State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Powell Creek Watershed

North Powell Creek

Final Report
April 7, 2009

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List of Acronyms and Abbreviations

ALU	aquatic life use
BMP	best management practice
CFU	colony forming unit
cm	centimeter
CNMP	Comprehensive Nutrient Management Plan
cnt/seas	counts per season
Corps	U.S. Army Corps of Engineers
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSO	combined sewer overflow
CSS	combined sewer system
CWA	Clean Water Act
DA	drainage area
DEFA	Division of Environmental and Financial Assistance
DFFOs	Directors Final Findings and Orders
DNAP	Division of Natural Areas and Preserves
DSW	Division of Surface Water
DSWC	Division of Soil and Water Conservation
EQIP	Environmental Quality Incentives Program
FC	Fecal Coliform
FSA	Farm Service Agency
gpd	gallons per day
GPS	geographic positioning system
GW	groundwater
HSTS	household sewage treatment system
HUC	hydrologic unit code
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
LA	load allocations
lb/yr	pounds per year
LEAP	Livestock Environmental Assurance Program
LID	low impact development
mg/L	milligrams per liter
MGD	million gallons per day
MHP	Mobile Home Park
MIWB	Modified Index of Well-Being
mi^2	square mile
ml	milliliter
MOR	monthly operating reports
MOS	margin of safety
MS4	municipal separate storm sewer system
MWH	Modified Warmwater Habitat
NACD	National Association of Conservation Districts
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resource Conservation Service

OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ORC	Ohio Revised Code
PCR	Primary Contact Recreation
QHEI	Qualitative Habitat Evaluative Index
RM	river mile
RU	recreational use
SCR	Secondary Contact Recreation
SCS	Soil Conservation Service
SWCD	Soil and Water Conservation District
SWMP	Storm Water Management Plan
TMDL	total maximum daily load
tn/yr	tons per year
TP	total phosphorus
TSS	total suspended solids
U.S. EPA	U.S. Environmental Protection Agency
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USGS	U.S. Geologic Survey
WLA	wasteload allocations
WQC	Water Quality Certification
WQS	water quality standards
WRP	Wetland Reserve Program
WRRSP	Water Resource Restoration Sponsor Program
WTP	water treatment plant
WWH	Warmwater Habitat
WWTP	Wastewater treatment plant

Acknowledgements

This TMDL report was drafted in the following manner:

Chapters 1 through 5 and Appendices A through C were prepared by
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Chapter 6 was prepared by Ohio EPA.

Tetra Tech's services were provided under contract to U.S. EPA.

The following Ohio EPA staff provided technical services for this project:
Biological and chemical water quality – Chuck Boucher, Dan Glomski, Janet Hageman, Tom Balduf
Nonpoint source issues – Katie McKibben
Point Source Issues – Dana Martin-Hayden, Raj Charkrabati
Storm water issues – Lynette Hablitzel
Agricultural issues – Rick Wilson, Melinda Harris
Project leader and coordinator – Gregg Sablak

Many full and part-time staff participated in field monitoring.

The Ohio EPA appreciates the cooperation of the property owners who allowed access to Powell Creek and its tributaries.

1.0 INTRODUCTION

The Powell Creek watershed drains approximately 98 square miles and includes one 11-digit Hydrologic Unit Code (HUC) Assessment Unit (AU) —Powell Creek (AU 04100007 110). The watershed lies in Paulding, Defiance, Putnam, and Henry counties in northwest Ohio and consists of mostly agricultural land, as shown in Figure 2-1. The Ohio Environmental Protection Agency (Ohio EPA) has evaluated the biological health and water quality of the watershed and determined that most segments of the Powell Creek watershed do not support designated aquatic life uses for Warm Water Habitat (WWH). Also, many segments do not support the Primary Contact Recreation use. Additional physical habitat impairments were determined using the Quality Habitat Evaluation Index (QHEI) scores (Rankin, 1989), which measure overall habitat and ecosystem health. Table 1-1 summarizes the impairment causes and sources of impairment reported on Ohio's 2008 Section 303(d) *Integrated Water Quality Monitoring and Assessment Report* (Ohio EPA, 2006).

Specifically, TMDLs that have been developed and are described in this report include:

- Nutrients (using total phosphorus and nitrate-nitrogen as the indicators of nutrient enrichment)
- Siltation (using total suspended solids as the sole indicator of in-stream siltation)
- Organic enrichment/DO (using biological oxygen demand as the sole indicator of organic enrichment/DO)

Due to an insufficient amount of data to perform loading analyses, TMDLs were not developed for fecal coliform bacteria to address recreational use impairments.

The Clean Water Act and U.S. Environmental Protection Agency (U.S. EPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters on the Section 303(d) lists. The TMDL and water quality restoration planning process involves several steps including watershed characterization, target identification, source assessment, and allocation of loads. The pollutant load is allocated among all sources within the watershed and voluntary (for nonpoint sources) and regulatory (for point sources) control measures are identified for attaining the source allocations. An implementation plan is also typically established to ensure that the control measures are effective at restoring water quality and all designated water uses.

The overall goals and objectives in developing the Powell Creek TMDLs were to:

- Assess the water quality within the watershed and identify key issues associated with the impairments and potential pollutant sources.

- Use the best available science and available data to determine water quality conditions that will result in all streams fully supporting their designated uses.

- Prepare a final TMDL report that meets the requirements of the Clean Water Act and provides information to the key stakeholders that can be used to facilitate implementation activities to improve water quality.

Consistent with Ohio=s current Continuous Planning Process (CPP), the draft TMDL report was public noticed from December 19, 2008 to January 26, 2009 and a copy of the draft report was available on Ohio EPA's web page at **http://www.epa.state.oh.us/dsw/tmdl/index.aspx** . General information on TMDLs, water quality standards, 208 planning, permitting, and other Ohio EPA programs are also available on this site. No public comments were received regarding this TMDL report.

This report documents the results of the TMDL analysis. Section 2 briefly describes the watershed and applicable water quality standards, Section 3 describes the methodology used to estimate the current and allowable pollutant loads, and Section 4 presents the resulting TMDLs. A discussion of additional water quality impairments in Powell Creek is presented in Section 5. Recommendations for implementation activities are presented in Section 6. Appendix A presents the detailed results of the load duration curve analysis, Appendix B provides all of the summary data used for TMDL development, and Appendix C lists alternative TMDLs for the possible Continental WWTP conversion to a lagoon treatment system.

Table 1-1. Summary of Section 303(d) listings in the Powell Creek watershed, Ohio.

Assessment Unit	Designated Uses	High Magnitude Causes	High Magnitude Sources
04100007 110 Powell Creek	Aquatic Life Use (WWH, LRW), and Recreational Use (Primary Contact)	Nutrients, Siltation, Organic Enrichment/DO, Flow Alterations, Direct Habitat Alterations, and Pathogens (fecal bacteria)	Non-irrigated Crop Production, Hydromodification-Agriculture

2.0 DESCRIPTION OF WATERBODIES, IMPAIRMENT STATUS AND WATER QUALITY STANDARDS

The purpose of this section of the report is to provide a brief background of Powell Creek and its corresponding watershed.

2.1 Description of the Powell Creek Watershed

Powell Creek drains a 98 square mile watershed in northwestern Ohio (Figure 2-1). The watershed lies within the glaciated Huron /Erie Lake Plains (HELP) ecoregion. The HELP ecoregion is a nearly flat, broad plain that has been mostly cleared and artificially drained for extensive corn, soybean, and vegetable farming. Livestock production, urban, and industrial areas are also commonly found within the ecoregion. Powell Creek flows from the southeast to the northwest and is divided among four counties. The headwaters originate in Putnam County as the North and South branches of Powell Creek wind their way towards Defiance County. A few tributaries of North Powell Creek reach into Henry County. The two branches meet near the Defiance/Paulding County line and briefly flow through the northeastern corner of Paulding County. Powell Creek then crosses back into Defiance County, eventually flowing into the Auglaize River. Cities within the watershed include Miller City, Continental, and Defiance.

The watershed is comprised of one 11-digit assessment unit (AU): Powell Creek (04100007-110). This single 11-digit AU is further subdivided into 14-digit hydrologic unit code (HUC) sub-watersheds as presented in Table 2-1.

Table 2-1. Assessment Unit (AU) and 14-Digit Hydrologic Unit Code (HUC) Designations for the Powell Creek Watershed.

11-Digit AU	14-Digit HUC	Description	Drainage Area (mi^2)
04100007-110		**Powell Creek**	**97.6**
	010	South Powell Creek (tributary to Powell Creek)	37.9
	020	North Powell Creek (tributary to Powell Creek)	46.9
	030	Powell Creek below junction of South and North Powell Creeks to Auglaize River	12.8

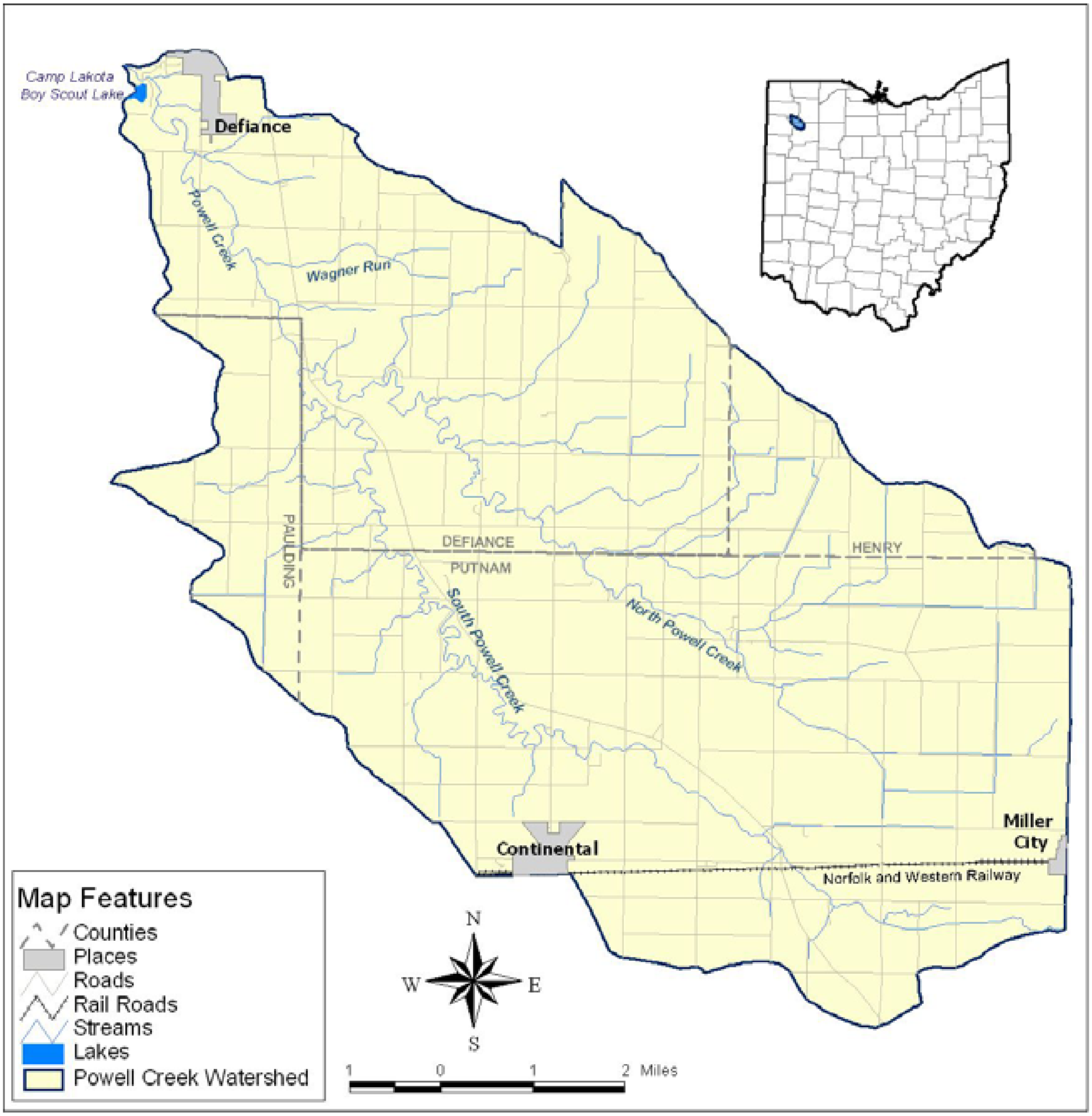

Figure 2-1. The Powell Creek watershed.

2.2 Land Use and Land Cover within the Powell Creek Watershed

The land use/land cover for the Powell creek watershed was extracted from the Ohio Statewide Land Cover Classification. This spatial database was derived from satellite imagery collected from 1999 to 2003 and is the most current detailed land use/land cover data known to be available for the watershed. Each 98-foot by 98-foot pixel contained within the satellite image was classified according to its reflective characteristics and the resulting land use and land cover characteristics of the Powell Creek watershed are presented in Figure 2-2 and summarized in Table 2-2. The figure and table show that cultivated crops are by far the dominant land cover in the watershed accounting for approximately 83 percent of the total area. Deciduous forest is the second most common land cover at 8.1 percent followed by developed, open space at 5.1 percent.

Table 2-2. Land Use and Land Cover Characteristics of the Powell creek Watershed.

Land Cover / Land Use	Area (acres)	Area (Sq. Miles)	Percent of Watershed
Open Water	108.24	0.17	0.2%
Developed, Open Space	3,204.52	5.01	5.1%
Developed, Low Intensity	977.93	1.53	1.6%
Developed, Medium Intensity	102.23	0.16	0.2%
Developed, High Intensity	31.63	0.05	0.1%
Barren Land (Rock/Sand/Clay)	213.70	0.33	0.3%
Deciduous Forest	5,083.89	7.94	8.1%
Evergreen Forest	2.26	0.00	0.0%
Grassland/Herbaceous	383.37	0.60	0.6%
Pasture/Hay	319.08	0.50	0.5%
Cultivated Crops	51,785.74	80.92	83.0%
Woody Wetlands	150.21	0.23	0.2%
Emergent Herbaceous Wetlands	41.70	0.07	0.1%
Total	**62,404.50**	**97.51**	**100.0%**

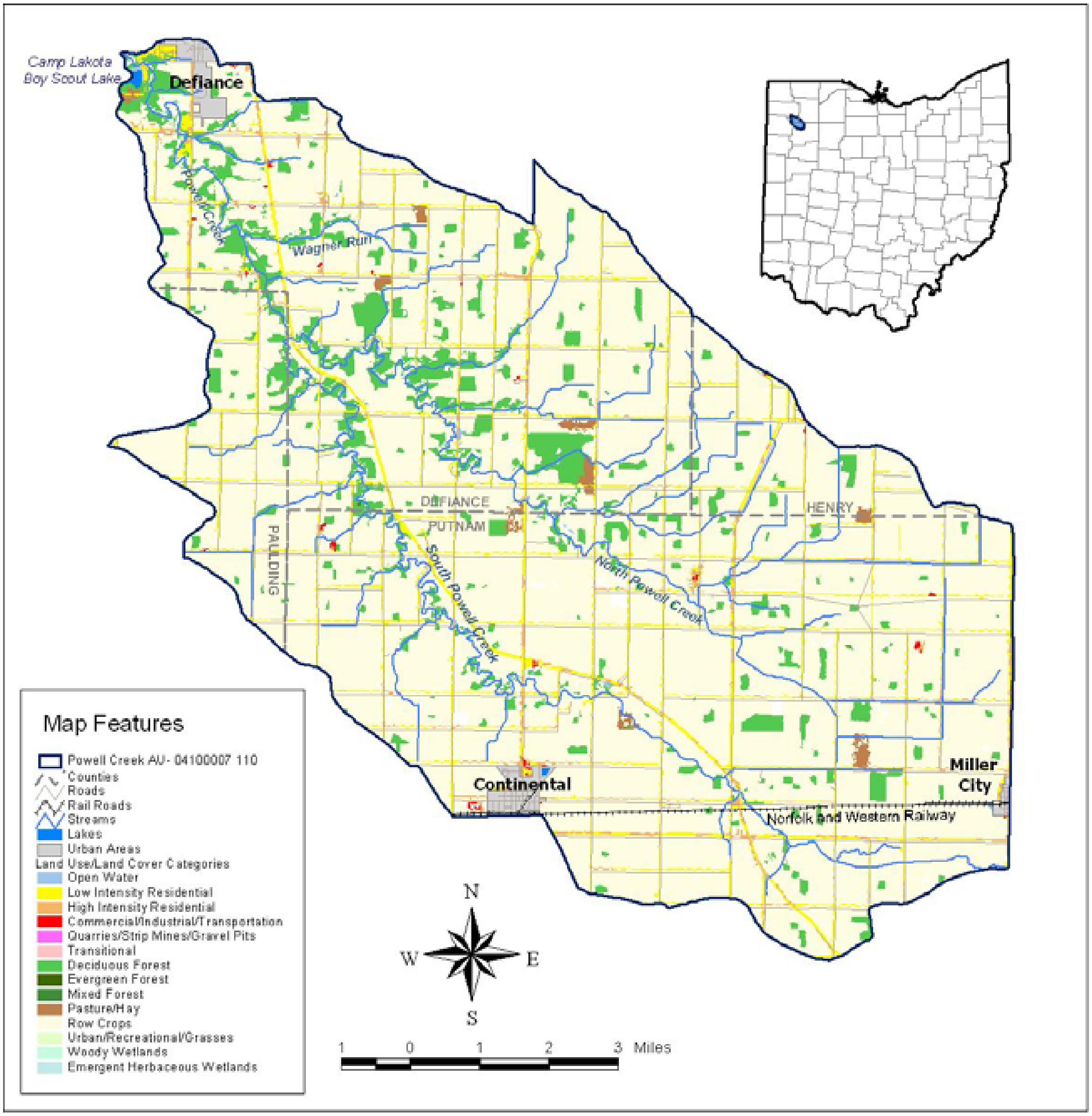

Figure 2-2. Land use and land cover within the Powell creek watershed.

2.3 Water Quality Standards

The purpose of developing a TMDL is to identify the pollutant loading that a waterbody can receive and still achieve water quality standards. Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of three components: designated uses, numeric or narrative criteria, and an antidegradation policy. Ohio's water quality standards are summarized in Table 2-3 and explained in greater detail below.

Table 2-3. Ohio water quality standards.

Component	Description
Designated Use	Designated use reflects how the water can potentially be used by humans and how well it supports a biological community. Every water in Ohio has a designated use or uses; however, not all uses apply to all waters (i.e., they are waterbody specific).*
Numeric Criteria	Chemical criteria represent the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. Biological criteria indicate the health of the in-stream biological community by using one of three indices: • Index of Biotic Integrity (IBI) (measures fish health). • Modified Index of well being (MIwb) (measures fish health). • Invertebrate Community Index (ICI) (measures benthic macroinvertebrate health).
Narrative Criteria	These are the general water quality criteria that apply to all surface waters. These criteria state that all waters must be free from sludge; floating debris; oil and scum; color- and odor-producing materials; substances that are harmful to human, animal or aquatic life; and nutrients in concentrations that may cause algal blooms.
Antidegradation Policy	This policy establishes situations under which Ohio EPA may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need. Refer to <http://www.epa.state.oh.us/dsw/wqs/index.aspx> for more information.

• According to OAC 3745-1-07(A)(1) each waterbody is assigned a designated use. However, some streams in Ohio are undesignated and receive a default Warm Water Habitat designation for chemical loadings. There is no default protection for recreational use.

2.3.1 Designated Uses

Powell Creek and its tributaries are designated by Ohio EPA as warmwater habitat (WWH) aquatic life use with the exception of Continental Ditch which is listed as limited resource waters (LRW).

2.3.2 Numeric Criteria

Ohio has not yet developed numeric criteria for the TMDL parameters in this report. Specifically, there are no existing applicable numeric criteria for nutrients (total phosphorus and nitrate), siltation (total suspended solids), and organic enrichment (biological oxygen demand).

2.3.3 Narrative Criteria

Only narrative criteria are available for nutrient-related causes of impairment. TMDL targets are therefore needed to compare existing water quality conditions to desired water quality conditions and to derive "maximum daily loads". Ohio EPA (1999) has established water quality targets for nutrients that vary based both on drainage area and the designated aquatic life use. The WWH values are shown in Table 2-4.

Table 2-4. Nutrient TMDL Target Values for the Powell Creek Watershed.

Water Quality Parameter	Drainage Area	WWH Target Value (mg/L)
Total Phosphorus	Headwaters (< 20 square miles)	0.08
	Wadeable (20 < 200 square miles)	0.10
	Small Rivers (200 < 1000 square miles)	0.17
Nitrate Nitrogen	Headwaters (< 20 square miles)	1.0
	Wadeable (20 < 200 square miles)	1.0
	Small Rivers (200 < 1000 square miles)	1.5

Water quality criteria have not yet been developed for total suspended solids (TSS) or biochemical oxygen demand (BOD) in the state of Ohio. The Ohio EPA has previously utilized reference site levels of TSS and BOD, in light of their corresponding biological indices, as a means of identifying potential aquatic life impairments. The Appendices of "Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams" (Ohio EPA, 1999) provide a summary of the links between these and other water column chemistry statistics, ecoregion, and IBI range. TSS and BOD 90th percentile values for the Huron/Erie Lake Plain (HELP) ecoregion are listed below and are proposed as TMDL target values for the Powell Creek TSS and BOD impairments.

Table 2-5. TMDL Total Suspended Solids and Biochemical Oxygen Demand Targets for the Powell Creek Watershed.

Water Quality Parameter	Source of TMDL Target	Target Value
Total Suspended Solids	Ohio EPA Reference Site Statistics	Headwaters (< 20 square miles): 49.0 mg/L Wadeable (20 < 200 square miles): 66.4 mg/L Small Rivers (200 < 1000 square miles): 75.2 mg/L
BOD (5-day)	Ohio EPA Reference Site Statistics	Headwaters (< 20 square miles): 2.31 mg/L Wadeable (20 < 200 square miles): 3.50 mg/L Small Rivers (200 < 1000 square miles): 7.73 mg/L

3.0 TECHNICAL APPROACH

Developing a TMDL requires estimating the allowable pollutant loading that a waterbody can receive and still support water quality standards. Estimates of the current loading to the waterbody are also useful for implementation planning purposes. This section of the report presents the technical approach used to estimate current and allowable loading to Powell Creek and its tributary streams. As discussed below, a load duration approach was used to make these estimates.

3.1 Load Duration Curves

Load reductions were determined through the use of load duration curves. This approach involves calculating the allowable loadings over the range of flow conditions expected to occur in the impaired stream by taking the following steps:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points to form a curve. The data reflect a range of natural occurrences from extremely high flows to extremely low flows.

2. The flow curve is translated into a load duration (or TMDL) curve by multiplying each flow value by the water quality standard/target for a particular contaminant, then multiplying by a conversion factor. The resulting points are plotted to create a load duration curve (LDC).

3. Each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected. Then, the individual loads are plotted as points on the TMDL graph and can be compared to the water quality standard/target, or LDC.

4. Points plotting above the curve represent deviations from the water quality standard/target and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load. Further, it can be determined which locations contribute loads above or below the water quality standard/target.

5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards/targets.

6. The final step is to determine where reductions need to occur. Those exceedences at the right side of the graph occur during low flow conditions, and significant sources might include septic systems, illicit sewer connections, or animals depositing waste directly to the stream; exceedences on the left side of the graph occur during higher flow events, and potential sources include a variety of activities related to runoff. Using the LDC approach allows Ohio EPA and local planners to determine which implementation practices are most effective for reducing loads based on flow regime. If loads are significant during wet weather events, implementation efforts can target those BMPs that will most effectively reduce storm water runoff.

An example load duration curve is presented in Figure 3-1 and illustrates that observed BOD loads exceed allowable loads across all flow zones sampled. The figure also indicates that excessive loads primarily occur when subsurface flows exceed surface flows. The proportion of surface versus subsurface flows was determined using the sliding-interval method for streamflow hydrograph separation contained in the USGS HYSEP program (Sloto and Crouse, 1996). Algorithms from HYSEP were incorporated into the load duration analysis to determine the proportion of daily mean discharge that was overland runoff (surface) or groundwater discharge (subsurface) components. A surface flow threshold value of 50 percent was used to identify water quality samples that were collected during primarily surface runoff events.

