Nonpoint Source Pollution in the Mosquito Creek Watershed

By

Baba Musah Yahaya

Submitted in Partial Fulfillment of the Requirements

For the Degree of

Master of Science

in the

Civil and Environmental Engineering

Program

YOUNGSTOWN STATE UNIVERSITY

August 2004

Nonpoint Source Pollution in the Mosquito Creek Watershed

Baba Musah Yahaya

I hereby release this thesis to the public. I understand that this thesis will be made available from the OhioLINK ETD Center and the Maag Library Circulation Desk for public access. I also authorize the university or ther individuals to make copies of this thesis as needed for scholarly research.

Signature: Baba Yahaya 7/30/04

Baba Musah Yahaya, Student — Date

Approvals: Scott C. Martin 7/30/04

Dr. Scott Martin, Thesis Advisor — Date

Lauren Schroeder 7/30/04

Dr. Lauren Schroeder, Committee Member — Date

Irfan A. Khan. 8/2/04

Dr. Irfan Khan, Committee Member — Date

Peter J. Kavinsky 8/2/04

Dr. Peter J. Kavinsky, Dean of Graduate Studies and Research — Date

ABSTRACT

The Mosquito Creek watershed is an important water resource in Trumbull County. Mosquito Creek Reservoir has served as a source of municipal water supply for the City of Warren since 1954; the reservoir is also used extensively for recreation.

The purpose of this study was to estimate major nonpoint source (NPS) pollutant loadings to the streams within the Mosquito Creek watershed by stream monitoring and computer modeling, and to identify potential locations for pollutant loading reduction.

Monitoring stations were established on Mosquito Creek and all major tributaries. The parameters monitored included flow, pH, turbidity, suspended solids, soluble reactive phosphorus, total phosphorus (TP), ammonia nitrogen, and nitrate nitrogen.

Total pollutant loads of 92,410 lb/yr for TP, 33,040 lb/yr for nitrate nitrogen, 48,540 lb/yr for ammonia nitrogen and 15,200 t/yr for suspended solids were obtained from the monitoring data. The computer model, STEPL, estimated the total loads as: 211,890 lb/yr for total nitrogen (N), 55,290 lb/yr for TP, 558,350 lb/yr for BOD and 9,040 t/yr for sediments (i.e. suspended solids). Loading estimates based on monitoring were significantly higher than those based on STEPL.

Based on monitoring results, the export rates of TP, N, and SS are highest in the northern and western parts of Mosquito Creek watershed, and lower in the southern and eastern parts. Cropland, urban land and septic systems were predicted by STEPL to be the major sources of NPS pollution in the Mosquito Creek Reservoir watershed.

DEDICATION

Dedicated to my daughter for the joy she brings to me, and to my wife for the love, understanding and wonderful support given me during my study, and for making me a dad.

ACKNOWLEDGEMENTS

I wish to extend my heartfelt and sincere appreciation to my advisor, Dr. Scott Martin for the time and invaluable assistance he offered me during my studies and especially in my research and thesis compilation. I wish to also thank Dr. Lauren Schroeder and Dr. Irfan Khan for their time in reviewing my thesis and their helpful comments. Thanks to John Bralich of YSU's Center for Urban and Regional Studies for providing me with GIS maps and data on the Mosquito Creek watershed.

TABLE OF CONTENTS

LIST OF TABLES

TABLE		PAGE
Table 4-7.	Summary of Monitoring Data for Site #7 - Unnamed Tributary at Hoagland-Blackstub Rd.	31
Table 4-8.	Summary of Monitoring Data for Site #8 - Runoff into Unnamed Tributary at Hoagland-Blackstub Rd.	31
Table 4-9.	Summary of Monitoring Data for Site #9 - Spring Run.	32
Table 4-10.	Summary of Monitoring Data for Site #10 - North Branch, Smith Run.	32
Table 4-11.	Summary of Monitoring Data for Site #11 - Unnamed Tributary at SR 46, South of Wakefield Creek Road.	32
Table 4-12.	Summary of Monitoring Data for Site #12 - South Branch, Mud Creek.	33
Table 4-13.	Mean Loading Rates at Sampling Stations, in lb/d.	34
Table 4-14.	Mean Loading Rates at Sampling Stations, in kg/d.	34
Table 4-15.	Areal Pollutant Loading Rates, W_m, in lb/acre/yr.	35
Table 4-16.	Areal Pollutant Loading Rates, W_m, in kg/ha/yr.	35
Table 4-17.	Watershed Area-Weighted Average Loading Rates for Drainage Areas Within the Mosquito Reservoir Watershed.	36
Table 4-18.	Average Nutrient Export Factors for the United States.	36
Table 4-19.	Phosphorus Export Factors for Wisconsin.	37
Table 4-20.	Suspended Solids Export Factors for Florida.	37
Table 4-21.	Estimated Total Pollutant Loads into Mosquito Creek Reservoir.	37
Table 4-22.	Land Use Distribution in the Mosquito Creek Watershed	38
Table 4-23.	Precipitation	38
Table 4-24.	Agricultural Animals	38
Table 4-25.	Septic System Information.	39
Table 4-26.	STEPL Output of Total Pollutant Loads from Mosquito Creek Reservoir Watershed and Loading Reductions From BMP.	39

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1-1 The Mahoning River Watershed Planning Project

Overview

The protection of water resources requires a cooperative effort on the part of many "stakeholders", including local, state, and federal environmental agencies, political officials, special interest groups, and private citizens. The Mahoning River Consortium (MRC) is one such citizens group formed in 1996 to protect the Mahoning River watershed, shown in Figure 1-1.

The MRC is developing a Watershed Action Plan to serve as a blueprint for future activities and projects. The main goals include restoration and protection of water quality in the Mahoning River watershed, with a primary focus on the Mosquito Creek watershed and the Lower Mahoning River Corridor (Figure 1-2). The plan will identify specific water quality goals and actions to be implemented to achieve such goals. The watershed planning process is supported by a grant from the US and Ohio Environmental Protection Agencies (EPA's) to the Trumbull Soil and Water Conservation District (SWCD) . The planning process conforms with the six steps recommended by the Ohio EPA (1997), including: building public support; creating a watershed inventory; defining the problem; setting goals and developing solutions; creating an action plan; implementing and evaluating the plan (Martin, 2002).

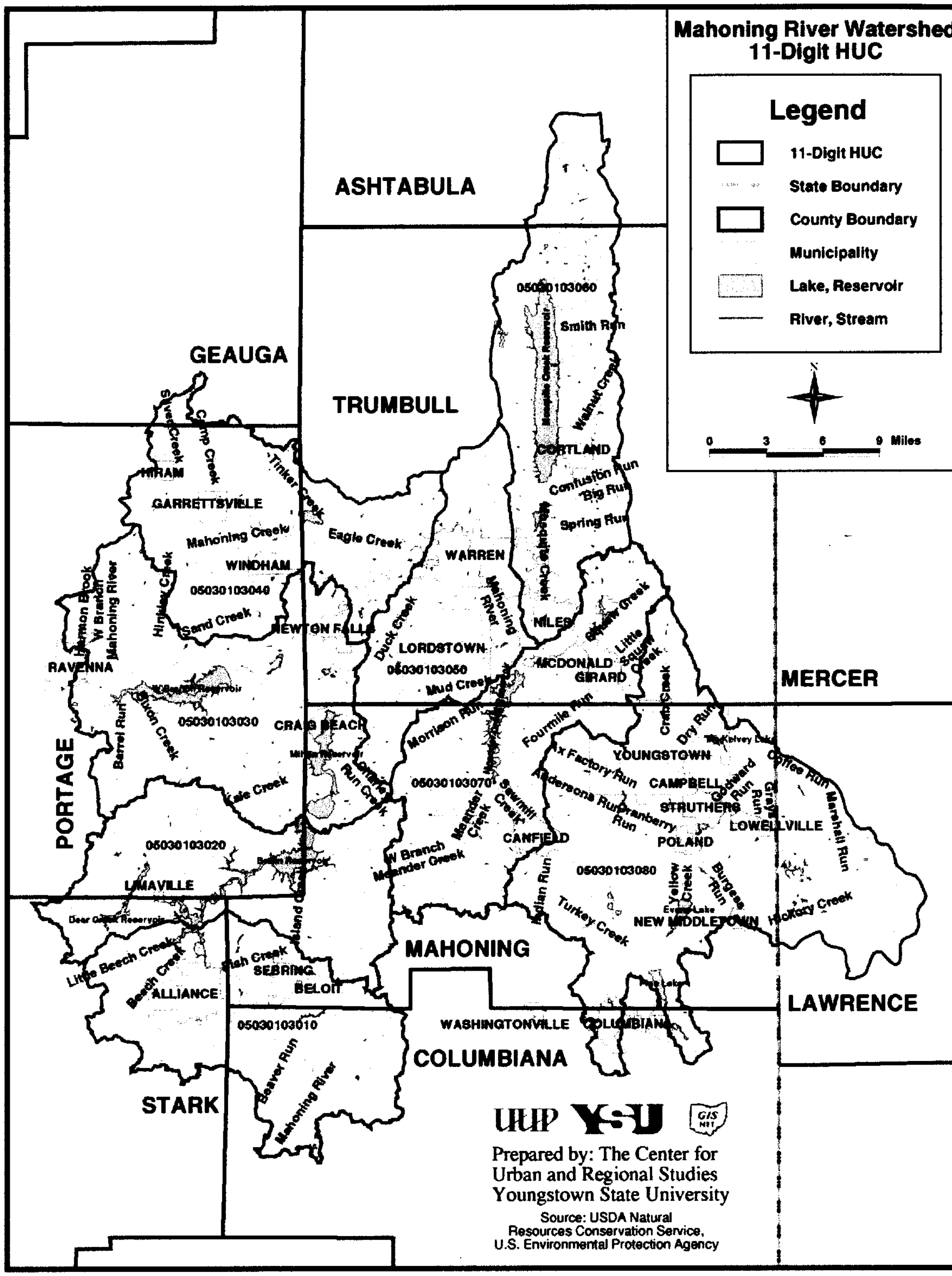

Figure 1-1. Mahoning River Watershed.

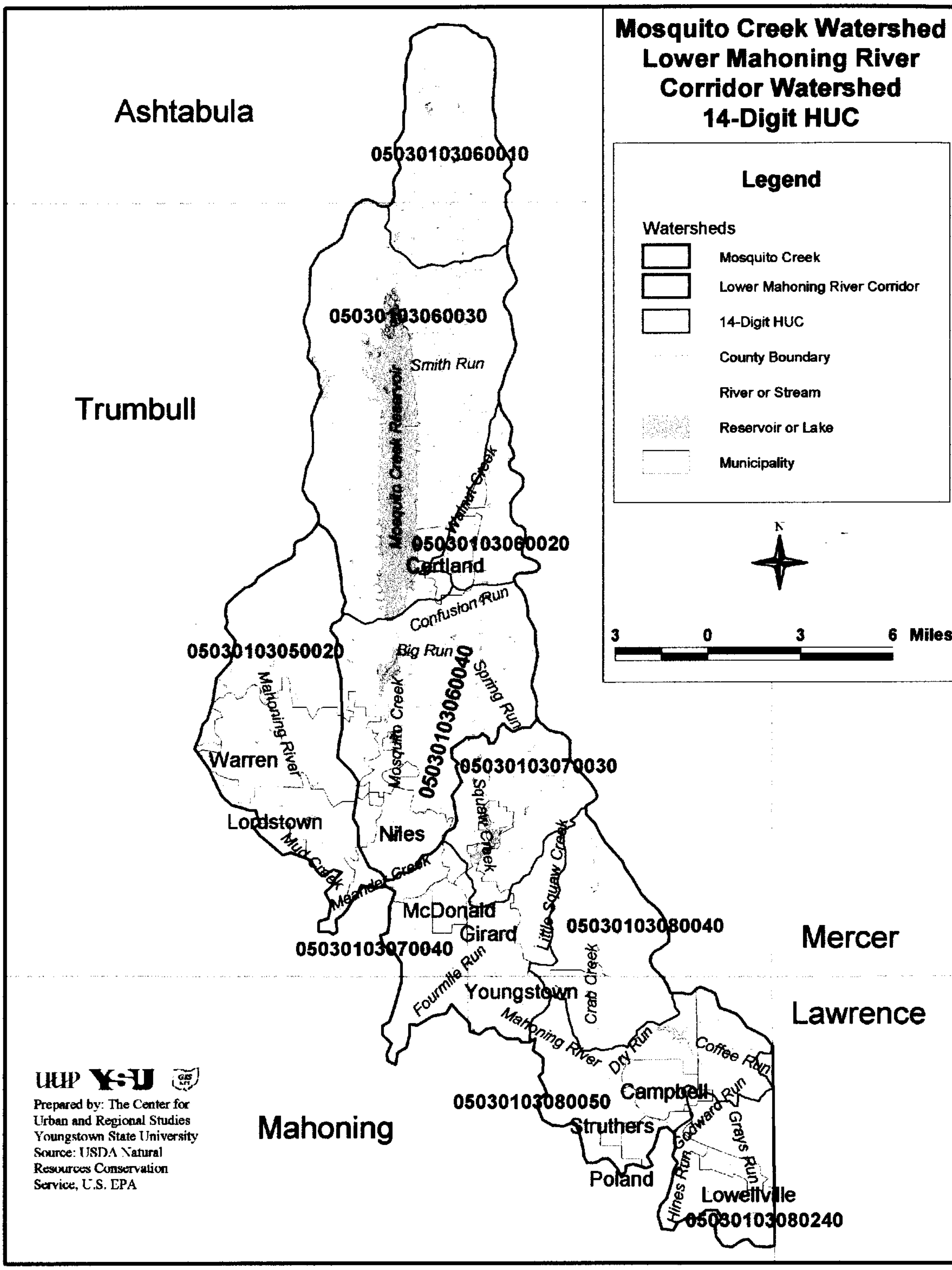

Figure 1-2. Mosquito Creek Watershed and Lower Mahoning River Corridor Watershed.

