State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Old Woman Creek and Chappel Creek Watersheds

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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[1]. Lists of these impaired waters (the section 303(d) lists) are made available to the public and submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval in even-numbered years. Further, the CWA and U.S. EPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the section 303(d) lists.

In the simplest terms, a TMDL can be thought of as a cleanup plan for a watershed that is not meeting water quality standards. A TMDL is defined as a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that quantity among the sources of the pollutant. Ultimately, the goal of Ohio's TMDL process is full attainment of Water Quality Standards (WQS), which would subsequently lead to the removal of the water bodies from the 303(d) list.

The Ohio Environmental Protection Agency (Ohio EPA) has traditionally listed impaired waters and developed TMDLs on a watershed basis, using the 11-digit Hydrologic Unit Code system as a basis for assessment. The Ohio EPA identified assessment unit 04100012 040 as impaired on the 2004 303(d) list. A copy of the report can be accessed at
http://www.epa.state.oh.us/dsw/TMDL/2004IntReport/2004OhioIntegratedReport.html

Description of the Watersheds

Assessment unit 04100012 040 contains tributaries to Lake Erie located east of the Huron River and west of the Vermilion River in northern Ohio. The total drainage area is 83.2 square miles. The principal subwatersheds from west to east drain Old Woman Creek, Chappel Creek and Sugar Creek.

At the mouth of Old Woman Creek (OWC) is the 571 acre Old Woman Creek National Estuary Research Reserve (NERR) and State Nature Preserve. Formed in 1980, OWC is the only non-ocean-coast NERR[2]. The Reserve's purpose is to ensure long-term protection of the estuary and to provide for long-term research, monitoring and education through the comprehensive on-site administration and management of the Reserve (Ohio Department of Natural Resources, OWC 2002 Annual Report). One of its goals is to facilitate research and information transfer to both government and private sectors. A wealth of information from over 100 studies, counted from the Old Woman

[1] A general overview of Ohio's water quality standards is included in Appendix A.

[2] Additional information at http://www.dnr.state.oh.us/dnap/owc/default.htm

Creek Research Bibliography (Herdendorf, 2000), is available for Old Woman Creek. This TMDL report takes advantage of this unique opportunity to use work already completed to address the impairments found during Ohio EPA's water quality assessment.

There are no municipal waste water point sources in the Old Woman Creek basin and only four small package plants located near the confluence of Chappel Creek and Lake Erie. However, there are storm water NPDES point sources in both of these watersheds.

Condition of the Watersheds

Ohio EPA surveyed the status of the water quality in assessment unit 04100012 040 during 2000 and 2002. The results of the study, on which the 2004 303(d) listing is based, were published by Ohio EPA in October 2004. The report, *Biological and Water Quality Study of the Vermilion River, Old Woman Creek, Chappel Creek, Sugar Creek, and Select Lake Erie Tributaries, 2002. Ashland, Huron, Erie, Richland and Lorain Counties, Ohio*, is available at http://www.epa.state.oh.us/dsw/document_index/psdindx.html. The study found impairment of the Aquatic Life Use, but no impairment of the Recreation Use. The main causes of impairment along with associated sources from the 2004 Integrated Report are listed in Table 1. Since drought is a natural condition, flow alteration is not addressed in this report.

The primary causes of impairment in the Old Woman Creek and Chappel Creek watersheds are nutrient/organic enrichment, siltation, and habitat alteration. Of the three impairment causes (siltation, nutrient enrichment and habitat alteration), siltation is the most important in the Old Woman Creek watershed. Siltation carries nutrients and reduces the quality of habitat. Actions taken to reduce siltation will also reduce nutrient enrichment and will improve habitat. For that reason the main emphasis regarding the calculation of needed reduction and margin of safety in this report is on siltation. Only one site on Sugar Creek was impaired, caused by the drought condition at the time of sampling. Since the Sugar Creek cause of impairment is due to a natural source, a TMDL is not needed for this stream.

Figure 1a shows the study area and summarizes the attainment status for the Aquatic Life Use. A schematic representation of Old Woman and Chappel Creeks is provided in Figure 1b.

TMDLs for Old Woman Creek and Chappel Creek

This report summarizes the water quality and habitat condition of the Old Woman Creek and Chappel Creek, quantitatively assesses the factors causing the impairment, provides for tangible actions to restore and maintain the streams, and specifies

monitoring to ensure actions are carried out and to measure the success of the actions taken. TMDLs have been completed for various impairments in this report for both Old Woman Creek and Chappel Creek. Because both streams are similar in many respects (see Table 2) and because there is inadequate site-specific data to support a nutrient TMDL for Chappel Creek, the nutrient based results and conclusions for Old Woman Creek should be applied to Chappel Creek.

Table 1. Attainment Status for Assessment Unit 04100012 040

Stream & RM	Attainment Status	QHEI	Impairment Cause	Impairment Source	Addressed in TMDL
Old Woman Creek					
11.3	(NON)		Flow alteration	Natural (drought)	no*
9.4	PARTIAL	41	Siltation/habitat alteration	Channelization-Ag.	yes
8.4	NON	74.5	Organic/nutrient enrichment	Livestock	**
5.4	FULL	66.0			
3.6	(FULL)				
1.9	(NON)		Siltation/nutrient enrichment	Non-irrigated crop production	yes
0.2	(NON)		Siltation/nutrient enrichment	Non-irrigated crop production	yes
East Trib. to OWC at RM 8.82					
0.9	(NON)		Siltation/habitat alteration	Channelization-Ag.	yes
Trib. to OWC at RM 3.70					
3.1/4.9	NON	67.5	Flow alteration	Natural (drought)	no*
0.9	(NON)		Flow alteration	Natural (drought)	no*
Chappel Creek					
16.6	(NON)	67.5	Nutrient/organic enrichment	Pasture/non-irrigated crop	yes[A]
14.1	(NON)	64.0	Nutrient/organic enrichment	Pasture	**
9.1	(NON)	64.0	Nutrient/organic enrichment	Pasture/non-irrigated crop	yes[A]
7.4	NON	64.0	Habitat alteration	Non-irrigated crop production	yes
1.3	FULL	58.5			
Sugar Creek					
3.5	(NON)	69.0	Flow alteration	Natural (drought)	no*
1.5	FULL	61.0			

Parentheses ( ) in the attainment column, e.g. (NON), indicate only one metric (fish or macroinvertebrates) was used as the attainment determinate.

* Because impairment is due to a natural condition the loading was not quantified in this report.

** Discussed in report but not quantified.

[A] Refer to the Old Woman Creek analyses for quantification.