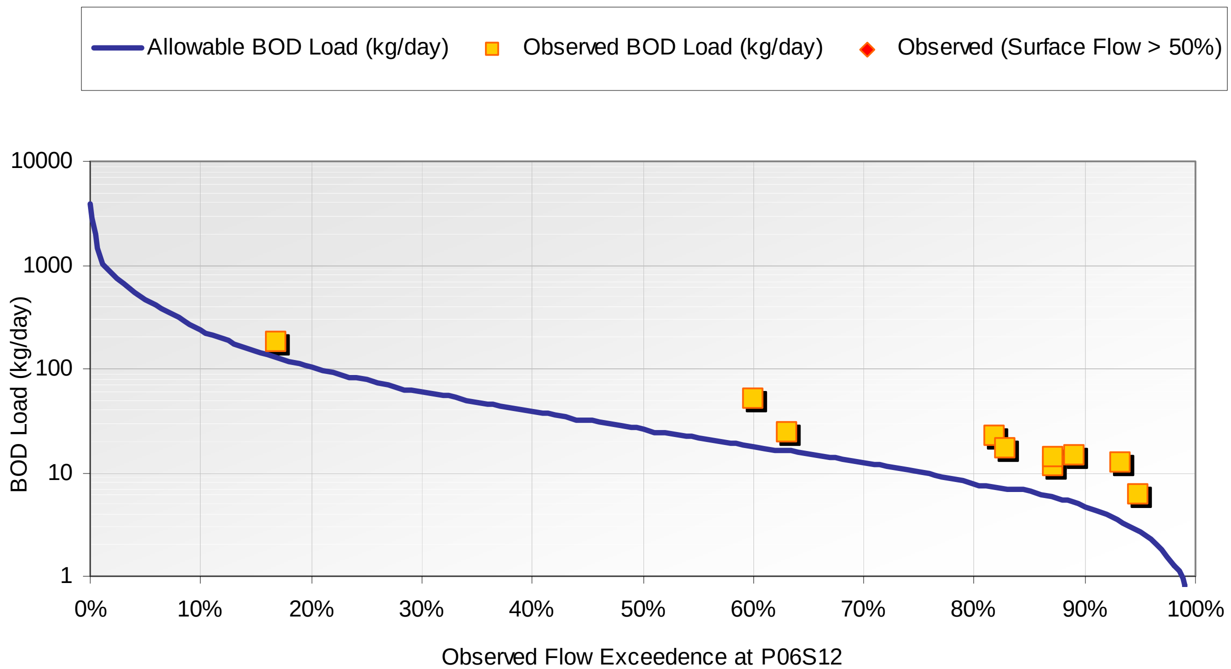

Figure 3-1. BOD load duration curve example for monitoring station P06S12 located on South Powell Creek.

The stream flows displayed on a load duration curve may be grouped into various flow regimes to aid with interpretation of the load duration curves. The flow regimes are typically divided into 10 groups which can be further categorized into the following five "hydrologic zones" (Cleland, 2005):

- High flow zone: stream flows that plot in the 0 to 10 percentile range, related to flood flows.
- Moist zone: flows in the 10 to 40 percentile range, related to wet weather conditions.
- Mid-range zone: flows in the 40 to 60 percentile range, median stream flow conditions;
- Dry zone: flows in the 60 to 90 percentile range, related to dry weather flows.
- Low flow zone: flows in the 90 to 100 percentile range, related to drought conditions.

The load duration approach helps to identify the issues surrounding the impairment and to roughly differentiate between sources. Table 3-1 summarizes the relationship between the five hydrologic zones and potentially contributing source areas (Cleland, 2005).

The load reduction approach also considers critical conditions and seasonal variation in the TMDL development as required by the Clean Water Act and EPA's implementing regulations. Because the approach establishes loads based on a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions.

Table 3-1. Relationship Between Load Duration Curve Zones and Contributing Sources.

Contributing Source Area	Duration Curve Zone				
	High	Moist	Mid-Range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
On-site wastewater systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Storm water: Impervious		H	H	H	
Combined sewer overflow (CSO)	H	H	H		
Storm water: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	
Bank erosion	H	M			

Note: Potential relative importance of source area to contribute loads under given hydrologic condition (H: High; M: Medium; L: Low)

The load duration curve approach is based upon the premise that loads vary depending upon the flow, and different sources may contribute loads under different flow conditions. Using the load duration curve approach assists with determining which implementation practices are most effective for reducing loads based on flow magnitude. For example, if existing loads exceed allowable loads primarily during storm and winter snow melt events, implementation efforts can target those best management practices (BMPs) that will most effectively reduce loads associated with runoff. The approach also aids in sharing the responsibility for nutrient and pathogen reductions among various stakeholders in the TMDL watershed, which encourages efficient and collective implementation efforts.

The load duration curve is a cost-effective TMDL approach that addresses the reductions necessary to meet target loads. This TMDL ties directly into Ohio's numeric water quality standard for pathogens and numeric criteria for nutrients, therefore meeting these loading capacities should result in attainment of water quality standards.

Weaknesses of this TMDL approach are that nonpoint source load allocations cannot be assigned to specific sources within the watershed, and the identified pollutant sources must be identified using a weight-of-evidence approach rather than determined by detailed monitoring and sampling efforts or modeling. Moreover, specific source reductions are not quantified. Despite the limitations of the load duration curve approach, Ohio EPA believes the strengths of the approach outweigh the weaknesses and that this methodology is appropriate based upon the information available.

3.2 Stream Flow Estimates

Daily stream flows for each monitoring site of interest are needed to apply the load duration curve. Continuous stream flow data are not available for the Powell Creek watershed. Since the load duration approach requires a stream flow time series for each site where the method is applied, stream flows were extrapolated from a surrogate gage station for each load duration site. The Auglaize River near Fort Jennings, Ohio USGS gage station (USGS gage 04186500) was used to estimate flows in the watershed. Daily average flows for the Auglaize River gage station were downloaded from **http://waterdata.usgs.gov/nwis**.

Flow time series for each load duration site were estimated using a multiplier based upon the ratio of the upstream drainage area for a given site to the drainage area of the Auglaize River. For example, the ratio of the drainage area at the North Powell Creek monitoring site (P06G05) is 44.5 square miles which, if divided by the drainage area of Auglaize River (332 square miles[1]), equals 0.134. Thus, the observed daily stream flows at the Auglaize River USGS gage were multiplied by 0.134 to estimate the daily stream flows at the North Powell Creek monitoring site. Table 3-2 presents the drainage area ratios used to estimate stream flow for all of the load duration sites included in this TMDL; the locations of the sites are shown in Figure 3-2.

Table 3-2. Drainage Area Ratios Used to Estimate Stream Flow for Load Duration Analyses in the Powell Creek Watershed.

14-Digit HUC	Station ID	Stream Name	Location	River Mile	Upstream Drainage Area (Sq. mi.)	Drainage Area Ratio*
010	P06G01	South Powell Creek	At State Route 613	19.58	5.351	0.016
010	P06S12	South Powell Creek	North of Continental at State Route 634	14.17	19.104	0.058
010	P06P06	South Powell Creek	At Township Road 22-B	8.22	27.679	0.084
010	P06G04	South Powell Creek	At Schubert Road	1.75	36.517	0.11
020	P06G02	North Powell Creek	At Township Road B-13	12.95	17.058	0.052
020	P06G03	North Powell Creek Tributary	At Kinner Road	0.72	5.539	0.017
020	P06S14	North Powell Creek	At Hill Road	8.55	28.327	0.086
020	P06G05	North Powell Creek	At State Route 15	0.10	44.521	0.135
030	P06G06	Wagner Run	At State Route 15	0.55	2.418	0.007
030	P06S01	Powell Creek	At Bowman Road	4.30	92.000	0.278
030	P06G07	Powell Creek	At Boy Scout Road	0.36	96.821	0.293

[1] The Auglaize River USGS gage station used for flow estimations has a drainage area of approximately 332 square miles, considerably larger than the Powell Creek watershed (98 square miles). This size discrepancy may introduce uncertainty to the flow estimates using the unit-area approach. However, this gage station is located in the same 8-digit HUC unit (04100007) as Powell Creek and therefore has the most similar hydrologic conditions, geology, etc. Other gage stations with drainage areas closer in size to Powell Creek were identified, but were located within different HUC units and also considerably distanced from Powell Creek.

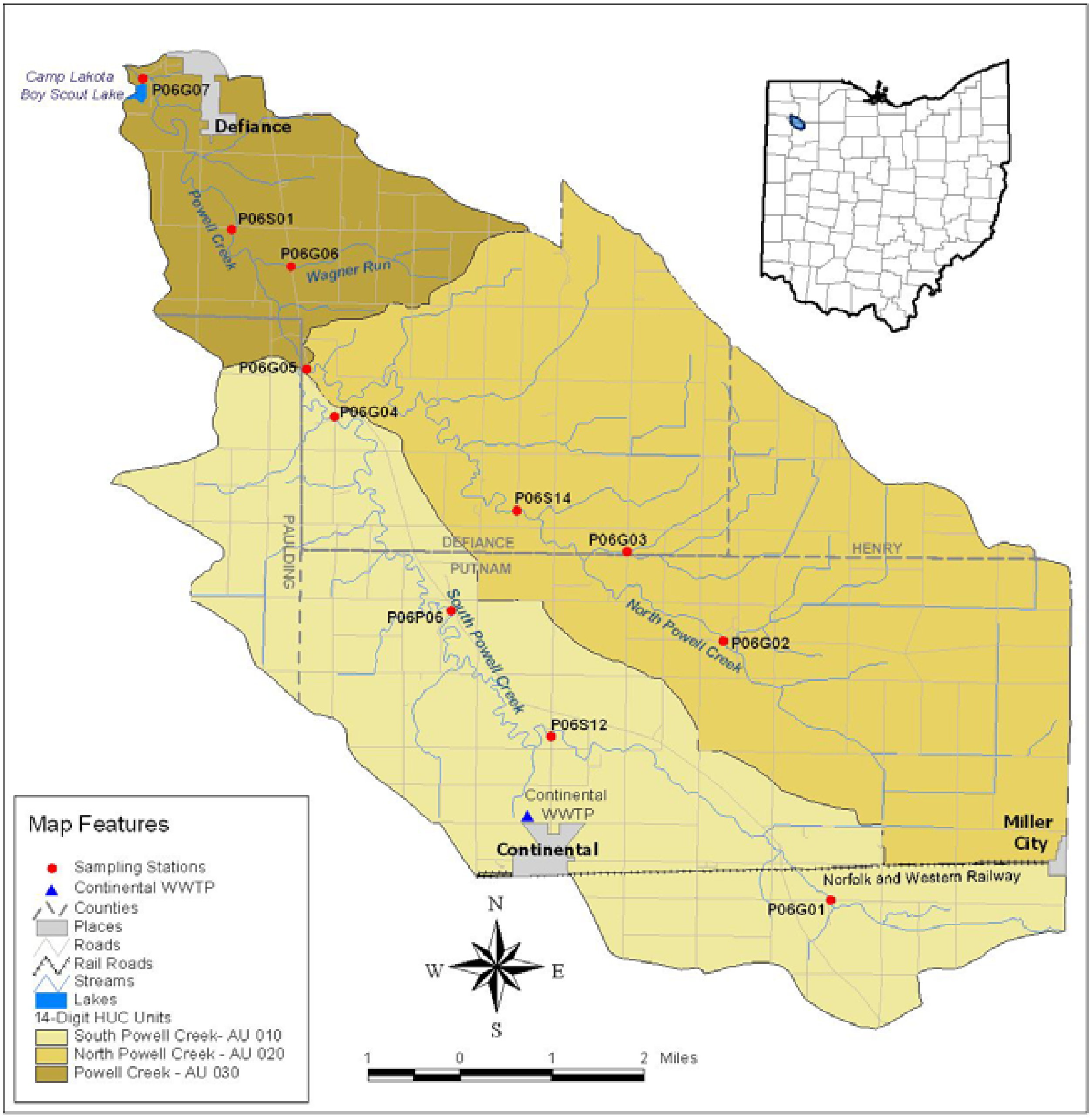

Figure 3-2. Location of load duration sites.

4.0 TMDL RESULTS

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this is defined by the equation:

$$TMDL = WLA + LA + MOS$$

A summary of the load reductions needed for total phosphorus (TP), nitrate-nitrogen (NN), biological oxygen demand (BOD), and total suspended solids (TSS) in the Powell Creek watershed is presented in this section of the report and is organized by 14-digit HUC units. The allocations by each of the various sources and parameters are shown in the following tables. WLAs were established for facilities with individual National Pollutant Discharge Elimination System (NPDES) permits and also for the designated Municipal Separate Storm Sewer Systems (MS4) in the City of Defiance (permit application due in May 2007). Occasionally, an allowance for Future Growth within the watershed is also factored into TMDL calculation. However, because rapid future growth is not anticipated in the Powell Creek watershed, this factor was excluded from the TMDL calculation.

The WLAs for the Continental Wastewater Treatment Plant (WWTP) are summarized in Table 4-4 and were established based on the facility's design flow and the following concentrations:

- TP: 2.6 mg/L
- BOD: 12.9 mg/L
- TSS: 12 mg/L
- NN: 5 mg/L

The BOD, TSS, and TP values are median concentrations obtained from the Continental WWTP Monthly Operating Reports (MORs). The median carbonaceous biochemical oxygen demand (CBOD) was converted into BOD by multiplying the CBOD value by 1.29. Nitrate+Nitrite is not sampled by the facility, thus a typical effluent concentration based on the treatment at the Continental WWTP was used for this parameter.

Two NPDES permitted Concentrated Animal Feeding Operations (CAFOs) discharge in the Powell Creek watershed: the Wezbra and Maple Grove dairies (Figure 4-1). Both facilities are located along unnamed tributaries that flow into North Powell Creek. The WLAs for Wezbra and Maple Grove dairies in the Powell Creek TMDL are for zero loads from production areas. The zero allocation is based on the Effluent Limitations Guidelines and New Source Performance Standards requiring, in general, zero discharge from these areas. This limit on load is reasonable due to the requirement for the proper design, construction, operation, and maintenance of the structures to contain all manure, litter, and process wastewater including the runoff and direct precipitation from a 25 year, 24-hour rainfall event. Further, the allocation is based on the conditions of the NPDES general permit providing that water quality standards shall not be exceeded in the event of an overflow from production areas.

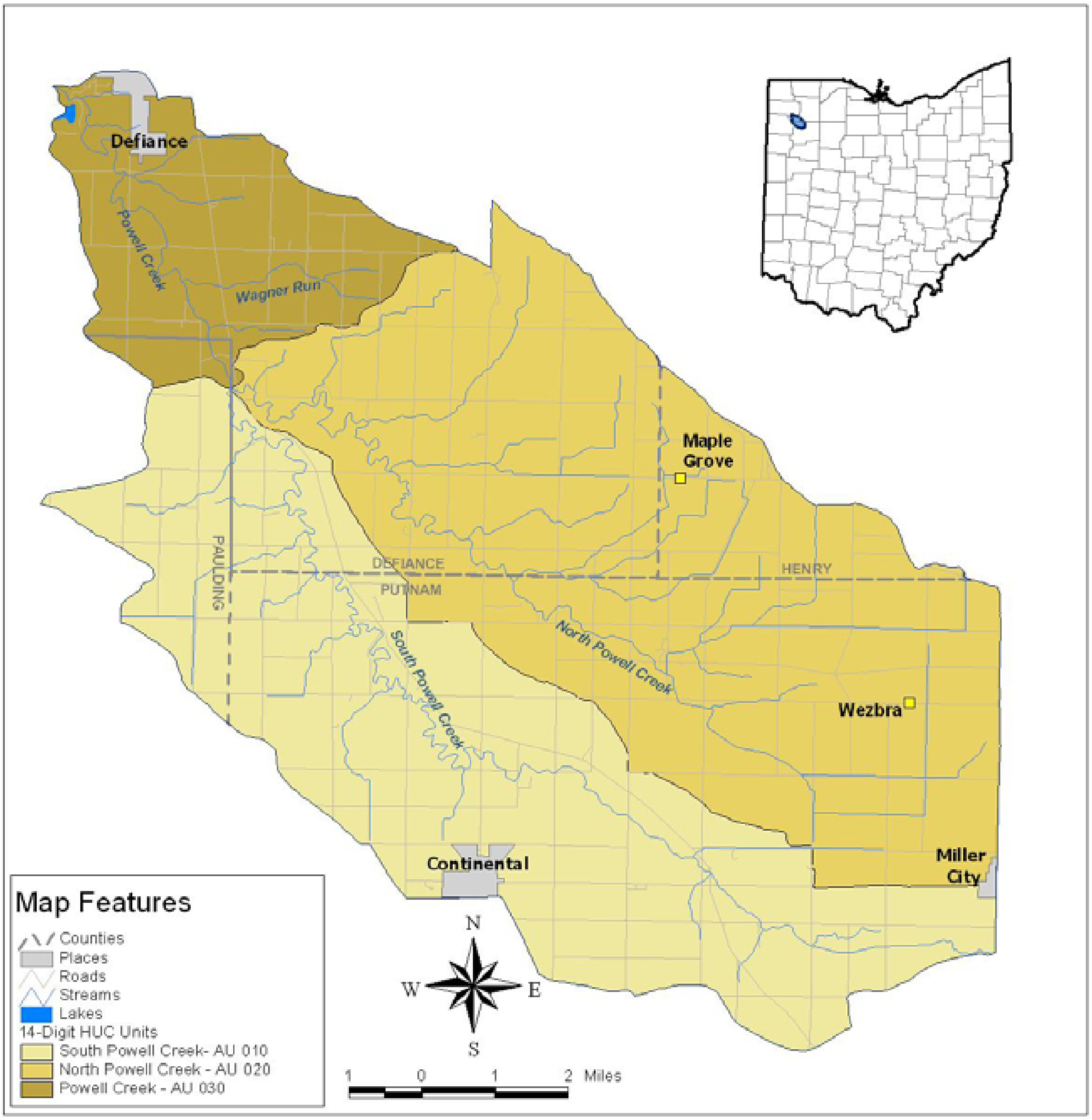

Figure 4-1. CAFOs within the Powell Creek watershed.

Load duration analyses were conducted for all sites with six or more samples within each of the three 14-digit HUC units. A variety of data have been used to assess water quality conditions in the Powell Creek watershed. The Ohio EPA Northwest District Office provided recent water quality data from survey sampling that took place in 1999 and 2000. These records include data for TP, NN, BOD, and TSS parameters and also limited fecal coliform data. Sampling was also conducted by the City of Ayersville in 2004 and 2005 providing additional fecal coliform data; however, only four of their sampling locations corresponded with the load duration sample sites. Because the data for fecal coliform are limited to no more than 4 samples per site, load duration analyses were not completed for this parameter and no fecal coliform TMDLs were developed for the Powell Creek watershed. A discussion of fecal coliform issues in the watershed can be found in Section 5.

Historic data from 1996 were obtained online at the U.S. EPA Legacy STORET database center (**http://www.epa.gov/storet/dbtop.html**). Available flow information was retrieved from the USGS online National Water Information System (**http://waterdata.usgs.gov/nwis**). Appendix A contains the detailed load duration analysis results for each parameter (TP, NN, BOD, and TSS) at each station and the results are summarized in the next section.

4.1 Subwatershed 010: South Powell Creek

South Powell Creek is highly maintained to promote drainage, and the accompanying impairment issues seen throughout this subwatershed include direct channel modification, hydromodification, sedimentation, and riparian encroachment. Channelization occurred in 1980 and regular maintenance for brush removal, vegetation control, and dipping to remove sand bars occurs about once every 3 to 4 years. This mostly occurs in the stream segments within Putnam County; the only maintenance downstream is for log jam removal. While the upstream reaches have more invasive drainage activities and maintenance, the downstream segments display slightly healthier habitat on the mainstem of South Powell Creek (Ohio EPA, 2000). Several tributaries in this subwatershed have also been channelized as seen in Figure 4-1.

Three biological assessments (two downstream at RM 1.8 and RM 8.2, and one upstream at RM 19.9) along the mainstem of South Powell Creek were reflective of the poor habitat availability and extensive hydromodification. Neither of the two downstream assessments attained the WWH biocriteria, indicating that the stream does not support healthy fish and macroinvertebrate communities. The upstream site did not attain WWH biocriteria, but due to the extensive habitat modification this segment was recommended for the Limited Resource Water (LRW) designation (Ohio EPA, 2000).

The load duration approach was applied to four sampling stations located within the South Powell Creek subwatershed (Figure 4-2). All sites in this subwatershed are located along the mainstem of South Powell Creek:

- RM 19.58- at State Route 613 (P06G01)
- RM 14.17- north of Continental at State Route 634 (P06 S12)
- RM 8.22- at Township Road 22-B (P06P06)
- RM 1.75- at Schubert Road (P06G04)

For each load duration site, all appropriate and available water quality and flow data were used. No load duration analyses were completed for fecal coliform at these sites; however a discussion of the available fecal coliform data can be found in Section 5. Table 4-1 summarizes the available data for the South Powell Creek watershed sample stations. All of the water quality data used during the development of the TMDLs can be found in Appendix B.

Table 4-1. Summary of Available Data for Load Duration Sites in South Powell Creek

Subwatershed/ Stream	Location (Monitoring Station)	Parameter	Count	Average	Maximum	Minimum	Period of Record
South Powell Creek	At State Route 613 (P06G01)	TP (mg/L)	6	0.205	0.320	0.110	6/28/2000-9/5/2000
		NN (mg/L)	6	1.18	3.72	0.22	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	3	441	870	62	7/12/2000-8/8/2000
		BOD (mg/L)	6	2.07	3.50	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	6	53	98	18	6/28/2000-9/5/2000
South Powell Creek	North of Continental at State route 634 (P06S12)	TP (mg/L)	10	0.305	0.470	0.170	7/6/1999-9/5/2000
		NN (mg/L)	10	0.70	2.37	0.05	7/6/1999-9/5/2000
		Fecal Coliform (#/100ml)	3	400	770	210	7/12/2000-8/8/2000
		BOD (mg/L)	10	5.52	8.00	3.20	7/6/1999-9/5/2000
		TSS (mg/L)	10	90	212	40	7/6/1999-9/5/2000
South Powell Creek	At Township Road 22-B (P06P06)	TP (mg/L)	6	0.287	0.520	0.180	6/28/2000-9/5/2000
		NN (mg/L)	6	0.63	2.10	0.05	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	3	897	2,100	130	7/12/2000-8/8/2000
		BOD (mg/L)	6	5.87	12.20	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	6	73	83	53	6/28/2000-9/5/2000
South Powell Creek	At Schubert Road (P06G04)	TP (mg/L)	6	0.255	0.390	0.170	6/28/2000-9/5/2000
		NN (mg/L)	6	0.61	1.73	0.05	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	4	898	1,600	62	7/12/2000-8/4/2005
		BOD (mg/L)	6	5.47	10.40	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	6	100	165	63	6/28/2000-9/5/2000

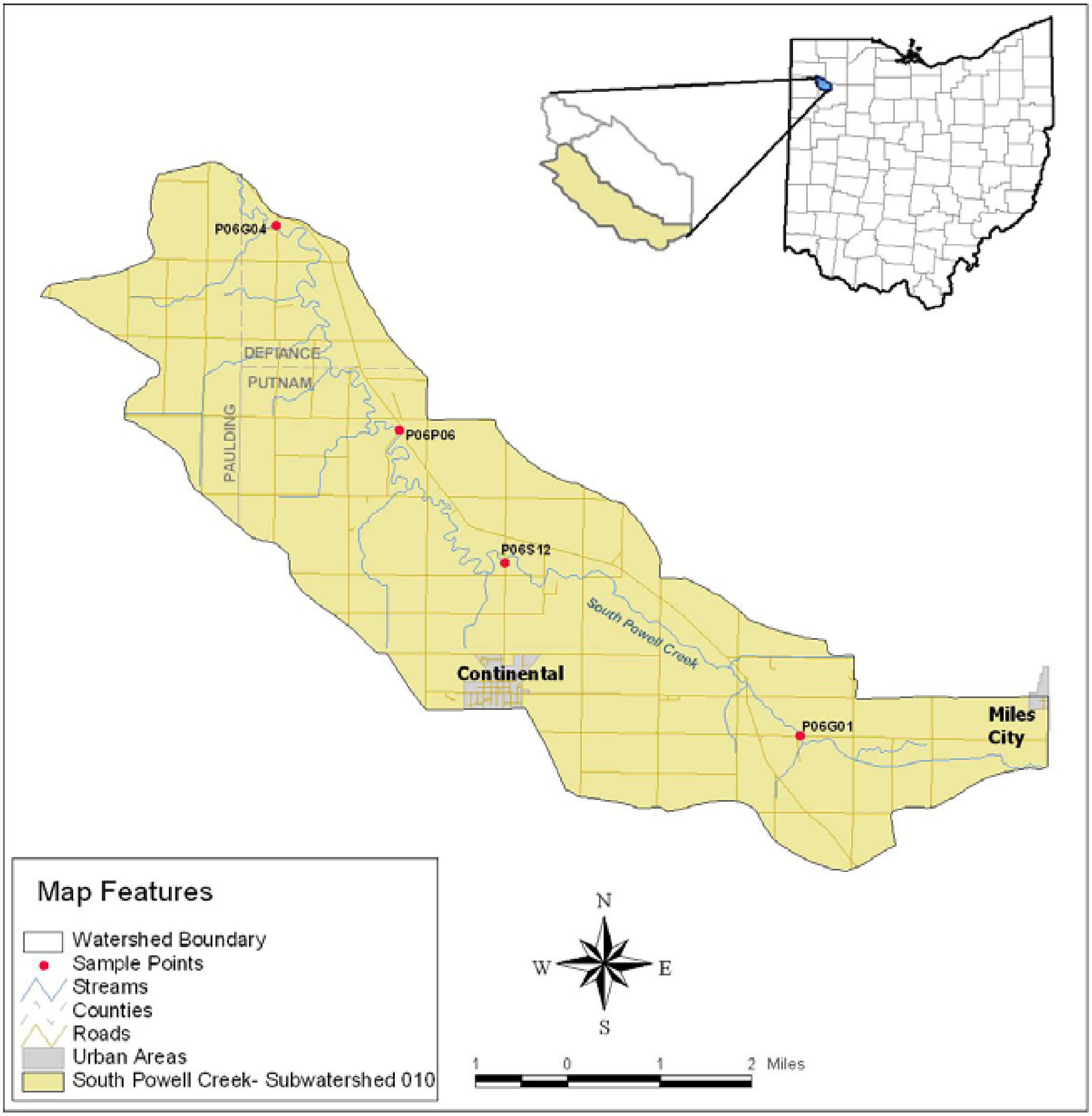

Figure 4-2. Load duration sites within the South Powell Creek- 14-Digit Subwatershed 010.

