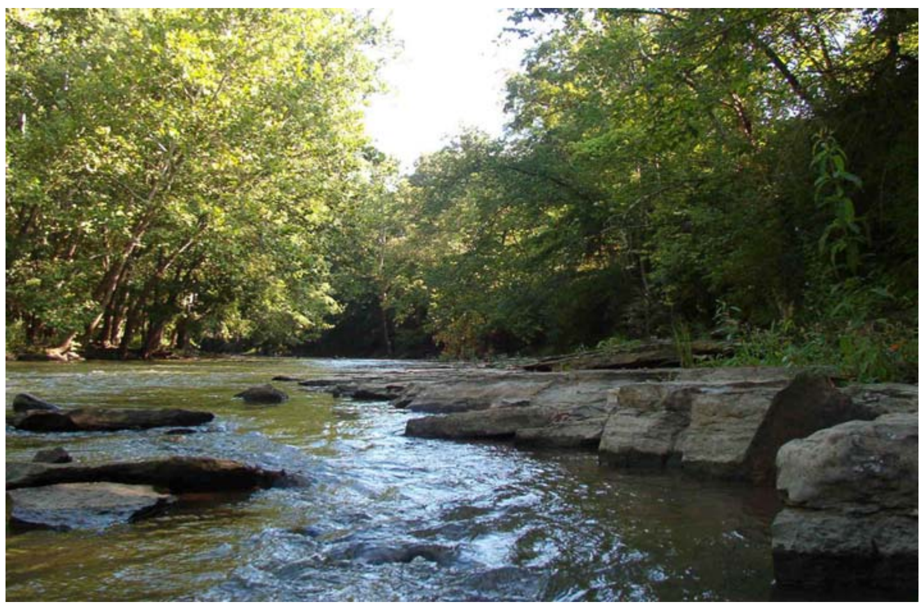
OhioEPA

State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Olentangy River Watershed



Olentangy River, just downstream of the City of Delaware

Final Report
August 24, 2007

Ted Strickland, Governor
Chris Korleski, Director

Table of Contents

List of Tables

List of Tables
(continued)

Appendix B: Supplemental Tables and Figures

List of Figures

Appendix A: Supplemental Maps

Appendix B: Supplemental Tables and Figures

List of Acronyms and Abbreviations

BIT	Bacteria Indicator Tool
BMP	best management practice
cm	centimeter
CNMP	Comprehensive Nutrient Management Plan
cnt/seas	counts per season
CO	consent agreement
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
CWH	Cold Water Habitat
DA	drainage area
DCRPC	Delaware Regional Planning Commission
DEFA	Division of Environmental and Financial Assistance
DFFOs	Directors Final Findings and Orders
DGHD	Delaware County General Health District
DNAP	Division of Natural Areas and Preserves
DSW	Division of Surface Water
DSWC	Division of Soil and Water Conservation
ECBP	Eastern Corn Belt Plains
EQIP	Environmental Quality Incentives Program
EWH	Exceptional Warmwater Habitat
FC	Fecal Coliform
FLOW	Friends of the Lower Olentangy River
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
LTCP	Long-Term Control Plan
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
MORPC	Mid-Ohio Regional Planning Commission
MOS	margin of safety
MS4	municipal separate storm sewer system
MWH	Modified Warmwater Habitat

NACD	National Association of Conservation Districts
NEMO	Nonpoint Education for Municipal Official
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resource Conservation Service
OAC	Ohio Administrative Code
OAEA	Ohio Agricultural Environmental Assurance
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OECC	Olentangy Environmental Control Center
OFAER	On Farm Assessment and Environmental Review
OFBF	Ohio Farm Bureau Federation
OLC	Ohio Livestock Coalition
ORC	Ohio Revised Code
OSU	The Ohio State University
OWA	Olentangy Watershed Alliance
PCR	Primary Contact Recreation
PIR	Pollution Investigation Report
PTI	Permit to Install
QHEI	Qualitative Habitat Evaluative Index
RC&D	Resource Conservation and Development
RI	return interval
RM	river mile
SCR	Secondary Contact Recreation
SCS	Soil Conservation Service
SECAP	System Evaluation and Capacity Analysis Plan
SSO	sanitary sewer overflow
SSO	separate sewer overflow
SSS	sanitary sewer system
SWAT	Soil and Water Assessment Tool
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
WHC	Wildlife Habitat Council
WLA	wasteload allocations
WPCLF	Water Pollution Control Loan Fund
WQC	Water Quality Certification
WQMP	Water Quality Management Plan
WQS	water quality standards
WRP	Wetland Reserve
WRP	Wetland Reserve Program
WRRSP	Water Resource Restoration Sponsor Program
WTP	water treatment plant
WWH	Warmwater Habitat
WWMP	Wet Weather Management Plan
WWTP	wastewater treatment plant

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1 Introduction

The Olentangy River watershed is an important water resource for central Ohio, providing drinking water, recreation and agricultural drainage for an estimated 250,000 residents and high-quality aquatic habitats for six state-listed endangered, threatened or special concern aquatic species. No other State Scenic River of Ohio drains landscapes with equivalent population growth rates.

The streams in the watershed are home to unique and diverse biological communities of fish, freshwater mussels and the associated benthic invertebrate fauna (aquatic insects, worms, etc.). However, recent studies document declines in water quality and stream habitat. Point source pollution (from pipes), runoff from urban areas and agricultural land, and poor stream bank land management are degrading some stream segments today.

Among the most visible and widely publicized future threats to the Olentangy is conversion of farm land to suburban and commercial land uses, especially in Delaware County. The Olentangy River watershed flows across Ohio's first and sixth most rapidly growing counties, Delaware and Morrow, respectively. In turn, Delaware County's most rapidly developing townships, Delaware, Liberty and Orange largely coincide with Exceptional Warmwater Habitat reaches and the State Scenic River portion of the mainstem.

Ohio EPA conducted a comprehensive physical, chemical and biological survey of the Olentangy River watershed in 2003 and 2004, and several problems were identified. The survey results were published in December 2005; major findings are summarized in this report. Having identified the problems, the next step is an analysis called the Total Maximum Daily Load (TMDL). This report documents the TMDL process for the Olentangy River watershed.

1.1 The Clean Water Act Requirement to Address Impaired Waters

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these impaired waters (the Section 303(d) lists) are made available to the public for comment, then submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval in even-numbered years. Further, the CWA and U.S. EPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the Section 303(d) lists. The Ohio EPA identified the Olentangy River watershed (assessment units 05060001 090, 100, 110, 120) as impaired on the 2006 303(d) list (available at http://www.epa.state.oh.us/dsw/tmdl/2006IntReport/2006OhioIntegratedReport.html).

In the simplest terms, a TMDL is a cleanup plan for a watershed that is not meeting water quality standards. A TMDL is defined as a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that quantity among the sources of the pollutant. Ultimately, the goal of Ohio's TMDL process is full attainment of Water Quality Standards (WQS), which would subsequently lead to the removal of the water bodies from the 303(d) list. **Table 1.1** summarizes how the impairments identified in the Olentangy River watershed are addressed in this TMDL report.

Table 1.1 Summary of TMDLs for the Olentangy River watershed

Hydrologic Unit Code (14 digit)	Listed causes of impairment	TMDL action taken
Upper Olentangy 05060001 090		
090 010 090 020 090 030 090 040	Nutrients Sediment Habitat alteration Flow alteration Bacteria	TMDLs generated for all causes of water quality impairment except for those attributed to flow alteration. Actions taken to address habitat impairments will also abate the negative impacts associated with flow alteration.
Whetstone Creek 05060001 100		
100 010 100 020 100 030	Nutrients Sediment Habitat alteration Temperature Bacteria	TMDLs generated for all causes of water quality impairment except for those attributed to temperature. Actions taken to address habitat impairments will also abate the negative impacts associated with elevated temperature.
Middle Olentangy 05060001 110		
110 010 110 020 110 030 110 040 110 050 110 060 110 070 110 080	Nutrients Sediment Habitat alteration Flow alteration Bacteria	TMDLs generated for all causes of water quality impairment except for those attributed to flow alteration. Actions taken to address habitat impairments will also abate the negative impacts associated with flow alteration.
Lower Olentangy 05060001 120		
110 090 110 100 110 110 120 010 120 020 120 030 120 040 120 050 120 060	Nutrients Sediment Habitat alteration Flow alteration Bacteria	TMDLs generated for all causes of water quality impairment except for those attributed to flow alteration. Actions taken to address habitat impairments will also abate the negative impacts associated with flow alteration.

1.2 Public Involvement

Public involvement is key to the success of water restoration projects, including TMDL efforts. From the beginning, Ohio EPA has invited participation in all aspects of the TMDL program. The Ohio EPA convened an external advisory group in 1998 to assist the Agency with the development of the TMDL program in Ohio. The advisory group issued a report in July 2000 to the Director of Ohio EPA on their findings and recommendations. The Olentangy River watershed TMDL project has been completed using the process endorsed by the advisory group.

To promote public involvement in this TMDL project, Ohio EPA assembled a TMDL team with representatives from all portions of the watershed. Members were drawn from the private sector, local government, non-government organization (NGO), academic, farm and resident citizen populations. The Agency shared with the Team progress reports and solicited assistance and feedback. Participating members included farmers, the operators of water and wastewater treatment facilities, county health department administrators, two watershed groups, city utility staff, county engineering staff, university faculty specializing in hydrogeomorphology and agricultural field drainage; regional planning commission staff, Ohio Department of Natural Resources Scenic Rivers personnel, and consulting engineering firms.

During the project period, Ohio EPA organized a meeting of individuals representing diverse interests throughout the watershed (The Olentangy Forum). Their interests intersect on themes of water resource use, protection and restoration. The purpose of the day-long meeting was the foundation of an Olentangy watershed network for information, resource sharing and mutual project work. A report on the planned TMDL project was presented to this audience in 2005. The public review draft of the Olentangy watershed TMDL was discussed at the Forum's 2006 meeting in September.

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report was available for public comment from October 17 through December 1, 2006. A copy of the draft report was posted on Ohio EPA's web page (www.epa.state.oh.us/dsw/tmdl/index.html). A summary of the comments received and the associated responses is included in Appendix D.

Continued public involvement is critical to the success of any TMDL project. Ohio EPA will continue to support the implementation process and will facilitate to the fullest extent possible, restoration actions that are acceptable to the communities and stakeholders in the study area and to Ohio EPA. Ohio EPA is reluctant to rely solely on regulatory actions and strongly upholds the need for voluntary actions facilitated by the local stakeholders, watershed organization, and agency partners to restore the Olentangy River watershed.

2 Waterbody Overview

The Olentangy River is located in Central Ohio in Crawford, Richland, Delaware, Franklin, Marion and Morrow Counties. The Olentangy River is approximately 93 miles long and flows from the east side of Galion; west then south through agricultural land surrounding Caledonia; past the Villages of Claridon and Waldo before entering Delaware Lake. Downstream from Delaware Lake the mainstem flows through the City of Delaware and areas of suburban development before reaching the City of Columbus. The mainstem joins the Scioto River in downtown Columbus. **Figure 2.1** shows the location of the Olentangy watershed.

2.1 Watershed Division

To facilitate analysis in this TMDL, the land drained by the Olentangy River is divided into four watersheds. The four watersheds are the upper Olentangy, middle Olentangy, lower Olentangy and Whetstone Creek. The upper Olentangy watershed begins at the origin of the mainstem and ends where Flat Run joins the mainstem. The middle Olentangy watershed continues downstream and ends at the Delaware Lake dam. The lower Olentangy watershed continues downstream and ends where the Olentangy River joins the Scioto River. Whetstone Creek is a major tributary to the Olentangy, and its watershed begins in north-central Morrow County and drains to Delaware Lake.

The upper, middle and lower Olentangy watersheds and the Whetstone Creek watershed roughly correspond to Hydrologic Units 05060001 090, 05060001 110, 05060001 120 and 05060001 100, respectively. A Hydrologic Unit is the contributing drainage-area to a stream or river as delineated by the U.S. Geologic Survey (USGS). Each numeric identifier is referred to as an 11-digit Hydrologic Unit Code (HUC11). The first eight characters (05060001) identify the Olentangy watersheds are tributary to the upper Scioto River. The last three characters identify individual divisions of the land drained by the Olentangy River.

The boundary between the middle and lower Olentangy watersheds differs from that between Hydrologic Units 05060001 110 and 05060001 120. The boundary between Hydrologic Units 05060001 110 and 05060001 120 is near the confluence of Delaware Run and the Olentangy Mainstem. However, the boundary between the middle and lower Olentangy watersheds was shifted north to the Delaware Lake Dam, because of the hydrologic significance of the structure. The boundaries of the upper Olentangy and Whetstone Creek watersheds match those of Hydrologic Units 05060001 090 and 05060001 100.

The average area of an Olentangy HUC11 watershed is 140 square miles. Often, when discussing water-quality assessment results or pollutant-loading rates, it is appropriate to examine the landscape at a finer scale. HUC11 watersheds are therefore divided into smaller sub-watersheds identified by a 14-digit Hydrologic Unit Code (HUC14). The average area of a HUC14 sub-watershed is 20 to 25 square miles. Throughout this report HUC14 sub-watersheds are identified first by the HUC11 they are within, followed by their own three-digit number. **Table 2.1** lists the HUC14 sub-watersheds in the Olentangy study area. **Plates A.1** through **A.4** are maps showing the locations of the HUC11 watersheds and HUC14 sub-watersheds.

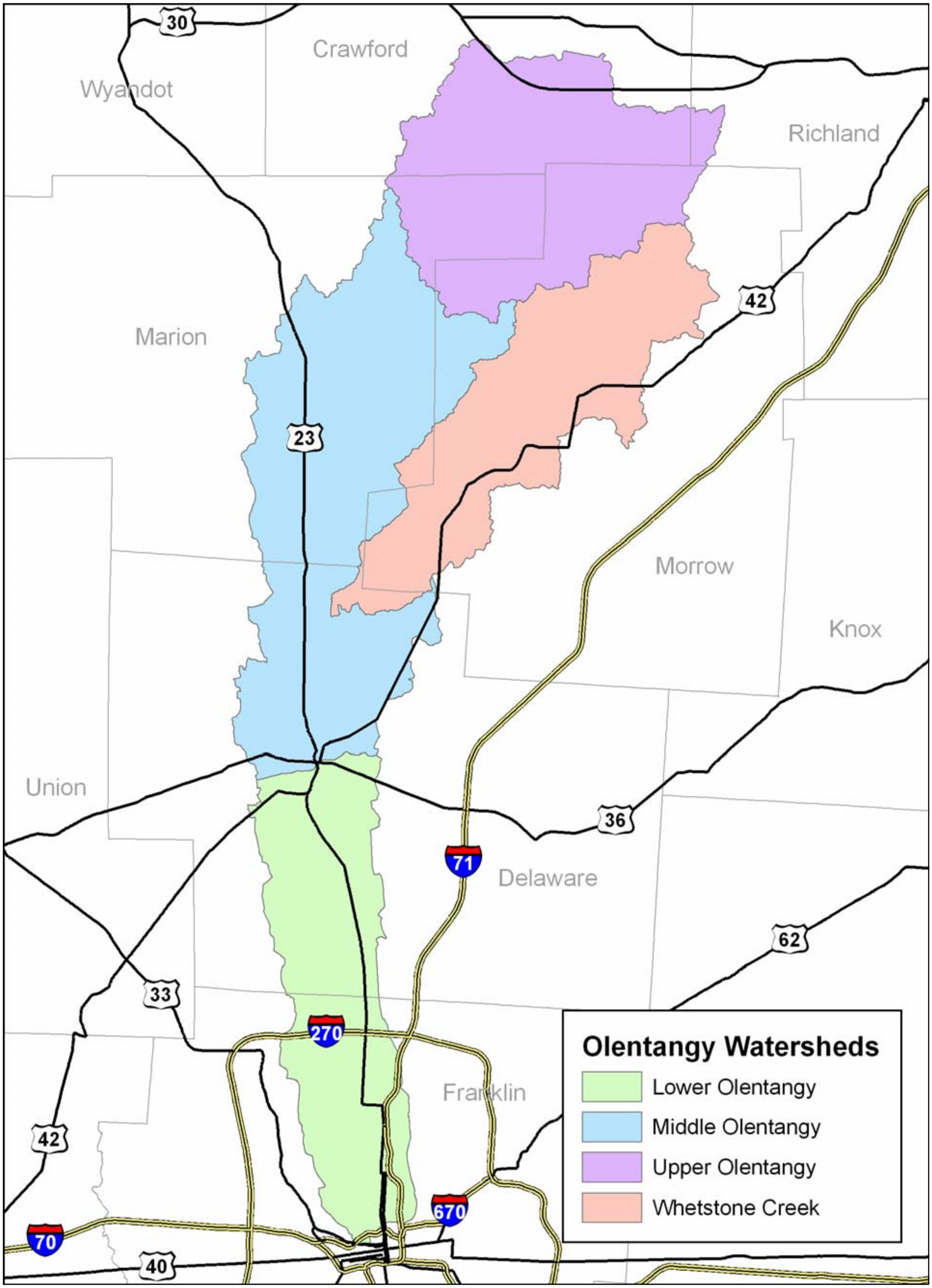

Figure 2.1 Location of the Olentangy watershed

2.2 Ecoregion

The Olentangy River is located within the Eastern Corn Belt Plains (ECBP) ecoregion. An ecoregion is an area having broad similarity with respect to climate, soil, topography and dominant natural vegetation. Less variation of aquatic biological-communities, chemical water quality and physical stream attributes is expected within an individual ecoregion compared to the variation of these characteristics throughout all of Ohio. For this reason some of Ohio's Water Quality Standards are ecoregion-specific.

Table 2.1 Olentangy HUC14 sub-watersheds

HUC14	TMDL Watershed	Narrative Description	Square Miles
090 010	upper Olentangy	Olentangy R. headwaters to near New Winchester	49.3
090 020	upper Olentangy	Olentangy R. near New Winchester to above Flat Run	21.2
090 030	upper Olentangy	Mud Run	20.5
090 040	upper Olentangy	Flat Run	42.5
100 010	Whetstone Creek	Whetstone Cr. headwaters to above Shaw Cr.	62.8
100 020	Whetstone Creek	Shaw Creek	30.0
100 030	Whetstone Creek	Whetstone Cr. below Shaw Cr. to Olentangy R.	21.7
110 010	middle Olentangy	Olentangy R. below Flat Run to below GS[1] at Claridon	23.3
110 020	middle Olentangy	Olentangy R. below GS[1] at Claridon to above Grave Cr.	23.9
110 030	middle Olentangy	Riffle Creek	17.4
110 040	middle Olentangy	Grave Creek	11.4
110 050	middle Olentangy	Olentangy R. below Grave Cr. to above Whetstone Cr.	17.4
110 060	middle Olentangy	QuQua Creek	17.1
110 070	middle Olentangy	Brondige Run	12.5
110 080	middle Olentangy	Olentangy R. below Whetstone Cr. to Delaware Res. Dam	14.9
110 090	lower Olentangy	Olentangy R. from Delaware Res. Dam to below Horseshoe Run	23.7
110 100	lower Olentangy	Horseshoe Run	11.3
110 110	lower Olentangy	Delaware Run	10.1
120 010	lower Olentangy	Olentangy R. below Horseshoe Run to below Delaware Run	13.5
120 020	lower Olentangy	Olentangy R. near Powell	37.1
120 030	lower Olentangy	Olentangy R. near Worthington	14.9
120 040	lower Olentangy	Olentangy R. from near Worthington to GS[2]	21.1
120 050	lower Olentangy	Olentangy R. from GS[2] to Dodridge Street	13.7
120 060	lower Olentangy	Olentangy R. from Dodridge Street to Scioto River	11.0

1. USGS Gage Station 03226800
2. USGS Gage Station 03226885

Topography of the ECBP is characterized by broad, nearly-level till plains and elevated, linear end moraines. Soils are primarily clay-rich, high-lime and are derived from the underlying glacial-drift parent materials. Dominant soil-associations include Centerburg-Bennington in the Olentangy River and Whetstone Creek headwaters; Blount-Pewamo in the middle region of the watershed; and Cardington-Alexandria or Medway-Genesee in the lower region of the watershed. The majority of the Olentangy watershed's soils are characterized by slow permeability, slow to moderate infiltration and are severely limited for use as septic-tank adsorption fields. The implication is surface and sub-surface drains are generally required for viable crop production, and effective household sewage treatment often requires additional controls upon traditional systems or alternative technologies.

2.3 Land Use

Land use in the Olentangy watershed can be divided into three distinct areas. North of the City of Delaware is primarily agricultural land interspersed with several small- to medium- sized villages and cities. South of the City of Delaware to the Delaware-Franklin county-line is a suburban area of rapid development. Franklin County south to the Scioto River is urban and almost entirely built-out. The Olentangy watershed is 56% cropland, 14% urban, 14% forested, 13% pasture/hay and three-percent other based upon the National Land Cover Dataset (NLCD) and other ancillary data where available. **Plate A.5** is map of land-use in the Olentangy watershed.

2.4 Population

Areas of notably rapid population growth and of slow-to-moderate decline exist in the Olentangy watershed. Between 1990 and 2000, the most dramatic growth occurred in southern Delaware County, between the City of Columbus and the City of Delaware. According to the U.S. Census Bureau's population estimate for the period from April 2000 to July 2004, Delaware County is the eleventh fastest growing county in the United States. Within Delaware County, the first and third most rapidly growing townships (1990 to 2000) are Orange and Liberty. Both are drained by the Olentangy mainstem and tributaries (Delaware County Regional Planning Commission, 2005)

During the same period, northern areas of the watershed in Crawford and Morrow counties experienced a slow decline. This represented population loss from the rural community and from small- to medium-sized villages and cities. **Table 2.2** presents population statistics summarized by HUC14 sub-watershed. **Plate A.6** illustrates relative population change in the Olentangy watershed.

The rapid suburban expansion and population growth in southern Delaware County represents a serious threat to the health of aquatic biological communities and chemical water quality in the Olentangy basin. Areas of the Olentangy mainstem with Exceptional Warmwater Habitat designation are mostly adjacent to landscapes projected to experience the most rapid population growth within the watershed.

Development typically impacts streams in two ways: first, an intense period of land disturbance during construction of roads, sewers, and buildings, then the resulting altered landscape that handles water differently than the pre-construction landscape. Near-term impacts include stream channelization and pollution from construction site runoff as housing and infrastructure expand to accommodate the growth. Long-term impacts include an increase in the watershed's total impervious surface, which results in faster runoff and higher-volume storm flows. This change in the hydrologic regime of a stream system can increase stream-bank erosion and destabilize channels, resulting in greater siltation downstream and increasingly ephemeral tributary stream flow.

Table 2.2 Population change in the Olentangy watershed

HUC14	Population[1]		Households[1]		Percent Change	
	1990	2000	1990	2000	Population	Housing
090 010	15,501	14,977	6,479	6,593	-3%	2%
090 020	901	877	338	360	-3%	7%
090 030	831	879	289	344	6%	19%
090 040	2,160	2,203	795	856	2%	8%
100 010	6,964	7,902	2,787	3,236	13%	16%
100 020	1,895	2,050	735	834	8%	13%
100 030	1,417	1,475	532	594	4%	12%
110 010	1,488	1,525	593	617	2%	4%
110 020	1,176	1,263	445	486	7%	9%
110 030	818	868	319	340	6%	7%
110 040	4,297	4,634	1,680	2,023	8%	20%
110 050	1,090	1,160	413	478	6%	16%
110 060	6,092	6,340	2,559	2,823	4%	10%
110 070	666	693	246	274	4%	12%
110 080	1,305	1,451	518	638	11%	23%
110 090	8,302	9,391	3,393	3,954	13%	17%
110 100	645	743	249	311	15%	25%
110 110	6,165	8,941	1,997	3,124	45%	56%
120 010	6,913	7,626	2,777	3,374	10%	21%
120 020	5,470	11,528	1,968	4,231	111%	115%
120 030	24,777	33,163	9,710	13,099	34%	35%
120 040	66,454	68,254	30,800	32,916	3%	7%
120 050	59,369	56,218	27,483	27,186	-5%	-1%
120 060	83,099	74,709	35,085	34,043	-10%	-3%

1. Source: Office of Strategic Research, Ohio Department of Development

3 Water Quality Standards

TMDLs are required when a waterbody fails to meet water quality standards (WQS). Every state must adopt WQS to protect, maintain, and improve the quality of the nation's surface waters. WQS represent a level of water quality that will support the Clean Water Act goal of swimmable and fishable waters. Ohio's WQS, set forth in Chapter 3745-1 of the Ohio Administrative Code (OAC), include four major components: beneficial use designations, narrative criteria, numeric criteria, and anti-degradation provisions.

Beneficial use designations describe the existing or potential uses of a waterbody. They consider the use and value of a waterbody for public water supply; protection and propagation of aquatic life; recreation in and on the water; and agricultural, industrial or other purposes. Ohio EPA assigns beneficial use designations to each waterbody in the state. Use designations are defined in paragraph (B) of rule 3745-1-07 of the OAC and are assigned in rules 3745-1-08 to 3745-1-32. Attainment of uses is based on specific numeric and narrative criteria.

Numeric criteria are estimations of chemical concentrations, degree of aquatic life toxicity, and physical conditions allowable in a waterbody without adversely impacting its beneficial uses. Narrative criteria, located in rule 3745-1-04 of the OAC, describe general water-quality goals that apply to all surface waters. These criteria state that all waters shall be free from sludge, floating debris, oil, scum, color and odor producing materials; substances that are harmful to human or animal health; and nutrients in concentrations that may cause excessive algal growth.

Antidegradation provisions describe the conditions under which water quality may be lowered in surface waters. Under such conditions water quality may not be lowered below criteria protective of existing beneficial uses unless lower quality is deemed necessary to allow important economic or social development. Antidegradation provisions are in Sections 3745-1-05 and 3745-1-54 of the OAC.

3.1 Aquatic Life Beneficial Use Designations

Four aquatic life beneficial use designations are applicable in the Olentangy watershed: Warmwater Habitat, Exceptional Warmwater Habitat, Cold Water Habitat, and Modified Warmwater Habitat. The aquatic life use assigned to a waterbody is dependent upon its present or potential condition and the biological community it is capable of supporting.

Warmwater Habitat (WWH) is characterized by the typical assemblage of aquatic organisms in Ohio rivers and streams. WWH represents the principal restoration target for the majority of water resource management efforts in Ohio, and is in line with the Clean Water Act goal of fishable waters.

Exceptional Warmwater Habitat (EWH) is applied to waters that support unusual and exceptional assemblages of aquatic organisms. These assemblages are characterized by a high diversity of species, particularly those that are highly intolerant, threatened, endangered, or of special status (i.e., declining species). EWH represents a protection goal for the management of Ohio's best water resources.

Cold Water Habitat (CWH) is applied to waters that support native communities of cold-water organisms, and/or those that support trout stocking and management under the auspices of the Ohio Department of Natural Resources. The Olentangy watershed does not currently have any segments designated CWH; however, CWH is proposed for two tributaries: an unnamed tributary to Whetstone Creek at river mile 33.71 and the East Branch of Whetstone Creek. The CWH designation is exceedingly rare in the Scioto River basin.

Modified Warmwater Habitat (MWH) is applied to waters that have been subject to maintained and essentially permanent modification. The MWH designation is appropriate if the modification is such that WWH criteria are unattainable. Additionally, the modification must be sanctioned by state or federal law. MWH aquatic communities are generally composed of species that are tolerant to low dissolved oxygen, silt, nutrient enrichment and poor quality habitat. Where this use designation is applied, the allowable conditions in the MWH-designated stream may be driven by the need to protect a higher downstream aquatic life use designation (e.g., WWH, EWH).

Aquatic life use attainment is dependent upon numeric biological criteria (biocriteria). Biocriteria are based on aquatic community characteristics that are measured both structurally and functionally. The rationale for using biocriteria has been extensively discussed elsewhere (Karr, 1991; Ohio EPA, 1987a,b; Yoder, 1989; Miner and Borton, 1991; Yoder, 1991; Yoder and Rankin, 1995).

Ohio's biocriteria are based upon three evaluation tools: the Index of Biotic Integrity (IBI), the Modified Index of Well-Being (MIWB) and the Invertebrate Community Index (ICI). These three indices are based on species richness, trophic composition, diversity, presence of pollution-tolerant individuals or species, abundance of biomass and the presence of diseased or abnormal organisms. The IBI and the MIWB apply to fish; the ICI applies to macroinvertebrates. Details regarding IBI, MIWB and ICI sampling procedures are described in the *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices* (Ohio EPA, 1987). Provisions addressing biocriteria are in paragraph (A)(6) of Section 3745-1-07 of the OAC.

Ohio EPA uses IBI, MIWB, and ICI assessment results of reference-site sampling to establish biocriteria. Least-impacted reference sites are periodically evaluated to determine minimum-expected index scores associated with various stream sizes, designations, and ecoregions. Attainment of aquatic life use designation is determined by comparison of biological assessment results to biocriteria. If an assessment site meets all applicable biocriteria for the IBI, MIWB and ICI, then it is in full attainment. If it achieves none of the applicable biocriteria, then it is in non-attainment. If it achieves some, but not all, then it is in partial attainment. **Table 3.1** presents biocriteria applicable in the Olentangy watershed. Biocriteria do not currently exist for CWH; attainment is determined on a case-by-case basis.

Table 3.1 ECBP biocriteria

Biological Index	Assessment Method	WWH	EWH	MWH
IBI	Headwater	40	50	24
IBI	Wading	40	50	24
IBI	Boat	42	48	24
MIWB	Headwater	NA[1]	NA[1]	NA[1]
MIWB	Wading	8.3	9.4	4.0
MIWB	Boat	8.5	9.6	4.0
ICI	All[2]	36	46	22

1. Not applicable to drainage areas less than 20 mi^2
2. Limited to sites with appropriate conditions for artificial-substrate placement

3.2 Recreational Beneficial Use Designations

Two recreational use designations are applicable to stream and river segments in the Olentangy watershed: Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR). PCR is applied to waters suitable for full-body contact such as swimming and canoeing. SCR is applied to waters suitable for partial-body contact recreation such as wading. Recreational use designations are in effect for only the recreation season. The recreation season is defined as May 1st through October 15th. Recreational use designations are further described in Section 3745-1-7 of the OAC.

Attainment of recreational use designation is evaluated by comparison to bacteriological numeric and narrative criteria. Ohio currently has bacteriological criteria for two parameters: fecal coliform and E. coli. Narrative criteria state that only one of the two criteria must be met to result in attainment. Bacteriological criteria apply outside the mixing zone of permitted discharges.

The numeric criteria for PCR state the geometric-mean fecal coliform content shall not exceed 1,000 per 100 ml, and fecal coliform content shall not exceed 2,000 per 100 ml in more than ten percent of samples taken. The numeric criteria for PCR also state that the geometric-mean E. coli content shall not exceed 126 per 100 ml, and E. coli content shall not exceed 298 per 100 ml in more than ten percent of samples takes. The numeric criteria for SCR state fecal coliform and E. coli content shall not exceed 4,000 per 100 ml and 576 per 100 ml, respectively, in more than ten percent of samples taken. Fecal coliform and E. coli content is to be evaluated on no less than 5 samples collected within a 30-day period for both PCR and SCR.

4 Beneficial Use Attainment

The Olentangy River watershed TMDL is required because portions of the Olentangy River and its tributaries do not attain their beneficial use designations for aquatic life and recreation. When a waterbody fails to attain its designated uses, it is said to be impaired. Impairment in the Olentangy watershed was determined based upon an assessment conducted primarily from June to October 2003 and June to October 2004. The assessment included biological, water chemistry and sediment sampling. Detailed results of the assessment can be found in the report titled *Biological and Water Quality Study of the Olentangy River, Whetstone Creek, and Select Tributaries 2003-2004* (Ohio EPA, 2006).

4.1 Aquatic life Use Attainment

Aquatic life use attainment was assessed at 74 sites in the Olentangy watershed that ranged in drainage area from 0.4 mi^2 to 543 mi^2. Thirty-four of the sites (46%) are in full attainment of their designated or recommended aquatic life use. Twenty-three of the sites (31%) are in partial attainment, and seventeen of the sites (23%) are in non-attainment. **Appendix C** provides a complete presentation of the attainment results, including biological index scores, causes, and sources of impairment. **Plates A.1** through **A.4** illustrate aquatic life use attainment in the Olentangy watershed.

Biological impairment in the upper Olentangy watershed was almost exclusively limited to the Olentangy River below Galion. Rocky Fork below Ammans Reservoir was the only tributary site of eight evaluated that was not in full attainment. Every site that was assessed in the upper Olentangy watershed was to some degree impacted by nutrient enrichment. However, habitat and flow conditions were sufficient in most instances to overcome degradation to aquatic life.

