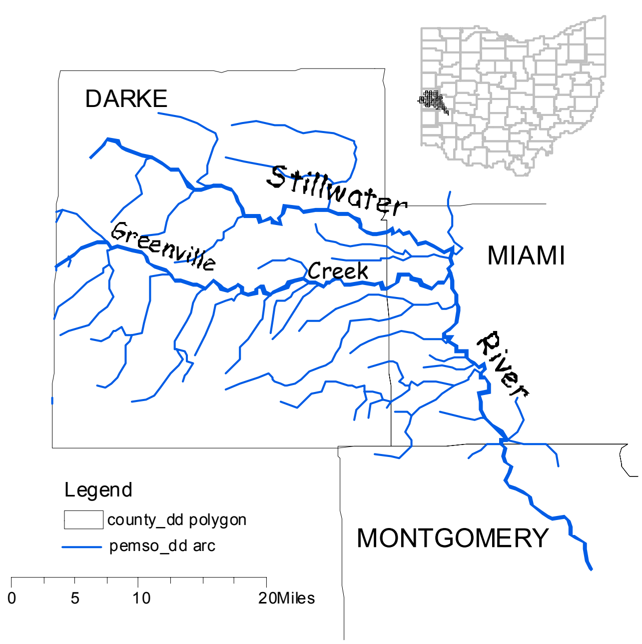
Total Maximum Daily Loads for the Stillwater River Basin

Final Report

prepared by

Ohio Environmental Protection Agency
Division of Surface Water

April 2004



Basin:
Stillwater River
Study Area:
The entire Stillwater River basin in Darke, Miami and Montgomery Counties, Ohio. See figure at left.
Goal:
Full attainment of numeric biological criteria for a given aquatic life use.
Major Causes:
Habitat alteration, organic enrichment, low dissolved oxygen, ammonia, nutrients
Major Sources:
Hydromodification - agriculture, animal feeding operations, municipal wastewater, on-site sewerage
Measure:
Habitat indices, phosphorus, BOD
Restoration Options:
Increase width and amount of stream buffers, stream habitat restoration, nutrient managment planning, elimination of failing septic systems, education and cost sharing for conservation and nutrient management

Table of Contents

Table of Contents
(continued)

Acknowledgments

The following Ohio EPA staff provided technical services for to this report:

Biological Assessment - Bob Miltner
Pollutant Loadings - Maryanne Mahr
Septic workgroup - Joseph Miller, Joseph Reynolds
Water Chemistry - Louise Snyder
NPDES Permit Issues - Gary Stuhlfauth
Non-point Pollution Assessment - Hugh Trimble
Animal Feeding Operations, NPDES Permit Issues - Rick Wilson
Water Quality Modeling Support - Dale White
Team Leaders - Bob Miltner, Dale White

The following stakeholders and public volunteers are acknowledged for their generous donations of time and help in framing this TMDL:

Brian Cron
George Shade
Terry Mescher
Jim Rismiller
Tim Rhoades
Tom Menke
Gerry Tipton
Don Lecklider
Jim McGarry
Merlin Baker
Art Burke
Ralph "Doc" Burkholder
Carrie Cusick
Mike Eckberg
Chris McKay
Ron Jackson
Merlin Baker
Lew McClelland
Jim Surber
Darrell S. Hollon
Steve Foster
Ron Barga
Harold Beisner
Jim Bennett
Bill Siefring
Terry Netzley
Bob Brill
Ed Francis
John Vehre
Sandy Netzley
Brian Rosengarten
Jim Surber
Kreig Smail
Tom Tweed
Terry Wackler
Mike Lucas
Randy Hoover
Tim Warner
Mike Ekberg

Special thanks to Nikki Reese for acting as liaison between Ohio EPA and local stakeholders, and Anne Baird for her work managing the stakeholder meetings.

The Systemic Inquiry Group at The Ohio State University provided valuable sociological expertise, outreach and education for the study team leaders.

Executive Summary

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 waters (the section 303(d) lists) are made available to the public and submitted to the U.S. Environmental Protection Agency (USEPA) in every even-numbered year (40 CFR 130.7(d)) did not require a 303(d) list submittal in the year 2000). The Ohio Environmental Protection Agency (Ohio EPA) identified the Stillwater River watershed as a priority impaired water on the 1998 303(d) list.

Twenty-four stream segments from the Stillwater River basin were listed on the 2002 303(d) list. Four of those segments are expected to meet their designated aquatic life uses through permit controls and infrastructure upgrades, and two segments were erroneously listed leaving 18 segments included in this TMDL.

The Stillwater River flows 67 miles from its headwaters in Indiana and northern Darke County to a confluence with the Great Miami River in Dayton. The Stillwater River flows in an eastward direction through Darke County into western Miami County where it turns southward to Montgomery County. Major tributaries include: Greenville Creek, Ludlow Creek, Painter Creek, Swamp Creek and North Fork Stillwater River. The watershed covers approximately 673 square miles with about 32 square miles in Randolph County Indiana, and is drained by 280 miles of streams, but many of those stream miles have been physically modified to maintain drainage for row crop agriculture. Historically, almost one-third of the watershed may have been wetlands, but tile drainage and stream channelization have reduced this to one-half of one percent. Agriculture composes over 80 percent of the landuse, and Darke County has the second highest concentration of animal feeding operations (AFOs) in Ohio.

The most pervasive problem facing streams in the basin is habitat destruction through channelization. Almost the entire stream network in Darke County has previously been channelized. Channelization is the removal of trees from stream banks coupled with deepening, and often straightening, the stream course. Channelization always results in long-term aquatic life use impairment, especially for sport fishing. It is a direct cause of sedimentation, and greatly magnifies the effects of introduced nutrients. This latter problem is especially troublesome in the northern portion of the basin where large amounts of synthetic and organic fertilizers are applied to the land. Because the streams are maintained in a channelized state with little or no riparian buffer, organic matter and nutrients are able to enter unimpeded during storm events. The absence of a shading riparian canopy allows full sunlight to reach the stream and cause algal blooms. The algal blooms then result, either through decomposition or respiration, in dissolved oxygen depletion to levels below that needed to sustain higher aquatic life. Further complicating matters is the loss or diminution of sustained stream flow in channelized headwaters, especially those less than 10 mi^2, as the whole point of channelization is to expedite drainage. The upshot being, from a pollution loadings standpoint, that less flow for a given drainage area means less assimilative capacity.

The other pervasive problem facing the basin, as mentioned in the previous paragraph, is organic and nutrient enrichment. Organic and nutrient enrichment in the Stillwater basin comes primarily from land-applied animal manure and secondarily from failing septic systems and

municipal wastewater treatment works. That enrichment is a problem in the basin was evidenced by biological and water quality results (*e.g.*, high fecal coliform bacteria and *E. coli* counts, high biochemical oxygen demand, wide diel oxygen swings, poor to very poor biological scores, and fish kills occurring in streams with sustained flow). Although channelized streams are expected to have less biological and water quality integrity compared to natural streams, channelized streams are expected to be free from nuisance conditions (*e.g.*, mats of decaying algae), safe for recreational contact (*i.e.*, fecal matter should not be present), and should have sufficient water quality to harbor aquatic life. Swamp Creek and its tributaries, the North Fork, and the Stillwater River upstream from Ansonia were similarly impacted from excess organic and nutrient enrichment from land-applied manure. Failing septic systems caused noticeable water quality impacts and biological impairment in Indian Creek, Greenville Creek downstream from Gettysburg, the Wayne Lakes area, and to Ludlow Creek or its tributaries near Phillipsburg and Pittsburgh. Because nutrients are associated with both organic enrichment from animal manure and synthetic agricultural fertilizers, nutrients (total phosphorus and nitrogen were selected as the target pollutant for this TMDL.

Nutrient loading and flow in the Stillwater River watershed from agricultural management practices and WWTP was simulated using the Soil and Water Assessment Tool (SWAT). SWAT is a river basin-scale model developed by the USDA ARS at the Blackland (Texas) Research Center (Arnold et al. 1998; Srinivasan, R. et al. 1998). The results of the model suggest that existing nitrogen loads can be assimilated; however, phosphorus loads exceed the assimilative capacity by an order of magnitude. Agricultural fertilizers account for approximately fifty to eighty-five percent of the phosphorus load depending on season and need to be reduced by approximately eighty percent during the winter and spring months. Similarly, loads from stormwater and on-site sewerage systems need to be reduced by seventy percent in the winter and spring. Loads from municipal wastewater need to be reduced by sixty-five percent across all seasons.

The following recommendations are suggested to affect full recovery of aquatic life uses:

- Comprehensive nutrient management plans for all animal feeding operations,
- Encourage the use of best demonstrated technologies for managing animal waste through cost sharing and other incentive programs,
- Increase the number and width of grass filter strips on maintained ditches through cost sharing and other incentive programs,
- Increase the number of agricultures acres in no-till or conservation tillage through cost sharing and other incentive programs,.
- Develop criteria for allowing ditch maintenance,
- Establish a Darke County Sewer District, and
- Establish residential on-site sewerage inspection programs in Darke and Miami Counties.

1.0 Introduction

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 waters (the section 303(d) lists) are made available to the public and submitted to the U.S. Environmental Protection Agency (USEPA) in every even-numbered year (40 CFR 130.7(d)) did not require a 303(d) list submittal in the year 2000). The Ohio Environmental Protection Agency (Ohio EPA) identified the Stillwater River watershed as a priority impaired water on the 1998 303(d) list. A summary of Stillwater basin stream segments listed in the 2002 303(d) list and associated causes and sources of impairment are given in Table 1.1. The status of those segments and how this TMDL address them is given in Table 1.2.

The Clean Water Act and USEPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the section 303(d) lists. A TMDL is 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 amount to the pollutant's sources. The process of formulating TMDLs for specific pollutants is therefore, a method by which impaired water body segments are identified and restoration solutions are developed. Ultimately, the goal of Ohio's TMDL process is full attainment of biological and chemical Water Quality Standards (WQS) and, subsequently, removal of water bodies from the 303(d) list. The Ohio EPA believes that developing TMDLs on a watershed basis (as opposed to solely focusing on impaired segments within a watershed) is an effective approach towards this goal.

This report serves to document the Stillwater River TMDL process and provide for tangible actions to restore and maintain this water body. The main objectives of the report are to: describe the water quality and habitat condition of the Stillwater River and to quantitatively assess the factors affecting non or partial attainment of WQS. A draft implementation plan is also included. This plan identifies actions to address these factors and specifies monitoring to ensure actions are carried out and to measure the success of the actions proscribed. The report is organized in sections forming the progression of the TMDL process. The primary causes of impairment in the Stillwater River watershed are organic and nutrient enrichment, ammonia and habitat degradation. TMDLs were calculated for organic/nutrient enrichment and habitat. Because ammonia as a cause of impairment was derived from organic enrichment, TMDLs were not calculated for ammonia. Habitat degradation is not a load based quantity; however, the regulations provide for these types of impairing causes, as such 'TMDL' numbers were calculated.

Because the 1999 biological and water quality survey of the Stillwater River basin was the most comprehensive to date, segments listed 2002 303(d) list replace and supercede any previous listing. If a segment listed in an earlier 303(d) list does not appear in this TMDL it is because that segment is now fully meeting its aquatic life use as judged by the 1999 comprehensive survey.

Table 1.1. Names of impaired stream segments and the miles impaired, and associated causative pollutants and pollutant sources in the Stillwater River basin identified in the 1992, 1998 and 2002 §305b assessment cycles.

Segment	URM	LRM	AQUATIC LIFE USE STATUS FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Stillwater River (Headwaters to North Fork) MWH											
OH57 45								Other habitat alterations	M	Channelization - Agriculture	M
2002	67.6	57.9	7	0	0	2.67	0	Organic enrichment/DO	H	Hydromodification - Agriculture	M
								Nutrients	M	Confined Animal Feeding Operations	H
Stillwater River (Headwaters to North Fork) MWH											
OH57 45								Other habitat alterations	H	Channelization - Agriculture	M
1998	67.6	57.9	0	0	0	9.67	9.67	Nutrients	M	Hydromodification - Agriculture	M
										Nonirrigated crop production	H
Stillwater River (Headwaters to North Fork) MWH											
OH57 45								Organic enrichment/DO	H	Combined Sewer Overflow	M
1992	67.6	57.9	0	0	9.67	0	9.67			Municipal Point Sources	H
Stillwater River (North Fork to Swamp Creek) WWH/EWH											
OH57 43								Nutrients	H	Channelization - Agriculture	H
2002	57.9	45.8	8.09	0	4	0	0			Hydromodification - Agriculture	H
										Confined Animal Feeding Operations	M
Stillwater River (Swamp Creek to Greenville Creek) EWH											
OH57 37								Nutrients	H	Channelization - Agriculture	H
2002	45.8	32.4	12.5	0	1	0	0			Hydromodification - Agriculture	H
										Confined Animal Feeding Operations	M

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

			AQUATIC LIFE USE STATUS								
Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes**		**Sources**	
Stillwater River (Swamp Creek to Greenville Creek) EWH											
OH57 37								Organic enrichment/DO	H	Combined Sewer Overflow	M
1992	45.8	32.4	5.5	0	8	0	13.5			Municipal Point Sources	H
Stillwater River (Greenville Cr. To Ludlow Cr.) EWH											
OH57 14								Other habitat alterations	H	Source Unknown	H
1992	32.4	21	8.6	0	2.8	0	11.4	Cause Unknown	H	Dam construction - Development	H
										Hydromodification - Development	H
Stillwater River (Brush Creek to Great Miami R.) EWH											
OH57 1								Nutrients	H	Confined Animal Feeding Operations	H
2002	14.2	0	13.2	0	0	1	0	Other habitat alterations	M	Nonirrigated crop production	H
										Hydromodification - Development	M
Stillwater River (Brush Creek to Great Miami R.) EWH											
OH57 1								Other habitat alterations	M	Dam construction - Development	M
1992	14.2	0	3.6	0	10.6	0	14.2	Organic enrichment/DO	H	Hydromodification - Development	M
										Combined Sewer Overflow	H
										Municipal Point Sources	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes		Sources	
			AQUATIC LIFE USE STATUS								
Pigeye Creek WWH											
OH57 2								Organic enrichment/DO	H	Onsite wastewater systems (septic tanks)	H
2002	1.9	0	0	0	1.9	0	0				
Mill Creek WWH											
OH57 3								Other habitat alterations	H	Channelization - Development	H
2002	5.7	0	0.5	0	0	5.2	0	Organic enrichment/DO	H	Hydromodification - Development	H
								Unionized Ammonia	H	Major Industrial Point Source	H
Mill Creek WWH											
OH57 3								Other habitat alterations	S	Spills	H
1998	5.7	0	0.6	0	0	3.8	5.7	Organic enrichment/DO	H	Other	H
								Unionized Ammonia	H	Channelization - Development	S
										Wastewater	H
Mill Creek WWH											
OH57 3								Organic enrichment/DO	H	Channelization - Development	S
1996	5.7	0	0	0.6	0	3.8	5.7	Unionized Ammonia	T	Industrial Permitted	T
								Unionized Ammonia	H	Industrial Permitted	H
										Urban Runoff/Storm Sewers (NPS)	T
										Urban Runoff/Storm Sewers (NPS)	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes		Sources	
			AQUATIC LIFE USE STATUS								
Jones Run WWH											
OH57 6								Organic enrichment/DO	H		
2002	0.6	0	0	0	0.6	0	0				
Painter Creek MWH/WWH											
OH57 18								Organic enrichment/DO	H	Combined Sewer Overflow	M
2002	19.7	0	3.25			16.5		Nutrients	M	Combined Sewer Overflow	H
								Unionized Ammonia	M	Minor Municipal Point Source	H
Painter Creek MWH/WWH											
OH57 18								Other habitat alterations	H	Natural	M
1998	19.7	0	4.75	0	0	15	19.7	Organic enrichment/DO	M	Other	M
								Nutrients	M	Channelization - Agriculture	H
										Hydromodification - Agriculture	H
										Nonirrigated crop production	M
										Minor Municipal Point Source	H
Painter Creek MWH/WWH											
OH57 18								Organic enrichment/DO	H	Hazardous waste	H
1992	19.7	0	11.9	0	0.2	7.65	19.7	Unionized Ammonia	H	Combined Sewer Overflow	M
										Municipal Point Sources	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes		Sources	
			AQUATIC LIFE USE STATUS								
Little Painter Creek MWH											
OH57 19								Organic enrichment/DO	H	Animal holding/management areas	H
2002	5.2	0	4.2	0	1	0	0				
Brush Creek WWH											
OH57 8								Organic enrichment/DO	H	Channelization - Development	M
2002	8	0	6	0	0	2	0	Unionized Ammonia	M	Hydromodification - Development	M
										Septage disposal	H
Brush Creek WWH											
OH57 8								Other habitat alterations	H	Channelization - Agriculture	H
1998	8	0	0	0	0	8	8	Nutrients	H	Hydromodification - Agriculture	H
										Nonirrigated crop production	H
Harris Creek MWH/WWH											
OH57 38								Organic enrichment/DO	H	Channelization - Agriculture	H
2002	9.1	0	6.1	0	3	0	0	Siltation	H	Hydromodification - Agriculture	H
										Minor Municipal Point Source	M
Harris Creek MWH/WWH											
OH57 38								Nutrients	H	Range Grazing - Riparian	S
1998	9.1	0	0	0	1.3	0	9.1			Nonirrigated crop production	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes		Sources	
			AQUATIC LIFE USE STATUS								
Ballinger Run MWH/WWH											
OH57 39								Other habitat alterations	H	Channelization - Agriculture	H
2002	4.6	0	0	0	0	4.6	0	Organic enrichment/DO	H	Hydromodification - Agriculture	H
										Combined Sewer Overflow	H
Ballinger Run MWH/WWH											
OH57 39								Other habitat alterations	H	Channelization - Agriculture	H
1998	4.6	0	0	0	0	4.6	4.6	Siltation	H	Hydromodification - Agriculture	H
								Nutrients	H	Nonirrigated crop production	H
										Minor Municipal Point Source	M
Greenville Creek (Headwaters to West Branch) EWH											
OH57 32								Organic enrichment/DO	H	Feedlots (Confined Animal Feeding Oper.)	H
1992	40.5	24.3	6.5	0	4.7	0	16.2			Nonirrigated crop production	H
Greenville Creek (West Br. To Dividing Br.) WWH											
OH57 26								Other habitat alterations	M	Channelization - Development	H
2002	24.3	15.2	2.6	0	6	0.5	0	Organic enrichment/DO	H	Hydromodification - Development	H
										Major Municipal Point Source	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes		Sources	
			AQUATIC LIFE USE STATUS								
Greenville Creek (West Br. To Dividing Br.) WWH											
OH57 26								Other habitat alterations	H	Dam construction - Development	H
1992	24.3	15.2	0	0	9.1	0	9.1	Flow alteration	H	Hydromodification - Development	H
								Organic enrichment/DO	H	Nonirrigated crop production	S
								Siltation	S	Municipal Point Sources	H
										Industrial Point Sources	S
Greenville Creek (Dividing Br. To Stillwater R.) EWH											
OH57 21								Organic enrichment/DO	H	Onsite wastewater systems (septic tanks)	H
2002	15.2	0	9.5	0	2.7	3	0	Nutrients	M	Major Municipal Point Source	H
Greenville Creek (Dividing Br. To Stillwater R.) EWH											
OH57 21								Other habitat alterations	M	Dam construction - Development	M
1992	15.2	0	0	0.3	7.3	7.6	15.2	Organic enrichment/DO	T	Hydromodification - Development	M
								Organic enrichment/DO	H	Nonirrigated crop production	T
										Nonirrigated crop production	M
										Municipal Point Sources	T
										Municipal Point Sources	H
										Industrial Point Sources	S

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes		Sources	
			AQUATIC LIFE USE STATUS								
Bolton Run WWH											
OH57 24								Organic enrichment/DO	H	Onsite wastewater systems (septic tanks)	H
2002	3.5	0	0	0	3.5	0	0				
Dividing Branch WWH											
OH57 25								Organic enrichment/DO	H	Channelization - Agriculture	M
2002	7	0	2.5		2.5			Nutrients	M	Hydromodification - Agriculture	M
										Onsite wastewater systems (septic tanks)	H
Mud Creek WWH											
OH57 28								Other habitat alterations	H	Channelization - Agriculture	H
1992	8	0	7.8	0	0.2	0	8	Siltation	H	Hydromodification - Agriculture	H
Prairie Outlet WWH											
OH57 29								Organic enrichment/DO	H	Onsite wastewater systems (septic tanks)	H
2002	2	0	0	0	2	0	0				
Prairie Outlet WWH											
OH57 29								Organic enrichment/DO	H	Onsite wastewater systems (septic tanks)	H
1992	2	0	0	0	1	0	2	Nutrients	H	Feedlots (Confined Animal Feeding Oper.)	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

			AQUATIC LIFE USE STATUS								
Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes**		**Sources**	
Dismal Creek WWH											
OH57 35								Other habitat alterations	H	Channelization - Agriculture	H
2002	9.5	0	2	0	2	1	0	Organic enrichment/DO	H	Hydromodification - Agriculture	H
										Wastewater	H
Swamp Creek WWH/MWH											
OH57 41								Other habitat alterations	M	Channelization - Agriculture	M
2002	13.8	0	4.8	0	6.5	2.5	0	Organic enrichment/DO	H	Hydromodification - Agriculture	M
								Nutrients	M	Confined Animal Feeding Operations	H
Swamp Creek WWH/MWH											
OH57 41								Other habitat alterations	H	Channelization - Agriculture	H
1992	13.8	0	7.3	0	1.6	4.9	13.8	Organic enrichment/DO	H	Hydromodification - Agriculture	H
								Nutrients	H	Feedlots (Confined Animal Feeding Oper.)	M
										Nonirrigated crop production	M
										Municipal Point Sources	M
Indian Creek WWH/MWH											
OH57 42								Other habitat alterations	H	Channelization - Agriculture	H
2002	5.2	0	0	0	0.5	6.1	0	Organic enrichment/DO	H	Hydromodification - Agriculture	H
								Nutrients	M	Septage disposal	H
										Confined Animal Feeding Operations	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	AQUATIC LIFE USE STATUS Fully	Threat	Partial	non	Unassessed	Causes		Sources	
Indian Creek WWH/MWH											
OH57 42								Other inorganics	H	Spills	H
1998	5.2	0	0	0	0	4.85	5.2			Other	H
Indian Creek WWH/MWH											
OH57 42								Other habitat alterations	H	Streambank destabilization - Ag	H
1992	5.2	0	0	0	1	0	5.2			Channelization - Agriculture	H
										Hydromodification - Agriculture	H
Boyd Creek MWH											
OH57 44								Other habitat alterations	M	Channelization - Agriculture	M
2002	3.3	0	3	0	1	0	0	Organic enrichment/DO	H	Hydromodification - Agriculture	M
										Onsite wastewater systems (septic tanks)	H
North Fork Stillwater River MWH											
OH57 46								Other habitat alterations	M	Channelization - Agriculture	M
2002	7.7	0				11		Organic enrichment/DO	H	Hydromodification - Agriculture	M
										Confined Animal Feeding Operations	H
South Fork Stillwater River WWH											
OH57 48								Other habitat alterations	H	Channelization - Agriculture	H
2002	7	0	1		6					Hydromodification - Agriculture	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

			AQUATIC LIFE USE STATUS								
Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes**		**Sources**	
Trib. To Stillwater R. (Rm 60.22) MWH											
OH57 45.1								Other habitat alterations	H	Channelization - Agriculture	H
2002	4.06	0	2	0	0.5	0	0			Hydromodification - Agriculture	H

1 Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.2. Status of 2002 303(d) listed segments included in this TMDL report.

WBID	URM	LRM	Segment Name	Causes	TMDL Component
OH57 1	14.2	0	Stillwater River	Nutrients Hydromodification	NPDES included in WLA Dam Removal
OH57 2	1.9	0	Pigeye Creek	Organic enrichment/DO	Septic & livestock implementation plans
OH57 3	5.7	0	Mill Creek	Unionized Ammonia Organic enrichment/DO Other habitat alterations	No, covered separately through NPDES permit
OH57 6	0.6	0	Jones Run	Organic enrichment/DO	Sewer line repaired
OH57 8	8	0	Brush Creek	Unionized Ammonia Organic enrichment/DO	Septic implementation plan
OH57 18	19.75	0	Painter Creek	Unionized Ammonia Nutrients Organic enrichment/DO	NPDES included in WLA, Major treatment plan upgrade underway to include CSO control
OH57 19	5.2	0	Little Painter Creek	Organic enrichment/DO	Livestock implementation plan
OH57 21	15.2	0	Greenville Creek	Organic enrichment/DO Nutrients	Septic implementation plan
OH57 24	3.5	0	Bolton Run	Organic enrichment/DO	Erroneously listed in 303(d) report, Bolton Run is in full attainment of its aquatic life use
OH57 25	7	0	Dividing Branch	Organic enrichment/DO Nutrients	Erroneously listed in 303(d) report, Dividing Branch is in full attainment of its aquatic life use
OH57 26	24.3	15.2	Greenville Creek	Other habitat alterations Organic enrichment/DO	NPDES included in WLA
OH57 29	2	0	Prairie Outlet	Organic enrichment/DO	Septic implementation plan
OH57 35	9.5	0	Dismal Creek	Organic enrichment/DO Other habitat alterations	NPDES included in WLA

Table 1.2. Continued.

WBID	URM	LRM	Segment Name	Causes	TMDL Component
OH57 37	45.88	32.4	Stillwater River	Nutrients	NPDES included in WLA; Livestock implementation plan
OH57 38	9.1	0	Harris Creek	Organic enrichment/DO	NPDES included in WLA, Major treatment plan upgrade underway to include CSO control
OH57 39	4.6	0	Ballinger Run	Other habitat alterations Organic enrichment/DO	NPDES included in WLA, Major treatment plan upgrade underway to include CSO control
OH57 41	13.8	0	Swamp Creek	Organic enrichment/DO Other habitat alterations Nutrients	Livestock and drainage and channelization implementation plans
OH57 42	5.2	0	Indian Creek	Nutrients Organic enrichment/DO Other habitat alterations	Livestock drainage and channelization, and septic implementation plans
OH57 43	57.97	45.88	Stillwater River	Nutrients	Livestock and drainage and channelization implementation plans
OH57 44	3.3	0	Boyd Creek	Organic enrichment/DO Other habitat alterations	Livestock and drainage and channelization implementation plans
OH57 45	67.64	57.97	Stillwater River	Other habitat alterations Organic enrichment/DO Nutrients	Livestock and drainage and channelization implementation plans
OH57	4.06	0	UNT to Stillwater	Other habitat alterations	Drainage and channelization implementation plan
OH57 46	7.7	0	North Fork	Organic enrichment/DO Other habitat alterations	Livestock and drainage and channelization implementation plans
OH57 48	7	0	South Fork	Other habitat alterations	Drainage and channelization implementation plan

2.0 Study Area Description

The Stillwater River flows 67 miles from its headwaters in Indiana and northern Darke County to a confluence with the Great Miami River in Dayton (Figure 2.1). The Stillwater River flows in a generally eastward direction through Darke County into western Miami County where it turns southward to Montgomery County. Major tributaries include: Greenville Creek, Ludlow Creek, Painter Creek, Swamp Creek and North Fork Stillwater River. The watershed covers approximately 673 square miles with about 32 square miles in Randolph County Indiana, and is drained by 280 miles of streams, but many of those stream miles have been physically modified to maintain drainage for row crop agriculture. Historically, almost one-third of the watershed may have been wetlands, but tile drainage and stream channelization have reduced this to one-half of one percent. Agriculture composes over 80 percent of the landuse, and Darke County has the second highest concentration of animal feeding operations (AFOs) in Ohio.

The topography of the Stillwater River watershed has been influenced by glaciation which left distinctive land forms and thick deposits of silt, sand, and gravel. This aquifer was designated as a Sole Source Aquifer by U.S. EPA. Designation requires extra review for any federally funded projects proposed for the surface above the aquifer. The watershed lies completely with in the Eastern Cornbelt Plains ecoregion which is characterized by level to gently sloping land and relatively low gradient streams. Most of the upland area is covered with a glacial drift of varying thicknesses over limestone bedrock**.** Downstream from the village of West Milton the valley narrows and deepens until reaching the Englewood Dam. The limestone bedrock is closer to the surface in this area and becomes the anchor for the dam at either end. This lower part of the river downstream from West Milton lies above a highly productive sand and gravel aquifer which is the water supply for three-fourths of the watershed's population of 66,266. Smaller pockets of sand and gravel aquifers are found in isolated areas of the watershed. These aquifers do not reflect current surface water flow patterns but are apparently part of an ancient river system known as the Teays River which was eliminated by glaciation. Soils tend to be poorly drained due to high clay content especially in the upland areas.

The concentration of livestock/poultry operations (218 in 1997) in the watershed produce more than 121,258 tons of solid manure annually. Based on the number of various animal types inventoried in the watershed, this waste produces about 2220 tons N/yr, 1665 tons P_2O_5/yr, and 1480 tons K_2O/yr, with a total annual value of $2.5 million. With a P_2O_5 application rate of 60 lbs./acre, nearly 150,000 acres are needed to utilize the yearly phosphorus production. Although twice this much cropland exists in the watershed, considerations of time of year, crop type, distance to streams and dwellings, availability of non-owned land for spreading, and hauling distance from the livestock/poultry facility, all combine to reduce the actual amount of useable acreage. The 121,258 tons, moreover, only accounts for the solid portion of the manure. When the liquid portion is added to the manure total, the figure increases to nearly 277,500 tons yearly. For the watershed as a whole, this amounts to 757 tons of manure per square mile, with individual drainage areas ranging from as little as 63 tons/mi^2 to more then 1250 tons/mile^2. This amounts to an average of about 222 gallons of manure per acre per year.

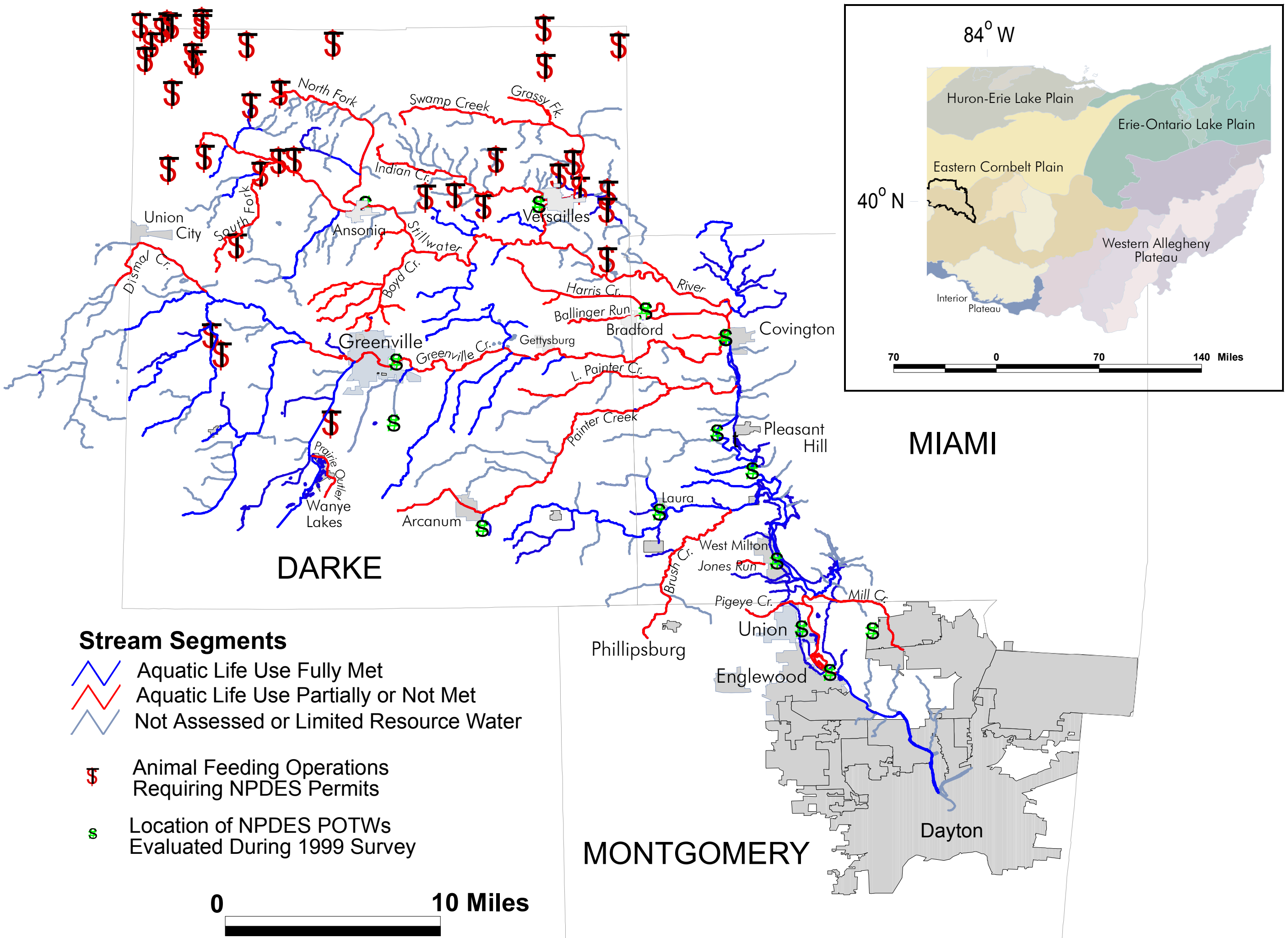


Figure 2.1. Geographic location of the Stillwater River watershed in Ohio, principal cities within the watershed, and waterbody segments with impaired aquatic life uses in relation to NPDES permitted facilities.

2.1 Water and Biological Quality Summaries

Biological and water quality conditions vary widely in the Stillwater River basin from the best of the best to the worst of the worst measured within Ohio (Table 2.1). The stream segments with the highest biological and water quality are the lower Stillwater River mainstem from Covington to the confluence with the Great Miami River, and Greenville Creek and its tributaries originating from the Farmersville Moraine. The reason the lower Stillwater River is in such good condition is because the riparian forest is intact, development within the adjacent flood plain is largely agricultural, and the agriculture practiced there employs conservation measures. The Stillwater River has the largest population of river redhorse in Ohio. River redhorse are listed as Special Interest on the Ohio Division of Wildlife Endangered Species list because of their comparative rarity and declining abundance in Ohio. Water quality and reasonably intact biological communities are maintained in Greenville Creek and its tributaries by groundwater-augmented baseflow.

The stream segments having the poorest water quality and the most degraded biological communities are, in order of severity of impairment, Painter Creek, the North Fork Stillwater, Swamp Creek, Indian Creek, the Stillwater River mainstem upstream from Ansonia, Ballinger Run, and Mill Creek. Painter Creek is degraded by Arcanum's failed sewage collection and treatment system. Swamp Creek, the North Fork Stillwater and the Stillwater mainstem are impacted by habitat destruction and organic enrichment from land-applied manure, Indian Creek from the preceding factors plus failing septic systems, Ballinger Run by organic enrichment from combined sewer overflows (CSOs), and Mill Creek from deicing chemicals used at the Dayton-Cox International Airport.

The most pervasive problem facing streams in the basin is habitat destruction through channelization. Almost the entire stream network in Darke County has previously been channelized. Channelization is the removal of trees from stream banks coupled with deepening, and often straightening, the stream course. Channelization always results in long-term aquatic life use impairment, especially for sport fishing, is a direct cause of sedimentation, and greatly magnifies the effects of introduced nutrients. This latter problem is especially troublesome in the northern portion of the basin where large amounts of manure are applied to the land. Because the streams are maintained in a channelized state with little or no riparian buffer, organic matter and nutrients are able to enter unimpeded during storm events. The absence of a shading riparian canopy allows full sunlight to reach the stream and cause algal blooms. The algal blooms then result, either through decomposition or respiration, in dissolved oxygen depletion to below levels needed to sustain higher aquatic life. Further complicating matters is the loss or diminution of sustained stream flow in channelized headwaters, especially those less than 10 mi^2, as the whole point of channelization is to expedite drainage. The upshot being, from a pollution loadings standpoint, that less flow for a given drainage area means less assimilative capacity.

The other pervasive problem facing the basin, as mentioned in the previous paragraph, is organic enrichment. Organic enrichment in the Stillwater basin comes primarily from land-applied animal manure and failing septic systems. That organic enrichment is a problem in the basin was evidenced by biological and water quality results (*e.g.*, high fecal coliform bacteria and *E. coli* counts, high biochemical oxygen demand, wide diel oxygen swings, poor to very poor

biological scores, and fish kills occurring in streams with sustained flow). Although channelized streams are expected to have less biological and water quality integrity compared to natural streams, channelized streams are expected to be free from nuisance conditions (*e.g.*, mats of decaying algae), safe for recreational contact (*i.e.*, fecal matter should not be present), and should have sufficient water quality to harbor aquatic life. Swamp Creek and its tributaries, the North Fork, and the Stillwater River upstream from Ansonia were similarly impacted from excess organic enrichment from land-applied manure. Failing septic systems caused noticeable water quality impacts and biological impairment in Indian Creek, Greenville Creek downstream from Gettysburg, the Wayne Lakes area, and to Ludlow Creek or its tributaries near Phillipsburg and Pittsburgh.

The existing problems should not, however, overshadow successes. Most of the point source problems along the Stillwater mainstem have been abated and considerable recovery has occurred since 1982 (Figure 2). The existing threat from point sources is now population growth over-running treatment capacity (Table 1.4). Several treatment plants are now approaching their design capacity and so occasionally have flows exceeding treatment ability.

The other area of success has been in the implementation of agricultural best management practices. Conversion of farmed acres to no-till, filter strips, and conservation easements have collectively resulted in improved biological communities for the entire Stillwater mainstem downstream from Ansonia.

2.2 Individual Waterbody Summaries

Stillwater River

Approximately sixty-six miles of the Stillwater River were assessed for the status of aquatic life uses and attainability of those uses. The Stillwater River is designated Warmwater Habitat (WWH) from its headwaters to Biesner Road (RM 57.0), and Exceptional Warmwater Habitat (EWH) from Biesner Road to the confluence with the Great Miami River. The WWH designation is not attainable upstream from Woodington Run/Ansonia (RM 61.8) as the river there is under active channel maintenance. Therefore, the appropriate and attainable aquatic life use designation is Modified Warmwater Habitat (MWH). The WWH designated segment should be extended downstream to Shroeder Road (RM 52.0) as the stream between RMs 57 and 52 has been previously channelized and has not recovered enough warmwater habitat attributes, either over time or due to proximity to the actively maintained headwaters, to make EWH a realistic use. Based on these adjusted use recommendations, the attainment status for the sixty-six miles of Stillwater River mainstem are 3.3 miles not attaining, 8.2 miles partially attaining and 55.0 miles fully attaining aquatic life uses. Aquatic life use impairment in the headwaters upstream from Ansonia is being caused by organic enrichment from land applied manure combined with poor habitat. Impairment downstream from Ansonia is being caused by a combination of organic and nutrient enrichment from CSOs (Ansonia), wastewater loadings (Ansonia and Versailles) and manure (North Fork and Swamp Creek), and by the downstream footprint resulting from keeping the headwaters maintained in a channelized state. A small reach of partial attainment also exists in and downstream from the Englewood dam pool. The impairment in the dam pool is caused by nutrient enrichment and siltation. The impairment downstream is due to a combination of being immediately downstream from the Englewood dam and wastewater loadings from the treatment plant.

Greenville Creek
The entire thirty-four miles of Greenville Creek in Ohio are designated Exceptional Warmwater Habitat. That use designation is appropriate for all segments except for the reach flowing through Greenville, which has been channelized and is maintained *de facto* by hard urban surfaces. The appropriate aquatic life use designation for this reach, based on demonstrated biological performance and habitat quality is Warmwater Habitat. Adjusting for this recommendation, 11.1 miles fully attain, 20.2 miles partially attain, and 3.2 miles do not attain aquatic life uses. The single most important factor responsible for impairing the aquatic life uses in Greenville Creek is habitat degradation. Portions of the creek upstream from Greenville have been recently channelized to accommodate development, most of the tributaries have been channelized and consequently are a source of sediment, and as previously mentioned, the creek in and downstream from Greenville has been altered. The collective effect of all this contributes to the impairment immediately downstream from the Greenville WWTP. Organic and nutrient enrichment from the Greenville WWTP and, more importantly, onsite sewage disposal (septic tanks) is the primary cause of impairment further downstream from Greenville.

Mill Creek
Mill Creek is designated WWH. This use was fully met in the lower 0.5 miles of the creek, and not met in the remaining 2.1 miles assessed. The biological communities remain impaired by releases of deicing chemicals used at the Cox-Dayton International Airport.

Ludlow Creek
Ludlow Creek is designated WWH. That designation is appropriate except for the channelized and actively maintained headwaters where a Modified Warmwater Habitat (MWH) designation is appropriate. When MWH is considered for the headwaters upstream from the Darke County line, the aquatic life uses are fully met.

Brush Creek
Brush Creek is designated WWH. That use designation was not met at RM 7.1 due to organic enrichment, presumably from on-site sewage disposal. The impact at RM 7.1 was likely exacerbated by the drought. The site sampled at RM 0.4 fully met WWH.

Painter Creek
Painter Creek has an unconfirmed EWH use designation from its confluence with the Stillwater River to the Darke County line (RM 5.5), and a MWH designation upstream from there. The EWH use has not been demonstrated; therefore, the appropriate aquatic life use is WWH. Given these designations, of the approximately eighteen miles assessed, 1.5 miles were in full attainment, 8.0 miles did not attain, and 5.5 miles partially attained their respective aquatic life use designations. The eight mile reach of non-attainment was caused by gross organic enrichment from the failing sewage collection and treatment system in Arcanum.

Harris Run and Ballinger Run
Harris Run and Ballinger Run are both designated WWH, and that designation has been confirmed for the portion of both streams in Miami County. However, both streams are actively maintained for drainage in Darke County where a MWH use designation is appropriate. The RM at the Darke-Miami county line for Harris Run is 5.2, and 1.7 for Ballinger Run. So designated, there were 4.2 miles of partial attainment and 1.0 mile of full attainment in Harris Run, and 3.0

miles of non-attainment in Ballinger Run. Bradford CSOs continued to be the main source of impairment to both Ballinger Run and Harris Creek.

Trotters Creek and Tributaries
Trotters Creek has an unconfirmed WWH aquatic life use designation. The fish and macroinvertebrate community downstream from Rike Road (RM 1.7) met expectations for EWH and should be so designated. Upstream from Rike Road, WWH is the appropriate aquatic life use.

Of the tributaries to Trotters Creek assessed, a WWH aquatic life use is appropriate for Sigmon Ditch and Bennett Ditch. Orr Ditch, Apple Ditch and Rudy Ditch should be resampled during a non-drought year to be properly designated as the macroinvertebrate samples were collected during the height of the drought.

Swamp Creek and Tributaries
Swamp Creek is designated MWH upstream from RM 6.5, and WWH downstream from that point. Of the 12.1 miles assessed, 5.6 miles fully attained, 4.2 miles partially attained, and 2.3 miles did not attain their respective use designations. The main cause of impairment was organic and nutrient enrichment, with conditions being so enriched as to result in critically low dissolved oxygen concentrations and fish kills. The source of the organic and nutrient enrichment is land applied manure.

Indian Creek is similarly impaired by organic and nutrient enrichment, but failing septic systems are an additional source of enrichment. Indian Creek is designated WWH and that designation has been confirmed for the lower 1.9 miles (Conover Road) of stream. Upstream, the creek is an actively maintained drainage ditch and therefore should be designated MWH. So designated, 4.1 miles - the entire assessed portion being proposed for MWH - were not attaining, and the lower 2.0 miles were partially attaining the WWH aquatic life use designation.

The tributary to Swamp Creek at RM 3.54 is actively maintained for drainage and should be designated as MWH. So designated, the 1.0 mile reach assessed was meeting its aquatic life use.

Grassy Fork is a maintained ditch and should be designated MWH. The MWH aquatic life use was not met due to drought related stresses.

Boyd Creek and Tributaries
The entire Boyd Creek drainage network is a series of maintained drainage ditches that should be designated MWH. Based on the MWH aquatic life use, Boyd Creek fully attained at RM 0.8, and partially attained at RM 3.5. The two tributaries to Boyd Creek (confluences at RM 2.46 and 2.67) did not attain due to very poor qualitative macroinvertebrate scores. The macroinvertebrate community from the tributary at RM 2.46 may have been limited by the drought, but the tributary at RM 2.67 was impaired by organic enrichment, most likely from failing onsite sewage disposal. On-site disposal was also the reason for partial attainment in Boyd Creek.

North Fork Stillwater River and Sycamore Ditch
The North Fork is appropriately designated MWH. All eleven miles evaluated did not attain the

MWH aquatic life use due to organic and nutrient enrichment from land-applied manure. Sycamore Ditch met MWH.

Woodington Run

Biological communities in Woodington Run met expectations for WWH at RM 4.9 and partially met expectations at RM 1.1. The limiting component at RM 1.1 was the bug community, which was evaluated as "fair" because of effects from nutrient enrichment. Because the fish community met WWH at both sites, the physical stream habitat has recovered some function since being channelized, and because the macroinvertebrate community was impaired beyond simply the effects of habitat, a WWH aquatic life use is recommended for Woodington Run.

South Fork Stillwater River

Biological communities in the South Fork met expectations for WWH at RM 0.4, did not meet based on one qualitative bug sample at RM 1.3, and partially met expectations at RM 3.0. Habitat function was admittedly worse than that for Woodington Run, but as the fish community met WWH, and the fish community is generally the more limiting component when habitat is the issue, a WWH aquatic life use is recommended for the South Fork.

Other Tributaries

Numerous other nameless and undesignated tributaries were assessed to determine the appropriate aquatic life use designation, more than can be conveniently discussed in the prior format; refer to Tables 1 and 3 for those recommendations. The rational for assigning a designation in all cases was based on demonstrated biological performance unconfounded by water quality impacts, or potential biological performance based on habitat quality in the absences of a direct water quality problem where such a problem existed.