4.1.1 South Powell Creek (P06G01)

Existing and allowable loads were calculated for South Powell Creek at State Route 613 (P06G01). This sampling station drains 5.35 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (89%), developed open space (5%), and deciduous forest (3%). A total of 6 TP samples, 6 NN samples, 6 BOD samples, and 6 TSS samples were available for the load duration analysis at site P06G01 (Table 4-1). Water quality data for this station include samples collected by the Ohio EPA during moist, mid-range, and dry flow conditions. There are no permitted facilities that discharge upstream of sampling station P06G01.

Table 4-2 presents the TMDL summary for site P06G01. All six TP, two of six NN, three of six BOD, and three of six TSS observed loads exceed the loading limits at this site (Appendix A). TP reductions are needed at all sampled flow conditions, and the needed reductions increase with increasing flows from 35 to 87 percent. NN displays needed reductions of 65 and 70 percent at mid-range and moist flow conditions, respectively; however no reductions are needed during dry conditions. Five percent reductions in BOD are needed during mid-range flows. During moist flow conditions, a 65 reduction in TSS loads are needed to achieve the TMDL. Additional sampling for all parameters is recommended at this station to further evaluate water quality, especially during flow conditions for which no data are currently available.

Table 4-2. Loading Statistics for South Powell Creek (P06G01).

P06G01 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	5.05	0.50	0.13	No Data
	TMDL= LA+WLA+MOS	**4.48**	**0.75**	**0.25**	**0.10**	**0.03**
	LA	4.03	0.67	0.22	0.09	0.03
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	0.45	0.08	0.03	0.01	0.00
	TMDL Reduction (%)	No Data	**87%**	**54%**	**35%**	No Data
NN (kg/day)	Current Load	No Data	28	8	0.34	No Data
	TMDL= LA+WLA+MOS	**56**	**9**	**3**	**1.22**	**0.32**
	LA	50	8.06	2.68	1.10	0.29
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	6	0.94	0.32	0.12	0.03
	TMDL Reduction (%)	No Data	**70%**	**65%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	16	7	2	No Data
	TMDL= LA+WLA+MOS	**129**	**22**	**7.29**	**2.82**	**0.75**
	LA	116	20	6.56	2.54	0.68
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	13	2	0.73	0.28	0.07
	TMDL Reduction (%)	No Data	**0%**	**5%**	**0%**	No Data
TSS (kg/day)	Current Load	No Data	1,199	141	26	No Data
	TMDL= LA+WLA+MOS	**2,744**	**462**	**155**	**60**	**16**
	LA	2,470	416	140	54	14
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	274	46	15	6	2
	TMDL Reduction (%)	No Data	**65%**	**1%**	**0%**	No Data

4.1.2 South Powell Creek (P06S12)

Existing and allowable loads were calculated for South Powell Creek, North of Continental at State Route 634 (P06S12). This sampling station drains 19.10 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (88%), developed open space (5%), and deciduous forest (4%). A total of 10 TP samples, 10 NN samples, 10 BOD and 10 TSS samples were available for the load duration analysis at site P06S12 (Table 4-1). Water quality data for this station include samples collected by the Ohio EPA during moist, mid-range, dry, and low flow conditions. This sampling station is just upstream of the Continental WWTP discharge.

Table 4-3 presents the TMDL summary for site P06S12. All ten of the TP and BOD, three of ten NN, and nine out of ten TSS observations were found to be exceeding the loading limit (Appendix A). All four parameters show reductions of 54 percent or greater at high flows. TP reductions are lower at mid-range and dry flow conditions (74 and 58 percent), but increase at both moist and low flow conditions to 90 and 82 percent. Needed NN reductions are highest at moist flows (54 percent), but fall to 40 percent at mid-range flows and zero percent at both dry and low flow conditions. BOD reductions are relatively consistent across all flow conditions at 42 percent or greater. TSS displays needed reductions of 44 to 88 percent at moist, mid-range, and low flows, but zero during dry flow conditions.

Table 4-3. Loading Statistics for South Powell Creek (P06S12).

P06S12 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	25.34	3.10	0.74	0.47
	TMDL= LA+WLA+MOS	**15.99**	**2.69**	**0.90**	**0.35**	**0.09**
	LA	14.39	2.42	0.81	0.32	0.08
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	1.60	0.27	0.09	0.03	0.01
	TMDL Reduction (%)	No Data	**90%**	**74%**	**58%**	**82%**
NN (kg/day)	Current Load	No Data	66	17	0.33	0.70
	TMDL= LA+WLA+MOS	**200**	**34**	**11**	**4**	**1.15**
	LA	180	31	9.87	3.56	1.03
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	20	3	1.13	0.44	0.12
	TMDL Reduction (%)	No Data	**54%**	**40%**	**0%**	**0%**
BOD (kg/day)	Current Load	No Data	180	52	16	9
	TMDL= LA+WLA+MOS	**462**	**78**	**26**	**10**	**3**
	LA	416	70	23	9	2.73
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	46	8	3	1	0.27
	TMDL Reduction (%)	No Data	**61%**	**55%**	**42%**	**74%**
TSS (kg/day)	Current Load	No Data	11,938	883	148	162
	TMDL= LA+WLA+MOS	**9,795**	**1,649**	**552**	**214**	**57**
	LA	8,815	1,484	497	193	51
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	980	165	55	21	6
	TMDL Reduction (%)	No Data	**88%**	**44%**	**0%**	**69%**

4.1.3 South Powell Creek (P06P06)

Existing and allowable loads were calculated for South Powell Creek at Township Road 22-B (P06P06). This sampling station drains 27.68 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (86%), developed open space (5%), deciduous forest (4%), and developed low intensity (3%). A total of 6 TP, NN, BOD, and TSS samples were available for load duration analysis at site P06P06 (Table 4-1). Water quality data for this station include samples collected by the Ohio EPA during moist, mid-range, and dry flow conditions.

The Continental WWTP (Ohio EPA permit # 2PB00039) discharges into Putnam County Ditch #322, which is confluent with South Powell Creek at river mile 13.36, upstream of sampling station P06P06. Design loads from this facility were made using the information presented in Table 4-4.

Table 4-4. Design loads for the Continental WWTP.

Parameter	Median Effluent Concentration Value (mg/L)	Parameter Load (kg/day)[1]
TP	2.62	1.72
NN	5.00[2]	3.27
BOD	12.90	8.45
TSS	12.00	7.86

[1] Based on design flow of 0.173 million gallons per day (MGD).
[2]No NN data was included in the MOR report; 5 mg/L is a typical effluent literature value (USEPA, 1997).

A comparison of the loads in Table 4-4 and Table 4-5 illustrates that the Continental WWTP has the potential to significantly impact water quality (nutrient and BOD loads) during lower flows as displayed by the increasing proportion of the allowable loads. The design load (i.e., design flow multiplied by median TP concentration of effluent) of this facility is greater than the total allowable load for TP in South Powell Creek from mid-range to low flow conditions. This is also seen at low flow conditions for NN and at low flows for BOD. To correct for this issue, the LA and MOS were both set to zero and the WLAs were reduced to match the TMDL. The 7Q10 was calculated for this station using DFLOW (USEPA, 2007) and was compared to in-stream flows to ensure that permit limits are still applicable at low flows in South Powell Creek. The 7Q10 was estimated to be 0.44 cfs and the lowest median observed flow was 0.95 cfs (Appendix A), which is above the estimated 7Q10.

Table 4-5 presents the TMDL summary for site P06P06. All six TP, two of six NN, five of six BOD, and four of six TSS observations exceed the loading limit at P06P06 (Appendix A). TP displays needed reductions of 39 percent or greater across moist to dry flow conditions. Needed NN reductions increase with increasing flow conditions and range from zero to 59 percent. No reductions are needed for BOD at moist and mid-range flow conditions, but a 48 percent reduction is needed during dry flow conditions. The only needed TSS reduction is 52 percent during moist flow conditions. Additional sampling for all parameters is recommended at this station to further evaluate water quality.

WLAs for the Continental WWTP may need to be modified for all downstream sampling stations (P06P06, P06G04, P06S01, and P06G07) based on the outcome of internal Ohio EPA discussions on the future of the facility. One possibility being discussed is to re-route the facility's discharge to an adjacent watershed, completely removing it from Powell Creek. If this is the case, the WLAs for Continental

WWTP can simply be removed from each table downstream of the discharge, and the WLA subtracted from each calculated TMDL.

A second possibility is to have the facility add lagoons for enhanced treatment. This option would likely result in streamflow restrictions and specific dilution ratios for the discharge seen at other lagoon facilities in the State. Alternative lagoon treatment TMDL tables for each downstream station are presented in Appendix C using the following streamflow restrictions and dilution ratios as found in other permits for WWTP facilities using lagoons for treatment:

- Stream flow restriction: The discharge of effluent is only allowed when the receiving stream's flow is greater than 1 cfs.

- Dilution Ratio: If stream flow criteria met, a total of 90 gpm can be discharged for every 1 cfs of instream flow (up to the facility's design flow).

If the Continental WWTP were to utilize lagoons, and the permit were to following the above mentioned stream flow restriction and dilution ratio, the facility would not be permitted to discharge during low flow periods (based on an estimated instream median flow of under 1 cfs at P06P06- the nearest sampling station downstream of the facility). All other estimated median flows (dry flow conditions, mid-range flows, moist flow conditions, and high flows) at P06P06 are greater than 1 cfs and are sufficiently high enough to meet the dilution ratio requirements, which would permit the facility to discharge at its maximum design flow.

Table 4-5. Loading Statistics for South Powell Creek (P06P06).

P06P06 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
TP (kg/day)	Current Load	No Data	42.77	3.92	1.02	No Data
	TMDL= LA+WLA+MOS	**29.03**	**4.94**	**1.70**	**0.70**	**0.23**
	LA	24.41	2.73	0.00[1]	0.00[1]	0.00[1]
	WLA: Continental WWTP	1.72	1.72	1.70	0.70	0.23
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	2.90	0.49	0.00[1]	0.00[1]	0.00[1]
	TMDL Reduction (%)	No Data	**90%**	**61%**	**39%**	No Data
NN (kg/day)	Current Load	No Data	109.38	24.93	0.24	No Data
	TMDL= LA+WLA+MOS	**290**	**49**	**17**	**7**	**2.33**
	LA	257.73	40.73	11.73	2.73	0.00[1]
	WLA: Continental WWTP	3.27	3.27	3.27	3.27	2.33
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	29	5	2	1	0.00[1]
	TMDL Reduction (%)	No Data	**59%**	**39%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	82	45	42	No Data
	TMDL= LA+WLA+MOS	**1,016**	**173**	**59**	**24**	**8**
	LA	906	148	45	14	0[1]
	WLA: Continental WWTP	8	8	8	8	8
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	102	17	6	2	0[1]
	TMDL Reduction (%)	No Data	**0%**	**0%**	**48%**	No Data
TSS (kg/day)	Current Load	No Data	6,168	962	355	No Data
	TMDL= LA+WLA+MOS	**19,276**	**3,280**	**1,127**	**463**	**155**
	LA	17,340	2,944	1,006	409	132
	WLA: Continental WWTP	8	8	8	8	8
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	1,928	328	113	46	15
	TMDL Reduction (%)	No Data	**52%**	**0%**	**0%**	No Data

[1] The LA and MOS values were set to zero and the WLA for the Continental WWTP was adjusted to match the TMDL where negative LAs were displayed.

4.1.4 South Powell Creek (P06G04)

Existing and allowable loads were calculated for South Powell Creek at Schubert Road (P06G04). This sampling station drains 36.52 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (86%), developed open space (5%), deciduous forest (5%), and developed low intensity (2%). A total of 6 TP samples, 6 NN samples, 6 BOD samples, and 6 TSS samples were available for the load duration analysis at site P06G04 (Table 4-1). Water quality data for this station were collected by the Ohio EPA during moist, mid-range, and low flow conditions.

The Continental WWTP discharges upstream of this sampling station and the appropriate WLAs have been included in TMDL calculation for P06G04. The WLA summary for the facility is presented in Table 4-4. As noted at station P06P06, the loads for TP, NN, and BOD are also close to or greater than the total allowable load at this sampling station. As with the upstream station (P06P06), the LA and MOS values were set to zero and the WLA for the Continental WWTP was adjusted to match the TMDL where negative LAs were displayed. At mid-range and dry flow conditions where the design loads are not greater than the total allowable load, the discharge continues to contribute to a large portion of the nutrient loads. TSS loads do not seem to be an issue with the Continental WWTP discharge at this sampling station. A 7Q10 analysis noted a 7Q10 of 0.50 cfs for this section of South Powell Creek which is lower than the median observed low flow of 1.17 cfs.

Table 4-6 presents the TMDL summary for site P06G04. All TP, two of six NN, three of six BOD, and five of six TSS observations at sampling station P06G04 exceed the loading limits for Prairie Creek (Appendix A). Needed TP reductions are 46 percent or greater across all flows sampled. NN loads display higher needed reductions at higher flow regimes and no needed reductions at dry conditions. A 47 percent reduction for BOD is needed at dry conditions. TSS load reductions are needed during moist and dry flow conditions at 66 and 30 percent, respectively. Additional sampling for all parameters is recommended at this station to further evaluate water quality.

Table 4-6. Loading Statistics for South Powell Creek (P06G04).

P06G04 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	42.24	3.71	1.57	No Data
	TMDL= LA+WLA+MOS	**38.28**	**6.50**	**2.22**	**0.90**	**0.29**
	LA	32.73	4.13	0.28	0.00[1]	0.00[1]
	WLA: Continental WWTP	1.72	1.72	1.72	0.90	0.29
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	3.83	0.65	0.22	0.00[1]	0.00[1]
	TMDL Reduction (%)	No Data	**86%**	**46%**	**49%**	No Data
NN (kg/day)	Current Load	No Data	187.35	26.58	0.30	No Data
	TMDL= LA+WLA+MOS	**383**	**65**	**22**	**9**	**2.86**
	LA	341.73	54.73	16.73	4.73	0.00[1]
	WLA: Continental WWTP	3.27	3.27	3.27	3.27	2.86
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	38	7	2	1	0.00[1]
	TMDL Reduction (%)	No Data	**69%**	**25%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	108	53	53	No Data
	TMDL= LA+WLA+MOS	**1,340**	**227**	**78**	**31**	**10**
	LA	1,198	196	62	20	1
	WLA: Continental WWTP	8	8	8	8	8
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	134	23	8	3	1
	TMDL Reduction (%)	No Data	**0%**	**0%**	**47%**	No Data
TSS (kg/day)	Current Load	No Data	11,263	1,267	765	No Data
	TMDL= LA+WLA+MOS	**25,417**	**4,314**	**1,473**	**597**	**190**
	LA	22,867	3,875	1,318	529	163
	WLA: Continental WWTP	8	8	8	8	8
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	2,542	431	147	60	19
	TMDL Reduction (%)	No Data	**66%**	**0%**	**30%**	No Data

[1] The LA and MOS values were set to zero and the WLA for the Continental WWTP was adjusted to match the TMDL where negative LAs were displayed.

4.2 Subwatershed 020: North Powell Creek

The upper segments of North Powell Creek are primarily impacted by drainage-way maintenance activities that result in hydromodification and riparian vegetation removal. North Powell Creek was channelized around 1996 and is routinely maintained for brush removal, vegetation control, and dipping to remove sand bars about once every 3 to 4 years. This mostly occurs in the stream segments within Putnam County; the only maintenance downstream is for log jam removal (Ohio EPA, 2000). Several of the tributaries to North Powell Creek are channelized running adjacent to agricultural fields or roads. The extensive channelization and relatively flat topography of this subwatershed create somewhat unnatural watershed boundaries, especially in the southeastern portions near Miller City. Two NPDES permitted dairy farms are within the North Powell Creek watershed: the Maple Grove Dairy (NPDES permit OHA000012) and the Wezbra Dairy (NPDES permit OH0132764).

The downstream segments (near the mouth at State Route 15) of North Powell Creek and the unnamed tributary to North Powell Creek were found to support fish and macroinvertebrate assemblages that support WWH biocriteria (Ohio EPA, 2000). However, the upstream segments of North Powell Creek were found to be in NON-attainment upstream of RM 12.5 where extensive hydromodification and habitat alteration occur.

Within North Powell Creek, the load duration approach was applied to four sampling stations (Figure 4-3):

- Three sites on the mainstem of North Powell Creek:
  - RM 12.95- at Township Road B-13 (P06G02)
  - RM 8.55- at Hill Road (P06S14)
  - RM 0.10- at State Route 15 (P06G05)
- One site on an unnamed tributary to North Powell Creek:
  - RM 0.72- at Kinner Road(P06G03)

For each load duration site, all appropriate and available water quality and flow data were used. No load duration analyses were completed for fecal coliform at these sites; however, a discussion of the limited available fecal coliform data can be found in Section 5. Table 4-7 summarizes the available data for the four North Powell Creek watershed sample stations. All of the water quality data used during development of the TMDL can be found in Appendix B.

Table 4-7. Summary of Available Data for Load Duration Sites in North Powell Creek.

Subwatershed/ Stream	Location (Monitoring Station)	Parameter	Count	Average	Maximum	Minimum	Period of Record
North Powell Creek	At Township Road B-13 (P06G02)	TP (mg/L)	6	0.149	0.245	0.100	6/28/2000-9/5/2000
		NN (mg/L)	6	0.93	4.66	0.05	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	3	1,333	1,700	1,100	7/12/2000-8/8/2000
		BOD (mg/L)	6	4.05	10.00	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	6	95	139	51	6/28/2000-9/5/2000
Tributary to North Powell Creek	At Kinner Road (P06G03)	TP (mg/L)	6	0.328	0.630	0.100	6/28/2000-9/5/2000
		NN (mg/L)	6	1.39	3.93	0.30	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	3	2,753	6,500	360	7/12/2000-8/8/2000
		BOD (mg/L)	6	8.75	33.00	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	6	59	156	19	6/28/2000-9/5/2000
North Powell Creek	At Hill Road (P06S14)	TP (mg/L)	10	0.177	0.270	0.120	7/17/1996-9/5/2000
		NN (mg/L)	10	0.54	4.11	0.05	7/17/1996-9/5/2000
		Fecal Coliform (#/100ml)	3	462	1,100	66	7/12/2000-8/8/2000
		BOD (mg/L)	6	4.72	9.80	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	10	74	132	23	7/17/1996-9/5/2000
North Powell Creek	At State Route 15 (P06G05)	TP (mg/L)	6	0.172	0.250	0.120	6/28/2000-9/5/2000
		NN (mg/L)	6	0.103	4.06	0.05	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	4	528	830	42	7/12/2000-8/4/2005
		BOD (mg/L)	6	3.63	5.30	1.00	6/28/2000-9/5/2000

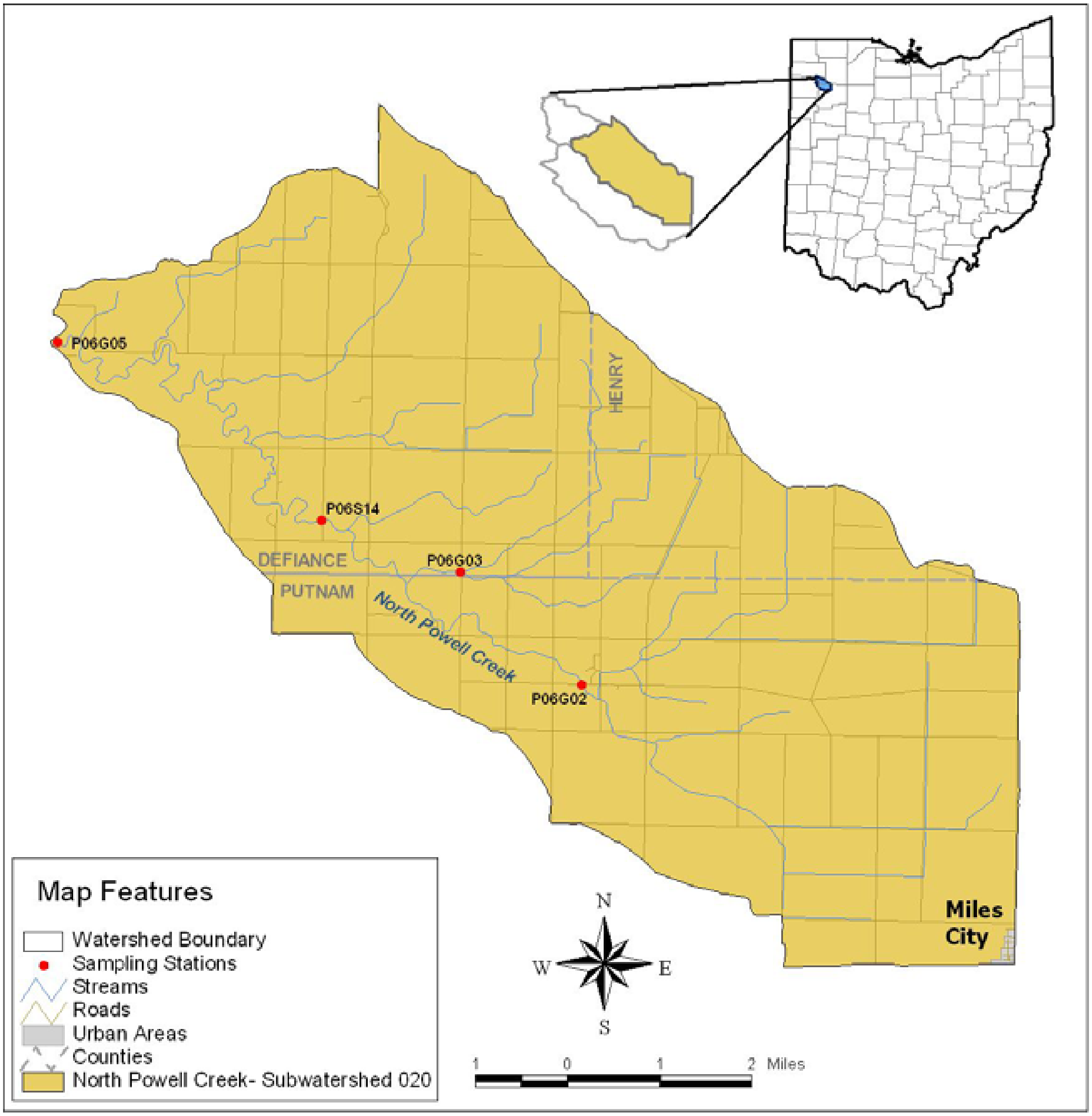

Figure 4-3. Load duration sites within North Powell Creek- 14-Digit subwatershed 020.

