ABSTRACT

MANAGING A WATERSHED INVENTORY PROJECT AND EXPLORING WATER QUALITY DATA IN THE FOUR MILE CREEK WATERSHED

by Travis Daniel Drury

From this practicum project I gained leadership and data analysis experience through the application of the watershed approach for reducing water pollution in the Four Mile Creek watershed in southwestern Ohio and southeastern Indiana. I was the junior project manager for a team of graduate students developing a watershed inventory and I was directly responsible for meeting with the project manager to collaborate on management decisions; assisting the team through issues they encountered; developing standards for geographic information science (GISci) metadata and data management; evaluating the accuracy and quality of maps, text, and geospatial data; and proposing improvements to the report based on my evaluation. Independently, I explored long-term sediment and nutrient data by calculating daily stormflow and baseflow loading of ammonium, nitrate, soluble reactive phosphorus, and suspended sediments. This type of analysis is crucial to understanding the influences of seasonality and weather events on water quality.
MANAGING A WATERSHED INVENTORY PROJECT AND EXPLORING WATER QUALITY DATA IN THE FOUR MILE CREEK WATERSHED

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by
Travis Daniel Drury
Miami University
Oxford, Ohio
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Major Advisor________________________

(Dr. Adam Berland)

Committee Member________________________

(Dr. William Renwick)

Committee Member________________________

(Dr. Donna McCollum)
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For Jean-Luc,
a friend through it all.
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I. Introduction

Clean water is an essential component of life for every human on Earth, but for most of United States history there was little to no regulation of pollutants entering the country's water bodies. Due to decades of increasing water pollution and the growth of the environmental movement throughout the 1960s, the Clean Water Act was passed in 1972. This new law gave the federal government the power to regulate discharges of pollutants and maintain water quality standards for the waters of the United States (U.S. EPA, 2012). The full implementation of the Clean Water Act requires cooperation between many levels of government, regulators, stakeholders, and researchers. This practicum project applied parts of the Clean Water Act implementation process to the Four Mile Creek watershed in southwestern Ohio and southeastern Indiana.

Legal Background of the Clean Water Act

In 1824, the U.S. Supreme Court ruled in the landmark case *Gibbons v. Ogden*, 22 U.S. 1 (1824) that the federal government has the power to control the navigable waters of the United States. While not directly addressing water quality, this ruling was the basis for The Commerce Clause in the U.S. Constitution. This grants the U.S. Congress the power to regulate interstate commerce, and because navigable waters are used for interstate commerce, Congress controls these waterways. The Supreme Court’s decision in *Gibbons v. Ogden* remains the backbone of federal authority to create laws regarding water quality (Downing et al., 2003).

The first piece of federal legislation to directly address the issue of water quality was the Water Pollution Control Act of 1948 (Ch. 758; P.L. 845). This law established a framework for cooperation between federal, state, and local governments, with the United States Surgeon General leading the effort to implement programs to reduce pollution in interstate waters and their tributaries. A provision was included to provide limited funding to states and local governments for the construction of wastewater treatment plants (U.S. FWS, 2000). While it was a major step in environmental policy, this law only provided limited authority to the federal government to directly regulate pollutants. In order to more effectively improve water quality, the Federal Water Pollution Control Act was amended several times over the following decades. Major amendments through 1970 expanded federal authority to control water quality, created a
process for setting enforceable water quality standards, allowed fines to be imposed on polluters, and attempted to prevent water quality degradation beyond desired standards (U.S. EPA, 1972).

These amendments to the Water Pollution Control Act caused challenges for implementation due to the lack of cohesion among various sections of the law. Additionally, pressure mounted in the 1960s and 1970s from the rapidly growing modern environmental movement to properly address water quality issues as negative impacts from pollution became more apparent across the nation. In the eyes of the public, the pinnacle of the water quality problems occurred on June 22, 1969, when *Time* magazine reported on a fire in the Cuyahoga River in northeast Ohio. The river had caught fire at least twelve times previously from its toxic mixtures of pollutants. However, the *Time* magazine article brought the issue to the forefront of the national fight for improved pollution control (U.S. EPA, nd).

Due to public pressure and complications from decades of minor amendments, an overhaul of the law was developed in the form of the Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. §1251 et seq. 1972), commonly referred to as the Clean Water Act. The overall goal of these new amendments was to “restore and maintain the chemical, physical, and biological integrity of the Nation's waters” (33 U.S.C. §1251 et seq. 1972). To solve the organizational issues with previous versions of the law, the 1972 amendments consolidated the power to manage national water quality goals under the new position of the Administrator of the Environmental Protection Agency (EPA). The second major component of the law was the National Pollutant Discharge Elimination System (NPDES), which made it illegal to discharge pollutants from point sources (i.e., direct routes like pipes or canals) into waters of the United States without a permit from the EPA specifying the type and amount of pollutant to be released. This process also establishes monitoring and reporting requirements for the permit holder; permit holders who fail to comply with NPDES requirements can face injunctions, fines, and imprisonment in cases of criminal violations (U.S. EPA, nd). The 1972 amendments also allowed for the creation of industrial wastewater standards and provided funding for the construction of wastewater treatment plants (U.S. EPA, 2012). Later amendments modified the Clean Water Act to grant money to states for water quality improvement projects, require that best management practices be developed and used for statewide planning, and alter the fines
given to non-compliant individuals (U.S. FWS, 2000). However, the major components of the Clean Water Act in use today were established in the 1972 amendments.

**The Clean Water Act Process**

All entities discharging pollutants into waters of the United States must obtain an NPDES permit under the Clean Water Act. This reduces pollutants by limiting the amount that can be discharged from point sources. However, in order to take into account the uses of water bodies and how those uses can be obtained or maintained there is a standard set of steps involved in the implementation of the Clean Water Act, including:

1. Establish water quality standards
2. Conduct monitoring to determine if standards are being met
3. If standards are not being met, place the water body on the list of impaired waters
4. Determine pollutant load and sources for the water body
5. Design and implement management strategy to reduce pollutant load to desirable levels
6. If standards are still not met, develop new management strategy. If standards are met, apply antidegradation policies to maintain high water quality

As delegated by the U.S. EPA, water quality standards are developed by states or other organizations. The first step of development is to outline the water body’s designated uses, the functions it should serve including recreation, aquatic habitat, and drinking water. Next the water quality criteria necessary to meet these designated uses are elucidated, including measurable water quality parameters such as the maximum concentrations of certain pollutants. The final component of water quality standards is antidegradation policies aimed at preventing water quality from deteriorating beyond present levels (U.S. EPA, nd).

