TEMPORAL ASSESSMENT OF MANAGEMENT PRACTICES AND WATER QUALITY IN THE DUCK CREEK WATERSHED, WISCONSIN.

Daniel A. Cibulka

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This one is for you, Mom.

ABSTRACT

TEMPORAL ASSESSMENT OF MANAGEMENT PRACTICES AND WATER QUALITY IN THE DUCK CREEK WATERSHED, WISCONSIN.

Daniel A. Cibulka

The Duck Creek watershed has degraded water quality due to non-point source pollution from agricultural lands within the basin. Through federal, state, and local non-point source control programs, Brown County, Outagamie County, and the Oneida Tribe of Indians have implemented various land management changes aimed at improving the water quality within the Duck Creek watershed. In addition, changes in land ownership and related management have occurred. In this study, a 20-year record of flow and phosphorus concentration data, fish and macroinvertebrate surveys and changes in land management were assembled from numerous entities. Using this fairly robust data set, changes in land management, water quality and biotic conditions were characterized in the Duck Creek watershed and the relationship between these changes were explored. Linear regression and other statistical techniques were applied to detect possible trends and relationships between watershed metrics. During the 20-year record, dairy farms, barnyards, and permitted point source discharges decreased while the prevalence of conservation tillage and cropland nutrient management increased. There was a statistically significant decrease in total and dissolved phosphorus concentrations from water year 1989 through 1995 (Period 1). There was also a significant decrease in total phosphorus and dissolved phosphorus concentrations from Period 1 to Period 3 (water years 2004-2008). Fish assemblages displayed a change in community health in multiple areas of the watershed through increasing abundance, increasing diversity, and increasing members of sensitive species. The macroinvertebrate dataset had several limitations therefore no trends were determined. Observed trends in phosphorus concentrations and fish biotic integrity are likely linked to improved management practices and changes in land use.

Trout Creek, a major tributary to Duck Creek, has received focused watershed management efforts in recent years. In 2008, a water quality monitoring study was conducted to characterize physical and chemical water quality conditions in Trout Creek. Phosphorus concentrations exceeded 0.1 mg/l in about half of the samples and were greater in an upstream location. Automated multi-probe monitoring indicated that the stream has characteristics similar to that of a cool-water stream and conditions suitable for species such as Brook Trout.

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Area of Concern (AOC)

Best Management Practice (BMP)

Brown County Land Conservation Department (BCLCD)

Clean Water Act (CWA)

Conservation Technology Information Center (CTIC)

Department of Agriculture and Trade and Consumer Protection (DATCP)

Dissolved Oxygen (DO)

Dissolved Phosphorus (DP)

Environmental Protection Agency (EPA)

Ephemeroptera, Plecoptera, Trichoptera Index (EPT)

Five-day Biological Oxygen Demand (BOD5)

Freedom Sanitary District #1 (FSD#1)

Lower Fox River Watershed Monitoring Program (LFRWMP)

Global Positioning Unit (GPS)

Green Bay Metropolitan Sewerage District (GBMSD)

Hilsenhoff Biotic Index (HBI)

Index of Biological Integrity (IBI)

National Pollutant Discharge Elimination System (NPDES)

National Weather Service (NWS)

Natural Resources Conservation Service (NRCS)

Outagamie County Land Conservation Department (OCLCD)

Oneida Tribe of Indians (OTI)

Program on Agricultural Technology Studies (PATS)

Suspended Solids Concentration (SSC)

Total Maximum Daily Load (TMDL)

Total Phosphorus (TP)

Total Suspended Solids (TSS)

Water and Sediment Control Basin (WASCOB)

Wisconsin Department of Natural Resources (WDNR)

United States Census Bureau (USCB)

United States Geological Survey (USGS)

United States Fish and Wildlife Service (UWFWS)

CHAPTER 1 - INTRODUCTION AND BACKGROUND

Introduction

The Duck Creek watershed drains approximately 393 km^2 of Brown (33%) and Outagamie (67%) counties in northeastern Wisconsin. Duck Creek is classified as a fifth-order, intermittent, warmwater stream. The headwaters of Duck Creek originate approximately 4 km south of Seymour, Wisconsin in an area known as Burma Swamp. From here, the stream flows 93 km until it eventually spills into the Bay of Green Bay. Seven subwatersheds comprise the Duck Creek watershed: Beaver Dam, Fish Creek, Lancaster Brook, Silver Creek, Oneida Creek, Trout Creek and one unnamed system. The tributary watersheds of Duck Creek total roughly 184 km^2, and several of these tributaries are classified as cold-water perennial streams. Many of the tributaries and a large portion of mainstem Duck Creek meanders through the Oneida Indian Reservation, which straddles the boundary of Brown and Outagamie counties. The watershed makes up a portion of the larger Lower Fox River Basin. The Lower Fox River drains a 1,654 km^2 basin and is the Bay of Green Bay's largest tributary (Figure 1.1).

According to 2005 land use data provided by the Lower Fox River Watershed Monitoring Program (LFRWMP), the Duck Creek watershed is predominately agricultural (55.3%) with urban / developed land (18.8%), forested land (13%) and wetlands (8.5%) comprising significant parts of the watershed as well.

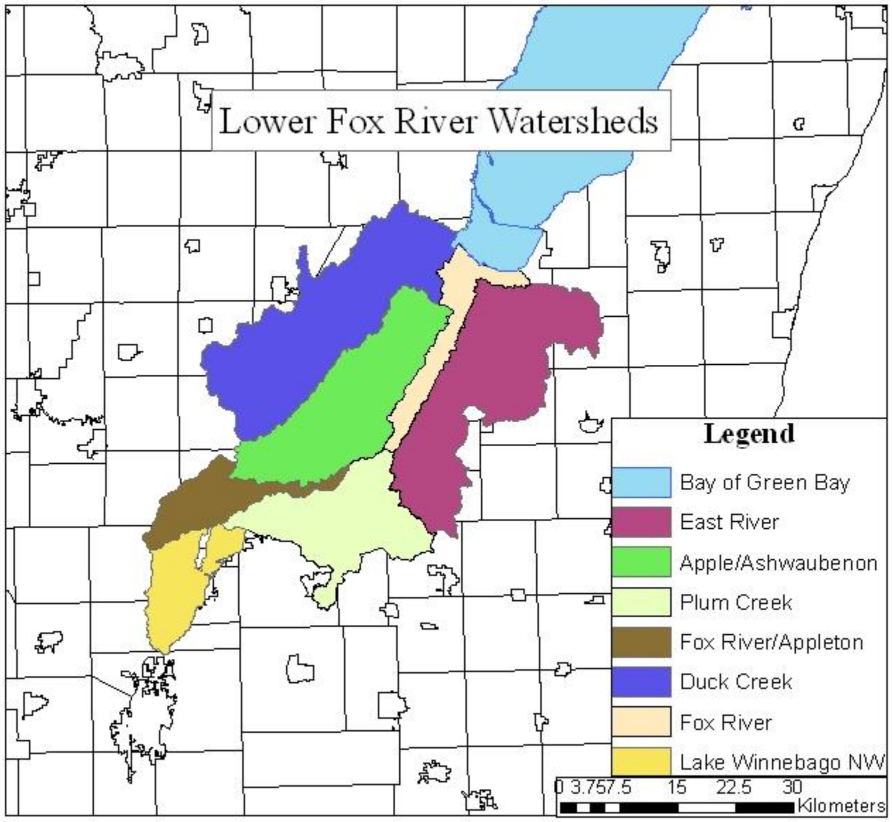

Figure 1.1: Sub-watersheds, including Duck Creek, within the Lower Fox River Basin.

Geology and Soils

Underlying the Duck Creek watershed is the Galena formation of the Sinnipee limestone group. This rock group originates from the latter part of the Paleozoic Era (600 million years ago) and consists of a dolomitic limestone layer, with some chert and shale. The Sinnipee Group is one of several sedimentary and Precambrian rock groups that tilt towards the east at about 30 to 40 ft/mi. (Batten and Bradbury, 1996). Once thought to be impermeable, more recent information indicates that the Sinnipee Dolomite allows water from Duck Creek to flow into underlying sedimentary layers that contain the water table (written communication, USGS, 1991).

Glaciation has had a profound effect on both the topography and the surface drainage patterns in the watershed. Quaternary glacial till deposits that are 50 to 200 ft deep, overlie the Sinnipee Group (Batten and Bradbury, 1996). The most recent of four glacial advancements, the Wisconsin stage, occurred from 25,000 to 10,000 years ago (Clayton et al., 2006). The first major substage of the Wisconsin advancement, the Cary ice sheet, melted to form present-day Lake Winnebago. As it melted the Cary ice sheet deposited large quantities of sand in the northern portion of the watershed, near the confluence of Duck and Trout Creeks. Years after the Cary ice sheet retreated, the Valders substage occurred. This ice sheet did little to change the existing topography, but did leave significant deposits of red clay till in the southern and middle portions of the watershed (WDNR, 1997). As a result, the soils in the upstream (south-west) portions of the watershed are comprised of fertile reddish-brown calcareous clays and reddish clay-loam mixtures, while the downstream (north-east) areas of the watershed are generally more sands and sandy loams.

Hydrology

Mean annual precipitation at the National Weather Service station in Green Bay, WI was 73.7 cm for 1976-2008, and ranged from 45.4 to 97.5 cm (Table A.1). In this region the majority of rainfall occurs during the months of June-September, though the streams receive considerable amounts of water in March and April due to snowmelt.

Historically, Duck Creek was likely a perennial stream. In a 1962 Green Bay Press Gazette article, area farmers Thomas and Anthony Chambers filed a lawsuit against Brown County for allowing the water supply in Duck Creek to dry up. The plaintiffs claimed damming of Trout and Duck Creeks by the Brown County Golf Course unreasonably reduced the quality and flow to their dairy farm (GBPG, 1962). The Chambers brothers were awarded $650 for losses sustained when they were suddenly forced to haul water for their herd of 35 dairy cows. Until the retention of the streams occurred this had reportedly not been a problem.

In recent years, Duck Creek has been classified as a warmwater intermittent stream by various investigators. In 1991, the United States Geological Survey (USGS) completed a study of the flow regimes of Duck Creek. It identified 15 losing reach reaches (groundwater recharge zones) on the mainstem of the stream. Some have the potential to lose about 390,000 gallons per day to local groundwater storage, depending on river flow conditions (written communication, USGS, 1991). This is likely due to the well-drained soils and permeable Sinnipee dolomite, which allows transport of stream water from the stream to the water table.

Literature Review

The Duck Creek watershed has a rich history of both agricultural use and water quality problems due to agricultural impacts. Kohler (1997) reported that in the 1990s phosphorus concentrations in mainstem Duck Creek regularly exceeded 0.1 mg/L, nitrate – nitrogen concentrations regularly exceeded 2.0 mg/L, and ammonia concentrations were recorded in excess of 3.0 mg/L (Kohler, 1997). Reports from the USGS, Wisconsin Department of Natural Resources (WDNR), Oneida Tribe of Indians (OTI), and the United States Fish and Wildlife Service (UWFWS) have classified the Duck Creek watershed's water quality and habitat as "poor" to "fair" (Cogswell, 1998; Santy, 2001; Moren, 2002; Gilmore, 2007; WDNR, 2006). Surveys have shown that the Duck Creek tributaries have higher water quality, more suitable stream habitat, and healthier biotic communities (Gilmore, 2007). Several of these tributary streams are able to hold intolerant coldwater species such as trout, while others are currently being managed for trout re-introduction by the Oneida Tribe (Stacy Gilmore, personal communication).

The water quality of Duck Creek and connecting tributaries is influenced by several factors including the natural environment, point sources of contamination, and non-point sources of contamination (USGS, 2000). The Environmental Protection Agency's (EPA) Clean Water Act (CWA), established in 1972, is the governing authority behind surface water quality protection in the United States. Through this piece of legislation point source pollution is regulated by the National Pollutant Discharge Elimination System (NPDES), as specified in Section 402 of the CWA. The NPDES is essentially a permitting process that authorizes discharges via a granted permit. Permits issued through the NPDES specify the control technology that is applicable to various pollutants, the effluent limitations a discharger must meet, and also indicate compliance deadlines. These original (and amended) laws still hold true today and are applicable to two point sources that discharge into the waters of the Duck Creek watershed – the Freedom Sanitary District #1 (FSD#1) and Provimi Foods.

In 1987 Section 319 was added to the CWA to address non-point source pollution. Although the EPA does not oversee programs directly to manage non-point source pollution, Section 319 allows the agency to finance state programs for non-point watershed management. As a result state and local governments have traditionally taken on the role of mitigating this form of water pollution.

The WDNR and Wisconsin Department of Agriculture and Trade and Consumer Protection (DATCP) have collectively worked to control non-point source pollution and soil erosion through the Non-point Source and Water Pollution Abatement and Soil Conservation Program. Although funding comes from several state and federal sources, it is ultimately the County Land Conservation Committees that oversee these funds through various soil and water conservation programs (Pollek, 2007).

Section 303(d) of the CWA requires the states to establish water quality standards. It also requires the state to identify those bodies of water that are not meeting the standards and place these on an "impaired waters" list. The bodies of water on this list are subject to Total Maximum Daily Load (TMDL) regulations in which assessments of the pollution contributions are made and a remedial plan is developed. Currently 39.5 of the Duck Creek's 57.6 miles are included in Wisconsin's impaired waterways with sediment, phosphorus, and ammonia listed as primary pollutants (WDNR, 2008).

In June of 2007, a TMDL committee was formed to set numeric water quality targets for tributary streams in the Lower Fox River basin, as well as the Lower Fox River and Green Bay Area of Concern (AOC). The TMDL Science Team and WDNR reviewed data collected in these water bodies, and calculated reduction targets for Total Phosphorus (TP) and Total Suspended Solids (TSS) in these water bodies. Preliminary targets can be seen in Table 1.1. These targets are expected to result in many water quality improvements including increased water clarity, assisted growth of submerged aquatic vegetation, decreased resuspension of sediment particles in the water column, reduced algal growth, and increased dissolved oxygen (Lower Fox River Basin TMDL Executive Summary, unpublished, 2009).

Table 1.1: Preliminary water quality targets established by the Lower Fox River Basin TMDL Science Team and WDNR (Lower Fox River Basin TMDL Executive Summary, unpublished, 2009). Target values are for summer median concentrations. TSS targets for tributaries will be determined based upon the total percent reduction needed to meet the 20 mg/L standard set for the Green Bay AOC.

Water Bodies	**TP Target**	**TSS Target**
Lower Fox River Basin Tributary Streams	0.075 mg/L	TBD for each stream
Lower Fox River (outlet of Lake Winnebago to Green Bay) and Green Bay AOC	0.10 mg/L	20 mg/L

Water quality management has largely focused on nutrient and sediment loading to streams and other bodies of water. A rich history of research has addressed these pollutants. As far back as the 1950s, the effects of anthropogenic (or man-influenced) sedimentation and its impacts on stream biotic communities were being studied (Tebo, 1955). Suspended sediments result in turbid waters that directly contribute to reducing light penetration and production of aquatic life, along with altering the taste, odor, and temperature of water (Oschwald, 1972).

Nutrients such as phosphorus and nitrogen and sediment from land runoff can alter both the biological diversity and habitat of streams when found in excessive amounts. Inputs of nutrients such as phosphorus and nitrogen contribute to eutrophication, which is an accelerated increase of the ecosystem's primary productivity. Aquatic systems experiencing high eutrophication often display adverse effects such as increased growth of algae and aquatic vegetation, which in turn may cause a decrease in dissolved oxygen concentrations, unfavorable conditions for aquatic organisms, and poor aesthetics (Carpenter et al., 1998).

Because the effects of anthropogenic pollution in streams are seen relatively quickly in biotic communities, organisms can be used as an indicator of a stream's ecological health. Fish and macroinvertebrates have been used to assess the quality of water because they integrate the effects of environmental stressors (Vannote et al., 1980; Lyons, 1992). Simply put, an organism will not thrive in a stream that displays conditions outside its tolerance range. Organisms that are tolerant of environmental degradation, however, will remain present in this stream. If sensitive species are not found within the stream, it can be concluded that a certain level of degradation has occurred.

There are many different techniques available to mitigate non-point pollution. Buffers may be one of the most effective means of reducing agricultural field runoff. A buffer is an undisturbed strip of land between a stream and neighboring fields. The buffer strip slows the water's velocity as it runs from the field towards streams. In doing this it allows filtration of sediment, infiltration of surface water into the soil, and exposes contaminants to longer periods of biological and chemical removal mechanisms (Gold, 2005). The Natural Resources Conservation Service (NRCS) has established technical standards for buffer strips in contour farming settings as well as in forest riparian areas (NRCS Field Office Technical Guide, Codes 332 and 391). The specifications in these documents allow managers to correctly install buffers for maximum pollution mitigation.

In addition to buffers, Best Management Practices (BMPs) that affect the hydrology of a watershed aid in reducing non-point pollution. Wet-weather events can contribute large quantities of pollutants to waterways – more so than during dry weather times (Field et al., 1998). The sudden rush of water associated with a significant rain event results in increased removal of pollutants from the land and quicker transport of both water and pollutants to waterways. Therefore a major goal of watershed managers should be to implement BMPs that reduce high surface flow associated with rain or snow-melt events. Some examples of these BMPs include wetlands and Water and Sediment Control Basins (WASCOBs). Wetlands are able to filter pollutants from runoff, channel rain to groundwater storage, serve for dissipation of flood energy, and slowly release base flow of water to streams (USEPA, 2001). WASCOBs are grassed ridge-and-channel structures built perpendicular to waterways. They are useful tools in preventing agricultural runoff, the formation of field gullies, and erosion control (MDOA, 2009).

Along with implementing land management BMPs designed to reduce harmful runoff, change in land use within a watershed is a significant factor in the health of its waters. Studies have consistently shown that in watersheds where natural vegetation is cleared in favor of agricultural fields or impervious urban surfaces, local streams experience an increase in both nutrient and sediment input (Cooper, 1995, Lowrance et al., 1984, Tong and Chen, 2002). Furthermore, this increase in nutrient and sediment input based upon land use changes has resulted in changes of the algae, macroinvertebrate, and fish communities (Cooper, 1995; Lenat and Crawford, 1994; Wang et al., 1997; Wang et al., 2001).

Trout Creek – Establishing a Trout Fishery

Trout Creek is one of several coldwater tributaries that flow into Duck Creek. The Trout Creek sub-watershed is located in the northern portion of the Duck Creek watershed and is located partly within the Oneida Reservation. It consists of the main perennial stream, a northern and western perennial branch, and many unnamed intermittent tributaries. The perennial portion of the stream flows 12.8 kilometers until it spills into Duck Creek near County Rd. FF, and drains 50.5 square kilometers of land (WDNR, 1997). The North Branch of Trout Creek runs through primarily forested land, while the West Branch of the stream drains considerably more agricultural land. In 1997 the sub-watershed composition was 77 percent agricultural, 18 percent wetland and wooded and 5 percent urban (WDNR, 1997).

According to Nelson and Fassbender (1972), the waters of Trout Creek were once considered to have a marginal trout fishery. However in the mid 1990s, habitat, dissolved oxygen levels, Hilsenhoff Biotic Index (HBI), Ephemeroptera, Plecoptera, Trichoptera Index (EPT) and Fish Index of Biological Integrity (IBI) evaluations ranged from "poor" to "fair" (WDNR, 1997). Following these monitoring studies, the authors concluded that intolerant aquatic life was likely stressed in the creek. What was once a trout stream became an impaired stream holding only redside dace, white suckers, johnny darters, and other forage species (WDNR, 1997).

The Oneida Tribe of Indians has focused much effort towards restoring this culturally significant stream. Many BMPs were implemented to address the major water quality problems established by the DAAPWP – streambank erosion, phosphorus from barnyard animal lots and sediment runoff from croplands. In addition to this, the tribe has restored habitat within the stream to coincide with their efforts of reintroducing brook trout in the future.

Brook trout (*Salvelinus fontinalis)* are a cold-water fish species that inhabits lakes and streams in most of North America and Canada, and have been introduced to temperate regions of other continents. They are the most generalized and adaptable of the trout species and are associated with cold temperate climates, though research has demonstrated the species does display preferred habitat and environmental conditions (Table 1.2).

Table 1.2: Environmental conditions and preferred habitat of brook trout species. Conditions may vary due to regional or genetic differences.

	Optimal Conditions	Range	Source
D.O.	>7mg/L @ <15C >9mg/L at >15C to saturation	5 mg/L to saturation	Raleigh 1982
Temperature	11-16C	0-24C	Raleigh 1982
Turbidity	0-30 NTUs	0-130 NTUs	Sykora et al. 1972
pH	6.5-8.0	3.5-9.8	Daye and Garside 1975
Flow	7-11 cm/sec	<25 cm/sec	Wesche 1974
Habitat	Clear, cold spring-fed water Approx. 1:1 pool-riffle ratio Areas of slow, deep water Well vegetated stream banks Abundant instream cover Overhanging vegetation Undercut banks Water surface turbulence		Raleigh 1982, Giger 1973

Brook trout survival in the Trout Creek watershed may be influenced heavily by sedimentation. Unlike the rest of the Duck Creek watershed, this sub-watershed contains significant sand deposits from the previous glaciation. Alexander and Hansen (1986) found through experimental introduction of suspended sand sediments that concentrations of only 80 mg L^{-1} significantly decreased vital habitat, physical parameters such as dissolved oxygen, and brook trout populations. Several studies have found that brook trout can be highly stressed due to sedimentation, primarily during the early life stages (Alexander and Hansen, 1986; Curry and MacNeill, 2003)

Research Objectives

The primary cause of water quality and biotic integrity degradation in the Duck Creek watershed has been pollution in the forms of excessive nutrients and sedimentation from non-point sources. With alteration in land management aimed at reducing non-point pollution, resulting effects should be reflected in the water chemistry and the biotic communities that reside in the streams of the Duck watershed. This research included the following objectives to determine if land management projects completed in recent years have had substantial effects on improving the health of the streams within the watershed:

1. Characterize changes in land use and land management in the Duck Creek watershed.

2. Analyze relationships between historical water quality and biotic integrity data and recently collected data on Duck Creek
    a. Examine trends in water quality from 1988-2008
    b. Explore differences in fish and macroinvertebrate communities in the watershed between 1988-1995 and 2003-2008.

3. Explore the relationship between land use changes and the water quality and biotic condition in Duck Creek.

4. Characterize the water quality at multiple sites within Trout Creek following strategic BMP implementation.

5. Assess the management implications of this watershed analysis, including the potential reintroduction of Brook Trout to Trout Creek.

CHAPTER 2 - CHANGES IN THE DUCK CREEK WATERSHED

Historical Context

The Duck Creek watershed has seen significant changes in recent years. In Jeanne and Les Rentmeester's book *Memories of Old Duck Creek* (1984), the authors recount early settler's writings of "Riviére aux Canard" (the French name for Duck Creek) and "PAISSACUE" (the Menominee Indian name for Duck Creek). At the mouth of the stream, vast stretches of wild rice attracted flocks of ducks. Although these ducks still inhabit the area in smaller populations the wild rice has disappeared, mostly due to increasing urbanization, pollution, and the introduction of carp to the region.

Early Duck Creek was much deeper than the stream we know today. Its current was also swifter, making it an ideal site for a sawmill. The first sawmill on the stream, one of the first built in the state, was built on its banks in 1827. The resulting erosion from harvested lands placed silts into the river, gradually filling the deeper pools. As Upper Michigan's iron mines peaked in the mid to late 1800's, deforestation of the region continued. The trees were harvested and burned in order to supply Green Bay mills with the energy needed for steel production (Rentmeester and Rentmeester, 1984).

The timber industry and deforestation of the area declined with a pivotal event in 1871. The largest fire in the history of the United States, the Peshtigo fire of 1871, tore through more than 1.5 million acres of Wisconsin and Upper Michigan (Hipke, 2009). With wood resources now depleted, brick and stone houses became more prevalent in the area. Production increased rapidly for the Duck Creek Brickyard and the Duck Creek Quarry, which began operations in 1829 and 1835 respectively. They eventually became two of the longest standing commercial businesses in Wisconsin history (Rentmeester and Rentmeester, 1989).

It was at this point in time that the region began to regrow its forests. The region also acquired a new powerful industry: dairy. From 1895 to 1910, cheese production in the area increased by 3.3 million lbs. per year (Martin, 1913). Agriculture blossomed and the area soon became well known for its dairy, cash crops, and meat production. To this day agriculture still has a strong presence in the region.

The Duck Creek watershed basin has a rich economic history due to the presence of diverse natural resources. Early Native Americans and European settlers alike realized this and moved to the area to take advantage of the rich soils, large forest plots, and plentiful streams. The population of the basin grew rapidly, and continues to do so today. According to data taken from the United States Census Bureau (USCB), the watershed has seen fairly rapid growth in recent years. Population data was accessed at the USCB website (USCB, 2009) at the town level. For towns that were partially in the Duck Creek watershed, population numbers were adjusted for approximate area with the assumption that individuals were equally distributed within the town. It was estimated that the watershed has experienced an increase of 3,818 individuals since 1990 – an average annual increase of 1.4 percent. Urban land has likely increased as well, though as previously stated, agricultural land still remains the largest land use in the watershed.

With agriculture plots and urban neighborhoods now dominating a once entirely forested watershed, the waters of nearby streams now document years of misuse. As discussed in Chapter 1, the water quality of Duck Creek is impaired from anthropogenic pollution, and the biotic communities and their habitats have been affected substantially. In Chapter 2, discussion will focus on the approaches that managers in the watershed have been taking to restore Duck Creek and its tributaries to their original state.

Duck, Apple and Ashwaubenon Creeks Priority Watershed Project

In 1994, the Duck, Apple, and Ashwaubenon Creeks were designated as “priority watersheds” under the Wisconsin Nonpoint Source Water Pollution Abatement Program. This program was created by the State Legislature in 1978 as a means of improving and protecting the water quality of streams, lakes, wetlands, and groundwater by reducing pollutants from urban and rural nonpoint sources (WIS Administrative Code, Chapter NR 120). Today, this program is overseen by the WDNR and the DATCP.

Following acceptance into the Wisconsin Nonpoint Source Water Pollution Abatement Program, assessments were completed in 1995 and 1996 within the watersheds by numerous entities including the Brown County Land Conservation Department (BCLCD), Outagamie County Land Conservation Department (OCLCD), and Oneida Nation Planning Department (ONPD) in cooperation with the WDNR and DATCP. The purpose of the assessments was to produce detailed inventories of land use and identify general pollution sources. The combined efforts of these groups resulted in a priority watershed plan that outlined the management practices needed to reduce nonpoint pollution within these three watersheds, outline agencies responsible for the various tasks, and determine time frames and budgets for the project (WDNR, 1997).

In 1997, the Duck, Apple and Ashwaubenon Priority Watershed Project (DAAPWP) was approved by the aforementioned parties as well as the state of Wisconsin, and scheduled to run through 2009. The detailed report included the following project goals:

- Reduce overall sediment delivered by 50 percent
- Reduce overall phosphorus load by 50 percent
- Reduce mass loading of urban pollutants so that loading in 2020 is 25 percent less than the 1995 load in some sub-watersheds and a "no change" from 1995 load is evident in others
- Increase public awareness and involvement in watershed plans
- Provide information to rural landowners about management cost-sharing opportunities

It was discovered during the assessment period of the DAAPWP that erosion of cropped fields was the largest source of phosphorus in the watershed, contributing 78 percent of the overall phosphorus load. Sediment became the primary parameter to assess, and phosphorus assessments were conducted using the assumption that 1-ton (907 kg) of sediment carries 1.78 lbs. (0.81 kg) of phosphorus (WDNR, 1997). Although the majority of nonpoint source pollutant load reductions were expected through volunteer participation, critical field sites were designated in the three watersheds during the assessment period of the DAAPWP, using a threshold of 5.5 tons/ac/yr (tons per acre per year) of sediment export. Landowners of these designated sites were required by law to reduce nonpoint source pollutant loads to an acceptable level. Critical site design targets were set for <5.5 tons/ac/yr if done at the landowner's expense, or <0.4 tons/ac/yr if done with cost-sharing and technical assistance through the DAAPWP. Landowners with fields in the 0.1–5.5 tons/ac/yr category were eligible for assistance as well, but were not required to implement conservation practices by law. If they chose to do so, with cost-sharing and technical assistance from the DAAPWP, they were required to reduce cropland sediment export to <0.4 tons/ac/yr (WDNR, 1997). Cost sharing and management criteria were also established for landowners who had critical streambank and gully erosion sites, or wished to change farming practices to include conservation tillage or increased residue cover.

Data obtained from the BCLCD and OCLCD documented numerous BMPs being placed within the watershed as a result of the DAAPWP. Information was limited as to their exact location – records were kept for all three watersheds as opposed to each individual watershed and could not be subdivided. Records were also held separately between Brown and Outagamie Counties. Tables 2.1 and 2.2 summarize the BMP placement efforts that have occurred in the Duck, Apple, and Ashwaubenon Creek watersheds as a result of the DAAPWP, with respect to Brown and Outagamie Counties.

Table 2.1: BMPs installed from 1997-2008 within Brown County as a result of the DAAPWP. Results represent placements in the Duck, Apple, and Ashwaubenon watersheds. Data obtained from Jim Jolly of the BCLCD.

DAAPWP Best Management Practice Summary - Brown County		
Practice	**Qty**	**Units**
Barnyard Runoff Control Structure	1	Number
Buffers	90	Acres
Conservation Tillage	31,064	Acres
Cover Crops	13,427	Acres
Manure Storage Facilities	2	Number
Milkhouse Waste Control	1	Number
Nutrient Management	10,275	Acres
Streambank and Shoreline Protection	222	Feet
Well Abandonment	2	Number
Wetland Restoration	15	Acres

Table 2.2: BMPs installed from 1997-2008 within Outagamie County as a result of the DAAPWP. Results represent placements in the Duck, Apple, and Ashwaubenon watersheds. Data obtained from Suzan McBurney of the OCLCD.

DAAPWP Best Management Practice Summary – Outagamie County		
Practice	**Qty**	**Units**
Access Road	60	Number
Animal Trails and Walkways	150	Number
Barnyard Runoff Management	40	Number
Buffer	64.5	Acres
Diversion	253	Feet
Earth Exercise Lot Relocation	1	Number
Fence	2,100	Feet
Fertilizer Spill Control Facility	1	Number
Grade Stabilization Structure	>2	Number
Grassed Waterways	1,924	Acres
Heavy Use Area Protection	4	Acres
Leachate Collection System	1	Number
Lined Waterway or Outlet	660	Feet
Milkhouse Waste Management	21	Number
Pond	10.5	Number
Prairie Plantings	42	Number
Prescribed Grazing	>67.5	Acres
Roof Runoff Management	46	Number
Stormwater Basin	9	Number
Stream Crossings	12	Number
Streambank and Shoreline Protection	380	Feet
Subsurface Drain	18	Number
Surface Drain Field Ditch	55,980	Feet
Underground Outlet	51	Number
Waste Storage Facility	97	Number
Water and Sediment control Basin	7	Number
Well Decommissioning	14	Number
Wetland Development or Restoration	98	Acres

DAAPWP Results

Inventories of sediment and phosphorus delivery in the Duck, Apple, and Ashwaubenon Creek watersheds were calculated using the WDNR's WINHUSLE modeling software. This program calculated annual loading estimates of 111,016 tons of sediment and 227,805 lbs. of phosphorus (WDNR, 1997). 11,501 tons of sediment and 19,382 lbs of phosphorus were estimated to come from urban lands in the watersheds, while the remaining majority was found to be delivered by rural lands. Outagamie County used the WINHUSLE model to calculate sediment and phosphorus runoff loads over the 10 years of the program. Managers in Brown County, however, concluded that this model had not been calibrated with enough hard data from the watersheds and therefore believed it did not perform correctly (Jim Jolly, personal communication). The BCLCD instead used a "sediment delivery ratio" (SDR) method to calculate sediment deliveries. The reductions in sediment delivery to the stream were calculated by multiplying estimates of average annual per acre soil loss reductions by the SDR.

Reduction estimates were collected from the BCLCD and the OCLCD for their portions of the three streams – the BCLCD results coming from the SDR method and the OCLCD methods coming from the WDNR's WINHUSLE model. Data was not separated between the three watersheds; each method calculates a total reduction for the three watersheds in the study. The results show substantial reductions in both sediment and phosphorus delivery to the three streams (Table 2.3).

Preliminary estimates show that the program has appeared to be a success, with reductions from Brown and Outagamie County meeting the total reduction goals for sediment and phosphorus. However, the actual numbers should be taken with caution. The two county conservation offices calculated pollutant delivery differently, based upon one county claiming inadequacy on the part of the pollutant delivery model (WINHUSLE).

Despite the weakness in record keeping and pollutant delivery calculation methods that were seen through the DAAPWP, managers from Brown and Outagamie County still feel the program was a success. Outagamie County managers felt the sediment and phosphorus delivery values were accurately depicted through the WINHUSLE model. Managers in Brown County felt that a major accomplishment of the program was changing behavior of farmers in the watershed. Farmers received both financial and technical assistance in changing their farming practices to include conservation tillage, nutrient management plans, cover crop planting, and overall conservation-conscious planting schemes. Rural "critical sites" were identified and BMPs installed to fix these problematic areas. Urban residents were informed of the impacts of fertilization, storm water controls, leaf collection, pet waste and other acts that affect water quality in nearby streams. In summary, although quantifiable data from the project was unreliable and somewhat vague, the Duck, Apple, and Ashwaubenon Creek watersheds certainly benefited from the implementation of this program.

Table 2.3: Estimated reductions achieved through DAAPWP projects from 1997-2008. Totals represent reductions in Duck, Apple, and Ashwaubenon Creeks combined. Reduction values were calculated using different methods for Brown and Outagamie Counties (WDNR, 1997; Jolly, 2009; McBurney, unpublished).