Table 2.1. Aquatic life use attainment status for stations sampled in the Stillwater River basin July-September, 1999. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Stillwater River (14-200) *WWH/MWH proposed*						
65.8	30	NA	MG	31	Partial/Full	
65.0	18^{*}	NA	F	31	NON/NON	Organic enrichment - AFOs
63.8	40	NA	MG	37	Full/Full	
63.0	34	5.3^{*}	F*	38	NON/NON	Organic enrichment - AFOs.
61.1/61.8	25	7.0	30	34	NON/Full	
WWH						
60.2	-	-	38		(Full)	
58.8	30^{*}	7.8^{ns}	32^{ns}	43	Partial	Organic enrichment - CSOs
58.1	38	9.0	-	47	Full	
57.9	37^{ns}	8.3	MG^{ns}	48	Full	
57.0	-	-	34^{ns}	-	(Full)	
EWH /WWH Proposed						
54.4	43	7.8^{ns}	-	44	NON/Full	
EWH						
52.0/51.2	46^{ns}	9.0^{ns}	44^{ns}	73	Full	
47.8	48	9.6	38^{*}	74	Partial	Sedimentation and nutrient enrichment
44.1	47	10.2	42^{ns}	73	Full	
41.4	50	9.2^{ns}	36^{*}	75	Partial	Sedimentation and nutrient enrichment
37.7	51	9.3^{ns}	44^{ns}	82	Full	
33.5	-	-	48		(Full)	
32.1	54	10.1	52	81	Full	
27.9	58	9.9	E	81	Full	
25.1	59	10.4	46	86	Full	
22.8/21.2	58	9.7	48	73	Full	
18.0	57	9.8	E	75	Full	
16.0	59	10.1	44^{ns}	81	Full	
11.4	52	9.8	48	77	Full	
8.9	28^{*}	7.5	--	52	Partial	Hydromodification - impoundment
8.8	--	--	40^{*}	--	(NON)	Hydromodification, organic enrichment
8.6	53	10.3	MG^{*}	88	Partial	Hydromodification, organic enrichment
5.0	59	10.5	46	86	Full	
1.2	55	10.5	46	86	Full	

Table 2.1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Pigeye Creek 14-201 WWH						
0.6	36^{ns}	NA	F^{*}	36	Partial	Organic enriched - septic/livestock
Mill Creek 14-202 WWH						
2.6	22^{*}	NA	F^{*}	47	NON	Toxics (deicers) - Dayton Airport
1.2	26^{*}	NA	G	57	NON	Toxics (deicers) - Dayton Airport
0.3	44	NA	52	50	Full	
Brush Creek 14-203 EWH/WWH - Proposed						
0.1	41	NA	G	63	Full	
Jones Run 14-204 WWH						
0.4	28^{*}	NA	G	57	Partial	Organic enrichment, sewer line leak
Rocky Run (14-205) WWH						
0.5	-	-	G	-	Full	
Opossum Run 14-206 WWH - EWH proposed						
0.8	46^{ns}	NA	E	70	Full	
Painter Creek 14-208 MWH						
16.9/17.9	28	NA	F	28	Full	
16.2/15.5	16^{*}	NA	10^{*}	32	NON	Organic enrichment - CSOs.
14.7	12^{*}	NA	4^{*}	28	NON	Toxics (NH_4) - CSOs & sewage lagoon
9.7/8.9	24	5.6^{*}	26	41	NON	Organic enrichment - CSOs
			EWH /WWH - proposed			
3.4/4.4	33^{*}	6.8^{*}	G	78	NON/Partial	Organic enrichment - CSOs
0.7/1.1	33^{*}	6.3^{*}	44	63	NON/Partial	Organic enrichment - CSOs
Little Painter Creek 14-209 MWH - proposed						
0.4	34	NA	F*	44	Partial	Organic enrichment - livestock
Ludlow Creek 14-210 MWH - Proposed						
12.6	34	NA	MG	51	Full	
				WWH		
6.4	36^{ns}	7.9^{ns}	VG	60	Full	
3.5	44	8.1^{ns}	VG	77	Full	
2.9	42	8.1^{ns}	-	78	Full	
2.3	40	7.9^{ns}	40	76	Full	

Table 2.1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Brush Creek 14-211 WWH						
7.1	38[ns]	NA	VP[*]	41	NON	Organic enrichment - on-site sewerage
0.4	40	NA	VG	76	Full	
Hog Run 14-213 WWH						
0.2	48	NA	MG	70	Full	
Baker Ditch LRW - Proposed						
0.6	-	-	VP	-	NON	Dry ditch
Feitshams Ditch LRW - Proposed						
0.6	-	-	F	-	Full	
Brown Ditch LRW - Proposed						
0.4	-	-	F	-	Full	
Heller Ditch 14-217 MWH - proposed						
0.1	26	NA	MG	43	Full	
Harris Run 14-218 WWH						
3.8/5.2	35[*]	NA	44	31	Partial	Sedimentation
2.0	30[*]	NA	G	58	Partial	Organic enrichment - CSOs
0.9	42	NA	38	73	Full	
Ballinger Run 14-219 MWH - proposed						
2.8	20[*]	NA	-	30	(NON)	
				WWH		
1.4	25[*]	NA	0[*]	57	NON	Organic enrichment, toxics - CSOs
0.6	34[*]	NA	32[ns]	62	Partial	Organic enrichment - CSOs
Greenville Creek 14-220 EWH -						
33.0/34.3	52	NA	58	76	Full	
30.2	48[ns]	9.1[ns]	42[ns]	61	Full	
28.9	45[*]	8.4[*]	50	49	Partial	Hydromodification - channelization
26.5	48[ns]	7.9[*]	46	57	Partial	Hydromodification - channelization
24.6	50	8.5[*]	50	72	Partial	Hydromodification - channelization

Table 2.1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Greenville Creek - Continued EWH - /WWH-proposed						
23.2/22.6	37[ns]	8.2[ns]	-	49	NON/Full	Hydromodification - Impounded
21.7/22.3	47	8.5	42	72	Partial/Full	
19.6	39[ns]	7.5*	34[ns]	45	NON/Partial	Hydromod. - urban, org. enrich.
19.3	*34*	*7.4*	*F*	-		
19.2	-	-	30*	-	(NON)/(NON)	Hydromod., org. enrich. - sewer line
18.3	36[ns]	7.2*	F*	53	NON/Partial	Hydromod, org. enrich., WWTP
				EWH -		
16.2	37*	8.6*	54	71	Partial	organic enrichment - WWTP
13.7	46[ns]	9.6	E	81	Full	
10.8	48[ns]	8.9*	50	86	Partial	Organic enrichment - on-site sewerage
6.1	46[ns]	9.1[ns]	44[ns]	84	Full	
3.7	38*	8.2*	-	75	NON	Organic enrichment - on-site sewerage
1.4	55	10.5	46	76	Full	
0.1	-	-	50	-	(Full)	
McQuay Ditch 14-221 WWH						
1.6/0.5	36[ns]	NA	VG	56	Full	
Poplar Ditch 14-222 WWH						
0.6	52	NA	G	61	Full	
Bolton Run 14-223 WWH						
0.6	50	NA	MG	45	Full	
Dividing Branch 14-224 WWH						
0.4	-	-	VG	-	Full	
2.4/3.1	48	NA	MG	41	Full	
Bridge Creek 14-225 WWH Existing						
1.4/0.2	38[ns]	NA	54	39	Full	
Mud Creek 14-226 WWH						
6.1	54	NA	40	58	Full	
4.7	51	NA	58	46	Full	
2.1/0.1	42	NA	54	35	Full	

Table 2.1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Prairie Outlet 14-227 WWH						
0.8	36^{ns}	NA	28^{*}	40	Partial	Organic enrich. - on site sewerage
W. Br. Greenville Cr 14-228 WWH						
10.2/10.7	42	NA	F^{*}	37	Partial	Hydromodification
7.4	52	NA	G	43	Full	
5.3/5.8	56	NA	G	50	Full	
0.3	44	9.1	G	78	Full	
Spring Branch 14-229 WWH						
0.3	48	NA	MG	57	Full	
Kraut Creek 14-230 WWH						
5.9	54	NA	E	62	Full	
4.4	50	NA	-	52	Full	
0.6	42	8.8	VG	70	Full	
N. Fk. Kraut Creek 14-231 WWH						
2.1	42	NA	E	69	Full	
0.8	46	NA	G	56	Full	
Dismal Creek 14-232 WWH						
3.8/4.7	27^{*}	NA	42	44	NON	Hydromodification
2.2/1.8	35^{*}	NA	MG	53	Partial	Org. enrich. - land application
0.1	36^{ns}	NA	36	48	Full	
Trotters Creek 14-234 WWH						
0.3/0.9	48	9.4	VG	74	Full	
Swamp Creek 14-235 MWH						
12.1	-	-	F	-	(Full)	
8.9	27	NA	28	33	Full	
6.5	17^{*}	4.8^{*}	30	35	NON	Organic enrichment - AFOs
				WWH		
4.5	32^{*}	6.5^{*}	G	42	Partial	Organic enrichment - AFOs
2.9	27^{*}	7.2^{*}	42	40	Partial	Organic enrichment - AFOs; hydromod
2.3	34^{*}	7.1^{*}	26^{*}	34	NON	Organic enrichment - AFOs; hydromod
2.0/1.6	32^{*}	6.4^{*}	34^{ns}	43	Partial	Organic enrichment - AFOs; hydromod
0.3	42	6.7^{*}	42	49	Partial	Organic enrichment - AFOs; hydromod

Table 2.1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Indian Creek 14-236 MWH - proposed						
5.2/6.1	32	NA	P*	38	NON	Organic enrichment - AFOs; hydromod
3.1/2.0	20*	NA	32	30	NON	Organic enrichment - on-site sewerage
				WWH		
0.5	41	NA	F*	47	Partial	Organic enrichment - on-site sewerage
Boyd Creek 14-237 MWH - proposed						
3.5	34	NA	F*	45	Partial	
0.8	40	NA	F	55	Full	
N. Fk. Stillwater R. 14-238 MWH						
10.5	12*	NA	VP*	22	NON	Organic enrichment - AFOs
8.3	-	-	VP*	-	NON	Organic enrichment - AFOs
4.4	20*	NA	F	25	NON	Organic enrichment - AFOs
0.4	27	NA	12*	36	NON	Organic enrichment - AFOs
Woodington Run 14-239 WWH						
4.9	42	NA	G	52	Full	
1.1	44	NA	F*	51	Partial	Hydromod, enrichment
S. Fk. Stillwater R. 14-240 WWH						
5.5	36[ns]	NA	F*	30	Partial	Hydromod, enrichment
1.3	-	-	F*	-	(NON)	Hydromod, enrichment
0.4	38[ns]	NA	MG	40	Full	
Sycamore Ditch 14-241 MWH - proposed						
0.2	24	NA	F*	35	Full	
Trib. to Kraut Creek 14-245 WWH						
0.2	46	NA	F*	55	Partial	Unkown
Trib. to Ludlow Cr. 14-247 MWH - proposed						
0.4	26	NA	MG	42	Full	

Table 2.1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Trib Stillwater 32.6 14-250 WWH - proposed						
0.6	34*	NA	G	64	Partial	Organic enrichment - on-site sewerage
Bitch Run (trib to Mud Creek @ RM 2.1) 14-251 WWH - proposed						
0.1	42	NA	-	51	(Full)	
Lake Branch Ditch 14-252 WWH						
4.1	46	NA	P*	30	NON	Organic enrichment - on-site sewerage
0.7	54	NA	54	56	Full	
Trib. to Harris C. 14-253 WWH - proposed						
0.2	34*	NA	VP*	44	NON	Unkown
Sigmon Ditch 14-254 WWH - proposed						
1.2	40	NA	G	56	Full	
Bennett Ditch 14-256 WWH - proposed						
0.6	42	NA	P*	56	NON	Organic enrichment - livestock
Trib. to Swamp Creek 14-259 MWH - proposed						
0.6	28	NA	24	37	Full	
Grassy Fork 14-260 MWH - proposed						
0.9	-	-	P*	-	(NON)	Drought & habitat
Trib. to Stillwater @ RM 38.3 14-261 WWH - proposed						
0.7	28*	NA	P*	71	NON	Organic enrichment - livestock
Trib Stillwater 51.0 14-262 WWH - proposed						
1.3	42	NA	G	54	Full	
2.2	-	-	F*	-	(Partial)	Hydromodification - channelization
Trib to trib to Stillwater 51.0/2.4 WWH - proposed						
0.3	44	NA	-	44	(Full)	
Trib. to Boyd (2.67) 14-264 MWH - proposed						
0.5	30	NA	VP*	26	NON	Hydromodification - channelization

Table 2.1.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Trib. to Boyd (2.46) 14-265 MWH - proposed						
1.2/1.7	30	NA	VP*	46	NON	Hydromodification - channelization
Trib to Stillwater 14-266 MWH - proposed						
0.4	-	-	F*	-	(NON)	Hydromodification - channelization
Trib Stillwater 55.4 14-267 MWH - proposed						
0.8	26	NA	P*	47	NON	Organic enrichment - on-site sewerage
Trib Stillwater 14-268 MWH - proposed						
0.3	-	-	F	-	(Full)	
Trib SF Stillwater 14-269 MWH - proposed						
1.6	32	NA	F*	29	Partial	Hydromodification - channelization
Trib Stillwater 64.9 14-270 MWH - proposed						
0.3	36	NA	-	42	(Full)	
1.1	30	NA	-	21	(Full)	

Index-Site Type	Biological Criteria Eastern Corn Belt Plains (ECBP) EWH	WWH	MWH
IBI-Headwaters	50	40	24
IBI-Wading	50	40	24
IBI-Boat	48	42	30
MIwb-Wading	9.4	8.3	6.2
MIwb-Boat	9.6	8.5	6.6
ICI	46	36	22

a The Modified Index of Well-being is not applicable (NA) to headwater site types.

b A qualitative narrative evaluation used when quantitative data were not available or unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates (P = Poor, F = Fair, MG = Marginally Good, G = Good, VG = Very Good, E = Exceptional).

c Use attainment status based on one organism group is parenthetically expressed.

A Boat sampling method

D Wading method

* Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

ns Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).

d Modified Warmwater Habitat criteria for channel modified habitats.

Table 1.4. Summary of performance and impacts to receiving waters for NPDES dischargers evaluated in the 1999 survey of the Stillwater River Basin

NPDES Discharger	Flow (mgd) Design /Median/ 95th	Toxicity Bioassay /Biosample	Receiving Water Impairment
Ansonia (1PB00005)	0.35/0.12/0.27	NA/ND	Slight from CSOs
Arcanum (1PB00000)	0.40/0.36/0.94	Acute/Acute	Extreme from CSOs and WWTP
Bradford (1PB00008)	0.24/0.21/0.38	NA/Acute (CSOs)	Severe from CSOs; moderate organic enrichment from WWTP
Covington (1PB00013)	0.75/0.29/0.51	None/ND	None
Englewood (1PD00001)	2.50/1.31/3.14	Acute and chronic/ND	Slight due to organic enrichment
Greenville (1PD00005)	3.50/2.14/3.24	None/ND	Slight due to organic enrichment
Pleasant Hill (1PB00026)	0.20/0.10/0.16	NA/ND	None
Union (1PB00030)	1.00/0.58/1.19	Acute/ND	None
Versailles (1PB00033)	0.38/0.28/0.53	NA/ND	Slight impact to Stillwater due to organic enrichment
West Milton (1PC00011)	1.20/0.6*/1.6*	None/ND	Minimal - small decrease in macroinvertebrate scores

* 1999 data were not available for West Milton.

3.0 Problem Statement

The Stillwater River basin (USGS Catalogue Number 05080001) is located in the Eastern Cornbelt Plains of west-central Ohio (Figure 2.1). Agriculture, both row crop and livestock production, dominates the landscape, and in so doing is responsible for most of the miles of stream impairment. Much of the stream network has been modified and is maintained in a modifide state to facilitate rapid drainage for rowcrop production; consequently, habitat alterations are a major cause of impairment. Manure from concentrated animal feeding operations (CAFOs) is applied to fields within the watershed. Direct runoff of manure to the streams and leaching of manure through the tile networks results in organic and nutrient enrichment as another major cause of impairment. Because the stream network is maintained for drainage, little or no riparian buffer exists on most headwater streams to filter errant manure.

Agriculture is not the only source of impairment, various stream segments in the Stillwater River basin are not meeting water quality standards for aquatic life use due to municipal point sources or onsite wastewater systems. The specific stream segments appearing either on the most recent §303(d) list or recently identified as not fully meeting aquatic life uses, their respective waterbody identification numbers, segment length, aquatic life use status, and causes and sources of impairment are listed Table 1.1. The geographic locations and place names of the stream segments and their proximity to sources of pollution are shown in Figure 2.1. For more detailed information on sources and locations of pollution in the Stillwater River basin please refer to Ohio EPA (2001). Based on results of a 1999 intensive water and biological quality survey of the Stillwater River Basin (Ohio EPA 2001), the following stream segments currently appearing on the §303(d) list are now fully meeting their aquatic life uses:

Stillwater River (Greenville Creek to Ludlow Creek; OH57 37);
Greenville Creek (Headwaters to West Branch Greenville Creek OH57 32);
Mud Creek (OH57 28).

For the remaining segments and those newly identified, regardless of the source, two causes organic enrichment and habitat alteration, ultimately effect most of the impairment. Other causes listed are, in most cases, secondary consequeces of the primary causes. For example, nutrient enrichment often co-occurs with organic enrichment as organic matter is often high in nutrient content and those nutrients are remineralized through microbial decomposition. Habitat alterations, specifically channelization to promote agricultural drainage, exacerbates deleterious effects from nutrient enrichment through loss of shading, filtration, the stream channel-flood plain connection, homogenization of stream substrates, and decreased nutrient spiral length (Newbold et al. 1983). Similarly, habitat alteration promotes siltation. Because the various causes listed are interrelated and occur on a watershed scale, the TMDL for the Stillwater River basin is not pollutant specific *per se*, although segment specific causes, sources and loads are addressed in this report, rather it is the watershed scale approach *in toto* to acheive restoration of aquatic life uses. It encompasses broadly prescriptive agricultural best management practices (BMPs), farm-specific BMPs, county-wide efforts to address failing on-site sewage disposal, suburban stormwater control, adoption of objective criteria for agricultural drainage maintenence (*i.e.*, hydromodification), and upgrades to publicly owned sewage collection and treatment systems.

3.1 Applicable Water Quality Standards and Water Quality Numeric Targets

Ohio Water Quality Standards: Designated Aquatic Life Uses
The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria protective of those uses, and an anitdegradation policy as outlined in OAC 3745-1-05. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses.

The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target for the majority of water resource management efforts in Ohio.*

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.*

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned and permitted by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 $mi.^2$ drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical, and biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations

employed in the Ohio WQS constitutes a tiered approach of graduated levels of protection. This hierarchy is especially apparent for parameters such as dissolved oxygen, NH_3-N, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses
In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliforms, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health are detailed in other documents.

The determination of use attainment status and assignment of probable causes and sources of impairment are the underpinnings of this TMDL. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al*. 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment to stream segments appearing on the §303d list represent the association of impairments (as judge by aquatic life use status) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function.

The establishment of instream numeric targets is a significant component of the TMDL process. The numeric targets serve as a measure of comparison between observed instream conditions

and conditions that are expected to restore the designated uses of the segment. The TMDL identifies the load reductions and other actions that are necessary to meet the target, thus resulting in the attainment of applicable water quality standards, ultimately judge by attainment of designated aquatic life uses.

Biocriteria

Full restoration of aquatic life uses is the stated goal of this TMDL, and numeric biocriteria are used to judge attainment of aquatic life use designations. After the control strategies have been implemented, biological measures including the IBI, ICI, QHEI and MIwb will be used to validate biological improvement and biocriteria attainment. The current attainment of the biocriteria along with the applicable standards is listed in Section 2.2, Table 2.1.

Organic Enrichment

Organic enrichment is not explicitly listed in Ohio water quality standards, but falls under the general water quality criteria of Ohio Administrative Code (OAC) 3745-1-04 applicable to all waters of the state, wherein, to every extent practical and possible as determined by the director, these waters shall be:

> (A) Free from suspended solids or other substances that enter the waters as a result of human activity and that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life;
>
> (C) Free from materials entering the waters as a result of human activity producing color, odor or other conditions in such a degree as to create a nuisance;
>
> (D) Free from substances entering the waters as a result of human activity in concentrations that are toxic or harmful to human, animal or aquatic life and/or are rapidly lethal in the mixing zone;
>
> (E) Free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae;
>
> (F) Free from public health nuisances associated with raw or poorly treated sewage.

Dissolved Oxygen

Apart from nuisance conditions, organic enrichment also results in dissolved oxygen concentrations insufficient to support aquatic life uses. One measurable endpoint of this TMDL is to attain the D.O. water quality criterion at all times including summer, low flow critical conditions. The D.O. criteria for the Warmwater Habitat segments is a 5.0 mg/l average over a 24-hour period and a 4.0 mg/l minimum. For the Exceptional Warmwater Habitat segments the criteria is a 6.0 mg/l average over a 24-hour period and a 5.0 mg/l minimum.

Ammonia-N

Ammonium ions are another by-product of organic enrichment and are toxic to aquatic life. Water quality standards for ammonia nitrogen are based on aquatic life use designation, pH and temperature. The standards are tabularized and can be found in OAC 3745-1-07, Tables 7-2 through 7-8.

Sedimentation and Habitat
Habitat alteration and siltation were identified as causes of impairment. OAC 3745-1-04 states that all waters of the state shall be free from suspended solids and other substances that enter the waters as a result of human activity and that will settle to form objectionable sludge deposits, or that will adversely effect aquatic life. However, no statewide numeric criteria have been developed specifically for sediment, TSS or habitat. Instead, target Qualitative Habitat Evaluation Index (QHEI) scores, based on reference data sites for some of the aquatic life use designations, can be used as surrogates. The QHEI measures several or more aspects of six physical habitat variables. The variables are: substrate, instream cover, riparian characteristics, channel characteristics, pool/riffle quality, and gradient and drainage area. The habitat attributes derived from the QHEI can be used to assess overall potential to support aquatic life, and which attributes are potentially the most limiting, and so, provide narrative targets for restoration (see Ohio EPA 1999).

Nutrients
Numeric targets are derived directly or indirectly from state narrative or numeric water quality standards (OAC 3745-1). In Ohio, applicable biocriteria are appropriate numeric targets (see Table 2.1). Determinations of current use attainment are based on a comparison of a stream's biological scores to the appropriate criteria, just as the success of any implementation actions resulting from the TMDLs will be evaluated by observed improvements in biological scores.

Ohio EPA currently does not have statewide numeric criteria for nutrients but potential targets have been identified in a technical report entitled *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (OEPA, 1999). This document provides the results of a study analyzing the effects of nutrients on the aquatic assemblages of Ohio streams and rivers. The study reaches a number of conclusions and stresses the importance of habitat and other factors, in addition to instream nutrient concentrations, as having an impact on the health of biologic communities. The study also includes proposed targets for nitrate+nitrite concentrations and total phosphorus concentrations based on observed concentrations at reference sites. Reference sites are relatively unimpacted sites that are used to define the expected or potential biological community within an ecoregion. The total phosphorus targets are shown in Table 5. It is important to note that these nutrient targets are not codified in Ohio's water quality standards; therefore, there is a certain degree of flexibility as to how they can be used in a TMDL setting.

Ohio's standards also include narrative criteria which limits the quantity of nutrients which may enter waters. Specifically, OAC 3745-1-04 states that all waters of the state shall be free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae, and shall be free from floating debris, oil, scum and other floating materials entering the waters as a result of human activity in amounts sufficient to be unsightly or cause degradation.

3.2 Pollutant Assessment

Ohio EPA (2001) provides a detailed source inventory of both pollutants and pollution. See Figure 2.1 for an overview of signficant point source locations.

3.3 Linkage Analysis

Rationale for the numerical targets appearing in Table 5 are as follows:

Biological index scores - Invertebrate Community Index (ICI), and Index of Biotic Integrity (IBI). Numeric standards for biological communities in Ohio streams are codified in OAC 3745-1-07, Table 7-17. Numeric scores by which stream communities are judged and compared to water quality standards are given by multimetric biological indexes. The Invertebrate Community Index (ICI) is used to measure stream macroinvertebrate communities, and the Index of Biotic Integrity for fish communities. The use of multimetric indexes is well accepted and widely employed (Karr 1981, Leonard and Orth 1986, Fausch et al.1984, Yoder and Smith 1995, Deshon 1995, Davis and Simon 1995).

Ammonia-nitrogen. Ammonia-nitrogen is given as a target value for the prevention of acute and chronic toxicity. The relationship between temperature, pH and ammonia toxicity is so well documented as to be codified into state law OAC 3745-1-07, Tables 7-3 through 7-8. Rationale for stratification by aquatic life uses is given in Ohio EPA (1997).

Dissolved oxygen. Target values for dissolved oxygen are the minimum concentrations, both instantaneous and average, needed to support a given aquatic life use. As with ammonia-nitrogen, the relationship between the target value and response indicator (*i.e.*, biological communities) is so well demonstrated as to be codified in to state law; OAC 3745-1-07, Table 7-1. Rationale for stratification by aquatic life uses is given in Ohio EPA (1995).

Fecal coliforms. The target values and measured values listed in Table 5 are used as indicators only to help identify sites where organic enrichment is the primary cause of aquatic life use impairment. The water quality standard and attendant rationale for fecal coliform applies to human health.

Total Kjeldahl Nitrogen (TKN). Target values for TKN are derived from Ohio EPA (1999) and simply approximate the upper bounds (*i.e.*, 90th percentiles) from a population of referecence sites. TKN is not associated with biological index scores, however, TKN is linearly related to ammonia-nitrogen and biochemical oxygen demand, and so is used here simply as an indicator of organic enrichment.

Nutrient parameters (NOx-N, TP) - Target values for nutrient parameters are based on Ohio EPA (1999), and Miltner and Rankin (1998). In brief, Ohio EPA (1999) lists percentile ranges of common water quality and chemistry parameters for mimimally impacted reference sites stratified by ecoregion and stream size. Ohio EPA (1999) also lists percentile ranges of those same paremeters measured in streams throughout Ohio with corresponding measured aquatic communities with narrative ranges of excellent, good, fair and poor. Miltner and Rankin (1998) demonstrated a signficant association between nutrient concentrations and biological index scores and provided thresholds values for TP and NOx-N corresponding to designated aquatic life uses. For either approach, percentile range or statistical association, significant variability exists between causal and response variables. In the case of the percentile approach, median and 90th percentile values for TP and NOx-N vary by an order of magnitude at reference sites, and excellent aquatic communities are frequently measured (25% of samples) at sites having nutrient

concentrations exceeding the 90th percentile reference site concentrations. And nutrients accounted for, at best, 16% of the variation in biological index scores in Miltner and Rankin (1998). The large variation between causal and response variables does not obviate any relationship which may exist, or imply that any relationship for any given stream is necessarily weak. Rather, the variablilty is simiply a manifestation of the number of biotic and abiotic factors controling biological communities in streams. Chief among those factors, and one that can be anthropogenically influenced, is habitat.

Habitat - Ohio EPA uses the Qualitative Habitat Evaluation Index (QHEI; as detailed in Rankin 1995) to measure habitat quality in steams. Several habitat attributes measured by the QHEI are strongly correlated with poor biological community performance. Those attributes are collectively called High Influence Modified Attributes (HIMA) as the attributes are characteristic of hydromodification, primarilly channelization for agricultural drainage. Target values in Table T correspond to statistically significant relationships between QHEI scores and biological index scores, and statistically signficant thresholds for the number of HIMAs found in a given stream segment that will likely preclude biological communties from meeting a given aquatic life use designation (Ohio EPA 1999). These relationships are described in detail in Rankin (1995) and Ohio EPA 1999.

3.4 Source Identification

The major source of habitat destruction is stream channelization for agricultural drainage. The major sources of of oxygen demanding substances and nutrients during the critical low-flow period, in order of greatest contribution to aquatic life use impairment, is the land application of animal waste originating from animal feeding operations, municipal wastewater treatment plants, and on-site wastewater management (septic) systems.

Table 5. Numeric targets for biological, habitat and water quality parameters and measured values by stream segment for the Stillwater River, 1999. Where biological impairment exists, bold font denotes deviation from target value.

WBID River URM	LRM	ICI Min	IBI Min	QHEI[‡]	HIMA[a†]	Ammonia-N* Max[†]	Ammonia-N* Max[‡]	D.O. Min[†]	D.O. Min[‡]	TKN[‡b]	Fecal Col[‡◊]	NO_x-N[‡b]	TP[‡b]
MWH		22	24	45	≤3	7.3	1.2	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 45 Stillwater River (Headwaters to North Fork) MWH													
67.6	57.9	**16**	**18**	**36**	**4**	0.38	0.08	3.4	4.3	0.11	315	0.65	0.16
OH57 43 Stillwater River (North Fork to Swamp Creek) WWH													
57.9	45.8	**24**	**34**	61	1	0.29	0.11	4.3	**4.8**	0.23	506	0.69	**0.17**
OH57 37 Stillwater River (Swamp Creek to Greenville Creek) EWH													
45.8	32.4	42	46	77	0	0.11	0.06	6.0	6.4	0.32	480	0.52	0.37
OH57 14 Stillwater River (Greenville Cr. To Ludlow Cr.) EWH													
32.4	21.0	**40**	50	81	0	0.08	0.06	5.5	6.7	**2.79**	118	**3.28**	**0.32**
OH57 1 Stillwater River (Brush Creek to Great Miami R.) EWH - Englewood Dam Pool													
14.2	0.0	**40**	**28**	**52**	**2**	0.12	0.07	7.1	7.1	0.59	30	0.49	0.15
OH57 1 Stillwater River (Brush Creek to Great Miami R.) EWH													
14.2	0.0	-	53	85	0	0.13	0.06	5.3	6.5	0.64	55	0.55	0.19
OH57 3 Mill Creek WWH													
5.7	0.0	**22**	**22**	**51**	**4**	0.50	0.09	4.3	5.6	**2.45**	438	0.48	0.08
OH57 4 Brush Creek WWH													
6.0	0.0	36	41	63	0	0.05	0.05	2.0	2.0	1.47	10	0.26	0.05

Table 5. Continued.

WBID River		ICI	IBI			Ammonia-N*		D.O.					
URM	LRM	Min	Min	QHEI‡	HIMA†	Max	Max‡	Min	Min‡	TKN‡	Fecal Col.‡	NO_x-N‡	TP‡
MWH		22	24	45	≤3	7.3	0.8	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 16 Opossum Run EWH													
2.0	0.0	48	46	70	0	0.07	0.06	6.4	6.4	0.66	285	0.23	0.06
OH57 18 Painter Creek MWH													
19.7	5.5	**4**	**12**	**32**	**5**	6.17*	**1.20**	**1.9**	**2.8**	0.10	**4249**	2.22	0.36
OH57 18.x Painter Creek WWH (new segment based on use designation break)													
5.5	0.0	36	**33**	78	0	0.14	0.09	5.0	5.0	0.68	150	0.78	0.17
OH57 19 Little Painter Creek MWH													
5.2	0.0	**20**	34	**44**	**2**	0.25	0.13	4.8	4.8	1.13	170	0.59	0.07
OH57 7 Ludlow Creek WWH													
13.5	0.0	32	36	67	3	0.15	0.06	3.5	4.4	1.96	891	0.40	0.11
OH57 8 Brush Creek WWH													
8.0	0.0	**0**	38	**57**	**3**	0.09	0.06	3.3	3.3	**3.51**	140	0.64	0.20
OH57 10 Hog Run WWH													
2.3	0.0	32	48	70	1	0.10	0.07	5.6	5.6	10.51	135	0.64	1.53
OH57 20 Heller Ditch MWH													
4.1	0.0	32	26	43	4	0.08	0.06	4.5	4.5	0.43	250	0.56	0.07

Table 5. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI‡	HIMA†	Ammonia-N* Max	Ammonia-N* Max‡	D.O. Min	D.O. Min‡	TKN‡	Fecal Col.‡	NO_x-N‡	TP‡
MWH		22	24	45	≤3	7.3	0.8	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 38 Harris Creek WWH													
9.1	0.0	36	**30**	**40**	**3**	0.19	0.12	5.6	5.9	0.89	**2633**	0.50	0.31
OH57 39 Ballinger Run WWH													
4.6	0.0	**0**	**25**	59	1	3.06*	0.53	4.3	6.0	**3.14**	**48193**	1.42	1.26
OH57 32 Greenville Creek (Headwaters to West Branch) EWH													
40.5	24.3	42	**45**	**64**	**1**	0.09	0.05	5.6	6.7	0.42	336	0.27	0.13
OH57 26 Greenville Creek (West Br. To Dividing Br.) WWH													
24.3	15.2	**26**	36	**56**	**2**	0.75	0.18	4.8	5.9	**2.23**	**1436**	0.48	**0.49**
OH57 21 Greenville Creek (Dividing Br. To Stillwater R.) EWH													
15.2	0.0	44	**37**	80	0	0.07	0.05	6.0	7.1	**1.89**	84	0.35	**0.28**
OH57 22 Mcquay Ditch WWH													
3.2	0.0	44	36	56	2	0.31	0.11	3.5	3.5	2.06	6043	0.56	0.13
OH57 23 Poplar Ditch WWH													
2.4	0.0	44	52	61	2	0.05	0.05	7.3	7.3	1.98	2550	0.32	0.11
OH57 24 Bolton Run WWH													
3.5	0.0	32	50	45	3	0.19	0.10	4.8	4.8	0.21	2050	0.29	0.15

Table 5. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI‡	HIMA†	Ammonia-N* Max	Ammonia-N Max‡	D.O. Min	D.O. Min‡	TKN‡	Fecal Col.‡	NO_x-N‡	TP‡
MWH		22	24	45	≤3	7.3	0.8	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 25 Dividing Branch WWH													
7	0.0	32	48	41	3	0.06	0.05	4.3	4.3	0.28	845	0.46	0.11
OH57 27 Bridge Creek WWH													
4.6	0.0	54	38	39	3	0.18	0.10	8.6	8.6	0.99	1215	0.35	0.14
OH57 28 Mud Creek WWH													
8.0	0.0	40	42	58	3	0.34	0.06	2.5	2.5	0.30	1070	0.25	0.08
OH57 29 Prairie Outlet WWH													
2.0	0.0	**28**	36	**40**	**5**	0.15	0.09	5.2	5.2	**1.20**	**10846**	0.30	0.10
OH57 30 West Branch WWH													
11.4	0.0	38	44	57	3	0.05	0.05	6.8	7.1	0.66	724	0.23	0.07
OH57 31 Spring Branch WWH													
0.5	0.0	32	48	57	1	0.05	0.05	7.4	7.4	0.60	155	0.22	0.10
OH57 33 Kraut Creek WWH													
7.0	0.0	44	42	66	1	0.06	0.05	6.5	8.1	0.61	358	0.32	0.07
OH57 34 North Fork Kraut Creek WWH													
2.7	0.0	38	46	56	1	0.05	0.05	8.3	8.3	0.72	390	0.22	0.11

Table 5. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI‡	HIMA†	Ammonia-N* Max	Ammonia-N* Max‡	D.O. Min	D.O. Min‡	TKN‡	Fecal Col.‡	NO_x-N‡	TP‡
MWH		22	24	45	≤3	7.3	0.8	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 35 Dismal Creek WWH													
9.5	0.0	32	**27**	**48**	**3**	0.32	0.12	**2.8**	**4.2**	0.37	604	0.47	0.36
OH57 40 Trotters Creek WWH													
4.8	0.0	44	48	74	0	0.11	0.10	2.8	2.8	0.10	1265	0.24	0.12
OH57 41 Swamp Creek MWH													
13.8	6.5	28	**17**	**34**	**3**	0.26	0.08	**2.5**	**2.8**	0.12	**2383**	0.76	0.32
OH57 41.x Swamp Creek WWH (new segment based on use designation break)													
6.5	0.0	**26**	**27**	**40**	**3**	0.45	0.14	**3.6**	**4.9**	**1.24**	**8635**	0.80	**0.69**
OH57 42 Indian Creek MWH													
5.2	0.0	**12**	**20**	**38**	**4**	1.55	0.14	**1.4**	**2.7**	0.17	797	0.72	0.16
OH57 44 Boyd Creek MWH													
3.3	0.0	**20**	34	45	2	0.13	0.10	4.9	4.9	0.63	**1118**	0.47	0.16
OH57 46 North Fork Stillwater River MWH													
7.7	0.0	**0**	**12**	**31**	**4**	3.22*	0.29	**2.2**	**3.3**	0.18	**1024**	1.10	**0.42**
OH57 47 Woodington Run WWH													
3.4	0.0	**22**	42	**51**	**2**	0.06	0.05	**3.4**	**4.1**	0.10	247	0.41	0.16

Table 5. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI‡	HIMA†	Ammonia-N* Max	Max‡	D.O. Min	Min‡	TKN‡	Fecal Col.‡	NO_x-N‡	TP‡
MWH		22	24	45	≤3	7.3	0.8	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 48 South Fork Stillwater River WWH													
7.0	0.0	**20**	38	**44**	**3**	0.25	0.09	5.3	5.3	0.11	325	0.66	0.13
OH57 7.1 Trib. To Ludlow Creek (Rm 11.80) MWH													
4.35	0.0	32	26	42	3	0.16	0.07	6.1	6.1	3.50	29000	0.41	0.20
OH57 37.1 Trib. To Stillwater R. (Rm 32.60) WWH													
2.4	0.0	38	**34**	64	0	0.08	0.06	7.0	7.0	**3.08**	**30225**	0.27	0.13
OH57 28.2 Lake Branch Ditch WWH													
5.55	0.0	54	54	56	1	0.06	0.05	5.8	5.8	0.53	5100	0.31	0.11
OH57 41.1 Trib. To Swamp Creek (Rm 3.54) MWH													
5.11	0.0	24	24	56	4	0.28	0.11	1.4	1.4	0.39	90	1.09	0.42
OH57 37.2 Trib. To Stillwater R. (Rm 38.30) WWH													
2.43	0.0	**12**	**28**	**37**	0	0.71	0.25	**1.5**	**1.5**	0.11	**10535**	0.88	0.42
OH57 48.1 Trib. To S. Fk. Stillwater R. (Rm 0.94) MWH													
4.78	0.0	**20**	32	**29**	**5**	0.05	0.05	4.4	4.4	0.10	85	0.60	0.16

‡ Table values are the segment average.

† Table values are the extreme (maximum or minimum) value

a HIMA - High Influence Modified Habitat Attributes

b Target values are adopted from Ohio EPA (1999; *i.e.*, the Associations Report).

* Specific numeric water quality exist in OAC 3745-1-07, Tables 7-3 through 7-8; target values are guidelines based on the 75th percentile values of temperature (24ºC) and field pH (8.1) from all samples collected during the 1999 Stillwater survey.

◊ Specific numeric water quality exist in OAC 3745-1-07, Table 7-2; target values are based on Primary Contact Recreation.

4.0 Total Maximum Daily Loads

A TMDL is a means for recommending controls needed to meet water quality standards (USEPA, 1991). 40 CFR 130.2(i) states that a TMDL calculation is the sum of the individual wasteload allocations for point sources and the load allocations for nonpoint sources and natural background in a given watershed, and that TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. Aquatic organisms are affected by a combination of variables that are not limited to load based pollutants. Therefore, the attainment of WQS in Ohio requires that both pollutant loads and environmental conditions (pollution, or non-load based parameters such as habitat) be addressed when identified as impairing causes.

The overall strategy for this TMDL is to follow an adaptive implementation approach outlined by Reckhow (2001). In this approach, a model strategy is developed to seek restoration targets for the most immediate and intense causes and sources of impairment. The ensuing implementation actions based on these targets should have a high degree of certainty associated with a successful restoration. Hence, we focus on the these causes and sources in our load calculation and restoration target. The 1998 §303(d) list of causes and sources of impairment for the Stillwater River TMDL suggest the following strategy depicted in Table 4.1a; §303(d) listed assessment units are described in Table 4.1.b and their geographical location shown in Figure 4.1. The key relationship in addressing sources and causes of impairment and corresponding load reductions/targets is in mitigating both nonpoint-source nutrient and organic enrichment through the same mechanisms. Our strategy was to effectively simulate nutrient production from NPS (mainly row-crop agriculture supplied with both organic/manure and synthetic dry fertilizer) and then develop load reductions for nutrients (total phosphorus and NO_2^-+NO_3^-). Reduction in organic/manure application to meet nutrient targets should subsequently reduce causes of organic enrichment from these same sources. Continued, follow-up monitoring, as adaptive implementation suggests (Reckhow 2001) will reveal the effectiveness of this restoration strategy.

Degraded or poor habitat is another non-load based impairing cause in the Stillwater River watershed. Identification of which aspects of the habitat are degraded at particular points in the watershed is provided in this report as are benchmarks which can be used to set habitat goals. This is analogous to allocations of loads for pollutants. These recommended "habitat allocations" are a necessary means to meet biocriteria and water quality standards (in combination with the other TMDLs described above) and thus can be considered a "habitat-based" TMDL.

The TMDL calculation must also include either an implicit or explicit margin of safety that accounts for the uncertainty concerning the relationship between pollutant load or the pollution (the non-load causes of impairment) and water quality. The calculations, then, provide a numeric basis for addressing the impairing causes.

Figure 4.1. Location of hydrologic assessment units and their tributary and mainstem drainage network within the Stillwater River TMDL.

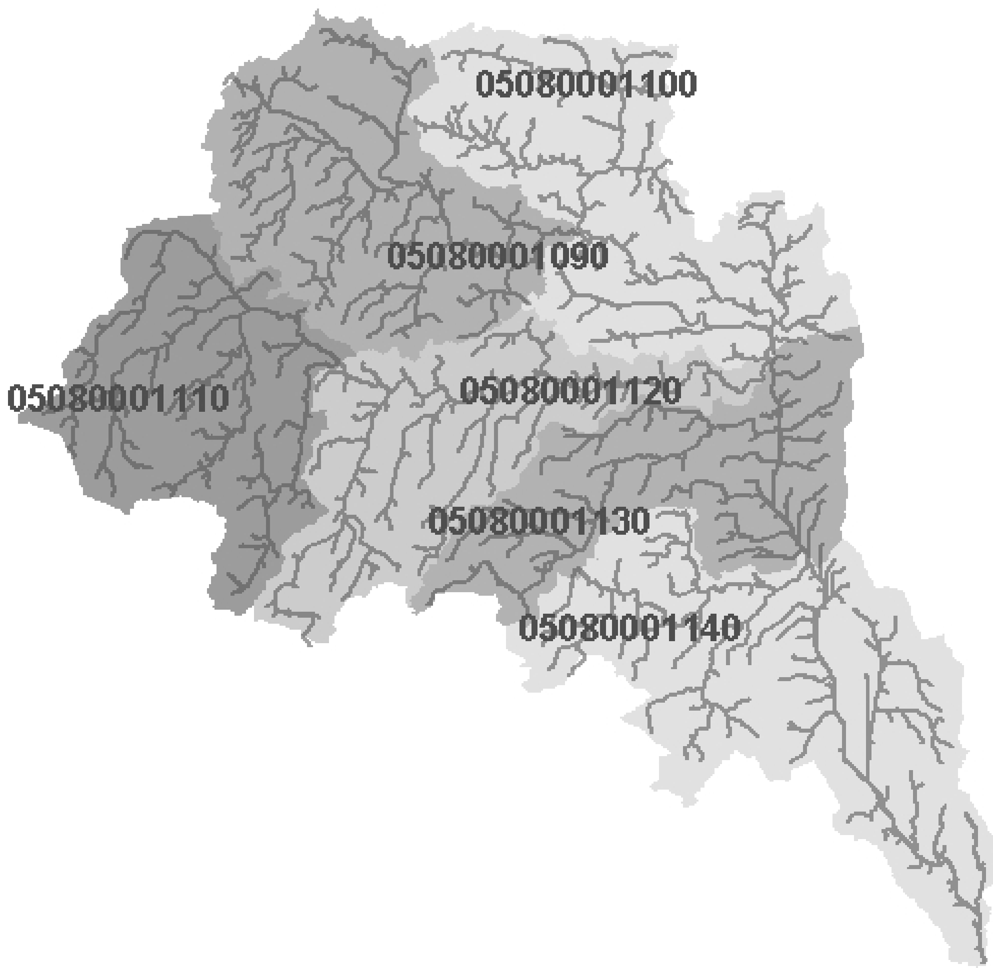


Table 4.1a. Summary of Major Causes/Sources of Impairment[a] and Approaches to Determining a Restoration Target		
Cause	**Source**	**Approach**
Organic enrichment / dissolved oxygen	‣ Combined Sewer Overflow (CSO) ‣ Municipal Point Source ‣ Animal Feeding Operations (AFO) ‣ Onsite Sewage Disposal	‣ Construction grant to affected communities ‣ NPDES permitting process ‣ Addressed (indirectly) through nutrient enrichment ‣ Load reductions determined through geographical analysis
Nutrient enrichment	‣ Agriculture (row crop) ‣ AFO ‣ Onsite Sewage Disposal	‣ Explicit representation of fertilizer rates by rotation-type and watershed location ‣ Load reductions determined through geographical analysis
Habitat degradation	‣ Streambank modification ‣ Channelization ‣ Surface erosion (agriculture, AFO) ‣ Dam construction/maintenance	‣ Stream segments targeted on basis of QHEI scores (see Table 4.23) ‣ Not considered in this TMDL
Siltation	‣ Dam construction/maintenance	‣ Not considered in this TMDL
Hazardous waste	‣ Cause unknown	‣ Not considered in this TMDL
Un-ionized ammonia	‣ Municipal Point Source	‣ NPDES permitting process
Notes: a): 1998 §303(d) Listing		

Table 4.1b. Assessment Units Considered in Stillwater River TMDL	
Assessment Unit	**Description**
05080001-090	Stillwater River (headwaters to upstream Swamp Creek); flows to 05080001-100
05080001-100	Stillwater River (upstream Swamp Creek to upstream Greenville Creek); flows to 05080001-130
05080001-110	Greenville Creek (headwaters to downstream West Branch); flows to 05080001-120
05080001-120	Greenville Creek (downstream West Branch to mouth); flows to 05080001-130
05080001-130	Stillwater River (downstream Greenville Cr. to upstream Ludlow Creek); flows to 05080001-140
05080001-140	Stillwater River (upstream Ludlow Creek to mouth)

4.1 Method of Calculation

Nutrient enrichment, organic enrichment, and habitat degradation are the primary causes of impairment for the Stillwater River TMDL. To address these causes of impairment, three approaches were selected for quantifying load reductions. They are:

1) Determine load contributions from nonpoint source activities originating on the watershed landscape, primarily from the intensive animal feeding operations and row-crop agriculture. Account for load contributions arising from the major wastewater sources in the watershed (namely those dischargers having conduit loads exceeding 0.500 MGD).

2) Establish current aquatic habitat conditions and quantify desired goals of the same.

3) Estimate load contributions from residential septic systems (or onsite sewage systems) – an atypical point-source of nutrient and organic enrichment – as a componet of total load reduction strategy.

Table 4.2 summarizes the modeling approach selected for this TMDL project.

4.1.1 Estimating Loads from SWAT

Nutrient loading and flow in the Stillwater River watershed from agricultural management practices and WWTP was simulated using the Soil and Water Assessment Tool (SWAT). SWAT is a river basin-scale model developed by the USDA ARS at the Blackland (Texas) Research Center (Arnold et al. 1998; Srinivasan, R. et al. 1998). The particular version used was AVSWAT2000 which is the most recent version of the model coupled with the ESRI Arcview interface. SWAT is a physically based model that operates on a daily time step (continuously) and efficiently over several years. It is not designed to simulate single-event flooding. SWAT has been used extensively in the USA for TMDL applications (e.g., Wisconsin, Illinois, Texas) and has been accepted by USEPA as a modeling strategy for TMDL load development (USEPA 1999).

The model geometry[1] consists of one complete watershed that is composed of 36 subbasins. These subbasins were generated by drainage divide discretization scheme using the USGS National Elevation Dataset for this drainage region. Each TMDL assessment unit (AU) comprises about 6 of the SWAT subbasins. Within each subbasin are an array of hydrologic representative units (HRUs), one main channel (that enables connection of subbasin to another), and one tributary channel (possesses no geographic position) that connects to a main channel. HRUs are unique combination of soil map unit (and associated textural and physical attributes) and land use/management; and like tributary channels, HRUs possess no geographic position.

[1]To inform the reader of the model structure, the discussion of SWAT subbasins is reserved for this section only. TMDL load calculations are conducted for each of the six assessment units and only this level of partitioning will be discussed in the remainder of Chapter 4.

Table 4.2. Modeling Approach Summary			
Model or Method	**Parameters Analyzed**	**Goals**	**How is it (or will be) used?**
Time- and space-distributed deterministic water quality modeling using *Soil and Water Assessment Tool (SWAT)*	Total phosphorus (by season) NO_2^-+NO_3^- (by season)	Quantify the total phosphorus and NO_2^-+NO_3^- loads from the terrestrial component of subwatersheds. Evaluate the instream water quality under non-varying flow conditions. Evaluate and compare nutrient loadings between sub-watersheds and between point and nonpoint sources Evaluate the effect of land use changes on loadings during the implementation plan phase	Quantify the existing loads from nonpoint sources. Employ the model in an interactive environment with watershed stakeholders. Build scenarios of proposed implementation plans to examine probable water quality response.
Ecological assessment and indexes	IBI ICI QHEI 1. Substrate 2. Instream cover 3. Riparian quality	Establish targets for parameters with no criteria. Evaluate parameters which are not directly incorporated in the other models. Directly addresses biocriteria impairment issues.	Determine numeric targets for total phosphorus and NO_2^- – NO_3^- and habitat where no criteria exists Compare reference (ECBP ecoregion) sub-watersheds to impaired sub-watersheds in the Stillwater River basin. Assist in determining needed changes in the impaired sub-watershed. Determine effects of habitat characteristics on instream concentrations of nutrients and dissolved oxygen.
Geographical analysis of residential septic system export	Total phosphorus (by season) NO_2^-+NO_3^- (by season)	Evaluate loads from residential septic systems which are not accurately modeled in SWAT (SWAT lacks a dynamic groundwater flow and chemical module).	Ensure responsibility in meeting nutrient load reduction by this sector relative to other sectors (cropland and manure). Provide planning tool for county health departments for enforcing local remediation efforts.

Multiple point source discharges are allowed in a single basin; however, each of their actual locations are simplified to a location at the subbasin outlet. On the basis of average daily conduit flow (major NPDES holders only), four wastewater dischargers were included in the Stillwater SWAT model (Table 4.3). The four were included to ensure that the mass balance of stream flow was as close to observed flow as possible. This represents 9% (27% of active) of the number of dischargers in the watershed (44 total; 33 are active). Sporadic measurements of nutrient concentrations were measured by selected NPDES dischargers; for documentation only as all but three of their effluent loads were *not* incoporated into the model, these entities are included in Table 4.4. In addition, three dischargers were included in the TMDL load analysis, though not included in the modeling effort. These facilities are included in Table 4.4 (see code=*l*) plus effluent loads from the Village of Bradford (1PB00008). A quantitative treatment of these additions is found later in this chapter (Section 4.4.2).

Table 4.3. Wastewater Dischargers Included in SWAT Model for Stillwater River TMDL

Ohio Facility ID	USEPA ID	Entity Name	Receiving Stream	Median Daily Discharge, Year 2001 (MGD)
1PC00011	OH0021857	Village of West Milton	Stillwater River	0.618
1PD00001	OH0025011	City of Englewood	Stillwater River	1.484
1PD00005	OH0025429	City of Greenville	Greenville Creek	1.792
1IJ00015	OH0009661	American Aggregates	Mud Creek	0.800
1IJ00044	OH0112615	C.F. Poeppelman Inc	Greenville Creek	7.400 (2000)

One reservoir is simulated in the model – Englewood Reservoir – though there are no control structures and water flows continuously. Daily precipitation data was compiled for the entire model period for 13 stations (Miami Conservancy District) distributed within and beyond the watershed boundary.

Runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed. SWAT simulates surface runoff volumes and peak runoff rates for each HRU using a modification of the SCS curve number method (USDA Soil Conservation Service 1972). SWAT simulates the land phase of the hydrologic cycle using a daily water balance equation; the equation consists of initial soil water content, precipitation, surface runoff, evapotranspiration, percolation and bypass flow, and return flow to predict final soil water content for each day of the simulation. Surface runoff, as predicted by the SCS curve number method, is a function of soil permeability, land use, and antecedent soil water conditions. The peak runoff rate, calculated using the modified rational method, is used to predict sediment loss on hillslopes. If time of concentration exceeds one day, SWAT uses a surface storage function to lag the release of runoff delivered to the main channel. This lag also applies to the movement of nutrients (introduced below). Flow is routed through the channel using a variable storage coefficient method developed by Williams (1969). Evapotranspiration was simulated using the Priestly-Taylor method (1972) which is a simpler form of the Penman-Monteith (Penman, 1965) and applied when surfaces are wet. The Priestley-Taylor equation provides potential evapotranspiration estimates for low advective conditions. Erosion caused by rainfall and runoff

is computed with the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975). Delivery ratios are not needed with MUSLE because the runoff factor represents energy used in detaching and transporting sediment.