1-2 Mosquito Creek Watershed

The subject of this project is the Mosquito Creek watershed. It is approximately 89,100 acres in size and includes portions of Ashtabula and Trumbull Counties in Ohio. Major water bodies in the watershed include the Mosquito Creek, Mosquito Creek Reservoir, Spring Run, Big Run, Confusion Run, Walnut Creek, Smith Run and Mud Creek. All of the streams are designated as warmwater habitat by Ohio EPA.

Mosquito Creek Reservoir

Completed in 1944, the Mosquito Creek Reservoir has a capacity of 4.5 billion cubic feet (1.3×10^8 m^3) and covers an area of 7,850 acres (3,177 ha) (ODNR, 2004). The reservoir is approximately 9.5 miles (15.3 km) long, extending from south of State Route 87, Greene Township to the dam southwest of the City of Cortland. The width is slightly over 1 mile (1.6 km) (USACE, 1994). It has served as the municipal water supply source for the City of Warren, since 1954 (ODNR, 2004) with an average daily withdrawal of 15 MGD (or 5.7×10^4 m^3/d) as of 1989. Water recreation, hiking, camping and picnicking also attract visitors to the lake. The Ohio Division of Wildlife manages a wildlife refuge area located north of Route 88 on the west side on the reservoir. The area is a safe haven for migratory birds including red-tailed hawks, marsh and sparrow hawks, and numerous species of waterfowl. The waterfowl refuge area on the west side is closed to the public. However, observation can be made from on-site parking areas or roadways (USACE, 2004).

Sources of Pollution

The major sources of pollution entering Mosquito Creek are nonpoint sources (NPS), such as septic systems and agricultural activities in the watershed. NPS pollution comes from a wide range of sources, often so diffuse in nature that they are difficult to quantify. The majority of the homes in the Mosquito Creek Reservoir watershed use septic systems in treating and disposing of wastewater. Septic systems are designed to pre-treat the sewage before it is applied to the soil. Pre-treatment removes solids suspended in sewage and separates oil and grease from sewage. After pre-treatment, the septic effluent flows to the drainfield where it is disposed into the soil. At this point the main pollutants found in the effluent are nitrogen, phosphorus, organic matter and pathogens. The soil matrix provides biological, chemical, and physical treatment for these pollutants. However, this treatment may or may not be complete, depending on the factors such as soils, hydrology, and weather conditions of the site (NCDENR, 2004). Improper installation and maintenance contributes to system failure. System failure increases the tendency of pollutants to reach and contaminate streams in a watershed. In Trumbull County, many systems do not even have tile fields for leaching into soil.

About half the land of the Mosquito Creek watershed is in agricultural use. Agricultural NPS pollution is a leading source of water quality impacts to rivers and lakes (USEPA, 2004). Agricultural activities that cause NPS pollution include confined animal facilities, grazing, plowing, pesticide spraying, fertilizing, planting, and harvesting. Major agricultural NPS pollutants that result from these activities are sediment, nutrients, pathogens, pesticides, and salts.

1-3 Goals of Project

The goals of this project were to estimate pollutant loadings to streams within the Mosquito Creek watershed by two methods – stream monitoring and computer modeling - and to identify potential locations for pollutant loading reduction.

The monitoring involved a biweekly collection and laboratory analysis of water samples from selected streams in the Mosquito Creek watershed, for a period of 16 weeks. Pollutant loading rates based on the monitoring data were determined and compared with output from STEPL (Spreadsheet Tool for Estimating Pollutant Load), a program for estimating pollutant loading rates, available from the USEPA.

CHAPTER 2

BACKGROUND

2-1 Characteristics of the Mosquito Creek Watershed

History of the Reservoir

Plans were drawn up in the 1930's to dam Mosquito Creek under the Federal Flood Control Act to alleviate floods on the Mahoning, Beaver and Ohio Rivers. The dam was also to provide domestic water supply for the City of Warren and pollution abatement as a result of the industrial steel production along the Mahoning River. Completed in April 1944, the reservoir's capacity is 34 billion gallons (4.5×10^9 ft^3, or 1.3×10^8 m^3) of water covering 7,850 acres (3177 ha) of land (ODNR, 2004). The reservoir has a relatively uniform (roughly rectangular) shape, with a shoreline punctuated with small bays and fingers where streams enter. The reservoir is approximately 9.5 miles (15.3 km) long and slightly over one mile (1.6 km) wide. It is the second largest inland lake in Ohio. The shore on both sides is predominantly wooded except where mowed lawns are maintained by private residents. Year-round residences are located adjacent to government property around the entire watershed (USACE, 1994).

Public Land and Facilities

The lake and most of its surrounding lands are leased by the U.S. Amry Corps of Engineers (USACE) to the Ohio Department of Natural Resources (ODNR) as Mosquito Lake State Park. The State of Ohio leases all government land and water area except for about 176 acres around the dam at the southern end of the lake and along the eastern shore upstream to State Route 305. The state provides recreation facilities and manages fish and wildlife resources (Table 2-1) within the leased area and adjacent state properties (USACE, 1994).

Table 2-1. Recreational Facilities in the Mosquito Creek Watershed (ODNR)

Activity	Facility	Quantity
Resource	Land, acres	2,483
	Water, acres	4,000
	Nearby Wildlife Area, acres	5,370
Activities	Fishing	yes
	Hunting	yes
	Hiking Trail, miles	20
	Bridle Trails, miles	20
	Picnicking	yes
	Swimming Beach, feet	600
Boating	Boat Rental	yes
	Boating Limits	UNL
	Fuel For Sale	yes
	Seasonal Dock Rental	250
	Launch Ramps	5
Winter	Snowmobiling	yes
	Ice Skating	yes
	Cross-Country Skiing	yes
	Ice Fishing	yes
	Ice Boating	yes
Camping	Non-Electric Campsites	16
	Campsites with Elec.	218
	Pets Permitted	yes
	Showers	yes
	Dump station	yes

Land Cover and Land Use

Land cover and land use data obtained in the form of geographic information system (GIS) files from the ODNR and the U.S Geological Services (USGS) are presented in Tables 2-2 and 2-3, respectively. Although there some discrepancies between these databases, ranges in land use/land cover can be estimated.

Table 2-2. Land Cover, Mosquito Creek Watershed (Source: ODNR, 1994)

Land Cover Classification	Acreage	% of Watershed
Agriculture/Open Urban	33,616	37.74
Barren	26	0.03
Nonforested Wetland	4,127	4.63
open water	7,032	7.89
Scrub/shrub	4,087	4.59
Urban Land	2,828	3.17
Wooded Land	37,365	41.94
Total	**89,081**	**100**

Table 2-3. Land Use, Mosquito Creek Watershed (Source: USGS, 1998)

Land Use Classification	Acreage	%
Commercial & Services	995	1.12
Cropland & Pasture	49,422	55.48
Deciduous Forest Land	9,628	10.81
Evergreen Forest Land	539	0.61
Forested Wetland	7,373	8.28
Industrial	102	0.11
Lakes	21	0.02
Mixed Forest Land	909	1.02
Mixed Urban or Built-up	1,081	1.21
Other Urban or built-up	1,085	1.22
Reservoirs	7,545	8.47
Residential	7,417	8.33
Transitional Area	365	0.41
Transp., Comm., Utilities	2,598	2.92
Total	**89,080**	**100**

Urban land makes up to about 2–4 % of the Mosquito Creek watershed. Most of this lies at the southern tip of the watershed in the Cities of Warren and Niles, and Howland Township. The City of Cortland, which lies just east of the southern end of Mosquito Creek Reservoir is another significant urban area. These urban areas are mostly served by sanitary sewers. The remainder of the watershed is unsewered and is served by home sewage treatment systems.

The Mosquito Creek watershed is used extensively for agriculture. Cropland and pasture constitute about 40-50 % of the watershed. Primary crops grown in the area include corn, soybeans, grains and hay. Livestock, consisting mostly of dairy cattle with some beef cattle, sheep and horses are also raised in the watershed.

Forestlands are found along the Mosquito Creek corridor above the reservoir and in the Mosquito Creek Wildlife Area. In addition, many areas with hydric soils that are too wet to farm are covered with forest. A recent study on the Meander Creek watershed indicates that the ODNR land cover database overestimates forestland and underestimates shrub land and urban land (Christou, 2003). Nevertheless, forestlands constitute a substantial portion of the watershed (about 18-35 %) including woods, wetlands and scrub/shrub land.

Population and Septic Systems

About 53,982 people inhabit the Mosquito Creek watershed from the headwaters in Ashtabula County to the portions below the dam down to the Mahoning River. About 28% (14,999) live in the watershed of the Mosquito Creek Reservoir, extending from the headwaters to the dam. According to the 1990 census, there were 5,078 housing units in this area; 49% had access to public sewer, whereas 50% used septic systems. A summary of the distribution of population, housing, and wastewater facilities within the watershed is presented in Table 2-4

Table 2-4. Population and Septic System Use by 14-Digit HUC in Mosquito Creek Watershed (U.S Bureau of Census 1990 and 2000)

14 Digit HUC	Watershed Name	Population, 2000	Housing Units, 1990	Public Sewer, 1990	%	Septic Treatment, 1990	%	Other Methods	%
5030103060010	Mosquito Creek headwaters	1504	504	76	15.1	422	83.7	6	1.2
5030103060020	Walnut Creek	5236	1772	1434	80.9	331	18.7	7	0.4
5030103060030	Mosquito Creek below headwaters to Mosquito Cr. Lake Dam[Except Walnut Cr.]	8259	2802	973	34.7	1801	64.3	28	1.0
5030103060040	Mosquito Creek below Mosquito Creek Lake Dam to Mahoning R.	38983	15789	13886	87.9	1864	11.8	39	0.3
Total For Mosquito Creek Watershed:		**53982**	**20867**	**16369**	**78.4**	**4418**	**21.2**	**80**	**0.4**
Total for Focus Area:		**14999**	**5078**	**2483**	**48.9**	**2554**	**50.3**	**41**	**0.8**

Flow and Weather Data

Precipitation and snowfall events are monitored and data recorded at a National Weather Service (NWS) station near the Mosquito Creek Dam, OH (Station Number 335505). Mean monthly precipitation and snowfall for the period of 1971 – 2000 are given in Table 2-5. Precipitation is fairly well distributed throughout the seasons. Snowmelt can occur throughout the winter, causing winter and early spring flood runoff.

Table 2-5. Mean Monthly Precipitation, and Snowfall Measured at the Mosquito Creek Dam, OH National Weather Station, 1971 – 2000.

Month	Mean Precipitation (inches)	Mean Snowfall (inches)
January	2.07	11.4
February	1.79	8.6
March	2.68	7.2
April	3.21	1.4
May	3.39	0.0
June	3.72	0.0
July	4.10	0.0
August	3.33	0.0
September	4.08	0.0
October	2.76	0.1
November	3.09	3.6
December	2.66	8.9
Total	**36.88**	**41.2**

During extended cold spells in the winter, the top layer of the lake becomes frozen. An ice cover, sometimes 10 inches thick, blankets the lake, providing an opportunity for ice fishing on the lake.

A USGS gaging station, (No. 03095500) is maintained on Mosquito Creek below Mosquito Creek Dam near Cortland, OH (Latitude 41° 17’59” N; Longitude 80 ° 45’31”

W; elevation 873.98 feet). Annual mean streamflow for the period 1927 – 1990, presented in Table 2-6, is 87.3 cfs.