Pollutant	Source	Inventory Result†	Reduction Goal†	Brown County Reduction‡	Outagamie County Reduction†	Total Reduction
Sediment	Upland Sediment (tons)	91,475	45,738 (50%)	20,149	28,726	48,875
	Streambank erosion (tons)	7,040	704 (10%)	502	1,503	2,005
	Gully erosion (tons)	1,000	250 (25%)	259	516	775
Phosphorus	Ag Upland / Cropland (lbs)	162,826	81,413 (50%)	44,513	54,726	99,239
	Barnyard Runoff (lbs)	9,034	4,517 (50%)	3,215	5,861	9,076
	Nutrient Management (lbs)	36,563	18,282 (50%)	13,170	8,623	21,793

† Results based on WDNR's WINHUSLE model.
‡ Results based on SDR method

Agricultural Survey

A survey was conducted in mid-March of 2009 to compare agricultural practices in the Duck watershed to those of previous years. Twenty-eight road-sites in the watershed were chosen, with the criteria that each road site be within agricultural land-use areas (Figure 2.1). Sites were selected from Arc-GIS maps previously created by Paul Baumgart through the Lower Fox River Watershed Monitoring Program (LFRWMP) that articulated areas of agricultural land-use. All but seven sites had agricultural fields on each side of the road, and these seven sites had agricultural land on one side and either restored wetland, pasture, or residential areas on the opposing side of the road. A location description and GPS coordinates were recorded at each site. For each agricultural field, the previous year's crop, fall tillage practice, and estimated residue cover on a scale of 0-5 were determined from roadside observations.

Previous surveys of the watershed were accessed through the Conservation Technology Information Center (CTIC) Conservation Tillage Reports. These surveys were done in 1996, 1999, 2000, and 2002. Due to limited data in the 1999 and 2000 surveys for these two years were combined into one category. To compare the March 2009 survey with previous surveys of the watershed that classified fields in terms of percent residue cover, the 2009 residue cover estimates were fit into four categories on the basis of percent residue cover: conventional tillage (CT: 0-15%), conventional / mulch tillage (CT / MT: 15-30%), mulch tillage (MT: 30-50%) and no till (NT >50%). Residue data that the CTIC placed into the CT / MT category was distributed equally between the CT and MT categories.

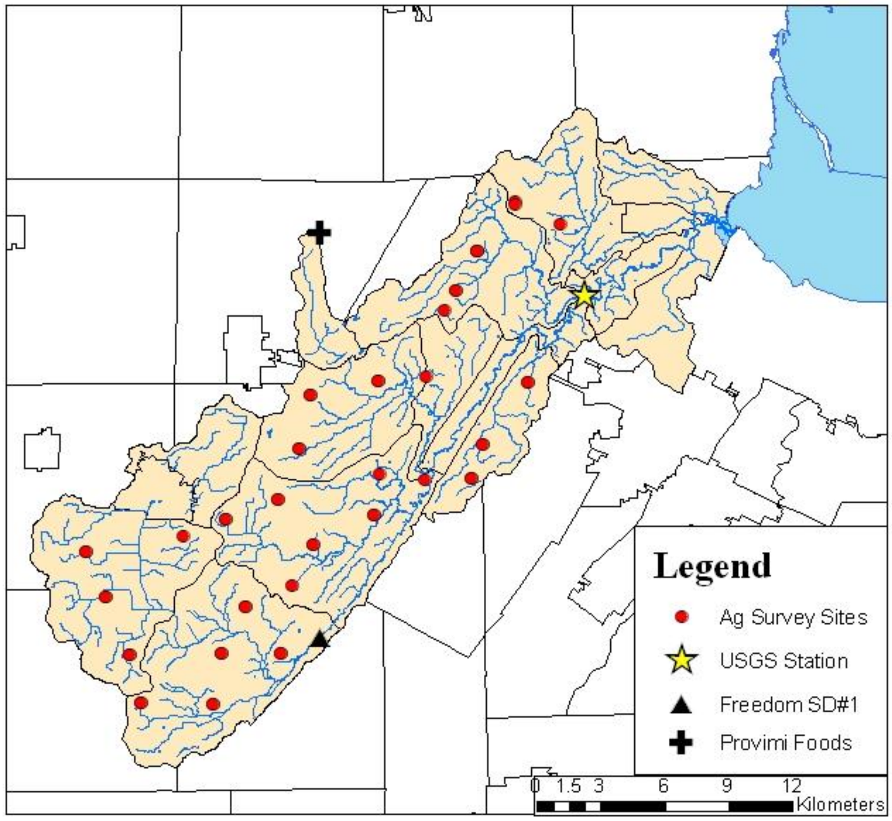

Figure 2.1: Agricultural practice survey sites, permitted point source discharges, and County Rd. FF USGS monitoring station in the Duck watershed. Agricultural practice survey took place on March 16, 2009.

Overall trends from the surveys indicate an increase in the use of mulch tillage and no till practices, which are sometimes referred to as "conservation tillage" because of the soil and water quality benefits they provide. The results of the survey show that conventional till practices have declined since 1996, with the exception of the year 2002 when 96 percent of the fields in the watershed were classified as having conventional tillage (Table 2.4). This may be due to changes in crop rotations in fields in the watershed and market demands, which would alter which types of crops were planted and also the tillage practices used to farm these crops.

Table 2.4: Tillage practices in the Duck Creek watershed, as determined by CTIC (1996, 1999/2000, and 2002) and investigator (2009) transect surveys.

Year	Survey Time	Conventional Till	Mulch Till	No Till
2009†	before spring tillage	50.0%	40.9%	9.1%
2002	after spring planting	96.0%	4.0%	0.0%
1999 / 2000	after spring planting	69.0%	28.8%	2.2%
1996	after spring planting	74.3%	25.7%	0.0%

† Tillage estimates based on roadside observation in March prior to spring tillage and planting. This method likely underestimated the percentage of conventional tillage.

Trends in Dairy Farms

The Program on Agricultural Technology Studies (PATS) was accessed to gain insight on the trends in dairy farms and cropping trends (PATS 2009). County and town data from 1989, 1997, and 2000 were accessed via the website, while 2008 data was received from PATS staff (Alan Turnquist, personal communication). To better estimate how this information applied specifically to the Duck Creek watershed the percentages of town, village, or city that resided within the watershed was calculated using Arc-GIS (ESRI, 2009). Town-based dairy numbers from PATS were adjusted by their respective percentages, with the assumption that dairy farms were distributed evenly throughout the town. In the Duck Creek watershed, dairy farm numbers decreased 67 percent from 21 farms in 1989 to 7 farms in 2008 within Brown County, and dairy farms decreased 58 percent from 148 farms in 1989 to 62 farms in 2008 within Outagamie County. As a whole there were 100 fewer dairy farms in the watershed in 2008 compared to 1989, reflecting an overall decrease of 59 percent.

Table 2.5: Dairy farm trends by town and county within the Duck Creek watershed (PATS 2009). Data is area weighted by proportion of town in watershed.

County	Town	1989	1997	2002	2008	% Change (1989-2008)
Brown	Hobart town	17	9	5	6	-64%
	Pittsfield town	3	2	1	1	-59%
	Suamico town	1	0	0	0	-86%
	Totals	**21**	**11**	**6**	**7**	**-67%**
Outagamie	Black Creek town	14	7	5	5	-67%
	Center town	18	13	10	9	-48%
	Freedom town	28	16	13	11	-62%
	Oneida town	50	36	23	17	-65%
	Osborn town	30	21	16	16	-46%
	Seymour town	8	5	4	4	-55%
	Totals	**148**	**98**	**71**	**62**	**-58%**
	Watershed Totals	**169**	**109**	**77**	**69**	**-59%**

As a whole there were 100 less dairy farms in the watershed in 2008 from 1989, reflecting a decrease of 59 percent. According to BCLCD official Jim Jolly, many dairy farmers chose to leave the dairy industry in the late 1990s when milk prices dropped and land prices increased. These farmers either sold their livestock and turned to cash cropping, or sold their lands to developers or the Oneida Tribe (Jim Jolly, personal communication).

On these dairy farms in Brown and Outagamie counties, the number of dairy cows has fluctuated over the years as well. Data was available from the United States Department of Agriculture's National Agricultural Statistics Service concerning the numbers of dairy cows on these farms. Although information was not recorded on a town basis trends at the county level show a moderate increase in the total number of cows for Brown County (7.9% between 1988 and 2007; Table 2.7), while the total number of dairy cows decreased greatly (19.6%) for Outagamie County (Table 2.8). Most of the reductions (11,500 cows) in Outagamie County occurred prior to 1999 (USDA 2009).

Table 2.6: Dairy cow numbers for Brown County between 1988 and 2007 (USDA, 2009). Although the number of dairy farms decreased, the number of dairy cows increased by 7.9% between 1988 and 2007.

Year	Annual Average Number of Milk Cows	Yearly Percent Change	Percent Change - 1988-2007
1988	38,000		
1989	38,200	0.5%	
1990	38,600	1.0%	
1991	37,700	-2.3%	
1992	36,200	-4.0%	
1993	35,200	-2.8%	
1994	36,500	3.7%	
1995	37,000	1.4%	
1996	37,000	0.0%	
1997	37,000	0.0%	
1998	36,500	-1.4%	
1999	37,000	1.4%	
2000	40,000	8.1%	
2001	40,500	1.3%	
2002	41,500	2.5%	
2003	41,500	0.0%	
2004	42,000	1.2%	
2005	40,000	-4.8%	
2006	40,000	0.0%	
2007	41,000	2.5%	+7.9%

Table 2.7: Dairy cow numbers for Outagamie County between 1988 and 2007 (USDA, 2009). Along with dairy farms, the number of cows decreased in Outagamie County by 19.6% between 1988 and 2007.

Year	Annual Average Number of Milk Cows	Yearly Percent Change	Percent Change - 1988-2007
1988	46000		
1989	44900	-2.4%	
1990	44600	-0.7%	
1991	43400	-2.7%	
1992	41500	-4.4%	
1993	39800	-4.1%	
1994	37000	-7.0%	
1995	37000	0.0%	
1996	36000	-2.7%	
1997	35000	-2.8%	
1998	34500	-1.4%	
1999	35000	1.4%	
2000	37000	5.7%	
2001	37500	1.4%	
2002	37500	0.0%	
2003	37000	-1.3%	
2004	36500	-1.4%	
2005	34200	-6.3%	
2006	36000	5.3%	
2007	37000	2.8%	-19.6%

Oneida Land Use and BMP Implementation

The Oneida Tribe has spent significant resources on improving the Duck Creek watershed. All tribal lands north of CTY Rd. 54 have been buffered, including parts of the Trout Creek, Oneida Creek, and Lancaster Brook watersheds as well as mainstem Duck Creek (Mike Troge, personal communication). The Oneida Nation Farm has implemented a managed intensive rotational grazing plan for beef cattle. Now over 600 acres of grazing are available for the cattle, and the farms boasts plenty of grassed waterways, cattle lanes, stream crossings, roof gutters and grazing paddocks (Mike Troge, personal communication). Throughout the Reservation, over 255 acres of buffers, 266 acres of grassed waterways, and 1070 acres of restored wetlands have been implemented with the intent of enhancing the water quality of nearby streams, benefiting the habitat of native organisms, and providing recreational value for the people of the Oneida Nation (Mike Troge, personal communication).

Nutrient management plans have been implemented for the farmlands owned by the Oneida Tribes, as well as many of the private farms in the Oneida Reservation. Of all fields under Oneida management in 2002 and 2007, soil test phosphorus levels appear to have decreased slightly (Table 2.9). In an analysis of available yearly soil test results from all fields under nutrient management, mean annual soil test phosphorus ranged from 22 to 55 ppm in 2001-2006. No trends in soil test phosphorus data could be determined from analysis of aggregated nutrient management plans supplied from the Oneida Tribe. This is most likely due to new fields being acquired each year and fields were not tested each year for phosphorus content.

Table 2.8: Acreage and soil phosphorus values (in ppm) for Oneida farms in the Duck Creek watershed. Data are based on field values from multiple years as reported in 2002 and 2007 nutrient management plans.

	2002	2007
Acreage	2,652	5,614
Avg Field Acreage	51	35
Number of Fields	52	160
Mean Phos	42	36
Max Phos	148	161
Min Phos	8	3
Std Dev Phos	31	32
Median Phos	30	25
95 Percentile Phos	106	111
90 Percentile Phos	87	78
75 Percentile Phos	54	42
25 Percentile Phos	22	15
10 Percentile Phos	12	10

Much of the Oneida's focus has been placed on the Trout Creek watershed. The state farm (~1,200 acres), located near the Sanger B. Powers Correctional Facility in the western basin of the Trout Creek watershed, was a major source of sediment, phosphorus and nitrogen to the stream due to the large cattle herd located there. The Oneida Water Team determined that manure runoff from this herd was the largest stressor to Trout Creek. A manure containment device was placed on the farm in 2002, and all of the banks of Trout Creek buffered as well. In a before / after study of this project, the Oneida water team monitoring efforts indicated a decrease in suspended sediments and nutrients as well as a positive shift in the macroinvertebrate communities of Trout Creek (Moren, 2002; Gilmore, 2007). Upstream of the farm, a project was designed to meander a straight channel of Trout Creek. In 2003, 1850 ft. of the stream was restored to a meandering state, which slowed down stream flow and allowed for establishment of a diverse community of macroinvertebrates (Snitgen and Melchior, 2008). Engineered logjams were created using large woody debris in several locations along Trout Creek. As the water runs over these logjams, riffles and pools will form. The devices themselves along with the structures they create will serve as essential habitat for fish in Trout Creek.

Permitted Point Source Dischargers

Although nonpoint sources were identified as the major source of impairments to Duck Creek by the DAAPWP (WDNR, 1997), data was collected from the two permitted point source dischargers located in the Duck Creek watershed and assessed for their potential impact on stream phosphorus concentrations. The FSD #1 and Provimi Foods are both located in upstream regions of the watershed (Figure 2.1). The FSD#1 discharges directly into mainstem Duck Creek, while Provimi Foods discharges into an unnamed tributary which flows towards Duck Creek. Data was obtained through the WDNR (Jim Schmidt, personal communication, 2009) for each of these dischargers and compared to recent load estimates calculated by the USGS for Duck Creek at County Rd. FF. Phosphorus loadings (in kg/year) have declined significantly for both the FSD#1 and Provimi Foods (Figure 2.2). The FSD#1 has decreased annual loads by 68% from 1993 to 2008, while Provimi Foods has reduced annual loads by 98% from 1996 to 2008. The total annual loads at County Rd. FF averaged 14,800 kg/year for 2004-2008 and ranged from 4,900 kg in 2007 to 28,800 kg in 2004.

The impact of these point sources in recent time is small, with annual loads from Provimi Foods making up <0.5% of the total annual load at County Rd. FF in 2004-2008, and the Freedom plant only producing 0.9% to 4.4% of the annual total load during this time. It is likely that these point sources contributed a greater portion (10% or more) of the annual phosphorus load to the creek prior to 1999.

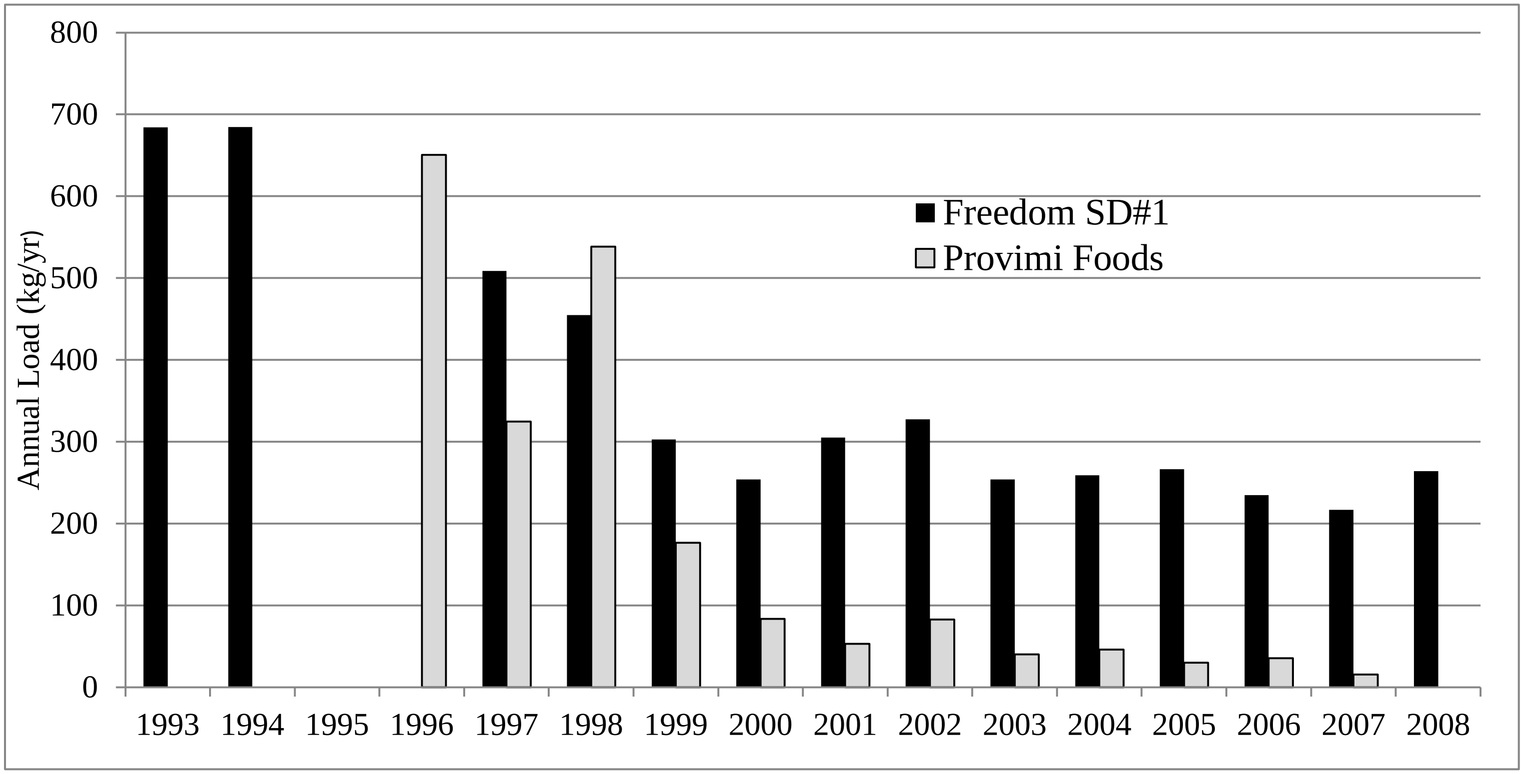

Figure 2.2: Point source phosphorus loads to Duck Creek for the Freedom Sanitary District #1 and Provimi Foods. Data source Wisconsin Department of Natural Resources.

Data from the FSD#1 shows that along with mean annual loads, mean phosphorus concentrations from this discharger have dropped noticeably from the mid to late 1990s, and have fluctuated since then but still display a general decreasing trend. The number of instances that concentrations have reached maximum limits set by Chapter NR 210.05 standards of the Wisconsin Administrative Code (Table 2.5) have dropped considerably from 1999 and, again, show several fluctuations amidst a decreasing trend.

Table 2.9: Simple statistics for Freedom Sanitary District #1 total phosphorus concentrations from 1999-2008.

Year	N	Mean (mg/L)	Median (mg/L)	Min (mg/L)	Max (mg/L)	Number of occurrences > 1.0 mg/L
1999	103	1.16	1.15	0.95	1.62	94
2000	102	0.94	0.92	0.70	1.21	19
2001	106	1.00	0.96	0.09	3.80	36
2002	105	0.93	0.82	0.16	2.70	30
2003	104	0.75	0.44	0.02	5.40	23
2004	104	0.67	0.63	0.03	2.50	9
2005	104	0.81	0.61	0.02	3.70	27
2006	104	0.70	0.66	0.21	2.40	9
2007	104	0.63	0.51	0.02	5.40	7
2008	106	0.65	0.62	0.11	5.20	3

Discussion

Although quantitative land management data for the Duck Creek watershed were hard to come by in this study, there have been significant advances in land management that have been documented by numerous entities on a more unofficial basis. Projects such as the DAAPWP have allowed expensive watershed management practices to become feasible in the Duck Creek watershed, while some groups such as the Oneida Tribe have gone above the call of duty to restore sub-watersheds with specific management goals (i.e. Brook Trout reintroduction) in mind. A widespread educational effort of farming practices and new legislation to force nutrient management on farms has led to the increased use of conservation tillage and cover crops in the watershed. Trends in the dairy industry have shown that fewer and fewer dairy farms are being found in the watershed, limiting the potential of this form of pollution. And finally, point source dischargers have reduced their impact on Duck Creek as well by reducing annual phosphorus loads and mean concentrations from 1993-2008. In Chapter 3 of this document the potential changes in water quality will be discussed that have, in part, been influenced by changes in land management practices.

CHAPTER 3 - DUCK CREEK WATER QUALITY ANALYSIS

Introduction

For years the Lower Fox River Basin and Bay of Green Bay have been significantly impacted through both point and nonpoint pollution. Regulations administered through the Clean Water Act have addressed point source discharges, however nonpoint source pollution still remains a significant problem in the Lower Fox River Basin. Others have identified this similar issue and have developed programs designed to track nonpoint source pollution in their waterbodies. As reliable datasets expand with time and computer programs are being designed to handle this type of data, the potential for long-term water quality monitoring exists. These datasets and their statistical interpretations have become critical tools for measuring anthropogenic pollution as well as discharge (Antonopoulos, et al 2001; Ryberg and Vecchia,, 2006; Johnson et al., 2009) and as a result have become invaluable tools for watershed managers and researchers aiming to track pollution mitigation.

As discussed in the previous chapter, in the past 10-15 years there have been substantial efforts to implement BMPs and manage agricultural lands with the goal of protecting water quality in the Duck Creek watershed from pollution associated with nonpoint sources. In this chapter, the effectiveness of these efforts were evaluated through the examination of water quality trends in Duck Creek. A 20-year water quality dataset for a Duck Creek monitoring station was assembled and statistically analyzed to determine if trends in water quality have occurred.

Duck Creek Water Quality Trend Analysis

Dataset Characteristics

The USGS has collected water quality data from Duck Creek and several tributaries since 1988 and continues today with a gauging/monitoring station (Station ID# 04072150) located at the County Rd. FF / Hillcrest Drive bridge located outside of Howard, WI. This station captures 280 of the 393 km^2 watershed, and is located about 11 km upstream from the mouth of Duck Creek. The station on Duck Creek is equipped with several pieces of monitoring equipment. A nitrogen-gas bubbler system is used to measure the water level of the stream. An ISCO 3700R refrigerated automatic sampler (Teledyne Isco, Inc., Lincoln, NE) is used to either manually collect samples or collect at pre-determined criteria, such as defined time intervals or water level heights.

Continuous water-stage and derived discharge have been recorded since the stations inception until present (a 20-year time span), with water quality samples being collected intermittently. Nutrient and suspended sediment sampling intensities have fluctuated throughout the entire monitoring record, likely as a result of funding limitations and management goals, and seem to fall into three distinct periods. For example, samples collected during the middle period (1996 to 2003) appear to have been collected on a monthly basis. Whereas, the sampling protocol for the first period (1989-1995) appeared to be a combination of event-based, low flow and biweekly sampling. The sampling protocol for the last period (2004-2008) was based on an objective of providing accurate daily loads, and sampling included a combination of event-based, low flow and biweekly samples (Reckinger, 2007). Distribution of total phosphorus samples, the most regularly sampled parameter during the 20-year monitoring record, can be seen in Figure 3.1.

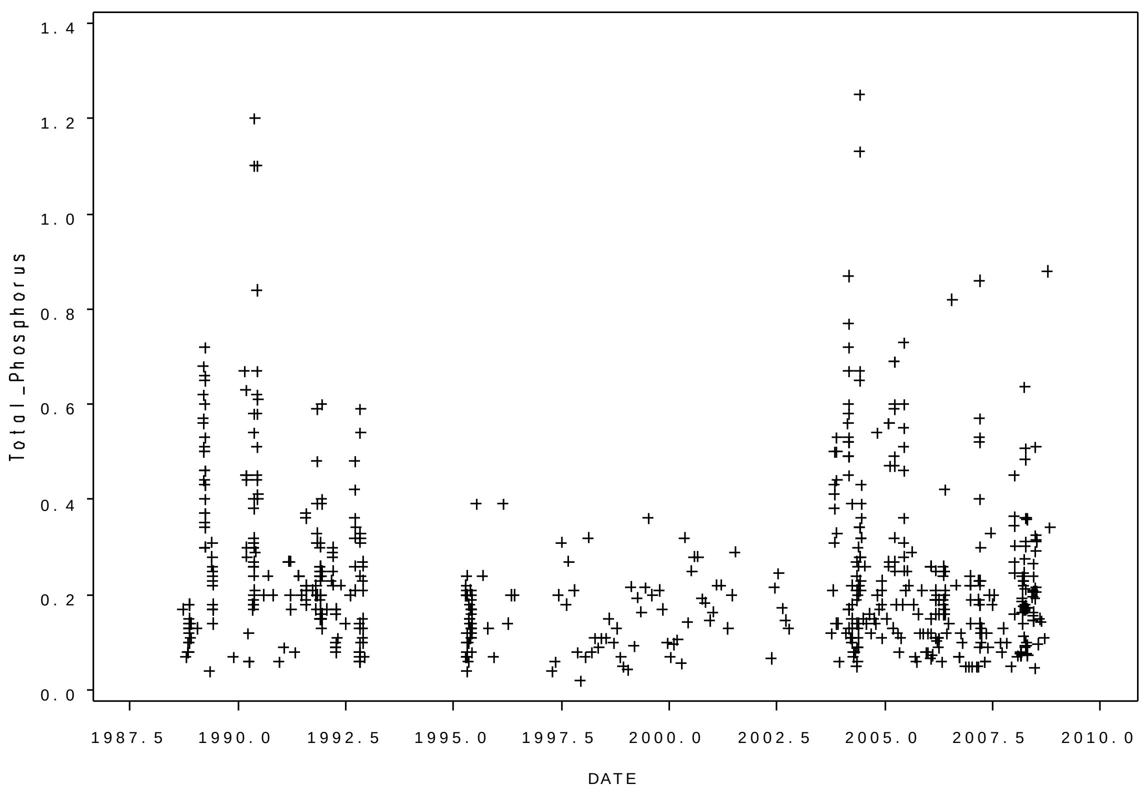

Figure 3.1: Distribution of total phosphorus concentration (mg/L) in samples collected throughout the 20-year monitoring record (1988-2008). In years 1996-2002, sampling was primarily performed monthly, resulting in fewer samples and no samples of larger concentrations (>0.5 mg/L).

Upon analyzing the sediment dataset, it was observed that two methods of suspended sediment analysis were utilized during the 20-year record. From 1990 to 2002 (along with 21 samples in 2004-2006), suspended sediment samples were analyzed for suspended sediment concentration (SSC; Gray et al. 2000). From 2003 through 2008 (along with 6 samples in 1999), samples were analyzed for total suspended solids (TSS). When measuring TSS, a subsample is taken from the original sample. Error may possibly be introduced when solid particles rapidly settle. In measuring SSC the whole sample is used, which eliminates the potential for this type of error. Because 21 samples were analyzed for both SSC and TSS, a linear regression was used on these coinciding samples to determine if a comparable relationship could be established between the two techniques. Although the regression displayed a moderate relationship between the variables (R^2=0.5051) it was felt the relationship was not strong enough to include in a long term statistical analysis. As a result, suspended sediment was not analyzed in this long-term trend analysis.

Methodology

Water Quality Sampling

Historical as well as recent water quality sampling at the USGS Duck Creek station followed methods established by the USGS (Shelton 1994) for nutrient and suspended sediment sampling. Water samples were collected in 2008 in an agreement between the Green Bay Metropolitan Sewerage District (GBMSD), the Oneida Tribe, the University of Wisconsin-Green Bay, and the USGS. These samples were collected in the same manner and added to the historical dataset. In spring of 2008 the collection hose that transports stream water to the ISCO sampling device was ripped from the streambed by large sheets of ice. Due to high flows it was too treacherous to replace this line in a timely manner, and as a result, some spring samples were collected manually using the equal width interval (EWI) sampling method (Thornton et al. 1999). Upon reinstallation of the ISCO sampling hose, the automated sampler was used to collect water samples. The samples were collected in 1 L bottles, and then divided into smaller quantities using a Teflon cone splitter. DP samples were filtered through a 0.45 μm membrane filter to remove particulate matter. Both TP and DP samples were preserved with a dilute sulfuric acid (3:1 concentration) solution and were refrigerated before analysis at the GBMSD. The USEPA Automated Block Digester Method 365.4 (1983) was used to determine phosphorus concentrations.

Statistical Analysis

Descriptive statistics of the dataset were analyzed from the 20-year record (Table 3.1). Flow varied immensely, from times of no flow to times of high event-based flow (3690 cfs). The unmodified dataset included TP (N = 601) and DP (N = 343) samples ranging from 0.2 to 2.79 mg/L (TP) and 0.2 to 0.56 mg/L (DP).

A trend analysis was conducted on total and dissolved phosphorus by using a linear regression model through the Statistical Analysis Software package (SAS version 9.1.3 © 2002-2003). In order to achieve accurate results with the regression model, various procedures were performed on the dataset to remove bias. TP outliers (equal to or greater than 1.3 mg/L) and other constituents analyzed with these samples (TSS, DP, etc.) were removed from the dataset. Periodically, manual samples and automatic samples were collected at the same time for comparison purposes. These duplicate samples were flagged and subsequently removed. Substantially more samples than normal were collected and analyzed for TP during a four month period in 1999, and these samples were often fairly close to each other. Therefore, data collected during 1999 were sub-sampled on a once-per-month basis to reduce serial correlation. The TP sample collected at the same time of a monthly collected DP sample was chosen for inclusion to the dataset.

Table 3.1: Simple statistics for water quality samples collected at the USGS monitoring station (ID #04072150) on Duck Creek, 1988-2008. Units for flow are in cfs, while units for all other variables are in mg/L except for the DP/TP variable which is a ratio.

Variable	N	Median	Mean	Std. Dev.	Min	Max	Lower 95% CL for Mean	Upper 95% CL for Mean
Flow	7282	6.0	51.0	153.1	0.0	3690	47.5	54.5
TSS	267	27.0	77.0	135.5	2.0	956.0	60.7	93.4
SSC	202	24.0	57.7	123.5	2.0	1080.0	40.6	74.9
TP	601	0.20	0.28	0.29	0.02	2.79	0.25	0.30
DP	343	0.13	0.16	0.11	0.02	0.56	0.15	0.17
DP / TP	343	0.73	0.68	0.22	0.08	1.00	0.66	0.70

Phosphorus concentrations (both TP and DP) and flow were log-transformed to achieve linearity and normality in the residuals. Through this commonly accepted procedure, normality was achieved as indicated by normal quantile plots generated through SAS (Figures B.1 and B.2). Flow was transformed in two ways: log-transformed and log of the flow squared (calculated as $[\log(\text{flow})]^2$). All references to log transformed data shall refer to natural logs, and not base-ten logarithms. Included in the regression analysis were total and dissolved phosphorus as dependent variables and decimal time, log of flow, and log of flow squared as independent variables. Decimal time serves as the independent time trend variable of interest, whereby a regression slope for this variable that is significantly different than zero indicates a probable change in the dependent variable over time. Flow is included in the regression analysis as an independent variable to account for potential changes in DP and TP that are related to flow. Including flow and other potential exogenous variables in the regression analysis can reduce model error and increase the ability of the regression model to detect a trend over time. Differences in water chemistry and flow can occur due to seasonal traits, such as rapid snowmelt, intense rainfall, changes in groundwater levels, and evapotranspiration. These changes may also be tied to seasonal biological activity and managed human activities such as fertilizer application. In trend analyses, it is recommended that the seasonal factor be removed to unbias the data set (Helsel and Hirsch, 1992). One way of accomplishing this is to perform the regression with periodic functions. Two functions, a sine and cosine curve, were therefore included in the regression equation to account for seasonal differences in the phosphorus concentrations in the manner recommended by Helsel and Hirsch (1992).

Because of recent efforts to reduce phosphorus concentrations in Duck Creek, the following hypothesis was formulated:

H_0: Phosphorus concentrations have either increased or remained the same.

H_A: Phosphorus concentrations have decreased.

Multiple Linear Regression Results

The selected regression equation format comes from a default option defined in the load estimator program LOADEST (Runkel et al., 2004). In this equation, steps are taken to eliminate collinearity. Collinearity occurs when two or more variables in a multiple regression are highly correlated. For example, if streamflow and precipitation are used as variables in the same regression, the results may be inaccurate because streamflow and precipitation are highly tied to each other. Runkel et al. (2004) suggests centering explanatory variables to reduce this problem. In the centering process the center of the independent variable, as defined by Cohn et al. (1992), is subtracted from the original values. The result is a “centered” model. The LOADEST model centered the flow as well as time (in decimal format). The regression equation is as follows:

$$\text{LN-constituent} = a0 + a1\ \text{LN\_Q} + a2\ \text{LN\_Q}^2 + a3\ \text{SIN}(2\pi\text{DEC\_TIME}) + a4\ \text{COS}(2\pi\text{DEC\_TIME}) + a5\ \text{DEC\_TIME}$$

where a is the regression parameter, LN_Q is the log of flow, LN_Q^2 is the log of flow squared, DEC_TIME is decimal time, and SIN_DAY and COS_DAY are the sine and cosine curves that describe the seasonal phase shift.

The model proved to be a good predictor of log-transformed TP and log-transformed DP. The adjusted R^2 value for the TP and DP models was 0.34 and 0.23, respectively. In both models the slope of decimal time was significantly different than zero, with $P<0.0001$ for each model. Also with respect to time, the model estimated an apparent decrease of TP and DP (2% and 3% per year respectively) over the 20-year record.