Once water quality standards have been established, a monitoring program is initiated to determine if these standards are being met. Specifically, data gathered during the monitoring program are compared with the measurable water quality criteria. If the water quality criteria are being met, then antidegradation policies are applied to maintain present water quality. However, if the criteria are not met the water body is placed on the 303(d) list, which is a list of impaired
waters named for the section of the Clean Water Act that requires it. Each water body on the 303(d) list may then have a total maximum daily load (TMDL) calculated for the pollutants causing impairment. A TMDL sets the maximum amount of a pollutant that can be present in the water body and have it still meet its water quality standards (U.S. EPA, nd).

When a TMDL is in place, a management plan must be developed to lead the water body toward meeting TMDL requirements. Once the plan has been implemented, the water body is monitored to determine whether it has reached attainment of the water quality standards. If not, the process is repeated and a new management plan is created to address the issue. If the water body has reached attainment, then antidegradation policies are developed and implemented to prevent any reduction in water quality (U.S. EPA, nd).

Managing Nonpoint Sources of Water Pollution

Unlike point sources of pollution, which are strictly managed and enforced through the NPDES program, the Clean Water Act does not contain any direct regulations for nonpoint sources of pollution, which includes any diffuse source of pollution not classified under the point source definition. Typical nonpoint sources of pollution include runoff from agricultural fields, residential lawns, and urban areas, which can cause nutrients, sediments, pathogens, toxins, and fertilizers to enter water bodies. Nonpoint sources contribute more pollution to the waters of the United States than point sources, but since these sources of pollution are not directly regulated, the effort to reduce them has focused on education and funding for best management practices (U.S. EPA, nd).

Section 319 of the Clean Water Act created a grant program that provides funding to states and tribes to address nonpoint source pollution. In order to receive grant funding, a management plan outlining the state’s plan to reduce nonpoint source pollution must be produced (U.S. EPA, nd). Due to the diffuse nature of nonpoint source pollution sources, in the late 1980s states began moving toward watershed-scale resource management. This watershed approach is holistic and includes all activities on the land area draining into the body of water. In this way, resource managers can be sure to account for all pollution sources affecting water quality. Additionally, a
watershed approach brings stakeholders into the process to create a group of citizens, business owners, and others who are invested in making positive changes in their watershed (U.S. EPA, 2008).

A watershed action plan is one way local resource managers can integrate all water quality issues and potential solutions in one cohesive document. The U.S. EPA has provided guidelines to help local planners achieve success in creating a watershed action plan. The first step is to assemble a group of stakeholders who are engaged in the process, because reducing nonpoint source pollution requires individuals to voluntarily change their behavior. Next, information about the watershed must be collected to inform the planning process. Once these data have been gathered, watershed planners and stakeholders can begin developing goals and an implementation program to achieve these goals. Once the plan is complete, it can be implemented, and since watershed action plans are adaptive, it can be adjusted as needed during the implementation process to meet unforeseen challenges (Ohio EPA, 1997).

**Applying the Watershed Approach to the Four Mile Creek Watershed**

The watershed approach is an adaptive method which can be applied to any watershed. In the Four Mile Creek watershed in southwestern Ohio and southeastern Indiana, this process is in the early stages of implementation. Neither a TMDL nor a watershed action plan exists to outline goals for water quality improvements. The remainder of this paper outlines a practicum project in which I helped create a watershed inventory as a junior project manager for a group of graduate students. The inventory advances the Four Mile Creek watershed in the water quality planning process and provides a starting point for a watershed action plan. In addition to the watershed inventory project, I also analyzed stream nutrient and discharge data in the same watershed to determine whether long term trends in nutrient levels related to storm events could be ascertained. The results of these efforts will aid resource managers in the reduction of pollutants in the Four Mile Creek watershed using a holistic watershed approach by providing a clearer picture of the resources in the watershed.
II. Four Mile Creek Watershed Inventory

This section of the paper discusses the process of creating a watershed inventory and my role as a junior project manager for one such project in which I was responsible for:

- Meeting with the project manager to collaborate on management decisions.
- Assisting the team through issues they encountered.
- Developing standards for geographic information science (GISci) metadata and data management.
- Evaluating the accuracy and quality of maps, text, and geospatial data.
- Proposing improvements to the report based on my evaluation.

Background of Master of Environmental Science Program

The Four Mile Creek watershed inventory was completed as a professional service project (PSP) by a group of six first-year master’s students in the Institute for the Environment and Sustainability (IES) at Miami University. All first-year students pursuing a Master of Environmental Science (M.En.) degree in the IES program must complete a PSP as part of a student group representing diverse undergraduate backgrounds. These projects utilize a problem solving process and the final reports provide solutions to environmental problems for real-world clients.

First, the student groups develop a project proposal and deliver it to the clients to demonstrate an understanding of the project goals and objectives. While engaged in the project, students are continually gathering data and consulting with Miami University faculty, researchers, and government officials to provide a thorough analysis and solution to their assigned environmental problem. Midway through the year, the students produce a poster of their project, publicly present their preliminary findings, and submit an interim report to the clients with a more detailed narrative of their progress. After further research and analysis, the groups produce final reports and publicly present their findings. The PSP provides students with experience in problem solving, collaboration, report writing, and public presentation while developing solutions for their clients.
In addition to completing a PSP, all IES graduate students must fulfill a professional experience requirement by completing an internship, practicum or thesis. A final written report and public presentation must be completed for each of the three professional experience options. Internships must be at least four months at a paid position, theses are traditional original research projects, and practicum projects involve developing solutions to an environmental problem much like a professional service project (IES, 2012). This report outlines my experiences during my practicum project in which I was the junior project manager for a watershed inventory and I explored stream pollutant data in the Four Mile Creek watershed.