Table 2-6. Annual Mean Streamflow at USGS Gaging Station (No. 05030103) on Mosquito Creek below Mosquito Creek Dam near Cortland, OH, 1927 – 1990.

Year	Annual Mean Streamflow (ft^3/s)	Year	Annual Mean Streamflow (ft^3/s)	Year	Annual Mean Streamflow (ft^3/s)	Year	Annual Mean Streamflow (ft^3/s)
1927	109	1955	116	1967	71.0	1979	142
1928	120	1956	139	1968	63.1	1980	67.5
1944	41.8	1957	76.9	1969	93.9	1981	102
1945	40.4	1958	66.2	1970	49.4	1982	95.1
1946	94.8	1959	121	1971	62.8	1983	86.7
1947	164	1960	84.9	1972	75.5	1984	129
1948	74.1	1961	67.9	1973	90.1	1985	90.4
1949	88.6	1962	37.3	1974	132	1986	98.2
1950	129	1963	37.1	1975	92.6	1987	82.4
1951	136	1964	38.8	1976	71.6	1988	32.2
1952	125	1965	78.8	1977	80.7	1989	115
1953	80.0	1966	38.8	1978	65.1	1990	126
1954	56.3						

Mean Streamflow for the period of records = 87.3 ft^3/s

2-2 Nonpoint Sources of Pollution

Nonpoint source (NPS) pollution comes from a wide range of sources, unlike point source pollution, which originates from industrial and sewage treatment plants. NPS pollution occurs when water runs over land or through the ground, picks up pollutants, and deposits them in surface waters or introduces them into ground water. Runoff and leachate from agricultural fields, feedlots and faulty septic systems, roads, lawns, golf courses, etc., are common nonpoint sources of pollutants such as pathogens, sediment, nitrogen phosphorus, salt, oil and grease. A summary of sources and types of NPS pollution is given in Table 2-7.

Table 2-7. Pollutants and Their Nonpoint Sources.

Pollutants	Nonpoint Sources
Sediment	Construction sites Crop and forest lands Eroding stream banks Mining operations
Oil, grease Toxic Chemicals	Urban runoff Oil/gas wells
Fertilizers Herbicides Insecticides	Agricultural lands Residential areas Golfcourses
Salts Acids	Irrigation fields Road runoff Abandoned mines
Bacteria Nutrients	Livestock waste, Pet waste Faulty septic systems Wildlife

2-3 Phosphorus Models

The phosphorus models used in this study include the Dillon and Rigler (1975) model, and the Vollenweider (1975) loading graph.

Dillon and Rigler Model

The Dillon and Rigler (1975) model predicts total phosphorus concentration in a reservoir (or lake) based on reservoir characteristics and loadings from the watershed. The mean total phosphorus concentration is estimated using equation 2-1.

$$[TP] = \frac{L(1-R)}{q_s} \tag{2-1}$$

Where:

$[TP]$ = mean total phosphorus concentration, g/m^3

L = areal TP loading rate, $g/m^2/yr$

q_s = areal water loading rate, m/yr

R = phosphorus retention coefficient

$$R = 0.426 \exp(-0.271 q_s) + 0.574 \exp(-0.00949 q_s) \tag{2-2}$$

Vollenweider Model

The Vollenweider (1975) developed a graph (Figure 2-1) to predict trophic condition of a lake by plotting areal total phosphorus loading rate versus the ratio of the depth to hydraulic retention time. The graph is divided into three regions – eutrophic (high productivity); mesotrophic (moderate productivity); and oligotrophic (low productivity)

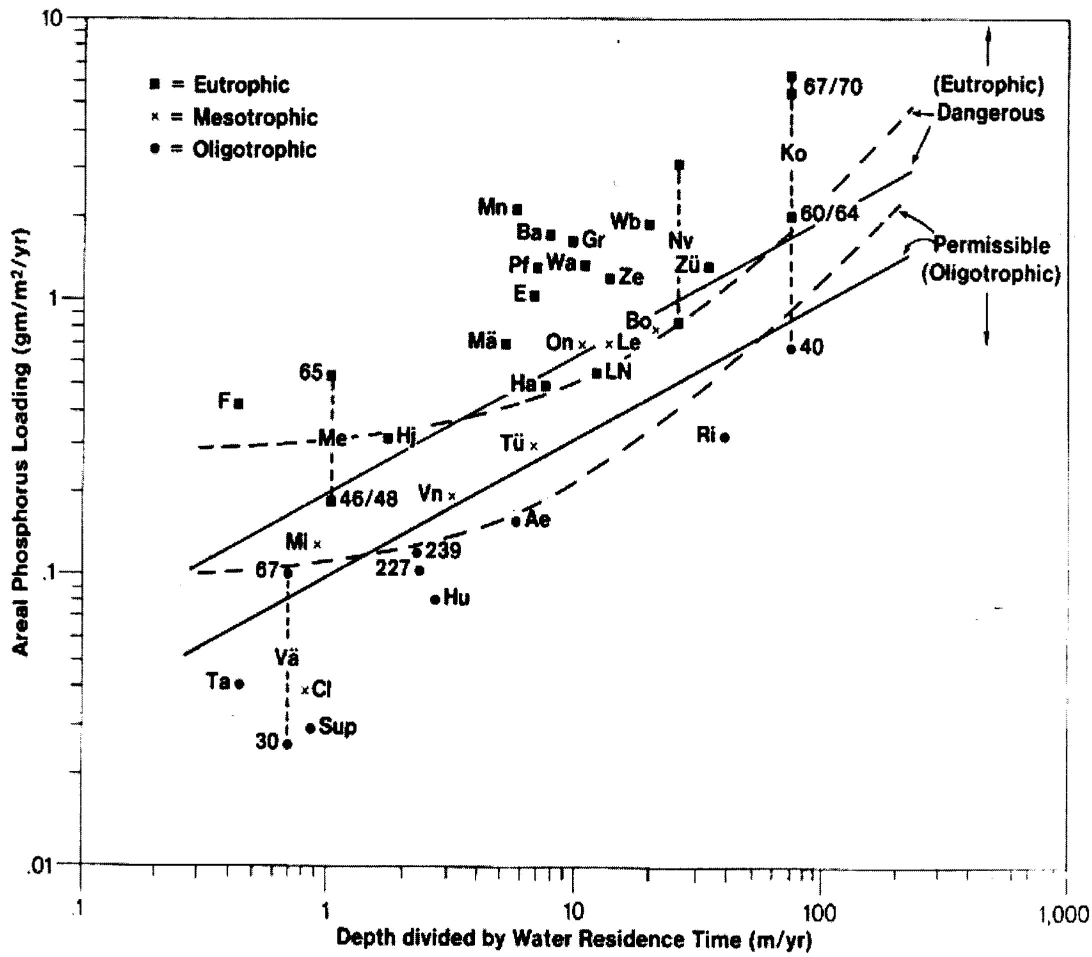

Figure 2-1. Vollenweider (1975) Graph for Prediction of Trophic Condition of Lakes.

2-4 STEPL Model

STEPL is a customized Microsoft Excel spreadsheet model that calculates nutrient and sediment loads from different land uses and the load reduction that would result from the implementation of various best management practices (BMPs). The model computes watershed surface runoff, nutrient loads, including nitrogen, phosphorus and 5-day biological oxygen demand (BOD_5), and sediment delivery based on various land uses and management practices (USEPA, 2003).

STEPL determines runoff by the curve number method (all land uses except urban area). The annual sediment load is calculated from the Universal Soil Loss Equation (USLE) and an assumed delivery ratio by Equations 2-3 and 2-4.

$$A_e = R\,K\,LS\,C\,P \tag{2-3}$$

$$M_S = A_e\,DR \tag{2-4}$$

Where:

A_e = average annual soil loss due to sheet or rill erosion, t/acre

R = rainfall erosivity factor

K = soil erodibility factor

LS = slope length and steepness factor

C = cover and management factor

P = support practice factor

DR = delivery ratio

M_s = sediment, t/yr

The annual nutrient loading is calculated as the product of runoff volume and the pollutant concentration in the runoff water, and is influenced by factors such as the land use distribution and management practices. The loading of sediment-bound pollutants is also included (Nandi, 2003). The relations are expressed as:

Load from urban source = Export coefficient x Source area

Dissolved Load (from other land uses) = Dissolved concentration x Runoff volume

Particulate Load (from other land uses) = Soil concentration x Sediment volume

The sediment and pollutant load reductions that result from the implementation of BMPs are computed using assumed or user defined BMP efficiencies. The pollutant loads after BMP applications are computed by the relationships:

$$\text{Load reduction} = \text{Load before BMP} \times \text{BMP efficiency}$$

$$\text{Load after BMP} = \text{Load before BMP} - \text{Load reduction}$$

CHAPTER 3

METHODS AND PROCEDURES

3-1 Water Sampling and Field Procedures

Twelve monitoring stations were established within the Mosquito Creek watershed. The sites with their locations are shown in Figure 3-1 and listed in Table 3-1. Sites # 1 to 7 were visited throughout the study (8 times in 16 weeks), from January 2004 to May 2004. The remaining sites were sampled one to three times each. Each visit involved collecting water samples; measuring velocity of flow with a Global Water velocity meter; and estimating the average depth and width of flow. 500 mL samples were collected with a plastic scoop and poured into an acid-washed plastic bottle. The samples were transported back to the laboratory and analyses carried out to measure various water quality parameters, including pH, turbidity, suspended solids, nitrate, phosphorus and ammonia. Samples were stored in a refrigerator prior to analysis. Analyses were completed within 3 days after sampling.

Table 3-1. Summary of Sampling Stations.

Site #	Site Name	Location
1	Mosquito Creek	Warren - Sharon Rd., Howland
2	Big Run	McCleary – Jacoby Rd.
3	Confusion Run	McCleary – Jacoby Rd.
4	Walnut Creek	SR 46, Cortland
5	Mosquito Creek Reservoir	Causeway on SR 88
6	Mosquito Creek	York Street, Greene Twp.
7	Unnamed Tributary	Hoagland - Blackstub Rd.
8	Runoff into Unnamed Trib.	Hoagland - Blackstub Rd.
9	Spring Run	SR 46, North of River Road, Howland
10	North Branch, Smith Run	SR 46, North of Mahan Denman Road
11	Unnamed Tributary	SR 46, South of Wakefield Creek Road
12	South Branch, Mud Creek	SR 46, South of Davis-Peck Road

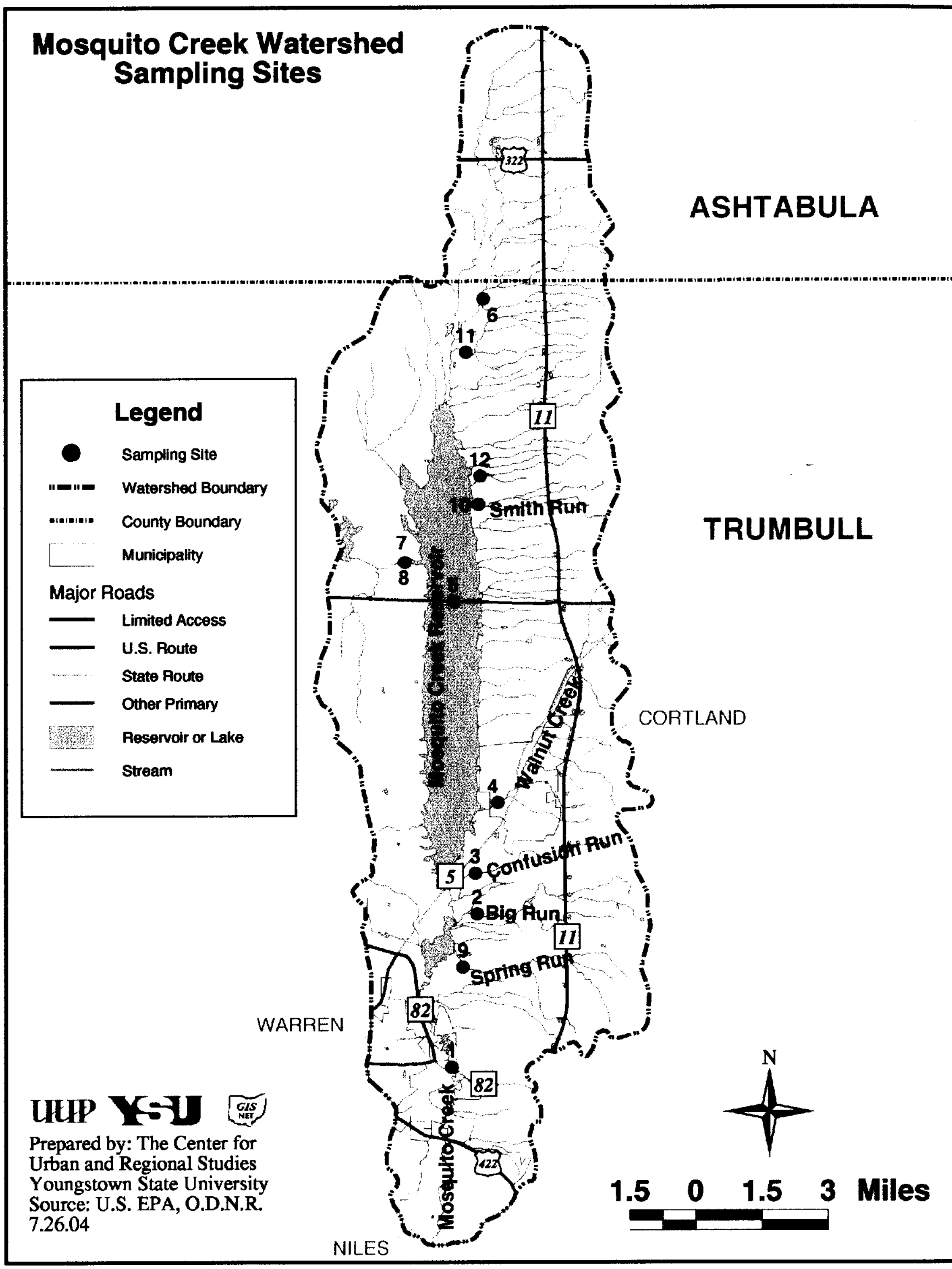

Figure 3-1. Monitoring Stations in the Mosquito Creek Watershed.