SWAT monitors five different pools of nitrogen in the soil. Two pools are inorganic forms of nitrogen, NH_4^+ and NO3, while the other three pools are organic forms of nitrogen. NO3 load is calculated by soil concentration and flow volume and is moved by SWAT using pathways of surface runoff, lateral flow, and percolation. Organic N is moved by SWAT as a function of the sediment loading from each HRU. SWAT monitors six different pools of phosphorus in the soil. Three pools are inorganic forms of phosphorus while the other three pools are organic forms of phosphorus. SWAT uses a diffusion equation to move soluble phosphorus through the soil column. Organic P and mineral P are moved in the same way as organic N (as above).

Nutrient transformations in the stream are controlled by the in-stream water quality component of the model. The in-stream kinetics used in SWAT for nutrient routing are adapted from QUAL2E (Brown and Barnwell, 1987). The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment.

Table 4.4. Wastewater Dischargers in Stillwater River Basin that Report Nutrient Concentrations

Ohio Facility ID	USEPA ID	Entity Name	Receiving Stream	Nutrient Parameters (STORET Code)
1PB00011	OH0020940	Village of Arcanum	Painter Creek	630
1PB00005 (l)	OH0023884	Village of Ansonia	N Fork Stillwater River	630
1PB00013	OH0020761	Village of Covington	Stillwater River	00615; 00620; 00630; 00665
1PB00030	OH0021644	Village of Union	Stillwater River	630
1PB00031	OH0022454	Union City	Dismal Creek	00615; 00620; 00665
1PB00033 (l)	OH0020656	Village of Versailles	Swamp Creek	00615; 00620; 00630; 00665
1PC00011 (s)	OH0021857	Village of West Milton	Stillwater River	630
1PD00001 (s)	OH0025011	City of Englewood	Stillwater River	00615; 00620; 00630
1PD00005 (s)	OH0025429	City of Greenville	Greenville Creek	630

(l): indicates nutrient loads were incorporated into the total load estimation
(s): indicates nutrient loads were incorporated into this SWAT modelling effort

The Stillwater River watershed, like most medium-sized agricultural operations in the eastern Midwest, has a complex mixture of agricultural management practices. In consultation with a regional nutrient management specialist and the USDA District Conservationist for Darke County, a detailed, realistic set of scenarios were developed for this simulation. The scenarios comprise varying crop rotation, tillage practice, and fertilizer type (Table 4.5). An example for a corn-soybean-wheat-perennial grass scenario is shown in Appendix I.

Table 4.5. Enumeration of Management Scenario Options		
Crop Rotation	**Tillage**	**Fertilizer Type**
‣ Corn-Soybean (C-S) ‣ Corn-Soybean-Winter Wheat (C-S-C-S-Wh) ‣ Corn-Soybean-Winter Wheat-Perennial Grass (C-S-Wh-G-G-G-G)	‣ generic no-till mixing ‣ field cultivator ‣ chisel plow	‣ synthetic dry (as function of time of year): 28-00-00, anhydrous ammonia, 10-34-60, 18-46-00, 00-46-00, 00-00-60 ‣ wet manure (beef, swine, dairy, chicken, or combinations of)
Other variations include: 1) Time of year for planting, tillage, fertilizer, and harvest (with or without full removal). 2) Fertilizer rate (kg/day). 3) Curve number for tillage operation; USLE cover factor (P).		

Detailed information on livestock types and numbers was provided by the Stillwater Watershed Project (the stakeholder group representing this watershed). This information was used to calibrate manure loads by amount and type of animal for each of the model subbasins (see Appendix V for distributions of numbers of livestock and livestock over the watershed). A simplifying assumption was made that the rate or yield (i.e., mass per area) and type (e.g., chicken vs. dairy-cattle) of applied manure per model subbasin was solely a function of the numbers and type of livestock located within the same subbasin.

Our version of the SWAT model was calibrated to flow using three US Geological Survey hydrologic gauges that exist in the watershed. The station identification number, station name, and long-term period of record exist in Table 4.6. The SWAT model was executed over the period October 1989 to September 2001 (12 years) but only the final seven years (beginning October 1994) were used for flow calibration and for estimating nutrient loads. In general the *pattern* of flow versus time matches quite well for each of the three gauges (Figures 4.2a--4.2c); however, model predictions consistently overestimate observed flow. This overestimation is apparent in the model comparison statistics enumerated in Figures 4.3a-4.3c and Tables 4.7a--4.7c; Willmott et al. (1985) suggest evaluating model success using several of these statistics. In particular in looking at Tables 4.7a--4.7c, the consistent overprediction is shown by the large y-intercepts of the statistical relationship between observed and predicted flows and the large proportion of systematic error to unsystematic error in the computation of RMSE (root-mean-square-error; a difference measure). For systematic error to be larger than its unsystematic component, a consistent error exists in the generation of model flow (compared to observed flow). Ideally, model output should produce larger unsystematic (random) error which cannot be solved by model computation. The solution to reducing systematic error is refining the calibration of hydrology.

Table 4.6. Hydrologic Stations Used in Stillwater River TMDL Modeling Study			
Station ID	**Station Name**	**Drainage Area (mi^2)**	**Period of Record**
03265000	Stillwater River at Pleasant Hill OH	503	Oct 1916 – present
03266000	Stillwater River at Englewood OH	650	Oct 1925 – present
03264000	Greenville Creek near Bradford OH	193	Oct 1930 – Sep 2000 (o)
(o): Station 0326400 no longer operating after 09-30-2000.			

Figure 4.2a. Hydrograph of average daily flow for a month between observed and model prediction for the period October 1994 to September 2000. Station shown is Greenville Creek near Bradford (gauging station is located near downstream end of assessment unit 05080001-120).

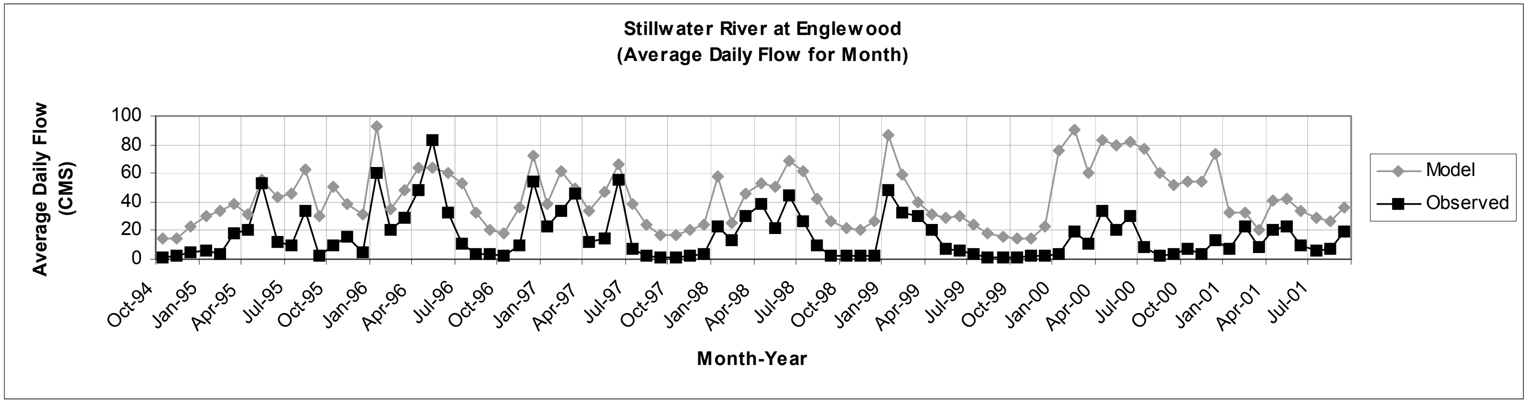


Figure 4.2b. Hydrograph of average daily flow for a month between observed and model prediction for the period October 1994 to September 2001. Station shown is Stillwater River at Pleasant Hill (gauging station is located near downstream end of assessment unit 05080001-130).

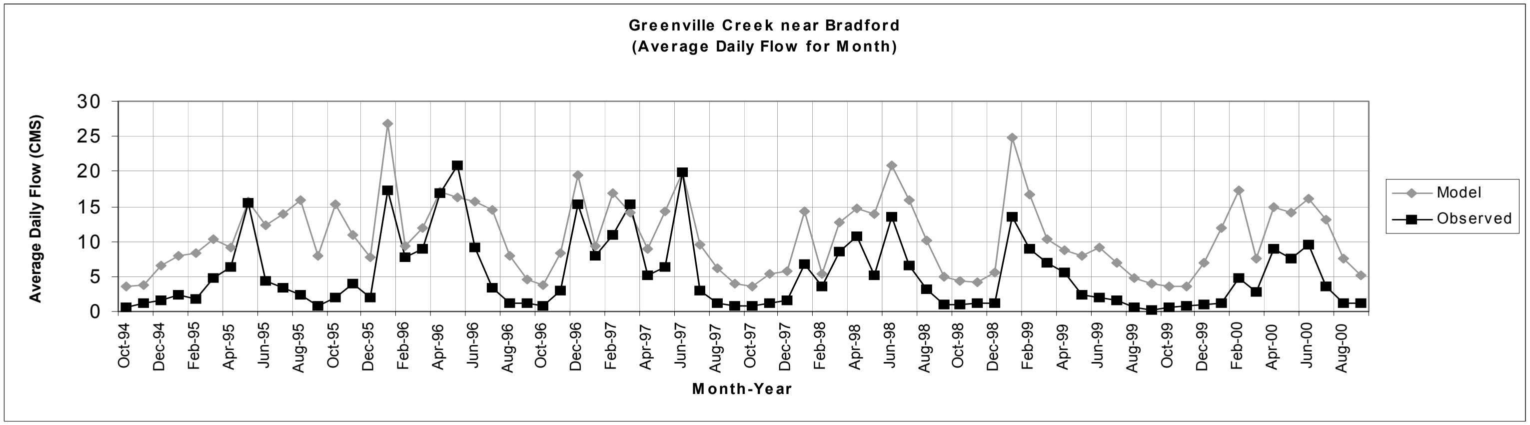


Figure 4.2c. Hydrograph of average daily flow for a month between observed and model prediction for the period October 1994 to September 2001. Station shown is Stillwater River at Englewood (gauging station is located near downstream end of assessment unit 05080001-140).

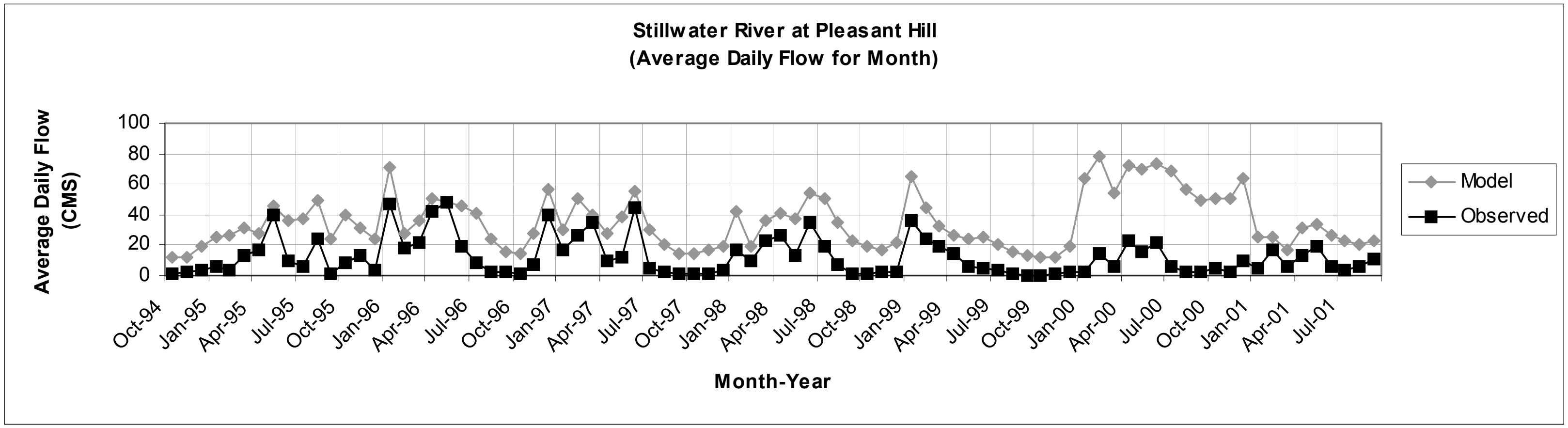


Figure 4.3a. Comparison of average daily flow for a month between observed and model prediction for the period October 1994 to September 2000. Station shown is Greenville Creek near Bradford (part of assessment unit 05080001-120).

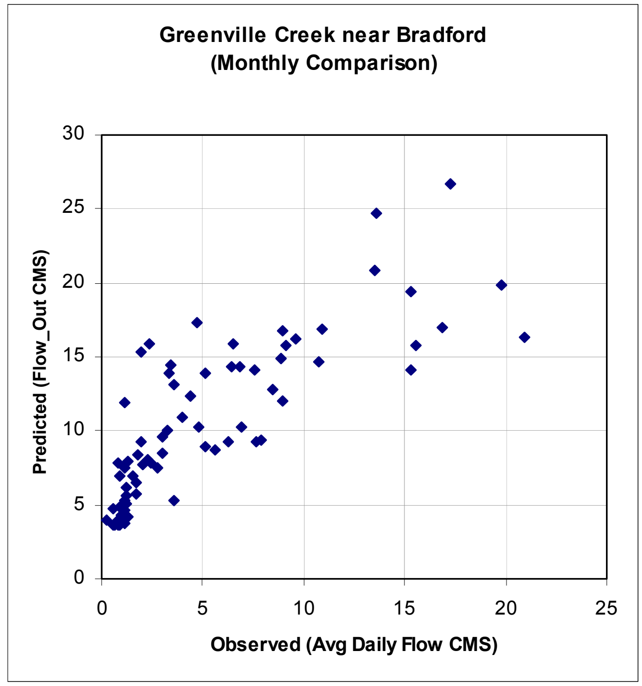


Table 4.7a. Model comparison statistics of average daily flow for a month between observed and model prediction for Greenville Creek near Bradford for the period October 1994 to September 2000 (N = 72 observations).

Summary Univariate Measures	**Parameter**	**Observed Value (cms)**	**Predicted Value (cms)**
	mean	5.28	10.62
	standard deviation	5.19	5.40
Simple Linear Regression (Ordinary Least Squares)	**Parameter**	**Value (cms)**	**p-value**
	y-intercept	6.20	0.00
	slope	0.84	0.00
	r (correlation)	0.80	
	r^2 (explained variance)	0.65	
Difference Measures	**Parameter**	**Value**	**Expected Range**
	d (difference index)	0.73	(worst) 0 to 1 (best)
	E (efficiency)	-0.49	(worst) -∞ to +1 (best)
	mean absolute error	5.50 (cms)	
	RMSE	6.28 (cms)	
	RMSE (systematic)	5.41 (cms)	
	RMSE (unsystematic)	3.19 (cms)	

Figure 4.3b. Comparison of average daily flow for a month between observed and model prediction for the period October 1994 to September 2001. Station shown is Stillwater River at Pleasant Hill (part of assessment unit 05080001-130).

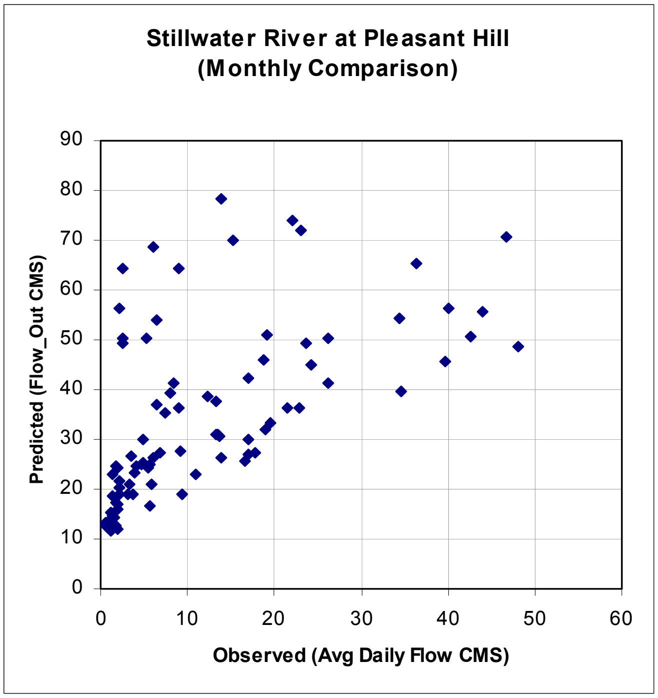


Table 4.7b. Model comparison statistics of average daily flow for a month between observed and model prediction for Stillwater River at Pleasant Hill for the period October 1994 to September 2001 (N = 84 observations).

Summary Univariate Measures	**Parameter**	**Observed Value (cms)**	**Predicted Value (cms)**
	mean	12.31	35.06
	standard deviation	12.31	17.32
Simple Linear Regression (Ordinary Least Squares)	**Parameter**	**Value (cms)**	**p-value**
	y-intercept	24.99	0.00
	slope	0.82	0.00
	r (correlation)	0.58	
	r^2 (explained variance)	0.34	
Difference Measures	**Parameter**	**Value**	**Expected Range**
	d (difference index)	0.51	(worst) 0 to 1 (best)
	E (efficiency)	-3.80	(worst) -∞ to +1 (best)
	mean absolute error	22.75 (cms)	
	RMSE	26.81 (cms)	
	RMSE (systematic)	22.86 (cms)	
	RMSE (unsystematic)	14.01 (cms)	

Figure 4.3c. Comparison of average daily flow for a month between observed and model prediction for the period October 1994 to September 2001. Station shown is Stillwater River at Englewood (part of assessment unit 05080001-140).

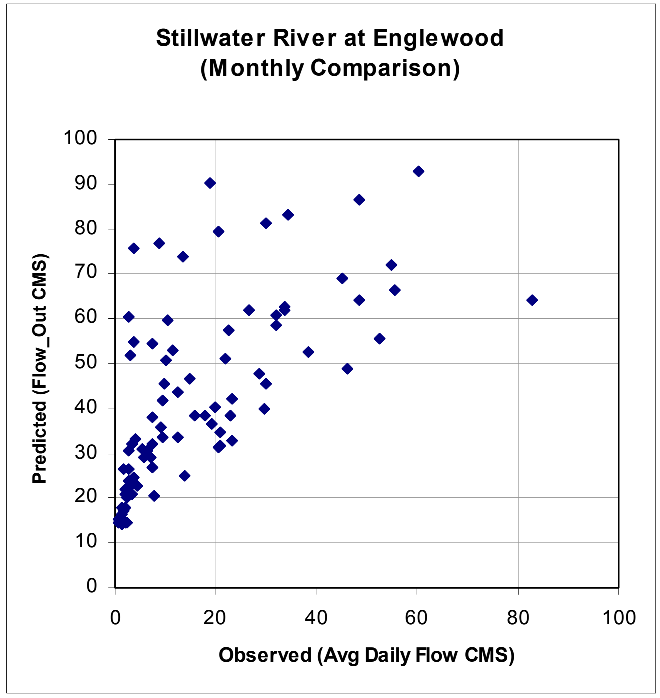


Table 4.7c. Model comparison statistics of average daily flow for a month between observed and model prediction for Stillwater River at Englewood for the period October 1994 to September 2001 (N = 84 observations).

Summary Univariate Measures	**Parameter**	**Observed Value (cms)**	**Predicted Value (cms)**
	mean	16.82	42.82
	standard deviation	16.98	20.48
Simple Linear Regression (Ordinary Least Squares)	**Parameter**	**Value (cms)**	**p-value**
	y-intercept	29.54	0.00
	slope	0.79	0.00
	r (correlation)	0.65	
	r^2 (explained variance)	0.43	
Difference Measures	**Parameter**	**Value**	**Expected Range**
	d (difference index)	0.58	(worst) 0 to 1 (best)
	E (efficiency)	-2.25	(worst) -∞ to +1 (best)
	mean absolute error	26.44 (cms)	
	RMSE	30.42 (cms)	
	RMSE (systematic)	26.24 (cms)	
	RMSE (unsystematic)	15.39 (cms)	

The strategy for flow calibration was to first adjust crop growth parameters so that model crop yield could match observed yields as closely as possible. The geographical coarseness of observed yield data (county units) permitted only broad comparisons (Table 4.8). Then adjustments to water balance parameters were made within the SWAT model to match long-term baseflow-to-total streamflow ratios. Parameter adjustments included:

1. increase estimates of hydraulic conductivity by replacing an EPIC equation with a simple average permeability equation;
2. reduce curve number estimates for selected land covers;
3. reduce available water capacity in the lower layers of soil units (layers 3-5); and
4. increase the threshold depth of the shallow aquifer before evaporation can occur[2].

Observed baseflow estimates for the same period of record (1994—2001) are 55-70% of total streamflow; this compares moderately well to model estimates of baseflow occupying 20-51% of total streamflow (Table 4.9).

Table 4.8. Comparison of Crop Yields – Observed vs. Model Predictions

Crop Type	Model Yield (kg/ha)[a]	Total # Rotations (Model)	Observed Yield (kg/ha)[b]
corn	4,228	110	8,582
soybean	3,464	110	2,810
winter wheat	3,611	38	4,277
hay - perennial grass	2,367	108	7,736

Notes:
(a): Median (N=8) of areal-weighted average of annual yield taken from period 1994-2001.
(b): County-based estimates taken from National Agriculture Statistics Service for the five counties encompassing the Stillwater River watershed.

Table 4.9. Comparison of Baseflow/Streamflow Ratios – Observed vs. Model Predictions

Station Name	*Ratio = Baseflow / Total Streamflow*	
	Observed (%)	Model (%)
Greenville Creek near Bradford OH	69.1[a]	40.9[b]
Stillwater River at Pleasant Hill OH	54.5[b]	51.4[b]
Stillwater River at Englewood OH	55.3[b]	20.6[b]

Notes:
(a) Median of N=72 monthly observations.
(b) Median of N=84 monthly observations.

4.1.2 Habitat Goals

[2]Increasing the threshold depth causes the shallow aquifer (in the model) to store a higher volume of water before it loses water to surface-based evaporation. Subsequently increased surface runoff is allowed to enter the subsurface zone as opposed to the stream channel.

The status of designated aquatic life uses of Ohio rivers and streams is determined using biological criteria for a given designated use. Biological criteria are met when the kinds and relative abundances of various aquatic life forms living in a given stream are present in amounts expected for that stream's aquatic life use, size and ecoregion. A stream's physical habitat quality, the sum of all individual habitat components, largely determines the kinds and amounts of species present, and is therefore a primary consideration in restoring beneficial uses. Also, because stream physical habitat quality is influenced by surrounding land use, and because non-point load reductions are accomplished by changing land uses, habitat quality can be an important measure of TMDL success.

Ohio EPA employs the Qualitative Habitat Evaluation Index (QHEI; Rankin 1989) to assess habitat quality in rivers and streams. The QHEI is a qualitative, visual assessment of the functional aspects of stream macrohabitats (*e.g*., amount and type of cover, substrate quality and condition, riparian quality and width, siltation, channel morphology, etc.). QHEI scores range from 12 to 100, scores greater than 75 indicate excellent stream habitat, scores between 60 and 75 indicate good habitat quality, and scores less than 45 demonstrate degraded habitat. Correlation analysis between component QHEI metrics and the IBI reveal individual habitat attributes that have either a strong positive association with the IBI or a strong negative association (Rankin 1995). The latter are called "high-influence" attributes, and there a five: recent channelization with little or no recovery, silt and muck substrates, no sinuosity, sparse or no cover, and no deep water (maximum depth less than 40 cm or about 15¾ inches). An accumulation of two or more of these high-influence habitat attributes in a stream reach typically precludes a biological community from attaining the criteria set for the basic warmwater habitat aquatic life use. For the Stillwater River TMDL, the QHEI was used as a guide to direct restoration efforts for habitat and provide a monitoring tool to measure progress towards habitat goals.

4.2 Critical Conditions and Seasonality

TMDL development should specify the environmental conditions assumed to define allowable loads. Determinations of TMDLs must take into account critical conditions for stream flow, loading, and water quality parameters (40 CFR 130.7(c)(1)). The critical condition is defined as the set of environmental conditions that, if controls are designed to be protective of them, will ensure attainment of objectives for all other conditions. For example, the critical condition for control of a continuous point source discharge is the drought stream flow. Point source pollution controls designed to meet water quality standards for drought flow conditions will ensure compliance with standards for all other conditions. The critical condition for a wet weather-driven source may be a particular rainfall event, coupled with the stream flow associated with that event.

Nutrient sources in the Stillwater River watershed arise primarily from wet weather sources. The application of organic fertilizer (manure) and synthetic-dry fertilizer to cropland during the period November to June is the main wet weather source of nutrients. However, the critical condition for instream nutrient concentrations and subsequent dissolved oxygen depletion is the summer low-flow period. During this is the period, water temperatures and incoming solar

radiation are highest, while stream flow is lowest. While SWAT model results suggest that critical period loads are below instream nutrient targets during the summer low-flow period (generally July through September), we observe widespread, excessive eutrophic conditions (herein called *hyper-eutrophy*) in these same streams. Characteristics of hyper-eutrophy include excessive periphyton, large amplitudes in diel dissolved oxygen curves, and obnoxious, putrid odors suggesting frequent decay of abundant aquatic plant biomass. SWAT model results show frequent and large magnitude exceedences of nutrient targets for the period November through June to suggest a strong link between summertime hyper-eutrophy and wintertime plugs of nutrients from land-based sources. Results of model predicted versus target loads for assessment unit 05080001-090 are shown in Figures 4.4a–4.4b; the comparisons for the five other assessment units are show in Appendix II. Model predicted nutrient loads include load generated by anthropogentic stressors, natural background conditions, and effluent from three WWTP (from Table 4.3). Target loads are defined and justified in Section 4.4.1 (below).

For phosphorus species, we hypothesize that these wet-weather nutrient surpluses are stored within the channel and utilized by the system during optimum plant growth conditions. The primary mechanism of channel storage is in sediments stored at the bottom of the streambed. The mechanisms at work include (Newbold 1992; Nguyen et al. 2002):

1) Large seasonal inputs of dissolved phosphorus that are attached to stream sediment and subsequently released into the overlying water column when the water phosphorus concentration is low; and/or
2) Large inputs of phosphorus-laden (usually fine) sediments into the stream system that are subsequently released into the water column when water column concentrations are low.

Therefore, based on observed low flow conditions of hyper-eutrophy and recent literature confirming a connection between excessive loads and the subsequent season's release of these nutrients into the water column, we are compelled to apply the nutrient targets *to each season* of the entire year.

Seasonality is addressed in the Stillwater River TMDL by using the SWAT model to predict monthly loadings over a multi-year period[3] using observed daily precipitation and minimum/maximum temperatures, observed seasonal point source loadings, and observed crop management schedules. Crop management schedules included the rate and timing of synthetic dry and organic (manure) fertilizer. We propose, then, that estimated loads are therefore reflective of seasonal changes in weather, treatment facility operating practices, and agricultural management practices.

[3] October 1989 – September 1993 for model equilibration; October 1994 – September 2001 for model application.

Figure 4.4a. Comparison of model predicted versus target total monthly NO_2^-+NO_3^- (kg-N/d) loads for the drainage segment at the outlet of assessment unit 05080001-090 between the period October 1994 and September 2001. Note the frequent and high magnitude exceedences in late winter and spring whereas little exceedence occurs during the low flow (summer-time) period. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

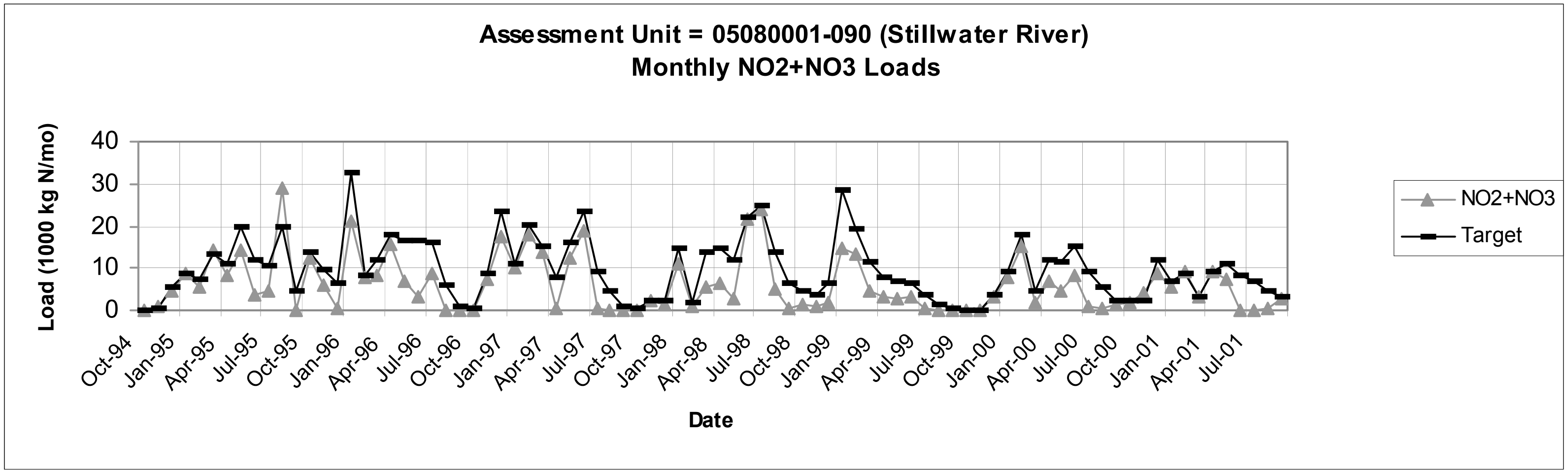
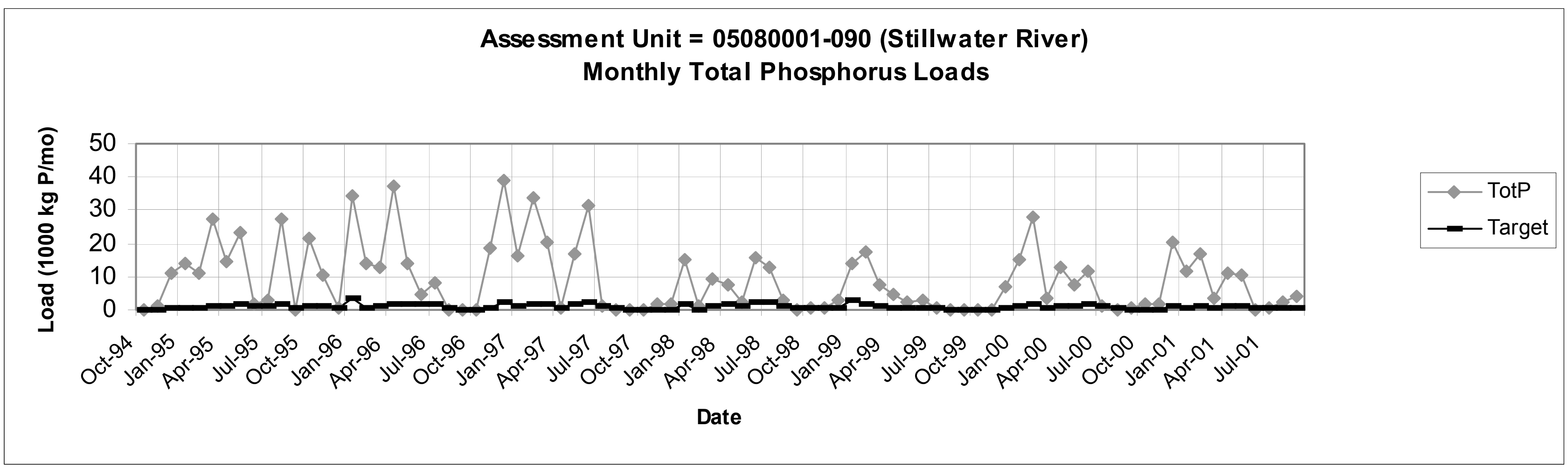


Figure 4.4b. Comparison of model predicted versus target total monthly total phosphorus (kg-P/d) loads for the drainage segment at the outlet of assessment unit 05080001-090 between the period October 1994 and September 2001. Note the frequent and high magnitude exceedences in late winter and spring whereas little exceedence occurs during the low flow (summer-time) period. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.



4.3 Margin of Safety

The margin of safety is incorporated implicitly into these TMDLs. One implicit safety factor is the use of nutrient targets that are based on data from relatively unimpacted reference sites (Ohio EPA 1999). This data constitutes a background or normal concentration of nutrients in a stream. It is important to note that these targets derived from reference sites do not imply a cause-and-effect relationship. Instead, these targets identify the point where nutrient concentration deviates strongly from a reference population. A direct cause-and-effect relationship between these nutrient targets and attainment of WQS is difficult to establish in a linear statistical sense due to the suite of other influencing factors such as physical habitat, gradient, stream order, shading, flood and scour, mode of nutrient delivery, and cumulative watershed condition. Therefore, choosing a target with a margin of safety from a linear model would produce a nutrient concentration that is increasingly small due to the wide confidence intervals implicit with a model having a low correlation coefficient. Deriving what constitutes a normal range of nutrient concentrations from a reference population of minimally impacted, biologically healthy reference sites, and setting the nutrient target as the median of the range is protective of the general population.

The habitat targets were selected using an analogous method as described above for nutrients. The habitat targets and the specific aspects of the habitat that are degraded as provided with the QHEI model combine to add another layer of potential protection to achieving the WQS by providing additional guidance on an alternate means to reduce the nutrient load to the stream, mitigate the impacts of the nutrients in the stream, and directly improve a vital aspect of the biology.

The selection of the nutrient target increases the margin of safety because it directly impacts the magnitude of the loading reduction needed. If a less stringent total phosphorus target was selected a greater loading capacity would be allowed. However, full attainment of water quality standards are occasionally observed even when concentrations are above this target (thus reinforcing the notion that habitat and other factors play an important role in supporting fully functioning biologic communities (Ohio EPA 1999)). It is with this recognition that Ohio EPA has used some flexibility in how nutrient loads have been allocated.

When considering an explicit margin of safety, we do reserve capacity of the NO_2^-+NO_3^- TMDL because 1) this component of nutrient enrichment rarely exceeds loads based on target concentrations, and 2) assigning the mainstem of each assessment unit with a less stringent target to better match the use designations residing in that assessment unit. The unallocated NO_2^-+NO_3^- load is discussed in more detail in Section 4.4.6 (Summary of Requested Load Allocations; item number 4).

4.4 TMDL Calculations

4.4.1 TMDL Target Estimation

TMDL target loads consider concentrations based on target concentrations defined in Ohio EPA (1999) and cumulative basin flow predicted by our version of the SWAT model. We chose to use predicted basin flow to determine target loads because the model consistently overestimates observed flows by 17% (Bradford gauge), 103% (Pleasant Hill gauge), and 76% (Englewood gauge). Hence, it is a more equitable comparison of actual loads generated by stressors existing in the watershed and target loads defined by biological integrity.

Target nutrient concentrations have been defined by Ohio EPA (1999) as a function of drainage basin size and aquatic life use designation (Table 4.10). However there are a few confounding factors in assigning the target concentration (and load) to an assessment unit. While the drainage area of each assessment unit unarguably defines the basin area criterion within Table 4.10, aquatic life use designation may vary among the drainage segments within the given assessment unit. In our domain, the outlet segment of each assessment unit, with the exception of 05080001-090[1], has an aquatic life use designation of EWH (exceptional warmwater habitat – the most stringent nutrient target), but the predominant use designation is WWH within the network of drainage segments of each assessment unit. In fact nearly all of the mainstem of the Stillwater River basin is EWH and use-attainment is fully attaining for most mainstem segment lengths (with some partial attainment in a few segment lengths). Because of a predominant WWH use designation in the tributaries and full attainment of EWH in the mainstem, we assign a WWH target concentration for each of the assessment units.

We define TMDL (the load limit), natural background load, and stressor load on a seasonal basis (ON = October-November, DJF = December-February, MAMJ = March-June, and JAS = July-September) because of the predominance of agricultural management and corresponding schedule of fertilizer applications (see Section 4.2 Critical Conditions and Seasonality). TMDL load allocations by assessment unit and entire drainage basin are identified in Tables 4.13a (total phosphorus) and 4.16a ($NO_2^-+NO_3^-$) for each season of the year (see also Figures 4.6a-b and 4.8a-b).

Natural background nutrient concentrations are depicted in Table 4.10 as well; they are derived from biological reference sites (Ohio EPA 1999). As prescribed by the conventional TMDL equation, the loads generated from these background concentrations are *subtracted* from the total allowable load (the TMDL) given to each assessment unit. Background loads were calculated using a percentage of predicted flow derived from the SWAT model and the corresponding concentrations identified in Table 4.10. Percentage of total flow was used to represent non-stormflow conditions; this percentage was identified from the ratio of model-predicted baseflow to total stream flow (from Table 4.9). Background loads for each assessment unit (expressed as an incremental or intervening drainage area) and the entire Stillwater River drainage are shown in Tables 4.13b (total phosphorus) and 4.16b ($NO_2^-+NO_3^-$) for each season of the year (see also Figures 4.6a-b and 4.9a-b).

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[1] Assessment unit 05080001-090 has an aquatic life use designation of WWH defined at its outlet segment.

Stressor or impairment sectors are defined as: point source discharge, non-point source discharge (limited to manure-fertilizer and synthetic-fertilizer applied to agricultural row crop), residential septic systems (on-site sewage disposal), and municipal stormwater discharge. Load estimations are defined for each of these sectors to determine the relative accountability in meeting the TMDL.

Table 4.10. Target and background nutrient concentrations defined for Ohio (based on Ohio EPA 1999) as a function of aquatic life use designation and drainage basin area.

Watershed Type	Drainage Area Range (mi²)	Nutrient Concentration (mg/L)							
		EWH		WWH		MWH		Background[b]	
		TP	NO_2^- $+NO_3^-$	TP	NO_2^- $+NO_3^-$	TP	NO_2^- $+NO_3^-$	TP	NO_2^- $+NO_3^-$
Headwater	0 – 20	0.05	0.5	0.08	1.0	0.34	1.0	0.028	0.40
Wading	20 – 200	0.05	0.5	0.10	1.0	0.28	1.6	0.05	0.40
Small River	200 – 1000	0.10	1.0	0.17	1.5	0.25	2.2	0.13	1.025
Large River	≥ 1000	0.15	1.5	0.30	3.0[a]	0.32	2.4	0.19	2.11

Notes:
(a) Upward adjusted (from 2.0 mg/L) from Ohio EPA (1999) to reflect a 10:1 nitrogen-to-phosphorus ratio.
(b) Background concentrations selected from a statewide distribution of biological reference sites according to drainage basin area (Ohio EPA 1999; Appendix I for total phosphorus, nitrate, and nitrite).

4.4.2 Point Source Discharge

Observed wastewater loads for the five major dischargers that exist in the watershed (from Table 4.3) were included in the SWAT model. Nutrient loads (total phosphorus and NO_2^-+NO_3^-) were calculated for 3 of the 5 entities according to procedures outlined in Appendix III). These loads were entered into the SWAT model as unvarying over a given annual cycle (i.e., the same average daily load was used for each day of a given year between 1989 and 2001).

Beyond these major dischargers in the Stillwater River watershed, eight additional facilities were incorporated into the TMDL assessment; three of these facilities were found to significantly impair biological integrity (Tables 4.11a and 4.11b). Nutrient effluent from these entities was not included in the SWAT model and, thus, the monthly output of nutrients in Figures 4.4a–4.4b and Appendix II does not reflect their effluent nutrient load. Using either measured (from MOR) or estimated nutrient concentrations below (Table 4.11a for total phosphorus and Table 4.11b for NO_2^-+NO_3^-), plus measured conduit discharge (STORET parameter code = 50050), we have determined point source effluent load. The total effluent load is based on the major dischargers within the SWAT model (3 total) and those having nonsignificant nutrient discharges (8 total); effluent load is reported by assessment unit and season in Tables 4.12a (total phosphorus) and 4.15a (NO_2^-+NO_3^-). Existing loads are also depicted in Figures 4.5 and 4.8, respectively.

Table 4.11a. Summary of wastewater effluent concentrations of total phosphorus as a means for determining TMDL wasteload allocations by assessment unit.

Ohio Facility ID	Facility Name	Total Phosphorus Concentration (mg/L)	Percent Reduction[a]	Period of Record	Notes
05080001-090 (assigned overall reduction of 70%)					
1PB00005	Village of Ansonia	3.00	67	estimated	b, d, e
05080001-100 (assigned overall reduction of 70%)					
1PB00008	Village of Bradford	3.00	67	estimated	b, d, e
1PB00033	Village of Versailles	4.33	77	2000-2001	b, e
05080001-110 (no reduction needed)					
1PB00031	Village of Union City	0.97	-3	1990-1994	b
05080001-120 (assigned overall reduction of 70%)					
1PD00005	City of Greenville	3.31	70	1990-2001	c
05080001-130 (assigned overall reduction of 65%)					
1PB00000	Village of Arcanum	3.00	67	estimated	b, d
1PB00013	Village of Covington	2.77	64	1995-2001	b
1PB00026	Village of Pleasant Hill	3.00	67	estimated	b, d
05080001-140 (assigned overall reduction of 60%)					
1PB00030	City of Union	3.00	67	estimated	b, d
1PC00011	Village of West Milton	3.06	67	1995	c
1PD00001	City of Englewood	2.23	55	1990	c

Notes:
(a): Based on best-available technology, represents percent reduction to achieve 1 mg/L total phosphorus concentration.
(b): These facilities were *not* included in the SWAT modeling exercise but were included in determining total loads produced by the point source sector.
(c): Facilities included in the SWAT modeling exercise because of their large magnitude conduit flow.
(d): Observed total phosphorus data was lacking for this entity so an expected effluent concentration for total phosphorus was assigned. This estimate was provided by Stuhlfauth (2002, personal communication Ohio EPA).
(e): Known to cause significant biological impairment.

Table 4.11b. Summary of wastewater effluent concentrations of $NO_2^-+NO_3^-$ as a means for determining TMDL wasteload allocations by assessment unit.

Ohio Facility ID	Facility Name	$NO_2^-+NO_3^-$ Concentration (mg/L)	Percent Reduction	Period of Record	Notes
05080001-090					
1PB00005	Village of Ansonia	0.39	a	1990-2001	b, e
05080001-100					
1PB00008	Village of Bradford	15.00	a	estimated	b, d, e
1PB00033	Village of Versailles	11.26	a	1990-2001	b, e
05080001-110					
1PB00031	Village of Union City	0.36	a	1990-2001	b
05080001-120					
1PD00005	City of Greenville	17.34	a	1990-2001	c
05080001-130					
1PB00000	Village of Arcanum	0.77	a	1990-2001	b
1PB00013	Village of Covington	12.70	a	1990-2001	b
1PB00026	Village of Pleasant Hill	15.00	a	estimated	b, d
05080001-140					
1PB00030	City of Union	3.48	a	1990-2001	b
1PC00011	Village of West Milton	9.07	a	1993-2001	c
1PD00001	City of Englewood	3.77	a	1990-2001	c

Notes:
(a): See Table 4.17a for assigned percent reduction. Due to general non-exceedence of the TMDL for $NO_2^-+NO_3^-$ and variation of treatment plant operation, a "technology-based" reduction is not assigned for $NO_2^-+NO_3^-$ load.
(b): These facilities were *not* included in the SWAT modeling exercise but were included in determining total loads produced by the point source sector.
(c): Facilities included in the SWAT modeling exercise because of their large magnitude conduit flow.
(d): Observed $NO_2^-+NO_3^-$ was lacking for this entity so an expected effluent concentration of 15 mg/L $NO_2^-+NO_3^-$ was assigned. This estimate was extrapolated from a 3:1 ratio determined from total phosphorus – estimated effluent concentrations of total phosphorus (3 mg/L), when unknown, to a concentration target of 1 mg/L.
(e): Known to cause significant biological impairment.

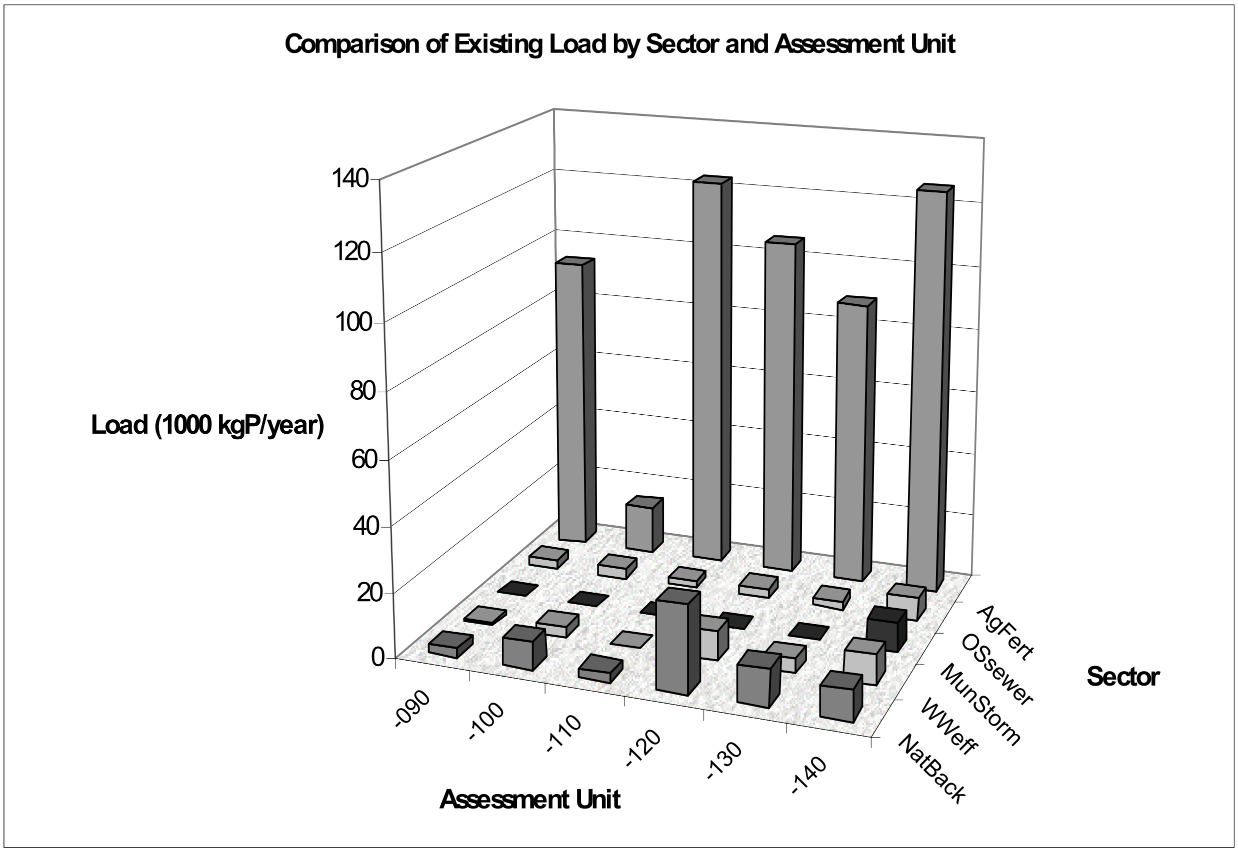
WWeff Load P	Table 4.12a. Existing wastewater effluent load for total phosphorus (kg-P/season) generated seasonally by individual assessment unit and total basin. Based on multiple years of monthly operating report data. (Season Codes: ON = October-November, DJF = December-February, MAMJ = March-June, and JAS = July-September)			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	161	237	321	242
05080001-100	493	727	985	743
05080001-110	67	99	134	101
05080001-120	1,495	2,205	2,989	2,254
05080001-130	706	1,041	1,412	1,064
05080001-140	1,545	2,280	3,091	2,331
Total Basin	4,466	6,589	8,932	6,736

AgFert Load P	Table 4.12b. Existing non-point source (agriculture fertilizer) load for total phosphorus (kg-P/season) generated seasonally by individual assessment unit and total basin. Median value of N=7 years.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	1,896	48,721	35,616	7,273
05080001-100	258	6,515	4,417	3,556
05080001-110	3,522	55,444	56,129	8,027
05080001-120	2,979	41,406	51,999	9,599
05080001-130	2,304	36,273	42,501	7,841
05080001-140	3,081	62,060	50,511	10,144
Total Basin	14,038	250,419	241,173	46,440

OSsewer Load P	Table 4.12c. Existing on-site sewage system load for <u>total phosphorus</u> (kg-P/season) generated seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	460	659	873	715
05080001-100	524	769	1,020	793
05080001-110	386	512	679	640
05080001-120	567	771	1,023	921
05080001-130	439	612	812	700
05080001-140	1,198	1,615	2,142	1,960
Total Basin	3,574	4,938	6,549	5,729

MunStorm Load P	Table 4.12d. Existing municipal stormwater load for <u>total phosphorus</u> (kg-P/season) generated seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	0	0	0	0
05080001-100	0	0	0	0
05080001-110	0	0	0	0
05080001-120	0	0	0	0
05080001-130	0	0	0	0
05080001-140	1,445	2,133	2,891	2,180
Total Basin	1,445	2,133	2,891	2,180

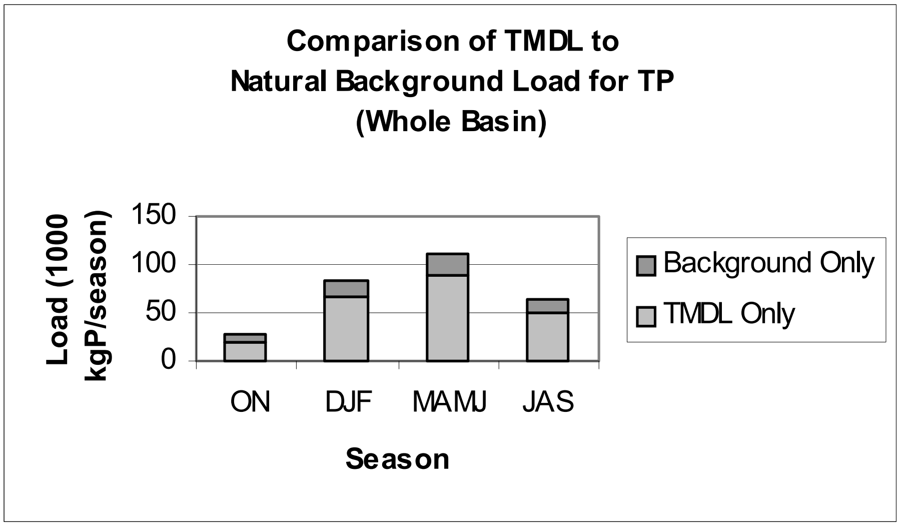
Figure 4.5. Distribution of existing <u>total phosphorus</u> load by pollution sector and assessment unit for an entire year. (Sector Codes: NatBack = natural background, WWeff = wastewater effluent, MunStorm = municipal stormwater, AgFert = agricultural fertilizer, OSsewer = onsite sewage system, and UnAlloc = un-allocated)

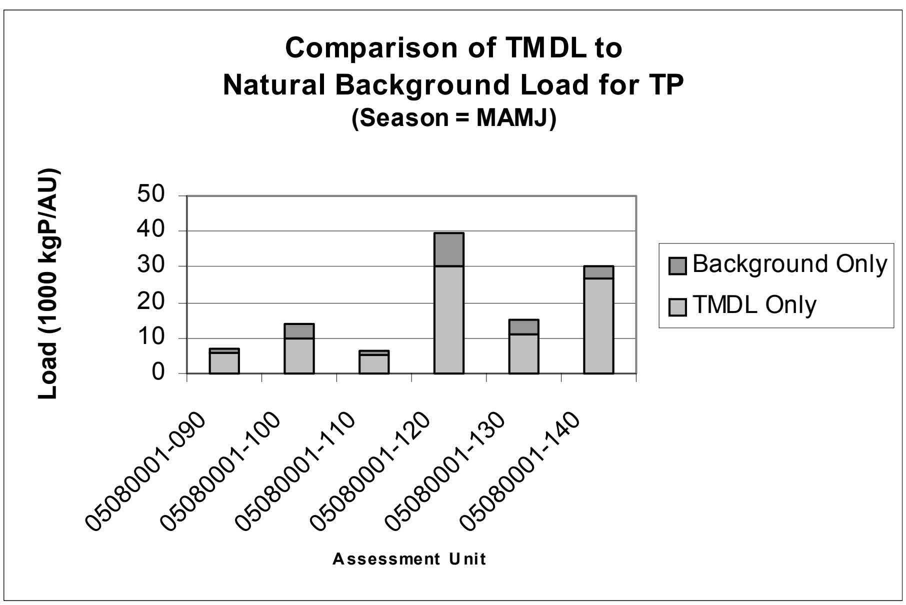


TMDL P	Table 4.13a. TMDL for total phosphorus (kg-P/season) assigned seasonally by individual assessment unit and total basin. Median value of N=7 years. (Season Codes: ON = October-November, DJF = December-February, MAMJ = March-June, and JAS = July-September)			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	484	3,095	5,572	1,701
05080001-100	1,332	5,344	9,773	4,388
05080001-110	332	3,368	5,078	2,003
05080001-120	11,122	22,693	30,147	19,609
05080001-130	1,837	9,890	11,001	6,247
05080001-140	5,621	21,095	26,549	17,161
Total Basin	20,728	65,485	88,121	51,108

Nat Back P	Table 4.13b. Natural background load for total phosphorus (kg-P/season) assigned seasonally by individual assessment unit and total basin. Median value of N=7 years.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	126	827	1,452	439
05080001-100	529	2,161	3,916	1,731
05080001-110	88	898	1,332	519
05080001-120	3,536	7,232	9,584	6,190
05080001-130	736	3,998	4,396	2,469
05080001-140	733	2,752	3,464	2,239
Total Basin	5,748	17,868	24,144	13,587

Figure 4.6a-b. Charts showing the proportion of the total phosphorus TMDL by season (a) and by assessment unit for the spring season or MAMJ (b) relative to the corresponding natural background load.





