Nutrient Loading from the Tributaries of Meander Creek Watershed

by

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ABSTRACT

The Mahoning Valley Sanitary District (MVSD) draws water from Meander Creek Reservoir to supply drinking water to over 300,000 customers. It has had complaints of a "cucumber" taste and order three times in the past decade. One species of algae, *Synura petersenii,* has been directly related to cucumber taste and odor problems (Schroeder and Martin, 2000). This project is part of a larger study to determine the cause of taste and odor problems in Youngstown's water supply, and propose solutions through reservoir monitoring and watershed management. The purpose was to make preliminary estimates of annual export rates of several chemical and physical constituents from the Meander Creek watershed. The approach taken was to establish flow-gaging stations on all major tributaries to Meander Creek Reservoir and monitor these tributaries for several parameters related to the growth of *Synura petersenii.* The parameters monitored were suspended solids, total and soluble phosphorus, silica, and two forms of nitrogen, i.e. ammonia and nitrate.

The average areal runoff rate for the project area was 8.68 in/yr. The following areal pollutant loading rates were obtained for the study area: 26.6 kg/ha/yr for suspended solids, 0.023 kg/ha/yr for soluble reactive phosphorous, 0.044 kg/ha/yr for total phosphorous, 1.412 kg/ha/yr for Nitrate, 0.012 kg/ha/yr for ammonia, and 6.76 kg/ha/yr for silica. Site #3 shows some signs of pollution, including high concentrations of soluble reactive phosphorus, total phosphorus and nitrate.

DEDICATION

Dedicated to my family, especially my parents, for providing me the education they did, and to my husband for giving me the support that he has given me in getting my thesis completed.

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CHAPTER 1

INTRODUCTION

The Mahoning Valley Sanitary District (MVSD) draws water from Meander Creek Reservoir and provides treated drinking water to over 300,000 residents of Youngstown and surrounding communities. The MVSD has experienced four episodes of "cucumber" taste and odor in the water; these were in Jan. 1984, Jan. 1993, Feb. 1996, and Jan. 1999.

The main cause of taste and odor problems as investigated by a related study is believed to be *Synura* (Martin and Schroeder, 2000), a genus of algae that can grow well in cold water and release offensive organic compounds. *Synura* is a flagellated, colonial genus of algae belonging to the class *Synurophyceae.* During the periods of intense taste and odor complaints associated with *Synura* growth, water has often been described as having a "cucumber " taste and odor. (Buffin *et al.*, 1993).

Only one species, *Synura petersenii,* has been directly related to cucumber taste and odor problems. *Synura* and other odor-producing organisms, such as *Aphanizomenon,* have been identified in Meander Creek Reservoir. Silicon, pH, specific conductance, and phosphorus have been implicated as causing heavy *Synura* growth. Other factors could be nutrients such as nitrogen, the availability of light to help in photosynthesis, temperature, etc.

This project is part of a larger study to determine the cause of taste and odor problems in Youngstown's water supply, and propose solutions through reservoir monitoring and watershed management. The project involved establishing flow-gaging stations on all major tributaries to Meander Creek Reservoir and monitoring these tributaries for several parameters related to the growth of *Synura petersenii*. These data were used to make preliminary estimates of annual loading rates for several chemical and physical constituents from the watershed. (Schroeder and Martin, 2000).

CHAPTER 2

LITERATURE REVIEW

2.1. Taste and Odor Problems

The Mahoning Valley Sanitary District's treatment plant has had a "cucumber" odor in it's finished water three or four times since operations began nearly seventy years ago. All of these problems have occurred since 1984 (Schroeder and Martin, 2000). Three episodes have occurred since 1993. During the winter of 1999, the residents of Youngstown complained of taste and odor problems in the water that lasted for two months. Schroeder and Martin (2000) reviewed the literature on taste and odor problems. Several findings reported in their paper are summarized below.

The "cucumber" flavor has been described by customers as metallic, oily, sweet, fruity and medicinal. Release of the chemical trans-2, cis-6-nonadienal that is produced by the alga, *Synura petersenii* Korshikov (Hayes and Burch, 1989, Sung, 1994) and perhaps by *Uroglenopsis* (Mallevialle and Suffet, 1987) causes the "cucumber odor" in the water. Of the two algal genera suspected to be responsible for the objectionable taste and odor, only *Synura* has been identified in the samples collected from Meander Creek Reservoir. *Synura petersenii* also produces 2-trans, 4-cis, 7-cis-decatrienal, which imparts a fishy/cod liver oil odor to water (Rashash *et al.*, 1993). Decomposition of *Synura* may form a lipid degradation product. Treatment for the fishy odor caused by *Synura petersenii* and other algae with $HOCl$ /OCl^-, $KMnO_4$, or ClO_2 can cause the development of, or perhaps the unmasking of, cucumber, grassy, or other objectionable odors (Buffin *et al.*, 1993).

Synura petersenii are always present at low densities or as cysts, and usually cause no detectable odor in water. Occasionally, conditions become favorable for the production of sufficient quantities of *Synura* to produce objectionable odors in the raw and finished water. The threshold density for the production of objectionable odors by *Synura petersenii* is about 100 colonies per ml (Mallevaille and Suffet, 1987) or about 6000 cells per ml.

Most species of *Synura* are associated with cold water, low pH, and low dissolved solids. However *Synura petersenii* are found in a wide variety of environmental conditions (Nichols and Gerrath, 1985; Siver, 1987). *Synura* population density is likely limited by one or more of several environmental factors including: nutrients (phosphorus, nitrogen, silica, iron and carbon dioxide); physiochemical conditions like pH, conductance, light and temperature; and biological conditions like competition, symbiosis, disease and /or predation (Schroeder and Martin, 2000). Since blooms of *Synura petersenii* sufficient to cause objectionable odors do not occur every year in Meander Creek Reservoir, there must be some environmental conditions that trigger the *Synura* blooms. The triggering factor may be correlated with secondary factors, including time of ice formation, duration of ice cover, depth and duration of snow cover, changes in water level, runoff incidents, water temperature, change in dissolved solids, or blooms of other algae. (Schroeder and Martin, 2001)

Based on a review of the environmental data collected by Schroeder and Martin (2000), and observations made by the MVSD, there are several factors that are suspected to be responsible for the "cucumber" odors in finished water. These are: early winter thermal stratification of the reservoir, runoff events that raise the water level of the reservoir by at least two feet; low initial water level (at least four feet below spillway elevation); and late January thaws (Schroeder and Martin, 2000). All of the above reasons may not be directly related to triggering the algal blooms, but might be correlated to the conditions favorable for algal blooms, e.g. increased nutrients.