Introduction to Watershed Inventories

A watershed inventory is an important document for managing water quality with the watershed approach, because it provides a detailed look at the water body in question and the natural and human features in its surrounding drainage area. Creating a watershed inventory involves gathering existing data about a watershed from many sources and then combining them into one cohesive document. Watershed inventories are important to resource managers because they provide data that can be used to identify potential sources of pollutants and then develop management strategies that use a holistic view of the watershed. This is often completed as an early step in the process of developing a watershed action plan.

One of the main challenges in creating a watershed inventory is identifying the necessary information and locating data sources, which may include federal, state, tribal, and local governments. The information gathered from these sources may be in the form of reports, lists, tables, maps, and geospatial data files. To facilitate the creation of a watershed inventory, resource managers use the *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (U.S. EPA, 2008). This document provides a detailed overview of the entire watershed action plan development process, including the creation of a watershed inventory. It lays out a framework for the required data, broken down into five major sections: physical and natural features, land use and population characteristics, water body and watershed conditions, pollutant sources, and water body monitoring data. The Ohio EPA (1997) produced a similar document called *A Guide to Developing Local Watershed Action Plans in Ohio*. This guide also
includes an appendix containing a watershed inventory template, which simplifies the process of developing a watershed inventory. An update to this appendix is available on the website for the Ohio Department of Natural Resources (Ohio DNR, 2005). The major data categories from this updated appendix are presented in Table 1 along with examples of data and the importance of each category of data for managing water resources.

Table 1: The components of a watershed inventory (Ohio DNR, 2005).

<table>
<thead>
<tr>
<th>Data Category</th>
<th>Examples</th>
<th>Value for Resource Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>Topography, soils, geologic and glacial history</td>
<td>Affect transport of water and pollutants in the watershed and influence the selection of best management practices.</td>
</tr>
<tr>
<td>Biological Features</td>
<td>Rare, threatened and endangered species; invasive nonnative species</td>
<td>Care must be taken to minimize impacts on sensitive species. Nonnative species can alter pollutant transport through land use changes.</td>
</tr>
<tr>
<td>Water Resources</td>
<td>Climate, precipitation, wetlands, streams, lakes, aquifers</td>
<td>Illustrates the amount of water in the watershed and its location. Wetlands and lakes can alter pollutant loads to streams.</td>
</tr>
<tr>
<td>Land Use</td>
<td>Land cover percentages, protected lands, land use trends</td>
<td>Used to identify nonpoint sources of pollution from fertilizers, chemicals and wastes associated with land use types.</td>
</tr>
<tr>
<td>Cultural Resources</td>
<td>Historically, culturally, or recreationally significant sites</td>
<td>Important sites may be given priorities in efforts to improve water quality.</td>
</tr>
<tr>
<td>Previous and Complementary Efforts</td>
<td>Management plans, TMDL, or other efforts to improve water quality</td>
<td>Watershed management is a holistic process and should incorporate all complimentary efforts.</td>
</tr>
<tr>
<td>Physical Attributes of Streams and Floodplains</td>
<td>Riparian buffers, dams, levees, channelization, and development trends</td>
<td>Stream alterations can change the volume and velocity of discharge in a stream, which can alter erosion patterns and pollutant transport.</td>
</tr>
<tr>
<td>Water Resource Quality</td>
<td>Designated use attainment, known sources of impairment, point sources and nonpoint sources of pollutants</td>
<td>Identifies known water quality issues and sources of pollutants to guide water resource management efforts.</td>
</tr>
</tbody>
</table>
Study Area: The Four Mile Creek Watershed

This report outlines the development of a watershed inventory for the Four Mile Creek watershed, which is located within four counties including Butler and Preble counties in Ohio and Union and Wayne counties in Indiana (Figure 1). Four Mile Creek originates in Preble County, Ohio and drains into the Great Miami River which in turn flows into the Ohio River. The watershed is 83,398 hectares (322 square miles) in area and the land use is approximately 53% cropland, 18% pasture or hay, 15% forest, 10% developed, and 4% other (Ohio EPA, 2013). The PSP watershed inventory characterized this watershed to provide resource managers with the information needed to improve water quality in Four Mile Creek.

Figure 1: Location of the Four Mile Creek watershed

Junior Project Manager Role

I helped complete the Four Mile Creek watershed inventory as a junior project manager for the PSP students as one component of my practicum project. This project was chosen because it provided experience in the field of water resources, my area of concentration. The head manager
for the project was Suzanne Zazycki, J.D., Project Coordinator for IES. As junior project
manager, I worked with Ms. Zazycki throughout the process from the initial planning stages
through the final report. My contributions to the project occurred during weekly one-on-one
meetings with Ms. Zazycki, weekly meetings with the PSP team, managing a subset of the team
working with geographic information systems (GIS), and creating maps for the team.

Development of the Four Mile Creek Watershed Inventory Project

Beginning in July 2012, I was involved in the process of developing the foundations for the PSP
project. The original idea was to complete a full watershed action plan for one of the watersheds
near Miami University. The Four Mile Creek watershed was chosen due to the research and data
that have been collected over more than fifteen years. Additionally, previous efforts toward
creating a watershed action plan had not materialized into a final product. Knowing that a
watershed action plan is a significant undertaking, it was decided that the entire watershed action
plan could span PSP projects over two years, with the first project in academic year 2012-2013
forming a group of community stakeholders and developing an early draft of the watershed
action plan.

Prior to the start of the 2012-2013 academic year, we consulted several experts were consulted to
formulate a broad plan for the PSP project. Dr. Donna McCollum, who worked closely with the
author of the action plan for the Twin Creek watershed in southwestern Ohio, provided general
guidance for the project. Additionally, Bob Lentz (Butler County Storm Water District) and
Kevin Fall and Lynn White (Butler County Soil and Water Conservation District) were asked to
serve as clients for the Four Mile Creek watershed action plan project. From the conversations
that resulted, it became clear that watershed action plans are long-term projects that can take as
long as a decade to complete. Watershed action plans involve many community stakeholders,
data collection, and a complete assessment of water quality issues in the watershed. Due to the
time constraints of a PSP, which must be completed in two semesters, the scope of the project
was reduced to only include the steps necessary to develop a watershed inventory. This would
still aid in the management of resources within the watershed and simplify the process of
creating a watershed action plan in the future.
After defining the scope of the Four Mile Creek PSP, Ms. Zazycki and I began in-depth research on the creation of a watershed inventory. We read the Ohio EPA (1997) and U.S. EPA (2008) guides to creating watershed action plans because as a manager and junior manager, we needed to have the background necessary to guide the PSP students. Additionally, we examined existing watershed action plans with inventories to find examples to share with the PSP team. Soon after the start of this literature review, the Fall 2012 semester began and the graduate students were assigned to PSP teams. The Four Mile Creek watershed inventory team consisted of first-year IES graduate students Allie Becknell, Justin Bedocs, Michelle Barrett, Jessica St. Pierre, Christine Rahtz, and Kristen Woodling.