Biological impairment in the middle Olentangy watershed was found on both the mainstem and tributaries. Impairment on the mainstem was primarily from nutrient enrichment in the upper portion and impoundment from dams in the lower portion. Indian Run and Otter Creek were the only tributaries in full attainment. Bee Run, Grave Creek, Riffle Creek, QuQua Creek and Brondige Run were all impaired by various causes including habitat alteration, nutrient enrichment, and siltation. Norris Run and Sugar Run were impaired due to urban influences including siltation, nutrient enrichment and habitat alteration.

Biological impairment in the lower Olentangy watershed was found on the mainstem and tributaries. Impairment on the mainstem was a result of nutrient enrichment and siltation in the EWH portion (north of I-270) caused by the rapid pace of development in the surrounding watershed. The lower portion of the mainstem was impaired as a result of impoundment by low head dams; organic/nutrient enrichment from sanitary and combined sewer overflow; and urban stormwater runoff. The Tributary to Olentangy River RM 20.71 was impaired as fish migration and thus recruitment is not possible due to isolation of segments by a waterfall and several dams. Walhalla Hollow, was determined to have primary headwater characteristics. Since Ohio currently does not have primary headwater aquatic life uses at this time, an aquatic life use assessment was not completed on this stream. All the remaining tributary streams assessed in the lower Olentangy watershed were in non-attainment of their designated aquatic life uses due primarily to nutrient enrichment from sanitary sewer overflows, failing household sewage treatment systems, altered flow regimes and urban stormwater runoff. Most of these tributaries also had modified channels and the associated problems that arise from a hardened (paved) watershed, habitat destruction and altered flow.

Biological impairment in the Whetstone Creek watershed stemmed mainly from nutrient enrichment contributed by agribusiness, the Mt. Gilead WWTP, and the Cardington WWTP. The East Branch of Whetstone Creek, Sam's Creek, Shaw Creek and Mitchell Run were all in full attainment of their designated aquatic life use. Agricultural activities influenced the water quality of Big Run and a Tributary to Whetstone Creek (RM 33.71) leading to biological impairments of these streams. Nutrient enrichment and siltation from channel modifications and failing household sewage treatment systems led to impairment of Claypool Run.

4.2 Recreational Use Attainment

Recreational use impairment is pervasive in the Olentangy watershed. Recreational use impairment is caused by bacterial contamination associated with warm-blooded animals. Human sources of contamination include poorly-operating WWTPs, small package wastewater treatment plants, household sewage treatment systems, sanitary sewer overflows and combined sewer overflows. Animal sources are usually more intermittent than human, as manure enters a stream via runoff associated with rainfall. However, if livestock has direct access to streams, the effects on water quality are much greater. Each Olentangy watershed, with the exception of the lower, has livestock operations that provided cattle unrestricted access to streams. Allowing livestock to enter streams provides bacteria a direct route to stream systems.

For the purpose of this TMDL, recreational impairment is determined on a HUC14 sub-watershed basis, using fecal coliform bacteria as the indicator. Impairment is assessed at the sub-watershed scale, because this level of detail is a compromise between project manageability and fidelity to the data.

Fecal coliform is used to establish impairment, because it is more commonly associated with attainment than E. coli in Ohio's streams and rivers. Ohio's current WQS require only one of the two bacteriological indicators to meet their minimum criterion to be in attainment, and fecal coliform is more often than not the least limiting. Even though selecting fecal coliform over E. coli is not a conservative approach, it is done so in conformity with the law. This approach was taken in light of the fact that Ohio's bacteriological standards are currently under review where it is likely that limits will be higher than what they currently are.

A pooled dataset is assembled for each HUC14 sub-watershed to determine recreational impairment. Each dataset contains all applicable fecal coliform sample results collected within the sub-watershed during the recreation season of 2003. The geometric mean of each dataset is compared to the fecal coliform geometric-mean criterion. Additionally, the 90^{th} percentile of each dataset is compared to the ten-percent allowable-exceedance level. The results of this analysis are presented in **Table 4.1**. **Plate A.7** is a map of recreational-use attainment status in the Olentangy watershed.

Table 4.1 Fecal coliform sample results and HUC14 sub-watershed attainment

HUC14	Recreation Use Designation[1]	Samples Collected	Geometric Mean *count/100 ml*	90th Percentile *count/100 ml*	In Attainment? Geometric Mean Criterion	In Attainment? 90th Percentile Criterion
090 010	PCR	68	1,561	10,000	**No**	**No**
090 020	PCR	34	1,110	5,240	**No**	**No**
090 030	SCR	12	898	3,660	NA[2]	Yes
090 040	PCR	31	1,251	6,400	**No**	**No**
100 010	PCR	98	1,378	15,000	**No**	**No**
100 020	PCR	28	2,411	12,000	**No**	**No**
100 030	PCR	21	1,262	5,500	**No**	**No**
110 010	PCR	27	1,047	7,020	**No**	**No**
110 020	PCR	16	845	7,980	Yes	**No**
110 030	SCR	15	366	1,920	NA[2]	Yes
110 040	SCR	15	633	1,033	NA[2]	Yes
110 050	PCR	14	2,321	11,080	**No**	**No**
110 060	PCR	18	1,420	3,800	**No**	**No**
110 070	PCR	6	589	1,360	Yes	Yes
110 080	PCR	8	598	860	Yes	Yes
110 090	PCR	57	214	1,840	Yes	Yes
110 100	SCR	5	503	2,603	NA[2]	Yes
110 110	PCR	12	315	963	Yes	Yes
120 010	PCR	25	260	1,150	Yes	Yes
120 020	PCR	52	331	3,000	Yes	**No**
120 030	PCR	15	367	1,192	Yes	Yes
120 040	PCR	45	395	3,160	Yes	**No**
120 050	PCR	38	586	5,000	Yes	**No**
120 060	PCR	46	914	4,978	Yes	**No**

1. Recreational-use designation at sub-watershed outlet as in OAC 3745-1-09 Table 9-1
2. Geometric mean criteria is not applicable to secondary-contact waters

5 Problem Statement and Numeric Targets

The Olentangy TMDL is required because portions of the watershed fail to achieve their beneficial use designations for aquatic life and recreation. The primary causes of impairment are siltation, nutrient enrichment, habitat alteration, flow alteration, and contamination by pathogens. A short summary about the nature of each impairment cause follows.

- **Siltation** describes the deposition of fine soil particles on the bottom of stream and river channels. Deposition typically follows high-flow events that erode and entrain soil particles. As the flow subsequently decreases, the entrained soil particles fall from suspension to the stream bottom. This reduces the diversity of stream habitat available to aquatic organisms.

- **Nutrient Enrichment** describes the excess contribution of organic and inorganic materials used by plants during photosynthesis. Excess nutrients are not toxic to aquatic life, but can have an indirect lethal effect through algal-mediated depressed dissolved-oxygen concentrations. Excess nutrients can also result in a trophic shift of the aquatic community, as less-desirable algal species may outperform others in an enriched condition.

- **Habitat Alteration** describes the straightening, widening, or deepening of a stream's natural channel. Habitat alteration can also include the degradation or complete removal of vegetated riparian areas that are essential to a healthy stream. These activities can effectively transform a stream from a functioning ecosystem to a simple drainage conveyance.

- **Flow Alteration** describes any disruption to the natural hydrologic regime of a stream system. Flow alteration includes stream impoundment, increased peak-flow magnitude associated with the urbanization of watersheds, and water-table regulation through sub-surface drainage.

- **Contamination by Pathogens** occurs when human or animal waste reaches the stream. Pathogenic organisms include bacteria, viruses, and protozoan. Contamination by pathogens is a human health issue, as skin contact or accidental ingestion can lead to various conditions such as skin irritation, gastroenteritis, or other more serious illnesses.

It is impossible to adequately characterize impairment in the Olentangy River watershed by addressing each cause independently. All the listed causes of impairment are related and must be discussed within an integrated framework. This TMDL attempts to construct such a framework by utilizing multiple predictive and empirical tools to describe the problem and prescribe a solution.

The intent of an integrated TMDL framework is to approach the problem of impairment from two directions. Impairment can result when pollutant loads to a stream become excessive, the capacity of the stream to assimilate pollutants is diminished, or some combination of both. This TMDL establishes goals and recommends corrective actions intended to reverse these changes and restore balance by addressing both pollutant loading and assimilation.

This TMDL uses total suspended solid, total phosphorus, and fecal coliform instream concentrations along with measures of habitat quality and geomorphologic stability as indicators of relative stream health and function. Each parameter serves as a primary or secondary indicator of one or more of the listed causes of impairment.

The following sections describe the numeric targets used to develop TMDLs for each cause of impairment. Numeric targets represent a “goal” condition at which the designated uses of the waterbody should be restored.

5.1 Total Suspended Solids and Total Phosphorus

Total suspended solids (TSS) is a measure of particles in the water column that can be trapped by a filter. TSS is a primary indicator of siltation because the suspended load it represents may eventually settle to the stream bottom. TSS is a secondary indicator of nutrient enrichment and contamination by pathogens because these pollutants can attach themselves to fine-grained soil particles such as silt and clay.

Total phosphorus (TP) is a measure of the organic and inorganic elemental phosphorus in the water column. For the purpose of this report, TP is used as an indicator of the degree of nutrient enrichment. TP is selected because phosphorus is typically the limiting nutrient to primary production in freshwaters.

The Ohio EPA does not currently have statewide numeric criteria for TSS or TP; however, narrative criteria specify the following: Waters of the state shall be free from suspended solids resulting from human activities that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life (OAC 3745-1-04 A). Additionally, waters of the state shall be free from nutrients resulting from human activity in concentrations that create nuisance growths of aquatic weeds and algae (OAC 3745-1-04 E).

The Ohio EPA has identified potential targets for TSS and TP in the report titled *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999). This document provides the results of a study analyzing the effects of nutrients and other parameters on aquatic biological communities in Ohio streams and rivers. TSS and TP target concentrations are identified based on observed concentrations associated with acceptable ranges of biological community performance within each ecoregion. TSS and TP targets applicable in the Olentangy watershed are presented in **Table 5.1**. It is important to note that these targets are not codified in Ohio’s WQS, so there is some flexibility as to how they can be used in a TMDL.

Table 5.1 TSS and TP numeric targets

Stream Type[1]	**Parameter**	**WWH** *mg/l*	**EWH** *mg/l*
Headwater	TSS	10	10
Wadeable	TSS	31	26
Small River	TSS	44	41
Headwater	TP	0.07	0.05
Wadeable	TP	0.11	0.08
Small River	TP	0.16	0.16

1. Headwater is < 20 mi^2. Wadeable is 20 - 200 mi^2. Small river is > 200 mi^2.

5.2 Fecal Coliform

Fecal coliform (FC) is a measure of the number of organisms in the water column within the fecal coliform sub-group of bacteria. FC bacteria are largely non-pathogenic organisms found naturally in the intestinal tracts of warm-blooded animals. FC is used as an indicator of pathogen contamination because most pathogenic organisms are found in the ambient environment in numbers too small and variable to directly quantify.

The numeric targets for fecal coliform are derived directly from WQS. The PCR fecal coliform geometric-mean criterion of 1,000 counts per 100 ml is the target for the average condition. The PCR ten-percent exceedance criterion of 2,000 counts per 100 ml is the target for the acute condition. These targets are also applied to SCR waters to protect for downstream use.

5.3 QHEI, Substrate, and Channel Scores

The Qualitative Habitat Evaluation Index (QHEI) is a tool developed and used by the Ohio EPA to assess stream habitat quality. It is designed to provide an empirical evaluation of general habitat characteristics that are essential to fish communities and generally important to other aquatic life. The QHEI is composed of six principal habitat categories, two of which are substrate and channel. Total QHEI score equals the sum of the habitat category scores, with a maximum possible QHEI score is one-hundred (100). The QHEI score of a stream segment is established in the field by a trained evaluator.

Substrate is a principal habitat category of the QHEI, measuring the type, origin, quality, and degree of embeddedness of stream substrates. Degree of embeddedness refers to the extent to which gravel, cobble, and boulders are surrounded, impacted in, or covered by fine materials such as sand or silt. The maximum possible substrate score, indicating the least detrimental embeddedness, is twenty (20).

Channel is another principal habitat category of the QHEI. This category measures the sinuosity, development, degree of channelization, and stability of the stream channel. The channel category also indicates the presence or absence of modifications such as impoundment or dredging. The maximum possible channel score is twenty (20).

Total QHEI, substrate, and channel scores have been correlated to aquatic community performance in streams and rivers of Ohio (Ohio EPA, 1999). The correlation was determined by regression and frequency analyses of combined and individual categories of the QHEI in relation to the IBI. The analysis was conducted such that QHEI, substrate, and channel scores at which the attainment of individual aquatic life uses is probable were identified. These scores are used as targets in this TMDL and are presented in **Table 5.2**.

Total QHEI score is used as an indicator of habitat and flow alteration. Substrate is used as an indicator of siltation. Channel is used as an indicator of flow alteration.

Table 5.2 QHEI, substrate, and channel targets[1]

Score	WWH	EWH
QHEI	≥ 60	≥ 75
Substrate	≥ 14	≥ 15
Channel	≥ 13	≥ 15

1. Source: Table 9 (Ohio EPA, 1999)

5.4 Stream Geomorphology and Floodplains

Stream geomorphology pertains to the shape of stream channels and their associated floodplains. In particular, it deals with aspects of the stream system that include riffle and pool features, sinuosity (meander patterns), slope, cross-sectional dimensions, floodplain connectivity as well as the processes that form and maintain them. Stream geomorphology and floodplain targets are established in this TMDL because they have a significant impact on habitat, water quality, and aquatic biological communities (Danehy et al., 1999; Clarke et al., 2003; Walters et al., 2003, Forshay and Stanley, 2005).

The QHEI (see **Section 5.3**) sub-metrics “channel morphology” and “pool/glide and riffle/run quality” qualitatively evaluate stream geomorphology as habitat. The “substrate” and “riparian zone and bank erosion” sub-metrics are also related to stream geomorphology. These considerations illustrate that it is an integral part of stream habitat. Additionally, stream stability, which is related to geomorphological processes, impacts the quality and sustainability of stream habitat (see below).

The capacity of a stream system to assimilate pollutants such as nutrients, sediment, and organic matter depends on features related to its geomorphology. This is especially the case for floodplains which, if connected to the channel, can store large quantities of sediment as well as process nutrients and organics that are flowing through its sub-surface (i.e., parafluvial flow). Nutrient loads entering streams from upland sources are also reduced by biological uptake occurring in floodplains (Forshay and Stanley, 2005).

A significant proportion of biological processing takes place in the hyporheous area within a stream (Battin et al., 2003). The hyporheic zone lies beneath the stream bed where flow moves through void spaces between the coarse channel substrates. The hyporheic zone is strongly associated with riffles and can be compromised in unstable streams especially if large quantities of fine sediment fill the void spaces of the bed substrate.

Aquatic community structure, which is integral to Ohio’s water quality standards, responds to habitat and water quality conditions intimately related to stream geomorphology (Danehy et al., 1999; Clarke et al., 2003). The remainder of this section discusses stream geomorphology conditions necessary to a well-functioning stream and key factors that adversely impact stream geomorphology.

5.4.1 Stable Stream Geomorphology

Streams are stable when there is a balance between sediment inputs to the system (i.e., supplied by the landscape) and sediment transport. In other words, erosion and deposition processes that normally occur in streams equal one another and neither occurs excessively. Habitat such as bed substrate, riffles, and pools maintain sufficient quality to support biological communities when streams are stable. However, stream instability leads to extremes in erosion that removes or damages these habitats or leads to excessive sediment deposition that degrades stream quality.

Stream stability is manifest in channels where stream bed elevation remains consistent over several decades or longer (Ward et al., 2003). Additionally, the average width and depth of the channel is consistent even though moderate erosion and depositional processes create changes in the stream. For example, even in stable stream systems channel meanders will migrate down their valley by eroding bank material on outside bends while sediment is deposited along inside bends. However, there is no net change in the average width and depth of the channel.

Excessive erosion is a common problem in unstable streams. This creates deeper or wider channels and liberates large quantities of sediment that are likely to be deposited downstream. A study carried out in the Western US showed that the majority of the bed substrate of a stream system in a highly agricultural area was derived from eroding banks (Nagle and Ritchie, 2004). Evidence from the Ohio region showing the significance of channel erosion on substrate quality is more anecdotal, although common. Unstable streams can be a source of impairment to downstream receiving waters by exporting high, channel-derived sediment loads.

5.4.2 Importance of Floodplains

A well-connected floodplain is critical for stream stability (Ward et al., 2003). Floodplains reduce the intensity of stream erosion once the bankfull depth (i.e., the channel is filled) is exceeded because flow depths increase slowly relative to increasing discharge. For most stable streams, floodplains begin to flood for flows that roughly correspond to a 1- to 2-year return interval (RI). Flow depth is directly related to shear stress acting on the stream's bed and banks, which is a fundamental cause of erosion. The power to erode bed and bank material increases at a much slower rate for streams with well connected floodplains compared to those that are entrenched and as a consequence, stream stability is closely tied to floodplain connectivity.

Floodplains are sinks for suspended sediment during high flows, which is when the landscape sediment load is large. Flow velocity, which is directly related to the flow's capacity to keep sediment suspended, is relatively slow in the floodplain allowing more material to fall out of suspension. This is due to the shallower depths, increased surface contact, and a greater amount of flow impedances in the floodplain compared to the channel. By storing a significant proportion of the landscape sediment load in the floodplain, the substrate within the channel has less fine material maintaining high quality for this habitat.

From a purely biological perspective, separation of a channel from its floodplain (e.g., from channelization), has deleterious effects on fish and other aquatic life. Important refugia associated with relatively slow flow velocities and cover becomes inaccessible during high flow events. The stress of high flows on aquatic organisms is substantial therefore refugia has an important role in stream ecosystems (Schwartz and Herricks, 2005). Reice et al. (1990) contends that disturbance associated with high flows is the primary factor determining aquatic community composition. In addition, floodplain disconnection limits the export of organic matter to the stream, which serves as food subsidies and structural habitats (Wallace et al., 1997; Baer et al., 2001).

5.4.3 Stream Geomorphology and Floodplain Target Conditions

Targets set for floodplain width in this TMDL are based on expert advice guided by unpublished research. Dan Mecklenberg of the Ohio Department of Natural Resources has proposed a “3-5-10 rule” which prescribes floodplain width based on bankfull width (Dan Mecklenberg, personal communication, 2006). This rule recommends that floodplains be 3, 5, or 10 times wider than the bankfull width of the channel.

Three times the bankfull width is considered the minimum needed for a stream to maintain stability. Floodplains widths that fall below this threshold are expected become unstable and undergo excessive erosion. Streams with an aquatic life use designation of MWH are recommended to achieve this minimum floodplain width. Floodplains that are five times the bankfull width are associated with well functioning, stable streams and are recommended for those designated as WWH. Ten times the bankfull width is associated with exceptional streams and is recommended for those designated as EWH.

Regional curves have been established for the use in the Olentangy River watershed (D’Ambrosio et al., 2006) for which bankfull width can be estimated based on the associated drainage area. The relationship is given by the following equation where bankfull width (W) is expressed in feet and drainage area (DA) is expressed in square miles:

$$W = 14.3 * DA^{0.41} \qquad \text{equation 5.1}$$

Applying the recommended widths for the three applicable aquatic life use designations in the Olentangy River watershed, EWH, WWH, and MWH, yields the following equations:

$$W_{EWH} = 143 * DA^{0.41} \qquad \text{equation 5.2}$$

$$W_{WWH} = 72 * DA^{0.41} \qquad \text{equation 5.3}$$

$$W_{MWH} = 43 * DA^{0.41} \qquad \text{equation 5.4}$$

The floodplain width is the total width including the floodplain on both sides of the stream and the bankfull width. The equations represent the minimum width needed based on scientific data specific to the Olentangy River watershed. It is also essential that the floodplain be accessible to the stream during bankfull storm events.

5.5 Deviation from Targets

This section presents a summary of water-chemistry and habitat results of an Ohio EPA assessment of the Olentangy watershed. Ohio EPA conducted the assessment primarily in June to October 2003 and June to October 2004. Detailed results of the assessment can be found in *Biological and Water Quality Study of the Olentangy River, Whetstone Creek, and Select Tributaries 2003-2004* (Ohio EPA, 2005).

5.5.1 Presentation of Assessment Results

Assessment results are summarized to facilitate comparison to the numeric targets presented in **Sections 5.1** to **5.3**. Sample results from individual sites are organized into pooled datasets based upon stream grouping, site type, and aquatic life use. Stream groupings include Olentangy mainstem, Olentangy tributary, Whetstone mainstem, and Whetstone tributary categories. Site types include headwater, wadeable, and small-river sites. These types refer to drainage areas of less than 20, between 20 and 200, and greater than 200 square miles, respectively. Finally, results are organized by the aquatic life use of the assessment site.

Water chemistry results for TSS and TP are presented in **Table 5.3** as percentiles for each dataset. The percentile values of each dataset reflect the spatial variation of sites within the group, and temporal variation of different sampling days and times. The type of variation within a dataset is primarily dependent upon site grouping. Mainstem groupings represent a more spatially contiguous unit; therefore, variation within mainstem groupings is more likely a product of different flow conditions. Tributary groupings represent a spatially distributed dataset; therefore, variation within these datasets could be illustrative of both different flow conditions and geographic locations.

Fecal coliform results are presented in **Table 5.4**. The geometric mean and 90^{th} percentile-value of each dataset is included for comparison to the FC numeric targets. Geometric-mean values are generally representative of the average condition, while 90^{th} percentile values are typically representative of high-flow storm events.

Habitat assessment results are presented in **Table 5.5**. **Table 5.5** contains a summary of all assessed sites, and includes average QHEI, substrate, and channel scores. Habitat condition in the Olentangy watershed can be generally described as good, which is evident by the QHEI scores; however, MWH-designated sites consistently show poor habitat scores

Values exceeding their target are displayed in red underlined font in **Tables 5.3, 5.4**, and **5.5**. MWH results are compared to WWH targets, because MWH-specific targets have not been developed.

Table 5.3 Summary of total suspended solid and total phosphorus results*

Site Grouping	Site Type	Aquatic Life Use	Dataset ID	Dataset Samples	50th	75th	90th	95th
Total Suspended Solids (mg/l)								
Olentangy Mainstem	Headwater	WWH	1	22	9	18	34	37
	Wadeable	WWH	2	65	40	71	108	191
	Small River	WWH	3	64	26	45	86	193
		EWH	4	19	28	68	111	129
		MWH	5	6	29	36	65	78
Olentangy Tributaries	Headwater	WWH	6	138	8	17	27	34
		MWH	7	46	11	29	47	59
	Wadeable	WWH	8	12	23	36	39	44
Whetstone Mainstem	Headwater	EWH	9	11	9	23	27	29
	Wadeable	EWH	10	73	12	32	61	87
Whetstone Tributaries	Headwater	WWH	11	54	12	35	78	211
	Wadeable	WWH	12	6	19	30	37	39
Total Phosphorus (mg/l)								
Olentangy Mainstem	Headwater	WWH	1	22	0.08	0.50	1.50	1.98
	Wadeable	WWH	2	65	0.20	0.26	0.48	0.61
	Small River	WWH	3	64	0.10	0.17	0.26	0.48
		EWH	4	19	0.12	0.18	0.31	0.53
		MWH	5	6	0.13	0.16	0.25	0.29
Olentangy Tributaries	Headwater	WWH	6	138	0.10	0.16	0.26	0.36
		MWH	7	48	0.13	0.20	0.25	0.30
	Wadeable	WWH	8	12	0.14	0.18	0.20	0.40
Whetstone Mainstem	Headwater	EWH	9	11	0.07	0.14	0.40	0.44
	Wadeable	EWH	10	73	0.15	0.28	0.61	1.59
Whetstone Tributaries	Headwater	WWH	11	54	0.08	0.13	0.27	0.32
	Wadeable	WWH	12	6	0.10	0.11	0.13	0.13

* Underlined (red) values exceed the target.

Table 5.4 Summary of fecal coliform results* (counts/100 ml)

Site Grouping	Site Type	Aquatic Life Use	Dataset ID	Dataset Samples	Geometric Mean	90th Percentile
Olentangy Mainstem	Headwater	WWH	1	22	2,413	6,880
	Wadeable	WWH	2	65	953	4,480
	Small River	WWH	3	78	391	4,260
		EWH	4	23	627	6,380
		MWH	5	8	1,159	7,960
Olentangy Tributaries	Headwater	WWH	6	152	293	5,485
		MWH	7	45	961	4,520
	Wadeable	WWH	8	11	954	3,400
Whetstone Mainstem	Headwater	EWH	9	15	286	3,832
	Wadeable	EWH	10	93	1,150	13,000
Whetstone Tributaries	Headwater	WWH	11	72	2,002	16,700
	Wadeable	WWH	12	8	1,399	5,250

* Underlined (red) values exceed the target.

Table 5.5 Average QHEI, substrate, and channel scores* for all sites

Site Grouping	Site Type	Aquatic Life Use	Dataset ID	Number of Sites	QHEI	Substrate	Channel
Olentangy Mainstem	Headwater	WWH	1	4	76	18	13
	Wadeable	WWH	2	9	63	10	13
	Small River	WWH	3	9	72	15	13
		EWH	4	3	78	16	14
		MWH	5	1	33	1	6
Olentangy Tributaries	Headwater	WWH	6	22	62	14	14
		MWH	7	6	37	8	6
	Wadeable	WWH	8	2	74	18	14
Whetstone Mainstem	Headwater	EWH	9	3	77	16	16
	Wadeable	EWH	10	8	69	15	12
Whetstone Tributaries	Headwater	WWH	11	8	60	13	11
	Wadeable	WWH	12	2	68	11	16

* Underlined (red) values exceed the target.

5.5.2 Discussion of Assessment Results

This following contains a brief summary of the assessment results for each dataset presented above. The numbered points below correspond to the dataset identification numbers in **Tables 5.3**, **5.4** and **5.5**. The following points discuss some issues related to sources of impairment, which will be discussed in greater detail in **Chapters 6** and **7**.

1. **Olentangy Mainstem, Headwater, WWH:** All sites in this group attain their aquatic life use. This is most likely the result of good habitat, as average QHEI, substrate, and channel scores meet or exceed targets. Median TSS is the only water-chemistry parameter meeting its target. The 75th, 90th, and 95th percentile TP values are elevated due to the large wasteload from Galion WWTP, which influences the downstream-most

sites in this group. Both fecal coliform measures exceed the target, and high values were observed both upstream and downstream of Galion. Disinfection may be an issue at the plant, as is sanitary sewer overflow from the Galion collection system and failing household sewage treatment systems.

2. **Olentangy Mainstem, Wadeable, WWH:** Seven of nine sites assessed in this group do not achieve their aquatic life use. TSS and TP values show a significant increase from upstream. The Galion WWTP has a pronounced impact on the TP values of this group. The average QHEI score meets the target but declines from upstream. The substrate score is below the target, which may be a result of multiple factors, including surrounding agricultural practices, increased channel erosion, and livestock with stream access.

3. **Olentangy Mainstem, Small River, WWH:** Three of nine sites assessed in this group do not achieve their aquatic life use. TP and TSS values decrease from upstream. The decrease in TSS is influence by Delaware Lake, which acts as a settling basin for upstream loading. The decrease in TP is linked to the decrease in TSS, and also to the assimilation and dilution of the wasteload from Galion WWTP. This group has higher-quality habitat than upstream wadeable segments, which may partially explain the greater percentage of attainment.

4. **Olentangy Mainstem, Small River, EWH:** One of three sites assessed in this group does not achieve its aquatic life use. The sites in this group are located in the most rapidly developing area of the watershed. TSS increases from upstream WWH segments, despite high-quality habitat. The increase could be the result of the stream equilibrating following the Delaware Lake release and stormwater runoff.

5. **Olentangy Mainstem, Small River, MWH:** All sites in this group are located within the 5th Avenue dam pool, near the Ohio State University. Aquatic life attainment was assessed at one site, which does not achieve its use. Water chemistry was sampled at two sites. TSS markedly decreases in this segment, which is reflective of settling that occurs in the impoundment. Settling is also evident by the very low substrate score. QHEI and channel scores are very low, which is expected due to severe flow alteration. Both fecal coliform measures of this group exceed their targets. This is probably the result of combined and separate sewer overflows in the area and urban stormwater runoff.

6. **Olentangy Tributaries, Headwater, WWH:** Thirteen of eighteen sites assessed in this group do not achieve their aquatic life use. TSS and TP values were observed over a wide range. This is because this dataset reflects significant spatial and temporal variation. Some tributaries experience high loading during storm events due to nonpoint sources of pollution. Others are effluent-dominated and higher instream concentrations are observed during low-flow. High TSS values were observed on Mud Run, Tomahawk Creek, QuQua Creek, and Norris Run. High TP values were observed on Zimmerman Ditch, Norris Run, Grave Creek, and Tomahawk Creek. The average habitat scores for this group meet their target.

7. **Olentangy Tributaries, Headwater, MWH:** Three of six sites assessed in this group do not achieve their aquatic life use. All TSS and TP values exceed counterpart values of the Olentangy Tributary headwater WWH sites. This indicates the modified channels of this group generate higher sediment loads and have a diminished capacity to assimilate nutrients. The QHEI, substrate, and channel scores of this group are very poor. Based

upon the observed conditions, stream segments within this group have the potential to impact downstream use.

8. **Olentangy Tributaries, Wadeable, WWH:** Aquatic life use was assessed at one site in this group, which was found to be in attainment. Water chemistry was sampled at two locations. Median TSS values of this group meet the target, but all other percentiles exceed. All TP values exceed their targets. This group serves as an example of upstream use affecting downstream use and chemistry. One of the chemistry sites of this group, located at the mouth of Grave Creek, is affected by the upstream MWH segments and a Marion County WWTP. The impact is present despite excellent local habitat scores.

9. **Whetstone Mainstem, Headwater, EWH:** Two of three sites assessed in this group fail to achieve their aquatic life use. Median TSS meets the target, but all other exceed. All TP values exceed the target. Sites in this group are affected by surrounding agricultural practices, loading from the Candlewood Lake WWTP, and failed household sewage treatment systems. Average habitat scores meet the targets for EWH.

10. **Whetstone Mainstem, Wadeable, EWH:** Six of eight sites assessed in this group fail to achieve their aquatic life use. Median TSS meets the target, but all other exceed. All TP values exceed the target. All habitat scores are below EWH targets; channel is below the target for WWH. While habitat likely plays a role in the non-attainment of this group, the largest impact is from the Mt. Gilead and Cardington WWTPs. Both fecal coliform measures exceed their targets. This could be due to poor disinfection at the WWTPs and failed household sewage treatment systems.

11. **Whetstone Tributaries, Headwater, WWH:** Two of the seven sites assessed in this group fail to achieve their aquatic life use. All TSS values exceed their targets, including the highest observed 95^{th} percentile TSS in the entire watershed. The high TSS values are influence by the concentrations observed on the Unnamed Tributary to Whetstone Creek at RM 33.71 and East Branch Whetstone Creek. All TP values exceed their targets. Both fecal coliform measure exceed their targets, including the highest observed 90^{th} percentile value. Bacterial contamination on these tributaries is due to failed household sewage treatment systems, livestock with stream access, and runoff from pasture.

12. **Whetstone Tributaries, Wadeable, WWH:** All assessed sites in this group achieve their aquatic life use. Values of TSS and TP at the 90^{th} and 95^{th} percentile levels exceed their target, but are generally low. Both fecal coliform measure exceed their target. Again, this likely because of failed household sewage treatment systems, livestock with stream access, and runoff from pastures.

6 Sources of Impairment

Sources of impairment are generators of pollutant loads or practices leading to the degradation of environmental conditions, which adversely impact water quality or threaten the heath of the aquatic biological community. TMDLs must identify significant sources of impairment, quantify their magnitude, and recommend a corrective action, such as load reduction or alternative management practice, to mitigate the effect of the source.

Two important terms concerning sources of impairment are load and wasteload. When describing the pollutant contribution of a source, *load* is applied to sources that are not regulated by permit. Pollutant runoff from agricultural fields is an example of a load. *Wasteload* is applied to the pollutant contribution of sources regulated by permit. A municipal wastewater treatment plant is an example of a source that contributes to the total wasteload. This distinction becomes important during the allocation process described in **Chapter 8**. Loads from all pollutant sources are assigned to either the load or wasteload categories; distinctions are discussed in the following sections.

6.1 Definition of Sources

Sources of impairment to the Olentangy River watershed include nonpoint, regulated point, household sewage treatment systems, livestock with stream access, combined and sanitary sewer overflow, channel maintenance, and stream impoundments. These sources are defined in following sections. Each section provides information concerning pollutant delivery pathways of and the primary environmental condition affected by the source.

6.1.1 Nonpoint Sources

Nonpoint source (NPS) pollution consists of contaminants contributed by diffuse sources. In the context of this TMDL, NPS pollution refers to sediment, phosphorus, and fecal coliform delivered to the stream system via surface runoff, ground water, and sub-surface tile drainage.