3-2 Laboratory Methods

A 250 mL portion was taken from each sample and filtered through a Fisher G4 glass fiber filter membrane (approx. pore size of 1.0 μm). The filtrate was stored and portions used for nitrate, ammonia and soluble reactive phosphorus tests. The filter and residue were dried at 103 °C in an oven for 1 hour and then reweighed to determine suspended solids concentration. Ammonia was determined by the phenate method, nitrate by the cadmium reduction method, and soluble reactive phosphorus by the ascorbic acid method (APHA, 1998).

50–100 mL of the unfiltered portion was used in the pH and turbidity measurements. The pH was measured using a Fisher Accumet Portable AP 61 pH meter and the turbidity determined using a Hach Ratio turbidimeter.

A 50 mL portion of the remaining unfiltered sample was used for total phosphorus determination. The persulfate digestion (APHA, 1998) was used to convert particulate phosphorus to soluble reactive form.

3-3 Pollutant Loading Calculations

Flow

The flow of each stream was calculated using the equation below and assuming a rectangular stream channel at the sampling station.

$$Q_s = V_s w z \tag{3-1}$$

Where:

Q_s = stream flow at sampling station, ft^3/s

V_s = average velocity at sampling station, ft/s

w = average stream width, ft

z = average stream depth, ft

Pollutant Loading Rates

The pollutant loading rate, W, in lb/d was calculated using the equation:

$$W = 5.39[P]Q_s \tag{3-2}$$

Where:

W = pollutant loading rate, lb/d

[P] = pollutant concentration, mg/L

Loading rates were also calculated in kg/d by applying the conversion, 1 lb = 0.4536 kg, and on a yearly basis by multiplying by 365.

Drainage Area

The drainage area for selected sampling stations, shown in Table 3-2, was estimated from USGS 7.5 minute series topographic maps using a Tamaya Planix 7 digital planimeter.

Table 3-2. Drainage Areas for Sampling Stations and 14-Digit HUC

Site # or 14-Digit HUC	Area	Area
	Acres	ha
2	3047.0	1234.0
3	1884.6	763.3
4	6654.7	2695.2
6	10801.6	4374.6
7	3417.5	1384.1
9	3334.7	1350.5
10	559.2	226.5
12	671.7	272.1
5030103060010	16670.0	6751.3
5030103060020	6190.8	2507.3
5030103060030	39455.9	15979.6

Mean Areal Pollutant Loading Rates

Mean areal pollutant loading rates were calculated for these sites using the equation:

$$L_a = \frac{W_m}{A} \tag{3-3}$$

L_a = mean areal pollutant loading, lb/acre/yr or kg/ha/yr

W_m = mean pollutant loading rate at sampling station, lb/yr or kg/yr

A = drainage area for sampling station, acre or ha

Watershed Area-Weighted Average Loading Rates

Watershed area-weighted average loading rate, $L_{a,MR}$, in lb/acre/yr and kg/ha/yr was calculated from Equation 3-4 using data from Sites # 4, 6 and 7. These sites are on tributaries flowing into the Mosquito Creek Reservoir, with data from eight sampling dates. Sites south of the reservoir as well as those with three or less sampling visits were not included.

$$L_{a,MR} = \frac{\sum L_{a,i} A_i}{\sum A_i} \tag{3-4}$$

This value was assumed to be representative of the entire Mosquito Creek Reservoir watershed.

Estimation of Total Pollutant Loads to the Mosquito Creek Reservoir

Estimates of mean annual pollutant loadings rates to Mosquito Creek Reservoir, based on monitoring data, were calculated from:

$$W_{MR} = L_{a,MR} A_{tot} \tag{3-5}$$

Where:

W_{MR} = total pollutant load, lb/yr or kg/yr

A_{tot} = total watershed area above Mosquito Lake dam, excluding the reservoir, acre or ha

3.4 Phosphorus Modeling

Two simple total phosphorus (TP) models were applied to Mosquito Creek Reservoir to evaluate the accuracy of TP loading estimates. The data and calculations required are described below.

Outflow

Combining data obtained from a USGS gaging station on Mosquito Creek (Table 2-6) and records of mean withdrawal from the City of Warren Water Treatment Plant (WTP) provides the total outflow from the reservoir. The mean flow at the USGS gaging station is 87.3 cfs and the average withdrawal by the Warren WTP is about 23.2 cfs. The combined total outflow from the reservoir is 110.5 cfs.

Hydraulic Residence Time

The Hydraulic residence time, t_R was obtained from the ratio of the volume to the total outflow:

$$t_R = \frac{V}{Q_{out}} \tag{3-6}$$

Where:

t_R = hydraulic residence time, yr

V = volume of reservoir, ft^3 or m^3

Q_{out} = mean outflow, ft^3/yr or m^3/yr

Reservoir Flushing Rate

The flushing rate, ρ of the reservoir (in yr^{-1}) is calculated as the inverse of the hydraulic residence time:

$$\rho = \frac{1}{t_R} \tag{3-7}$$

Areal Water Loading Rate

The areal water (or hydraulic) loading rate was calculated as:

$$q_s = \frac{Q_{out}}{A} = \frac{z}{t_R} \tag{3-8}$$

Where:

q_s = areal water loading rate, ft/yr or m/yr

A = reservoir surface area, ft^2 or m^2

z = mean depth of reservoir, ft or m

Areal TP Loading Rate

The areal TP loading rate was calculated using:

$$L_{a,TP} = \frac{W_{TP}}{A} \tag{3-9}$$

Where:

$L_{a,TP}$ = areal TP loading rate, lb/acre/yr or kg/ha/yr

W_{TP} = annual TP loading rate, lb/yr or kg/yr

A summary of Mosquito Creek Reservoir characteristics obtained from these calculations is presented in Table 3-3

Table 3-3. Mosquito Creek Reservoir Characteristics

Parameter	Original or U.S. Units	SI Units
Volume	3.24×10^{9} ft^3	9.17×10^{7} m^3
Surface Area	7850 acres	3.18×10^{7} m^2
Mean Depth	9.45 ft	2.88 m
Outflow, Q_{out}	3.49×10^{9} ft^3/yr	9.87×10^{7} m^3/yr
Hydraulic Residence Time, t_R	0.93 yr	0.93 yr
Areal Water Loading Rate, q_s	10.2 ft/yr	3.1 m/yr

TP Concentration and Trophic Condition

The Dillon and Rigler (1975) model (Equations 2-1 and 2-2) was used to estimate the total phosphorus concentration in the reservoir and the Vollenweider (1975) model was applied to determine trophic condition.

3-5. Evaluation of Sediment Loading Rate

To evaluate the suspended solids loading estimates from monitoring data and STEPL, a comparison was made to the sediment accumulation rate of 4.53×10^5 m^3/yr reported by the U.S. Army Corps of Engineers (1994). The following relationship was used to convert sediment volume to sediment mass:

$$M_s = V_T \rho (1 - \phi) \tag{3-10}$$

Where:

M_s = mass loading rate, kg/yr

V_T = sediment accumulation rate, m^3/yr

ρ = density of solids, kg/m^3

ϕ = porosity

3-6. STEPL Application

STEPL utilizes input data on land use area, animal counts, septic system numbers and failure rates, precipitation and soil characteristics, including universal soil loss equation (USLE) parameters for soil erosion estimation, soil hydrologic group for runoff estimation and soil nitrogen, phosphorus and BOD concentrations for load calculations.

Data Sources

STEPL maintains default data from various sources, including rainfall by county and rainfall correction factors by stations; USLE values by county, etc. A STEPL online input data server is also available and can be used to obtain preliminary values for STEPL input parameters, including land use area, agricultural animal distribution, population and septic system information, and soil hydrological group, all by 7-digit HUCs. Local data can replace the preliminary or default data if available. Sources of input data used in this study are presented in Table 3-4.

Table 3-4. Sources of Data for STEPL Input

Parameter	Source
Watershed Land Use Areas	GIS Database files for: USGS Land Use, and ODNR Land Cover
Annual Rainfall	NWS
Septic Systems Population	U.S. Bureau of Census
System Failure Rate	Crist et al.
Agricultural Animals	Ohio Department of Agriculture
Feedlot Feedlot Percent Rain Days Rain Correction Factors USLE Parameters Runoff Curve Numbers Nutrient Concentration in Runoff Urban Land Use Distribution	STEPL Default for Trumbull County

CHAPTER 4

RESULTS AND DISCUSSION

4-1 Summary of Monitoring Data

Summaries of the monitoring data for Sites # 1 through 12 are presented in Tables 4-1 through 4-12. A complete listing of all monitoring data is included in the Appendix.

Table 4-1. Summary of Monitoring Data for Site # 1 - Mosquito Creek at Warren-Sharon Rd.

Parameter	Units	N*	Range	Mean	Std. Dev.
SRP	μg/L	8	1 - 105	33.4	34.5
TP	μg/L	8	60 - 123	84.1	28.8
NO_3^- - N	μg/L	8	55 - 663	371.7	179.2
NH_3 - N	μg/L	8	91 - 220	156.5	44.8
TURB	NTU	4	7 - 21	11.8	6.3
SS	mg/L	8	3 - 26	9.7	7.2
pH		4	7.1 - 7.4	7.3	0.1

* N = number of times parameter was measured.

Table 4-2. Summary of Monitoring Data for Site # 2 - Big Run at McCleary-Jacoby Rd.

Parameter	Units	N	Range	Mean	Std. Dev.
SRP	μg/L	8	2 - 54	17.1	18.7
TP	μg/L	7	25 - 77	49.2	20.5
NO_3^- - N	μg/L	8	24 - 714	228.3	247.1
NH_3 – N	μg/L	8	5 - 537	120.3	186.3
TURB	NTU	4	4 - 15	9.0	5.5
SS	mg/L	8	2 - 26	8.0	7.8
pH		4	7.5 - 8	7.7	0.2
Flow	cfs	6	3 - 37	16.8	17.9

Table 4-3. Summary of Monitoring Data for Site #3 - Confusion Run at McCleary-Jacoby Rd.

Parameter	Units	N	Range	Mean	Std. Dev.
SRP	µg/L	8	7 - 30	17.5	7.8
TP	µg/L	8	24 - 90	49.3	24.3
NO_3^- - N	µg/L	8	49 - 985	461.4	343.4
NH_3 – N	µg/L	8	5 - 425	114.4	164.3
TURB	NTU	4	3 - 26	13.3	11.5
SS	mg/L	8	3 - 14	7.4	4.0
pH		4	7.4 - 8.5	7.9	0.5
Flow	cfs	6	3 - 15	7.2	5.9

Table 4-4. Summary of Monitoring Data for Site #4 - Walnut Creek at SR 46.

Parameter	Units	N	Range	Mean	Std. Dev.
SRP	µg/L	8	0 - 28	16.9	9.0
TP	µg/L	8	19 - 112	55.3	34.8
NO_3^- - N	µg/L	8	147 - 1274	542.2	376.3
NH_3 - N	µg/L	8	4 - 333	103.8	136.3
TURB	NTU	4	6 - 38	20.7	14.5
SS	mg/L	8	2 - 28	10.3	9.0
pH		4	7.6 - 8.5	8.0	0.4
Flow	cfs	8	8 - 74	30.0	26.6

Table 4-5. Summary of Monitoring Data for Site #5 - Mosquito Creek Reservoir at SR 88.

