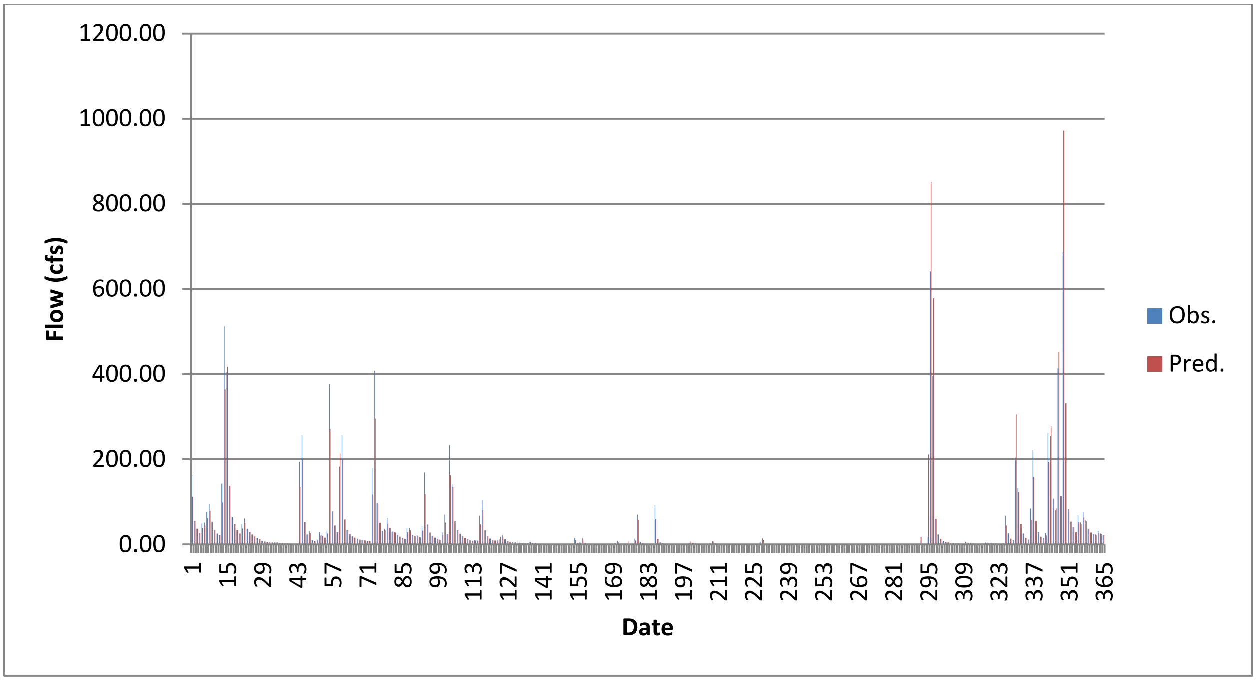


Figure B.3.2 Time Series Plot of 2007 Calibration

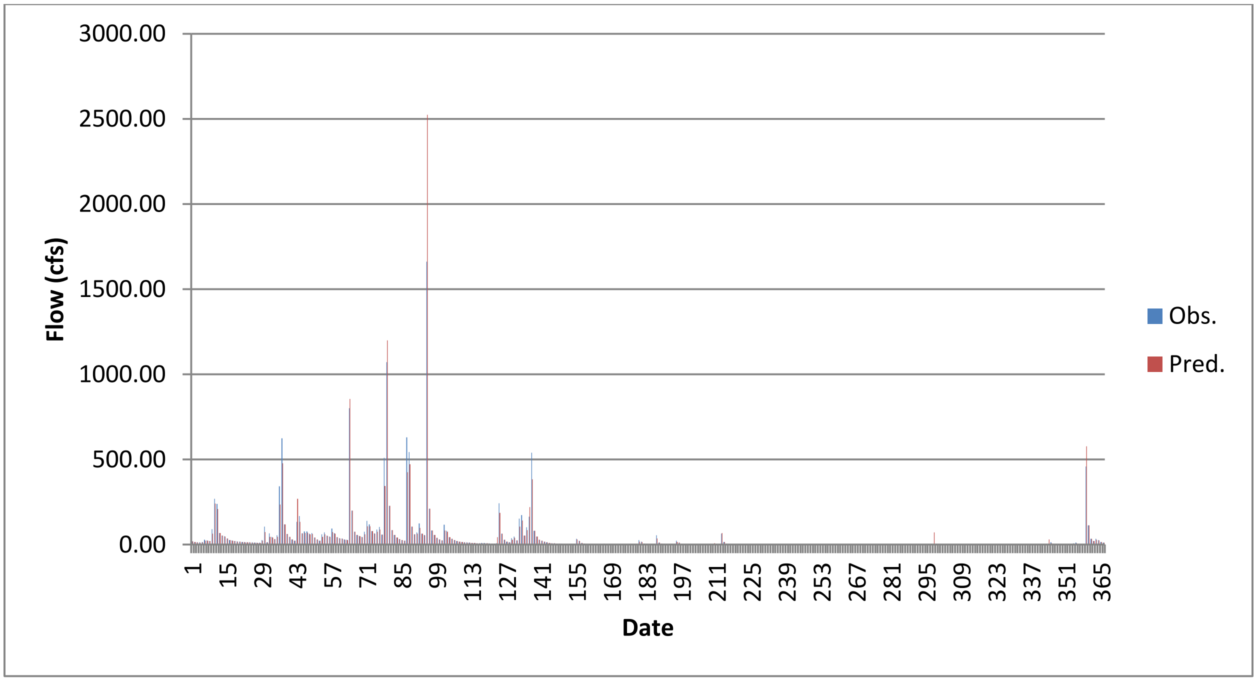


Figure B.3.3 Time Series Plot of 2008 Validation

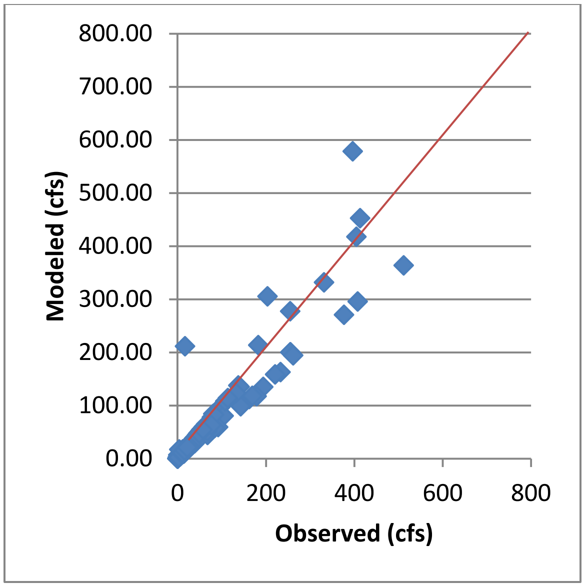


Figure B.3.4 Scatter Plot of 2007 Flow Calibration

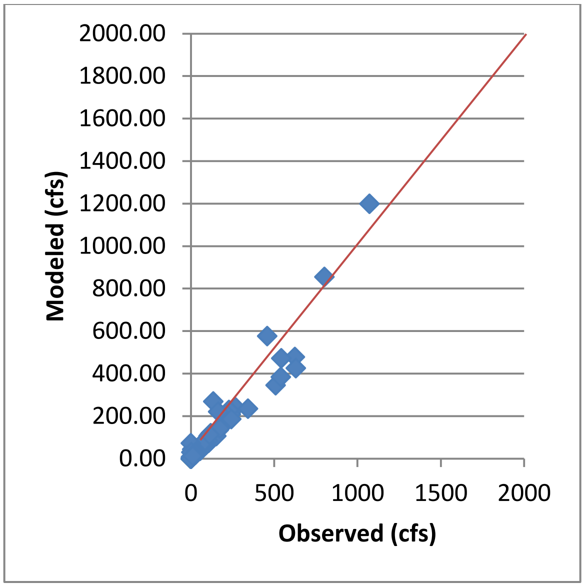


Figure B.3.5 Scatter Plot of 2008 Flow Validation

Table B.3.3 Flowrate Calibration/Validation Statistics for Long Run Watershed

Year	R2	RMSE	RSR	% BIAS	NSE
2007 Calibration	0.83	34.88	0.42	14.48	0.82
2008 Validation	0.81	61.57	0.45	13.38	0.79

B.3.3 2007 Water Quality Calibration/2008 Validation (Total Nitrogen):

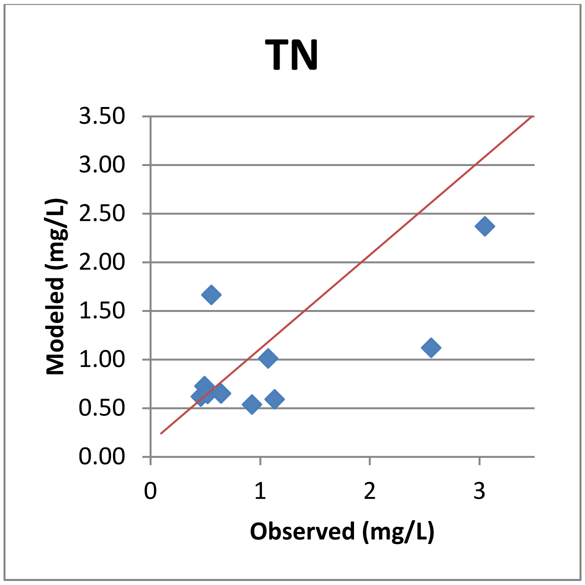


Figure B.3.6 Scatter Plot of 2007 TN Calibration

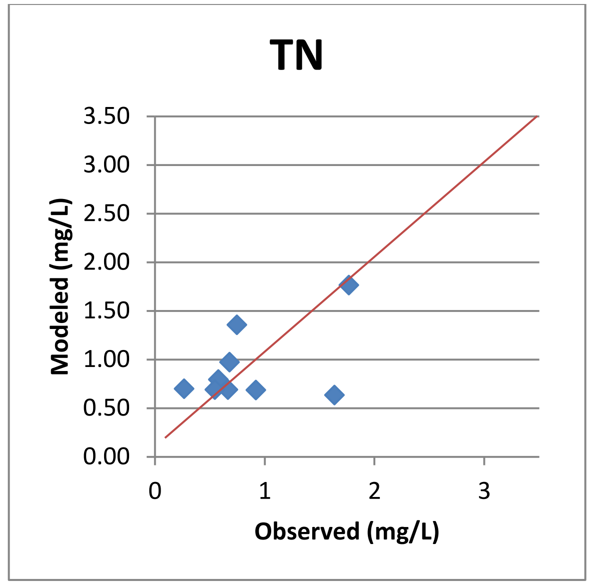


Figure B.3.7 Scatter Plot of 2008 TN Validation

Table B.3.4 Total Nitrogen Calibration/Validation Statistics for Long Run Watershed

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	51903	60368	-14.02	76221	-31.90	100921	-48.57	85712	-39.44
2008	Validation	71609	77990	-8.18	92780	-22.82	70865	1.05	48564	47.45

B.3.4 2007 Water Quality Calibration/2008 Validation (Total Phshporus):

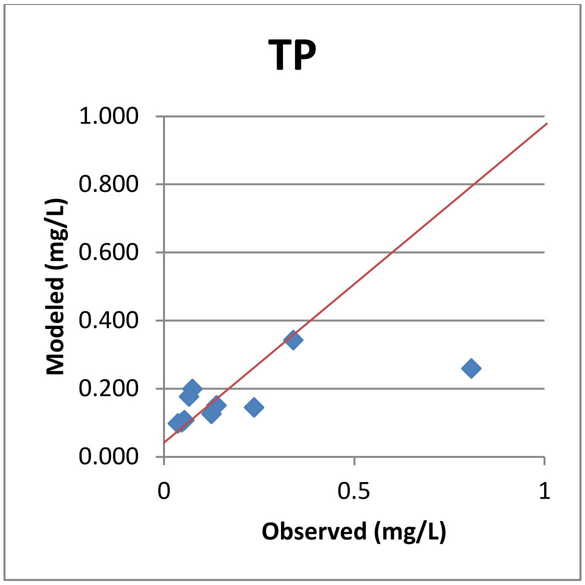


Figure B.3.8 Scatter Plot of 2007 TP Calibration

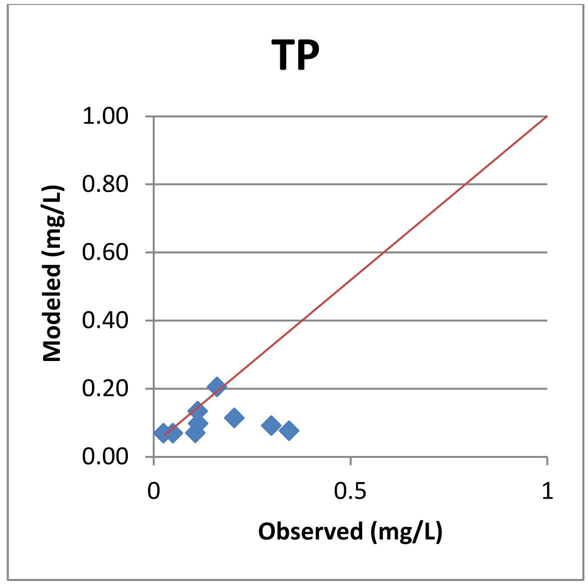


Figure B.3.9 Scatter Plot of 2008 TP Validation

Table B.3.5 Total Phosphorus Calibration/Validation Statistics for Long Run Watershed

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	10129	7046	43.76	123714	-91.81	26736	-62.11	19036	-46.79
2008	Validation	17622	10226	72.33	151173	-88.34	11930	47.71	8066	118.47

B.4 CHENOWETH RUN AT RUCKRIEGAL PARKWAY (AT USGS 03298135)

B.4.1 Watershed Characteristics:

Watershed Name: Chenoweth Run at Ruckriegal Parkway

Watershed Area: 5.44 sq mi. (3,484 acres)

USGS Flow Station: 03298135

USGS Water Quality Station: 03298135

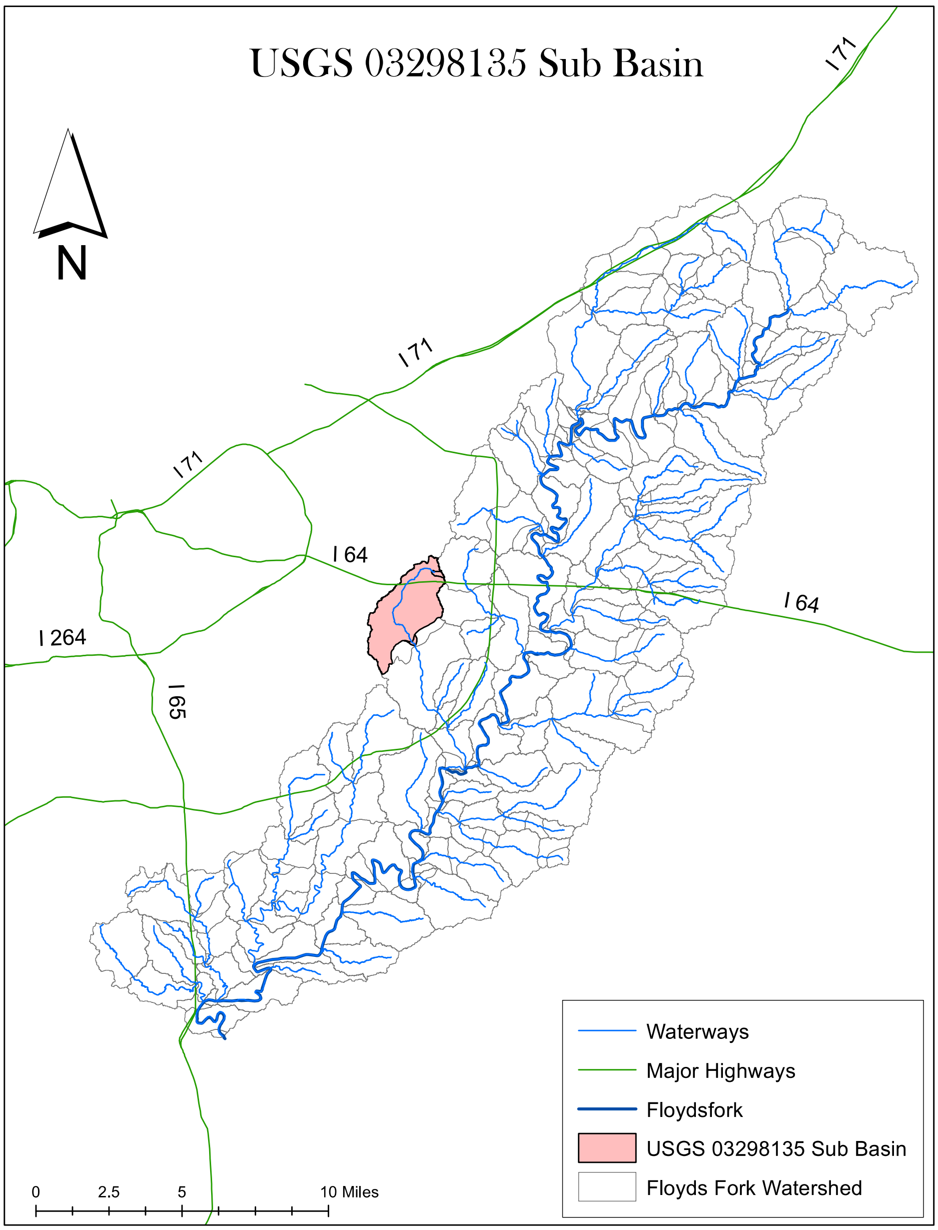


Figure B.4.1 Map of Chenoweth Run at 8135

Table B.4.1 Point Source Data for Chenoweth Run at 8135

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
Total	0	0	0
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
Total	0	0	0
# Households	485	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.081**	0.1263	0.1287

Table B.4.2 Non-Point Source Data for Chenoweth Run at 8135

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	(acres)		EMC (mg/L)	EMC (mg/L)
Barren Land	0.0	N/A	N/A	N/A
Residential	1608.3	80	1.25	0.08
Commercial	878.7	94	1.3	0.09
Industrial	325.5	91	0.66	0.07
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	494.6	74	0.45	0.01
Grassland	5.1	77	0.45	0.01
Agriculture				
Pasture	113.0	77	1.6	0.25
Row Crops	39.7	84	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	0.0	N/A	N/A	N/A
Wetlands	0.0	N/A	N/A	N/A
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	18.8	80	0.18	0.02
	Total Area (ac)	Average CN	Tot Load (tons)	Tot Load (tons)
	3484	84	0.12	0.01

B.4.2 2007 Hydrology Calibration/2008 Validation:

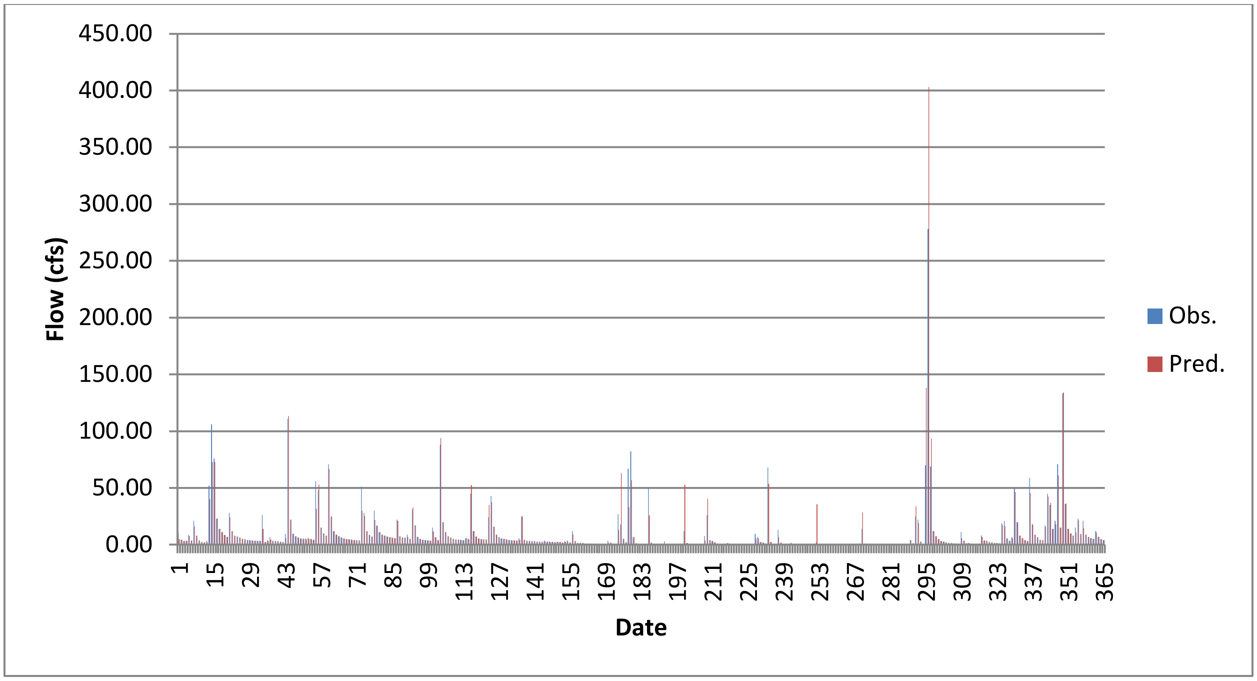


Figure B.4.2 Time Series Plot of 2007 Calibration

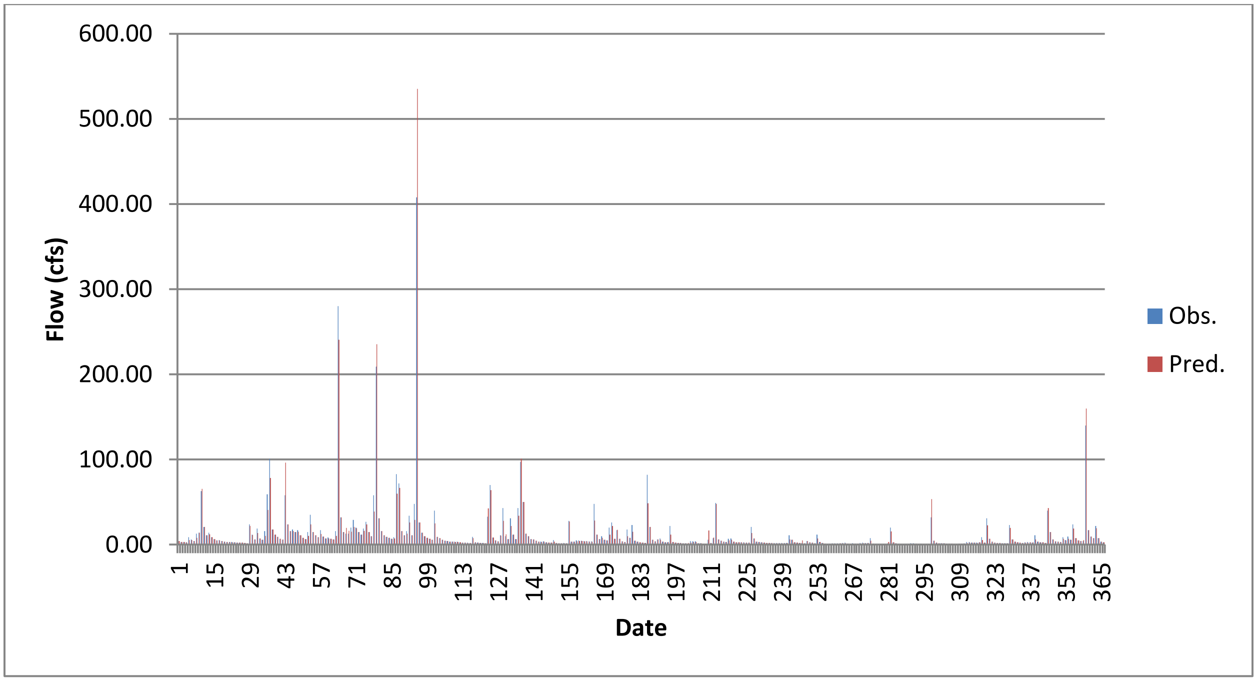


Figure B.4.3 Time Series Plot of 2008 Validation

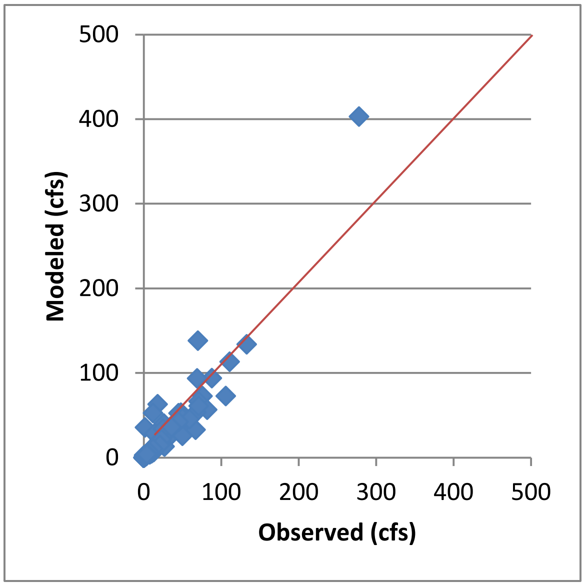


Figure B.4.4 Scatter Plot of 2007 Flow Calibration

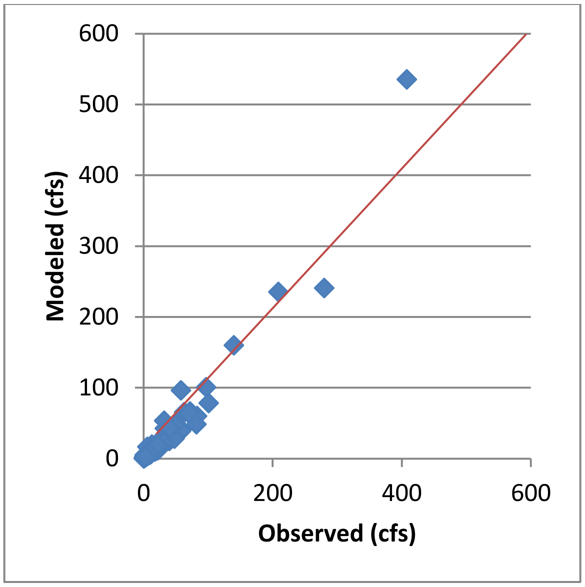


Figure B.4.5 Scatter Plot of 2008 Flow Validation

Table B.4.3 Flowrate Calibration/Validation Statistics for Chenoweth Run at 8135

Year	R2	RMSE	RSR	% BIAS	NSE
2007 Calibration	0.88	9.83	0.44	2.92	0.81
2008 Validation	0.95	8.52	0.27	4.15	0.93

B.4.3 2007 Water Quality Calibration/2008 Validation (Total Nitrogen):

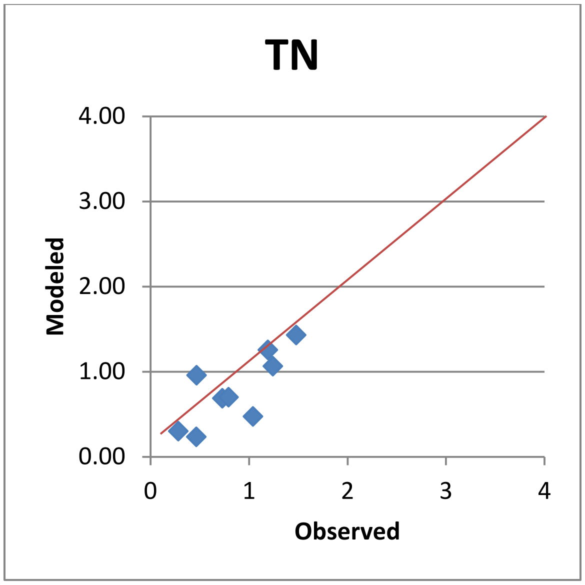


Figure B.4.6 Scatter Plot of 2007 TN Calibration

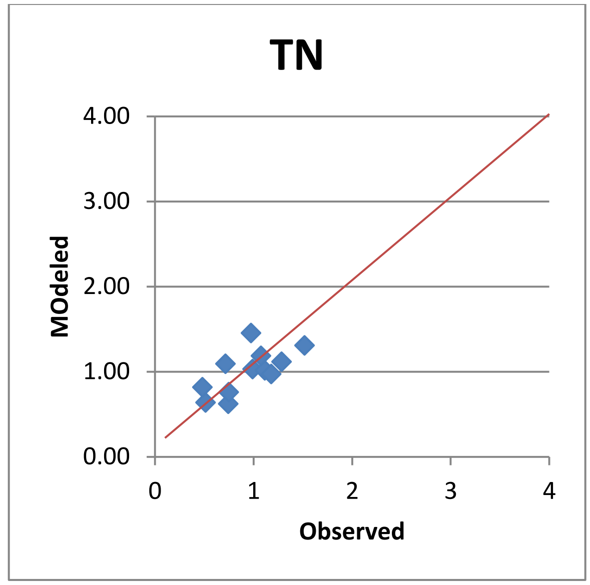


Figure B.4.7 Scatter Plot of 2008 TN Validation

Table B.4.4 Total Nitrogen Calibration/Validation Statistics for Chenoweth Run at 8135

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	27071	16103	68.11	22076	22.63	18885	43.35	23263	16.37
2008	Validation	32602	19038	71.25	22374	45.71	40821	-20.13	36041	-9.54

B.4.4 2007 Water Quality Calibration/2008 Validation (Total Phoshporus):

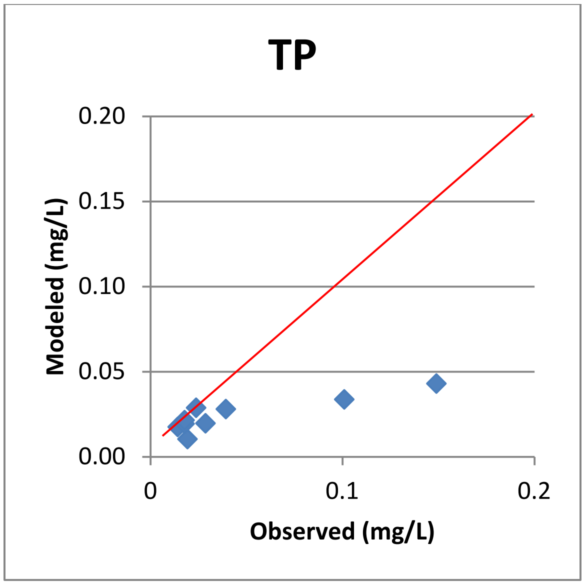


Figure B.4.8 Scatter Plot of 2007 TP Calibration

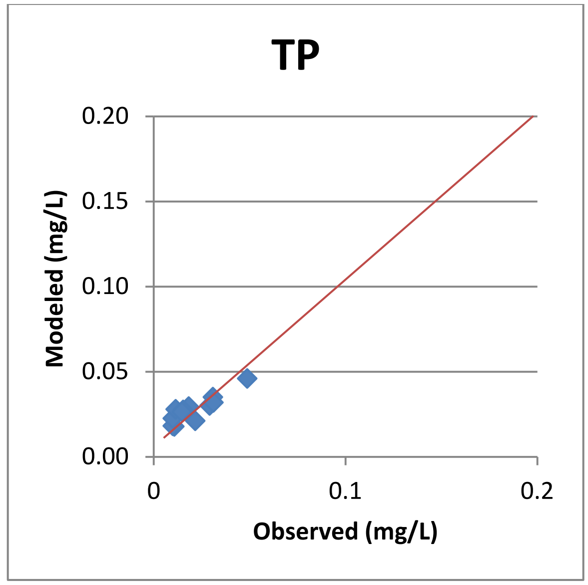


Figure B.4.9 Scatter Plot of 2008 TP Validation

Table B.4.5 Total Phoshporus Calibration/Validation Statistics for Chenoweth Run at 8135

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	804	878	-8.43	5978	-86.55	738	8.94	709	13.40
2008	Validation	964	983	-1.93	6060	-84.09	598	61.20	552	74.64

B.5 CHENOWETH RUN AT USGS 03298150

B.5.1 Watershed Characteristics:

Watershed Name: Chenoweth Run at USGS 03298150

Watershed Area (acres): 11.61 sq mi. (7430 acres)

USGS Flow Station: 03298150

USGS Water Quality Station: 03298150

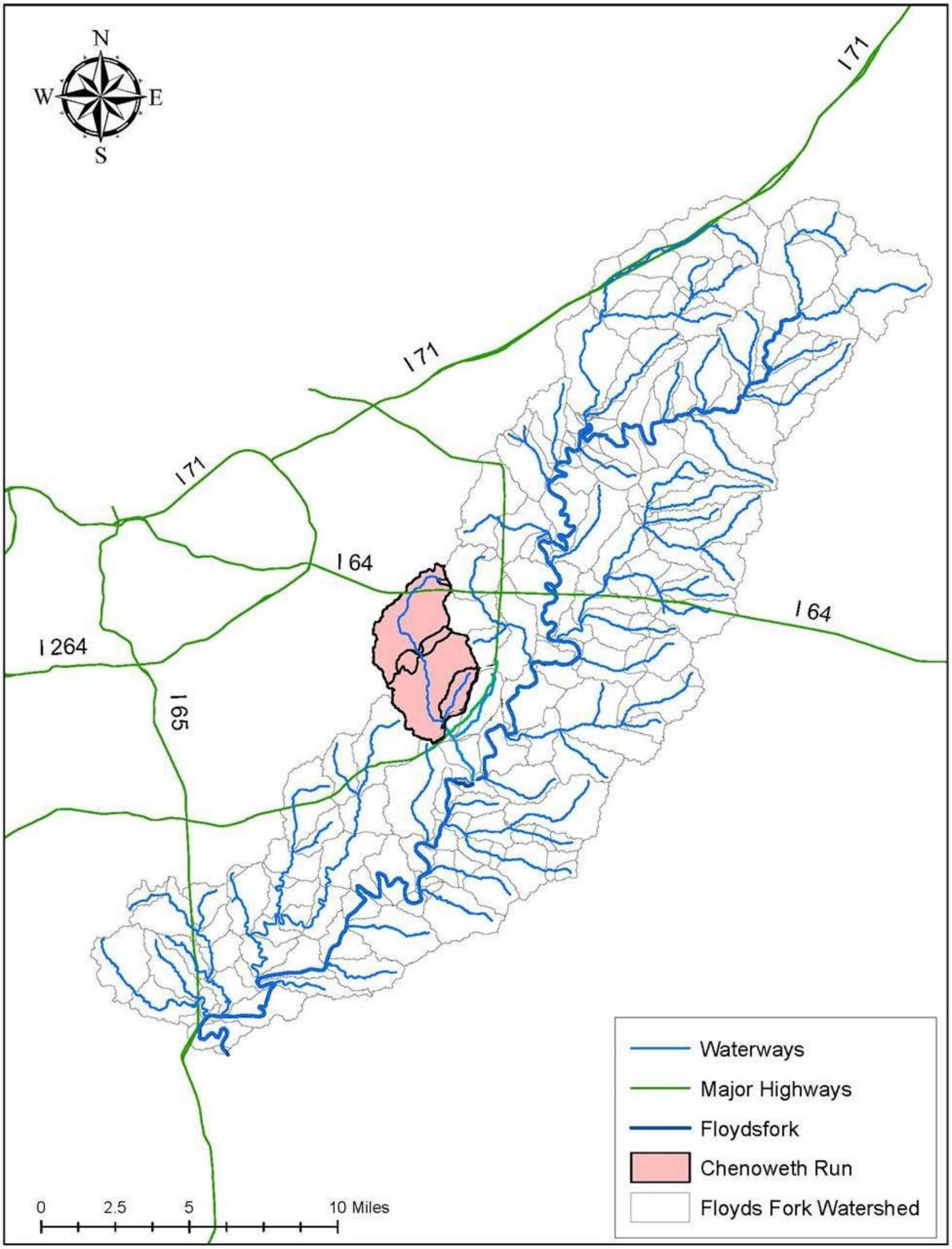


Figure B.5.1 Map of Chenoweth Run at 8150

Table B.5.1 Point Source Data for Chenoweth Run at 8150

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400010	0.001	25	4
KYG400150	0.001	25	4
KYG400161	0.001	25	4
KYG400251	0.001	25	4
Total	0.004	25	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
Total	0	0	0
# Households	1032	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.173**	0.1263	0.1287

Table B.5.1 (Continued) Point Source Data for Chenoweth Run at 8150

Jefferson Town WWPT has daily data for flow and total phosphorus. Total nitrogen was decided based on water quality data immediately upstream and downstream of the plant.