2.2. Nutrient Loading

Nutrient loading can affect the growth of algae in reservoirs, and it can also lead to eutrophication in lakes. Eutrophication is the excessive growth of aquatic plants, both attached and planktonic levels, which are considered to be an interference with desirable water uses. The principal external sources of nutrient loading are municipal and industrial wastes, agricultural and forest runoff, suburban and urban runoff, and finally atmospheric fallout. These factors could vary depending on population and land use. The growth of algal blooms, as mentioned earlier, can be a consequence of increased uptake of available phosphorus and nitrogen in water. It is possible that many nutrients could limit algal growth. Macronutrients include CO_2 (the carbon source), phosphorus, nitrogen (ammonia or nitrate), magnesium, potassium, calcium, and dissolved silica for diatom frustule formation. Several micronutrients are important for photosynthesis. Algae and rooted aquatic plants are photoautotrophs - they use sunlight as their energy source and CO_2 for their carbon source. The terminal electron acceptor is usually dissolved oxygen in the electron transfer of photosynthesis (Kotwal, 1992).

2.3. Sources and Forms of Phosphorus

Phosphorus is supplied to lakes in various forms and amounts from numerous sources. Natural sources include direct precipitation runoff from the surrounding watershed area, animal wastes, vegetation deposits, and groundwater influxes. Human sources include domestic and industrial wastewaters, agricultural runoff, urban runoff, septic tank leachate, and landfill drainage. Also, phosphorus is supplied through recycling from sediments.

Phosphorus can be found in the lakes and reservoirs in various forms, including: (1) as soluble inorganic phosphate (PO_4^{-3}); (2) as acid–soluble sestonic phosphorus, consisting of inorganic phosphorus, mostly as ferric and calcium phosphates, becoming soluble phosphate under acidic conditions; (3) as organic soluble phosphorus consisting of phosphorus present in organic excretions; and (4) as organic sestonic phosphorus consisting of phosphorus mostly associated with dead and living plants and animals (Hutchinson, 1957). A very large fraction, often greater than 90%, of the phosphorus in lake water is bound in organic phosphates and cellular constituents of living and dead plankton (Wetzel, 1975). Of the total organic phosphates, about 70% or more is within the particulate organic material (Wetzel, 1975), and the remainder is present as dissolved and colloidal organic phosphorus. Littoral vegetation and phytoplankton readily take up the soluble inorganic phosphates for growth. Organic matter undergoes decomposition before the phosphorus present in it can be utilized. This is partly accomplished by the heterotrophic bacteria that use organic matter as a source of carbon and energy. Inorganic phosphorus compounds often make up less than 10% of total phosphorus in water columns. Therefore, algae depend largely on the recycling of nutrients to support biological growth (Kotwal, 1992).

2.4. Forms and Sources of Silica

Silica is present in one form or another in all natural waters. Silica may be present in fresh waters in the forms of: (1) dissolved silicic acid which forms stable solutions of H_4SiO_4 at much higher concentrations than are encountered in fresh waters; and (2) particulate silica in two forms - that in biotic material, in particular diatoms and a few other organisms that use large amounts of silica, and that adsorbed to inorganic particles and in the form of inorganic complexes (Wetzel, 1975).

Water contains carbonic acid or CO_2 (dissolved), which in turn reacts with silicates to form carbonates and silica. Concentrations of dissolved silica increase with an increase in temperature, and decrease with increasing pH values (McKeague and Cline, 1963). The silica content of rivers tends to be uniform with change in discharge rates. The concentrations of silica in lakes show variations in spatial and seasonal distribution. Utilization of silica by living diatoms occurs during photosynthesis and increases somewhat in darkness. Adsorption of SiO_2 to dead cells under some conditions can lead to reduction of silica content even below the trophogenic zones of lakes during both summer and winter periods of stratification (Wetzel, 1975).

The development of phytoplankton algae in temperate waters usually undergoes a spring maximum. This population development may begin beneath the ice as light conditions improve, but is most conspicuous during and following spring circulation when water is relatively rich in nutrients as the winter accumulations are mixed throughout the water column. One or a few species usually dominate during this period of rapid population growth. In a large number of lakes, diatoms constitute the predominant algae of the spring. Increasing light, and to a lesser extent a rise in temperatures, are major factors initiating the development of diatom population in water. Circulatory turbulence is much higher in the spring than later in the season, and assists in the retention of the relatively dense diatom cells in the optimal light zones (Wetzel, 1975).

Silica can be a limiting nutrient for diatoms, and may limit the growth of algae bearing silicaceous scales (Klaveness and Guillard, 1975). *Synura*, on the other hand continues to grow at low concentrations of silica, but produces abnormal scales and shows a decline in growth rate. After the silica content is increased, the rate of growth of *S. petersenii* goes up, with maxima at 5-8 ppm (Sandgren *et al.*, 1996). *Synura*, at low temperatures, can be excellent competitors for silica. Schroeder and Martin (2001) reported that the levels of silica in Meander Creek Reservoir were low enough to be a possible limiting nutrient for the growth of *Synura*. Diatoms may remove most of the silica from the water, limiting the growth of *Synura*. On the other hand, runoff events that replenish the supply of silica might increase the growth rate of *Synura*. Also, since light and silica can both be limiting factors for *Synura*, the increase in light simultaneous with the increase in silica could be a potential reason to trigger the population of *Synura* (Schroeder and Martin, 2001)

2.5. Sources and Forms of Nitrogen

Nitrogen occurs in fresh waters in different forms, including dissolved molecular nitrogen (N_2), nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+) ions, in conjunction with organic compounds such as amino acids, amines and proteins. Sources of nitrogen include precipitation on the lake surface, N_2 fixation both in water and sediments, wastewater discharges, runoff from agricultural land and other surface drainage, and groundwater inflows. Losses of nitrogen occur from reduction of NO_3^- to N_2 by bacterial denitrification with subsequent return of N_2 to the atmosphere, as well as permanent loss of inorganic and organic nitrogen containing compounds to the sediments. Microbial fixation of molecular N_2 in soils by bacteria is a major source of nitrogen compounds. In lakes, N_2 fixed by bacteria and certain blue-green algae is quantitatively bound and cycled in photosynthesis. Nitrogen, as one of the major constituents of cellular protoplasm of organisms, is a major nutrient that affects the productivity of fresh waters. Although the nitrogen cycle of freshwaters is understood qualitatively in appreciable detail, quantitative transformation is not very clearly defined. Nitrogen concentrations in fresh water can affect algal productivity. Although phosphorus is the major nutrient limiting algal productivity in lakes, loading rates of nitrogen are of major importance to the maintenance of high flux rates within the nitrogen cycle (Wetzel, 1975).

Ammonia (NH_3) or ammonium (NH_4^+) is generated by heterotrophic bacteria as the primary end-product of decomposition of organic matter, either directly from compounds or from other sources. Ammonia is present in water as NH_4^+ and as undissociated NH_4OH. The distribution of ammonia in fresh waters is highly variable regionally, seasonally and spatially within the lakes. Generally the ammonia-nitrogen of well-oxygenated lakes is low (Wetzel, 1975).