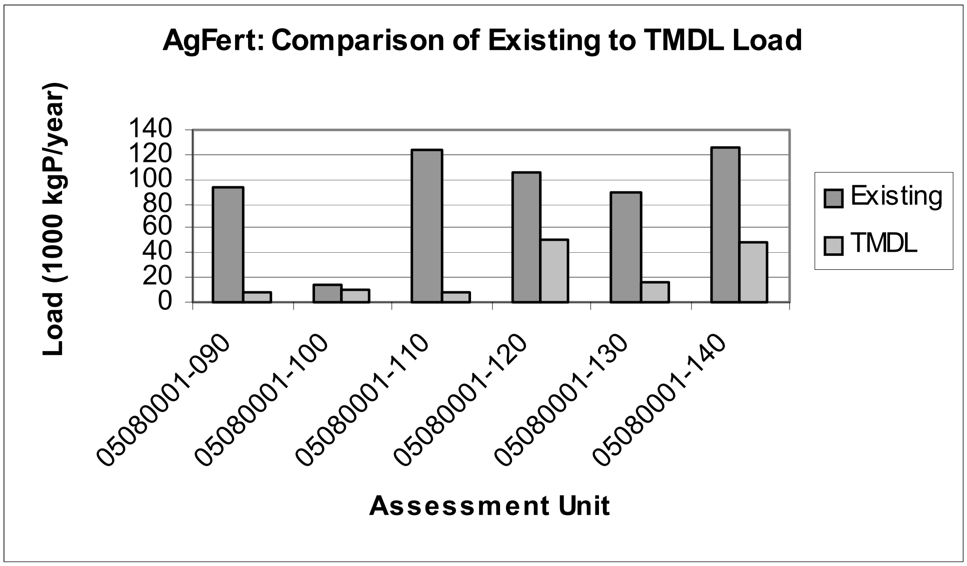
WWeff WLA P	Table 4.14a. Wasteload allocation (WLA) for wastewater effluent for total phosphorus (kg-P/season) assigned seasonally by individual assessment unit and total basin. Percent reduction from existing load in parentheses. (Season Codes: ON = October-November, DJF = December-February, MAMJ = March-June, and JAS = July-September)			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	48 (70)	71 (70)	96 (70)	73 (70)
05080001-100	148 (70)	218 (70)	296 (70)	223 (70)
05080001-110	67 (0)	99 (0)	134 (0)	101 (0)
05080001-120	448 (70)	662 (70)	897 (70)	676 (70)
05080001-130	247 (65)	364 (65)	494 (65)	373 (65)
05080001-140	618 (60)	912 (60)	1,236 (60)	932 (60)
Total Basin	1,577 (65)	2,326 (65)	3,153 (65)	2,378 (65)

AgFert LA P	Table 4.14b. Load allocation (LA) for non-point source (agriculture fertilizer) for total phosphorus (kg-P/season) assigned seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	283 (85)	2,228 (95)	4,009 (89)	1,140 (84)
05080001-100	216 (16)	2,652 (59)	4,518 (-2)	1,990 (44)
05080001-110	159 (95)	2,349 (96)	3,569 (94)	1,280 (84)
05080001-120	5,997 (-101)	14,528 (65)	19,286 (63)	11,628 (-21)
05080001-130	718 (69)	5,436 (85)	5,997 (86)	3,126 (60)
05080001-140	2,298 (25)	16,438 (74)	19,870 (61)	9,935 (2)
Total Basin	9,671(31)	43,632 (83)	57,249 (76)	29,100 (37)

OSsewer LA P	Table 4.14c. Load allocation (LA) for on-site sewage system load for total phosphorus (kg-P/season) assigned seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	69 (85)	30 (95)	98 (89)	112 (84)
05080001-100	439 (16)	313 (59)	1,043 (-2)	444 (44)
05080001-110	17 (95)	22 (96)	43 (94)	102 (84)
05080001-120	1,141 (-101)	271 (65)	379 (63)	1,115 (-21)
05080001-130	137 (69)	92 (85)	115 (86)	279 (60)
05080001-140	893 (25)	428 (74)	842 (61)	1,920 (2)
Total Basin	2,697 (25)	1,155 (77)	2,521 (61)	3,972 (31)

MunStorm WLA P	Table 4.14d. Wasteload allocation (WLA) for municipal stormwater for total phosphorus (kg-P/season) assigned seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	0 (0)	0 (0)	0 (0)	0 (0)
05080001-100	0 (0)	0 (0)	0 (0)	0 (0)
05080001-110	0 (0)	0 (0)	0 (0)	0 (0)
05080001-120	0 (0)	0 (0)	0 (0)	0 (0)
05080001-130	0 (0)	0 (0)	0 (0)	0 (0)
05080001-140	1,078 (25)	565 (74)	1,137 (61)	2,135 (2)
Total Basin	1,078 (25)	565 (74)	1,137 (61)	2,135 (2)

Figure 4.7a-b. Comparison of existing total phosphorus load to allocated load (TMDL) by assessment for the entire year for agriculture fertilizer (non-point source load) (a) and wastewater effluent (b).



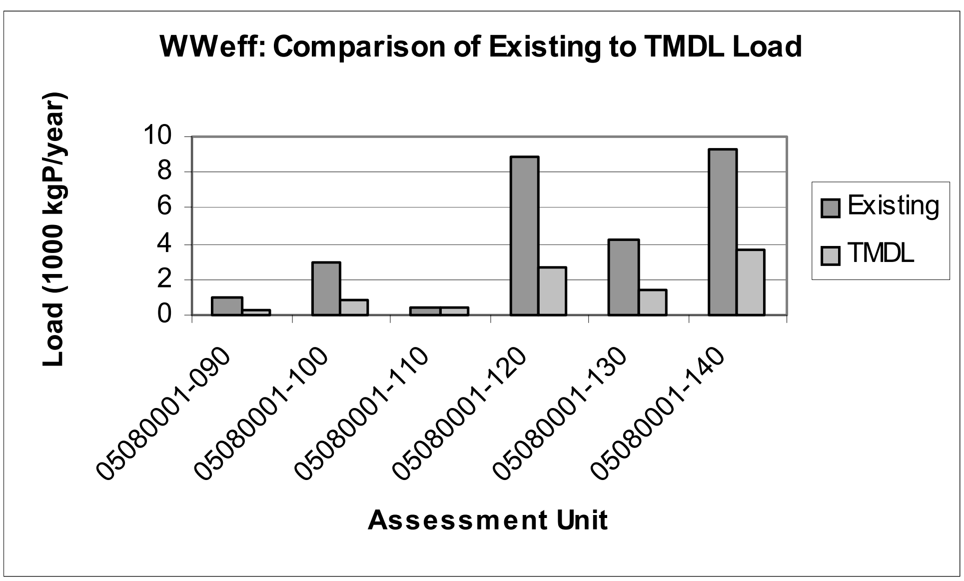
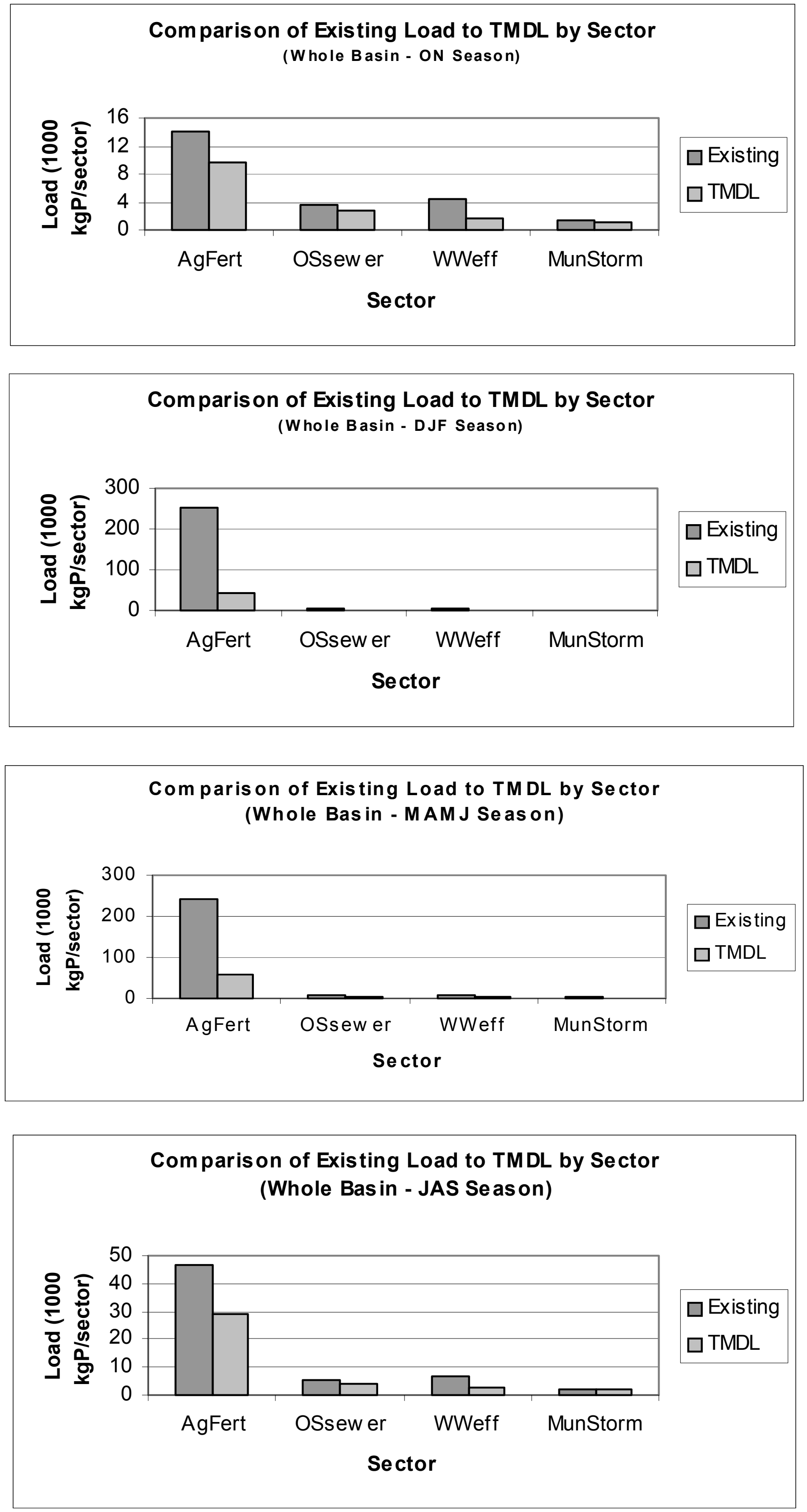


Figure 4.7c-f. Comparison of existing total phosphorus load to allocated load (TMDL) by sector considering the entire Stillwater River basin for ON (c), DJF (d), MAMJ (e), and JAS (f).



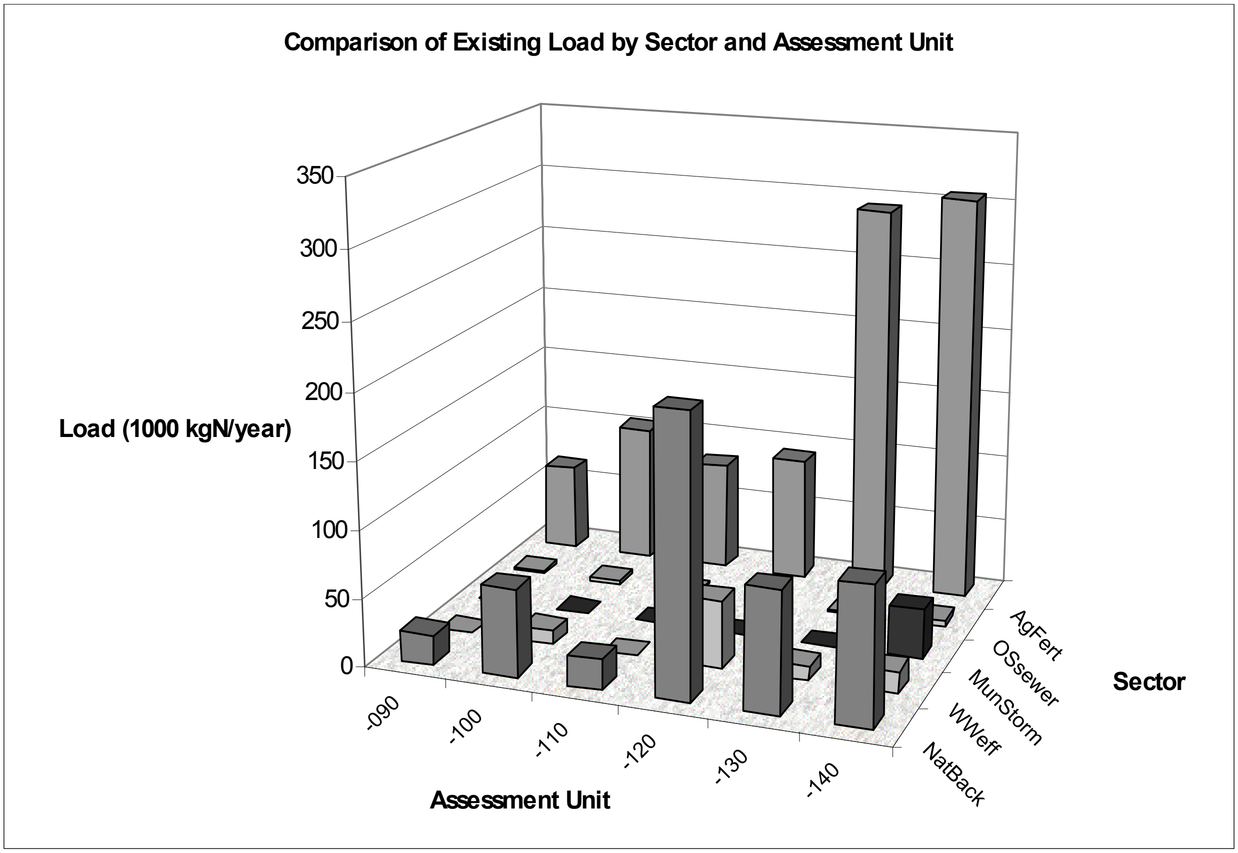
WWeff Load N	Table 4.15a. Existing wastewater effluent load for $NO_2^-+NO_3^-$ (kg-N/season) generated seasonally by individual assessment unit and total basin. Based on multiple years of monthly operating report data. (Season Codes: ON = October-November, DJF = December-February, MAMJ = March-June, and JAS = July-September)			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	26	38	52	39
05080001-100	1,718	2,534	3,436	2,591
05080001-110	25	37	50	38
05080001-120	8,340	12,305	16,680	12,578
05080001-130	1,799	2,654	3,598	2,713
05080001-140	2,650	3,909	5,299	3,996
Total Basin	14,557	21,478	29,115	21,955

AgFert Load N	Table 4.15b. Existing non-point source (agriculture fertilizer) load for $NO_2^-+NO_3^-$ (kg-N/season) generated seasonally by individual assessment unit and total basin. Median value of N=7 years.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	2,213	26,063	34,346	3,323
05080001-100	2,904	31,323	54,795	14,889
05080001-110	2,948	29,293	38,937	10,872
05080001-120	1,586	27,336	52,158	12,212
05080001-130	5,816	89,931	162,678	34,110
05080001-140	455	112,413	155,235	37,712
Total Basin15,923	15,923	316,359	498,149	113,118

OSsewer Load N	Table 4.15c. Existing on-site sewage system load for $NO_2^-+NO_3^-$ (kg-N/season) generated seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	315	464	615	477
05080001-100	354	527	699	529
05080001-110	274	390	517	427
05080001-120	397	572	759	614
05080001-130	305	443	588	466
05080001-140	843	1,210	1,604	1,307
Total Basin	2,488	3,606	4,782	3,819

MunStorm Load N	Table 4.15d. Existing municipal stormwater load for $NO_2^-+NO_3^-$ (kg-N/season) generated seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	0	0	0	0
05080001-100	0	0	0	0
05080001-110	0	0	0	0
05080001-120	0	0	0	0
05080001-130	0	0	0	0
05080001-140	6,143	9,064	12,286	9,265
Total Basin	6,143	9,064	12,286	9,265

Figure 4.8. Distribution of existing NO_2^-+NO_3^- load by pollution sector and assessment unit. (Sector Codes: NatBack = natural background, WWeff = wastewater effluent, MunStorm = municipal stormwater, AgFert = agricultural fertilizer, OSsewer = onsite sewage system, and UnAlloc = un-allocated)

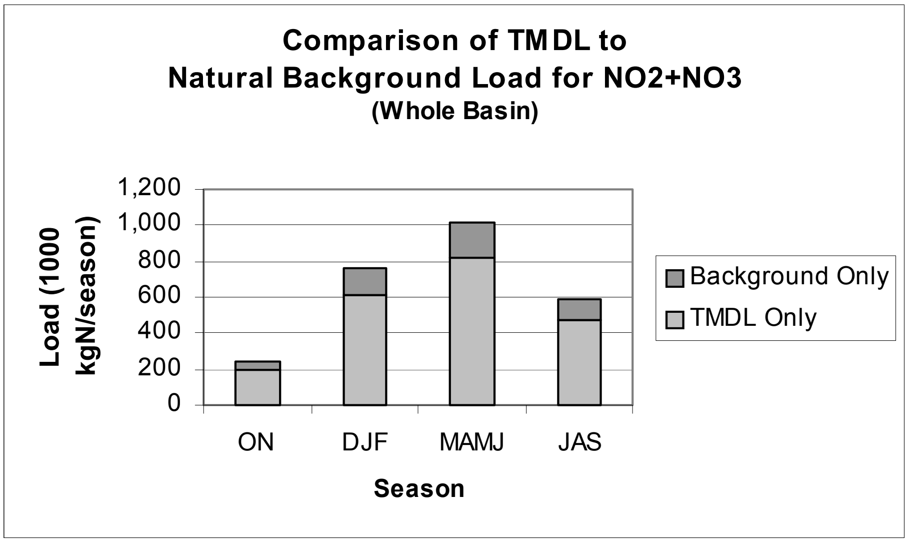


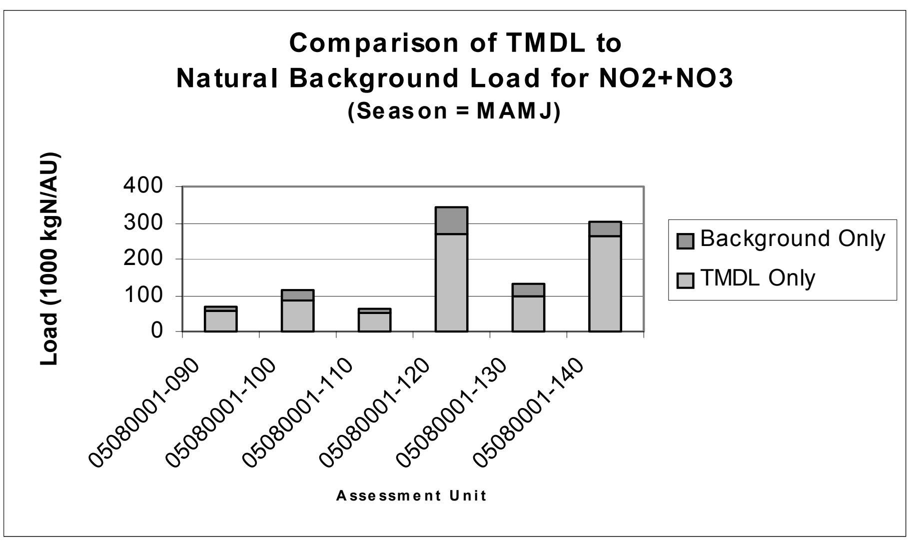
TMDL N	Table 4.16a. TMDL for $NO_2^-+NO_3^-$ (kg-N/season) assigned seasonally by individual assessment unit and total basin. Median value of N=7 years. (Season Codes: ON = October-November, DJF = December-February, MAMJ = March-June, and JAS = July-September)			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	4,840	30,946	55,719	17,012
05080001-100	11,755	47,151	86,236	38,717
05080001-110	3,317	33,683	50,783	20,027
05080001-120	98,136	200,229	265,999	173,023
05080001-130	16,210	87,269	97,068	55,116
05080001-140	56,210	210,949	265,494	171,607
Total Basin	190,469	610,226	821,299	475,503

Nat Back N	Table 4.16b. Natural background load for $NO_2^-+NO_3^-$ (kg-N/season) assigned seasonally by individual assessment unit and total basin. Median value of N=7 years.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	995	6,362	11,456	3,498
05080001-100	4,129	16,561	30,289	13,599
05080001-110	682	6,925	10,441	4,117
05080001-120	27,427	55,961	74,342	48,357
05080001-130	5,693	30,652	34,093	19,359
05080001-140	8,144	30,564	38,467	24,864
Total Basin	47,071	147,025	199,088	113,793

Reserved N	Table 4.16c. Amount of reserved (un-allocated) load for $NO_2^-+NO_3^-$ (kg-N/season) assigned seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	1,291	0	9,250	9,675
05080001-100	2,650	0	0	7,110
05080001-110	0	0	838	4,573
05080001-120	60,386	104,055	122,060	99,262
05080001-130	2,597	0	0	0
05080001-140	37,975	53,789	52,603	94,464
Total Basin	104,898	157,844	184,751	215,084

Figure 4.9a-b. Charts showing the proportion of the NO_2^-+NO_3^- TMDL by season (a) and by assessment unit for the spring season or MAMJ (b) relative to the corresponding natural background load.



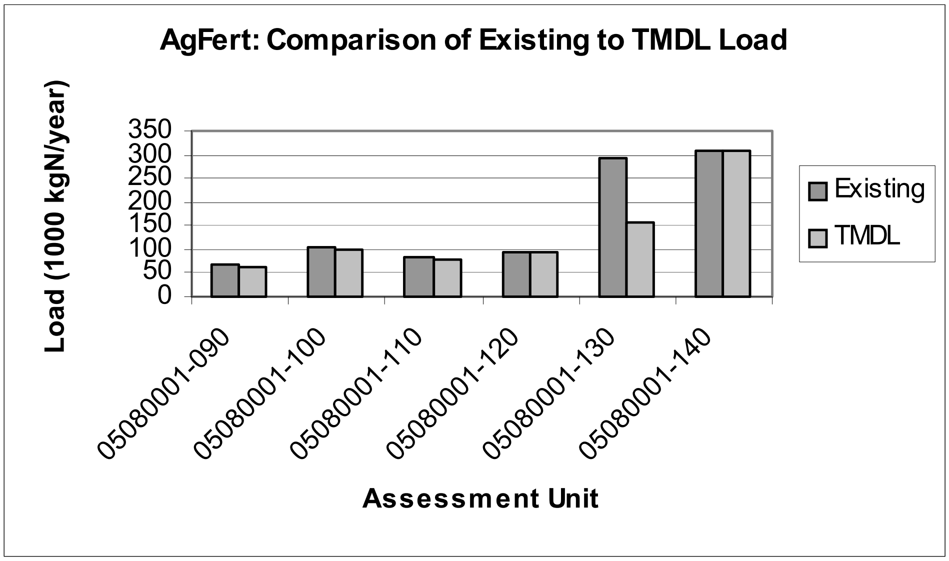


WWeff WLA N	Table 4.17a. Wasteload allocation (WLA) for wastewater effluent for NO_2^-+NO_3^- (kg-N/season) assigned seasonally by individual assessment unit and total basin. Percent reduction from existing load in parentheses. (Season Codes: ON = October-November, DJF = December-February, MAMJ = March-June, and JAS = July-September)			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	26 (0)	36 (7)	52 (0)	39 (0)
05080001-100	1,718 (0)	2,255 (11)	3,262 (5)	2,591 (0)
05080001-110	20 (19)	33 (10)	50 (0)	38 (0)
05080001-120	8,340 (0)	12,305 (0)	16,680 (0)	12,578 (0)
05080001-130	1,799 (0)	1,615 (39)	1,358 (62)	2,602 (4)
05080001-140	2,650 (0)	3,909 (0)	5,299 (0)	3,996 (0)
Total Basin	14,553 (0)	20,153 (0)	26,701 (0)	21,844 (0)
AgFert LA N	Table 4.17b. Load allocation (LA) for non-point source (agriculture fertilizer) for NO_2^-+NO_3^- (kg-N/season) assigned seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	2,213 (0)	24,119 (7)	34,346 (0)	3,323 (0)
05080001-100	2,904 (0)	27,866 (11)	52,022 (5)	14,889 (0)
05080001-110	2,393 (19)	26,373 (10)	38,937 (0)	10,872 (0)
05080001-120	1,586 (0)	27,336 (0)	52,158 (0)	12,212 (0)
05080001-130	5,816 (0)	54,732 (39)	61,395 (62)	32,708 (4)
05080001-140	455 (0)	112,413 (0)	155,235 (0)	37,712 (0)
Total Basin	15,368 (0)	272,839 (0)	394,093 (0)	111,717 (0)

OSsewer LA N	Table 4.17c. Load allocation (LA) for on-site sewage system load for $NO_2^-+NO_3^-$ (kg-N/season) assigned seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	315 (0)	429 (7)	615 (0)	477 (0)
05080001-100	354 (0)	469 (11)	663 (5)	529 (0)
05080001-110	222 (19)	351 (10)	517 (0)	427 (0)
05080001-120	397 (0)	572 (0)	759 (0)	614 (0)
05080001-130	305 (0)	270 (39)	222 (62)	447 (4)
05080001-140	843 (0)	1,210 (0)	1,604 (0)	1,307 (0)
Total Basin	2,437 (0)	3,301 (0)	4,380 (0)	3,800 (0)

MunStorm WLA N	Table 4.17d. Wasteload allocation (WLA) for municipal stormwater for $NO_2^-+NO_3^-$ (kg-N/season) assigned seasonally by individual assessment unit and total basin.			
Assessment Unit	**ON**	**DJF**	**MAMJ**	**JAS**
05080001-090	0 (0)	0 (0)	0 (0)	0 (0)
05080001-100	0 (0)	0 (0)	0 (0)	0 (0)
05080001-110	0 (0)	0 (0)	0 (0)	0 (0)
05080001-120	0 (0)	0 (0)	0 (0)	0 (0)
05080001-130	0 (0)	0 (0)	0 (0)	0 (0)
05080001-140	6,143 (0)	9,064 (0)	12,286 (0)	9,265 (0)
Total Basin6,143	6,143 (0)	9,064 (0)	12,286 (0)	9,265 (0)

Figure 4.10a-b. Comparison of existing $NO_2^-+NO_3^-$ load to allocated load (TMDL) by assessment for the entire year for agriculture fertilizer (nonpoint source load) (a) and wastewater effluent (b).



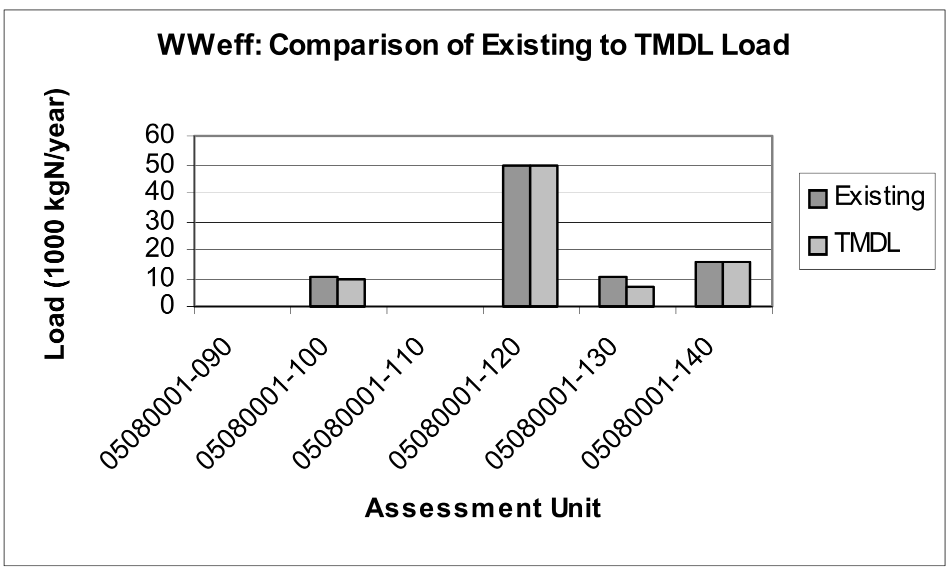
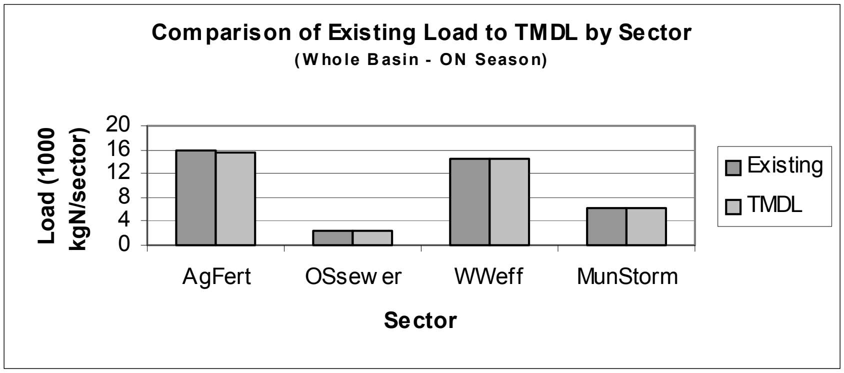
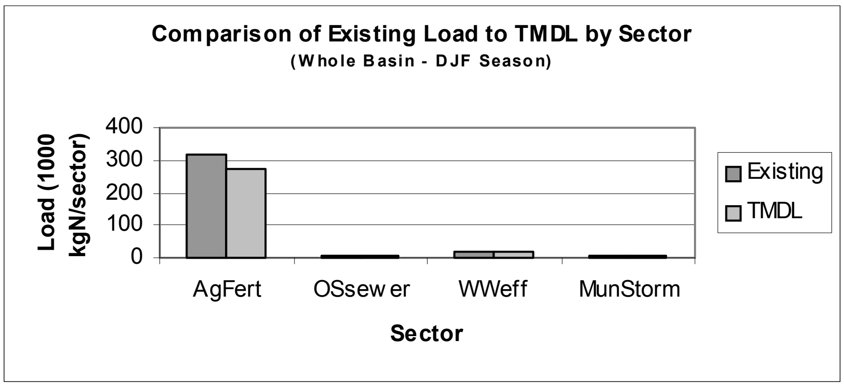
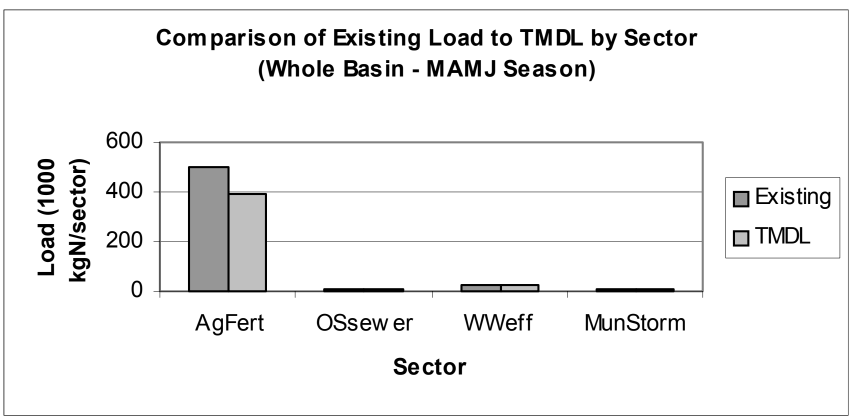
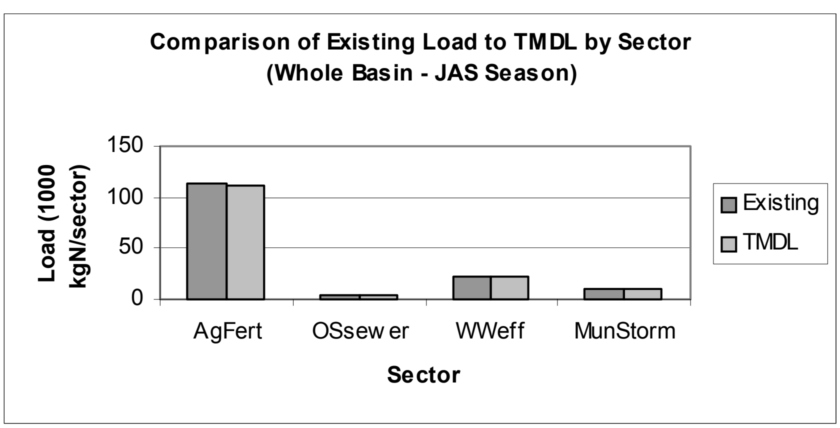


Figure 4.10c-f. Comparison of existing $NO_2^-+NO_3^-$ load to allocated load (TMDL) by sector considering the entire Stillwater River basin for ON (c), DJF (d), MAMJ (e), and JAS (f).









Seasonal load totals were calculated by multiplying the average daily load ($kg \cdot d^{-1}$) for the year by the total number of days in a given season (i.e., ON = 61, DJF = 90, MAMJ = 122, and JAS = 92). The same average daily load was used for each season because there was insufficient measured daily concentration data to estimate loads with inter-seasonal variation.

Load reductions in total phosphorus effluent flow were based on achievement of technology-based concentration targets of 1 mg/L (Novak, P and Stuhlfauth, G., Ohio EPA, 2003; personal communication). The same percent reduction needed to meet the technology-based limit was applied to the load reduction for the same facility (Table 4.11a). Then, load reductions for total phosphorus were made by assessment unit where an overall reduction was estimated from the distribution of individual facility reductions in each unit (Table 4.11a).

Load reductions for NO_2^-+NO_3^- were *not* based on technology limits (Table 4.11b). Due to general non-exceedence of NO_2^-+NO_3^- in this TMDL and variation in existing treatment plant operation within and between the assessment units, it would be unequitable and impracticable to assign limits on technological availability alone. Rather, we assign NO_2^-+NO_3^- load reduction and allocations on an equal percentage basis (Table 4.17a). This strategy assigns percent reduction based on the percent of load contribution made by this sector relative to the total load generated by all sectors.

Allocations for the wastewater effluent sector, under the wasteload category (or WLA), are subsequently made in Tables 4.14a (total phosphorus) and 4.17a (NO_2^-+NO_3^-). A comparison of existing load versus allocated load is depicted in Figures 4.7b and 4.10b, respectively for total phosphorus and NO_2^-+NO_3^-; comparisons to other sectors are shown in Figures 4.7c-f and 4.10c-f, respectively.

4.4.3 Non-Point Source Discharge

Based on biological assessments, measured in-stream nutrient concentrations, and observed nutrient-related nuisance conditions, the sector labeled “non-point source discharge” focusses on the rate and timing of organic manure and synthetic fertilizer applied to cropland. Detailed agricultural management scenarios were developed for each SWAT model sub-basin within each assessment unit to portray the load generation as accurately (and fairly) as possible. As mentioned in Section 4.1.1, we assumed that the rate or yield (i.e., mass per area) and type (e.g., chicken vs. dairy-cattle) of applied manure per model subbasin was solely a function of the numbers and type of livestock (housed in AFOs) located within the same subbasin. Numerical values of loads from agriculture fertilizer sources are identified in Tables 4.12b (total phosphorus) and 4.15b (NO_2^-+NO_3^-) by assessment unit and season of year. Existing loads are also depicted in Figures 4.6 and 4.9, respectively.

The reduction in loading amounts for the non-point source sector were determined on an equal percentage basis (defined in Section 4.4.2). Load allocations for the non-point source sector are identified in Tables 4.14b (total phosphorus) and 4.17b (NO_2^-+NO_3^-). A comparison of existing load versus allocated load is depicted in Figures 4.7a and 4.10a, respectively for total phosphorus and NO_2^-+NO_3^-; comparisons to other sectors are shown in Figures 4.7c-f and 4.10c-f, respectively.

While a discussion with stakeholders (particularly agricultural nutrient specialists) on the best approaches for reducing agriculturally-based nutrient loads is forthcoming, we propose the following brief but preliminary implementation strategies:

1) marketing sales of and transporting quantities of manure product outside the Stillwater River drainage basin to other watersheds not having any substantial production of animal manure; solicit subsidies and grants to reduce expenses in transportation of manure product outside of watershed;

2) examine and adjust differences between rates and timing (i.e., time of year) of manure vs. synthetic fertilizer in selected headwater sub-basins (Figure 4.11) through human interaction with the SWAT model by adjusting management strategies (overview provided in Table 4.18);

3) improve terrestrial and bank habitat with inclusion of woody trees and other perennials to improve nutrient uptake (assimilation) and reduce sediment export from uplands to channels; and

4) exploration of crop-rotation and tillage practice scenarios to reduce overland sediment transport and overall nutrient yields through interaction with the SWAT model by adjusting management strategies (overview provided in Table 4.18).

Figure 4.11. Distribution of animal feeding operations by total animal unit (1st box) and individual animal type (one map per animal type); size of circle represents number of animals housed at facility (based on data provided by Stillwater Watershed Project in conjunction with Miami Valley Regional Planning Commission; MVRPC 1998 and 1999).

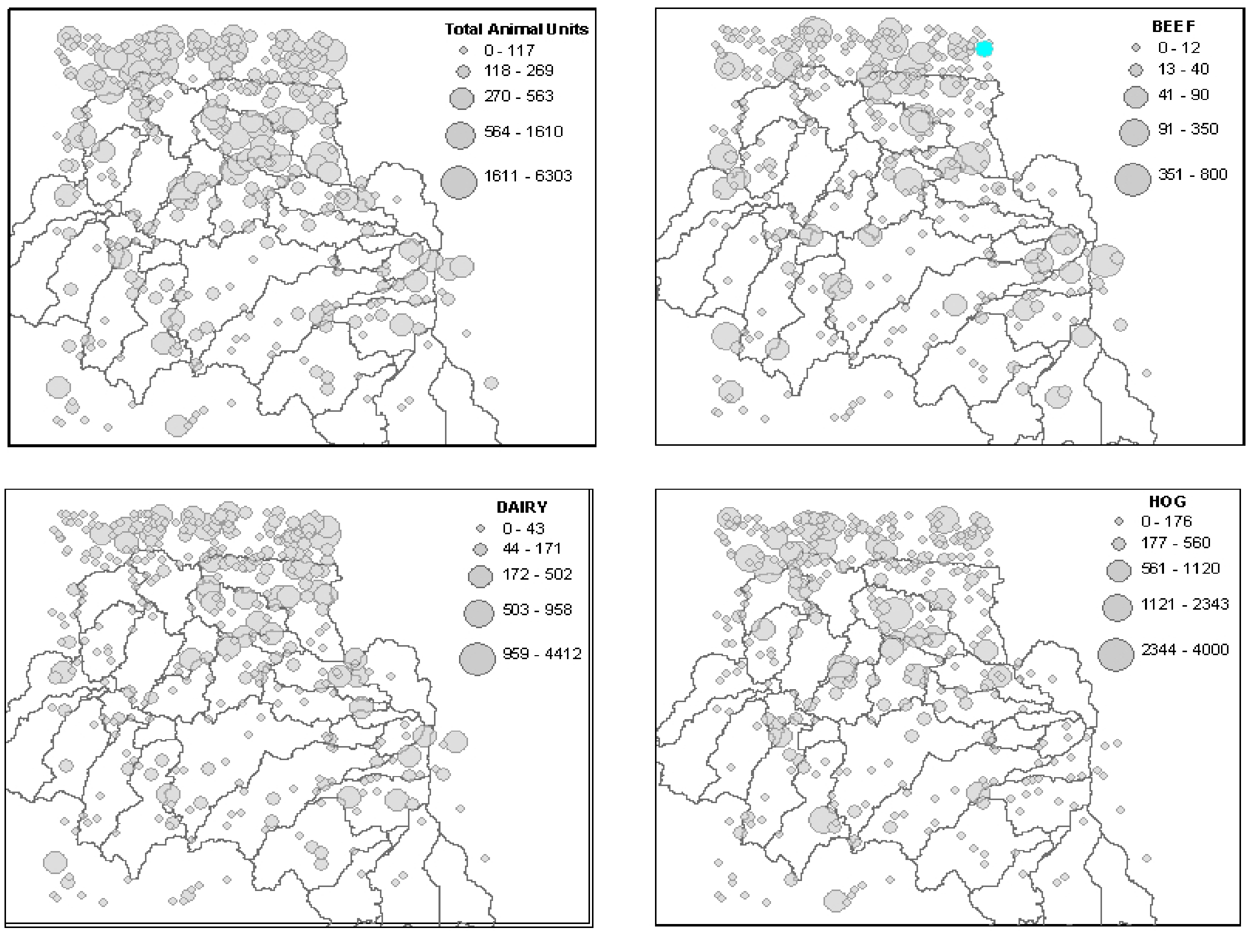


Figure 4.11 (continued).

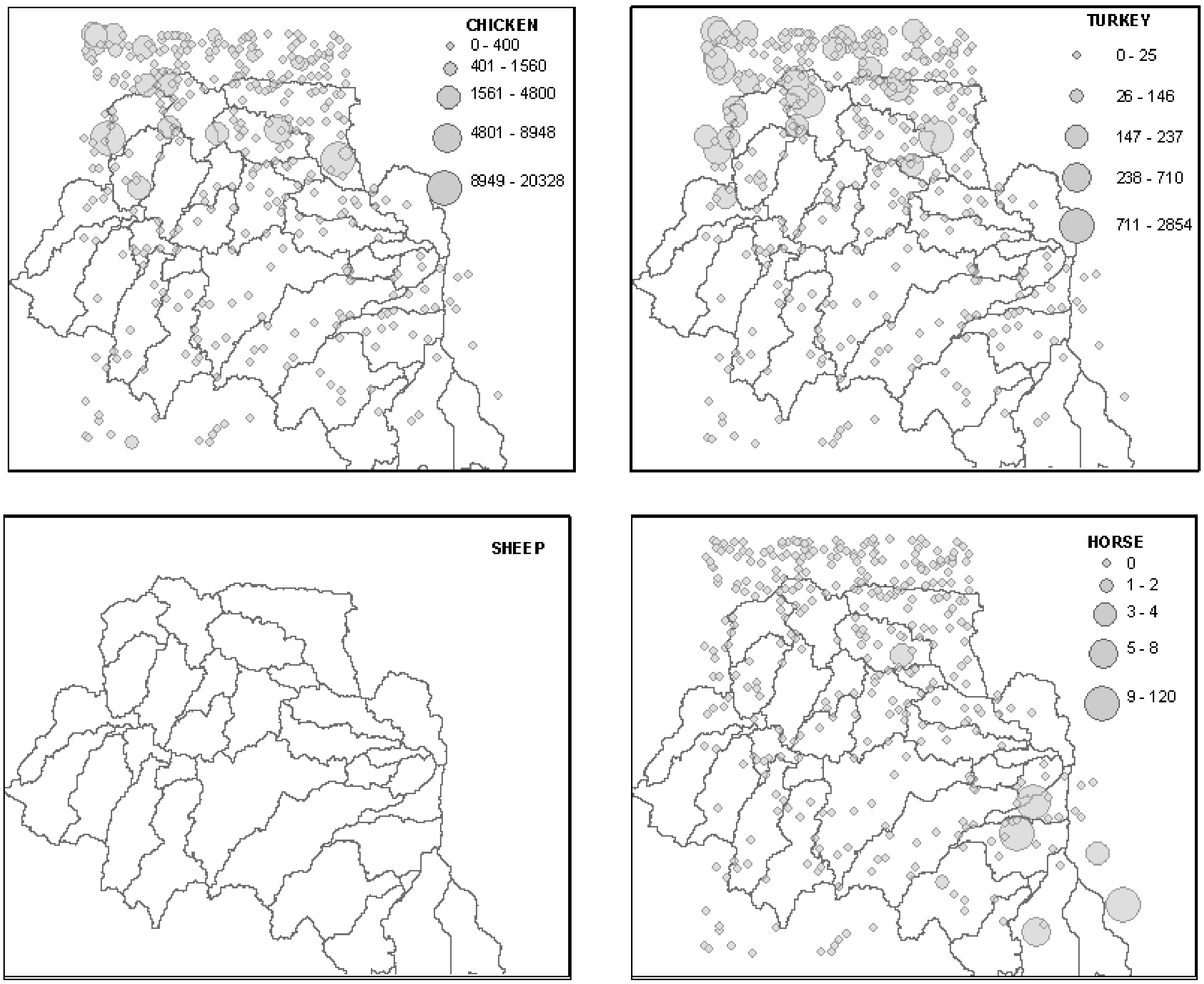


Table 4.18. Agricultural management scenarios assigned to sub-units (SWAT basins) within each assessment unit. Scenarios are differentiated by crop rotation, tillage type, manure type, and relative rate of manure application.