Management Meetings

During the two semesters of the watershed inventory project, I participated in weekly management meetings with the PSP team and Ms. Zazycki. In addition to meetings with the team, Ms. Zazycki and I met separately each week to discuss the team’s progress and identify guidance the team needed.

At the meetings with Ms. Zazycki, we collaborated to provide the best management possible for the PSP team. Since neither of us had experience developing a watershed inventory, we each researched the process and then compared our findings. With my assistance, Ms. Zazycki was better prepared to guide the PSP team than if she had to conduct all of the background research on her own. Also in these meetings, Ms. Zazycki and I developed weekly plans for the project including contacts each of us would make with the PSP team and agendas for team meetings.

In management meetings with the PSP team, Ms. Zazycki and I led the PSP team through the process of creating a watershed inventory. In the beginning of the project, we introduced them to the watershed inventory process by assigning readings from the watershed action plan guides and watershed inventories that Ms. Zazycki and I had already reviewed. Then, throughout the project we received updates on the team’s work and ensured that they were making adequate progress to complete the inventory within two semesters. Ms. Zazycki and I also helped answer questions that arose during the project including issues regarding the overall scope of the project, research, report writing, and presentations.
Aside from management meetings, I helped manage the PSP team through emails and work sessions to help them resolve any issues they were experiencing. I provided help with all aspects of the watershed inventory, but I came to the project with particular expertise with GIS, so my role gravitated toward that part of the process. The next section of this paper focuses on my oversight of the GIS aspects of the Four Mile Creek watershed inventory.

**GIS Manager Role**

Early in the watershed inventory project, I began organizing the efforts to use GIS for the creation of maps and calculating land cover percentages. GIS theories and techniques provide a framework for managing geospatial data using computer hardware and software. The software used during this project was ArcGIS (versions 10 and 10.1).

As head of the GIS aspects of the Four Mile Creek watershed inventory, I was involved in creating maps, helping the team find geospatial data, and ensuring best practices for high quality maps and accompanying metadata, or detailed information describing the geospatial data. I also helped Ms. Zazycki manage the inventory project by maintaining contact with the team members working on GIS and updating her on their progress. Early in the project, I began downloading geospatial data and creating maps for the team including a large poster to use as a reference throughout the project. Later, I adapted the large poster-sized map for use on the poster created by the PSP team to summarize their project at the time of the interim progress report. I also helped with the land use section of the inventory by creating maps and calculating percentages of land use types in the watershed. At this early stage, I independently gathered GIS data and created maps for the team.

Later in the first semester of the project, the entire PSP team became involved in the GIS process. Since most team members did not have previous GIS experience, I helped them understand what to look for when downloading GIS data to use in this project. I created and distributed a one-page handout that outlined the basics of GIS data and how to find it (Appendix A). Additionally, during a management meeting I walked the team through the process of finding GIS data sources using Ohio’s Earth Resources Information Network (ERIN; Ohio DNR, 2013).
This website summarized Ohio natural resource information and provided links to much of the data we needed for the watershed inventory. With these tools, the team began acquiring data that was then used to create maps and perform geospatial analyses.

I also guided the team through a review of other watershed inventories and watershed action plans to find the best examples of map making and GIS utilization. We found that many inventories had very few maps and most information was only presented through text and tables. However, a few watershed action plans had exceptional maps that were used as models for our own mapping goals. The Tinkers Creek watershed action plan (McNutt et al., 2010) was an example of one such document, and we printed and displayed maps from this plan as visual reminders of what we were striving to create.

During the first semester of the project, I began working closely with Justin Bedocs and Michelle Barrett, who each had some previous GIS experience. The three of us worked cooperatively to create maps for the remainder of the project. I developed some practices to ensure that the maps we produced were uniform and met the team’s needs. First, I encouraged Justin and Michelle to develop templates for maps at all sizes and for all geographic areas that would be used in the report. This created a uniform look between maps and streamlined map making because the person creating a map only needed to add the necessary data and edit a small amount of text to create a title and list the map author and data source. We also worked with the rest of the PSP team to develop, and constantly update, a list of maps needed for the project. Ranking them according to priority increased our efficiency by focusing on completing the most important maps while saving the others for a later date. This list was also used to indicate who was working on a map to prevent multiple people from working on the same map.

We knew that the team would be providing the GIS data files to their clients along with their final watershed inventory report, so I continually reminded Justin and Michelle about the importance of quality metadata. In the handout I created for the team about acquiring geospatial data (Appendix A), I included a section about generating some basic metadata about the files such as data source, data creator, and acquisition date. I also provided a link to an ArcGIS Resource Center page describing the basics of editing metadata in ArcGIS to help familiarize
them with the process (ArcGIS Resource Center, 2011). Toward the end of the project, I checked that all GIS data delivered to the clients contained complete metadata.

As the watershed inventory neared completion and preliminary drafts were prepared for review by Ms. Zazycki, PSP team members became more focused on writing. As such, I took on a more prominent role in map creation. Ms. Zazycki also asked me to review the maps that were previously been made for the inventory to verify their accuracy and that the data had been properly cited. I then consulted with Justin and Michelle to be sure we were providing high quality maps to the clients. The final maps produced from these GIS efforts are presented in Appendix B.