Further Investigation

Period-Specific Regression Analysis

Although the model suggests that there was a significant decrease in log-transformed TP and log-transformed DP over the monitored record, further investigation was taken to confirm this finding, and to examine potential trends within the 20-year dataset. Figure 3.2 is a plot of log-transformed TP residuals versus decimal time over the entire monitoring record; however decimal time is excluded as an independent variable in the regression equation so that patterns among time and the flow and seasonally adjusted residuals can be more easily observed. The residuals seems to show a downward trend in TP concentrations during the first period of the 20-year record, followed by a leveling off period, and then a potential decrease during the latter portion of the third period. A similar pattern was observed with log-transformed DP (Figure 3.3). Clearly, the relationship between time and the residuals is not stationary. Similarly, an uneven distribution of points along the zero error axis was observed when residuals were plotted against decimal time for the previous TP and DP regression models which included decimal time as an independent variable (figures not shown). Consequently, the regression models are not valid when applied over the entire 20-year record.

The same regression model was applied to Period 1 (1989-1995) and Period 3 (2004-2008). In the Period 1, decimal time was a highly significant explanatory variable for log-transformed TP ($p<0.0001$). The slope however was much greater (-0.1044), indicating a greater decrease in phosphorus concentrations (about 10% per year) for this period. Concentrations of log-transformed DP saw a significant decrease ($p=0.0001$) as well. The slope was also larger (-0.11421) and translates to an 11% decrease per year.

Residual trends for log-transformed TP and DP have been plotted for the Period 1 to provide visual context (Figures 3.4 and 3.5).

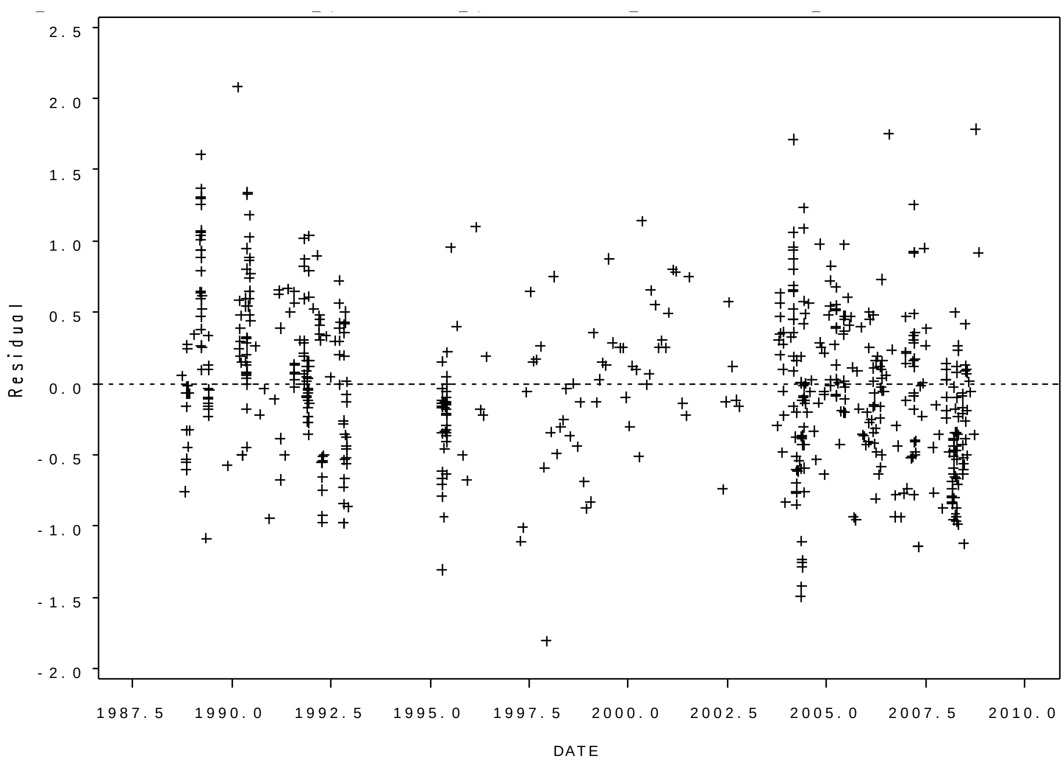

Figure 3.2: Flow and seasonally-adjusted residuals of log-transformed TP for the 20-year USGS monitoring record (1988-2008).

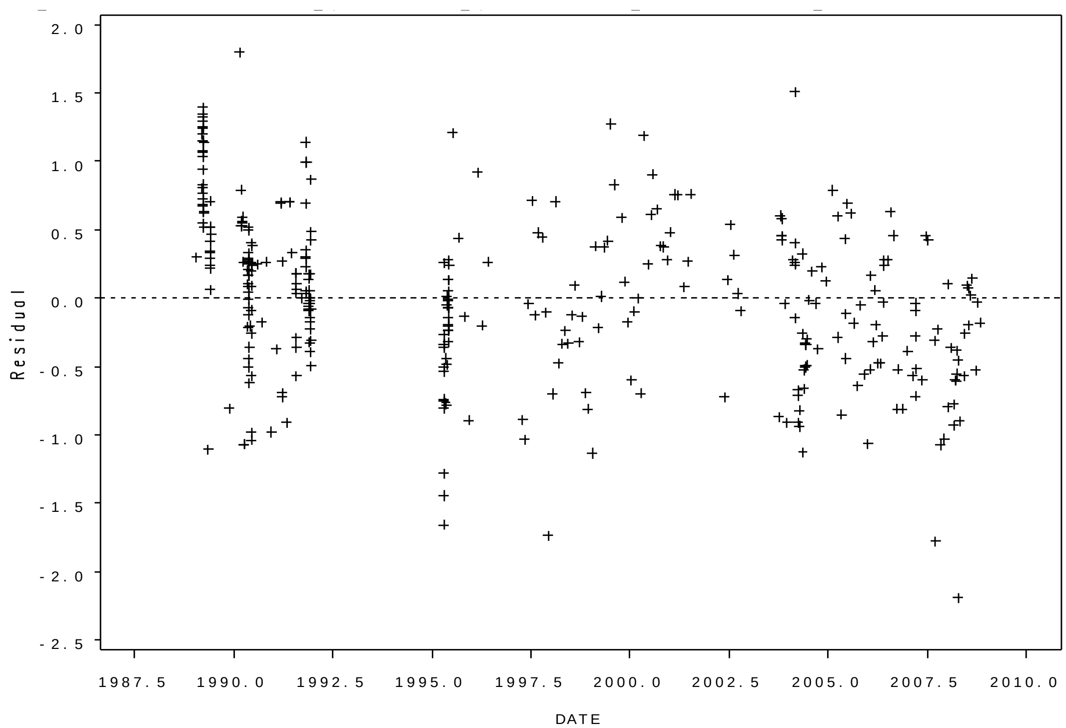

Figure 3.3: Flow and seasonally-adjusted residuals of log-transformed DP for the 20-year USGS monitoring record (1988-2008).

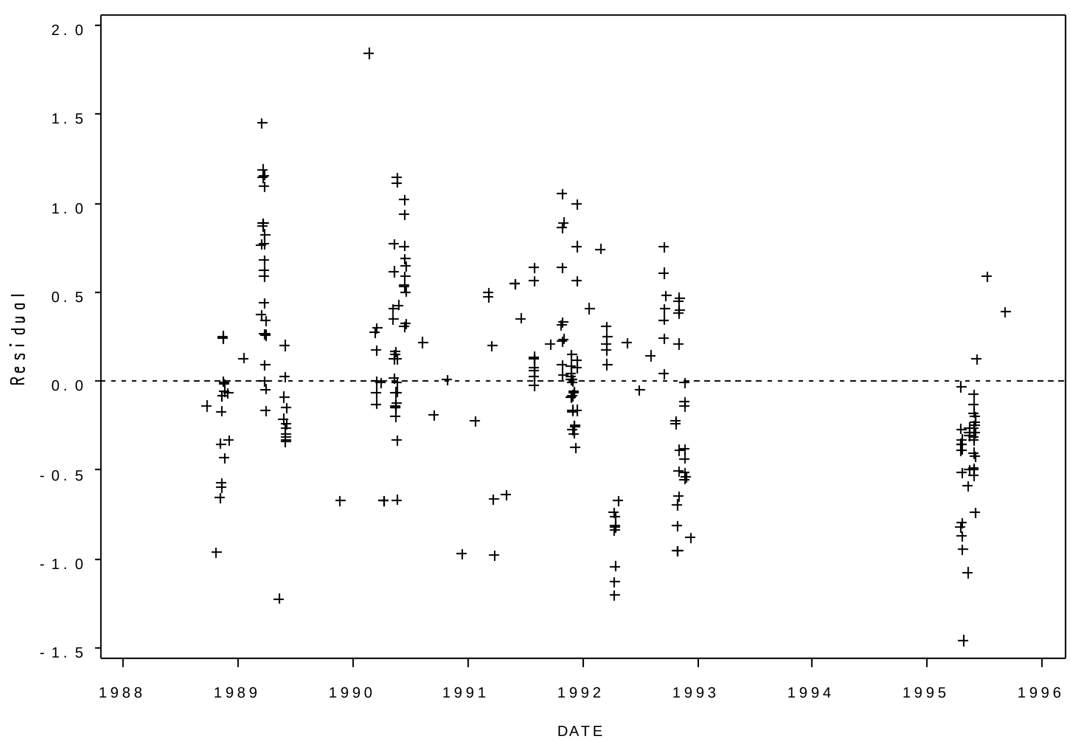

Figure 3.4: Flow and seasonally-adjusted residuals of log-transformed TP during Period 1 (water years 1989-1995).

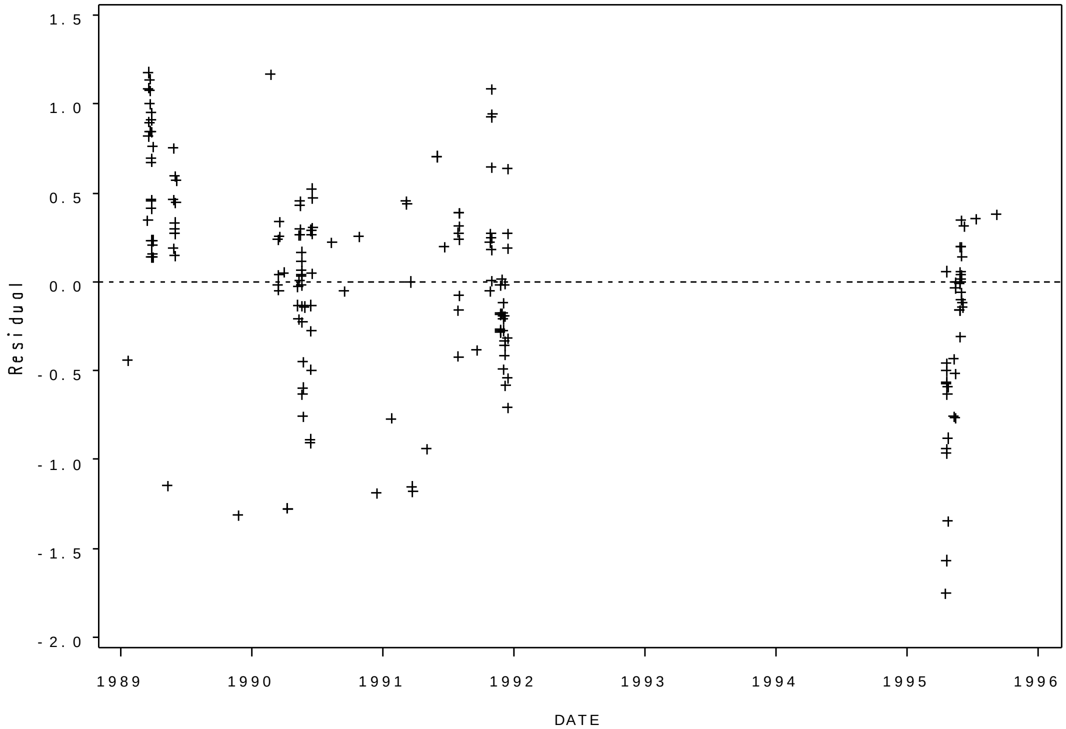

Figure 3.5: Flow and seasonally-adjusted residuals of log-transformed DP during Period 1 (water years 1989-1995).

To test how sensitive the regression model was to changing the range of data included during the Period 1, data from some of the years was added or subtracted to see if there was a substantial change in the regression model coefficients and level of significance. In addition, there was a gap in the data during the Period 1 because phosphorus was not analyzed from 1993 or 1994, so the data set was not continuous. Overall, only small changes were observed with regards to decimal time slope or level of significance when 1995 data were excluded, or when data from 1996, 1996-1997, and 1996-1998 data were added. The latter ranges were also added, but without the 1995 data. Again, little change was observed; thereby increasing confidence in the observed trend of decreasing log-transformed TP.

In the Period 3, two regressions were run. An initial regression was modeled without data from 2008. Following formal certification of the data by the USGS, the new dataset (including 2008) was modeled. The initial model showed no significant decrease of log-transformed TP (p=0.786). However with the 2008 data, the results changed dramatically. Decimal time became a significant explanatory variable (p=0.0007). The slope of 0.0689 is equal to an annual decrease in log-transformed phosphorus concentrations of 6.7%. Log-transformed DP showed a significant decrease as well (p=0.0053). The slope of 0.0952 is equal to approximately a 9.0% decrease. Flow and seasonally adjusted residuals of log-transformed TP and DP were plotted against decimal time for the Period 3 to verify that there does not seem to be a decrease in TP or DP until 2008 (Figures 3.6 and 3.7); as in Figures 3.1 and 3.2, decimal time is excluded as an independent variable for analysis purposes.

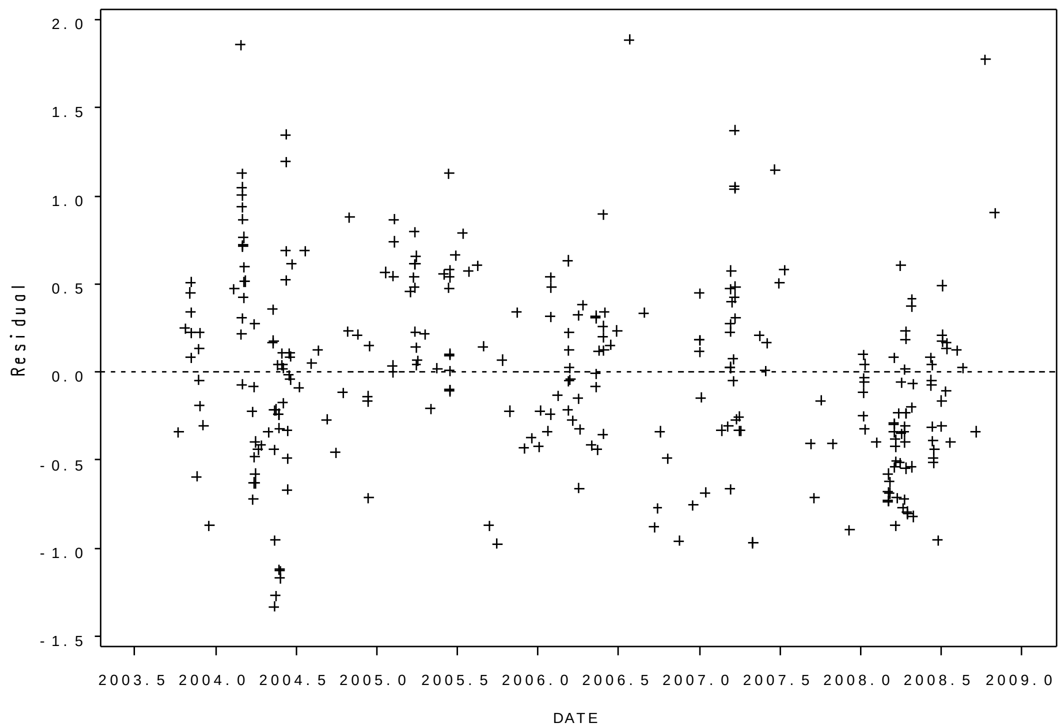

Figure 3.6: Flow and seasonally-adjusted residuals of log-transformed DP during Period 1 (water years 1989-1995).

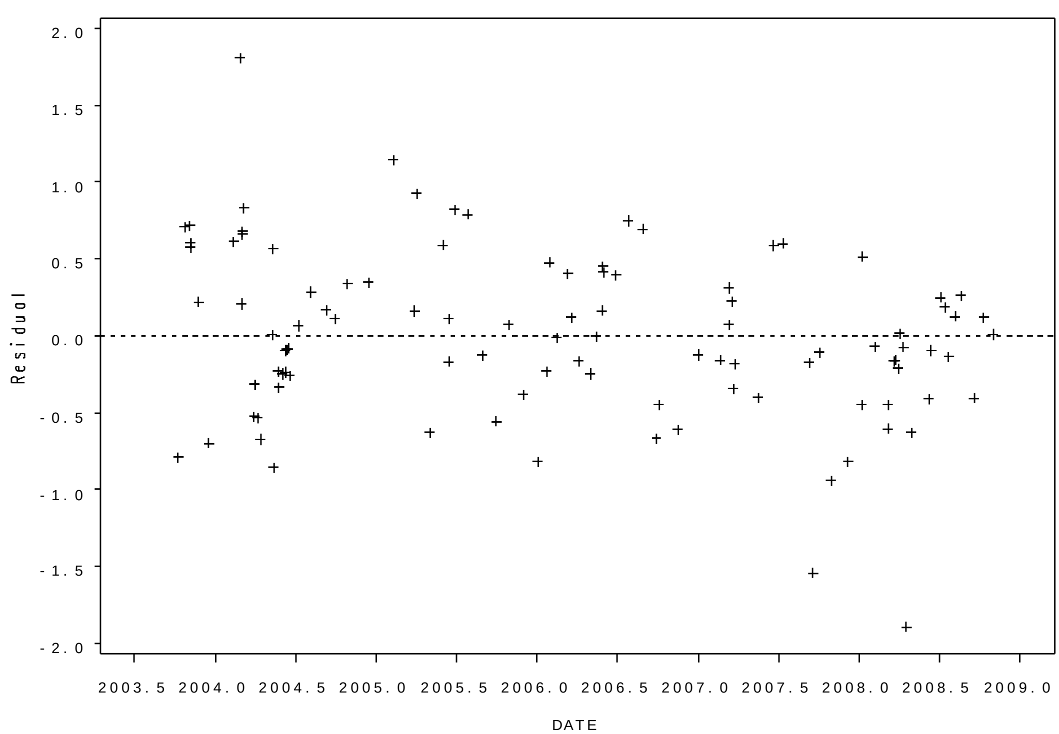

Figure 3.7: Flow and seasonally-adjusted residuals of log-transformed DP during Period 1 (water years 1989-1995).

In 2008, there were several factors that could influence the analysis. As previously discussed, the automated sampler line from the USGS monitoring station was pulled out twice during very large spring flow events. As a result, samples were taken manually using depth integrating sampling device. The events were so large that the weighted sampling device did not collect depth-integrated samples as it is designed to do, collecting primarily surface samples instead because of the high stream velocity (personal communication, Baumgart, 2008). The 2007-2008 winter snowfall was the 3rd highest snowfall on record in Green Bay (Table 3.2; NOAA, 2009). Relative to the previous four winters, there was twice as much snowfall from December to February. The water equivalent precipitation in December 2007 and January 2008 was the second most and most, respectively, in the previous 30 years (Table A.1.) January 2008 precipitation was three times the average. Meltingof the accumulated snow had a significant influence on the high flows observed in Duck Creek. With normal event sampling, rainfall causes greater erosion on surrounding lands and the samples usually contain greater suspended solids as a result. Virtually no rainfall occurred over the Duck Creek watershed during the 2008 snow melt runoff period. The only significant rainfall (2 cm) in March occurred on March 2nd and only caused a consolidation of the snowpack and very little runoff. The snowpack melted during mid-March causing high flows. Event samples collected during this time were lower in suspended solids and phosphorus than would normally be expected for these flows because of a lack of raindrop impact energy. The two regressions run on the Period 3 show dramatically different results because 2008 data may be an outlier, or a second decreasing trend may be starting (personal communication, Baumgart, 2008).

Table 3.2: Snowfall data from the National Weather Service Station in Green Bay, WI (NOAA 2009). Snowfall is displayed in total centimeters per month. USGS water year 2008 is indicated in bold.

	2003	2004	2005	2006	2007	2008	Average
Jan	24	41	45	5	25	**72**	36
Feb	23	42	28	40	46	**62**	40
Mar	23	21	30	9	23	**11**	20
Apr	13	2	0	0	17	**13**	8
May - Oct	0	0	0	0	0	0	0
Nov	1	0	10	4	**2**	-	3
Dec	6	37	32	11	**61**	-	30
Winter Total	-	114	141	97	125	222	140

To further evaluate whether the apparent trend of decreasing phosphorus concentrations was real, the regression equation that was utilized for phosphorus was applied to the natural log of TSS for the Period 3, except decimal time was excluded as an independent variable. The plot of the resulting flow and seasonally adjusted residuals versus decimal time shown in Figure 3.8 reveals that LN-TSS concentrations remain fairly level until a sharp decrease is observed in 2008. It is not likely that this decrease is related to recent implementation of BMP’s because the expected effect on a watershed the size of Duck Creek ought not to be so sudden. It seems more likely that this apparent decrease is related to a climatic effect such as the aforementioned rain-less large snow melt event in 2008, sampling bias or other factors.

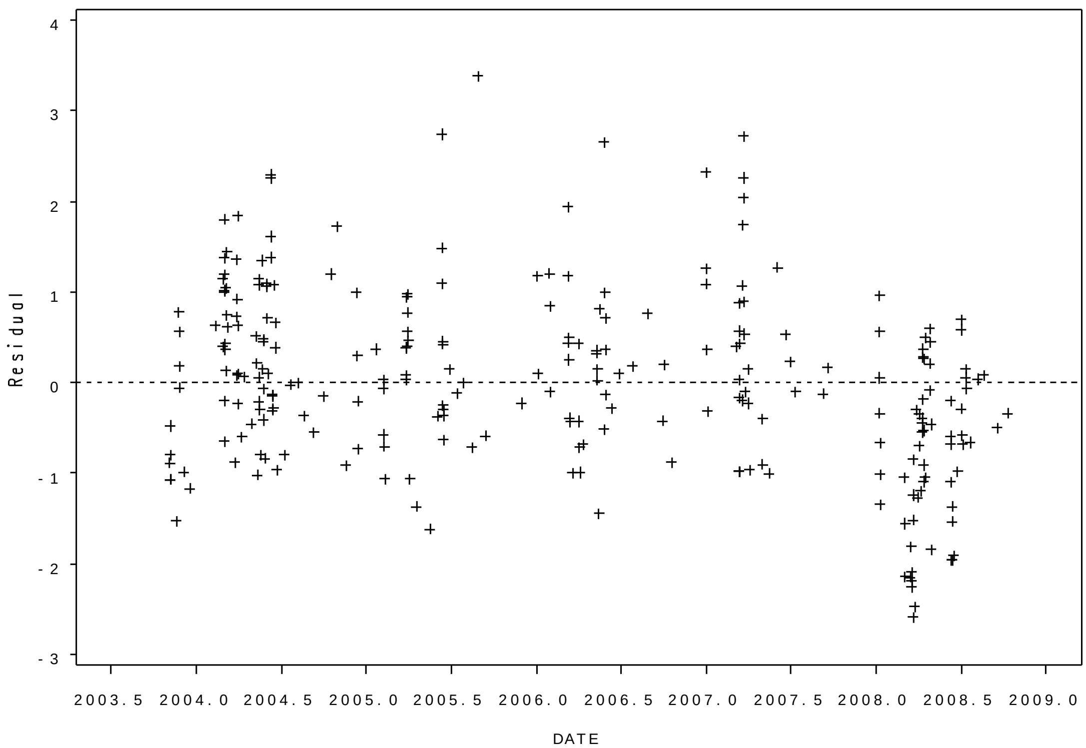

Figure 3.8: Flow and seasonally-adjusted residuals of log-transformed TSS during Period 3 (water years 2004-2008).

Period-Specific Comparisons

The results from the regression analysis strongly suggest that phosphorus concentrations have decreased from Period 1 to Period 2. To further verify the regression results, the non-parametric Wilcoxon Rank sum test was used to compare the first to the Period 3with regards to several constituents. Phosphorus concentrations appear to be lower in the Period 3 for both phosphorus forms, TP ($p=0.049$) and DP ($p<0.0001$). The flow in Duck Creek was significantly different between Period 1 and Period 3 (Wilcoxon Rank sum test, $p<0.0001$) for the data subsets, with the Period 3 having greater flow than the Period 1. This does not conflict with the finding that phosphorus concentrations were lower in Period 3, because phosphorus is correlated with flow ($r=0.43$ and $p<0.0001$ for the Period 1, r=0.46 and p<0.0001 for Period 3). As flow increases, phosphorus concentrations should increase as well. In this situation, both TP and DP concentrations are decreasing from Period 1 to Period 3, while the flow associated with their sampling is increasing. This may provide evidence for decreasing phosphorus concentrations, however high flows in Period 3 could be the result of relatively clean snow melt or groundwater recharge (particularly in 2008), which would dilute phosphorus concentrations in the stream.

The non-parametric Wilcoxon Rank sum test was performed on phosphorus data with regards to various flow and data-censoring scenarios. In Period 1, there were only 7 samples collected when flow was greater than 1,000 cfs, whereas there were 23 samples collected over 1,000 cfs in the Period 3. Additionally, the proportion of samples collected with flows less than 75 cfs were greater in Period 1, compared to Period 3 (Figure 3.9).

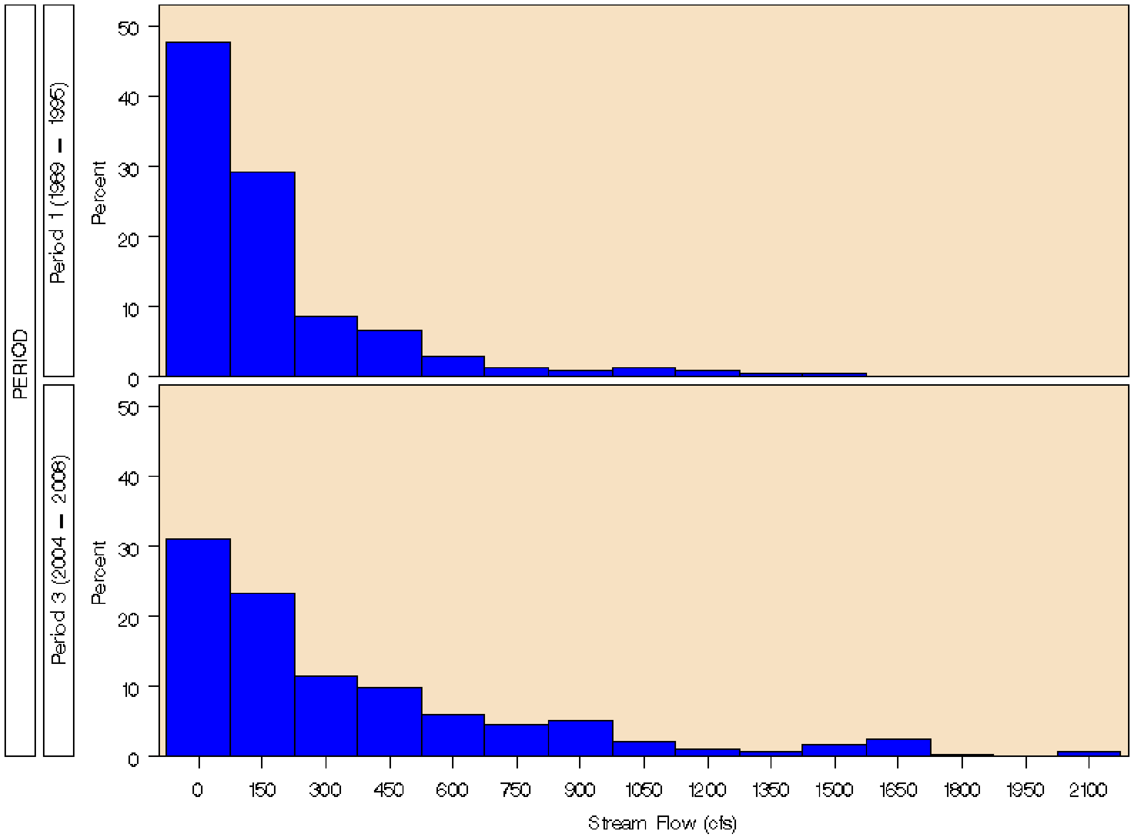

Figure 3.9: Histogram of streamflow during phosphorus sampling between Period 1 and Period 3. In Period 1 fewer samples were taken at higher flows (>1,000 cfs) while fewer samples at low flow (<75 cfs) were taken during Period 3.

Distribution of collected samples and their respective flows can be seen in Figure 3.10. In this graph, the low-flow Period 2 samples are easily distinguished from the moderate flow Period 1 and the relatively high-flow Period 3. This phenomenon is likely due to a difference in sampling protocols, as previously discussed.

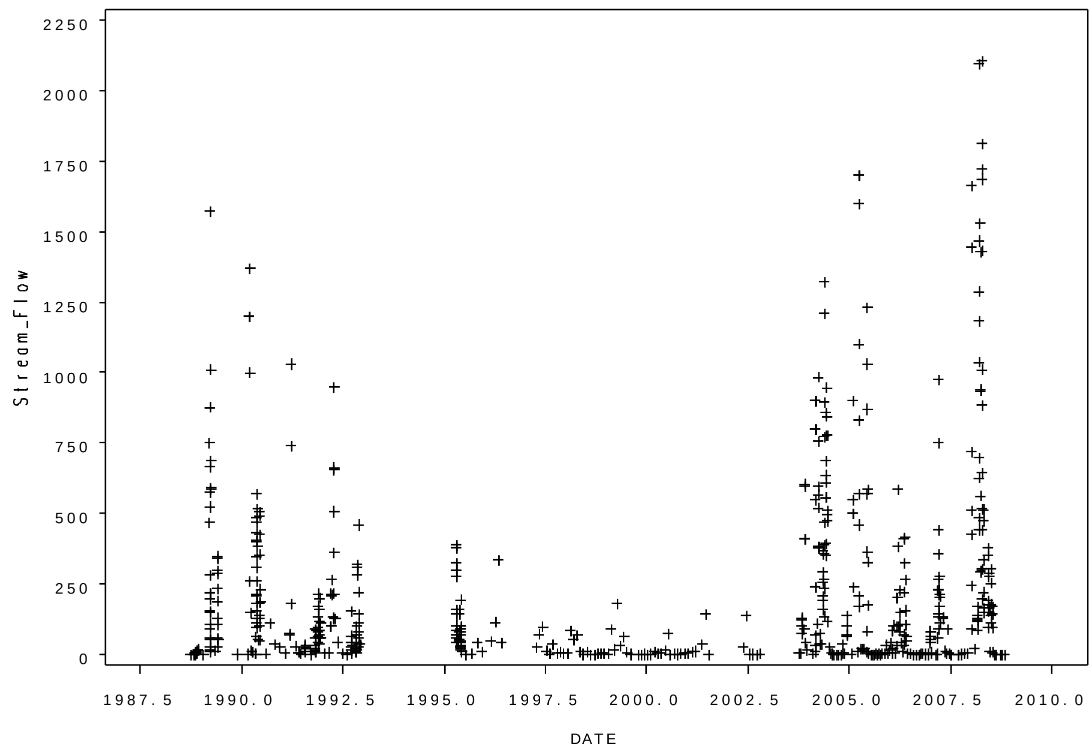

Figure 3.10: Measured streamflow (cfs) during phosphorus sampling throughout the 20-year monitoring record (1988-2008). Note the three distinguishable periods that appear which coincide with changing sampling protocols.

The previous regression analysis showed that a substantial decrease in phosphorus concentrations occurred by 1995. There is a sharp decrease during Period 1 that may indicate 1995 is the end of this apparent change. In addition, there were no samples collected during 1993 and 1994, so there was a significant break in the data record. Due to the sharp drop-off in phosphorus concentrations in 1995, data from 1995 was omitted in all but one of the period comparison scenarios because data from 1995 might be better categorized as belonging with data from an extended leveling off period, which includes Period 2 and Period 3. Wilcoxon Rank sum test results are summarized in Table 3.3.

Various scenarios were created to analyze the difference between phosphorus concentrations between Period 1 and Period 3 under several flow regimes and with the removal of year 1995 data. Under all flow and water year censoring scenarios, the concentrations of both TP and DP were significantly greater in Period 1 compared to Period 3 ($p < 0.05$).

Mid-Month Sub-Sampled Statistical Comparison

When sampling frequency is relatively high, serial correlation amongst samples from a hydrologic data set such as the Duck Creek data set can pose problems because the samples are not likely to be independent of one another; thereby violating a key assumption of most statistical tests. The Durbin-Watson test is a common method used to check a model for serial correlation (Draper and Smith, 1998). This statistic was tested for the full 20-year record regression, as well as the Period 1 and Period 3 regression models. The Durbin-Watson statistic was significant for all of these models suggesting some degree of serial correlation; however the 1st order autocorrelation values were weak to moderate rather than strong suggesting that the highly significant regression models may still be valid (Table 3.4).

To reduce potential serial correlation to a minimum, the full data set was sub-sampled similar to that described by Robertson et al. (2006b). Sub-sampling took place on a once/month basis whereby only a single sample collected closest to the middle of each month was retained for further statistical analysis.

Table 3.3: Non-parametric Wilcoxon Rank sum test (t-approximation) for several constituents under different flow and data censoring scenarios: Period 1 vs Period 3. Flow scenarios were created to account for differing sampling protocols and unusual weather events that occurred over the 20-year time record. All flow scenarios omit water-year 1995, with the exception of "All Flow". NOTE: P1 indicates Period 1 (USGS water years 1989 to 1995), P3 indicates Period 3 (USGS water years 2004 to 2008). To reflect the different null hyphotheses, statistical tests for TP and DP were one-sided, whereas tests for DP/TP and flow were two-sided.