Figure 1a. Assessment unit 04100012 040 study area and attainment status

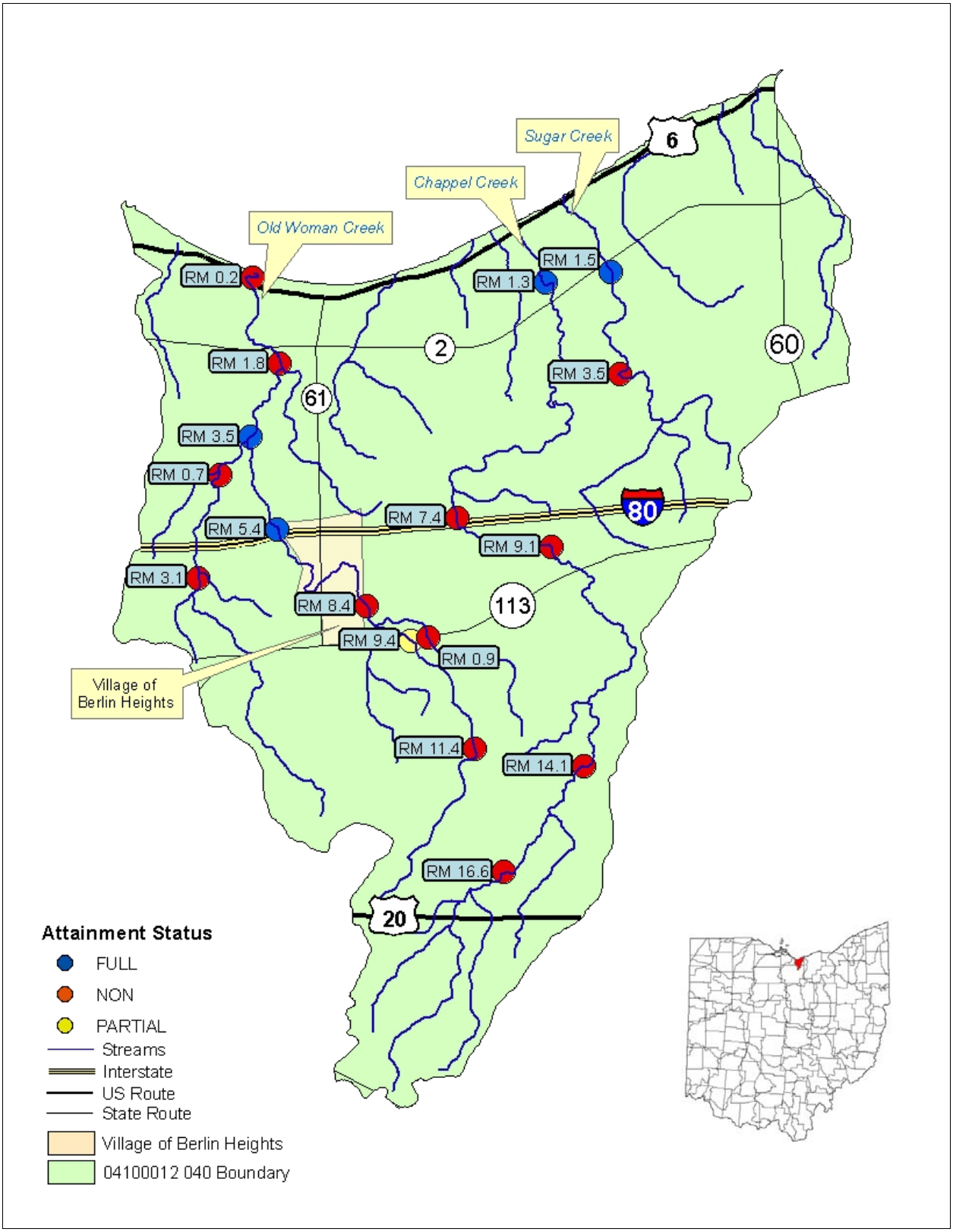
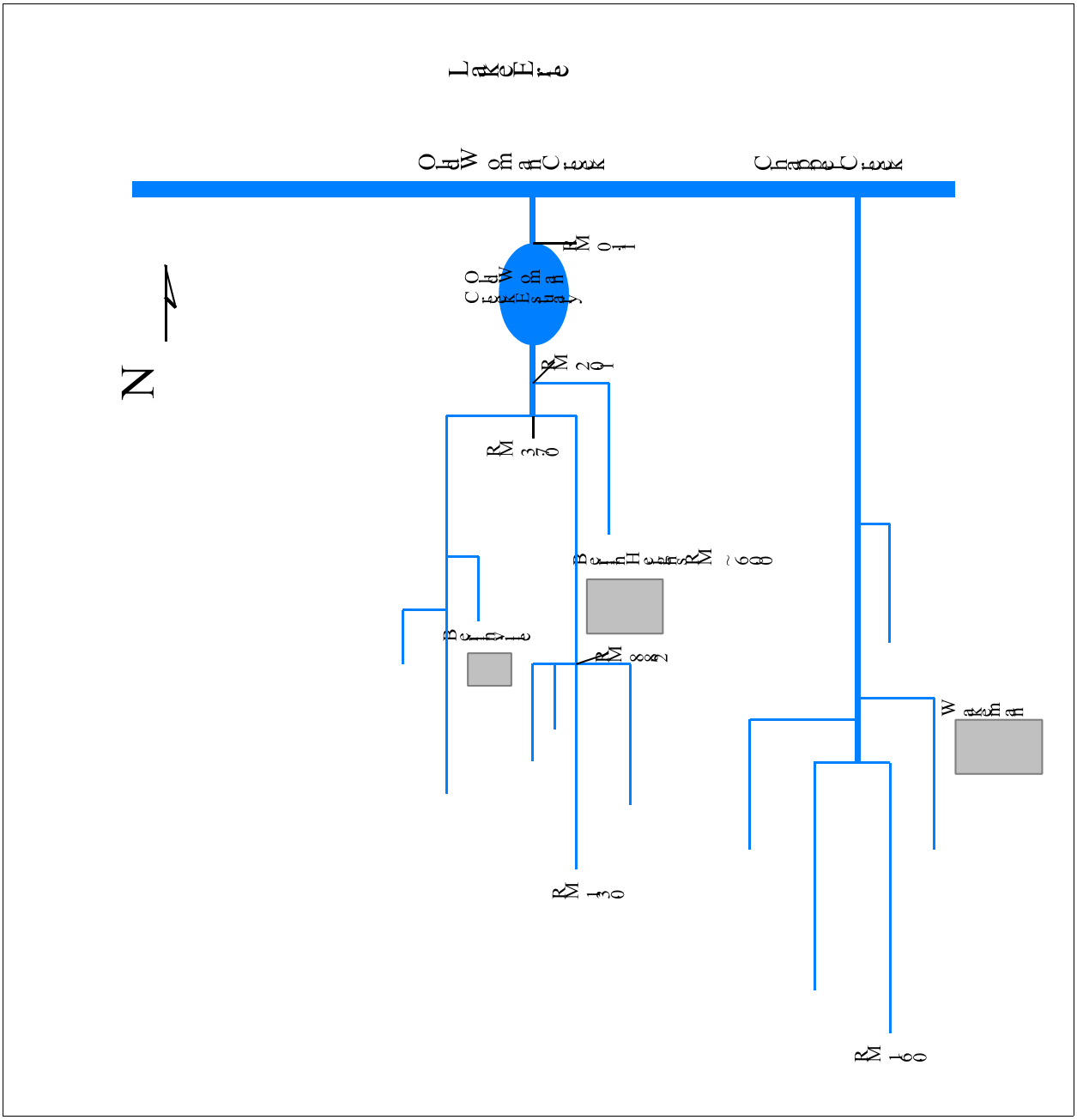


Figure 1b. Schematic Representation of Old Woman Creek and Chappel Creek



2.0 Loading Analysis

Chappel Creek and Old Woman Creek border each other and are similar in size, land use and impairments. The main difference is that Old Woman Creek, as a National Estuary Research Reserve, has been more extensively studied; many studies have been written on its condition. There is little available data for Chappel Creek. Table 2 compares the two basins and illustrates their similarity.

Table 2. Comparison of Old Woman Creek and Chappel Creek

		Old Woman Creek	Chappel Creek
	DA (sq. mi)	26.5	24.0
	Tributary to Lake Erie	✓	✓
	Agriculturally influenced	✓	✓
	Estuary	✓	✓
	USGS gage	✓	
Causes of Impairment	Nutrient/organic enrichment	✓	✓
	Habitat alteration	✓	✓
	Siltation	✓	*
Sources of Impairment	Channelization-Ag	✓	
	Non-irrigated crop production	✓	✓
	Livestock	✓	**
	Pasture	**	✓

* Siltation is not formally presented as an impairment in this basin because the substrate in Chappel Creek is generally more diverse having gravel, cobbles and sand where as the substrate in Old Woman Creek is dominated by silt, particularly in the estuary. However, some siltation is occurring in Chappel Creek.

** Livestock and pasture are interchangeable in this case.

Different approaches can be used to calculate TMDLs for streams with limited data. Whereas it is possible to construct a mathematical model using limited data and many assumptions for inputs, a more reliable approach is to use results from a more robust application in a similar watershed as a basis for comparison where data is scarce. This is the method used for Chappel Creek: the conclusions drawn for Old Woman Creek, for which there is much data, are applied directly in Chappel Creek, for which there is little data, to address the sources of impairment in that creek.

The intent of this report section is not to generate original loadings from impairment sources, as this has already been documented and fully described by many studies and reports, but rather to serve as a compendium of related information and study results. The data and information are presented to demonstrate and quantify the load reductions needed to allow the stream to meet its use designation. The key information sources, other than Ohio EPA, are

1) Fluvial Erosion, Sedimentation, and Hydraulic Geometry in the Contributing Watershed of Old Woman Creek National Estuarine Research Reserve, Woods, A. J. C. 1987.

2) A GIS Model to Calculate Sediment Yields from a Small Rural Watershed, Old Woman Creek, Erie and Huron Counties, Ohio, Evans, J. E. 1997.

3) Effectiveness of a Coastal Wetland in Reducing the Movement of Agricultural Pollutants into Lake Erie. Old Woman Creek National Estuarine Research Reserve and State Nature Preserve Tech. Report No. 15, Krieger, K. A. 2000.

This report deals primarily with load allocations (i.e., from nonpoint sources) to both Old Woman Creek and Chappel Creek because the sources of impairment are nonpoint sources. Point sources are not a factor for this TMDL analysis. Old Woman Creek does not have any permitted point sources, and Chappel Creek has four near the confluence of Lake Erie. Of these four, two will soon be connected to a waste water treatment plant outside of the basin. The four treatment plants also discharge below the most downstream site that is impaired due to nutrients. Therefore, they do not contribute to the impairment and thus are not quantified in this report. These facilities are discussed in more detail under the Point Source Controls section of this report.