**My Junior Project Manager Role as a Learning Experience**

Serving as a junior project manager was a learning experience that will improve my ability to perform as an environmental professional in the future. I gained experience in aspects of management such as setting agendas, running meetings, delegating work, evaluating progress, and suggesting courses of action to meet deadlines. These aspects of my practicum experience will be valuable for any professional position I may acquire.

Prior to this project, I had the opportunity to run meetings as a member of a team but not in a formal leadership role. There are subtle differences between the two because as a formal manager, the team is looking to you for guidance and direction whereas a fellow teammate would probably not have those same expectations. When I ran meetings with the PSP team, Ms. Zazycki was in the room contributing as well. However, I regularly held meetings with only Justin and Michelle to discuss the GIS components of the project. Through this project I learned the value of having a well-planned agenda prior to the beginning of a meeting. An agenda keeps the meeting on track and ensures that all necessary topics will be discussed. In the past I have run meetings with very few notes prepared in advance, but now I recognize the importance of meeting agendas.

In many meetings I was involved in delegating work to members of the team. This aspect of a
team project was new to me since I had never had a managerial position. I typically enjoy volunteering for work to move the project along and thus complete it within the necessary timeframe. However, as a junior project manager I learned to assign tasks to others instead of completing them myself. With guidance from Ms. Zazycki, I had to assess the skills of the team members and delegate tasks accordingly. This primarily occurred during my GIS work with Justin and Michelle. Through delegating work to the PSP team members, this project has taught me to recognize the capabilities of others in a team and allow them to do their work while I perform my own duties.

The final major learning experience from this project was diligent progress evaluation. During most meetings with Ms. Zazycki, we discussed how the team was proceeding with each step of the watershed inventory process and determined if the project was on schedule. When the team lagged behind the expected schedule, Ms. Zazycki and I discussed ways in which the project could be brought back on schedule. Successful strategies included reminding team members to submit their work on a section of the report, delegating extra work at the next PSP meeting, or by having me assist the team with some of the GIS work to free them up for other work. Keeping the project on schedule was an important management responsibility which helped the team complete its final report on time.
III. Exploring Water Quality Data from the Four Mile Creek Watershed

This section of the paper discusses the process of exploring long-term water quality data from the Four Mile Creek Watershed. I describe the importance of this information in guiding future research assessing yearly and seasonal water quality trends.

Introduction

Excess sediments and nutrients are among the primary reasons for water quality impairment in Ohio’s lakes and streams (U.S. EPA, 2013). Suspended sediments enter a water body from terrestrial and stream erosion. Once suspended in the water, the sediment will negatively impact water quality by absorbing light, which reduces the light available for organisms and simultaneously increases the temperature of the water above natural levels. When sediments settle, they may fill in and destroy the benthic habitats of many riverine and lacustrine organisms (NOAA, nd). Nutrients also enter aquatic systems from terrestrial sources and those of primary concern in water quality management are nitrogen and phosphorus. Algae exposed to increased levels of nitrogen and phosphorus can become exceedingly productive and cause eutrophic conditions. As the algal cells are decomposed, oxygen is removed from the water which can lead to anoxic conditions and fish kills (U.S. EPA, 1998). The combined effects of sediments and nutrients are responsible for the majority of water quality issues in the state of Ohio (U.S. EPA, 2013).

The amount of sediments and nutrients entering aquatic systems differs between normal baseflow conditions and stormflow events. Previous research in the Four Mile Creek watershed showed that the majority of yearly sediments, nitrogen, and phosphorus are transported during storm events (Vanni et al., 2001). However, that research only examined loading from storm events during a one-year period. Since watersheds are dynamic, the influences of natural and anthropogenic systems are continually changing. Therefore, this report involves an examination of 18 years of data in the Four Mile Creek watershed to explore potential long-term trends in the proportion of sediments, nitrogen, and phosphorus entering the streams during baseflow and stormflow.
**Study Site**

Water samples were taken from three streams in the Four Mile Creek Watershed in southwestern Ohio: Four Mile Creek, Little Four Mile Creek, and Marshall’s Branch (Figure 2). These subwatersheds draining to each sampling point are 12,875 hectares, 7,968 hectares, and 1,206 hectares, respectively.

![Figure 2: Monitoring sites and their watersheds](image)

**Methods**

Stream discharge and nutrient load measurements were acquired from Drs. Vanni and Renwick at Miami University. Stream data were recorded using gaging stations at each sampling point as described by Vanni et al. (2001). Stream stage was recorded at 10-minute intervals and converted to discharge using rating-curve techniques. Concentrations of ammonium (NH₄), nitrate (NO₃), soluble reactive phosphorus, and suspended sediments were quantified from water samples collected with ISCO programmable pumping samplers. These samples were collected at 2-6 hour
intervals during storm events and approximately daily during baseflow conditions. Once these samples were analyzed, the data were interpolated to produce hourly values. These hourly values were then summed to produce total daily discharges and loads which were used in this report.

Using the daily discharge and data from the three sampling sites, the amount of discharge from baseflow was calculated using the smoothed-minima technique developed by Gustard et al. (1992), as described by Jordan et al. (1997). The steps for calculating the baseflow portion of discharge are as follows:

- Daily discharge values were divided into non-overlapping blocks of five days and the minimum for each block was determined.
- The minimum was considered baseflow if 0.9 times the minimum was less than the minima of the previous and next blocks.
- Daily baseflow values were then linearly interpolated between the minima considered as baseflow.
- If the interpolated values were greater than the measured discharge, then the measured discharge was used for baseflow discharge.

This technique was previously used by Vanni et al. (2001) on one year of the Four Mile Creek watershed data, but for this report it was applied to the entire dataset from 1994 to 2011 using spreadsheet methods developed by Leslie Knoll of Miami University. Next, ammonium, nitrate, soluble reactive phosphorus, and suspended sediment loads from the separated baseflow and stormflow were calculated using the method described in Vanni et al. (2001). Baseflow concentrations during storm events were linearly interpolated from concentrations during baseflow conditions—days in which discharge was at least 80% baseflow. Daily load from baseflow was then calculated by multiplying the baseflow discharge by the baseflow concentration. Daily load from stormflow was calculated by subtracting the baseflow load from the measured load.
Results

A summary of the baseflow and stormflow loading results for Four Mile Creek, Little Four Mile Creek, and Marshall’s Branch are presented in Table 2 which indicates that stormflow contributes the majority of each pollutant in all watersheds.