Major Facility #1 Point Source Results			
SSO Flows (ac-ft)	Predicted Q (ac-ft)	Pred .TN (lbs)	Pred. TP (lbs)
0	4292	117	36662
SSO Flows (MG)	Predicted Q (MGD)	Predicted TN (mg/L)	Predicted TP (mg/L)
	3.86	20.00	0.58
	3.86	20.00	0.58
	3.86	20.00	0.58
	3.86	20.00	0.58
	4.25	20.00	0.58
	4.25	20.00	0.58
	3.86	20.00	0.58
	4.25	20.00	0.58
	3.86	20.00	0.58
	.		
	3.50	20.00	0.27
	4.80	20.00	0.53
	4.01	20.00	0.42
	3.60	20.00	0.42
	3.08	20.00	0.42
	3.23	20.00	0.42
	3.08	20.00	0.21
	3.20	20.00	0.32
	3.23	20.00	0.28
	3.73	20.00	0.42
	3.07	20.00	0.42
	3.11	20.00	0.42
	8.64	20.00	0.42
	6.10	20.00	0.38
	4.54	20.00	1.11
	3.92	20.00	0.29
	3.39	20.00	0.42

Table B.5.1 (Continued) Point Source Data for Chenoweth Run at 8150

Major Facility #2 Point Source Menu			
Name	Chenoweth Hill	**KPDES #**	KY0029459
	Discharge	TN EMC	TP EMC
Design (limits)			
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.270	25.00	2.05
2	0.390	25.00	2.73
3	0.270	25.00	3.26
4	0.160	25.00	3.84
5	0.103	25.00	4.80
6	0.055	25.00	4.41
7	0.094	25.00	4.03
8	0.087	25.00	4.32
9	0.069	25.00	4.98
10	0.079	25.00	4.60
11	0.073	25.00	3.33
12	0.097	25.00	2.53

Major Facility #3 Point Source Menu			
Name	Lake of Woods	**KPDES #**	KY0044342
	Discharge	TN EMC	TP EMC
Design (limits)			
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.028	25.00	1.89
2	0.026	25.00	2.49
3	0.030	25.00	2.59
4	0.025	25.00	2.06
5	0.023	25.00	1.60
6	0.011	25.00	2.14
7	0.071	25.00	2.00
8	0.020	25.00	2.04
9	0.020	25.00	2.60
10	0.042	25.00	2.80
11	0.029	25.00	2.68
12	0.051	25.00	2.24

Table B.5.2 Non-Point Source Data for Chenoweth Run at 8150

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	(acres)		EMC (mg/L)	EMC (mg/L)
Barren Land	0.0	N/A	N/A	N/A
Residential	2994.4	80	3.76	0.555
Commercial	1065.9	94	6.08	0.435
Industrial	346.0	91	2.9	0.305
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	2089.1	74	0.51	0.015
Grassland	119.8	77	2.8	0.08
Agriculture				
Pasture	687.6	77	5.09	0.61
Row Crops	74.6	84	13.89	1.025
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	12.0	0.01	0	0
Wetlands	1.1	0.01	0	0
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	40.0	80	0.18	0.02
	Total Area (ac)	Average CN	Tot Load (tons)	Tot Load (tons)
	7430	81	2.37	0.24

B.5.2 2007 Hydrology Calibration/2008 Validation:

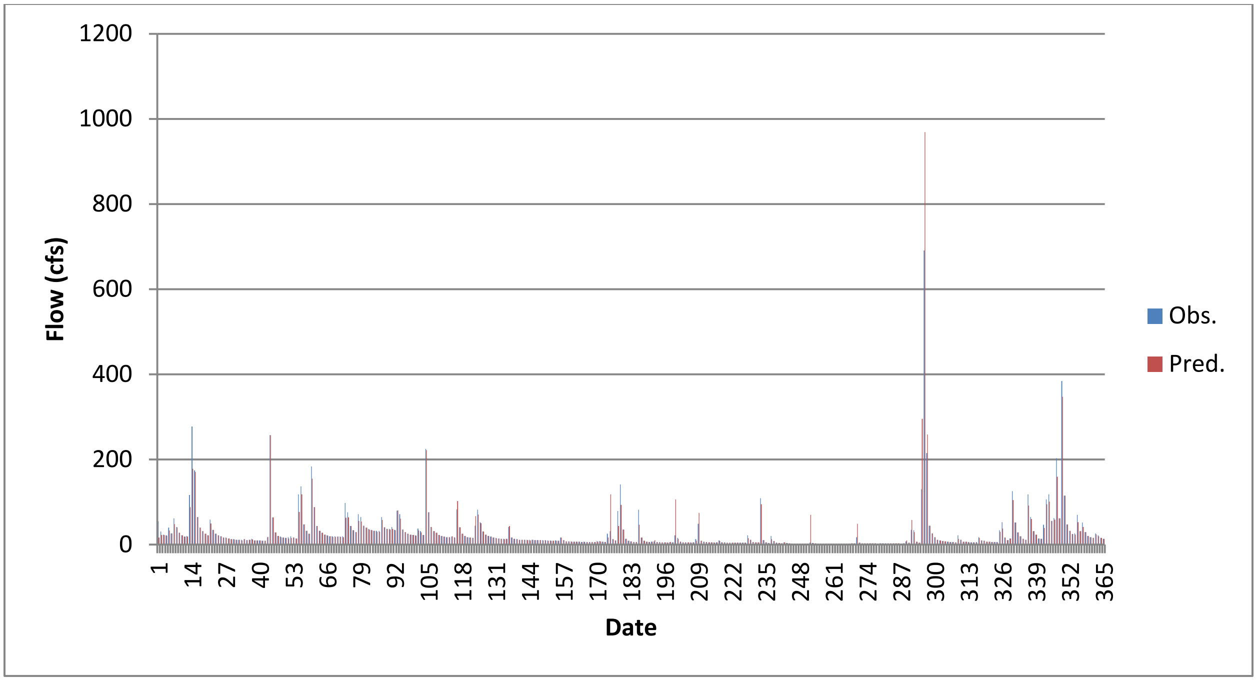


Figure B.5.2 Time Series Plot of 2007 Calibration

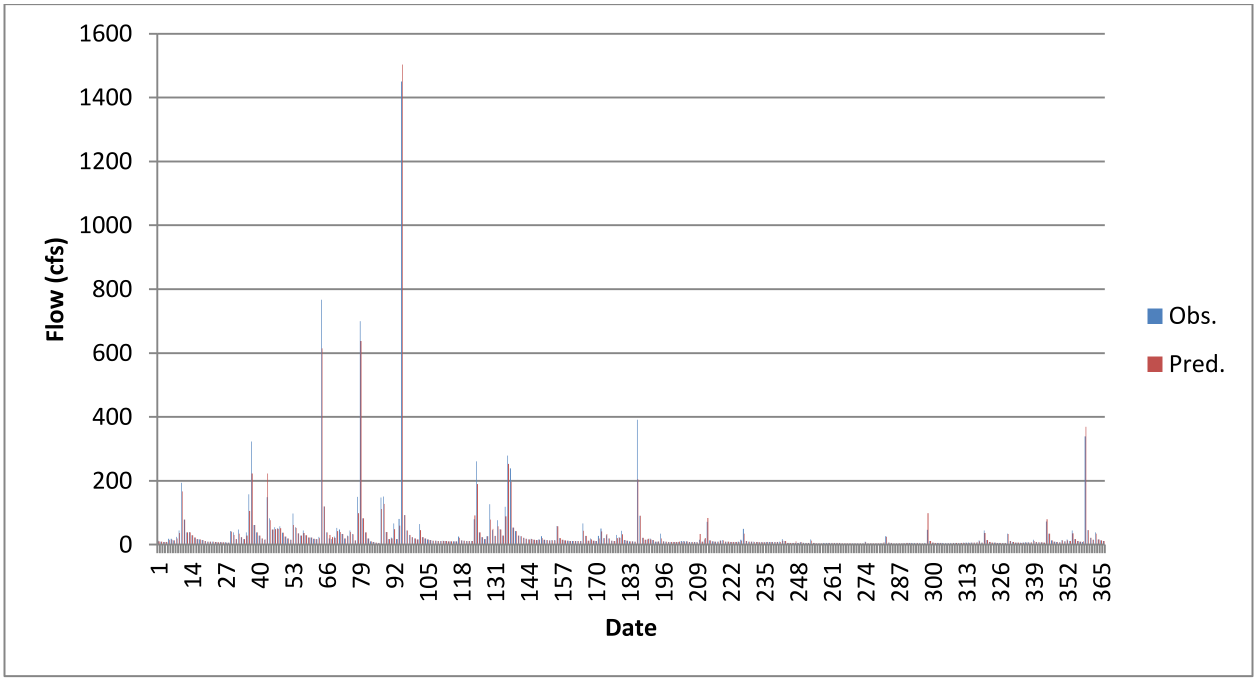


Figure B.5.3 Time Series Plot of 2008 Validation

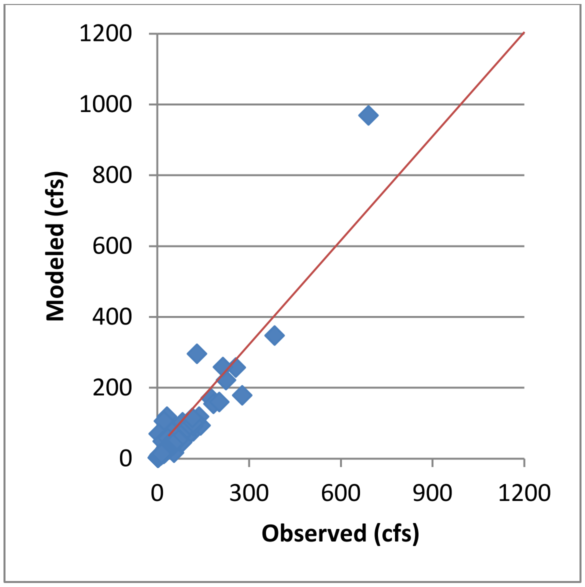


Figure B.5.4 Scatter Plot of 2007 Flow Calibration

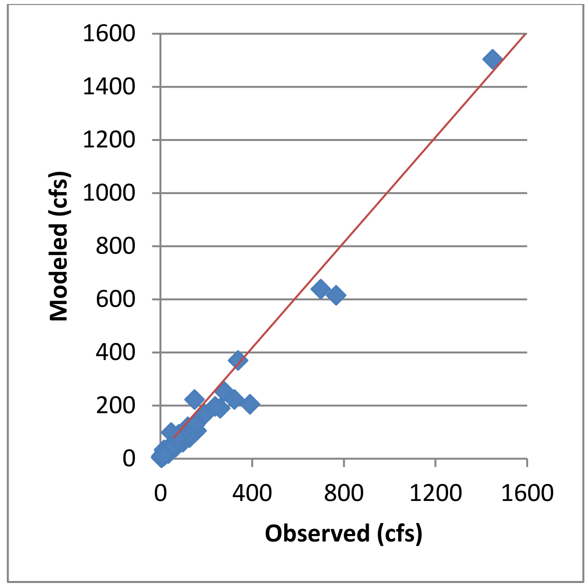


Figure B.5.5 Scatter Plot of 2008 Flow Validation

Table B.5.3 Flowrate Calibration/Validation Statistics for Chenoweth Run at 8150

Year	R2	RMSE	RSR	% BIAS	NSE
2007 Calibration	0.85	22.87	0.42	0.18	0.82
2008 Validation	0.97	17.29	0.17	8.56	0.97

B.5.3 2007 Water Quality Calibration/2008 Validation (Total Nitrogen):

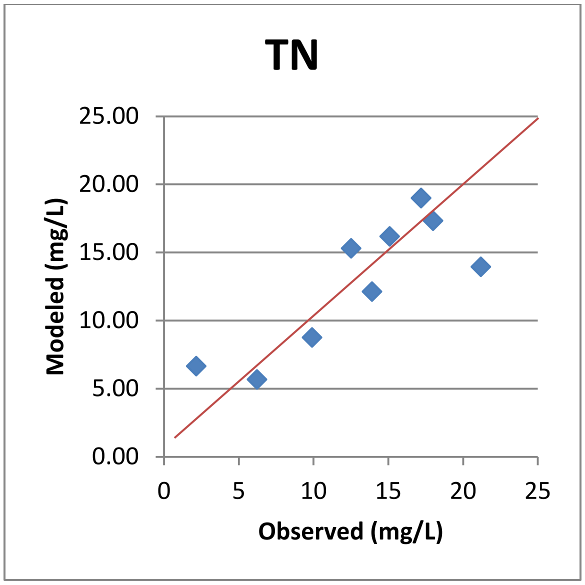


Figure B.5.6 Scatter Plot of 2007 TN Calibration

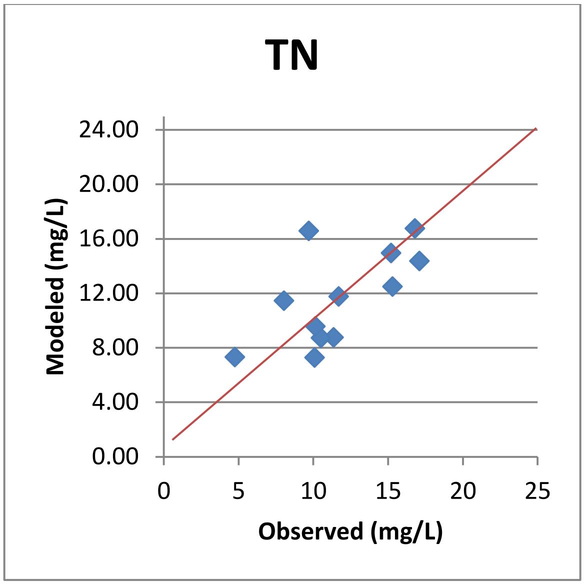


Figure B.5.7 Scatter Plot of 2008 TN Validation

Table B.5.4 Total Nitrogen Calibration/Validation Statistics for Chenoweth Run at 8150

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	405429	146534	176.68	45231	796.35	454824	-10.86	495609	-18.20
2008	Validation	504538	260725	93.51	45843	1000	695282	-27.43	734674	-31.32

B.5.4 2007 Water Quality Calibration/2008 Validation (Total Phoshporus):

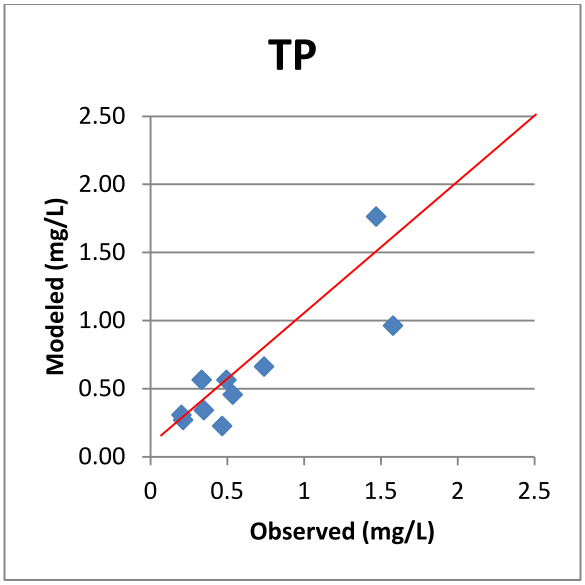


Figure B.5.8 Scatter Plot of 2007 TP Calibration

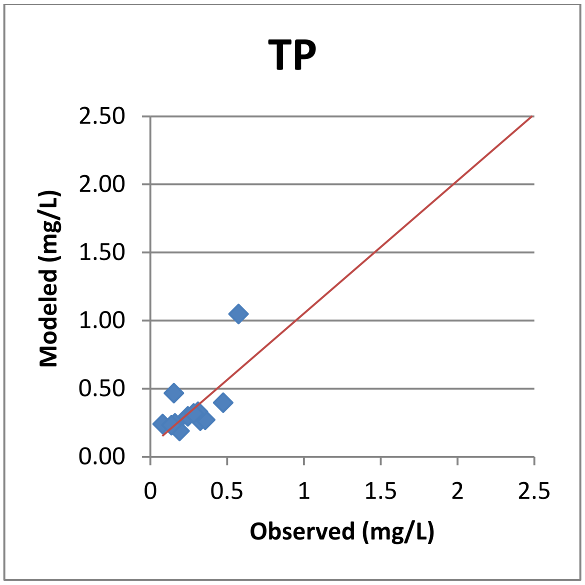


Figure B.5.9 Scatter Plot of 2008 TP Validation

Table B.5.5 Total Phoshporus Calibration/Validation Statistics for Chenoweth Run at 8150

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	13865	12167	13.96	15073	-8.01	24041	-42.33	24514	-43.44
2008	Validation	18418	17262	6.70	15281	20.53	16285	13.10	16079	14.55

B.6 LOWER FLOYDS FORK AT USGS 03298200

B.6.1 Watershed Characteristics:

Watershed Name: Lower Floyds Fork near Mount Washington (at USGS 03298200)

Watershed Area: 213.98 sq mi (136,951 acres)

USGS Flow Station: 03298200

USGS Water Quality Station: 03298200

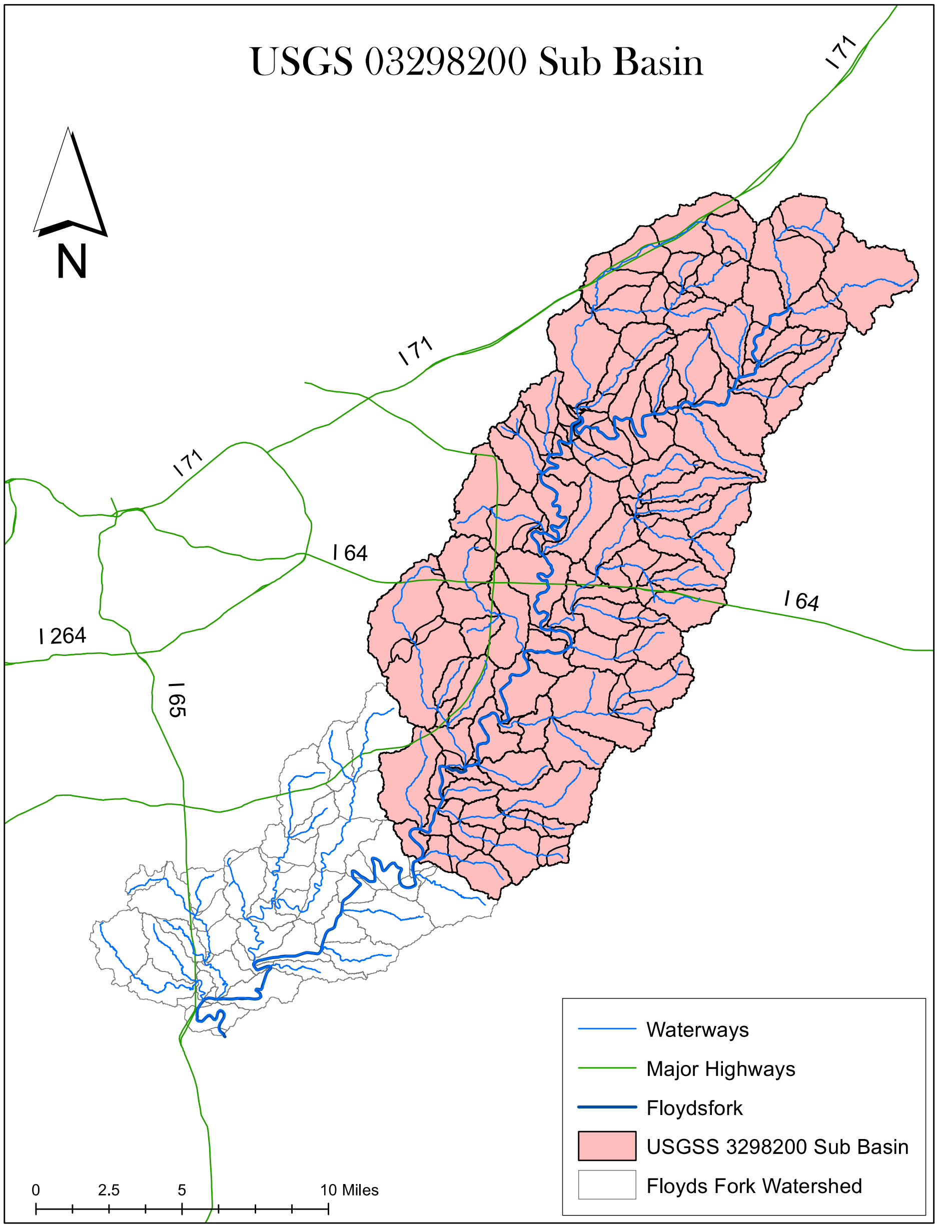


Figure B.6.1 Map of Lower Floyds Fork at 8200

Middle Chenoweth Run's point sources drain into this point. See Middle Chenoweth Run for that basin's point source inputs. Many other point source inputs were combined for this basin model and input as a lump sum.