AU	AU (upstream)	SWAT Basin#	Subbasin Characteristics		
			CROP[a]	**TILLAGE**[b]	**MANURE ASSIGNMENTS (by HRU)**[c]
05080001-090	headwater	1	CSW	till (corn)	chickenC=2,3 swineB=1
		2	CS	till (corn)	swineB=1,2 chickenA=3,4
		5	CS	till (corn)	swineD=1 chickenB=2
		6	CSW	till (corn)	swineB=all HRUs
		9	CS	till (corn)	swineD=2,4 dairyB=1,3
		10	CSW	till (corn)	swineB=all HRUs
		8 (outlet)	CSWG	till (corn)	dairyD=2 swineD=1 beefA=3
05080001-100	-090	3	CSWG	no-till (corn)	swineE=1 dairyD=3 beefC=2
		4	CSWG	no-till (corn)	dairyE=1 swineD=2
		7	CSWG	no-till (corn)	swineC=1 dairyB=2,3,4
		15	CSWG	no-till (corn)	dairyC=2 swineB=1
		16	CSWG	no-till (corn)	swineA=all HRUs
		17	CSWG	till (corn)	dairyB=2,3 swineB=1,4
		18	CSWG	till (corn)	none assigned
		20 (outlet)	CSWG	till (corn)	none assigned
05080001-110	headwater	11	CSW	till (corn)	dairyB=2 swineA=1
		12	CS	till (corn)	dairyA=all HRUs
		13	CS	till (corn)	none assigned
		14	CS	no-till (corn)	dairyA=all HRUs
		21	CS	no-till (corn)	swineC=3,4 dairyB=1,2
		22	CS	no-till (corn)	swineB=1,2 dairyB=3
		23 (outlet)	CS	no-till (corn)	none assigned
05080001-120	-110	24	CS	till (corn)	swineC=1 dairyB=2,3
		33	CS	till (corn)	dairyD=1,3 swineC=4 beefA=2
		19 (outlet)	CS	till (corn)	none assigned
05080001-130	-100	25	CS	till (corn)	swineC=1 dairyB=2
	-120	26	CS	till (corn)	beefB=1 swineA=2
		34	CS	till (corn)	dairyC=1,2
		27 (outlet)	CS	till (corn)	dairyC=2 beefA=1
05080001-140	-130	28	CS	till (corn)	none assigned
		29	CS	till (corn)	dairyB=3 swineB=1,2
		30	CS	till (corn)	swineA=all HRUs
		31	CS	no-till (corn); till (corn)	none assigned
		32	CS	till (corn)	none assigned
		35	CS	till (corn)	none assigned
		36 (outlet)	CS	till (corn)	none assigned

Notes:

(a): Crop rotation defined by: CS (corn-soybean), CSW (corn-soybean-corn-soybean-winter wheat), and CSWG (corn-soybean-winter wheat-grass-grass-grass-grass).

(b): All soybean, winter wheat, and perennial grass completed in no till method.

(c): Manure assignments distributed across multiple HRUs within each basin. All manure considered fresh manure. Format defined as: {manure_type: chicken|swine|dairy|beef} {rate or intensity of application: A|B|C|D|E}={HRU #: 1|2|3|4}. For intensity of application, A is lowest rate and E is highest rate within recommended guidelines.

4.4.4 On-Site Sewage Disposal

The biological assessment for the Stillwater River TMDL suggests that impairment due to causes of nutrient and organic enrichment from on-site sewage systems has occurred in the following populated communities of the drainage basin (Table 4.19).

Table 4.19. Locations of on-site sewage systems in Stillwater River TMDL basin.

Community or Region	Assessment Unit
Wayne Lakes	05080001-110
Gettysburg (Greenville Creek downstream to mouth)	05080001-120
Bradford (south of incorporation near Greenville Creek)	05080001-120
Pitsburg and Philipsburg (as part of the Ludlow Creek	05080001-140
Indian Creek at Wolf Road	05080001-100

For assessment unit 05080001-120, on-site wastewater systems were identified as a direct cause on the 1998 §303(d) list of impaired watersheds. SWAT does not explicitly model the nutrient and BOD loads from septic systems entities. Though none were chosen for this TMDL, there are several paths to model these loads indirectly within SWAT. They are:

1) For all on-site systems except those that have ponding at the surface, model the system outflow as a steady-state daily load (similar to a WWTP discharge);

2) For ponded on-site systems (note this is considered a failed system), model the system by adding a daily fertilizer/irrigation application. The existing SWAT source code only allows this scenario to occur during the growing season so source code would need to be modified to allow this scenario to continue daily throughout the year.

A direct (and ideal) approach for modeling septic system loads considers the combination of SWAT with a deterministic groundwater flow model, such as the USGS MODFLOW. Through this combination, the long delay times of septic loads through groundwater flow paths can be simulated. And further, a complete mass-balanced groundwater component can be simulated. However, building a model hybrid of this type was beyond the scope of this TMDL effort. Hence, other solutions were sought to characterize the nutrient component of on-site sewage systems.

Alternatively, the GWLF (Generalized Watershed Loading Function; Haith et al 1992) model can generate empirical estimates of daily total nitrogen and total phosphorus loads from septic systems. GWLF represents septic system types as: (1) normal, (2) short-circuited, (3) ponded, and (4) direct discharge. The latter three characterizations are considered “failed” septic systems. The approach used in this TMDL combines GWLF empirical equations for normal and failed systems with a GIS-based procedure for determining the actual numbers of either system within each assessment unit. Informal polls taken from the septic system workgroup of this TMDL suggest that 80-90% of all systems in Miami and Darke counties are failing systems. Estimates

of nutrient load are derived from equations and per capita loading estimates in the following table (Table 4.20).

Table 4.20. Estimation of nutrient loads from on-site sewage disposal.		
Equation[ab]		**e=Mass Loading**
Total Phosphorus (non-phospate detergents)		
$DS_{n.p} = a * d_m * (e - u_p)$	Functioning	1.5
$DS_{n.p} = a * d_m * e$	Failing	1.5
$NO_2^- + NO_3^-$		
$DS_{n.n} = a * d_m * (e - u_n)$	Functioning	1.0
$DS_{n.n} = a * d_m * e$	Failing	1.0

Notes:

Assumes septic system loads are entirely in dissolved form.
Parameters include a = human population for a given month, d_m = number of days in a given month, and u_x = plant uptake (generally grasses) occurring over months March through October (u_p = 0.4 g/d and u_n = 1.6 [g Total N] / (12/1) [Total N:NO_2^-+NO_3^-] = 0.13 g/d). Values of u_p and u_n taken from Reed et al. (1988).
Estimate taken from USEPA design manual for on-site wastewater treatment and disposal systems (EPA 625/1-80-012; Table 4-3).

The GIS-based procedure operates in a grid-cell environment to determine whether a system is functioning or failing (Appendix IV). Once these numbers are totalled by grid units, they are accumulated to the assessment unit to generate a total load. The decision on whether a household uses on-site (septic) or alternative (community treatment system) was based on a 1990 US Census Bureau parameter by block group – type of sewage system[2]. Then the number of people using a septic system was determined by US Census 2000 block group data on average size of household and number of households. We then considered several geographic factors that might predict whether the septic system was functioning or failing – age of house, soil permeability, and soil drainage class (Appendix IV). Older houses are likely to have systems that were installed prior to newer county-based health department codes whereas soil flow properties affect the residence time of septic system leachate in the soil profile. Though not considered here, size of lot may help determine likelihood of failure where smaller lots yield smaller leach fields.

Based on this geographical analysis, we summarize our results with charts and maps showing the distribution of septic systems within each assessment unit when considering total functioning and failed, total failed, and total normal. Then to examine the prevalence of failed systems (Figure 4.12), we show the distribution of failed systems as a percentage of total within each assessment unit. In summary, the larger (area) assessment units have the highest total number of septic systems ("more land means more households"); however, the smaller assessment units

[2]The 2000 US Census no longer includes a parameter for describing type of sewage system. However, we believe our use of 1990 data was reasonable because we sought to estimate load from failing systems. Failing systems are most likely to have the greatest age and thus would be identified in a census conducted 10-12 years ago (i.e., the 1990 census). Surveys from nearby Loramie Creek watershed suggest that 87% of all systems are older than 20 years and 71% of all systems have failed functional requirements.

(05080001-090 and 05080001-100) have the highest relative number of failed systems (Figures 4.13a–4.13b).

The geographical pattern of nutrient loading generally follows the pattern of percent failure described above. The highest (per area) NO_2^-+NO_3^- and total phosphorus loads occur in 05080001-120, 05080001-130, and 05080001-140 assessment units (Figures 4.14a–4.14b). Numerical values of loads from on-site sewage systems are identified in Tables 4.12c (total phosphorus) and 4.15c (NO_2^-+NO_3^-) by assessment unit and season of year. Existing loads are also depicted in Figures 4.5 and 4.8, respectively.

Figure 4.12. Distribution of number of people using failed on-site sewage disposal systems according to SWAT model sub-basin. Shading represents the estimated total number people using a failed system per sub-basin unit: light grey= 0-500, medium grey= 500-1000, and dark grey= 1000-1650.

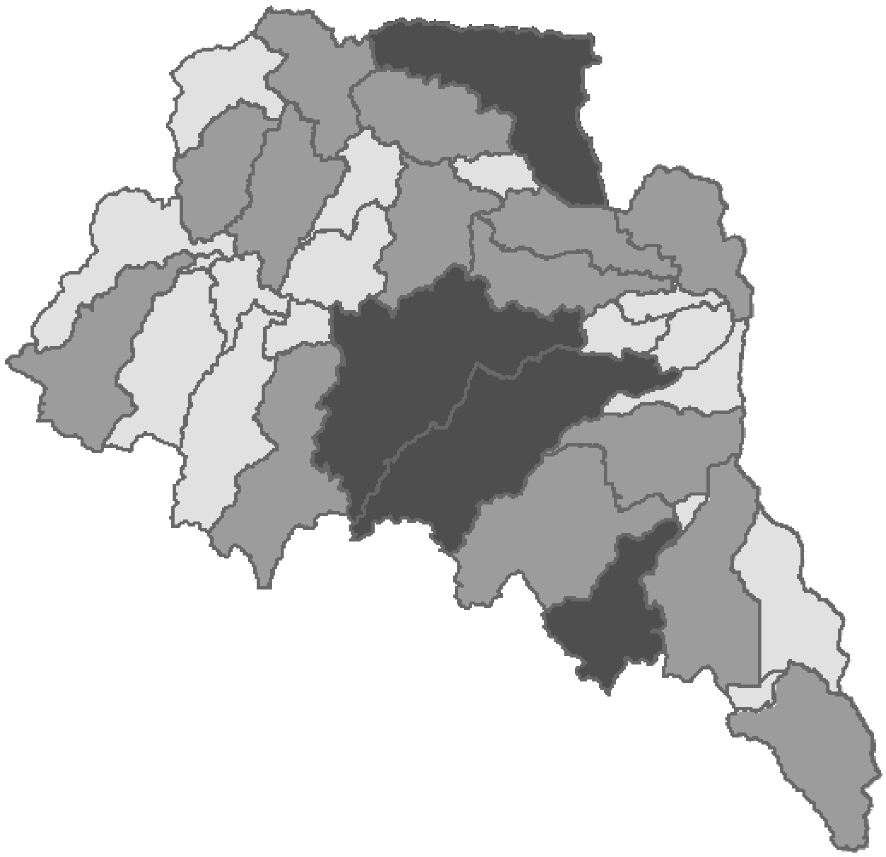


Figure 4.13a. Distribution by number of people using on-site sewage disposal in each of the six assessment units in each of three classes – all septic systems (total), normal functioning septic systems (normal), and malfunctioning septic systems (fail).

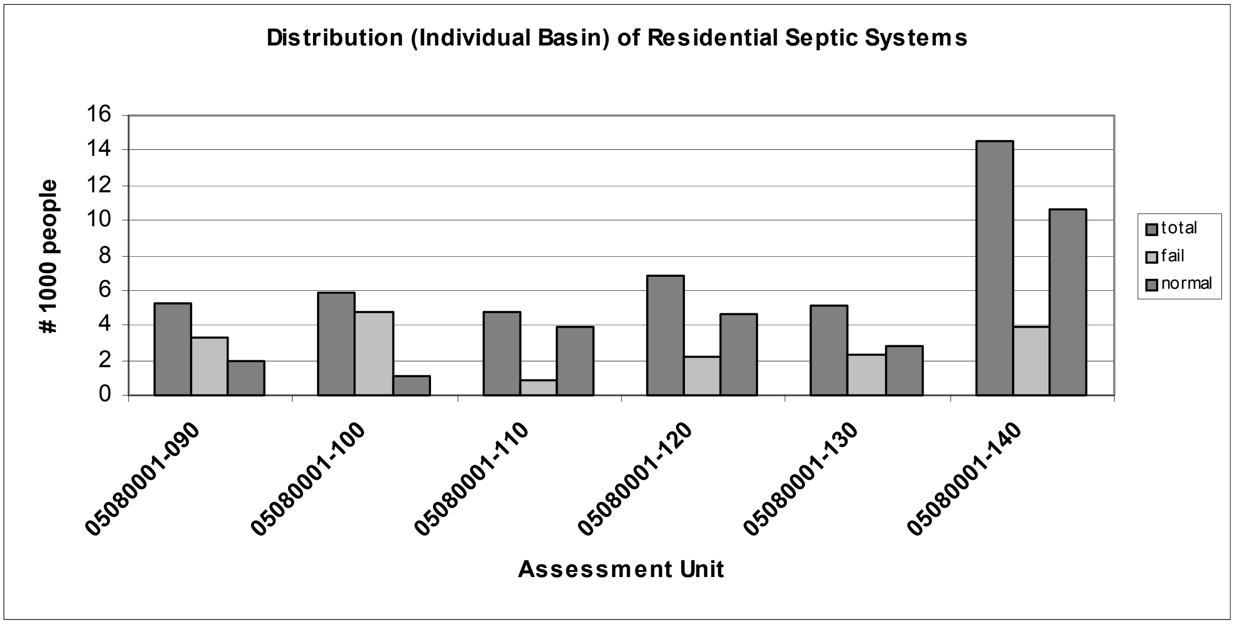


Figure 4.13b. Distribution by percent malfunctioning on-site sewage systems (#failed / #total) in each of the six assessment units.

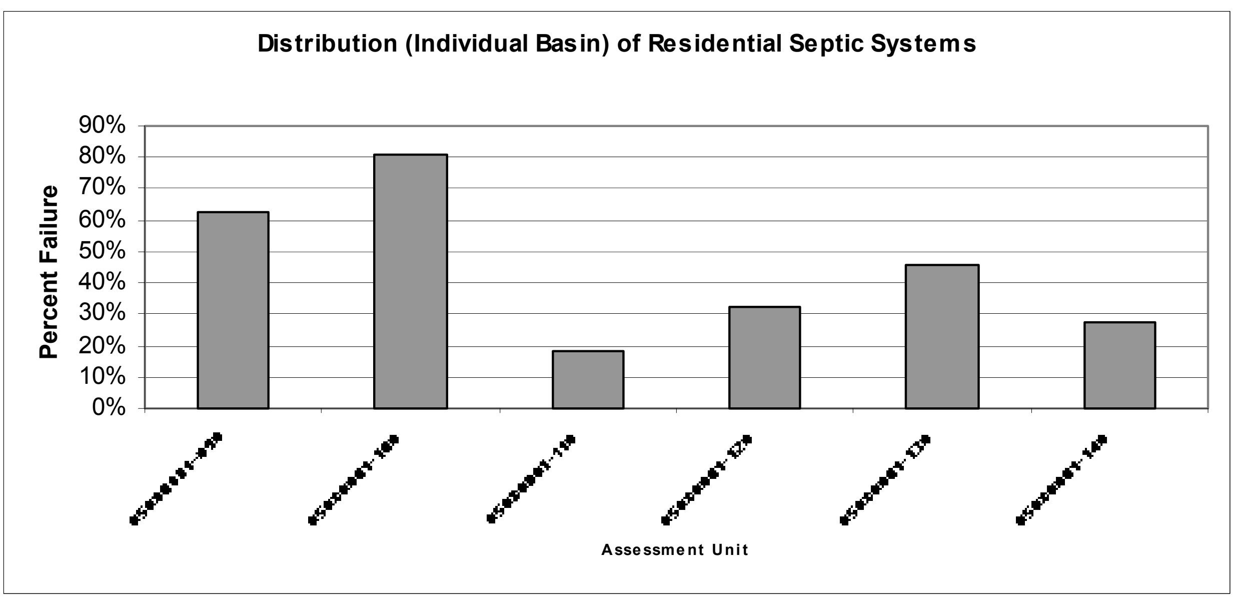


Figure 4.14a. Distribution of $NO_2^- + NO_3^-$ load estimated from on-site sewage disposal systems as an areal yield for each season.

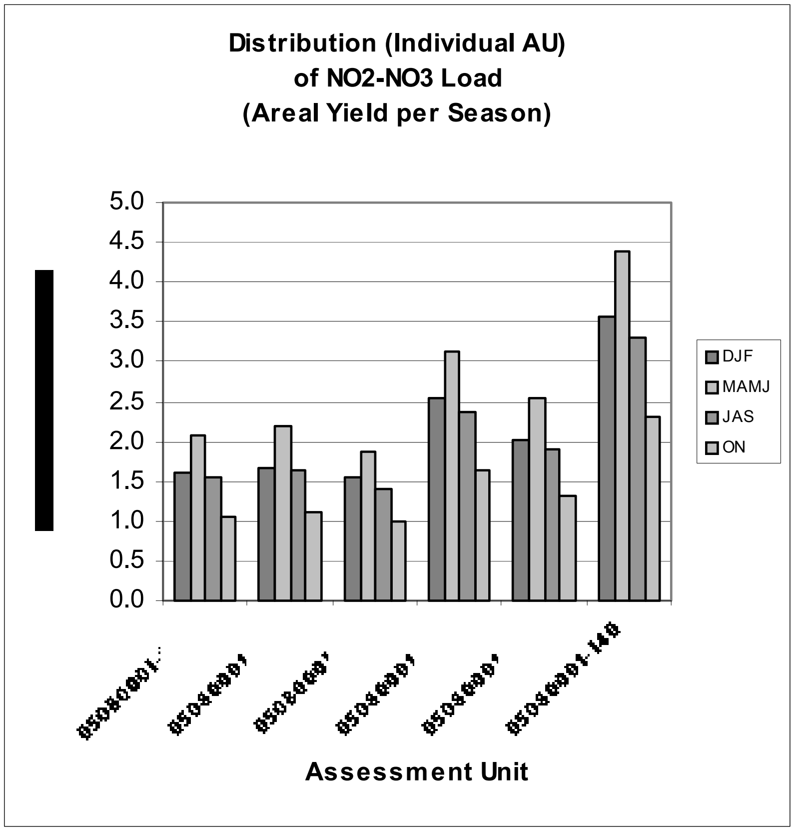
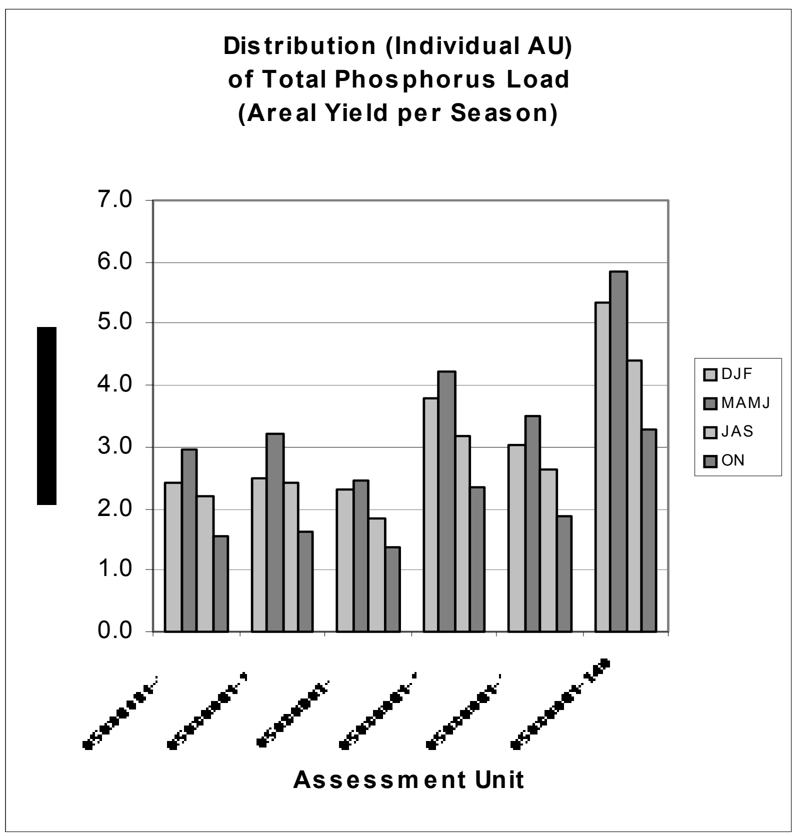


Figure 4.14b. Distribution of total phosphorus load estimated from on-site sewage disposal systems as an areal yield for each season.



The reduction in loading amounts for on-site sewage disposal systems were determined on an equal percentage basis (as in the non-point source/agriculture fertilizer sector). Load allocations for on-site sewage are identified in Tables 4.14c (total phosphorus) and 4.17c (NO_2^-+NO_3^-). Comparisons to other sectors are shown in Figures 4.7c-f and 4.10c-f, respectively for total phosphorus and NO_2^-+NO_3^-.

4.4.5 Stormwater

An assessment of the nutrient contributions from identified stormwater-generating communities was made in this TMDL. Table 4.21 lists those jurisdictions required to meet stormwater discharge guidelines under the Small Municipal Separate Storm Sewer System (MS4) program (i.e., Phase II). All of the jurisdictions are located in assessment unit 05080001-140 (the furthest downstream at the mouth of the Stillwater River drainage basin).

Table 4.21. Jurisdictions responsible for stormwater management under the MS-4 program.

Jurisdiction	Category - MS4	Area (sq.mi)	Assessment Unit
Miami County	Baseline	3.00	05080001-140
Village of West Milton	Baseline	3.00	05080001-140
Union Township (Miami Co)	Baseline	5.68	05080001-140
Montgomery County	RDW	1.00	05080001-140
Union City	Baseline	2.00	05080001-140
Vandalia City	Baseline	11.00	05080001-140
Englewood City	RDW	2.50	05080001-140
Clayton City	RDW	7.00	05080001-140
Butler Township (Montgomery Co)	Baseline	11.20	05080001-140
	Total Area	46.38	

Nutrient loads for each jurisdiction were determined from Horner et al. (1994) cited under *USEPA guidance for nutrient TMDLs* (USEPA 1999). Yields (as measured as total mass per area per year) for various land uses were used to determine the actual load generated for each jurisdiction (Table 4.22); each jurisdiction was assumed to comprise a percentage of each of the five land use types (see last column on right in Table 4.22). Thus, a weighted-average yield was computed for each jurisdiction based on the estimated land use distribution below. To account for the NO_2^-+NO_3^- portion of total nitrogen, the minimum yield of the distribution of total nitrogen yields from Horner et al. (1994) was applied. The median yield of the distribution of total phosphorus yields from Horner et al. (1994) was applied to generate total phosphorus loads.

Table 4.22. Nutrient yields corresponding to various urban/suburban land use types (from Horner et al. 1994).

Land Use	Total Phosphorus (kg/ha/y) Median	NO_2^-+NO_3^- (kg/ha/y) (as Total Nitrogen) Minimum	Percent Occupying Jurisdiction
roadway	1.10	1.3	5
commercial	0.80	1.6	35
single-family low density	0.55	3.3	15
single-family high density	0.65	4.0	25
multi-family residential	0.70	4.7	20

Based on estimated yields depicted in Table 4.22 and jurisdictional areas in Table 4.21, the total load generated by the stormwater sector of the TMDL for each assessment unit (in this case only assessment unit 05080001-140 contains non-zero loads) is summarized by season of year in Tables 4.12d (total phosphorus) and 4.15d (NO_2^-+NO_3^-). Existing loads are also depicted in Figures 4.5 and 4.8, respectively. The reduction in loading amounts for this same sector were determined on an equal percentage basis (as in the non-point source/agriculture fertilizer sector). Allocations for the municipal stormwater sector, considered as a wasteload category (or WLA), are identified in Tables 4.14d (total phosphorus) and 4.17d (NO_2^-+NO_3^-). Comparisons to other sectors are shown in Figures 4.7c-f and 4.10c-f, respectively for total phosphorus and NO_2^-+NO_3^- .

4.4.6 Summary of Requested Load Allocations

Load allocations are summarized graphically based on the numerical load allocations in Tables 4.14a–4.14d and 4.17a–4.17d, for the entire drainage basin in Figures 4.15a and 4.15b as a percentage of the total nutrient allocation. Further, a similar comparison of load allocations for the spring-early summer season (MAMJ) is made between a headwater assessment unit (05080001-090) and the assessment unit at the basin mouth (05080001-140) for both nutrient species in Figures 4.16a and 4.16b.

The following general statements can be made about this TMDL analysis:

1) The goal of is analysis, in employing a deterministic water quality model, was to provide refined numerical load allocations over geographic space and time. In this report, load allocations are distributed by season of year and by assessment unit, including an allocation for the entire drainage basin.

2) Expressed as a percentage and magnitude of the TMDL, the non-point source discharge (agriculture fertilizer) is allocated the highest magnitude load for each of the seasons, for each of the assessment units, and for the total basin allocation.

3) Exceedence of total phosphorus goals occurs almost all of the time (except late summer) whereas exceedence of NO_2^-+NO_3^- goals rarely occurs. This results in significant

percentage reductions of total phosphorus loads for all sectors for all seasons, and for the each of the assessment units.

4) However, percentage reductions for NO_2^-+NO_3^- loads are small or even negative, which could be wrongly interpreted as a potential loading increase. We caution that the NO_2^-+NO_3^- load allocations not be viewed as allowable increases, and therefore we have re-assigned all negative percentage reductions to zero (Tables 4.17a--d) and maintained an unallocated portion of the NO_2^-+NO_3^- load (Table 4.16c; Figures 4.15b and 4.16b) as a margin of safety (see Section 4.3) for the following reasons:

   a) Given the co-occurrence of phosphorus and nitrogen, it is unlikely that total phosphorus can be reduced in the load allocation (LA) portion of the TMDL while NO_2^-+NO_3^- can be increased or even maintained;

   b) We believe that keeping a portion of the NO_2^-+NO_3^- load as unallocated for a margin of safety is warranted because we globally assigned a warmwater habitat (WWH) NO_2^-+NO_3^- target to the TMDL, whereas the Stillwater River and Greenville Creek segments have exceptional warmwater habitat (EWH) use designations;

   c) Several segments of the Great Miami River (GMR) downstream from the Stillwater River basin are listed as nutrient impaired, and the Clean Water Act states that downstream uses must be protected. The general TMDL approach that Ohio has taken is to work first in headwater basins with the intent of alleviating loads to downstream reaches of larger streams prior to TMDL development for those larger streams [*e.g.*, TMDLs for the upper Little Miami River, Sugar Creek (Tuscarawas headwaters), upper Sandusky River, and Sunday and Monday Creek (Hocking River headwaters) are such examples]. Given that portions of the GMR downstream from the Stillwater basin are impaired by nutrients, nutrient reductions from upstream contributors (i.e., those in the Stillwater River basin) are likely to be required in the future; and lastly,

   d) The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (2001) has recommended that a 40 percent reduction in total nitrogen loads to the Gulf is necessary to return to pre-1970 conditions, and that an estimated 20-30 percent reduction is minimally needed to increase bottom-water dissolved oxygen concentrations between 15 and 50 percent. The GMR is one of the larger nutrient load sources to the Mississippi River basin.

5) It seems counter-intuitive to have the NO_2^-+NO_3^- goal rarely exceeded while observing widespread hyper-eutrophy in numerous tributary drainages. Why is the NO_2^-+NO_3^- goal rarely exceeded then? We may consider that all generated NO_2^-+NO_3^- load is utilized by terrestrial plant growth. *Or the target concentration may in fact be too lenient.* NO_2^-+NO_3^- target concentrations were based on the accepted 10:1 ratio to total phosphorus targets. Perhaps this ratio is too large and the TMDL for NO_2^-+NO_3^- should be smaller. The other aspect of non-exceedence is that the estimate of background concentrations for NO_2^-+NO_3^- may be too small as well; when the background load is small, the remaining load for allocation is high.

6) Because available treatment technology determines limitations of wastewater effluent loads, total phosphorus load allocations for this sector were set independently of other stressors (i.e, agriculture fertilizer, stormwater, and on-site sewage) existing in the watershed. However, NO_2^-+NO_3^- load reductions for the wastewater community were established on an equal percentage basis with the other three sectors.

Figure 4.15a. Total phosphorus load allocations for each sector over the four seasons of the year. Allocations are for the entire drainage basin. 100 percent of the circle is the TMDL for total phosphorus for a particular season. (Sector Codes: NatBack = natural background, WWeff = wastewater effluent, MunStorm = municipal stormwater, AgFert = agricultural fertilizer, OSsewer = onsite sewage system, and UnAlloc = un-allocated)

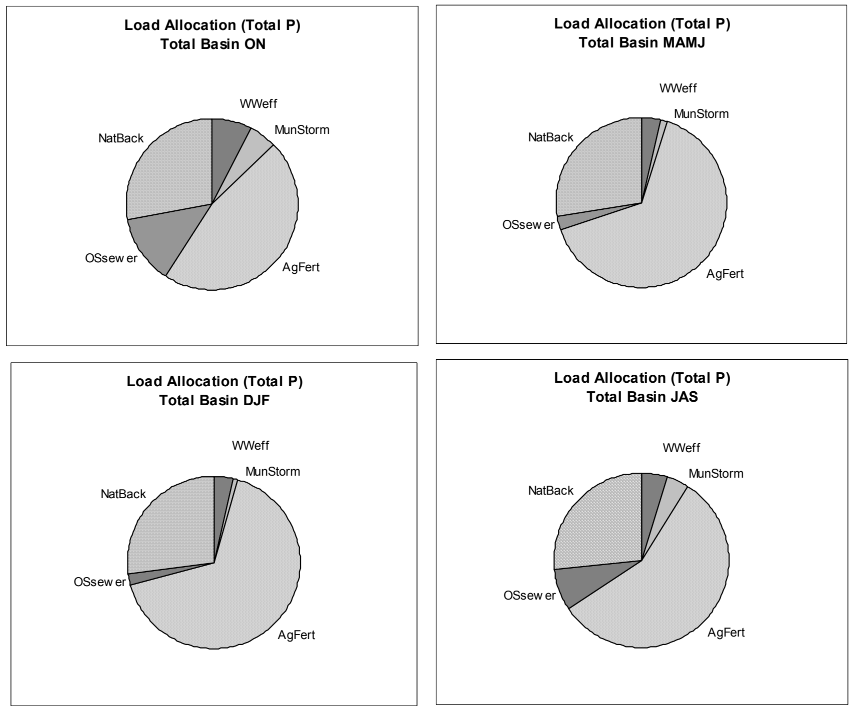


Figure 4.15b. NO_2^-+NO_3^- load allocations for each sector over the four seasons of the year. Allocations are for the entire drainage basin. 100 percent of the circle is the TMDL for NO_2^-+NO_3^- for a particular season.

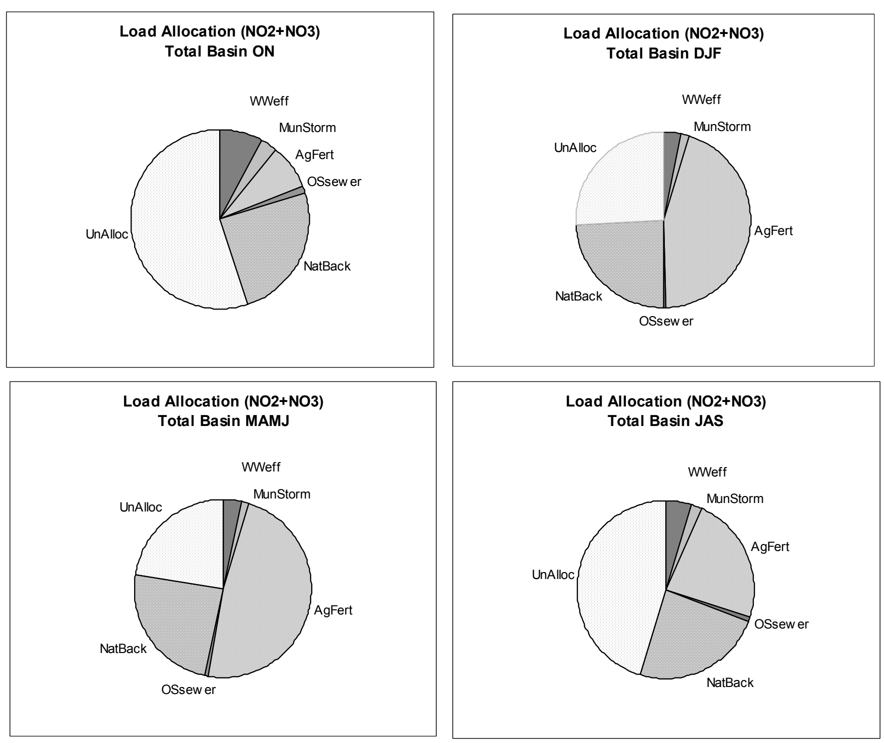
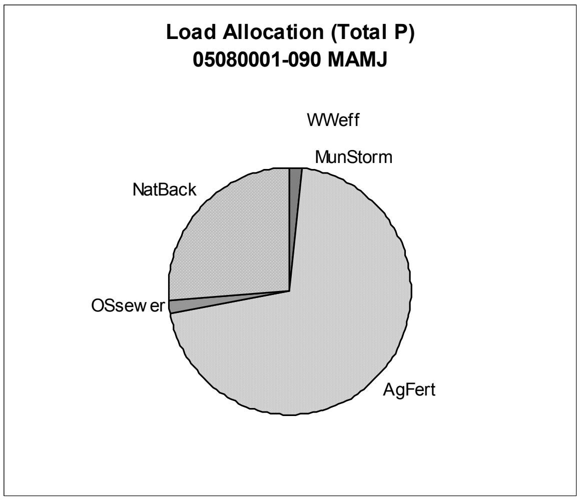


Figure 4.16a. Comparison of total phosphorus load allocations for each sector between assessment units 05080001-090 and 05080001-140 for the period MAMJ (spring-early summer). (Sector Codes: NatBack = natural background, WWeff = wastewater effluent, MunStorm = municipal stormwater, AgFert = agricultural fertilizer, OSsewer = onsite sewage system, and UnAlloc = un-allocated)



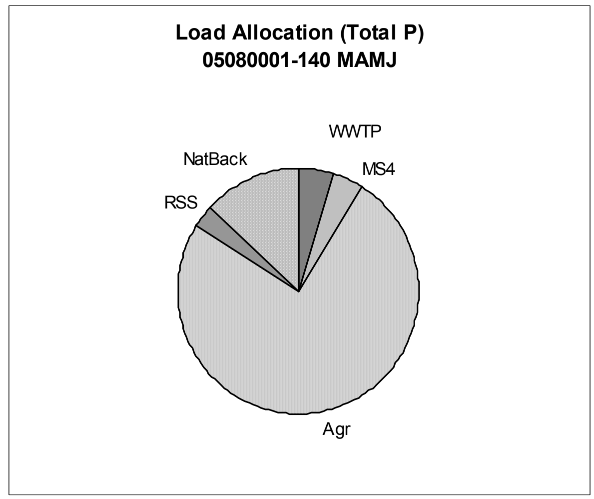
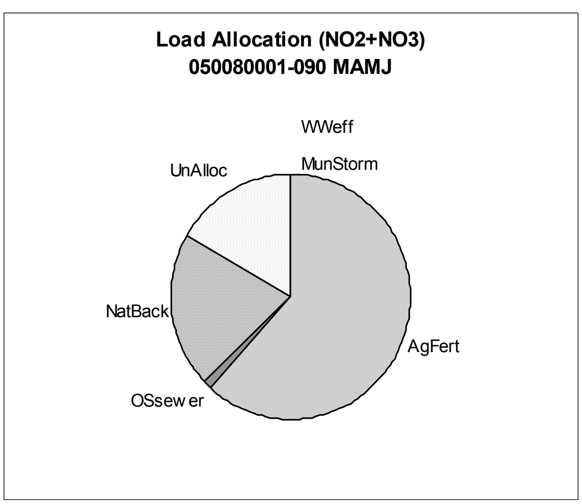
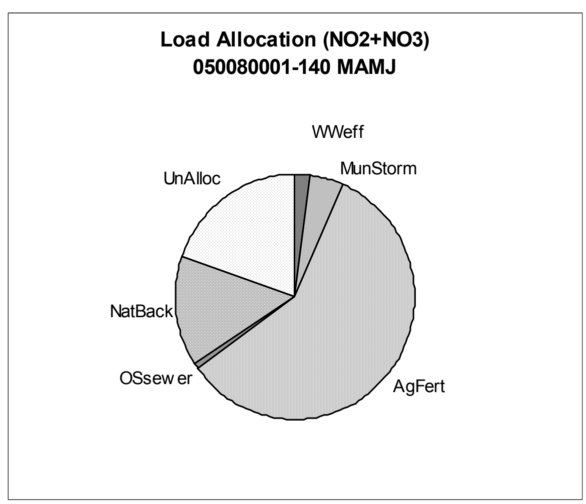


Figure 4.16b. Comparison of $NO_2^- + NO_3^-$ load allocations for each sector between assessment units 05080001-090 and 05080001-140 for the period MAMJ (spring-early summer).





4.5 Habitat Quality for the Support of Designated Aquatic Life Uses

Most of the small tributaries (< 20 mi^2) in the Stillwater River basin, including those to Greenville Creek, and the headwaters of larger tributaries (Ludlow Creek and Painters Creek) have been modified into an agricultural drainage network through ditching and dredging. Consequently, the headwaters lack habitat attributes typical of natural, warmwater streams. Channelized streams, that is those that have been either straightened or "dipped" (see photos below) become, by design, simplified drainage conveyances, and therefore lack habitat features required to support a diverse fish community. Besides the immediate physical destruction of stream habitat, channelization also destabilizes the stream channel and increases bank erosion. Bank erosion leads to increased sedimentation and contributes more to sediment bed-load than over-land erosion (Figure 4.17; right panel). Also, because channelized streams expedite drainage, and typically drain land that is tiled for drainage, residual base flow is often very low. The streams that most typify these conditions are the entire Swamp Creek subbasin and the catchment upstream from Ansonia, including the North Fork. Channelization for agricultural drainage is sanctioned and streams so altered are given a Modified Warmwater Habitat aquatic life use designation. This designation obviously has lower expectations with respect to biological criteria. However, because channelized streams export sediment and nutrients downstream, and impair downstream aquatic life and other beneficial uses, targets for the minimum level of habitat quality are warranted to preserve downstream beneficial uses. In general, modified streams should have QHEI scores of at least 45, and no more than two high-influence attributes.

The Stillwater mainstem and the lower reaches of most larger tributaries have either not been channelized or have recovered some natural function. However, some habitat problems are rather ubiquitous, principally excessive sedimentation and sparse cover (*e.g.*, large woody debris, boulders), both the result of historic channelization, current channelization in the headwaters, and denuded riparian zones. In general, EWH designated segments should have no high-influence attributes and QHEI scores exceeding 75, and WWH designated segments should have no more than one high-influence attributes and QHEI scores above 60.

Figure 4.17. **Left panel** - a typical headwater tributary to the Stillwater River in Darke County. This stream is maintained as an agricultural drainage channel and lacks habitat capable of supporting a fish community expected for the stream size and ecoregion. **Right panel** - another maintained headwater tributary with unstable, eroding banks. Notice the amount of sediment in the stream. This stream is trying to reestablish an equilibrium with its channel. Reforesting the banks after allowing the stream to meander will result in a stable channel that provides drainage conveyance without the present sediment load.

Figures 4.18 and 4.19 show deviations from respective QHEI and high-influence habitat targets for the Stillwater River mainstem and Greenville Creek plotted by river mile. Figure 4.20 shows the Stillwater River catchment color-coded to narrative ranges of habitat quality based on QHEI scores. Figure 4.21 shows the locations where, for the respective aquatic life uses, biological criteria were not attained and the number of high-influence attributes exceeded the target for that use. High-influence attributes are those that are most strongly correlated with biological health because they represent basic functional units of stream habitat. Also, because high-influence attributes are large-scale features of the stream habitat, they are more easily and reliably observed by volunteers, watershed groups, land owners, and others in the local community. Therefore, the number of high-influence attributes are preferred as targets for habitat restoration over QHEI scores, though both are listed in Table 4.23. As a first step toward recovering functional stream habitat and reducing the number of high-influence attributes, riparian reforestation will help stabilize the stream banks and reduce sedimentation, and provide cover via rootmats, rootwads and fallen trees.

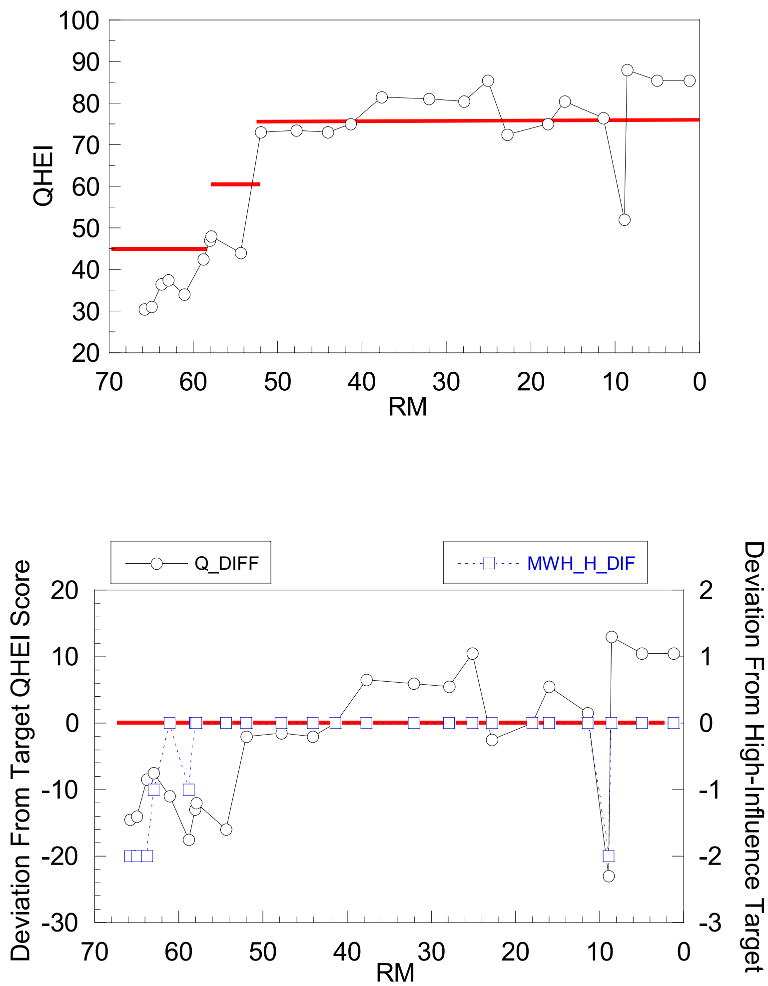
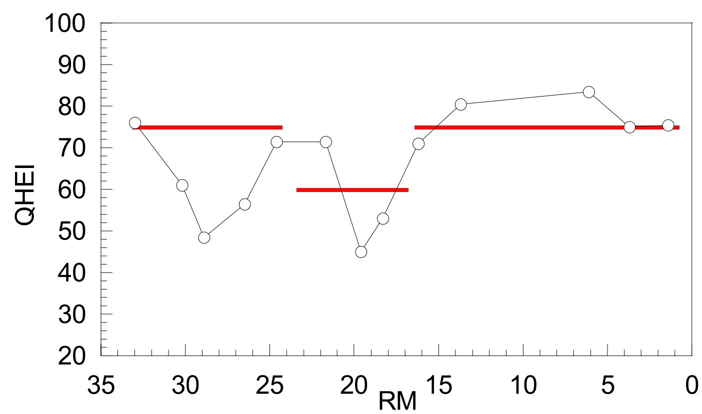


Figure 4.18. For the Stillwater River mainstem: QHEI scores and target QHEI score by river mile (**top panel**), and deviations from respective QHEI and high-influence targets (**bottom panel**).



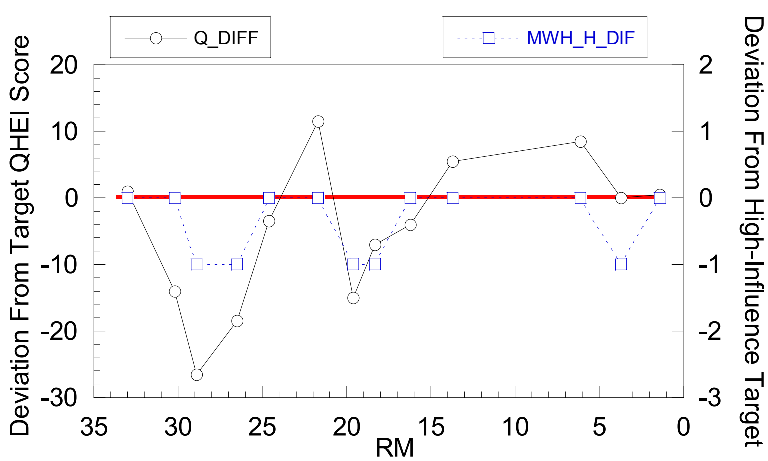


Figure 4.19. For Greenville Creek: QHEI scores and target QHEI score by river mile (**top panel**), and deviations from respective QHEI and high-influence targets (**bottom panel**).

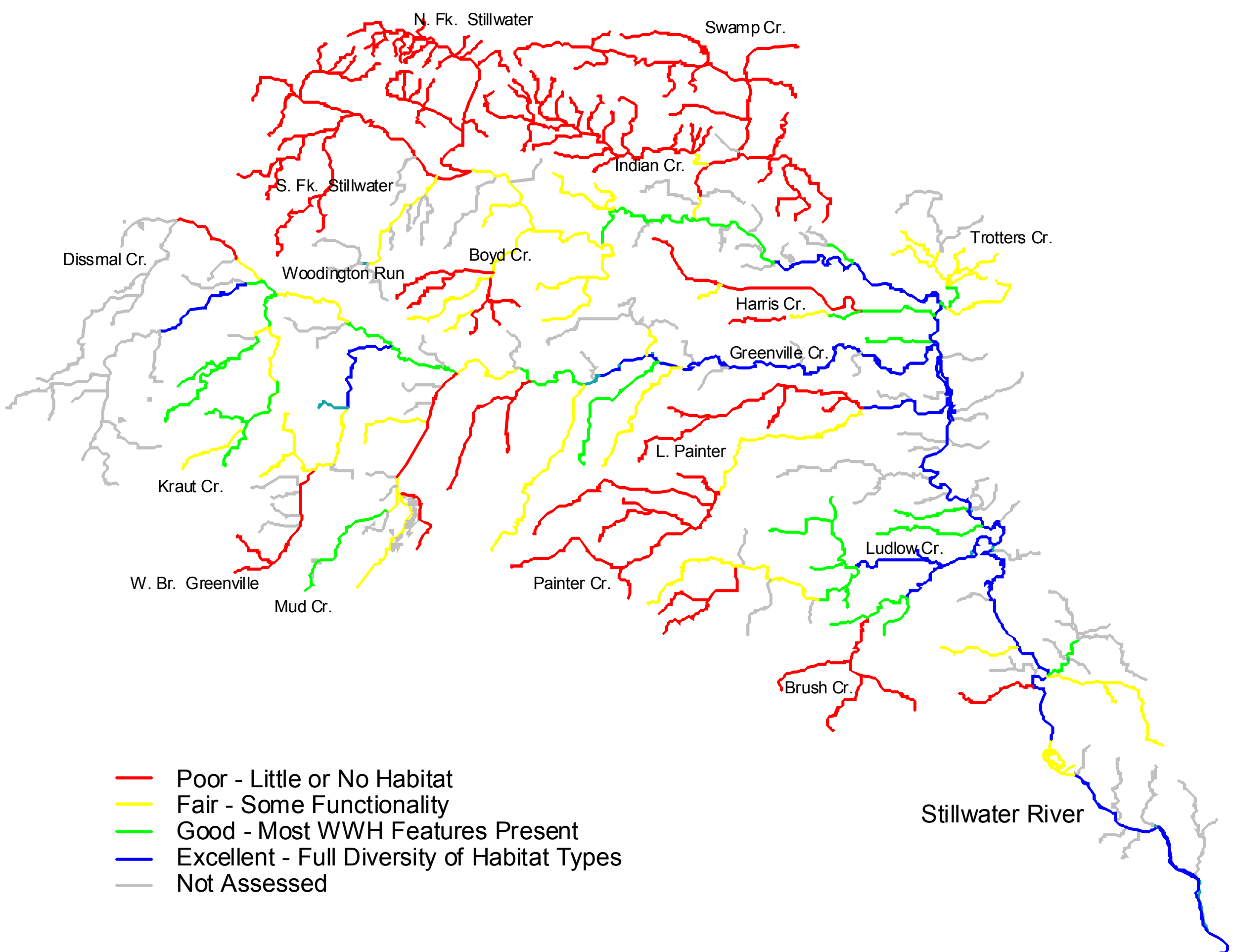


Figure 4.20. The Stillwater River drainage network color-coded by narrative ranges of habitat quality from QHEI scores.