Siltation

In Ohio EPA's 2004 integrated report four sites sampled are considered to be in non or partial attainment of their use designation due to siltation. Those sites are located on Old Woman Creek at RMs 9.4, 1.9 (upper portion of estuary), 0.2 (mouth of estuary) and the east tributary at RM 8.82/0.9.

There is much information about the Old Woman Creek basin in the form of technical studies, Ohio EPA work, Old Woman Creek informational brochures, Lake Erie Agricultural Systems for Environmental Quality Projects (LEASEQ) information, etc., and the major causes of water quality problems are clearly siltation which stems mostly from the headwater area, and nutrients which can come attached to silt or leach from soil and flow to the stream. Likely implementation will be in the form of BMPs to reduce siltation. Ohio EPA survey results verify what the Old Woman Creek NERR staff, the County Soil and Water district staff and scientists from Heidelberg College, The Ohio

State University, and Case Western Reserve have already determined, that siltation reduction is needed.

This section of the TMDL report explores the siltation problem by using data from the report "Fluvial Erosion, Sedimentation, and Hydraulic Geometry in the Contributing Watershed of Old Woman Creek National Estuarine Research Reserve" (Woods, 1987). In this report twelve separate sampling runs were done over the course of seven months to measure suspended sediment concentrations (SSC) and flows in 1984 and 1985. The data is somewhat old, however it is the only report that was found to measure SSC. Other studies measure total suspended solids, a less reliable method for the quantification of sediment and siltation. In the U.S. Geological Survey report "Comparability of Suspended - Sediment Concentration and Total Suspended Solids Data", it is recommended that SSC be used for the measurement of suspended solid phase materials in natural waters over total suspended solids (TSS). The TSS method, which was originally designed for analyses of waste water samples, is shown to be fundamentally unreliable for the analysis of natural water samples (Gray, 2000). Woods' (1987) report is a good study to use not only because it uses SSC but also, though on the brink of land use change by developers, the land use today is still similar enough to the early 1980s to permit comparability of results from that study. In the 1980s the area was and still is today primarily agricultural, and the siltation problems reported then still exist today.

Siltation Methods

Of nine sampling stations distributed throughout the Old Woman Creek basin in Woods' (1987) study the station with the highest loading, station 8, and the station with the lowest loading, station 2, are compared. Lacking a formal water quality standard for suspended sediment (SS) a target is derived by Ohio EPA using the data from Station 2. In the Wood's study there are twelve sample dates with eleven successful samples taken from these two stations. Loading for station 8 is calculated by Ohio EPA by multiplying the flow in cubic feet per second (cfs) by the concentration in ounces per cubic foot then converting to kilograms per day (kg/d). Ohio EPA calculated the target load by multiplying the flow from station 8 by the concentration from station 2 and converting to kg/d. This is done for each sample date. In doing so the target is derived under the same weather conditions as the load to which it is being compared. This is important since siltation is weather dependent. Greater siltation will occur during periods of high precipitation even in undisturbed areas.

Using the concentration from station 2 and the flow from station 8 effectively compares the concentration from the low load site to the concentration from the high load site. The concentrations are converted to loads in order to add and subtract one load from the other, see Figure 2. From these differences a range and average is calculated to determine the overall needed load reduction. Below is a thorough description and explanation of why these stations were selected.

Of nine stations in Woods' (1987) study, station 2 (see Figure 3 for location) is most

suitable to determine a target since it had the lowest SS concentrations and the least impacted riparian zone. The site is located in the transitional area between two geomorphic provinces (Berea Escarpment and Lake Plain), 1.3 miles northwest of Berlinville where Huff Road crosses the west branch of Old Woman Creek at RM 3.70/3.17. Much of the watershed is in the Till Plain although station 2 itself is in the transition between the Escarpment and the Lake Plain. The total upstream drainage area for station 2 is described in Woods' report (although the percentages do not add up to 100% he describes them as such) as 64% row crops or fallow and 20% woodland in October 1984. "However, within the Escarpment portion of the total watershed, landuse was very different; 52% was in row crop or fallow and 30% was in woodland. Of the total upstream length of about 6.8 miles, 75% had a forested bank and 32% had a fallow or row cropped stream bank" (Woods, 1987). See Table 3 for the complete landuse breakdown.

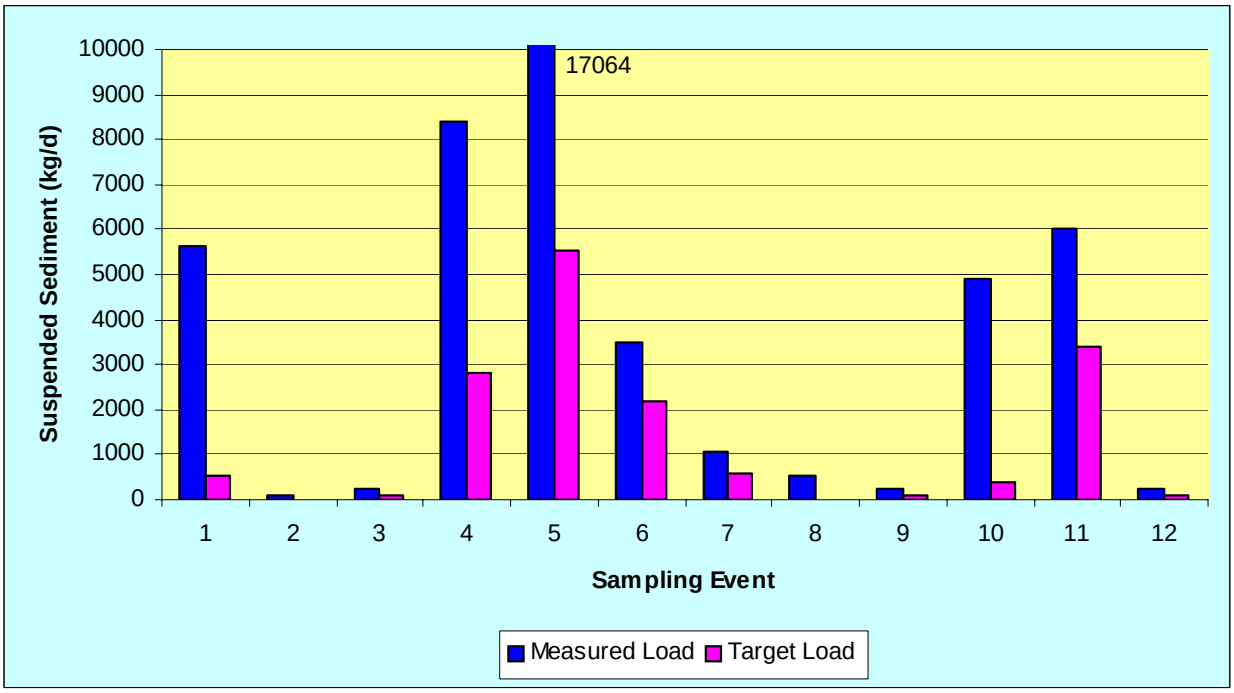
Table 3. Comparison of Land Use above Sites 2 and 8 (from Woods' Table 4 Land-Use Within a Station's Watershed and within the Morphologic Province)

	Land-Use (Percent)			
	Site 2		**Site 8**	
	sq mi in sub-basin above station*	sq mi in basin above station*	sq mi in sub-basin above station*	sq mi in basin above station*
	4.85	4.85	1.32	19.98
Field crops				
soybeans	21	21	7	19
wheat	8	8	2	5
corn	28	28	30	25
Woodlands	20	20	26	18
Orchards	1	1	5	6
Pastures	3	3	11	3
Fallow	10	10	4	12
Residential	4	4	4	4
Roads	3	3	6	4
Creek	3	3	6	3
Lakes	.2	.2	0	.4
Other	.2	.2	0	.3
Total	101.4	101.4	101	99.7

*Sub-basin area is that drainage area from the station upstream to the next station; basin area is the total drainage area above the station inclusive of that of the other upstream stations.

Based on the Qualitative Habitat Evaluation Index (QHEI) scores at RM 3.1 (site 2) the habitat is good, scoring 92 in 2000 and 67.5 in 2002, well over the WWH threshold of 60, see Figure 4. The substrate scores, out of a maximum of 20, for 2000 and 2002 are 16 and 17, respectively, see Figure 5. That the QHEI scored well above the WWH threshold is further evidence that the RM 3.1 site is a good one from which to derive a target for SSC.

Figure 2. Comparison of Suspended Sediment Loads to Target Loads for Old Woman Creek



Note: There are no data to develop a target load for sampling event 8 which occurred on 3/2/1985.