Table B.6.1 Point Source Data for Lower Floyds Fork at 8200

Minor Facilities	~ .001 MGD	20 mg/L	4 mg/L
KPDES #	Discharge	TN EMC	TP EMC
Various (sum)	0.02282	20	4
Total	0.02282	20	4
Sub/Schools	< .5 MGD	9 mg/L	1.2 mg/L
KPDES #	Discharge	TN EMC	TP EMC
Various (sum)	2.9385	9	1.2
Total	2.9385	9	1.2
# Households	11584	Septic	Systems
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**1.946**	0.1263	0.1287

Table B.6.2 Non-Point Source Data for Lower Floyds Fork at 8200

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	(acres)		EMC (mg/L)	EMC (mg/L)
Barren Land	0.0	N/A	N/A	N/A
Residential	18307.3	82	2.505	0.56
Commercial	2987.4	93	3.69	0.44
Industrial	846.7	90	1.78	0.31
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	60002.4	75	0.48	0.02
Grassland	5723.6	73	1.625	0.08
Agriculture				
Pasture	40899.9	78	3.345	0.61
Row Crops	6339.5	83	7.57	1.025
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	824.9	0.00	0	0
Wetlands	521.2	0.00	0	0
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	498.2	80	0.18	0.02
	Total Area (ac)	Average CN	Tot Load (tons)	Tot Load (tons)
	136951	78	151.08	23.54

B.6.2 2007 Hydrology Calibration/2008 Validation:

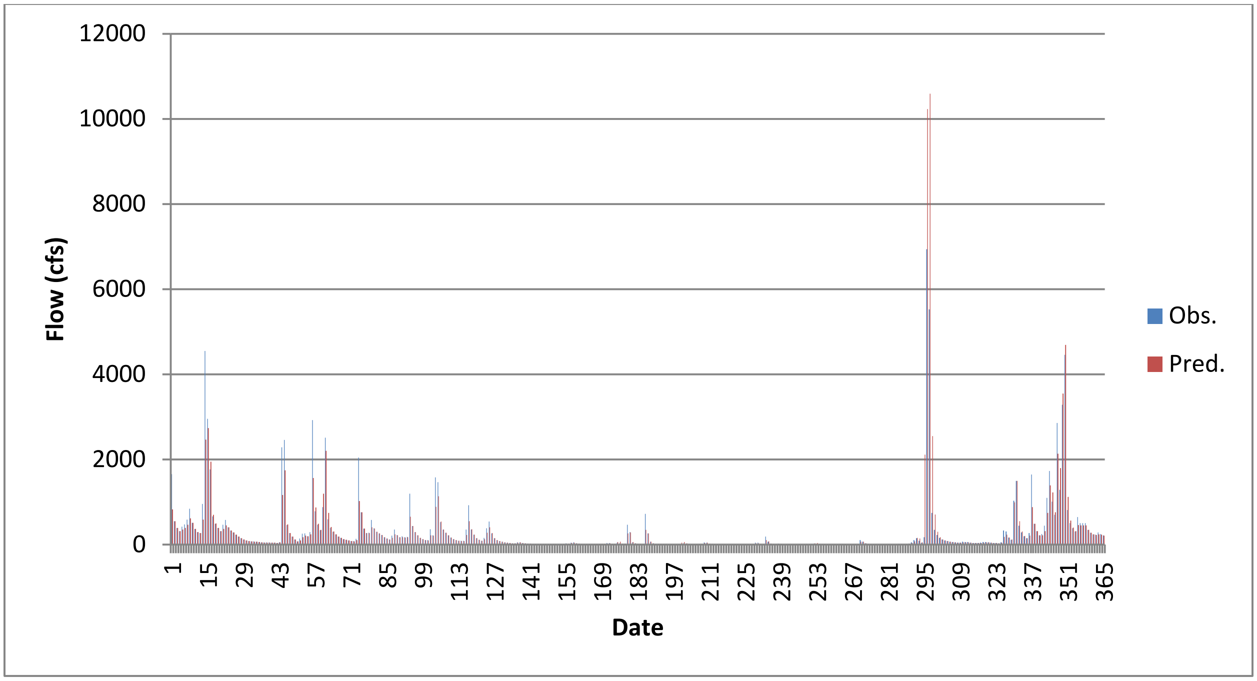


Figure B.6.2 Time Series Plot of 2007 Calibration

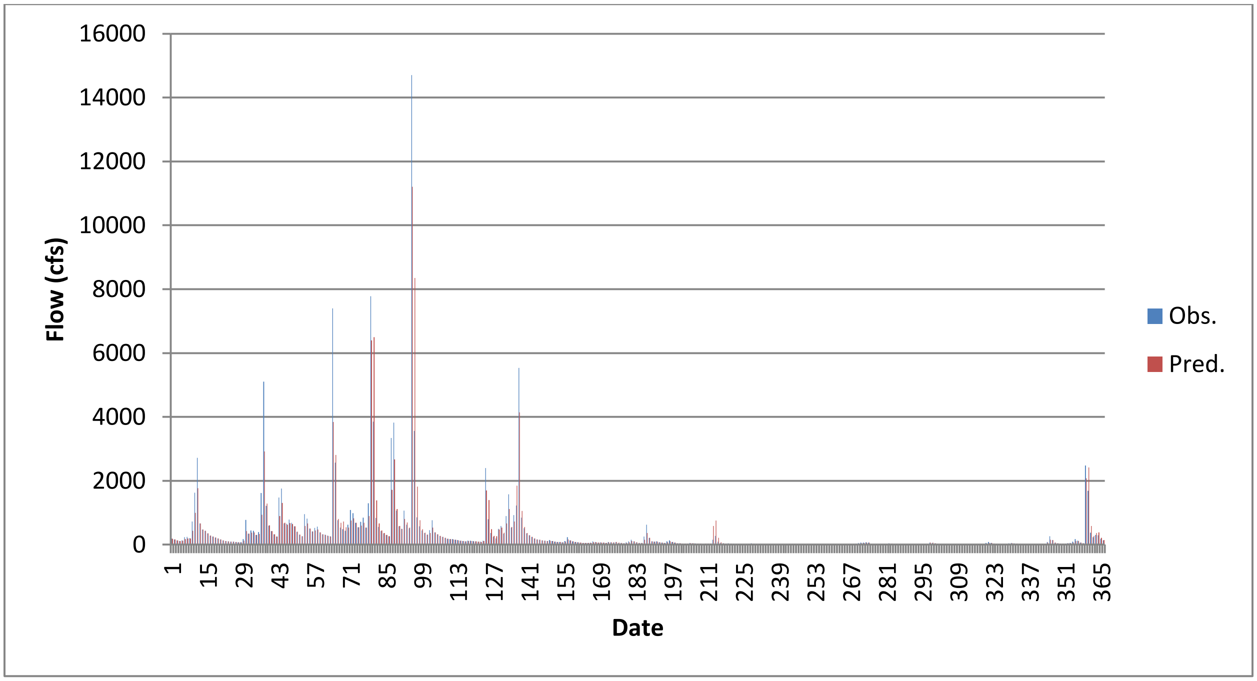


Figure B.6.3 Time Series Plot of 2008 Validation

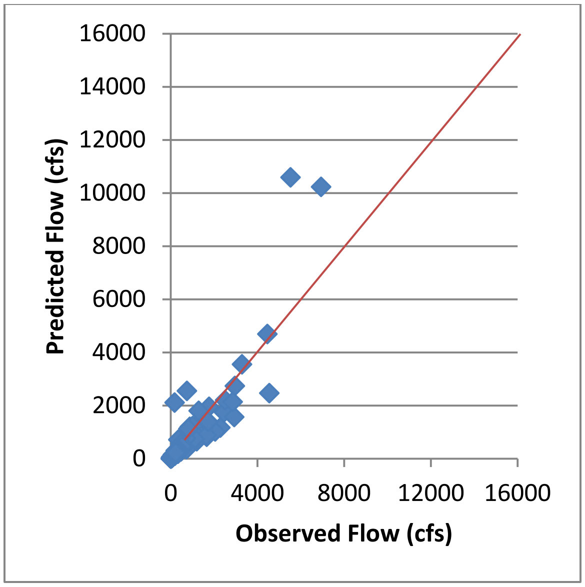


Figure B.6.4 Scatter Plot of 2007 Flow Calibration

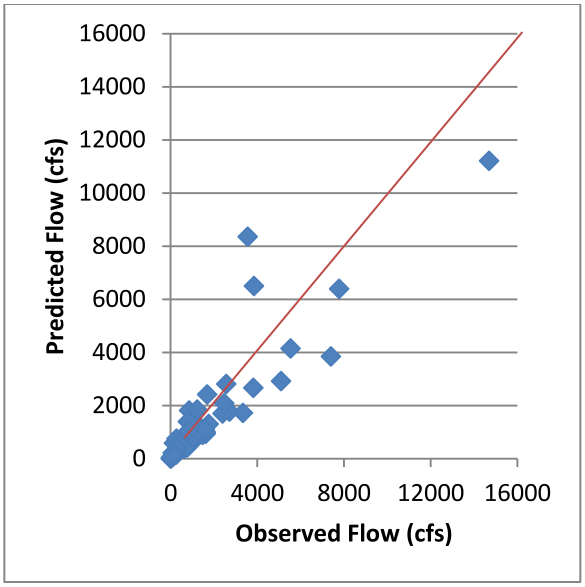


Figure B.6.5 Scatter Plot of 2008 Flow Validation

Table B.6.3 Flowrate Calibration/Validation Statistics for Lower Floyds Fork at 8200

Year	R2	RMSE	RSR	% BIAS	NSE
2007 Calibration	0.82	395.70	0.55	0.46	0.70
2008 Validation	0.84	453.09	0.40	7.63	0.84

B.6.3 2007 Water Quality Calibration/2008 Validation (Total Nitrogen):

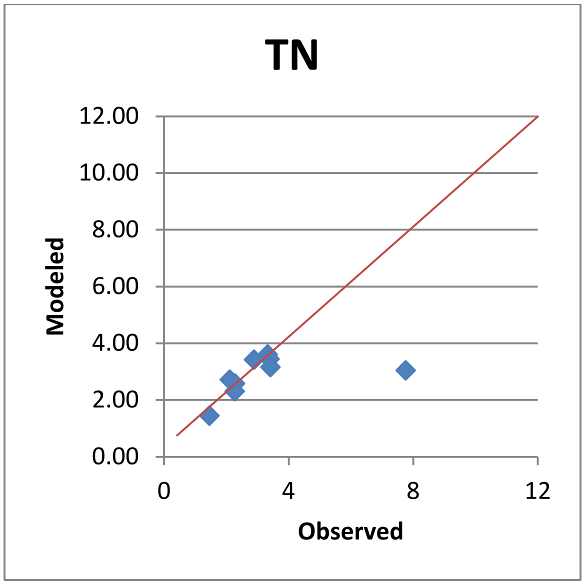


Figure B.6.6 Scatter Plot of 2007 TN Calibration

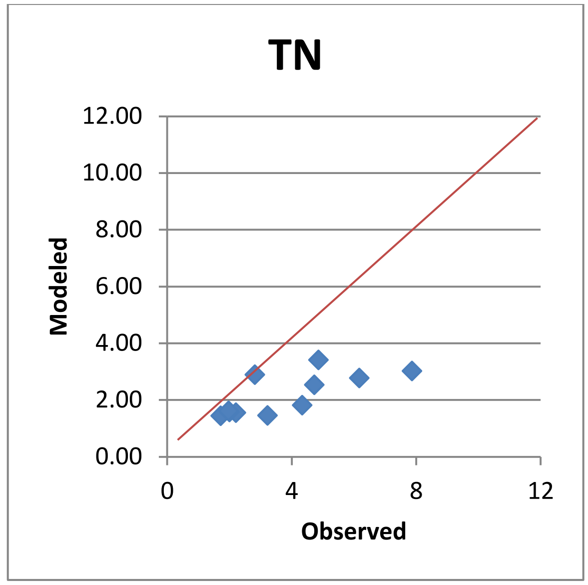


Figure B.6.7 Scatter Plot of 2008 TN Validation

Table B.6.4 Total Nitrogen Calibration/Validation Statistics for Lower Floyds Fork at 8200

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	1110174	642160	72.9	694103	59.9	1610815	-31.08	1396224	-20.49
2008	Validation	1616276	849716	90.2	703533	129.7	1846219	-12.45	1746585	-7.46

B.6.4 2007 Water Quality Calibration/2008 Validation (Total Phosphorus):

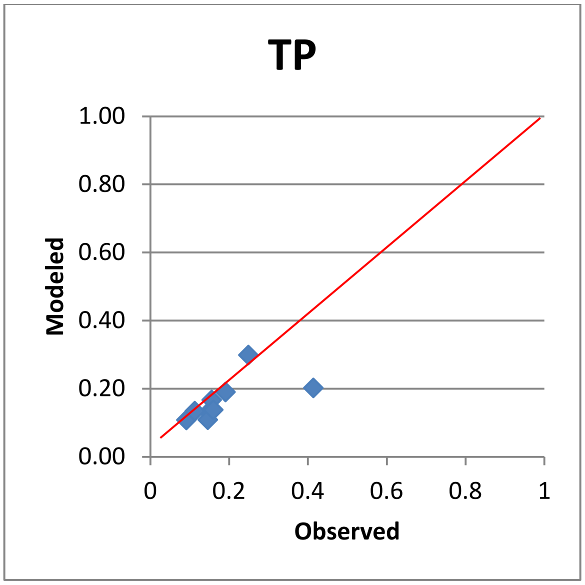


Figure B.6.8 Scatter Plot of 2007 TP Calibration

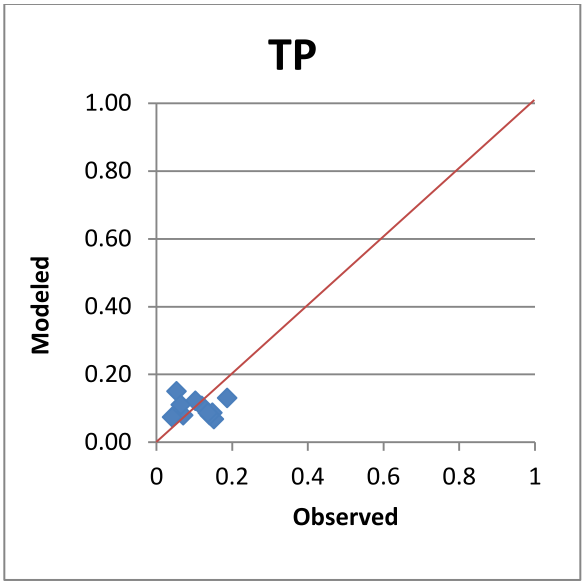


Figure B.6.9 Scatter Plot of 2008 TP Validation

Table B.6.5 Total Phoshporus Calibration/Validation Statistics for Lower Floyds Fork at 8200

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	78747	71056	10.82	507398	-84.48	125796	-37.40	109496	-28.08
2008	Validation	97649	99182	-1.55	514380	-81.02	72462	34.76	57689	69.27

B.7 PENNSYLVANIA RUN AT USGS 03298300

B.7.1 Watershed Characteristics:

Watershed Name: Pennsylvania Run at Mt. Washington Road.(at USGS 03298300)

Watershed Area: 6.96 sq mi (4,455 acres)

USGS Flow Station: 03298300

USGS Water Quality Station: 03298300

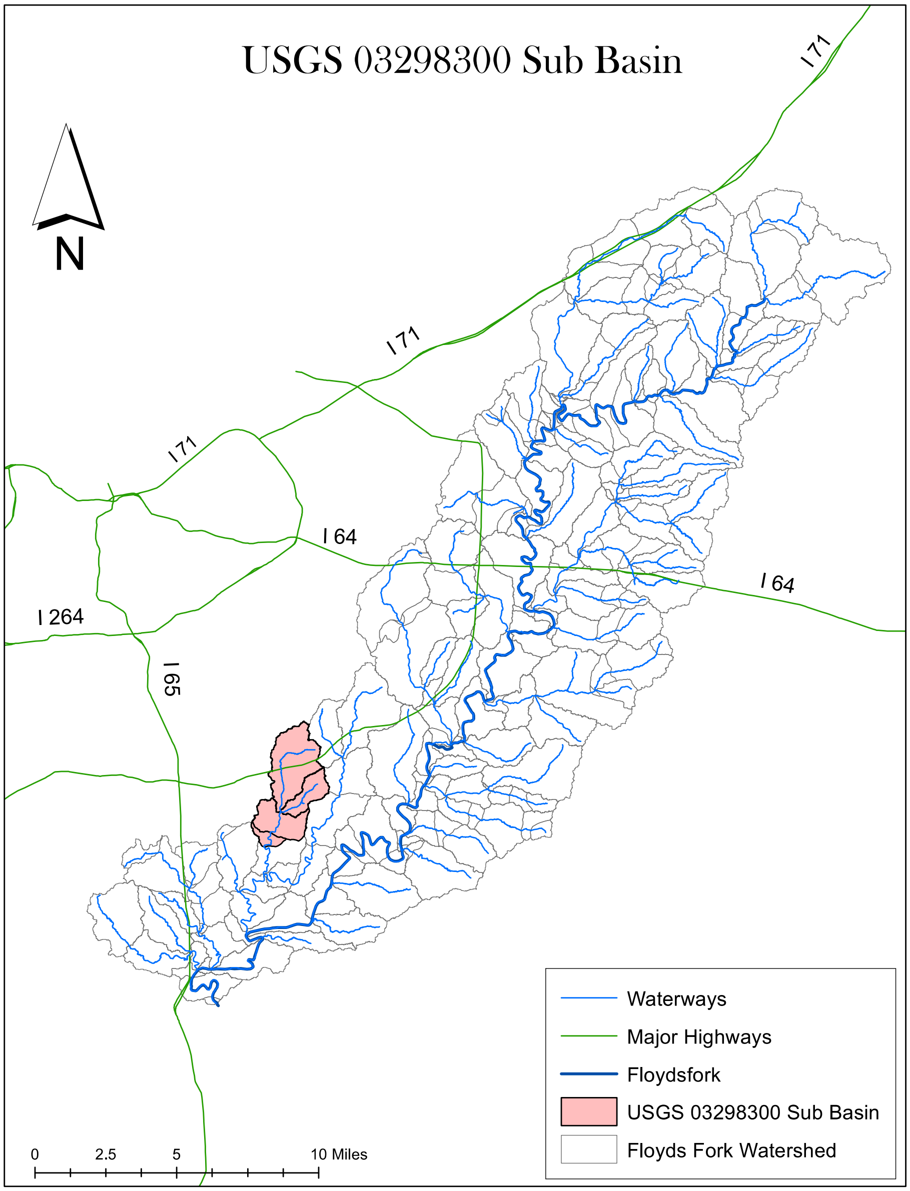


Figure B.7.1 Map of Pennsylvania Run at 8300

Table B.7.1 Point Source Data for Pennsylvania Run at 8300

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400137	0.001	20	4
Total	0.001	20	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
Total	0	0	0
# Households	620	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.104**	0.1263	0.1287

Table B.7.1 (Continued) Point Source Data for Pennsylvania Run at 8300

Major Facility #2 Point Source Menu			
Name	Mcneely Lake	**KPDES #**	KY0029416
	Discharge	TN EMC	TP EMC
Design (limits)			
Month (2007)	**Discharge (MGD)**	TN EMC	TP EMC
1	0.050	11.00	1.70
2	0.160	11.00	0.83
3	0.208	11.00	0.64
4	0.130	11.00	0.45
5	0.130	11.00	0.82
6	0.080	11.00	4.10
7	0.080	11.00	3.80
8	0.083	11.00	4.70
9	0.086	11.00	2.70
10	0.080	11.00	2.00
11	0.078	11.00	2.40
12	0.102	11.00	2.40

Major Facility #2 Point Source Menu			
Name	Mcneely Lake	**KPDES #**	KY0029416
	Discharge	TN EMC	TP EMC
Design (limits)	0.205	10.1	2.93
Month (2008)	**Discharge (MGD)**	TN EMC	TP EMC
1	0.130	11.00	2.15
2	0.101	11.00	2.06
3	0.095	11.00	3.60
4	0.104	11.00	3.22
5	0.087	11.00	3.03
6	0.070	8.00	3.19
7	0.079	11.00	4.26
8	0.086	11.00	4.63
9	0.087	8.00	4.13
10	0.120	8.00	3.35
11	0.092	11.00	2.15
12	0.180	11.00	1.56

Table B.7.2 Non-Point Source Data for Pennsylvania Run at 8300

Landuse	**Area**	**Curve Number**	Tot. Nitrogen	**Tot. Phosphorus**
Urban	(acres)		EMC (mg/L)	EMC (mg/L)
Barren Land	0.0	N/A	N/A	N/A
Residential	1785.0	80	2.505	0.555
Commercial	109.3	94	3.69	0.435
Industrial	22.7	91	1.78	0.305
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	1742.6	74	0.48	0.015
Grassland	84.7	77	1.625	0.08
Agriculture				
Pasture	552.2	77	3.345	0.61
Row Crops	57.5	84	7.57	1.025
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	62.6	0.01	0	0
Wetlands	14.5	0.01	0	0
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	24.0	80	0.18	0.02
	Total Area (ac)	Average CN	Tot Load (tons)	Tot Load (tons)
	4455	78	3.02	0.53