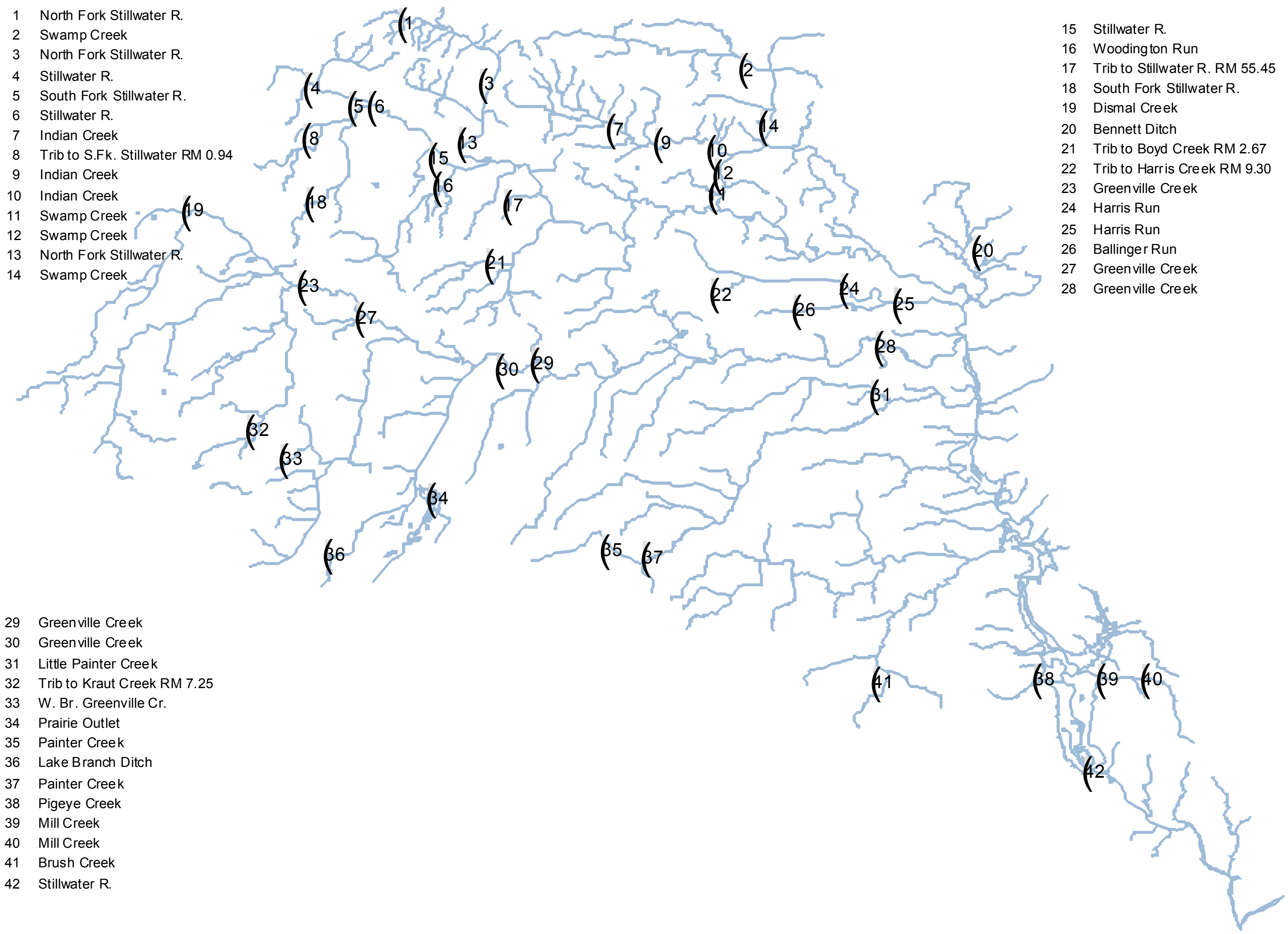


Figure 4.21. Locations in the Stillwater River basin where poor habitat quality was identified as one of the causes of aquatic life impairment.

Table 4.23. Stream locations where poor habitat quality is one factor impairing the designated aquatic life use. For each location, the observed QHEI (see text) and associated number of highly modified habitat attributes (i.e., attributes of degraded habitat) is compared to the minimum expected.

River	RM	Drainage Area	QHEI Obs	QHEI Exp	QHEI Diff	High-Influence Attributes Obs	High-Influence Attributes Exp	High-Influence Attributes Diff
Aquatic Life EWH								
Stillwater River	8.9	650	52	75	-23	2	0	-2
Greenville Creek	28.9	69	48.5	75	-26.5	1	0	-1
Greenville Creek	26.5	73	56.5	75	-18.5	1	0	-1
Greenville Creek	3.7	196	75	75	0	1	0	-1
Aquatic Life MWH								
Stillwater River	65	8.2	31	45	-14	4	2	-2
Stillwater River	63	29	37.5	45	-7.5	3	2	-1
Painter Creek	16.2	2.8	32	45	-13	4	2	-2
Painter Creek	14.7	4.6	28	45	-17	5	2	-3
Ballinger Run	2.8	3.7	30	45	-15	5	2	-3
Swamp Creek	6.5	21	34.5	45	-10.5	3	2	-1
Indian Creek	5.2	10.8	37.5	45	-7.5	3	2	-1
Indian Creek	3.1	16.4	30	45	-15	4	2	-2
North Fork Stillwater	10.5	2.1	21.5	45	-23.5	4	2	-2
North Fork Stillwater	4.4	10.5	36	45	-9	4	2	-2
North Fork Stillwater	0.4	18.3	32.5	45	-12.5	3	2	-1
Trib. to Boyd Creek (RM 2.67)	0.5	3.4	25.5	45	-19.5	4	2	-2
Trib. to Stillwater R. (RM 55.45)	0.8	0.8	46.5	45	1.5	3	2	-1
Trib. to S.Fk. Stillwater (RM 0.94)	1.6	3.4	28.5	45	-16.5	5	2	-3

Table 4.23. (continued)

River	RM	Drainage Area	QHEI Obs	QHEI Exp	QHEI Diff	High-Influence Attributes Obs	High-Influence Attributes Exp	High-Influence Attributes Diff
Aquatic Life WWH								
Stillwater River	58.8	51	42.5	60	-17.5	2	1	-1
Pigeye Creek	0.6	5.9	36	60	-24	3	1	-2
Mill Creek	2.6	3.1	46.5	60	-13.5	4	1	-3
Mill Creek	1.2	5.5	57	60	-3	3	1	-2
Little Painter Creek	0.4	11.6	43.5	60	-16.5	2	1	-1
Brush Creek	7.1	4.8	40.5	60	-19.5	3	1	-2
Harris Run	3.8	10.4	31	60	-29	3	1	-2
Harris Run	2	17	57.5	60	-2.5	2	1	-1
Greenville Creek	19.6	140	45	60	-15	2	1	-1
Greenville Creek	18.3	142	53	60	-7	2	1	-1
Prairie Outlet	0.8	2.8	39.5	60	-20.5	5	1	-4
W. Br. Greenville Cr.	10.2	2.6	37	60	-23	4	1	-3
Dismal Creek	3.8	14.2	44	60	-16	3	1	-2
Swamp Creek	2.9	38	39.5	60	-20.5	2	1	-1
Swamp Creek	2.3	58	34	60	-26	3	1	-2
Swamp Creek	2	58	43	60	-17	2	1	-1
Indian Creek	0.5	19.8	47	60	-13	2	1	-1
Woodington Run	1.1	10.1	50.5	60	-9.5	2	1	-1
South Fork Stillwater	5.5	3	30	60	-30	5	1	-4
South Fork Stillwater	0.4	16.7	44	60	-16	3	1	-2
Trib. to Kraut Creek (RM 7.25)	0.2	1.3	54.5	60	-5.5	2	1	-1
Lake Branch Ditch	4.1	1.7	30	60	-30	4	1	-3
Trib. to Harris Creek (RM 9.30)	0.2	0.7	44	60	-16	3	1	-2
Bennett Ditch	0.6	1.2	55.5	60	-4.5	2	1	-1

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5.0 Public Participation

The Ohio EPA convened an external advisory group (EAG) in 1998 to assist the Agency with the development of the TMDL program in Ohio. The EAG met multiple times over eighteen months and in July, 2000, issued a report to the Director of Ohio EPA on its findings and recommendations.

Initial public outreach for the Stillwater TMDL began with the release of the *Biological and Water Quality Study of the Stillwater River Watershed* on November 7, 2000, which reported on the results from the 1999 biological and water quality survey of the basin. The first of three public meetings was held on January 25, 2001 to discuss the results from the 1999 survey, provide an overview of designated beneficial uses and water quality standards, explain the need for a Total Maximum Daily Load (TMDL) study, and encourage participation and information exchange among the watershed stakeholders. The other two public meetings were held on February 15, and March 1, 2001, both having similar objectives as the first meeting.

From the series of three public meetings, a representative cross section of stakeholders who volunteered for the TMDL workgroup were identified and brought together to discuss restoration options and an implementation strategy. The entire workgroup was subdivided into three subgroups, each assigned to work on specific causes and sources of impairment. Membership into a subgroup was assigned based on expertise or a vested interest in the outcome. The three subgroups created were Animal Waste (organic and nutrient enrichment, low dissolved oxygen), Septic (organic enrichment, low dissolved oxygen), and Drainage and Channelization (hydromodification). Each subgroup was responsible for preparing an implementation plan addressing their respective issues. A time-line and synopsis of each subgroup's efforts are detailed in Table 5.1.

The three subgroups were reconvened as a whole on December 13, 2001 to discuss the respective draft implementation plans, give an update on use designation changes, describe the water quality model being developed for the basin, and discuss how various BMPs could be used in conjunction with the model to predict water quality outcomes.

An effort toward fostering sustained community involvement in and beyond the TMDL effort was started on a second front by partnering with the Systemic Inquiry Group (SIG) of The Ohio State University's Ohio Agricultural Research and Development Center. This second front was opened because of the realization that much of the TMDL's success hinges on cultural change, the domain of sociologists. The partnership with SIG had two basic results. First, the social concerns and attitudes farmers have about water quality, land ethic and stewardship were brought to light, and techniques to work within those social constructs were explained. The most important of those techniques being Appreciative Inquiry. Briefly, Appreciative Inquiry asks of watershed residents what aspects of their community, including rivers and streams, do they most value. To help frame and elicit what is valued, Appreciative Inquiry further asks an individual to recount positive experiences in their watershed, describe what it was about those experiences that made them positive, and identify the aspects of the watershed that contributed to the positive experience. In this way people gain an intimate appreciation for their watershed and thereby seek to sustain and augment the positive aspects of their watershed, and in doing so, correct or

diminish negative aspects more or less by default. In other words, Appreciative Inquiry affects systemic change by focusing attention on the positives, a change not accomplished by a singular focus on problem identification and solution.

The second outcome from the SIG partnership was a SIG-led workshop to educate watershed coordinators and several stakeholders each from the Stillwater, Sandusky, Sugar Creek, and Wabash basins in the Appreciative Inquiry technique. SIG is currently sustaining the effort to further train watershed coordinators to independently lead Appreciative Inquiry workshops in their own respective watersheds.

As part of an effort to reconcile the existing Stillwater Watershed Plan, which was first drafted in 1993 and later revised in 1995, with the implementation plans drafted by the three TMDL subgroups, two stakeholder meetings were convened starting in August of 2002. The focus of these meeting was twofold. First, a new mission statement for the Stillwater Joint Board was drafted for consideration. Second, the individual recommendations listed in the implementation plans drafted by the three TMDL workgroups were examined, refined and augmented using local stakeholder knowledge.

Local discussions and work on a watershed action plan continued while the Ohio EPA experienced a lengthy delay in completing the water-quality model. When the model was nearing completion during early to middle 2003, Ohio EPA scheduled meetings with numerous local stakeholders to discuss results and seek comments.

Consistent with Ohio's current Continuing Planning Process (CPP), public outreach activities included a public comment period associated with the review of the draft TMDL report prior to its submittal to U.S. EPA Region 5. The draft TMDL report was public noticed for 30 days on September 17, 2002, and a copy of the report was posted on Ohio EPA's web page (http://www.epa.state.oh.us/dsw/tmdl/index.html). The comment period was extended to November 19, 2003, at the request of local stakeholders. A summary of the comments received and the associated responses is included in Appendix V.

The 1998 303(d) list public comment period, and the selection of the Stillwater River as a priority watershed for TMDL development, provided an additional opportunity for public input concerning information contained in the list (e.g., causes and sources of impairment, priority, restorability, etc.). Subsequent 303(d) lists in 2002 and 2004 have provided additional opportunities for public input.

Public involvement is the keystone to the success of this TMDL project. Ohio EPA will continue to support the implementation process and will facilitate to the fullest extent possible a watershed action plan. Ohio EPA is reluctant to rely solely on regulatory actions and strongly upholds the need for voluntary actions to bring the Stillwater River watershed into attainment with water quality standards.

Table 5.1. Stillwater River TMDL time-line of public outreach and participation.

Date	Event	Synopsis
11/17/00	Public Notice	Results from the 1999 biological and water quality study of the Stillwater River are released.
12/6/00	TMDL Organizational Meeting	Plan for public noticed meeting to solicit participation in the TMDL process.
1/25/01	Public Meeting at the Bruckner Nature Center, Troy, Ohio	The first of three public meetings to present information on the status of the Stillwater River and its tributaries, and to solicit the public for participation in the TMDL.
2/15/01	Public Meeting at the Bruckner Nature Center	The second of three public meetings to present information on the status of the Stillwater River and its tributaries, and to solicit the public for participation in the TMDL.
2/27/01	Partnering with OSU's Systemic Inquiry Group	Through The Ohio State University's Ohio Agricultural Research and Development Center, the Systemic Inquiry Group (SIG) was contacted to explore avenues for outreach to the Stillwater basin. Dr. Chet Bowling explained how Appreciative Inquiry, a sociological tool, could be applied toward fostering stakeholder participation in and beyond the TMDL experience to effect positive environmental outcomes in the basin.
3/1/01	Public Meeting at the Darke County Nature Center, Greenville, Ohio	The third of three public meetings to lay out the strategy for public involvement in the TMDL process by forming three theme-related subgroups to develop implementation plans addressing theme related causes and sources of impairment.
3/21/01	Partnering with OSU's Systemic Inquiry Group	Results of the 1999 Biological and Water Quality Survey for the Stillwater River Basin were presented to SIG, along with an overview of how Ohio EPA applies Designated Uses and Water Quality Standards to making section 305b waterbody assessments and section 303d listings.
4/3/01	Subgroups Convened; Darke County Nature Center	The three implementation subgroups are convened: drainage and channelization, residential on-site sewerage (septic), and animal waste.
4/18/01	Drainage and Channelizatoin Workgroup, Darke Co. Nature Center	Began dialogue on what the best course of action will be to address waterbody impairment associated with stream channelization. Consensus of the workgroup was that increasing the amount acreage in no-till and increasing the width and quality of grass filter strips would be the most acceptable to area farmers.
4/20/01	Animal Waste Workgroup, Darke Co. Nature Center	Discussed magnitude of the problem associated with manure runoff, identified manure management problems that could contribute to eutrophication, also suggested that residential septic systems are as much/more of a problem.

Table 5.1. Stillwater River TMDL time-line of public outreach and participation.

Date	Event	Synopsis
4/23/01	Septic Workgroup, Darke Co. Nature Center	Subgroup became familiarized with issues regarding home septic systems. Identified chief impediment to correcting failing systems as inability of homeowners to foot the bill. Opportunities for area-wide financial assistance are to be sought. Also, noted that educating the general public about the problem is needed.
5/2/01	Partnering with OSU's Systemic Inquiry Group	Continued dialogue with SIG on water quality problems in the Stillwater and how to effect cultural change. SIG members shared their experiences with the Sugar Creek TMDL.
5/21/01	Septic Workgroup, Brukner Nature Center, Miami Co.	Ohio EPA DEFA explained WRRSP funds for watershed restoration; 319 funding for abatement of nonpoint pollution was discussed.
5/30/01	Animal Waste Workgroup, Darke Co. Nature Center	Gained consensus on which aspects of manure/waste management needed improvement. Discussed how water quality could help predict outcome of management changes.
6/14/01	Septic Workgroup, Darke Co. Nature Center	Identified two factors limiting remediation of failing septic systems: funding, and lack of political support for health districts.
6/26/01	Drainage and Channelizatoin Workgroup, Darke Co. Nature Center	Continued discussion on which BMPs are most culturally acceptable. Outlined implementation plan.
6/27/01	Partnering with OSU's Systemic Inquiry Group	Continued dialogue with SIG about the Stillwater, but more specifically on how to generally effect cultural change in watersheds. SIG members shared their experiences with the Olentangy River and a canoe float on the Stillwater River.
7/19/01	Septic Workgroup, Bruckner Nature Center, Miami Co.	Discussed aspects of the GWLF water quality model as related to loads from septic systems
8/10/01	Partnering with OSU's Systemic Inquiry Group	Discussed avenues (funding, participatory events, education) for encouraging watershed community and stakeholder involvement and concern for water quality and environmental health. SIG suggested a watershed workshop using Appreciative Inquiry for several of Ohio's current TMDL watersheds.
8/29/01	Septic Workgroup, Darke Co. Nature Center	Estimated number of failing systems by type of failure in both Darke and Miami Counties. Discussed possibility of a creating a sewer district for Darke County.

Table 5.1. Stillwater River TMDL time-line of public outreach and participation.

Date	Event	Synopsis
8/31/01	Drainage and Channelizatoin Workgroup, NRCS, Greenville	Finalized implementation plan.
10/2/01	Septic Workgroup Brukner Nature Center, Miami County	Discussed handling and land-application of waste. Formulated a strategy to estimate and identify the number of failing systems, educate system owners about need for maintenance and environmental effects from failing systems
11/6/01	Septic Workgroup, Darke Co. Nature Center	Finalized implementation plan.
12/13/01	Subgroups reconvened; Darke County Nature Center	Implementation plans from each respective subgroup were presented and discussed. Next steps for model development were explained.
4/24/02	Partnering with OSU's Systemic Inquiry Group	Learned about the SIG plan for a watershed workshop for the Stillwater and other agricultural watersheds currently having a TMDL.
11/12/02	Partnering with OSU's Systemic Inquiry Group	Confirmed participation in the planned Appreciative Inquiry workshop.
8/5/02	Stillwater Watershed Project, plan revision	Meeting facilitated by OSU Ag. Extension with stakeholders to reconcile TMDL implementation plans drafted by the three TMDL workgroups with local knowledge of the watershed.
9/4/02	Stillwater Watershed Project, plan revision	Meeting facilitated by OSU Ag. Extension with stakeholders to take an in-depth look at BMPs/management scenarios identified in workgroup implementation plans.
1/3/03	Partnering with OSU's Systemic Inquiry Group	Finalized last minute details concerning Appreciative Inquiry workshop.
1/10/03	Partnering with OSU's Systemic Inquiry Group	Attended Appreciative Inquiry workshop. Provided education and outreach material to workshop participants.
8/22/03	Meet with Ohio Dept. of Agriculture (ODA)	Discussed TMDL model results with ODA staff. ODA suggested methods of model verification to ensure that manure applications were not "over-budgeted"
8/26/03	Presentation to Stillwater Joint Advisory Board (SWCD)	Presented results of TMDL model to members of the Stillwater Joint Board, the three TMDL workgroups and other interested stakeholders.
9/4/03	General stakeholder meeting	Presented TMDL results to stakeholders responding to an open invitation.

Table 5.1. Stillwater River TMDL time-line of public outreach and participation.		
Date	**Event**	**Synopsis**
9/4/03	Meeting with Tom Menke, Menke Consulting, Inc, and Mark Wilson, LandSteweard, Inc.	Discussed model results. Both stakeholders, especially Tom Menke, work with farmers to develop manure nutrient management plans.
9/9/03	Darke County SWCD	TMDL workgroup members reviewed model and bioassessment results and began to identify sub-areas in the watershed where implementation plans would start.
9/12/03	Canoe float	Discussed TMDL results with local landowners during a conoe float sponsored by the SWCD

6.0 Implementation Plans and Monitoring Recommendations

Restoration methods to bring an impaired waterbody into attainment with water quality standards generally involve an increase in the waterbody's capacity to assimilate pollutants, a reduction of pollutant loads to the waterbody, or some combination of both. As described in Section 2.0, the causes of impairment in the Stillwater River are primarily nutrient enrichment, sedimentation, and stream habitat degradation. Therefore, an effective restoration strategy would include habitat improvements and reductions in pollutant loads potentially combined with some additional means of increasing the assimilative capacity of the stream.

The Stillwater River Restoration Project Workgroup has developed a list of potential restoration strategies. These strategies have been screened and evaluated using selected criteria (including feasibility, acceptability, sustainability, economical, reasonable assurance, and measurability) to identify the actions to be used to achieve the TMDL restoration targets. The proposed strategies are as follows (listed in no particular order):

- Stormwater management plans
- Reduce the use of agricultural and residential fertilizers and pesticides
- Riparian buffers; agricultural erosion control (bioremediation)
- Erosion control in urban/residential areas
- Septic system management and maintenance
- Public education for appreciation of watersheds and water quality
- Increase no-till farming practices
- Point source controls - permit effluent limitations (numerical restrictions and/or BMPs)
- Limit and reuse point source discharge water
- Encourage all livestock producers to manage their operations in accordance with manure nutrient management plans
- Encourage all livestock producers to participate in the Livestock Environmental Assurance Program (LEAP)
- Develop criteria for implementation of ditch maintenance program
- Develop Home Sewage Treatment System (HSTS) plans
- Health Department manifest program for septic tank handlers
- Establish Darke County Sewer District
- Establish pilot performance standards program with 10-15 producers that links payments for best management practices to load reductions in small stream segments.

Founded in 1993 the Stillwater Watershed Project has been implementing best management practices (BMPs) for the control of erosion and nutrient runoff, purchase of conservation easements, and education within the watershed. This effort has been funded through a combination of grants from Ohio EPA (CWA Section 319), Ohio DNR (Watershed Management, Streambanking, Manure Nutrient Management, Geographic Information Systems and Watershed Coordinator), and USDA (Water Quality Incentive Program). More than $2 million have been spent within the watershed with 69% going directly to landowners for BMP installation and/or conservation easements. While the results have been noticeable in both land management and water quality much remains to be accomplished. In addition to these grants, Ohio EPA's Division of Environmental & Financial Assistance (DEFA) has established a linked-

deposit low interest loan program for agricultural equipment and practices within the watershed.

Since 2001 the project has been the recipient of a watershed coordinator grant to gradually shift personnel funding from reliance on grants to local support. As part of the grant requirements, an update of the Watershed Action Plan (WAP)is currently in development to keep the project competitive for future funding. This plan will incorporate this TMDL report and serve as a primary means of implementation for it. The draft WAP is due to be submitted for review and eventual endorsement by the end of 2003.

In 2002 the Miami County Health Department received a section 319 grant to inventory and upgrade residential septic systems throughout the county including the Stillwater watershed. One requirement of the grant was completion of a HSTS plan for the county. Another 319 grant is pending final approval for the Darke County Health Department to accomplish an inventory and assessment of all the septic systems in the Darke Co. Portion of the watershed. Once the Darke Co. HSTS plan is approved, Ohio EPA's DEFA will make arrangements for low-interest loans to be available to homeowners for septic system upgrades and repairs.

Ohio EPA is taking an iterative, adaptive approach to implementation for this TMDL project. NPDES permits will be issued such that:

- reasonable reductions of total phosphorus and instream monitoring of phosphorus and other TMDL parameters will be required;
- enough time will be incorporated into the permit process to allow for nonpoint source controls to become effective and additional data to be collected;
- trends in instream concentrations will be tracked, and the NPDES permits will include an option for permit modifications should data indicate instream total phosphorus levels have achieved stable and desirable levels or that the use designations are being fully met.

Generally, implementation of BMPs relies on voluntary and incentive programs, such as government cost-sharing. Therefore, the implementation plan should show: 1) there is reasonable assurance that nonpoint source controls will be implemented and maintained; or 2) nonpoint source reductions are demonstrated through an effective monitoring program. Long-term watershed water quality monitoring will also be important in evaluating the effectiveness of BMPs. The implementation plan will include a time schedule describing when the activities necessary to implement the TMDL will occur. This would include a schedule for issuance of NPDES permits consistent with the TMDL and a time line for implementation of BMPs and/or control actions. The plan should also contain reasonable assurances the implementation activities will occur. A draft implementation plan is included in the following section; the final implementation plan (watershed action plan) will be forwarded to USEPA as an addendum to this report.

6.1 Reasonable Assurances

As part of an implementation plan, reasonable assurances provide a level of confidence that the wasteload allocations and load allocations in TMDLs will be implemented by Federal, State, or local authorities and/or by voluntary action. The stakeholders will develop and document a list that differentiates the enforceable and non-enforceable selected actions necessary to achieve the restoration targets. Reasonable assurances for planned point source controls, such as wastewater

treatment plant upgrades and changes to NPDES permits, will be a schedule for implementation of planned NPDES permit actions. For non-enforceable actions (certain nonpoint source activities), assurances must include 1) demonstration of adequate funding; 2) process by which agreements/arrangements between appropriate parties (e.g., governmental bodies, private landowners) will be reached; 3) assessment of the future of government programs which contribute to implementation actions; and 4) demonstration of anticipated effectiveness of the actions. It will be important to coordinate activities with those governmental entities that have jurisdiction and programs in place to implement the nonpoint source actions (e.g., county soil and water conservation district offices, county health departments, local Natural Resource Conservation Service offices of the U.S. Department of Agriculture, municipalities and local governmental offices).

A summary of the regulatory, non-regulatory and incentive based actions applicable to or recommended for the Stillwater watershed:

Regulatory:

- basin wide phosphorus limit of 1 mg/l for NPDES discharge
- basin wide ammonia nitrogen, dissolved oxygen, and CBOD limits for NPDES dischargers
- new requirements for household sewage treatment systems (statewide requirement)
- sewage sludge disposal standards to regulate sludge application rates (statewide)
- phase I and II stormwater requirements

Non-regulatory:

- finalization of an implementation plan which includes:
  - education activities
  - stormwater management
  - septic system improvements
  - agricultural BMPs
  - stream channel restoration
- the Stillwater Watershed Joint Board of Supervisors to promote the implementation plan and other activities contributing to the goals of the TMDL project
- periodic stream monitoring to measure progress

Incentive-based:

- 319-funded projects for the entire Stillwater watershed which support the goals of this TMDL
- 319-funded (in part) watershed coordinator to promote watershed improvement activities
- various loan opportunities for WWTP, septic system, agriculture practices and riparian/habitat improvements
- a pilot program to test tying conservation payments to performance standards for reducing loads in impaired stream segments with 10-15 farmers

6.2 DRAFT Implementation Plan

The Stillwater Watershed TMDL Workgroup recognized five important strategies to focus efforts in developing an implementation plan. They are: 1) animal waste management, 2) on-site sewage management, 3) drainage and channelization management, 4) and urban issues and point source controls. Committees or "subgroups" were formed to develop implementation actions for these strategies, including actions and management measures, time lines, reasonable assurances, and monitoring plans.

Given the current capacity already present under the leadership of the Stillwater Watershed Project, and available support from University professionals, a decisional stakeholder process (i.e., the public was involved in decision making and will help implement the decisions) was utilized. 11 subgroup, and 9 public meetings were held in various locations in the watershed between January 2001-September 2003.

In the winter of 2001, 55 watershed community members attended two public meetings. The TMDL process was introduced, questions were addressed, current community capacity was analyzed, and a plan for structuring the TMDL implementation effort was established. The subgroups consisted of local stakeholders with decision-making ability in each of the focus areas including village and municipal government leaders (e.g. utilities directors, health department and land use professionals), agricultural producers and consultants, as well as soil and water conservation staff.

After the subgroups analyzed the problems to be addressed and evaluated the effectiveness of each proposed management alternative criteria were established to rank impairment stream segments. This process allowed the subgroups to "triage" impaired segments all subgroup used a social capacity criteria (i.e., willingness to participate and potential increase in scientific understanding) and then each subgroup utilized different scientific criteria based on modeling data. For example, the animal waste subgroup ranked impaired segments based on total phosphorus reduction (i.e., the greater the reduction required the higher the ranking) and the drainage and channelization subgroup used QHEI score.

This implementation plan will be incorporated into the updated watershed action plan for the Stillwater watershed which will use targets set in this TMDL and locally identified needs for restoration and protection of water quality in streams that already attain their aquatic life use expectations. The WAP will contain more specific details on the agreements reached with cooperating landowners and government officials.

Animal Waste Management

Animal waste is a significant contributor to nonpoint source pollution in the Stillwater watershed. Darke County has one of the highest concentrations of confined animal feeding operations in the state with a number of facilities covered under the ODA/OEPA permitting programs. Implementation actions include the voluntary development of manure nutrient management plans, promotion of evolving technologies for safe land application of manure, grid soil sampling of lands proposed for manure application, establishment of grassed filter strips, building of manure storage facilities according to NRCS specifications, exclusion of livestock from streams with alternate water supplies, and certification of manure applicators. Assessment

units were ranked based on total phosphorus reduction required and willingness of landowner participation.

Drainage and Channelization Management

Most, if not all, of the tributary streams in the Stillwater watershed have been channelized at some time. A significant number have been maintained in this state to allow for drainage of crop fields to maintain productivity. It is unlikely that these streams will ever achieve more than a Limited Warmwater biota. The watersheds of these streams do deliver significant amounts of sediment and nutrients to downstream segments and need to be managed to maximize the length of time between maintenance activities. Implementation actions include development of criteria for ditch management programs that assess the need for and process to be followed in maintenance, the use of newer technologies such as two-stage ditches, conservation planning to reduce sediment and nutrients entering the ditch and watershed wide stormwater control standards. .

The sub-committee is developing a ranking system for streams identified in Table 4.19 as impaired because of poor habitat quality. This system uses factors such as the deviation from expected QHEI scores, drainage area, and probability of BMP adoption by adjacent landowners to rank streams for implementation actions. The ranking exercise indicated a number of management practices have been put in place (e.g., filter strips) in impaired segments since TMDL data was collected. These sites, where landowner cooperation is available, would be make good sites for additional monitoring. The stream segments of West Branch of Greenville Creek and South Fork will be targeted for management efforts initially because of high ratings on the criteria of QHEI, drainage size, and social capacity. County and township officials will educated about innovative ditch maintenance procedures such as two-stage ditches. These same officials will be consulted on development of criteria for beginning drainage maintenance activities and the identification of particular drainage problems.

On-site Sewage Management

Septic systems impact water quality in the Stillwater River watershed through nonpoint discharges from failed, faulty, or discharging systems and improper disposal of wastes (septage) from septic systems. Implementation actions to address these sources of pollution would include oversight of septic tank waste haulers, identification of faulty septic systems, elimination of on-site septic systems through extension of municipal sanitary sewers, and public education on septic system maintenance.

The Miami County Health Department has an approved HSTS plan, is implementing a Section 319 grant and is instituting an Ohio EPA DEFA linked deposit low interest loan program. The Darke County Health Department is awaiting final approval of a 319 grant which will allow for inventory of on-site systems in the Darke Co. portion of the watershed and upgrade of some systems along with an education component. A HSTS plan for the county will also be developed to make the county eligible for the linked deposit program. The sub-committee recommends the establishment of a county wide sewer district for Darke Co. This would make it easier to extend sewers to currently unsewered areas.

Urban Issues
Urban related issues are not as major a problem in the Stillwater watershed that they are in more urbanized areas. Greenville is the only community in the Darke and Miami County portions of the watershed included in the Phase II stormwater regulations that became effective in 2003. In Montgomery County the cities of Englewood and Clayton as well as Butler and Union Townships are included. The City of Dayton has stormwater regulations enacted as part of its Phase I stormwater permit which includes the Cox International Airport. Nutrients are contributed to the river through normal permitted discharge and through discharges from combined sewer overflows (CSOs). As NPDES permits are renewed limits will be established for phosphorus and nitrogen to levels that supplement reductions from nonpoint sources. Requirements for best available control technology will be the primary mechanism used for reaching the desired limits. Three communities have combined sewers with documented water quality problems from the overflows. All of these communities have begun to or plan to begin elimination of the overflows as part of schedules established with Ohio EPA. All of the municipal sludge management plans will also be updated to meet 40 CFR 503 requirements to insure that land application of sludge does not impact on water quality.

Implementation Plans

Minimum Elements of an Approvable Implementation Plan
Whether an implementation plan is for one TMDL or a group of TMDLs, it must include at a minimum the following eight elements:

- Implementation actions/management measures: a description of the implementation actions and/or management measures needed to implement the allocations contained in the TMDL, along with a description of the effect-iveness of these actions and/or measures in achieving the required pollutant loads or reductions. (Tables 6.1, 6.5, 6.9, & 6.10)

- Time line: a description of when activities necessary to implement the TMDL will occur. It must include a schedule for revising NPDES permits to be consistent with the TMDL. The schedule must also include when best management practices and/or controls will be implemented for source categories, subcategories and individual sources. Interim milestones to judge progress are also required. (Tables 6.2, & 6.6)

- Reasonable assurances: reasonable assurance that the implementation activities will occur. Reasonable assurance means a high degree of confidence that wasteload allocations or load allocations in TMDLs will be implemented by Federal, State or local authorities or voluntary action. For point sources, reasonable assurance means that NPDES permits (including coverage under applicable general NPDES permits) will be consistent with any applicable wasteload allocation contained in the TMDL. For nonpoint sources, reasonable assurance means that nonpoint source controls are specific to the pollutant of concern, implemented according to an expeditious schedule and supported by reliable delivery mechanisms and adequate funding. (Tables 6.2 & 6.6)

- Legal or regulatory controls: a description of the legal authorities under which implementation will occur (as defined in 40 CFR 130.2(p)). These authorities include, for example, NPDES, Section 401certification, Federal Land Policy and Management programs,

legal requirements associated with financial assistance agreements under the Farm Bills enacted by Congress and a broad variety of enforceable State, Territorial, and authorized Tribal laws to control nonpoint source pollution. (Tables 6.2 & 6.6)

- Time required to attain water quality standards: an estimate of the time required to attain water quality targets. The estimates of the time required to attain and maintain water quality standards must be specific to the source category, subcategory or individual source and tied to the pollutant for which the TMDL is being established. It must also be consistent with the geographic scale of the TMDL, including the implementation actions. (Tables 6.3 & 6.7)

- Monitoring plan: a monitoring or modeling plan designed to determine the effectiveness of the implementation actions and to help determine whether allocations are met. The plan must be designed to describe whether allocations are sufficient to attain water quality standards and how it will be determined whether implementation actions, including interim milestones, are occurring as planned. The monitoring approach must also contain an approach for assessing the effectiveness of best management practices and control actions for nonpoint sources. (Tables 6.4 & 6.8)

- Milestones for attaining water quality standards: a description of milestones that will be used to measure progress in attaining water quality standards. The milestones must reflect the pollutant(s) for which the TMDL is being established and be consistent with the geographic scale of the TMDL, including the implementation actions. The monitoring plan must contain incremental, measurable milestones consistent with the specific implementation action and the time frames for implementing those actions. (Tables 6.4 & 6.8)

- TMDL revision procedures: a description of when or under what conditions a TMDL revision would be triggered. EPA expects that the monitoring plan would describe when failure to meet specific milestones for implementing actions or interim milestones for attaining water quality standards will trigger a revision of the TMDL. (Narrative)

Animal Waste Implementation Plan

Table 6.1. Description of implementation actions and measures - animal waste.

#	Implementation Actions & Management Measures	Streams Affected	Parameters Affected/Benefits	Estimated Effectiveness[1]
1	Develop manure nutrient management (MNM) plans for livestock producers.	SRW	Phosphorus, Organic Matter, Nitrogen Reduction	20-40% reductions in planned areas. Estimated 10 years
2	Promote the adoption of evolving technologies (tile plugs, flow meters, high pressure release valves, remote pump control	SRW	Phosphorus, Organic Matter (OM), Nitrogen Reduction	Highly Variable
3	Encourage all livestock producers to participate in the Livestock Environmental Assurance Program (LEAP) and On-Farm Environmental Odor Audit. Track with monitoring to determine effectiveness.	SRW	Overapplication, storage, and land stewardship	??????
4	Encourage all livestock producers to build storage facilities to NRCS specs.	SRW	Phosphorus, Organic Matter, Nitrogen Reduction	??????
5	Exclude livestock from streams and other water sources	SRW	Sediment, Organic Matter, BOD	95% reduction
6	Monitor compliance with random soil samples with cooperators	SRW	Phosphorus/Potassium /Nitrogen	100% Compliance with MNM plan
7	Establish ???? acres of new grassed filter strips per year in the watershed.	SRW	Phosphorus/OM/ N reduction	??????
8	Milkhouse Waste			
9	Certification of manure applicators			

[1] The effectiveness of actions and measures will be measured in whatever way is appropriate to that action or measure. Percent reductions of loads, buffer zones in meters or feet, conversion of acreage to fallow or forest, etc.

Table 6.2. Timeline and reasonable assurances - animal waste.

Action #	Managing Party	Schedule		Reasonable Assurance Description/Specifics	Type[1]
		Start	Finish		
1	NRCS/ SWCD	Jan. 2002	Dec. 2004	Assistance will be provided to landowners who wish or are required to have detailed management plans. Education programs will be accelerated.	Regulations Incentive Education
2	Stillwater Watershed Project (SWP)	Jan. 2002	Dec. 2003	SWP has a Ohio EPA 319 grant devoted to increasing application awareness	Funding Incentive
3	NRCS/ SWCD	Jan. 2002	Dec. 2004	ODNR, NatureWorks funding for proper storage facilities	Funding Incentive
4	OSU Extension, SWP, SWCD	Jan. 2002	Dec. 2004	Continuing education programs are available free of charge	Education
5	NRCS/ SWCD /SWP	Jan. 2002	Dec. 2004	Financial incentives are in place to encourage landowners to install fencing and reconstruct riparian corridor	Incentives
6	SWCD/ NRCS	Jan. 2002	Dec. 2004	Financial incentives are in place through 319 funding for grid soil sample	Incentives
7	NRCS / SWCD	Jan. 2002	Dec. 2004	Financial incentives are in place to encourage landowners to construct filter strips, continuing education	
8	Miami Conservancy and OSU Extension	Dec. 2003	July 2004	Begin monitoring for pilot performance standards program. Begin developing a contract that targets specific load or concentration reductions. Once base line data is developed farmers will be paid for specific load or concentration reductions	

[1] Types of assurances include legal or other regulatory actions and authority, funding, incentive programs, etc.

Table 6.3. Timeline: monitoring, tracking and implementation (see key below) - animal waste.

Action/ Milestone — Year	2004				2005				2006				2007				2008				2009	2010	2011	2012	2013
Quarter:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4					
Develop manure nutrient management (MNM) plans for all livestock producers																									
Promote the adoption of evolving technologies (tile plugs, flow meters, high pressure release valves, remote pump control																									
Encourage all livestock producers to participate in the Livestock Environmental Assurance Program (LEAP) and On-Farm Environmental Odor Audit																									
Encourage all livestock producers to build storage facilities to NRCS specs.																									
Exclude livestock from streams and other water sources																									
Monitor compliance with random soil samples with cooperators																									
Establish ???? acres of new grassed filter strips per year in the watershed.																									
Begin monitoring for pilot performance standards program. Begin developing a contract that targets specific load or concentration reductions. Once base line data is developed farmers will be paid reduce for load or concentration reductions.																									

Key: A- Action completed/installed/incorporated C- Check point to track action implementation E- Expected target attainment
M - Monitoring of indicators begins (indicators specified in monitoring plan)
V- Validation; biological survey to determine if targets are attained

Table 6.4. Monitoring plan - animal waste.

Implementation Action	Stressor, Indicator or Impairing Cause[1]	Measure	Managing Party	Desired Target (Milestones)	Location or applicable area	Frequency/ Schedule
MNM Plans (including on-going monitoring)	Nutrient levels Overapplication	Various	SWCD / NRCS OSU Extension		A ranked listing of impaired areas will be utilized to set priorities.	10 / year
Promotion of Evolving Technologies	Over-application	Various	SWCD / NRCS / Ohio EPA		All AG land	Various
Storage Facilities	Inadequate Storage	# of storage facilities	SWCD / ODA / NRCS		All AG land	Various
Education Programs	Inadequate storage / Over-application	# of producers	OSU Extension / SWP / Ohio Livestock Coalition		All AG land	Various
Livestock exclusion	Manure in streams / channel degradation	Miles Protected	NRCS / SWCD / SWP		All AG land	Various
Monitoring Compliance	Over-application	Soil Samples	NRCS / SWCD / SWP		All AG land	Various
Grassed Waterways	Over-application	# of miles protected	NRCS / SWCD / SWP		All AG land	Various
Performance Standards Pilot Program					North Fork and Canyon Rum subwatersheds	

[1] A stressor is anything that causes stress on the environment and usually refers to stress to the biology of the stream. An indicator is something that is measurable and can be used to track a condition. Often an indicator is used as a surrogate measure to track progress on something that is not as easily measured. For example, total suspended solids in the water column of a stream or the depth or type of stream substrates are both indicators of erosion. An impairing cause is any condition that is resulting in an impairment to a stream use. Abnormally high concentrations of a pollutant or lack of habitat are both considered potential impairing causes.

Drainage and Channelization Implementation Plan

Table 6.5. Description of implementation actions and measures - drainage and channelization.

#	Implementation Actions & Management Measure	Streams Affected	Parameters Affected	Estimated Effectiveness
1	Targeted Conservation Planning	All	All	
2	Develop comprehensive list and map of all stream designations - update existing list of proposed changes	All	All	
3	Develop criteria for implementation of ditch maintenance program	Currently modified and headwater streams	Habitat - flood control & logjams	
4	Education for the public and targeted education for public officials involved with drainage programs	All	All	
5	Meet with additional stakeholders to continue to prioritize impaired segments	All	All	
6.	Analyze findings from other subgroups to assess appropriate stakeholders to contact to discuss protential manaagement alternatives	All	All	
7	Gather information on impaired segments where uncertainties exist (e.g., stream side land ownership)	All	All	
8	Develop mailing list of stakeholders to discuss appropriate management alternatives	All	All	
9	Create 2-stage ditch demonstration	Southfork, West Branch of Greenville Creek		

Table 6.6. Timeline and reasonable assurances - drainage and channelization.

Action #	Managing Party	Schedule		Reasonable Assurance Description/Specifics	Type[1]
		Start	Finish		
1	SWCDs & NRCS	Ongoing	Ongoing	Goals: - 60% conservation tillage on non highly erodible soils - 90% conservation tillage on highly erodible soils - 75% of acreage on conservation plans developed and implemented within seven years	Funding incentives
2	Ohio EPA Bob Miltner	8/01	1/1/02	100% complete by 1/1/02	
3.	Co. Eng. Twp Trust. SWCDs	1/1/03	12/04	Develop watershed wide criteria for program	Criteria adoption by agencies
4.	Co. Comm. Cities Engineers Zoning Off. Ohio EPA	1/1/03	12/03	Develop watershed wide criteria for program in place and implementation ongoing.	Regulatory

[1] Types of assurances include legal or other regulatory actions and authority, funding, incentive programs, etc.

Table 6.7. Timeline: monitoring, tracking and implementation (see key below) - drainage and channelization.

Action / Milestone Year:	**2003**				**2004**				**2005**				**2006**				**2007**				**2008**	**2009**	**2010**	**2011**	**2012**
Quarter:	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**					
Example BMP X			A			C	M								E				V						
Conservation Planning					A				C		M					E			V						
Develop comprehensive list and map of all stream designations			A		E														V						
Develop criteria for implementation of ditch maintenance program					A				C			E							V						
Education for the public and targeted education for public officials involved with drainage programs					A				C			E							V						

Key:
A - Action completed/installed/incorporated
C - Check point to track action implementation (did action get completed?)
M - Monitoring of indicators begins (indicators specified in monitoring plan)
E - Expected target attainment
V - Validation; biological survey to determine if targets are attained

Table 6.8. Monitoring plan - drainage and channelization.

Implementation Action	**Stressor**	**Measure**	**Managing Party**	**Desired Target (Milestones)**	**Location or applicable area**	**Frequency/ Schedule**
BMP Example	*Erosion*	*Pebble Count*	*Party Y*	*z depth of fines*	*Clifton Rd*	*1/month*
Conservation Planning	Sediment, nutrients, habitat	Acres of land in conservation planning	NRCS & SWCDs	75% of cropland	Entire watershed	
Develop comprehensive list and map of all stream designations			Ohio EPA	All streams designated	Entire watershed	
Develop criteria for implement-ation of ditch maintenance program	Erosion & sedimentation	Criteria development	Co. Eng. Twp Trust. SWCDs	Program implement-ation	Entire watershed	
Education for the public and targeted education for public officials involved with drainage programs	Channelization/Habitat modification	QHEI scores	Co. Eng. Twp Trust. SWCDs		Entire watershed	

On-site Sewage Implementation Plan

Table 6.9. Description of implementation actions and measures - on-site sewage.

#	Implementation Actions & Management Measure	Streams Affected	Parameters Affected/Benefits	Estimated Effectiveness
E	*Example BMP: Increase conservation tillage in the headwaters of the Stillwater by n acres (or m percent or to a total of p percent of watershed, etc.)*	*Stillwater*	*Sediment & Phosphorus reductions, improved habitat*	*60-90% reduction in erosion per field converted*
1	Establish Darke County Sewer District	Entire upper watershed	Organic enrichment/ D.O., ammonia, nutrients, & siltation	Evaluation and installation of centralized wastewater treatment in unsewered areas
2	~425 Septic tanks taken offline and sanitary sewer w/ treatment provided for Village of New Madison (discharge to Whitewater basin)	Mud Creek	Elimination	100% - 2003
3	Health Department manifest program for septic tank handlers	Entire watershed	Sediment, CBOD, TSS, phosphorus, ammonia, bacteria, heavy metals	Proper land application of septage, % compliance
4	Darke County Health Department on-site inspection program	Entire upper watershed	Organic enrichment/ D.O., ammonia, nutrients, siltation	Identification and correction of failing on-sites, variable
5	Miami County Health Department on-site inspection program	Stillwater mainstem and tribs.	Organic enrichment/ D.O., ammonia, nutrients, siltation	Identification and correction of failing on-sites, variable
6	Homeowner Education Program on septic tank maintenance, etc.	Entire watershed	Sediment, CBOD, TSS, phosphorus, ammonia, bacteria, heavy metals	Improved operation and maintenance of on-site systems, variable

#	Implementation Actions & Management Measure	Streams Affected	Parameters Affected/Benefits	Estimated Effectiveness
7	Collaborate health department on-site inspections with appropriate zoning or building inspectors	Entire watershed		More efficient implementation of requirements
8	Provided cost share for pump out of on-site systems	Entire watershed		
9	Monitor impaired areas where model indicates high numbers of failing systems	Entire watershed		
10	Stillwater watershed project representation at all public hearings and in planning and zoning meetings	Entire watershed		

Urban Issues

Table 6.10. Description of implementation actions and measures - urban stormwater.

#	Implementation Actions & Management Measure	Streams Affected	Parameters Affected/Benefits	Estimated Effectiveness
E	*Example BMP X: Increase conservation tillage in the headwaters of the Stillwater by n acres (or m percent or to a total of p percent of watershed, etc.)*	*Stillwater*	*Sediment & Phosphorus reductions, improved habitat*	*60-90% reduction in erosion per field converted*
1	CSO communities Arcanum, Ansonia and Bradford complete sewer separate projects.	Stillwater, Paint Creek, Ballinger Run and Harris Run.	CBOD, TSS, ammonia, bacteria, control of floatables and solids. Maximize flow to treatment. Eliminate overflows directly to stream.	100 % reduction in loading from overflow structures.
2	Nutrient Limits (Phosphorus 1mg/l, Total Nitrogen 2mg/l- 7 mg/l) to be added to all the municipal point source dischargers.	Stillwater watershed.	Phosphorus and Nitrogen reductions, improved habitat.	Reduction in eutrophication, improved habitat.
3	Phase II storm water compliance for jurisdictions in urbanized areas.	Stillwater watershed.	Reduce urban NPS loadings.	Reduce urban NPS loadings.
4	Point source sludge management plan development and implementation.	Stillwater watershed.	Develop and implement sludge mgt. plans in compliance with federal (503) regulations.	Reduction in waste loadings resulting from run-off from sludge sites.

6.3 Process for Monitoring and Revision

An initial monitoring plan to determine whether the TMDL has resulted in attainment of water quality standards and to support any revisions to the TMDL that might be required begins with instream water quality chemical monitoring. This sampling will be done at a minimum by NPDES permit holders at locations upstream and downstream of their outfalls and at ambient monitoring stations to be collected by Ohio EPA. A more detailed and inclusive monitoring plan could be developed by the Stillwater Watershed Project which would describe steps in a monitoring program, including timing and location of monitoring activities, parties responsible for monitoring, and quality assurance and quality control procedures. It may include a method to determine whether actions identified in the implementation plan are actually being carried out and criteria for determining whether these actions are effective in reaching the TMDL targets. It is recommended that the Stillwater Watershed Project work with the Ohio EPA to develop the monitoring plan. Consideration must be given to the lag time between source control actions (habitat improvements and loading reductions) and observable/measurable instream effects, especially for nonpoint sources.

A tiered approach to monitoring progress and validating the TMDL will be followed; the tiered progression includes:
1. Confirmation of completion of implementation plan activities;
2. Evaluation of attainment of chemical water quality criteria;
3. Evaluation of biological attainment.

A TMDL revision will be triggered if any one of these three broad validation steps is not being completed or if the WQS are not being attained after an appropriate time interval. If the implementation plan activities are not being carried forth within a reasonable time frame as specified in the implementation plan then an intercession by the Watershed Improvement Group or other appropriate parties would be needed to keep the implementation activities on schedule. Once the majority of or the major implementation plan items have been carried out and/or the chemical water quality has shown consistent and stable improvements then a full scale biological and chemical watershed assessment would be completed to evaluate attainment of the use designations. If chemical water quality does not show improvement and/or waterbodies 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.