Figure 3. Old Woman Creek Basin Locator Map for Sites

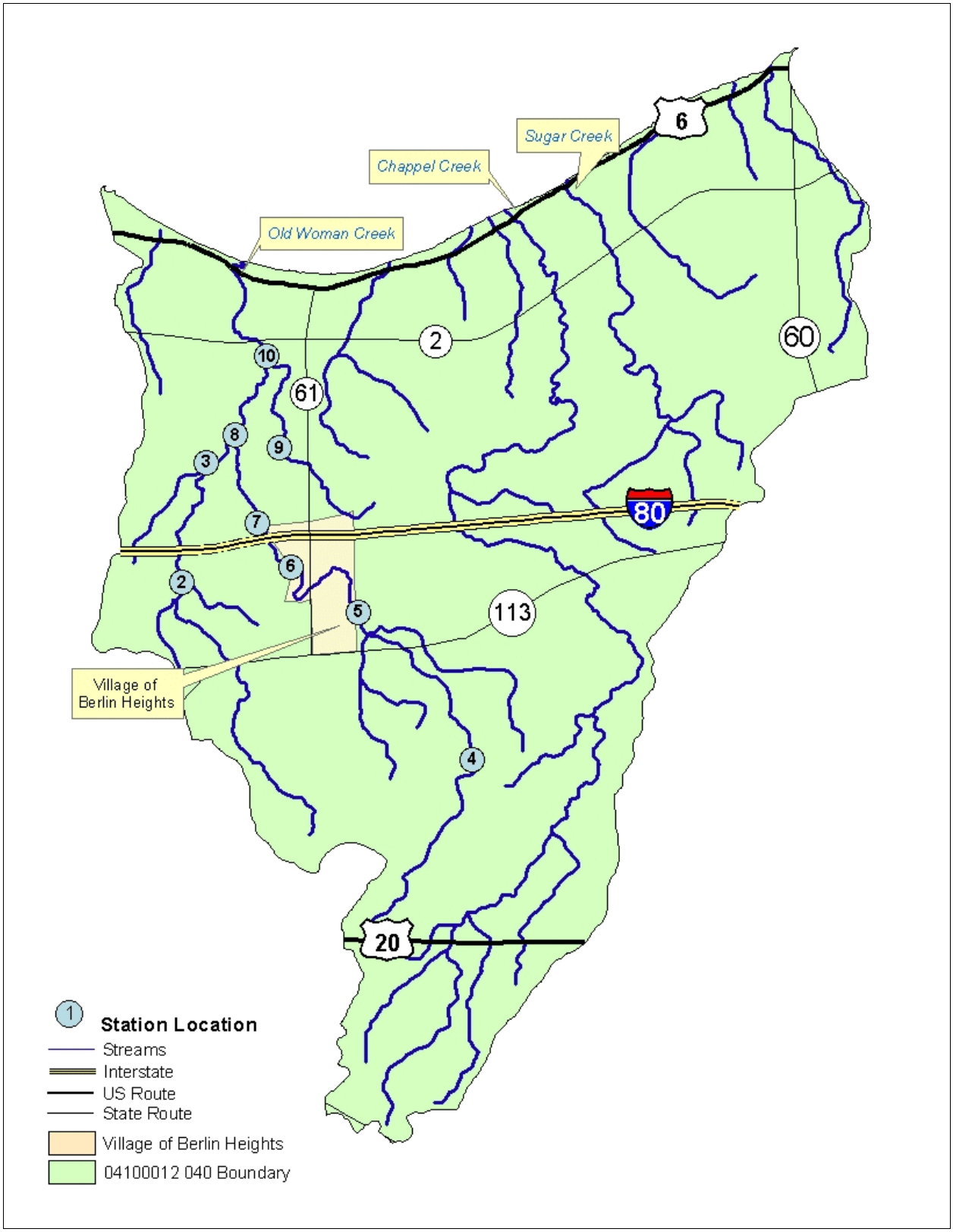


Figure 4. QHEI Values for RM 3.1, (Site 2)

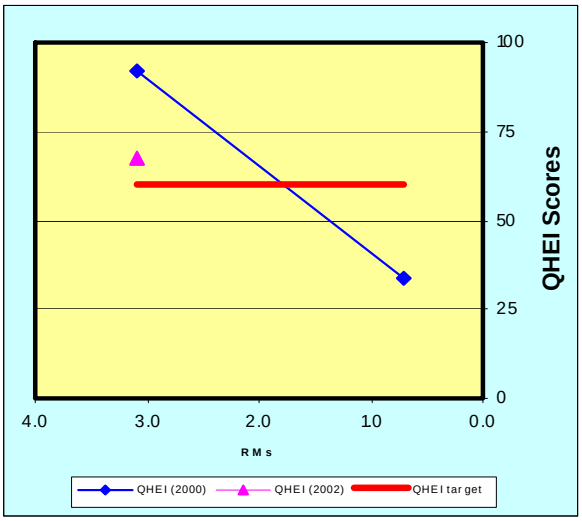
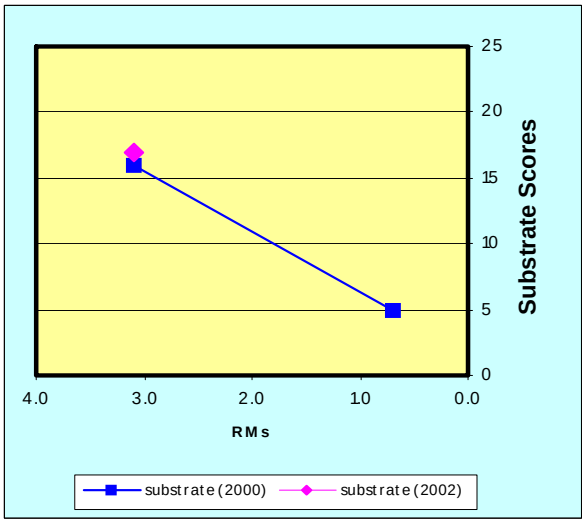


Figure 5. QHEI Subscore Values for Substrate for Site 2, maximum possible is 20



Analysis of data at station 2 by Woods (1987) found that the SSC was always comparatively low because, “the immediate upstream area lacks a readily available sediment supply and it usually had the overall lowest concentration of all escarpment stations”. Because this site has the least affected riparian zone and the lowest SSCs it is a good one from which to derive target SS loadings. During the summer of 2002 when Ohio EPA collected biological data to determine use attainment status there was drought and this site was deemed in non-attainment due to natural (drought) sources (Ohio EPA, 2004). However, based on the description of this site and the fact that the SSCs are the lowest of the nine sites studied by Woods (1987) it is the best candidate for deriving SSC target values.

Station 8 (see Figure 3 for location) is located on the Lake Plain 2 miles northwest of Berlin Heights where the Norfolk and Western Railroad crosses the creek at RM 3.65. Its bed is comprised of fine sediments. It is an important site for an estuary sediment based study because it is just downstream of the junction between the western and middle branches of Old Woman Creek and above any back-water effect of the estuary. Two of the three sites listed as impaired due to siltation include the upper and lower estuary sites. Station 8 lies just upstream of the estuary. The best way to control siltation in the estuary is to prevent it from entering, thus station 8 serves as a good measuring point for the siltation TMDL.

Woods described the situation as follows (again, not totalling 100% but described as such): “Station 8's twenty square miles of watershed is composed of several soil associations and three geomorphic provinces. Of station 8's total watershed, 61% was in field crops or fallow, 3% was in pasture, 18% was wooded, 6% was in orchard, and 4% was urban in October, 1984. However, if only the smaller watershed between

station 8 and both stations 3 and 7 is considered, a different picture emerges; 41% was in field crops or fallow, 11% was in pasture, 25% was wooded, 5% was in orchard, and 4% was urbanized or suburbanized in October, 1984" (Woods, 1987).

“Average SSC at station 8 was higher than that of the other Lake Plain stations and second only to that of station 4 on the Till Plain. Station 8 placed first twice and second three times in the daily sediment concentration rankings. The mean recorded sediment concentration at station 8 is higher than any station except station 4 on the Till Plain. Station 8 has the largest drainage area of the nine stations and also had the highest mean discharge and the second highest maximum discharge. Solely, station 10 surpassed station 8 in discharge and then only when the estuary bar was open; when it was closed, station 10 became functionally a part of the estuary. Thus, station 8 is pivotal to understanding the totality of stream input into the estuary” (Woods, 1987). Station 4 was not selected for use in determining needed silt load reductions. Because it has a small drainage area, only 2.3 square miles, the station had zero flow on 4 out of the 12 sampling dates. Station 4 did have the highest measured silt concentration, however the sample was collected on a day when there was no measureable stream flow. Station 8 was selected for use in determining the needed load reduction because it has good flow to load relationships, historically has been the focal point for sampling, and is the conduit for all upstream (including much of the till plain) sediment.