2.6. Nonpoint Sources

Nonpoint source (NPS) pollution originates from many different locations rather than one specific, identifiable source. NPS pollution occurs when rainfall, snow melt, or irrigation runs over land or through the ground and picks up pollutants, and then deposits them into rivers, lakes, and coastal waters or introduces them into ground water. Non-point sources of nutrients include nitrogen and phosphorus, which can be found in fertilizers and leaky septic systems. They can cause explosive plant growth, depletion of oxygen, and fish kills. Nonpoint source sediment pollution is tiny soil and rock particles that carry chemical pollutants into water. Examples are soil erosion and runoff from construction sites and agriculture. Sediments can transport other contaminants, clog drainage systems, smother aquatic life, cause turbidity, lead to a decrease in the aquatic food supply, and transmit diseases. Of the greatest concern are pollutants that get into water from both rural and urban activities (Wetzel, 1975). Table 2-1 summarizes the types and sources of nonpoint source pollution.

Several studies have been performed to estimate the export rates of nonpoint source pollutants. Examples are shown in Tables 2-2 and 2-3. Table 2-2 contains export rates for several pollutants measured by Line *et al.* (2002) in North Carolina. Table 2-3 presents average export rates of total nitrogen and total phosphorus for the entire United States, from Reckhow *et al.* (1980).

Table 2-1. Sources and types of nonpoint source pollution.

Type of Pollutant	**Nonpoint Sources**
Sediment	Construction sites Mining exploration and operations Croplands Logging roads and trails
Nutrients (e.g. fertilizers, grease, organic matter)	Croplands and livestock pens Gardens, lawns, and forests Petroleum storage areas Landfills
Acids, Salts	Irrigation fields Mines Roads and parking lots Landfills
Heavy Metals (e.g. lead , zinc)	Mining operations Vehicle emissions Landfills
Toxic Chemicals (e.g. pesticides, herbicides, fungicides)	Croplands Waste from building sites Forestry Landfills
Pathogens	Domestic sewage Livestock wastes Landfills
Heat	Denuded streambanks

Table 2-2. Export rates of nonpoint source pollutants reported by Line *et al.* (2002) for watersheds in North Carolina.

Land Use	NO_3-N (kg/ha/yr)	TKN (kg/ha/yr)	NH_3-N (kg/ha/yr)	TN (kg/ha/yr)	TP (kg/ha/yr)	TSS (kg/ha/yr)
Residential	3.2	20.7	2.4	23.9	2.3	387
Golf Course	4.8	26.4	3	31.2	5.3	658
Pasture	1.2	5.5	0.4	6.7	4.3	143
Construction-I	1.4	6.9	0.6	8.3	3	22600
Construction-II	7.3	29	4.1	36.3	1.3	6560
Wooded	3.6	7.8	0.3	11.4	1	986
Developed	5.1	25.4	3.2	30.5	3	2535

Table 2-3. Average nonpoint source export rates for the United States for total nitrogen (TN) and total phosphorus (TP), from Reckhow *et al.* (1980).

Land Use	TN (kg/ha/yr)	TP (kg/ha/yr)
Forest	1.8	0.11
Corn	11.1	2
Cotton	10	4.3
Soybeans	12.5	4.6
Small Grain	5.3	1.5
Pasture	3.1	0.1
Feedlot Dairy	2900	220
Idle	3.4	0.1
Residential	7.5	1.2
Business	13.8	3
Industrial	4.4	3.8

2.7. Flow Gaging Stations

A flow gaging station can be established to measure the flow rate across a stream cross-section. Flow gaging sites are chosen to obtain information on water quality standards and rates of stream flow. The gaging station measures stage, which is the height of the surface of the water above a certain reference elevation. Discharge information is derived from rating curves that quantify the relationship between stage and discharge. Discharge is the volume of flow passing through a given cross-sectional area in a given time. It is measured in cubic feet per second. Discharge includes not only water but also sediments or pollutants that may be dissolved or mixed in the stream. (State of New Jersey, 2002).

An approach to determine discharge, which is used by USGS, is the midsection method, where a current meter is utilized to measure stream velocities at different points along the cross-section of the stream (Buchanan and Somer, 1984). Discharge through each portion of the cross-section is determined from the product of velocity and cross-sectional area. Measurements of velocity are not required for calibrated weirs or flumes, since discharge is related to stage directly by a calibration formula for the device. When these devices are installed and operated properly, runoff records are more accurate compared to those of a natural stream channel that is field calibrated.

CHAPTER 3

METHODS AND PROCEDURES

3.1. Overview

The procedure used in this study involved establishing monitoring stations at five stream locations in the Meander Creek watershed. Site #1 was located on Meander Creek at Gibson Road; Site #2 was located on Sawmill Run at Turner Road; Site #3 was an unnamed tributary located on Lipkey Road; Site #4 was an unnamed tributary located on Gault Road at Geeburg; and finally, Site #5 was located on Morrison Run at Silica Road. Figure 3-1 shows the various sites and the corresponding locations. These sites were visited 6-8 times and the monitoring was done between the months of March, 2001 and June, 2001. Each visit involved collecting a representative water sample, and measuring the velocity of flow with a Global FP-101 current meter, as well as the depth and width of the flow. The samples collected were transported back to the laboratory and analyses were carried out to measure various water quality parameters, including pH, turbidity, suspended solids, nitrate, silica, phosphorus, and ammonia. Watershed areas and the percentage of total watershed were also determined and are summarized in Table 3-1. The annual pollutant loading rates were also estimated.

3.2. Flow Measurements at Site #1

Since the drainage area and stream channel are much larger at Site #1 than at other sites, several steps were involved in setting up the gaging station.