Variable	**All Flow**	**w/o 1995**	**Flow < 1000**	**Flow < 750**	**Flow < 500**	**Flow < 250**	**Flow < 75**	**Flow > 75 and < 750**	**Flow > 75 and < 750 w/o 2008**
TP	P1>P3 p=0.049	P1>P3 p=0.0015	P1>P3 p=0.0003	P1>P3 p=0.0001	P1>P3 p=0.0001	P1>P3 p=0.0001	P1>P3 p=0.0026	P1>P3 p<0.0001	P1>P3 p=0.0031
DP	P1>P3 p<0.0001	P1>P3 p<0.0001	P1>P3 p<0.0001	P1>P3 p<0.0001	P1>P3 p<0.0001	P1>P3 p<0.0001	P1>P3 p<0.0019	P1>P3 p<0.0001	P1>P3 p<0.0001
DP/TP	P1=P3 p=0.059	P1>P3 p=0.048	P1=P3 p=0.098	P1=P3 p=0.450	P1=P3 p=0.996	P1=P3 p=0.99	P1=P3 p=0.84	P1=P3 p=0.082	P1=P3 p=0.15
Flow	P3>P1 p<0.0001	P3>P1 p<0.0001	P3>P1 p<0.0001	P3>P1 p<0.074	P3>P1 p<0.017	P3=P1 p=0.9	P1>P3 p=0.0003	P1=P3 p=0.18	P1=P3 p=0.24
N for TP	243 – P1 288 – P3	205 288	199 264	196 237	182 210	157 167	98 89	97 148	97 102

Table 3.4: Durbin-Watson statistics and Autocorrelation values for Duck Creek regression models. Durbin-Watson tests were performed on original models and those models with additional mid-month data sub-sampling.†

	Sub-sampled data set	Period	N	Durbin Watson Statistic (DW)	Prob < DW	1st Order Autocorrelation	Time trend (Dec_Time) P value
LN_TP	ALL samples	1989-2008	593	1.048	< 0.0001	0.472	<0.0001
		1989-1995	243	0.992	< 0.0001	0.499	<0.0001
		2004-2008	288	1.118	< 0.0001	0.432	0.0007
	Mid-month	1989-2008	157	1.741	0.0315	0.117	0.1302
		1989-1995	43	-	-	-	0.5566
		2004-2008	53	-	-	-	0.8737
LN_DP	ALL samples	1989-2008	343	1.213	< 0.0001	0.393	<0.0001
		1989-1995	177	1.152	< 0.0001	0.414	<0.0001
		2004-2008	105	1.571	0.0048	0.196	0.0053
	Mid-month	1989-2008	136	1.916	0.234	0.042	0.0232
		1989-1995	28	-	-	-	0.7892
		2004-2008	48	-	-	-	0.1494

† For regressions that had small sample sizes, the Durbin-Watson test was not applicable.

The median TP concentration of the sub-sampled data set was 0.18 mg/L during Period 1 and 0.13 mg/L during Period 2 (n = 43 and 53, respectively). The median DP concentration of the sub-sampled data set was 0.14 mg/L during the Period 1 compared to 0.09 mg/L during Period 2 (n = 43 and 54, respectively). The non-parametric Wilcoxon Rank sum test was performed on the sub-sampled data set with regards to flow and phosphorus concentrations. The concentrations of both TP and DP were found to still be significantly greater in Period 1 than Period 3 ($p = 0.023$ for both; one-sided tests using the normal approximation). The median flow of this sub-sampled data set was 18 cfs during the Period 1 and 4.9 cfs during Period 3; and the mean flows were 102 cfs and 97 cfs, respectively. However, the flow was not significantly different between the two periods ($p = 0.143$; two-sided tests using the normal approximation). Similar results were found when data from 1995 were excluded from Period 1, as was done in the previous section. The concentrations of both TP ($p = 0.0337$) and DP ($p = 0.0249$) were still significantly greater in Period 1 compared to Period 3 (both one-sided tests using the normal approximation). The ratio of DP to TP was not significantly different between Period 1 and Period 3 for the sub-sampled data set, with or without data from 1995 ($p > 0.8$, two sided test using the normal approximation).

Regression analysis was also performed on the sub-sampled data with the same regression model that was used earlier. Decimal time was not a significant explanatory variable for TP or DP for both Period 1 and Period 3 (Table 3.4). This result is contrary to that found for the whole data set. One possible explanation is that the number of samples is simply too few to provide enough statistical power given the variability of the TP and DP data.

Trend Analysis Summary

A total of four statistical procedures were used to examine the USGS Duck Creek dataset for trends in TP and DP. They include:

- A 20-year multiple linear regression on the variables, which indicated that TP had decreased 2% per year, and DP had decreased 3% per year. However this trend was not stationary.
- A multiple linear regression on Period 1 (1989-1995) and Period 3 (2004-2008) within the 20-year dataset. This test found that in Period 1 TP had decreased 10% per year and DP had decreased 11% per year. A decrease in TP and DP concentrations was observed in Period 3 only when data from 2008 was included. However, further analysis indicated that it is more likely that this decrease was due to unusual climate or sampling problems in 2008, rather than an abrupt change in the watershed between 2007 and 2008.
- A Wilcoxon Rank sum test on TP and DP between Periods 1 and 3 under a variety of censoring and flow scenarios, which found that in all cases Period 1 TP and DP concentrations were significantly greater than Period 3 concentrations.
- A Wilcoxon Rank sum test performed on one sample per month, taken in the middle of the month to reduce potential serial correlation bias. This test found that Period 1 TP and DP concentrations were significantly greater than Period 3 concentrations.

Discussion

Statistical methods to analyze long-term water quality trends are becoming more robust and more common as monitoring datasets grow. They are, however, not without complex problems that may lead to a misinterpretation of their results. These factors may include natural variability, management practices of different degrees, and seasonal and climatic variations (Johnson et al., 2009). The time lag between watershed changes and water quality effects is often difficult to identify as well. Richards et al. (2008) report that changes occurring within 5 years of land-use management efforts should be ignored in trend detection studies due to the aforementioned factors. Landers (2005) suggests that datasets reflect at least 10 years of monitoring to adequately assess if watershed changes are responsible for a given water quality trend. The 20-year monitoring record also experienced factors such as changing sampling regimes, changing sampling methods, and several years in which no monitoring took place. Although these considerations may have complicated the procedures, a robust statistical analysis was able to be performed.

The 20-year Duck Creek water quality dataset was scrutinized in a variety of ways to attempt to account for some of the recognized factors that may bias the trend analysis. What started as a relatively straightforward 20-year trend analysis quickly evolved into a comprehensive investigation in which several statistical tests were used to analyze micro trends occurring within the larger dataset. The four statistical procedures that were utilized indicate that TP and DP concentrations have decreased over the 20-year record, primarily within Period 1 of this timeframe. This conclusion does not mean that phosphorus concentrations decreased solely during Period 1; only that there was insufficient evidence to conclude that a significant decrease in phosphorus concentrations occurred after Period 1.

CHAPTER 4 - BIOLOGICAL INTEGRITY OF THE DUCK CREEK WATERSHED

Introduction

The stated objective of the Clean Water Act is to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters” (33 U.S.C. § 1251 (a), CWA § 101(a)). Title I of the act lists the protection of aquatic organisms as a major goal, stating that:

> “It is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved...”

Thus, there is a legal basis for ensuring the waters of the Duck Creek watershed are hospitable to aquatic organisms. The CWA is based upon years of research on aquatic systems which has identified pollutants and their impacts. Two of the most researched pollutant areas have been nutrient and sediment input.

Phosphorus and nitrogen are considered critical because as “limiting” nutrients they control photosynthesis in aquatic systems. As these nutrient concentrations increase, they stimulate phytoplankton and aquatic macrophyte growth. Excessive nutrients can lead to excessive organic material, which leads to an increased oxygen demand as microbes decompose the material. Thick mats of phytoplankton or macrophytes may also disrupt vertical mixing of aquatic systems, reducing oxygen in this manner. The results of lowered dissolved oxygen can be detrimental to aquatic organisms. In a study examining nutrient concentrations on stream biotic communities (periphytic diatoms, macroinvertebrates, and fish), Robertson et. al. (2006a) found that nutrient concentrations are important in controlling the biotic health of streams. Specifically, their study suggests that phosphorus has more control over the health in biotic communities than nitrogen.

Sedimentation in aquatic systems is considered one of the greatest causes of water quality impairment by the USEPA (2003). Besides the aesthetic impairments that results from excessive sediment (turbidity) the pollutant can clog filtration mechanisms in invertebrates, impair ingestion rates in mussels, reduce available light for aquatic macrophytes, interfere with physiological functions in fish, as well as alter aquatic habitat and nesting sites (Berry et al., 2003).

The effects of organic matter, nutrient and sediment pollution on aquatic organisms have been extensively researched (Lyons 1992; 2006) and methods to quantitatively describe these impacts have been developed. In this chapter, trends in the biological integrity of Duck Creek are statistically and quantitatively investigated using a variety of established methods. Fish and macroinvertebrates, two biological indicators of environmental stress, have been surveyed by numerous entities in the Duck Creek watershed. Data from these surveys were collected and analyzed to detect temporal trends that may have occurred in these sensitive biological communities.

Biological Indices

Biological Assessment of Fish Communities

The term "healthy" biotic community may seem somewhat arbitrary if not defined. For the purpose of management goals, standardized methods of assessing biological communities have been developed for numerous aquatic communities (e.g., Lyons, 1992; 2006; others). In 1986, Karr et. al. (1986) developed a method to measure the biological integrity of a fisheries community in Midwestern U.S. streams. Karr's Index of Biological Integrity (IBI) has since been modified for the streams of Appalachia, Ontario, North Carolina, Colorado, Tennessee, Idaho, Missouri, and Mexico, larger streams in Oregon, France, Ohio, Australia, Africa, Belgium, and India, as well as Tennessee river reservoirs and Great Lakes bays (Simon and Lyons, 1995; Hughes and Oberdorff, 1998). IBI's are useful management tools because they reflect vital components of a fish community: taxonomic richness, habitat and trophic guild composition, and individual health and abundance.

In 1992 Lyons calibrated the Karr IBI system to Wisconsin warmwater, wadeable streams (Lyons, 1992). The Wisconsin IBI was developed using 10 metrics, with an additional 2 "correction factors". These metrics and their scoring criteria are summarized in Table 4.1.

Table 4.1: Metrics and scoring criteria for the Wisconsin warmwater wadeable streams IBI (Lyons, 1992). The sum of each metric score results in the overall IBI for the sample.

IBI Metric or Correction Factor	**Scoring Criteria**				
	10	**7**	**5**	**2**	**0**
Total number of native species	>20	20	11-19	10	<10
Number of darter species	>4	4	3	2	<2
Number of sucker species	>4.7	4.7	2.4-4.6	2.3	<2.3
Number of sunfish species	>2.7	2.7	1.4-2.6	1.3	<1.3
Number of intolerant species	>5.3	5.3	2.8-5.2	2.7	<2.7
Percent that are tolerant	0-19	20	21-49	50	51-100
Percent that are omnivores	0-19	20	21-39	40	41-100
Percent that are insectivores	100-61	60	59-31	30	29-0
Percent that are top carnivores	100-15	14	13-8	7	6-0
Percent that are simple lithophilous spawners	100-51	50	49-21	20	19-0
Number of individuals (excluding tolerant species) per 300 m sampled	If <50 fish, subtract 10 from overall IBI score				
Percent with deformities, eroded fins, lesions, or tumors (DELT)	If ≥4 percent, subtract 10 from overall IBI score				

Lyons later took this same concept and developed an IBI specifically tailored towards wadeable, warmwater intermittent streams (Lyons, 2006). Intermittent streams are defined as streams without continuous flow – they may naturally be reduced to a series of isolated pools or go completely dry during summer months. These stream systems can be harsh environments, and may naturally have chemical and physical parameters that severely impact fish survival, growth, and reproduction (Zale et al., 1989). The fish that do exist in these systems tend to display several characteristics such as being small-bodied, short-lived, fast maturing, capable of rapid population increase, and tolerant of physiochemical extremes (Lyons, 2006). The intermittent stream IBI relies upon different metrics than Lyons' 1992 IBI, and as a result is better suited for evaluating these types of streams. These metrics and their scoring criteria are summarized in Table 4.2.

Table 4.2: Lyons (2006) stream metrics and scoring criteria used to create the Wisconsin Intermittent streams IBI. The sum of each metric score results in the overall IBI for the sample.

IBI Metric or Correction Factor	**Scores for Metric Values**		
	0	**10**	**20**
Number of native species	0-2	3-5	>5
Number of intolerant species	0	-	>0
Number of minnow species	0-1	2	>2
Number of headwater species	0	1	>1
Catch per 100 m of all fish, excluding tolerant species	0-9	10-35	>35
Catch per 100 m of brook stickleback	0	1-10	>10
Percent with deformities, eroded fins, lesions, or tumors (DELT)	If >1% DELT = 20, if 0-1% DELT = 0		

While an IBI is a useful method of determining whether a stream fish community is degraded due to environmental stressors, the total score cannot identify what stressor is causing the biological response. To investigate the relationship of anthropogenic stresses on a fish community, one method is to explore trends in the individual metrics of the IBI instead of the total IBI score itself (O'Reilly et al., 2007). From analyzing these components of a fish community, one may speculate as to what kind of environmental degradations are occurring. For example a decrease in darter species may indicate a change in habitat, as members of this species prefer hunting aquatic insects in stream riffles or runs. Simple lithophilous spawners require clean substrates for spawning, so a decrease in this metric may indicate embeddness of rocky substrates (O'Reilly et al., 2007).

Biological Assessment of Macroinvertebrate Communities

Macroinvertebrates may respond to environmental stressors faster than fish species due to their limited mobility. In addition, because they have tolerance ranges for pollutants as well, macroinvertebrates may be monitored to analyze the biotic health of streams. A well-known and often used index for measuring macroinvertebrate health in streams is the Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1987). The HBI evaluates water quality and degree of organic pollution based upon tolerance levels of macroinvertebrates. The degree of organic pollution strongly influences dissolved oxygen levels in the stream. As a result, only invertebrates that require dissolved oxygen for respiration are used in the calculation of the HBI.

The HBI is calculated using macroinvertebrates identified to either the genus or species level. The formula for calculating the HBI is:

$$HBI = \sum (x_i * t_i) / (n)$$

where x_i is the number of individuals within a genus or species, t_i is the tolerance value of a genus or species, and n is the total number of organisms in the sample. Organisms that are sensitive to low concentrations of dissolved oxygen are assigned low tolerance values, and organisms that have a higher tolerance are assigned a higher tolerance value. The computed values should range within a scale of 0 to 10, and coincide with varying degrees of organic pollution as described in Table 4.3.

Although the HBI is a helpful tool in assessing macroinvertebrate communities' response to organic pollution, it is sometimes difficult to perform, as macroinvertebrates must be identified to the genus and species level. This can be very time consuming and requires a certain level of experience and expertise with macroinvertebrate identification. In 1988, Hilsenhoff created the Family Biotic Index (FBI) as a way to more rapidly assess macroinvertebrate communities (Hilsenhoff, 1988). This method involves the identification of macroinvertebrates to the Family level. Although the FBI does sacrifice some accuracy, it allows for sufficient evaluation of stream sites by novice investigators in a timely manner. It is similar to the HBI equation except instead of assigning tolerance values to insect genera and species taxa area assigned a tolerance value at the family level. The number of individuals within a taxon are weighted by a tolerance value of the taxon (t_i), summed and normalized by the total number of organisms in the sample (n). Again, similar to the HBI, the values range from 0 to 10 and describe the levels of organic pollution a stream has received, as summarized in Table 4.3.

Table 4.3: Evaluation of water quality based upon biotic indices associated with macroinvertebrate communities (Hilsenhoff 1987 and 1988).

HBI Value	FBI Value	Water Quality	Degree of Organic Pollution
0.00-3.50	0.00-3.75	Excellent	Organic pollution unlikely
3.51-4.50	3.76-4.25	Very good	Possible slight organic pollution
4.51-5.50	4.26-5.00	Good	Some organic pollution probable
5.51-6.50	5.01-5.75	Fair	Fairly substantial pollution unlikely
6.51-7.50	5.76-6.50	Fairly poor	Substantial pollution likely
7.51-8.50	6.51-7.25	Poor	Very substantial pollution likely
8.51-10.00	7.26-10.00	Very poor	Severe organic pollution likely

A third commonly used macroinvertebrate metric is EPT (Ephemeroptera-Plecoptera-Trichoptera) Richness, generally expressed as a percentage of the sample. This metric represents insects from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Insects in these orders are particularly sensitive to organic pollution. As a result, their numbers should decrease as pollution increases (Lillie et al., 2003).

Methods

Fish Methods

Fish data was collected from several agencies that have performed surveys on Duck Creek. These agencies included the Lower Fox River Watershed Monitoring Program, the Oneida Tribe of Indians, the USGS through the NAWQA Program, the WDNR and Kirby Kohler, a former graduate student of the University of Wisconsin – Stevens Point. The agencies had all surveyed Duck Creek with the intention of using the data for Lyons' 1992 IBI calculation, so it was assumed that sampling methodology was consistent with the methods described in Lyons (1992). The as-delivered data was in various forms – some agencies delivered basic survey data only, while others delivered basic survey data and IBI values. For all datasets, 1992 and 2006 IBI values were calculated using the criteria seen in Tables 4.1 and 4.2. The individual IBI metrics were calculated for each sampling event using both IBI methods as well. The total dataset included 12 sites sampled through 148 surveys from 1993 to 2007 along the mainstem of Duck Creek. Due to potential seasonal differences in fish communities, the dataset was limited to those sampling dates occurring from late April to early October, as recommended by Lyons (2006). This limited the dataset to 91 surveys (Table 4.4).

Table 4.4: Fish survey data for mainstem Duck Creek, WI. Data was collected from several agencies and was reduced to summer (late April through early October) sampling dates only.

Location	Site†	N	Sampling Range	Sources‡
Upstream	CTY Rd. S	5	1995-2004	Kohler, NAWQA
	Center Valley Rd.	7	1995-2005	Kohler, Oneida
	CTY Rd. J	6	1995-1996	Kohler
	Tip Rd.	4	1995-1996	Kohler
Mid-Stream	CTY Rd. EE	10	1998-2006	Oneidas, LFRWMP
	Seminary Rd.	17	1993-2008	NAWQA, Kohler, Oneida
	CTY Rd. U and E	4	1995-1996	Kohler
Downstream	CTY Rd. GE	4	1995-1996	Kohler
	CTY Rd. FF	4	2003-2007	LFRWMP
	D/S of CTY FF	4	1995-1996	Kohler
	Oneida G&C Club	13	1995-2008	Kohler, Oneida
	Pamperin Park	13	1995-2008	Kohler, Oneida

† D/S: downstream.
‡ Kohler, 1997; NAWQA: USGS National Water Quality Assessment Program; Oneida: Oneida Environmental, Health and Safety Division; LFRWMP: Lower Fox River Watershed Monitoring Program UW-Green Bay and UW-Milwaukee.

The resulting dataset was somewhat limited in that many survey sites had few surveys performed, and often during a short time span. In order to examine long-term trends in the fisheries data, several modifications had to be made. First, the data was aggregated into three classes that coincided with the changing water quality sampling objectives at the USGS monitoring station and also coincided with land management and monitoring program initiatives (i.e. the DAAPWP and LFRWMP). The three classes were from 1988-1995 (Period 1), 1996-2002 (Period 2), and 2003-2008 (Period 3). The location of each survey site was entered into an ArcGIS database of the watershed. Tributary streams were identified and their entry to Duck Creek was located. The twelve survey sites were then aggregated into three spatial classes of Upstream, Midstream, and Downstream reaches (Figure 4.1) to minimize potential influences of stream flow and duration variability between sites.

Fish survey IBI and individual metrics, along with total abundance of each survey was compiled into Microsoft Excel and then analyzed using SAS (version 9.1.3 © 2002-2003). Boxplots illustrating the median, minimum, maximum and 25th and 75th quartiles for each metric are presented in Figure C.1. These boxplots show the non-normal tendencies many of the metrics which could not be alleviated with transformations. Therefore, the non-parametric Wilcoxon Rank Sum Test (exact p-value option) was used to test for significant differences in the medians of each metric between Period 1 and Period 3 of the fisheries data. These periods roughly represent time periods “before and after” the implementation of management activities in the watershed. Period 2 was considered a transitional stage.

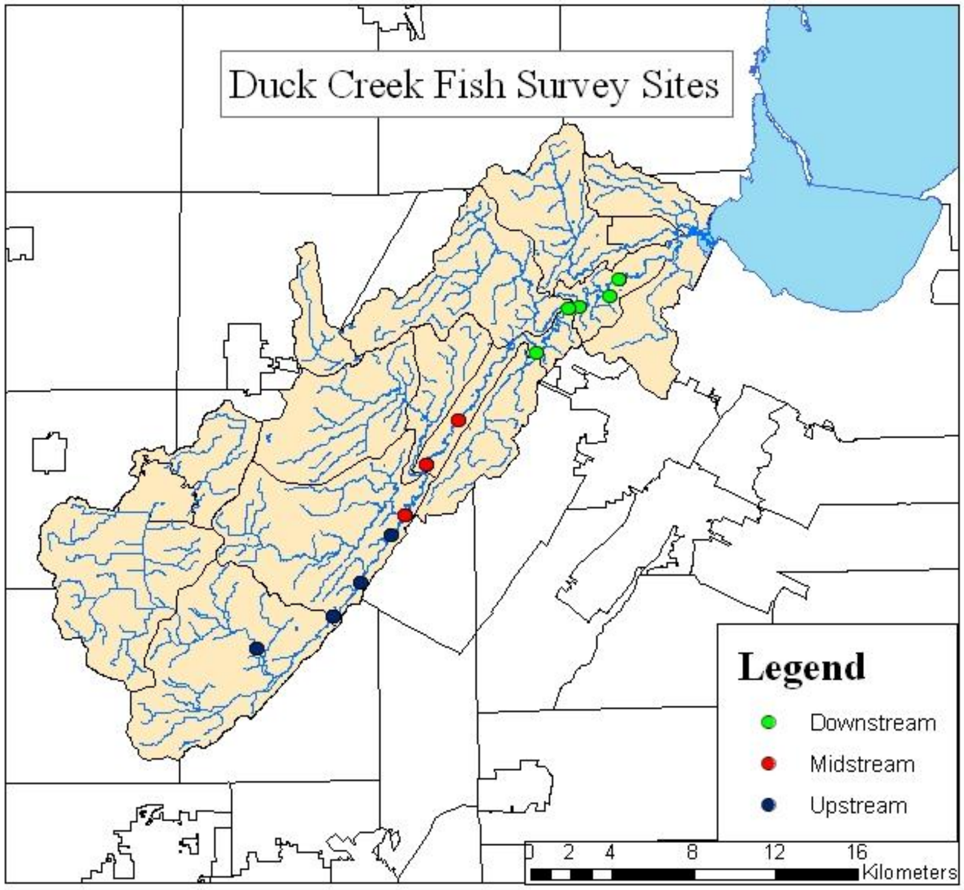

Figure 4.1: Fish survey locations within the Duck Creek watershed. 12 locations were combined into categories of Downstream, Midstream, and Upstream based upon the entry of tributary streams to the mainstem of Duck Creek.

Macroinvertebrate Methods

Data were pooled from several agencies that had performed macroinvertebrate surveys on the mainstem of Duck Creek including the LFRWMP, the Oneida Tribe of Indians, USGS (through the NAWQA program) and the UWSP aquatic entomology lab, which is an analysis lab and repository for macroinvertebrate data collected primarily by the WDNR. Although these agencies may have used different yet relatively similar techniques to collect the organisms it was assumed that any differences in macroinvertebrate samples were the result of varying stream conditions, and not of the agency field collection and processing method. This assumption was based upon Lenz and Millers (1996) study which found that although four different macroinvertebrate sampling techniques by four separate government agencies produced a collection of different total abundances and proportions of individual taxa, the water quality ratings from calculated indices (HBI, FBI, etc.) were similar. Two of the agencies compared in this study, the USGS (NAWQA program) and WDNR, have provided the majority of the data for this Duck Creek analysis. The remaining two agencies (LFRWMP and Oneida Tribe) have used generally accepted methods for macroinvertebrate collection.

Sampling for macroinvertebrates has varied over the past 20 years, both in terms of watershed location and years of sampling. It appears that most of the sampling done by all agencies has been the result of watershed specific projects, and not with the intent of examining long term trends. The locations of macroinvertebrate surveys are shown in Figure 4.2.

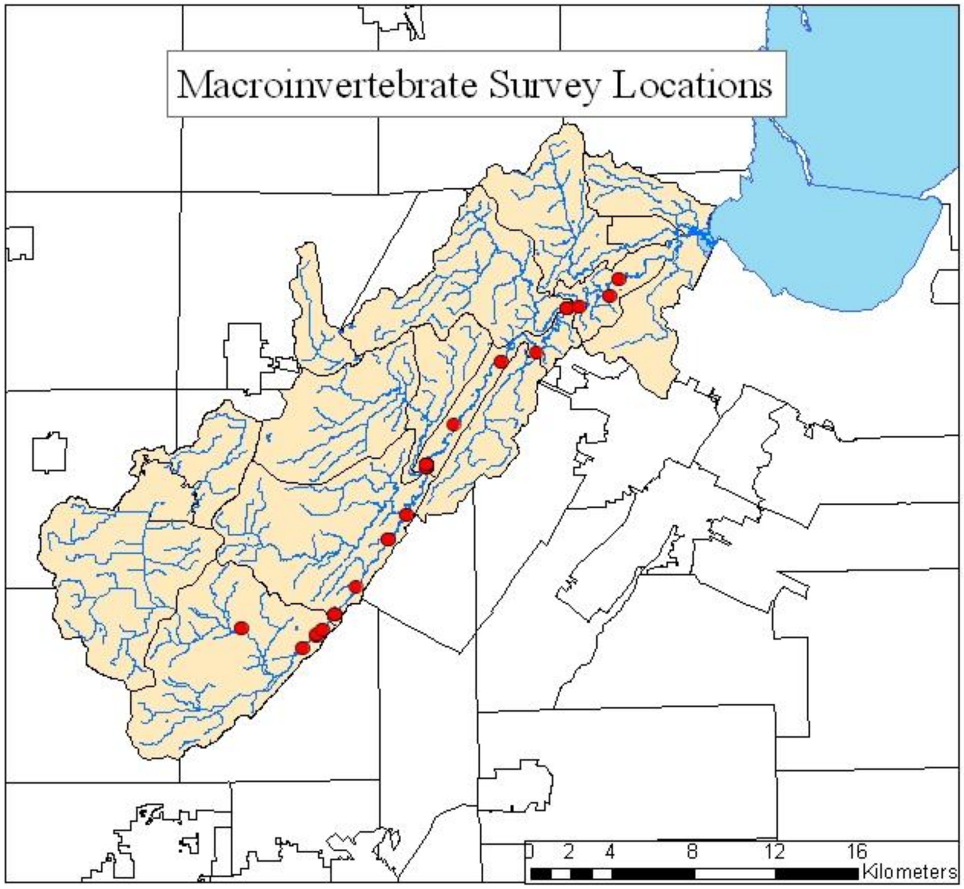

Figure 4.2: Locations of macroinvertebrate surveys in the Duck Creek watershed. All locations are located on the main stem of Duck Creek.

Macroinvertebrate data was analyzed using the UWSP BUG Biomonitoring Program (Lillie et al., 2003), developed by Stanley Szczytko's aquatic entomology lab at the University of Wisconsin Stevens Point. This program calculates 25 macroinvertebrate community metrics that are commonly used for bioassessments of water quality. Although many metrics are reported, the most commonly utilized metrics (# of species, HBI, FBI, and EPT%) were focused on due to their widespread use and acceptance (Lillie et al., 2003). It was discovered during the investigation that, due to the nature of the data, some benthic data could not be analyzed with the BUG Program. For example, the LFRWMP samples were identified only to the Family taxonomic level, with the intent of analyzing FBI and EPT% for these sampling periods. The HBI metric, which applies tolerance values to a specific genus or species, and the Species # metric, which counts the number of species, could not be applied to these samples. As a result, HBI and Species # metrics were calculated for a smaller dataset, while FBI and EPT% were calculated for all collected data.

Fish Community Trend Results

There were 20 significant changes in fisheries metrics between the first and third time periods within the three watershed locations. For each metric, it was determined if the metric value increased or decreased. These changes were related to either a positive or negative response in the fish community, based upon the nature of the metrics (Table 4.5). Metrics that exhibited a statistically significant change (either positive or negative) are presented in Table 4.6.

Table 4.5: Metric categories for Lyons' 1992 and 2006 IBI classification system, and their tendencies under increasingly stressful situations.

Metric	Lyons' Indices	Expected Response with Increasing Human Impact
Total Abundance	Neither	Decrease
Number of Native Species	Both	Decrease
Number of Intolerant Species	Both	Decrease
Number of Native Minnows	2006	Decrease
Number of Sucker Species	1992	Decrease
Number of Sunfish Species	1992	Decrease
Number of Darter Species	1992	Decrease
Number of Headwater Species	2006	Decrease
Percentage Insectivores	1992	Decrease
Percentage Omnivores	1992	Increase
Percentage Top Carnivores	1992	Decrease
Percentage Simple Lithophils	1992	Decrease
Percentage Tolerants	1992	Increase
Catch of Non Tolerants	2006	Decrease
Catch of Brook Stickleback	2006	Decrease
1992 IBI	1992	Decrease
2006 IBI	2006	Decrease

Table 4.6: Fish metrics with significant change (P<0.05), their locations in the watershed, the direction of change, and fish community implication between Periods 1 and 3 in Duck Creek, WI. The bottom portion of the table summarizes the number of positive and negative changes for each watershed location.

Metric	P-Value	Location†	Change	Implication
Abundance	0.0057	DS	Increase	Positive
	0.0424	US	Increase	Positive
No. of Native Species	<0.0001	DS	Increase	Positive
	0.0201	MS	Increase	Positive
No. of Darters	0.0022	DS	Increase	Positive
No. of Suckers	0.0019	DS	Decrease	Negative
No. of Sunfish	0.0394	US	Increase	Positive
No. of Intolerant Species	0.0356	MS	Decrease	Negative
% Tolerant Species	0.0263	DS	Increase	Negative
% Insectivores	0.0071	DS	Increase	Positive
% Top Carnivores	0.0148	DS	Decrease	Negative
	0.0154	MS	Decrease	Negative
1992 IBI	0.0452	DS	Increase	Positive
No. of Minnow Species	<0.0001	DS	Increase	Positive
	0.0028	MS	Increase	Positive
Catch of Non-Tolerant Species	0.0037	DS	Increase	Positive
	0.0439	MS	Increase	Positive
	0.0394	US	Increase	Positive
Catch of Brook Stickleback	0.0122	MS	Increase	Positive
2006 IBI	0.0045	DS	Increase	Positive

Summary by Watershed Location

Location	Significant Changes	Positive	Negative
DS	11	8	3
MS	6	4	2
US	3	3	0

† DS: downstream, US: upstream, MS: midstream.

Macroinvertebrate Trend Results

The Duck Creek macroinvertebrate dataset was limited in several ways. Sampling locations varied throughout the watershed over time, with many samples being collected in site-specific locations for various projects, such as the assessments for the DAAPWP. The LFRWMP consistently sampled the same two locations for several years, but only during the recent time period and this information was limited to only the family level of macroinvertebrate identification. The various sampling locations were not lumped together in to “watershed areas” as was done with the fish data because of the limited mobility and habitat specific nature of macroinvertebrates. As a result, several commonly used macroinvertebrate metrics were calculated on the given data, and no detailed trend analysis was performed.

Metrics were calculated for all applicable survey samples. Table D.1 details these metric results, along with site locations. BUG Program descriptions are identified in Table D.2 and output for all locations is listed in Table D.3.. There were a substantial number of surveys completed at two locations on mainstem Duck Creek – at Seminary Rd. and County Rd. FF. Figure 4.3 shows calculated metrics for all survey data, in all locations of the watershed, with respect to time. Seminary Rd. surveys are distinguished from all other sites (labeled as “other”) for all four metrics, while County Rd. FF, which had numerous data points collected through the LFRWMP, is isolated from “other” sites and Seminary Rd. sites for the FBI and EPT% metrics.

For all Duck Creek locations between 1979 and 2007, FBI values ranged from 4 (water quality “very good”) to 8 (water quality “very poor”), and the mean value was 5.7

("Fair" water quality). Mean values were similar for the Seminary Rd. site (5.8 – close to 5.7 yet included in the "Fairly Poor" category) and the County Rd. FF site (5.2). The number of species varied widely as well, ranging from 5 to 40 species. The mean number of species at all sites (without data from the LFRWMP) was 21, while the Seminary Rd. site averaged more diversity in the number of macroinvertebrates (30). The percent of the count that were Ephemeroptera, Plecoptera, and Trichoptera varied the most, ranging from 0 to 100%, though average values were similar between all sites (32%), the Seminary Rd. sites (30%), and the County Rd. FF sites (48%). HBI values included several potential outliers at 3 and 10 (water quality ratings of "Excellent" and "Very Poor"), while averages for all sites and the Seminary Rd. location each averaged 6.1 (water quality "Fair"). There were no apparent trends when these metric values were analyzed with respect to time or location in the watershed.