B.7.2 2007 Hydrology Calibration/2008 Validation:

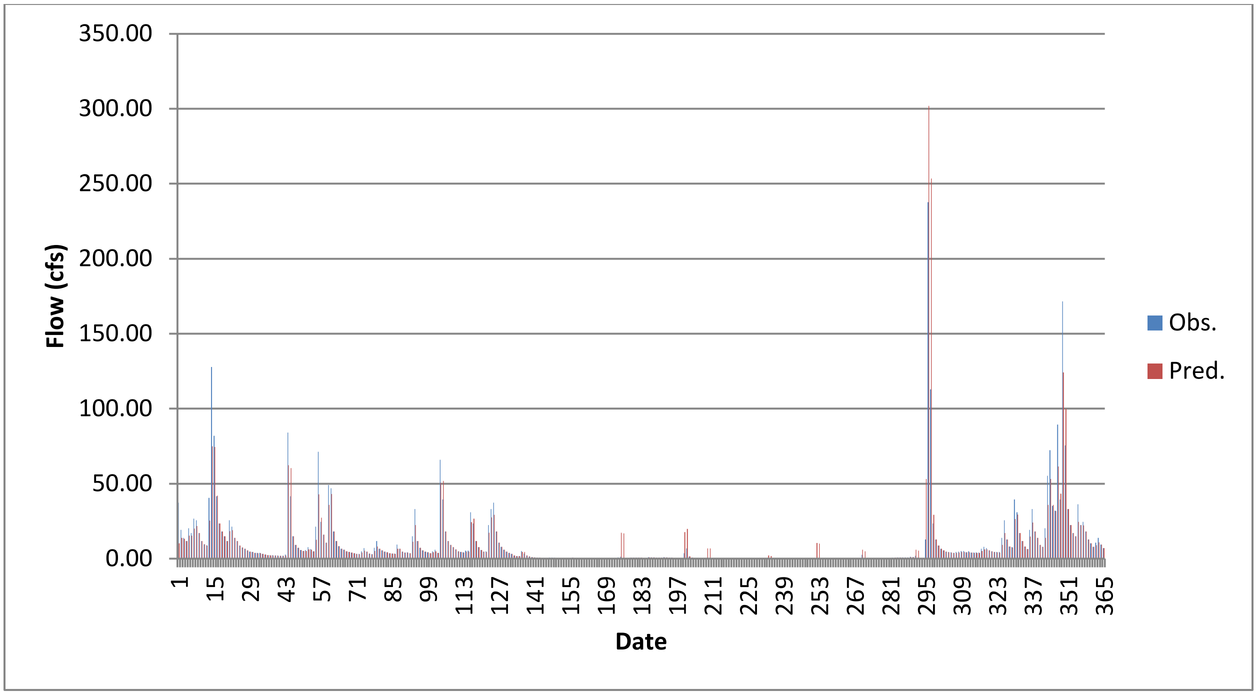


Figure B.7.2 Time Series Plot of 2007 Calibration

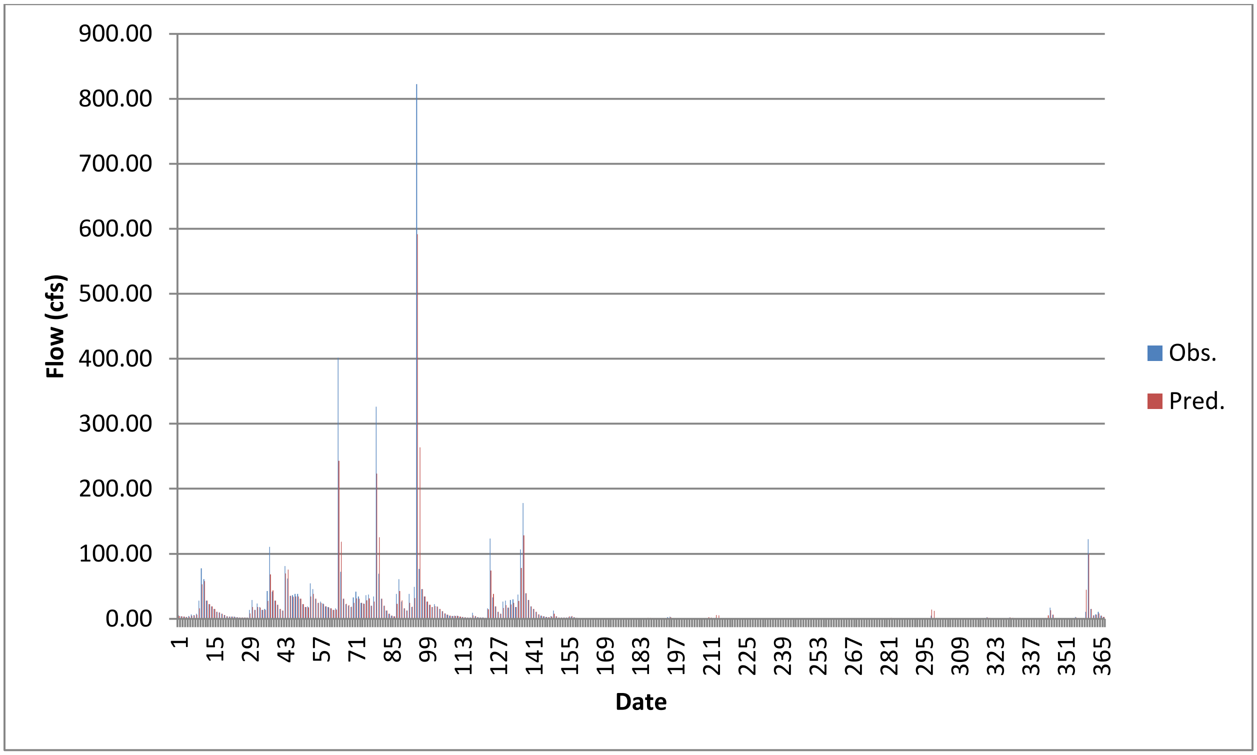


Figure B.7.3 Time Series Plot of 2008 Validation

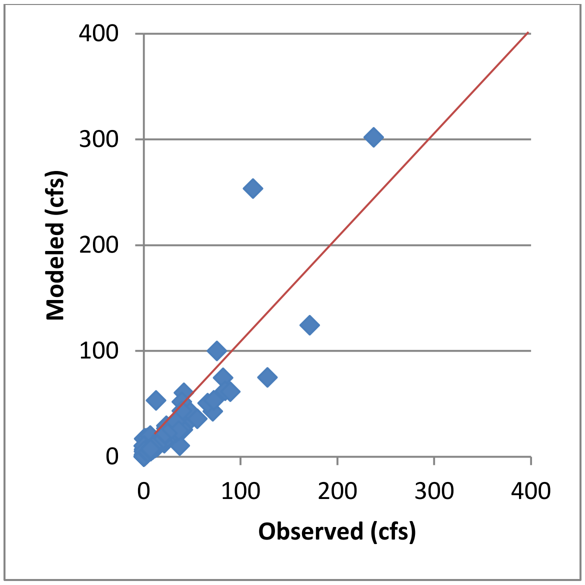


Figure B.7.4 Scatter Plot of 2007 Flow Calibration

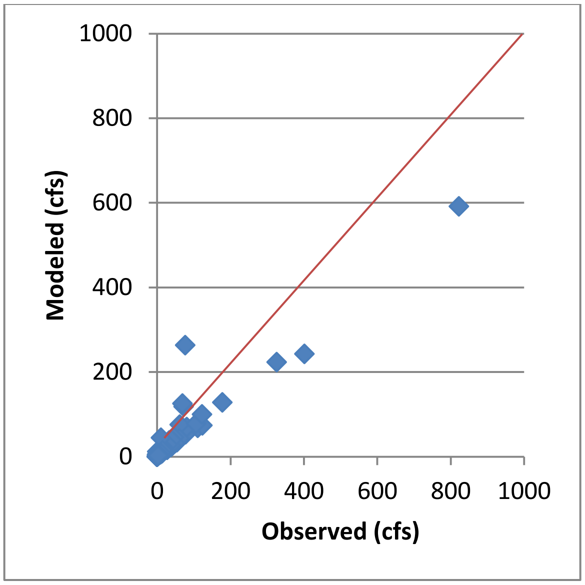
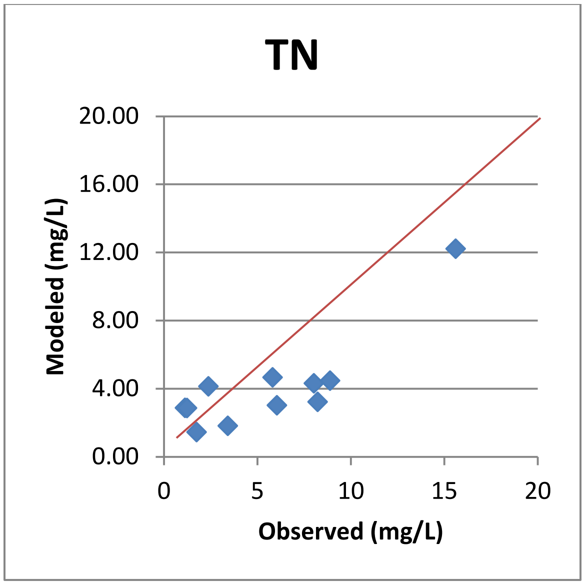


Figure B.7.5 Scatter Plot of 2008 Flow Validation

Table B.7.3 Flowrate Calibration/Validation Statistics for Pennsylvania Run at 8300

Year	R2	RMSE	RSR	% BIAS	NSE
2007 Calibration	0.86	9.30	0.43	5.00	0.82
2008 Validation	0.93	26.06	0.48	14.77	0.77

B.7.3 2007 Water Quality Calibration/2008 Validation (Total Nitrogen):



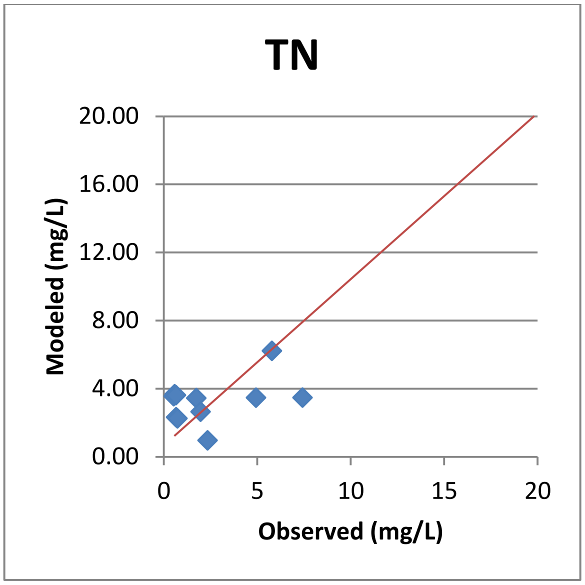


Figure B.7.6 Scatter Plot of 2007 TN Calibration **Figure B.7.7 Scatter Plot of 2008 TN Validation**

Table B.7.4 Total Nitrogen Calibration/Validation Statistics for Pennsylvania Run at 8300

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	29039	26585	9.23	27977	3.80	28722	1.10	30365	-4.37
2008	Validation	31198	31109	0.29	28622	9.00	52922	-41.05	42079	-25.86

B.7.4 2007 Water Quality Calibration/2008 Validation (Total Phoshporus):

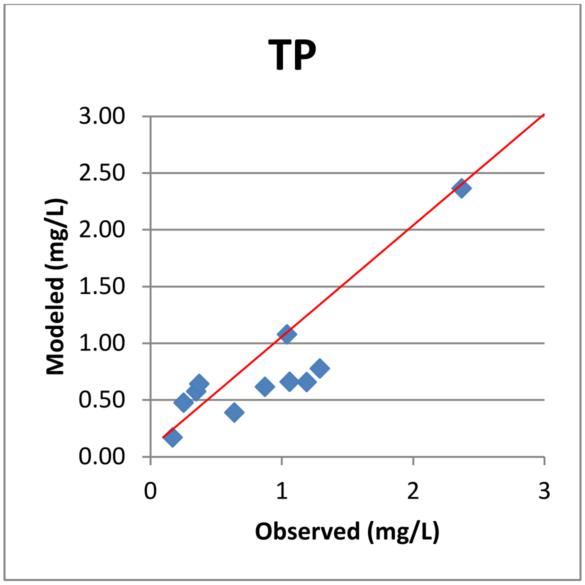


Figure B.7.8 Scatter Plot of 2007 TP Calibration

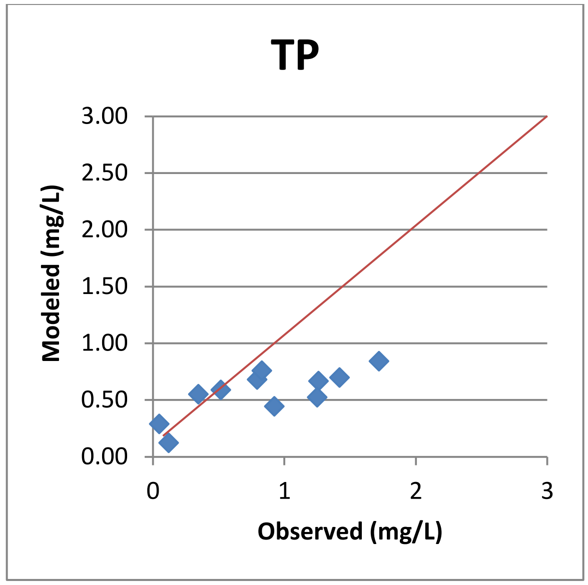


Figure B.7.9 Scatter Plot of 2008 TP Validation

Table B.7.5 Total Phoshporus Calibration/Validation Statistics for Pennsylvania Run at 8300

Year	Analysis	KWRRI	Tetra Tech		USGS		Stepwise		Interpolated	
		lbs/yr	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff	lbs/yr	%Diff
2007	Calibration	3813	2719	40.24	15378	-75.20	4209	-9.41	4042	-5.67
2008	Validation	3823	2493	53.35	15738	-75.71	3883	-1.55	3735	2.36

APPENDIX C: INPUTS FOR ADDITIONAL FLOYDS FORK WATERSHED MODELS

C.1 BROOKS RUN

Watershed Name: Brooks Run

Watershed Area: 9.6 sq. mi. (6,167.4 acres)

USGS Flow Gauge: Used USGS 03298250 as surrogate gauge to estimate daily flows

USGS Water Quality Station: None

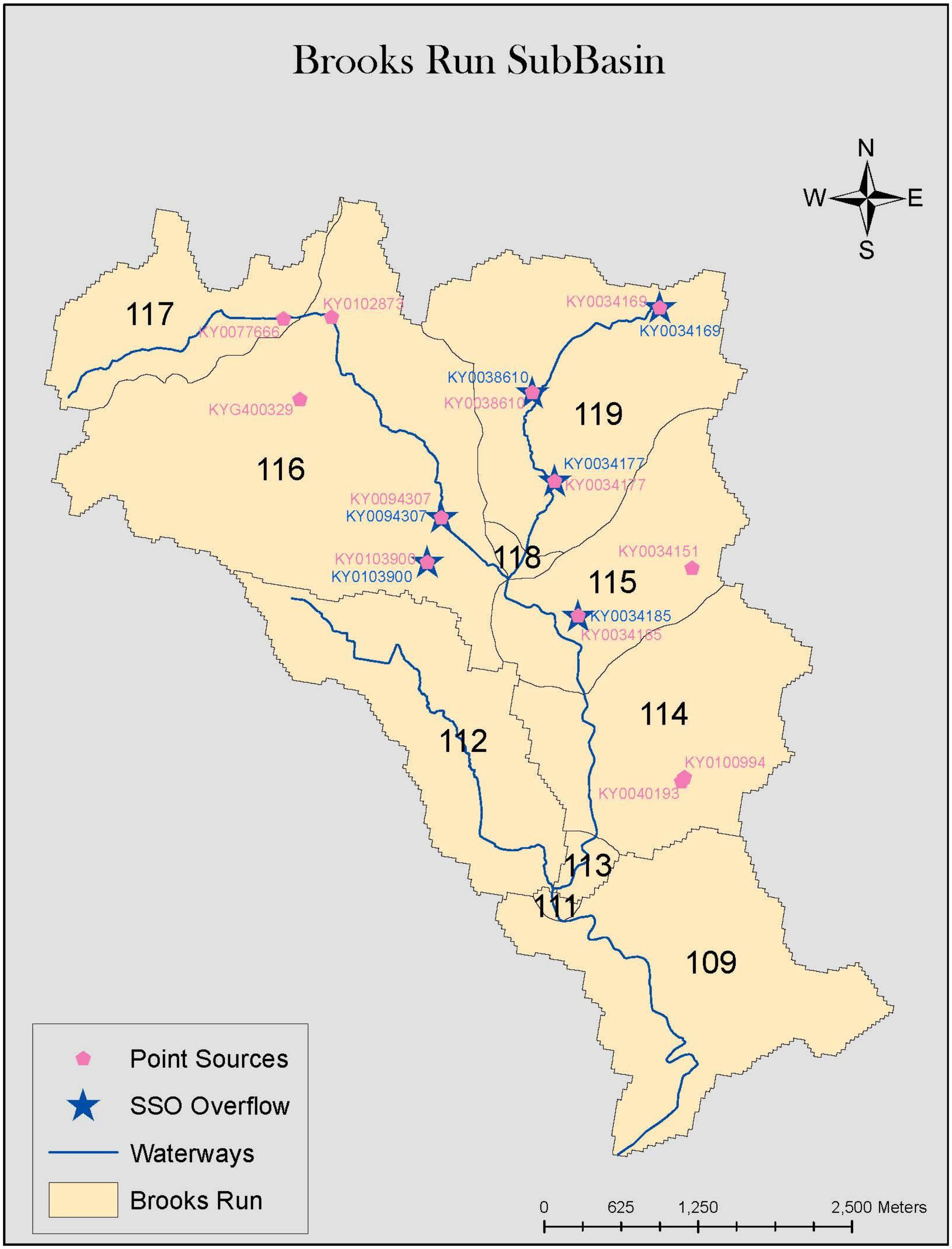


Figure C.1.1 Map of Brooks Run Watershed

Table C.1.1 Point Source Data for Brooks Run Watershed

Major Facility #1 Point Source Menu			
Name	Hillview STP	**KPDES #**	KY0103900
	Discharge (MGD)	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.011	19.40	5.51
2	0.011	19.40	8.15
3	0.01	19.40	8.36
4	0.01	19.40	14.94
5	0.01	19.40	9.60
6	0.008	19.40	13.09
7	0.009	19.40	11.14
8	0.009	19.40	10.81
9	0.011	19.40	8.68
10	0.012	19.40	7.90
11	0.009	19.40	8.12
12	0.011	19.40	7.22

Major Facility #2 Point Source Menu			
Name	Hunters Hollow S	**KPDES #**	KY0038610
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.230	8.00	1.20
2	0.206	8.00	1.20
3	0.270	8.00	1.20
4	0.260	8.00	1.20
5	0.290	8.00	1.20
6	0.280	8.00	1.20
7	0.260	8.00	1.20
8	0.260	8.00	1.20
9	0.260	8.00	1.20
10	0.304	8.00	1.20
11	0.290	8.00	1.20
12	0.330	8.00	1.20