NPS pollution is intermittent by nature because it is primarily driven by rainfall or snowmelt. It is most apparent during high stream-flow as increased pollutant concentrations, but its effects extend to average and low-flow conditions. Settling sediment contributes to siltation, while phosphorus and bacteria adsorbed to the sediment influence water-chemistry even as the flow recedes.

This TMDL divides NPS pollution into two-classes based upon source area. NPS pollution originating from land areas regulated by the Municipal Separate Storm Sewer System (MS4) Program are differentiated from areas that are not. NPS pollution from MS4 areas contributes to the total watershed *wasteload*. NPS pollution from non-MS4 areas contributes to the total *load*.

6.1.2 Point Source Dischargers

NPDES dischargers are entities that possess a permit through the National Pollutant Discharge Elimination System (NPDES). NPDES permits limit the quantity of pollutants discharged and impose monitoring requirements. NPDES permits are designed to protect public health and the aquatic environment by helping to ensure compliance with state and federal regulations.

NPDES entities generally discharge wastewater continuously. They primarily affect water quality under average- to low-flow conditions, because the potential for dilution is lower. NPDES dischargers located near the origin of a stream or on a small tributary are more likely to cause severe water-quality problems, because their effluent can dominate the natural stream-flow.

This TMDL classifies NPDES dischargers as major, minor, or miscellaneous. Majors are those identified as such by their NPDES permit, and discharge more than one-million gallons per day (MGD). Minors are small- or medium-sized waste-water treatment plants (WWTPs), such as those serving small municipalities, schools, private businesses, and developments. Miscellaneous facilities are those discharging process, cooling, or storm water, such as industrial complexes, water treatment plants (WTPs), and quarries. The Olentangy River watershed TMDL includes wasteload calculations for four major, 32 minor, and 14 miscellaneous NPDES dischargers.

6.1.3 Household Sewage Treatment Systems

Household Sewage Treatment Systems (HSTSs) are small wastewater treatment units serving individual homes or businesses. HSTSs are typically located on the property of the home or business from which they treat waste. HSTSs are often referred to as onsite wastewater treatment systems (OWTSs) or on-lot systems. These terms are approximately synonymous.

There are many types of HSTSs, but those most common in the Olentangy River watershed are septic tanks with soil-adsorption fields, septic tanks with sand filters, and aeration systems. The efficacy with which each system treats waste is dependent upon its age, the manner in which it is maintained, and characteristics of the site where it is located. Important site characteristics include soil drainage, water-table depth, bedrock depth, land slope, and parcel-lot size.

HSTSs affect water quality under multiple conditions. HSTSs discharging directly to a stream or river, such as many aeration or illicit systems, behave similarly to a point source. These types of systems primarily affect water quality under dry, low-flow conditions. HSTSs discharging indirectly to a stream via a tile drain or intermittent ditch may exhibit effects akin to a nonpoint source. Wastewater discharged to a dry tile or ditch may be of insufficient volume to sustain flow to the stream, but pollutants can accumulate and eventually be flushed by rainfall. These types of systems primarily affect water quality under wet-weather, high-flow conditions. Additional pollutant delivery pathways associated with HSTSs exist, but those discussed above are believed the most significant in the Olentangy River watershed.

HSTSs are regulated by general permits issued by local health authorities. Pollution from HSTSs contributes to the total *wasteload*.

6.1.4 Livestock with Stream Access

Grazing livestock with stream access is a source of impairment to the Olentangy River watershed. Livestock is granted stream access to provide a source of water or to allow movement to pasture. Either of these situations can result in the contribution of large pollutant loads to the stream system. Of particular concern is bacterial contamination, because unrestricted livestock can deposit waste directly into the stream. This results in very-high local bacteria concentrations, and can potentially affect downstream use as well.

Grazing livestock with stream access can also contribute to habitat and channel degradation. Livestock often graze to the stream edge, eliminating essential riparian vegetation. Further, livestock trample, collapse, and de-stabilize stream banks. This can result in elevated instream TSS concentrations and downstream siltation.

The pollution from livestock with stream access is not regulated by permit; therefore, it contributes to the total watershed load.

6.1.5 Combined and Sanitary Sewer Overflow

Combined sewer overflow (CSO) is discharge from a wastewater collection system designed to transport both sanitary and storm flow. This type of collection system is called a combined sewer system (CSS). In the absence of rainfall, a CSS conveys sanitary waste from its origin to a WWTP. During wet-weather events, the capacity of a CSS may be exceeded by the inflow of stormwater. In these situations combined sewage can overflow the system and be discharged at an engineered relief point to a stream or river.

Sanitary sewer overflow (SSO) is discharge from a wastewater collection designed to transport only sanitary flow. This type of collection system is called a sanitary sewer system (SSS). Infiltration of ground water and inflow of storm water can cause the capacity of an SSS to be exceeded. Ground water infiltration results when the integrity of underground sewer pipes is compromised. Inflow of stormwater results from the improper connection of roof downspouts or from poorly-sealed man holes. When the capacity of an SSS is exceeded, it may overflow and discharge to a storm sewer or city street. The overflow often drains to a stream or river.

The impact of CSO and SSO on water quality is most apparent as high bacteria concentrations during high flow. However, pollutants contributed to the stream by CSO and SSO can also affect water quality during average- to low-flow conditions. CSO and SSO contain organic solids that can settle to the stream bottom downstream of the overflow outfall. The resulting sludge beds contribute to the enrichment of the stream, degrade habitat quality, and can act as a source of bacterial contamination.

CSO outfalls are often permitted through the NPDES program. SSO is considered an illicit discharge and is not permitted. Therefore, pollutants from CSO contribute to the total watershed wasteload, and pollutants from SSO contribute to the total watershed load.

6.1.6 Channel Maintenance

Ohio EPA defines channel maintenance as any activity resulting in modification to the natural course of a stream or river. Ohio Revised Code (ORC) § 6131 allows for the widening, deepening, straightening, or change in location of any ditch, drain, watercourse, or floodway when such modification results in public benefit. Additionally, ORC allows the removal of obstructions such as silt bars, log jams, debris, or drift from any river, creek, or run. These and various other modifications are collectively referred to herein as channel maintenance.

Channel maintenance has multiple benefits. It is performed to speed the downstream movement of water, reduce local flooding, and maintain outlets for sub-surface tile drainage. Channel maintenance is often required in low-gradient areas to sustain viable crop production or to establish suitable building conditions. Channel maintenance also reduces the prevalence of standing water that can sometimes represent a health concern.

Channel maintenance can be detrimental for the same reasons it is beneficial. Increasing the speed of the downstream movement of water also increases the downstream movement of pollutants. Natural streams store water longer, allowing the system more time to assimilate pollutants such as sediment and nutrients. Local water-storage also helps to prevent downstream flooding by decreasing peak-flow magnitudes.

Channel maintenance is a source of impairment because of its effects upon aquatic life. It has short- and long-term consequences that impact both the local and downstream system. Short-term effects upon the local system include the extirpation of aquatic life and severe soil-disturbance. Long-term effects upon the local system include habitat destruction and decreased capacity for the assimilation of pollutants. Habitat destruction diminishes the potential for aquatic life recolonization. Decreased local-assimilation yields increased pollutant-export, which impacts the downstream system.

The effects of channel maintenance are reflected in the water-quality concentrations, QHEI scores, and geomorphology measurements of the modified areas. Modified stream channels often exhibit higher TSS concentrations than comparable natural streams. Poor QHEI scores in modified channels demonstrate their inability to support a functional aquatic community. Unstable geomorphology indicates the potential for modified channels to export large pollutant loads.

Streams, rivers, and ditches subject to routine channel maintenance are often designated MWH. The MWH designation represents lower expectations for the abundance and diversity of aquatic life than the EWH or WWH designations (OAC § 3745-1-07). Modified segments are considered to be in attainment if they can achieve these lower expectations. Regardless of their local attainment status, modified segments may be affecting downstream uses for those reasons discussed above.

Providing adequate drainage for the development of lands and production of crops is a recognized and legitimate use of waters of the State of Ohio. Landowners in Ohio have the right to maintain clean, free-flowing channels to prevent excessive flooding and facilitate drainage. However, Ohio law does not provide landowners the unqualified right to the disposal of water to the detriment of downstream areas.

A commonly ignored provision of Ohio Ditch Law is that all proposed channel maintenance projects shall give consideration to the protection of environmentally significant areas when those areas could be adversely affected by the modification (ORC § 6131.12). Ohio EPA contends downstream waters, particularly those designate EWH or superior high-quality waters, represent environmentally significant areas.

6.1.7 Stream Impoundment

Stream impoundment describes the installation of a flow-control structure that restricts the downstream movement of water. Stream impoundment results in an area of pooled water behind the flow-control structure. The pooled area is characterized by greater depth and slower velocity than what would be expected if the flow was unrestricted. Stream impoundment could be considered a category of channel maintenance; however, it is distinguished by the fact that channel maintenance is typically performed to speed the downstream movement of water, while stream impoundment retards it.

Streams are impounded for multiple reasons. Flow control structures are installed for downstream flood-control, to create a public water supply reservoir, to simplify sewer or utility crossing, to enhance recreational opportunities, or for aesthetic purposes. Historically, dams were used to provide local power for industries such as mills. The extent of the impoundment is depended upon the intended use.

Stream impoundment is a severe flow alteration that has multiple effects on the health of the stream system. Stream impoundment alters the natural channel such that pool-riffle-run complexes are inundated, thereby reducing the diversity of habitat available to aquatic organisms. Stream impoundment increases the settling of solids, which can result in very poor substrate. Finally, stream impoundment increases the residence time of water behind the flow control structure, which has multiple impacts upon chemical and physical water properties. **Plate A.8** is a map of dams on the lower Olentangy River.

6.2 Summary of Methods to Quantify Source Loading

A TMDL is required to quantify the effect of each source of impairment. If the source of impairment contributes a pollutant to the stream system, then the magnitude of the contribution must be determined. If the source results in habitat destruction or reduction of the stream system's assimilative capacity, then the impact must be measured using some quantifiable non-chemical parameter. The following sections describe the tools and methods used to quantify the magnitude of the pollution contribution from each source of impairment.

6.2.1 Soil and Water Assessment Tool

The Soil and Water Assessment Tool (SWAT) was used to simulate the hydrology and predict the NPS loading of sediment and nutrients to the Olentangy River watershed. SWAT is a daily time step, watershed-scale model developed and supported by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS). SWAT was developed to predict the impact of land management practices on water, sediment, and nutrient yields in large complex watersheds with varying soils, topography, land use and land management practices. The model used in this study is a customized version of SWAT 2005. This version is capable of simulating a restrictive layer of material in the soil profile and its impact on subsurface drainage, watershed hydrology, and pollutant transport.

The primary goal of applying SWAT to the Olentangy River watershed is to determine the impact of various management activities on water quality. To do so, representative management scenarios are developed using statistical data on agriculture, sources of literature applicable to Ohio, and the judgment of experts, extension personnel, local agencies, and producers.

Statistical agricultural data from Ohio is used extensively to develop management scenarios that are representative of the agricultural practices in the watershed. Twenty agricultural management scenarios are developed to represent variation in crop types, management strategies, and timing of management activities from year to year. Each of the twenty scenarios is then applied to 5% ($1/20^{th}$) of the agricultural land in the watershed.

For more information pertaining to the parameterization, calibration, and results of SWAT, please refer to Chapters 2 and 3 of the accompanying report *Olentangy River Watershed Total Maximum Daily Load Study* (D'Ambrosio et al., 2006).

6.2.2 Bacteria Indicator Tool

The U.S. EPA's Bacteria Indicator Tool (BIT) is used to estimate the fecal coliform loads accumulated on the land surface and contributed by livestock with stream access. BIT operates by creating an accounting of all manure sources within a sub-watershed. BIT then distributes the total quantity of manure among various methods of disposal. BIT accounts for the waste contribution of livestock and wildlife through direct deposition to cropland, pasture, or forest; barn or feedlot deposition and subsequent field application; or direct deposition in the stream or river. BIT outputs the daily accumulation rate of fecal coliform bacteria on each land-use type (counts/acre/day), and the fecal coliform load contributed to the stream by livestock with direct access (counts/hour).

6.2.3 Spreadsheet Methods

Spreadsheet methods are used to estimate the pollutant loads from bacteria washoff, NPDES dischargers, HSTSs, CSOs and SSOs. These methods use combination of empirical data and literature or default values in each calculation. The following points briefly discuss each method.

- Bacteria washoff is estimated using the daily land-surface accumulation rate generated by BIT, and a washoff equation common to other models (SWMM, HSPF, and GWLF). In addition to the daily accumulation rate, the washoff equation requires daily runoff and a washoff coefficient as inputs. Daily runoff is estimated using the SCS curve-number method.

- The method used to calculate pollutant loads from NPDES dischargers is dependent upon the type of discharger. The loads from major dischargers and several significant minors are calculated individually for each facility based upon self-monitoring data. Pollutant loads from other minors are estimated as the product of each facility's design flow and representative water-quality information from a pooled dataset of self-monitoring data. Miscellaneous point source loads are calculated based upon observed wastewater flow-rates and representative wastewater-quality values.

- HSTS pollutant loads are estimated as the product of the number persons served by failing systems in each sub-watershed, a per capita wastewater flow rate, and representative wastewater-quality information.

- CSO and SSO pollutant loads are estimated as the product of measured or modeled flow volumes and representative water-quality information. CSO and SSO load calculations pertaining to the City of Columbus's collection system are benefited by the City's Wet Weather Management Plan (City of Columbus, 2005), which contains information regarding the water quality of sewer overflow from their system.

7 Watershed Source Summary

This chapter presents the sources of impairment to each Olentangy River watershed. Sections begin with brief summary of the geographic extent of the watershed and the major sources impacting it. A presentation of the various sources and their associated impact follows, and the sections conclude with a tabular summary of the pollutant loads to the watershed.

7.1 Upper Olentangy River (HUC 090)

The upper Olentangy River watershed corresponds with hydrologic unit 05060001 090. This watershed marks the origin of the Olentangy River and ends near the river's confluence with Flat Run. Aquatic life impairment in the upper Olentangy is limited to the Olentangy River below Galion and one site on Rocky Fork. Recreational impairment is pervasive. Causes of impairment include nutrient enrichment, siltation, habitat alteration, and bacterial contamination. The upper Olentangy is impacted by numerous sources, including NPS pollution from farm fields and city streets, the Galion WWTP, failing HSTSs, livestock with stream access, and channel maintenance.

7.1.1 Nonpoint Source Pollution and Municipal Storm Sewer Systems

NPS pollution to the upper Olentangy watershed originates from Municipal Separate Storm Sewer Systems (MS4s) and non-MS4 areas. The City of Galion, the only MS4 in the upper watershed, was recently designated a Phase II Appendix 7 community. At the time of this writing, the City of Galion does not have an approved Storm Water Management Plan (SWMP). SWMP development is a requirement of the designation. Annual NPS loading-rates from the City of Galion, located in sub-watershed 090 010, are presented in **Table 7.1** under the MS4 Area column heading.

NPS pollution is also contributed from crop, pasture, and forested areas of the watershed. These loading rates are presented in **Table 7.1** under the NPS Area column heading. As can be seen, there is considerable variation in the loading rates between sub-watersheds. Results indicate the Olentangy Headwater Sub-watershed (090 010) has the highest sediment loading rate, and the Mud Run Sub-watershed (090 040) has the highest phosphorus loading rate.

NPS and MS4 loads contributed by each HUC14 are presented in **Table B.1**.

Table 7.1 NPS and MS4 Existing Loading Rates to Stream

HUC14	NPS Areas				MS4 Areas			
	Area *ac*	TP *lb/ac/yr*	TSS *tn/ac/yr*	FC *cnt/ac/seas*	Area *ac*	TP *lb/ac/yr*	TSS *tn/ac/yr*	FC *cnt/ac/seas*
090 010	29,482	0.81	0.58	2.71E+10	1,782	0.13	0.02	2.19E+08
090 020	13,475	0.36	0.06	1.38E+11	-	-	-	-
090 030	13,085	1.37	0.41	1.08E+11	-	-	-	-
090 040	27,051	0.95	0.50	5.49E+09	-	-	-	-

7.1.2 Point Source Dischargers

The pollutant wasteload contributed to the upper Olentangy watershed by NPDES dischargers is summarized in **Table 7.2**. The only major facility is the City of Galion WWTP, located at river mile 85.96. Minor facilities include the Swiss Village Mobile Home Park (MHP), Spring Valley MPH, Village of Caledonia, General Mills Operations, Specialty Fertilizer Products Company, and Glen Gery Corporation. Miscellaneous dischargers include Marathon Ashland Pipeline Inc., and Glen Gery Corporation.

The City of Galion WWTP contributes a large portion of the annual phosphorus load to the upper Olentangy watershed. The impact of the discharge is magnified by the plant's location in the headwaters of the Olentangy River. There are less than fifteen square miles of drainage area above the point of discharge, and the nearly three-million gallons per day of wastewater Galion discharges often overwhelms the natural stream flow. Instream phosphorus concentrations increase dramatically immediately downstream of the point of discharge, and do not return to levels near the target for thirty river miles (see **Figure B.1**). The wasteload from the Galion WWTP is simply too large for the Olentangy River to assimilate; a point that is supported by the non-attainment of aquatic life use downstream.

The pollutant loads contributed by minor and miscellaneous dischargers are small when compared to the wasteload from the City of Galion, but can have local detrimental effects. For example, the Spring Valley MHP, discharging to Zimmerman Ditch at river mile 1.30, is outdated, does not disinfect its effluent, and frequently violates NPDES permit limits. Spring Valley entered into a Consent Order (Case # 01-CV-0436) with the Ohio Attorney General on May 22, 2003 to comply with water pollution control laws. Pollutant wasteloads from all minor and miscellaneous dischargers are presented in **Table B.2 and B.3**.

Table 7.2 Existing point source loads to the upper Olentangy watershed

Facility	**TP** *lb/yr*	**TSS** *tn/yr*	**FC** *cnt/seas*
City of Galion WWTP	15,716	30.0	6.31E+11
Minor WWTPs	1,299	3.0	9.10E+11
Miscellaneous Dischargers	94	4.6	0.00E+00
Total	**17,108**	**37.6**	**1.54E+12**

7.1.3 Home Sewage Treatment Systems

Pollutant wasteloads contributed to the upper Olentangy watershed from HSTSs are presented in **Table 7.3**. Failing HSTSs are one of the largest sources of bacterial contamination in the watershed. HSTSs are distributed throughout the entire area, but clusters of residences often constitute the largest problem. Several areas of concern are the Village of Blooming Grove, Westmoor Subdivision, Sugar Grove Lake, the Village of Martel, and homes along Crawford-Marion Line Road that impact Rocky Fork. These areas are detailed below.

- The Village of Blooming Grove is located in North Bloomfield Township of Morrow County near the intersection of State Route 97 and Williamsport Road. This small community of 15 to 20 homes is near the headwaters of the Olentangy River and may be affecting water quality downstream, particularly instream fecal coliform.

- Westmoor Subdivision is located on the west side of Galion in Polk Township and contains about 230 homes on one-half-acre lots. The area has posed a public health problem for many years because of failing HSTSs. The Ohio EPA issued Directors Final Findings and Orders (DFFOs) to the Crawford County Commissioners as long ago as July 16, 1980 to improve sanitation. The problem was not resolved because negotiations between the county and Galion to extend sanitary sewers failed. Sampling was done by the Ohio EPA in 1994 and again in 2003 document a public health nuisance still exists. New draft DFFOs concerning Westmoor were issued on October 26, 2004.
- Sugar Grove Lake is located in Whetstone Township of Crawford County. Sugar Grove Lake was once a small resort, but is now utilized for year round living. There are approximately 40 homes in the area. The Crawford County Health Department considers Sugar Grove Lake a public health nuisance because of failing HSTSs. On September 12, 2003 the Ohio EPA issued a Permit to Install (PTI) a small treatment plant to serve Sugar Grove Lake, but the plant never went on-line because of a problem with the grant intended to fund the project.
- The Village of Martel is located in Tully Township of Marion County. Failing HSTS in this small community of approximately 60 homes may partially explain the high fecal coliform levels found in Shumaker Ditch.
- Several homes in the vicinity of Crawford Morrow Line Road and State Route 19 are contributing to septic conditions in a branch of Rocky Fork. Immediate action is needed because Rocky Fork drains into Ammans Reservoir, which is the source of drinking water for the City of Galion.

Table 7.3 Existing HSTS loads

HUC14	**Number of HSTS**	**TP** *lb/yr*	**TSS** *tn/yr*	**FC** *cnt/seas*
090 010	865	450	1.69	9.39E+14
090 020	212	94	0.35	1.96E+14
090 030	160	71	0.27	1.49E+14
090 040	900	1,633	6.12	3.41E+15
Total	**2,137**	**2,248**	**8.43**	**4.69E+15**

7.1.4 Livestock with Stream Access

Livestock with stream access exists at several locations throughout the upper Olentangy watershed. As previously stated, unrestricted livestock can have a significant impact on instream fecal coliform concentrations as well as degrade habitat quality. Livestock with stream access are found along the Olentangy River mainstem at Taylor Road Road, Iberia Road, Galion-New Winchester Road, and Crawford-Marion Line Road. These locations correspond to river miles 84.1, 82.9, 81.7, and 68.1, respectively. Livestock with stream access are also found on Flat Run near State Routes 309 (RM 11.3) and Thorn Run at Marion-Williamsport Road (RM 1.11). The fecal coliform load from these sources is summarized in **Table 7.4** at the end of this section.

7.1.5 Sanitary Sewer Overflows

The sanitary sewer system serving the City of Galion includes several known SSO locations. SSOs are primarily a result of the system's age, as the majority of the infrastructure was constructed between 1930 and 1960. Ground-water infiltration and storm-water inflow are both severe problems that lead to the sanitary sewer system and WWTP exceeding their capacities. The City of Galion is actively working to correct these problems, as evidenced by the installation of a new lift station near Columbus Street in 2000 to eliminate a sewage discharge. However, SSOs from the City of Galion may still be a source of impairment to the Olentangy River. Insufficient data is available to calculate a pollutant load associated with SSOs from Galion, but this should not be interpreted as an exclusion from responsibility. SSOs are considered an illicit discharge and must be eliminated where they exists.

7.1.6 Channel Maintenance

Channel maintenance is a source of impairment in the upper Olentangy watershed. Individual landowners are responsible for some of the maintenance activity, but the largest, most dramatic example of a maintained stream in the upper Olentangy watershed is Mud Run. Mud Run was channelized in 1975 and is currently maintained by the Crawford County Engineer. Ohio EPA noted spot excavations of the Mud Run channel during a survey in 2003. Spraying and mowing are known to be conducted on a regular basis.

Mud Run is designated MWH for its entirety because of the extent of modification to its channel. Mud Run supports an aquatic community consistent with its use, but it is likely a source of sediment and nutrients to the Olentangy mainstem. This statement is supported by the water-quality results and geomorphologic characteristics of Mud Run. Mud Run exhibited the highest average TSS concentration of all upper Olentangy tributaries. Further, the average TSS concentration of Mud Run exceeded the 80th percentile value of all Olentangy tributaries. Mud Run also exhibited the highest average TP concentration of all upper Olentangy tributaries not directly impacted by a point source.

The geomorphologic characteristics of Mud Run indicate the potential for pollutant export to downstream segments is high. OSU measured a floodplain-width ratio of 1.0 at Monnett-Chapel Road, indicating the stream is poorly connected to its floodplain. Additionally, OSU found the average instream soil-particle size to be significantly smaller than expected given the dimension and gradient of the channel. This is indicative that channel aggradation is occurring, which is another sign of instability.

7.1.7 Existing Pollutant Load Summary

All of the pollutant loads are summarized in **Table 7.4**.

Table 7.4 Summary of existing loads to the upper Olentangy watershed

Source	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
(1) Major NPDES	15,716	30.0	6.31E+11
(2) Minor NPDES	1,299	3.0	9.10E+11
(3) Miscellaneous NPDES	93.6	4.6	0
(4) MS4	227	28.5	3.90E+11
(5) HSTS	2,248	8.4	4.69E+15
(6) CSO	0	0	0
(7) Livestock Access	0	0	3.41E+14
(8) SSO	0	0	0
(9) NPS	72,445	36,680	4.21E+15
(10) Wasteload Existing[1]	19,583	74.5	4.69E+15
(11) Load Exising[2]	72,445	36,680	4.55E+15
(12) Total Existing[3]	92,028	36,755	9.24E+15

1. Equals the sum of 1, 2, 3, 4, 5, 6 and 8.
2. Equals the sum of 7 and 9.
3. Equals the sum of 10 and 11.

7.2 Middle Olentangy Watershed (HUC 110)

The middle Olentangy watershed begins at the confluence of the Olentangy River and Flat Run, and ends at the Delaware Lake Dam. Aquatic life impairment is found of the mainstem, and all but two of the assessed tributaries. Recreational impairment is pervasive. The primary causes of impairment are nutrient enrichment, habitat and flow alteration, and bacterial contamination. The primary sources are maintained ditches, stream impoundment, regulated point-sources, and failing HSTSs.

7.2.1 Nonpoint Source Pollution and Municipal Storm Sewer Systems

NPS pollution to the middle Olentangy watershed originates from MS4 and non-MS4 areas. MS4 communities in the watershed include the City of Marion. The City of Marion was recently designated Phase II, Appendix 7 community. The City does not have an established SWMP; however, development of a plan is a requirement of the designation. The pollutant wasteload associated with the City of Marion is presented in **Table 7.5** under the MS4 Areas heading.

NPS pollution also originates from crop, pasture, and forested areas. These loads are presented in **Table 7.5** under the NPS Areas heading. As can be seen, considerable variation exists in pollutant loading rates from each sub-watershed. Results indicate that sub-watershed 110 040, Grave Creek, has the highest sediment loading rate. Sub-watershed 110 050 and 110 060, the Olentangy River below Grave Creek and QuQua Creek, have the highest phosphorus loading rates.

NPS and MS4 loads contributed by each HUC14 are presented in **Table B.1**.

Table 7.5 NPS and MS4 Existing Loading Rates to Stream

HUC14	NPS Areas				MS4 Areas			
	Area *ac*	**TP** *lb/ac/yr*	**TSS** *tn/ac/yr*	**FC** *cnt/ac/seas*	**Area** *ac*	**TP** *lb/ac/yr*	**TSS** *tn/ac/yr*	**FC** *cnt/ac/seas*
110 010	14,817	0.91	0.29	1.55E+10	-	-	-	-
110 020	15,098	1.09	0.34	1.01E+10	-	-	-	-
110 030	11,096	1.12	0.33	3.35E+10	-	-	-	-
110 040	6,606	1.37	0.40	2.42E+09	625	0.14	0.02	1.92E+08
110 050	10,598	1.62	0.38	2.09E+11	-	-	-	-
110 060	9,869	1.63	0.39	2.21E+11	1,007	0.13	0.01	2.18E+08
110 070	7,926	0.91	0.27	1.79E+10	-	-	-	-
110 080	8,697	0.52	0.18	2.03E+09	-	-	-	-

7.2.2 Point Source Dischargers

The Marion County Richland Road WWTP, discharging to Grave Creek, is the only major discharger in the middle Olentangy watershed. There are six minors, the largest of which is the Marion County Fountain Place WWTP, which discharges to QuQua Creek. Miscellaneous dischargers include the City of Delaware WTP, BP Oil Company, and Wiliamette Industries. **Table 7.6** presents a summary of the NPDES discharger wasteload, and **Tables B.2 and B.3** contain additional information regarding minor and miscellaneous entities.

The Marion County Richland Road WWTP has a significant impact upon the water quality of Grave Creek. The impact is exacerbated by the location of the WWTP on a small stream. A the point of discharge of the Richland Road WWTP, Grave Creek drains less than nine square miles. Effluent from the WWTP composes the majority of stream flow during dry conditions, the impact of which is evident from water chemistry results.

Water chemistry was sampled on Grave Creek at one location upstream (RM 3.2) and two locations downstream (RM 1.7 and 0.03) of the Richland Rd WWTP outfall. The average TP concentration of the upstream location was 0.086 mg/l (n = 6). The average TP concentration downstream of the WWTP was 0.330 mg/l (n = 6) at RM 1.4 and 0.237 mg/l (n = 6) at RM 0.03. This data shows a sharp increase in TP concentration downstream of the WWTP, followed by a gradual decline downstream to the mouth of Grave Creek. The average TP concentrations at RM 1.4 and 0.3 exceed their respective targets of 0.07 and 0.11 mg/l. The TP data collected downstream of the WWTP outfall exhibit a general trend of decreasing concentration with increasing flow. This trend is typical of an effluent dominated stream such as Grave Creek.

Table 7.6 Existing point source loads to the middle Olentangy watershed

Facility	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
Marion County Richland Rd. WWTP	3,807	2.0	3.37E+11
Minor WWTPs	1,578	3.7	1.17E+12
Miscellaneous Dischargers	4.2	0.5	0.00E+00
Total	**5,389**	**6.1**	**1.50E+12**

7.2.3 Home Sewage Treatment Systems

Failing HSTSs are a source of impairment to the middle Olentangy watershed. The City of Marion and the City of Delaware are both served by a centralized sewer system, and several MHPs and subdivisions within the watershed are served by small WWTPs. However, the majority of homes in the middle Olentangy watershed are served by HSTSs. Like the upper Olentangy watershed, HSTSs are distributed throughout the entire area, but villages and clusters of homes represent the greatest threat to water quality. Several areas of concern include the Villages of Waldo and Claridon. These villages are discussed below. Pollutant loads contributed by HSTSs to the middle Olentangy watershed are presented in **Table 7.7**.

- The Village of Waldo is located in Southeast Marion County. Failing HSTSs in this community of about 350 result in very poor water quality in Tomahawk Ditch, a tributary to the Olentangy River at RM 40.41. This problem has been an issue for many years and there is a long history of negotiations between the village, Ohio EPA, and the Marion County Health Department. Detailed plans to install gravity sewers and construct a series of lagoons were submitted in 1972, but council members voted against the project and declined Farmers Home Administration funding that had already been approved. Failing HSTSs in Waldo create a documented public health nuisance in Tomahawk Ditch. This problem is more than just a local health issue because Tomahawk Ditch flows into Delaware Lake, a popular swimming and recreation area required to meet stringent bacteriological criteria.

- The Village of Claridon is located along the Olentangy River in Eastern Marion County. Failing HSTSs in this small community are believed to impact the health of the fish community in the Olentangy River at RM 54.8. Marion County recently extended a sanitary sewer line from the Richland Road WWTP to serve the River Valley High and Middle School complex. This is only about 1 mile west of the village, so it may be feasible to extend this line to Claridon and eliminate these systems.

Table 7.7 Existing HSTS loads

HUC14	Number of HSTS	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
110 010	200	223	0.84	4.65E+14
110 020	300	271	1.02	5.65E+14
110 030	185	249	0.93	5.19E+14
110 040	155	201	0.75	4.19E+14
110 050	180	159	0.60	3.32E+14
110 060	457	686	2.57	1.43E+15
110 070	500	560	2.10	1.17E+15
110 080	100	129	0.48	2.68E+14
Total	**2,077**	**2,477**	**9.29**	**5.17E+15**

7.2.4 Livestock with Stream Access

Livestock with stream access was observed at two locations in the middle Olentangy watershed, including in the Olentangy River near Roberts Road and Beaver Run near Salem Road. This short list is likely not inclusive all problem areas, but these are the documented locations. The fecal coliform load contributed by livestock with stream access is presented in **Table 7.8** at the end of this section.

7.2.5 Channel Maintenance

Channel maintenance is a source of impairment to the middle Olentangy watershed. Several actively-maintained channels include portions of Bee Run, Grave Creek, Riffle Creek, and QuQua Creek. In their modified condition these segments are not only incapable of supporting an aquatic community appropriate to their designated use, but can effectively act as point sources to downstream segments.

Bee Run has historically been maintained by the Marion County Engineer. Bee Run is currently undesignated, but WWH is recommended based upon results of the Ohio EPA 2003 survey. Bee run is in partial attainment of WWH at RM 4.9 and 0.3.

The total QHEI score of Bee Run at RM 4.9 is 33.0, with a substrate score of 1.0 and a channel score of 6.5. Total QHEI at RM 0.3 is 59.0, with a substrate score of 14.3 and a channel score of 13.0. Results of the upper site are clearly demonstrate the impact of channelization, while the lower site shows signs of recovery from past maintenance activity.

At the time of this writing, the Marion County Engineer was reviewing plans to channelize the lower segment of Bee Run. Should the plans be approved, the water and habitat quality of Bee Run will be further degraded. Any recovery the lower segment has made from past maintenance will be lost. Additionally, the assimilative capacity of the lower segment will be diminished, removing the buffering effect this segment imposes between the poor headwater conditions and the Olentangy mainstem.