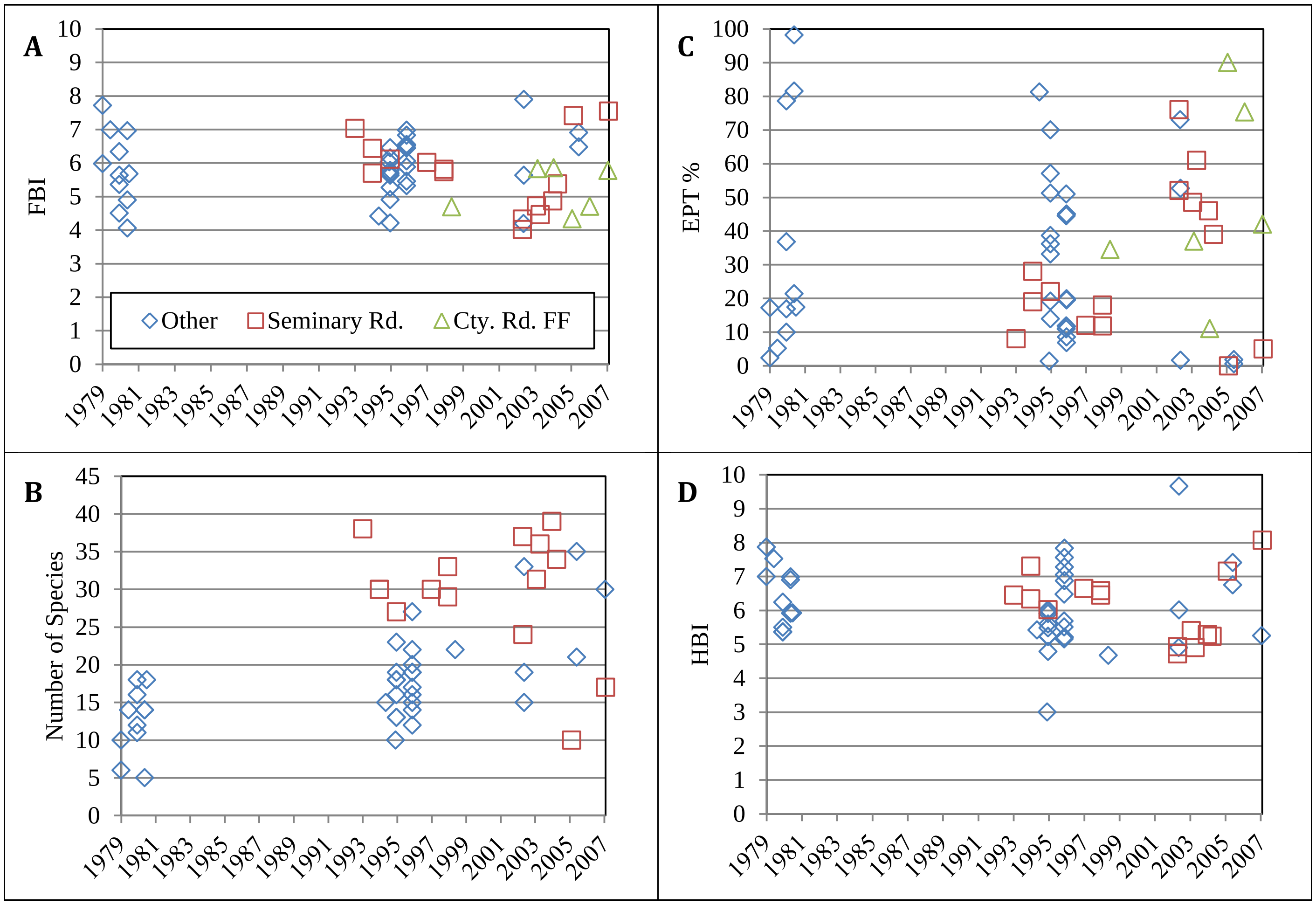

Figure 4.3: Calculated metrics for Duck Creek macroinvertebrate surveys. Metrics include FBI (A), Number of Species (B), EPT% (C), and HBI (D) for Seminary Rd., County Rd. FF and all other watershed locations with respect to time.

Discussion

Management practices have been implemented within the Duck Creek watershed with the goal of not only reducing sediment and nutrient export to the streams, but also in improve habitat conditions for aquatic organisms that live in these streams. As water quality of Duck Creek improves, the biotic communities in the stream are expected to exhibit signs of improvement as well.

Individual IBI metrics can be used to infer habitat conditions and presence of environmental degradation. Lyons (1992) and Gatz and Harig (1993) reports that low numbers of simple lithophilous species such as the common shiner (*Notropis cornutus*) and creek chub (*Semotilus atromaculatus*) and benthic species such as darters and suckers are typically present where siltation and loss of coarse substrate has occurred. In Duck Creek, although the numbers of darter species has increased downstream, the number of sucker species has decreased, and the number of simple lithophils has not changed (P = 0.2789) in any of the three watershed locations. This may indicate that Duck Creek is still experiencing heavy siltation in riffle and run areas of the stream, which would result in a loss of habitat and reproductive opportunity for these indicator species. Lyons (1992) also reports that top carnivores and sunfish species favor deep pools and instream cover habitats. The top carnivores metric significantly decreased in the mid and downstream reaches of Duck Creek, while the number of sunfish increased significantly in only the upstream locations. This may suggest lower reaches of the stream have lost the critical habitat required for predatory fish such as rock bass, smallmouth bass, and pike, while the upstream areas may still have this essential habitat. Minnow species and un-tolerant species have significantly increased in the watershed, which may indicate organic pollution has decreased, allowing these sensitive species to recover.

Several of the metrics may be more encompassing than others with respect to Duck Creek. Total abundance of fish species and the number of native species have increased in two of the three watershed locations. These trends indicate that the fish communities are not only becoming more diverse, but also more prolific. And finally, the 1992 and 2006 overall IBI values have increased in the downstream portions of the creek.

Overall, the fish communities of Duck Creek have begun to show signs of improvement in all areas of the watershed. In the downstream reaches, 73% of all significant metric changes were in a positive direction, while midstream and upstream reaches show 67% and 100% positive changes, respectively. The downstream reaches showed the largest number of both positive and negative changes (8 positive and 3 negative). This stream section may exhibit more community adjustments because it encompasses more of the watershed than the upstream and midstream reaches, and therefore is more reflective of overall conditions.

The macroinvertebrate data was assessed with respect to time, yet further analysis was unable to be performed due to the lack of consistent site-based monitoring through the analysis period. The current data set shows great variability, especially in the EPT % index. This index may be the most vulnerable to sampling bias due to the macroinvertebrates in these families being very selective of habitat. With multiple agencies contributing data for this analysis, it is possible that differing sampling methodology is responsible for this variability. The number of species may also be influenced by using different sampling methods for invertebrate collection for this same reason. However even though these metrics displayed much variability the Biotic Indices developed by Hilsenhoff (1987; 1988) seem to show greater consistency, just as Lenz and Millers (1996) had discovered. Some outlier values exist, yet values seem to be centered fairly well over the means of the HBI and FBI, which are consistent in their water quality counterpart (both values indicate “Fair” to “Fairly Poor” water quality).

It is unfortunate that the macroinvertebrate dataset was limited. In order for trends to be investigated on this biotic community, it is important that studies be completed in the same locations year after year, using a similar sampling protocol. Macroinvertebrates are highly limited in terms of their mobility, and very selective of habitat. Sampling in one location followed by a location downstream would not be ideal for comparison purposes due to the nature of these organisms. However, the efforts at analyzing the dataset were not without merit because these surveys were further characterized through the use of the BUG Program, and several possible long-term trend sites have been established (Seminary Rd. and County Rd. FF).

CHAPTER 5 - TROUT CREEK WATER QUALITY ANALYSIS

Introduction

In the DAAPWP assessment study, officials noted that Trout Creek was one of the few streams in the region to have “good flow” throughout the year (WDNR, 1997). The geology of this small watershed is likely the reason this stream is able to flow continuously. Approximately 14,000 years ago, the Cary ice sheet retreated in several phases, leaving behind recessional moraines through modern day Bonduel, Cecil and Black Creek, WI. It melted further and eventually paused on the eastern side of the creek basin. In doing this, it formed another moraine that impounded a lake between this eastern boundary and the moraine in Bonduel. Early Lake Oshkosh was fairly shallow and deposited large quantities of sand in its place (Dorney et al., 1973). Later on, the ice melted further and the drainage systems of the watershed developed.

These sandy deposits still dominate the watershed soils today. In late March of 2008 temperatures climbed rapidly, allowing a record-setting winter snowfall to melt in a short period of time. The waters of Trout Creek rose past the tops of the streambank and left deposits of sand on the forest floor surrounding the stream. It was undoubtedly a high-flow event, and raises questions about how the biotic communities in the stream are impacted by harsh conditions.

With the possible re-introduction of brook trout to Trout Creek by the Oneida Tribe of Indians, it is important to understand the nature of the waters these fish will inhabit. The waters of Trout Creek were assessed for nutrients and physical characteristics in 2008 at two locations, with this re-introduction in mind. This chapter presents results of a comparison in phosphorus and sediment concentrations between an upstream and downstream location on Trout Creek and documents temperature, DO and other characteristics at the two sites in 2008. An interpretation of the findings is also presented in the context of potential problems regarding the survival of brook trout, a particularly sensitive species.

Methods

Monitoring Locations and Nutrient and Sediment Monitoring

Two Trout Creek locations were monitored in this portion of the study– at the stream crossing of County Rd. FF / Hillcrest Drive (TC1) and off of Oak Ridge Rd. near the former Desjardin Farm (TC2) (Figure 5.1). Bi-weekly and rain event samples were collected at the downstream TC1 site, which accounted for the entire Trout Creek watershed. At the upstream site, TC2, bi-weekly samples were collected within one hour of collection of the TC1 samples. At this location only one event sample was collected.

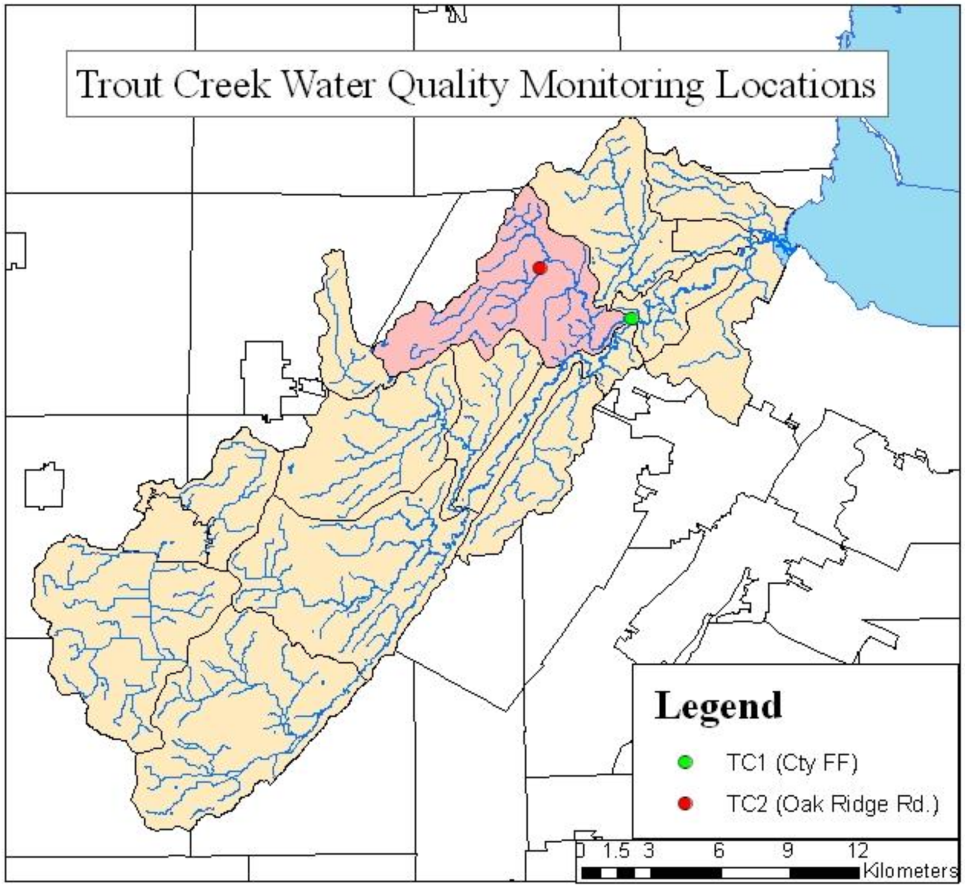

Figure 5.1: Location of the Trout Creek watershed and 2 water quality monitoring locations. Nutrient and physical water quality parameters were measured at TC1 (downstream) and TC2 (upstream) during 2008.

Bi-weekly water quality samples were collected through the use of equal width interval sampling devices. Event samples of higher flow were sampled through the use of siphon samplers (Gracyk et al., 2000). All samples were transported to the UWGB water quality lab and then divided into smaller quantities using a Teflon cone splitter, which allowed several parameters to be tested on one sample. Samples were analyzed for TP, DP, and TSS concentration. Samples for DP analysis were filtered through a 0.45 µm membrane filter to remove particulate matter. Both TP and DP samples were preserved with diluted sulfuric acid (3:1 concentration) and refrigerated until analysis at the Green Bay Metropolitan Sewerage District (GBMSD). Total phosphorus and DP analyses followed USEPA's Automated Block Digester Method 365.4 (USEPA 1983). Total Suspended Solids samples were also analyzed at the GBMSD using Standard Method 240 D (Clesceri et al., 1988).

Physical Water Quality Monitoring

In addition to nutrient and sediment sampling, physical water quality parameters (temperature, pH, conductivity, depth, turbidity, and dissolved oxygen) were measured with continuously recording YSI 6600 EDS Sondes (YSI Inc, Yellow Springs, OH). The sondes were deployed at site TC1 from June 6 through November 21 and at site TC2 from July 2 through October 31. Each parameter was measured and recorded at 10 minute intervals. The sondes were removed from the field and re-calibrated about once every 2-3 weeks to ensure accuracy of the collected data. A number of QA/QC procedures were implemented on the dataset. Dissolved oxygen values were removed when the charge of the oxygen probe strayed outside of its recommended limits (a charge of 25 to 75). The erroneous DO data often occurred when the DO probe membrane was damaged. Damage to the membranes was likely caused by crayfish crawling over the sonde. Raw turbidity data was adjusted by adding the lowest negative reading (if any) for a deployment period to each turbidity reading for that respective period. On two occasions the monitoring probes experienced battery related errors, resulting in several days of missing data. Data were extracted from the sondes and compiled using Ecowatch (YSI Inc, Yellow Springs, OH) analysis software. Following the previously mentioned

QA/QC procedures, daily and monthly summary statistics were estimated for each parameter.

An atmospheric pressure-compensated pressure transducer and temperature probe were connected to a CR-10 datalogger (Campbell Scientific, Inc., Logan, UT) and deployed at County Rd. FF to continuously (10 min. intervals) record gage height and stream water temperature. This datalogger was in operation from May 1 through November 21 and recorded several moderate flow events that were missed with the YSI sondes. The datalogger and a 75 mm PVC pipe which housed the probes were attached to a USGS crest gage on the downstream side of the County Rd. FF culvert. The USGS crest gage served as a reference point for establishing stream gage height. The upper lip of the cap at the bottom of the crest gage pipe was assumed to be at 10 feet, to be consistent with the markings on the wood staff inside the pipe. Readings from the water depth probe were adjusted to coincide with the crest gage readings by adding 8.900 feet to the recorded water height.

Results

Flow and Physical Water Quality Parameters

Weather in 2008 was anomalous in several respects. Many areas of the state reported record snowfalls in the winter of 2007 – 2008. Green Bay received 90 cm more snowfall than the 30-yr average (NWS, 2009). Total January-April, water-equivalent precipitation was nearly double the 30-yr. average (+16 cm). Early spring (March and April) was characterized by rapid snowmelt and few rain events. Water levels in Trout Creek receded throughout May, a month in which rainfall was about one-half the typical amount (Fig. 5.2). In early June, the Midwestern United States experienced very heavy rainfall, which fell upon soils that were still saturated from the spring snowmelt and impacted stream levels that were already higher than average (Fitzpatrick et al., 2008). While daily rainfall records of more than 10 cm were set at numerous sites in southern Wisconsin, Northeastern Wisconsin received considerably less rain in that period (3.5 cm on June 8, 2008 at the Duck Creek USGS monitoring station). Water levels in Trout Creek rose nearly two feet (60 cm) in response to the rain storm (Fig. 5.2). The rest of the summer was characterized by smaller (< 2.5 cm) rain events with the exception of July 2nd, in which a rainfall of 3.0 cm was recorded at the Duck Creek USGS monitoring station. Water levels in Trout Creek dropped to their lowest values in August in response to less than one cm of rainfall for the month (Fig. 5.2). Total rainfall from August through November was about 14 cm below average resulting in modest flow increases following the growing season (see Table A.1 for NWS data).

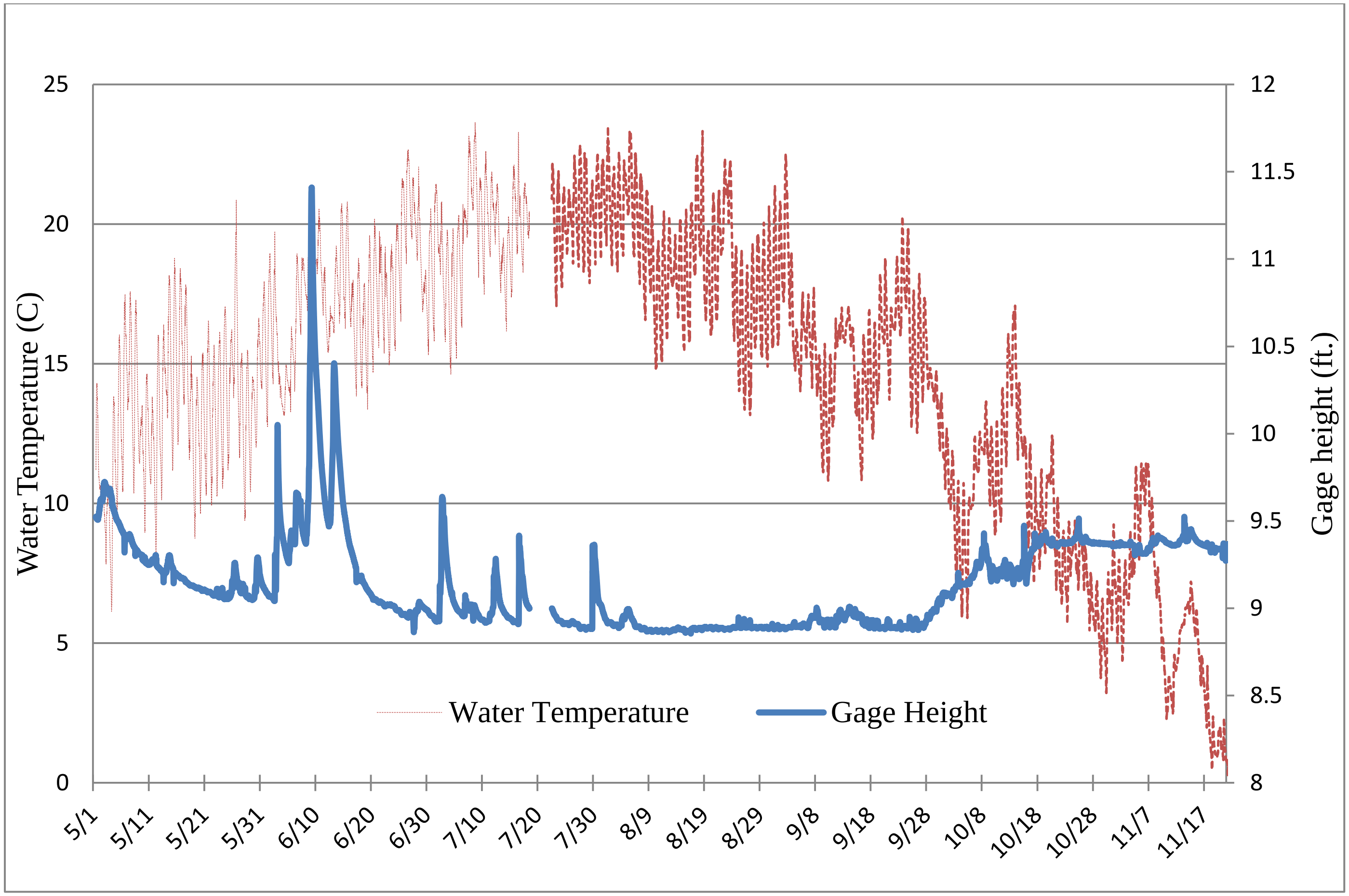

Figure 5.2: Gage height and water temperature for Trout Creek during May-November of 2008. Data was recorded at County Rd. FF using a CR-10 datalogger and pressure transducer (Campbell Scientific, Inc., Logan, UT).

The downstream (TC1) and upstream (TC2) multiparameter sondes were operational from July through October. Limited data were collected at site TC1 in and June and early November. Daily mean, maximum and minimum from 10 minute data for each monitoring site are presented in Tables E.1 and E.2. Monthly data are summarized in Tables 5.1 and 5.2.

Table 5.1: Monthly physical water quality parameter statistics for Trout Creek at County Rd. FF (site TC1). Data was continuously collected at 10 min. intervals using a multiparameter sonde.

Trout Creek at County Rd. FF (TC1)

		Jun.	Jul.	Aug.	Sept.	Oct.	Nov.
Temp (C)	Mean	17.4	19.5	18.4	15.2	8.3	4.7
	Max	20.6	23.0	22.8	20.8	15.9	10.9
	Min	14.9	14.4	13.6	10.7	2.2	-0.2
pH	Mean	8.2	8.3	8.4	8.3	7.9	7.7
	Max	8.3	8.5	8.6	8.5	8.2	7.9
	Min	7.9	6.7	8.2	8.2	7.6	7.6
D.O. (mg/L)	Mean	7.9	9.0	9.1	9.3	9.7	10.1
	Max	9.7	11.0	13.1	11.3	14.1	14.5
	Min	6.0	7.0	7.2	7.2	4.7	5.8
D.O. %	Mean	83	98	97	92	82	78
	Max	103	122	138	110	111	101
	Min	60	75	75	78	45	51
Spc. Cond (mS/cm)	Mean	0.598	0.724	0.789	0.782	0.848	0.849
	Max	0.818	0.817	0.817	0.812	0.881	0.922
	Min	0.318	0.447	0.712	0.689	0.791	0.753
Turbidity (NTU)	Mean	26	11	12	10	4	6
	Max	222	302	48	23	21	33
	Min	3	1	2	4	2	2.0
Depth (m)	Mean	0.38	0.21	0.09	0.14	0.28	0.17
	Max	0.66	0.62	0.16	0.27	0.40	0.36
	Min	0.11	0.00	0.00	0.00	0.07	0.00

Table 5.2: Monthly physical water quality parameter statistics for Trout Creek at Oak Ridge Rd. (site TC2). Data was collected using a multiparameter sonde.

Trout Creek at Oak Ridge Rd. (TC2)					
		Jul.	Aug.	Sept.	Oct.
Temp (C)	Mean	18.9	17.8	14.8	8.7
	Max	22.9	22.3	21.2	16.0
	Min	14.8	13.5	10.7	2.4
pH	Mean	7.9	7.9	7.9	7.7
	Max	8.1	8.1	8.2	7.9
	Min	7.5	7.6	7.7	7.6
D.O. (mg/L)	Mean	7.2	8.4	7.8	7.6
	Max	9.6	11.5	11.8	11.2
	Min	5.2	5.6	5.7	3.1
D.O. %	Mean	78	88	78	65
	Max	107	124	118	91
	Min	56	61	56	29
Spc. Cond (mS/cm)	Mean	0.553	0.801	0.799	0.828
	Max	0.841	0.846	0.844	0.869
	Min	0.254	0.645	0.654	0.692
Turbidity (NTU)	Mean	22	7	10	10
	Max	934	107	382	55
	Min	0	2	2	3
Depth (m)	Mean	0.18	0.20	0.17	0.21
	Max	0.48	0.29	0.29	0.35
	Min	0.08	0.10	0.05	0.00

Maximum water temperatures occurred during July at both sites (Fig. 5.2 and Tables 5.1 and 5.2). Recorded measurements at TC1 were similar to previous temperature data collected by the Oneida Tribe (Stacy Gilmore, personal communication) and the USGS (USGS online database, http://nwis.waterdata.usgs.gov/nwis/qwdata/?site_no=04072185&). The maximum temperature at TC1 in 2008 was 23.0 degrees C on July 8. A maximum temperature of 26.8 degrees C was recorded at this site by the USGS in the afternoon of July17, 2002. Temperatures were either the same or slightly lower at TC2.

Dissolved oxygen concentration and percentage fluctuated widely during the monitoring period, both seasonally and diurnally. The stream water remained well oxygenated through the hot summer months of June, July, August and September. However, oxygen levels dropped below 5.0 mg/L at the TC1 site for approximately 7 hours during the early morning hours of October 14th, before returning to the monthly average of 9.7 mg/L later in the day. At TC2, oxygen concentrations dropped below 5.0 mg/L on two occasions, once on October 13th for a 9-hour period, and then again that same day onward for a duration of 64 hours. During this time concentrations ranged from 3.1 mg/L to 4.9 mg/L (Table E.2)

The pH and conductivity at the two Trout Creek monitoring sites are not different from those measurements taken by the Oneida Tribe or USGS. The WDNR (2006) reports that the northeastern region of Wisconsin typically sees higher pH and specific conductivity due to the carbonate rich bedrock groups in the area. The pH levels remained slightly alkaline (>7) for both locations during the monitoring period and reached maximums of 8.5 and 7.9 for TC1 and TC2, respectively. The mean pH also dropped slightly during the period at both sites. Specific conductance means increased from the early, wet summer months to the drier fall months. The observed trend in pH and specific conductance was expected as the proportion of the water in the stream shifted to become more groundwater dominated, instead of mostly rainwater.

Daily mean turbidity at both sites were fairly low, rarely exceeding 25 NTU (Tables 5.1 and 5.2). Daily mean turbidity exceeded 130 NTU in early July at TC2 and had a maximum of more than 900 NTU's. This maximum value lasted only briefly (10 minutes) though the stream remained fairly turbid (100-400 NTU) during the 20 hours that followed this sharp turbidity peak. These readings were taken on July 2nd and July 3rd during an isolated rain event. In general turbidity values less than 130 NTU occurred immediately following rainfall events, and only remained that high for a few hours.

It should be noted that although the descriptive statistics indicate that depth reached a minimum level of 0.0 meters, this was not observed at any time during the monitoring period. A depth value of 0.0 should indicate that water levels had decreased to the sonde unit itself, however this also was not observed at anytime. YSI reports that the accuracy range of the sonde's depth probe is ± 0.02 meters (YSI 6600 Sonde Specification manual 0103 E33-02). Although flow decreased in the late summer / early fall months, field reports indicate that considerable flow was observed in the driest of times at TC1, even when nearby Duck Creek dried up completely at the County Rd. FF bridge. It was noted on October 3rd that at TC2 flow did decrease to the point where water appeared to be standing in the center channel of the stream and moving at only a small trickle.

Nutrient and Sediment Monitoring Results

Descriptive statistics for water quality samples collected at the two sampling sites are presented in Table 5.3. Sample dates, times and analytical results for individual samples from each site are given in Table E.3. Recall that bi-weekly samples were collected at both sites for site comparison purposes. In addition, rain event samples were also collected at site TC1.

Table 5.3: Summary statistics for water quality samples collected at two Trout Creek locations in 2008. All concentrations are in mg/L.

	TC1 - County Rd. FF			TC2 - Oak Ridge Rd.		
	TSS	TP	DP	TSS	TP	DP
N	18	18	17	10	10	10
Mean	198	0.296	0.057	64	0.224	0.073
Median	49	0.161	0.044	4	0.095	0.055
Max	1490	1.160	0.156	442	0.830	0.210
Min	2	0.015	0.015	2	0.015	0.015

The bi-weekly samples were isolated from the dataset to perform a statistical comparison between sites (Table 5.4). Samples were arranged pairwise and analyzed statistically with the Statistical Analysis Software package (SAS version 9.1.3 © 2002-2003). Samples that were recorded below the GBMSD lower detection level of 2.2 mg/L for TSS and 0.015 mg/L for phosphorus were treated as that lower detection limit. TSS, TP, and DP were log-transformed to achieve normality. Log-transformed TP showed a strong, significant correlation between TC1 and TC2 (Pearson's $r = 0.84$, $p = 0.009$) and log-transformed DP also showed this same relationship (Pearson's $r = 0.79$, $p=0.02$). Log-transformed TSS showed a weak correlation (Pearson's $r = 0.27$) that was not significant ($p=0.5$). This was likely due to several outliers in the relatively small dataset (Table 5.4).

Table 5.4: Summary of bi-weekly water quality samples collected at two locations on Trout Creek in 2008. All concentrations are in mg/L.

	Parameter	TC1	TC2
Pair 1 6/25/2008	TSS	16.0	7.0
	TP	0.113	0.133
	DP	0.060	0.092
Pair 2 7/22/2008	TSS	9.8	3.0
	TP	0.083	0.151
	DP	0.044	0.064
Pair 3 8/19/2008	TSS	8.9	4.0
	TP	0.073	0.085
	DP	0.058	0.049
Pair 4 9/8/2008	TSS	3.2	2.2
	TP	0.035	0.074
	DP	0.016	0.050
Pair 5 9/18/2008	TSS	3.2	2.9
	TP	0.064	0.070
	DP	0.048	0.048
Pair 6 10/3/2008	TSS	2.5	14.0
	TP	0.043	0.105
	DP	0.038	0.059
Pair 7 10/31/2008	TSS	<2.2	<2.2
	TP	<0.015	0.046
	DP	<0.015	0.017
Pair 8 11/21/2008	TSS	2.1	2.0
	TP	<0.015	<0.015
	DP	<0.015	<0.015

A Paired T-Test was run on log-transformed TSS, TP, and DP to determine if a difference existed in the mean concentrations between the two sites. Significant differences were seen between the two locations for log-transformed TP (p=0.0163) and log-transformed DP (p=0.0031), but not for TSS (p=0.5421) (Table 5.5). Both phosphorus forms were found in higher concentrations at the upstream site (TC2).

Table 5.5: Simple statistics and p-values for a paired t-test performed on three water quality parameters monitored at two sites in Trout Creek (N=8). All concentrations are in mg/L.

	TSS		TP		DP	
	TC1	TC2	TC1	TC2	TC1	TC2
Mean	6.0	4.7	0.060	0.085	0.037	0.049
Min	2.1	2.0	0.015	0.015	0.015	0.015
Max	16.0	14.0	0.113	0.151	0.060	0.092
Std	5.1	4.1	0.034	0.044	0.019	0.025
p-value	0.5421		0.0163		0.0031	

Discussion

Water temperature means of 17 to 19 degrees C seem to be the norm in Trout Creek, based upon 2008 intensive monitoring and historical data collected by the Oneida Tribe and USGS. The peak temperature of 23 degrees C occurred at TC1 in July during the hottest part of the summer.

Oxygen is an important factor to aquatic life. At TC1, mean dissolved oxygen levels were close to saturation during the entire monitoring period (means ranging from

81.7% to 97.6%) while the upstream site displayed lower saturation percent means (65.2% to 87.9%). Bottom substrate likely plays a key role in oxygen concentrations, as the downstream monitoring site is located near an artificially created riffle/pool/riffle series, whereas TC2 has a primarily smooth, sandy bottom. Thus, more oxygen may be dissolving into the water where physical mixing of the water is occurring. Dissolved oxygen was able to deplete below a critical level of 5 mg/L twice for an extended period of time (9 and then 64 hours) whereas the TC1 site saw a dip below this threshold during only one 7-hour period.

The Oneida Tribe of Indians has a Water Quality Standard of 0.1 mg/L for total phosphorus concentrations in Trout Creek and other tributary streams (Gilmore 2007). 38% of samples collected at TC1 met this standard, while 50% did so at the upstream (TC2.) site. However, more "event" based samples were collected at the downstream site. Of the baseflow samples collected, 7 of the 8 TC1 samples met the Oneida Water Quality Standard and 6 of the 8 TC2 samples met the standard. A comparison of low-flow TP and DP samples between two sites in Trout Creek revealed that upstream concentrations of both parameters were significantly higher than downstream concentrations. While measured TSS means were higher at the downstream site, a significant difference was not detected between sites.

Although the element of hydrology was partially minimized by sampling during summer and fall baseflow, there may be several other factors influencing these results. Within short distances the stream changes from flat pools to short, swift riffles. The width of the stream changes as well, allowing for diverse riparian areas which may alter the flow and nutrient concentration of the stream. Bilby and Likens (1980) found that instream structure can trap particulate matter and Bencala (1984) determined that storage of dissolved constituents may occur in pools, side channels, and subsurface spaces. Studies have shown that phosphorus uptake by organisms can occur in less than 100 m, and that if this nutrient is not adequately resupplied to the streamwater, phosphorus availability downstream will decline (Mulholland et al. 1990, Munn and Meyer 1990). Mulholland and Rosemond (1992) discovered that instream processes were primarily responsible for longitudinal depletion of phosphorus. Furthermore, water inputs may influence nutrient concentrations in streams. A smaller tributary (north branch of Trout Creek) flows through heavily wooded areas and eventually enters the mainstem of Trout Creek shortly downstream of the TC2 site. This tributary may be causing a “dilution effect” in which well-filtered, relatively cleaner water is diluting the downstream portions of Trout Creek. Thus, a number of hydrologic and biotic mechanisms may be responsible for the dilution, transient storage, or uptake of phosphorus as it moves downstream.

As of May 2008, the Oneida Tribe has already begun stocking Trout Creek with brook trout in several locations. The collected sonde data shows that conditions appear to be suitable in Trout Creek for survival of this species. Monthly and daily means of dissolved oxygen, temperature, pH, and turbidity at both Trout Creek locations fell within the optimal ranges reported for brook trout (discussed in Chapter 1). Table 5.6 summarizes these reported conditions and ranges as well as those ranges observed in Trout Creek in 2008.

Table 5.6: Published ranges of various parameters for brook trout, along with daily mean and 95% confidence intervals measured in Trout Creek at two locations (TC1 and TC2) in 2008.