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Appendix I. Management Scenario - Corn/Soybean/Wheat/Perennial Grass Rotation

SUBBASIN: 15 **HRU:** 2 **AGRR** OH037CrA

IGRO	NROT	NCRP	CN2	USLE_P
0	7	0	81	1.00

YR	MON	DAY	OPERATION	CROP	FERTILIZER	FRT_KG	TILLAGE	CNOP
1	1	30	Fertilizer		Dairy-Fresh Manure	1681.00		0
1	3	20	Tillage			0.00	GENERIC NO-TILL MIXING	79
1	4	5	Plant	CORN		0.00		79
1	6	1	Fertilizer	CORN	Anhydrous Ammonia	98.10		0
1	10	20	Harvest & Kill	CORN		0.00		0
1	11	1	Fertilizer		Dairy-Fresh Manure	101.00		0
1	11	5	Fertilizer		00-00-60	175.70		0
1	11	15	Tillage			0.00	GENERIC NO-TILL MIXING	79
2	1	30	Fertilizer		Dairy-Fresh Manure	34.00		0
2	2	1	Fertilizer		00-00-60	32.90		0
2	4	15	Tillage			0.00	GENERIC NO-TILL MIXING	79
2	4	15	Fertilizer		00-00-60	11.00		0
2	5	15	Plant	SOYB		0.00		79
2	10	5	Harvest & Kill	SOYB		0.00		0
2	10	5	Fertilizer		Dairy-Fresh Manure	134.00		0
2	10	15	Plant	WWHT		0.00		78
3	3	1	Fertilizer		28-00-00	54.90		0
3	5	1	Fertilizer	WWHT	28-00-00	197.70		0
3	6	10	Fertilizer	WWHT	28-00-00	54.90		0
3	6	10	Tillage	WWHT		0.00	GENERIC NO-TILL MIXING	78
3	7	20	Harvest & Kill	WWHT		0.00		0
3	7	20	Fertilizer		Dairy-Fresh Manure	538.00		0

3	8	5	Tillage			0.00	CHISEL PLOW	78
3	8	10	Tillage			0.00	FIELD CULTIVATOR	65
3	8	30	Plant	HAY		0.00		65
3	11	15	Fertilizer	HAY	00-00-60	165.00		0
3	11	15	Fertilizer	HAY	00-46-00	82.50		0
4	2	15	Fertilizer	HAY	00-46-00	15.50		0
4	2	15	Fertilizer	HAY	00-00-60	30.90		0
4	5	30	Harvest only			0.00		0
4	5	30	Fertilizer	HAY	00-00-60	10.30		0
4	5	30	Fertilizer	HAY	00-46-00	5.60		0
4	7	10	Harvest only	HAY		0.00		0
4	8	20	Harvest only	HAY		0.00		0
4	9	30	Fertilizer	HAY	Dairy-Fresh Manure	538.00		0
4	9	30	Harvest only	HAY		0.00		0
4	11	15	Fertilizer	HAY	00-00-60	179.30		0
4	11	15	Fertilizer	HAY	00-46-00	89.70		0
5	2	15	Fertilizer	HAY	00-00-60	33.60		0
5	2	15	Fertilizer	HAY	00-46-00	16.80		0
5	5	30	Fertilizer	HAY	00-46-00	5.20		0
5	5	30	Harvest only			0.00		0
5	5	30	Fertilizer	HAY	00-00-60	10.20		0
5	7	10	Harvest only	HAY		0.00		0
5	8	20	Harvest only	HAY		0.00		0
5	9	30	Harvest only	HAY		0.00		0
5	9	30	Fertilizer	HAY	Dairy-Fresh Manure	538.00		0
5	11	15	Fertilizer	HAY	00-00-60	165.00		0
5	11	15	Fertilizer	HAY	00-46-00	82.50		0
6	2	15	Fertilizer	HAY	00-00-60	30.90		0
6	2	15	Fertilizer	HAY	00-46-00	15.50		0

6	5	30	Harvest only			0.00		0
6	5	30	Fertilizer	HAY	00-46-00	5.20		0
6	5	30	Fertilizer	HAY	00-00-60	10.30		0
6	7	10	Harvest only	HAY		0.00		0
6	8	20	Harvest only	HAY		0.00		0
6	9	30	Harvest only	HAY		0.00		0
6	9	30	Fertilizer	HAY	Dairy-Fresh Manure	538.00		0
6	11	15	Fertilizer	HAY	00-00-60	165.00		0
6	11	15	Fertilizer	HAY	00-46-00	82.50		0
7	2	15	Fertilizer	HAY	00-00-60	30.90		0
7	2	15	Fertilizer	HAY	00-46-00	15.50		0
7	5	30	Fertilizer	HAY	00-00-60	10.30		0
7	5	30	Fertilizer	HAY	00-46-00	5.20		0
7	5	30	Harvest only			0.00		0
7	7	10	Harvest only	HAY		0.00		0
7	8	20	Harvest only	HAY		0.00		0
7	9	30	Harvest & Kill	HAY		0.00		0
7	10	30	Fertilizer		Dairy-Fresh Manure	5043.00		0
7	11	15	Tillage			0.00	GENERIC NO-TILL MIXING	65

Figure AII.1. Comparison of model predicted versus target total monthly NO_2^-+NO_3^- (kg-N/d) loads for the drainage segment at the outlet of assessment unit 05080001-100 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

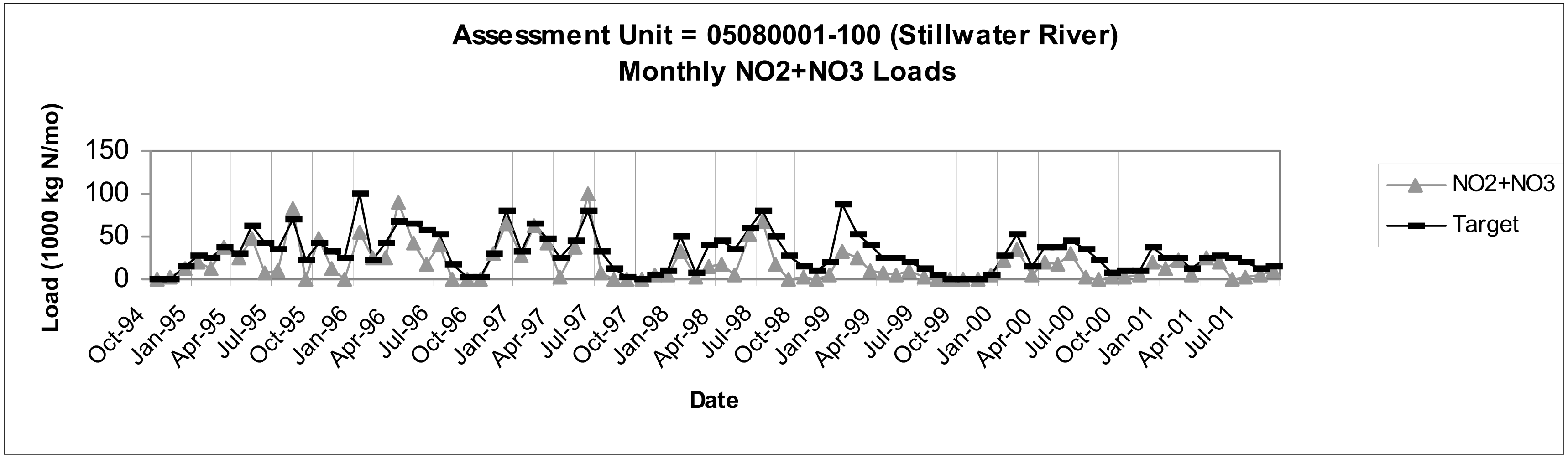


Figure AII.2. Comparison of model predicted versus target total monthly total phosphorus (kg-P/d) loads for the drainage segment at the outlet of assessment unit 05080001-100 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

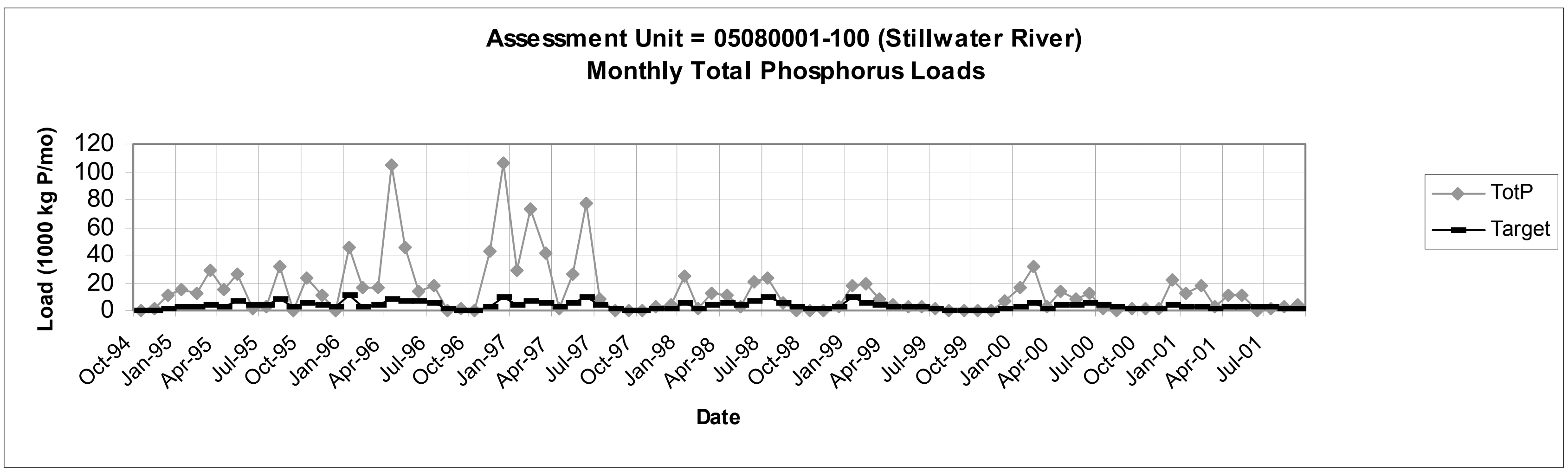


Figure AII.3. Comparison of model predicted versus target total monthly NO_2^-+NO_3^- (kg-N/d) loads for the drainage segment at the outlet of assessment unit 05080001-110 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

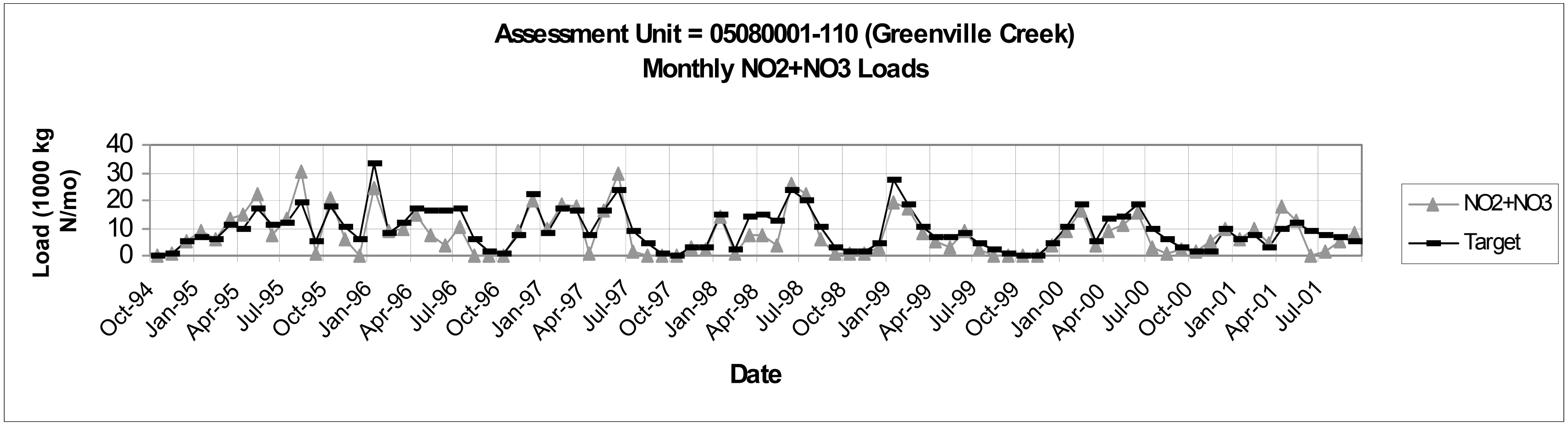


Figure AII.4. Comparison of model predicted versus target total monthly total phosphorus (kg-P/d) loads for the drainage segment at the outlet of assessment unit 05080001-110 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

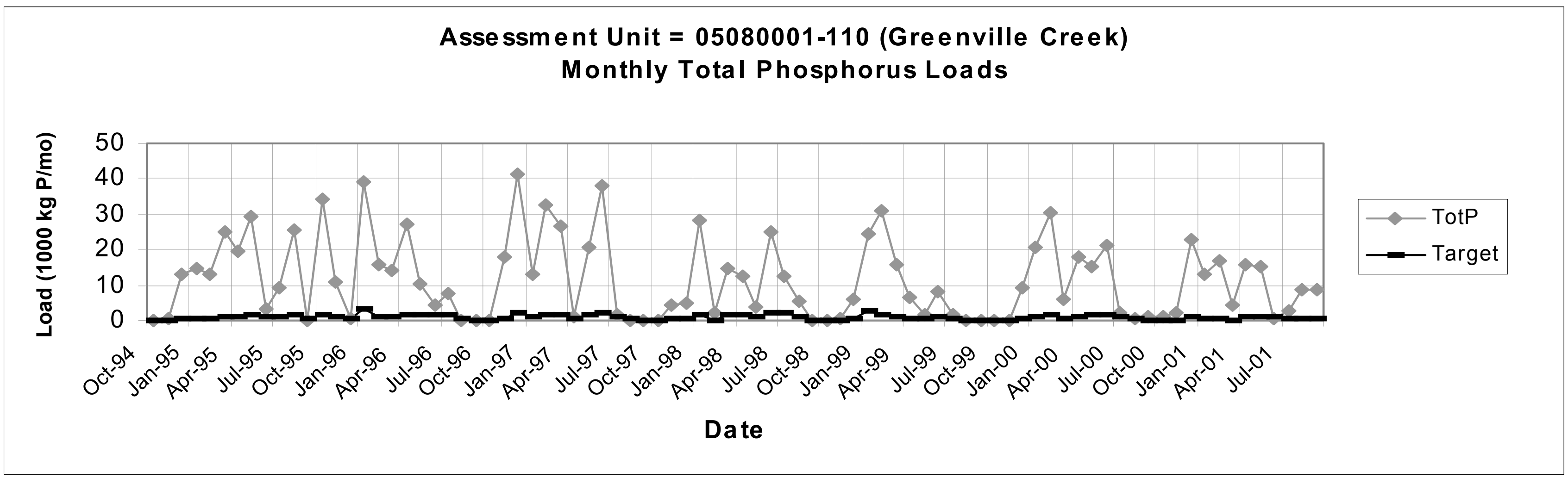


Figure AII.5. Comparison of model predicted versus target total monthly NO_2^-+NO_3^- (kg-N/d) loads for the drainage segment at the outlet of assessment unit 05080001-120 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

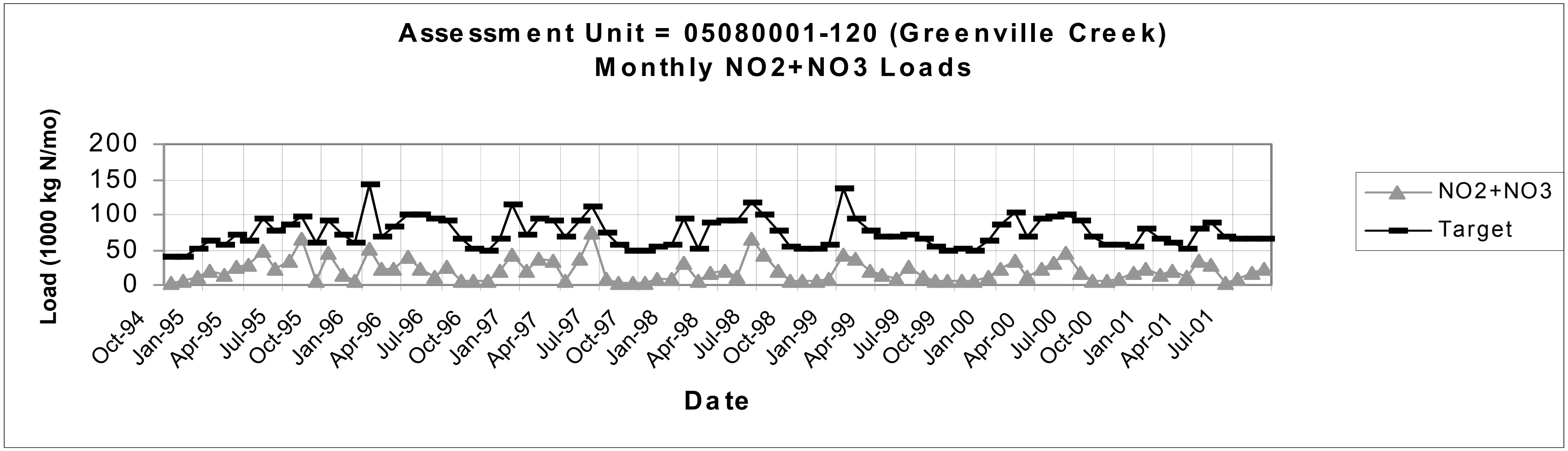


Figure AII.6. Comparison of model predicted versus target total monthly total phosphorus (kg-P/d) loads for the drainage segment at the outlet of assessment unit 05080001-120 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

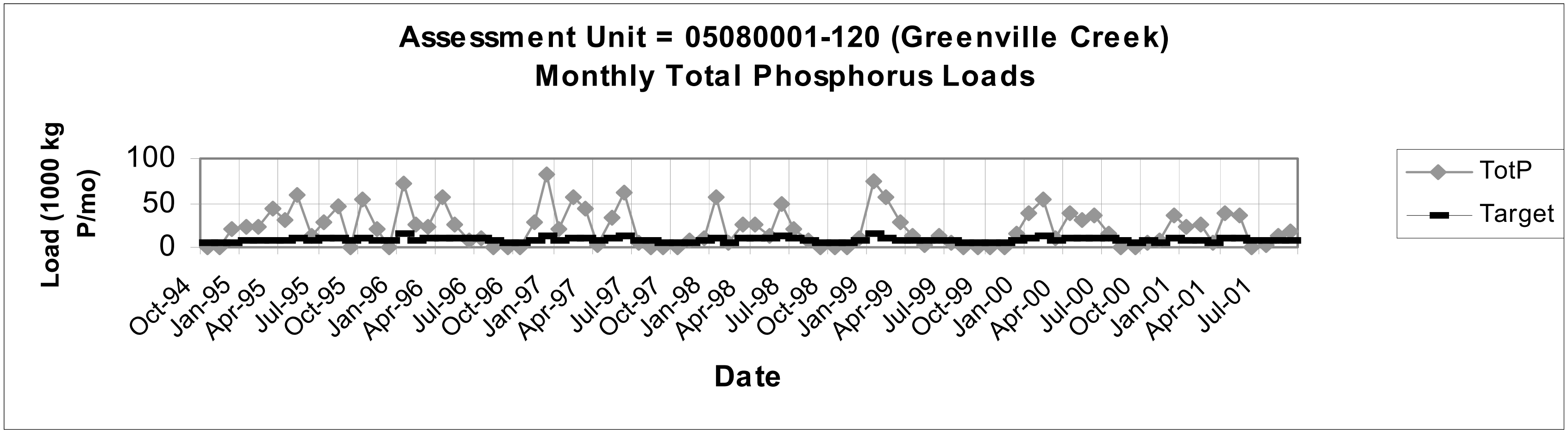


Figure AII.7. Comparison of model predicted versus target total monthly $NO_2^-+NO_3^-$ (kg-N/d) loads for the drainage segment at the outlet of assessment unit 05080001-130 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

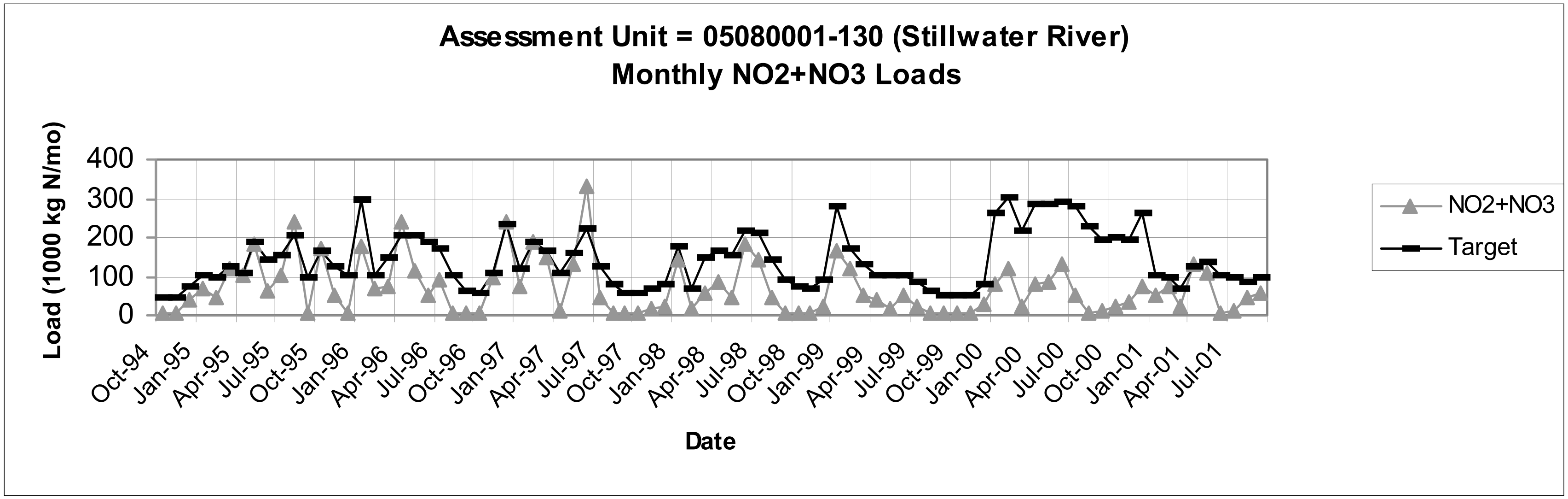


Figure AII.8. Comparison of model predicted versus target total monthly total phosphorus (kg-P/d) loads for the drainage segment at the outlet of assessment unit 05080001-130 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

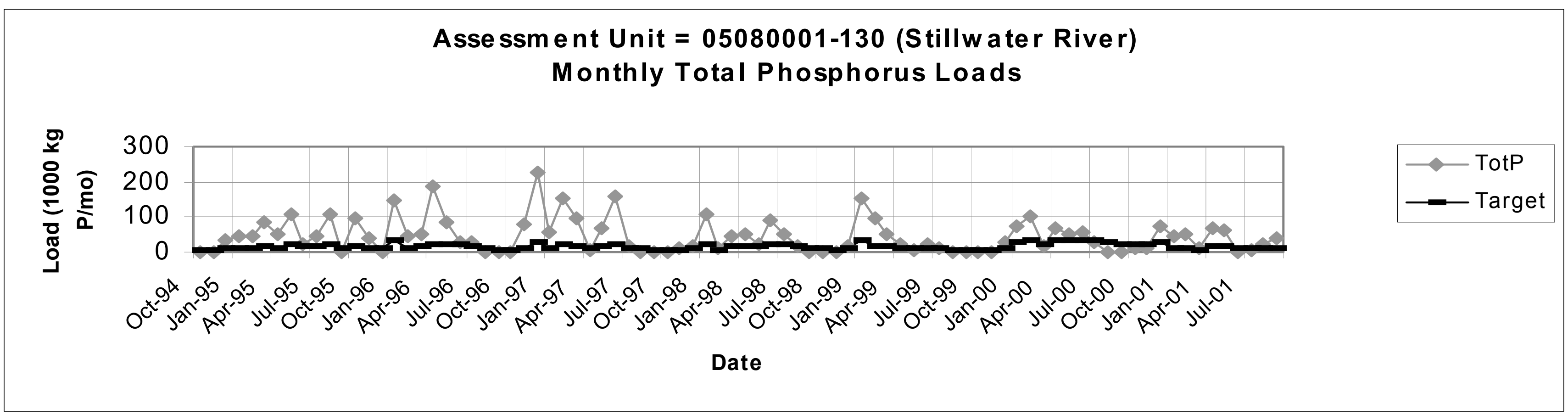


Figure AII.9. Comparison of model predicted versus target total monthly NO_2^-+NO_3^- (kg-N/d) loads for the drainage segment at the outlet of assessment unit 05080001-140 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.

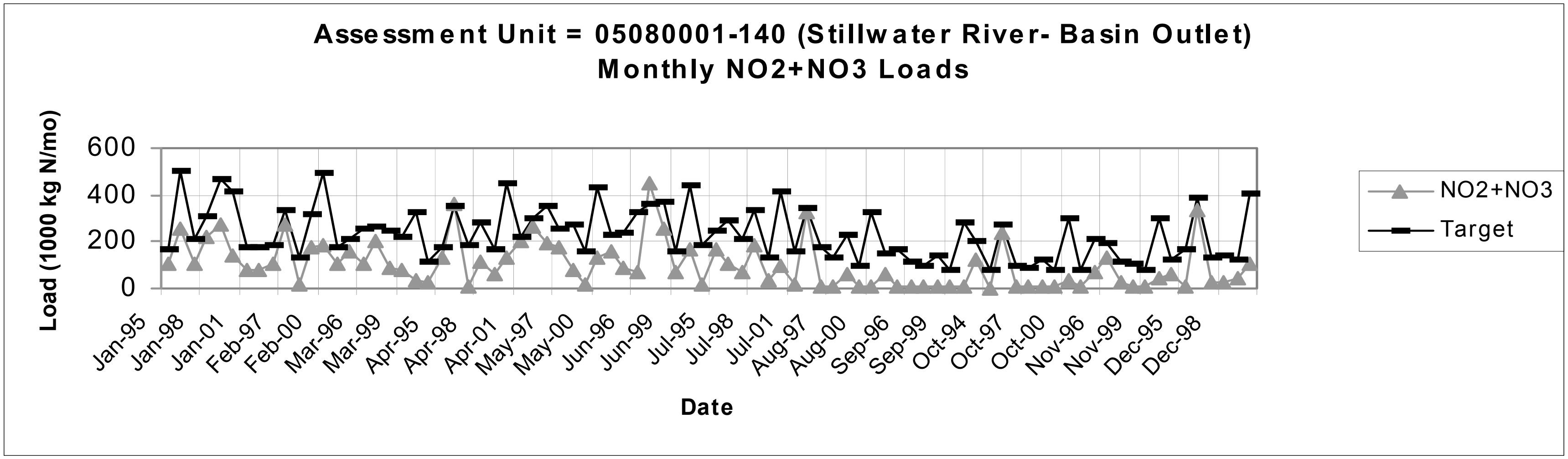
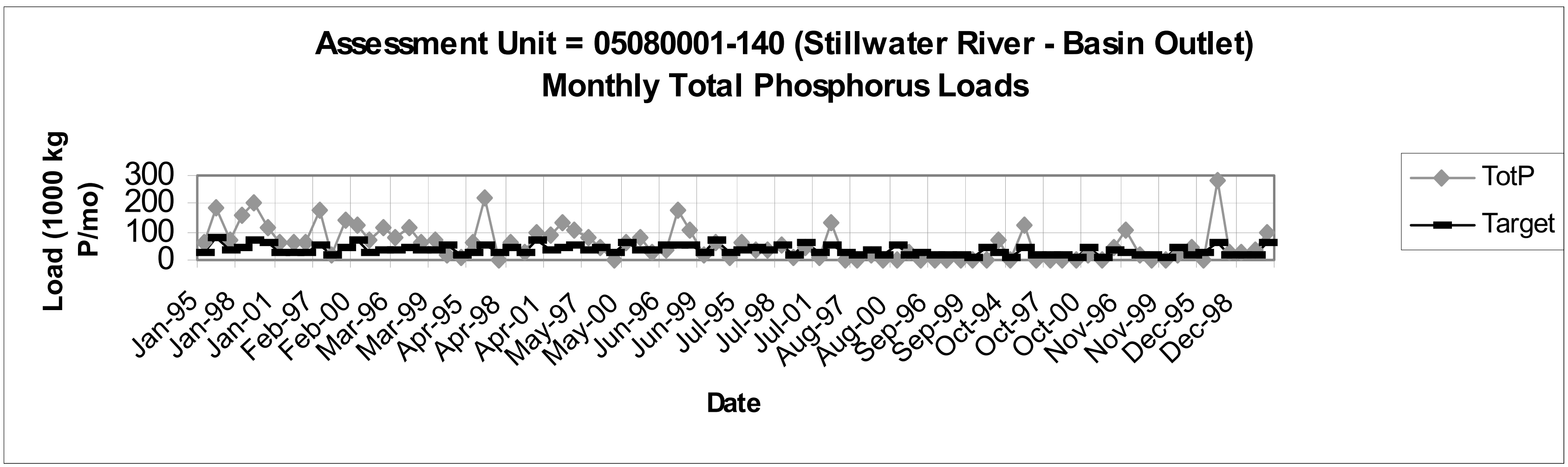


Figure AII.10. Comparison of model predicted versus target total monthly total phosphorus (kg-P/d) loads for the drainage segment at the outlet of assessment unit 05080001-140 between the period October 1994 and September 2001. Target load is defined for a warmwater habitat (WWH) aquatic life use criterion.



Appendix III. Wastewater Discharge – SWAT Input

To simulate the loading of water and pollutants from sources not associated with a land area (e.g. sewage treatment plants), SWAT allows point source information to be read in at any point along the channel network. The point source loadings may be summarized on a daily, monthly, yearly, or average annual basis. For the Stillwater River TMDL, point source loadings will be summarized on a *monthly basis* where the mean[1] or median daily loading ($kg \bullet d^{-1}$) for the month will be employed. Because the Monthly Operating Reports (MOR) from WWTP facilities do not contain both flow and effluent quality on a daily basis, estimating *daily* loadings for days without effluent monitoring may be computationally imprecise.

Tables AIII.1 and ***AIII.2*** describe the comparison between the point-source based input data needs for SWAT (defined as measured input) and information available for these same entities through STORET[2] and Ohio monthly operating reports (MOR).

[1] The mean or median loading for the month is calculated from a series of *daily* concentration and flow combinations.

[2] STORET (short for STOrage and RETrieval) is a repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others.

Table AIII.1. **Comparison of STORET parameters to SWAT input data needs.**

Parameter (generic)	SWAT Parameter (specific)		STORET Parameter Name	STORET Parameter Code[2]	
Water Temperature	Not used directly.	--	Water temperature (C)	**00010**	
Water	Contribution to streamflow.	FLO__	Flow rate (GPD)	00056	
			Flow rate (MGD)	**50050**	
Dissolved Oxygen / Oxygen Demand	Not used directly.	--	Dissolved oxygen (mg/l)	**00300**	
			BOD, 5 day (mg/l)	00310	
			COD, low level (mg/l)	**00335**	
			CBOD, 5 day (mg/l)	**80082**	
pH	Not used directly.	--	S.U.	**00400**	
Sediment	Sediment loading to reach (metric tons)	SED__	Residue, tot (mg/l)	00500	
			Total suspended solids (non-filterable[1]) (mg/l)	**00530**	mining effluent
			Residue, settleable (mg/l)	00546	
			Residue, tot filterable[1] (mg/l)	70300	
Nutrients Nitrogen species	Organic nitrogen (kg N)	ORGN__	Total organic nitrogen (mg/l)	00605	
	Ammonia (kg N)	NH3__	Ammonia [NH_3] nitrogen (mg/l)	**00610**	
	Nitrite (kg N)	NO2__	Nitrite [NO_2^-] nitrogen (mg/l)	00615	
	Nitrate (kg N)	NO3__	Nitrate [NO_3^-] nitrogen (mg/l)	00620	
			Total Kjeldahl nitrogen (mg/l)	**00625**	
			Nitrite plus nitrate [NO_2^-+NO_3^-] nitrogen (mg/l)	**00630**	
Nutrients – Phosphorus species	Organic phosphorus (kg P)	ORGP__	Total phosphate (mg/l)	00650	
	Mineralized phosphorus (kg P)	MINP__	Total orthophosphate [PO_4^-] (mg/l)	00660	
			Total phosphorus (mg/l)	00665	
			Dissolved phosphorus (mg/l)	00666	
Bacteria (SWAT2001)	Persistent load (#)	BACTP__	Fecal coliform (#/100 ml)	**31616**	
	Less-persistent load (#)	BACTLP__	E. coli (#/100 ml)	31648	

Notes:
(1) Filterable defined as able to pass through a filter".
(2) STORET code in **bold** indicates LEAPS data likely available for major POTW in Stillwater River watershed.

Table AIII.2. **Transforming monthly operating report data to swat measured input.**

Parameter (generic)	SWAT Parameter (specific)		STORET Parameter Name	STORET Parameter Code	Solution
Water	Contribution to streamflow (m^3/d).	FLO__	Flow rate (GPD) Flow rate (MGD)	00056 **50050**	Convert either to m^3/d. See note (1).
Sediment	Sediment loading to reach (metric tons/d)	SED__	Residue, tot (mg/l) Total suspended solids (non-filterable[1]) (mg/l) Residue, settleable (mg/l) Residue, tot filterable[1] (mg/l)	00500 **00530** 00546 70300	Sum 00500, 00530, 00546, and 70300. Divide sum by flow rate (00056 or 50050). See note (2).
Nutrients – Nitrogen species	Organic nitrogen (kg N/d) Ammonia (kg N/d) Nitrite (kg N/d) Nitrate (kg N/d)	ORGN__ NH3__ NO2__ NO3__	Total organic nitrogen (mg/l) Ammonia [NH_3] nitrogen (mg/l) Nitrite [NO_2^-] nitrogen (mg/l) Nitrate [NO_3^-] nitrogen (mg/l) Total Kjeldahl nitrogen (mg/l) Nitrite plus nitrate [NO_2^-+NO_3^-] nitrogen (mg/l)	00605 **00610** 00615 00620 **00625** **00630**	See note (6). See note (5). See note (3). See note (6). See note (3-4).
Nutrients – Phosphorus species	Organic phosphorus (kg P/d) Mineralized phosphorus (kg P/d)	ORGP__ MINP__	Total phosphate (mg/l) Total orthophosphate [PO_4^-] (mg/l) Total phosphorus (mg/l) Dissolved phosphorus (mg/l)	00650 00660 **00665** 00666	 See note (8). See note (8).

Notes:
1) Factor-label conversion to cubic meters of water per day.

2) Factor-label conversion to metric tons sediment per day.

3) Determine NO_2^- as kg-N per day: Assume approaches zero for wastewater effluent (Kroeger and Van Dommelen; 2002, personal communication). In nitrogen species kinetics, $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$, NO_2^- is short-lived and often exits (denitrifies) system as N_2 (g).

4) Determine **NO_3^-** as kg-N per day: Given (3) above, apply parameter code 00630 (nitrate plus nitrite). Because 00630 is reported as mg-N per liter (Standard Methods for the Examination of Water and Wastewater, 1992), a ratio of molecular weight does not need to apply.

5) Determine **NH_4^+ (NH_3)** as kg-N per day: Apply parameter code 00610. Note that 00610 is reported as NH_3 but NH_4^+ is the parameter that is actually measured. During the analysis of an effluent sample, the pH is shifted toward the higher end of the scale (14.0) where NH_4^+ dominates (Kroeger and Van Dommelen; 2002, personal communication). In a wastewater stream, ammonium ions exist in equilibrium with ammonia. In normal ranges of pH (6.0-8.0) and at 20 ÉC, the composition of effluent is 96–99.96% NH_4^+ and 0.04–4% NH_3 (USEPA 1985, p 264). Because 00610 is reported as mg-N per liter (Standard Methods for the Examination of Water and Wastewater, 1992), a ratio of molecular weight does not need to apply.

6) Determine **organic nitrogen** as kg-N per day: The following approximation can be made:

Total Organic Nitrogen = Total Kjeldahl Nitrogen – Ammonia Nitrogen

Subtract parameter code 00610 from parameter code 00625 (in loading units) to generate the load for total organic nitrogen. Because 00625 is reported as mg-N per liter (Standard Methods for the Examination of Water and Wastewater, 1992), a ratio of molecular weight does not need to apply.

7) Parameter code 00665 **(total phosphorus**) is the total amount of phosphorus in the sample after all forms (of phosphorus) have been converted to PO_4^{3-} (phosphate). Organic phosphate is produced mostly from industrial process sources; only a very small amount occurs in most municipal wastewaters (Hauser 1996, p 74). All forms of phosphate can occur in solution, in particles or detritus, or in bodies of aquatic organisms (***Table AIII.3***).

Biological processes are mainly responsible for forming organic phosphates. Organic phosphates are contributed to sewage by body wastes and food residues, and may also be formed from orthophosphates in biological treatment processes or by receiving water biota.

Table AIII.3 **Chemical forms of phosphate in USA sewage [1,2].**

Phosphate Form	Typical Concentration (mg-P/L)
Orthophosphate	3-4
Condensed Phosphates (e.g., pyrophosphate, tripolyphosphate, trimetaphosphate)	2-3
Organic Phosphates (e.g., sugar phosphate, phospholipids, nucleotides)	1

[1]Where no regulations exist on phosphorus content of synthetic detergents.
[2]Source: Sedlak (1991, p 91)

Because of the lack of MOR information on phosphorus species for most facilities located in the Stillwater River watershed, estimates for wastewater effluent will be based on the following in concert with corroborative information presented in ***Table AIII.4***:

1) For those stations with MOR data containing concentrations for parameter 00665 and a corresponding flow (50050 or 00056), calculate the median load (in kg/d) for the most recent reporting period.
2) For those stations with MOR data containing concentrations for parameter 00665 and no corresponding flow, calculate the median concentration (in mg/L) for the most recent reporting period and apply the design flow to estimate a load (in kg/d).
3) For those stations with no MOR data for parameter 00665, a concentration of 3.0 mg/L and the design flow for that facility will be used to estimate a load (in kg/d). This designation is temporary and will be revised once additional MOR data is received.

Table AIII.4 **Median concentration and loading of total phosphorus by survey (based on data from *Table AIII.5*)**

Survey	Sample Size	Median Total P			
		Concentration (mg/l)		Loading (kg/d)	
		Average	Maximum	Average	Maximum
Lake Erie – With No Filtration	10	0.62	1.05	13.40	22.26
Lake Erie – With Filtration	6	0.72	1.26	7.60	11.49
Upper Little Miami River Watershed	11	1.99	nd	17.62	nd
Personal Communication (Gary Stuhlfauth)	na	2.0-4.0	--	--	--
Stillwater River Watershed	3-6	2.83	3.7	5.08	8.4

Fractionalization of the total phosphorus load to **mineralized** [3] **P** (total inorganic form) and **organic P** is required for input to the SWAT model. This fractionalization will be based on results of the Little Miami River Preliminary Assessment of USE Attainability or PAUSE (Buchburger et al. 1997) where 85 percent (by load) of all phosphorus discharged by the 14 WWTPs in that basin was soluble reactive phosphorus (SRP) [4].

References Cited

Buchburger, S.G. and others (1997) *Little Miami River Preliminary Assessment of USE Attainability (PAUSE)*, University of Cincinnati, 53 pp.

Greenberg, A.E. and others (1992) *Standard methods for the examination of water and wastewater*. 18th Edition, Published by APHA, AWWA, and WEF.

Hauser, B. (1996) *Practical manual of wastewater chemistry*. Ann Arbor Press, Chelsea MI, 135 pp.

Sedlak, R.I. (ed.) (1991) *Phosphorus and nitrogen removal from municipal wastewater: principles and practices*. The Soap and Detergent Association, 240 pp.

USEPA (1985) *Rates, constants, and kinetics formulations in surface water quality modeling*. EPA/600/3-85/040, 2nd Edition, 455 pp.

[3] Mineralization (or sometimes re-mineralization) is the process in which organic compounds are broken down into simple inorganic components. Complete mineralization typically involves oxidation (using oxygen), but it can also occur under anoxic conditions.

[4] From April 1996 to March 1997 (12 months), WWTP effluent yielded 168.3 metric tons. Of that total, 142.3 metric tons were in the form of SRP (or 84.6 percent).

Table AIII.5. – Performance Data for Phosphorus (Various Tables)

Performance Data from Selected Ohio Facilities that Discharge into the Lake Erie Basin[1]

Facilities With No Filtration	Permit No.	Design Flow (MGD)	Average Flow (MGD)	Total Phosphorus PEQ (mg/l) Average	Total Phosphorus PEQ (mg/l) Maximum
Wauseon	2PD00016	1.5	nd[2]	0.6	1.11
Upper Sandusky	2PD00039	2	1.419	0.44	0.64
Wapakoneta	2PD00019	2.25	2.257	0.63	1.04
Defiance	2PD00013	4	3.955	1.02	1.89
Tiffin	2PD00025	4	3.431	0.75	1.18
Willard	2PD00005	4.5	nd	0.42	0.66
Fostoria	2PD00031	8.25	5.273	1.3	1.82
Findlay	2PD00008	11	10.18	0.67	1.06
Elyria	3PD00034	13	nd	0.56	0.91
Lima	2PE00000	18.5	13.15	0.37	0.77

Notes:
(1) Source: Upper LMR Draft TMDL Report: Phosphorus Control Strategies (December 2000)
(2) nd: no data supplied

Performance Data from Selected Ohio Facilities that Discharge into the Lake Erie Basin[1]

Facilities With Filtration	Permit No.	Design Flow (MGD)	Average Flow (MGD)	Total Phosphorus PEQ (mg/l) Average	Total Phosphorus PEQ (mg/l) Maximum
McFarland Creek	3PK00010	1.2	0.956	0.77	1.36
Aurora	3PC00016	1.5	0.716	0.95	1.62
Chardon	3PB00010	1.8	1.036	0.62	1.2
Norwalk	2PD00024	3.5	2.701	0.74	1.04
Fremont	2PD00007	7.6	6.158	0.35	0.78
Bowling Green	2PD00009	8	5.548	0.7	1.31

Notes:
(1) Source: Upper LMR Draft TMDL Report: Phosphorus Control Strategies (December 2000)

Performance Data from All Facilities that Discharge into the Upper Little Miami River Watershed[1]

Facility (POTW)	Design Flow (MGD)	Total P Concentration Average (mg/l)	Total P Load @ Design (kg/d)
Clifton	0.029	nd	nd
South Charleston	0.24	1.13	1.03
Jamestown	0.30	nd	nd
Cedarville	0.56	3.10	6.57
Yellow Springs	0.6	2.13	4.84
Waynesville	0.71	2.62	7.04
Xenia (Glady Run)	2.6	1.79	17.62
Xenia (Ford Rd)	3.6	1.85	25.21
Greene Co (Sugar Cr)	4.9	1.40	25.97
Greene Co (Beavercreek)	8.5	2.28	73.36
Montgomery Co Eastern Regional	13.0	2.46	121.06

Notes: (1) Source: Upper LMR Draft TMDL Report: Phosphorus Control Strategies (December 2000)

Appendix IV. **Geographical analysis model for determining probability of failure for onsite sewage disposal.**

	Name	Reclassification Old Values	New Values	Name
Average house age per block group	House_age	24-40 40-55 55-63	1 (Great) 2 (Average) 3 (Poor)	Reclass_age
				+
Soil Permeability	Perm	13.3-1.0 1.0-.20 .20-0.0	1 2 3	Reclass_prem
				+
Soil Drainage	Drainage	1.0-3.0 3.0-5.0 50.-7.0	1 2 3	Reclass_drain

Weight Grid = weightg

	Name	Old Values	New Values	Name
Weight Grid	weightg	3-5 5-6 6-9	0.0 0.5 1.0	Re_weightf

People with Septic Systems per unit cell | Weighted Grid unit cell with failing | Number of people per septic systems

Still_sep X Re_weightf = Still_grsum

Zonal Sum

outgrid = zonalsum(zonegrid , ingrid)

Still_sumw = Zonalsum(wshedhuc14 , Still_grsum)

Total number of people | Sub-watershed | Each cell has a number of people

Appendix V. Summaries of and Responses to Public Comments

The response summaries are organized into two sections to reflect the two categories of comments received: TMDL specific comments (*e.g.*, load allocations, NPDES issues, aquatic life use designations, etc) and model-specific comments.

Authors of written comments on the draft Stillwater River TMDL are identified by number following each comment.

#	Date Received	Name	Organization
1, PR[1]	10/07/2003	Jean Chrusciki	USEPA, Region V, Chicago
2	10/15/2003	Scott Ankrom Stephen Haughey	ATS Engineering, Inc., and Frost, Brown and Todd, LLC
3, PR	10/17/2003	John C. Fisher	Ohio Farm Bureau, Columbus, Ohio 43218-2383
4, PR	10/23/2003	Jean Chrusciki	USEPA, Region V, Chicago
5	11/24/2003	Scott Ankrom	ATS engineering, Inc., Frost Brown Todd, Cities of Union and Englewood
6.	11/25/2003	Darrell S. Hollon	City of Greenville, Wastewater Superintendent

Part 1. TMDL Related Comments and Responses

1. **Comment:** Can you add RM on Stillwater to the map on page 16 that matches the info in table 1.2? [1]

Response: It simply is not practical; however principal streams are named on the map. A GIS data layer containing the information referenced Table 1.2 can be obtained via email by contacting: bob.miltner@epa.state.oh.us

2. **Comment:** The 30-day comment period should be extended an additional 30 days given the complexity of the water quality model. [2]

Response: The public comment period was extended an additional 30 days as requested.

3. **Comment:** (page 1, para 5) The Ohio EPA TMDL team has not been able to calibrate the SWAT model to this watershed. Until the model is adequately calibrated, OFBF questions the appropriateness of using the output generated...in the development of this TMDL and the associated nutrient reduction targets. ...given the inability to calibrate the SWAT model, the same iterative adaptive approach [suggested by Ohio EPA] must be taken when estimating

[1]PR - Proof reading. Comments were specific to highlighting formatting and typographical errors, and editorial comments aimed at making the document more readable. These comments are thankfully acknowledged, and have been duly noted and applied to the TMDL document.

> current and projecting future nutrient loads. Rather than establishing a firm target, Ohio EPA should identify target ranges which will be "firmed up" when the SWAT model is adequately calibrated. The use of an uncalibrated model to develop this TMDL place unrealistic expectations and financial burdens on the landowners in the Stillwater River Basin. The values presented in this report will take on a life of their own. Landowners and permitted dischargers will be required to make management decisions and capital outlays based on faulty and suspect information. Putting out a report just to meet a deadline is a disservice to the citizens of Ohio. Ohio EPA must put appropriate resources into the calibration phase if this model and report are to be deemed credible. Take the time to get it right.
>
> I am particularly concerned...that the Stillwater River Basin TMDL will become the defacto [sic] template for all future agricultural TMDLs developed by Ohio EPA. [Lacking] proper... resources... the future credibility of the TMDL program is lost in the agricultural community. [3]

Response: Ohio EPA freely acknowledges that the SWAT model used for the Stillwater TMDL has not been completely calibrated. However, Ohio EPA contends that the model, as it currently exists, is showing the magnitudes of nutrient loads relative to the various sources of those loads. Ohio EPA also acknowledges that, because the model is not completely calibrated, the estimated load reductions may change with further model refinement, and has consequently embraced an adaptive management approach toward implementing water quality restoration in the Stillwater River Basin. The only firm target that must be met is attainment of the biological criteria for individual water bodies as set forth in Ohio Administrative Code Chapter 3745-1-07 and 3745-1-21. Therefore, the target loads identified in the Stillwater River TMDL can neither be construed as "firm" nor to "take on a life of their own," as the biological criteria carry the weight of law and supercede these target values.

The need for water quality restoration in the Stillwater River Basin is most emphatically not "based on faulty and suspect information." Rather, the need has been based entirely on hard data and evidence as collected during 1999 and reported on in the Biological and Water Quality Survey of the Stillwater River Basin, 1999 (or Stillwater TSD for short). The Stillwater TSD clearly showed biological and water quality impairment in numerous streams segments, in some cases egregiously so. Restoration and implementation plans identified in the Stillwater TMDL are more an extension of recommendations made by watershed-resident workgroups based, in large part, on information contained in the Stillwater TSD, than they are of results from the water quality model. These implementation plans have been advanced with the full knowledge and consensus of the watershed-resident workgroups that biological and water quality impairments do exist in the Stillwater River Basin, and that actions are needed to begin restoration. Again, those actions are clearly to be implemented in a graduated and adaptive approach. That significant costs associated with water quality restoration are likely to be incurred by land and business owners have been considered in the implementation plans; consequently, most of the restoration strategies outlined in the implementation plans have existing funding mechanisms. Ohio EPA is committed to identifying or providing further financial assistance through a variety of programs (e.g., Section 319 Funding, CREP, WRRSP) via Ohio EPA's Nonpoint Source Program.

Ohio EPA has completed several TMDLs for agricultural basins around the state. All have been

tailored to the basin-specific causes and sources of impairment identified during respective biological and water quality monitoring surveys. Ohio EPA has invested heavily in partnering with land and business owners in the Stillwater River watershed, consulting OSU's Agricultural Extension Agents, and conducting public meetings so as to tailor the Stillwater TMDL specifically to both the biological and water quality problems of the basin, as well as the needs of the local constituents. Ohio EPA has been credible in freely acknowledging and communicating to all parties involved with this TMDL the SWAT model calibration issue.

4. **Comment:** (page 2, para 3) Pages 2 - 12...problems with numbers not adding up [in Table 1.1]. [3]

Response: Threatened miles should not be counted when tallying up stream miles within a given segment (i.e., a Fully attaining segment could have some miles listed as Threatened).