Table C.1.1 Point Source Data for Brooks Run Watershed

Major Facility #3 Point Source Menu			
Name	Hillview Sewer Sy	**KPDES #**	KY0034151
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.310	8.00	1.20
2	0.310	8.00	1.20
3	0.250	8.00	1.20
4	0.280	8.00	1.20
5	0.202	8.00	1.20
6	0.170	8.00	1.20
7	0.150	8.00	1.20
8	0.130	8.00	1.20
9	0.140	8.00	1.20
10	0.240	8.00	1.20
11	0.190	8.00	1.20
12	0.410	8.00	1.20

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0077666	0.00125	20	4
KYG400329	0.001	20	4
KY0102873	0.004	20	4
Total	0.00625	20	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0040193	0.01	8	1.2
KY0100994	0.019	8	1.2
KY0034185	0.200	8	1.2
KY0034177	0.100	8	1.2
KY0094307	0.058	8	1.2
KY0034169	0.340	8	1.2

# Households	284	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.048**	0.1263	0.1287

Table C.1.2 Non-Point Source Data for Brooks Run Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	261.9	72.00	1.32	0.21
Residential	2427.4	80.00	2.36	0.08
Commerical	475.5	93.07	3.52	0.09
Industrial	190.4	91.00	1.74	0.07
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	35.0	79.00	3.23	0.03
Natural				
Forest	1729.9	74.00	0.47	0.01
Grassland	44.7	77.00	0.86	0.01
Agricuture				
Pasture	673.9	77.00	1.60	0.25
Row Crops	165.4	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	30.5	0.01	0.00	0.00
Wetlands	121.8	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	11.0	80.00	0.18	0.02

C.2 CEDAR CREEK

Watershed Name: Cedar Creek

Watershed Area: 23.0 sq. mi. (14,700.0 acres)

USGS Flow Gauge: 03298250, 03298300

USGS Water Quality Station: 03298250, 03298300

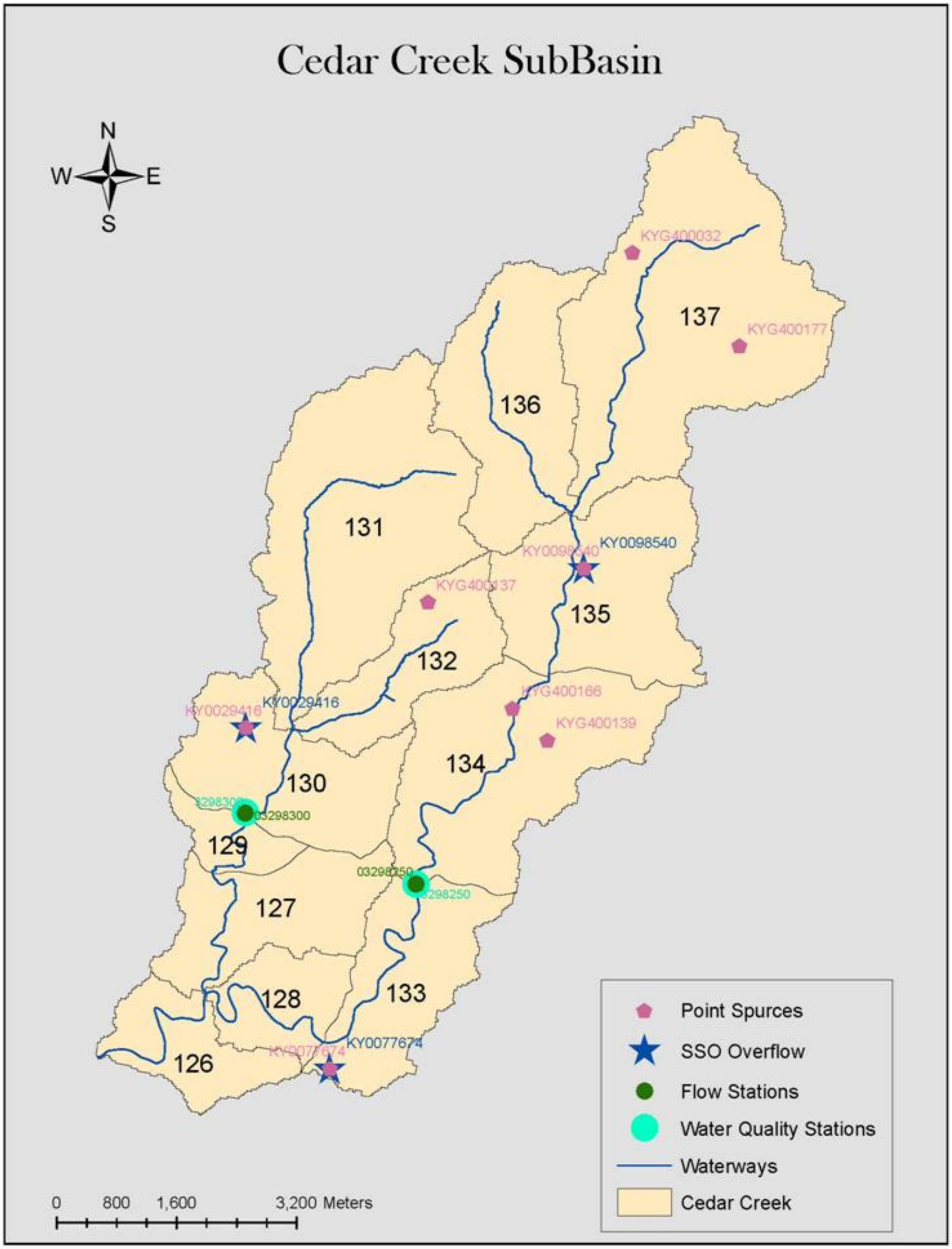


Figure C.2.1 Map of Cedar Creek Watershed

Table C.2.1 Point Source Data for Cedar Creek Watershed

Major Facility #1 Point Source Menu			
Name	Mcneely Lake	KPDES #	KY0029416
	Discharge (MGD)	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	Discharge (MGD)	TN EMC	TP EMC
1	0.13	11.00	2.15
2	0.101	11.00	2.06
3	0.095	11.00	3.60
4	0.104	11.00	3.22
5	0.087	11.00	3.03
6	0.07	11.00	3.19
7	0.079	11.00	4.26
8	0.086	11.00	4.63
9	0.087	11.00	4.13
10	0.12	11.00	3.35
11	0.092	11.00	2.15
12	0.18	11.00	1.56

Major Facility #2 Point Source Menu			
Name	Cedar Creek WQT	KPDES #	KY0098540
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	Discharge (MGD)	TN EMC	TP EMC
1		5.30	0.90
2		5.30	0.55
3		5.30	0.71
4		5.30	0.39
5		5.30	0.46
6		5.30	1.17
7		5.30	1.10
8		5.30	1.21
9		5.30	0.69
10		5.30	0.91
11		5.30	0.75
12		5.30	0.97

Table C.2.1 (Continued) Point Source Data for Cedar Creek Watershed

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400137	0.001	20	4
KYG400139	0.001	20	4
KYG400166	0.001	20	4
KYG400177	0.001	20	4
KYG400032	0.001	20	4
Total	0.005	20	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0077674	0.006833333	8	1.2

# Households	1764	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.296**	0.1263	0.1287

Table C.2.2 Non-Point Source Data for Cedar Creek Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	2.8	72.00	1.32	0.21
Residential	4339.5	80.00	2.50	0.08
Commerical	538.3	93.00	3.68	0.09
Industrial	115.2	91.00	1.78	0.07
Recreational				
Parks	503.0	79.00	1.35	0.12
Golf Course	335.0	79.00	3.59	0.03
Natural				
Forest	5126.9	74.00	0.48	0.01
Grassland	235.1	77.00	1.61	0.01
Agricuture				
Pasture	2859.6	77.00	1.60	0.25
Row Crops	332.6	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	138.1	0.01	0.00	0.00
Wetlands	105.7	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	68.3	80.00	0.18	0.02

C.3 CHENOWETH RUN

Watershed Name: Chenoweth Run

Watershed Area: 16.7 sq. mi. (10,700.5 acres)

USGS Flow Gauge: 03298135, 03298150

USGS Water Quality Station: 03298135, 03298138, 03298150, 03298160

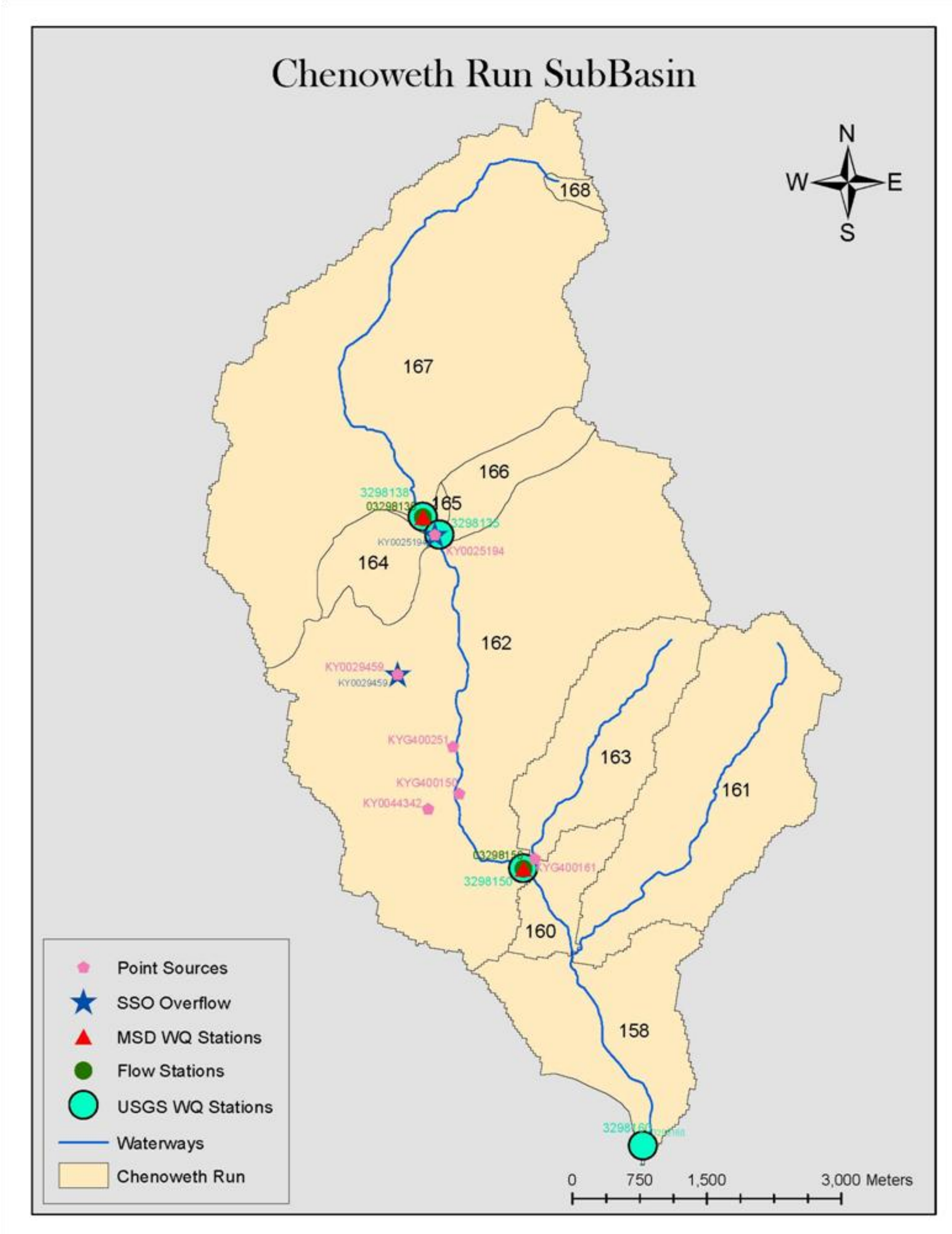


Figure C.3.1 Map of Chenoweth Run Watershed

Table C.3.1 Point Source Data for Chenoweth Run Watershed

Major Facility #1 Point Source Menu			
Name	J Town	**KPDES #**	KY0025194
	Discharge (MGD)	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1		20.00	
2		20.00	
3		20.00	
4		20.00	
5		20.00	
6		20.00	
7		20.00	
8		20.00	
9		20.00	
10		20.00	
11		20.00	
12		20.00	

Major Facility #2 Point Source Menu			
Name	Chenowth Hill	**KPDES #**	KY0029459
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.270	20.00	2.05
2	0.390	20.00	2.73
3	0.270	20.00	3.26
4	0.160	20.00	3.84
5	0.103	20.00	4.80
6	0.055	20.00	4.41
7	0.094	20.00	4.03
8	0.087	20.00	4.32
9	0.069	20.00	4.98
10	0.079	20.00	4.60
11	0.073	20.00	3.33
12	0.097	20.00	2.53

Table C.3.1 (Continued) Point Source Data for Chenoweth Run Watershed

Major Facility #3 Point Source Menu			
Name	Lake of Woods	**KPDES #**	KY0044342
	Discharge	TN EMC	TP EMC
Constant Values			
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.028	20.00	1.89
2	0.026	20.00	2.49
3	0.030	20.00	2.59
4	0.025	20.00	2.06
5	0.023	20.00	1.60
6	0.011	20.00	2.14
7	0.071	20.00	2.00
8	0.020	20.00	2.04
9	0.020	20.00	2.60
10	0.042	20.00	2.80
11	0.029	20.00	2.68
12	0.051	20.00	2.24

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400010	0.001	20	4
KYG400150	0.001	20	4
KYG400161	0.001	20	4
KYG400251	0.001	20	4

# Households	284	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.048**	0.1263	0.1287

Table C.3.2 Non-Point Source Data for Chenoweth Run Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	0.0	N/A	N/A	N/A
Residential	3232.7	80.00	1.25	0.08
Commerical	1178.1	93.00	1.30	0.09
Industrial	410.4	91.00	0.66	0.07
Recreational				
Parks	161.0	79.00	1.20	0.12
Golf Course	167.0	79.00	1.10	0.03
Natural				
Forest	3788.1	74.00	0.45	0.01
Grassland	241.7	77.00	0.45	0.01
Agricuture				
Pasture	1270.4	77.00	1.60	0.25
Row Crops	60.8	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	68.5	0.01	0.00	0.00
Wetlands	64.2	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	57.5	80.00	0.18	0.02

C.4 LOWER FLOYDS FORK AT BETHEL BRANCH

Watershed Name: Lower Floyds Fork at Bethel Branch

Watershed Area: 228.7 sq. mi. (146,361.4 acres)

USGS Flow Gauges: 03298200, 03298000, 03298150, 03298135, 03297990

USGS Water Quality Stations: 03298200,03298160, 03298120, 03298150, 03298138, 03298135, 03298005, 03298000, 03297930, 03298110, 03298100, 03297975, 03297950, 03297845, 03297990, 03297880, 03297860, 03297855, 03297830, 03297850

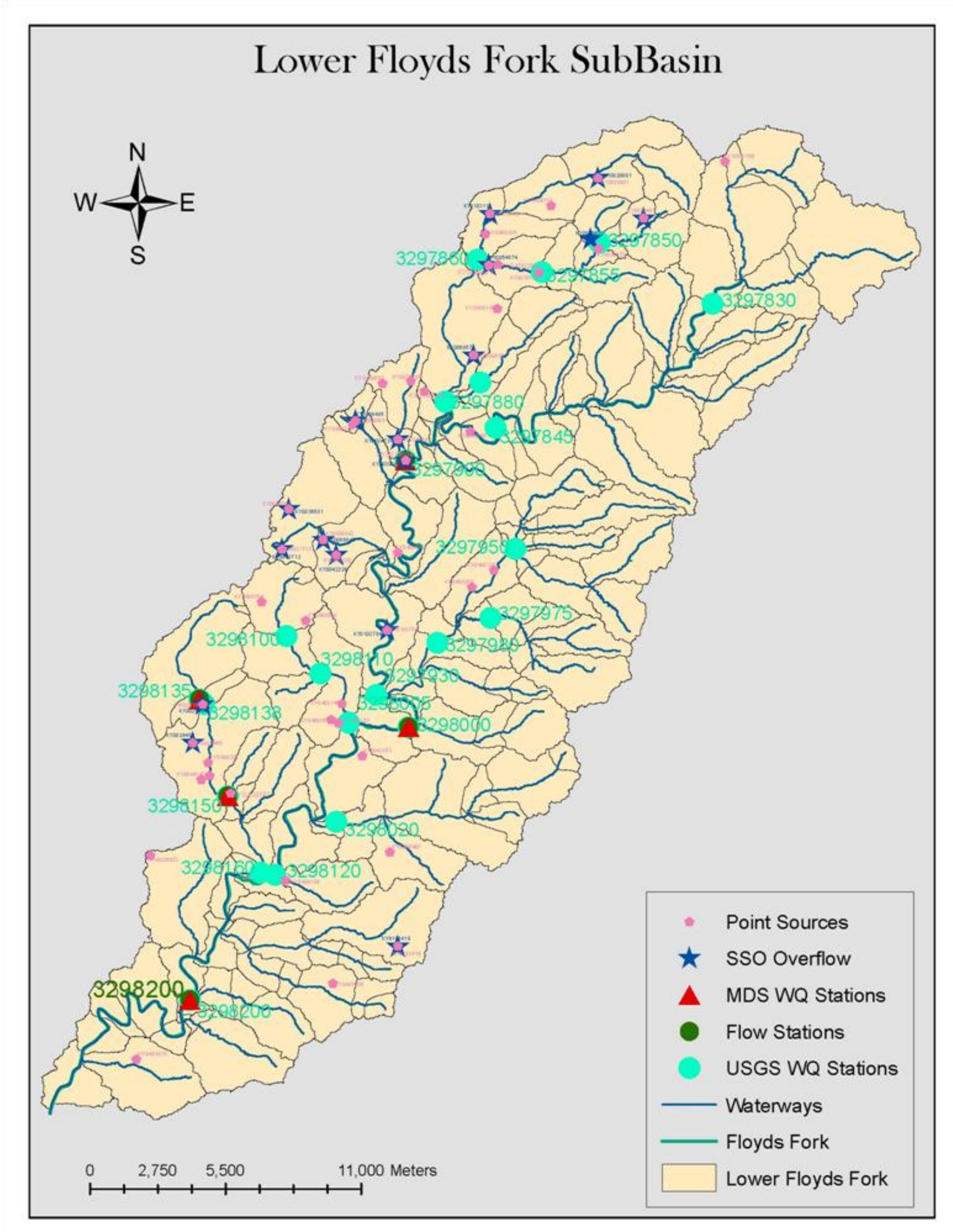


Figure C.4.1 Map of Lower Floyds Fork at Bethel Branch Watershed

Table C.4.1 Point Source Data for Lower Floyds Fork at Bethel Branch Watershed

Major Facility #1 Point Source Menu			
Name	J Town	**KPDES #**	KY0025194
	Discharge (MGD)	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1		20.00	
2		20.00	
3		20.00	
4		20.00	
5		20.00	
6		20.00	
7		20.00	
8		20.00	
9		20.00	
10		20.00	
11		20.00	
12		20.00	

Major Facility #2 Point Source Menu			
Name	Chenoweth Hill	**KPDES #**	KY0029459
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.27	25.00	2.05
2	0.39	25.00	2.73
3	0.27	25.00	3.26
4	0.16	25.00	3.84
5	0.103	25.00	4.80
6	0.055	25.00	4.41
7	0.094	25.00	4.03
8	0.087	25.00	4.32
9	0.069	25.00	4.98
10	0.079	25.00	4.60
11	0.073	25.00	3.33
12	0.097	25.00	2.53

Table C.4.1 (Continued) Point Source Data for Lower Floyds Fork at Bethel Branch Watershed