Parameter	Optimal Conditions	Range	TC1 July, August, September Daily Means	95 % CI	TC1 October Daily Means	95 % CI
D.O. (mg/L)	7.0 to 9.0	5.0 to Sat.	9.2	8.5, 9.9	10.1	8.6, 11.6
Temperature (degrees C)	11 to 16	0 to 24	16.1	14.0, 18.2	4.7	2.1, 7.3
pH	6.8 to 8.0	3.5 to 9.8	8.2	8.0, 8.4	7.7	7.65, 7.75
Turbidity (NTU)	0 to 30	0 to 130	11	6.5, 15.5	6	3.2, 8.8

Parameter	Optimal Conditions	Range	TC2 July, August, September Daily Means	95 % CI	TC2 October Daily Means	95 % CI
D.O. (mg/L)	7.0 to 9.0	5.0 to Sat.	7.8	7.2, 8.4	7.6	6.3, 8.9
Temperature (degrees C)	11 to 16	0 to 24	17.2	16.2, 18.2	8.6	6.8, 10.4
pH	6.8 to 8.0	3.5 to 9.8	7.9	7.8, 8.0	7.7	7.6, 7.8
Turbidity (NTU)	0 to 30	0 to 130	7	5, 9	9.8	7.8, 11.8

CHAPTER 6 – PROJECT SUMMARY

This study was undertaken with the intention of linking water quality trends and biotic community indices with substantial efforts by multiple agencies to restore this anthropogenically degraded watershed. The specific objectives were previously stated in Chapter 1 of this thesis. In this chapter, each of the objectives is addressed in order. Difficulties experienced during the course of the study are examined and significant findings are highlighted.

Objective 1 – Land Management Analysis

Despite rapid population increases in recent years, agricultural lands still dominate the Duck Creek watershed. The DAAPWP was initiated in 1997 with several goals in mind, including identification of "critical" areas in the watershed and reducing runoff pollution from rural and urban areas to the streams in the three watersheds. The program appears to be a success, though lack of detailed record keeping and use of different methods to quantify nutrient and sediment reductions has resulted in somewhat incomplete results. However the underlying mission of reducing runoff pollution, fixing critical locations/problems, and increasing awareness of water quality issues was ultimately accomplished.

The agricultural survey of the watershed indicated an increase in the use of conservation tillage, though data were somewhat limited and these results should be taken with caution. There is a general belief that more land managers are becoming aware of the benefits of conservation tillage (both environmental and economic) and are incorporating this method where applicable. The Oneida Tribe has also strongly enforced nutrient management plans on their farms in the watershed.

Farm numbers have decreased in the watershed substantially. In Brown County the numbers of cows on these farms have increased while farms in Outagamie County have seen a sharp decrease in cows. This decrease took part primarily during 1989-1998. It is likely that national trends have affected northeastern Wisconsin as well and smaller farms are closing down in favor of larger operations.

The Oneida Tribe has spent tremendous effort restoring the lands within the reservation. Their focus has not only been on BMP implementation, restoring native lands, and intensive nutrient management, but also on creating habitat for fish, invertebrates, birds, and other wildlife. Although their efforts have been taking place for quite some time, quantitative data was only available for recent years.

Objective 2 – Trend Analysis of Water Quality and Biotic Data

The statistical trend analysis of water quality produced several interesting results. First, it was determined that an analysis of suspended solids was not achievable. Differences in the laboratory processing of suspended solid samples prevented a distinguishable relationship between TSS and SSC, and the two methods were utilized at different times within the data analysis record. This is unfortunate as many of the efforts aimed at restoring the Duck Creek watershed have focused on reducing sediment erosion to the stream.

The trend analysis focused on phosphorus. Total and dissolved phosphorus had been monitored continuously throughout the 20-year period by the USGS and others using the same collection and laboratory procedures. However, as previously discussed, the timing and frequency in which these samples were collected varied as according to specific monitoring goals and financial constraints that changed during the period. Numerous approaches were researched and attempted to mitigate this dilemma before deciding on the procedures discussed in Chapter 3. The four statistical procedures employed in this study led to the same general conclusion that both TP and DP concentrations have decreased significantly during the past 20 years, although not at a steady rate. Decreases occurred primarily in the beginning (USGS water years 1989-1995) of this 20-year period. Overall, concentrations were larger at the beginning of the 20 year record and lower towards the end.

The fish communities in Duck Creek have likely adapted to changing water quality. When IBI metrics of the communities in three watershed localities were examined, it was found that 11 metrics changed significantly in the downstream portions of the watershed had (73% of which were positive changes), while the midstream and upstream portions experienced 6 (67% positive) and 3 (100% positive) changes, respectively. The overall conclusion is that fish communities are showing more diversity in Duck Creek, and that species sensitive to organic pollution are becoming more prevalent.

The macroinvertebrate analysis was limited by the number of surveys conducted at similar locations in the watershed. Biotic index calculations from these surveys were rated as "Poor" to "Fair" with several "Good" assessments, indicating that macroinvertebrates are experiencing a fair amount of organic pollution or other stressors. Although it is important to continue site-specific macroinvertebrate collections for the purposes of individual projects, it is recommended that several reference sites be established in the watershed, so that in the future long-term trends may be examined for macroinvertebrates.

Objective 3 – Relationships among Land-Use, Water Quality, and Biotic Condition

It is especially difficult to determine the effects of BMP placement and other land management activities on water quality unless the project design is such that influential variables are controlled. For watersheds undergoing a "treatment" (i.e. BMP additions or other land management changes), the USEPA recommends a Paired Watershed Study design (USEPA 1993). This design calls for a minimum of two watersheds (a control and treatment) and two periods of study (a calibration and treatment). Using this method, year-to-year or seasonal climate variations are accounted for. Year-to-year variations in climate were certainly a factor in the Duck Creek watershed during the study period, and unfortunately the nearest watershed of similar size and climate (Popple Creek watershed in Florence County, WI) did not have sufficient data collection (water quality or biotic community surveys) for comparison purposes to Duck Creek. This coupled with the fact that BMP and land management quantitative and spatial data were difficult to obtain, makes creating a link between land management and water quality extremely problematic.

The decreases observed in TP and DP through the statistical trend analysis are substantial. There are several factors identified in this study that may have supported this decreasing trend. The increase in BMP implementation through the DAAPWP has produced substantial reductions in both sediment and phosphorus for both Brown and Outagamie Counties, though the exact results are debatable. Education about cropland and general land management was also an important outcome of the DAAPWP. A decrease in barnyards through both counties and decrease in cows in Outagamie County have likely played a role in reducing phosphorus concentrations, particularly in the dissolved form. And the reductions seen in permitted point source discharges have certainly contributed towards this trend, with both permitted dischargers reducing annual phosphorus loads significantly since 1993.

If a large decrease was only observed following the years of BMP implementation and land management activities, it may be easier to assume the water quality has changed due to these factors. However with large decreases occurring before and after the defined "transitional period", this assumption cannot be made. Although it is likely that these efforts have not been in vain and have contributed to a decrease in phosphorus concentrations in Duck Creek, climatic conditions such as dry years and years with above average snowfall are a major contributing factor to these trends, and the decrease in phosphorus concentrations cannot be linked to land-use and land-management changes alone.

Objective 4 – Characterization of Trout Creek Water Quality

Trout Creek is a cool-water tributary stream that originates in the northeastern part of the Duck Creek watershed before flowing into Duck Creek. During baseflow conditions, the waters of the stream carry concentrations of total and dissolved phosphorus that met the Oneida Tribe of Indians Water Quality standard 81% of the time between the two sampling locations. The concentration exceeds this standard during most rain events. Sediment concentrations were found to be relatively high during moderate flow events, possibly due to the larger sand particles that were visually observed in this watershed. The two sites monitored displayed different habitat settings and also different water quality characteristics. The instream structure and overhead canopy at County Rd. FF as well as the likely dilution effect from the north branch of Trout Creek accounted for the differences seen in the phosphorus concentrations, temperature, and dissolved oxygen between these sites.

With respect to Brook Trout suitability to these waters, the somewhat large TSS concentrations are probably not that worrisome, as fine-grained sediments are reported to be more problematic to this species in Wisconsin streams (Scudder et. Al. 2000). Trout Creek appears to be hospitable to this species in terms of physical water characteristics as well. Temperature, dissolved oxygen, pH, and turbidity daily means during the 2008 monitoring period all fall within ranges that are either optimal or tolerable to this species. And with the Oneida Tribe putting the effort forth to re-create crucial habitat (logjams, riffles and pools, streambank stability, etc.) in the stream, there is a good chance Brook Trout will soon be established in the stream.

Objective 5 – Management Implications and Recommendations

It is difficult to manage a stream that is classified as intermittent in some portions for aquatic organisms, aesthetic value or recreational opportunity. Common conservation practices have been implemented on this stream, but there are specific management actions that could be improved upon for Duck Creek. In March of 2008 spring snowmelt caused Duck Creek's flow to soar to 2,000 cfs. Because this intermittent stream is able to experience wide fluctuations in flow, restoring native streambank vegetation will play an important role in mitigating erosion. Streambank vegetation or other riparian zone stability plays a critical role in preventing the stream from eroding the shoreline. Roads, trails or other crossings should be routed over or around the stream and its buffer area. Particularly in dry periods, stock must not be permitted to enter the stream channel or riparian zones. Besides the nutrient input that results from stock animals, the erosion that takes place during times of no/low flow settles to the streambed rather than being transported downstream. This will contribute directly to the loss of pools in the stream.

Alteration to the natural hydrological regime is not recommended. This would include the effects of urbanization on the stream. Increased urban landscapes near Duck Creek would undoubtedly reduce infiltration within the watershed, contributing to the "flashiness" of the stream. Small man-made barriers (weirs, culverts, dams) should be prevented as much as possible, as these devices can restrict access to pools of water which may serve as refuge habitats for organisms during times of low flow.

It is of great importance that the management of Duck Creek include a plan for long-term monitoring. With continuing efforts to conserve this resource being implemented, it is necessary to be able to quantify and document success stories that may occur as a result. Changes in land management (BMP's, field tillage transitions, land-use changes etc.) should be well documented. The USGS monitoring station on County Rd. FF has enabled collections of 20 years of reliable and diverse data, and should remain in operation in order to continue monitoring long term trends. The biological communities are likely to change both annually and seasonally in an unstable system such as Duck Creek, but nevertheless it is important to establish reference monitoring sites in the watershed that can be used for long term trend analysis. And finally, the information collected from management and monitoring efforts in the Duck Creek watershed needs to be fully disclosed, so everyone has the opportunity to contribute to the conservation of this unique resource.

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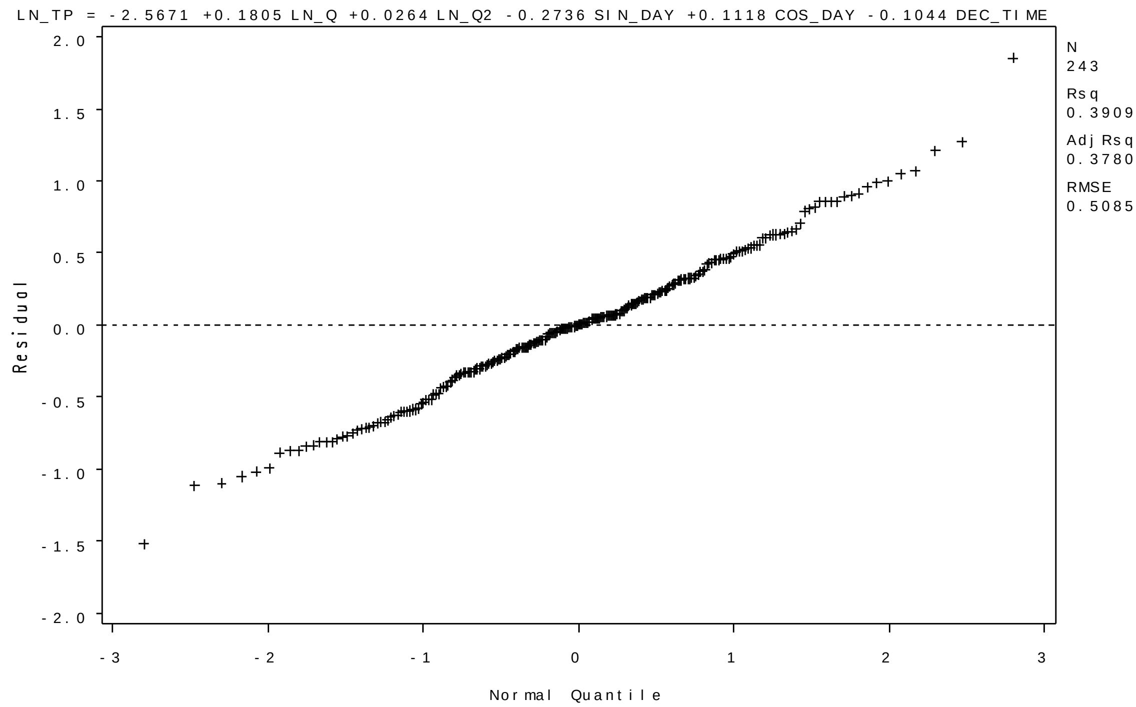
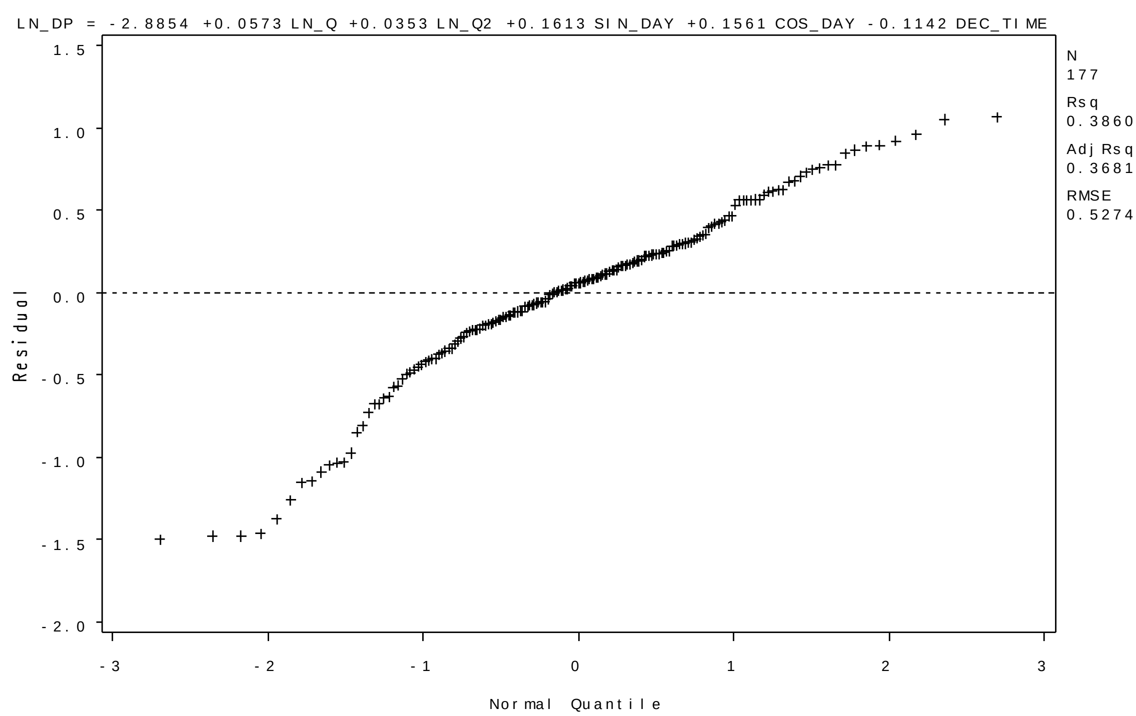
APPENDIX A: MONTHLY PRECIPITATION

A.2: Monthly precipitation (1976-2008) measured at the National Weather Service station in Green Bay, WI (NOAA 2009)

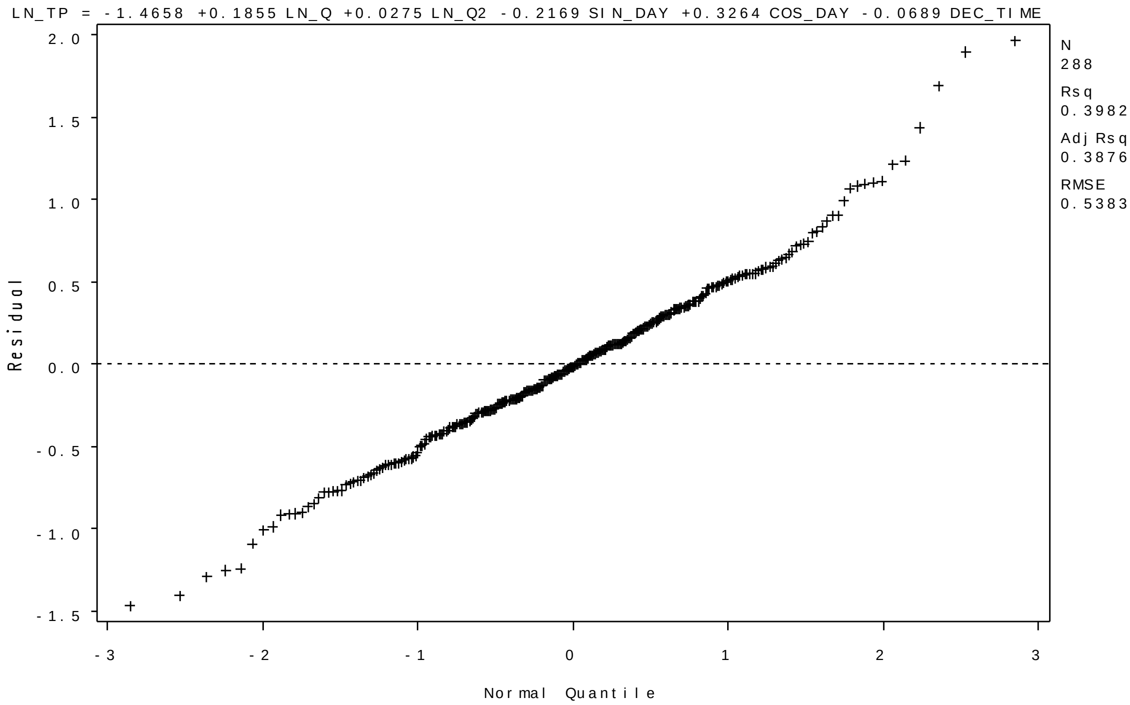
	Monthly Total Precipitation (cm)												Total (cm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1976	4.4	3.4	9.3	6.2	6.2	0.8	7.5	2.9	0.7	2.1	0.4	1.6	45.4
1977	1.7	3.5	11.9	8.5	6.3	5.8	5.4	6.0	6.2	3.5	6.9	5.9	71.5
1978	3.4	0.9	0.8	8.8	9.4	9.1	12.3	11.1	12.3	5.9	7.5	3.3	84.8
1979	4.6	3.0	11.5	4.9	7.7	5.6	9.0	15.2	1.9	6.9	6.3	3.3	79.8
1980	4.9	0.9	2.6	6.9	4.5	9.7	4.8	18.6	8.7	4.6	3.2	3.4	72.7
1981	0.3	7.0	1.1	10.7	1.4	6.7	2.1	8.6	8.3	8.8	2.8	2.8	60.5
1982	3.4	0.4	5.0	6.8	7.0	6.8	13.0	7.4	3.6	3.1	11.5	6.4	74.2
1983	1.9	3.7	3.9	3.5	12.2	4.6	9.6	13.4	9.1	5.7	6.7	3.1	77.4
1984	1.5	4.1	4.2	8.5	4.2	14.2	8.1	9.6	14.4	12.5	6.5	4.4	92.1
1985	2.2	6.5	6.9	5.7	6.5	5.6	10.3	20.4	9.3	6.9	12.6	4.7	97.5
1986	1.5	2.1	6.3	5.7	2.9	10.3	12.6	9.8	19.1	4.8	3.3	1.2	79.7
1987	1.2	1.0	3.9	5.9	6.6	4.7	5.5	8.7	4.0	4.5	7.8	5.2	58.9
1988	4.6	1.9	2.8	6.4	0.2	1.7	6.0	8.8	10.4	5.0	11.3	2.2	61.1
1989	1.1	1.0	7.3	1.3	10.7	4.0	5.8	2.7	1.5	12.1	3.2	1.4	51.9
1990	1.6	1.5	8.3	3.2	10.2	26.2	7.5	6.4	13.0	6.0	4.1	5.4	93.2
1991	1.5	1.0	7.3	7.0	6.2	2.8	10.6	5.4	6.5	8.9	6.9	3.6	67.5
1992	1.8	1.4	6.3	7.7	3.9	4.1	10.6	5.3	14.2	2.3	13.6	5.8	77.0
1993	3.6	0.9	1.9	10.2	10.9	17.3	17.4	5.9	7.1	5.8	4.0	1.1	86.0
1994	3.7	2.8	2.9	15.0	4.3	7.2	17.8	9.4	5.6	2.5	3.6	0.9	75.8
1995	1.7	1.0	4.9	5.6	7.3	4.6	2.9	18.6	7.0	12.2	8.4	3.2	77.4
1996	4.5	1.9	3.0	9.8	3.6	14.1	6.3	3.5	3.5	7.3	2.1	4.4	64.0
1997	4.6	3.6	4.9	4.3	6.6	14.0	5.4	14.6	7.0	2.4	0.8	1.6	69.6
1998	5.6	2.1	9.3	4.7	5.6	15.7	4.7	7.5	9.0	4.0	4.2	0.8	73.1
1999	6.0	2.8	0.4	5.4	9.6	10.1	14.4	3.4	3.2	1.7	4.0	2.1	63.0
2000	2.2	2.7	2.5	5.5	11.2	13.6	15.9	8.6	10.0	1.2	3.2	3.0	79.4
2001	3.0	3.2	1.1	9.3	12.1	13.1	2.2	8.7	6.0	4.4	4.3	3.1	70.5
2002	1.5	3.8	5.3	7.7	7.1	11.9	5.5	10.2	6.8	8.3	1.1	1.9	71.1
2003	1.5	1.4	5.9	6.0	8.1	9.4	10.8	10.6	8.4	2.7	9.8	4.3	78.8
2004	3.2	4.1	9.1	4.0	21.1	12.4	4.5	5.1	1.2	9.4	4.6	5.7	84.4
2005	4.1	3.4	3.4	3.9	6.4	8.7	3.7	10.8	7.8	4.0	7.8	2.7	66.6
2006	4.2	3.4	3.0	5.0	15.0	7.2	8.0	5.4	8.5	7.9	3.1	7.3	77.9
2007	1.6	3.5	7.0	4.4	6.1	9.4	6.1	6.9	8.0	9.2	0.3	6.5	69.1
2008	9.3	3.6	5.8	9.1	5.5	12.1	12.0	1.5	4.8	4.0	3.8	9.5	81.1
Mean	3.1	2.6	5.1	6.6	7.5	9.2	8.4	8.8	7.5	5.8	5.4	3.7	73.7
Max	9.3	7.0	11.9	15.0	21.1	26.2	17.8	20.4	19.1	12.5	13.6	9.5	97.5
Min	0.3	0.4	0.4	1.3	0.2	0.8	2.1	1.5	0.7	1.2	0.3	0.8	45.4

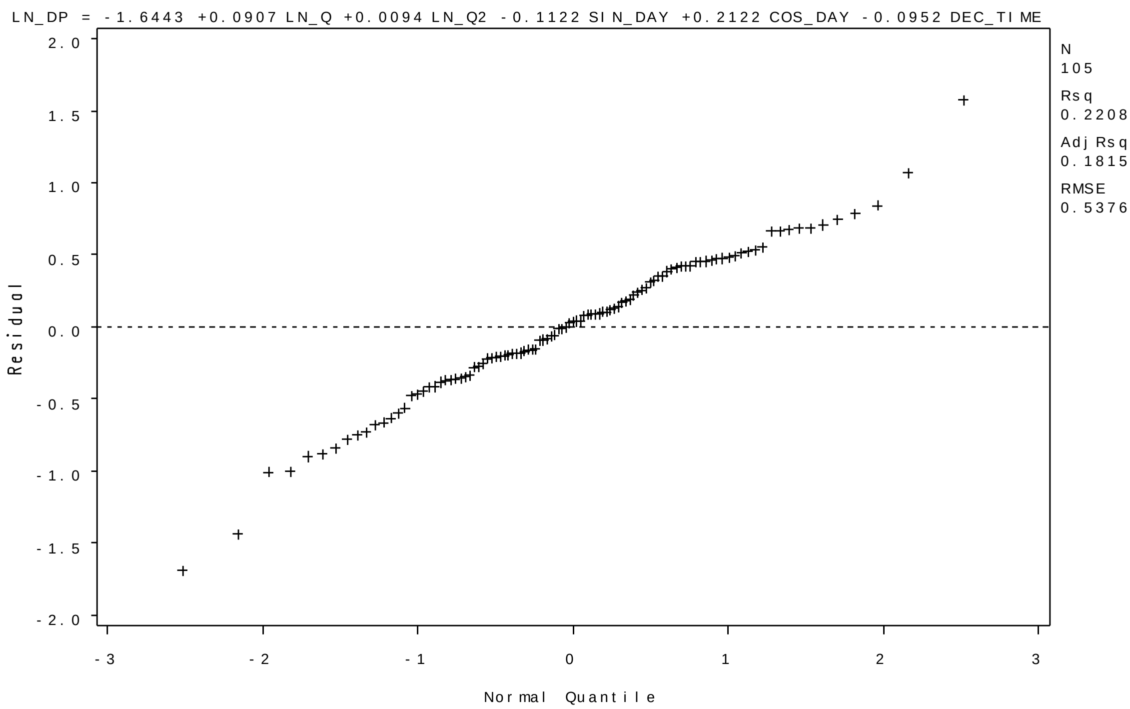
APPENDIX B: NORMAL PROBABLITY PLOTS TP AND DP





B.1: Normal probability plot of log-transformed TP (upper chart) and log-transformed DP (lower chart) residuals for USGS water years 1989-1995.

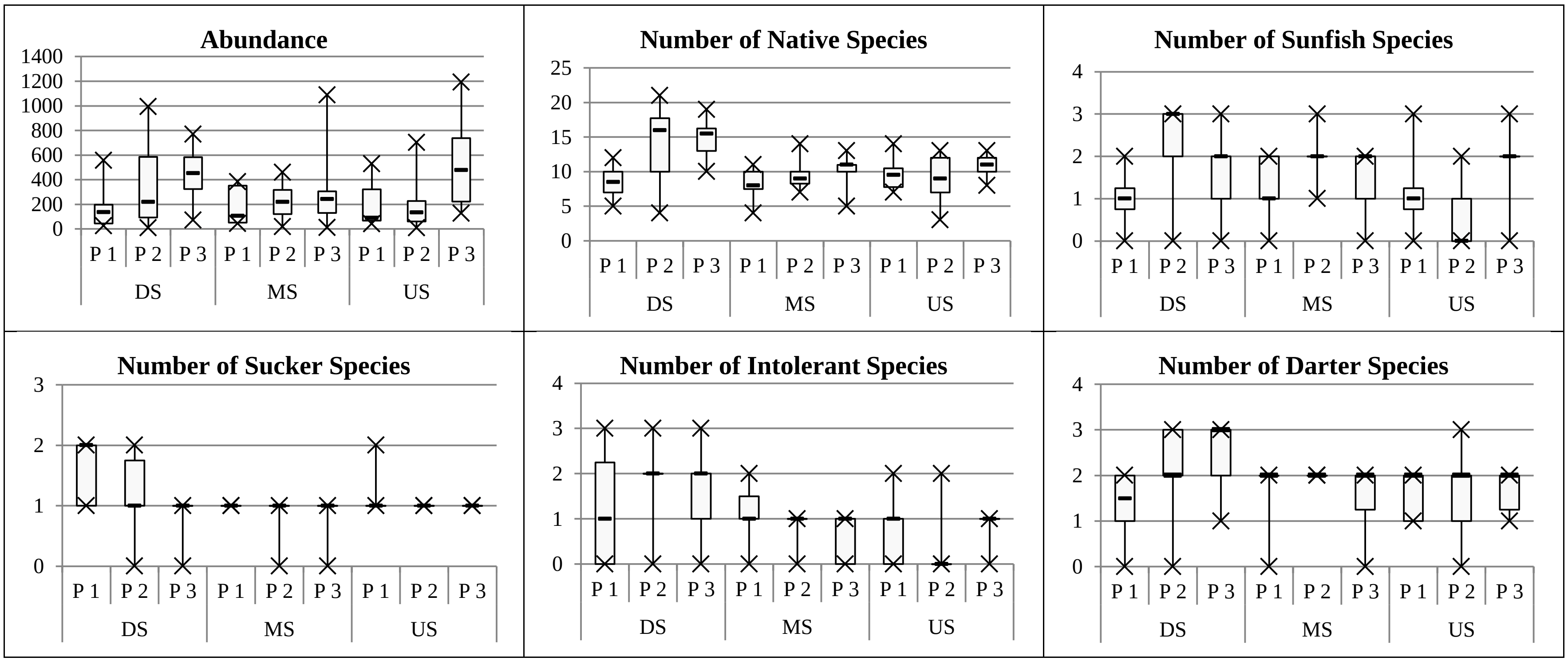




B.2: Normal probability plot of log-transformed TP (upper chart) and log-transformed DP (lower chart) residuals for USGS water years 2004-2008.

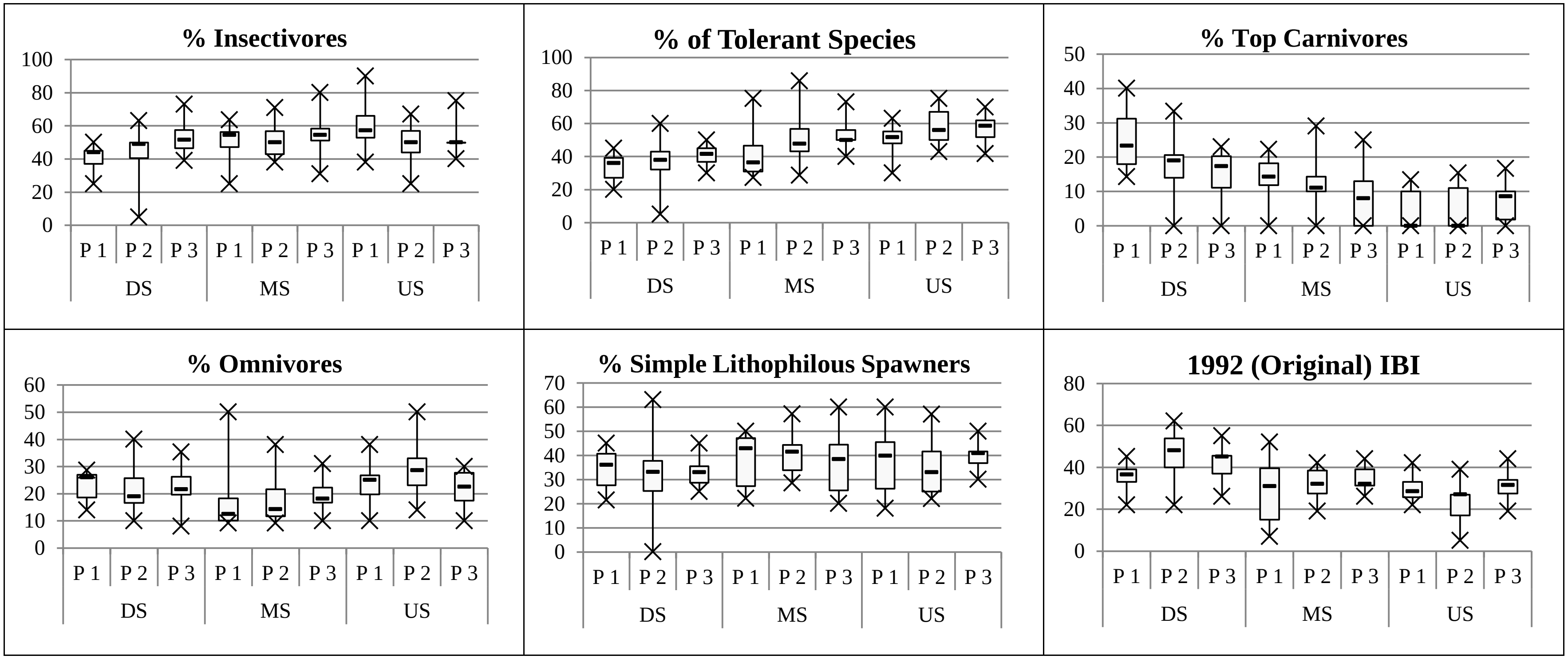
APPENDIX C: BOXPLOTS OF FISH METRICS INCLUDED IN LYONS' INDEX OF BIOTIC INTEGRITY

C.1: Boxplots of fish metrics included in Lyons' Index of Biotic Integrity (1992 and 2006) for surveys performed on Duck Creek, WI (1993-2008). Boxplots include the median, 25th and 75th percentiles, minimum, and maximum for three periods in three locations of the Duck Creek watershed. Total 1992 and intermittent stream IBI values as well as total abundance are shown. †

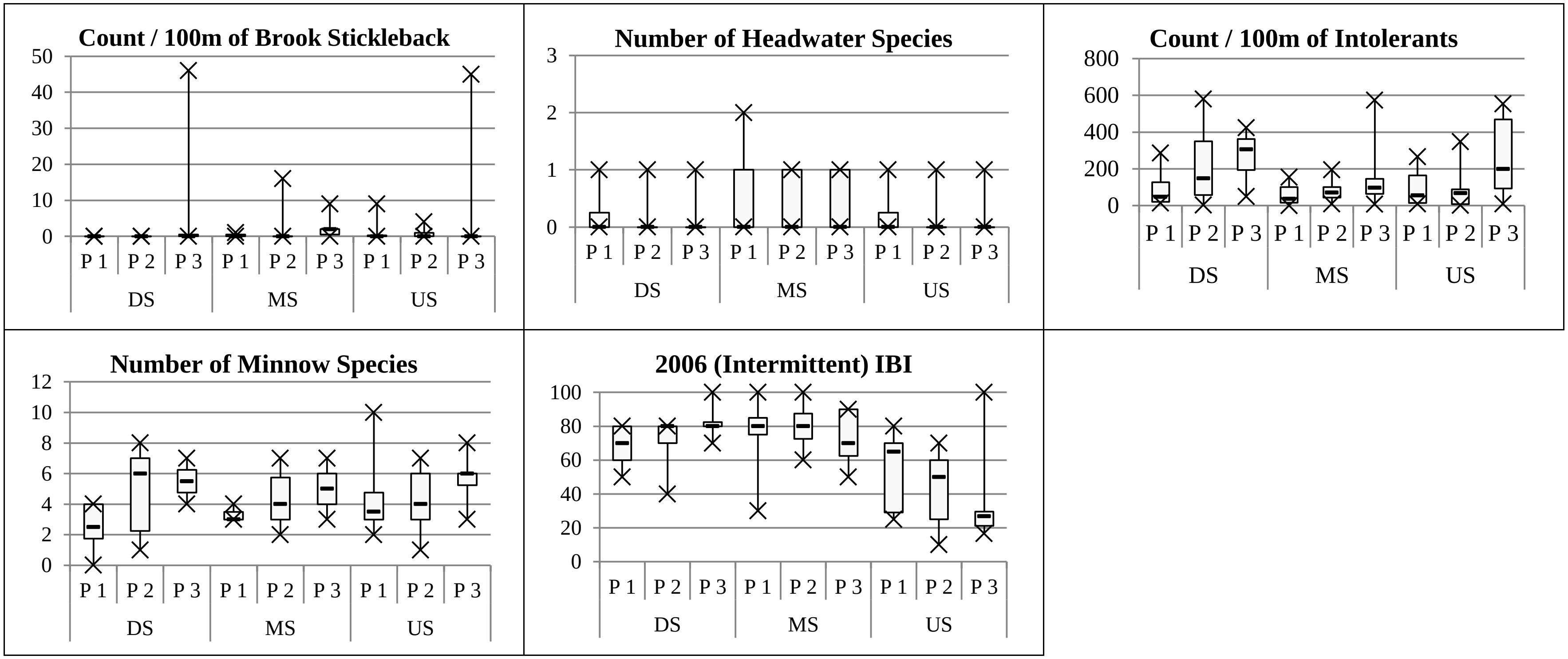


† P1: 1988-1995, P2: 1996-2002, P3: 2003-2008; DS: downstream, US: upstream, MS: midstream.