Grave Creek was channelized in 1969 and is currently maintained by the Marion County Engineer. The maintained segment of Grave Creek begins at RM 1.4 and extends to the origin. Grave Creek is designated WWH from its confluence with the Olentangy River to RM 1.4 near Firstenberger Road, and MWH for the remainder. Aquatic life attainment was assessed at three locations, the upper-most of which is in non-attainment of MWH, the middle assessment-site is in non-attainment of WWH, and the lower is in partial attainment of WWH. QHEI scores improve as moving downstream from MWH to WWH segments. The total QHEI scores at RM 4.9, 1.4, and 0.8 are 42.0, 44.5, and 81.0, respectively.

TP concentration of Grave Creek cannot be evaluated within this context, because they are heavily influenced by the Marion County Richland Road WWTP. However, the average TSS concentration of Grave Creek equals the 69th percentile value of all Olentangy tributaries. This indicates the modified condition of Grave Creek may be resulting in elevated instream sediment.

Geomorphologic characteristic of Grave Creek were evaluated by OSU. OSU measured the floodplain-width ratio of Grave Creek at Firstenberger Road to be 1.9, which falls significantly short of the target 5.0. OSU also found this site on Grave Creek to be narrower and deeper than a stream of its size should be, indicating instability.

The assessment results of Grave Creek indicate habitat degradation as a result of channel maintenance is contributing to local impairment. Further, elevated pollutant concentrations, combined with unstable stream geomorphology, likely result in the significant export of pollutant loads to the Olentangy mainstem.

Riffle Creek, a tributary to Grave Creek, was channelized in 1946. Riffle Creek is not currently maintained by the county, but stream’s naturally low-gradient and landowner maintenance has slowed its recovery. Riffle Creek is designated WWH from its mouth to RM 4.0, near Marion-Edison Road. The remaining portion is MWH. Riffle creek is in non-attainment of MWH at RM 4.6, and partial attainment of WWH at RM 0.1.

QHEI results of Riffle Creek are good in the downstream WWH segment, and poor in the upstream MWH segment. It is not surprising the upstream segment, with a total QHEI score of 29.0, is not attaining its aquatic life use. Habitat conditions degraded to such an extent simply cannot support a healthy aquatic community. The lower segment received a total QHEI score of 75.0, which significantly exceeds its target and absent of other impacts should support an aquatic community consistent with its use. The partial attainment of this segment could therefore be a result of pollutant loading from upstream.

QuQua Creek was channelized in 1949 from its origin to RM 2.8 near Newmans-Cardington Road. The most recent maintenance to this segment occurred in 2003, and was performed by the Marion County Engineer. QuQua Creek is in non-attainment of MWH at RM 4.6 and WWH at RM 0.1.

Habitat assessment results of the upper segment of QuQua Creek are very poor, with a total QHEI score of 29.0, substrate score of 11, and channel score of 4.5. In contrast, the habitat quality of the lower assessment sites is good, with a total QHEI of 75.0, substrate score of 19.5, and channel score of 11.

Like Grave Creek, the instream phosphorus concentration of QuQua Creek is impacted by point source discharge, so it cannot be examined in this context. However, the average TSS concentration in QuQua Creek is elevated, and equals the 73rd percentile value of all Olentangy tributaries.

OSU evaluated the geomorphology of QuQua Creek at RM 0.1, near Owens Road, which is downstream of the modified channel. At this location OSU measured a floodplain-width ration of 1.2, which is below the target of 5.0, but otherwise stable stream characteristics. Of note was a wooded floodplain slightly above the level associated with yearly floods, but still considered functional in that it would likely help to assimilate pollutants under very high flows.

The QHEI, water-chemistry, and geomorphologic results of QuQua creek indicate the degraded habitat conditions associated with channel maintenance in the upper segment are contributing to the local non-attainment. Further, the inability of the upper-segment to assimilate pollutants could be impacting the lower, unmodified segment. The relatively stable geomorphology of the lower segment is, however, likely providing some buffering effect between the degraded upper segment and the Olentangy mainstem.

7.2.6 Stream Impoundment

Stream impoundment is a source impairment to the middle Olentangy watershed. Impoundment resulting from the Delaware Lake Dam is believed to contribute to the partial attainment of WWH at RM 40.8 of the Olentangy River. Since the Delaware Lake Dam in considered an essentially permanent modification, impairment resulting from its effects is not a subject of this TMDL.

7.2.7 Existing Pollutant Load Summary

The pollutant loads for the middle Olentangy watershed are summarized in **Table 7.8**.

Table 7.8 Summary of existing loads to the middle Olentangy watershed

Source	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
(1) Major NPDES	3,807	2.0	3.37E+11
(2) Minor NPDES	1,578	3.7	1.17E+12
(3) Miscellaneous NPDES	4.0	0.5	0
(4) MS4	218	26.2	3.39E+11
(5) HSTS	2,477	9.3	5.17E+15
(6) CSO	0	0	0
(7) Livestock Access	0	0	1.50E+15
(8) SSO	0	0	0
(9) NPS	96,341	27,263	5.33E+15
(10) Wasteload Existing[1]	8,083	41.6	5.17E+15
(11) Load Exising[2]	96,341	27,263	6.83E+15
(12) Total Existing[3]	104,425	27,305	1.20E+16

1. Equals the sum of 1, 2, 3, 4, 5, 6 and 8.
2. Equals the sum of 7 and 9.
3. Equals the sum of 10 and 11.

7.3 Lower Olentangy River (HUC 120)

The lower Olentangy watershed begins at the Delaware Lake Dam and ends where the Olentangy River joins the Scioto River in Columbus. Aquatic life impairment exists on the mainstem in WWH, EWH, and MWH segments. All assessed tributaries with applicable WQS are also impaired. Recreation impairment is common, particularly violations of the maximum criterion. Causes of impairment are nutrient enrichment, siltation, habitat and flow alteration, and bacterial contamination. Sources of impairment include urban stormwater runoff, CSO and SSO, failing HSTSs, and stream impoundments.

7.3.1 Nonpoint Source Pollution and Municipal Storm Sewer Systems

NPS pollution to the lower Olentangy watershed originates from MS4 and non-MS4 areas. MS4 communities include Phase I, Phase II, and Appendix 7 areas. The City of Columbus is the only Phase I community, and they have an established SWMP. Phase II communities include the urbanized areas of Liberty and Orange Townships in Delaware County; Perry and Sharon Townships in Franklin County; the Villages of Powell and Riverlea; and the Cities of Upper Arlington, Worthington, and Grandview Heights. The City of Delaware is the only Appendix 7 community in the watershed. NPS pollutions loading rates from MS4 areas are include in **Table 7.9** under the heading MS4 Areas.

NPS pollution also originates from crop, pasture, and forested areas of the lower Olentangy watershed. Results indicate that sub-watershed 120 010, the Olentangy River below Horseshoe Run, exhibits the highest sediment and nutrient loading rates of the lower Olentangy watershed.

NPS and MS4 loads contributed by each HUC14 are presented in **Table B.1**.

Table 7.9 NPS and MS4 Existing Loading Rates to Stream

HUC14	NPS Areas				MS4 Areas			
	Area *ac*	**TP** *lb/ac/yr*	**TSS** *tn/ac/yr*	**FC** *cnt/ac/seas*	**Area** *ac*	**TP** *lb/ac/yr*	**TSS** *tn/ac/yr*	**FC** *cnt/ac/seas*
110 090	13,533	1.29	0.58	2.12E+09	1,469	0.15	0.03	2.33E+08
110 100	7,087	1.51	0.47	2.21E+09	114	0.14	0.02	2.03E+08
110 110	4,908	0.49	0.29	2.06E+09	1,535	0.14	0.02	2.09E+08
120 010	7,159	2.25	1.07	1.82E+09	1,435	0.15	0.03	1.64E+08
120 020	21,362	0.47	0.25	1.48E+09	2,183	0.35	0.05	1.92E+08
120 030	4,120	0.25	0.09	1.26E+09	5,335	0.32	0.05	2.36E+08
120 040	2,953	0.03	0.01	1.10E+09	10,283	0.33	0.04	1.89E+08
120 050	1,373	0.05	0.01	7.45E+08	7,310	0.23	0.03	2.13E+08
120 060	580	0.64	0.19	9.05E+08	6,361	0.52	0.07	1.27E+08

7.3.2 Point Source Dischargers

Major dischargers in the lower Olentangy watershed include the City of Delaware Upper Olentangy Reclamation Center (hereinafter the City of Delaware WWTP) and the Delaware County Olentangy Environmental Control Center (OECC). Additionally, there are 14 minor and 9 miscellaneous dischargers in the lower Olentangy watershed. A summary of the wasteload from NPDES dischargers is presented in **Table 7.10**. **Tables B.2 and B.3** provide additional information regarding loading from minor and miscellaneous entities.

Table 7.10 Existing point source loads to the lower Olentangy watershed

Facility	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
City of Delaware WWTP	17,467	23.1	2.84E+11
Delaware County OECC WWTP	6,417	4.2	6.25E+11
Minor WWTPs	2,008	4.7	1.59E+12
Miscellaneous Dischargers	59	2.8	0.00E+00
Total	**25,951**	**34.8**	**2.50E+12**

The City Delaware WWTP has a design treatment capacity of 5.5 MGD with a discharge to the Olentangy River at RM 25.26. Wet stream processes provided at the plant include primary screening, grit removal, first stage aeration, intermediate clarification, second stage aeration, final settling, tertiary sand filtration, chlorination, dechlorination and post aeration. A flow equalization basin equipped with a bypass (outfall 002) is provided for use during wet weather. Solids handling facilities consist of aerobic digestion, a belt filter press for sludge dewatering followed by disposal at a landfill. The average daily flow at outfall 001, for the time period between January - December 2003 was 4.27 MGD. The maximum flow during this period of record was 10.28 MGD. Delaware WWTP has broken ground on a plant expansion to increase the design average flow to 10 MGD. The upgraded facility includes primary clarification, nutrient removal, ultra-violet disinfection, and elimination of the plant bypass.

OECC has a design treatment capacity of 6.0 MGD with a discharge to the Olentangy River at RM 13.39. Wet stream process provided at the facility include comminution, single-stage extended aeration with nutrient removal, final clarification, tertiary sand filtration, ultraviolet disinfection and post-aeration. Solids handling facilities consist of aerobic digestion, gravity belt thickening and sludge storage followed by land application. The average daily flow at outfall 001, for the time period between January - December 2003 was 2.78 MGD. The maximum flow during this period of record was 8.95 MGD. It is anticipated that flows to the plant will increase significantly following completion of the Perry-Taggart interceptor sewer along the Olentangy River.

The City of Delaware WWTP and OECC do not appear to currently be negatively impacting water quality in the Olentangy River beyond what is reasonably expected. Both are major facilities discharging large wasteloads, but they provide adequate treatment and have the benefit of dilution in a moderate-sized river. However, the rapid development of southern Delaware County and the associated increase in wastewater flow, which is expected to continue, emphasize the need to maintain their existing, acceptable wasteload contribution to the Olentangy River.

7.3.3 Home Sewage Treatment Systems

Failing HSTSs are a source of impairment to the lower Olentangy watershed. The Cities of Columbus and Delaware as well as Delaware County provide centralized sewage collection and treatment for large percent of the residences in the watershed, but a significant number of unsewered areas still exist. Northern Delaware County is almost entirely unsewered, and southern Delaware County still has many homes utilizing HSTSs despite the substantial expansion of sewer infrastructure by Delaware County. The Franklin County portion of the watershed is largely sewered, but several small unsewered areas exist, particularly in unincorporated zones. A summary of the pollutant wasteload from failing HSTS is presented in **Table 7.11**.

Table 7.11 Existing HSTS loads

HUC14	Number of HSTS	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
110 090	427	566	2.12	1.18E+15
110 100	251	340	1.28	7.10E+14
110 110	212	281	1.05	5.86E+14
120 010	296	432	1.62	9.02E+14
120 020	1,602	2,208	8.28	4.61E+15
120 030	465	1,026	3.85	2.14E+15
120 040	530	1,054	3.95	2.20E+15
120 050	86	167	0.63	3.48E+14
120 060	13	25	0.09	5.21E+13
Total	**3,882**	**6,098**	**22.87**	**1.27E+16**

Priority areas for the repair, replacement, or elimination of failing HSTSs have been identified in the lower Olentangy watershed. Priority areas in Delaware County were identified by the Health Department using a spatial analysis that considered the type and age of HSTSs, as well as water-quality sampling results and documented complaints. Priority areas in Franklin County were identified through consultation with the Franklin County Board of Health.

The Delaware General Health District identified the homes along Wren and Carriage Lane in Liberty Township as the highest-priority area in the Delaware County portion of the Olentangy watershed. This area is also known as the Westchester Sub-Division. Several surrounding communities, such as the Wingate Farms Sub-division, may also be affecting water quality in the same general area.

There are approximately 170 HSTSs in the Westchester and Wingate Farms area. Approximately 90 of these systems are discharging sewage off-lot. As of this writing, the average home age in the area is 48 years, indicating the HSTSs serving these homes have likely exceed their lifespan unless they have been already replaced. This fact, combined with the large number of homes is a small area, strongly indicates HSTSs are affecting local water quality. An Un-named Tributary to the Olentangy at RM 16.5 is receiving stream for much of the associated waste. This stream is marked as intermittent on USGS topographic maps, but is probably impacting the Olentangy mainstem during high-flow.

HSTSs in southern Delaware County are too numerous and widely distributed to be adequately and concisely described in this report. Delaware County is actively working to expand its sewer infrastructure, which will allow for the future connection of many systems. For example, completion of the Perry-Taggart interceptor may allow for the future connection of the Westchester area described above. This could represent the beginning of a long-term effort to connect other problem areas including homes along Liberty, Bunty Station, Berlin Station, and Hyatts Road, as well as clusters of homes like Lewis Center.

The HSTS situation is very different is Franklin County. There HSTS are not widely distributed; rather, they are found in dense pockets is several discrete locations. These pockets may still represent a significant water-quality concern, because of the age of the systems and the small lot-size upon which they are situated. Areas of concern in the Franklin County portion of the lower Olentangy watershed are listed in **Table 7.12**.

Table 7.12 HSTS areas of concern in Franklin County

HSTS Areas of Concern	Roads Area is Inclusive Of	Number of Sytems		Average Home Build Year	Average Lot Size in Acres
		Off-Lot	Septic		
Cooke Road	Cooke Maize Karl	15	2	1948	1.93
Dublin-Granville	SR 161 Danbury Greendale Brookdown McVey	24	48	1963	0.73
Flint	Flint Forest Ridge Pocono Melyers	39	65	1961	2.30
Linworth	Linworth Postlewaite Sharon Hill Larkstone	44	183	1957	0.65
Mt. Air	Highview Old Woods Plumbtree Edgecliff Mulberry Elm Beech	60	65	1960	0.77
Rosslyn	Rosslyn Kanawha	17	70	1947	0.16
Snouffer East	Snouffer	9	24	1962	0.88
Snouffer West	Snouffer Skyline	5	40	1962	0.77
West Case	West Case	4	1	1965	1.09

7.3.4 Combined Sewer Overflows and Sanitary Sewer Overflows

Combined and sanitary sewer overflows are a source of impairment to the lower Olentangy watershed. CSO and SSO outfalls exist along the Olentangy from near Worthington to First Avenue. **Plate A.11** is a map of CSO outfalls from the City of Columbus's collection system to the Olentangy River. **Plate A.12** is a map of SSO discharge points. **Plate A.13** is a map depicting the number of overflow events associated with individual SSO discharge points.

The City of Columbus entered into a consent agreement (CO) with the Ohio EPA in 2002 to resolve issues pertaining to SSOs. In 2004 the City and Ohio EPA entered a CO concerning CSOs. These two COs required the City of Columbus to complete several studies and develop a plan that will eventually result in the elimination of SSOs from its collection system and mitigate CSOs to the standards set forth in the consent decree.

The SSO CO required the City of Columbus to complete a System Evaluation and Capacity Assurance Plan (SECAP). The stated goal of SECAP development and implementation is to provide adequate capacity to treat base and peak flows for all parts of the Columbus collection system. The CSO CO required the City of Columbus to complete a Long-Term Control Plan (LTCP) update. The stated goal of the LTCP development and implementation is to bring all wet-weather CSOs and CSO outfall discharge points into compliance with the water quality and technology based requirements of the Clean Water Act.

The City of Columbus chose to combine these two efforts into one, and submitted its Wet Weather Management Plan (WWMP) to the Ohio EPA in July of 2005. This plan is currently under review. The pollutant contribution from CSOs to the lower Olentangy watershed is presented in **Table 7.12**. The pollutant contribution from SSOs is summarized in **Table 7.13** at the end of this section.

Table 7.13 CSO overflow volume and load for a typical year

CSO Outfall Location	**Overflow Volume** *MG/yr*	**TP** *lb/yr*	**TSS** *tn/yr*	**FC** *cnt/seas*
Hudson St.	0.18	1.8	0.2	1.36E+12
Frambes Ave.	2.63	26.3	3.0	1.99E+13
Indianola Ave.	5.94	59.5	6.7	4.50E+13
King Ave.	1.26	12.6	1.4	9.54E+12
Third Ave.	9.08	90.9	10.2	6.87E+13
Doe Alley	0.72	7.2	0.8	5.45E+12
First Ave.	0.28	2.8	0.3	2.12E+12
TOTAL:	**20.1**	**201**	**23**	**1.52E+14**

7.3.5 Stream Impoundment

Stream impoundment is a source of impairment to the lower Olentangy watershed. Two dams are considered to be direct sources of impairment. The Fifth Avenue Dam is contributing to the non-attainment of MWH at RM 2.1 of the Olentangy River. The Fifth Avenue Dam is the largest flow-control structure in the lower Olentangy watershed, and impounds an extensive length of river along the Ohio State University Campus. Physical habitat quality of the Olentangy River in the lower watershed is generally good to very good. In the Fifth Avenue Dam pool, however, physical habitat quality as measured by the QHEI is poor. This is because of the monotonous channel condition created by the large impoundment, which reduces the diversity of habitat available to aquatic life. Removal of the Fifth Avenue Dam is recommended to improve the habitat condition and to improve chemical and physical water quality in the impounded area.

The second dam resulting in impairment to the Olentangy River is the Panhandle Road Dam. This dam is believed to contribute to the partial attainment of WWH at RM 28.1 of the Olentangy River. The Panhandle Road Dam is a four-foot high structure, which has shared ownership by the Ohio Department of Transportation and a private party. The original purpose of this dam is unknown, and this TMDL recommends its removal to help restore full attainment immediately upstream.

7.3.7 Existing Pollutant Load Summary

Table 7.14 summarizes the existing loads to the lower Olentangy River watershed.

Table 7.14 Summary of existing loads to the lower Olentangy watershed

Source	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
(1) Major NPDES	23,884	27.3	9.09E+11
(2) Minor NPDES	2,008	4.7	1.59E+12
(3) Miscellaneous NPDES	59.3	2.8	0
(4) MS4	11,453	1,597	6.91E+12
(5) HSTS	6,098	22.9	1.27E+16
(6) CSO	201	22.6	1.52E+14
(7) Livestock Access	0	0	0
(8) SSO	155	6.1	4.76E+14
(9) NPS	58,144	26,074	1.09E+14
(10) Wasteload Existing[1]	43,858	1,677	1.29E+16
(11) Load Exising[2]	58,144	26,080	5.85E+14
(12) Total Existing[3]	102,002	27,758	1.35E+16

1. Equals the sum of 1, 2, 3, 4, 5, 6 and 8.
2. Equals the sum of 7 and 9.
3. Equals the sum of 10 and 11.

7.4 Whetstone Creek (HUC 100)

The Whetstone Creek watershed corresponds to hydrologic unit 05060001 100. Whetstone Creek is a major tributary to the Olentangy River. This watershed begins in north-central Morrow County and ends where Whetstone Creek drains into Delaware Lake. Whetstone Creek is unique in the Olentangy watershed because it is designated EWH for almost its entire length. Aquatic life impairment is found on the mainstem and the tributaries. Recreational impairment is common, and some of the highest bacteria concentrations of the entire Olentangy watershed are observed here. The primary causes of impairment are nutrient enrichment, siltation, habitat alteration, and bacterial contamination. The primary sources are municipal WWTPs, crop and pasture runoff, and failing HSTSs.

7.4.1 Nonpoint Source Pollution and Municipal Storm Sewer Systems

NPS pollution to the Whetstone Creek watershed originates from non-MS4 areas. No MS4 communities exist in the watershed. NPS pollution is primarily the result of runoff from crop, pasture, forested, and urban areas. NPS loading rates for each Whetstone Creek sub-watershed are presented in **Table 7.15**.

NPS and MS4 loads contributed by each HUC14 are presented in **Table B.1**.

Table 7.15 NPS and MS4 existing loading rates to stream

HUC14	NPS Areas				MS4 Areas			
	Area *ac*	**TP** *lb/ac/yr*	**TSS** *tn/ac/yr*	**FC** *cnt/ac/seas*	**Area** *ac*	**TP** *lb/ac/yr*	**TSS** *tn/ac/yr*	**FC** *cnt/ac/seas*
100 010	39,213	0.50	0.34	4.16E+10	-	-	-	-
100 020	19,156	0.89	0.43	2.43E+11	-	-	-	-
100 030	13,661	0.83	0.36	2.36E+09	-	-	-	-

7.4.2 Point Source Dischargers

Major dischargers to the Whetstone Creek watershed include the Candlewood Lake, Mount Gilead, and Cardington WWTPs. Minor facilities include the treatment works serving the Village of Edison and Northmoor Local Schools. Marathon Ashland Pipeline is the only miscellaneous discharger in the watershed. A summary of the pollutant wasteload from regulated point sources is presented in **Table 7.16**. **Tables B.2** and **B.3** provide additional information regarding individual wasteloads from minor and miscellaneous facilities.

Table 7.16 Existing point source loads to the Whetstone Creek watershed

Facility	**TP** *lb/yr*	**TSS** *tn/yr*	**FC** *cnt/seas*
Candlewood Lake WWTP	689	1.5	4.21E+11
Mt. Gilead WWTP	6,317	7.2	3.15E+11
Cardington WWTP	2,014	2.6	1.52E+11
Minor WWTPs	103	0.2	4.84E+11
Miscellaneous Dischargers	2	0.0	0.00E+00
Total	**9,124**	**11.6**	**1.37E+12**

The Candlewood Lake WWTP was originally constructed in 1980 with a design average treatment capacity of 15,000 gpd. The existing plant consists of two facultative lagoons which are operated in series. Four surface aerators were added to the lagoons in 1995. The lagoons were deepened to a total depth of 5'8" in 1996 to improve the treatment efficiency. Since 1980, the Candlewood Lake development has continued to grow without a commensurate expansion of their WWTP. The existing plant is hydraulically overloaded (average daily flow 84,200 gpd) which has resulted in chronic noncompliance with the effluent loading limits contained in the effective NPDES permit.

Candlewood Lake recently completed construction of a new wastewater treatment plant that is now functioning. The new plant is designed for an average daily flow of 300,000 gpd and will meet tertiary treatment limits (i.e., nutrient removal). The treatment train consists of flow equalization, extended aeration, clarification, rapid sand filtration, ultraviolet disinfection and post aeration.

The Mount Gilead WWTP is a conventional activated sludge plant designed to treat an average daily flow of 0.474 MGD. Unit processes at the plant include influent bar screens, a comminutor, primary settling, extended aeration, final clarification, chlorination, dechlorination and post aeration. Solids are treated through anaerobic (sludge from primary settling) and aerobic digestion (sludge from secondary settling) followed by sand drying beds or liquid land application. The average daily flow at outfall 001, for the time period between January - December 2003 was 0.59 MGD, significantly over the design average. The maximum flow during this period of record was 2.31 MGD.

The Cardington WWTP has a design average treatment capacity of 0.5 MGD. The wet stream process at the facility includes an influent lift station, comminution, screening, aerated grit removal, extended aeration, clarification, chlorine disinfection, post aeration and dechlorination. Solids handling consists of aerobic digestion, dewatering with sludge drying beds, sludge storage and land application. The average daily flow at outfall 001, for the time period between January - December 2003 was 0.43 MGD. The maximum flow during this period of record was 1.35 MGD.

The Candlewood Lake, Mt. Gilead, and Cardington WWTPs each contribute to the problems of nutrient enrichment and bacterial contamination in Whetstone Creek. The Candlewood Lake WWTP is associated with the non-attainment of EWH at RM 29.3 of Whetstone Creek because of nutrient enrichment. The Mt. Gilead WWTP is associated with the partial attainment of EWH at RM 21.5 of Whetstone Creek, again due to nutrient enrichment. Whetstone Creek does not return to full attainment anywhere downstream of Mt. Gilead or Cardington.

These three WWTPs have a pronounced impact on the chemical water quality of Whetstone Creek. Average instream TP increases downstream of all three plants, most noticeably immediately below Mt. Gilead and Cardington. Average instream TSS increases sharply downstream of Mt. Gilead and Cardington. Similarly, average instream FC increase downstream of Mt. Gilead and Cardington, indicating disinfection may be an issue. **Figures B.4** through **B.6** depict water-chemistry results of Whetstone Creek, and illustrate the effect of these points sources.

7.4.4 Home Sewage Treatment Systems

Failing HSTSs are a source of impairment to the Whetstone Creek watershed. Failing HSTSs contribute significantly to elevated phosphorus and fecal coliform concentration observed. Failing HSTSs in the Candlewood Lake area are believed to contribute the partial attainment of EWH at RM 30.5 of Whetstone Creek. HSTSs are also believed to be the source of recreational use impairment on Shaw Creek, and the partial attainment of WWH on Claypole Run. The pollutant contributions associated with failed HSTSs in the Whetstone Creek watershed are presented in **Table 7.17**

Table 7.17 Existing HSTS loads

HUC14	Number of HSTS	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*
100 010	2,000	1,336	5.01	2.79E+15
100 020	310	348	1.31	7.27E+14
100 030	430	384	1.44	8.02E+14
Total	**2,740**	**2,068**	**7.76**	**4.32E+15**

7.4.5 Livestock with Stream Access

Livestock with stream access was observed at two locations in the Whetstone Creek watershed, including in Whetstone Creek at RM 18.2 and 9.2, and Sam's Creek at RM 1.4. This short list is likely not inclusive all problem areas, but these are the documented locations. The fecal coliform load contributed by livestock with stream access is presented in **Table 7.18** at the end of this section.

7.4.6 Channel Maintenance

Channel maintenance is a source of impairment to the Whetstone Creek watershed. The upper segment of Shaw Creek is the only area known to be actively maintained by the Morrow County, but many other areas are in various stages of past channelization.

Shaw Creek is actively maintained from Thatcher Road to South Canaan Road (RM 13.2 to 10.3). This segment is in full attainment of WWH, but may be contributing to downstream siltation due to its degraded condition. The average TSS concentration of Shaw Creek equals the 87th percentile value of all Whetstone tributaries and the 93rd percentile of all Olentangy

Tributaries. These elevated values indicate the Shaw Creek may be exporting large sediment loads downstream.

7.4.7 Stream Impoundment

Stream impoundment is a source of impairment to the Whetstone Creek watershed. The Delaware Lake Dam results in an impounded area at the mouth Whetstone Creek and extending upstream nearly three-miles. The partial attainment of EWH at RM 2.6 is partially attributed to the impoundment. Delaware Lake is considered an essentially permanent modification; therefore, it is not a subject of this TMDL. However, siltation is also listed as a cause of impairment at RM 2.6 and is likely exacerbated by the impoundment. If upstream sediment loading can be reduced, the impounded segment may improve regardless of the dam.

7.4.8 Existing Pollutant Load Summary

The existing loads to the Whetstone Creek watershed are summarized in **Table 7.18**.

Table 7.18 Summary of existing loads to the Whetstone Creek watershed

Source	**TP** *lb/yr*	**TSS** *tn/yr*	**FC** *cnt/seas*
(1) Major NPDES	0	0	0
(2) Minor NPDES	9,122	11.5	1.37E+12
(3) Miscellaneous NPDES	1.8	0	0
(4) MS4	0	0	0
(5) HSTS	2,068	7.8	4.32E+15
(6) CSO	0	0	0
(7) Livestock Access	0	0	3.10E+14
(8) SSO	0	0	0
(9) NPS	47,895	26,581	6.32E+15
(10) Wasteload Existing[1]	11,192	19	4.32E+15
(11) Load Exising[2]	47,895	26,581	6.63E+15
(12) Total Existing[3]	59,087	26,600	1.10E+16

1. Equals the sum of 1, 2, 3, 4, 5, 6 and 8.
2. Equals the sum of 7 and 9.
3. Equals the sum of 10 and 11.

8 TMDLs and Allocations

A TMDL is a tool for implementing water quality standards, and is based on the relationship between pollution sources and instream water quality conditions. TMDLs establish allowable loadings or other quantifiable parameters for a waterbody, and thereby provide the basis for states to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.

A TMDL is defined as the sum of its load allocations, wasteload allocations, and a margin of safety. Load allocations (LA) are the portion of the TMDL reserved for nonpoint sources of pollution. Wasteload allocations are the portion reserved for point sources. The margin of safety (MOS) is a portion of the TMDL reserved for uncertainty in the method of calculation. MOS may be included explicitly or implicitly. TMDLs are required to consider both critical condition and seasonality for each parameter of concern.

TMDLs may be expressed in terms of either mass per time, toxicity, or other appropriate measure. Additionally, TMDLs may be developed at variable temporal and spatial resolutions. The name “TMDL” implies the maximum load is expressed in days; however, TMDLs are often calculated on a monthly, seasonal, or annual basis dependent upon the nature of the parameter of concern. The spatial scale at which a TMDL is calculated is dependent upon the distribution of impairment within the TMDL study area. TMDLs can be calculated for individual stream segments, sub-watershed, or even entire basins.

TMDL development requires the definition of the existing load, calculation of the loading capacity, and allocation of the TMDL. The existing load is the quantity of a pollutant that is contributed to a waterbody prior to TMDL implementation. The existing load includes contributions from all sources, including point, nonpoint, and natural. The loading capacity is the quantity of a pollutant that a waterbody can receive and still maintain water quality standards. The loading capacity is dependent upon the physical, chemical, and biological processes occurring in the waterbody. Allocation of the TMDL involves the equitable distribution of the loading capacity to all known sources in consideration of technical and economical feasibility as well as water-quality related implications.

Ultimately, the goal of a TMDL is the attainment of use designation. Attainment of aquatic life use designation in the State of Ohio is primarily dependent upon biocriteria (ORC 3745-1-07). Biocriteria are defined by multiple biological indices that measure the diversity and relative abundance of aquatic organisms. Aquatic organisms are affected by a combination of variables that are not limited to load based pollutants: those for which a TMDL are traditionally developed. Environmental conditions, such as instream dissolved oxygen and physical habitat quality, play an equally important role. As such, TMDLs are also developed for non-load based parameters in a method analogous to that for traditional TMDLs.

The following sections present the method of calculation and TMDL values for the Olentangy River watershed. **Section 8.1** presents load-based TMDLs. **Section 8.2** presents non-load-based, or environmental condition-based, TMDLs.

8.1 Load-Based TMDLs

TP, TSS, and FC TMDLs are calculated for the upper, middle, and lower Olentangy watersheds, as well as the Whetstone Creek watershed. The temporal scale of the TMDLs is dependent upon the parameter of concern. TP and TSS TMDLs are calculated on an annual basis. FC TMDLs are calculated for the recreation season, May 1st to October 15th.

8.1.1 Method of TMDL Calculation

The TP, TSS, and FC TMDLs equal the difference of the assimilative capacity of each watershed and any upstream loading. The assimilative capacity of a watershed equals the product of the average flow volume for the calculation period and the instream target for the parameter of concern. The flow volumes used are simulated using SWAT or calculated from USGS gages.

The Ohio State University applied SWAT to the Olentangy watershed. SWAT results are used to determine the flow volumes for the upper and lower Olentangy watersheds, as well as the Whetstone Creek watershed. A detailed description of the set-up and calibration of SWAT for the Olentangy watershed is presented in the accompanying report *Olentangy River Watershed Total Maximum Daily Load Study* (D'Ambrosio et al., 2006). USGS gage #03225500, located on the Olentangy River immediately below the Delaware Lake Dam, is used to calculate flow volumes for the middle Olentangy watershed.

Where appropriate, upstream loading to each watershed equals the TMDL of any contributing areas. Upstream loading to the middle Olentangy watershed equals the sum of the TMDLs for the upper Olentangy and Whetstone Creek watersheds. Upstream loading to the lower Olentangy watershed is calculated differently because of Delaware Lake. Delaware Lake functions as a settling basin, and more assimilative capacity is available in water exiting the reservoir than water entering. For this reason upstream loading to the lower Olentangy watershed is calculated as the product of the flow volume from the middle Olentangy watershed for the calculation period and a representative instream concentration for the parameter of concern. The 75th percentile values of TP, TSS, and FC samples taken directly below the dam as part of the 2003 assessment are used as the representative instream concentrations.