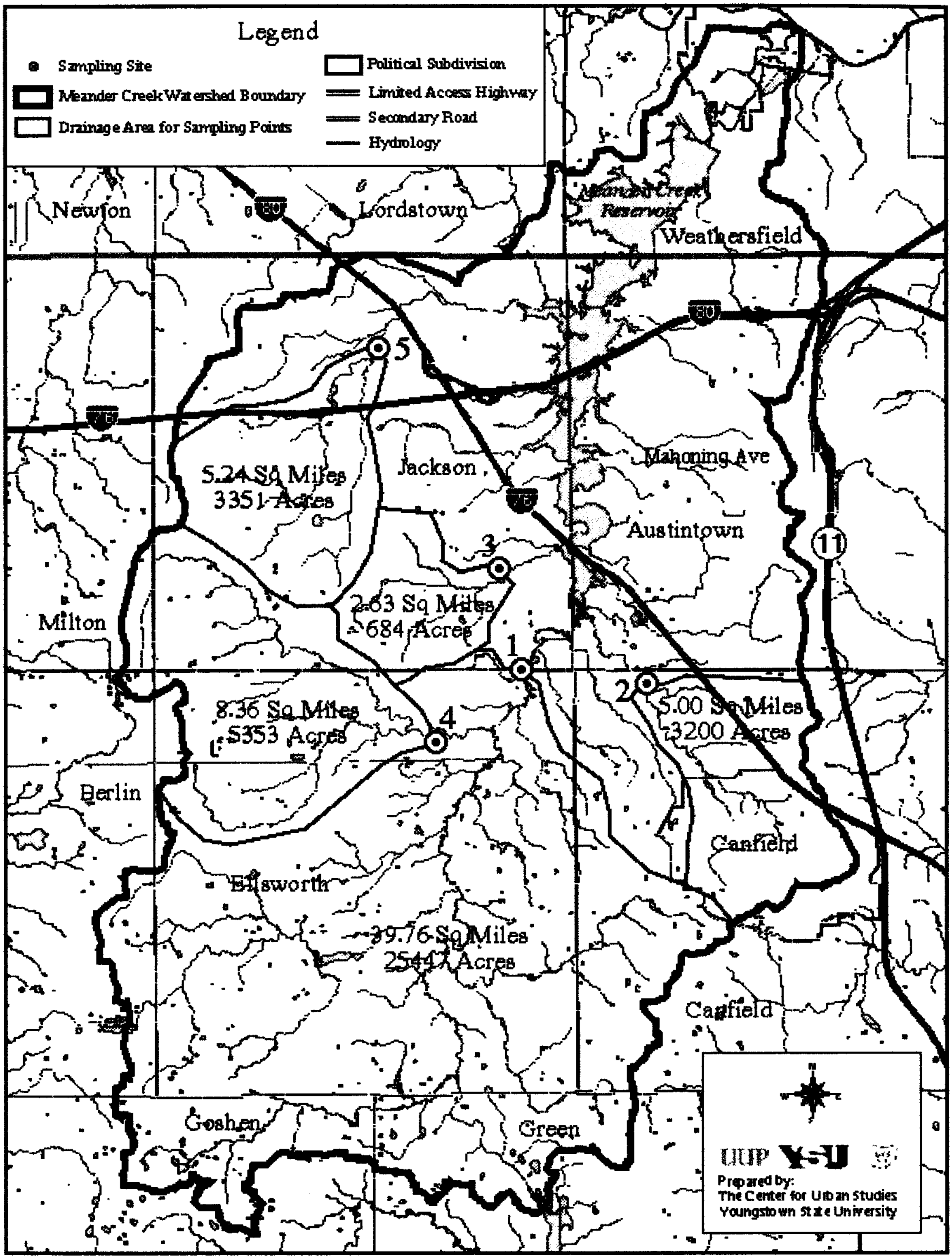

Figure 3-1. Watershed areas for sampling sites in the Meander Creek watershed.

Table 3-1. Location and watershed areas of sampling sites.

Site No.	Location	Watershed Area (Sq. mi.)	% of Meander Creek Watershed
1	Meander Creek at Gibson Road	39.76	46.45
2	Saw Mill Run at Turner Road	5.00	5.84
3	Unnamed Tributary at Lipkey Road	2.63	3.07
4	Unnamed Tributary on Gault Road at Geeburg	8.36	9.77
5	Morrison Run at Silica Road	5.24	6.12

(Note: Watershed areas determined by J. Bralich of YSU Center for Urban Studies using ArcView GIS)

a. Determining the stream channel cross-section

First a suitable bridge was located on Meander Creek. A few criteria were considered in selecting the bridge - the bridge should be close to the mouth of the stream; the flow and channel should be straight for at least 50-100 ft. upstream; the bridge should have a convenient level railing to work from; and the height above the stream should be less than 15 ft. Although the Gibson Road bridge was not ideal due to a meander in the stream channel, it was deemed to be the best available site. A surveyor's level was used to measure the relative elevation of the railing at 5 ft. intervals. An arbitrary elevation of the instrument of 1000 ft. was assumed. Then a baseline was established along the railing of the bridge, on the upstream side. A surveyor's tape was used to measure and mark 5 ft. increments on the baseline. The distances to the ground, water surface, and stream bottom were measured next, from each 5 ft. mark on the baseline (top of railing).

The data obtained and a plot of the stream channel cross-section are shown in Appendix A, Table A-1 and Figure A-1, respectively.

b. Performing stream flow measurements

On each sampling date, the distance from the bridge railing to the water surface was first measured at the 60, 70, and 80 ft. marks. Then, subtracting the distance to the water from each corresponding railing elevation, three values were calculated for water surface elevation and these were averaged. The stream was divided into 4 to 6 sections, each 5 ft. wide, considering the width of flow in the stream. The cross-sectional area of each section was calculated and tabulated with the measured velocity in an Excel spreadsheet. The flow was calculated using the formula:

$$Q = \sum_{i=1}^{n} V_i A_i \qquad \text{(Eq 3.1)}$$

where,

Q = flow, cfs

V_i = velocity of flow in section i, ft/s

A_i = cross-sectional area of section i, ft^2

Sample spreadsheets containing water surface elevation and flow calculations are shown in Appendix, Table A-2.

c. Developing a rating curve

Flow measurements were performed on eight different dates at Site# 1, and flow was plotted versus water surface elevation to develop a preliminary rating curve.

3.3. Flow Measurements at Other Sites

a. Site #2

Site #2 was located on Sawmill Run at Turner Road. Since a formal gaging station was not established at this site, the procedure was relatively simple. First, a point in the stream was chosen where flow measurements could be taken. Samples were collected and flow was measured about 150 ft. below the Turner Road bridge. The stream bottom was relatively flat over bedrock and was of fairly uniform depth across the width of the stream. The stream was divided in two sections. Depth, velocity and width measurements were taken on each site visit.

b. Site #3

Site #3 was on an unnamed tributary at Lipkey Road. At Site #3, the flow was measured across two culverts, each of 7 ft. diameter and made of corrugated metal. Velocity was measured using the current meter, and the depth and width of flow were measured at the entrance of each culvert and recorded in a field notebook. Samples were collected upstream of the culverts.

c. Site #4

Site #4 was on an unnamed tributary located on Gault Road at Geeburg. At Site #4 the flow was divided into three corrugated metal culverts each of 10 ft. diameter. Measurements of velocity, width and depth of flow were recorded at the exit of each culvert. Samples were collected downstream of the culverts.

d. Site #5

Site #5 was located on Morrison Run at Silica Road. The channel is a rectangular cross-section beneath the bridge. At this site, depth, width and velocity measurements were taken immediately upstream of the bridge, and a sample was also taken.

3.4. Flow Calculations

a. *Site #2 and Site #5*

At Site #2 and Site #5, the flow was calculated using the formula:

$$Q = W*Z*V \qquad \text{(Eq. 3.2)}$$

where:

Q = stream flow rate, cfs

W = width of the stream or section, ft.

Z = depth of flow, ft.