Major Facility #3 Point Source Menu			
Name	Floyds Fork WQT(	**KPDES #**	KY0102784
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1		9.00	0.09
2		9.00	0.09
3		9.00	0.09
4		9.00	0.07
5		9.00	0.06
6		9.00	0.10
7		9.00	0.73
8		9.00	0.08
9		9.00	0.79
10		9.00	0.66
11		9.00	0.63
12		9.00	0.59

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
Various (summed)	0.02282	20	4
KYG401875	0.001	20	4

Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
Various (summed)	2.9385	9	1.2

# Households	12866	Septic	Systems
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**2.161**	0.1263	0.1287

Table C.4.2 Non-Point Source Data for Lower Floyds Fork at Bethel Branch Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	176.5	72.00	1.31	0.21
Residential	18466.2	80.00	2.26	0.08
Commerical	3409.6	93.07	3.52	0.09
Industrial	1111.1	91.00	1.69	0.07
Recreational				
Parks	290.0	79.00	1.31	0.12
Golf Course	2610.0	79.00	2.94	0.03
Natural				
Forest	63329.0	74.00	0.47	0.01
Grassland	5700.5	77.00	1.34	0.01
Agricuture				
Pasture	41151.8	77.00	1.60	0.25
Row Crops	7218.0	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	1197.0	0.01	0.00	0.00
Wetlands	1233.8	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	467.8	80.00	0.18	0.02

C.5 MIDDLETOWN CHENOWETH RUN

Watershed Name: Middletown Chenoweth Run

Watershed Area: 7.5 sq. mi. (4,775.0 acres)

USGS Flow Gauge: Used USGS 03298135 as surrogate gauge to estimate daily flows

USGS Water Quality Station: None

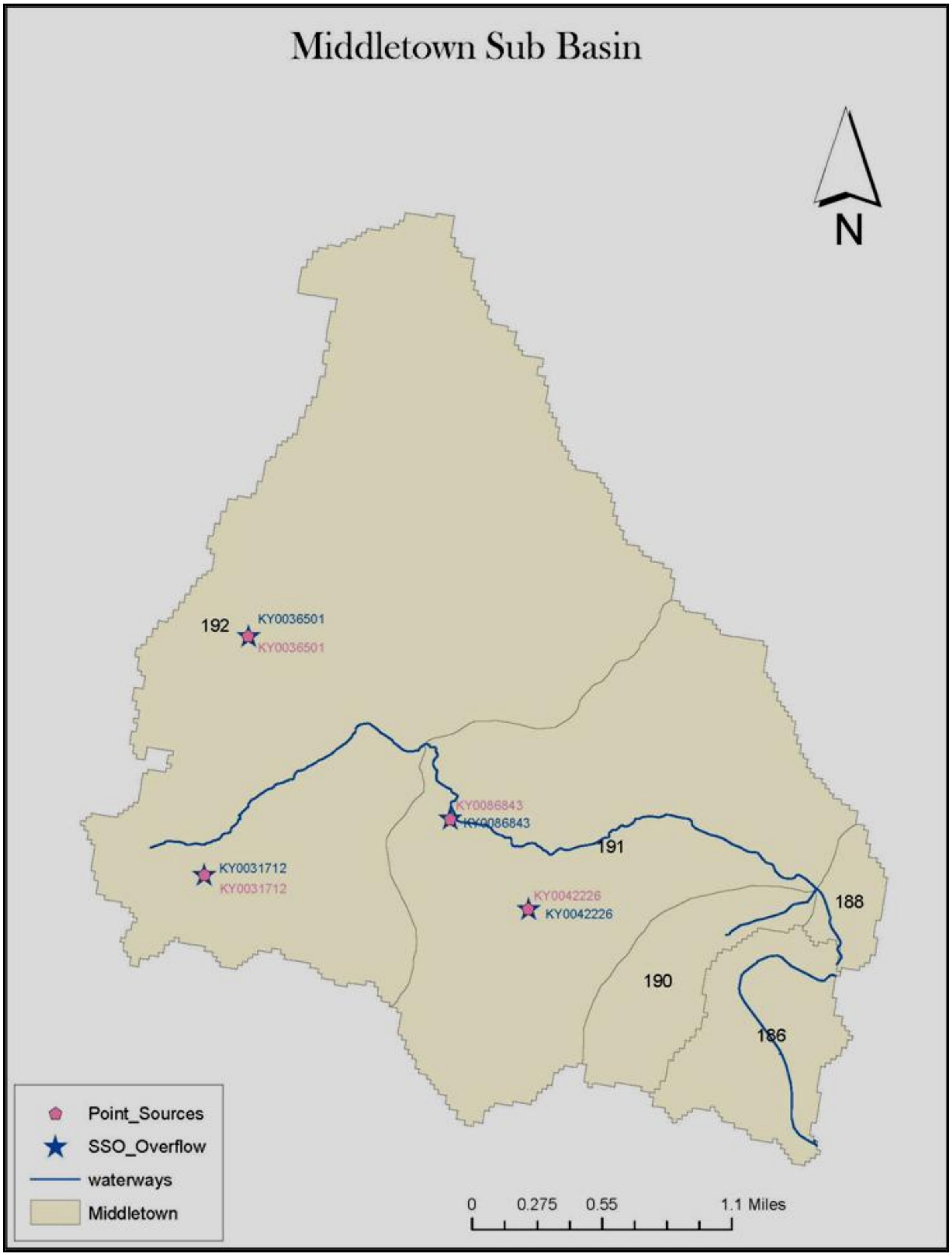


Figure C.5.1 Map of Middletown Chenoweth Run Watershed

Table C.5.1 Point Source Data for Middletown Chenoweth Run Watershed

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0086843	0.075833333	20	4
Total	0.075833333	20	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0036501	0.09775	8	1.2
KY0031712	0.106	8	1.2
KY0042226	0.379	8	1.2

# Households	660	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.111**	0.1263	0.1287

Table C.5.2 Non-Point Source Data for Middletown Chenoweth Run Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	95.6	72.00	1.32	0.21
Residential	1713.6	80.00	2.50	0.08
Commerical	614.9	93.00	3.69	0.09
Industrial	326.5	91.00	1.78	0.07
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	299.0	79.00	3.60	0.03
Natural				
Forest	1157.6	74.00	0.48	0.01
Grassland	15.4	77.00	1.62	0.01
Agricuture				
Pasture	341.1	77.00	1.60	0.25
Row Crops	44.7	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	84.6	0.01	0.00	0.00
Wetlands	56.2	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	25.6	80.00	0.18	0.02

C.6 NORTH CURRYS FORK

Watershed Name: North Currys Fork

Watershed Area: 10.1 sq. mi. (6483.6 acres)

USGS Flow Gauge: Used USGS03297880 as surrogate gauge to estimate daily flows

USGS Water Quality Station: 03297860

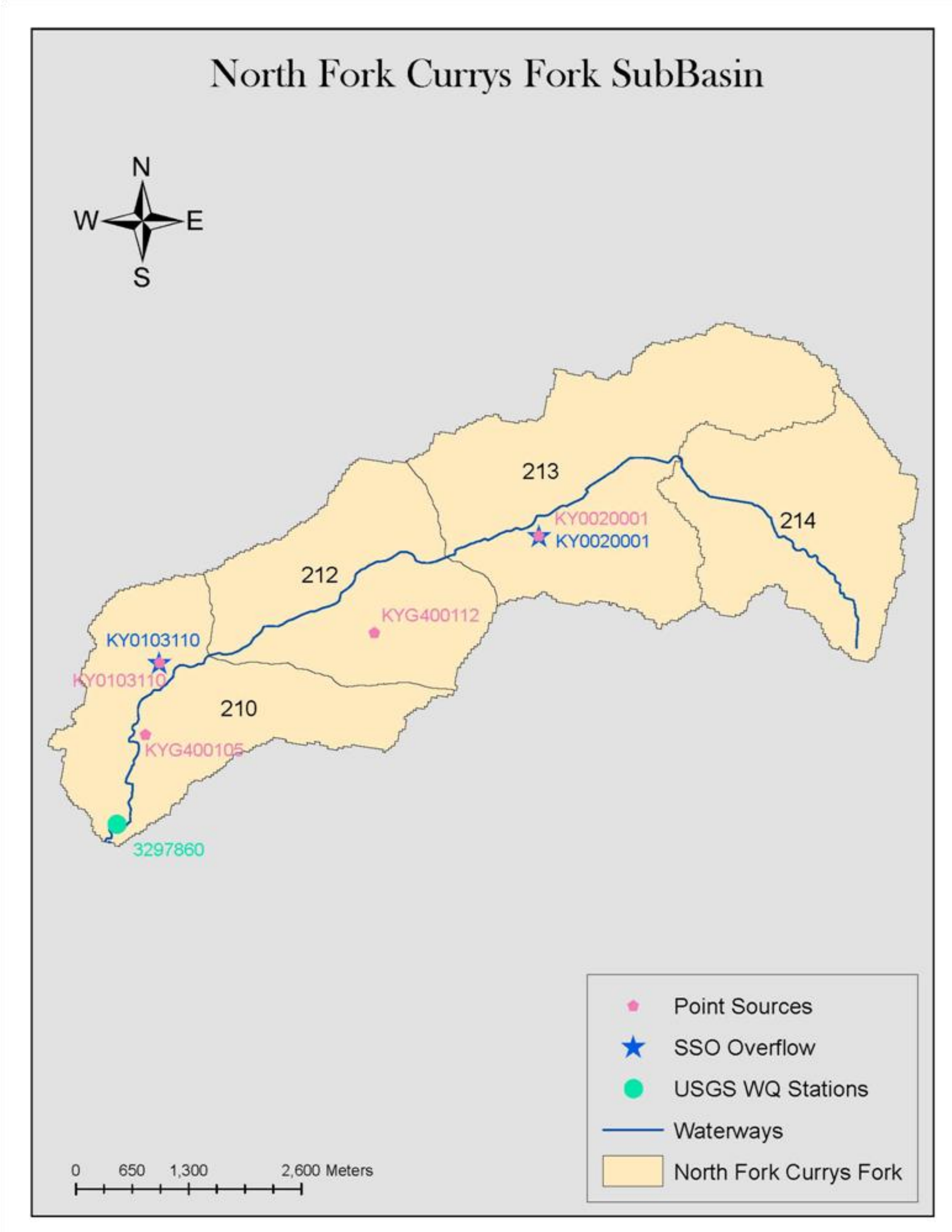


Figure C.6.1 Map of North Currys Fork Watershed

Table C.6.1 Point Source Data for North Currys Fork Watershed

Major Facility #1 Point Source Menu			
Name	Buckner STP	**KPDES #**	KY0103110
	Discharge (MGD)	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.18	39.20	1.54
2	0.17	39.20	2.57
3	0.19	39.20	2.27
4	0.18	39.20	3.24
5	0.14	39.20	1.28
6	0.12	39.20	3.83
7	0.12	39.20	5.71
8	0.13	39.20	3.48
9	0.12	39.20	3.59
10	0.17	39.20	2.60
11	0.17	39.20	4.01
12	0.28	39.20	0.84

Major Facility #2 Point Source Menu			
Name	LAGRANGE STP	**KPDES #**	KY0020001
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.720	24.50	1.03
2	0.650	24.50	1.03
3	0.640	24.50	1.03
4	0.660	24.50	1.03
5	0.540	24.50	1.03
6	0.510	24.50	1.03
7	0.510	24.50	1.03
8	0.509	24.50	1.03
9	0.490	24.50	1.03
10	0.550	24.50	1.03
11	0.580	24.50	1.03
12	0.840	24.50	1.03

Table C.6.1 (Continued) Point Source Data for North Currys Fork Watershed

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400112	0.001	20	4
KYG400105	0.001	20	4

# Households	418	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.070**	0.1263	0.1287

Table C.6.2 Non-Point Source Data for North Currys Fork Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	22.7	72.00	1.29	0.21
Residential	1584.4	80.00	2.17	0.08
Commerical	220.2	93.36	2.83	0.09
Industrial	121.1	91.00	1.38	0.07
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	2896.3	74.00	0.47	0.01
Grassland	42.3	77.00	0.89	0.01
Agricuture				
Pasture	1307.2	77.00	1.60	0.25
Row Crops	174.1	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	65.4	0.01	0.00	0.00
Wetlands	46.7	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	3.4	80.00	0.18	0.02

C.7 PENNSYLVANIA RUN

Watershed Name: Pennsylvania Run

Watershed Area: 8.4 sq. mi. (5386.3 acres)

USGS Flow Gauge: 03298300

USGS Water Quality Station: 03298300

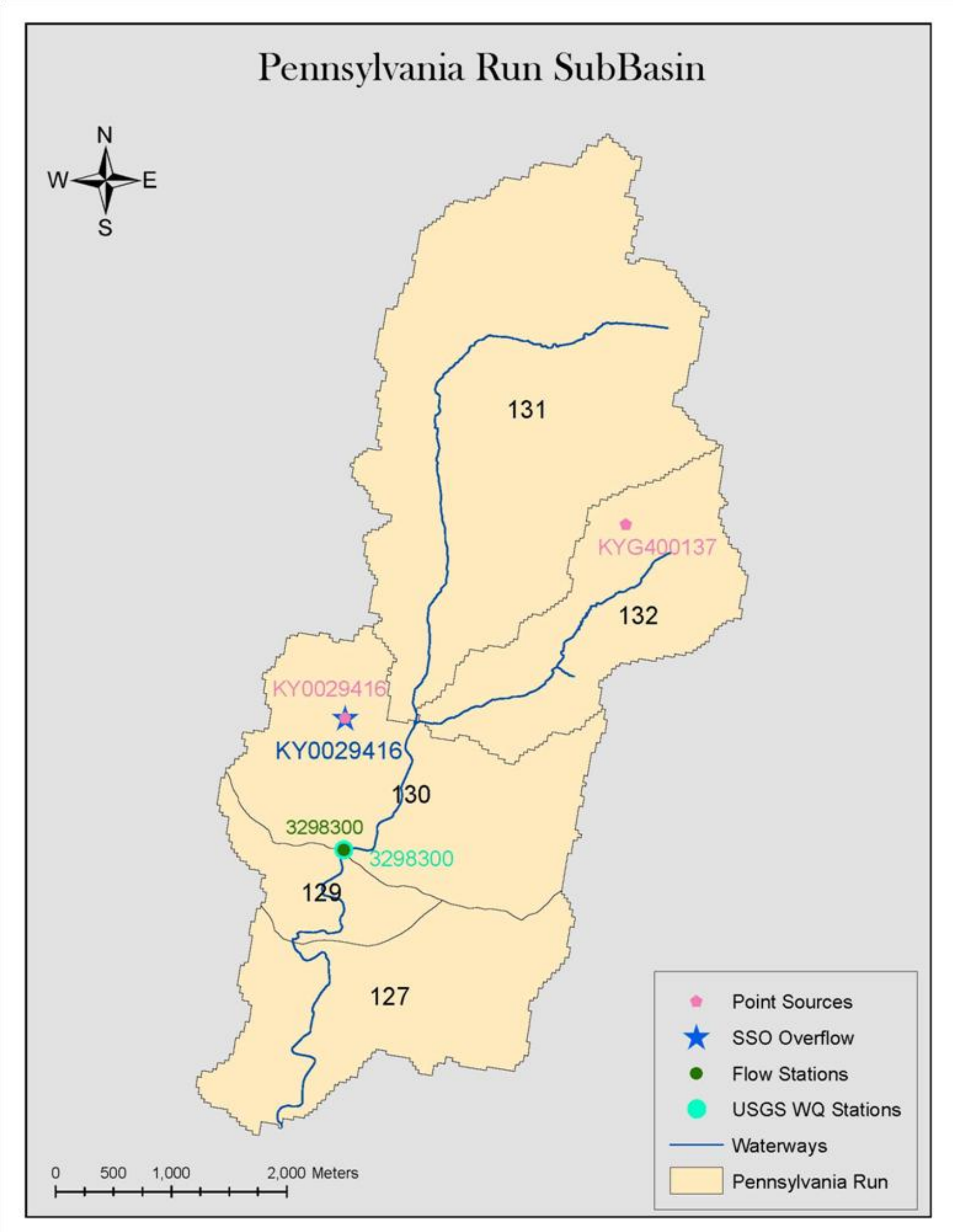


Figure C.7.1 Map of Pennsyvania Run Watershed

Table C.7.1 Point Source Data for Pennsyvania Run Watershed

Major Facility #2 Point Source Menu			
Name	Mcneely Lake	**KPDES #**	KY0029416
	Discharge	TN EMC	TP EMC
Constant Values	N/A	N/A	N/A
Month	**Discharge (MGD)**	TN EMC	TP EMC
1	0.130	11.00	2.15
2	0.101	11.00	2.06
3	0.095	11.00	3.60
4	0.104	11.00	3.22
5	0.087	11.00	3.03
6	0.070	11.00	3.19
7	0.079	11.00	4.26
8	0.086	11.00	4.63
9	0.087	11.00	4.13
10	0.120	11.00	3.35
11	0.092	11.00	2.15
12	0.180	11.00	1.56

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400137	0.001	20	4

# Households	664	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.112**	0.1263	0.1287

Table C.7.2 Non-Point Source Data for Pennsyvania Run Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	0.0	N/A	N/A	N/A
Residential	1081.4	80.00	2.50	0.08
Commerical	132.7	93.00	3.69	0.09
Industrial	22.6	91.00	1.78	0.07
Recreational				
Parks	503.0	79.00	1.35	0.12
Golf Course	335.0	79.00	3.61	0.03
Natural				
Forest	2138.3	74.00	0.48	0.01
Grassland	98.2	77.00	1.62	0.01
Agricuture				
Pasture	783.7	77.00	1.60	0.25
Row Crops	142.2	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	55.8	0.01	0.00	0.00
Wetlands	67.9	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	25.7	80.00	0.18	0.02

C.8 SOUTH CURRYS FORK

Watershed Name: South Currys Fork

Watershed Area: 7.5 sq. mi. (4,775.0 acres)