4.2.1 North Powell Creek (P06G02)

Existing and allowable loads were calculated for North Powell Creek at Township Road B-13 (P06G02). This sampling station drains 17.06 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (89%), developed open space (4%), deciduous forest (4%), and developed low intensity (1%). A total of 6 TP, 6 NN, 6 BOD, and 6 TSS samples were available for the load duration analysis at site P06G02 (Table 4-7). Water quality data for this station were collected by the Ohio EPA during moist, mid-range, and low flow conditions.

The Wezbra Dairy discharges in the headwaters of North Powell Creek, upstream of station P06G02. An allocation of zero has been assigned to all parameters based on the Wezbra Dairy NPDES permit conditions. This facility is not expected to influence water quality if permit conditions are met.

Table 4-8 presents the TMDL summary for site P06G02. All six TP and TSS, one NN, and five BOD observations were found to exceed the loading limit for North Powell Creek at site P06G02. TP, NN, and TSS loads appear to be an issue during moist flow conditions as needed reductions are 52 percent or greater for all three parameters. Needed TP reductions decrease with decreasing flows and NN displays no needed reductions at mid-range and dry flow conditions. BOD loads increase with decreasing flows from zero to 33 percent. The TSS loads do not display needed reductions at mid-range flows, but a 49 percent reduction at dry conditions is shown. Additional sampling for all parameters is recommended at this station to further evaluate water quality.

Table 4-8. Loading Statistics for North Powell Creek (P06G02).

P06G02 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	8.04	1.69	0.31	No Data
	TMDL= LA+WLA+MOS	**14.28**	**2.40**	**0.80**	**0.31**	**0.08**
	LA	12.85	2.16	0.72	0.28	0.07
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	1.43	0.24	0.08	0.03	0.01
	TMDL Reduction (%)	No Data	**73%**	**57%**	**8%**	No Data
NN (kg/day)	Current Load	No Data	234	5	0.13	No Data
	TMDL= LA+WLA+MOS	**178**	**30**	**10**	**4**	**1.03**
	LA	160	27	8.99	3.61	0.93
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	18	3	1.01	0.39	0.10
	TMDL Reduction (%)	No Data	**88%**	**0%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	50	25	12	No Data
	TMDL= LA+WLA+MOS	**412**	**69**	**23**	**9**	**2**
	LA	371	62	21	8.10	1.76
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	41	7	2	0.90	0.24
	TMDL Reduction (%)	No Data	**0%**	**16%**	**33%**	No Data
TSS (kg/day)	Current Load	No Data	2,765	353	340	No Data
	TMDL= LA+WLA+MOS	**8,746**	**1,472**	**493**	**191**	**51**
	LA	7,871	1,325	444	172	46
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	875	147	49	19	5
	TMDL Reduction (%)	No Data	**52%**	**0%**	**49%**	No Data

4.2.2 Unnamed Tributary North Powell Creek (P06G03)

Existing and allowable loads were calculated for an unnamed tributary to North Powell Creek at Kinner Road (P06G03). This sampling station drains 5.54 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (88%), deciduous forest (6%), and developed open space (5%). Six samples for TP, NN, BOD, and TSS parameters were available for the load duration analysis at site P06G03 (Table 4-7). The samples were collected by the Ohio EPA during moist through dry flow conditions.

The Maple Grove Dairy is a Confined Animal Feeding Operation (CAFO) that discharges in the headwaters of the unnamed tributary to North Powell Creek, upstream of station P06G03. An allocation of zero has been assigned to all parameters based on the Maple Grove Dairy NPDES permit conditions. This facility is not expected to influence water quality if permit conditions are met.

Table 4-9 presents the TMDL summary for site P06G03. All six TP, three of six NN and BOD, and two of six TSS observations exceeded the daily loading limits in the unnamed tributary to North Powell Creek. TP needed reductions are highest at dry flow conditions (75 percent) and are 50 percent or greater at moist and mid-range flow conditions. NN loads need reduced by 86 percent at moist conditions, and BOD displays a needed reduction of 61 percent during dry conditions. Two noted TSS reductions at moist and dry conditions are 20 and 21 percent, respectively. Additional sampling for all parameters is recommended at this station to further evaluate water quality.

Table 4-9. Loading Statistics for Unnamed Tributary to North Powell Creek (P06G03).

P06G03 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	1.63	0.47	0.36	No Data
	TMDL= LA+WLA+MOS	**4.64**	**0.78**	**0.26**	**0.10**	**0.03**
	LA	4.18	0.70	0.23	0.09	0.03
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	0.46	0.08	0.03	0.01	0.00
	TMDL Reduction (%)	No Data	**57%**	**50%**	**75%**	No Data
NN (kg/day)	Current Load	No Data	64	2	0.79	No Data
	TMDL= LA+WLA+MOS	**58**	**10**	**3**	**1.27**	**0.33**
	LA	52	9	2.67	1.14	0.30
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	6	1	0.33	0.13	0.03
	TMDL Reduction (%)	No Data	**86%**	**0%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	16	2	7	No Data
	TMDL= LA+WLA+MOS	**134**	**23**	**8**	**3**	**0.77**
	LA	121	21	7.25	2.71	0.69
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	13	2	0.75	0.29	0.08
	TMDL Reduction (%)	No Data	**0%**	**0%**	**61%**	No Data
TSS (kg/day)	Current Load	No Data	539	43	70	No Data
	TMDL= LA+WLA+MOS	**2,840**	**478**	**160**	**62**	**16**
	LA	2,556	430	144	56	14
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	284	48	16	6	2
	TMDL Reduction (%)	No Data	**20%**	**0%**	**21%**	No Data

4.2.3 North Powell Creek (P06S14)

Existing and allowable loads were calculated for North Powell Creek at Hill Road (P06S14). This sampling station drains 28.33 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (86%), deciduous forest (6%), developed open space (5%), and pasture/hay (1%). A total of 10 TP samples, 10 NN samples, 6 BOD samples, and 10 TSS samples were available for the load duration analysis at site P06S14 (Table 4-7). The data were collected by the Ohio EPA during moist, mid-range, and dry flow conditions.

The Wezbra and Maple Grove Dairies are CAFOs that discharge upstream of station P06S14; however, the dairies have zero allocations for all parameters based on their NPDES permit conditions and are not expected to influence water quality if permit conditions are met.

Table 4-10 presents the TMDL summary for site P06S14. All TP, one of ten NN, four of six BOD, and five of ten TSS observations exceeded load limits at this station in North Powell Creek (Appendix A). The TP and TSS load reductions that are needed at this site are both 73 percent at moist flow conditions and gradually decrease with decreasing flow conditions. NN only displays one needed load reduction of 87 percent and there are no needed BOD reductions at P06S14.

Table 4-10. Loading Statistics for North Powell Creek (P06S14).

P06S14 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	16.70	3.10	0.77	No Data
	TMDL= LA+WLA+MOS	**29.64**	**4.99**	**1.67**	**0.65**	**0.17**
	LA	26.68	4.49	1.50	0.59	0.15
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	2.96	0.50	0.17	0.06	0.02
	TMDL Reduction (%)	No Data	**73%**	**52%**	**24%**	No Data
NN (kg/day)	Current Load	No Data	343	9	0.27	No Data
	TMDL= LA+WLA+MOS	**296**	**50**	**17**	**6**	**2**
	LA	266	45	15	5.35	1.83
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	30	5	2	0.65	0.17
	TMDL Reduction (%)	No Data	**87%**	**0%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	83	51	19	No Data
	TMDL= LA+WLA+MOS	**1,037**	**175**	**58**	**23**	**6**
	LA	933	158	52	21	5
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	104	17	6	2	1
	TMDL Reduction (%)	No Data	**0%**	**0%**	**0%**	No Data
TSS (kg/day)	Current Load	No Data	11,022	1,033	339	No Data
	TMDL= LA+WLA+MOS	**19,683**	**3,313**	**1,109**	**430**	**114**
	LA	17,715	2,982	998	387	103
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	1,968	331	111	43	11
	TMDL Reduction (%)	No Data	**73%**	**3%**	**0%**	No Data

4.2.4 North Powell Creek (P06G05)

Existing and allowable loads were calculated for North Powell Creek at State Route 15 (P06G05). This sampling station drains 44.52 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (84%), deciduous forest (9%), developed open space (5%), and pasture/hay (1%). A total of 6 samples were collected by the Ohio EPA at this station for TP, NN, BOD, and TSS parameters during moist, mid-range, and dry flow conditions (Table 4-7).

The Wezbra and Maple Grove Dairies discharge upstream of this sample station. Zero allocations were assigned to these facilities based on their NPDES permit conditions because they are not expected to influence water quality if permit conditions are met.

Table 4-11 presents the TMDL summary for site P06G05. All six TP, two of six NN, four of six BOD, and four of five TSS observations exceed the loading limits for North Powell Creek at this site (Appendix A). TP and TSS observed loads display the most widespread needed reductions at this site that decrease with decreasing flow conditions. NN reductions of 87 percent during moist conditions are the only other needed load reductions at this site. Additional sampling for all parameters is recommended at this station to further evaluate water quality.

Table 4-11. Loading Statistics for North Powell Creek (P06G05).

P06G05 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	27.56	4.51	0.99	No Data
	TMDL= LA+WLA+MOS	**46.59**	**7.84**	**2.62**	**1.02**	**0.27**
	LA	41.93	7.06	2.36	0.92	0.24
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	4.66	0.78	0.26	0.10	0.03
	TMDL Reduction (%)	No Data	**74%**	**48%**	**8%**	No Data
NN (kg/day)	Current Load	No Data	533	21	0.48	No Data
	TMDL= LA+WLA+MOS	**466**	**78**	**26**	**10**	**3**
	LA	419	70	23	9	2.73
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	47	8	3	1	0.27
	TMDL Reduction (%)	No Data	**87%**	**0%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	131	70	27	No Data
	TMDL= LA+WLA+MOS	**1,631**	**274**	**92**	**36**	**9**
	LA	1,468	247	83	32	8.06
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	163	27	9	4	0.94
	TMDL Reduction (%)	No Data	**0%**	**0%**	**0%**	No Data
TSS (kg/day)	Current Load	No Data	11,942	1,895	460	No Data
	TMDL= LA+WLA+MOS	**30,934**	**5,207**	**1,743**	**675**	**179**
	LA	27,841	4,686	1,569	607	161
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	3,093	521	174	68	18
	TMDL Reduction (%)	No Data	**61%**	**17%**	**0%**	No Data

4.3 Subwatershed 030: Powell Creek (Downstream of Junction of North and South Powell Creeks, to the Auglaize River)

Drainage practices within the north and south branches have resulted in significantly diminished summer flows in the mainstem of Powell Creek. Hypereutrophic conditions often exist in Powell Creek as nutrient loads become concentrated, resulting in algae blooms and elevated biological oxygen demand.

These conditions do not support healthy fish and macroinvertebrate communities, as displayed by the results of a biological assessment performed near the mouth of Powell Creek. Fish and macroinvertebrate assemblages were found to be severely degraded and the poor IBI scores were well below the biocriteria for the HELP ecoregion (Ohio EPA, 2000). Wagner Run was recommended for the Modified Warmwater Habitat (MWH) designation and its fish and macroinvertebrate communities were found to be in full attainment.

The load duration approach was applied to three sampling stations located within the Powell Creek subwatershed (Figure 4-3):

- Two sites on the mainstem of Powell Creek:
  - RM 4.30- at Bowman Road (P06S01)
  - RM 0.36- at Boy Scout Road (P06G07)
- One site on Wagner Run:
  - RM 0.55- at State Route 15 (P06G06)

The two Powell Creek mainstem sites are downstream of the confluence of North and South Powell Creek branches. Therefore the WLAs for the Continental WWTP, Wezbra Dairy, and Maple Grove Dairy discharges are included in TMDL calculation for these sites (excluding the Wagner Run tributary site). For each load duration site, all appropriate and available water quality and flow data were used. No load duration analyses were completed for fecal coliform at these sites, however a discussion of the limited available fecal coliform data can be found in Section 5. Table 4-12 summarizes the available data for the three Powell Creek watershed sample stations.

Table 4-12. Summary of Available Data for Load Duration Sites in Powell Creek.

Subwatershed/ Stream	Location (Monitoring Station)	Parameter	Count	Average	Maximum	Minimum	Period of Record
Wagner Run (Tributary to Powell Creek)	At State Route 15 (P06G06)	TP (mg/L)	6	0.255	0.400	0.150	6/28/2000-9/5/2000
		NN (mg/L)	6	2.87	9.5	0.26	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	4	270	430	100	7/12/2000-8/4/2005
		BOD (mg/L)	6	1.18	2.10	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	6	27	43	13	6/28/2000-9/5/2000
Powell Creek	At Bowman Road (P06S01)	TP (mg/L)	10	0.164	0.360	0.050	7/17/1996-9/5/2000
		NN (mg/L)	10	0.59	2.37	0.05	7/17/1996-9/5/2000
		Fecal Coliform (#/100ml)	4	526	1,200	64	7/12/2000-8/4/2005
		BOD (mg/L)	9	5.31	16.00	1.00	8/12/1996-9/5/2000
		TSS (mg/L)	10	63	133	22	7/17/1996-9/5/2000
Powell Creek	At Boy Scout Road (P06G07)	TP (mg/L)	6	0.208	0.355	0.145	6/28/2000-9/5/2000
		NN (mg/L)	6	0.82	2.44	0.05	6/28/2000-9/5/2000
		Fecal Coliform (#/100ml)	3	734	1,450	52	7/12/2000-8/8/2000
		BOD (mg/L)	6	2.63	3.80	1.00	6/28/2000-9/5/2000
		TSS (mg/L)	6	72	146	24	6/28/2000-9/5/2000

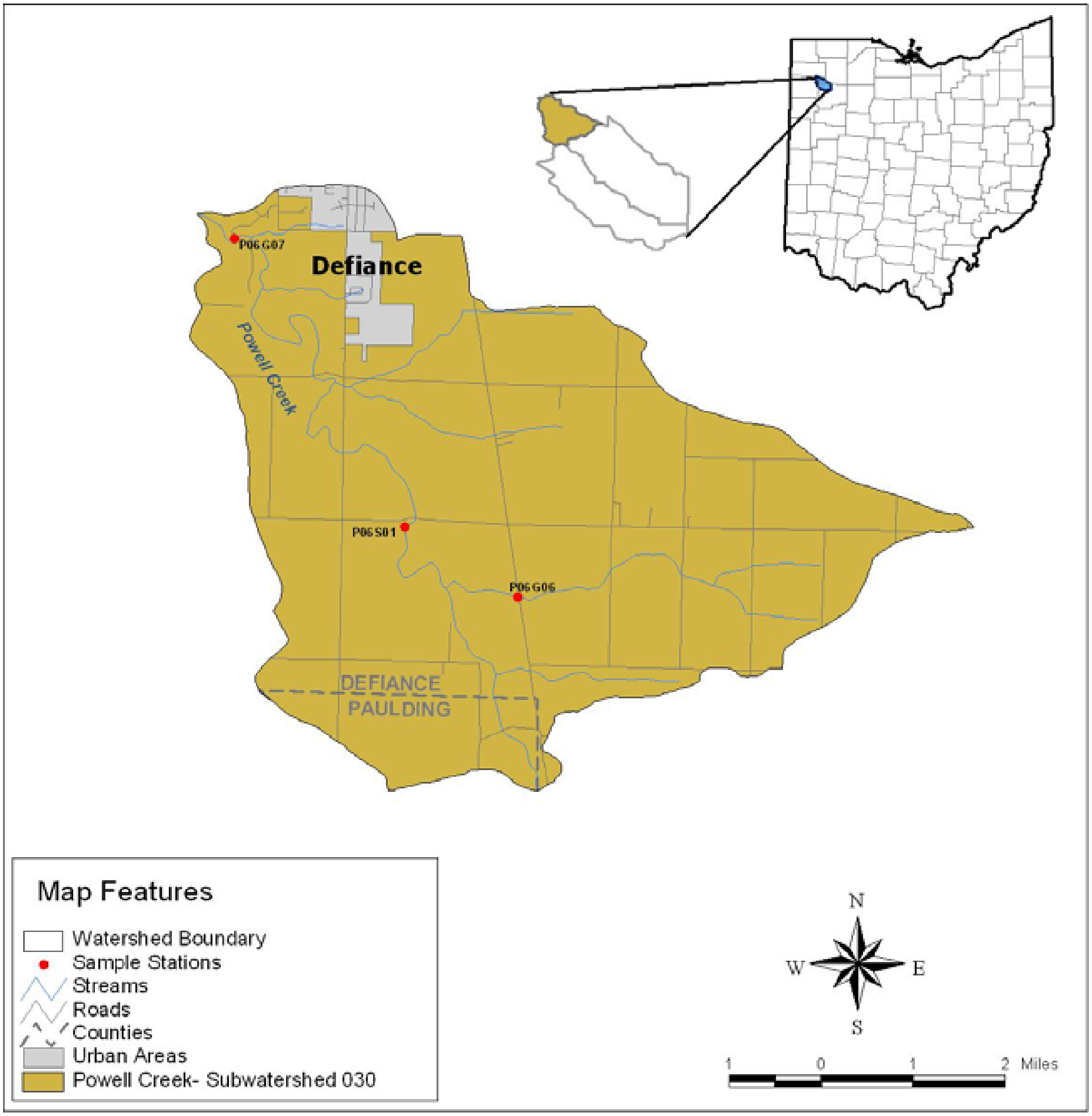

Figure 4-4. Load duration sites within the Powell Creek subwatershed.

4.3.1 Wagner Run (P06G06)

Existing and allowable loads were calculated for Wagner Run at State Route 15 (P06G06). This sampling station drains 2.42 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (79%), deciduous forest (12%), developed open space (5%), grassland/herbaceous (2%), and pasture/hay (1%). A total of 6 TP samples, 6 NN samples, 6 BOD samples, and 6 TSS samples were available for the load duration analysis at site P06G06 (Table 4-12). The data were collected by the Ohio EPA from moist to dry flow conditions. There are no permitted facilities discharging in Wagner Run.

Table 4-13 presents the TMDL summary for site P06G06. All six TP and four of six NN observations exceeded the daily loading limits. However, no BOD or TSS observations displayed loads above the allowable limit in Wagner Run. TP needed reductions are consistently high at this sampling station with values of 66 percent or greater across all sampled flow conditions. Needed NN reductions range from 94 percent to zero, decreasing with decreasing flow conditions. The only other reduction displayed at this station is a 20 percent reduction needed for TSS during high flows. Additional sampling for all parameters is recommended at this station to further evaluate water quality.

Table 4-13. Loading Statistics for Wagner Run (P06G06).

P06G06 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	1.07	0.39	0.12	No Data
	TMDL= LA+WLA+MOS	**2.02**	**0.34**	**0.11**	**0.04**	**0.01**
	LA	1.82	0.31	0.10	0.04	0.01
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	0.20	0.03	0.01	0.00	0.00
	TMDL Reduction (%)	No Data	**71%**	**74%**	**66%**	No Data
NN (kg/day)	Current Load	No Data	68	3	0.25	No Data
	TMDL= LA+WLA+MOS	**25**	**4**	**1**	**1**	**0.15**
	LA	22	3.57	0.86	0.94	0.14
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	3	0.43	0.14	0.06	0.01
	TMDL Reduction (%)	No Data	**94%**	**57%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	7	2	0.36	No Data
	TMDL= LA+WLA+MOS	**58**	**10**	**3**	**1.28**	**0.34**
	LA	52	9.02	2.67	1.15	0.31
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	6	0.98	0.33	0.13	0.03
	TMDL Reduction (%)	No Data	**0%**	**0%**	**0%**	No Data
TSS (kg/day)	Current Load	No Data	235	19	10	No Data
	TMDL= LA+WLA+MOS	**1,240**	**209**	**70**	**27**	**7**
	LA	1,116	188	63	24	6
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	124	21	7	3	1
	TMDL Reduction (%)	No Data	**20%**	**0%**	**0%**	No Data

4.3.2 Powell Creek (P06S01)

Existing and allowable loads were calculated for Powell Creek at Bowman Road (P06S01). This sampling station drains 92.00 square miles and land use/land cover upstream of this station consists primarily of cultivated crops (84%), deciduous forest (8%), developed open space (5%), and developed low intensity (1%) land cover. A total of 10 TP samples, 10 NN samples, 9 BOD samples, and 10 TSS samples were available for the load duration analysis at site P06S01 (Table 4-12). The Ohio EPA collected data for this site during moist, mid-range, and dry flow conditions.

Station P06S01 is downstream of three permitted facilities. The Wezbra and Maple Grove Dairies have zero allocations for all parameters based on their NPDES permit conditions and are not expected to influence water quality if these conditions are met. The existing load summary for the Continental WWTP can be found in Table 4-4. Design loads for the Continental WWTP display minimal contributions to the TSS and BOD loads at this site; however current design loads are a large portion of the total allowable nutrient loads (TP and NN) during low flow conditions. At low flows, the design load for TP is greater than the total allowable load has been adjusted to match the TMDL and setting the MOS and LA to zero. The Continental WWTP design load for NN contributes over half of the allowable load at this site. A low flow analysis displayed a 7Q10 of 0.87 cfs at this station and a median observed flow during low flow conditions of 2.54 cfs indicating that permit limits are still applicable at low flows.

Table 4-14 presents the TMDL summary for site P06S01. Six of ten TP, three of ten NN, seven of nine BOD, and three of ten TSS observations exceed load limits at this site in Powell Creek (Appendix A). TP, NN, and TSS loads display needed reductions of 68 percent or greater during moist conditions. As flow conditions decrease, the needed load reductions for these three parameters decrease to 3 percent or lower during dry conditions. BOD only displays one needed load reduction of 12 percent at dry flow conditions.

Table 4-14. Loading Statistics for Powell Creek (P06S01).

P06S01 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	97.86	10.62	2.00	No Data
	TMDL= LA+WLA+MOS	**96.34**	**16.27**	**5.49**	**2.17**	**0.62**
	LA	84.99	12.92	3.22	0.23	0.00[1]
	WLA: Continental WWTP	1.72	1.72	1.72	1.72	0.62
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	9.63	1.63	0.55	0.22	0.00[1]
	TMDL Reduction (%)	No Data	**85%**	**53%**	**3%**	No Data
NN (kg/day)	Current Load	No Data	644	51	1	No Data
	TMDL= LA+WLA+MOS	**963**	**163**	**55**	**22**	**6**
	LA	863.73	143.73	46.73	16.73	2.11
	WLA: Continental WWTP	3.27	3.27	3.27	3.27	3.27
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	96	16	5	2	0.62
	TMDL Reduction (%)	No Data	**77%**	**4%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	272	148	78	No Data
	TMDL= LA+WLA+MOS	**3,372**	**569**	**192**	**76**	**22**
	LA	3,027	504	165	60	12
	WLA: Continental WWTP	8	8	8	8	8
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	337	57	19	8	2
	TMDL Reduction (%)	No Data	**0%**	**0%**	**12%**	No Data
TSS (kg/day)	Current Load	No Data	30,174	5,046	785	No Data
	TMDL= LA+WLA+MOS	**63,968**	**10,803**	**3,645**	**1,439**	**413**
	LA	57,563	9,715	3,273	1,287	364
	WLA: Continental WWTP	8	8	8	8	8
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	6,397	1,080	364	144	41
	TMDL Reduction (%)	No Data	**68%**	**35%**	**0%**	No Data

[1] The LA and MOS values were set to zero and the WLA for the Continental WWTP was adjusted to match the TMDL where negative LAs were displayed.

4.3.3 Powell Creek (P06G07)

Existing and allowable loads were calculated for Powell Creek at Boy Scout Road (P06G07). This sampling station is near the mouth and drains 96.82 square miles. The land use/land cover upstream of this station consists primarily of cultivated crops (83%), deciduous forest (8%), developed open space

(5%), and developed low intensity (2%) land uses. A total of 6 TP samples, 6 NN samples, 6 BOD samples, and 6 TSS samples were available for the load duration analysis at site P06G07 (Table 4-12).