V = velocity of flow, ft/s

b. Site #3 & Site #4

At Site #3 and Site #4, the flow was calculated using the formula:

$$Q = V*A \qquad \text{(Eq. 3.3)}$$

where:

Q = flow rate, cfs

V = velocity of the flow, ft/s

A = cross-sectional area of flow, ft^2

Cross-sectional area of flow in the culverts was calculated by the formula (see Figure 3-3):

$A = A_p - A_t$ (Eq. 3.4)

where:

$A_p = \pi * R^2 * (\theta/360)$ (Eq. 3.5)

$A_t = (0.5)*(c*d)$ (Eq. 3.6)

$c = 2*R*\mathrm{Sin}(\theta/2)$ (Eq. 3.7)

$d = R - h$ (Eq. 3.8)

$\theta = 2*\mathrm{Cos}^{-1}(d/R)$ (Eq. 3.9)

h = depth of flow, ft.

R = radius of the culvert, ft.

c = length of water surface, ft.

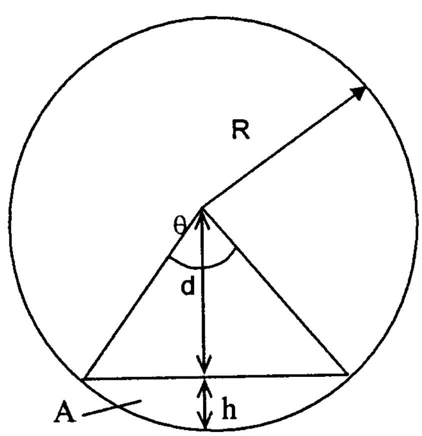

Figure 3-3. Geometry of culverts.

3.4. Water Quality Measurements

Water quality monitoring was conducted on five tributaries in the watershed of Meander Creek Reservoir. These sites (see Figure 3-1) were visited 6-8 times between March, 2001 and June, 2001. During each site visit, flow measurements were taken and a grab sample was collected in a 1 liter plastic bottle.

Within three hours of collection, samples were transported to the Environmental Engineering Lab at Youngstown State University. The samples were stored in labeled bottles, which were acid washed before being used. Measurements of turbidity (Hach Ratio Turbidimeter) and pH (Fisher Accumet pH meter) were performed the same day. In the analyses for suspended solids, a Fisher G4 glass fiber filter (effective pore size = 1.0 μm) was used. Deionized water was run through the filters to eliminate loose fibers, and they were dried at 103 C in the oven overnight. Then, filters were weighed on a Mettler AE 1000 balance and a measured portion of each sample was filtered. The filters plus residue were dried again at 103 C for at least one hour and the final weight was then measured. The filtrate and remaining unfiltered sample was stored at 4 C in acid-washed plastic bottles for future analyses.

Laboratory analyses were performed on filtered samples for ammonia nitrogen, nitrate nitrogen, soluble reactive phosphorus and silica. Total phosphorus was measured on unfiltered samples. In general, laboratory measurements were completed within 3-4 days of sample collection. All analytical methods were taken from Lind (1985). Analytical blanks (deionized water) and several standards were included in each analysis. Composite standard curves were developed by Dr. Lauren Schroeder (Professor

Emeritus, Biological Sciences, YSU) using all data for blanks and standards obtained throughout a related study on Meander Creek Reservoir.

Pollutant loading rates were calculated by multiplying concentrations by the flow rate for each sampling site and date.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Monitoring Results

Summaries of the monitoring results for Sites #1 through #5 are presented in Tables 4-1 through 4-5, respectively.

a. Flow Rates

As expected, the sites with the largest drainage areas (#1 and #4) had the highest flow rates, while the one with the smallest drainage area (#3) had the lowest flow rate. Table 4-6 gives the areal flow rates at the five sites. This value is obtained by dividing the mean flow by the drainage area. Site #2 had the highest value, which could be correlated to the land use. Site #2 (Sawmill Creek) drains an urban area (the City of Canfield), and urban areas have higher percentages of impervious surfaces, such as parking lots, rooftops, roads, driveways etc. Site #4 had the second largest value of areal flow rate. This could be an indicator of the mostly agricultural use of land in the drainage area. The land in this area has been disturbed and has been stripped of it's natural cover, although crops have been planted on this land. Sites #1 and #5 had intermediate values of areal flow rate, which may be due to a variety in land use in these drainage areas. Site #3 had the lowest value of areal flow rate, which indicates that a higher percentage of precipitation infiltrates to the groundwater table. This may be due to the presence of forested land in this drainage area.

Table 4-1. Summary of monitoring results for Site #1 - Meander Creek at Gibson Rd.

Date	Flow (ft^3/s)	Flow (m^3/s)	pH	SS (mg/L)	Turb. (NTU)	SRP (µg/L)	TP (µg/L)	NO_3-N (µg/L)	NH_4-N (µg/L)	Si (mg/L)
3/14/2001	97.8	2.77	7.93	21.8	37					
3/23/2001	40.4	1.14						1183	0	5.08
3/30/2001	13.1	0.371		4.6		5.8	10.7	559	4.6	3.06
4/5/2001	8.1	0.229	8.23	11	12.5	27.6	11.1	336	12.5	3.21
4/13/2001	17.6	0.499	7.57	8.6	19.8	13.8	29.1	328	0	3.64
4/19/2001					9.7	17.6	48.5	625	0	5.13
5/10/2001	3.3	0.0940	7.62	11.7	15.5	5.5	16.1	96	18.7	6.04
5/30/2001	10.0	0.282	8.14	9.2	8.2	9.3	27.5	1207	0	4.93
6/7/2001	15.0	0.424	7.07	4.8	6.8		44.7	1345	28.3	5.82
Avg	25.7	0.727	7.76	10.2	15.6	13.3	26.8	710	8.01	4.61
Std Dev	31.2	0.883	0.43	5.80	10.4	8.4	15.4	473	10.8	1.16
CV	122	122	5.55	56.6	66.7	63.6	57.3	66.6	135	25.1

Table 4-2. Summary of monitoring results for Site #2 - Sawmill Run.

Date	Flow (ft^3/s)	Flow (m^3/s)	pH	SS (mg/L)	Turb. (NTU)	SRP (µg/L)	TP (µg/L)	NO_3-N (µg/L)	NH_4-N (µg/L)	Si (mg/L)
3/14/2001			8.5	7	10.1					
3/23/2001	13.89	0.393						1383	26	5.75
3/30/2001	3.84	0.109		4.8		5.1	16.5	77		1.67
4/5/2001	1.88	0.053	8.17	12	13.4	16.9	12.3	96		1.53
4/13/2001	2.66	0.075	8.38	1.2	2.8	8.6	15.7	54		4.45
4/19/2001					3.3	8.2	20.3	146		5.61
5/10/2001	1.29	0.037	8.25	2.2	1.3	3	11.1	95	1.9	4.98
5/30/2001	1.90	0.054	8.73	0.4	2.1	14.8	27	388	2.3	10.5
6/7/2001	3.76	0.107	7.63	2.4	5.5		39.2	1006	3.4	11.22
Avg	4.17	0.118	8.28	4.29	5.5	9.43	20.3	405	8.4	5.71
Std Dev	4.39	0.124	0.37	4.08	4.56	5.42	9.89	508	11.75	3.57
CV	105	105	4.51	95.1	82.96	57.5	48.7	125	140	62.5

Table 4-3. Summary of monitoring results for Site #3 - unnamed tributary near Lipkey Road.