Station 2 has the lowest mean suspended sediment concentration overall, so the SS value from this site is used as the target concentration for each sampling date. The concentration was then multiplied by the flow from station 8 and compared to station 8's loads. A percent needed reduction is then calculated for station 8 for all the sampling dates. Station 2, from the till plain has the lowest concentrations on average because the immediate upstream area lacks a readily available sediment supply (Woods, 1987). Since our goal is to reduce the readily available load of sediment and because it is best if sediment targets are developed from within the watershed, station 2 is a good reference site to develop a target for sediment.

Siltation Results

Using the data from the eleven complete sampling dates in Woods’ (1987) study, the needed load reduction in kg/d, from station 8 based on the site 2 derived target, ranges from 50.6 to 11524. The average needed load reduction from these 11 sites is 2876 kg/d. The percent reductions needed to meet the target ranges from 37.7 to 91.6, with an average of 66.7 (see Table 4).

Table 4. Load Comparison of Stations 2 and 8 with Needed Reductions, Data from Woods, 1987

> Sampling Event/Date	1	2	3	4	5	6	7	8	9	10	11	12	Mean
	10/1/1984	11/29/1984	12/2/1984	12/15/1984	2/25/1985	2/26/1985	3/1/1985	3/2/1985	3/23/1985	3/24/1985	4/7/1985	4/19/1985	
Station 2													
Q[a]	1.5	0.8	0.7	6.8	22	12.4	5	3.1	1.8	4.2	8.8	2.1	6.0
C[b]	1.17	0.39	0.53	2.75	2.15	1.33	0.71	-	0.36	0.65	2.7	0.31	1.19
G[c]	1.75	0.31	0.37	18.68	47.25	16.47	3.55	-	0.65	2.71	23.73	0.65	10.56[◊]
Station 8													
Q[a]	19.2	2.4	7	41.6	105.2	67.2	34.1	26.8	11.7	25.8	51.3	9.9	33.52
C[b]	11.94	1.25	1.47	8.26	6.63	2.13	1.29	0.85	0.89	7.79	4.79	0.92	4.02
G[c]	228.98	3	10.28	343.43	696.66	143.4	43.93	22.75	10.4	200.75	245.49	9.1	163.18[◊]
Load at Station 8 (kg/d)	5608.6	73.5	251.8	8412.0	17064.0	3512.4	1076.0	557.2	254.7	4917.2	6013.0	222.9	4309.6
Target load* (kg/d)	550.2	22.9	90.9	2802.1	5540.0	2189.2	593.0	-	103.2	410.8	3392.7	75.2	1433.7
Needed reduction (kg/d)	5058.4	50.6	160.9	5609.9	11523.9	1323.3	483.0	-	151.6	4506.4	2620.4	147.7	2876.6
Needed reduction (%)	90.2	68.8	63.9	66.7	67.5	37.7	44.9	-	59.5	91.6	43.6	66.3	66.7**

Q[a] = stream discharge in cubic feet per second.
C[b] = suspended sediment conc. In ounces/cubic ft. x 10^{-2} {i.e. 0.04oz/ft^3 would be recorded here as 4.00}.
G[c] = suspended sediment yield in ounces/second x 10^{-2} and is the product of Q X C.
* equals the product of the concentration from site 2 and the flow from site 8 for each date.
Conversions: 1 oz. = 0.02834952 kg 1 day = 86400 seconds 1 oz./sec. = 2449.3985 kg/day
** The reduction was calculated as a percent change from 4309.6 to 1433.7.
◊ G[c] in this column is the mean of the G[c] values in the individual "date" columns.

Siltation Margin of Safety

Ohio EPA does not have a Water Quality Standard for Suspended Sediment (SS). Therefore a target is derived based on the SS data from site 2, a site that is comparatively low in SS and overall has high QHEI scores (good surrounding habitat and stream characteristics). The target is the average of the SS load from eleven samples taken over seven months. Suspended Sediment is detrimental to aquatic life because it degrades the habitat and eliminates living spaces for fish and macroinvertebrates. Because SS is a chronic problem as opposed to a toxic problem it is appropriate to derive the target from an average value as opposed to needing an exact value such as with toxic chemicals, which if exceeded cause death to aquatic life.

Since site 2 has good riparian habitat and good stream attributes, and site 8 has poor riparian habitat and poor stream attributes, one would expect to find a greater difference between SS loads and the target loads during high loading conditions such as high flows, exposed soil, etc. The data from Woods' (1987) study found this to be true. From Table 4, the five highest SS loading events were averaged. These are the events whose daily load exceeded the average load of 4309.6 kg/d for all of the site 8 events. The target loads for those days are also averaged and a needed reduction is calculated by subtracting the target load average from the average SS load for those days. The percent needed reduction is averaged for each of those days and as expected is greater than the average of the percent needed reduction for all eleven sampling events, see Table 5.

Table 5. Summary of Five Highest Loading Events for Site 8

	1	4	5	10	11	
Sampling Event/Date	**10/1/1984**	**12/15/1984**	**2/25/1985**	**3/24/1985**	**4/7/1985**	**Mean**
Station 2						
Q^a	1.5	6.8	22	4.2	8.8	8.66
C^b	1.17	2.75	2.15	0.65	2.7	1.88
G^c	1.75	18.68	47.25	2.71	23.73	18.8
Station 8						
Q^a	19.2	41.6	105.2	25.8	51.3	48.6
C^b	11.94	8.26	6.63	7.79	4.79	7.88
G^c	228.98	343.43	696.66	200.75	245.49	343
Load at Station 8 (kg/d)	5608.6	8412	17064.0	4917.2	6013.0	8403.0
Target load* (kg/d)	550.2	2802.1	5540.0	410.8	3392.7	2539.2
Needed reduction (kg/d)	5058.4	5609.9	11523.9	4506.4	2620.4	5863.8
Needed reduction (%)	90.2	66.7	67.5	91.6	43.6	69.8**

Q^a = stream discharge in cubic feet per second.
C^b = suspended sediment conc in ounces/cubic ft. x 10^{-2} {i.e. 0.04oz/ft^3 would be recorded here as 4.00}.
G^c = suspended sediment yield in ounces/second x 10^{-2} and is the product of Q X C.
* equals the product of the concentration from site 2 and the flow from site 8 for each date.
Conversions: 1 oz. = 0.02834952 kg 1 day = 86400 seconds 1 oz./sec. = 2449.3985 kg/day
** The reduction was calculated as a percent change from 8403.0 to 2539.2.

If the percent needed SS load reduction for each of the eleven sampling events in Woods' (1987) study is averaged the percent SS load reduction needed for site 8 to meet the target SS load is 66.7 %, see Table 4. If these reductions in SS are made site 8 would no longer be impaired for SS. If the highest five loading events are used, a more conservative approach, the average needed reduction increases to 69.8 %, see Table 5. Therefore, by using the average percent needed reduction from only the five highest loading events for site 8 there is an explicit 3.1% (69.8% - 66.7% = 3.1%) margin of safety, see Table 6.

Table 6. Siltation Load Summary for Site 8, Old Woman Creek, RM 3.65

	Existing Siltation Load			
	Existing Load (kg/d)	**Target Load (kg/d)**	**Needed Reduction (kg/d)**	**Needed Reduction (%)**
11 Sample Dates	4309.6	1433.7	2876.6	66.7
	Existing Siltation Load with Margin of Safety			
5 Highest Loading Dates	8403.0	2539.2	5863.8	69.8

Note: Site 8 is the representative site for all siltation impaired sites. It is the site just upstream of the estuary and thus measures the sum of most of the influences which flow into the estuary. Because the majority of nutrients entering the estuary come attached to silt, the % needed reduction also applies to the nutrient enrichment impairment.

Table 6 can be misleading if one only focuses on the targets for row 1 (11 samples) and row 2 (5 highest loading dates). Row 2 is counter intuitive because it allows for a higher target. The focus should be on the percent reduction and not the loads because the calculations are for two different and separate conditions. Row 1 summarizes the siltation runoff from an average storm. Row 2 (the MOS row) summarizes a "worst storm" scenario. Determining the needed reduction from the worst case scenario creates a margin of safety over and above the average storm.

As mentioned under Siltation Methods, the target load is calculated using the concentration from a site with desirable land uses (site 2), such as wooded riparian, and the flow from the site where ultimately basin wide siltation reduction will be reflected, site 8. The loads are calculated for each sampling date and averaged to derive an overall needed siltation load reduction. This method is advantageous because it accounts for the basin weather conditions for each sampling date. Even though all of the data was collected during storms, some storms were more intense than others. However, this method accounts for the variability in storms. In the same vein, the margin of safety can be calculated. By using the data from the five most intense storms, measured by highest loads, we can derive a needed reduction over and above the needed reduction from all the sampling dates. It is a whole different set of circumstances, more intense, erosion causing, conditions.