Parameter	Units	N	Range	Mean	Std. Dev.
SRP	µg/L	8	0 - 3	2.1	1.8
TP	µg/L	8	20 - 66	55.2	20.5
NO_3^- - N	µg/L	8	50 - 455	305.5	151.6
NH_3 – N	µg/L	8	4 - 38	17.5	12.6
TURB	NTU	4	8 - 15	11.8	2.8
SS	mg/L	8	8 - 18	12.9	3.5
pH		4	7.4 - 8	7.7	0.2

Table 4-6. Summary of Monitoring Data for Site #6 - Mosquito Creek at York Street, Greene Twp.

Parameter	Units	N	Range	Mean	Std. Dev.
SRP	µg/L	8	5 - 72	28.2	20.1
TP	µg/L	7	27 - 263	105.6	92.4
NO_3^- - N	µg/L	8	216 - 891	607.0	271.7
NH_3 – N	µg/L	8	12 - 128	65.1	53.1
TURB	NTU	4	11 - 119	55.5	52.1
SS	mg/L	8	0 - 110	26.6	37.6
pH		4	7.3 - 8.5	7.7	0.5
Flow	cfs	6	16 - 211	65.6	77.0

Table 4-7. Summary of Monitoring Data for Site #7 - Unnamed Tributary at Hoagland-Blackstub Rd.

Parameter	Units	N	Range	Mean	Std. Dev.
SRP	µg/L	8	22 - 94	58.1	26.5
TP	µg/L	7	87 - 170	132.3	33.7
NO_3^- - N	µg/L	8	78 - 1182	342.1	400.2
NH_3 – N	µg/L	8	31 - 669	243.7	288.3
TURB	NTU	4	19 - 58	31.8	18.0
SS	mg/L	8	6 - 54	16.3	15.9
pH		4	7 - 8.5	7.5	0.7
Flow	cfs	6	3 - 47	16.0	16.8

Table 4-8. Summary of Monitoring Data for Site #8 - Runoff into Unnamed Tributary at Hoagland-Blackstub Rd.

Parameter	Units	N	Mean
SRP	µg/L	1	72.1
TP	µg/L	1	579.3
NO_3^- - N	µg/L	1	187.4
NH_3 - N	µg/L	1	320.6
TURB	NTU	1	412.0
SS	mg/L	1	358.0

pH		1	7.2

Table 4-9. Summary of Monitoring Data for Site #9 - Spring Run.

Parameter	Units	N	Range	Mean
SRP	µg/L	2	3 - 7	5.2
TP	µg/L	2	16 - 52	34.4
NO_3^- - N	µg/L	2	78 - 117	97.7
NH_3 – N	µg/L	2	7 - 32	19.5
TURB	NTU	2	2 - 14	8.4
SS	mg/L	2	2 - 10	6.0
pH		2	7 - 9	8.0
Flow	cfs	2	5 - 18	11.5

Table 4-10. Summary of Monitoring Data for Site #10 - North Branch, Smith Run.

Parameter	Units	N	Range	Mean	Std. Dev.
SRP	µg/L	3	41 - 88	63.9	23.2
TP	µg/L	3	89 - 172	130.7	41.3
NO_3^- - N	µg/L	3	870 - 1046	948.3	89.3
NH_3 – N	µg/L	3	21 - 51	35.2	14.8
TURB	NTU	3	4 - 24	11.4	10.9
SS	mg/L	3	5 - 148	54.1	80.6
pH		3	7.8 - 8.3	8.1	0.2
Flow	cfs	3	0 - 5	1.9	2.0

Table 4-11. Summary of Monitoring Data for Site #11 - Unnamed Tributary at SR 46, South of Wakefield Creek Road.

Parameter	Units	N	Range	Mean
SRP	µg/L	2	16 - 22	19.0
TP	µg/L	2	54 -63	58.8
NO_3^- - N	µg/L	2	738 - 739	763.7
NH_3 – N	µg/L	2	20 - 28	23.6
TURB	NTU	2	9 - 10	9.3
SS	mg/L	2	4 - 6	5.2
pH		2	7.5 - 7.7	7.6
Flow	cfs	2	3 - 7	4.8

Table 4-12. Summary of Monitoring Data for Site #12 - South Branch, Mud Creek.

Parameter	Units	N	Mean
SRP	μg/L	1	6.5
TP	μg/L	1	22.8
NO_3^- - N	μg/L	1	836.7
NH_3 - N	μg/L	1	24.2
TURB	NTU	1	4.4
SS	mg/L	1	3.2
pH		1	8.6
Flow	cfs	1	1.3

The following trends in pollutant concentrations were observed in selected streams that were visited three or more times:

TP: Unnamed tributary > Smith Run > Upper Mosquito Creek > Lower Mosquito Creek > Walnut Creek > Confusion Run > Big Run

NO_3^- - N: Smith Run > Upper Mosquito Creek > Walnut Creek > Confusion Run > Unnamed tributary > Lower Mosquito Creek > Big Run

NH_3 – N: Lower Mosquito Creek > Big Run > Confusion Run > Walnut Creek > Upper Mosquito Creek > Smith Run > Unnamed tributary

SS: Smith Run > Upper Mosquito Creek > Unnamed tributary > Walnut Creek > Lower Mosquito Creek > Big Run > Confusion Run

Smith Run, the Unnamed tributary (Site #7), and Upper Mosquito Creek apparently receive high loadings of NPS pollution, whereas Lower Mosquito Creek, Big Run, Confusion Run and Walnut Creek receive moderate loadings.

4-2 Loading Calculations from Monitoring Data

Mean Loading Rate

The mean loading rates (W, in lb/d) presented in Table 4-13 were obtained by using Equation 3-2. Table 4-14 gives the mean loading rates in kg/d, obtained by multiplying the rates in lb/d by a conversion factor of 0.4536 kg/lb.

Table 4-13. Mean Loading Rates at Sampling Stations, in lb/d.

Site #	SRP	TP	NO_3^- - N	NH_3 - N	SS
	lb/d	lb/d	lb/d	lb/d	lb/d
2	0.73	6.48	9.94	1.43	900
3	0.75	2.65	13.10	1.34	380
4	3.20	12.61	62.10	5.80	2660
6	18.47	71.72	225.49	38.87	26300
7	3.64	12.70	17.66	6.31	2960
9	0.37	2.76	5.40	1.63	480
10	0.84	1.63	9.48	0.29	260
11	0.49	1.50	19.60	0.60	140
12	0.04	0.15	6.00	0.18	20

Table 4-14. Mean Loading Rates at Sampling Stations, in kg/d.

Site #	SRP	TP	NO_3^- - N	NH_3 - N	SS
	kg/d	kg/d	kg/d	kg/d	kg/d
2	0.33	2.94	4.51	0.65	408.2
3	0.34	1.20	5.94	0.61	172.4
4	1.45	5.72	28.17	2.63	1206.6
6	8.38	32.53	102.28	17.63	11930.0
7	1.65	5.76	8.01	2.86	1342.7
9	0.17	1.25	2.45	0.74	217.7
10	0.38	0.74	4.30	0.13	117.9
11	0.22	0.68	8.89	0.27	63.5
12	0.02	0.07	2.72	0.08	9.1

As expected, upper Mosquito Creek (site #6) had the highest loading rate of all pollutants due to both elevated concentrations and the large drainage area.

Mean Areal Loading Rates

The mean areal loading rates, L_a in lb/acre/yr and kg/ha/yr, presented in Tables 4-15 and 4-16, respectively, were obtained using Equation 3-3.

Table 4-15. Areal Pollutant Loading Rates, W_m, in lb/acre/yr.

Site #	SRP	TP	NO3- - N	NH3 - N	SS
	lb/acre/yr	lb/acre/yr	lb/acre/yr	lb/acre/yr	lb/acre/yr
2	0.09	0.78	1.19	0.17	107.81
3	0.15	0.51	2.54	0.26	73.60
4	0.18	0.69	3.41	0.32	145.90
6	0.62	2.42	7.62	1.31	888.71
7	0.39	1.36	1.89	0.67	316.14
9	0.04	0.30	0.59	0.18	52.54
10	0.55	1.06	6.19	0.19	169.70
12	0.02	0.08	3.26	0.10	10.87

Table 4-16. Areal Pollutant Loading Rates, W_m, in kg/ha/yr.

Site #	SRP	TP	NO_3^- - N	NH_3 - N	SS
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
2	0.10	0.87	1.33	0.19	133.10
3	0.16	0.57	2.84	0.29	90.86
4	0.20	0.77	3.82	0.36	180.12
6	0.70	2.71	8.53	1.47	1097.18
7	0.44	1.52	2.11	0.75	390.29
9	0.05	0.34	0.66	0.20	64.86
10	0.61	1.19	6.93	0.21	209.50
12	0.03	0.09	3.65	0.11	13.42

Upper Mosquito Creek (Site #6) was the highest in areal pollutant rates for all pollutants, followed in general by the unnamed tributary (Site # 7).

Watershed Area-Weighted Average Loading Rates

The area-weighted average loading rates for the mosquito Creek Reservoir watershed, ($L_{a,MR}$ in lb/acre/yr and kg/ha/yr), presented in Table 4-17, were obtained using Equation 3-4.

Table 4-17. Watershed Area-Weighted Average Loading Rates for Drainage Areas Within the Mosquito Creek Reservoir Watershed.

Pollutant	Area-weighted Average Loading Rate	
	kg/ha/yr	lb/acre/yr
TP	1.90	1.70
NO_3^--N	5.98	5.34
NH_3-N	1.00	0.89
SS	689.08	558.15

Export factors for total phosphorus, nitrogen and suspended solids obtained from various literature sources are presented in Tables 4-18 to 4-20. Overall, the loading rate estimates for Mosquito Creek Reservoir watershed are comparable to the literature values. TP loading for Walnut Creek (Site #4) compares well with the average residential export factor for the United States and the urban factor for Wisconsin (Table 4-18 and 4-19, respectively). The watershed weighted average loading rates for Mosquito Creek watershed (Table 4-17) also agree well with the Florida export factors (Table 4-20).

Table 4-18. Average Nutrient Export Factors for the United States.

Land Use	N (kg/ha/yr)	TP (kg/ha/yr)
Forest	1.8	0.11
Pasture	3.1	0.1
Residential	7.5	1.2

Source: U.S. EPA & Reckhow et al. (1980)

Table 4-19. Phosphorus Export Factors for Wisconsin.

Land Use	TP (kg/ha/yr)
Agriculture > 75%	0.74
Agriculture > 50%	0.56
Forest	0.09
Urban	0.52

Source: Punuska & Lillie (1995)

Table 4-20. Suspended Solids Export Factors for Florida.

Land Use	SS (lb/acre/yr)	SS (kg/ha/yr)
Residential (Low Density)	28	31
Residential (High Density)	344	386
Wetlands	24	27
Pasture	591	664
Agriculture	1997	2243
Woodland	57	64

Source: Northeast Florida Water Management District, 1994

Total Pollutant Loads

Total pollutant loads into the Mosquito Creek Reservoir, W_{MR} in lb/yr and kg/yr (Table 4-21), were estimated using Equation 3-5.

Table 4-21. Estimated Total Pollutant Loads into Mosquito Creek Reservoir.

Pollutant	Estimated Loads	
	kg/yr	lb/yr
TP	41,916	92,407
NO_3^--N	131,870	290,722
NH_3 - N	22,020	48,545
SS	15,200,435	30,400,734

4-3. Input Data for STEPL

The STEPL input data for Mosquito Reservoir watershed presented in Tables 4-22 to 4-25, were obtained from the sources listed in Table 3-4.

Table 4-22. Land Use Distribution in the Mosquito Creek Reservoir Watershed.

Land Use	Area Acres
Urban	3712
Cropland	27683
Pastureland	2779
Forest	11634
User Defined	10363
Feedlots	0

The "user defined" land use listed in Table 4-22 represents scrub/shrub land and was assigned the same properties as forestland in STEPL.

Table 4-23. Precipitation

Annual Rainfall (in)	37.0
Rain Days	135.0

Table 4-24. Agricultural Animals

Animal Type	Number
Beef Cattle	200
Diary Cattle	900
Swine	350
Sheep	30
Horse	50
Chicken	100
Turkey	100
Duck	100

Average number of months manure is applied: 4 months/year

Table 4-25. Septic System Information.