Table 2: Summary of stormflow and baseflow loading results for 1994-2011.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Four Mile Creek</th>
<th>Little Four Mile Creek</th>
<th>Marshall's Branch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge (m³/second)</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>Ammonium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseflow loading (kg/day)</td>
<td>2.38</td>
<td>4.61</td>
<td>3.37</td>
</tr>
<tr>
<td>Stormflow loading (kg/day)</td>
<td>13.19</td>
<td>61.33</td>
<td>6.64</td>
</tr>
<tr>
<td>Nitrate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseflow loading (kg/day)</td>
<td>209.04</td>
<td>318.53</td>
<td>293.33</td>
</tr>
<tr>
<td>Stormflow loading (kg/day)</td>
<td>720.00</td>
<td>2391.90</td>
<td>560.44</td>
</tr>
<tr>
<td>Soluble Reactive Phosphorus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseflow loading (kg/day)</td>
<td>0.76</td>
<td>1.56</td>
<td>0.89</td>
</tr>
<tr>
<td>Stormflow loading (kg/day)</td>
<td>18.94</td>
<td>126.25</td>
<td>5.54</td>
</tr>
<tr>
<td>Suspended Sediments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseflow loading (kg/day)</td>
<td>1712.97</td>
<td>9340.72</td>
<td>1235.79</td>
</tr>
<tr>
<td>Stormflow loading (kg/day)</td>
<td>18273.26</td>
<td>129177.66</td>
<td>8323.33</td>
</tr>
</tbody>
</table>

Statistical analyses were beyond the scope of this project, but the yearly baseflow and stormflow loads were plotted to allow for the visual examination of potential long-term trends in the data. Additionally, monthly averages were plotted to examine seasonality in the data. The resulting graphs can help guide future research on this dataset (Appendix C). I analyzed three sets of graphs which show apparent patterns (Figures 3, 4, 5). Figure 3b appears to show a decreasing trend in the proportion of ammonium from baseflow in Four Mile Creek from 1994 to 2005, then increasing through 2011. Figure 4b shows that the proportion of soluble reactive phosphorus from baseflow in Little Four Mile Creek was consistently less than 15% between 1994 and 2006 and then abruptly increased to over 30% for three consecutive years. Figure 5b indicates a potential decreasing trend in the proportion of nitrate from baseflow in Marshall’s Branch over the entire study period.
Figure 3: Four Mile Creek NH$_4$ data averaged per year: (a) average NH$_4$ load from baseflow and stormflow, (b) percentage of NH$_4$ load from baseflow, (c) total precipitation and average stream discharge.
Figure 4: Little Four Mile Creek SRP data averaged per year: (a) average SRP load from baseflow and stormflow, (b) percentage of SRP load from baseflow, (c) total precipitation and average stream discharge.
Figure 5: Marshall's Branch NO₃ data averaged per year: (a) average NO₃ load from baseflow and stormflow, (b) percentage of NO₃ load from baseflow, (c) total precipitation and average stream discharge.
Discussion

Baseflow and Stormflow Loading

The proportion of ammonium from baseflow in Four Mile Creek appears to decrease from 1994 to 2005 and then increase again through 2011 (Figure 3). This appears to be negatively associated with the total discharge in Four Mile Creek during those periods, indicating that the increasing discharge is primarily in the form of stormflow. Further supporting this hypothesis, the total discharge begins to decrease in 2007 and the proportion of ammonium from baseflow increases.

Unlike the previous data, the abrupt increase in the proportion of soluble reactive phosphorus from baseflow in Little Four Mile Creek during the period between 2007 and 2010 does not appear to be related to total discharge (Figure 4). Since total precipitation does not appear to be anomalous during that period, one explanation for the increase in the baseflow proportion is that the storms during those months may have been less intense and more evenly distributed through the years. As a result, the estimated average baseflow would increase using the smoothed minima technique and thus the proportion of soluble reactive phosphorus attributed to baseflow would also increase.

In Marshall’s Branch, the proportion of nitrate from baseflow appears to have a decreasing trend over the entire study period (Figure 5). As with the ammonium in Four Mile Creek, this appears to be negatively associated with the total discharge in the stream. Discharge appears to have a positive trend over the entire study period.

Although statistical analyses were beyond the scope of this paper, future research on these data should employ an autoregressive moving average (ARIMA) model to isolate trends due to discharge and trends independent of discharge. This method has been used successfully on data from this watershed to uncover trends masked by the strong correlations between loading and discharge (Renwick et al., 2008). Additionally, seasonal trends may be found using Fourier
analysis with discharge as a covariate due to the apparent correlation between load and discharge in the data.

**Potential Drivers of Trends**

Due to a lack of statistical testing and apparent correlations with discharge, it is difficult to ascertain long-term trends and their potential drivers. This section presents some drivers of trends that can be explored in future research on these data.

Previous research with a subset of these data from 1994 to 2006 found significant declines in mean monthly concentrations of ammonium and soluble reactive phosphorus in Four Mile Creek, ammonium and suspended sediments in Little Four Mile Creek, and ammonium, nitrate, and soluble reactive phosphorus in Marshall’s Branch. These reductions are consistent with increases in conservation tillage, agricultural nutrient management, and consolidation of livestock production in the watershed (Renwick et al., 2008). This correlation between an increase in conservation agricultural practices and declining sediments and nutrients can be explored further due to a larger dataset and separations into baseflow and stormflow.