To use a needed reduction derived from these intense conditions adds an explicit margin of safety. It is somewhat counter-intuitive if one compares only the target loads

from Table 5 because the target load from the five highest load sampling dates is higher than the target load from all 12 sampling dates. Because everything -- weather conditions, stream conditions, field conditions -- intensify during the five worst storms, the only value that is comparable in Table 5 is the percent needed reduction. Comparing loads or targets is not logical because the circumstances are different. It does make sense, however to consider the increase in percent needed reduction from the worst case scenario as an explicit MOS over that from the average of all storms.

Siltation Critical Condition

In the Discussion section there are a number of accounts explaining that the time when agricultural fields are not vegetated is the critical condition for siltation. This is approximately October through May. Because this is the time of greatest siltation loading to the stream, this is when Woods' study occurred, and thus the collection time for all the data in this TMDL report.

Siltation Discussion

Woods (1987) found cropping, raindrop impact and sediment availability to be greater determinants of sediment concentration than either discharge or velocity at some stations. Field preparation in the spring and harvesting in the autumn heavily affected the recorded sediment concentrations. Raindrop impact on the disturbed field was an especially erosive agent on the Till Plain. Feedlot activity above station 3 is also an important contributor to sediment load. At the time of Woods' (1987) study urbanization and suburbanization and roads covered only about 8% of the Old Woman Creek basin but he noted that their local effect on the magnitude of sediment could be large. With more development occurring now, this source of sediment may become even greater. Recently, an area totaling 200 acres has been converted from pervious to impervious due to development (Klarer, 4/15/04 meeting notes).

"The highest erosion rates in the basin are likely to occur in the upper Till Plain of the basin where soil texture, higher slopes, and agricultural activity have served to maximize all the erosional factors involved. The wooded midsection of the basin probably contributes less eroded material because of land cover, even though the slopes here are the steepest in the basin. The lower Lake Plain soils probably contribute slightly less eroded material per acre than the Till Plain soils, in part as a result of soil texture but also because of the lower slopes", (Buchanan, 1983). Woods (1987) generally agreed with this but pointed out that it was also true that Lake Plain stations could sporadically record high sediment concentrations.

Woods (1987) developed power relationships for the different sites and noted that the two lowest exponents came from Till Plain sites reiterating the fact that high sediment yields occur in that part of the basin. He summarized by stating, "sediment concentration in the Old Woman Creek system is determined first by the level of human disturbance and secondly by its soil erosion potential."

Evans' (1997) routing model results indicates that the greatest quantity of sediment loading in the Old Woman Creek stemmed from the south eastern portion of the basin due to its highly erodible soils and moderate relief. He mentions that improvement of agricultural management practices could have beneficial effects on sediment management for Old Woman Creek estuary.

Matisoff (1999) concludes that "Since tilled basins had higher sediment yields than their no-till counterparts, these findings indicate that erosion control methods implemented in the portion of the watershed where erosion is greatest should be reflected quickly in the receiving waters". Also, in a brochure based on his Fine Sediment Movement (1999) study Matisoff states, "The rate at which sediment is delivered to Old Woman Creek wetland has increased tenfold due to human activities in the last 150 years, which included clearing land for farming and agriculture".

In a (LEASEQ) brochure three points are made that are especially relevant to this TMDL report,

1) small portions of the watershed can be disproportionately responsible for sediment loads,

2) tilled sub-basins yield four to six times more sediment, and undergo more erosion than similar no-till sub-basins, and

3) erosion control methods are needed at traditional tillage sites high in the watershed.

On April 15, 2004, a meeting was held between Ohio EPA, Old Woman Creek NERR staff and Erie County Soil and Water Conservation District Staff at the Old Woman Creek NERR building. Discussions occurred regarding the areas of greatest concern, what has been done in the past to control erosion, and what can be done now to reduce erosion and siltation loading to Old Woman Creek. Generally everyone agreed that the area in greatest need of implementation is in the Till Plain headwaters located in the southeast portion of the basin (see Figure 8). The Erie County Soil and Water Conservation District Staff explained that there was a Farm Service Agency program from 1991 to 1994 whereby $250,000 was spent in this portion of the Old Woman Creek basin in an effort to reduce erosion. Farmers were paid $1/ acre to use conservation tillage. During this program approximately 40% of the farmers participated. In 1996, after the program ended, participation dropped to 30% and by 2000 it was back up to 40%.

Though on the brink of development, the basin is now as it was in the early 1980s, mostly agriculture. The agriculture makeup is basically the same as it was then, mostly corn and soybeans, with the exception that now approximately 40% of the farmers are using no-till. There is no long term suspended sediment data for the basin. In order to compare instream conditions before and after the no-till initiative, instream nutrient concentrations were examined. Phosphorus enters streams attached to soil particles so

it is an indicator of sedimentation. Figures 6 and 7 show the data for two nutrients, Phosphate (PO4) and Nitrate and Nitrite (NO3+NO2) over time.

Table 7 helps to quantify Figures 6 and 7 by looking at low, medium and high statistical values for these nutrients for two time periods 1980 to 1987, and 1997 to 2003. These data sets represent stream nutrient levels before and after the 1991 conservation tillage introduction effort by the Erie County Soil and Water Conservation District. Comparison of these data sets help to demonstrate the changes in nutrient concentrations brought on by changing tillage practices.

Figure 6. Old Woman Creek PO4 Trend Since 1980

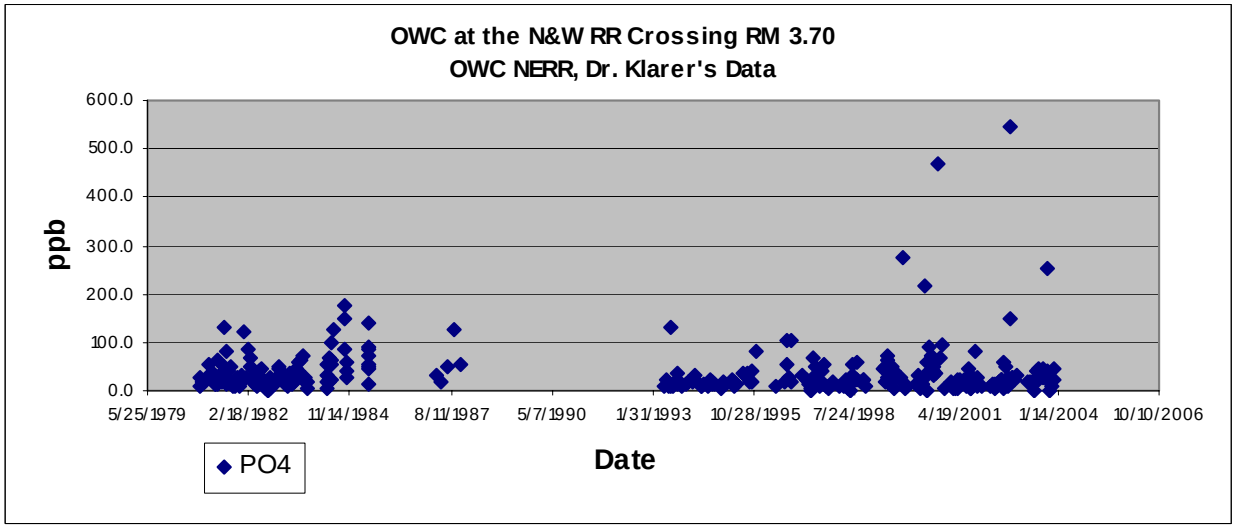


Figure 7. Old Woman Creek NO3+NO2 Trend Since 1980

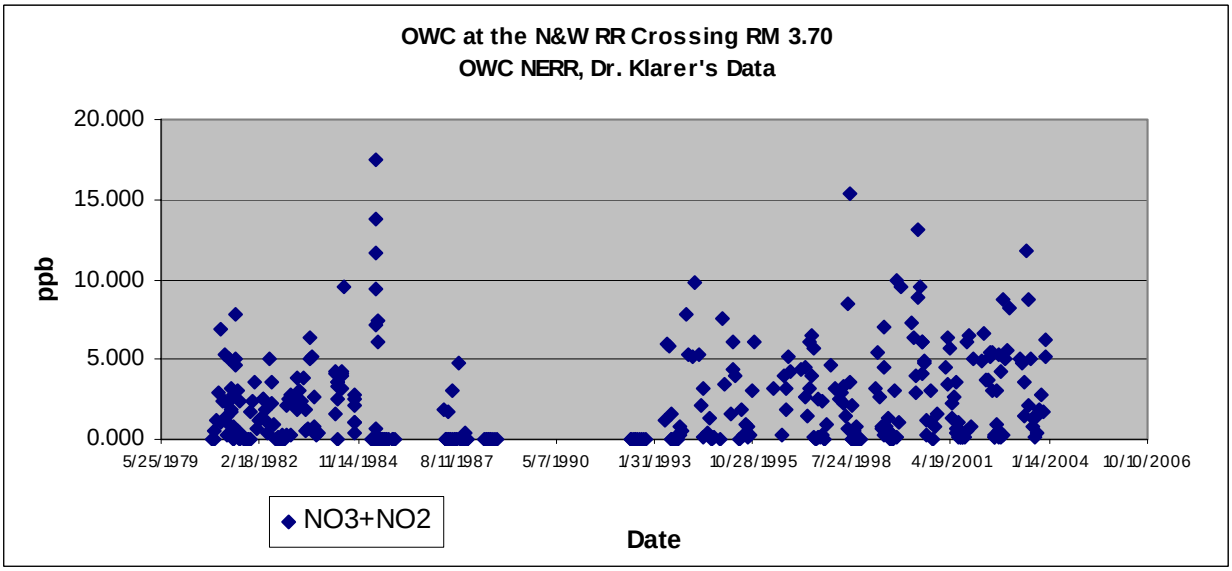


Table 7. Comparison of Nutrients for Pre and Post No-Till Agriculture in the Old Woman Creek Basin (all data from 1980 to 2003)*