No. of Septic Systems	2554
Population per Septic System	2.96
Septic System Failure Rate, %	50

To evaluate and demonstrate the use of STEPL to estimate pollutant loading reductions, one best management practice (BMP) was applied. Filter strip was selected as the BMP and was applied only on cropland. This application assumed that filter strips treats runoff from all cropland in the watershed. In reality, only a portion of cropland would have filter strips.

4-4 Loading Predictions from STEPL

Total Pollutant Loads from Watershed

STEPL output of total pollutant loads from the Mosquito Creek Reservoir watershed is presented in Table 4-26 and shown graphically in Figures 4-1 and 4-2.

Table 4-26. STEPL Output of Total Pollutant Loads from Mosquito Creek Reservoir Watershed and Loading Reductions From BMP.

Pollutant	Load (Without BMP)	Reduction	Load (With BMP)[1]	% Reduction
N (lb/yr)	211,890.8	85,088.6	126,802.2	40.2
TP (lb/yr)	55,291.0	21,923.6	33,367.4	39.7
BOD (lb/yr)	558,348.2	26,572.1	531,776.1	4.8
Sediments (t/yr)	9,039.3	4,151.9	4,887.4	45.9

[1] BMP: Filter Strip applied on cropland

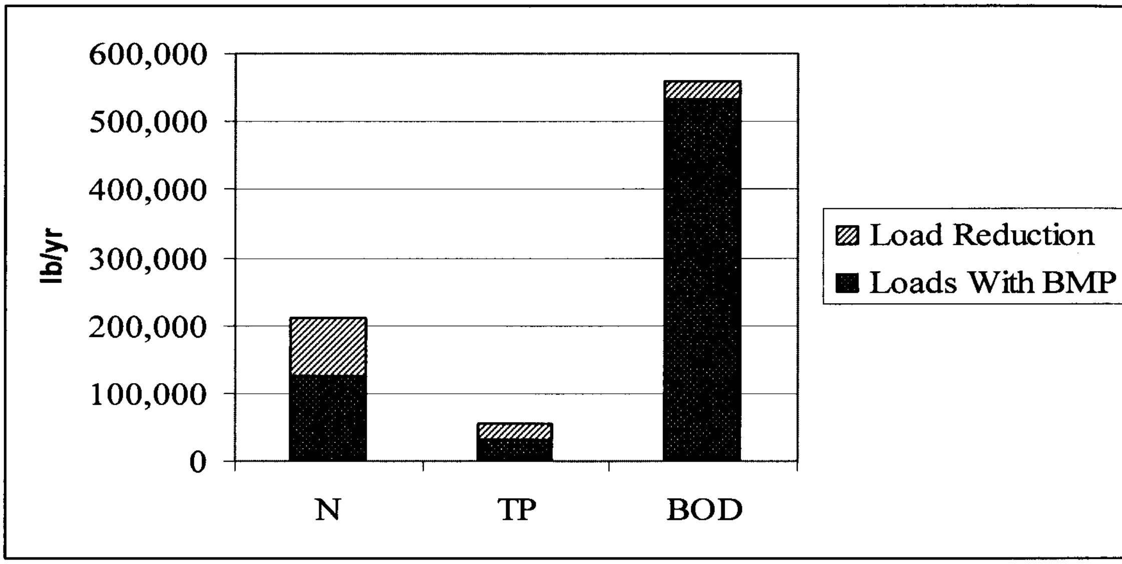

Figure 4-1. Nonpoint Source Pollutant Loads From Mosquito Creek Reservoir Watershed Predicted by STEPL.

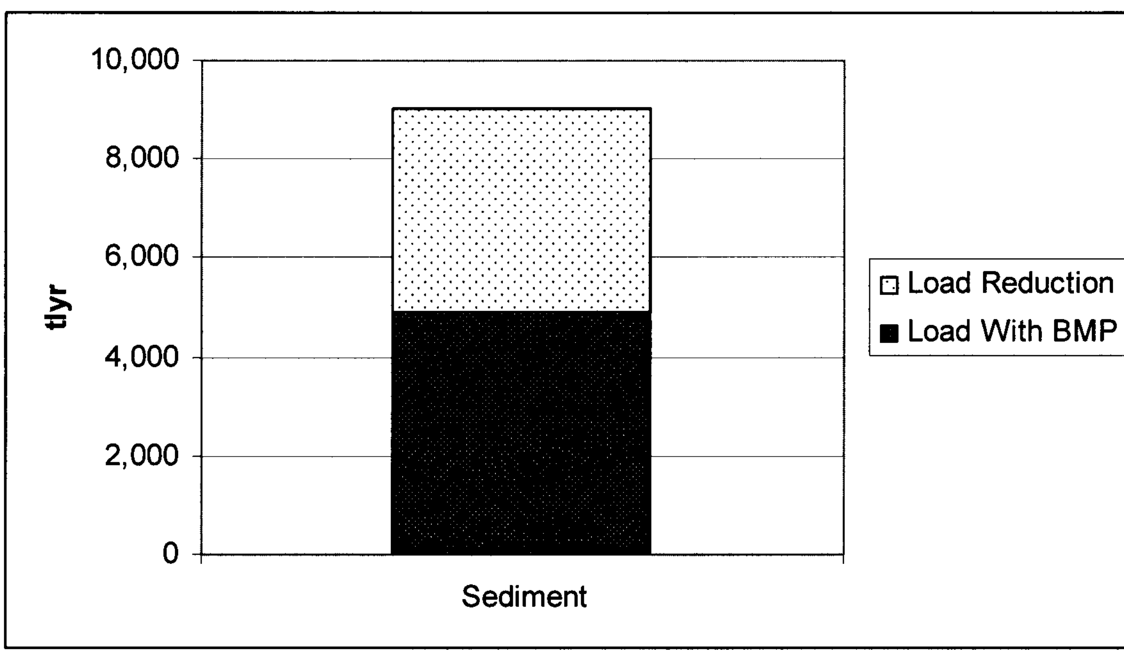

Figure 4-2. Sediment Load From Mosquito Creek Reservoir Watershed, Predicted by STEPL.

TP and sediment loadings estimated by STEPL are lower than estimates based on monitoring results by about 60 %. Normally, measured values are considered more reliable than model predictions. However, the monitoring data were collected during a period of above average rainfall, so loading estimates may be somewhat higher than the long term average. No attempt was made to calibrate the STEPL model to the monitoring estimates.

Total Pollutant Loads By Land Uses

Total pollutant loads by land uses are presented in Tables 4-27 and 4-28, and shown graphically in Figures 4-3 and 4-4, without and with BMPs, respectively.

Table 4-27. STEPL Output of Total Pollutant Loads Without BMP by Land Uses.

Sources	N Load lb/yr	P Load lb/yr	BOD Load lb/yr	Sediment Load t/yr
Urban and Septic	75,506.6	21,777.2	306,209.4	1,213.4
Cropland	123,015.1	30,280.8	215,861.1	6,387.5
Pastureland	7,289.9	675.2	23,174.2	129.5
Forest	1,130.2	550.1	2,760.4	40.7
Feedlots	0	0	0	0
User Defined	4,948.9	2,007.7	10,343.1	1,268.2
Total	**211,890.7**	**55,291**	**558,348.2**	**9,039.3**

Table 4-28. STEPL Output of Total Pollutant Loads With BMP by Land Uses.

Sources	N Load (lb/yr)	P Load (lb/yr)	BOD Load (lb/yr)	Sediment Load (t/yr)
Urban and Septic	75,506.6	21,777.2	306,209.4	1,213.4
Cropland	37,926.5	8,357.1	189,289.0	2,235.6
Pastureland	7,289.9	675.2	23,174.2	129.5
Forest	1,130.2	550.1	2,760.4	40.7
Feedlots	0.0	0.0	0.0	0.0
User Defined	4,948.9	2,007.7	10,343.1	1,268.2
Total	**126,802.2**	**33,367.4**	**531,776.1**	**4,887.4**

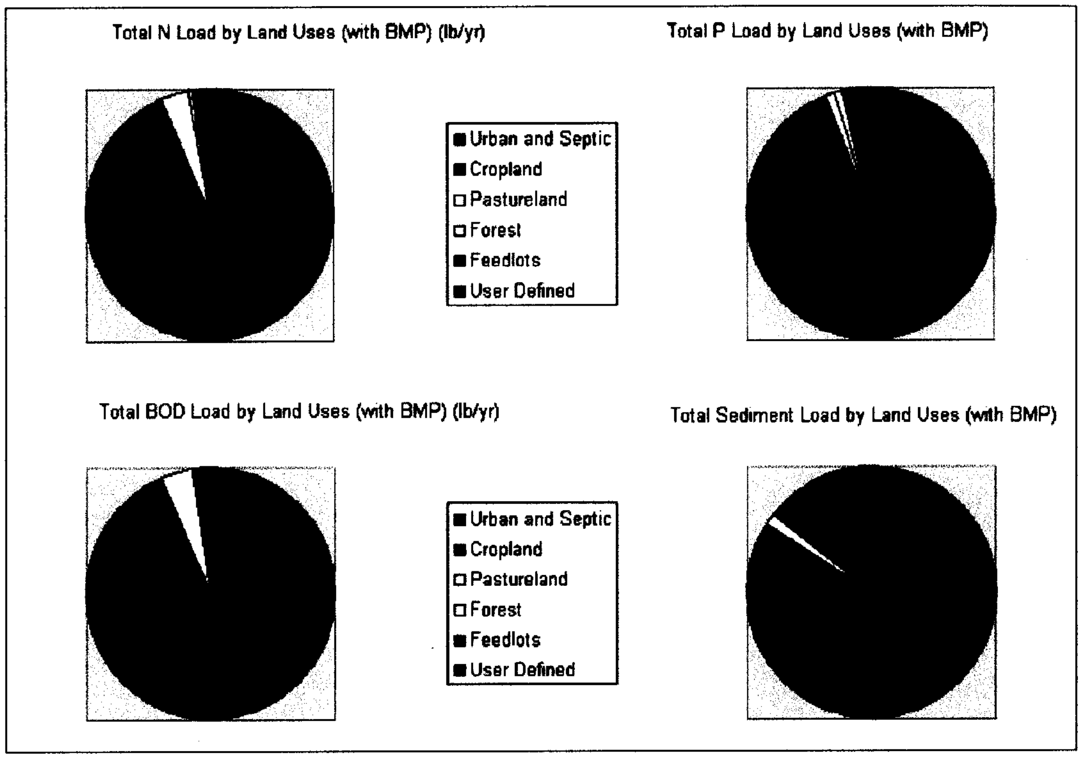

Figure 4-3. STEPL Prediction of Total Pollutant Loads Without BMP by Land Uses

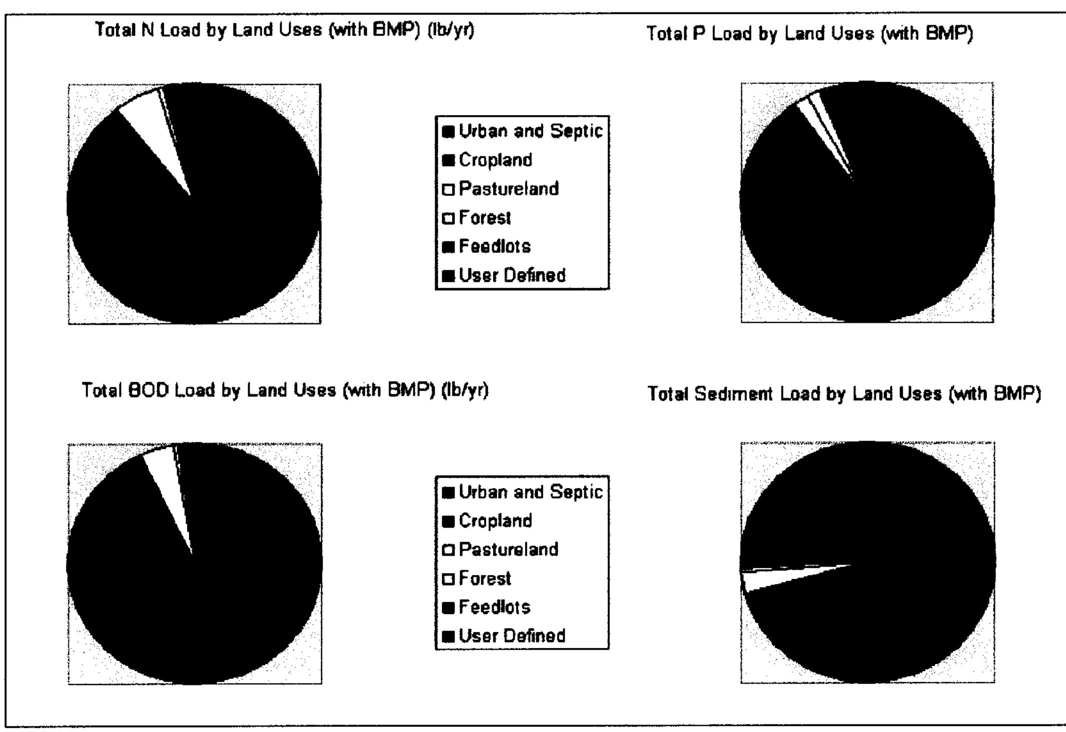

Figure 4-4. STEPL Prediction of Total Pollutant Loads With BMP by Land Uses.