Potential trends in the proportions of load from baseflow and stormflow may reveal effects of climate change on the hydrologic cycle in the watersheds. The global temperature is rising and the mean yearly temperature in southwest Ohio is projected to increase 5-10° Fahrenheit by the end of the century (Karl et al., 2009). Concurrently, precipitation is projected to increase by 15% in winter and spring months, but decrease by 10% in the summer (Karl et al., 2009). The combination of an increase in evapotranspiration rates due to increased temperature and a decrease in summer precipitation may reduce the discharge in these three streams during the summer. Currently, summer months deliver the lowest seasonal loads in the Four Mile Creek, Little Four Mile Creek, and Marshall’s Branch watersheds, so this reduction in discharge may not have drastic effects on overall loads. However, winter and spring months contribute the highest loads of sediments and nutrients and this may increase as winter and spring precipitation increase. A projected 31% increase in very heavy rains in southwest Ohio (Karl et al., 2009) may alter the percentage of load from stormflow by causing more dramatic runoff erosion during these high volume storm events.
Currently, it is unknown whether significant long-term trends in sediment and nutrient loading from baseflow and stormflow will be found within the Four Mile Creek watershed. Potential drivers of trends could be evolving agricultural practices, a warmer climate, and changing precipitation patterns.
IV. Project Summary

For this practicum project, I was the junior project manager for a team of graduate students developing a watershed inventory for the Four Mile Creek watershed in southwestern Ohio and southeastern Indiana. I provided overall management support to the team, with a special focus on the development of maps and geospatial data management. In this managerial role, I learned to develop agendas, run meetings, and evaluate the progress of the project and suggest changes as needed.

In addition to managing the inventory project, I used stream discharge, sediment, and nutrient data from the same watershed to analyze the portions of loading entering the streams through baseflow and stormflow. Not only can this help guide future research in the watershed, but it also allowed me to gain valuable experience with data management and analysis.

This project has been an asset to my growth as an environmental scientist for several reasons. First, it supported my concentration of water resources through a direct application of the watershed approach to improving water quality that is used by real-world resource managers. Second, I developed managerial skills that can be applied in any environmental career. Third, environmental scientists must be familiar with data analysis techniques and my work with the stream data has demonstrated my data analysis capabilities. Finally, this practicum integrated my entire Master of Environmental Science education into one project because I relied upon my knowledge of the problem solving process and the principles of hydrology, limnology, hydrogeology, ecology, and statistics I learned in the Institute for the Environment and Sustainability at Miami University.
References


Ohio DNR (Ohio Department of Natural Resources). 2005. Appendix 8 Update.


Appendix A: GIS Data Handout

I produced this handout on gathering GIS data and provided it to the PSP team near the beginning of the watershed inventory project.

Four Mile Creek Inventory: Downloading GIS Information

- Start with OhioERIN.com and compare available data with the categories in Appendix A.
  - Click “The Data” then “STATEWIDE DATA” then the category you want.
  - Follow links that say “Link:” or “For more information”
  - You may still have to search around on the website it links you to in order to find the data you want.
- Also, check some watershed action plans to see where they got data.
  - If all WAPs use the same source, it’s probably the best source.
- If you get data from an Ohio government website, you will then have to find the same data on an Indiana website.

What are you looking for?

- **Tables** (.dbf, .csv, .xls, etc.)
  - These will contain data that can be used either as tables in the report or combined with spatial files to create maps.
- **Vector spatial files** (.e00 or .shp)
  - These will be points, lines, or polygons of spatial features.
- **Raster spatial files** (.tif, .sid, or other “image” file types)
  - These will be files with pixels coded to specific information. An example would be the land cover data on the large poster we have.
- **Metadata**
  - This will tell us how the data were made, who made it, when it was made, etc.
  - Very important! If they have metadata for a file you’re downloading, download it!
- Overall, get whatever they have! If they have spatial files and tables and metadata, get it all!

Once you’ve got the data...

- Save it to the PSP folder on the network drive.
- Create a Word document and save it in the same location as the GIS files.
  - Include: date you downloaded it, where you got it, who made it, when it was made, and any other information possible.
- Look around the site for explanations of the data which will help in explaining it in the report. Save anything that seems relevant.

Figure 6: GIS data handout
Appendix B: Watershed Inventory Maps

This appendix includes all maps produced for the Four Mile Creek watershed inventory in the order they are presented in the watershed inventory. As the manager of the GIS component of the project, I provided the team with the support they needed to produce high-quality maps while also contributing to the map-making process.
Figure 7: The original poster I made for the Four Mile Creek inventory project.
Figure 8: Subwatershed Map
Figure 9: Topography map
Four Mile Creek Watershed
Soils: Flood Frequency
Under Dominant Conditions

Legend
- Stream
- Acton Lake, Water Body

Soils
- Flood Frequency
  - Frequent
  - Occasional
  - None

Figure 10: Flood frequency map
Figure 11: Hydric soils map
Figure 12: Potential erosion hazard map
Figure 13: Runoff potential map
Figure 14: Slope map
Figure 15: Hydrologic soils map
Figure 16: Wetland suitability map
Figure 17: Bedrock map
Figure 18: Glacial deposits map
Figure 19: Wetlands and deepwater habitat map
Figure 20: Named streams map
Figure 21: Consolidated aquifer map
Figure 22: Indiana unconsolidated aquifer map
Figure 23: Ohio unconsolidated aquifer map
Figure 24: DRASTIC map

Legend
- Water Body
- Stream
- Watershed Boundary

Ground Water Pollution Potential
- 0
- 1 - 101
- 102 - 124
- 125 - 157
- 158 - 211

Four Mile Creek Watershed Ohio DRASTIC Map

Created by Michelle Barrett, March 21, 2013
Data Source: ODNR
Data Published: 8/6/1995
Figure 25: Crop type map
Figure 26: Acton Lake watershed land use/land cover map
Figure 27: Cotton Run watershed land use/land cover map
Figure 28: East Fork watershed land use/land cover map
Figure 29: Four Mile Creek Headwaters watershed land use/land cover map
Figure 30: Little Four Mile Creek watershed land use/land cover map
Figure 31: NPDES permit locations map
Appendix C: Baseflow and Stormflow Loading Graphs

This appendix contains graphs based on the sediment and nutrient loading in baseflow and stormflow for the Four Mile Creek, Little Four Mile Creek, and Marshall’s Branch subwatersheds within the larger Four Mile Creek Watershed.