The Continental WWTP discharges into South Powell Creek upstream of station P06G07 and two permitted dairy facilities also located upstream of this site. The Wezbra and Maple Grove Dairies have zero allocations for all parameters based on their NPDES permit conditions and are not expected to influence water quality if permit conditions are met. A Continental WWTP load summary can be found in Table 4-4. Based on the calculated design loads for this discharge, the current TP design load is greater than the total allowable TP load at low flows for Powell Creek. The design loads also makes up a large portion of the observed TP load during dry flow conditions as well as the NN load during low flows. The Continental WWTP has minimal influence on water quality during mid-range and higher flows and does not appear to be a significant source of BOD or TSS at this site. The median observed flow during low flow conditions at this station is 2.66 cfs (Appendix A) which is much higher than the 7Q10 value of 0.90 cfs. This indicates that permitted limits still apply to the Continental WWTP during low flows.

Runoff from the City of Defiance has recently been designated an MS4, and requires a WLA under the Phase II Storm Water Program. The WLA was estimated based on an assumption that the allowable loads for the MS4 are in proportion to the allowable loads at station P06G07, based on the drainage area located within the city’s boundaries compared to entire area draining to station P06G07. Furthermore, storm water runoff is only assumed to occur during high, moist, and mid-range flow conditions. Overall, the Defiance MS4 appears to have minimal influence on water quality in Powell Creek at station P06G07.

Table 4-15 presents the TMDL summary for site P06G07. All six TP, two of six NN, one of six BOD, and three of six TSS observations exceeded loading limits for Powell Creek at this site. TP loads display the highest needed reductions across all flows sampled. The percent reductions for TP loads range from 85 percent at moist conditions to 14 percent at dry conditions. NN displays one needed reduction at moist conditions of 78 percent and BOD loads show no reductions at this site. TSS reductions of 69 and 41 percent are needed at moist and mid-range flows, respectively. Additional sampling for all parameters is recommended at this station to further evaluate water quality.

Table 4-15. Loading Statistics for Powell Creek (P06G07).

P06G07 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	TMDL Component	0-10	10-40	40-60	60-90	90-100
TP (kg/day)	Current Load	No Data	101.55	10.49	2.39	No Data
	TMDL= LA+WLA+MOS	**101.38**	**17.12**	**5.77**	**2.28**	**0.65**
	LA	89.06	13.61	3.43	0.33	0.00[1]
	WLA: Continental WWTP	1.72	1.72	1.72	1.72	0.65
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: Defiance MS4	0.46	0.08	0.03	0.00	0.00
	MOS (10%)	10.14	1.71	0.58	0.23	0.00[1]
	TMDL Reduction (%)	No Data	**85%**	**50%**	**14%**	No Data
NN (kg/day)	Current Load	No Data	698	48	3	No Data
	TMDL= LA+WLA+MOS	**1,014**	**171**	**58**	**23**	**7**
	LA	905.18	149.96	48.47	17.73	2.73
	WLA: Continental WWTP	3.27	3.27	3.27	3.27	3.27
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: Defiance MS4	4.55	0.77	0.26	0.00	0.00
	MOS (10%)	101	17	6	2	1
	TMDL Reduction (%)	No Data	**78%**	**0%**	**0%**	No Data
BOD (kg/day)	Current Load	No Data	286	152	39	No Data
	TMDL= LA+WLA+MOS	**3,548**	**599**	**202**	**80**	**23**
	LA	3,169	528	173	64	13
	WLA: Continental WWTP	8	8	8	8	8
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: Defiance MS4	16	3	1	0.00	0.00
	MOS (10%)	355	60	20	8	2
	TMDL Reduction (%)	No Data	**0%**	**0%**	**0%**	No Data
TSS (kg/day)	Current Load	No Data	32,896	5,825	769	No Data
	TMDL= LA+WLA+MOS	**67,317**	**11,366**	**3,834**	**1,512**	**432**
	LA	60,275	10,170	3,426	1,353	381
	WLA: Continental WWTP	8	8	8	8	8
	WLA: Wezbra Dairy	0	0	0	0	0
	WLA: Maple Grove Dairy	0	0	0	0	0
	WLA: Defiance MS4	302	51	17	0.00	0.00
	MOS (10%)	6,732	1,137	383	151	43
	TMDL Reduction (%)	No Data	**69%**	**41%**	**0%**	No Data

[1] The LA and MOS values were set to zero and the WLA for the Continental WWTP was adjusted to match the TMDL where negative LAs were displayed.

4.4 Pollutant Sources

Because the Powell Creek watershed is mostly rural land with cultivated crops as the dominant land use (approximately 83 percent; Table 2-2), many of the probable sources of impairment in this watershed are tied to agricultural practices. As these practices encroach on riparian and aquatic areas, habitat may be altered through stream channelization, riparian vegetation removal, and flow alteration that can lead to stream bank destabilization. Without the natural filtering capabilities of a healthy, vegetated riparian buffer, runoff from pasturelands/row crops carries pathogens and nutrients from recent manure and fertilizer applications directly into streams.

Livestock operations are also a possible source of pollution in a number of ways. Manure application on agricultural fields is a common practice in this watershed, but over application can lead to heavy nutrient, bacteria, TSS, and BOD loads as it washes off fields and into streams during wet weather events. Managing on-site manure at livestock operations is also important to protecting and maintaining water quality in the Powell Creek watershed. Without proper manure management plans, livestock operations can have significant impacts on water quality. For example, a nearby manure spill in 2003 caused in-stream fecal coliform concentrations of 43,000 counts/100ml, TP concentrations of 2.78 mg/L, and BOD of 380 mg/L.

Land application of manure is a common practice for livestock operations in the Powell Creek watershed. As much as 20 tons of manure may be spread per acre in some areas. It is important to note that these applications fall into the LAs as they are not accounted for in the facilities' WLAs. Manure application areas have the potential to impair water quality as runoff from wet weather events delivers excessive nutrient, pathogen, and sediment loads to nearby streams.

Livestock grazing with open access to streams can also severely impair the water quality and physical habitat of streams. This practice can result in direct deposition of manure in streams, streambank erosion, riparian vegetation trampling, and increased sedimentation.

Another source of pathogen and nutrient impairment in the Powell Creek watershed comes from human waste. Unsewered areas with failing or poorly maintained septic systems are of concern as untreated sanitary wastewater from residential areas is discharged directly into streams. There are several small villages (Kieferville, Hector, Wisterman, Rice, and North Creek) that do not have a centralized wastewater collection and treatment facility. These villages rely on septic tanks, leaching fields, or sub-surface sand filters for sewage treatment. If these systems are not properly designed, installed, and maintained they have the potential to significantly impact local water quality with excessive nutrient and bacteria loads causing algal blooms, strong odors, and/or aquatic life impairments.

The only permitted discharge in the Powell Creek watershed is the Continental WWTP. This facility does not seem to impact water quality during mid-range and higher flows, but may have a greater influence on nutrient loads and BOD during dry and low flow conditions especially in the downstream reaches of South Powell Creek. Downstream of the North and South Powell Creek confluence, the Continental WWTP design loads continue to be of concern at low flows. The City of Defiance MS4 storm water appears to have a minimal influence on water quality at the mouth of Powell Creek.

4.5 Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. U.S. EPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS). An explicit MOS has been applied as part of all of the Powell Creek TMDLs by reserving ten percent of the allowable load (see allocation tables in Sections 4.1 and 4.2). A relatively moderate MOS was selected based on the use of load duration curves, which minimize potential uncertainties associated with calculating the allowable loads (i.e., the allowable loads are based on observed data rather than modeling simulations). The MOS was not lower (e.g., 5 percent) because of the rather limited water quality data available to apply the load duration curves.

4.6 Critical Conditions and Seasonality

The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. Through the load duration curve approach it has been determined that load reductions are needed for specific flow conditions; however, the critical conditions (the periods when the greatest reductions are required) vary by location and are inherently addressed by specifying different levels of reduction according to flow.

The allocation of point source loads (i.e., the WLA) also takes into account critical conditions by assuming the facilities will always discharge at their maximum design flows. In reality, many facilities discharge at below their design flows.

The Clean Water Act also requires that TMDLs be established with consideration of seasonal variations. The load duration approach accounts for seasonality by evaluating allowable loads on a daily basis over the entire range of observed flows and presenting daily allowable loads that vary by flow. Seasonal variations are also addressed in the fecal coliform discussion by only assessing conditions during the season when the water quality standard applies (May through October).

5.0 ADDITIONAL WATER QUALITY IMPAIRMENTS IN THE POWELL CREEK WATERSHED

5.1 Fecal Coliform

As previously mentioned, limited fecal coliform sampling only resulted in 2 to 4 samples per station. Though load duration analysis could not be performed for this parameter, a discussion of possible impairments based on the available data are provided in this section.

There are several sites with fecal coliform counts that exceed or nearly exceed the Ohio EPA primary contact water quality standard of 2,000/100mL (Table 5-1). The samples listed have one or more fecal coliform counts that are at a level of concern.

Fecal coliform is a parameter of concern in all three 14-digit HUC subwatersheds, as noted by the limited sampling, and should be further monitored to determine if impairments exist and what the possible sources may be. As noted in previous studies by the Ohio EPA, sources of fecal contamination are most likely from nonpoint sources including:

- Row crop farming (over application of manure for fertilizer)
- Livestock operations (without manure management plans)
- Livestock grazing (with direct access to streams)
- Failing/poorly managed septic systems

In some streams where fecal contamination is probable, the impairments are likely coupled with additional impairments (e.g. nutrients and/or BOD). Further investigation is needed in these subwatersheds and tributaries to confirm fecal coliform impairments and allow for load duration analysis/TMDL development. While there are several potential sources noted, specific areas still need to be identified so that the appropriate Best Management Practices (BMPs) can be implemented to improve and maintain water quality in the Powell Creek watershed.

Table 5-1. Fecal coliform areas of concern.

STORET Station Number	Stream Name	Sample Location (River Mile)	Fecal Coliform Count (#/100mL)[1]			
			Sample 1	Sample 2	Sample 3	Sample 4
P06G04	South Powell Creek at Schubert Road	1.75	1,600 (7/12/2000)	62 (7/26/2000)	1,200 (8/8/2000)	730 (8/4/2005)
P06P06	South Powell Creek at TR 22B	8.22	460 (7/12/2000)	130 (7/26/2000)	2,100 (8/8/2000)	n/a
P06G03	North Powell Creek at Kinner Road	0.72	1,400 (7/12/2000)	6,500 (7/26/2000)	360 (8/8/2000)	n/a
P06S14	North Powell Creek at Hill Road	8.55	220 (7/12/2000)	66 (7/26/2000)	1,100 (8/8/2000)	n/a
P06G02	North Powell Creek at TR B-13	12.95	1,100 (7/12/2000)	1,700 (7/26/2000)	1,200 (8/8/2000)	n/a
P06G07	Powell Creek at Boy Scout Road	0.36	700 (7/12/2000)	52 (7/26/2000)	1,450 (8/8/2000)	n/a
P06S01	Powell Creek at Bowman Road	4.30	350 (7/12/2000)	64 (7/26/2000)	1,200 (8/8/2000)	490 (8/4/2005)
P06G11	Tributary to Powell Creek (at RM 2.55) at SR 15	1.35	120,000 (8/4/2005)	1,600 (8/14/2008)	n/a	n/a
P06G10	Tributary to Powell Creek (at RM 4.4) at Bowman Road	0.00	42,000 (8/30/2005)	>200,000 (8/11/2008)	>200,000 (8/14/2008)	n/a
P06G09	Tributary to Powell Creek (at RM 4.7) at SR 66	0.00	10,000 (8/4/2005)	4,600 (8/30/2005)	2,400 (8/11/2008)	5,600 (8/14/2008)
P06G14	Wagner Run downstream of Dohoney Road	1.25	24,000 (8/30/2005)	9,500 (8/11/2008)	47,000 (8/14/2008)	n/a
P06G15	Tributary to Wagner Run at Bowman Road	---	102,000 (7/21/2004)	>2,000,000 (8/4/2005)	>200,000 (8/11/2008)	>200,000 (8/14/2008)
P06G16	Dahoney Road Ditch north of Bowman Road	---	79,500 (7/21/2004)	950,000 (8/4/2005)	160,000 (8/11/2008)	200,000 (8/14/2008)
P06G17	Blanchard Road Ditch west of Hill Road	0.00	33,000 (8/4/2005)	n/a	n/a	n/a

6.0 WATER QUALITY IMPROVEMENT STRATEGY

6.1 Purpose and approach

This section provides a strategy for making water quality improvements. The ultimate goal is meeting water quality standards. The recommendations will guide actions related to NPDES effluent limits, storm water permit requirements, consideration for 319 grants, 401 certifications, and technical assistance and outreach. However, it will be important to have participation from others in making improvements, particularly those dealing with non point source pollution.

This strategy is based on results from water quality surveys, watershed analyses and current scientific and technical information. An adaptive management approach is taken where progress towards the goals is measured. If improvements are unsatisfactory or implementing the recommendations is too difficult then a revision is warranted.

6.2 Problem Summary

Most of the streams in the Powell Creek watershed are not supporting the aquatic communities expected for comparable streams in this part of Ohio. The result is failure to meet water quality standards. Also, based on the data collected, there is indication that human exposure to these streams may lead to water-borne illnesses because of high concentrations of bacteria associated with fecal matter. Another important water quality consideration is the export of pollutants from the Powell Creek watershed to downstream waters such as nutrient export to Lake Erie.

Table 6-1. Summary of activities and land uses impacting water quality.

Land use, management practices, and/or other activities	Effects on water resource	Extent found within the watershed
Row crop production • Tillage • Land applied fertilizers and manure	• Increased transport of sediment, nutrients and possibly bacteria to waterbodies from the upland areas • Likely increases runoff rate and volume relative to natural vegetative land covers.	Dominant land use accounting for more 80% of the total area
Drainage ditch construction and maintenance	• Increase in stream power and potential for channel erosion • Reduced capacity to assimilate pollutants, accelerated downstream transport • Removal of habitat structure for aquatic animals	Most small channels have been modified or constructed to enhance land drainage
Sub-surface drainage	• Likely reduction in runoff under some circumstances (and *runoff* transported pollutants) • Possible route for land applied manures and nitrogen fertilizers as well as illicit connections from septic systems	Estimated to be extensively used in the watershed based on the predominance of row crop agriculture and poorly drained soils
Home septic systems that are not operating correctly or are illicitly connected to surface waters	• Contributes nutrients, bacteria, and organic material (especially BOD) through direct discharges and/or runoff coming from failed leach fields (e.g., via surface ponding)	Numerous unsewered areas in the watershed, however failure rates are unknown.
Livestock production	• Direct manure inputs resulting in higher concentrations of bacteria, nutrients, and organic material • Manure related pollutants transported in surface runoff from source areas (e.g., pasture, feedlots)	Two large CAFOs and other small scale livestock production. Overall livestock production is relatively low.

Land use, management practices, and/or other activities	Effects on water resource	Extent found within the watershed
Point source discharge	• Contributes nutrients and organic material	One discharger in the Powell Creek watershed is believed to have a significant impact on water quality

Specific water quality issues identified in the watershed are ***high nutrient***, ***sediment, and organic loading***, ***low dissolved oxygen concentrations, poor aquatic habitat, and high levels of fecal bacteria***. The sources for these stressors are primarily activities related to the production of row crops and land drainage. Less significant sources include activities related to livestock operations, inadequate treatment of human waste by home septic treatment systems (HSTS) and point sources discharges from wastewater treatment facilities.

6.3 Abatement of water quality problems: technical considerations

This section provides the technical justification for the practices recommended to improve water quality. This is done by providing a link between the problems and the actions that can adequately address them. A summary of the specific problems is given followed by appropriate abatement measures. Rationale for the selected measures is provided.

This section is organized according to the various stressors that are causing impairment to the designated water uses. The stressors addressed here are the following:

- Poor habitat quality and high sediment loading
- High concentrations of nutrients and biological oxygen demand
- High concentrations of bacteria

6.3.1 Poor habitat quality and high sediment loading

Problem statement

The dominant factor stressing aquatic communities in the Powell Creek watershed is the pervasiveness of poor aquatic habitat. The absence or low quality of stream habitat hampers the ability of aquatic organisms to successfully reproduce, acquire food, or find protection from other species and stressful environmental conditions. This drastically reduces or eliminates the number of individuals within several aquatic species, particularly those more sensitive to environmental stressors. A compounding effect of wide spread degraded habitat is that source populations of sensitive aquatic species dwindle, leading to diminishing recruitment to areas that do have suitable habitat quality.

The Qualitative Habitat Evaluation Index (QHEI) is used to determine the adequacy of stream habitat to support aquatic communities. This index provides a score which is arrived at by assigning points based on the presence or absence and relative abundance of discrete habitat features. QHEI scores have demonstrated a strong direct correlation to measures of biological community health (OEPA, 1999). Since this index is designed to only evaluate a relatively short stream segment, each evaluation must be viewed separately. However, basin-wide habitat conditions can be inferred through the collection of these evaluations. In the Powell Creek watershed all QHEI habitat scores were below the target value for typical stream systems (see Section 5.3).

Sub-metrics to the QHEI consider six aspects of stream habitat separately: the stream's *bed material (i.e., substrate), cover habitat, channel morphology, bank conditions and riparian zone, pool/glide and* *riffle/run quality, and stream gradient*. In Powell Creek poor substrate quality is one of the most widely and severely limiting factors to adequate habitat quality. On average, the sites evaluated are achieving 18% of the total possible points for this sub-metric (3.6 out of a possible 20). The target associated with typical streams is 70% of the total (14 points). The other component of stream habitat showing the highest degree of impairment is riffle development. Riffle development is related to stream substrate and sediment loading as well as stream power. Other aspects of stream habitat can be improved, particularly those dealing with channel morphology. However, *abating excessive sediment problems should be the primary focus of efforts to restore habitat.*

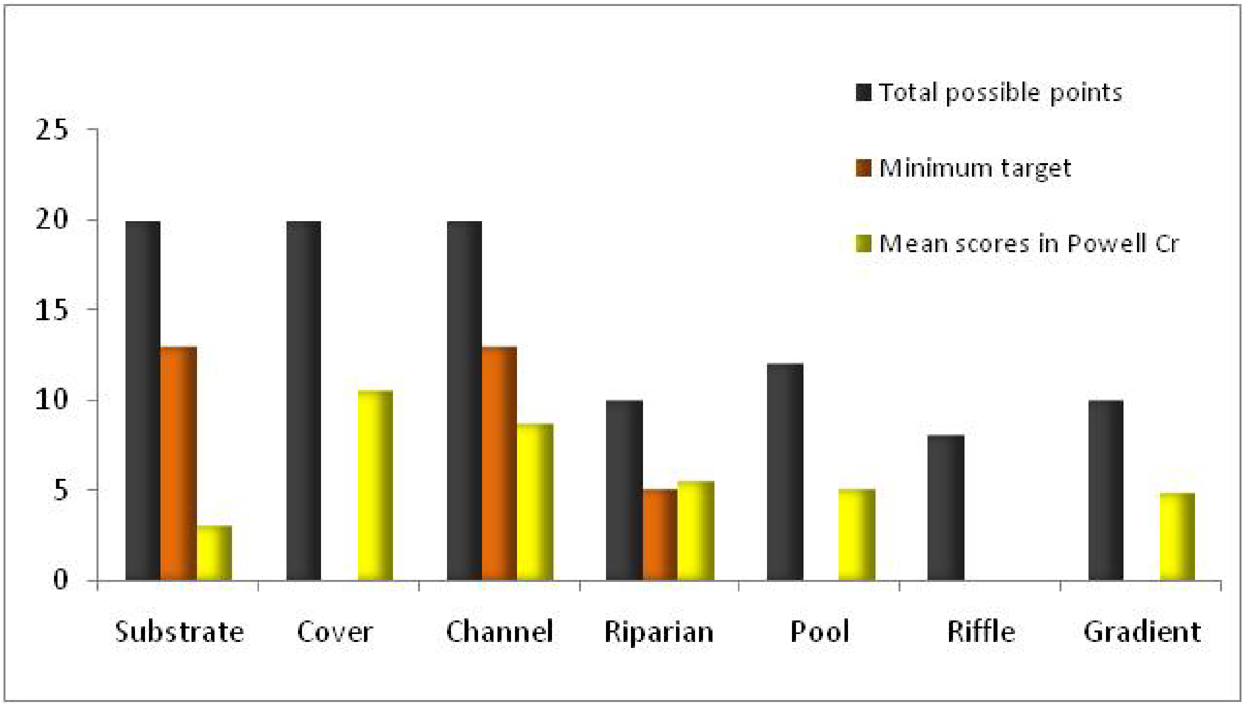

Figure 6-1. Habitat quality in the Powell Creek watershed as measured by the Qualitative Habitat Evaluation Index (QHEI) based on evaluations conducted in the 2000 survey. Pool/glide and riffle/run quality have been viewed separately in this graph resulting in seven categories instead of six. The black bars indicate the total number of points possible for that sub-metric, orange (medium shade) indicates the target value to be achieved which is related to the probability of meeting the biological water quality standards, and yellow (lightest shade) indicates the mean of the scores that were calculated for the sites within the Powell Creek watershed. The cover, pool, riffle, and gradient categories do not have minimum targets established. The mean value for "Riffle" in Powell Cr was 0.15, however this is difficult to see in this figure.

Substrate is considered poor because of the dominance of silts and clays to the exclusion of coarser and more useful bed substrates such as gravels and small cobbles. There is little variation in the coarseness of substrate and riffles are poorly developed and filled with fine material. Other habitat problems stem from channels being deeply entrenched relative to the surrounding landscape.

Entrenched or incised channels commonly found in the Powell Creek watershed experience fewer out of bank flows which are important for sorting sediment material (i.e., depositing fine material out of bank leaving a higher proportion of coarser material on the bed). Out-of-banks flows also reduce stream power making severe bed and bank erosion less likely. Other water quality benefits associated with out-of-bank flows will be discussed later in this section.

Management approach for abatement
The most significant way to improve stream habitat is to reduce the proportion of fine material in the bed substrate. This can be achieved by:

1) limiting contributions of this material from upland sources,
2) abating channel erosion, and
3) increasing the capacity of the stream network to process sediment

Reducing surface erosion and/or intercepting sediment before it reaches the stream abates upland loading. Alternatives to current drainage maintenance can limit channel erosion as well as increase the streams capacity to sort and transport fine sediment.

<u>Reducing upland surface erosion</u>
In this watershed upland sediment loading is overwhelmingly derived from crop fields during runoff events and contributions from other land uses are comparatively minor. Management options for reducing erosion involve ***providing cover to the soil***, and ***reducing the power of concentrated overland flows***.

The Natural Resource Conservation Service (NRCS) defines conservation practices that are able to address environmental concerns related to land management as well as those that are naturally occurring. These conservation practices are identified by a conservation practice number and definitions of these practices can be found on the NRCS website at: **http://www.nrcs.usda.gov/Technical/efotg/**. The following (NRCS) conservation practices would be beneficial for reducing erosion of upland soils:

- Conservation cover (327)
- Conservation crop rotation (328)
- Cover and green manure crop (340)
- Critical area planting (342)
- Diversion (362)
- Grassed waterway (412)
- Mulching (484)
- Pasture and hayland planting (512)
- Residue management (329 A,B,C)

<u>Intercepting sediment from upland sources</u>
Intercepting upland sediment loads can be achieved along ***buffer zones*** between the source of sediment and the stream. Buffer zones are created by converting cropland or pasture to land covered by trees, shrubs, grasses or broad-leaved plants. Buffers reduce runoff velocity, which limits sediment transport to streams. Buffers also reduce pollutant loading by not allowing these areas to be significant sources themselves. Buffer zones have year round vegetative cover that limits surface erosion. Additionally, they typically receive little to no fertilizer and chemical applications. This is significant because of their closeness to surface waters and the fact these areas typically produce a large proportion of the annual runoff.

The concept of ***variable source areas*** in hydrology is that low lying areas on the landscape, such as those near streams where buffers are located, experience saturated conditions a greater proportion of the time than other areas on the landscape. This is due to accumulation of surface and sub-surface flows in those areas following precipitation. These saturated areas then produce runoff under smaller rain events because there is little water storage capacity in the soil. With a greater amount of runoff coming from these areas it is important that they be minimal sources of sediment and other pollutants. The vegetative cover associated with buffers greatly reduces the potential for soil erosion.

Other management practices that intercept sediment include sediment storage ponds or wetlands that are positioned to receive concentrated and/or sheet flow. Detaining runoff in these structures allows fine sediment material to fall out suspension and be removed from the flow to the stream. The following NRCS practices would be beneficial for intercepting sediment:

- Filter strip (393)
- Riparian forest buffer (391)
- Water and sediment control basin (638)
- Wetland restoration (657)

<u>Mitigating channel erosion and increasing capacity to process fine sediment</u>

The shape of a channel affects how water flows through it and how much stream power it has which is related to how much channel erosion can occur. Stream power increases as flow becomes deeper and faster. Water depth in a typical ditch can increase rapidly because it lacks floodplains and flows do not spread out laterally.