Table 8.1 presents the flow volume and instream target values used to calculate the TP, TSS, and FC TMDLs for each Olentangy watershed. Also presented in **Table 8.1** are the upstream loadings to each watershed.

Table 8.1 Flow, Loading Capacity, and TMDL Values

Parameter	Flows		Targets		Loads			
	Value	Unit	Value	Unit	Assimilative Capacity	Upstream	TMDL	Units
Upper Olentangy watershed								
TP	1.05E+08	*m³/yr*	0.11	*mg/l*	25,457	0	25,457	*lb/yr*
TSS	1.05E+08	*m³/yr*	31	*mg/l*	3,587	0	3,587	*tn/yr*
FC	3.36E+07	*m³/seas*	1,000	*cnt/100ml*	3.36E+14	0	3.36E+14	*cnt/seas*
Middle Olentangy watershed								
TP	3.05E+08	*m*³/yr	0.16	*mg/l*	107,388	57,411	49,977	*lb/yr*
TSS	3.05E+08	*m*³/yr	44	*mg/l*	14,766	6,183	8,583	*tn/yr*
FC	9.90E+07	*m*³/seas	1,000	*cnt/100ml*	9.90E+14	6.21E+14	3.68E+14	*cnt/seas*
Lower Olentangy watershed								
TP	4.61E+08	*m³/yr*	0.16	*mg/l*	162,287	55,708	106,579	*lb/yr*
TSS	4.61E+08	*m³/yr*	41	*mg/l*	20,793	11,158	9,635	*tn/yr*
FC	1.55E+08	*m³/seas*	1000	*cnt/100ml*	1.55E+15	1.58E+14	1.39E+15	*cnt/seas*
Whetstone Creek watershed								
TP	9.08E+07	*m*³/yr	0.16	*mg/l*	31,955	0	31,955	*lb/yr*
TSS	9.08E+07	*m*³/yr	26	*mg/l*	2,596	0	2,596	*tn/yr*
FC	2.85E+07	*m*³/seas	1,000	*cnt/100ml*	2.85E+14	0	2.85E+14	*cnt/seas*

8.1.2 Method of Allocation

The following section describe the method of allocation to NPDES dischargers, HSTSs, CSOs, SSOs, livestock with stream access, MS4s, and NPS. The allocations, along with the existing condition and TMDLs, are summarized for each watershed in **Tables 8.2**, **8.3**, **8.4**, and **8.5**. Where indicated below, detailed information regarding individual allocations is presented in **Appendix B**.

<u>Point Source Dischargers</u>
The method of allocation to NPDES dischargers is dependent upon the parameter of concern and the type of discharge. The allocation scenario used considers both the size and location of the discharge, as well as the value and quality of the receiving stream. No permit changes are necessary for TSS or FC; therefore, the wasteload allocations for TSS and FC equal the estimated existing loads. Several permit changes are recommended regarding TP. Where TP permit changes are recommended, the following allocation method is used:

- Major WWTPs discharging to EWH or superior high-quality waters receive a 1.0 mg/L TP permit limit for the winter/spring period, and a 0.5 mg/L TP limit for the summer/fall period.
- Major WWTPs discharging to other waters in the watershed receive a 1.0 mg/L annual TP limit.
- Significant minor WWTPs discharging to EWH or superior high-quality waters receive a 1.0 mg/L annual TP limit
- All other NPDES dischargers receive no TP limit; their wasteload allocation equals their estimated existing load.

Table 8.2 TP wasteload allocations for NPDES dischargers

Facility Name	TMDL Watershed	Permit #	Facility Type	Design Flow *MGD*	Permit Period[1]	Permit Limit *mg/l*	WLA *lb*
City of Galion WWTP	upper	2PD00030	Major	2.70	Annual	1.0	8,224
Candlewood Lake WWTP	Whetstone	4PU00005	Minor	0.30	Annual	1.0	914
Mt. Gilead WWTP	Whetstone	4PB00102	Minor	0.82	Annual	1.0	2,498
Cardington WWTP	Whetstone	4PA00100	Minor	0.50	Annual	1.0	1,523
Marion County WWTP	middle	2PJ00002	Major	1.75	Annual	1.0	5,331
City of Delaware WWTP	lower	4PD00004	Major	10.00	Summer-Fall	0.5	6,384
					Winter-Spring	1.0	17,692
Delaware County OECC	lower	4PK00001	Major	6.00	Summer-Fall	0.5	3,831
					Winter-Spring	1.0	10,615

1. Summer-Fall = June 1 through October 31. Winter-Spring = November 1 through May 31.

Home Sewage Treatment Systems

Wasteload allocations for HSTSs equal the product of the existing wastewater flow-rate and wastewater-quality concentrations associated with an acceptable level of treatment. Wastewater-quality concentrations associated with acceptable treatment are referenced from Table 3-19 of the U.S. EPA HSTS Manual (USEPA, 2002). The values used for TP, TSS, and FC are 4 mg/l, 40 mg/l, and 1000 cnt/100 ml, respectively. HSTS wasteload allocations for individual sub-watersheds are presented in **Table B.5**.

Combined Sewer Overflows

The CSO allocations for TP, TSS, and FC equal the product of CSO volume for a typical year and water-quality values associated with urban stormwater. This method of allocation assumes a stormwater load will exist following the elimination of all CSO. The water-quality values for urban stormwater are referenced from Table 15-3 of *Wastewater Engineering* (Metcalf & Eddy, 1999). Values of 0.67mg/l, 67 mg/l, and 1000 counts/100ml are used for TP, TSS, and FC, respectively.

Sanitary Sewer Overflows and Livestock with Stream Access

Allocations for SSO and livestock with stream access equal zero. SSO is considered an illicit discharge; therefore, it receives no allocated load. The preferred management practice for livestock with stream access is exclusion from the stream. If implemented this practice eliminates the pollutant contribution; therefore, livestock with stream access receives no allocation.

Municipal Separate Storm Sewer System Areas and Nonpoint Source Pollution Runoff

The method of allocation for MS4 areas and NPS runoff is as follows. First, allocations are made to major NPDES, minor NPDES, HSTSs, SSO, CSO, and livestock with stream access. The un-allocated portion of the TMDL is then determined. The remaining TMDL load is allocated to the MS4s and NPS run-off

This amount is compared to the existing MS4 and NPS runoff loads, and the collective percent they must be reduced is determined. This percent reduction is applied to both the MS4 and

NPS runoff existing load to calculate their allocations. MS4 and NPS allocations for individual sub-watersheds are presented in **Table B.4.**

Table 8.3 TMDL Summary of the upper Olentangy watershed

Group	Line	Source	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*	Calculation (Lines or report section)
Existing Loads	1	Major NPDES	15,716	30.0	6.31E+11	§ 7.1.2
	2	Minor NPDES	1,299	3.0	9.10E+11	§ 7.1.2
	3	Miscellaneous NPDES	93.6	5	0	§ 7.1.2
	4	MS4	227	28.5	3.90E+11	§ 7.1.1
	5	HSTS	2,248	8.4	4.69E+15	§ 7.1.3
	6	CSO	0	0	0	-
	7	Livestock Access	0	0	3.41E+14	§ 7.1.4
	8	SSO	0	0	0	-
	9	Runoff, GW, Tile	72,445	36,680	4.21E+15	§ 7.1.1
	10	Wasteload Existing	19,583	74.5	4.69E+15	1+2+3+4+5+6+8
	11	Load Existing	72,445	36,680	4.55E+15	7+9
	12	Total Existing	92,028	36,755	9.24E+15	*10+11*
TMDL	13	TMDL	25,457	3,587	3.36E+14	§ 8.1
Allocations	14	Major NPDES	8,224	30.0	6.31E+11	§ 8.2.1
	15	Minor NPDES	1,299	3.0	9.10E+11	§ 8.2.1
	16	Miscellaneous NPDES	93.6	5	0	§ 8.2.1
	17	MS4	46.6	2.8	3.10E+10	§ 7.2
	18	HSTS	899	4.5	4.69E+11	§ 8.2.2
	19	CSO	0	0	0	-
	20	Livestock Access	0	0	0	§ 8.2.3
	21	SSO	0	0	0	-
	22	Runoff, GW, Tile	14,894	3,542	3.34E+14	§ 8.2.4
	23	Total Wasteload Allocation	10,562	45	2.04E+12	14+15+16+17+18+19+21
	24	Total Load Allocation	14,894	3,542	3.34E+14	20+22
Percent Reductions	25	Major NPDES	48%	0%	0%	*(1-14)/1*
	26	Minor NPDES	0%	0%	0%	*(2-15)/2*
	27	Miscellaneous NPDES	0%	0%	-	*(3-16)/3*
	28	MS4	79%	90%	92%	*(4-17)/4*
	29	HSTS	60%	47%	100%	*(5-18)/5*
	30	CSO	-	-	-	*(6-19)/6*
	31	Livestock Access	-	-	100%	*(7-20)/7*
	32	SSO	-	-	-	*(8-21)/8*
	33	Runoff, GW, Tile	79%	90%	92%	*(9/22)/9*

Table 8.4 TMDL Summary of the middle Olentangy watershed

Group	Line	Source	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*	Calculation (Lines or report section)
Existing Loads	1	Major NPDES	3,807	2.0	3.37E+11	§ 7.2.2
	2	Minor NPDES	1,578	3.7	1.17E+12	§ 7.2.2
	3	Miscellaneous NPDES	4.0	0.5	0	§ 7.2.2
	4	MS4	218	26.2	3.39E+11	§ 7.2.1
	5	HSTS	2,477	9.3	5.17E+15	§ 7.2.3
	6	CSO	0	0	0	-
	7	Livestock Access	0	0	1.50E+15	§ 7.2.4
	8	SSO	0	0	0	-
	9	Runoff, GW, Tile	96,341	27,263	5.33E+15	§ 7.2.1
	10	Wasteload Existing	8,083	41.6	5.17E+15	1+2+3+4+5+6+8
	11	Load Existing	96,341	27,263	6.83E+15	7+9
	12	Total Existing	104,425	27,305	1.20E+16	10+11
TMDL	13	TMDL	49,977	8,583	3.68E+14	§ 8.1
Allocations	14	Major NPDES	5,331	2.0	3.37E+11	§ 8.2.1
	15	Minor NPDES	1,578	3.7	1.17E+12	§ 8.2.1
	16	Miscellaneous NPDES	4.0	0.5	0	§ 8.2.1
	17	MS4	94.9	8.2	2.33E+10	§ 7.2
	18	HSTS	991	5.0	5.17E+11	§ 8.2.2
	19	CSO	0	0	0	-
	20	Livestock Access	0	0	0	§ 8.2.3
	21	SSO	0	0	0	-
	22	Runoff, GW, Tile	41,979	8,563	3.66E+14	§ 8.2.4
	23	Total Wasteload Allocation	7,998	19	2.04E+12	14+15+16+17+18+19+21
	24	Total Load Allocation	41,979	8,563	3.66E+14	20+22
Percent Reductions	25	Major NPDES	-40%	0%	0%	(1-14)/1
	26	Minor NPDES	0%	0%	0%	(2-15)/2
	27	Miscellaneous NPDES	0%	0%	-	(3-16)/3
	28	MS4	56%	69%	93%	(4-17)/4
	29	HSTS	60%	47%	100%	(5-18)/5
	30	CSO	-	-	-	(6-19)/6
	31	Livestock Access	-	-	100%	(7-20)/7
	32	SSO	-	-	-	(8-21)/8
	33	Runoff, GW, Tile	56%	69%	93%	(9/22)/9

Table 8.5 TMDL Summary of the lower Olentangy watershed

Group	Line	Source	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*	Calculation (Lines or report section)
Existing Loads	1	Major NPDES	23,884	27.3	9.09E+11	§ 7.3.2
	2	Minor NPDES	2,008	4.7	1.59E+12	§ 7.3.2
	3	Miscellaneous NPDES	59.3	3	0	§ 7.3.2
	4	MS4	11,453	1,597.2	6.91E+12	§ 7.3.1
	5	HSTS	6,098	22.9	1.27E+16	§ 7.3.3
	6	CSO	201	23	1.52E+14	§ 7.3.4
	7	Livestock Access	0	0	0	-
	8	SSO	155	6	4.76E+14	§ 7.3.4
	9	Runoff, GW, Tile	58,144	26,074	1.09E+14	§ 7.3.1
	10	Wasteload Existing	43,858	1,663.2	1.28E+16	1+2+3+4+5+6+8
	11	Load Existing	58,144	26,080	5.85E+14	7+9
	12	Total Existing	102,002	27,743	1.34E+16	10+11
TMDL	13	TMDL	106,579	9,635	1.39E+15	§ 8.1
Allocations	14	Major NPDES	38,522	27.3	9.09E+11	§ 8.2.1
	15	Minor NPDES	2,008	4.7	1.59E+12	§ 8.2.1
	16	Miscellaneous NPDES	59.3	3	0	§ 8.2.1
	17	MS4	10,439	553	6.91E+12	§ 7.2
	18	HSTS	2,439	12.2	1.27E+12	§ 8.2.2
	19	CSO	112	5.6	7.60E+11	-
	20	Livestock Access	0	0	0	-
	21	SSO	0	0	0	-
	22	Runoff, GW, Tile	52,999	9,029	1.09E+14	§ 8.2.4
	23	Total Wasteload Allocation	53,580	606	1.14E+13	14+15+16+17+18+19+21
	24	Total Load Allocation	52,999	9,029	1.09E+14	20+22
Percent Reductions	25	Major NPDES	-61%	0%	0%	(1-14)/1
	26	Minor NPDES	0%	0%	0%	(2-15)/2
	27	Miscellaneous NPDES	0%	0%	0%	(3-16)/3
	28	MS4	9%	65%	0%	(4-17)/4
	29	HSTS	60%	47%	100%	(5-18)/5
	30	CSO	44%	75%	100%	(6-19)/6
	31	Livestock Access	-	-	-	(7-20)/7
	32	SSO	100%	100%	100%	(8-21/8
	33	Runoff, GW, Tile	9%	65%	0%	(9/22)/9

Table 8.6 TMDL Summary of the Whetstone Creek watershed

Group	Line	Source	TP *lb/yr*	TSS *tn/yr*	FC *cnt/seas*	Calculation (Lines or report section)
Existing Loads	1	Major NPDES	0	0	0	§ 7.4.2
	2	Minor NPDES	9,122	11.5	1.37E+12	§ 7.4.2
	3	Miscellaneous NPDES	1.8	0	0	§ 7.4.2
	4	MS4	0	0.0	0.00E+00	§ 7.4.1
	5	HSTS	2,068	7.8	4.32E+15	§ 7.4.3
	6	CSO	0	0	0	-
	7	Livestock Access	0	0	3.10E+14	§ 7.4.4
	8	SSO	0	0	0	-
	9	Runoff, GW, Tile	47,895	26,581	6.32E+15	§ 7.4.1
	10	Wasteload Existing	11,192	19.3	4.32E+15	1+2+3+4+5+6+8
	11	Load Existing	47,895	26,581	6.63E+15	7+9
	12	Total Existing	59,087	26,600	1.10E+16	10+11
TMDL	13	TMDL	25,457	3,587	3.36E+14	§ 8.1
Allocations	14	Major NPDES	0	0	0	§ 8.2.1
	15	Minor NPDES	5,038	11.5	1.37E+12	§ 8.2.1
	16	Miscellaneous NPDES	1.8	0	0	§ 8.2.1
	17	MS4	0	0	0	§ 7.2
	18	HSTS	827	4.1	4.32E+11	§ 8.2.2
	19	CSO	0	0	0	-
	20	Livestock Access	0	0	0	§ 8.2.3
	21	SSO	0	0	0	-
	22	Runoff, GW, Tile	19,589	3,571	3.35E+14	§ 8.2.4
	23	Total Wasteload Allocation	5,867	16	1.80E+12	14+15+16+17+18+19+21
	24	Total Load Allocation	19,589	3,571	3.35E+14	20+22
Percent Reductions	25	Major NPDES	-	-	-	(1-14)/1
	26	Minor NPDES	45%	0%	0%	(2-15)/2
	27	Miscellaneous NPDES	0%	0%	-	(3-16)/3
	28	MS4	-	-	-	(4-17)/4
	29	HSTS	60%	47%	100%	(5-18)/5
	30	CSO	-	-	-	(6-19)/6
	31	Livestock Access	-	-	100%	(7-20)/7
	32	SSO	-	-	-	(8-21)/8
	33	Runoff, GW, Tile	59%	87%	95%	(9/22)/9

8.1.3 Critical Condition and Seasonality

The critical condition for aquatic organisms is the summer when the aquatic life activity and biomass production are at their highest levels, and the organisms are most sensitive to environmental conditions. Summer is also when excessive algal growth, high instream temperatures, and reduced stream flows occur leading to the lowest dissolved oxygen levels. Ohio EPA biological, habitat, and nutrient targets are protective of the critical period because they are based on data collected only during the summer months. Further, assessing the biology during the summer months evaluates the biological performance during the most critical time of the year.

Seasonality is accounted for in the aquatic life indices. Biological and habitat indices are measures of aggregate annual conditions reflecting compounding factors over time. The use of these indices reflects the collective seasonal effects on the biota. The measurement of these indices during the summer period reflects the biotic performance during critical conditions.

The critical condition for nutrient enrichment is the summer warm season, when the potential for primary production is highest. The summer concentration of phosphorus in the water column, however, is dependent upon more than summer phosphorus load contributed to the stream. As phosphorus readily attaches to sediment, detachment of adsorbed phosphorus in bottom sediments can lead to elevated in-stream concentrations regardless of the magnitude of short-term loads. As a result, it is the long-term, or chronic, phosphorus load and sediment load that is more directly related to the degradation of water quality. For this reason phosphorus and sediment TMDLs were developed on an annual basis.

The critical condition for pathogens is a “first flush” situation during the summer when pre-storm flows are the lowest and build-up of bacteria is at its highest. Summer is also the period when the probability of recreational contact is the greatest. For these reasons recreational use designations are only applicable in the period from May 1 to October 15. Pathogen TMDLs were developed for the same May to October time-period in consideration of the critical condition and for agreement with Ohio WQS.

8.1.4 Margin of Safety

The statute and regulations require that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA § 303(d)(1)(C), 40 C.F.R. § 130.7(c)(1)). U.S. EPA guidance explains that the margin of safety may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as a loading set aside. TMDLs for the Olentangy River watershed include an implicit margin of safety that is incorporated into the process for listing impaired waters, the selection of TP and TSS targets, and the method of calculation for the FC TMDL.

The List of Impaired Waters (the 303(d) List)
It is important to keep in mind during the evaluation of the TMDL a major difference in Ohio’s program from other state programs. In Ohio, one way a stream segment is listed on the 303(d) list is for failure to attain the appropriate aquatic life use as determined by direct measurement of the aquatic biological community. Other State programs rely solely on chemical samples in comparison to chemical criteria to determine water quality and designated use attainment. However, relying solely on chemical data does not take into account any of the parameters or other factors for which no criteria exist but that affect stream biology nor does it account for multiple stressor situations. Therefore, the chemical specific approach misses many biologically

impaired streams and may not detect a problem until it is severe. Ohio's approach incorporates an increased level of assurance that Ohio's water quality problems are being identified. Likewise, delisting requires attainment of the aquatic life use determined by the direct measurement of the aquatic biological community. This provides a high level of assurance (and an implicit margin of safety) that if the TMDL allocations do not lead to sufficiently improved water quality then the segments remain on the list until true attainment is achieved.

Total Phosphorus and Sediment
A margin of safety was incorporated implicitly into the TP and TSS TMDLs through the target development process. A conservative assumption implicit in target development lies in the selection of the median statistic used to represent the phosphorus and TSS targets for the WWH streams and the 75th percentile for EWH streams that corresponds to an unimpaired biological community. Since Ohio EPA's evaluation of data for generating target values is based on measured performance of aquatic life and since full attainment can be observed at concentrations above these targets (reinforcing the concept that habitat and other factors play an important role in supporting fully functioning biological communities), water quality attainment can occur at levels higher than the targets. The difference between the actual level where attainment can be achieved and the selected target is an implicit margin of safety.

Pathogens
A margin of safety was implicitly incorporated into the pathogen TMDL. The fecal coliform load to the streams in each sub-watershed was quantified, as was the fecal coliform loading capacity at the outlet of each sub-watershed. Loading capacity was calculated as the product of the seasonal flow volume and the fecal coliform target concentration. No attempt was made to link downstream loading capacity with upstream loading via in-stream processing. Rather, the load reductions recommended by this report are based upon a direct comparison between the two quantities. In reality, considerable die-off occurs between the source of loading and the TMDL endpoint therefore, this unaccounted die-off provides an implicit margin of safety.

8.2 Condition-Based TMDLs

The purpose of the condition-based TMDLs presented in this section is to provide targets that, when achieved, will increase the assimilative capacity of the stream for pollutants and improve upon the physical habitat quality available to aquatic organisms. The condition-based TMDLs are designed to work in concert with the load reductions recommended in the previous section to return impaired stream segments to full attainment. In some circumstances land owners and point source managers may find it preferable to focus upon the condition of the stream as a means of restoration. In others it may be more practical or cost-effective to primarily address pollutant loading. Some combination of both is the most likely to be effective with regard to adequately addressing impairment.

Condition-based TMDLs are included in this report for habitat and bedload. Habitat TMDL targets are primarily designed to address the issues of habitat and flow alteration. Bedload TMDL targets are designed to address the issue of siltation. As discussed above, achievement of the targets provides the secondary benefit of increased assimilative capacity, which will increase the likelihood of achieving the instream targets for TP, TSS, and FC.

In the context of this TMDL, bedload is the streambed material and the soil particles and solids that have settled out of the water column. The total sediment load carried by the stream is the sum of TSS and bedload. The sediment load to the stream generally implies the runoff of soil particles and the solids loading from septic and point sources. The actual quantity of bedload is difficult to calculate accurately, and this load is not necessarily indicative of impairment as it is not necessarily the quantity of streambed sediment that is a stressor but rather the size and quality of the sediment particles themselves. Therefore, a qualitative approach similar to habitat measurements is used to determine the relative difference in the bedload between stream sites.

8.2.1 Method of Development

The habitat and bedload TMDL targets are based upon the QHEI. As discussed in **Section 5.3**, analyses were conducted upon a paired dataset of QHEI and IBI scores to determine the level of habitat quality at which the attainment of WWH and EWH are probable. Simple linear and exponential regressions and frequency analyses of combined and individual components of QHEI metrics in relation to the IBI were examined. The regressions indicated that the QHEI is significantly correlated with the IBI. Scores greater than 75 indicate excellent stream habitat; scores between 60 and 75 indicate good habitat quality; and scores less than 45 demonstrate habitat not conducive to WWH. Scores between 45 and 60 need separate evaluation by trained field staff to determine the potential aquatic life use for the stream.

The analysis of the QHEI components as they relate to IBI scores led to the development of a list of attributes that are associated with degraded communities. These modified (MWH) attributes were further divided into high-influence or moderate-influence attributes based on the statistical strength of the relationships. The presence of MWH attributes can strongly influence the aquatic biology and the QHEI score itself may not reflect this effect. This explains why habitat can be impaired even with a QHEI score above 60 (because other less-influential habitat components are in place). **Table 8.7** lists the high- and moderate- influence MWH attributes.

Table 8.7 MWH Attributes

MWH Attributes		
High Influence	*Moderate Influence*	
• Recent Channelization or No Recovery	• Recovering Channelization	• Two or Less Cover Types
• Silt or Muck Substrate	• Silt Heavy or Silt Moderate	• Intermittent Pools and Maximum Pool Depth < 40 cm
• Low or No Sinuosity and Drainage Area ≤ 20 mi^2	• Sand Substrate (Boat Sites)	• No Fast Current Velocity
• Sparse or Nearly Absent Cover	• Hardpan Substrate Origin	• Extensive or Moderate Substrate Embeddedness
• < 40 cm Maximum Pool Depth for Headwater and Wadeable Sites	• Fair or Poor Development	• No Riffle
	• Low or No Sinuosity and Drainage Area > 20 mi^2	

Total QHEI score and the relative absence of MWH attributes appear to have an approximately equal effect upon the probability of attainment. An accumulation of four MWH attributes corresponds to fewer than 50% of sites achieving a WWH target IBI score of 40. High-influence MWH attributes are particularly detrimental given that the presence of one is likely to result in impairment, and two will likely preclude a site from achieving an IBI of 40 (OEPA, 1999). The QHEI score of 60 or greater is correlated with IBI scores of 40 or greater. A complete habitat

TMDL needs to reflect both a good QHEI score and the relative presence or absence of these MWH attributes.

The QHEI is a macro-scale approach that measures the emergent properties of habitat (sinuosity, pool/riffle development) rather than the individual factors that shape these properties (current velocity, depth, substrate size). The QHEI is used to evaluate the characteristics of a short stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. However, QHEI evaluations are segment specific and do not give a strong indication of the quality of the habitat in other stream segments.

The habitat TMDL equation presented in **Table 8.8** reflects the relationship between the QHEI score, MWH attributes, and aquatic community performance. It is based upon a total score of three (3), and is the sum of the QHEI, high-influence, and total MWH-attribute sub-scores, which are each worth one (1) point. The QHEI sub-score awards one point if the QHEI score of a site is greater than or equal to the target. The high-influence sub-score awards one point if the number of high-influence MWH-attributes present is less than or equal to the target. The total MWH-attribute sub-score awards one point if the total number of MWH attributes present is less than the target.

The bedload TMDL equation presented in **Table 8.8** represents the QHEI factors that most directly related to sediment type, quality, build up, and source origin. The sediment TMDL is a score of 32 for WWH sites and 35 for EWH sites. The individual components of the bedload TMDL (QHEI scores for substrate, channel, and riparian) are allocated as described below.

Table 8.8 Bedload and Habitat TMDL Equations

Bedload TMDL Equation			**Habitat TMDL Equation**			
QHEI Category	*Targets*		*Sub-Score Category*	*Targets*		*Score*
	WWH	*EWH*		*WWH*	*EWH*	
Substrate	≥ 13	≥ 15	QHEI	≥ 60	≥ 75	+1
Channel	≥ 14	≥ 15	# High-Influence	< 2	0	+1
Riparian	≥ 5	≥ 5	Total # MWH	< 5	< 3	+1
Bedload TMDL ►	**≥ 32**	**≥ 35**			**Habitat TMDL ►**	**3**

8.2.2 Habitat and Bedload TMDL Results

Table 8.9 presents results of the bedload and habitat TMDL analysis. Habitat and bedload targets are included for the 77 site assessed in 2003 or 2004. **Table B.6** presents the individual MWH attributes found at each site.

Table 8.9 Habitat and Bedload TMDLs

		Bedload TMDL					Habitat TMDL						
WWH Targets:		≥ 13	≥ 14	≥ 5	≥ 32	-	≥60 = 1 pt	<2 = 1 pt	<5 = 1 pt	+1	+1	+1	3
EWH Targets:		≥ 15	≥ 15	≥ 5	≥ 35	-	≥75 = 1 pt	0 = 1 pt	<3 = 1 pt	+1	+1	+1	3
River Mile	Attainment Status	Substrate Score	Channel Score	Riparian Score	**Total Bedload TMDL Score**	Deviation from Target	QHEI Score	# High-Influence MWH Attributes	Total # MWH Attributes	QHEI Sub-Score	High-Influence Sub-Score	Total MWH-Attribute Sub-Score	**Total Habitat TMDL Score**
Olentangy River (WWH)													
89.3	Full	16.5	16.5	9.5	**42.5**	-	83.0	0	1	1	1	1	**3**
86.1	Full	19.5	6.5	3.5	**29.5**	8%	59.5	3	5	0	0	0	**0**
85.9	Full	18.0	11.0	5.5	**34.5**	-	78.0	1	6	1	1	0	**2**
85.2	Full	18.0	16.5	7.5	**42.0**	-	82.5	0	1	1	1	1	**3**
79.7	*Partial*	8.0	14.5	7.5	**30.0**	6%	69.0	1	5	1	1	0	**2**
74.0	*Partial*	6.0	15.0	5.5	**26.5**	17%	58.5	1	5	0	1	0	**1**
68.1	**Non**	8.0	12.0	4.0	**24.0**	25%	57.0	1	6	0	1	0	**1**
63.4	*Partial*	9.0	14.0	4.0	**27.0**	16%	58.5	1	6	0	1	0	**1**
59.5	-	5.0	6.0	1.5	**12.5**	61%	40.5	2	8	0	0	0	**0**
56.6	-	5.0	5.5	2.5	**13.0**	59%	37.0	3	9	0	0	0	**0**
54.7	*Partial*	15.0	15.5	6.5	**37.0**	-	77.5	0	3	1	1	1	**3**
50.1	Full	17.0	17.0	7.5	**41.5**	-	83.5	0	0	1	1	1	**3**
45.5	Full	19.0	15.0	7.5	**41.5**	-	84.5	0	1	1	1	1	**3**
40.8	*Partial*	13.0	14.0	10.0	**37.0**	-	63.0	0	6	1	1	0	**2**
32.1	Full	15.0	12.0	6.0	**33.0**	-	66.0	0	7	1	1	0	**2**
28.1	*Partial*	15.5	9.0	5.0	**29.5**	8%	55.5	1	7	0	1	0	**1**
27.5	Full	15.5	11.5	6.0	**33.0**	-	76.5	0	5	1	1	0	**2**
24.5	Full	17.5	12.0	7.5	**37.0**	-	75.5	0	5	1	1	0	**2**
Olentangy River (EWH)													
19.4	*Partial*	14.0	17.0	6.5	**37.5**	-	81.5	0	4	1	1	0	**2**
15.0	Full	16.5	12.0	6.5	**35.0**	-	78.0	0	5	1	1	0	**2**
12.4	Full	16.5	14.0	7.0	**37.5**	-	73.5	0	5	0	1	0	**1**
Olentangy River (WWH)													
7.8	Full	18.0	17.0	7.0	**42.0**	-	87.0	0	1	1	1	1	**3**
3.9	Full	12.0	13.0	6.0	**31.0**	3%	71.0	0	6	1	1	0	**2**
Olentangy River (MWH)													
2.1	**Non**	1.0	6.0	3.5	**10.5**	*	32.5	3	9	*	*	*	*****
Olentangy River (WWH)													
1.8	*Partial*	15.0	14.5	4.5	**34.0**	-	75.0	0	3	1	1	1	**3**
0.9	Full	14.0	16.0	6.5	**36.5**	-	79.5	0	5	1	1	0	**2**
Rocky Fork (WWH)													
2.9	Full	15.5	16.5	8.5	**40.5**	-	75.0	0	2	1	1	1	**3**
0.4	**Non**	20.0	13.0	6.5	**39.5**	-	74.0	1	2	1	1	1	**3**
Flat Run (WWH)													
12.6	Full	13.0	12.5	4.0	**29.5**	8%	57.0	2	4	0	0	1	**1**
7.3	Full	20.0	17.0	6.5	**43.5**	-	84.0	0	0	1	1	1	**3**
0.6	Full	17.0	14.5	3.5	**35.0**	-	71.5	0	1	1	1	1	**3**
Thorn Run (WWH)													
1.1	Full	13.0	13.0	4.5	**30.5**	5%	57.5	2	5	0	0	0	**0**
Mud Run (MWH)													

6.7	Full	10.0	5.5	3.0	**18.5**	*	35.0	4	9	*	*	*	*****
2.7	Full	6.0	5.5	3.0	**14.5**	*	37.0	4	9	*	*	*	*****
Bee Run (WWH)													
4.9	*Partial*	1.0	6.5	3.5	**11.0**	66%	33.0	4	9	0	0	0	**0**
0.3	*Partial*	14.5	13.0	7.0	**34.5**	-	60.0	2	6	1	0	0	**1**
Otter Creek (WWH)													
1.1	Full	7.0	9.0	5.5	**21.5**	33%	43.0	4	10	0	0	0	**0**
Grave Creek (MWH)													
3.2	**Non**	6.5	8.0	4.0	**18.5**	*	40.0	4	9	*	*	*	*****
Grave Creek (WWH)													
1.4	**Non**	8.5	4.5	3.5	**16.5**	48%	45.5	3	8	0	0	0	**0**
0.8	*Partial*	18.5	17.5	8.0	**44.0**	-	78.0	0	1	1	1	1	**3**
0.3	-	19.0	16.0	8.0	**43.0**	-	80.0	1	1	1	1	1	**3**
Riffle Creek (MWH)													
4.4	Full	5.0	6.0	3.5	**14.5**	*	33.5	4	8	*	*	*	*****
Riffle Creek (WWH)													
1.4	*Partial*	5.0	13.0	4.0	**22.0**	31%	54.5	0	5	0	1	0	**1**
QuQua Creek (MWH)													
4.6	**Non**	11.0	4.5	2.0	**17.5**	*	29.0	4	10	*	*	*	*****
QuQua Creek (WWH)													
0.1	*Partial*	19.5	11.0	10.0	**40.5**	-	75.0	1	3	1	1	1	**3**
Brondige Run (WWH)													
0.7	**Non**	17.0	16.5	9.0	**42.5**	-	75.5	0	3	1	1	1	**3**
Whetstone Creek (EWH)													
30.5	*Partial*	14.5	15.5	8.5	**38.5**	-	78.5	0	3	1	1	0	**2**
29.3	**Non**	17.0	16.0	8.0	**41.0**	-	74.0	0	2	0	1	1	**2**
28.1	Full	16.0	16.0	5.0	**37.0**	-	79.0	0	1	1	1	1	**3**
25.5	Full	19.0	10.0	7.0	**36.0**	-	75.5	0	4	1	1	0	**2**
22.4	Full	17.5	11.0	5.0	**33.5**	4%	72.0	1	6	0	0	0	**0**
21.7	*Partial*	17.0	10.5	5.5	**33.0**	6%	66.5	0	5	0	1	0	**1**
21.5	*Partial*	17.0	12.0	8.5	**37.5**	-	67.0	1	5	0	0	0	**0**
18.2	*Partial*	17.0	14.5	5.5	**37.0**	-	74.5	0	1	0	1	1	**2**
13.5	*Partial*	10.5	10.5	4.5	**25.5**	27%	65.5	0	5	0	1	0	**1**
9.2	*Partial*	16.0	13.5	3.0	**32.5**	7%	69.5	0	5	0	1	0	**1**
2.5	*Partial*	6.5	16.0	10.0	**32.5**	7%	61.5	1	6	0	0	0	**0**
Trib. to Whetstone Creek (RM 33.71) (WWH)													
0.4	*Partial*	14.0	12.5	4.0	**30.5**	5%	57.5	0	6	0	1	0	**1**
East Branch Whetstone Creek (WWH)													
0.4	*Partial*	15.0	15.5	6.5	**37.0**	-	78.0	0	3	1	1	1	**3**
Sams Creek (WWH)													
1.4	Full	17.0	12.5	6.0	**35.5**	-	66.5	1	3	1	1	1	**3**
Shaw Creek (WWH)													
13.2	Full	6.5	4.0	3.0	**13.5**	58%	35.5	4	9	0	0	0	**0**
10.6	Full	11.0	5.5	3.0	**19.5**	39%	52.5	3	8	0	0	0	**0**
5.2	Full	11.0	16.5	7.0	**34.5**	-	65.0	0	3	1	1	1	**3**
1.6	Full	11.0	15.5	6.5	**33.0**	-	69.5	0	4	1	1	1	**3**
Mitchell Run (WWH)													
0.2	Full	19.0	13.5	5.5	**38.0**	-	72.0	0	2	1	1	1	**3**
Big Run (WWH)													
0.1	**Non**	14.0	13.5	4.5	**32.0**	-	65.0	0	5	1	1	0	**2**
Claypool Run (WWH)													
1.2	*Partial*	9.0	11.0	3.5	**23.5**	27%	56.0	2	6	0	0	0	**0**
Indian Run (WWH)													
0.9	Full	15.0	12.0	7.0	**34.0**	-	69.0	1	7	1	1	0	**2**
Norris Run (WWH)													
1.3	**Non**	14.0	11.0	3.5	**28.5**	11%	62.0	1	5	1	1	0	**2**
Sugar Run (WWH)													

1.3	**Non**	13.5	17.0	6.5	**37.0**	-	69.0	0	2	1	1	1	**3**
Mill Run (WWH)													
0.9	**Non**	15.0	17.5	8.0	**40.5**	-	69.0	0	2	1	1	1	**3**
Trib. to Olentangy R. (RM 20.71) (WWH)													
0.2	**Non**	9.0	14.0	8.5	**31.5**	2%	53.5	3	4	0	0	1	**1**
Trib. to Olentangy R. (RM 18.19) (WWH)													
0.1	**Non**	15.0	16.0	8.5	**39.5**	-	69.0	2	3	1	0	1	**2**
Deep Run (WWH)													
1.1	**Non**	8.5	15.5	4.5	**28.5**	11%	47.5	2	4	0	0	1	**1**
Turkey Run (WWH)													
0.7	**Non**	18.0	14.0	5.0	**37.0**	-	55.0	2	5	0	0	0	**0**
Walhalla Ravine (NA)													
0.9	-	17.0	15.0	5.5	**37.5**	*	58.5	2	4	*	*	*	*****
Glen Echo Ravine (WWH)													
1.0	**Non**	15.0	15.0	5.0	**35.0**	-	61.0	1	2	1	1	1	**3**

8.2.3 Critical Condition

The critical condition for the habitat and bedload TMDLs is the summer when environmental stress upon aquatic organisms is greatest. It is during this period that the presence of high-quality habitat features, such as deep pools and un-embedded substrate, is essential to provide refuge and breeding and feeding locations for aquatic life. QHEI scores, the basis of the habitat TMDLs, are assessed during the summer field season. The habitat and bedload TMDLs are therefore reflective of the critical condition.