USGS Flow Gauge: Used USGS 03297855 as surrogate gauge to estimate daily flows

USGS Water Quality Station: None

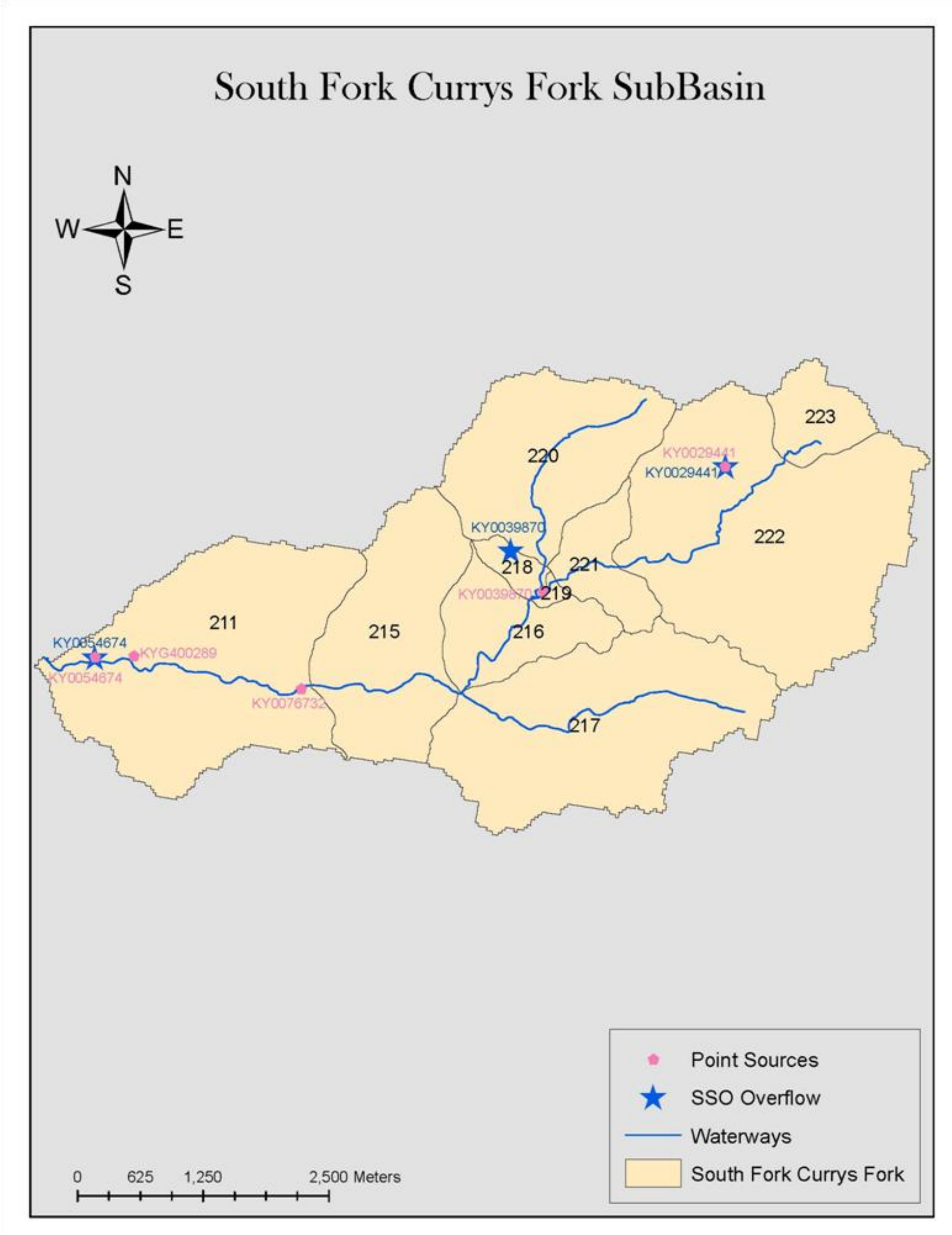


Figure C.8.1 Map of South Currys Fork Watershed

Table C.8.1 Point Source Data for South Currys Fork Watershed

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400289	0.001	20	4
Total	0.001	20	4
Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0076732	0.01	8	1.2
KY0029441	0.027	8	1.2
KY0039870	0.068	8	2.5
KY0054674	0.042	8	1.2

# Households	383	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.064**	0.1263	0.1287

Table C.8.2 Non-Point Source Data for South Currys Fork Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	2.3	72.00	1.29	0.21
Residential	984.0	80.00	1.92	0.08
Commerical	28.8	93.37	2.80	0.09
Industrial	12.3	91.00	0.82	0.07
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	159.0	79.00	2.41	0.03
Natural				
Forest	2733.3	74.00	0.47	0.01
Grassland	152.0	77.00	1.07	0.01
Agricuture				
Pasture	1673.9	77.00	1.60	0.25
Row Crops	153.9	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	38.3	0.01	0.00	0.00
Wetlands	27.5	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	3.1	80.00	0.18	0.02

C.9 SOUTH LONG RUN

Watershed Name: South Long Run

Watershed Area: 7.7 sq. mi. (4,912.5 acres)

USGS Flow Gauge: Used USGS03298135 as surrogate gauge to estimate daily flows

USGS Water Quality Station: 03297975

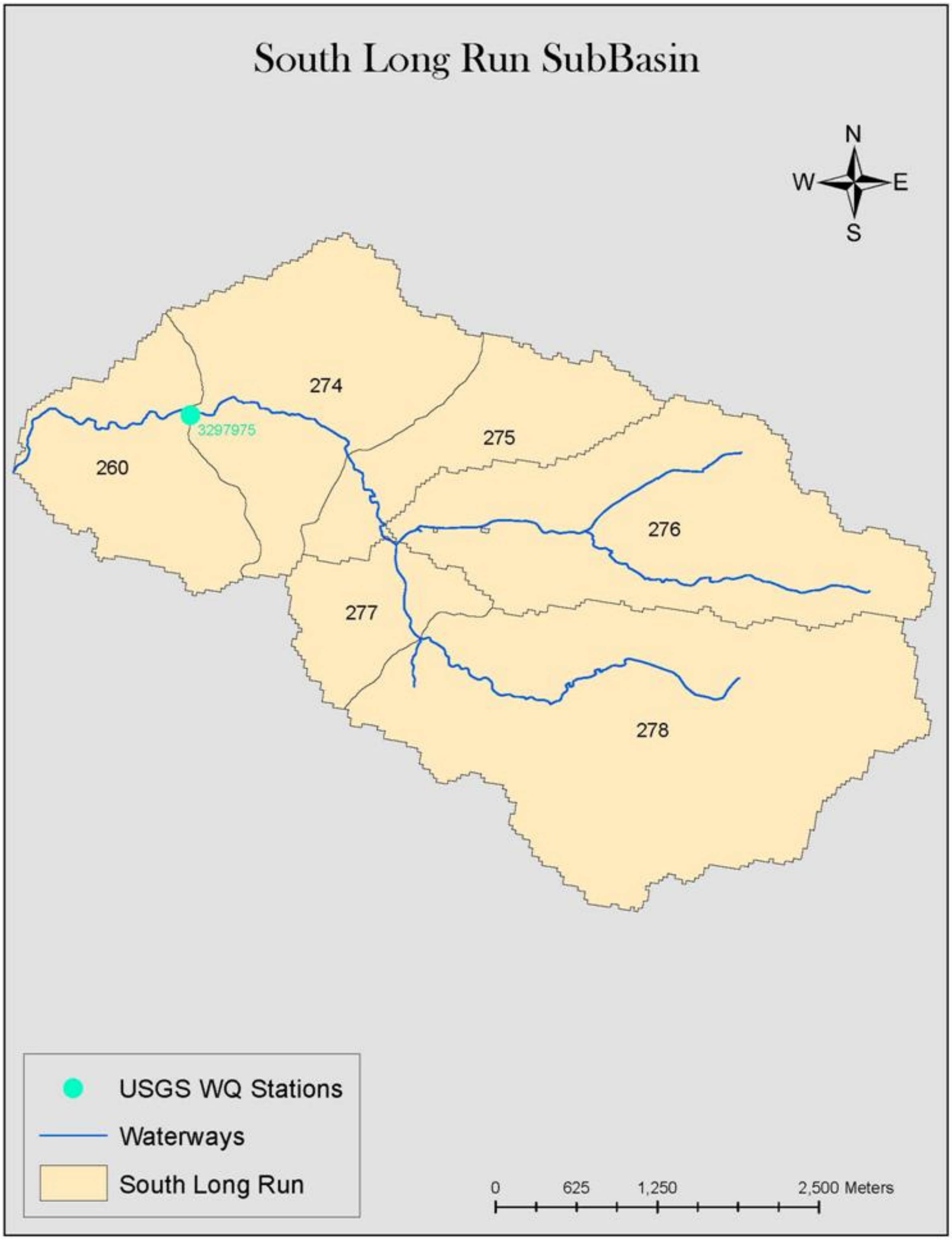


Figure C.9.1 Map of South Long Run Watershed

Table C.9.1 Point Source Data for South Long Run Watershed

# Households	280	**Septic**	**Systems**
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.047**	0.1263	0.1287

Table C.9.2 Non-Point Source Data for South Long Run Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	5.0	72.00	1.29	0.21
Residential	477.1	80.00	1.69	0.08
Commerical	44.6	93.53	2.43	0.09
Industrial	0.0	N/A	N/A	N/A
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	143.0	79.00	1.87	0.03
Natural				
Forest	1627.9	74.00	0.46	0.01
Grassland	248.7	77.00	1.36	0.01
Agricuture				
Pasture	2089.1	77.00	1.60	0.25
Row Crops	107.9	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	80.0	0.01	0.00	0.00
Wetlands	57.9	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	31.4	80.00	0.18	0.02

C.10 UPPER FLOYDS FORK AT CURRYS FORK

Watershed Name: Upper Floyds Fork at Currys Fork

Watershed Area: 28.6 sq. mi. (18,321 acres)

USGS Flow Gauge: Used USGS03297900 as surrogate gauge to estimate daily flows

USGS Water Quality Station: 03297845, 03297830

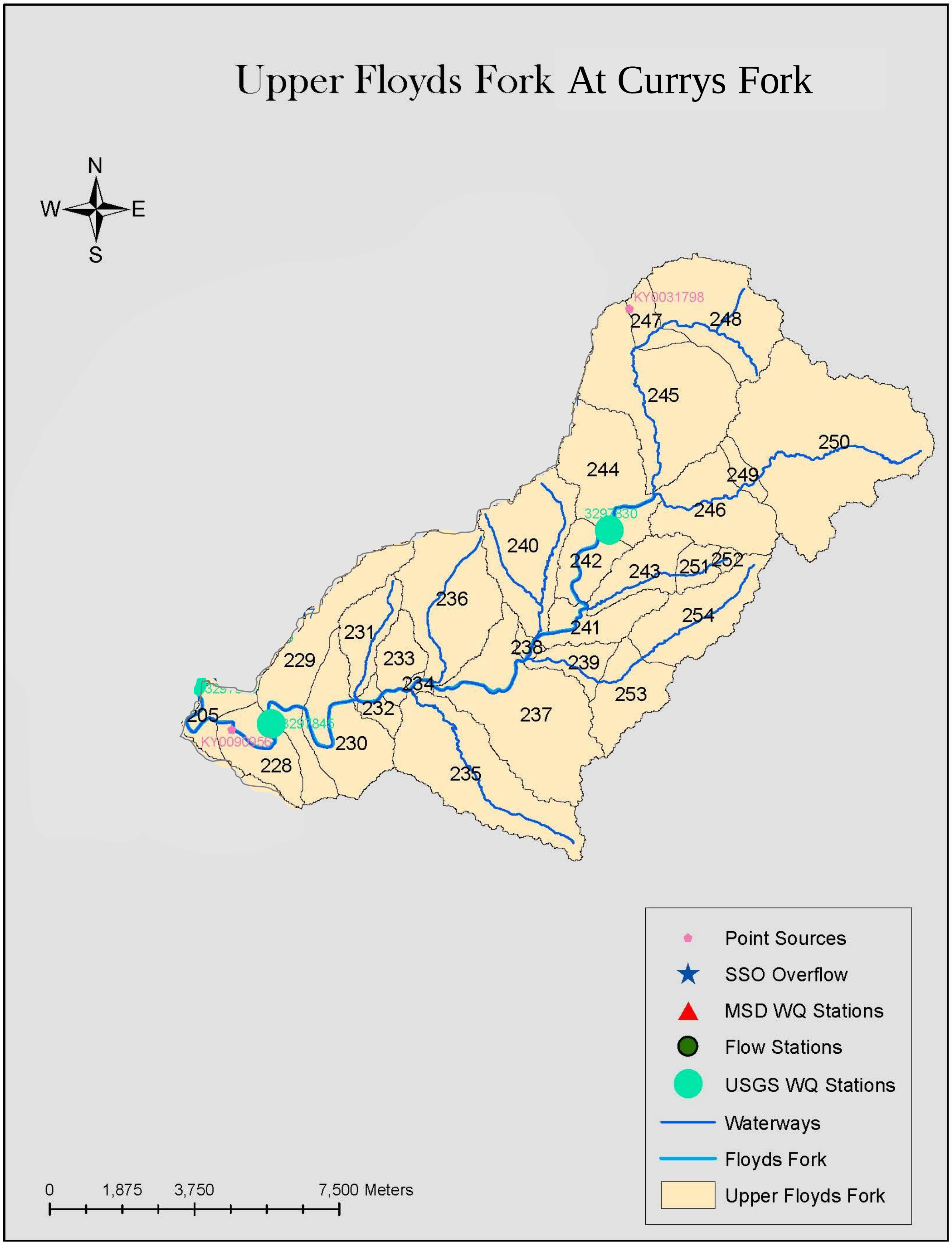


Figure C.10.1 Map of Upper Floyds Fork at Currys Fork Watershed

Table C.10.1 Point Source Data for Upper Floyds Fork at Currys Fork Watershed

Sub/Schools	< .5 MGD	9 mg/L	1.2 mg/L
KPDES #	Discharge	TN EMC	TP EMC
KY0031798	0.015	9	1.2
KY0090956	0.095	9	1.2

# Households	1207	Septic	Systems
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.203**	0.1263	0.1287

Table C.10.2 Non-Point Source Data for Upper Floyds Fork at Currys Fork Watershed

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	24.7	72	1.29	0.21
Residential	3575.7	80	2.16	0.08
Commerical	253.6	93	2.86	0.09
Industrial	139.5	91	1.36	0.07
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	8119.4	74	0.47	0.01
Grassland	290.6	77	1.19	0.01
Agricuture				
Pasture	4915.3	77	1.60	0.25
Row Crops	732.9	84	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	155.0	0	0.00	0.00
Wetlands	114.6	0	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	0.0	0	0.00	0.00

C.11 UPPER FLOYDS FORK AT USGS 03297900

Watershed Name: Upper Floyds Fork at USGS 03297900

Watershed Area: 83.03 sq. mi. (53,141 acres)

USGS Flow Gauge: 03297900

USGS Water Quality Station: 03297900

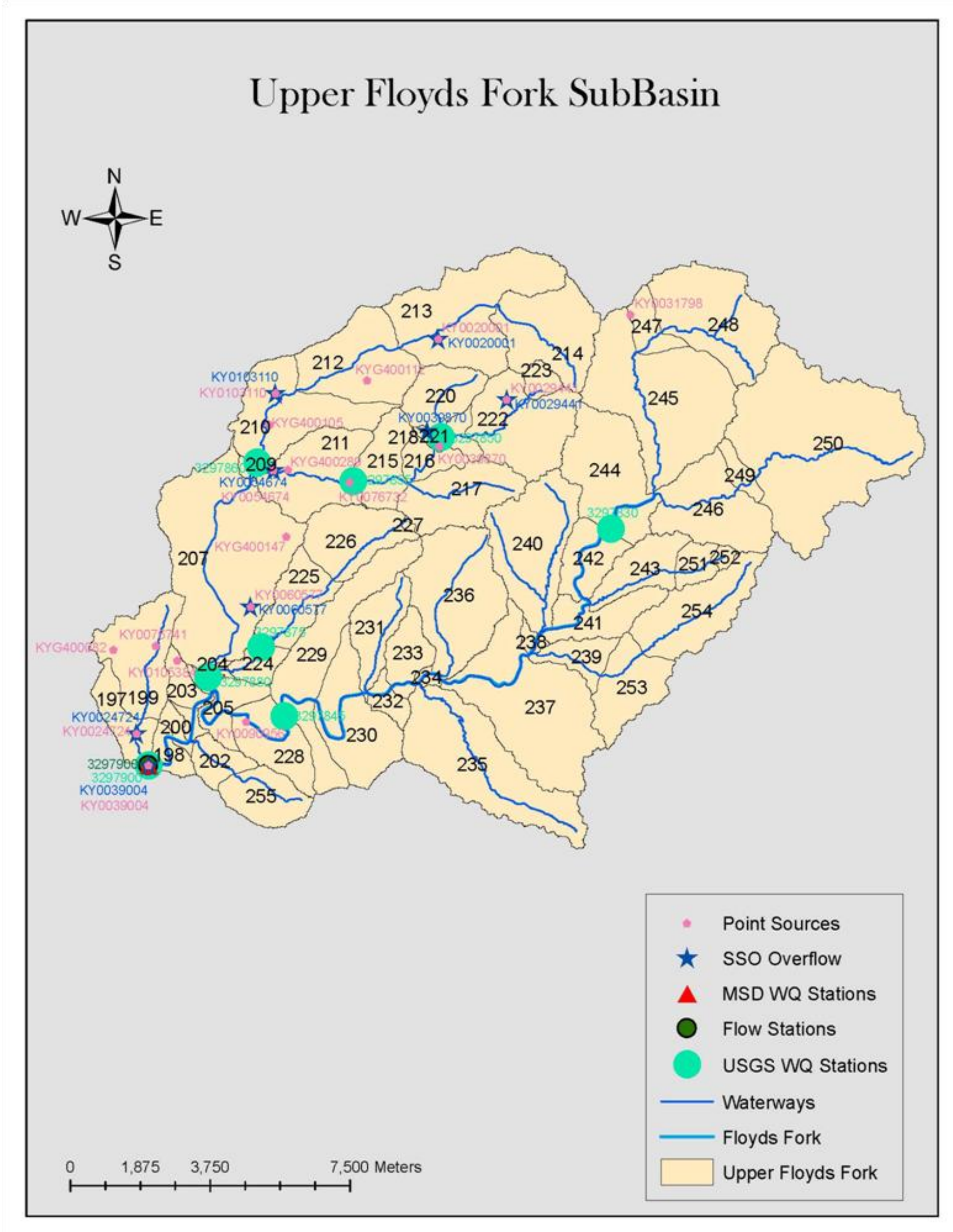


Figure C.11.1 Map of Upper Floyds Fork at USGS 03297900 Watershed

Table C.11.1 Point Source Data for Upper Floyds Fork at USGS 03297900 Watershed

Floyds Fork at USGS 03297900 was modeled using three separate models which were then aggregated into a composite result: Upper Floyds Fork at Currys Fork, Currys Fork, and an incremental area from the confluence of Currys Fork to USGS 03297900. For point sources in Upper Floyds Fork at Currys Fork see Appendix C.10. For point sources in North Currys Fork see Appendix C.6. The point sources for the increment between Upper Floyds Fork at Currys Fork and Upper Floyds Fork at 7900 are listed below:

Minor Point Source/Septic System Menu			
Minor Facilities	**~ .001 MGD**	20 mg/L	4 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KYG400082	0.001	20	4

Sub/Schools	**< .5 MGD**	9 mg/L	1.2 mg/L
KPDES #	**Discharge**	TN EMC	TP EMC
KY0076741	0.002	9	1.2
KY0024724	0.286	9	1.2
KY0039004	0.060	9	1.2
KY0105384	0.001	9	1.2

# Households	1337	Septic	Systems
Persons/House	2.8		
Q per capita (gal/day)	60	TN EMC (mg/L)	TP EMC (mg/L)
Total Flow (MGD)	**0.225**	0.1263	0.1287

Table C.11.2 Non-Point Source Data for Upper Floyds Fork at USGS 03297900 Watershed

For non-point sources in Upper Floyds Fork at Currys Fork see Appendix C.10. For non-point sources in North Currys Fork see Appendix C.6. The non-point sources for the increment between Upper Floyds Fork at Currys Fork and Upper Floyds Fork at 7900 are listed below:

Landuse	Area	Curve Number	Tot. Nitrogen	Tot. Phosphorus
Urban	**(acres)**		**EMC (mg/L)**	**EMC (mg/L)**
Barren Land	0.0	N/A	N/A	N/A
Residential	849.3	80.00	2.33	0.08
Commerical	35.6	93.10	3.45	0.09
Industrial	10.0	91.00	1.59	0.07
Recreational				
Parks	0.0	N/A	N/A	N/A
Golf Course	0.0	N/A	N/A	N/A
Natural				
Forest	1603.9	74.00	0.47	0.01
Grassland	71.1	77.00	1.33	0.01
Agricuture				
Pasture	610.1	77.00	1.60	0.25
Row Crops	296.7	84.00	1.25	0.06
Silvicuture	0.0	N/A	N/A	N/A
Hydraulic				
Open Water	39.2	0.01	0.00	0.00
Wetlands	33.7	0.01	0.00	0.00
Septic Systems			**lb/acre/day**	**lb/acre/day**
F. Septic Sys.	0.0	0.00	0.00	0.00