4-5 Model Applications

Total Phosphorus by Dillon and Rigler Model

The Dillon and Rigler (1975) model (Equations 2-1 and 2-2) was used to estimate the total phosphorus concentration in the reservoir. Two estimates were obtained (Table 4-29), one based on TP loading from the monitoring sturdy and another based on STEPL results.

Table 4-29. Summary of TP Concentrations in Mosquito Creek Reservoir.

Parameter	Based On	
	Monitoring	STEPL
Annual TP Loading Rate, W_{TP} (g/yr)	4.2×10^7	2.8×10^7
Areal TP Loading Rate, L ($g/m^2/yr$)	1.3	0.9
Total Phosphorus Concentration, [TP] µg/L	111	73

Phosphorus Retention Coefficient, R = 0.74

The total phosphorus concentration in Mosquito Creek Reservoir obtained from monitoring (Table 4-5) is lower than estimates from the Dillon and Rigler model (Table 4-29). It is possible that the actual TP loading rate is less than the estimates, or the actual phosphorus retention coefficient, R, may be greater than predicted by Equation 2-2.

Trophic Condition by Vollenweider Model

Applying the Vollenweider (1975) model using the areal TP loading rates (1.1 g/ m^2/yr, obtained by averaging values from monitoring and STEPL) and depth divided by hydraulic residence time (i.e, areal water loading rate = 3 m/yr) for Mosquito Creek Reservoir (MCR) indicates that the Reservoir is in a eutrophic state (Figure 4-5). This is consistent with the Wetzel's (1983) trophic status classification based on TP concentrations.

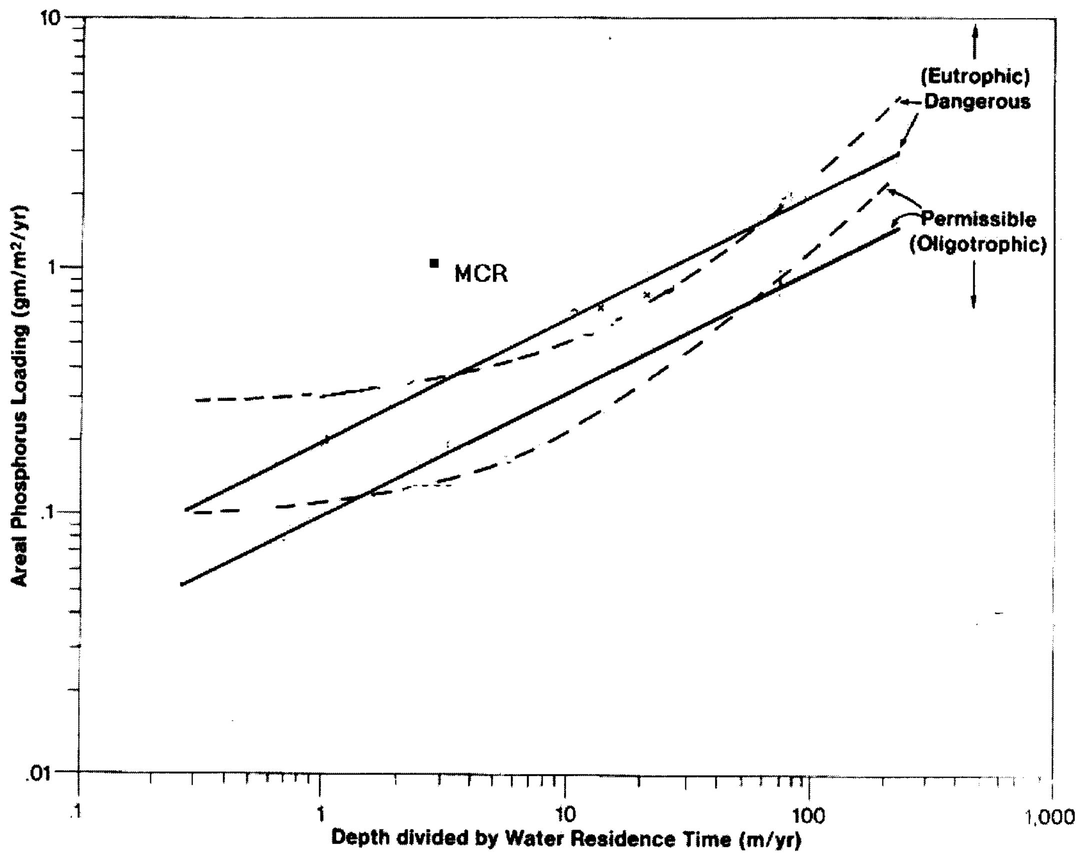

Figure 4-5. Vollenweider Chart Depicting the Trophic State of Mosquito Creek Reservoir (MCR).

Sediment Loading Rates

Sediment loading rates for different porosity values, presented in Table 4-30, were obtained using Equation 3-10 with sediment density of 2000 kg/m^3 and accumulation rate of 4.53 x 10^5 m^3/yr. For suspended solids loading estimates to be consistent with the USACE sediment accumulation rate, the porosity of bottom sediments would have to be 0.98 – 0.99. Sampling and analysis of sediments would be required to confirm this; however, based on this high porosity values, the sediment accumulation rate reproted by USACE may be high.

Table 4-30. Sediment Loading Rates at Different Porosity.

Φ	ρ Kg/m^3	V_T m^3/yr	M t/yr
0.75	2000	453,000	226,500
0.8	2000	453,000	181,200
0.85	2000	453,000	135,900
0.9	2000	453,000	90,600
0.95	2000	453,000	45,300
0.96	2000	453,000	36,240
0.97	2000	453,000	27,180
0.98	2000	453000	18120
0.99	2000	453000	9060

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5-1 Conclusions

1. Based on monitoring results, the export rates of TP, N, and SS are highest in the northern and western parts of Mosquito Creek watershed, and lower in the southern and eastern parts.

2. Based on tributary monitoring, the following areal pollutant loading rates were obtained for the Mosquito Creek Reservoir watershed: 1.70 lb/acre/yr for total phosphorus, 5.34 lb/acre/yr for nitrate nitrogen, 0.89 lb/acre/yr for ammonia nitrogen and 558.15 lb/acre/yr for suspended solids.

3. Total pollutant loads to Mosquito Creek Reservoir were estimated as 92,410 lb/yr for TP, 33,040 lb/yr for nitrate nitrogen, 48,540 lb/yr for ammonia nitrogen and 15,200 t/yr for suspended solids from the monitoring data, whereas the computer model, STEPL, estimated the total loads as: 211,890 lb/yr for N, 55,290 lb/yr for TP, 558,350 lb/yr for BOD and 9,040 t/yr for sediments. Loading estimates based on monitoring were significantly higher than those based on STEPL.

4. Cropland, urban land and septic systems were predicted by STEPL to be the major sources of NPS pollution in the Mosquito Creek Reservoir watershed. Pollutant loads from cropland were estimated as 123,015 lb/yr for nitrogen, 30,280 lb/yr for total phosphorus, 215,860 lb/yr for BOD and 6,390 t/yr for sediments. Loads from urban and septic were 75,510 lb/yr for N, 21,780 lb/yr for phosphorus, 306,210 lb/yr for BOD and 1,210 t/yr for sediments.

5. Simple TP models indicate that TP loading estimates obtained in this study may be high.

6. Calculations of bottom sediment porosity indicate that an estimate of sediment accumulation rate in the Mosquito Creek Reservoir by the U.S. Army Corps of Engineers is high.

5-2 Recommendations

In order to improve the comparison of models in this study with future work, the following recommendation can be taken into consideration.

1. Perform an extended period of sampling, to include all four seasons of the year and more sampling stations around (and in) the reservoir, for more accurate and representative estimates of NPS pollutant loading in the Mosquito Creek watershed;

2. Investigate the effect of various BMPs on pollutant loading in the Mosquito Creek watershed;

3. Sample and analyze bottom sediments in the reservoir to determine porosity and wet density for a more conclusive comparison between predicted sediment accumulation rates and literature values.

REFERENCES

APHA, AWWA, and WEF., 1998. Standards Methods for the Examination of Water and Wastewater, 20th Edition, L.S. Clesceri *et al.* (eds.), American Public Health Association, New York.

Christou, C., 2002. Impact of Historic Trends in Nutrient Loading on the Trophic Status of Meander Creek Reservoir. Master's thesis, Civil and Environmental Engineering Program, Youngstown State University, OH.

Crist, S., R. Monroe, and J. Poats, 1996. "Environmental Impact of Septic Systems," Groundwater Pollution Primer, Civil Engineering Department, Virginia Tech, Web Site, http://www.cee.vt.edu/program_areas/environmental/teach/gwprimer/group03/sgwpintro.htm

Dillon, P.J., and F.H. Rigler, 1974. "The Phosphorus-Chlorophyll Relationship in Lakes," *Limnology and Oceanography,* 19: 733-767.

Dillon, P.J., and F.H. Rigler, 1975. "A Simple Method for Predicting the Capacity of a Lake for Development Based on Lake Trophic Status," *Journal of Fisheries Research Board of Canada,* 32(9): 1519-1531.

Martin, S., and H. Burnett, 2002. Brochure on Mahoning River Watershed Action Plan.

Nandi, R., T. Dai, and H. Manguerra, 2003. STEPL 2.2: Spreadsheet Tool for Estimating Pollutant Load. PowerPoint Presentation on STEPL.

NCDENR, 2004. "Non-Point Source (NPS) Pollution from Septic Systems." N. Carolina Department of Environment and Natural Resources, Division of Environmental Health Web Site, http://www.deh.enr.state.nc.us/oww/nonpointsource/NPSseptic/npsintro.htm

Northeast Florida Water Management District, 1994. St. Marks and Wakulla Rivers Resource Assessment and Greenway Protection Plan, Appendix 4.

ODNR 2004. Mosquito Lake State Park. Ohio Department of Natural Resources Web Site, http://ohiodnr.com/parks/parks/mosquito.htm

Ohio EPA, 1997. A Guide to Developing Local Watershed Action Plans in Ohio.

Panuska, J.C., and R.A. Lillie, 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watershed, Wisconsin

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson, 1980. Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients, U.S. Environmental Protection Agency, EPA 440/5-80-011, Washington, DC.

USEPA, 2003. Spreadsheet Tool for Estimating Pollutant Load. U.S. Environmental Protection Agency Web Site, http://it.tetratech-affx.com/stepl/default.htm

USEPA, 2004. Managing Nonpoit Source Pollution from Agriculture. U.S. Environmental Protection Agency Web Site, http://www.epa.gov.owow/nps/facts/point6.htm

USACE, 1994. Mosquito Creek Lake Master Plan. U.S. Army Corps of Engineers, Pittsburgh District.

USACE, 2004. Mosquito Creek Lake. U.S. Army Corps of Engineers Web Site, http://www.lrp.usace.army.mil/rec/lakes/mosquito.htm

Wetzel, R.G., 2001. Limnology, 3rd edition, Academic Press.

APPENDIX

TABLES OF MONITORING DATA

Table A-1. Monitoring Data for Site # 1 - Mosquito Creek at Warren-Sharon Rd.