		Data from 10/22/1980 - 11/30/1987	**Data from 2/21/1997 - 12/15/2003**	**Percent Change in Nutrients**
PO4 (ppb)	# of data points	114	141	
	5th Percentile	7.9	3.1	-61
	50th Percentile	28	21	-25
	95th Percentile	124	91	-27
NO3+NO2 (ppm)	# of data points	109	145	
	5th Percentile	0.04	0.07	75
	50th Percentile	2.2	2.4	9
	95th Percentile	7.6	8.9	17

* Table 7 is based on data supplied by Dr. Klarer of the OWC NERR.

Table 7 shows the results of all the data for the years listed in the header. There is a marked decrease in PO4 with the 50th percentile having a 25% decrease. On the other hand NO3+NO2 actually increased with a 50th percentile increase of 9%.

Since the greatest siltation occurs in the spring when precipitation is high and vegetation sparse it is worth looking at what happens under these conditions. Table 8 shows only the spring data (April, May and June). For PO4, 50th percentile results show a decrease of 44%. For NO3+NO2 the change for 50th percentile is 0%.

Based on this data it seems that the increase in no-till had a definite effect on PO4 reducing it by 44% with little effect to NO3+NO2 which showed a slight increase of 9%. These results are not surprising since phosphorus binds to soil particles and nitrogen tends not to bind to soil; rather it is taken up by vegetation, leaches or becomes volatile and moves to the atmosphere. Thus the reduction in erosion and sedimentation reduced the phosphorus to the stream but did not reduce nitrogen to the stream. Though nitrogen is not reduced, the benefit to the stream is still realized with conservation tillage since phosphorus is the limiting nutrient to overwhelming algal growth and resulting low dissolved oxygen (DO) concentrations.

Table 8. Comparison of Nutrients for Pre and Post No-Till Agriculture in the Old Woman Creek Basin for Spring Months Only (April, May and June)

		Data from 1981 - 1987	**Data from 1997 - 2003**	**Percent Reduction in Nutrients**
PO4 (ppb)	no. of data points	47	48	
	5th Percentile	12	2.5	-79
	50th Percentile	32	18	-44
	95th Percentile	118	66	-44
NO3+NO2 (ppm)	no. of data points	48	48	
	5th Percentile	0.59	0.62	5
	50th Percentile	3.6	3.6	0
	95th Percentile	11	11	0

Regardless of the effect the no-till effort had on nutrients, there is still a siltation problem and if 40% of the farmers are using no-till that means that approximately 60% of the row crop farmers are still using conventional tilling methods. One of the limiting factors to no-till use in the basin is the high percentage of corn grown in the basin. No-till works better for soybeans than corn and there is a lot of corn grown in the basin. In fact there is a lot of seed corn grown in the basin and “clean” fields are essential for corn grown for seed stock. Regardless, the staff at the Erie County Soil and Water Conservation District feel that the farmers in the area are now receptive to innovative methods since they were exposed to them in the early 1990s and that another push for conservation tillage would be accepted and utilized.

As an example of the positive effect of conservation tillage, the suspended sediment discharge in parts of the Auglaize River basin decreased by 50% between 1970-98 as the acreage under conservation tillage increased to over 50% during the same period (USGS, 2000). It is estimated by staff from the Erie County Soil and Water Conservation District that approximately 40% of cropland in the OWC watershed is currently utilizing no-till planting. A target to push that number to over 50% for the Old Woman Creek basin should be pursued as an effective way to reduce sediment as well as phosphorus loads.

Dr. Klarer mentioned, in the 2004 meeting with Ohio EPA, OWC NERR staff and Erie County Soil & Water Conservation District staff, that new development will create an increase in the impervious areas which will make streams more flashy and will result in greater bank cuts of the highly erodible Till Plain banks (see Figure 8 for Till Plain location). As development occurs an effort should be made to slow hard surface runoff with use of retention basins, wetlands or other drainage control methods.

Figure 8. Map of Old Woman Creek Basin Showing Location of Till Plain (Buchanan, 1983, p. 35)

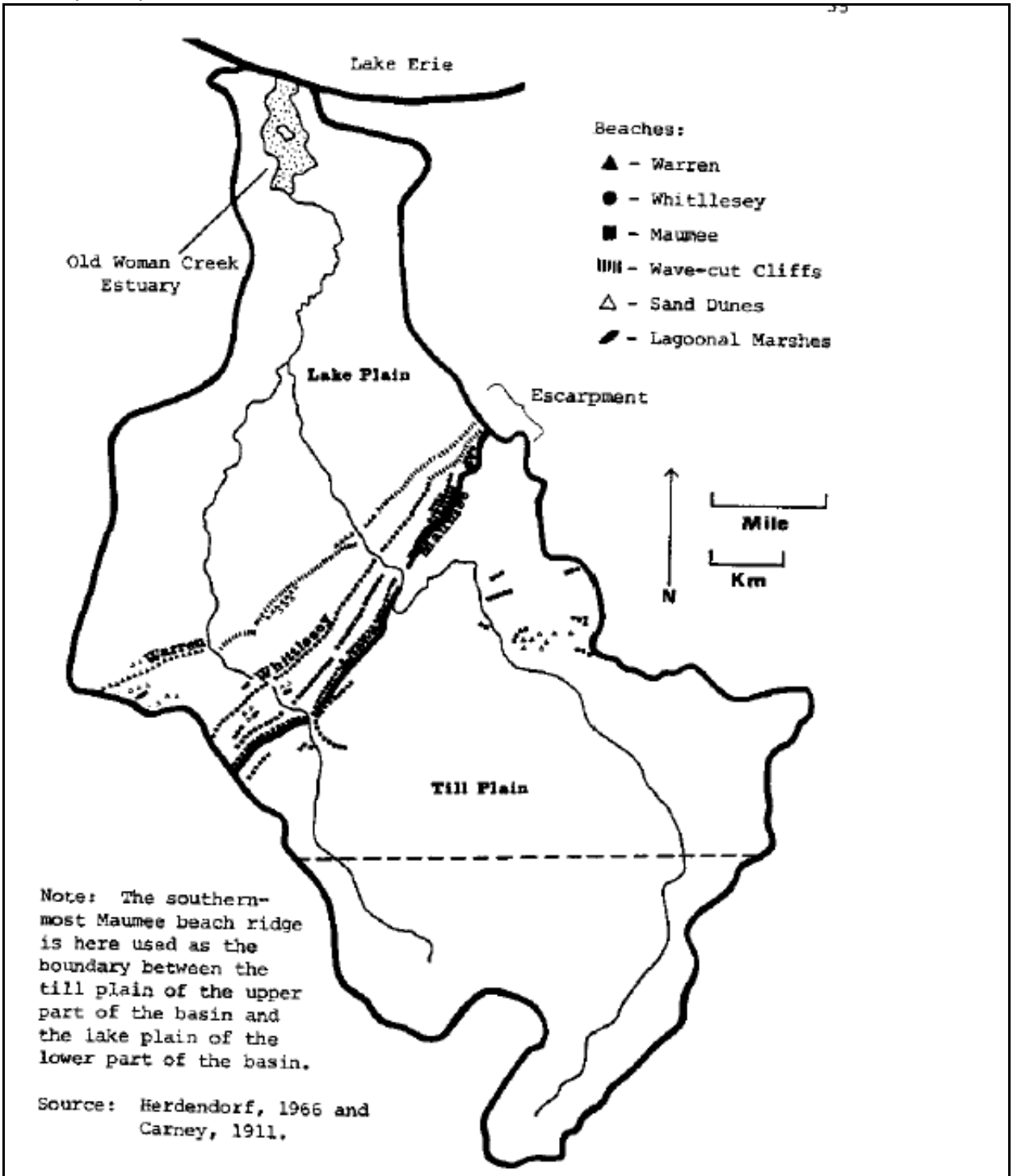


Figure 3-4. Location of postglacial beach ridges and wave-cut cliffs in the Old Woman Creek drainage basin.