Date	Flow (ft^3/s)	Flow (m^3/s)	pH	SS (mg/L)	Turb. (NTU)	SRP (μg/L)	TP (μg/L)	NO_3-N (μg/L)	NH_4-N (μg/L)	Si (mg/L)
3/14/01			7.78	10	24					
3/23/01	2.08	0.0588						2491	6.8	4.89
3/30/01	0.73	0.0207		2.4		99.6	27	1778	19.3	16.02
4/5/01	0.31	0.0088	8.02	2.4	3.7	111	152	820	13	0
4/13/01	1.14	0.0323	8.02	2.3	5.7	196	237	1442	0	4.69
4/19/01	1.61	0.0456				134	190	2773	0	6.23
5/10/01	0.05	0.0015	8.1	1	2.2	175	204	610	37.9	3.73
5/30/01	0.33	0.0094	7.99	2.6	5.6	193	251	6851	0	8.1
6/7/01	0.73	0.0208	7.26	1.8	5		290	3628	26	8.01
Avg	0.87	0.025	7.86	3.21	7.70	151	193	2549	12.9	6.46
Std Dev	0.70	0.020	0.314	3.04	8.09	42.0	85.5	2011	14.0	4.65
CV	79.6	79.6	3.99	94.6	105	27.8	44.4	78.9	109	72.0

Table 4-4. Summary of monitoring results for Site #4 – unnamed tributary at Gault Rd.

Date	Flow (ft^3/s)	Flow (m^3/s)	pH	SS (mg/L)	Turb. (NTU)	SRP (μg/L)	TP (μg/L)	NO_3-N (μg/L)	NH_4-N (μg/L)	Si (mg/L)
3/30/01	2.33	0.0659		3.8		7.2	23.7	1550		0.95
4/5/01	2.41	0.0681		2		21.7	18.2	774		1.05
4/13/01	23.99	0.679	8.26	1.2	3.3	16.9	30	401		1.67
4/19/01	5.63	0.159				22.1	46.8	1373		6.18
5/10/01	0.349	0.0099	8.10	1.2	0.9	7.2	17	107		1.81
5/30/01	2.00	0.0566	8.47	0.4	2.2	25.5	42.2	3051	5.7	5.37
6/7/01	7.03	0.199	7.52	1.8	4.4		58.5	3175	0	6.64
Avg	6.25	0.177	8.09	1.73	2.700	16.8	33.8	1490	2.850	3.381
Std Dev	8.15	0.231	0.41	1.16	1.50	7.90	15.8	1218	4.03	2.55
CV	131	131	5.04	66.8	55.5	47.1	46.7	81.8	141	75.5

Table 4-5. Summary of monitoring results for Site #5 - Morrison Run at Silica Road.

Date	Flow (ft^3/s)	Flow (m^3/s)	pH	SS (mg/L)	Turb. (NTU)	SRP (µg/L)	TP (µg/L)	NO_3-N (µg/L)	NH_4-N (µg/L)	Si (mg/L)
3/30/01				3.8		6.8	28.7	361.9	0.0	5.94
4/5/01				2.8						
4/13/01	2.295	0.0650	7.95	13.2	32.0	30.4	51.4	248.5	13.0	7.29
4/19/01	3.960	0.1121			24.0	43.5	82.9	291.7	1.2	4.69
5/10/01	0.000	0.0000	7.79	3.2	2.6	5.5	18.2	100.0	1.2	3.59
5/30/01	1.872	0.0530	8.12	5.6	12.4	24.5	57.3	1097.6	21.5	1.72
6/7/01	3.600	0.1019	7.15	4.4	9.8		56.9	1298.8	20.4	9.83
Avg	2.93	0.083	7.75	5.50	16.16	22.14	49.2	566	9.55	5.51
Std Dev	1.01	0.028	0.42	3.90	11.7	16.1	23.01	501	10.03	2.85
CV	34.3	34.3	5.46	70.9	72.6	72.9	46.7	88.4	105	51.80

Table 4-6. Areal flow rates for sampling sites.

Site No.	Areal Flow Rate (cfs /sq. mile)	Areal Flow Rate (in/yr)	Areal Flow Rate (cm/yr)
Site#1	0.645	8.76	22.25
Site#2	0.835	11.26	28.78
Site#3	0.332	4.48	11.46
Site#4	0.747	10.18	25.76
Site#5	0.560	7.60	19.29
Entire study area	0.639	8.68	22.03

The areal flow rates in in/yr are presented in Table 4-6. The average value for Site #1, which drains almost one half of the Meander Creek watershed, was 8.76 in/yr (22.2 cm/yr). A map of average annual streamflow from the Ohio Water Atlas (Ohio Dept. of Natural Resources, www.ohiodnr.com) shows an approximate value of 13 in/yr (33 cm/yr) for the Meander Creek area. The most likely cause of the difference in these values is that the flow measurements were all taken within a three month period, and did not include storm events. Most of the flow measurements were taken during low flow conditions. To get a more accurate estimate of the average annual flow rates, more measurements would be needed, including some from storm events.

b. Water Quality Measurements

The pH of all samples fell in the range of 7.0 to 8.5, or slightly above neutral. This is typical of water that does not have any input from industry or mining.

The mean suspended solids (SS) concentrations for all sites were below 11 mg/l, which is typical for low flow conditions. Site #4 had the lowest average SS concentration. Site #1 had the highest SS concentrations. This could be caused by the removal of riparian vegetation along the stream, or by the resuspension of sediments from the stream channel. Turbidity is proportional to SS, in most cases. In general the sites that had higher values of turbidity had a correspondingly high value for SS.

The average soluble reactive phosphorus (SRP) values for all sites ranged from 9.4 μg/L to 151.2 μg/L. The concentration at Site #3 was much higher than all of the other sites, indicating that there is a significant source of pollution. This could be due to effluent from onsite septic systems that are not working properly. On the days the samples were taken, the flow rates were not very high; hence any septic system effluent would not have been diluted much by the flow of the stream. Septic systems normally consist of two parts – a septic tank that removes suspended solids, and a tile field that allows the wastewater to infiltrate into the soil, removing other pollutants such as organic matter and nutrients. Since the SS values at Site #3 were not higher than the other sites, it appears that the septic tanks were actually functioning properly but the tile fields were not. SRP at the other sites was fairly low, indicating no major sources of pollution.