C.1. (continued)



C.1. (continued)



APPENDIX D: MACROINVERTEBRATE SAMPLE INFROMATION AND STATISTICS

D.1: Sources, sample numbers, dates and locations of macroinvertebrate sampling on Duck Creek. Lat/Long coordinates were received from reporting source. Coordinates not matching location descriptions were removed from the dataset. See Chapter 4 for details on contributing sources.

Source	Sample number	Date	Lat.	Long.
LFRWMP	200307154514	07/15/2003	44.535322	-88.128684
LFRWMP	200307224513	07/22/2003	44.444197	-88.232693
LFRWMP	200406084515	06/08/2004	44.444197	-88.232693
LFRWMP	200406084516	06/08/2004	44.535322	-88.128684
LFRWMP	200506164517	06/16/2005	44.535322	-88.128684
LFRWMP	200606154521	06/06/2006	44.535322	-88.128684
NAWQA	199306034501	06/03/1993	44.4661	-88.219255
NAWQA	199405204502	05/20/1994	44.4661	-88.219255
NAWQA	199405214503	05/21/1994	44.4661	-88.219255
NAWQA	199505174504	05/17/1995	44.4661	-88.219255
NAWQA	199705254505	05/25/1997	44.4661	-88.219255
NAWQA	199805044506	05/04/1998	44.4661	-88.219255
NAWQA	200209104507	09/10/2002	44.4661	-88.219255
NAWQA	200209114508	09/11/2002	44.4661	-88.219255
NAWQA	200309094509	09/09/2003	44.4661	-88.219255
NAWQA	200405194510	05/19/2004	44.4661	-88.219255
NAWQA	200408274511	08/27/2004	44.4661	-88.219255
Tribe	200306204520	06/25/2003	44.4661	-88.219255
Tribe	200507084512	07/08/2005	44.4661	-88.219255
Tribe	200706144519	6/14/2007	44.535322	-88.128684
Tribe	200706264518	06/26/2007	44.4661	-88.219255
UWSP	197906054515	06/05/1979	44.401000	-88.277472
UWSP	197906054516	06/05/1979	44.386889	-88.296806
UWSP	197911084516	11/08/1979	44.401000	-88.277472
UWSP	198005120503	05/12/1980	44.510695	-88.171774
UWSP	198005120514	05/12/1980	44.545690	-88.098184
UWSP	198005124501	05/12/1980	44.395782	-88.333999
UWSP	198005124502	05/12/1980	44.433341	-88.243393

Source	Sample number	Date	Lat.	Long.
UWSP	198010170503	10/17/1980	44.510695	-88.171774
UWSP	198010174501	10/17/1980	44.395782	-88.333999
UWSP	198010174522	10/17/1980	44.433341	-88.243393
UWSP	198011260504	11/26/1980	44.545690	-88.098184
UWSP	199409294503	09/29/1994	44.401000	-88.277472
UWSP	199504254503	04/25/1995	44.401000	-88.277472
UWSP	199505174501	05/17/1995	44.465111	-88.219139
UWSP	199505174502	05/17/1995	44.465111	-88.219139
UWSP	199505174513	05/17/1995	44.465111	-88.219139
UWSP	199505174523	05/17/1995	44.465111	-88.219139
UWSP	199505174533	05/17/1995	44.465111	-88.219139
UWSP	199604140507	04/14/1996	44.514191	-88.150074
UWSP	199604140508	04/14/1996	44.534038	-88.122720
UWSP	199604140509	04/14/1996	44.538068	-88.104086
UWSP	199604140510	04/14/1996	44.538068	-88.104086
UWSP	199604154501	04/15/1996	44.386889	-88.296806
UWSP	199604154502	04/15/1996	44.394889	-88.285167
UWSP	199604154503	04/15/1996	44.413019	-88.263588
UWSP	199604154504	04/15/1996	44.433341	-88.243393
UWSP	199604154505	04/15/1996	44.465111	-88.219139
UWSP	199604154506	04/15/1996	44.483153	-88.201801
UWSP	199805044501	05/04/1998	44.466194	-88.219028
UWSP	199810120521	10/12/1998	44.532827	-88.129783
UWSP	200210080523	10/08/2002	44.533472	-88.124389
UWSP	200210104501	10/10/2002	44.394889	-88.285167
UWSP	200210104502	10/10/2002	44.392194	-88.288361
UWSP	200510264501	10/26/2005	44.392778	-88.288111
UWSP	200510264502	10/26/2005	44.392194	-88.288361

D.2: Descriptions for macroinvertebrate statistics as calculated by the University of Wisconsin-Stevens Point BUG Program. (Lillie et. al, 2003).

Column Heading	Description
SAMPLENUM	Sample number
REP	Rep designation of sample
SR	Species richness - total
GR	Generic richness - total
GR_EPT	% of genera that are EPT taxa
HBI	HBI
HBI_COUNT	Count of organisms in HBI
HBI10	HBI 10 MAX Modification
HBI10_CNT	Count of organisms in HBI 10 MAX Modification
HBI_EPT	% of individuals in HBI that are EPT
FBI	FBI
FBI_COUNT	Count of organisms in FBI
FBI_EPT	% of individuals in FBI that are EPT
COUNT	Count of organisms in sample - includes non-HBI specimens
COUNT_EPT	% of individuals in total count that are EPT
EPT_COUNT	# EPT individuals in sample
EPT_GENERA	# EPT genera in sample
DIV	Shannon's diversity index
TOLVAL	Mean tolerance value

D.3: Statistics for macroinvertebrate samples collected on the mainstem of Duck Creek. Samples were analyzed using the UW-Steven's Point BUG Program (version 8.02; Lillie et. al., 2003). See Table D.2 for descriptions of BUG Program statistics.

SAMPLENUM	REP	SR	GR	GR_EPT	HBI	HBI_COUNT	HBI10	HBI10_CNT	HBI_EPT	FBI	FBI_COUNT	FBI_EPT	COUNT	COUNT_EPT	EPT_COUNT	EPT_GENERA	DIV	TOLVAL
200307154514	1	6	6	33	-	0	-	0	-	5.250	16	56	31	29	9	2	2.022	-
200307224513	1	8	8	38	-	0	-	0	-	7.232	82	27	120	18	22	3	2.019	-
200406084515	1	8	8	38	-	0	-	0	-	6.103	116	22	276	9	25	3	2.406	-
200406084516	1	11	11	45	-	0	-	0	-	4.171	35	71	91	27	25	5	2.678	-
200506164517	1	4	4	75	-	0	-	0	-	5.000	16	75	16	75	12	3	1.703	-
200606154521	1	8	8	50	-	0	-	0	-	4.366	112	84	113	83	94	4	2.147	-
200307154514	2	7	7	43	-	0	-	0	-	5.208	53	62	58	57	33	3	2.352	-
200307224513	2	10	10	50	-	0	-	0	-	7.178	107	22	129	19	24	5	1.852	-
200406084515	2	8	8	38	-	0	-	0	-	5.443	61	26	100	16	16	3	2.546	-
200406084516	2	12	12	42	6.000	1	6.000	1	0	4.366	41	61	80	31	25	5	2.661	6.000
200506164517	2	6	6	67	-	0	-	0	-	4.056	161	98	162	98	158	4	1.099	-
200606154521	2	9	9	44	-	0	-	0	-	5.162	235	68	245	65	160	4	2.310	-
200307154514	3	7	7	43	-	0	-	0	-	7.027	37	30	42	26	11	3	1.908	-
200307224513	3	8	8	38	-	0	-	0	-	7.519	52	12	62	10	6	3	1.510	-
200406084515	3	9	9	44	-	0	-	0	-	6.022	45	31	162	9	14	4	2.180	-
200406084516	3	13	13	46	6.000	1	6.000	1	0	5.889	27	41	120	9	11	6	1.531	6.000
200506164517	3	5	5	80	-	0	-	0	-	3.948	116	100	120	97	116	4	0.997	-
200606154521	3	10	10	50	-	0	-	0	-	4.587	254	80	261	78	204	5	2.098	-
199306034501	1	38	37	24	6.451	6442	6.052	173	3	7.028	7727	9	8921	8	694	9	2.990	6.000
199405204502	1	25	24	25	7.084	915	6.090	89	22	5.992	2438	12	3750	28	1054	6	3.321	5.750
199405214503	1	30	28	29	7.309	973	5.856	111	23	6.434	1297	30	2084	19	391	8	3.508	5.688
199505174504	1	27	27	30	6.020	2231	5.966	146	19	6.114	3788	20	4323	22	964	8	3.171	5.833
199705254505	1	30	28	25	6.646	2514	5.196	184	14	6.014	6756	8	7812	12	957	7	3.116	5.100
199805044506	1	33	32	28	6.583	1351	5.667	222	16	5.813	2239	13	2919	18	525	9	3.537	5.667
200209104507	1	39	39	28	4.658	1390	5.358	193	69	4.198	1780	66	1920	61	1166	11	3.645	5.435
200209114508	1	24	22	36	4.717	2153	4.915	153	75	4.012	2681	78	2748	76	2096	8	2.416	4.941
200309094509	1	36	36	22	4.906	2372	5.203	182	70	4.464	3298	71	3863	61	2356	8	3.609	5.050
200405194510	1	39	39	31	5.289	987	5.934	166	55	4.868	1627	51	1793	46	825	12	4.127	6.000
200408274511	1	34	33	18	5.233	4741	5.537	164	40	5.379	5810	45	6723	39	2603	6	3.719	5.500
199405204502	2	34	32	25	5.589	990	5.877	162	48	5.409	1980	31	2667	28	758	8	4.003	5.889
200209104507	2	35	34	29	5.191	444	5.563	158	58	4.458	550	57	737	42	311	10	4.162	5.684
200306204520	1	27	27	19	6.081	479	6.127	63	0	5.836	512	6	1804	2	31	5	2.573	6.000
200507084512	1	8	8	0	6.643	14	6.643	14	0	7.571	14	0	24	0	0	0	2.678	6.333
200706144519	1	30	28	18	5.259	143	5.469	98	44	5.779	412	44	429	42	181	5	3.009	5.417
200706264518	1	12	11	27	8.182	302	6.386	57	4	7.656	302	4	305	4	12	3	1.440	6.083
200306204520	2	19	19	21	7.881	218	6.473	55	2	7.161	236	8	1045	2	19	4	2.131	6.500
200507084512	2	9	9	0	7.786	28	7.381	21	0	7.714	28	0	70	0	0	0	1.916	6.400
200706264518	2	17	16	19	8.336	387	6.768	69	4	7.732	395	4	399	4	15	3	1.830	6.188
200306204520	3	16	16	19	7.937	302	6.154	52	0	7.199	321	6	874	2	18	3	2.045	6.500

D.3. (continued)

SAMPLENUM	REP	SR	GR	GR_EPT	HBI	HBI_COUNT	HBI10	HBI10_CNT	HBI_EPT	FBI	FBI_COUNT	FBI_EPT	COUNT	COUNT_EPT	EPT_COUNT	EPT_GENERA	DIV	TOLVAL
200507084512	3	12	12	0	7.050	40	6.563	32	0	6.950	40	0	54	0	0	0	2.929	5.889
200706264518	3	23	22	14	7.682	198	6.694	85	6	7.248	202	7	203	7	14	3	2.903	6.190
197906054515	1	10	10	10	7.866	67	7.917	48	22	7.713	87	17	87	17	15	1	2.687	8.000
197906054516	1	6	6	17	7.000	125	7.000	17	2	5.984	126	2	126	2	3	1	0.478	7.400
197911084516	1	14	14	14	7.522	92	7.375	40	7	6.991	116	5	116	5	6	2	2.619	7.091
198005120503	1	12	10	30	5.368	106	5.548	42	37	5.358	106	37	106	37	39	3	1.820	5.667
198005120514	1	16	16	38	6.243	70	6.217	60	17	6.338	77	17	77	17	13	6	3.418	6.143
198005124501	1	11	9	11	5.505	99	5.091	55	10	5.636	99	10	100	10	10	1	1.411	6.200
198005124502	1	18	17	41	5.363	102	5.434	53	86	4.500	108	81	112	79	88	7	2.969	5.688
198010170503	1	5	5	60	5.914	93	5.619	21	98	4.056	108	98	108	98	106	3	1.121	6.000
198010174501	1	14	14	21	6.992	124	6.509	53	22	6.960	126	21	126	21	27	3	2.445	6.769
198010174522	1	14	14	29	6.905	116	6.904	52	84	4.897	116	84	119	82	97	4	2.276	7.538
198011260504	1	18	17	29	5.923	143	5.911	56	15	5.676	148	18	149	17	26	5	2.319	6.125
199409294503	1	15	15	27	5.426	148	5.750	44	85	4.413	150	84	155	81	126	4	2.037	6.000
199504254503	1	10	9	11	3.000	166	5.500	32	2	6.033	211	1	212	1	3	1	1.655	6.000
199505174501	1	23	22	32	5.480	127	5.506	81	18	6.457	138	20	146	19	28	7	3.485	5.438
199505174502	1	16	16	25	5.902	153	5.284	74	14	6.153	163	15	172	14	24	4	2.857	5.333
199505174513	1	18	17	35	6.016	128	5.699	83	57	5.632	133	58	199	39	77	6	3.080	5.692
199505174513	2	19	16	31	5.986	146	5.676	74	42	5.696	161	40	196	33	65	5	3.032	5.643
199505174513	3	18	16	44	5.602	133	5.400	85	41	5.779	140	39	152	36	55	7	3.169	5.125
199505174523	1	18	18	50	4.784	116	4.894	66	52	4.215	121	53	125	51	64	9	3.093	5.286
199505174533	1	13	13	38	5.234	141	5.190	58	60	5.274	146	58	149	57	85	5	2.614	5.000
199505174533	2	13	13	46	5.227	141	5.396	53	72	4.905	148	71	150	70	105	6	2.066	5.455
199604140507	1	14	14	36	5.157	134	5.857	63	13	6.447	152	11	155	11	17	5	2.528	6.077
199604140508	1	27	27	37	5.689	132	5.750	88	57	5.324	148	52	151	51	77	10	3.616	5.630
199604140509	1	17	17	47	5.512	125	6.030	67	49	5.455	132	45	137	45	61	8	2.825	5.600
199604140510	1	19	19	21	6.476	126	6.185	81	14	6.063	143	13	152	12	18	4	3.303	6.294
199604154501	1	22	20	20	7.280	107	7.015	67	7	6.512	123	7	131	7	9	4	3.157	6.722
199604154502	1	16	15	27	6.870	92	6.529	51	58	6.551	118	46	120	45	54	4	2.552	6.357
199604154503	1	19	19	16	7.049	102	7.156	64	15	6.828	157	10	175	9	15	3	3.305	6.938
199604154504	1	12	12	17	7.561	82	7.176	51	21	6.540	87	20	87	20	17	2	2.576	6.917
199604154505	1	15	15	20	5.207	121	5.446	65	25	5.884	147	20	151	20	30	3	2.728	5.813
199604154506	1	20	19	26	7.831	124	6.500	58	16	6.975	157	13	172	12	20	5	2.574	5.941
199805044501	1	29	29	21	6.452	115	6.048	83	13	5.737	152	13	169	12	20	6	3.655	5.591
199810120521	1	22	21	33	4.674	132	4.827	98	37	4.695	141	35	142	35	49	7	3.427	5.238
200210080523	1	19	17	41	4.901	192	5.057	87	74	4.190	200	75	204	73	149	7	2.926	5.278
200210104501	1	15	15	13	9.663	160	8.138	29	2	7.893	169	2	178	2	3	2	1.334	7.000
200210104502	1	33	32	25	6.008	130	5.807	88	62	5.632	133	60	152	53	80	8	3.954	5.962
200510264501	1	21	19	5	6.747	162	7.277	65	1	6.476	168	1	174	1	1	1	2.716	7.500
200510264502	1	35	35	9	7.410	195	7.648	105	2	6.911	203	2	220	2	4	3	3.942	7.560

APPENDIX E: MULTI-PARAMETER SONDE DATA AND WATER QUALITY SAMPLE INFORMATION FOR TROUT CREEK

E.1: Water quality daily statistics for Trout Creek at County Rd. FF (TC1), June 8, 2008 – November 20, 2008. Data was taken at 10 minute intervals with an YSI 6600 multi-parameter sonde (YSI Inc, Yellow Springs, OH) and summarized on a daily basis here.

Trout Creek Daily Statistics at Cty FF

		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
June	8	17.22	18.01	16.73	8.11	8.08	8.08	8.38	8.65	8.26	87	91	85	0.528	0.582	0.318	27	72	9	0.30	0.44	0.22
	9	17.55	18.37	16.40	8.01	8.10	7.92	8.17	8.29	7.97	86	88	84	0.447	0.541	0.396	114	222	53	0.61	0.66	0.43
	10	18.53	19.59	17.71	8.09	8.12	8.04	7.76	7.96	7.36	83	86	77	0.391	0.406	0.384	34	53	24	0.64	0.65	0.63
	11	16.83	17.68	15.42	8.18	8.21	8.11	7.14	7.38	6.61	74	77	66	0.446	0.484	0.407	16	26	12	0.57	0.65	0.46
	12	15.57	16.13	14.94	8.20	8.22	8.15	6.34	6.61	5.95	64	66	60	0.579	0.614	0.485	13	26	7	0.39	0.46	0.32
											* Sonde data collection interrupted *											
	28	19.24	20.57	17.94	8.18	8.23	8.13	8.01	8.70	7.49	87	97	81	0.792	0.818	0.769	10	15	7	0.13	0.14	0.11
	29	16.97	17.90	16.44	8.24	8.29	8.19	8.76	9.19	8.11	91	96	86	0.805	0.808	0.799	7	15	4	0.17	0.23	0.13
	30	17.28	19.48	15.18	8.26	8.31	8.22	8.92	9.67	8.14	93	103	87	0.799	0.801	0.798	5	9	3	0.25	0.26	0.23
June Total		17.40	20.57	14.94	8.16	8.31	7.92	7.93	9.67	5.95	83	103	60	0.598	0.818	0.318	28	222	3	0.38	0.66	0.11

E.1. (continued)

Trout Creek Daily Statistics at Cty FF																						
		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
July	1	18.29	20.77	15.96	8.25	8.33	6.72	8.61	9.49	7.67	92	104	84	0.803	0.810	0.797	6	70	3	0.21	0.24	0.08
	2	18.62	19.64	16.92	8.20	8.25	8.13	8.32	8.89	7.71	89	94	84	0.732	0.811	0.588	26	64	7	0.21	0.35	0.13
	3	17.05	18.82	15.51	8.18	8.26	8.13	9.12	9.60	8.65	95	100	90	0.577	0.605	0.537	24	37	18	0.55	0.62	0.34
	4	16.61	18.65	14.37	8.17	8.23	8.11	9.10	9.75	8.45	93	102	89	0.603	0.609	0.599	18	25	13	0.44	0.51	0.36
	5	17.53	19.55	15.37	8.21	8.29	8.15	9.01	9.83	8.20	94	105	88	0.608	0.624	0.600	15	30	10	0.30	0.36	0.24
	6	18.30	19.83	16.31	8.24	8.32	8.18	8.86	9.78	7.91	94	105	87	0.645	0.664	0.624	11	79	6	0.21	0.25	0.18
	7	20.84	22.49	19.36	8.19	8.29	8.09	8.24	9.23	7.44	92	105	85	0.670	0.689	0.619	10	23	4	0.20	0.23	0.16
	8	21.61	23.03	20.51	8.22	8.30	8.13	8.06	9.04	7.50	92	104	85	0.713	0.735	0.668	7	12	4	0.17	0.20	0.16
	9	19.83	21.21	18.33	8.29	8.35	8.21	8.95	10.27	7.00	98	115	75	0.750	0.757	0.736	5	8	3	0.22	0.24	0.20
	10	19.67	21.92	17.63	8.31	8.38	8.26	9.71	10.98	8.91	106	122	98	0.763	0.768	0.757	5	20	3	0.22	0.24	0.18
	11	19.88	21.35	18.44	8.32	8.37	8.28	8.68	9.68	7.10	95	107	79	0.755	0.770	0.738	6	11	3	0.22	0.25	0.19
	12	19.93	20.79	19.11	8.31	8.37	8.23	x	x	x	x	x	x	0.699	0.762	0.646	14	34	8	0.22	0.26	0.18
	13	17.91	19.06	17.03	8.34	8.40	8.30	x	x	x	x	x	x	0.697	0.705	0.689	5	15	2	0.29	0.31	0.25
	14	17.89	20.05	15.83	8.37	8.42	8.31	x	x	x	x	x	x	0.721	0.737	0.696	4	17	1	0.23	0.28	0.21
	15	19.46	21.99	17.12	8.37	8.43	8.32	x	x	x	x	x	x	0.746	0.753	0.737	4	8	2	0.22	0.25	0.20
	16	19.98	21.31	19.02	8.30	8.39	8.12	x	x	x	x	x	x	0.705	0.767	0.451	25	254	4	0.29	0.37	0.25
	17	19.67	21.12	18.07	8.27	8.36	8.18	x	x	x	x	x	x	0.648	0.710	0.566	12	44	5	0.28	0.34	0.24
	18	20.67	21.91	19.45	8.32	8.38	8.27	x	x	x	x	x	x	0.720	0.749	0.699	5	19	2	0.23	0.24	0.23
	19	21.19	22.49	20.21	8.37	8.43	8.30	x	x	x	x	x	x	0.754	0.759	0.743	4	7	1	0.23	0.24	0.20
	20	21.30	22.55	20.16	8.37	8.43	8.30	x	x	x	x	x	x	0.764	0.781	0.740	9	41	3	0.22	0.23	0.21
	21	20.28	21.33	19.35	8.41	8.46	8.36	x	x	x	x	x	x	0.775	0.781	0.762	12	48	3	0.23	0.25	0.21
	24	19.03	20.85	17.27	8.32	8.39	8.25	9.57	10.73	8.70	103	117	95	0.797	0.799	0.792	6	17	3	0.12	0.15	0.10
	25	19.64	20.47	18.79	8.31	8.37	8.25	9.23	10.09	8.69	101	112	95	0.802	0.805	0.793	7	25	4	0.09	0.11	0.08
	26	20.04	21.67	18.79	8.31	8.38	8.25	9.31	10.41	8.64	103	117	95	0.806	0.808	0.802	6	11	4	0.08	0.10	0.07
	27	20.01	21.93	18.40	8.33	8.40	8.27	9.30	10.39	8.51	103	117	94	0.809	0.813	0.804	6	15	4	0.05	0.07	0.04
	28	19.80	21.76	18.30	8.32	8.38	8.27	9.27	10.32	8.51	102	116	93	0.809	0.815	0.803	7	10	5	0.08	0.09	0.05
	29	19.09	20.34	17.73	8.30	8.37	8.07	9.39	10.54	8.29	102	115	91	0.780	0.817	0.484	21	302	7	0.05	0.10	0.00
	30	20.34	22.01	18.70	8.18	8.28	7.95	8.95	9.88	8.21	99	110	90	0.666	0.757	0.447	26	92	11	0.07	0.11	0.04
	31	20.40	21.60	18.90	8.20	8.31	8.10	9.07	10.16	8.42	101	115	94	0.674	0.714	0.630	14	18	11	0.05	0.06	0.04
July Total		19.48	23.03	14.37	8.29	8.46	6.72	8.99	10.98	7.00	98	122	75	0.724	0.817	0.447	11	302	1	0.21	0.62	0.00

E.1. (continued)

Trout Creek Daily Statistics at Cty FF																							
		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)			
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	
August	1	20.79	22.76	19.27	8.25	8.34	8.18	9.04	10.09	8.36	101	116	94	0.717	0.721	0.712	15	25	12	0.05	0.08	0.03	
	2	20.04	21.92	18.45	8.27	8.36	8.21	9.22	10.26	8.43	102	116	94	0.727	0.739	0.712	15	18	13	0.10	0.12	0.08	
	3	19.76	21.85	18.18	8.29	8.38	8.23	9.30	10.42	8.59	102	117	95	0.752	0.764	0.738	14	25	12	0.10	0.13	0.06	
	4	20.03	21.18	18.61	8.28	8.35	8.23	9.19	10.32	8.60	101	116	95	0.756	0.768	0.738	17	20	15	0.08	0.10	0.06	
	5	21.20	22.65	20.08	8.29	8.37	8.22	9.16	10.29	8.56	103	118	96	0.759	0.765	0.753	18	20	15	0.10	0.13	0.09	
	6	20.01	21.49	18.68	8.32	8.40	8.26	9.42	10.55	8.66	104	118	96	0.765	0.768	0.752	18	26	16	0.10	0.13	0.08	
	7	19.34	20.80	18.01	8.33	8.40	8.29	9.57	10.62	8.82	104	117	96	0.778	0.789	0.763	17	20	15	0.09	0.11	0.00	
	8	18.63	20.60	16.84	8.34	8.42	8.29	9.85	11.03	9.01	106	121	97	0.788	0.793	0.781	17	22	16	0.09	0.11	0.05	
	9	18.39	19.65	17.03	8.35	8.42	8.30	9.75	10.77	9.00	104	117	97	0.790	0.796	0.785	18	21	17	0.06	0.10	0.05	
	10	16.79	18.68	15.11	8.44	8.51	8.35	11.39	13.13	7.23	118	138	75	0.799	0.805	0.791	18	22	16	0.10	0.11	0.10	
	11	17.01	19.29	15.10	8.49	8.56	8.45	x	x	x	x	x	x	0.804	0.808	0.800	19	21	17	0.10	0.12	0.07	
	12	17.34	18.92	15.72	8.51	8.60	8.45	x	x	x	x	x	x	0.804	0.811	0.798	17	20	15	0.05	0.08	0.03	
	13	17.70	18.48	17.22	8.44	8.50	8.39	x	x	x	x	x	x	0.805	0.811	0.798	18	21	15	0.03	0.05	0.02	
	14	17.67	19.43	16.35	8.47	8.54	8.42	x	x	x	x	x	x	0.807	0.812	0.801	17	21	12	0.08	0.13	0.05	
	15	17.30	19.52	15.57	8.49	8.54	8.45	x	x	x	x	x	x	0.811	0.817	0.803	14	20	13	0.14	0.16	0.13	
	16	17.79	19.99	15.74	8.49	8.55	8.46	x	x	x	x	x	x	0.808	0.814	0.801	13	48	10	0.11	0.14	0.07	
	17	19.71	21.74	17.99	8.46	8.53	8.42	x	x	x	x	x	x	0.804	0.810	0.798	13	16	12	0.05	0.08	0.03	
	18	20.18	21.91	18.93	8.46	8.53	8.41	x	x	x	x	x	x	0.801	0.809	0.795	15	21	13	0.05	0.10	0.03	
	21	18.23	19.83	16.54	8.34	8.43	8.27	8.72	9.97	7.83	93	108	84	0.796	0.803	0.793	4	6	2	0.11	0.13	0.08	
	22	19.72	21.19	18.49	8.30	8.37	8.26	8.13	9.09	7.37	89	102	82	0.801	0.805	0.796	4	8	2	0.08	0.09	0.06	
	23	20.89	21.96	19.93	8.28	8.36	8.23	7.75	8.76	7.19	87	100	80	0.800	0.805	0.796	4	9	3	0.08	0.10	0.06	
	24	17.88	19.86	16.80	8.32	8.41	8.25	8.48	9.62	7.31	89	102	80	0.800	0.806	0.796	4	11	3	0.12	0.13	0.10	
	25	16.19	17.63	14.61	8.34	8.41	8.28	8.96	9.98	8.23	91	104	84	0.798	0.805	0.794	5	7	4	0.14	0.15	0.12	
	26	15.59	17.34	13.80	8.34	8.41	8.29	9.18	10.19	8.42	92	105	85	0.801	0.807	0.797	5	7	4	0.12	0.14	0.09	
	27	15.65	17.65	13.58	8.34	8.41	8.29	9.17	10.16	8.27	92	105	85	0.800	0.808	0.794	5	6	4	0.07	0.09	0.03	
	28	16.65	17.95	15.40	8.32	8.39	8.27	8.71	9.51	8.13	90	100	84	0.798	0.806	0.792	5	9	4	0.01	0.04	0.00	
	29	17.07	18.87	15.52	8.31	8.40	8.25	8.72	9.79	8.10	91	104	83	0.799	0.806	0.794	6	17	4	0.06	0.09	0.03	
	30	16.96	18.98	15.11	8.32	8.40	8.29	8.84	9.86	8.05	92	104	85	0.801	0.806	0.797	5	6	4	0.11	0.12	0.09	
	31	17.90	19.98	15.95	8.30	8.36	8.26	8.57	9.78	7.74	91	102	83	0.800	0.806	0.796	5	42	4	0.12	0.14	0.11	
Aug. Total		18.36	22.76	13.58	8.36	8.60	8.18	9.10	13.13	7.19	97	138	75	0.789	0.817	0.712	12	48	2	0.09	0.16	0.00	

E.1. (continued)

Trout Creek Daily Statistics at Cty FF

		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
September	1	18.22	19.69	16.39	8.30	8.37	8.25	8.45	9.91	7.70	90	104	82	0.800	0.809	0.793	5	10	4	0.11	0.13	0.09
	2	19.19	20.81	17.47	8.31	8.37	8.25	8.27	9.42	7.40	90	103	81	0.797	0.809	0.782	5	10	4	0.07	0.09	0.04
	3	18.50	20.31	17.05	8.30	8.38	8.23	8.14	9.09	7.19	87	98	78	0.792	0.802	0.776	5	9	5	0.10	0.11	0.08
	4	15.49	17.02	14.78	8.31	8.38	8.27	8.58	9.09	8.05	86	91	82	0.782	0.796	0.757	6	10	5	0.06	0.10	0.02
	5	15.08	16.26	14.17	8.31	8.42	8.23	9.18	10.46	8.40	92	106	83	0.764	0.781	0.755	8	10	7	0.06	0.09	0.01
	6	15.42	16.28	14.81	8.36	8.45	8.30	9.36	10.45	8.74	94	106	87	0.778	0.783	0.772	7	10	6	0.09	0.10	0.08
	7	15.05	16.25	14.09	8.38	8.44	8.32	9.55	10.71	8.94	95	108	89	0.786	0.798	0.777	9	10	8	0.11	0.13	0.10
	8	13.84	14.88	13.05	8.37	8.43	8.30	9.86	10.64	9.05	96	103	90	0.789	0.791	0.785	9	19	7	0.17	0.20	0.13
	9	12.69	14.20	11.31	8.39	8.45	8.35	10.20	11.16	9.54	96	108	91	0.792	0.796	0.787	8	9	7	0.19	0.21	0.17
	10	12.46	14.18	10.81	8.40	8.47	8.36	10.29	11.27	9.52	97	108	90	0.789	0.793	0.784	8	9	7	0.21	0.23	0.19
	11	13.65	14.96	12.41	8.37	8.47	8.30	9.71	10.71	8.78	94	105	87	0.766	0.792	0.700	10	18	8	0.15	0.19	0.10
	12	15.34	15.77	14.98	8.29	8.38	8.19	9.19	9.98	8.69	92	101	87	0.746	0.763	0.689	12	16	10	0.14	0.16	0.11
	13	15.38	15.98	14.95	8.28	8.34	8.24	8.94	9.25	8.61	90	93	87	0.752	0.761	0.740	12	16	11	0.05	0.13	0.00
	14	15.13	15.92	14.15	8.31	8.38	8.24	9.18	9.81	8.62	91	98	87	0.752	0.763	0.746	12	21	11	0.06	0.14	0.00
	15	12.99	14.12	11.88	8.37	8.45	8.31	10.02	11.04	9.17	95	106	89	0.756	0.760	0.752	11	19	9	0.19	0.21	0.14
	16	12.58	14.80	10.68	8.38	8.43	8.34	10.17	10.97	9.27	96	106	89	0.762	0.771	0.752	10	13	9	0.18	0.21	0.15
	17	14.19	15.92	12.96	8.35	8.42	8.31	9.61	10.44	9.08	94	104	89	0.776	0.782	0.770	10	12	8	0.20	0.24	0.16
	18	13.80	15.37	12.33	8.36	8.44	8.27	9.88	11.17	9.14	96	110	89	0.783	0.789	0.779	9	16	9	0.22	0.27	0.17
	19	14.97	16.93	13.45	8.35	8.41	8.30	9.48	10.58	8.55	94	107	87	0.787	0.793	0.783	10	13	9	0.13	0.17	0.10
	20	16.06	17.05	15.25	8.33	8.41	8.28	9.08	10.32	8.50	92	107	85	0.791	0.796	0.785	11	12	10	0.14	0.18	0.12
	21	15.05	15.90	14.00	8.35	8.44	8.30	9.43	10.89	8.50	94	109	85	0.793	0.799	0.788	12	13	11	0.19	0.20	0.18
	22	16.36	17.53	15.49	8.31	8.39	8.26	8.97	10.14	8.21	92	106	84	0.797	0.802	0.792	12	23	11	0.20	0.22	0.19
	23	17.09	18.55	15.79	8.29	8.36	8.23	8.68	10.05	7.66	90	106	80	0.799	0.805	0.795	13	19	12	0.18	0.21	0.16
	24	17.30	18.27	15.90	8.25	8.33	8.19	8.38	9.71	7.58	87	103	79	0.802	0.807	0.795	13	14	12	0.17	0.20	0.15
	25	14.68	15.82	13.23	8.26	8.34	8.20	9.16	10.98	7.96	90	109	80	0.802	0.809	0.799	13	15	13	0.20	0.23	0.18
	26	14.56	16.28	12.75	8.26	8.33	8.20	9.27	11.02	8.12	91	110	82	0.806	0.812	0.800	15	16	14	0.15	0.18	0.12
Sept. Total		15.19	20.81	10.68	8.33	8.47	8.19	9.27	11.27	7.19	92	110	78	0.782	0.812	0.689	10	23	4	0.14	0.27	0.00