5. **Comment:** (page 2, para 4) Pages 13 & 14...The summation of the miles of streams [in Table 1.2] with each identified cause contradicts the statements made in the executive summary. [This contradiction] raises the question as to whether or not the Ohio EPA has a clear understanding of the causes of impairment in the Stillwater River basin. If there is not a clear understanding of the causes of aquatic life impairment, how can appropriate restoration targets be established and accurate TMDL be calculated? [3]

Response: There is no contradiction between the Executive Summary and Table 1.2. Table 1.2 merely shows the boundaries, in river miles, of stream segments having some portion of their length impaired by one or more of the associated listed causes. The entire stream segment may or may not be impaired by those causes. The Executive Summary correctly points out that significant stream habitat degradation has occurred throughout the headwaters of the Stillwater River basin as a result of stream ditching and dredging (channelization), and that maintaining streams in a state of degraded physical condition for aquatic life exacerbates water quality problems and exports problems downstream. Table 1.2 reflects the fact that much of the channelization in the Stillwater basin has been sanctioned through petitioned ditch laws; consequently, Ohio EPA has recognized this by designating much of the headwater network in Darke County as having a Modified Warmwater Habitat (MWH) aquatic life use. MWH is a less than Clean Water Act use, and as such, requires a triennial review. Furthermore, an MWH designation does not absolve a segment so designated from causing harm to a downstream segment. In other words, downstream beneficial uses must be maintained. In this regard, habitat destruction can be an overarching problem without the stream miles in Table 1.2 tallying up to show "Other habitat alterations" as impairing the greatest number of stream miles.

6. **Comment:** (starting with page 2, para 6) Various stream segments should be designated Modified Warmwater Habitat not Warmwater Habitat. [3]

Response: Aquatic life use designations are made based on demonstrated performance and reasonable potential. If a stream segment demonstrates full attainment of WWH biocriteria, that segment must be designated as WWH, even if the existing use is MWH, as MWH is a less than Clean Water Act use. Reasonable potential, based on a use attainability analysis, establishes what aquatic life use designation is most appropriate for a given waterbody where biological information are lacking, scarce, or where biological communities are impaired by an existing pollution source. All stream segments called into question above have either demonstrated full attainment of WWH based on biological information, or have demonstrated reasonable potential

by having a combination of habitat capable of supporting a WWH biological community, biological communities fully or partially meeting the WWH biocriteria in at least one location, and an existing pollution source causing impairment.

7. **Comment:** (page 3, para 1) Page 31, First Paragraph. The author of the report makes some pretty bold statements as to the major causes of stream impairment. Do you have the data to support these claims? [3]

Response: These are statements of fact, not opinion or judgement. The data have been presented in the 1999 Stillwater River TSD, available online at http://www.epa.state.oh.us/dsw/documents/Stillwater1999TSD.pdf

8. **Comment:** (page 3, para 6) Page 37...“Habitat destruction” is not an identified cause of aquatic life impairment. Replace with the more appropriate “habitat modification.” [3]

Response: In terms of describing the problem as it applies to biological impairment, “habitat destruction” is more accurate and descriptive than the euphemistic “habitat modification.”

9. **Comment:** (page 3, para 7) Pages 38 - 43. Table 5. There are numerous instances where the values in Table 5 deviate from the target values and are not shown in bold font. [3]

Response: The caption for Table 5 reads, “Where biological impairment exists, bold font denotes deviation from target value.” The caption will change to read, “Bold font is used to denote deviations from target values *only* where deviations from target values co-occur with biological impairment.”

10. **Comment:** Stillwater River TMDL segments...I count 21 segments, how do you get 18 from page ES-I? [4]

Response: Table 1.2 lists all twenty-four segments mentioned at the start of the second paragraph of the Executive Summary, two of those twenty-four were listed erroneously, and four of those segments are expected to, or are already meeting their designated beneficial aquatic life use through NPDES permit controls and collection system upgrades, specifically separation of storm and sanitary sewers.

11. **Comment: (page 2)** “...why [is] a TMDL-based wasteload reduction...necessary in the lower mainstem segments of the Stillwater River...” and “...why [is] Ohio EPA...not taking the formal steps to delist the lower segments of the Stillwater River from the list of impaired streams when, as a matter of federal and state law, the maintenance of such listing is not supported...” [5]

Response: The 1999 Biological and Water Quality Survey of the Stillwater River Basin found approximately 1.0 mile impairment in the lower Stillwater River mainstem in and immediately downstream from the Englewood Dam. Although this impairment is primarily due to the hydrologic alteration caused by the dam, the dam pool is hypereutrophic. Given that the Englewood dam is not likely to be removed in the foreseeable future, serves as a flood control structure, and has a following of bird fanciers, the dam pool should be listed as Modified-Impounded in the Water Quality Standards. Even so, the IBI score obtained in the dam pool would fail to meet the WQS for Modified-Impounded. Furthermore, several segments in the Great Miami River (GMR) mainstem downstream from the confluence with the Stillwater River are listed as nutrient impaired. Given that the Stillwater basin is a significant source of nutrient

loads to the GMR, and the Clean Water Act mandates that downstream uses be protected, apportioning load reductions among all sources is justified. Moreover, the approach taken with the Stillwater TMDL was to establish the maximum daily load for the entire basin, identify the percent load reduction needed to achieve the maximum daily load, and ask each source sector to reduce their respective loads by that percentage.

12. **Comment:** (page 4, first paragraph, and a running theme throughout) The draft TMDL report contains no explanation why Ohio EPA decided to address the impairments found in particular segments of the basin through basin-wide, mandatory nutrient reductions. Why is that? [This question is a running theme throughout the Cities of Englewood and Union's comments on the Stillwater TMDL - to paraphrase and summarize: Englewood and Union should not be subject to mandatory nutrient limits as neither are a source of demonstrable impact to the receiving stream, and both discharge to a stream segment that is meeting its use except for a small portion where the impact can be attributed to other sources]. [5]

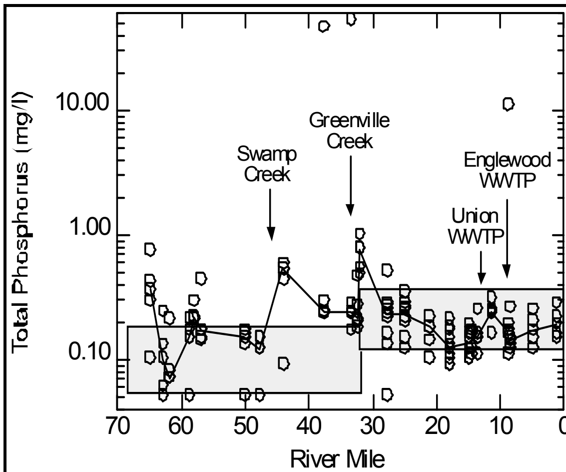
Response: Ohio EPA agrees that reasons for using the basin-wide reduction approach were not well articulated in the draft TMDL report. As stated in the previous response, several segments of the GMR downstream from the Stillwater River basin are listed as nutrient impaired, and the CWA states that downstream uses must be protected. The general TMDL approach Ohio has taken is to work first in headwater basins with the intent of alleviating loads to downstream reaches of larger streams prior to TMDL development for those larger streams [e.g., TMDLs for the upper Little Miami River, Sugar Creek (Tuscarawas headwaters), upper Sandusky River]. Given that portions of the GMR downstream from the Stillwater are impaired by nutrients, and given that the GMR is one of the larger nutrient load sources to the Mississippi River basin, nutrient reductions from upstream contributors (i.e., those in the Stillwater basin) are likely to be required in the future. This is the rationale for apportioning the load reductions in an across-the-board manner.

13. **Comments:** (page 3) The chemical and biological survey report also found that the measured nutrient loadings entering the lower segments of the mainstem of the Stillwater River were extremely low and easily assimilated due to the excellent natural physical habitat and stream canopy that exists on those lower segments..etc. [5]

Response: On the contrary, the measured <u>loads</u> and concentrations entering the lower segments of the Stillwater mainstem (defined as downstream from the confluence with Greenville Creek) were extremely high, as shown in the accompanying illustration. Ohio EPA agrees with the observation that the base flow nutrient loads are largely assimilated in the lower mainstem owing to the excellent habitat in that reach. This can be seen by the decreasing total phosphorus concentrations in the reach downstream from the Greenville Creek confluence. The relatively low base flow concentrations in the lower mainstem suggest that the heavy loads of non-point source-derived nutrients are exported downstream and to the flood plain during high flow events with minimal impact to the lower mainstem, save for the Englewood dam pool. These points were made abundantly clear in the 1999 Stillwater River TSD.

14. Comment: (page 4, paragraph 2) Perhaps more importantly, Ohio EPA knows that both Cities are in the process of undergoing voluntary steps to reduce existing nutrient loadings, notwithstanding the fact that the chemical and biological survey report indicates that such reductions are not warranted or otherwise necessary. In addition, the survey report and the draft TMDL indicate that there are numerous ongoing stream improvements, physical habitat improvements, non-point source reductions, and other water quality improvement projects, including implementation of best management agricultural practices, the totality of which the Agency readily admits is having a dramatic positive effect on improved stream quality and reduced nutrient loadings in the entire Stillwater River basin. Furthermore, each of these other point and non-point source reduction initiatives are ongoing. [5]

Response: Ohio EPA appreciates the effort Englewood and Union are taking and will continue to take to voluntarily reduce nutrient loads coming from their respective plants. Ohio EPA also acknowledges that the biological and chemical survey does show full attainment of the EWH aquatic life use designation in the lower segment of the Stillwater River, save for in the vicinity of the Englewood Dam which is impaired by nutrients. However, the Stillwater River, as whole,



Concentrations of total phosphorus in water quality grab samples collected from the Stillwater River during the summer and fall of 1999. The solid line running through the data points shows the median value at each sampling location. The gray-shaded rectangles in the plot show the range of total phosphorus concentrations from least impacted reference sites sampled in the Eastern Cornbelt Plains Ecoregion of Ohio. The lower bounds of the rectangles show the median values, the upper bounds show the 90th percentile.

remains a significant source of nutrients to the GMR, which, as previously stated, is nutrient impaired and is one of the largest nutrient sources in the Ohio River basin. Because the lower Stillwater River mainstem is largely in full attainment of EWH, Ohio EPA is willing to offer flexibility to Union and Englewood to achieve nutrient reductions, for both phosphorus and nitrogen, through a combination of increasing mechanical efficiencies at the treatment plants, and credit for habitat restoration and non-point source (NPS) reductions. Please refer to the attached draft phosphorus reduction (Appendix VI) and nitrogen reduction (Appendix VII) schedules.

Although there has been a significant amount of progress made in reducing non-point pollution in the Stillwater basin, that progress has largely been limited to a conversion in the number of acres farmed using conventional tillage to conservation tillage. Much of that progress has been out-stripped by the increases in land applied manure, and limited by habitat destruction in the headwaters. For example, the Swamp Creek basin has, despite receiving more targeted funds for NPS reductions than any other Stillwater sub-basin over the last decade, shown deteriorating

biological and water quality over the same time period. The numerous habitat improvements, NPS reductions, et al. alluded to in the above comment and detailed in the TMDL document have only recently been initiated, and then not in totality. Assuming a concerted and veracious effort is made in this regard, the positive effects from it are not likely to be measurable in terms of water (statistically) and biological (demonstrably) quality for another decade.

15. Comment: (page 4, paragraph 3) The draft TMDL correctly notes that the process of addressing stream impairments is supposed to be phased in so that the most significant sources of impairment are addressed first... Despite this admission, the draft TMDL for the Stillwater River basin proposes to implement mandatory reductions, not in a phased approach, but in a "scattergun" approach across the entire basin...and regardless whether evidence of impairment even exists. [5]

Response: Nowhere does the draft TMDL document use the phrase "mandatory reductions" or the word mandatory, nor does the draft TMDL document imply it with respect to nutrients and point sources. The draft TMDL document does encourage shared ownership of the responsibility of all load contributors to reduce a share of the load. Although point sources are a relatively small fraction of the total load, both seasonally and annually, during low flow periods the fractional contribution of point sources increases. Our rationale for a suggested across-the-board reduction approach has been detailed in previous responses.

In addition, the survey report and the draft TMDL indicate that there are numerous ongoing stream improvements, physical habitat improvements, non-point source reductions, and other water quality improvement projects, including implementation of best management agricultural practices, the totality of which the Agency readily admits is having a dramatic positive effect on improved stream quality and reduced nutrient loadings in the entire Stillwater River basin.

16. Comment: (Recommendations and Alternatives) [Several specific comments are addressed first, followed by a response to the general approach outlined by the Cities] [5]

a. (page 9, and reiterated several times throughout) Page 19 of the TMDL report indicates partial attainment downstream of the Englewood WWTP discharge is due to the combination of the Englewood Dam and the WWTP loadings to the stream. Again, we are of the opinion that down stream impact is solely from the Englewood Dam and more specifically from Mill Creek and Pigeye Creek tributaries directly above the Englewood Dam.

Response: The dam pool is hypereutrophic and impaired when judged against the biological criteria for Modified-Impounded waters. The reason the dam pool is hypereutrophic is, in all probability, a function of all upstream loads. Ohio EPA agrees that the biological impairment found immediately downstream from the dam is due primarily to the presence of the dam.

b. (page 6) Additionally, results from the 2003 "Stream and Lakes Teams" sponsored by Ohio Parks and Recreation Association, and MetroParks indicate the Englewood Dam fish diversity to be excellent...Based upon this survey, the fishery habitat is excellent.

Response: The dam pool is hypereutrophic and impaired when judged against the biological criteria for Modified-Impounded waters.

c. (page 7) The TMDL report clearly shows the highest percentage of non-attainment and

impact on the basin rest directly on the areas of feed lot operation, agricultural runoff, upstream channelization and habitat destruction, failing on-site systems (septic tanks) and storm water runoff in the northern and north western quadrant on the basin. Taking a basin wide approach of solving the problems and sources in the basin will prove to be ineffective and inefficient at best. It seems by focusing more resources and attention to the specific problems in the basin would have greater and longer lasting impacts in bringing the basin into full attainment. Selecting these two (2) communities and other point source discharges because they are able to be regulated through their NPDES permit(s) will have little or no impact on improving the basin.

Response: Ohio EPA recognizes that non-point sources of pollution are the overarching problem in the Stillwater River basin and has, and will be, aggressively pursuing all available means to effect restoration of NPS impaired streams identified in the TMDL report. Aggressive steps have already been taken by Miami County and Darke County to address the issue of failing on-site septic systems. Many agricultural BMPs, equipment buy-downs, and conservation easements have been funded through 319 funds sponsored by Ohio EPA. Several specific problems associated with municipal wastewater dischargers have been or are currently being corrected through funding sponsored by Ohio EPA's Division of Emergency and Financial Assistance. The reasons Ohio EPA is asking all load contributors to share in the responsibility of reducing the overall loads have already been stated.

d. (General Approach) [The following is a paraphrased and summarized version of the approach outlined by the Cities] The Cities are committed to maintaining water quality in the Stillwater River and are committed to working to reduce nutrient loads to the Stillwater River. In stead of a mandatory permit limit for total phosphorus (TP) and nitrate-nitrite nitrogen (NOx), the Cities want to continue voluntary work already started that should result in lower nutrient loadings. Part of the plan the Cities advance is to conduct upstream, effluent and downstream monitoring of TP and NOx, and use that information to guide further process control changes to see how effective they can be at increasing their removal of both phosphorus and NO2+NO3 before a sustainable investment is made in plant modifications.

Response: Fundamentally, Ohio EPA agrees with the approach outlined in the Cities letter. Ohio EPA would like to formalize the commitment suggested by the Cities by having that commitment encapsulated in their respective NPDES permits. Such language would include provisions for upstream, effluent and downstream monitoring, a time schedule for the evaluation of the capability of the existing treatment facilities to reduce the effluent loadings of total phosphorus and nitrate-nitrite nitrogen wherein operational procedures, unit process configuration, and other appropriate measures are evaluated. Also included will be a deadline for the Cities to implement measures identified in their evaluations that can reasonably be expected to maximize the ability of the existing treatment facilities to achieve reductions in nutrient loads, and a requirement for the submittal of plan details that include projected load reductions. Plan details may also include cost/benefit analysis of capital improvements needed to gain further reductions in nutrient loads following implementation of process, control and operational changes.

On the subject of credit (trading) for non-point controls, Ohio EPA will require detailed plans stating expected load reductions and monitoring schedules to verify such expected load

reductions.

Finally, the approach outlined by the Cities is open-ended with respect to anticipated load reductions. Ohio EPA understands that the Cities may not know what their capabilities are for reducing loads until work is initiated. Rather than an initial permit limit of 3.0 mg/l TP and 2-7 mg/l NOx, Ohio EPA proposes a 10 year goal of 1.0 mg/l TP and a 30% reduction in NOx from current loadings.

17. Comment: Darrel S. Hollon was excluded from the contributor list. [6]
Response: We regret the omission. The contributor list will be amended to include Mr. Hollon.

18. Comment: Greenville STP was assigned a 70% removal figure for total phosphorus. What does this mean? [6]
Response: The 70% figure is the amount of TP loads projected to be reduced from current loads if the Greenville STP were to use BADCT to meet an effluent limit of 1.0 mg/l TP. Ohio EPA understands that point sources will need maximum flexibility and a relatively long time horizon to meet nutrient reduction goals. Please see comments and responses to author #5 above.

19. Comment: How appropriate is [sic] the limited data used determine the Greenville STP loading? Could I have a copy of the data...? [6]
Response: A copy of the spread sheet containing the data has been furnished. Data for nitrogen were not limited (n = 137) relative to that for total phosphorus. For total phosphorus there were nine data points from 1990 through 2001 with a mean of 3.314 mg ± 0.650 mg (95% confidence interval) and a variance of 0.714 mg^2. How appropriate are those data for estimating phosphorus loads is an open question. In a statistical sense, the data are what they are, and the confidence interval shows the range of what the true mean is likely to be based on the sample size and variance. A larger sample size generally yields a more precise estimate of the mean (*i.e.*, narrower confidence intervals). So "how appropriate" may really be asking, "with what level of confidence," and that is something that one has to choose. For the available data, the level of confidence is ± 0.650 mg. If one wanted to estimate the mean with a 95% confidence interval of ± 0.25 mg, then the minimum sample size needed, based on a variance of 0.714 mg^2 would be approximately 176. Of course, as more samples were collected, one would expect the variance to decrease, so the minimum sample size, upon recomputation, would follow suit.

In terms of estimating potential load reductions, if one uses the confidence limits based on the nine samples rather than the mean, then estimated load reduction to reach an average effluent concentration of 1.0 mg/l would be between 75% and 62%.

20. Comment: The method of implementing stringent nutrient removal requirements on points [sic] sources without a methodology to enforce removal by the more significant non-point sources of pollution is illogical and "unfair." [6]
Response: Ohio EPA recognizes that non-point sources of pollution are the overarching problem in the Stillwater River basin and has, and will be, aggressively pursuing all available means to effect restoration of NPS impaired streams identified in the TMDL report. Aggressive steps have already been taken by Miami County and Darke County to address the issue of failing on-site septic systems. Many agricultural BMPs, equipment buy-downs, and conservation

easements have been funded through 319 funds sponsored by Ohio EPA. Several specific problems associated with municipal wastewater dischargers have been or are currently being corrected through funding sponsored by Ohio EPA's Division of Emergency and Financial Assistance.

21. **Comment:** How does implementing costly nutrient reduction limitations on point sources without an enforcement mechanism in place for non-point sources meet the objective of the TMDL? [6]

Response: Several segments of the Great Miami River (GMR) downstream from the Stillwater River basin are listed as nutrient impaired, and the CWA states that downstream uses must be protected. The general TMDL approach Ohio has taken is to work first in headwater basins with the intent of alleviating loads to downstream reaches of larger streams prior to TMDL development for those larger streams [e.g., TMDLs for the upper Little Miami River, Sugar Creek (Tuscarawas headwaters), upper Sandusky River, and Sunday and Monday Creek (Hocking River headwaters)]. Given that portions of the GMR downstream from the Stillwater are impaired by nutrients, and given that the GMR is one of the larger nutrient load sources to the Mississippi River basin, nutrient reductions from upstream contributors (i.e., those in the Stillwater basin) are likely to be required in the future. This is the rationale for apportioning the load reductions in an across-the-board manner, to both point and non-point sources. As previously stated, Ohio EPA is working aggressively to reduce non-point loads, including issuing and enforcing permits on non-point sources of pollution (e.g., AFOs).

22. **Comment:** It is very clear that point sources are being singled out to reduce loadings without any immediate, quantitative, or enforceable means toward non-point source reduction. The concepts of pollutant trading, incentives, etc. have been discussed [to trade loads between point and non-point sources]. Why doesn't the EPA work with other Federal and State agency to require non-point sources to reduce [pollutant loads]? [6]

Response: Given the current regulatory structure, most efforts toward non-point pollution will depend on voluntary action of local land owners and watershed residents.

Part 2. Model-Specific Comments

23. Comment: Page 71 (Table 4.13g) TMDL for NO2+NO3 is drastically in error; a simple 4.13g = 4.13h + 4.13i + 4.13j + 4.13k + 4.13i was done and many numbers appear wrong, some are exactly right unless I am doing something wrong. [1]

Response: The calculations are correct; the tables are not in error. The corresponding text for these tables state (note tables have been renumbered):

> *"4) However, percentage reductions for NO_2^-+NO_3^- loads are small or even negative, which could be wrongly interpreted as a potential loading increase. We caution that the NO_2^-+NO_3^- load allocations not be viewed as allowable increases, and therefore we have re-assigned all negative percentage reductions to zero (**Tables 4.17a--d**) and maintained an unallocated portion of the NO_2^-+NO_3^- load (**Figures 4.15b** and **4.16b**) as a margin of safety (see Section 4.3) for the following reasons:*
>
> > *a) Given the co-occurrence of phosphorus and nitrogen, it is unlikely that total phosphorus can be reduced in the load allocation (LA) portion of the TMDL while NO_2^-+NO_3^- can be increased or even maintained;*
> >
> > *b) We believe that keeping a portion of the NO_2^-+NO_3^- load as unallocated for a margin of safety is warranted because we globally assigned a warmwater habitat (WWH) NO_2^-+NO_3^- target to the TMDL, whereas the Stillwater River and Greenville Creek segments have exceptional warmwater habitat (EWH) use designations;*
> >
> > *c) Several segments of the Great Miami River (GMR) downstream from the Stillwater River basin are listed as nutrient impaired, and the Clean Water Act states that downstream uses must be protected. The general TMDL approach that Ohio has taken is to work first in headwater basins with the intent of alleviating loads to downstream reaches of larger streams prior to TMDL development for those larger streams [e.g., TMDLs for the upper Little Miami River, Sugar Creek (Tuscarawas headwaters), upper Sandusky River, and Sunday and Monday Creek (Hocking River headwaters) are such examples]. Given that portions of the GMR downstream from the Stillwater basin are impaired by nutrients, nutrient reductions from upstream contributors (i.e., those in the Stillwater River basin) are likely to be required in the future; and lastly,*
> >
> > *d) The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (2001) has recommended that a 40 percent reduction in total nitrogen loads to the Gulf is necessary to return to pre-1970 conditions, and that an estimated 20-30 percent reduction is minimally needed to increase bottom-water dissolved oxygen concentrations between 15 and 50 percent. The GMR is one of the larger nutrient load sources to the Mississippi River basin."*

24. Comment: There were several concerns with the readability and ease of discriminating Tables 4.12a-e and 4.13a-e. [1]

The use of multiple tables is confusing and unclear to the reader. Presenting this information as a series of bar graphs would greatly enhance the readability of this section. [3]

Response: The tables have been completely revised. Tables for total phosphorus and nitrate+nitrite have been separated; easily recognized headings have been added to each table and these headings are referenced in subsequent tables and figures; the table for TMDL and background load have been separated from the existing load sequence of tables. Bar charts have been added following each group of tables to better demonstrate differences in numerical values.

The revised tables are now referenced as:

Table #	Nutrient	Description
4.12a-d	TP	Existing loads for 4 sectors (wastewater effluent, agriculture fertilizer, onsite sewage system, and municipal stormwater).
4.13a-b	TP	TMDL and natural background load.
4.14a-d	TP	Allocated loads for 4 sectors (wastewater effluent, agriculture fertilizer, onsite sewage system, and municipal stormwater).
4.15a-d	NN	Existing loads for 4 sectors (wastewater effluent, agriculture fertilizer, onsite sewage system, and municipal stormwater).
4.16a-b	NN	TMDL and natural background load.
4.17a-d	NN	Allocated loads for 4 sectors (wastewater effluent, agriculture fertilizer, onsite sewage system, and municipal stormwater).

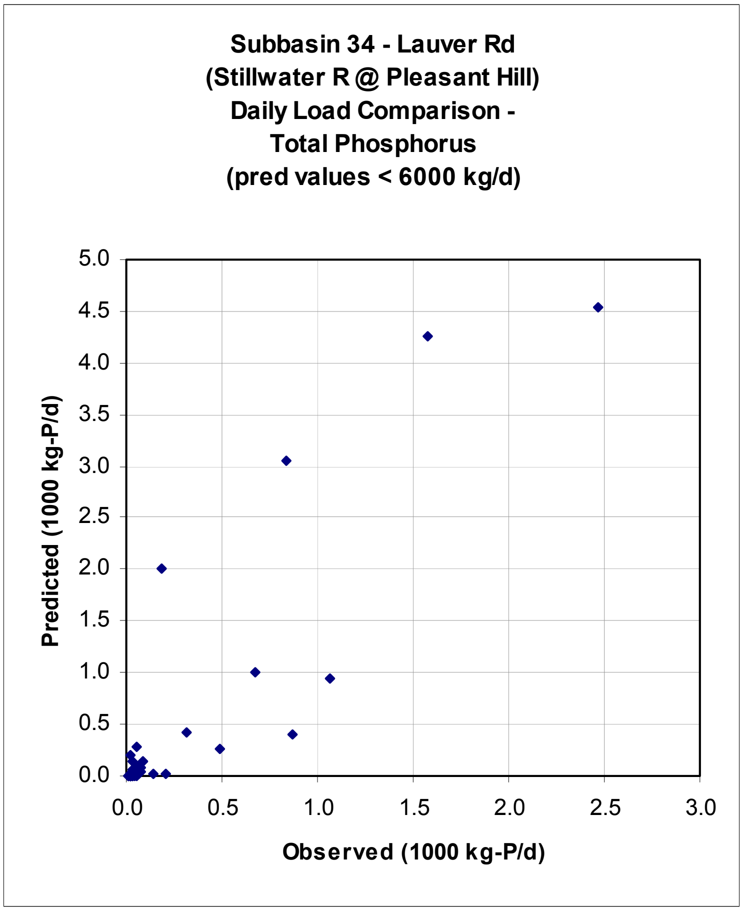
25. Comment: What table is referenced in Table 4.1a (in the Approach column)? [3]
Response: This is Table 4.23.

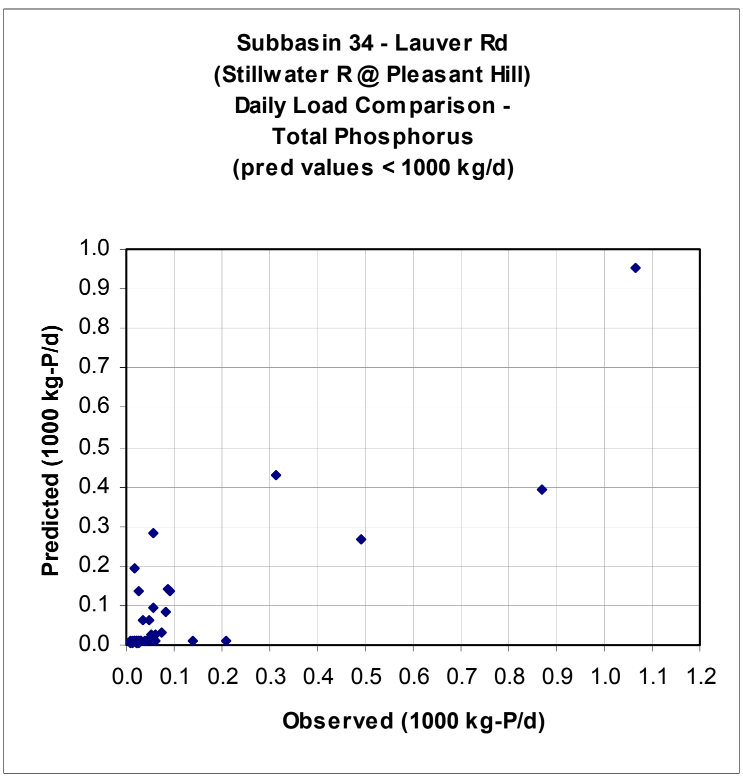
26. Comment: The text in one cell in Table 4.2 was eliminated. Bullets and numbering are incorrect. [3]
Response: Text was inserted from the original document; it had been lost in a transfer from one application to a second. Bullets and numbering have been corrected.

27. Comment: The reviewer expressed concern with the lack of calibration of the hydrology portion of the model. [3]
Response: As more information becomes available from stakeholders to refine the model parameterization, the OEPA will publish new model results. Some of these results are forthcoming in January-February, 2004. However, in using the existing model results, the following compensation were made:

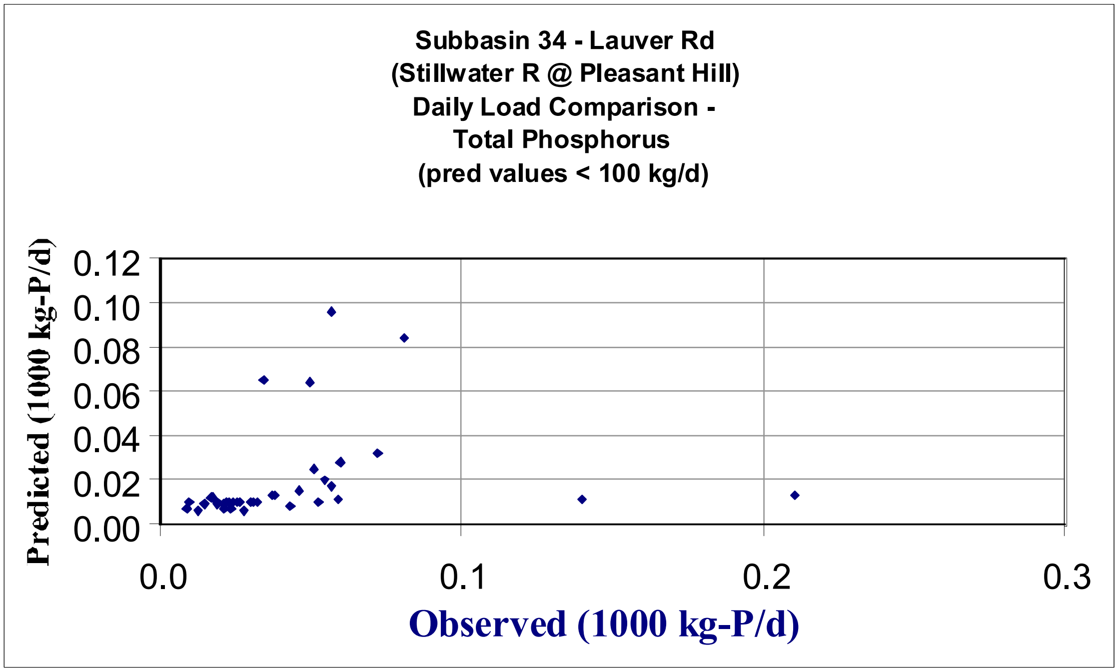
a) A WWH aquatic life use criterion was applied instead of the assigned EWH criterion. This alleviated the burden of reaching a target nutrient load.

b) While model flows were over-estimated and subsequent nutrient loads may also be over-estimate, target loads *will also be over-estimated* because model flows were also used in determining the target load (as was used in predicting existing loads).





Further inspection of observed nutrient loads were examined for total phosphorus at the Ohio EPA long-term ambient monitoring site (Stillwater River at Lauver Road). Grab concentrations are taken at this site and the nearby USGS gauge (Stillwater River at Pleasant Hill) provides simultaneous flow information. For the three largest values of predicted TP load, the model overestimates observed TP load (see accompanying figure top left). For intermediate (see figure bottom left) and small values (see figure next page) of predicted TP load, the model actually *underestimates* observed TP load.



28. **Comment:** The report is silent on the process used to estimate the NPS load using the SWAT model. [3]

Response: The final report contains an explanation of how surface runoff, stream flow, and nutrient loads (to soil and to stream) are calculated. The following text was added to the TMDL report:

> *Runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed. SWAT simulates surface runoff volumes and peak runoff rates for each HRU using a modification of the SCS curve number method (USDA Soil Conservation Service 1972).SWAT simulates the land phase of the hydrologic cycle using a daily water balance equation; the equation consists of initial soil water content, precipitation, surface runoff, evapotranspiration, percolation and bypass flow, and return flow to predict final soil water content for each day of the simulation. Surface runoff, as predicted by the SCS curve number method, is a function of soil permeability, land use, and antecedent soil water conditions. The peak runoff rate, calculated using the modified rational method, is used to predict sediment loss on hillslopes. If time of concentration exceeds one day, SWAT uses a surface storage function to lag the release of runoff delivered to the main channel. This lag also applies to the movement of nutrients (introduced below). Flow is routed through the channel using a variable storage coefficient method developed by Williams (1969). Evapotranspiration was simulated using the Priestly-Taylor method (1972) which is a simpler form of the Penman-Monteith (Penman, 1965) and applied when surfaces are wet. The Priestley-Taylor equation provides potential evapotranspiration estimates for low advective conditions. Erosion caused by rainfall and runoff is computed with the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975). Delivery ratios are not needed with MUSLE because the runoff factor represents energy used in detaching and transporting sediment.*
>
> *SWAT monitors five different pools of nitrogen in the soil. Two pools are inorganic forms of nitrogen, NH_4^+ and NO3, while the other three pools are organic forms of nitrogen. NO3 load is calculated by soil concentration and flow volume and is moved by SWAT using pathways of surface runoff, lateral flow, and percolation. Organic N is moved by SWAT as a function of the sediment loading from each HRU. SWAT monitors six different pools of phosphorus in the soil. Three pools are inorganic forms of phosphorus*

while the other three pools are organic forms of phosphorus. SWAT uses a diffusion equation to move soluble phosphorus through the soil column. Organic P and mineral P are moved in the same way as organic N (as above).

Nutrient transformations in the stream are controlled by the in-stream water quality component of the model. The in-stream kinetics used in SWAT for nutrient routing are adapted from QUAL2E (Brown and Barnwell, 1987). The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment.

29. **Comment:** Why are background concentrations for small and large rivers higher than target values for EWH designations (Table 4.10)? [3]

Response: Bearing in mind that the EWH targets listed in Table 4.10 were not used in this TMDL, the background values listed are median concentrations sampled from least impacted reference sites. The "target" EWH concentrations were derived from a combination of linear statistical analysis of the Ohio EPA databases, and a review of the scientific literature concerning both ambient nutrient concentrations and nutrient guidelines for the prevention of eutrophication in temperate rivers and streams. For headwaters and wadeable streams, statistically significant relationships between mean IBI scores and phosphorus concentrations were evident, and the targets in Table 4.10 for headwater and wadeable EWH streams reflect the results of those analyses. However, because most Ohio rivers and streams are enriched with respect to nitrogen, and nearly all streams greater than 200 square miles are enriched with both phosphorus and nitrogen, statistical relationships between the IBI and nutrient concentrations are obliterated. In those cases literature values were used for EWH targets.

30. **Comment:** Reference is made to Figures 4.4a - 4.4b that are not contained in the document. Cannot read the text in Figure 4.5. [3]

Response: The reference to these figures was removed as Figures 4.4a and 4.4b were subsequently subsumed into another figure. Figure 4.5 was revised and divided into two figures. Font size was enlarged so that text is now readable.

31. **Comment:** We are underestimating the failure rate of traditional on-site wastewater treatment systems. The reviewer provides information on the distribution of unsuitable soils present in the counties within the Stillwater River watershed. [3]

Response: Soil information was included in the GIS model to estimate septic system failure. We included a detailed distribution of soil map units (SSURGO-like scale) to account for the spatial variability in soil permeability and soil drainage suitability. A table of failure estimation is included below (see next page); the mean failure rate is 43.3 percent for the distribution of 36 model subwatersheds. We also explored the total septic system load if *all systems* have failed (a "worst-case" scenario). We then compared these new loads to both the 1) original septic system load and the 2) load generated by the agricultural fertilizer sector. Based on results (see paired tables in following pages) for total phosphorus and nitrate+nitrite, the increase in load represents a very small fraction of the load produced by agricultural fertilizer. There are a few assessment units for certain seasons when this increase is somewhat greater than zero (see shaded cells) but in the worst case it is less than 10% of the total agricultural fertilizer load for that assessment unit and season.

We conclude that 1) soil properties have been considered in our GIS-based model of septic

system load and, 2) if our estimates of percent system failure are incorrect, the increases represent only a small fraction of the largest producer of agricultural load in the Stillwater River watershed.

SUBBASIN	PERSONS_total	PERSONS_fail	PERSONS_norm	%Fail
1	425	424	1	99.8%
2	596	528	68	88.6%
3	643	563	80	87.6%
4	1678	1608	70	95.8%
5	700	694	6	99.1%
6	1012	542	470	53.6%
7	245	139	106	56.7%
8	975	634	341	65.0%
9	437	284	153	65.0%
10	1154	221	933	19.2%
11	805	0	805	0.0%
12	955	303	652	31.7%
13	29	0	29	0.0%
14	854	203	651	23.8%
15	911	655	256	71.9%
16	1095	793	302	72.4%
17	1035	879	156	84.9%
18	4	0	4	0.0%
19	644	266	378	41.3%
20	263	116	147	44.1%
21	387	34	353	8.8%
22	1253	317	936	25.3%
23	456	22	434	4.8%
24	2669	603	2066	22.6%
25	2882	1226	1656	42.5%
26	469	212	257	45.2%
27	1347	680	667	50.5%
28	193	49	144	25.4%
29	3225	755	2470	23.4%
30	2734	1421	1313	52.0%
31	3421	703	2718	20.5%
32	2181	433	1748	19.9%
33	3506	1340	2166	38.2%
34	485	262	223	54.0%
35	127	6	121	4.7%
36	2640	584	2056	22.1%
mean	1179	486	693	43.3%
median	883	429	347	41.9%

	Total P - %Increase (base= original OSsewer load)			
AU	DJF_Pkg	MAMJ_Pkg	JAS_Pkg	ON_Pkg
05080001-090	0.0%	12.8%	12.2%	5.3%
05080001-100	0.0%	7.1%	6.5%	2.7%
05080001-110	0.0%	29.8%	29.1%	12.4%
05080001-120	0.0%	24.0%	23.3%	10.1%
05080001-130	0.0%	18.8%	18.1%	7.9%
05080001-140	0.0%	26.1%	25.4%	10.9%
	Total P - %Increase (base= AgFert load)			
AU	DJF_Pkg	MAMJ_Pkg	JAS_Pkg	ON_Pkg
05080001-090	0.0%	0.3%	1.1%	1.3%
05080001-100	0.0%	1.6%	1.4%	**5.4%**
05080001-110	0.0%	0.4%	1.9%	1.4%
05080001-120	0.0%	0.5%	1.9%	1.9%
05080001-130	0.0%	0.4%	1.4%	1.5%
05080001-140	0.0%	1.1%	**4.0%**	**4.3%**

	NO2+NO3 - %Increase (base= original OSsewer load)			
AU	DJF_Pkg	MAMJ_Pkg	JAS_Pkg	ON_Pkg
05080001-090	0.0%	6.8%	6.2%	2.5%
05080001-100	0.0%	4.2%	3.7%	1.3%
05080001-110	0.0%	13.7%	13.1%	5.7%
05080001-120	0.0%	11.4%	10.8%	4.7%
05080001-130	0.0%	9.3%	8.7%	3.7%
05080001-140	0.0%	12.3%	11.7%	5.1%
	NO2+NO3 - %Increase (base= original OSsewer load)			
AU	DJF_Pkg	MAMJ_Pkg	JAS_Pkg	ON_Pkg
05080001-090	0.0%	0.2%	0.1%	0.4%
05080001-100	0.0%	0.1%	0.0%	0.2%
05080001-110	0.0%	0.2%	0.1%	0.5%
05080001-120	0.0%	0.3%	0.1%	1.2%
05080001-130	0.0%	0.1%	0.0%	0.2%
05080001-140	0.0%	0.2%	0.1%	**9.4%**

Appendix VI Draft NPDES Language for Phosphorus Reduction Schedule

Part I, C - Schedule of Compliance

A. Stillwater TMDL Phosphorus Reduction Implementation Schedule **(Draft 1-9-04)**

As soon as possible, but not later than the dates developed in accordance with the following schedule, the permittee shall achieve an allowable total phosphorus load of ___ kg/day. The permittee may achieve the allowable phosphorus load by reducing phosphorus loads discharged through wastewater treatment plant station number ________001 and/or by implementing alternative load reduction projects that are reviewed by and are acceptable to Ohio EPA.

The allowable total phosphorus load may be expressed as:

___ kg/day total phosphorus = (med Qeff x med Peff x F) - (estimated total phosphorus load reduction from alternative load reduction initiatives)

where:

med Qeff = 5-year median daily effluent flow rate (MGD). This flow value shall be the median of the daily flows at station number ________001 for the previous 5 consecutive calendar years.

med Peff = median daily effluent total phosphorus concentration during January - December (mg/l)

F = conversion factor, 3.7854

Alternative load reductions = estimated average daily total phosphorus load reductions achieved since 1999

1. The permittee shall immediately begin an evaluation of the capability of its existing treatment facilities to reduce the effluent loadings of total phosphorus. Both operational procedures, unit process configuration, and other measures shall be evaluated as appropriate.

2. Not later than 12 months from the effective date of this permit, the permittee shall submit to the Ohio EPA Southwest District Office a status report on the evaluation of the capability of its existing treatment facilities to reduce the effluent loadings of total phosphorus and a summary of other projects, initiatives or activities the permittee has taken to achieve the loading reductions necessary to meet the final allowable phosphorus load of ___ kg/day. (Event Code 95999)

3. Not later than 24 months from the effective date of this permit, the permittee shall submit to the Ohio EPA Southwest District Office a status report on the capability of its existing treatment facilities to reduce the effluent loadings of total phosphorus and a summary of other projects, initiatives or activities the permittee has taken to achieve the loading reductions necessary to meet the final allowable phosphorus load of ___ kg/day. (Event Code 95999)

4. Not later than 36 months from the effective date of this permit, the permittee shall complete implementation of measures identified in its evaluation that can reasonably be expected to maximize the ability of the existing treatment facilities to achieve an allowable total phosphorus load of ___ kg/day. Permits To Install shall be obtained if necessary.

5. Not later than 48 months from the effective date of this permit, the permittee shall submit to the Ohio EPA Southwest District Office a status report that includes the following (Event Code 95999):

a. A summary of changes in operational procedures, unit process configuration, and other measures taken to maximize the ability of its treatment facilities to achieve an allowable total phosphorus load of ___ kg/day.
b. The phosphorus load discharged from station number ________001 during each calendar year since the effective date of this permit. The loads shall be determined using the following equation: kg/day total phosphorus = med Qeff x med Peff x F, where the terms are defined as above.
c. A summary of other projects, initiatives or activities the permittee has taken to achieve the loading reductions necessary to meet the final allowable phosphorus load of ___ kg/day.

6. Not later than 54 months from effective date of this permit, the permittee shall submit a general plan for achieving the loading reductions necessary to meet the final allowable phosphorus load of ___ kg/day. In developing the plan, the permittee shall evaluate various alternatives for achieving the necessary loading reduction. The alternatives may include, but are not limited to: implementation of nonpoint source loading reduction projects; implementation of projects that increase the capacity of the receiving waters to assimilate total phosphorus loads; entering into cooperative agreements with other parties to implement projects that will achieve the point source loading reductions identified in the report "Total Maximum Daily Load for the Stillwater River Basin"; and/or upgrading the existing wastewater treatment facilities. (Event Code 1299)

Any alternative load reduction projects or other initiatives identified and undertaken by the permittee to achieve the phosphorus loading reductions must comply with the wasteload allocations (WLA) and load allocations (LA) assigned in the Stillwater River Basin TMDL report. Loading reductions achieved by the permittee must be applied to meeting the point source WLA for phosphorus. After review and acceptance by Ohio EPA, any portion of loading reductions achieved by one stakeholder may be credited to it or to another stakeholder(s) so long as such credit is not duplicated.

The general plan for achieving the loading reductions shall address, as a minimum, the following:

a. The alternative(s) chosen to achieve the loading reductions.
b. Cost estimates of implementing the chosen alternatives, including any applicable operation, maintenance, and replacement costs.
c. A fixed date compliance schedule for meeting the reduction targets for total phosphorus. As a minimum, this schedule should include dates for: submission of approvable detail plans (if

applicable); completion of implementation/construction; attainment of operational level; notification of the Ohio EPA Southwest District Office within 14 days of attaining operational level (if applicable); and achieving the loading reductions required by Schedule of Compliance Item A.7 not later than 118 months from the effective date of this permit.
d. The financial mechanism to be used to fund the required improvements, operation, maintenance, and replacement costs (if applicable).
e. For alternatives other than upgrading the existing wastewater treatment facilities, demonstrate reasonable assurance by providing information that: the proposed projects are technically feasible based on accepted modeling, data from similar projects, and commonly accepted professional expectations; there is a reasonable expectation that the proposed controls will be implemented; and other appropriate measures identified by the permittee.

7. The permittee shall achieve the final allowable total phosphorus load of ___ kg/day not later than 118 months from the effective date of this permit. (Event Code 5699)

This NPDES permit, Ohio EPA permit number ________*__, expires on ________________. This Schedule of Compliance includes an item that extends beyond the term of the permit. The requirements of Schedule of Compliance Item A.7, including the compliance date, will be included in permit ________ when it is renewed.

In the event that evidence becomes available demonstrating to the Director's satisfaction that biological indices applicable to the Stillwater River Basin are in full attainment, or that monitoring data collected at appropriate locations within the TMDL study area show that the median total phosphorus concentration measured at those locations is less than or equal to the instream target for two consecutive years, the Director will evaluate any proposed modification of the TMDL Implementation Schedule included in this NPDES permit.

This permit may be modified or revoked and reissued for the following reasons:

- To include new or revised conditions based on new information resulting from implementation of the TMDL recommendations.

- To include new or revised conditions based on plans submitted by the permittee to upgrade the existing wastewater treatment facilities to achieve the allowable total phosphorus load of ___ kg/day.

Appendix VII Draft NPDES Language for Nitrogen Reduction Schedule

Part I, C - Schedule of Compliance

B. Stillwater TMDL Nitrite/Nitrate Reduction Implementation Schedule **(Draft 1-9-04)**

As soon as possible, but not later than the dates developed in accordance with the following schedule, the permittee shall reduce the nitrite/nitrate loads discharged through wastewater treatment plant station number ________001 to the maximum extent practicable up to a reduction equal to 30 percent of the current discharge level of ___ kg/day.

Current discharge level = med Qeff x med Neff x F, where med Qeff = 5-year median daily effluent flow rate (MGD), the median of the daily flows at station number ________001 for the previous 5 consecutive calendar years; med Neff. = median daily effluent nitrite+nitrate-N concentration during January - December (mg/l); F = conversion factor, 3.7854

1. The permittee shall immediately begin an evaluation of the capability of its existing treatment facilities to reduce the effluent loadings of nitrite+nitrate-N to the maximum extent practicable. Both operational procedures, unit process configuration, and other measures shall be evaluated as appropriate.

Compliance with the "maximum extent practicable" (MEP) standard will typically require the permittee to evaluate the operation procedures and unit process configuration of its existing treatment facilities and to implement measures that can reasonably be expected to reduce the discharge of nitrite+nitrate-N. Compliance with the MEP standard does not require the permittee to construct new unit processes or other major upgrades to its existing treatment facilities.

2. Not later than 12 months from the effective date of this permit, the permittee shall submit to the Ohio EPA Southwest District Office a status report on the evaluation of the capability of its existing treatment facilities to reduce the effluent loadings of nitrite+nitrate-N. The report shall also include a summary of other projects, initiatives or activities the permittee has taken to reduce the discharge of nitrite+nitrate-N to the maximum extent practicable. (Event Code 95999)

3. Not later than 24 months from the effective date of this permit, the permittee shall submit to the Ohio EPA Southwest District Office a status report on the capability of its existing treatment facilities to reduce the effluent loadings of nitrite+nitrate-N. The report shall also include a summary of other projects, initiatives or activities the permittee has taken to reduce the discharge of nitrite+nitrate-N to the maximum extent practicable. Permits To Install shall be obtained if necessary. (Event Code 95999)

4. Not later than 36 months from the effective date of this permit, the permittee shall submit to the Ohio EPA Southwest District Office a status report on the capability of its existing treatment facilities to reduce the effluent loadings of nitrite+nitrate-N. The report shall also include a summary of other projects, initiatives or activities the permittee has taken to reduce the discharge

of nitrite+nitrate-N to the maximum extent practicable. Permits To Install shall be obtained if necessary. (Event Code 95999)

5. Not later than 48 months from the effective date of this permit, the permittee shall submit to the Ohio EPA Southwest District Office a status report on the capability of its existing treatment facilities to reduce the effluent loadings of nitrite+nitrate-N. The report shall also include a summary of other projects, initiatives or activities the permittee has taken to reduce the discharge of nitrite+nitrate-N to the maximum extent practicable. Permits To Install shall be obtained if necessary. (Event Code 95999)

6. Not later than 54 months from the effective date of this permit, the permittee shall complete implementation of measures identified in its evaluation that can reasonably be expected to reduce the discharge of nitrite+nitrate-N to the maximum extent practicable up to a reduction equal to 30 percent of the current discharge level of ___ kg/day. Permits To Install shall be obtained if necessary.

This permit may be modified or revoked and reissued for the following reasons:

- To include new or revised conditions based on new information resulting from implementation of the TMDL recommendations.

- To include new or revised conditions based on plans submitted by the permittee to upgrade the existing wastewater treatment facilities to reduce the nitrite/nitrate loads discharged through wastewater treatment plant station number ________001 to the maximum extent practicable up to a reduction equal to 30 percent of the current discharge level of ___ kg/day.