8.2.4 Margin of Safety

A MOS was implicitly incorporated into the habitat and bedload TMDLs through the use of conservative target values. The target values were developed though comparison of paired IBI and QHEI evaluations. Using an IBI score of 40 as representative of the attainment of WWH, individual components of the QHEI were analyzed to determine their magnitude at which WWH attainment is probable (OEPA, 1999). Attainment does, however, occur at levels lower than the established targets. The difference between the habitat and bedload targets and the levels at which attainment actually occurs is an implicit margin of safety.

9 Water Quality Improvement Strategy

This section provides a strategy for improving water resources in the Olentangy watershed to the full attainment of applicable water quality standards (WQS). The actions recommended are aimed at reaching the water quality goals and load reductions discussed in this report and address the documented sources of impairment (Ohio EPA, 2005; D'Ambrosio et al., 2006). Additionally, protections are recommended for sustaining water quality in areas currently meeting the applicable WQS. Some recommendations rely on regulatory authority, while others are based on voluntarily action.

Several factors related to the recommended actions are addressed, including:

- Water quality problems addressed
- Effectiveness
- Relative costs
- Potential barriers to success
- Resources available for assistance
- Locations where activities should take place
- Participation needed for successful implementation
- Timeframe under which actions should occur.

A process for validating that the recommended actions are effectively achieving the water quality goals is also provided. Details include a recommended monitoring strategy, conditions sufficient to warrant revising the existing recommendations, and a methodology for selecting alternative actions.

This remainder of this chapter is organized as follows:

- Implementation approach and rationale
- Recommendations for each of the sub-watersheds (assessment units)
- Reasonable Assurance that recommended actions are carried out
- Process for evaluation and revision of the water quality improvement strategy

9.1 Implementation Approach and Rationale

TMDLs are developed for ***pathogens*** to address impairment of recreational uses and also for ***habitat***, ***sediment***, and ***total phosphorus (TP)*** to address impairment of aquatic life uses. Recreational use impairment is pervasive throughout most of the basin while aquatic life use impairment occurs more discretely on a segment by segment basis. The recommendations that follow provide a basic approach for addressing each of these causes of impairment and their respective sources. Also included are recommendations regarding ***stream geomorphology, floodplain connectivity***, and ***stormwater management*** that are intended to provide further enhancement and protection of aquatic life uses.

It is possible that some stream segments not surveyed are impaired by sources that have been identified in surveyed segments. A broad application across the watershed of some of the recommendations is likely to abate those sources as well.

The discussion in this section is organized according to the cause of impairment, providing a broad overview of what is necessary for meeting and maintaining water quality standards and often includes technical or scientific rationale. Recommendations being made for specific locations will be discussed in the following section, and a more detailed discussion regarding causes and sources of impairment can be found in Chapter 7 of this report as well as the Technical Support Document for the Olentangy River (Ohio EPA, 2005).

Table 9.1 Summary of the cause/source associations for impaired recreational and/or aquatic life uses.

Region of watershed and dominant land use	Major cause/source associations leading to impairment
Upper portion of the watershed with agricultural land use • upper Olentangy (05060001 090) • middle Olentangy (05060001 110) • Whetstone Creek (05060001 100)	• Channelization (for drainage improvement) resulting in habitat degradation and sedimentation • Point source discharges from WWTPs resulting in high nutrient loading • Row crop production resulting in nutrient loading and sediment loading (also degrades habitat) • Failing HSTS resulting in nutrient and pathogen loading • Livestock production resulting in nutrient and pathogen loading
Middle to lower portion of the watershed where land use is transitioning from agriculture to commercial and residential • middle Olentangy (05060001 110) • lower Olentangy (05060001 120)	• Changing land cover and land disturbance (i.e., urbanization) resulting in nutrient loading and sediment loading (also degrades habitat) and altered hydrology (also degrades habitat) • Failing HSTS resulting in nutrient and pathogen loading • Lowhead dam impoundment resulting in poor habitat and siltation
Lower portion of the watershed where land use is urban • lower Olentangy (05060001 120)	• CSO/SSO discharges resulting in nutrient and pathogen loading • Urban runoff resulting in nutrient loading and elevated stream discharge • Lowhead dam impoundment resulting in poor habitat, siltation, and low dissolved oxygen concentrations
Refer to the Technical Support Document for the Olentangy River (OEPA, 2004) for detailed impairment and cause/source information.	

9.1.1 Pathogens

Recreation use impairments in the rural part of the Olentangy River watershed (i.e., Crawford, Marion, Morrow, and parts of Delaware counties) are primarily attributable to point source discharges, failing HSTS, and manure originating from livestock operations. Livestock farming is not intense in the watershed, however a number of operations are sources of impairment. Wildlife is believed to make a relatively small contribution to the pathogen load. In urban areas, namely the City of Columbus, pathogen contamination is primarily the result of CSOs and SSOs and to a lesser degree failing HSTS.

Combined Sewer Overflows / Sanitary Sewer Overflows

CSOs and SSOs causing recreational use impairments occur within the City of Columbus and are being addressed through the actions that satisfy Consent Decrees issued in 2002 and 2004 and are in accordance to the Wet Weather Management Plan developed by the City. Reductions in this source of pollution are expected to continue over the next 40 years, however up to 70% of the discharge volume should be abated by 2010. For details regarding the Wet Weather Management Plan refer to the following web address: http://utilities.ci.columbus.oh.us/sewers_drains/Project%20Clean%20Rivers.htm .

Home Sewage Treatments Systems

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. However it is not practical to extend sanitary sewers to some of the problematic areas in the watershed due to prohibitive costs and the potential for environmental degradation during the installation of sewer lines. An effective alternative to centralization requires improving failed systems through upgrades or the installation of new systems. Installation of new systems must be in compliance with applicable regulations (OAC 3701-29). Ensuring that HSTS be properly maintained is important for preventing pollution problems in the future.

Any direct routing of septic lines to surface waters, such as by-passing leach fields and/or septic tanks, is an illegal practice (OAC 3701-29) and creates unhealthy and unsafe conditions. These types of connections should be identified and enforcement and/or other actions be taken to correct the situation. Local Health Departments are responsible for responding to complaints issued regarding illicit connections and are expected to be proactive in locating them (OAC 3701-29).

Livestock Production

Pathogen contamination 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 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) and 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 run off. 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/).

Table 9.2 Summary of the strategies for addressing each listed cause of impairment in the Olentangy River watershed.

PATHOGENS	
• Reduce point sources o Implement CSO and SSO plans • Reduce manure sources o Eliminate/reduce livestock access to streams o Improve storage and handling operations o Improve land application methods and rates o Utilize drainage water management	• Reduce loading from HSTS o Identify/detect failing systems o Upgrade/replace as appropriate o Protect against future failures through training and education on system maintenance o Provide sewers (where feasible)
HABITAT	
Channelization	*Stream Stability*
• Increase heterogeneity of channel morphology and flow conditions o Natural Channel design and stream restoration o Two-stage approach to drainage ditches • Create and protect in-stream habitat o Stream restoration and bio-engineering techniques • Increase floodplain connection	• Approximate natural hydrology of watershed o Reduce urban runoff ▪ Minimize imperviousness of landscape ▪ Increase stormwater infiltration o Water table management o Increase natural vegetative cover o Wetland creation and restoration • Increase floodplain connection
TOTAL PHOSPHORUS	
• Reduce point sources o Permit restrictions • Reduce overland sources o Reduce overland sediment loading (see below) o Reduce land application o Improve timing of fertilizer application o Provide stream side buffering	• Increase assimilative capacity of stream system o Increase floodplain connection o Improve bed substrate (e.g., reduce fines) o Increase stream detention time ▪ Increase sinuosity ▪ Increase riffle-pool development
SEDIMENT	
• Reduce overland source loading o Reduce potential for surface erosion ▪ Protective cover ▪ Conservation tillage o Provide stream side buffering	• Reduce in-stream erosion o Improve stream stability (see habitat above) • Increase assimilative capacity of stream system (see total phosphorus above)

9.1.2 Habitat

In the Olentangy watershed degraded stream habitat is primarily the result of channelization and ongoing maintenance activities carried out to improve water conveyance. These activities are related to agricultural drainage improvements however, there is also channelization in urban areas where buildings and other infrastructure lie in close proximity to the streams. Most channelization is found on small to medium sized tributaries but also along some parts of the mainstem of the Olentangy River.

Habitat is also impaired or threatened by channel instability resulting from altered hydrology. In agricultural areas, practices specifically designed to increase drainage efficiency (e.g., sub-surface drainage, channelization) as well as unintended impacts of farming (e.g., soil compaction, poor vegetative cover) increase storm flows. Efficient drainage also results in more extreme and more frequent low flow conditions. This diminishes the capacity of the system to assimilate pollutants and support diverse aquatic communities. In urban and developing areas, impervious surfaces create substantial increases in runoff which increases channel erosion and decreases stability.

Other habitat impairments include impounded flows from lowhead dams and sedimentation. Sedimentation impairs substrate habitat and the aquatic communities, however discussion regarding its abatement will be reserved for **Section 9.2.3**. The following three sub-sections discuss habitat improvements that address channelization, stream instability, and impoundments, respectively.

Channelization

Channelization creates deeply incised and straight ditches or streams. This disconnects waterways from floodplains, which have damaging impacts on the quality of the system (see **Section 5.4**). Channelized streams change little along their length, lack features such as riffles and pools and have minimal variation in flow characteristics. This homogenous configuration reduces biological diversity (Hahn, 1982, Mathias and Moyle, 1992). Additionally, the in-stream cover important for diverse aquatic communities is often absent.

In the upper and middle part of the watershed, channelization enhances the drainage of agricultural land, which increases field accessibility and improves and/or protects crop growth (OSU, 1998 Bulletin 871-98 http://ohioline.osu.edu/b871/index.html). These practices are sanctioned through Ohio's drainage laws (ORC 6131 and OAC 1511) despite the deleterious effects on water resources. A challenge is to carry out actions that improve water quality while maintaining adequate drainage for profitable agriculture.

In terms of drainage related to agriculture, a primary function of a stream or ditch is to provide an outlet for sub-surface drainage infrastructure (i.e., drain tiles). This requires that the elevation of the channel bottom be far below (usually several feet) the elevation of the surrounding crop fields, which results in floodplain disconnections. Adequate outlets can be provided and habitat improvements achieved through stream restoration and a two-stage ditch approach.

The following three minor sub-sections discuss stream restoration, two-stage ditch management, and bio-engineering techniques as a means to improve habitat and water quality in channelized streams and ditches.

<u>Stream Restoration</u>

The recommended stream restoration will create or lead to the development of well connected floodplain areas, channel sinuosity, and also riffle and pool habitats where appropriate. The detention and temporary storage of high flows in created floodplains will likely mitigate downstream impacts associated with flooding. Stream restoration provides greater capacity to accommodate sub-surface drainage and enhances that use of the system. Although land drainage is not a goal of the Clean Water Act, this may provide some compensatory benefits that make landowners more willing to take this approach.

Restoration of agricultural ditches is not commonly done, and there is only one such project that is known to the Ohio EPA to have taken place in Ohio (www.oxbowriver.com/Web_Pages/Project_pages/P-Bokes-03.html). Early monitoring results are showing marked improvement in the resource (Steve Phillips, *personal communication*, 2005).

To provide the maximum benefit of stream restoration (i.e., suitable physical habitat), the location of potential projects should be considered from the perspective of the sub-basin scale or larger. Higher priority should be given to locations that facilitate upstream migration of high quality fish communities to areas with good habitat and adequate water quality. In essence restored stream segments should bridge gaps between segments of high quality habitat. Generally speaking, downstream areas of degraded habitat should be addressed first in order to maximize continuous (or nearly continuous) high quality habitat, providing the greatest opportunity for upstream re-colonization by downstream source populations.

Additional information regarding natural channel design can be accessed at http://www.epa.gov/region4/water/watersheds/coordination/streamrestoration.html.

Two-stage approach

Stream restoration that employs natural channel design is superior to a two-stage ditch approach when strictly considering environmental benefits, but since stream restoration entails more earth moving and is considerably more expensive, a two-stage approach may be practical for addressing channelization on a large scale.

A two-stage ditch is similar to a typical drainage ditch (i.e., one-stage) but differs in some key ways. Two-stage ditches are wider at the top of their banks which increases the overall capacity of the ditch and out-of-bank flooding occurs less often. The bottom of a two-stage ditch has low elevation benches that are inundated during moderately high and higher flow events. The low flow channel is narrower than a typical ditch bottom and often develops a low-amplitude, sinusoidal pattern within the larger ditch. More information regarding two-stage ditches can be found at http://streams.osu.edu/naturalchannel.php. See **Figure 9.1** for depictions of a two-stage ditch.

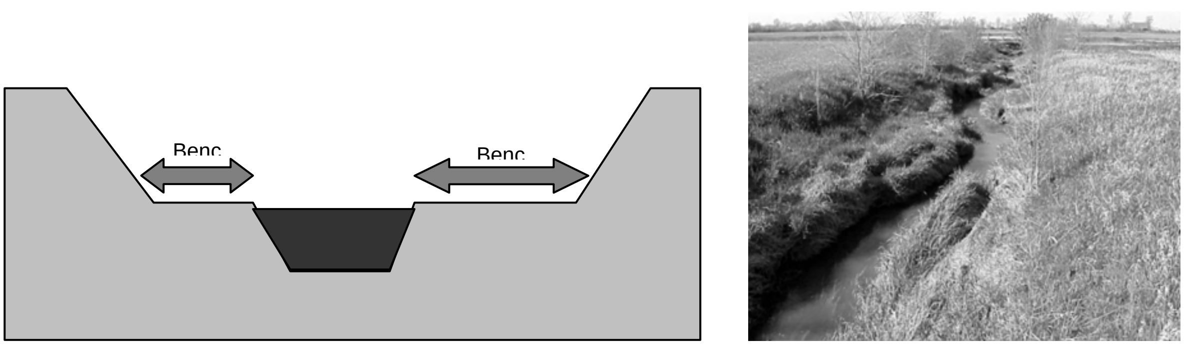

Figure 9.1 Graphical depiction of a two-stage ditch (left) and photo (right) taken in Wood County, Ohio. Notice the slight meander pattern along the ditch bottom in the picture.

Two-stage channels yield modest improvements to stream habitat as compared to one-stage ditches. These benefits are realized because benches function to some degree like floodplains and the channels undergo more stable erosion and deposition processes. Bank erosion is less likely to occur because the toe (i.e., where the bank meets the channel bottom) is protected by vegetated bench deposits and flow depths are lower, which results in lower shear stress (see **Section 5.4**). Less bank erosion in these fairly unstable systems is beneficial to immediate and downstream reaches because in-stream sources of sediment are reduced.

Stream flow in the narrower low flow channel is more competent to move and redistribute fine sediment than wider channel bottoms typical of highly maintained ditches. Fine sediment is deposited and stored on the benches, which increases assimilative capacity of the system.

Channel substrate has less fine material (i.e., is of higher quality) and habitat associated with channel sinuosity and riffle-pool development is likely to increase (Sablak, 2004), which adds habitat heterogeneity to these extremely homogenous systems. Two-stage channels may also have greater assimilative capacity for nutrients (Powell, 2004), which will be discussed in following sections.

Construction of a two-stage channel requires widening the ditch and/or creating the low-elevation benches. However, if conditions permit, two-stage ditches form on their own; in this case simply refraining from removing bench sediment (i.e., dipping) is nearly all that is necessary from a maintenance or management perspective. Simon and Hupp (1986) describe a model for channel evolution of incised streams in which the end result is analogous to a two-stage channel. Optimal conditions for two-stage channels to develop on their own are when the channel is overly wide for the amount of contributing drainage area, banks are steep, and riparian trees are absent.

The Ohio Department of Natural Resources is promoting over-wide ditch construction as a lower cost means for achieving two-stage form in ditches. The over-wide channel approach may avoid problems associated with errors in design and/or construction that result in inappropriate channel dimensions (i.e., does not facilitate desirable sediment transport processes). Over-wide channels also rely on fluvial deposits to form the benches, which are likely to have large contributions from upland soils that are richer in organic matter and have a greater potential for de-nitrification and other biological processing of pollutants.

Applying a two-stage channel approach to highly maintained ditches (e.g., streams designated as MWH) is likely to be a reasonably cost-effective way to improve these resources over a substantial percentage of the drainage network. Although cost analysis for three two-stage ditch construction projects show expenses to range from $5 to $25 per linear foot (Jeong, 2005, unpublished), when the two-stage approach is applied by leaving existing benches intact, costs may be lower than typical ditch maintenance that includes periodic re-construction. It is probable that a two-stage approach can be widely adopted at relatively low costs for landowners, county governments, and/or local organizations.

Important for the adoption of a two-stage approach is to effectively communicate the overall benefits to decision makers and designers who rely on familiar methods or ones they are comfortable using. Individuals who are particularly important to communicate with regarding a two-stage ditch approach include County Engineers and their staff, SWCD/NRCS personnel, and drainage contractors who conduct much of the design and construction work associated with drainage improvement. The benches that form in two-stage channels are often regarded as flow impedances that result in a reduction in the flow capacity of ditches. Ohio EPA is unaware of hydrologic analyses that support this idea but rather concurs that the capacity of the ditch to contain high flows increases if the ditch widens in forming the benches (http://streams.osu.edu/streams_pdf/2stage(ward).pdf).

Two-stage construction may be inappropriate for improving the stream biota and/or water quality when it is necessary to remove riparian trees in the process. Such consideration is particularly important when the channel demonstrates that it is recovering from past channelization. Two-stages ditches are clearly inappropriate when it results in a reduction in the amount of floodplain connectivity. This includes natural to moderately modified streams that have an intact connection to a floodplain and riparian areas. Such action would degrade the resource and the ameliorative effects of the benches will be far inferior to those of an established floodplain.

Bio-engineering Techniques
Bank stabilization and channel erosion controls that use hard engineering techniques (e.g., placement of concrete and/or rock) have little to no value in terms of aquatic habitat. Bio-engineering techniques promoted by the Ohio Department of Natural Resources (http://www.dnr.state.oh.us/water/pubs/fs_st/streamfs.htm) use more natural materials and construction techniques that provide bank habitat structure. When bank erosion control is necessary, bio-engineering approaches should be promoted by local conservation authorities (e.g., NRCS and SWCD) and used by private and public entities as a means for abatement. However, it should be noted that channel erosion and lateral migration occurs naturally even in stable streams. If property loss is not an issue, abating bank erosion should be considered in light of whether it is occurring under stable stream conditions, and avoided if unnecessary.

Stream Stability
Stream stability is related to habitat quality and sedimentation in streams and can have a significant impact on stream biota (see **Section 5.4**). The geomorphology of a stream is a primary indicator of stability. Data regarding the stream geomorphology within the Olentangy River watershed was collected by a team of researchers from the Ohio State University and published in the Olentangy River Watershed: Total Maximum Daily Load Study (D'Ambrosio et al., 2006). Based on this study, areas of the basin that currently exhibit poor stream geomorphology (i.e., unstable) are associated with channelization in the upper and middle sub-watersheds. Other areas include incised channels in the urban or urbanizing areas of the watershed. Additionally there is a significant threat to the stability of stream channels in the rapidly developing areas of the basin (e.g., Delaware County) because of the changes in land cover, sediment supply, and hydrology.

Floodplains are important for maintaining stream stability and provide additional water quality benefits (see **Section 5.4**). For this reason, it is recommended that throughout the entire Olentangy River watershed an effort should be made to maintain, create, or facilitate the development of floodplains such that they are at least as wide as the widths prescribed in **Section 5.4** of this report.

Agricultural Areas
Ameliorating the impact of channelization can be achieved by methods discussed in the preceding sub-section (Channelization). Natural channel design and/or a two-stage ditch approach can reduce the severity of erosion processes and provide some storage of fine sediment. Additionally, the strong relationship between hydrology and stream stability and aquatic communities (see **Section 5.4**), indicates that steps taken to stabilize watershed hydrology will be beneficial.

Activities related to agriculture may be substantially impacting watershed hydrology (Baker et al., 2004) and the stability of stream channels. Baker et al. (2004) suggest that subsurface drainage in combination with reduced surface water retention (i.e., due to smoothing of the landscape and altering vegetation and soil properties) is increasing peak storm discharges. At the other extreme, more efficient drainage results in less infiltration and storage in the watershed which leads to a reduction in baseflow (i.e., flows based on groundwater contributions) during drier periods (Baker et al., 2004; Robinson and Rycroft, 1999). The two phenomena result in an increase in the flashiness of the watershed, which is a measure of the rate and magnitude of changes in stream flow.

Although the causes of the observed increase in flashiness are not yet entirely known, activities that are likely to increase infiltration and reduce runoff should be pursued. In areas where drainage improvement practices are applied intensely, the use of infrastructure and management measures such as water table management and wetland detention are recommended.

Water table management (NRCS Practice Standard 554) is a means to reduce the discharge of sub-surface drainage water (http://ohioline.osu.edu/aex-fact/0321.html). Water table management requires the use of controlled drainage structures (e.g., Agri-Drain or Hancore types) that are installed within new or retrofitted to existing sub-surface tile systems. Drainage water passing through these structures must have adequate hydraulic head to rise to an elevation that is pre-set according to the height of the flashboard risers that are part of the structure. This system allows for management of the effective elevation of the drainage tile outlets. When this elevation is set high enough the effect is analogous to there being no sub-surface drainage infrastructure.

Benefits of water table management are reductions in annual drainage water discharges. These reductions have been estimated over several years of research to be approximately 40% (Fausey, 2004). Although Ohio EPA is unaware of comprehensive water budgets completed for water table management, 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.

The use of water table management may be limited in some areas. Topography dictates the area that can be controlled by a given structure because water table elevations greater than the top of the control structure are no longer influenced by it. This means that control of the water table depth is reduced when moving upslope from the control structure. Additional structures would often be needed within fields (i.e., as opposed to along the field margins) to be able to manage an entire sub-surface drainage system. Other factors that may limit use of water table management include the layout of the sub-surface drainage system and whether or not the pipes can be readily located.

A viable way to offset the problem of limited control associated with a given water table control structure is aligning the drain tiles of new sub-surface drainage systems along elevation contours. This decreases the slope of the drain tiles which allows drainage management infrastructure to have control over a larger area. Additionally, it is possible that significant benefits are realized even if it is only the lower portion of the sub-surface drainage system (i.e., near the outlet) that is controlled.

Wetlands provide detention capacity for runoff and increase infiltration. 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. The NRCS standards for wetland creation (NRCS Practice Standard 658) and wetland enhancement (NRCS Practice Standard 659) provide details regarding size and site condition considerations.

Depressions on the landscape with appropriate soils (i.e., hydric) are ideal locations for creating or enhancing wetlands, since it is likely that they were wetlands prior to land use conversions. In such cases, reversion to wetland is likely to require less effort and will have a greater probability of meeting the goals of the water resource improvements. The placement of wetlands adjacent to or near streams or ditches allows for treatment just prior to entering those waters, which may facilitate the treatment of a large volume of runoff due to the wetland's position in the drainage system.

Land use conversions from crop fields to grassland or forest also increases the retention and/or detention of rainwater. These land covers result in greater infiltration and a higher degree of storage through initial abstraction compared to row crops and/or barren ground and may help restore a more suitable hydrology. Such improvement may take several years to reach their full benefits, especially when land returns to forest cover. The Conservation Reserve Program (see **Section 9.3.3**) compensates producers for land set-asides.

<u>Developing Areas</u>
The most serious threat to channel stability, and possibly overall water quality and biological integrity, in the Olentangy River watershed is the rapid conversion of forest and/or agriculture land uses to residential, commercial, and industrial uses. Numerous scientific studies show that increasing impervious cover in a watershed (i.e., through development) is commensurate with the degradation of water quality and biological communities (Booth et al., 2005; Brabec et al., 2002; Roy et al., 2003; Roy et al., 2006; Morgan and Cushman, 2005).

This type of land use conversion substantially increases the volume of runoff, which is eventually routed to the stream system. Ultimately the sediment transport capacity of the system increases resulting in more channel erosion and instability (Booth, 2005). The resulting morphology provides poor habitat and may have a reduced capacity for nutrient assimilation (Walsh et al., 2005). Higher runoff volume increases pollutant loading (e.g., nutrients, metals, salts, pesticides, sediment). Additionally stream temperatures can be raised when runoff is heated by impervious surfaces such as asphalt and concrete or while residing in detention basins. Temperature increases reduce dissolved oxygen concentration and create stressful conditions for aquatic biota (Ward, 1992; Cossins and Bowler, 1987).

Controlling run off associated with development typically consists of end-of-pipe measures such as storm water detention and retention. These controls abate flooding and reduce erosion, thus providing some water quality protection. However, studies show that water quality degradation occurs in developing watershed despite these controls due to the altered hydrologic regime (Brabec et al., 2002; Booth, 2005).

A hydrologic regime that approximates that of pre-development conditions is important for protecting water quality and aquatic biological communities (Roy et al., 2006). Initial abstraction of rainfall by vegetation, surface storage, long sub-surface flow paths, evapo-transpiration, and deep percolation, which are associated with relatively undisturbed watersheds, often preclude flashy hydrology. Peak flows are often smaller as a significant proportion of precipitation is delayed or altogether diverted from reaching the stream system. Base flows are usually higher because of the greater subsurface discharges during dry periods as a result of increased stormwater infiltration and storage.

Approximating the pre-development hydrology is not likely to be achieved with centralized controls (i.e., end of pipe retention/detention basins). However, onsite retention and infiltration is a realistic and potentially effective way to accomplish this (Andoh and Declerck, 1997). With an onsite approach, stormwater is managed near the area generating the runoff and infiltration is maximized. Onsite stormwater management contrasts centralized systems that collect runoff over a broad area and provide relatively little opportunity for infiltration and consequently must manage very large volumes. Individual onsite controls operate on a small scale but systems are distributed to act collectively in managing runoff across a large area. Incentives, utilities and/or market based programs should be explored as a means to achieve more effective and ecologically meaningful stormwater management. Parkyn et al. (2005) provide an analysis of options for addressing stormwater management in an environmentally and economically sustainable manner.

Onsite, or decentralized, stormwater management increases infiltration and reduces runoff generation by decreasing imperviousness. This is accomplished through appropriate planning, such as that used for Low Impact Development (LID). Low Impact Development is based on maximizing contiguous open space, protecting sensitive areas, namely floodplains and wetlands, and preserving existing vegetation (especially trees). Web based resources for LID include: www.lowimpactdevelopment.org/ . In a Low Impact Development, houses are located closer to one another, roadways are narrower, and bio-retention and infiltration techniques are used. LID reduces runoff and can provide cost savings in stormwater infrastructure. Additional non-environmental benefits include a greater than average increase in property values.

One potential barrier to LID is zoning ordinances that set minimum lot sizes. In the rapidly developing part of the Olentangy River watershed, township zoning has made allowances for these types of developments. However, employing LID at the level needed to provide significant protections for the Olentangy River watershed requires action on the part of land planners, zoning officials, and developers. Serious communication between these groups and LID experts who can address the conditions of this basin is needed.

Watersheds that retain relatively large areas of forest are able to better mitigate the impacts of increasing imperviousness than those with little forest cover (Brabec et al., 2006, Booth, 2005). The procurement of conservation easements, and the establishment of parkland and nature preserves can help retain some of the existing forest cover as well as facilitate the conversion from open land to forest. Although land preservation alone is not likely to occur at a level necessary to mitigate development impacts, it will augment other measures that are taken (e.g., LID and/or discrete onsite stormwater management).

Stormwater abatement techniques that are employed in commercial developments and on individual residences (i.e., that are not a part of a LID) will provide protections to water quality. In particular, parking lots often account for a very high proportion of the impervious surfaces in urban watersheds. According to the University of Connecticut Extension, impervious cover associated with automobile traffic accounts for a significant proportion of the total impervious cover in a given watershed (http://nemo.uconn.edu/).

At the scale of individual residences or business stormwater abatement techniques can be used that include diverting drainage from rooftops, driveways, and other impervious surfaces away from a centralized collection system (e.g., outlets to either curb-and-gutter drains or stormwater sewer lines) and to permeable areas that can provide infiltration and/or temporary storage. Minimizing the extent of impervious surfaces by limiting their size or substituting them with permeable surfaces will also increase infiltration and detention for a given property. Outreach and education activities are likely to result in some increase in this type of voluntary action taken by watershed residents, however to what extent would be very difficult to predict. Outreach efforts that include landscape design and construction companies may also be beneficial as they can present options for enhanced stormwater management to their prospective clients.