Date	SRP µg/L	TP µg/L	NO_3^- - N µg/L	NH_3 - N µg/L	SS mg/L	TURB NTU	pH
1/20/2004	52.9	64.7	435.5	123.2	4.9		
2/3/2004	104.7	110.5	662.8	219.3	3.6		
2/24/2004	47.9	61.8	459.5	204	7.6		
3/11/2004	28.8	122.6	55.7	172	6.0		
3/19/2004	1.9	60.3	404.1	116.6	8.4	8.2	7.40
4/9/2004	6.7	69.7	409.0	179.7	7.2	7.2	7.27
4/22/2004	15.6	122.2	331.2	146.4	26.0	21.0	7.13
5/6/2004	8.4	60.8	215.9	91.1	13.6	10.6	7.29
Mean	**33.4**	**84.1**	**371.7**	**156.5**	**9.7**	**11.8**	**7.27**
Std Dev	**34.5**	**28.8**	**179.2**	**44.8**	**7.2**	**6.3**	**0.11**

Table A-2. Monitoring Data for Site # 2 - Big Run at McCleary-Jacoby Rd.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 - N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft^3/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004		38.5		47.8		475.5		246.5		2.1			
2/3/2004		54		77		713.6		536.3		25.2			
2/24/2004		12.4		25.3		259.5		77.9		5.6			
3/11/2004	4	2.6	0.03			74.9	0.73	60.2	0.59	2.8	0.03		
3/19/2004	36.6	6.5	0.58	46.2	4.14	178.2	15.96	18.7	1.67	11.6	1.14	12.2	7.52
4/9/2004	5.51	5	0.07	29.9	0.40	24.9	0.34	7.8	0.11	3.2	0.05	4.6	7.75
4/22/2004	36.4	10	0.89	76.2	6.79	56.8	5.06	9.1	0.81	10.0	0.98	15.0	7.55
5/6/2004	4.3	7.5	0.08	41.8	0.44	44.4	0.47	5.9	0.06	3.2	0.04	4.1	7.96
Mean	**17.4**	**17.1**	**0.33**	**49.2**	**2.94**	**228.5**	**4.51**	**120.3**	**0.65**	**8.0**	**0.45**	**9.0**	**7.70**
Std Dev	**17.5**	**18.7**	**0.39**	**20.5**	**3.10**	**247.3**	**6.70**	**186.3**	**0.66**	**7.8**	**0.56**	**5.5**	**0.20**

Table A-3. Monitoring Data for Site #3 - Confusion Run at McCleary-Jacoby Rd.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 – N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft^3/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004		20.9		24.6		841.4		323		4.1			
2/3/2004		29.5		39.2		985.8		424.4		5.2			
2/24/2004	7.5	19.1	0.35	35.2	0.65	626.8	11.50	80.8	1.48	6.0	0.12		
3/11/2004	3	ND		32.9	0.24	355.2	2.61	7.2	0.05	4.4	0.04		
3/19/2004	12.6	17.5	0.54	81.4	2.51	523.9	16.15	48.4	1.49	13.6	0.46	26.0	7.44
4/9/2004	2.93	7.2	0.05	35.3	0.25	206.8	1.48	5.5	0.04	3.6	0.03	3.9	8.04
4/22/2004	14.4	20.4	0.72	90.3	3.18	102.5	3.61	15.3	0.54	11.2	0.43	20.0	7.62
5/6/2004	2.5	8.1	0.05	55.3	0.34	49.0	0.30	10.7	0.07	5.6	0.04	3.3	8.48
Mean	**7.2**	**17.5**	**0.34**	**49.3**	**1.20**	**461.4**	**5.94**	**114.4**	**0.61**	**6.7**	**0.19**	**13.3**	**7.90**
Std Dev	**5.3**	**7.8**	**0.30**	**24.3**	**1.30**	**343.4**	**6.38**	**164.3**	**0.70**	**3.7**	**0.21**	**11.5**	**0.46**

Table A-4. Monitoring Data for Site #4 - Walnut Creek at SR 46.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load)	NH_3 - N	NH_3 - N Load)	SS	SS Load	TURB	pH
	ft^3/s	μg/L	kg/d	μg/L	kg/d	μg/L	kg/d	μg/L	kg/d	mg/L	t/d	NTU	
1/20/2004		12.1		19.1		841.4		307		1.6			
2/3/2004		21.6		28.5		1273.2		332.4		13.2			
2/24/2004	16.5	22.5	0.91	39.1	1.58	656.5	26.50	89.4	3.61	8.4	0.37		
3/11/2004	11	0	0.00	32.2	0.87	348.6	9.38	4.2	0.11	2.0	0.06		
3/19/2004	73.9	24.7	4.47	104.5	18.90	520.8	94.17	54.2	9.80	28.0	5.58	38.0	7.63
4/9/2004	23.4	14	0.80	46.2	2.65	368.6	21.10	17.2	0.98	4.4	0.28	10.8	8.08
4/22/2004	33.6	27.5	2.26	111.3	9.15	181.4	14.91	11.9	0.98	17.2	1.56	27.0	7.66
5/6/2004	8.1	12.7	0.25	61.1	1.21	147.0	2.91	14.2	0.28	7.2	0.16	6.8	8.45
Mean	**27.8**	**16.9**	**1.45**	**55.3**	**5.72**	**542.2**	**28.17**	**103.8**	**2.63**	**10.3**	**1.33**	**20.7**	**7.96**
Std Dev	**24.4**	**9.0**	**1.67**	**34.8**	**7.15**	**376.3**	**33.39**	**136.3**	**3.73**	**9.0**	**2.15**	**14.5**	**0.39**

Table A-5. Monitoring Data for Site #5 - Mosquito Creek Reservoir at SR 88.

Date	SRP µg/L	TP µg/L	NO_3^- - N µg/L	NH_3 - N µg/L	SS mg/L	TURB NTU	pH
1/20/2004							
2/3/2004							
2/24/2004	5	20.7	367.3	37.8	8.8		
3/11/2004	ND	65.8	382.9	8.4	16.4		
3/19/2004	1	49.2	382.6	26.8	10.0	8.5	7.40
4/9/2004	2.5	63.6	454.1	4.4	10.8	14.1	7.74
4/22/2004	1.9	81	195.5	15.5	17.2	14.1	7.84
5/6/2004	0.3	51.1	50.5	11.8	14.4	10.6	7.95
Mean	**2.1**	**55.2**	**305.5**	**17.5**	**12.9**	**11.8**	**7.73**
Std Dev	**1.8**	**20.5**	**151.6**	**12.6**	**3.5**	**2.8**	**0.24**

Table A-6. Monitoring Data for Site #6 - Mosquito Creek at York Street, Greene Twp.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 - N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft^3/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004		20.4		32		890.3		70.8		6.1			
2/3/2004		17.6		27.9		937.6		68.2		0.8			
2/24/2004	36	34.2	3.01	61.5	5.42	216.5	19.07	127.2	11.20	23.2	2.25		
3/11/2004	18	5.2	0.23		0.00	742.1	32.68	12	0.53	6.4	0.31		
3/19/2004	210.9	71.1	36.69	262.9	135.67	804.3	415.05	155	79.99	110.0	62.52	119.0	7.34
4/9/2004	16.2	17.3	0.69	62	2.46	433.2	17.17	15.5	0.61	5.6	0.24	11.1	7.84
4/22/2004	93.2	37.9	8.64	209.3	47.73	500.7	114.18	55.6	12.68	52.4	13.16	77.0	7.30
5/6/2004	19.1	22.1	1.03	83.6	3.91	331.5	15.49	16.6	0.78	8.4	0.43	14.7	8.45
Mean	**65.6**	**28.2**	**8.38**	**105.6**	**32.53**	**607.0**	**102.28**	**65.1**	**17.63**	**26.6**	**13.15**	**55.5**	**7.73**
Std Dev	**77.0**	**20.1**	**14.21**	**92.4**	**53.64**	**271.7**	**157.80**	**53.1**	**31.05**	**37.6**	**24.70**	**52.1**	**0.54**

Table A-7. Monitoring Data for Site #7 - Unnamed Tributary at Hoagland-Blackstub Rd.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 - N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft^3/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004		79.5		102.3		288.9		603.7		7.2			
2/3/2004		67.6		87.3		717.0		668.1		6.4			
2/24/2004	8	93.3	1.83	138.1	2.70	1181.6	23.13	488.2	9.56	8.0	0.17		
3/11/2004	4	25.2	0.25		0.00	87.2	0.85	33.7	0.33	7.6	0.08		
3/19/2004	46.6	22.7	2.59	156.3	17.82	132.1	15.06	33.8	3.85	53.3	6.69	58.0	7.13
4/9/2004	9.36	37.8	0.87	105.9	2.43	148.5	3.40	53.2	1.22	12.4	0.31	21.0	7.29
4/22/2004	24.3	61.6	3.66	169.4	10.07	78.9	4.69	31.8	1.89	22.8	1.49	29.0	7.05
5/6/2004	3.7	77.3	0.70	166.8	1.51	102.6	0.93	36.7	0.33	12.4	0.12	19.1	8.45
Mean	**16.0**	**58.1**	**1.65**	**132.3**	**5.76**	**342.1**	**8.01**	**243.7**	**2.86**	**16.3**	**1.48**	**31.8**	**7.48**
Std Dev	**16.8**	**26.5**	**1.30**	**33.7**	**6.87**	**400.2**	**9.08**	**288.3**	**3.53**	**15.9**	**2.61**	**18.0**	**0.65**

Table A-8. Monitoring Data for Site #8 - Runoff into Unnamed Tributary at Hoagland-Blackstub Rd.

Date	SRP µg/L	TP µg/L	NO_3^- - N µg/L	NH_3 - N µg/L	SS mg/L	TURB NTU	pH
1/20/2004							
2/3/2004							
2/24/2004							
3/11/2004							
3/19/2004	72.1	579	187.4	320.6	358.0	412.0	7.19
4/9/2004							
4/22/2004							
5/6/2004							
Mean	**72.1**	**579.3**	**187.4**	**320.6**	**358.0**	**412.0**	**7.19**

Table A-9. Monitoring Data for Site #9 - Spring Run.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 - N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft^3/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004													
2/3/2004													
2/24/2004													
3/11/2004													
3/19/2004													
4/9/2004													
4/22/2004	18	6.8	0.30	52	2.29	78.9	3.48	31.8	1.40	9.2	0.45	13.8	7.89
5/6/2004	5	3.6	0.04	16.7	0.20	116.4	1.42	7.1	0.09	2.8	0.04	2.9	8.13
Mean	**11.5**	**5.2**	**0.17**	**34.4**	**1.25**	**97.7**	**2.45**	**19.5**	**0.74**	**6.0**	**0.24**	**8.4**	**8.01**
Std Dev	**9.2**	**2.3**	**0.18**	**25.0**	**1.47**	**26.5**	**1.45**	**17.5**	**0.93**	**4.5**	**0.29**	**7.7**	**0.17**

Table A-10. Monitoring Data for Site #10 - North Branch, Smith Run.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 - N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft^3/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004													
2/3/2004													
2/24/2004													
3/11/2004													
3/19/2004													
4/9/2004	0.63	41.4	0.06	89.3	0.14	928.5	1.43	51	0.08	147.2	0.25	4.5	8.11
4/22/2004	4.3	87.8	0.92	171.9	1.81	870.5	9.16	21.6	0.23	10.0	0.12	24.0	7.88
5/6/2004	0.9	62.4	0.14	130.9	0.29	1045.8	2.30	33.1	0.07	5.2	0.01	5.8	8.29
Mean	**1.9**	**63.9**	**0.38**	**130.7**	**0.74**	**948.3**	**4.30**	**35.2**	**0.13**	**54.1**	**0.13**	**11.4**	**8.09**
Std Dev	**2.0**	**23.2**	**0.48**	**41.3**	**0.92**	**89.3**	**4.23**	**14.8**	**0.09**	**80.6**	**0.12**	**10.9**	**0.21**

Table A-11. Monitoring Data for Site #11 - Unnamed Tributary at SR 46, South of Wakefield Creek Road.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 - N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft³/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004													
2/3/2004													
2/24/2004													
3/11/2004													
3/19/2004													
4/9/2004	6.21	16.6	0.25	54.6	0.83	738.7	11.22	20	0.30	5.6	0.09	9.1	7.59
4/22/2004													
5/6/2004	3.4	21.4	0.18	63	0.52	788.6	6.56	27.2	0.23	4.8	0.04	9.5	7.63
Mean	**4.8**	**19.0**	**0.22**	**58.8**	**0.68**	**763.7**	**8.89**	**23.6**	**0.27**	**5.2**	**0.07**	**9.3**	**7.61**
Std Dev	**2.0**	**3.4**	**0.05**	**5.9**	**0.22**	**35.3**	**3.30**	**5.1**	**0.05**	**0.6**	**0.04**	**0.3**	**0.03**

Table A-12. Monitoring Data for Site #12 - South Branch, Mud Creek.

Date	Flow	SRP	SRP Load	TP	TP Load	NO_3^- - N	NO_3^- - N Load	NH_3 - N	NH_3 - N Load	SS	SS Load	TURB	pH
	ft^3/s	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	µg/L	kg/d	mg/L	t/d	NTU	
1/20/2004													
2/3/2004													
2/24/2004													
3/11/2004													
3/19/2004													
4/9/2004	1.33	6.5	0.02	22.8	0.07	836.7	2.72	24.4	0.08	3.2	0.01	4.4	8.56
4/22/2004													
5/6/2004													
Mean	**1.3**	**6.5**	**0.02**	**22.8**	**0.07**	**836.7**	**2.72**	**24.4**	**0.08**	**3.2**	**0.01**	**4.4**	**8.56**