Average total phosphorus (TP) values ranged from 20.3 μg/L to 192.8 μg/L. Here also, Site#3 has the highest values. This could also be due to the reasons mentioned above.

The average ammonia nitrogen values ranged from 0.81 μg/L to 12.9 μg/L, and the nitrate nitrogen values range from 405 μg/L to 2549 μg/L. Once again, Site# 3 had the highest values. This could be due to the improper functioning of home septic systems and also to the fertilizer runoff from neighboring areas.

Site #4 had the lowest values of SS, SRP, TP and nitrate. This could be due to the use of proper methods of wastewater disposal, runoff control, and agriculture, and also to greater dilution of runoff by stream flow (i.e. relatively high areal flow rate).

Silica concentrations did not show significant variation among sites. Mean silica concentrations ranged from 3.4 to 6.5 mg/L, which is a fairly narrow range. Silica is mostly from natural sources; hence the differences in silica export as a function of land use are small compared to the other parameters. Human activities do not affect the silica concentration very much.

4.2. Pollutant Loading Rates

Nonpoint source pollutant loading (or export) rates for each site are tabulated in units of kg/d and kg/hectare/yr in Tables 4-7 and 4-8, respectively. Pollutant loading rates were calculated by multiplying concentrations by the flow rate and averaging all available values for each parameter and site. Loading rates are dependent on the watershed area,

Table 4-7. Pollutant loadings in kg/day for sampling sites.

Pollutant Loadings in kg/day						
	SS	SRP	TP	NO_3-N	NH_4-N	Si
Site No.	kg/d	kg/d	kg/d	kg/d	kg/d	kg/d
Site #1	921.10	0.320	0.709	33.58	0.226	150.37
Site #2	23.17	0.052	0.139	8.55	0.133	51.86
Site #3	3.00	0.252	0.332	5.45	0.016	14.07
Site #4	22.96	0.266	0.553	17.92	0.004	48.10
Site #5	46.17	0.235	0.464	5.17	0.091	36.16

Table 4-8. Pollutant loadings in kg/hectare/yr for sampling sites.

Areal Loadings in kg/ha/yr						
	SS	SRP	TP	NO_3-N	NH_4-N	Si
Site No.	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
Site #1	32.65	0.011	0.025	1.19	0.008	5.33
Site #2	6.53	0.015	0.039	2.41	0.038	14.62
Site #3	1.61	0.135	0.178	2.92	0.009	7.54
Site #4	3.87	0.045	0.093	3.02	0.001	8.11
Site #5	12.42	0.063	0.125	1.39	0.024	9.72
Entire study area	26.60	0.023	0.044	1.412	0.012	6.760

the flow rate and the concentration. Since Site #1 has the largest watershed area (over 15 times the size of Site #3), the loading rates (in kg/yr) are higher. Nutrient loading is also related to land use. Impervious surfaces in more urban or residential areas (Site #2, Site #5) can also result in a higher runoff, and hence a higher flow rate and a higher value for nutrient loading. The combined areal loading rates for the entire study area (sum of Sites # 1, 2, 3 and 5) are presented in the Table 4-8. Site #4 is excluded because it is a part of the drainage area of Site #1. These combined values reflect pollutant loadings from the entire watershed area included in this study. This area represents 61.5% of the Meander Creek watershed.

The samples were taken at low flow conditions; in other words, no storm events were included. Also, the monitoring period was over three months; hence the data are insufficient to provide reliable information about average pollutant loadings. The actual loadings of most substances may be higher than the values listed in Tables 4-7 and 4-8.

Data from the literature for North Carolina (Line *et al.*, 2002) give a total phosphorus (TP) export rate of 3.0 kg/hectare/yr for developed areas (Table 2-2), which is much higher than the value of 0.044 kg/hectare/yr calculated in this study. The ammonia and suspended solids export rates reported by Line *et al.* (2002) were over 100 times higher than the values from this study. The ammonia export rate for the study area was 0.012 kg/hectare/yr, compared to 3.2 kg/hectare/yr for North Carolina. The suspended solids export rate of 26.6 kg/hectare/yr for the Meander Creek watershed was much less than the values of 2535 kg/hectare/yr reported by Line *et al.* (2002). The literature value for total nitrogen (TN) is 12 kg/hectare/yr, which is very high compared to the value of 1.424 kg/hectare/yr calculated by adding the NO_3-N and NH_4-N export rates from this study. It should be noted, however, that TN also includes organic nitrogen in addition to ammonia, nitrate, and nitrite. The calculated pollutant export rates for this study are much lower than literature values because the data set does not include any storm events and the monitoring was only conducted for a period of three months.

4.3. Rating Curve

In establishing gaging stations, it is useful to develop a functional relationship relating water surface elevation to flow. An attempt was made to determine this relationship for Site #1. Figure 4-1 shows the rating curve relating elevation and flow.

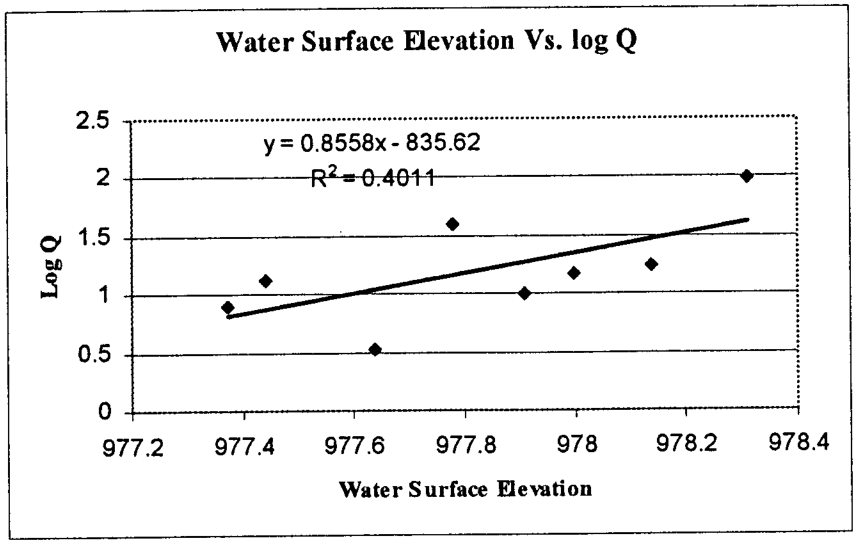

Figure 4-1. Rating curve for Site #1.