The current draft of the Rainwater and Development Guide that is posted on the ODNR website at ftp://ftp.dnr.state.oh.us/Soil_&_Water_Conservation/rainwater/ provides a great deal of information regarding stormwater management. This resource highlights the goals, effectiveness, and limiting conditions for both planning and structural controls. The following topics are discussed:

- o Reduction in impervious area
- o Low Impact Development
- o Conservation Development (similar to LID)
- o Setbacks
- o Water quality ponds
- o Infiltration trenches
- o Sand and organic filters
- o Grass filters
- o Bioretention area

Floodplains abate the impacts of development on stream systems (see **Section 5.4**). The reduction of the erosive power of storm flows, temporary flood storage, and sediment assimilation all act to mitigate the damage caused by increased runoff volume during flood events. Wetlands also provide stormwater retention, increase infiltration and reduce the energy of surface flows (i.e., reduces erosion potential). These important environmental areas must be protected and preserved to the greatest reasonable extent.

Provisions for floodplain filling vary across the Olentangy watershed under county, township and municipality ordinances and zoning codes. Timely and adequate public notification of fill requests (permitting process) and opportunity for public hearings are recommended to ensure that permitting decisions are based on an adequate array of information, scientific as well as socio-economic.

Construction management must be carried out to control the volume and quality of runoff. Due to the substantially greater potential for water quality degradation during construction, special permit restrictions are recommended to protect the sensitive nature and exceptional quality of the Olentangy River in this part of the watershed.

Impoundments

Eleven lowhead dams impound waters in the Olentangy River watershed. Two lowhead dams located near Panhandle Rd (Delaware County) and Fifth Ave (City of Columbus) are listed as a source of impairment. Dam removal is often sufficient to result in the attainment of the applicable designated use as this has been indicated in several cases (e.g., St. Johns dam removal along the Sandusky River in Ohio). Dam removal immediately and permanently eliminates the source and associated causes of impairment (with possible exception of siltation).

The primary benefits of dam removal are the increase in flow velocities and turbulence that corresponds to increased air entrainment and dissolved oxygen concentrations. Increased flow facilitates the movement of nutrients that are otherwise stagnated in a lentic type of condition when impoundments exist. Algae and associated biomass accumulates in these stagnate areas creating poor water quality conditions (e.g., low dissolved oxygen). Habitat quality and diversity is impacted by impoundment and consequently impounded areas often can only support tolerant assemblages that have little biological diversity.

One lowhead dam has been removed on the Olentangy River in Delaware County since the 2003 and 2004 biological survey was completed by Ohio EPA (OEPA, 2005). Four other lowhead dams located in Delaware County are being considered for removal. Also, there are discussions regarding the removal of the lowhead dam located just upstream of Fifth Avenue in Columbus (known as the Fifth Avenue dam). The Ohio EPA recommends that each of these proposed dam removal projects be carried out in order to improve habitat and water quality. In particular, the removal of the Fifth Avenue dam will very likely bring the segment immediately upstream from a non-attainment status to an attaining status of its WWH use designation.

A feasibility study carried out by the consulting firm Fuller Mossbarger Scott and May (FMSM) recommends that all four lowhead dams on the Olentangy River in Franklin County upstream of the Fifth Ave dam remain intact due to the high cost and risks associated with their removal (FMSM, 2005). Those dams were constructed to facilitate sanitary sewer crossing and are currently used for that purpose.

9.1.3 Nutrient and Sediment

Nutrient and sediment loads in the upper Olentangy, middle Olentangy, and Whetstone Creek sub-watershed is primarily due to point source discharges, polluted run-off from row crop agriculture, and channel degradation. NPDES permit revisions for point source dischargers will be carried out according to recommendations in **Chapter 8** of this report. Other sources include failing HSTS and livestock manure and abatement strategies for these sources of nutrients and solids are identical to those discussed earlier (see **Section 9.1.1**). In the urban and developing areas of the watershed, polluted run-off from residential and commercial land uses as well as CSOs and SSOs are creating elevated nutrient loads. Stream instability and landscape sediment loads will potentially threaten or impair the quality of the water resources as a result of the high rate of land development occurring in Delaware County.

Point Source Discharges
Changes in permit conditions are the most straightforward means to achieve the necessary reductions in nutrients from point sources. It is therefore recommended that permits be modified to reflect the load limits prescribed by this TMDL. Costs for total phosphorus removal are variable and depend on the concentration of total phosphorus (TP) in the treated water, the size of the facility, the chemicals used for treatment and when they are applied in the system. However, for a 1 MGD facility under somewhat average conditions costs are estimated to be $475 per day (OEPA, 2006). It should be noted that estimates may vary throughout the watershed. Recent data provided by the Olentangy Environmental Control Center indicate that the facility’s annual cost is $3,200 to reduce the phosphorus concentration to 0.62 mg/L (this estimate does not include costs associated with increased sludge production and handling).

Sources from Agricultural Run-off and Drainage Infrastructure
Many management practices abate sediment and nutrient loading to surface waters from crop fields. Examples include vegetated buffer strips, grassed waterways, nutrient management, conservation tillage, conservation crop rotations, wetland restoration, and water table management. For decades conservation professionals have researched these practices, improved their effectiveness, and worked with private landowners to implement them. Programs currently funded under the Farm Bill provide cost share and dollar incentives for land set asides, and structural and management conservation practices.

The results of the TMDL study carried out by the Ohio State University suggests that the use of buffer strips in the agricultural areas of this basin would be a particularly beneficial means to reduce phosphorus and sediment loads (D’Ambrosio et al., 2006). Output from the SWAT model used for the analysis suggests that buffers strips would reduce phosphorus loading by 60% or more for each of the dominant soil types in the watershed (D’Ambrosio et al., 2006). Vegetative buffer strips have also been shown to be very effective at reducing overland loading of nutrients and sediment in scientific literature (Peterjohn and Correll, 1986; Osborne and Kovacich, 1993).

Vegetated buffer strips (e.g., riparian trees or grass filter strips) slow the velocity of overland surface flow allowing sediment particle to fall out of suspension. Buffers also increase infiltration of surface water due to better soil structure, macropores created by roots and soil invertebrates, and reduced surface crusting (Prichard, 1998). Greater infiltration reduces surface discharges and the associated sediment and nutrient loads (Prichard, 1998). However, the effectiveness of buffers decreases dramatically when small concentrated flow paths allow water to rapidly move across them. Such flow paths typically develop at low points along the fields/buffer border or where the vegetation of the buffer is disturbed. These situations should be corrected as they are identified by landowners, farm operators, and conservation professionals (e.g., NRCS/SWCD staff). Sub-surface drainage creates a by-pass to the buffer strips where there is no contact between the vegetation and the drainage water and flow is not slowed. However, water table management (e.g., NRCS practice 554) is a means to reduce the volume and/or rate of discharging sub-surface drainage water thereby counteracting the short circuiting that occurs through buffer strips.

Benefits of buffer strips that go beyond improving chemical water quality of surface runoff are related to channel stability, structural habitat, light availability, stream temperature, and food resources. Providing a stream buffer may reduce the need and/or importance for stream bank management and erosion control as crop losses would not be occurring. In some cases armoring stream banks to minimize erosion prevents the naturalization of the stream's geomorphology (i.e., channel evolution) and perpetuates stream instability (see **Section 5.4**. Additionally, tree cover shades streams which may limit algal growth and reduce stream temperatures. Temperature is inversely proportional to the stream's capacity to hold dissolved oxygen, and high temperatures can severely impact aquatic life. Woody debris and detritus contributed to the stream system by riparian trees also have a significant role in the quality and diversity of habitat and food resources of the aquatic ecosystem (Ward, 1992; Wallace et al., 1997; Baer et al., 2001). These factors have a significant impact on the aquatic biological community and therefore the capacity for the system to attain its designated aquatic life use.

Sources from Urban and Residential Run-off

The relatively high volume of runoff generated in urban and high density residential areas increases the potential for pollution. Sediment and nutrient residues on surfaces that are impervious or poorly pervious (e.g., compacted lawns, gravel drives, etc.) are more easily transported in this higher volume of runoff and negligible attenuation of the loading occurs due to infiltration. Reducing imperviousness and improving onsite retention and infiltration can abate sediment and nutrient loading by reducing the runoff discharge.

Lawn care and yard maintenance that limits the application of nutrients and increases the likelihood of uptake and retention are recommended. This includes reducing the amount and/or frequency of fertilizer applications. The timing of application should be such that it is unlikely immediately precede a runoff event (e.g., precipitation or irrigation). More stable alternatives to chemical fertilizers should be adopted such as organic based materials (e.g., composts and manures). Organic materials also provide carbon which improves soil structure and increases permeability (i.e., leads to greater stormwater infiltration).

The NRCS in collaboration with the National Association of Conservation Districts (NACD) and the Wildlife Habitat Council (WHC) developed a backyard conservation manual that highlights ten activities that collectively are designed to improve water and soil quality and wildlife habitat. This document can be found on the world-wide web at http://www.nrcs.usda.gov/feature/backyard/

Assimilative Capacity
Increasing the assimilative capacity of the stream system itself is a viable means to help achieve water quality goals. Such an increase can help abate pollutant loads in the event that controls for landscape based and point sources are inadequate. One of the most important ways to increase the assimilative of the system is to provide and/or preserve floodplain connection (see **Section 5.4**). Other means include ensuring high quality substrate (i.e., an adequate hyporheic zone), and appropriate channel morphology (e.g., sinuosity, width depth relationships). A sufficient source of carbon is needed to support many of the organisms that are critical for in-stream biological processing therefore detritus from riparian trees and floodplains is important (Wallace et al., 1997; Baer et al., 2001; Crenshaw et al., 2002).

9.1.4 Summary

The diverse sources of impairment in the Olentangy River watershed related to three major land uses require a number of various implementation actions. The basic principles of providing floodplain connectivity, stable stream morphology and watershed hydrology that approximates natural conditions (i.e., there is adequate infiltration) are applicable to the agricultural, developing, and urban areas of the watershed. Likewise stream buffers are appropriate for all land use types in the watershed.

Point sources reductions are needed at six facilities throughout the basin. Home Sewage Treatment Systems (HSTS) must be addressed in rural, urban, and developing areas. Overland sediment loading is primarily a concern in the agricultural areas and where residential and commercial development is rapid. Nutrient loading from agrochemicals and manure sources is primarily restricted to the upper and middle Olentangy River and Whetstone sub-watersheds and conservation and management practices promoted by NRCS are recommended to abate these sources. Residential, commercial and otherwise urban areas can reduce overland loading by reducing the application rate of fertilizers and improved timing. Reduction in runoff volume through onsite stormwater management will also reduce loading from urban areas and improve watershed hydrology and consequently stream stability.

9.2 Recommended Implementation Actions by Sub-watershed

Actions recommended to address the causes and sources of impairment are arranged according to the sub-watersheds (assessment units) discussed earlier in this report. The major causes and sources of impairment are listed for each sub-watershed. Locations are given for areas that are known to have impairment or are threatened by the presence of sources of impairment. Included with the implementation actions are the organizations important for successful implementation. When possible, attention was given to issues of timeframe, resource availability to assist implementation, and potential barriers to success. The technical support document for the Olentangy River watershed (Ohio EPA, 2005) and Chapter 7 of this report provide more information regarding causes and sources of impairment.

9.2.1 Upper Olentangy (05060001 090)

Major causes and sources of impairment in the sub-basin:
- Pathogen and nutrient loading from failed HSTS
- Pathogen and nutrient loading from livestock operations

- Habitat degradation by channelization and ditch maintenance
- High nutrient and sediment loads from row crop agriculture
- Nutrients from point sources

Pathogen Loading

HSTS

Areas of particular importance for addressing failed HSTS are the following:

- Village of Blooming Grove (Morrow County)
- Westmoor Subdivision
- Sugar Grove Lake (Crawford County)
- Village of Martel (Marion County)
- Residences along Crawford-Morrow County Line Road impacting the Rocky Fork

Crawford, Marion, and Morrow County Health Departments should take steps to improve the condition of failing HSTS in this part of the basin. Detailed information regarding the location of failing systems as well as the number and types of failures would improve chances of reaching the appropriate landowners. Actions recommended include providing information to residents owning these systems regarding upgrades and improvements, proper maintenance, and the consequences for having a failed system. Enforcement actions should be pursued for flagrant violations of HSTS rules. Planning and implementation should be done with the participation of local health departments to ensure that existing resources, programs, and expertise are used to the greatest extent possible.

The Ohio Department of Health offers technical assistance to Local Health Departments and provides training for staff as well as residents who own HSTS. Funding may be provided for upgrades and replacement systems through Water Pollution Control Loan Fund (WPCLF) grants that are administered through the Division of Environmental and Financial Assistance (DEFA) at the Ohio EPA. Other sources for funding may include private grants and local governments.

The pervasiveness of the pathogen problem in this part of the watershed suggests that prioritizing these areas within the respective counties is appropriate. It is recommended that steps be taken immediately to determine the resource needs for addressing these failed systems as well as a search for appropriate sources of funding.

Livestock

Areas where cattle have been observed to have access to the stream are the following:

- Olentangy mainstem at Taylor Rd. (RM 84.1)
- Olentangy mainstem at Iberia Rd. (RM 82.9)
- Olentangy mainstem at Galion-New Winchester Rd. (RM 81.7)
- Olentangy mainstem at Crawford-Marion Line Rd. (RM 68.1)
- Flat Run near State Route 309 (RM 11.3)
- Thorn Run at Marion-Williamsport Rd. (RM 1.1)

NRCS and SWCD staff should work to inform livestock farm operators of the water quality threat posed by poor or inadequate management practices, particularly within the areas identified in this report as being a source of impairment. Technical assistance and cost share should be extended to such operations as appropriate. Some appropriate conservation practices are given in **Section 9.1.1** of this report. The Environmental Quality Incentives Program (EQIP) provides both cost share and incentive payments for structural and management BMPs (see **Section 9.3.3**).

It is also recommended that the farmer coalitions and advocacy groups that have established programs to address environmental issues associated with livestock production take an active role in educating and providing technical and financial assistance where appropriate. Examples include the Ohio Farm Bureau Federation's Agricultural Ecology program and the Ohio Livestock Coalition. The Olentangy Watershed Alliance (OWA) works specifically to improve water resources and has a focus on abating deleterious impacts caused by agricultural production. OWA's continued efforts are encouraged. It is recommended that these groups work collectively to promote sound conservation practices and land stewardship within the agricultural community. Also, the development of partnerships with industry that supports livestock production (e.g., feed industry, various equipment dealers) may lead to more efficient and successful promotion of best management practices.

Habitat Degradation

Channelization

An area of particular importance is the following:

- Mud Run (maintained by Crawford County Engineer)

Stream restoration is recommended wherever possible however, areas in non-attainment should be prioritized, especially Mud Run. It is recommended that a two-stage channel approach be taken for drainage ditches in this basin that exhibit poor, one-stage morphology. A three year USEPA Section 319 grant (see **Section 9.3.11**) was awarded in 2005 that should facilitate the use of a two-stage ditch approach in the upper three watershed units of the Olentangy watershed. The activities associated with this grant may act as a spring board towards wider adoption of a two-stage ditch approach.

Buffer strips, particularly forested buffers, should be promoted through the Scioto Conservation Reserve Enhancement Program (see **Section 9.3.3**), other forms of assistance, and/or uncompensated voluntary adoption. The enrollment for the Scioto CREP is planned to conclude sometime in 2007, therefore a focused effort to promote buffers should be made as soon as possible. Land purchases and easements secured by land preservation organizations or private entities should consider giving priority to stream side areas.

Nutrient and Sediment Loading

Row Crop Agriculture

Areas of particular importance are the following:

- Headwaters of Olentangy mainstem (090 010) for sediment
- Mud Run (090 040) for phosphorus

NRCS and SWCD staff should actively promote the Scioto CREP to maximize participation in that set-aside program. Both buffers (i.e., forested and grassed) and wetlands are available for funding and are appropriate to abate sediment and nutrient loading. Other NRCS practices to be promoted that address nutrients are listed in **Section 9.1.5**. Two-stage ditches are likely to increase the assimilative capacity of ditches that have poor, one-stage morphology and should be promoted as described in the preceding sub-section.

Water table management should be promoted by NRCS and SWCD staff for its potential to reduce some forms of phosphorus loading (e.g., soluble forms). The same Section 319 grant mentioned above that will be used to promote two-stage ditching is also available for the promotion of water table management. It is recommended that risk management instruments be explored as a means reduce the risk of yield loss through the adoption of this and/or other types of management practices that reduce nutrient export. Such instruments have been developed in other part of the United States as well as in the Mad River watershed here in Ohio.

Point sources
The Galion WWTP should have an annual NPDES permit limit for phosphorus set at 1 mg/L. For more detail see **Section 8.1** of this report.

9.2.2 Middle Olentangy (05060001 110)

Major causes and sources of impairment in the sub-basin:
- Pathogen and nutrient loading from failed HSTS
- Habitat degradation from channelization and ditch maintenance
- High nutrient and sediment loads from row crop agriculture
- Nutrients from point sources

Pathogen Loading
Areas of particular importance for addressing failed HSTS are the following:
- Village of Waldo (Marion County)
- Village of Claridon (Marion County)

Recommendations and sources for assistance in this sub-watershed are similar as those for the upper Olentangy. Delaware County General Health District (DGHD) has generated a plan to address failing HSTS located in the Olentangy River watershed. It is recommended that DGHD continue their efforts in addressing system failures to prevent areas from becoming problematic in the future. It is recommended that Marion and Morrow Health Departments follow a similar course as DGHD. The following paragraph highlights the objectives and actions included in the DGHD plan, which provide a good example of the kind of activities that would be supported and/or recommended by the Ohio EPA.

The objectives of the grant are identifying all failing and underperforming HSTS systems in the watershed and upgrading or replacing failed systems or providing connection to sanitary sewers. Specific actions include:
- Identification of concentrated HSTS pockets
- Description of the impact and location (GPS followed by addition to ArcGIS) of HSTS in the watershed
- Identification of alternatives available for the conversion of HSTS to community sewer systems
- Promotion of a community planning process and community education/awareness efforts
- Promotion of a cooperative process among jurisdictions providing sewer services
- Promotion of voluntary adoption of BMPs by households served by a HSTS
- Documentation of failing HSTS and enforcement - correction procedures undertaken
- Collection, analysis and provision of data supporting the expansion of the Delaware County sanitary sewer system and associated WWTPs.

Habitat Degradation
Areas of particular importance are the following:
- Bee Run (maintained by Marion County Engineer)
- Grave Creek (maintained by Marion County Engineer)
- Riffle Creek
- Qu Qua Creek (maintained by Marion County Engineer)

Ulsh and Tomahawk Ditches also appear to be actively maintained and should be considered for stream improvements. Recommendations and sources for assistance in this sub-watershed are similar as those for the upper Olentangy River sub-watershed.

Nutrient and Sediment Loading
<u>Row crop agriculture</u>
Areas of particular importance are the following:
- Grave Creek (110 040) for sediment
- Olentangy mainstem (110 050) below Grave Creek
- Qu Qua Creek (110 060) for nutrients

Recommendations and sources for assistance in this sub-watershed are similar as those for the upper Olentangy.

<u>Point sources</u>
The Marion County WWTP should have annual NPDES permit limits for phosphorus set at 1 mg/L. For more detail see **Section 8.1** of this report.

9.2.3 Lower Olentangy (05060001 120)

Major causes and sources of impairment in the sub-basin:
- Pathogen loading from failed HSTS and CSO/SSO
- Habitat degradation from stream impoundment
- High nutrient and sediment loads from urbanization/development
- Threatened by rapid land development to residential and commercial uses

Pathogen Loading
Areas of particular importance for addressing failed HSTS are the following:
- Westchester Sub-Division (Liberty Township, Delaware County)
- Wingate Sub-Division (Liberty Township, Delaware County)
- Linworth area (Franklin County)
- Mount Air (Franklin County)
- Flint area (Franklin County)
- Rosslyn Road area (Franklin County)
- Dublin-Granville Road area (Franklin County)
- Cooke Road area (Franklin County)
- Snouffer Road east area (Franklin County)
- Snouffer Road west area (Franklin County)
- West Case Road area (Franklin County)

Recommendations and sources for assistance that addressed failed HSTS in this sub-watershed are similar as those for the middle Olentangy.

Additionally, Ohio EPA is working with the Franklin and Delaware County Sanitary Engineers to provide sewer service to problematic unsewered areas in portions of the Olentangy watershed. Mount Air, an area with failing systems on small lots and poor soils in close proximity to the river, is currently being evaluated for sewer service through the City of Columbus. Both the Franklin County Health Department and the Delaware General Health District will be working with Ohio EPA to address issues in Mount Air and other areas. Certain new or replacement off-lot systems will be covered under an NPDES permit, which requires additional maintenance and effluent monitoring to demonstrate compliance with discharge limits (as long as on-lot soil dissipation is not feasible). The general permit for select new or replacement off-lot HSTS became effective on January 1, 2007. A permit for existing off-lot discharges is under consideration.

To address CSO/SSO events the City of Columbus will adhere to plans that are provided in their Wet Weather Management Plan through the Project Clean Rivers initiative (http://utilities.ci.columbus.oh.us/sewers_drains/default.htm).

Habitat Degradation
Stream impoundments due to lowhead dams that are causing impaired biota are the following:

- Panhandle Road dam (located just downstream of Panhandle Road in the City of Delaware)
- Fifth Avenue dam (located just upstream of Fifth Avenue in the City of Columbus)

The Panhandle Road dam will potentially be removed by the Ohio Department of Transportation (ODOT) for stream mitigation credits under the 401 certification program. Issues related to a water supply line and multi-ownership of the dam may preclude this project from moving forward. However, if the dam is to be removed, this is expected to occur by the end of 2008. A Section 319(b) grant has been awarded to the City of Columbus for the express purpose of restoring the upstream portion of the river following removal or modification of the Fifth Avenue dam. Modification to the dam is to result in improved in-stream habitat and/or water quality. Dam removal or modification is anticipated to occur by the close of 2008.

Nutrient and Sediment Loading
<u>Urbanization/development</u>
Urban run-off should be reduced and onsite stormwater retention increased by the means discussed in **Section 9.1.2**. Nutrient loads can be abated by reducing fertilizer application rates on property owned by both the public and private (e.g., businesses and individual residents) entities.

The Friends of the Lower Olentangy River Watershed (FLOW) has established a strong outreach program to promote voluntary adoption of residential BMPs that address run-off and the associated pollutant loading. Ohio EPA encourages FLOW to continue these efforts and particularly notes the downspout disconnection program which is intended to reduce stormwater generated from rooftops. The Ohio NonPoint Education for Municipal Officials (NEMO) and Campu-shed programs of the Ohio State University Extension can also facilitate the adoption of management practices that reduce the volume of stormwater generated and improves the chemical quality of the runoff (e.g., less fertilizer loss in runoff). Ohio EPA recommends that the Ohio State University adopt management practices that are consistent with the recommendation made in Sections 9.1.2 and 9.1.3 of this report.

The Ohio EPA recommends that buffers strips and conservation easements be used where appropriate in the urban and developing areas of the watershed. Franklin SWCD has an easement program designed to help parties that are interested in securing easements. Ohio EPA recommends that Franklin SWCD continue these efforts and expand its program if possible. Such expansion may include increasing collaboration with other organizations in joint initiatives.

The Delaware SWCD has a watershed program that works on stormwater-related issues through its partnership with the local Phase II stormwater communities. Delaware SWCD collaborates with the Delaware County Engineers office in education and outreach activities and has carried out a storm drain labeling initiative throughout the county for several years. The

Ohio EPA recommends that Delaware SWCD expand its program to accommodate the rapid development occurring in the Olentangy River watershed (and other watersheds) and establish a conservation easement program to facilitate the protection of riparian areas or other lands valuable to the protection of water quality.

<u>Point sources</u>
The City of Delaware and the Olentangy Environmental Control Center WWTPs should have NPDES permit limits for phosphorus set at a 1 mg/L during the spring and summer and 0.5 mg/L during the summer and fall. For more detail see **Section 8.1** of this report.

Threat to Resource Quality from Development
To protect against the degradation of water quality in one of the nations most rapidly developing areas, the Ohio EPA recommends that general stormwater permits for construction activities be revised for the Delaware County and the uppermost Franklin County portion of the watershed downstream of the Delaware Reservoir. It is recommended that the NPDES General Permit for Storm Water Associated with Construction Activity Located within Portions of the Olentangy River Watershed include additional requirements, beyond the current statewide construction storm water general permit requirements. The additional requirements should include requiring submittal of the storm water pollution prevention (SWP3), riparian setback requirements and more stringent sediment and erosion controls which include performance standards.

Regional planning and local zoning authorities should adhere to the principals of Low Impact Development and encourage land preservation. Additionally, onsite stormwater management should be encouraged and incentives, utilities and/or market based programs should be explored as a means to achieve this.

Governmental entities provide oversight and/or have permitting authority for floodplain fill requests. Timely public notice of floodplain fill requests is encouraged as well as the provision for comment through public hearing.

9.2.4 Whetstone Creek (05060001 100)

Major causes and sources of impairment in the sub-basin:
- Pathogen and nutrient loading from failed HSTS
- Pathogen and nutrient loading from livestock operations
- High nutrient and sediment loads from row crop agriculture
- Nutrients and pathogens from point sources
- Threat of land development and conversion to residential and commercial uses

Pathogen loading
<u>HSTS</u>
Areas of particular importance for addressing failed HSTS are the following:
- Candlewood Lake area homes
- Residences in the Shaw Creek area
- Residences in the Claypole Run area

Recommendations and sources for assistance in this sub-watershed are similar as those for the upper Olentangy.

<u>Livestock</u>
Areas where livestock are likely sources of impairment are the following:

- Whetstone Creek (RM 18.2)
- Whetstone Creek (RM 18.2)
- Sam's Creek (RM 1.4)

Recommendations and sources for assistance in this sub-watershed are similar as those for the upper Olentangy.

Habitat Degradation
Although channelization has not been directly associated with impairment in this sub-basin, there may be some downstream impacts associated with increased erosion and elevated storm flows. Shaw Creek is under county maintenance from Thatcher Road to South Canaan Road and management strategies that reduce erosion and improve habitat would likely be beneficial for the quality of downstream waters and the sustainability of the system.

Nutrient and Sediment Loading
Row Crop Agriculture
Recommendations and sources for assistance in this sub-watershed are similar as those for the upper Olentangy.

Point Sources
The Mount Gilead, Cardington, and Candlewood Lake WWTPs should have annual NPDES permit limits for phosphorus set at 1 mg/L. For more detail see **Section 8.1** of this report.

Threat to Resource Quality from Development
To protect against the degradation of water quality in a rapidly developing area of the watershed that is of exceptional quality, the Ohio EPA recommends that general stormwater permits for construction activities be revised for the Whetstone Creek watershed. It is recommended that the NPDES General Permit for Storm Water Associated with Construction Activity Located within Portions of the Olentangy River Watershed include additional requirements, beyond the current statewide construction storm water general permit requirements. The additional requirements should include requiring submittal of the storm water pollution prevention (SWP3), riparian setback requirements and more stringent sediment and erosion controls which include performance standards.

9.3 Reasonable Assurances

The recommendations made in this TMDL report will be carried out if the appropriate entities work to implement them. In particular, activities that do not fall under regulatory authority require that there be a committed effort by state and local agencies, governments, and private groups to carry out and/or facilitate such actions. The availability of adequate resources is also imperative for successful implementation.

The following discusses organizations and programs that have an important role or can provide assistance for meeting the goals and recommendations of this TMDL. This section establishes why it is reasonable to be assured of successful implementation.

9.3.1 Ohio EPA

The several programs that Ohio EPA Division of Surface Water administers are designed to control pollution from point sources and certain stormwater discharges as well as provide assistance for abating nonpoint sources of pollution. Other divisions within the Ohio EPA provide assistance such as funding, technical assistance, and education for water resource related issues. Information regarding the specific programs within the Ohio EPA Division of Surface Water (DSW) can be found on the web at http://www.epa.state.oh.us/dsw/, and information about the Division of Environmental and Financial Assistance (DEFA) at http://www.epa.state.oh.us/defa/. What follows are programs within the agency that are especially important for the implementation of this TMDL.

NPDES Program

National Pollution Discharge Elimination System (NPDES) permits authorize the discharge of substances at levels that meet the more stringent of technology or water-quality-based effluent limits and establish requirements related to combined sewer overflows, pretreatment, and sludge disposal. All entities that wish to discharge to the waters of the state must obtain a NPDES permit and both general and individual permits are available for coverage. Through the NPDES program (http://www.epa.state.oh.us/dsw/permits/permits.html), the Ohio EPA will use its authority to ensure that recommended effluent limits are applied to the appropriate permit holders within the Olentangy River watershed. Ohio EPA staff in the NPDES Program can provide technical assistance for permitted entities when needed. Permits issued under the NPDES program must be consistent with the point source recommendations in a TMDL that has been approved by the U.S. EPA.

Combined Sewer Overflow Program

Ohio EPA implements CSO controls through provisions included in NPDES permits and by using orders and consent agreements when appropriate. The NPDES permits for CSO communities require the implementation of nine minimum control measures (Ohio EPA, 1995; http://www.epa.state.oh.us/dsw/cso/csostrem.pdf). Requirements to develop and implement Long Term Control Plans are also included where appropriate. Through the CSO program, the Ohio EPA will use its authority to ensure that recommended control activities are conducted by the permit holders within the Olentangy River watershed.

Stormwater Program

Ohio EPA implements the federal regulations for storm water dischargers (http://cfpub1.epa.gov/npdes/home.cfm?program_id=6). Dischargers currently covered include the City of Columbus (Phase I) and the City of Powell, and Liberty and Orange Townships (Phase II) with municipal separate storm sewer systems (MS4s) and those facilities that meet the definition of industrial activity, including construction, in the federal regulations. Both general and individual permits can be used for coverage of stormwater effluent. Through the Stormwater Program, the Ohio EPA will ensure that the stormwater permit related recommendations of this TMDL are applied, including development of a special general stormwater permit for construction activities in specified areas of the Olentangy watershed (see sections 9.2.3 and 9.2.4).

Staff within the Stormwater Program provides technical assistance to permitted entities when needed. District Office staff within the Stormwater Program respond to and investigate complaints received by individuals and organizations.

401 Water Quality Certification Program

In Ohio, anyone wishing to discharge dredged or fill material into the waters of the United States, regardless of whether on private or public property, must obtain a Section 404 permit from the U.S. Army Corps of Engineers (Corps) and a Section 401 Water Quality Certification (WQC) from the state.

Stream and wetland mitigation is used as a condition for granting 401 certificates and is the means of ensuring that water resources do not experience a net decline in quality. When a wetland or stream segment is impacted, an appropriate mitigation is required such that there is no net loss of wetlands or unimpaired stream length. Restoration, creation, or other forms of enhancement is required at a level that depends upon the original quality of the resource.

Currently there are proposed rules changes to the 401 Program that are designed to provide a more scientific basis for determining appropriate criteria for 401 permit decisions (i.e., acceptance or denial) as well as mitigation stipulations for the respective projects (http://www.epa.state.oh.us/dsw/401/401Section.html). These rule changes are expected to be finalized in 2006. Ohio EPA staff will conduct reviews and issue permits to provide the most reasonable protections and improvements, where possible, of surface waters in the Olentangy River watershed.

Wetland Protection Program
House Bill 231 established a permanent permitting process for isolated wetlands. Reviewers in the 401 Water Quality Certification Section are responsible for the isolated wetland permits required by this state law. Ohio EPA staff will conduct reviews and issue permits to provide the most reasonable protections and improvements of surface waters in the Olentangy River watershed.

Enforcement Program
When Ohio EPA is unable to resolve continuing water quality problems due to violations of permitting rules or laws, the Division of Surface Water may recommend that enforcement action be taken. The enforcement and compliance staffs work with Ohio EPA attorneys, as well as the Attorney General's Office to resolve these cases. Where possible, an added emphasis and priority is given to actions in sensitive watersheds. All completed enforcement actions are posted on the DSW web page.

208 Program (State Water Quality Management Plans)
Ohio EPA oversees the State Water Quality Management (WQM) Plan. The State WQM Plan is like an encyclopedia of information used to plot and direct actions that abate pollution and preserve clean water. A wide variety of issues is addressed and framed within the context of applicable law and regulations. The Olentangy River TMDL becomes a part of the State WQM Plan when it is approved by the U.S. EPA and the recommendation found herein align with and support the state's overall plan for clean waters. More importantly, the requirement and intention to review and update the State Water Quality Management Plan on an annual basis creates an avenue to apply adaptive management and make adjustments in these recommendations as necessary.