Figure 32: Monitoring sites and their watersheds.
Four Mile Creek – Ammonium (NH$_4$) Yearly Data

Figure 33: Four Mile Creek NH$_4$ data averaged per year: (a) average NH$_4$ load from baseflow and stormflow, (b) percentage of NH$_4$ load from baseflow, (c) total precipitation and average stream discharge.
Figure 34: Four Mile Creek NH$_4$ data averaged per month: (a) average NH$_4$ load from baseflow and stormflow, (b) percentage of NH$_4$ load from baseflow, (c) average precipitation and average stream discharge.
Figure 35: Four Mile Creek NO₃ data averaged per year: (a) average NO₃ load from baseflow and stormflow, (b) percentage of NO₃ load from baseflow, (c) total precipitation and average stream discharge.
Four Mile Creek – Nitrate (NO₃) Monthly Data

![Graphs showing average NO₃ load from baseflow and stormflow, percentage of NO₃ load from baseflow, and average precipitation and stream discharge.]

Figure 36: Four Mile Creek NO₃ data averaged per month: (a) average NO₃ load from baseflow and stormflow, (b) percentage of NO₃ load from baseflow, (c) average precipitation and average stream discharge.
Four Mile Creek – Soluble Reactive Phosphorus (SRP) Yearly Data

Figure 37: Four Mile Creek SRP data averaged per year: (a) average SRP load from baseflow and stormflow, (b) percentage of SRP load from baseflow, (c) total precipitation and average stream discharge.
Figure 38: Four Mile Creek SRP data averaged per month: (a) average SRP load from baseflow and stormflow, (b) percentage of SRP load from baseflow, (c) average precipitation and average stream discharge.
Four Mile Creek – Suspended Sediment (SS) Yearly Data

Figure 39: Four Mile Creek SS data averaged per year: (a) average SS load from baseflow and stormflow, (b) percentage of SS load from baseflow, (c) total precipitation and average stream discharge.
Four Mile Creek – Suspended Sediment (SS) Monthly Data

(a) Mean SS Load (kg/day)

(b) Percent of total SS Load

(c) Average precipitation and average stream discharge.

Figure 40: Four Mile Creek SS data averaged per month: (a) average SS load from baseflow and stormflow, (b) percentage of SS load from baseflow, (c) average precipitation and average stream discharge.
Little Four Mile Creek – Ammonium (NH₄) Yearly Data

Figure 41: Little Four Mile Creek NH₄ data averaged per year: (a) average NH₄ load from baseflow and stormflow, (b) percentage of NH₄ load from baseflow, (c) total precipitation and average stream discharge.
Little Four Mile Creek – Ammonium (NH₄) Monthly Data

Figure 42: Little Four Mile Creek NH₄ data averaged per month: (a) average NH₄ load from baseflow and stormflow, (b) percentage of NH₄ load from baseflow, (c) average precipitation and average stream discharge.
Figure 43: Little Four Mile Creek NO$_3$ data averaged per year: (a) average NO$_3$ load from baseflow and stormflow, (b) percentage of NO$_3$ load from baseflow, (c) total precipitation and average stream discharge.
Little Four Mile Creek – Nitrate (NO₃) Monthly Data

(a) Mean NO₃ Load (kg/day)

(b) Percent of total NO₃ Load

(c) Mean Monthly Precipitation and Discharge

Figure 44: Little Four Mile Creek NO₃ data averaged per month: (a) average NO₃ load from baseflow and stormflow, (b) percentage of NO₃ load from baseflow, (c) average precipitation and average stream discharge.
Figure 45: Little Four Mile Creek SRP data averaged per year: (a) average SRP load from baseflow and stormflow, (b) percentage of SRP load from baseflow, (c) total precipitation and average stream discharge.
Figure 46: Little Four Mile Creek SRP data averaged per month: (a) average SRP load from baseflow and stormflow, (b) percentage of SRP load from baseflow, (c) average precipitation and average stream discharge.
Figure 47: Little Four Mile Creek SS data averaged per year: (a) average SS load from baseflow and stormflow, (b) percentage of SS load from baseflow, (c) total precipitation and average stream discharge.
Figure 48: Little Four Mile Creek SS data averaged per month: (a) average SS load from baseflow and stormflow, (b) percentage of SS load from baseflow, (c) average precipitation and average stream discharge.
Marshall’s Branch – Ammonium (NH$_4$) Yearly Data

Figure 49: Marshall's Branch NH$_4$ data averaged per year: (a) average NH$_4$ load from baseflow and stormflow, (b) percentage of NH$_4$ load from baseflow, (c) total precipitation and average stream discharge.
Marshall’s Branch – Ammonium (NH$_4$) Monthly Data

Figure 50: Marshall’s Branch NH$_4$ data averaged per month: (a) average NH$_4$ load from baseflow and stormflow, (b) percentage of NH$_4$ load from baseflow, (c) average precipitation and average stream discharge.
Marshall’s Branch – Nitrate (NO$_3$) Yearly Data

Figure 51: Marshall’s Branch NO$_3$ data averaged per year: (a) average NO$_3$ load from baseflow and stormflow, (b) percentage of NO$_3$ load from baseflow, (c) total precipitation and average stream discharge.
Marshall’s Branch – Nitrate (NO$_3$) Monthly Data

Figure 52: Marshall’s Branch NO$_3$ data averaged per month: (a) average NO$_3$ load from baseflow and stormflow, (b) percentage of NO$_3$ load from baseflow, (c) average precipitation and average stream discharge.
Marshall’s Branch – Soluble Reactive Phosphorus (SRP) Yearly Data

Figure 53: Marshall’s Branch SRP data averaged per year: (a) average SRP load from baseflow and stormflow, (b) percentage of SRP load from baseflow, (c) total precipitation and average stream discharge.
Marshall’s Branch – Soluble Reactive Phosphorus (SRP) Monthly Data

Figure 54: Marshall’s Branch SRP data averaged per month: (a) average SRP load from baseflow and stormflow, (b) percentage of SRP load from baseflow, (c) average precipitation and average stream discharge.
Marshall’s Branch – Suspended Sediment (SS) Yearly Data

Figure 55: Marshall’s Branch SS data averaged per year: (a) average SS load from baseflow and stormflow, (b) percentage of SS load from baseflow, (c) total precipitation and average stream discharge.
Marshall’s Branch – Suspended Sediment (SS) Monthly Data

Figure 56: Marshall’s Branch SS data averaged per month: (a) average SS load from baseflow and stormflow, (b) percentage of SS load from baseflow, (c) average precipitation and average stream discharge.