E.1. (continued)

Trout Creek Daily Statistics at Cty FF																						
		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
October	11	10.81	12.87	9.08	7.99	8.09	7.92	9.69	11.22	8.36	88	104	77	0.796	0.806	0.791	2	3	2	0.29	0.30	0.27
	12	12.98	14.83	11.31	7.93	8.03	7.82	8.77	10.59	6.81	83	103	66	0.808	0.815	0.804	2	4	2	0.29	0.31	0.28
	13	14.74	15.87	13.51	7.79	7.83	7.69	6.82	8.11	5.13	67	81	51	0.820	0.841	0.814	2	3	2	0.25	0.29	0.20
	14	12.92	15.16	12.02	7.69	7.74	7.63	5.97	7.48	4.67	57	71	45	0.837	0.851	0.829	2	3	2	0.26	0.29	0.23
	15	11.15	11.99	10.08	7.73	7.84	7.66	6.73	8.43	5.60	61	77	52	0.851	0.856	0.842	2	14	2	0.23	0.27	0.20
	16	9.31	10.66	8.14	7.83	7.92	7.75	8.48	9.80	7.00	74	88	62	0.866	0.880	0.856	2	3	2	0.30	0.33	0.24
	17	7.99	9.04	6.81	7.89	7.97	7.84	9.60	10.86	8.71	81	94	74	0.866	0.881	0.841	3	4	3	0.33	0.34	0.32
	18	8.46	9.81	7.28	7.90	7.96	7.85	9.51	10.48	8.88	82	92	75	0.862	0.868	0.851	3	5	3	0.33	0.35	0.32
	19	8.80	9.84	7.52	7.94	7.98	7.91	9.55	10.35	8.52	82	91	75	0.865	0.870	0.860	3	5	3	0.28	0.32	0.25
	20	10.11	11.17	8.53	7.91	7.96	7.86	8.72	9.46	8.26	78	86	73	0.866	0.869	0.863	4	5	3	0.30	0.35	0.26
	21	7.57	8.77	6.43	7.94	8.00	7.90	9.81	10.89	8.64	82	94	74	0.868	0.874	0.863	4	5	4	0.37	0.38	0.35
	22	6.60	7.78	5.64	7.98	8.05	7.93	10.57	11.70	9.78	87	98	80	0.861	0.867	0.855	4	4	3	0.39	0.40	0.37
	23	6.61	8.07	5.30	7.99	8.06	7.94	10.62	11.75	9.91	87	99	81	0.862	0.870	0.850	4	6	3	0.35	0.38	0.29
	24	7.36	7.94	6.78	7.94	7.97	7.90	9.61	9.91	9.33	80	84	77	0.846	0.870	0.824	4	17	3	0.21	0.29	0.16
	25	7.08	8.03	6.16	7.99	8.08	7.90	10.33	11.65	9.42	86	98	77	0.848	0.858	0.834	7	21	4	0.13	0.17	0.07
	26	6.64	7.21	5.91	8.02	8.09	7.96	10.43	11.67	9.48	85	97	78	0.847	0.857	0.833	6	12	4	0.11	0.20	0.07
	27	5.26	6.02	4.57	8.06	8.15	7.99	11.47	13.17	10.16	91	106	81	0.845	0.854	0.834	5	7	4	0.29	0.36	0.20
	28	4.73	5.82	4.00	8.08	8.18	8.01	12.00	13.74	11.02	94	110	85	0.844	0.853	0.836	5	10	4	0.32	0.36	0.26
	29	3.59	4.97	2.41	8.08	8.17	8.03	12.39	13.93	11.31	94	108	86	0.847	0.856	0.837	5	7	5	0.29	0.31	0.26
	30	4.04	5.95	2.23	8.09	8.18	8.03	12.38	14.06	10.93	95	111	86	0.844	0.860	0.835	5	7	4	0.29	0.32	0.27
Oct. Total		8.34	15.87	2.23	7.94	8.18	7.63	9.67	14.06	4.67	82	111	45	0.848	0.881	0.791	4	21	2	0.28	0.40	0.07

E.1. (continued)

Trout Creek Daily Statistics at Cty FF																						
		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
November	3	6.80	8.13	5.66	7.70	7.75	7.67	8.41	9.66	7.49	69	82	62	0.865	0.869	0.857	2	5	2	0.21	0.23	0.19
	4	8.59	10.68	7.02	7.68	7.74	7.65	7.59	8.85	6.49	65	80	56	0.861	0.866	0.832	3	17	2	0.18	0.19	0.16
	5	9.42	10.87	7.94	7.68	7.76	7.64	7.18	8.92	6.13	63	81	54	0.859	0.863	0.850	4	29	2	0.13	0.16	0.11
	6	10.19	10.81	9.32	7.65	7.71	7.61	6.44	7.59	5.78	58	69	51	0.836	0.860	0.753	6	20	3	0.11	0.12	0.09
	7	8.40	9.93	6.87	7.67	7.76	7.63	7.37	9.25	6.01	63	80	53	0.829	0.847	0.815	6	18	5	0.07	0.11	0.03
	8	6.01	6.83	5.39	7.70	7.76	7.66	8.65	10.30	7.38	70	84	60	0.818	0.826	0.791	7	11	4	0.04	0.09	0.00
	9	3.86	5.39	2.04	7.74	7.79	7.69	10.03	11.53	8.71	76	88	67	0.834	0.843	0.812	8	22	3	0.14	0.18	0.09
	10	2.09	2.78	1.28	7.78	7.83	7.75	11.68	12.99	10.75	85	96	78	0.844	0.848	0.836	6	23	3	0.24	0.28	0.18
	11	2.54	3.50	1.65	7.78	7.83	7.75	11.75	13.08	10.98	87	99	80	0.848	0.853	0.835	4	15	4	0.27	0.30	0.24
	12	4.25	5.18	3.19	7.72	7.76	7.70	10.28	10.96	9.56	79	82	75	0.825	0.842	0.803	5	6	4	0.18	0.24	0.11
	13	5.77	6.23	5.19	7.71	7.76	7.68	9.50	10.34	9.01	76	83	72	0.825	0.845	0.781	5	9	4	0.04	0.11	0.01
	14	6.35	7.04	5.74	7.73	7.81	7.68	9.76	11.36	8.89	79	94	72	0.815	0.825	0.787	6	11	5	0.09	0.14	0.02
	15	5.01	5.69	4.04	7.75	7.81	7.69	10.20	11.92	9.05	80	95	71	0.832	0.855	0.822	10	27	6	0.15	0.16	0.13
	16	3.28	4.02	2.39	7.78	7.84	7.73	11.20	12.82	10.00	84	97	75	0.856	0.865	0.836	8	13	5	0.15	0.21	0.13
	17	1.59	2.43	0.11	7.81	7.86	7.77	12.36	13.67	11.28	89	100	82	0.872	0.883	0.859	7	12	5	0.26	0.33	0.21
	18	0.16	0.67	-0.14	7.78	7.82	7.75	13.10	14.06	12.58	90	98	86	0.898	0.911	0.883	9	19	6	0.32	0.36	0.25
	19	0.52	1.15	0.16	7.78	7.81	7.75	12.88	13.74	12.40	90	97	86	0.875	0.891	0.865	7	27	6	0.17	0.24	0.13
	20	0.13	0.56	-0.17	7.81	7.86	7.75	13.31	14.53	12.58	92	101	87	0.886	0.922	0.868	8	33	6	0.28	0.32	0.23
Nov. Total		4.72	10.87	-0.17	7.74	7.86	7.61	10.09	14.53	5.78	77	101	51	0.849	0.922	0.753	6	33	2	0.17	0.36	0.00

E.2: Water quality daily statistics for Trout Creek at Oak Ridge Rd. (TC2), July 2, 2008 – October 31, 2008. Data was taken at 10 minute intervals with an YSI 6600 multi-parameter sonde (YSI Inc, Yellow Springs, OH) and summarized on a daily basis here.

Trout Creek Daily Statistics at Oak Ridge Rd.

		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
July	2	19.48	20.47	18.56	7.94	7.98	7.87	7.53	9.35	6.42	82	100	69	0.668	0.686	0.665	2	7	1	0.15	0.18	0.13
	3	18.24	21.26	16.83	7.70	7.87	7.46	6.80	8.05	5.62	72	87	60	0.445	0.670	0.254	179	934	4	0.25	0.48	0.10
	4	17.36	18.47	16.01	7.57	7.64	7.47	7.07	7.25	5.89	74	76	62	0.293	0.332	0.267	182	368	60	0.32	0.36	0.29
	5	17.06	19.95	14.82	7.80	7.86	7.73	7.55	8.24	6.88	78	90	72	0.432	0.459	0.402	14	28	9	0.23	0.26	0.20
	6	17.55	19.41	15.43	7.85	7.91	7.80	7.41	8.14	6.61	78	88	71	0.476	0.491	0.459	10	17	6	0.18	0.21	0.15
	7	19.78	22.21	17.85	7.85	7.95	7.78	6.97	8.07	5.99	76	92	66	0.498	0.509	0.490	12	172	4	0.16	0.18	0.12
	8	20.53	22.86	19.15	7.88	7.97	7.80	6.72	7.91	5.95	75	92	65	0.504	0.508	0.499	9	53	4	0.13	0.16	0.12
	9	19.07	21.06	17.52	7.94	8.02	7.86	7.09	8.36	6.14	77	93	66	0.504	0.507	0.497	7	33	3	0.18	0.20	0.16
	10	18.96	21.15	16.96	7.96	8.04	7.90	7.27	8.67	6.49	79	97	69	0.510	0.514	0.506	5	15	2	0.18	0.21	0.15
	11	18.92	20.64	17.49	7.92	7.98	7.85	7.10	8.50	6.37	77	95	68	0.506	0.516	0.490	10	130	4	0.18	0.22	0.15
	12	18.86	20.23	17.75	7.90	7.95	7.79	7.40	8.18	6.58	80	90	71	0.460	0.512	0.438	25	203	7	0.18	0.23	0.13
	13	17.45	18.33	16.73	7.87	7.92	7.82	6.79	7.34	6.43	71	78	66	0.489	0.512	0.463	7	18	4	0.12	0.15	0.11
	14	17.37	20.04	15.28	7.89	7.99	7.81	7.43	8.79	6.45	78	96	66	0.461	0.463	0.458	5	14	2	0.17	0.18	0.15
	15	18.77	21.59	16.42	7.94	8.04	7.87	7.36	8.67	6.39	79	97	69	0.466	0.474	0.459	5	17	2	0.19	0.21	0.17
	16	18.99	20.22	18.10	7.90	7.99	7.82	6.99	8.08	6.32	75	89	68	0.460	0.482	0.411	17	233	2	0.25	0.32	0.21
	17	19.01	20.53	17.58	7.87	7.93	7.82	7.13	7.93	6.47	77	88	70	0.435	0.450	0.426	12	18	7	0.22	0.26	0.19
	18	19.89	21.63	18.53	7.92	8.01	7.84	7.07	8.29	6.32	78	94	70	0.476	0.491	0.449	5	23	2	0.19	0.20	0.18
	19	20.40	22.13	19.13	7.95	8.05	7.88	6.97	8.32	6.12	78	95	68	0.490	0.494	0.469	10	35	2	0.18	0.20	0.16
	20	20.24	21.79	19.13	7.93	8.02	7.86	6.83	8.12	6.00	76	92	65	0.482	0.489	0.471	6	15	2	0.17	0.18	0.16
	21	19.32	20.43	18.37	7.97	8.08	7.90	7.04	8.60	6.11	77	95	67	0.486	0.491	0.477	5	13	0	0.19	0.21	0.16
	22	18.77	21.02	17.34	8.00	8.11	7.92	7.50	8.98	6.61	81	100	70	0.488	0.495	0.476	4	12	0	0.23	0.25	0.21
	25	18.62	19.32	17.79	7.84	7.92	7.78	7.75	9.30	6.88	83	101	73	0.831	0.836	0.823	7	23	4	0.17	0.18	0.15
	26	19.29	21.19	17.87	7.86	7.97	7.76	7.85	9.40	6.89	85	105	73	0.835	0.837	0.830	6	19	4	0.16	0.17	0.14
	27	19.28	21.01	17.54	7.88	7.98	7.80	7.89	9.57	6.85	86	107	72	0.826	0.831	0.810	6	14	3	0.13	0.14	0.12
	28	19.25	21.14	17.71	7.88	7.97	7.81	7.82	9.39	6.86	85	105	73	0.823	0.841	0.811	6	10	4	0.16	0.17	0.13
	29	18.39	19.79	17.24	7.85	7.96	7.64	7.99	9.64	6.98	85	104	73	0.792	0.828	0.455	24	485	4	0.14	0.21	0.08
	30	19.58	21.72	18.13	7.70	7.80	7.61	7.14	8.28	5.55	78	94	61	0.691	0.791	0.607	24	48	12	0.12	0.21	0.09
	31	19.63	21.29	18.16	7.63	7.73	7.55	6.13	7.63	5.22	67	86	56	0.660	0.705	0.646	8	18	4	0.11	0.12	0.10
July Total		18.93	22.86	14.82	7.86	8.11	7.46	7.23	9.64	5.22	78	107	56	0.553	0.841	0.254	22	934	0	0.18	0.48	0.08

E.2. (continued)

Trout Creek Daily Statistics at Oak Ridge Rd.

		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
August	1	20.02	22.29	18.53	7.74	7.88	7.60	6.87	8.69	5.60	76	100	61	0.670	0.682	0.657	6	9	4	0.13	0.15	0.10
	2	19.24	21.13	17.68	7.84	7.96	7.75	7.38	9.14	6.21	80	102	66	0.693	0.707	0.657	8	46	5	0.17	0.20	0.15
	3	18.99	20.69	17.41	7.97	8.12	7.79	x	x	x	x	x	x	0.720	0.732	0.697	7	18	5	0.18	0.21	0.14
	4	18.92	19.91	17.73	7.96	8.06	7.83	x	x	x	x	x	x	0.726	0.756	0.645	11	107	6	0.15	0.17	0.14
	5	20.06	22.03	18.74	7.89	8.01	7.79	x	x	x	x	x	x	0.746	0.760	0.717	9	14	6	0.17	0.19	0.15
	6	19.33	20.75	18.00	7.92	8.01	7.83	x	x	x	x	x	x	0.748	0.755	0.741	9	15	6	0.18	0.20	0.16
	9	17.74	19.23	16.43	7.92	8.00	7.85	8.18	9.86	7.03	86	107	73	0.831	0.837	0.824	5	10	3	0.20	0.23	0.18
	10	16.36	17.83	14.74	7.94	8.02	7.87	8.61	10.58	7.45	88	112	74	0.838	0.844	0.832	4	9	2	0.24	0.25	0.23
	11	16.44	18.18	14.60	7.95	8.04	7.87	8.83	10.90	7.77	91	115	77	0.838	0.842	0.833	4	19	2	0.24	0.26	0.21
	12	16.75	17.96	15.24	7.97	8.08	7.87	9.08	11.30	7.50	94	120	75	0.836	0.839	0.833	4	9	2	0.19	0.21	0.16
	13	17.04	17.67	16.62	7.91	8.00	7.84	8.26	10.21	7.14	86	107	74	0.841	0.846	0.833	4	9	2	0.17	0.18	0.16
	14	17.16	18.61	15.94	7.94	8.05	7.85	8.70	10.63	7.42	91	114	76	0.842	0.844	0.839	5	46	2	0.22	0.26	0.18
	15	16.78	18.40	15.13	7.94	8.03	7.86	8.57	10.50	7.42	89	112	74	0.841	0.845	0.838	4	8	2	0.28	0.29	0.26
	16	17.32	19.00	15.26	7.95	8.05	7.87	8.59	10.78	7.22	90	116	73	0.834	0.841	0.830	4	13	2	0.24	0.27	0.21
	17	19.06	20.70	17.39	7.92	8.02	7.85	8.08	10.49	6.97	88	117	73	0.835	0.840	0.829	4	10	2	0.19	0.21	0.17
	18	19.65	21.43	18.26	7.92	8.02	7.80	7.78	9.96	6.30	85	113	67	0.839	0.844	0.834	7	101	2	0.19	0.25	0.17
	19	17.78	19.10	16.75	7.95	8.08	7.87	8.50	11.47	6.98	90	124	73	0.836	0.841	0.830	5	14	3	0.25	0.28	0.23
	20	17.40	18.80	15.90	7.95	8.03	7.87	8.66	10.90	7.52	91	117	76	0.825	0.835	0.820	5	10	3	0.24	0.26	0.22
	21	17.95	19.33	16.44	7.95	8.06	7.86	8.72	11.17	7.37	92	122	76	0.820	0.825	0.814	5	19	3	0.20	0.23	0.18
	22	19.33	20.82	18.08	7.91	8.03	7.82	8.06	11.02	6.91	88	122	73	0.817	0.822	0.810	5	10	3	0.17	0.18	0.16
	23	20.33	21.73	18.79	7.89	7.98	7.81	7.37	9.36	6.31	82	107	69	0.815	0.821	0.811	8	100	4	0.17	0.19	0.16
	24	17.43	18.73	16.05	7.93	8.04	7.84	8.28	10.62	6.67	87	113	71	0.813	0.819	0.807	8	24	5	0.21	0.22	0.19
	25	15.94	17.52	14.25	7.97	8.05	7.91	8.94	10.79	7.98	91	113	79	0.802	0.811	0.793	8	14	6	0.23	0.25	0.22
	26	15.42	17.38	13.61	7.96	8.03	7.91	9.04	10.76	8.28	91	112	80	0.801	0.806	0.789	9	19	6	0.21	0.23	0.18
	27	15.61	17.54	13.52	7.97	8.05	7.91	9.14	11.15	8.20	92	116	80	0.803	0.808	0.779	11	42	8	0.16	0.19	0.13
	28	16.50	17.64	15.33	7.93	8.02	7.88	8.52	10.77	7.82	88	113	79	0.803	0.809	0.780	9	17	7	0.11	0.14	0.10
	29	16.81	18.26	15.40	7.91	7.97	7.86	8.46	10.11	7.66	88	107	77	0.809	0.816	0.795	9	17	7	0.16	0.18	0.13
	30	16.87	18.83	15.01	7.94	8.02	7.88	8.61	10.40	7.72	89	111	78	0.812	0.816	0.807	8	16	6	0.20	0.22	0.18
	31	17.82	19.61	15.91	7.93	8.00	7.87	8.29	9.92	7.44	88	108	77	0.809	0.815	0.794	8	17	6	0.22	0.24	0.21
Aug. Total		17.79	22.29	13.52	7.93	8.12	7.60	8.38	11.47	5.60	88	124	61	0.801	0.846	0.645	7	107	2	0.20	0.29	0.10

E.2. (continued)

Trout Creek Daily Statistics at Oak Ridge Rd.

		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
September	1	18.37	20.59	16.53	7.93	8.03	7.87	8.04	10.00	6.87	86	110	73	0.802	0.807	0.796	10	55	6	0.21	0.23	0.18
	2	19.11	21.22	17.09	7.93	8.05	7.85	7.93	10.59	6.34	86	118	69	0.798	0.804	0.790	8	16	5	0.17	0.19	0.14
	3	18.28	19.54	16.48	7.92	8.01	7.85	7.78	9.83	6.33	83	106	69	0.790	0.801	0.774	10	33	6	0.20	0.22	0.18
	4	15.39	16.44	14.72	7.89	7.96	7.83	8.06	9.19	7.24	81	92	74	0.781	0.796	0.750	11	23	7	0.17	0.21	0.14
	5	14.98	16.01	14.12	7.89	7.95	7.83	8.83	10.24	7.91	88	104	78	0.778	0.797	0.760	12	19	10	0.16	0.17	0.13
	6	15.13	15.91	14.47	7.93	8.00	7.86	9.03	10.51	7.91	90	106	78	0.790	0.800	0.772	12	53	9	0.17	0.19	0.17
	7	14.75	16.01	13.81	7.95	8.04	7.89	9.25	11.32	8.26	92	114	80	0.760	0.774	0.730	11	27	7	0.18	0.20	0.17
	8	13.40	14.27	12.51	7.94	7.99	7.88	9.47	10.63	8.31	91	103	79	0.774	0.797	0.739	15	372	9	0.22	0.24	0.20
	9	12.47	13.82	11.17	7.98	8.05	7.93	10.18	11.76	9.31	96	114	86	0.804	0.814	0.793	12	19	10	0.24	0.26	0.22
	10	12.28	13.67	10.69	7.99	8.05	7.94	x	x	x	x	x	x	0.815	0.822	0.807	12	17	10	0.26	0.28	0.24
	11	13.52	14.68	12.35	8.10	8.20	8.00	x	x	x	x	x	x	0.785	0.821	0.654	19	276	10	0.20	0.24	0.15
	12	14.84	15.37	14.45	8.04	8.12	7.95	x	x	x	x	x	x	0.785	0.804	0.751	17	23	12	0.18	0.20	0.16
	13	15.03	15.47	14.64	7.89	8.06	7.79	x	x	x	x	x	x	0.752	0.790	0.714	16	32	11	0.10	0.17	0.05
	14	14.86	15.42	13.93	7.86	7.94	7.79	x	x	x	x	x	x	0.773	0.787	0.725	12	24	9	0.10	0.18	0.07
	15	12.91	13.90	11.81	7.92	8.00	7.84	x	x	x	x	x	x	0.771	0.781	0.744	12	51	9	0.23	0.26	0.18
	16	12.46	14.06	10.78	7.91	7.97	7.88	x	x	x	x	x	x	0.776	0.787	0.764	15	22	11	0.22	0.25	0.19
	17	13.94	15.24	12.83	7.89	7.95	7.84	x	x	x	x	x	x	0.784	0.792	0.777	12	21	10	0.25	0.29	0.21
	22	16.05	17.17	15.22	7.87	7.92	7.82	7.55	8.57	6.92	77	89	69	0.837	0.839	0.834	6	14	3	0.19	0.20	0.18
	23	16.66	17.97	15.51	7.84	7.90	7.81	6.89	7.88	6.17	71	83	64	0.839	0.844	0.835	6	23	3	0.16	0.19	0.13
	24	16.81	18.16	14.86	7.81	7.86	7.76	6.35	7.39	5.67	66	78	58	0.833	0.839	0.816	5	18	3	0.15	0.18	0.13
	25	14.45	15.80	13.00	7.81	7.85	7.78	6.85	7.74	6.22	67	78	60	0.827	0.834	0.819	4	17	2	0.18	0.21	0.16
	26	14.39	16.15	12.63	7.81	7.85	7.78	6.95	7.86	6.35	68	80	62	0.826	0.829	0.818	5	15	3	0.13	0.16	0.10
	27	14.75	15.85	13.41	7.77	7.81	7.75	6.41	7.36	5.93	63	74	59	0.823	0.832	0.818	7	161	3	0.10	0.13	0.08
	28	14.01	14.90	13.35	7.76	7.79	7.73	6.23	6.83	5.74	61	67	56	0.825	0.828	0.819	6	38	3	0.15	0.16	0.13
	29	13.07	13.50	12.59	7.79	7.82	7.76	6.97	7.71	6.29	66	74	60	0.821	0.826	0.815	5	12	4	0.10	0.14	0.07
	30	12.15	12.80	11.27	7.82	7.85	7.79	7.58	8.19	6.87	71	78	64	0.821	0.826	0.811	6	14	4	0.07	0.08	0.05
Sept. Total		14.77	21.22	10.69	7.89	8.20	7.73	7.80	11.76	5.67	78	118	56	0.799	0.844	0.654	10	372	2	0.17	0.29	0.05

E.2. (continued)

Trout Creek Daily Statistics at Oak Ridge Rd.

		Temp (C)			pH			D.O. (mg/L)			D.O. %			Spc. Cond (mS/cm)			Turbidity (NTU)			Depth (m)		
Month	Day	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
October	1	10.85	11.53	9.73	7.84	7.87	7.80	8.08	8.82	7.35	73	81	66	0.817	0.820	0.810	5	22	3	0.08	0.09	0.06
	2	9.80	10.54	8.89	7.84	7.86	7.82	8.41	8.79	7.93	74	79	70	0.810	0.818	0.796	6	41	4	0.04	0.07	0.01
	3	8.18	9.27	7.17	7.88	7.93	7.84	9.63	10.61	8.63	82	91	73	0.787	0.814	0.755	5	14	4	0.15	0.21	0.07
	4	7.37	8.63	6.14	7.89	7.92	7.87	10.07	10.53	9.69	84	90	79	0.777	0.794	0.768	6	20	4	0.23	0.24	0.21
	5	7.91	9.03	6.41	7.88	7.91	7.83	9.94	10.44	9.20	84	90	79	0.783	0.787	0.775	8	13	5	0.24	0.26	0.22
	6	10.02	11.22	9.03	7.83	7.86	7.80	9.01	9.67	8.32	80	88	75	0.782	0.804	0.763	11	20	6	0.26	0.28	0.24
	7	10.91	11.45	10.17	7.79	7.83	7.70	8.19	8.62	7.82	74	79	70	0.797	0.818	0.692	14	30	6	0.19	0.24	0.13
	8	11.59	12.70	11.11	7.76	7.81	7.70	8.06	8.63	7.29	74	81	66	0.777	0.816	0.693	13	41	8	0.10	0.13	0.09
	9	10.51	11.62	9.61	7.74	7.77	7.70	7.57	8.21	7.11	68	76	63	0.787	0.803	0.760	13	31	8	0.15	0.20	0.11
	10	9.81	11.24	8.59	7.70	7.72	7.68	7.29	7.77	6.89	64	71	59	0.778	0.807	0.759	12	26	8	0.23	0.25	0.20
	11	10.84	12.73	9.35	7.70	7.73	7.68	7.18	7.74	6.57	65	73	61	0.796	0.822	0.779	11	43	7	0.25	0.26	0.23
	12	13.13	15.08	11.35	7.68	7.71	7.64	6.29	6.93	5.05	60	68	49	0.815	0.840	0.795	12	55	8	0.25	0.27	0.24
	13	14.80	15.97	13.45	7.62	7.65	7.58	4.57	5.33	3.41	45	54	34	0.827	0.852	0.810	x	x	x	0.22	0.25	0.17
	14	12.71	15.07	11.49	7.58	7.60	7.57	3.52	4.06	3.10	33	39	29	0.832	0.864	0.819	x	x	x	0.24	0.26	0.20
	15	11.10	11.66	9.99	7.59	7.61	7.57	4.06	4.58	3.49	37	42	32	0.846	0.863	0.812	x	x	x	0.20	0.23	0.17
	16	9.08	10.45	7.93	7.64	7.66	7.60	5.35	6.08	4.40	46	55	39	0.859	0.868	0.822	x	x	x	0.27	0.28	0.23
	17	8.09	9.35	6.82	7.67	7.70	7.65	6.42	7.25	5.52	54	63	47	0.850	0.868	0.811	x	x	x	0.28	0.29	0.26
	18	8.39	9.70	7.20	7.67	7.71	7.64	6.63	7.57	5.59	57	67	47	0.845	0.860	0.821	x	x	x	0.29	0.31	0.26
	19	8.81	10.07	7.29	7.67	7.70	7.64	6.52	7.21	5.62	56	64	50	0.854	0.863	0.822	x	x	x	0.22	0.26	0.19
	20	10.23	11.42	8.46	7.64	7.67	7.62	5.62	6.15	5.19	50	56	46	0.857	0.862	0.838	x	x	x	0.25	0.30	0.21
	21	7.34	8.56	6.11	7.66	7.69	7.64	6.72	7.50	5.58	56	64	48	0.858	0.865	0.832	x	x	x	0.32	0.33	0.30
	22	6.29	7.63	5.16	7.70	7.73	7.67	8.06	8.87	7.25	65	74	58	0.861	0.866	0.833	x	x	x	0.33	0.35	0.32
	23	6.43	7.98	5.04	7.70	7.72	7.68	8.03	8.57	7.52	65	73	60	0.864	0.869	0.839	x	x	x	0.30	0.33	0.23
	24	7.41	8.07	6.85	7.66	7.69	7.65	7.33	7.67	6.71	61	64	56	0.836	0.866	0.798	x	x	x	0.17	0.24	0.12
	25	7.42	8.55	6.44	7.70	7.75	7.67	7.88	8.96	7.13	66	77	59	0.846	0.854	0.826	x	x	x	0.05	0.12	0.00
	26	6.94	7.76	6.26	7.70	7.73	7.67	7.74	8.56	6.99	64	72	57	0.840	0.847	0.824	x	x	x	0.05	0.14	0.00
	27	5.50	6.26	4.74	7.73	7.77	7.69	8.96	10.17	7.81	71	82	62	0.844	0.852	0.818	x	x	x	0.23	0.30	0.14
	28	5.00	6.25	4.02	7.73	7.75	7.69	9.35	10.11	8.09	73	82	63	0.853	0.860	0.831	x	x	x	0.26	0.30	0.20
	29	3.58	5.01	2.55	7.76	7.79	7.74	10.52	11.23	9.72	80	88	74	0.861	0.867	0.843	x	x	x	0.23	0.25	0.20
	30	4.07	6.03	2.39	7.76	7.79	7.74	10.57	11.13	9.74	81	89	77	0.863	0.869	0.837	x	x	x	0.24	0.26	0.21
	31	5.09	5.76	4.93	7.74	7.75	7.73	9.52	9.73	9.31	75	77	73	0.863	0.865	0.839	x	x	x	0.24	0.27	0.00
Oct. Total		8.68	15.97	2.39	7.72	7.93	7.57	7.65	11.23	3.10	65	91	29	0.828	0.869	0.692	10	55	3	0.21	0.35	0.00

E.3: Water quality samples collected at two Trout Creek locations during 2008. TC1 samples were taken near County Rd. FF, while TC2 samples were taken near Oak Ridge Rd.

Sample Number	Date	Time	Method	TSS (mg/L)	Total P (mg/L)	Diss P (mg/L)
TC1-101	4/2/2008	14:25	Grab	136.0	0.279	X
TC1-102	4/9/2008	10:50	Grab	106.0	0.184	0.022
TC1-103	4/11/2008	8:50	Grab	1490.0	1.160	0.038
TC1-104	6/3/2008	11:00	Grab	460.0	0.550	0.026
TC1-105	6/9/2008	12:20	Grab	264.0	0.546	0.117
TC1-106	6/10/2008	13:45	Grab	58.0	0.216	0.095
TC1-107	6/10/2008	N/A	Siphon	182.0	0.332	0.063
TC1-108	6/10/2008	N/A	Siphon	668.0	1.000	0.156
TC1-109	6/13/2008	11:35	Grab	106.0	0.485	0.123
TC1-110	6/25/2008	13:15	Grab	16.0	0.113	0.060
TC1-111	7/3/2008	11:40	Grab	40.0	0.137	0.033
TC1-112	7/22/2008	14:10	Grab	9.8	0.083	0.044
TC1-113	8/19/2008	11:05	Grab	8.9	0.073	0.058
TC1-114	9/8/2008	12:00	Grab	3.2	0.035	0.016
TC1-115	9/18/2008	11:25	Grab	3.2	0.064	0.048
TC1-116	10/3/2008	12:40	Grab	2.5	0.043	0.038
TC1-117	10/31/2008	12:07	Grab	<2.2	<0.015	0.015
TC1-118	11/21/2008	12:35	Grab	<2.1	<0.015	<0.015
TC2-101	6/25/2008	14:20	Grab	7.0	0.133	0.092
TC2-102	7/2/2008	N/A	Siphon	442.0	0.830	0.130
TC2-103	7/3/2008	12:15	Grab	165.0	0.730	0.210
TC2-104	7/22/2008	15:00	Grab	3.0	0.151	0.064
TC2-105	8/19/2008	11:45	Grab	4.0	0.085	0.049
TC2-106	9/8/2008	12:45	Grab	2.2	0.074	0.050
TC2-107	9/18/2008	11:55	Grab	2.9	0.070	0.048
TC2-108	10/3/2008	11:45	Grab	14.0	0.105	0.059
TC2-109	10/31/2008	11:21	Grab	<2.2	0.046	0.017
TC2-110	11/21/2008	11:25	Grab	<2.0	<0.015	<0.015