The regression coefficient shows a positive slope and a correlation between flow and water surface elevation. Due to the small size of the data set, the equation should not be used for predictive purposes. A larger data set would be needed, including high flow measurements during runoff events, in order to obtain a more reliable rating curve.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to collect preliminary monitoring data on streams that contribute to the Meander Creek Reservoir, with the goal of estimating nonpoint source loadings of nutrients and suspended solids. Flow measurements and samples were taken from a total of six stream locations on eight different dates. Samples were analyzed for soluble and total phosphorus, ammonia and nitrate nitrogen, dissolved silica, suspended solids, turbidity and pH. The average areal flow rates for the sampling sites were 8.8 in/yr (22.2 cm/yr) for Site #1, 11.3 in/yr (28.8 cm/yr) for Site # 2, 4.5 in/yr (11.5 cm/yr) for site #3, 10.2 in/yr (25.8 cm/yr) for Site #4, and 7.6 in/yr (19.3 cm/yr) for Site #5.

The following areal pollutant loadings were calculated for the study area, which includes 61.5% of the Meander Creek Watershed: 0.044 kg/hectare/yr for total phosphorus; 0.023 kg/hectare/yr for soluble phosphorus;1.41 kg/hectare/yr fornitrate nitrogen, 0.012 kg/hectare/yr for ammonia nitrogen, 6.76 kg/hectare/yr for silica, and 26.6 kg/hectare/yr for SS. The values are much lower than literature values, and the likely reason is that samples were collected during low flow periods. Evidence of some source of pollution was found at Site # 3, a small unnamed tributary near the center of the Meander Creek watershed. Concentrations of phosphorous, nitrate, and ammonia were all much higher than any other site. Runoff from home wastewater disposal systems that are not working properly is the suspected source of the pollution.

More monitoring is needed, including some high flow periods, to get more accurate estimates for nutrient loadings and a more reliable rating curve. It is recommended that the monitoring program be continued, including weekly flow measurements and water quality analyses throughout the year, and additional sampling during (and immediately after) several storm events.

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APPENDIX

Table A-1 Elevation data for stream cross-section at Site #1.

Date 3/14/01 Distance	Rod Reading	Depth to water(ft)	Depth of water(ft)	Velocity (ft/s)	ft Elev. Rail	ft Depth to Ground	ft Elev. Bottom
5	2.97				997.03	7.32	989.71
10	2.83				997.17	8.90	988.27
15	2.62				997.38	11.23	986.15
20	2.52				997.48	12.40	985.08
25	2.43				997.57	12.40	985.17
30	2.34				997.66	13.40	984.26
35	2.22				997.78	14.65	983.13
40	2.09				997.91	17.32	980.59
45	1.96				998.04	20.07	977.97
50	1.85	18.96	1.54	0.65	998.15	21.40	976.75
55	1.73	19.06	1.78	1.27	998.27	21.74	976.53
60	1.63	19.17	2.36	1.83	998.37	22.43	975.94
65	1.52	19.25	3	1.95	998.48	23.15	975.33
70	1.43	19.33	3	1.7	998.57	23.23	975.34
75	1.35	19.43	2.88	1.16	998.65	22.31	976.34
80	1.26		0		998.74	20.42	978.32
85	1.16				998.84	18.03	980.82
90	1.06				998.94	16.07	982.87
95	0.95				999.05	14.23	984.82
100	0.84				999.16	12.32	986.84
105	0.72				999.28	9.40	989.88
110	0.63				999.37	6.98	992.39
113.8	0.56				999.44	6.23	993.21
edge of water=44'							
19.521 **(edge of water)							

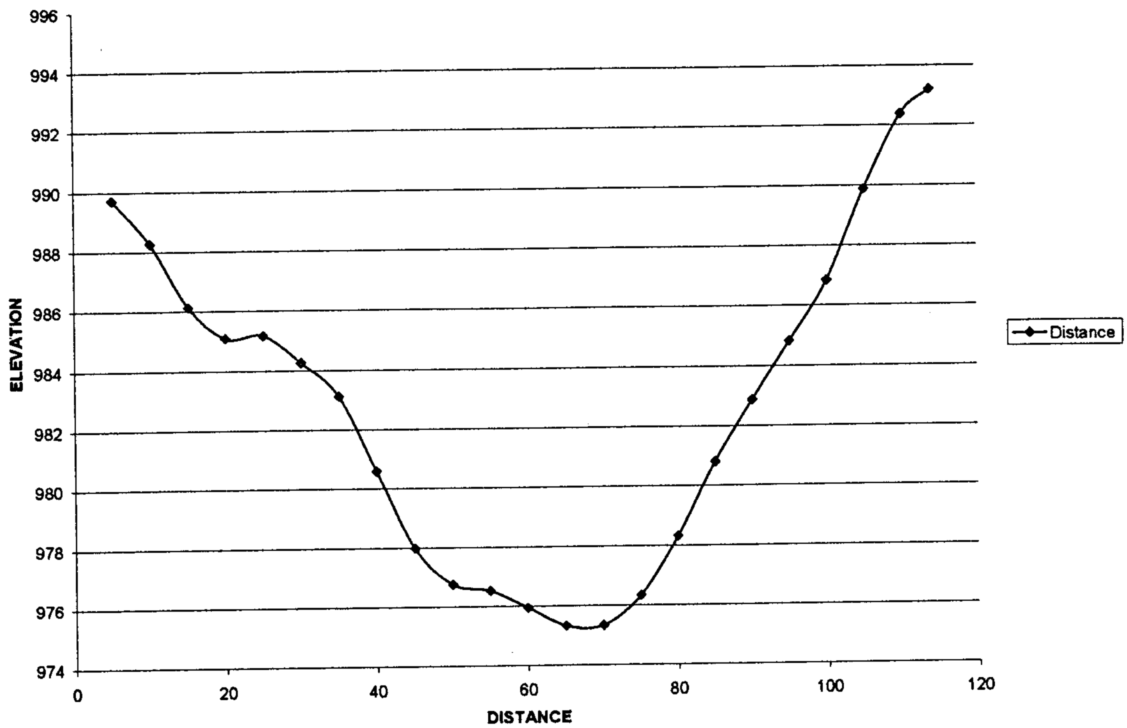

Figure A-1. Plot of Stream Cross-Section at Site #1

Table A-2. Spreadsheet for flow calculations at Site #1 – water surface elevation.

3/14/2001				
	Tape readings		**Depth to**	
Dist	**feet**	**inches**	**water, ft**	**Elev.**
50	18	11.5	19.85833	978.2917
60	19	2	20.06667	978.3033
70	19	4	20.23333	978.3367
Average				978.3106

Table A-3. Spreadsheet for flow calculations at Site #1 – area and flow rate.

	Elev. For x	h_a	h_b	**A**	**V**	**Q**
0-52.5	976.6395833	0	1.670972	4.177431	0.65	2.71533
52.5-57.5	976.2354167	1.670972	2.075139	9.365278	1.27	11.8939
57.5-62.5	975.6366667	2.075139	2.673889	11.87257	1.83	21.7268
62.7-67.5	975.3333333	2.673889	2.977222	14.12778	1.95	27.54917
67.5-72.5	975.83975	2.977222	2.470806	13.62007	1.7	23.15412
72.5-80		2.470806	0	9.265521	1.16	10.748
Total						97.78732