Floodplains increase the capacity of streams to sort the sediment load it transports. Fine sediment is easily taken up and stays in suspension longer than gravels and cobbles, therefore a larger proportion is transported to the floodplain where it can be stored. Coarser material tends to stay in the main channel which ultimately provides a means for separating fine material from the stream bed.

The Powell Creek watershed has many ditches used to provide outlets for sub-surface drainage. Reconfiguring typical drainage ditches to a two-stage or over-wide channel would continue to provide outlets for sub-surface drainage while providing benefits to water quality.

Two-stage ditches create a floodplain within the ditch or stream by excavating bank material and widening the channel leaving behind an elevated “bench” of parent (already present) material (see Figure 6-2). Benches are densely vegetated and inundated 15-20 times per year, resulting in deposition of finer grained material. Additionally, benches may better detain and/or assimilate nutrients and pesticides than the bed and banks of one-stage channels.

Two-stage channel development has been observed at several locations across Ohio in relatively over-sized ditches. These channels tend to form naturally and their development is facilitated when the bottom width of the channel is relatively large (i.e., larger than it needs to be to accommodate the flows that it receives). The Ohio Department of Natural Resources (ODNR) proposed the concept of over-wide channels which involves creating a large channel that will eventually develop into a two-stage configuration. This happens as water transported sediment is deposited along the margins of the widened channel where flows are typically slower and have less power. The result is that transported material aggrades, or accumulates over time to build the floodplain benches that are constructed when using a two-stage channel approach. Figure 6-3 shows an over-wide channel where floodplain benches form from aggraded sediment.

The over-wide approach has the benefit of simpler construction and design than a two-stage channel but has a disadvantage in that more material must be excavated. Over-wide channels also increase the capacity to detain in-stream sediment because this sediment is stabilized by vegetation that grows on the benches.

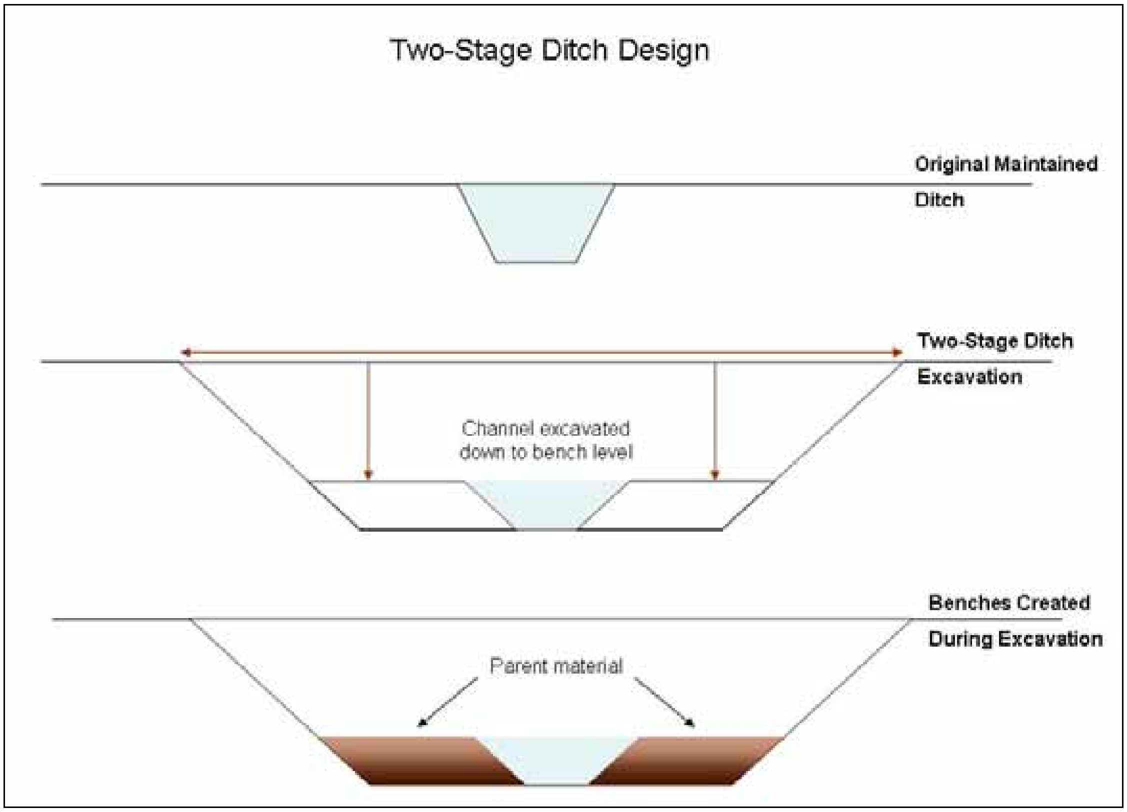

Figure 6-2. Converting a maintained ditch into a two-stage ditch.

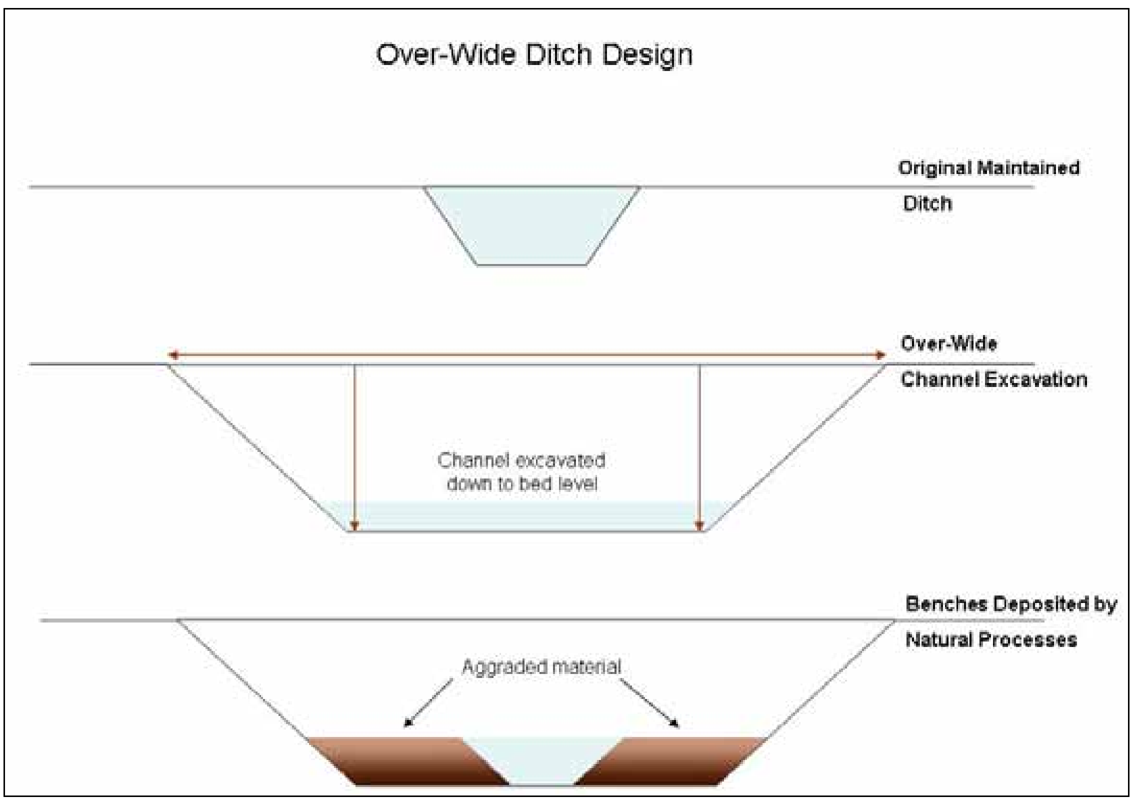

Figure 6-3. Converting a maintained ditch into an over-wide channel.

Areas most suitable for applying two-stage or over-wide channel construction include drainage ditches, previously or currently channelized agricultural streams, and low gradient headwater streams (Personal communication, Dan Mecklenburg of the ODNR). Channelized streams or ditches in which some bench development has occurred typically display floodplain ratios (flood-prone width across benches/bankfull width of stream) of well under 3, while natural streams in Ohio have ratios of well over 10. For successful implementation, a minimum constructed floodplain ratio of 3 to 5 is recommended to ensure stability and treatment processes (Mecklenburg, 2005). An estimation of the necessary increase in channel width associated with two-stage ditches is presented in Table 6-2. Over-wide channels require similar sized channels with a recommended minimum width of 3 to 5 times the channel's self-forming width (Mecklenburg, no date).

Table 6-2. Typical increases in channel width associated with over-wide ditches.

Drainage Area (mi^2)	Total increase[1] (includes both sides) (ft)	Estimated increase in cross-sectional area[2] (ft^2)	Estimated volume of excavated material per linear foot of channel[2] (yd^3)
1	9.8	49 – 69	1.8 – 2.5
5	18.6	93 – 130	3.4 – 4.8
10	24.4	122 – 171	4.5 – 6.3

[1] From Mecklenburg 2005.
[2] Assumes bottom depths range from 5 feet to 7 feet and side slopes ratios are 1.5 : 1.

One method for applying these BMPs is selecting a suitable stream reach for implementing a small scale project. For example, a 1,000 foot long over-wide ditch project with a floodplain ratio of 5 has an estimated 21.0 percent sediment trapping efficiency for a 1 square mile watershed (Mecklenburg, 2005). This value was calculated using a depositional rate of 1 inch of sediment per year as the floodplain initially develops over the first 18 years. Once a floodplain is established within the over-wide channel the sediment deposition rates and trapping efficiency values decrease. A literature value depositional rate of 0.2 inches per year is estimated after floodplain development, resulting in a long-term trapping efficiency of 4.2 percent for the 1 square mile watershed (Mecklenburg, 2005).

Another method involves applying the over-wide channel to the entire stream within a watershed. An over-wide project along the entire drainage network of a watershed provides enhanced treatment, greater sediment storage capacity, and is most likely to be employed in agricultural watersheds (Mecklenburg, 2005). A floodplain width ratio of 3 (the minimum recommended ratio) has an estimated 23.0 percent sediment trapping efficiency when applied to a 0.5 square mile watershed (Mecklenburg, 2005). This value was calculated using a depositional rate of 0.5 inches of sediment per year as the floodplain initially develops over a 19 year period. Once a floodplain is established an estimated depositional rate of 0.2 inches per year results in a long-term trapping efficiency of 9.3 percent (Mecklenburg, 2005).

6.3.2 Nutrients and other non point source pollutants

Problem statement

Results from the TMDL analysis shows that phosphorus loading is very high relative to the water quality targets. Nitrogen loading is also high but to a lesser degree than that of phosphorus. These nutrient enriched conditions lead to high algae production which is damaging to water quality and negatively impacts biological communities. Organic loading is high in some areas which impacts dissolved oxygen concentrations and biological communities. Sediment loading is extremely high, and not only impacts stream habitat but also carries phosphorus and organic material.

Normalizing the average daily watershed loading based drainage area (e.g., load divided by drainage area) helps in comparing individual sites or the sub-watersheds. This is called the yield for the given pollutant. Figure 6-4 shows that the South Powell Creek sub-watershed generally has the highest total phosphorus (TP) and total suspended solids (TSS) yield while the North Powell Creek and Powell Creek sub-watersheds have higher nitrate-nitrogen (N-N) yield.

The data can also be examined for differences in pollutant loading across the various flow conditions, which is useful when considering contributions to the total annual load. Total phosphorus loading is about 3 to 11 times higher under moist flow conditions than under mid-range flows at each of the sites and 5 to 49 times higher for moist flows than dry flows. For nitrate-nitrogen this trend is more pronounced with loading under moist flows being 4 to 47 times more than that of mid-range flows and 81 to 1,800 times higher than dry flow conditions. The trend for total suspended solids (TSS) follows very closely to that of total phosphorus. Biological oxygen demand (BOD) also follows the general trend but at a much smaller magnitude.

The load reductions that have been shown in Section 4 of this report are based on the current loading and the established targets. Watershed-wide the average reductions needed to meet the phosphorus targets is 79% for flows in the moist range. Phosphorus reductions averaging 56% were needed for flows in the mid-range. Phosphorus was still elevated in dry or relatively low flow conditions with the average reduction needed being 40%. Nitrogen reductions were primarily needed for flows in the moist range and to a lesser degree for the mid-range flows

Phosphorus concentrations are higher than the target for the majority of flow conditions, including low flows that contain little to no runoff. A possible explanation for this is that the stream system is saturated with phosphorus. The relative absence of point sources to contribute phosphorus under dry weather conditions supports this idea. Additionally, fine grained material like that which dominates the bed substrate is efficient at holding phosphorus and can, under low flow conditions, release it from the sediment. Other possible sources of phosphorus during low flow conditions include illicit contributions made from home sewerage treatments systems (HSTS) and manure loading from livestock production. Phosphorus concentrations are highest during high flows, probably resulting from upland loading in runoff as well as re-suspension of phosphorus from the bottom sediment.

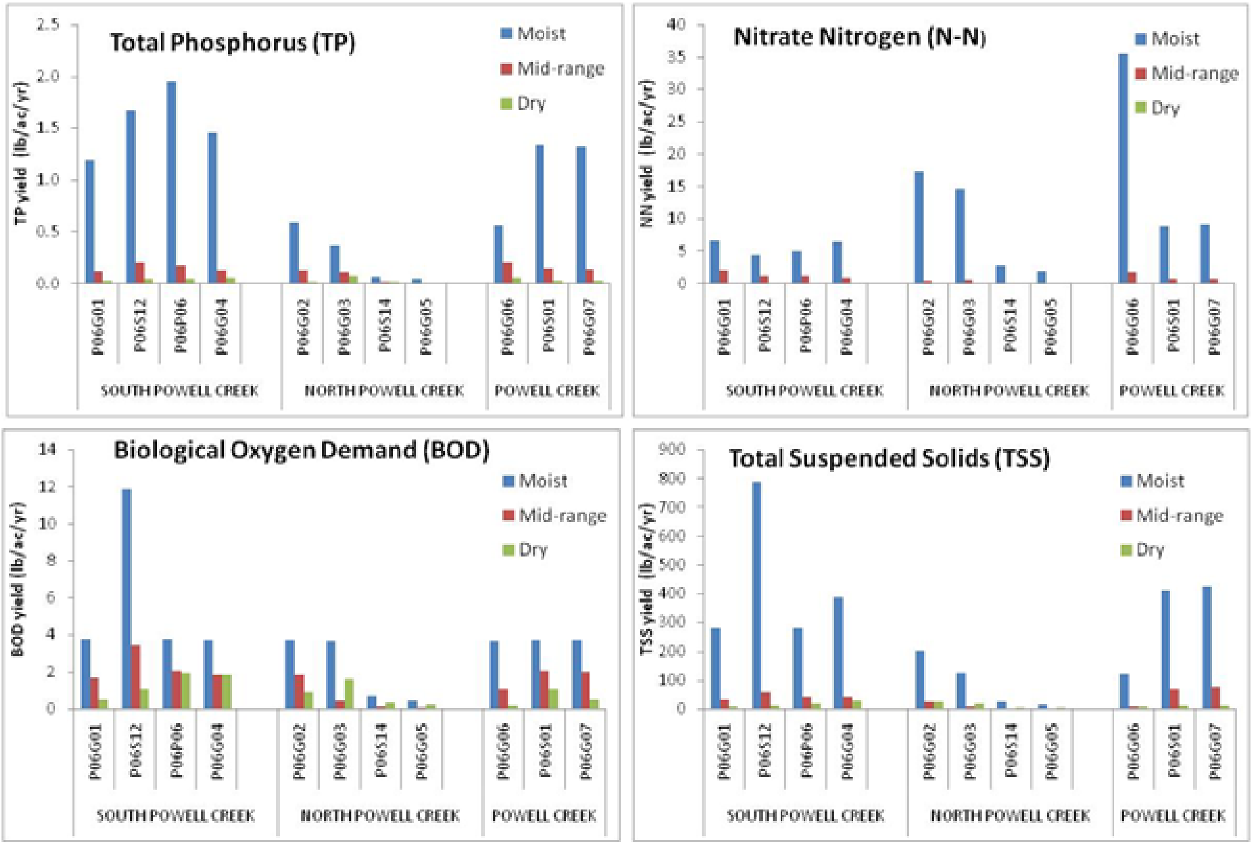

Figure 6-4. Annual load estimates for each sampling site normalized based on drainage area. Three flow conditions are included in this figure, moist, mid-range, and dry. Station locations are shown in Figure 3-1.

The loading of organic material expressed as BOD is less problematic than that of phosphorus and nitrogen where only half of the sites sampled showed a need for reduction. At one site BOD reductions are needed across most flow regimes and ranged from 42 to 74 percent. However at the other sites BOD reductions are primarily needed for dry conditions and range from 12 to 61 percent. Possible sources for BOD under low flow conditions include failing HSTS or illicit connections to waterways from these systems.

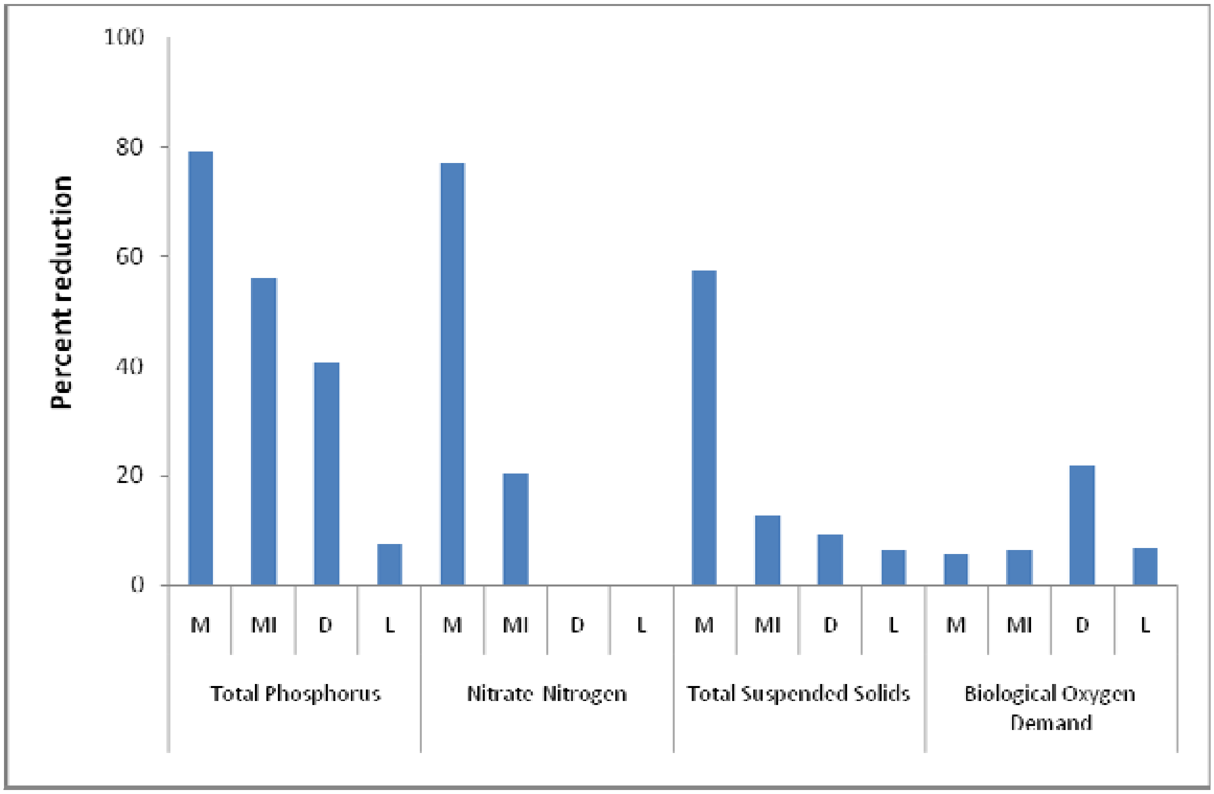

Figure 6-5. Mean percent reductions for modeled pollutants for all sample site locations with respect to flow conditions. M represents Moist conditions, MI represents Mid-range conditions, D represents Dry conditions, L represents Low flow conditions.

Management approach for abatement
Reducing the negative impact of nutrient loading on streams in the Powell Creek watershed can be achieved by:

1) reducing point source loading
2) reducing the loading from the upland landscape and,
3) better processing of phosphorus and nitrogen within the stream system itself.

Point sources loading can be reduced through greater pollutant removal from the effluent, or by changing the discharge protocols to allow for more in-stream dilution (i.e., controlled discharge type systems).

Nonpoint nutrient loading is reduced when nutrients are not available for transport and when transport is disrupted. In row crop production areas, availability of nutrients for transport to surface waters is a function how much crops can take up and assimilate versus how much is stored in the soil and land applied. Nutrient transport is related to the timing and intensity of rainfall compared with nutrient availability and mobility as well as the pathways available for transport. Reducing sediment loading and intercepting and sequestering nutrients before they can reach the stream are effective means for disrupting transport.

<u>Reducing point source pollutant loading</u>
The Continental WWTP is the only NPDES discharger in the basin that is believed to be having a negative impact on water quality. Currently Continental is under orders from the Director of the Ohio

EPA to construct a treatment lagoon that will have control over its discharge. This new lagoon must be completed by August 1, 20011.

Reducing nutrient availability

The following NRCS practices would be beneficial for reducing nutrient availability:

- Nutrient management (590)
- Waste utilization (633)
- Cover and green manure crop (340)

Manure as a source of phosphorus can be reduced by using more optimal livestock feeds or the use of feed additives. Phytate is a phosphorus containing chemical constituent of corn that is indigestible, and accounts for a significant proportion of the phosphorus content of manure. Corn feed with lower phytate concentrations or the use of enzyme additives that help digest phytate result in lower phosphorus content in manures. However, although not confirmed through scientific research, enzyme additives have been suspected of breaking down soil phosphorus and making it more available for transport in runoff.

Disrupting nutrient transport by controlling soil erosion

The following NRCS practices would be beneficial for disrupting nutrient transport by reducing sediment loading through erosion controls:

- Conservation cover (327)
- Cover and green manure crop (340)
- Conservation crop rotation (328)
- Mulching (484)
- Residue management (329 A,B,C)
- Pasture and hayland planting (512)
- Grassed waterway (412)
- Diversion (362)
- Water and sediment control basin (638)

Disrupting nutrient transport through interception and sequestration

Intercepting and sequestering nutrients requires runoff to be slowed long enough for the nutrients to be converted into biomass (e.g., plant or bacteria) or other less mobile or less biologically available forms (e.g., via de-nitrification of nitrate or mineralization). Vegetative buffer strips and wetlands are effective at slowing the movement of nutrients as well as transforming them to biomass or forms that do not lead to algae production. The following NRCS practices are relevant to this mode of nutrient abatement:

- Filter strip (393)
- Riparian forest buffer (391)
- Constructed wetland (656)
- Wetland restoration (657)
- Wetland creation (658)

Wetlands and depressional areas are proficient at storing precipitation on the surface of the landscape. While being stored, there is a much greater opportunity for this water to infiltrate into the ground recharging groundwater supplies and/or increasing the proportion of rainfall that becomes part of the shallow sub-surface flow. Shallow sub-surface flow often improves in quality as it passes through the soil profile because nutrients and sediment particles are sequestered. Sub-surface flow also tends to be cooler, which provides a less stressful environment for aquatic organisms during the hottest times of the year by facilitating higher concentrations of dissolved oxygen and preventing damaging elevated metabolic rates.

Numerous studies have shown that wetlands improve water quality and watershed hydrology as well as provide excellent wildlife habitat (Mitsch and Gosselink, 2000; Vellidis, 2003). Establishing wetlands often entails disabling a portion of the drainage infrastructure servicing that area and a relatively minor amount of earth work.

Drainage water management (NRCS practice 554) can be used to reduce nutrient loading, especially nitrogen, from sub-surface drainage systems. This is primarily achieved by reducing the annual volume of tile water discharges to streams. These reductions have been estimated over several years of research to be approximately 40% and correspond to a similar reduction in annual nitrogen loading (Fausey, 2004). Although it is uncertain whether comprehensive water budgets have been completed for this practice, it is reasonable to assume that a significant proportion returns to the stream as baseflow and interflow over a protracted timeframe (David Baker, *email*, 2006) or is otherwise taken up through evapo-transpiration. The extended period of discharge can also benefit the aquatic community by providing flow during critical drier periods.