Nonpoint Source Program
The Ohio Nonpoint Source program focuses on identifying and supporting implementation of management practices and measures that reduce pollutant loadings, control pollution from nonpoint sources and improve the overall quality of these waters. Ohio EPA receives federal Section 319(h) funding to implement a statewide nonpoint source program, including offering grants to address nonpoint sources of pollution. Staff from the NPS program work with state and local agencies, governments, watershed groups, and citizens.

In addressing sources of impairment related to agricultural activities, NPS staff will correspond with Ohio DNR to promote BMPs as well as cost-share and incentive based conservation programs. In particular, Ohio EPA will encourage the Ohio DNR to continue to work with Farm Service Agency personnel and staff from local SWCD and NRCS offices. NPS staff will also provide assistance to agencies and groups actively promoting conservation as well as direction to other appropriate resources within the Ohio EPA.

NPS staff will continue to work with the two watershed groups that are active in the Olentangy River basin, each with a watershed management plan (see watershed groups below). Local NPS implementation is critical to achieving state environmental targets. Additionally, there is a reliance on watershed management plans to identify and outline actions to correct water quality problems caused by NPS pollution.

Section 319(h) grants are expected to be directed to projects that eliminate or reduce water quality impairments caused by nonpoint sources of pollution. Applicants may apply for a maximum of $500,000 for a three year period. Each project funded must provide an additional 40% matching share and the total federally funded share of project costs may not exceed 60%. Because a TMDL exists, grant proposals for work within the Olentangy River watershed will receive special consideration for funding.

Division of Environmental and Financial Assistance
The Division of Environmental and Financial Assistance (DEFA) provides incentive financing, supports the development of effective projects, and encourages environmentally proactive behaviors through the Ohio Water Pollution Control Loan Fund (WPCLF). Municipal wastewater treatment improvements – sewage treatment facilities, interceptor sewers, sewage collection systems and storm sewer separation projects – are eligible for financing. Nonpoint pollution control projects that are eligible for financing include:

- Improvement or replacement of on-lot wastewater treatment systems
- Agricultural runoff control and best management practices
- Urban storm water runoff
- Septage receiving facilities
- Forestry best management practices.

The Water Resource Restoration Sponsor Program (WRRSP) is a part of the WPCLF and directs funding towards stream protection and restoration projects. The primary focus of this program is to improve and protect stream habitat. Like Section 319 (h) grants, proposals for stream improvements within the Olentangy River watershed will receive special consideration.

9.3.2 Ohio Department of Natural Resources

The Ohio Department of Natural Resources (ODNR) works to protect land and water resources throughout Ohio. A specific objective in regards to water resources is to *“Lead in the development and implementation of stream and wetlands conservation initiatives, applying advanced science, technology and research to restore and protect stream and wetlands habitats”*. This commitment attests that the Ohio DNR will be a reliable partner in addressing causes and sources of impairment in the Olentangy watershed.

The following are programs and divisions within the Ohio DNR that are particularly instrumental in protecting and improving water resources within the Olentangy River watershed.

Pollution Abatement Program
Under Ohio’s Pollution Abatement Rules (OAC 1501) the Ohio DNR is required to respond to written and non-written complaints regarding agricultural pollution. As defined by OAC 1501, agricultural pollution is the “failure to use management or conservation practices in farming or silvicultural operations to abate wind or water erosion of the soil or to abate the degradation of

waters of the state by animal waste or soil sediment including substances attached thereto." In cooperation with Soil and Water Conservation Districts (SWCD), an investigation is begun within five days of receipt of the complaint and a Pollution Investigation Report (PIR) is generated within ten days. Resource management specialists from Ohio DNR within the Division of Soil and Water Conservation (DSWC) typically become involved with pollution abatement cases in their respective areas of the state.

If it is determined necessary, an operation and management plan will generated to abate the pollution. This plan is to be approved by the SWCD or Ohio DNR and implemented by the landowner. Cost share funding may be available to assist producers in implementing the appropriate management practices to abate the pollution problems and such practices may be phased in if necessary. If a landowner fails to take corrective action within the required timeframe, the Chief of the Division of Soil and Water Conservation (Ohio DNR) may issue an order such that failure to comply is a first degree misdemeanor. This program safeguards against chronic problems that lead to the degradation of water quality within the Olentangy River watershed.

SWCD Program
Ohio DNR-DSWC has a cooperative working agreement with the Soil and Water Conservation Districts throughout Ohio and the NRCS. According to the agreement Ohio DNR-DSWC is responsible to "provide leadership to Districts in strategic planning, technical assistance, fiscal management, staffing, and administering District programs." The Division also provides "training and technical assistance to District supervisors and personnel in their duties, responsibilities, and authorities." Program Specialists from Ohio DNR work with the SWCDs to identify program needs and training opportunities. Ohio DNR also ensures that program standards and technical specifications are available to SWCDs and NRCS personnel.
State matching dollars from the Ohio DNR constitute roughly half of the annual operating budgets of SWCDs.

Through the partnership established by the working agreement and their history of collaboration, Ohio DNR can communicate the goals and recommendations highlighted in this TMDL to SWCDs and provide guidance to actively promote conservation efforts that are consistent with those goals. One such example of this is the U.S. EPA Section 319 grant that has been awarded to ODNR to improve drainage ditch management and assist in promoting buffer strips associated with the Scioto CREP.

Urban Stormwater Program
Ohio DNR staff provides technical expertise regarding stormwater management and controls as well as administers urban stormwater related grants. The urban stormwater program has been responsible for the development and maintenance of the Rainwater Manual for the State of Ohio which provides guidance regarding stormwater management and sediment and erosion control measures.

Staff from the urban stormwater program will be an important resource for communicating with the development community and promoting storm water management that is consistent with recommendations and goals of this TMDL.

Scenic River Program
The Scenic River Program is administered within the Division of Natural areas and Preserves (DNAP) and functions according to the Scenic Rivers Act of 1968. By statute, ODNR has the authority to approve or disapprove any publicly funded projects on streams with a Scenic River designation that lie outside of municipal boundaries. Decisions are based on the potential

impact that such projects may have on stream quality. An appointed citizens' advisory council, representing local officials, landowners and conservation organizations, provides advice regarding local river preservation and protection concerns.

Staff within the Scenic River program communicates with private citizens, businesses, local governments, watershed groups, and other organizations in regards to streamside preservation and other actions that protect and/or improve water quality. Scenic River coordinators for the 22 continuous miles of scenic river designation along the Olentangy River south of the Delaware Lake dam will be useful resources in communicating with the development community in this part of the watershed and advancing appropriate planning, setbacks, preservation, and management strategies.

Division of Forestry
The mission of the Division of Forestry is to promote sustainable use and protection of forests on public and private lands. The division provides technical expertise and other forms of assistance regarding riparian forest establishment and protection.

Division of Wildlife
Through efforts to increase the amount of habitat for game birds and other forms of wildlife, private lands biologists actively promote the establishment of warm season grass in buffer strips and on cropland set asides. Private lands biologists come into contact with private landowners and conservation groups to educate, and provide assistance regarding these types of habitat improvements.

9.3.3 Agricultural Services and Programs

Local Soil and Water Conservation District (SWCD), Natural Resource Conservation Service (NRCS), and Farm Service Agency (FSA) offices often work to serve the county's agricultural community. Staff from these offices establishes working relationships with private landowners and operators within their county, which are often based on trust and cooperation.

SWCD and NRCS staff are trained to provide sound conservation advice and technical assistance (based on standard practices) to landowners and operators as they manage and work the land. Sediment and erosion control and water quality protections make up a large component of the mission of their work. SWCD and NRCS activities also include outreach and education in order to promote stewardship and conservation of natural resources. SWCD and NRCS staff also serve county residents not associated with agricultural and some districts have well developed urban conservation programs (e.g., Franklin SWCD).

The close working relationships that SWCD and NRCS staff typically maintain with local land owners and producers make them well suited for promoting both widely used conservation practices as well as some that are more innovative. The SWCD and NRCS staff within the Olentangy watershed are currently working with the ODNR in a grant that will fund a two-stage ditch project in the upper part of the Olentangy River watershed. Although two-stage ditching shows promise (see **Section 9.1.2**) it is not yet widely employed nor included as a NRCS practice standard.

Federal Farm Bill programs are administered by the local NRCS and FSA offices. NRCS is responsible for the Environmental Quality Incentives Program (EQIP), while FSA is responsible for set-aside programs such as the Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), and the Wetland Reserve Program (WRP).

Environmental Quality Incentives Program
The Environmental Quality Incentives Program (EQIP) is an incentive based, voluntary program designed to increase the use of agriculturally related best management and conservation practices. EQIP is available to operators throughout the entire Olentangy River watershed irrespective of whether they own or rent the land that they farm. Through this program operators receive cost share and/or incentive payments for employing conservation management practices. Contracts are five years in length.

Eligible conservation practices cover broad categories such as nutrient and pesticide management, conservation tillage, conservation crop rotation, cover cropping, manure management and storage, pesticide and fertilizer handling facilities, livestock fencing, pastureland management, and drainage water management among others. However, funding for these practices is competitive and limited to the allocations made to any respective county in Ohio. Each county in receives a minimum of $100,000 per year and may receive more depending on state priorities for that year. More information on this program is available on the NRCS website at www.nrcs.usda.gov.

Conservation Reserve Program and Wetland Reserve Program
The Conservation Reserve and Wetland Reserve Programs (CRP and WRP respectively) are set aside programs much like the CREP (see below), which is the enhanced version of CRP. The goals of these programs are to protect environmentally sensitive lands (e.g., highly erodible soils) and improve water quality and wildlife habitat.

Set aside programs are voluntary and incentive-based and provide compensation to farmers for establishing and maintaining buffers, wetlands, grasslands or woodlands on land that would otherwise be used for agricultural production. Compensation is restricted to the timeframe established in the contract agreement. Incentive payments for these two programs are lower than the enhanced versions (i.e., CREP and WREP), which are limited to areas that have been approved by the USDA for the additional funding. These programs can assist in creating land use changes that improve water resource quality in the Olentangy River watershed.

Scioto River Watershed Conservation Reserve Enhancement Program
The Scioto River Watershed Conservation Reserve Enhancement Program (CREP) is aimed at creating 70,000 acres in a combination of buffers and wetlands on cropland and marginal pastureland throughout the entire Scioto basin. Although the Olentangy River watershed makes up only a part of the entire CREP project area (about 8.3% of the total land area), this program can serve as an important means for establishing buffer strips.

The Scioto CREP officially began in February of 2005 with an expected enrollment period of two years. There are no acreage limits per county, so it is hard to predict the extent to which the program's conservation practices will be installed in any given area. As of the time of the completion of this report, about 50% of the eligible acres have been enrolled throughout the basin, and the Olentangy River watershed has received only a modest proportion of those enrolled acres.

Practices that are eligible through this program include both native and non-native grass filter strips, hardwood and coniferous tree plantings, wildlife habitat buffers, wetland restoration, and the installation and use of water table management infrastructure. CREP contracts are for 14 to 15 years in duration and enrollees are under no obligation to maintain those conservation practices after that time. Information regarding this program is available on the web at: http://www.dnr.state.oh.us/soilandwater/sciotocrep/default.htm

9.3.4 Extension and Development Services

Each county in Ohio has an extension agent dedicated to agricultural and natural resource issues. The primary purpose of extension is to disseminate up-to-date science and technology so it can be applied for the betterment of the environment and society. Like SWCD and NRCS staff, extension agents provide technical advice to landowners and operators and often develop strong relationships with the local community. Local extension agents are particularly well suited for promoting innovative conservation measures that have not yet been established in the standard practices developed by NRCS.

The Heart of Ohio Resource Conservation and Development Service (RC&D) works to facilitate sustainable uses of natural and economic resources (http://www.oh.nrcs.usda.gov/programs/RCD/heartofohiohome.html). RC&Ds are non-profit organizations that receive technical support from the NRCS. The Heart of Ohio RC&D has been involved with developing a program to facilitate the establishment of conservation easements, particularly in association with the Scioto CREP. The Heart of Ohio RC&D is available to the public for assistance in developing water quality improvements initiatives in the Olentangy River watershed.

9.3.5 Agricultural Organizations and Programs

Agricultural organizations are working to address water quality problems associated with traditional farming practices. The Ohio Farm Bureau Federation (OFBF) seeks to improve water quality through the employment of economically sound conservation management practices (http://www.ofbf.org/). In order to pursue this mission OFBF initiated programs aimed at engaging producers in voluntary water quality protection and improvement efforts. At the local level most county Farm Bureaus have a chairperson of an Agricultural Ecology committee that is responsible to administer OFBF programs related to environmental quality. The Agricultural Ecology chairperson often works with the county's Organizational Director who is a staff member of the OFBF to implement program initiatives.

The Agricultural Watershed Awareness and Resource Evaluation program within the OFBF promotes water quality monitoring and education so that producers have more information when making decisions regarding their operations. OFBF has collaborated with other organizations through the Ohio Agricultural Environmental Assurance Alliance (OAEAA) in developing a self assessment program aimed at identifying source of water pollution on farms and developing strategies to abate those problems. OFBF also offers assistance to producers who are having difficulties in complying with environmental regulations. The OFBF has participated in workshops in the Olentangy River watershed and has collaborated with the Olentangy Watershed Alliance in outreach activities. Such efforts are anticipated to continue.

The Ohio Livestock Coalition (OLC) developed the Livestock Environmental Assurance Program (LEAP). This program provides training to producers in employing best management practices in regards to their livestock operations. The On Farm Assessment and Environmental Review (OFAER) is a national program similar to LEAP but provides a more comprehensive analysis. Livestock producers can request an evaluation of their operation which is conducted by a two person assessment team. Following the assessment, OFAER participants receive a confidential report that highlights the specific areas on their operation that can be improved in terms of environmental soundness and has recommendations for such improvements. Both of the programs are available to persons operating farms in the Olentangy River watershed.

9.3.6 Local Health Departments

Under OAC 3701-29 local health departments are responsible for code enforcement, operational inspections, and nuisance investigations of household sewage treatment systems serving 1, 2, or 3 family dwellings. The Ohio Department of Health works with locals health departments and provides technical assistance and training.

The Delaware General Health District (DGHD) has focused efforts to address failing HSTS in the county with additional emphasis on the Olentangy River watershed. DGHD has received funding through a Section 319(h) grant that was awarded in 2005. The Delaware County Health Department intends to seek funding (Ohio EPA, Water Pollution Control Loan Fund) for assistance of selected property owners with repair or replacement of existing HSTS or conversion to available sanitary systems. DGHD efforts reflect recommendations made in the endorsed watershed action plan submitted by the Friends of the Lower Olentangy Watershed (FLOW). For more detail regarding the efforts of DGHD see **Section 9.2.2**.

9.3.7 Local Zoning and Regional Planning

In Delaware County, townships within the Olentangy watershed have recently updated their Comprehensive Plans regarding land development. The City of Delaware also updated its plan in 2004. Several of the goals and objective found within these plans call for the protection and preservation of sensitive environmental areas such as 100 year floodplains, wetlands, and steep areas (slope > 20%) that are subject to high erosion rates. Additionally, preservation of open space, protection and growth of forested areas, and low impact development are actions supported in these plans that will help alleviate the impact of altered hydrology due to development. Highlighted below are some of the major aspects of these plans.

<u>Delaware County - Liberty Township</u>
The comprehensive plan for Liberty Twp recommends that no development or filling occur within the one hundred year floodplain except for project necessary for public construction or drainage improvements. Low Impact Development is possible where one unit per developable acre is allowed with a minimum of 50% permanent open space.

<u>Delaware County – Orange Township</u>
Goals listed in the Orange Township plan include the preservation of open space and natural resources such as floodplains, wetlands and other surface waters. A specific objective in some areas of the township is to preserve the deep ravines that run to the Olentangy River as common open space and/or wooded corridors in planned developments. Orange Township recommends that the Delaware Regional Planning Commission (DCRPC) change its county-wide sub-division regulations to provide protections for 100 year floodplains. Conservation development is also to be encouraged.

<u>Delaware County - Troy Township</u>
The comprehensive plan for Liberty Twp recommends that no development or filling occur within the 100-year floodplain with a provision of hardship criteria for possible variances. Additionally, there is a 500-foot buffer established along the mainstem of the Olentangy River in which commercial development that produces toxic runoff will be discourages and/or limited. Parking

lot designs will be recommended to minimize impervious surfaces. Conservation Development will also be permissible regardless of density restrictions.

City of Delaware

The City of Delaware has a number objectives designed for the protection of water resource quality. Such objectives include:

- Limit development in the 100 year floodplain to less than 5% impervious cover
- Purchase land and promote the establishment of conservation easements within the 100 year floodplain
- Promote forested buffers of 120 feet in width on along the mainstem of the Olenatngy River
- Promote forested buffers of 60 and 30 feet in width along major and minor tributaries respectively
- Reforest areas without tree buffers
- Encourage Low Impact Development
- Facilitate the establishment of a land trust
- Require an environmental analysis map for all new development
- Create a GIS based resource inventory

Mid-Ohio Regional Planning Commission

The Mid-Ohio Regional Planning Commission (MORPC) is a voluntary association of governments and is supported financially through federal, state and local government funds, contributions from utility companies, and membership dues. Staff from MORPC provide legislative representation, training and educational forums, consulting services, and networking opportunities. MORPC addresses development planning in Central Ohio and strives to promote a healthy and sustainable environment. In particular, the Greenways Program under MORPC is dedicated to increasing green space along rivers and streams.

9.3.8 Phase II Stormwater Communities

Phase II storm water communities must develop stormwater management plans that include controls for the six minimum control measures outlined by the U.S. EPA (www.epa.state.oh.us/dsw/storm/ms4.html). In the Olentangy River watershed, the City of Powell, Orange and Liberty townships and Delaware County are designated Phase II communities and have initiated stormwater programs which include construction site permitting and inspections, good housekeeping training, and public outreach and education. These communities work with the Delaware Soils and Water Conservation District and have participated in activities sponsored by the Friends of the Lower Olentangy River Watershed. Through their commitment to their storm water programs there is opportunity to proactively address storm water sources of impairment in some of the rapidly developing area of the watershed.

9.3.9 Local Watershed Groups

Two watershed organizations steward the complete Olentangy stream system: FLOW (Friends of the Lower Olentangy Watershed) and OWA (the Olentangy Watershed Alliance). Both evolved with the funding support of Ohio EPA 319 grants. FLOW, established in 1997 and claiming 300 dues paying members, plays a strong public education role in urbanized Franklin and rapidly developing southern Delaware Counties. The organization focus is on urban and transitional suburban water quality issues. It has provided extensive comment at public hearings (401) on river – development topics and appeared on local radio call-in programs. The organization holds monthly public meetings, publishes a newsletter distributed throughout Franklin and Delaware Counties and maintains a website.

The Olentangy Watershed Alliance, formed with support from Ohio EPA, ODNR and Ohio State Extension has a group membership and focus centering on the agricultural landscapes of the upper watershed in northern Delaware, Morrow, Marion and Crawford Counties. OWA's recent watershed coordinator, located at Morrow County SWCD, has worked to promote the Scioto CREP program and educate local producers about the Upper Olentangy Watershed Action Plan's recommendations.

Each watershed organization has produced or co-produced a watershed plan under Ohio EPA 319 funding support. The FLOW plan, addressing urban and suburban challenges, was fully endorsed by ODNR and Ohio EPA in 2006. Full state endorsement is presently pending for The Upper Olentangy Watershed Action Plan, noted above. Multiple action items contained in these watershed plans parallel topics and recommendations contained in this report.

Both OWA and FLOW actively participate on the plenary Olentangy TMDL Team.

9.3.10 Easements and Land Preservation

The preservation and protection of high quality riparian acres is advanced by multiple private and public entities throughout the watershed.

The Ohio Department of Natural Resources, Division of Natural Areas and Preserves works with local communities and development interests to advance protection and setbacks for the riparian corridor in the State Scenic River reaches of the Olentangy. A series of low head dams have been (2004, 2005) or are slated to be removed by the division. They include Dennison dam, the dam at Delaware WWTP, Panhandle dam and two dams at the intersection at US 23. These removals enhance water quality, fish habitat and recreational/aesthetic values of the river.

In 2004, Preservation Parks of Delaware County, worked with OEPA's Watershed Resource and Restoration Sponsorship Program, developers and the Boy Scouts of America; to purchase 60 acres of pristine wooded stream corridor (Big Run) and 121 acres of perpetual conservation easements (Camp Lazarus) within two heavily forested tributary ravines flanking the mainstem's east bank in Liberty Township. Both sites experienced increasingly intense development pressure prior to acquisition. The Big Run acreage carries preserve status. In 2006, Preservation Parks accepted a donation of approximately 100 acres within the same township. These acres include two ravines draining to the mainstem. The organization continues to seek high quality lands for acquisition and preservation as parks and preserves throughout Delaware County and the Olentangy River corridor.

9.3.11 Other Sources of Funding and Special Projects

A U.S. EPA Section 319(h) grant was awarded in 2005 to fund demonstrations of alternative approaches to drainage. In particular, a two-stage ditch is to be constructed and monitored using these and other funds. In addition, education and outreach is a deliverable of this grant where such alternative drainage management approaches will be disseminated, buffer strips through the Scioto CREP and permanent conservation easements will be promoted. Entities directly or indirectly involved with this project include the Ohio DNR; Morrow, Marion, and

Crawford SWCDs; Agricultural Research Service (USDA); Ohio Water Development Authority; Ohio State University; Heidelberg College; and the Ohio EPA. Through this grant several brochures, fact sheets, and workshops and signage will be developed.

9.4 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).

This section of the report provides a general strategy for continued monitoring and evaluation and lists parties who can potentially carry out such work. It highlights past efforts and those planned to be carried out in the future by the Ohio EPA and others. It also outlines a process by which changes to the implementation strategy can be made if needed.

9.4.1 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 8), 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 within the Olentangy River watershed in 1994, and in 2003 and 2004 (Ohio EPA, 1995, 2005). The Ohio EPA is scheduled to perform biological, water quality, habitat, and sediment chemistry monitoring in all four assessment units in the basin in 2018 (OEPA, 2006).

Past and continued monitoring in the watershed includes analysis of raw water from water treatment plants (WTPs), and ambient and effluent discharges from six NPDES permitted facilities. Raw water is monitored for several water quality parameters by the Cities of Delaware and Galion and the DelCo Water Company. The City of Galion monitors water from within the Amans Reservoir for TOC and DOC on a monthly basis. Delaware WTP measures the concentration of TP, NO3, TOC, and triazines in river water near the water intake (located just downstream from the Delaware Reservoir) on a monthly basis. Nitrate, TOC, and triazines are measured on a weekly basis or more frequently from May to August. Effluent quality is monitored by six WWTPs in the watershed including those servicing Galion, Mount Gilead, the Candlewood Lake area, Cardington, Marion County at its Richland Road facility, and from the Olentangy Environmental Control Center that serves Delaware County residents south of the

City of Delaware. These data are included in the Monthly Operating Reports (MOR) that are submitted to the Ohio EPA by these facilities.

Institutions that have actively monitored water resources in the Olentangy for either research based initiatives or educational purposes are Otterbein College, Ohio Wesleyan University, and the Ohio State University (the main and Marion campuses). Other entities conducting monitoring work include the Ohio Department of Natural Resources (especially through the Scenic Rivers Program), Delaware County General Health District, and the City of Columbus Division of Water and Division of Sewers and Drains. The City of Columbus collected extensive water quality data in preparing its Wet Weather Management Plan.

Potential and Future Evaluation

A request for proposals for a Section 319 grant was issued in October of 2005 that solicits monitoring and evaluation work to be done in the three HUC-11 sub-basins of the upper Olentangy watershed. The grant amount is for $125,000 and local match is to be $83,000 for a total monitoring budget of $208,000. Two HUC-11 sub-basins are likely to be monitored at their respective outlets, while a paired watershed study is to occur at the HUC-14 scale. The paired watershed study will be used to help evaluate the effectiveness of BMPs that are to be targeted for implementation in one of these two basins with additional funds from the grant. The overall monitoring effort is to include 16 biological surveys, 180 water chemistry samples (e.g., TSS, NH3, NO2-NO3, and TP), 8 habitat assessments, and 2 stage-discharge stations.

The Soil Drainage Unit (SDU) for the Agricultural Research Service (USDA-ARS) located on the campus of the Ohio State University is currently carrying out a detailed study of the effectiveness of BMPs within the upper Big Walnut Creek watershed (HUC 0506000 130). This study measures water chemistry, flow volume, habitat, and biological communities in relation to landscape and field scale management practices, land uses and other variables (e.g., soil types). Collaboration with the SDU may be feasible due to the close proximity of the upper Big Walnut Creek watershed to the Olentangy River watershed. The resources and expertise of the SDU make them an attractive potential partner.

The Ohio State University Department of Civil and Environmental Engineering and the consulting firm Malcolm Pirnie have been hired by the City of Delaware to collect water quality data and develop computer models to simulate hydraulics, sediment transport, and water quality conditions on a segment of the mainstem of the Olentangy River that is just downstream of the Delaware Reservoir and extends through the City of Delaware. The objectives of this work include determining sediment dynamics in relation to changing flow regimes over this relatively short section of the mainstem. This evaluation may provide insight to impacts to habitat in this area and downstream areas.

The close proximity of colleges and universities within the Olentangy watershed increases the potential for collaboration and/or the availability of independently collected data regarding water resources in the watershed.

Recommended Approach for Gathering and Using Available Data

Early communications should take place between the Ohio EPA and the potential collaborators mentioned above to discuss research interests and objectives. Through this, areas of overlap should be identified and ways to make all parties research efforts more efficient should be discussed. Ultimately important questions can be addressed by working collectively and through pooling resources, knowledge, and data.

9.4.2 Revision to the Implementation Approach

An adaptive management approach will be taken in the Olentangy River watershed. Adaptive management is recognized as a viable strategy for managing natural resources (Baydack et al., 1999) and this approach is applied on federally owned lands. 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 Olentangy River 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.

References

Andoh R.Y.G. and Declerck C. 1997. A cost effective approach to stormwater management? Source control and distributed storage. Water Science Technology. 36(8-9): 307-311.

Baer S.G., Siler E.R., Eggert S.L., and Wallace J.B. 2001. Colonization and production of macroinvertebrates on artificial substrata: upstream-downstream responses to a leaf litter exclusion manipulation. Freshwater Biology 46: 347-365.

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

Baker D.B., Richards R.P., Loftus T.T., and Kramer J.W. 2004. A new flashiness index: Characteristics and applications to Midwestern rivers and streams. Journal of the American Water Resource Association. April: 503-522

Battin T.J., Kaplan L.A., Newbold D., and Hendricks S.P. 2003. A mixing model analysis of stream solute dynamics and the contribution of a hyporheic zone to ecosystem function. Freshwater Biology 48: 995-1014.

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

Booth D.B. Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America. Journal of the North American Benthological Society. 24(3): 724-737.

Brabec E., Schulte S., and Richards P.L. 2002. Impervious Surfaces and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning. Journal of Planning Literature. 16(4): 499-514.

Clarke S.J., Bruce-Burgess L., and Wharton G. 2003. Linking form and function: towards an eco-hydromorphic approach to sustainable river restoration. Aquatic Conservation – Marine and Freshwater Ecosystems 13 (5): 439-450.

Cossins A.R., and Bowler K. 1987. Temperature biology of animals. Chapman and Hall, New York, New York.

Crenshaw C.L., Valett H.M., and Webster J.R. 2002. Effects of augmentation of coarse particulate organic matter on metabolism and nutrient retention in hyporheic sediments. Freshwater Biology. 47: 1820-1831.

D'Ambrosio J., Ward A., and Witter J. 2006. Olentangy River Watershed Total Maximum Daily Load Study. Department of Food, Agricultural, and Biological Engineering, Ohio State University, Columbus, Ohio.

Danehy R.J., Ringler N.H., and Ruby R.J. 1999. Hydraulic and geomorphic influence on macroinvertebrate distribution in headwaters of a small watershed. Journal of Freshwater Ecology 14 (1): 79-91.

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.

[FMSM] Fuller Mossbarger Scott and May. 2005. The Lower Olentangy River Watershed Lowhead Dams: Feasibility Study. December 2005.

Forshay K.J. and Stanley E.H. 2005. Rapid nitrate loss and denitrification in a temperate river floodplain. Biogeochemistry 75: 43-64.

Hahn S. 1982. Stream channelization: effects on stream fauna. Geological Survey Circular 848-A pp. 43-49.

Jeong H. 2005. Two-stage drainage ditch construction cost. Post doctoral researcher, Ohio State University.

Mathias M.E. and Moyle P. 1992. Wetland and aquatic habitats. Agriculture Ecosystems and Environment 42 (1-2):165-176

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

Morgan R.P. and Cushman S.F. 2005. Urbanization effects on stream fish assemblages in Maryland, USA. Journal of the North American Benthological Society. 24(3): 643-655.

Ohio EPA. 1987a. Biological criteria for the protection of aquatic life. Volume I. The role of biological data in water quality assessments. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, OH.

Ohio EPA. 1987b. Biological criteria for the protection of aquatic life. Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, OH.

Ohio EPA. 1999. Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams. Ohio EPA Technical Bulletin. MAS/1999-1-1. Columbus, OH.

Ohio EPA. 1995. Biological and Water Quality Study of the Olentangy River, Whetstone Creek and Select Tributaries , 2003-2004. Division of Surface Water, Columbus, OH. EAS/2005-12-6

Ohio EPA. 2005. Biological and Water Quality Study of the Olentangy River, Whetstone Creek and Select Tributaries , 2003-2004. Division of Surface Water, Columbus, OH. EAS/2005-12-6

Ohio EPA. 2006. Analysis of Treatment and Disposal Standards for Phosphorus for Publicly Owned Treatment Works. Ohio EPA Division of Surface Water. April 4, 2006

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

Parikh P., Taylor M.A., Hoagland T., Thurston H., and Shuster W. 2005. Application of market mechanisms and incentives to reduce stormwater runoff: and integrated hydrologic, economic a legal approach. Environmental Science and Policy. 8: 133-144.

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.

Phillips S. 2005, Oxbow Stream Restoration Inc. personal communication, November 2005.

Powell K. 2004. Denitrification in agricultural headwater ditches. Master's Thesis. Ohio State University, Columbus, Ohio.

Prichard D. 1998. Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. Technical Reference 1737-15. U.S. Department of the Interior, Bureau of Land Management, National Applied Resource Sciences Center, Denver, CO. 126 p.

Reice S. R., Wissmar R. C., and Naiman R. J. 1990. Disturbance regimes, resilience and recovery of animal communities and habitats in lotic ecosystems. Environmental Management. 14 (5): 647-659.

Richards R.P. and Grabow G.L. 2003. Detecting reductions in sediment loads associated with Ohio's Conservation Reserve Enhancement Program. Journal of the American Water Resource Association. October: 1261-1268

Robinson M. and Rycroft D.W. 1999. The impact of drainage on streamflow. In: Agricultural Drainage Monograph (38). Eds. Skaggs R.W. and Schilfgaarde., American Society of Agronomy, Madison, Wi. p 767-800

Roy A.H., Rosemond A.D., Paul M.J., Leigh D.S., and Wallace J.B. 2003. Stream macroinvertebrate response to catchment urbanisation (Georgia, U.S.A.). Freshwater Biology 48: 329-346.

Roy A.H., Freeman M.C., Freeman B.J., Wenger S.J., Meyer J.L., Ensign W.E. 2006. Importance of riparian forests in urban catchments contingent on sediment and hydrologic regimes. Environmental Management. 37(4): 523-539.

Sablak G. 2004. Link between macroinvertebrate community, riparian vegetation and channel geomorphology in agricultural drainage ditches. Master's Thesis. Ohio State University, Columbus, Ohio.

Schwartz J.S. and Herricks E.E. 2005. Fish use of stage-specific fluvial habitats as refude patches during a flood in a low-gradient Illinois stream. Canadian Journal of Fisheries and Aquatic Sciences. 62: 1540-1552.

Simon A. and Hupp C. R. 1986. Channel evolution in modified Tennessee channels. In: Proceedings of the 4th Federal Interagency Sedimentation Conference, Las Vegas, Nevada, US Governmental Printing Office, Washington, DC, 5.71-5.82.

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.

Wallace J.B., Eggert S.L., Meyer J.L., and Webster J.R. 1997. Multiple trophic levels of a forest stream linked to terrestrial litter inputs. Science 277:102-104.

Walsh C.J., Roy A.H., Feminella J.W., Cottingham P.D., Groffman P.M. and Morgan R.P. 2005. The urban stream syndrome: current knowledge and the search for the cure. Journal of the North American Benthological Society. 24(3): 706-723.

Walters D.M., Leigh D.S., Freeman M.C., Freeman B.J., and Pringle C.M. 2003. Geomorphology and fish assemblages in a Piedmont river basin, U.S.A. Freshwater Biology 48:1950-1970.

Ward J. V.1992. Aquatic Insect Ecology. John Wiley & Sons Inc. US.