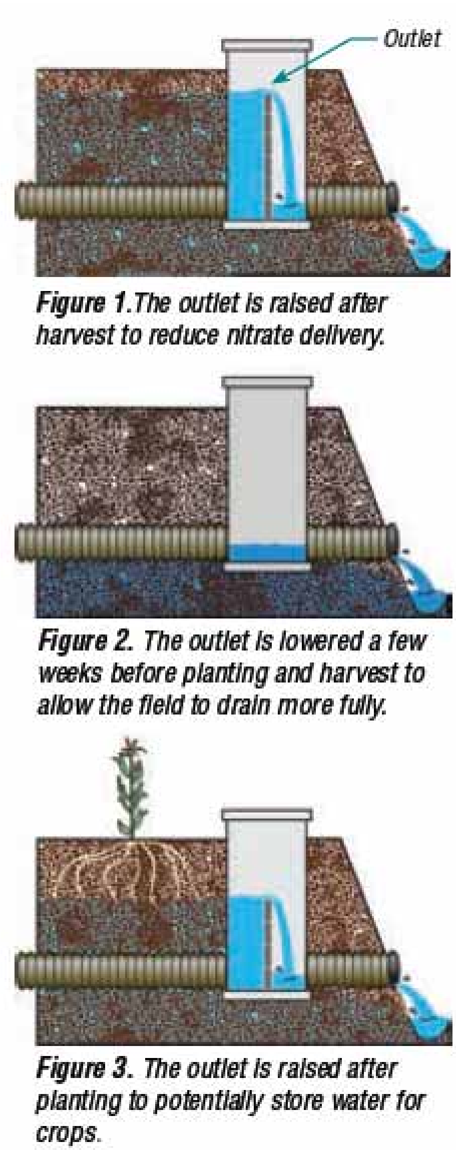

Figure 1. The outlet is raised after harvest to reduce nitrate delivery.

Figure 2. The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.

Figure 3. The outlet is raised after planting to potentially store water for crops.

Figure 6-6. Illustration of a drainage control structure.

<u>Increasing efficiency of nutrient processing within ditches and streams</u>

The ability of a channel to process nutrients is determined by a number of factors such as temperature, channel morphology, stream size, availability of organic material, nutrient concentrations of the stream water, and residence time among other things. Factors that are most affected by stream management are related to channel morphology, residence time and the availability of organic matter.

The most important aspect of channel morphology is the connection to a floodplain. As with sediment, floodplains improve the stream system's capacity to process the nutrients it transports. The vegetation on the floodplain and the microorganisms living in the soil take up available nutrients and convert them to forms that are less damaging to water quality (e.g., from nitrate to organic nitrogen or nitrogen gas).

The capture of nutrients and other pollutants in the floodplain occurs when water passes through the floodplain soils. At relatively low flows water infiltrates into the floodplain because floodplain soils are permeable and water in the channel is able to move laterally through the bank. Over-wide channels develop floodplain-like benches that are made up of somewhat coarser, water transported sediment. This differs from constructed two-stage channels where the floodplain benches are made from the parent soils and are often dense, poorly permeable clays. The relative coarseness of the deposits (e.g., silts and sands) of the over-wide channel allows for more flow through these soils as water is traveling down the channel and results in more treatment of water. For this and other reasons *an over-wide channel approach is likely to be a more effective and efficient way to improve water quality*.

An over-wide channel may be one of the most practical ways of increasing residence time in small ditches because of the formation of the mini-floodplains or benches. Additionally, sinuosity is somewhat greater in over-wide ditches than conventional ditches, which may have an effect of increasing residence time.

Organic matter is important for bacteria that convert nutrients to biomass. In streams that are limited in the amount of available carbon (i.e., organic matter) nutrient processing occurs at a lower rate than comparable stream that are not limited. Plants growing next to channels in the riparian zone are a primary source for stream organic matter in small streams.

Table 6-3. Summary of conservation practices and estimated effectiveness.

BMP	Description and Removal Mechanism	Estimated Sediment Reductions
Conservation tillage	Reduced tillage practice with a minimum of 30 percent cover of crop residuals. Reduces erosion rates and phosphorus losses. Increases soil quality by providing organic material and nutrient supplementation.	75 to 88 percent reduction in soil loss rates [1; 2]
Cover crop	Use of ground cover plants on fallow fields. Reduces erosion, provides organic materials and nutrients to soil matrix, reduces nutrient losses, suppresses weeds, and controls insects.	88 percent reduction in soil erosion [3]
Filter Strips	Placement of vegetated strips in the path of field drainage to treat sediment and nutrients.	60 to 65 percent reduction in sediment [1]
Restoration of Riparian Buffers	Conversion of land adjacent to stream channels to vegetated buffer zones. Removes pollutants by sedimentation and plant uptake. Provides stream bank stability, stream shading, and aesthetic enhancement.	97 percent removal of sediment from treated area, assuming a 90 ft buffer width [4]
Two-stage ditches	Perform minimal ditch excavation in channelized headwater streams- creates benches within the channel that allow natural processes and vegetation to stabilize streambanks while increasing discharge capacity, sediment retention, and in-stream water quality treatment.	Qualitative evidence suggests that two-stage ditches accumulate and retain sediment resulting in lower sediment export downstream and an increase in bank stability [5]
Over-wide channels	Excavate 5 to 10 times the existing channel width allowing natural processes to deposit a floodplain within the over-wide channel. Vegetation growth and deposited materials trap sediment, nutrients, and organic loads.	Numerous over-wide project sites in the Great Lakes region are currently being monitored for water quality improvements. Increased sediment and pollutant retention anticipated as in-stream ecological treatment is enhanced [6]

1.U.S. EPA. 2003. National Management Measures to Control Nonpoint Source Pollution from Agriculture. EPA 841-B-03-004, July 2003.
2.USDA. 2004. Illinois Conservation Reserve Enhancement Program, Final, Programmatic Environmental Assessment June 3, 2004. Prepared by the U.S. Department of Agriculture, Farm Service Agency in partnership with the USDA Natural Resources Conservation Service, Illinois Department of Natural Resources, Illinois Department of Agriculture, Illinois Environmental Protection Agency, County Soil and Water Conservation Districts and Association of Illinois Soil and Water Conservation Districts.
3.HRWCI. 2005. Agricultural Phosphorus Management and Water Quality in the Midwest. Heartland Regional Water Coordination Initiative. Iowa State University, Kansas State University, the University of Missouri, the University of Nebraska–Lincoln and the USDA Cooperative State Research, Education and Extension Service.
4 NCSU. 2002. Riparian Buffers and Controlled Drainage to Reduce Agricultural Nonpoint Source Pollution. Departments of Soil Science and Biological and Agricultural Engineering, North Carolina Agricultural Research Service, North Carolina State University Raleigh, North Carolina. Technical Bulletin 318, September 2002.
5 Ward, A., Moore, M. T., Bouchard, V., Powell, K., Mecklenburg, D., Cooper, C. M., Smith, and S. Jr. 2004. Water quality benefits of grassed fluvial features in drainage ditches. *Advances in Hydro-Science and Engineering. 4:1-14.*
6 ODNR Annual Report. January, 2007. ODNR, Division of Soil and Water Conservation. **www.ohiodnr.com/soilandwater/**

6.3.3 Bacteria

Problem statement

It is known that several streams in the Powell Creek watershed including Wagner Run have unsafe levels of bacteria associated with fecal matter. This has been the subject of an ongoing enforcement case between the Ohio EPA and the Ayersville Water and Sewer District (AWSD). Exposure to such high levels of bacteria can lead to illness in humans and animals (e.g., cattle or other livestock). The minimum number of bacteria samples required to document a recreation use impairment was not collected during the study period in 1999 and 2000. However, in 1972, 1974, 1978, 1988, 1993, 2004, 2005 and 2008 Ohio EPA sampled the ditches and streams in the AWSD and documented unsanitary conditions and a public health nuisance. In April 2003, the local Health Department submitted a complaint to the Director of Ohio EPA under Ohio Revised Code (ORC) Section 6117.34 describing a sewage nuisance in the Ayersville Ave. and Dohoney Road area. A bacteria TMDL was not calculated for this watershed.

Management approach for abatement

Reducing fecal bacteria loading to surface waters is achieved by limiting the amount of manure or human waste that is available to be transported in runoff or through sub-surface drainage tile.

Addressing HSTS as a source of bacterial pollution is best served by eliminating reliance on these systems for treating human wastes. Connecting unsewered residences to centralized treatment systems is an effective and permanent way to eliminate this source of impairment.

The Ohio EPA issued Director’s Final Findings and Orders (DFFOs) to Ayersville in November 1993. These orders required AWSD to submit detail plans for wastewater collection and treatment facilities sufficient to abate the unsanitary conditions. Construction was to be complete by December 1997. AWSD failed to comply with these orders. Consequently, DFFOs were again issued by Ohio EPA on December 30, 2005. These orders required AWSD to complete Phase B1 and Phase B2 according to the schedule contained in the orders. The orders also included Phase C which was the area outlined by the ORC 6117.34 complaint from the Health Commissioner. AWSD has not met any of the dates in these DFFOs. However, in July 2008, AWSD submitted a Permit to Install (PTI) for both Phase B areas. The PTI was issued by the Director on August 25, 2008. They plan to start construction of the sewers in May 2009.

In the Powell Creek watershed, the sewers will run along State Route 66, east on Bowman Road to just past Fulmer Road and east on Watson Road to Dohoney Road. Sewers will extend south on Dohoney Road to pick up the houses on the south side of Wagner Run. Sewers will also be installed on State Route 15. The Phase C area will be served by the city of Defiance. All AWSD drinking water customers will eventually be served by a sewer connection to the city of Defiance.

Pollution from livestock manure can be reduced by fencing or other exclusion practices that limit or deny livestock access to streams. Proper manure handling and storage reduces runoff contamination and is achieved through the construction of adequate storage facilities and stormwater controls. Manure that is land applied should be done so according to guidance from the Natural Resource Conservation Service (NRCS) and applicable standards (Standard 633) or a Manure Management Plan (MMP) or Comprehensive Nutrient Management Plan (CNMP) that is specific to a given operation. Manure discharges occurring through sub-surface drainage tiles following field application can often be avoided if drainage water management control structures are in place. NRCS conservation practices that are appropriate for abating this source of pollution include:

- Livestock Use Exclusion (472)
- Waste utilization (633)
- Nutrient Management (590)

- Watering Facility (614)
- Waste Storage Facility (313)
- Drainage Water Management (554).

Composting manures may also be a viable way to utilize livestock waste and reduce the threat to water quality. The stabilization of the manure materials during the composting process and the proper handling and storage of this material reduces the risk of pollutant loading via storm water runoff. More information regarding composting can be found on the Ohio Composting and Manure Management Program's web site (**http://www.oardc.ohio-state.edu/ocamm/**).

6.4 High priority conservation areas

The conservation management needed to improve water quality often requires more resources and funding assistance than are readily available (e.g., through Farm Bill programs). Therefore it is important to prioritize locations within the watershed that will lead to the greatest water quality improvement.

Ways to abate water quality problems were discussed in the preceding section. Areas to focus on in implementing these management practices will be discussed in this section. The following are priority areas for conservation:

- Areas with relatively high runoff rates
- Near channel areas
- Wetlands and depressional areas
- Areas conducive for applying water table management
- Areas conducive for over-wide or a two-stage ditch approach

Areas with relatively high runoff rates

The data for this basin show that runoff-related flows transport the biggest pollutant loads. High runoff areas are low areas on the landscape and areas that have poorly drained soils. Such areas are associated with frequently flooded and hydric (i.e., wetland-type) soils. Figure 6-7 is a map of the watershed that indicates the frequently flooded soils (shown in red) and the hydric soils (both blue-green and tan colored).

Watershed-wide it estimated that there are 2188 acres of frequently flooded soils accounting for approximately 3.5% of the total watershed area. Just over half of these soils are found within the first 100 feet closest to the stream. Soils that strongly exhibit wetland characteristics are considered completely hydric and account for 1,919 acres in the watershed (3%). Soils that show varying degrees of wetland characteristics are partially hydric and make up 43,937 acres of the total (70%). The large proportion of hydric soils is due to the fact that the region had formerly been a part of the Great Black Swamp, which was a massive swamp that formed following the last glacial retreat and extended southwest of the current Lake Erie shoreline. This swamp was drained as the north western part of Ohio was settled in the mid 1800s.

Other areas likely to produces a large proportion of runoff are steeply sloping soils. Since the watershed is very flat, such areas are rare and almost always occur along ravines located near stream channels.

Near-channel areas

Areas immediately adjacent to water courses, or riparian areas, have been shown to be particularly important in buffering upland pollutants (Osborne and Kovacic 1993, Peterjohn and Correll 1984). Near channel areas also impact stream temperatures and provide organic matter that is important for stream processes.

Wetlands and depressional areas
Wetland restoration should be pursued as a means for reducing non-point source pollution coming from cropland and areas supporting livestock production. Wetlands located between the pollution source areas and the ditch or stream channel are optimal.

Prerequisites for appropriate wetland restoration, creation and/or enhancement are appropriate hydrology and soils. The areas selected should be consistent with NRCS standards (656, 657, and 658). The pervasiveness of hydric soils makes it likely that most areas within the watershed are suitable for wetland restoration or creation. Low lying areas that are problematic for crop production should be particularly well-suited.

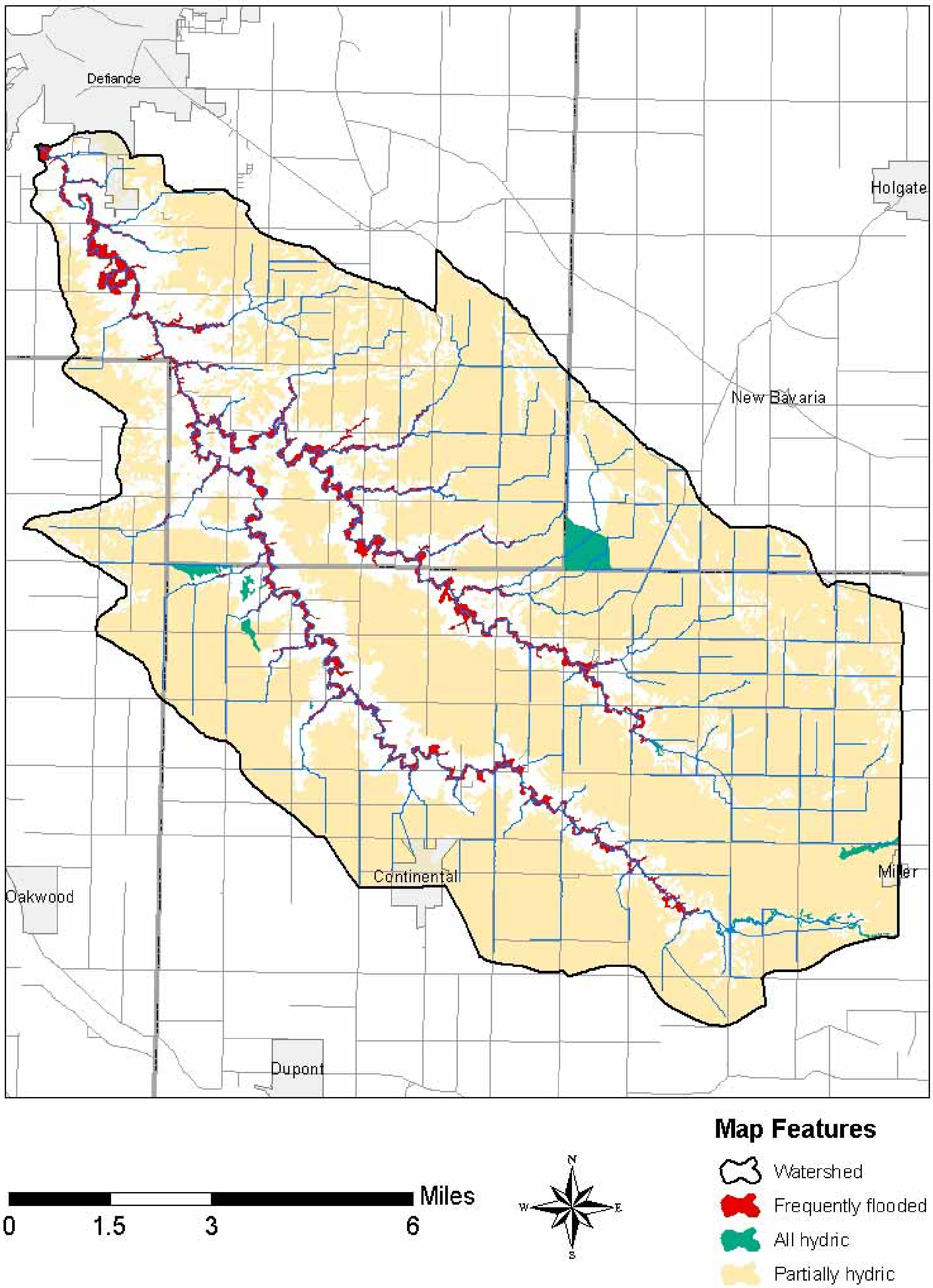

Figure 6-7. High priority conservation areas related to soils characteristics.

Areas conducive for applying water table management

Water table management (NRCS practice 554) can be applied to land where there is an appropriate outlet for the sub-surface drainage system. Water table management should not be applied on land that will create significant impact to the drainage patterns of adjacent land unless there is consent from those property owners.

Water table management is optimized when the greatest amount of land is effected with the fewest number of water table control structures. The following are conditions where water table management is optimized:

- Flat, relatively uniform topography (preferably slopes less than 1%).
- Appropriate arrangement of the sub-surface drainage system
  - Systematic or pattern drainage is preferred to random drainage
  - Tiles arranged along elevation contours

The flat topography and the likely extensive use of sub-surface drainage make the Powell Creek watershed exceptionally well-suited for the use of water table management. Priority areas should be those with high nitrate loading since sub-surface drainage is a primary pathway for this pollutant. The North Powell Creek sub-watershed and the tributary stream Wagner Run, are particularly important.

Areas conducive for over-wide or a two-stage ditch approach

Over-wide or two-stage channels can more easily be established in relatively small ditches due to the fact that the amount of excavation required is related to the size of the channel. Therefore it is most practical to focus on headwater ditches or ditches where the required increase in channel width is smaller.

Another reason for focusing on small ditches lies in the fact small streams tend to more efficient in terms of processing nutrients (Alexander et al., 2000, Petersen et al., 2001). Small streams have been shown to have uptake rates for nitrogen that are almost two orders of magnitude greater than larger streams (Alexander et al., 2000).

Stream segments within the Powell Creek watershed with the following characteristics were selected and identified using geographic information systems (GIS) as target areas for using an over-wide channel approach:

- Signs of channelization or significant modification
- Drainage area of 5 square mile or less
- Low gradient
- Headwater stream segments

Suggested two-stage ditch or over-wide channel implementation areas within the Powell Creek watershed are displayed in Figures 6-8, 6.9, and 6-10 and described in Tables 6-4, 6-5, and 6-6. Table 6-7 is the soil loss estimated for the upstream drainage area, a sediment load delivered to each stream segment, and sediment trapping effectiveness values based on pre- and post- floodplain development.

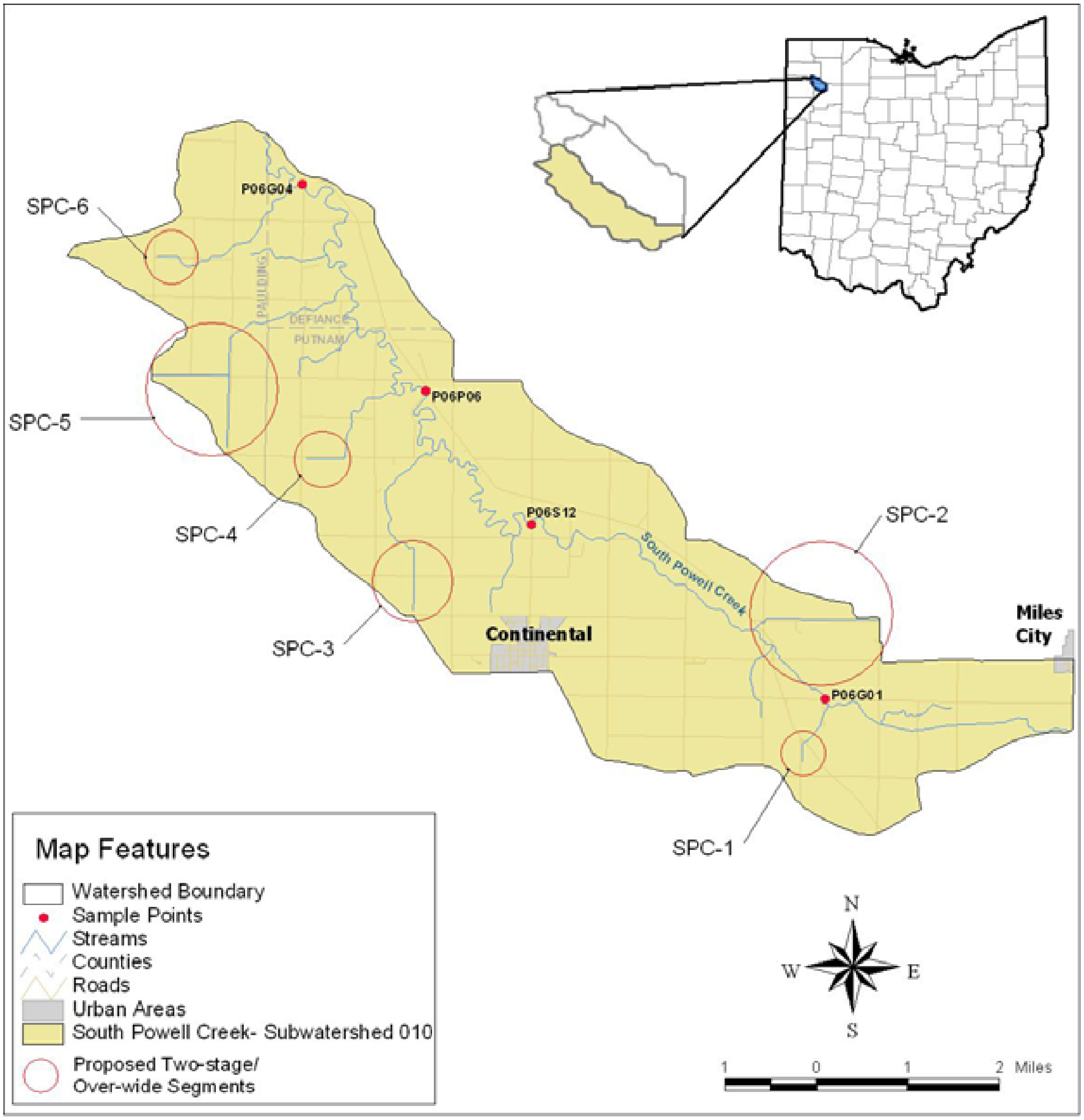

Figure 6-8. Potential sites for employing a two-stage or over-wide drainage channel approach in the South Powell Creek sub-watershed.

Table 6-4. Descriptions of potential sites for employing a two-stage or over-wide drainage channel approach in the South Powell Creek sub-watershed.

Site Number	Stream Segment Length (feet)	Gradient (feet/mile)	Drainage Area (mi^2)	Location Within the South Powell Creek Watershed
SPC-1	1,250	12.56	0.5	Section of tributary adjacent to the eastern side of State Route 115, south of State Route 15
SPC-2	7,700	6.78	0.8	Section of tributary adjacent on the northern side of Road E, between Road 18 and Township Road 16-C
SPC-3	4,250	0.15	0.9	Section of tributary between Road D and Road E to the north and south and Road 22 and Road 23 to the east and west
SPC-4	2,600	6.72	0.5	Section of tributary adjacent to the southern side of Road C, east of Road 23
SPC-5	7,439 S→N reach	2.83	1.2	Sections of tributary flowing to the north alongside County Road 263 and flowing east alongside County Highway C-148
	5,252 W→E reach	3.55		
SPC-6	1,375	2.20	0.8	Section of tributary north of Township Highway T-174 between Township Highway T-213 and County Road 209.

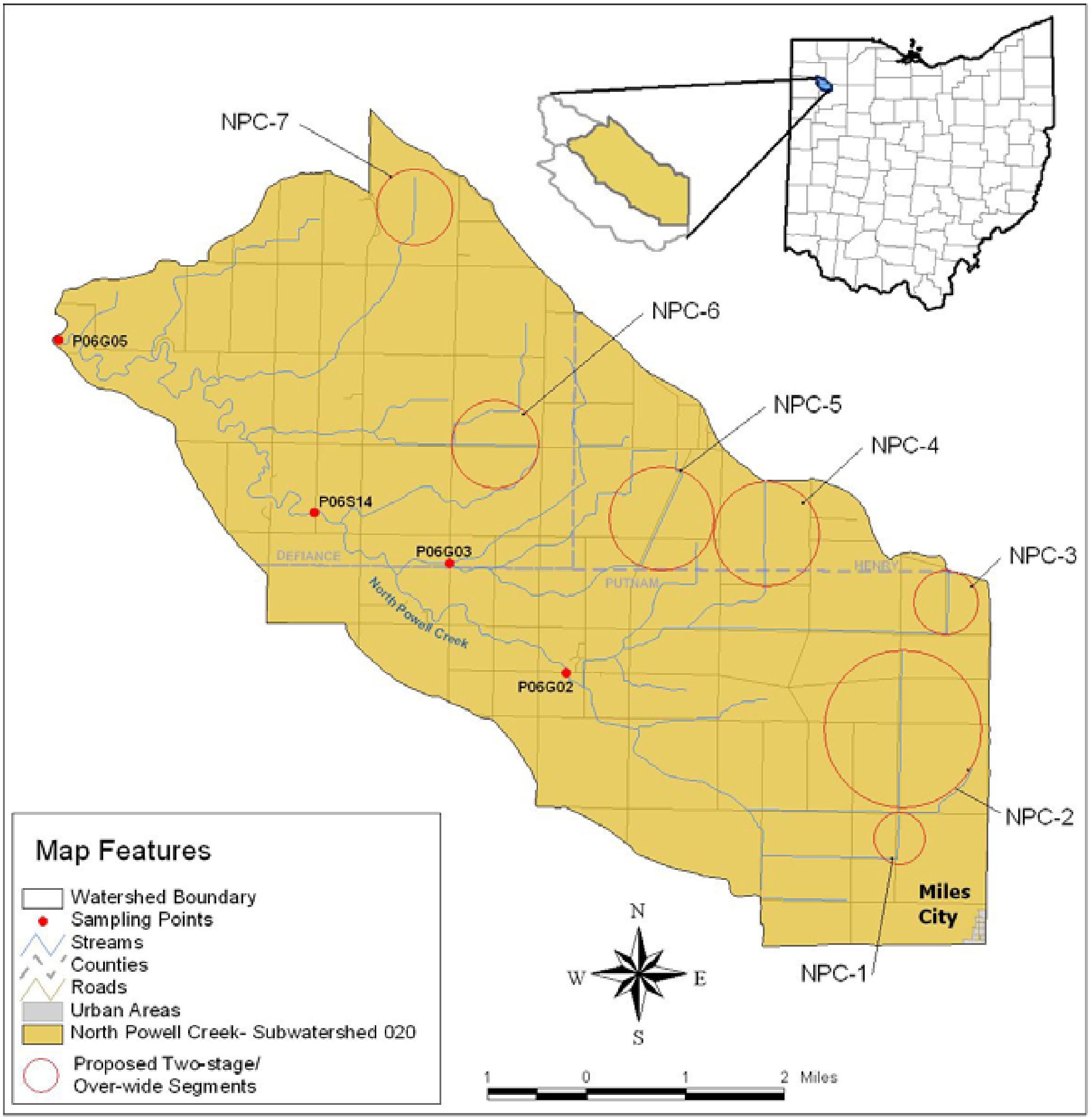

Figure 6-9. Potential sites for employing a two-stage or over-wide drainage channel approach in the North Powell Creek sub-watershed.

Table 6-5. Descriptions of potential sites for employing a two-stage or over-wide drainage channel approach in the North Powell Creek sub-watershed.

Site Number	Stream Segment Length (feet)	Gradient (feet/mile)	Drainage Area (mi^2)	Location Within the North Powell Creek Watershed
NPC-1	2,550	10.33	0.2	Section of tributary flowing north to south, adjacent to and east of Road 15, between Road D and Road E
NPC-2	6,460	8.92	1.8	Section of tributary flowing north to south, adjacent to and east of Road 15, between Road B and Road D
NPC-3	3,620	7.27	0.4	Section of tributary flowing north to south, adjacent to and east of Road 14-A, between the Henry-Putnam County line and Road B
NPC-4	6,000	7.29	1.0	Section of tributary flowing north to south, east of Twp. Road 17, west of Co. Road 16, and north of Twp. Road A-16
NPC-5	5,770	9.14	0.8	Section of tributary flowing northeast to southwest, adjacent to Co. Road 17A, between Co. Road B and the Henry-Putnam County line
NPC-6	4,890	5.39	0.6	Section of tributary flowing east to west, adjacent to and north of Mansfield Road, between Defiance-Henry County Line Road and Kinner Road
NPC-7	3,050	8.23	0.9	Section of tributary flowing north to south, north of Blanchard Road, West of Kinner Road, and East of Harris Road

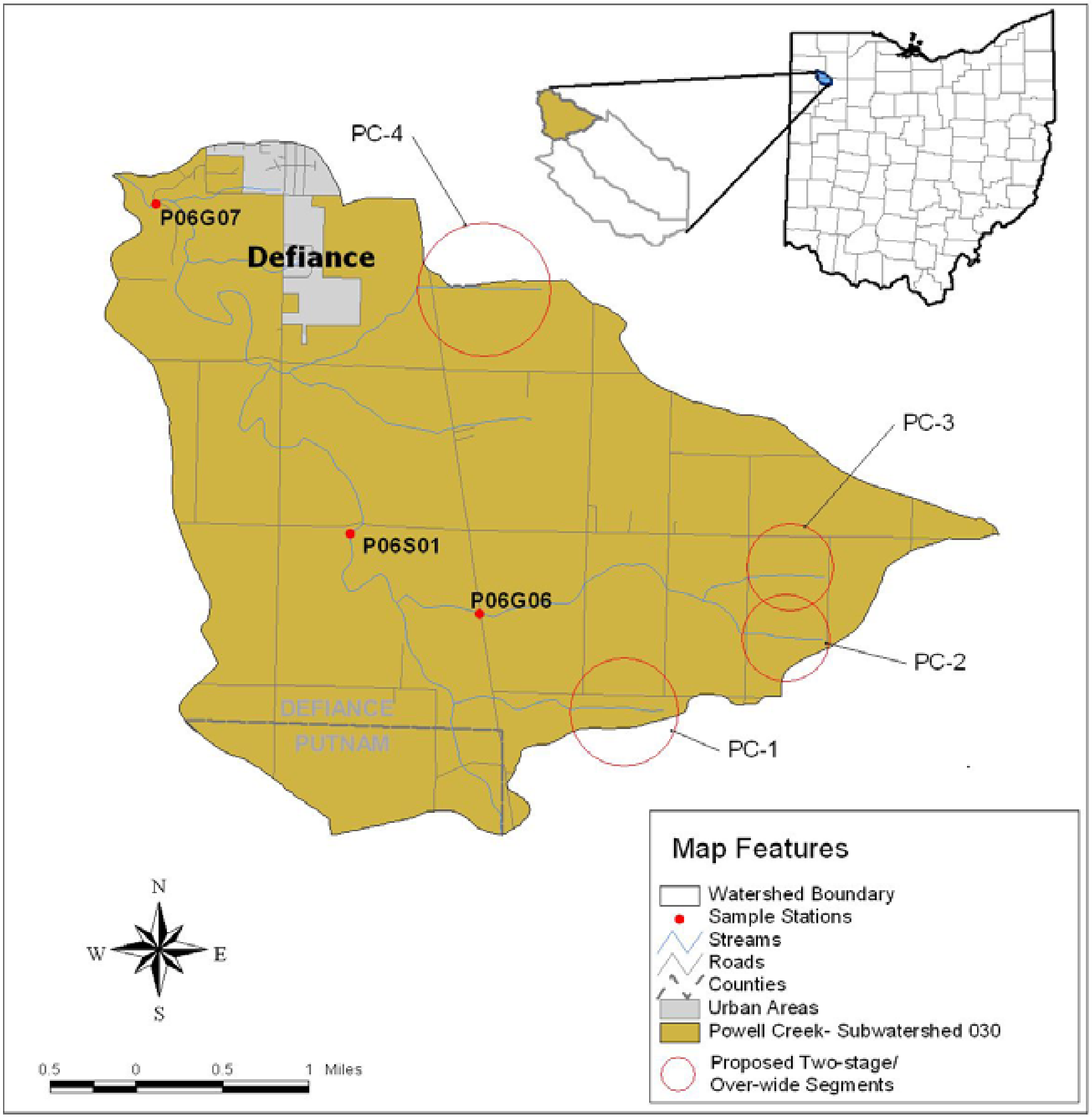

Figure 6-10. Potential sites for employing a two-stage or over-wide drainage channel approach in the Powell Creek sub-watershed.

Table 6-6. Descriptions of potential sites for employing a two-stage or over-wide drainage channel approach in the Powell Creek sub-wateshed.

Site Number	Stream Segment Length (feet)	Gradient (feet/mile)	Drainage Area (mi^2)	Location Within the Powell Creek Watershed
PC-1	2,690	14.20	0.2	Section of tributary flowing east to west, adjacent to and south of Blanchard Road
PC-2	2,630	10.02	0.3	Section of tributary flowing east to west, north of Blanchard Road, east of Twp. Road 179, and west of Painter Road
PC-3	2,550	10.33	0.7	Section of tributary flowing east to west, south of Bowman Road, east of Twp. Road 179, and west of Painter Road
PC-4	4,075	7.76	0.3	Section of tributary flowing east to west located east of State Route 15, north of Watson Road, and west of Dohoney Road

Table 6-7. Estimated sediment trapping efficiency for over-wide channel projects.

Reach	Watershed Soil Loss (Tons/Year)	Sediment Delivered to Stream (Tons/Year) [1]	1,000 ft Project Sediment Retention[2] (Tons/Year)		Entire Drainage Network Project Sediment Retention[3] (Tons/Year)	
			Pre-floodplain (20% efficiency)	Post-floodplain (4% efficiency)	Pre-floodplain (23% efficiency)	Post-floodplain (9% efficiency)
SPC-1	537	177	35	7	41	16
SPC-2	966	319	64	13	73	29
SPC-3	1,066	352	70	14	81	32
SPC-4	669	221	44	9	51	20
SPC-5	1,421	469	94	19	108	42
SPC-6	964	318	64	13	73	29
Resulting Sediment Reductions for South Powell Creek			**371**	**74**	**427**	**167**
NPC-1	246	81	16	3	19	7
NPC-2	2,181	720	144	29	166	65
NPC-3	505	167	33	7	38	15
NPC-4	1,083	357	71	14	82	32
NPC-5	967	319	64	13	73	29
NPC-6	720	238	48	10	55	21
NPC-7	1,121	370	74	15	85	33
Resulting Sediment Reductions for North Powell Creek			**450**	**90**	**518**	**203**

Reach	Watershed Soil Loss (Tons/Year)	Sediment Delivered to Stream (Tons/Year)[1]	1,000 ft Project Sediment Retention[2] (Tons/Year)		Entire Drainage Network Project Sediment Retention[3] (Tons/Year)	
			Pre-floodplain (20% efficiency)	Post-floodplain (4% efficiency)	Pre-floodplain (23% efficiency)	Post-floodplain (9% efficiency)
PC-1	236	78	16	3	18	7
PC-2	292	96	19	4	22	9
PC-3	783	258	52	10	59	23
PC-4	263	87	17	3	20	8
Resulting Sediment Reductions for Powell Creek			**104**	**21**	**119**	**47**

1 Sediment delivery ratio of 0.33 used.
2 Based on conservative estimates- a 1,000 ft long over-wide channel in a 1 mi^2 watershed has estimated sediment trapping efficiency of 21.0 and 4.2 percent. Floodplain development is estimated to occur in about 18 years.
3 Based on conservative estimates- an entire drainage network over-wide channel in a 0.5 mi^2 watershed has estimated sediment trapping efficiency of 23.0 and 9.3 percent. Floodplain development is estimated to occur in about 19 years.

If improvements are made in the noted headwater reaches, reductions in the sediment load entering the mainstem of Powell Creek will likely occur. The potential improvements that two-stage and over-wide ditches may offer have yet to be fully quantified, but multiple pilot projects are currently being monitored for water quality, habitat, and aquatic life improvements after project implementation. The anticipated benefits have also been qualified in several previously maintained ditches that have undergone natural stream evolution processes by adjusting towards two-stage ditches (Ward et al., 2004).

6.5 Current land management

Watershed planning efforts occur over a shorter period than the long-term commitment that conservation professionals have to their county or region. For this reason it is important that planning processes account for the existing conservation work being done and make connections between these efforts and the resource needs identified through water quality studies and planning processes.

Section 6.3 discussed conservation practices for abating water quality problems. This section considers current management in the basin relative to those recommendations and focuses on the following:

- Cropping systems, tillage and residue management
- Land set-asides and buffers

6.5.1 Cropping systems, tillage and residue management

Residue management are conservation practices that are eligible for cost share through the Environmental Quality Incentives Program (EQIP). Common cost-share practices include conservation crop rotation (328), mulch tillage (329A), no-till and strip tillage (329B), ridge tillage (329C), and seasonal tillage (344).

Current status in the watershed

The exact number of acres employing conservation tillage in the Powell Creek watershed is unknown, but it is likely that 25to 50 percent of the row crop acres are currently being planted in this way. Table 6-9 shows the cropland acres that employed conservation tillage through federal cost share programs.

Table 6-8. Cropland acres employing conservation tillage using cost share programs.

Conservation Practice		2006	2005	2004	2003
Conservation Crop Rotation (328)		447	2028	1167	0
Residue Management	Mulch Till (329B)	0	457	248	321
	No-Till/Strip Till (329A)	445	1530	894	192
	Ridge Till (329C)	0	0	0	0
	Seasonal Tillage (344)	1	24	1	0
TOTAL		893	4039	2310	513

The effectiveness of conservation in reducing soil losses estimated to be between 75 and 88 percent as compared to conventional tillage (see Table 6-3). A comparison of the soil losses between these two tillage practices are illustrated in Table 6-10, which is based upon the Universal Soil Loss Equation. Table 6-10 assumes that 50% of the cropland in the watershed employs conventional tillage while the remaining 50% employs conservation tillage.

Table 6-9. Comparison of soil loss and delivery to surface waters between conventional and conservation tillage.

Tillage Practice	Area (acres)	Percent of Total Area	Estimated Soil Loss[1] (tons/year)	Soil Delivery to streams[2] (tons/year)
South Powell Creek Sub-watershed				
Conventional Tillage	10,982.46	42.7%	32,132	3,856
No Till	10,982.46	42.7%	13,450	1,614
North Powell Creek Sub-watershed				
Conventional Tillage	12,537.17	41.8%	36,680	4,035
No Till	12,537.17	41.8%	15,355	1,689
Powell Creek Sub-watershed				
Conventional Tillage	2,994.42	36.5%	8,761	1,489
No Till	2,994.42	36.5%	3,667	623
Watershed Total				
Conventional Tillage	26,514.05	42.4%	77,573	9,380
No Till	26,514.05	42.4%	32,472	3,926

[1] Soil loss estimated using the Universal Soil Loss Equation (USLE).

[2] Assuming a sediment delivery ratio of 0.17 based on watershed size (Vanoni, 1975).

6.5.2 Buffers and land set-asides

The Conservation Reserve Program (CPR) and the Conservation Reserve Enhancement Program (CREP) are significant ways to compensate farmers for taking land out of production to improve environmental quality. These programs provide cost-share assistance for the establishment of vegetative cover on the land to be set-aside. Rental payments are also made to compensate for the loss of income from crop production on those lands.

Current status in the watershed

In the Powell Creek watershed there are approximately 2007 acres enrolled in either CRP or CREP. This accounts for about 3.9% of the total cropland. Permanent wildlife habitat (CP4D) is the predominant CRP conservation practice installed in the Powell Creek watershed and accounts 28.1% (564 acres) of the total. Grassed filters strips are the second most widely used CRP conservation practice and has 23.5% (507 acres) of the total. These practices, along with those protecting escarpment areas and providing filtered recharge, account for over 78% (1685 acres) of all of the CRP land in the watershed.

The priorities areas identified in Section 6.4 are riparian zones and variable source areas as defined by areas of more frequent runoff. Specifically these were defined as frequently flooded soils and hydric soils. Currently 212 acres of CRP (including CREP) coincide with frequently flooded soils in the Powell Creek watershed accounting for nearly 10% of the 2188 frequently flooded acres.

If a 100 foot buffer were to be applied throughout the entire drainage network the total area would be 4,443 acres accounting for 7.1% of the watershed. A similarly placed 50 foot buffer would have an area of 2,229 acres and make up 3.7% of the watershed. Within the 100 foot buffer there would be 1,139 acres of frequently flooded soils (25.6 % of the total buffer area), whereas for the 50 foot buffer there would be 639 acres (28.7 % of the total buffer area).

Table 6-10 shows the extent and overlap of areas in the watershed that are particularly relevant for conservation practices that were discussed above. These areas are those that are environmentally sensitive based on position in the watershed or soil characteristics. Also included in Table 6-10 are cropland acres enrolled in CRP or CREP as of early 2007.

Table 6-10. Overlap of specific land areas that have characteristics, uses, and/or critical locations within the watershed that are important for water quality protection. The values below the darker grey boxes indicate the area of overlap between the two respective land categories measured in acres. The "watershed total" column shows how many total acres there are of each category in the entire basin. The percentages shown above the darker grey boxes indicate the percent that the overlap accounts the total area of the category of the respective row.

	Watershed total	Frequently flooded soils	All hydric soils	Partially hydric soils	100 ft buffer zone	50 ft buffer zone	CRP/ CREP
Watershed total	**62,404**	**4%**	**3%**	**70%**	**7%**	**4%**	***3%***
Frequently flooded soils	**2,188**		63%	8%	52%	29%	*10%*
All hydric soils	**1,919**	1,380		0%	45%	25%	*9%*
Partially hydric soils	**43,937**	178	0		6%	3%	*2%*
100 ft buffer zone	**4,443**	1,139	857	2,578		50%	*8%*
50 ft buffer zone	**2,230**	639	488	1,302	2,230		*8%*
CRP/CREP	***2,007***	*212*	*182*	*759*	*335*	*170*	

6.6 Process for Evaluation and Revision

The effectiveness of actions implemented based on the TMDL recommendations should be validated through ongoing monitoring and evaluation. Information derived from water quality analyses can guide changes to the implementation strategy to more effectively reach the TMDL goals. Additionally, monitoring is required to determine if and when formerly impaired segments meet applicable water quality standards (WQS).

6.6.1 Evaluation and Analyses

Aquatic life and recreational uses are impaired in the watershed, therefore monitoring that evaluates the river system with respect to these uses is a priority to the Ohio EPA. The degree of impairment of aquatic life use is exclusively determined through the analysis of biological monitoring data. Recreational use impairment is determined through bacteria counts from water quality samples. Ambient conditions causing impairment include high phosphorus and sediment concentrations (or loads) and degraded habitat. This report sets targets values for these parameters (e.g., in-stream concentrations or loads and habitat features; see Chapter 4), which should also be measured through ongoing monitoring.

A serious effort should be made to determine if and to what degree the recommended implementation actions have been carried out. This should occur within an appropriate timeframe following the completion of this TMDL report and occur prior to measuring the biological community, water quality or habitat.

Past and Ongoing Water Resource Evaluation
The Ohio EPA has conducted water quality surveys in the Powell Creek watershed in 1984, 1991, and 2000. The Ohio EPA is scheduled to perform biological, water quality, habitat, and sediment chemistry monitoring in all four assessment units in the basin in 2015 (OEPA, 2008).

Recommended Approach for Gathering and Using Available Data
Early communications should take place between the Ohio EPA and any potential monitoring collaborators to discuss research interests and objectives. Through this, areas of overlap should be identified and ways to coordinate all parties' research efforts to maximize the information gathered should be discussed. Ultimately important questions can be addressed by working collectively and through pooling resources, knowledge, and data.

6.6.2 Revision to the Implementation Approach

An adaptive management approach will be taken in the Powell Creek watershed. Adaptive management is recognized as a viable strategy for managing natural resources (Baydack et al., 1999). An adaptive management approach allows for changes in the management strategy if environmental indicators suggest that the current strategy is inadequate or ineffective. The recommendation put forth for the Powell Creek watershed largely center on improving in-stream habitat, increasing floodplain connectivity, and the abatement of sediment and nutrients loads. If chemical water quality does not show improvement and/or water bodies are still not attaining water quality standards after the implementation plan has been carried out, then a TMDL revision would be initiated. The Ohio EPA would initiate the revision if no other parties wish to do so.

7.0 REFERENCES

Alexander, R. B., R. A. Smith, and G. E. Schwarz. 2000. Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico. Nature 403:758–761.

Baker D.B. Heidelberg College – Water Quality Lab, personal communication, March, 2006.

Baydack R.K., Campa H., and Haufler J.B. Eds. 1999. Practical approaches to the conservation of biological diversity. Island Press, Washington D.C.

Cleland, B. 2005. TMDL Development Using Duration Curves. Update & Habitat TMDL Applications. Presentation made at Region 5 TMDL Practitioners' Workshop
Hickory Corners, MI. November 15, 2005.

Fausey N.R. 2004. Comparison of Free Drainage, Controlled Drainage, and Subirrigation Water management Practices in an Ohio Lakebed Soil. ASAE/CSAE Meeting Paper No. 042237, St Joseph, Michigan.

Mecklenburg, D. September 2005. Low Gradient Headwater Channel Form and Function. Ohio Department of Natural Resources- Division of Soil and Water Conservation.

Mitsch W.J. and Gosselink J.G. 2000. Wetlands, 3rd edition, John Wiley and Sons, NY.

Ohio EPA (Ohio Environmental Protection Agency). 1999. *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams*. OEPA Technical Bulletin MAS/1999-1-1. Columbus, Ohio.

Ohio EPA (Ohio Environmental Protection Agency). 2000. Technical Support Document for the Powell Creek Watershed. Columbus, Ohio.

Ohio EPA (Ohio Environmental Protection Agency). 2006. Ohio 2006 Integrated Water Quality Monitoring and Assessment Report. State of Ohio. Environmental Protection Agency. Division of Surface Water. May 1, 2006.

Ohio EPA. 2008. Biological and Water Quality Study of the Paint Creek Watershed, 2006. Clinton, Fayette, Greene, Highland, Madison, and Ross Counties, Ohio.. Division of Surface Water, Columbus, OH. EAS/2008-1-2

Osborne L. L. and Kovacic D. A. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. Freshwater Biology. 29: 243-258.

Peterjohn W.T., and Correll D.L. 1984. Nutrient dynamics in an agricultural watershed – observations on the role of a riparian forest. Ecology. 65 (5): 1466-1475.

Peterson, B. J., W. M. Wolheim, P. J. Mulholland, J. R.,Webster, J. L. Meyer, J. L. Tank, E. Marti, W. B. Bowden, H. M. Valett, A. E. Hershey, W. H., McDowell, W. K. Dodds, S. K. Hamilton, S. Gregory, D. D. Morrall, 2001. Control of nitrogen export from watersheds by headwater streams. *Science* 292: 86-90.

Rankin, Ed. 1989. The Qualitative Habitat Evaluation Index (QHEI). Rationale, methods, and applications. Division of Water Quality Planning and Assessment, Ecological Analysis Section. Columbus, Ohio.

Sloto, Ronald A. and Crouse, Michele Y. 1996. HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis. U.S. Geological Survey. Water-Resources Investigations Report 96-4040.

U.S. EPA (United States Environmental Protection Agency). 1997. Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and Rivers.

U.S. EPA (United States Environmental Protection Agency). 2007. DFLOW 3.1- a Windows based tool developed for low flow analysis. Available for download at :
http://www.epa.gov/waterscience/models/dflow/

Vellidis G., Lowrance R.R., Gay P., Hill R., and Hubbard R.K. 2003. Nutrient Transport In A Restored Riparian Wetland. Environmental Quality. 32: 711-726.

Ward, A.D., Moore, M.T., Bouchard, V.L., Powell, K., Mecklenburg, D., Cooper, C.M., and Smith, S. Jr. 2004. Water quality benefits of grassed fluvial features in drainage ditches. *Advances in Hydro-Science and Engineering*. 4: 1-14.