Based on the studies summarized above and personal discussions with the people from the Old Woman Creek Sanctuary and the Erie County Soil and Water Conservation Districts, the implementation of solutions to the sediment problems can be prioritized by geomorphic region and land use. Top priority should be given to the headwaters of the basin which occur in the Till Plain region. These soils, 40% of which are highly erodible Mahoning soils (Woods, 1987), are heavily utilized by agriculture which make them high risk for erosion. Different levels of erosion control should be utilized. First, keep the soil on the fields with conservation tillage. Second, keep soil out of the streams with filter strips and riparian improvement. Third, improve the instream habitat by discontinuing channelization and shading the water with trees.

Nutrient Enrichment

Old Woman Creek and Chappel Creek

In Ohio EPA's 2004 Integrated Report, six sites sampled are considered to be in non-attainment of their use designation due to nutrient enrichment in Chappel and Old Woman Creeks. Nutrient enrichment occurs when nutrients such as nitrogen or phosphorus enter a stream and elevate these parameters to higher than normal concentrations. The nutrient sources listed in the 2004 Integrated Report for Old Woman Creek are livestock and non-irrigated crop production. For Chappel Creek, the source is listed as pasture and non-irrigated crop production. Manure from livestock contains nutrients and therefore manure control is essential in order to reduce or eliminate this source. Crop production becomes a source when fertilized soil particles are washed off the field and into the stream or when fertilizer leaches out of the soil and to the stream. Therefore, reduction or elimination of erosion and leaching are essential for control of this source.

Old Woman Creek

Krieger found, during his study, that maximum upstream loads of specific materials into the wetland occurred either in May 1989 or January or February 1990. Evans (1997) took this observation one step further in his review of Krieger's data indicating that sediment transport in Old Woman Creek is highly episodic, occurring mostly during spring melt off. He goes on to say that for example, the three 8-hour recordings for a single day (5/26/89) totaled 863 metric tons. In other words, one day of record represented 26% of the average annual suspended sediment load. Buchanan also reported large amounts of soil transported during brief periods of intense precipitation (Buchanan, 1983, p. 183). These findings highlight that high flows in this basin result in high sediment loads and thus high nutrient loads to the estuary.

Nutrient Enrichment Methods

Old Woman Creek

Load duration curves (LDCs) were created for phosphorus and nitrate and nitrite to see at which flow intervals these parameters exceed water quality targets. The LDCs were developed for the site located at the USGS gage because both long term flow and

chemistry data were available. However, not only was this site used because we have data for it but it is also a very important location for determining loadings to the estuary where the two nutrient impaired sites exist (RMs 1.9 and 0.2). Results from this site capture most of the influences from upstream of the estuary that ultimately end up in the estuary. The USGS gage, number 04199155, is located on Old Woman Creek on the left downstream side of Berlin Road bridge, 3.8 miles southeast of Huron.

Nutrient Enrichment Results

Old Woman Creek

To create the LDCs, flows from the gage were matched to frequent, but not daily, chemistry results from Krieger's work which range from 11/1987 to 10/1990. The results show that the majority of target exceedances occurred at higher flows, see Figure 9. LDCs were developed for both nitrate and nitrite and phosphorus. However since in eastern U.S. streams, phosphorus more frequently is limiting than nitrogen, the focus is on phosphorus (Ohio EPA, 1999). Of the 1,017 samples for which phosphorus loads are calculated, 23% exceeded the 0.1 mg/l target. If one looks at the highest 15.7% of flows for which loads are calculated, which includes 160 samples, the percentage of target exceedance jumps to 80%. Conversely, if one looks at the remaining lower values, of which there are 857 samples, the number of exceedance is only 12%, demonstrating that the majority of exceedances occur at higher flows, see Figure 9.

Figure 9. Load Duration Curve for Total Phosphorus in Old Woman Creek

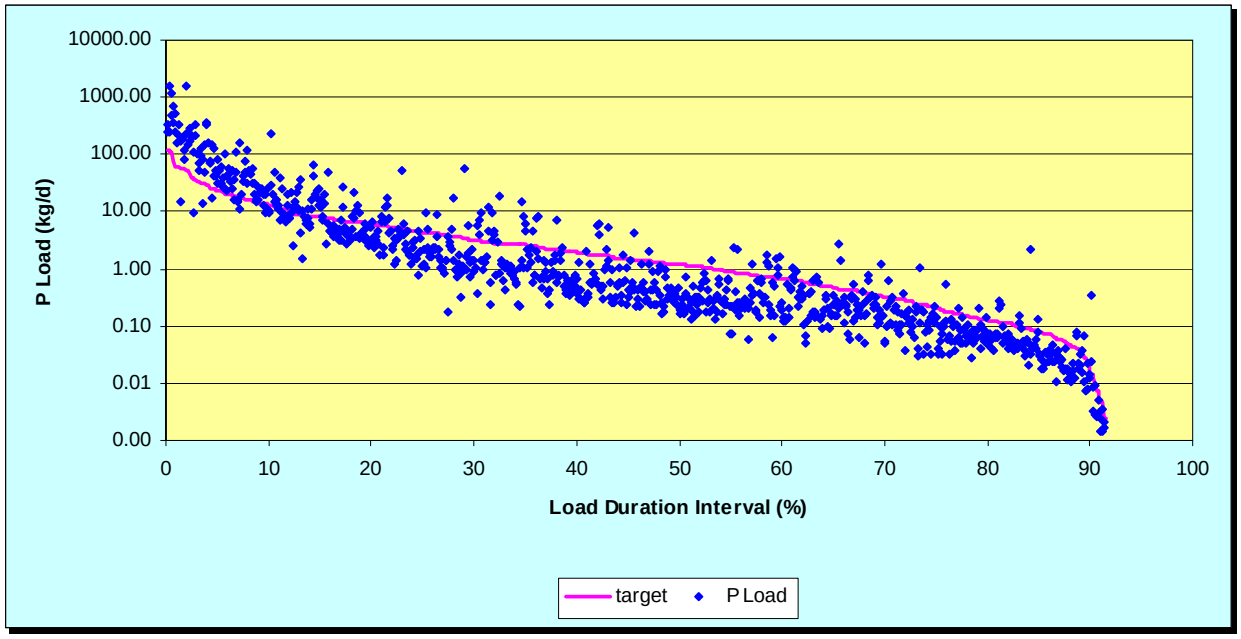
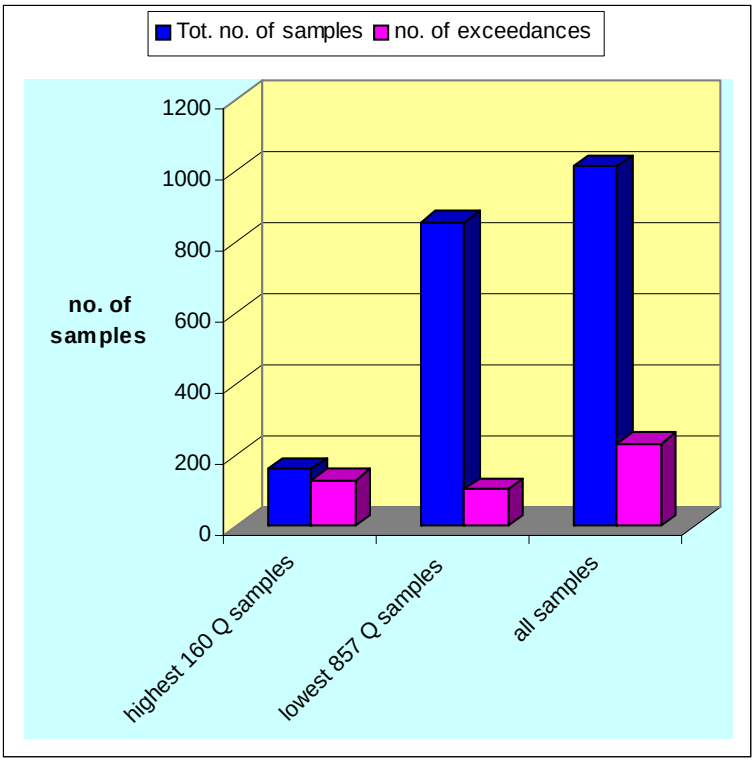


Figure 10. Comparison of Number of Samples to that Sample Set's Number of Exceedances



Figures 9 and 10 show that phosphorus exceedances occur most frequently at higher flows because erosion of phosphorus laden soil particles occurs at higher flows.

Nutrient Enrichment Discussion and Margin of Safety

Old Woman Creek and Chappel Creek

The reduction of nutrient enrichment in OWC lies with proper nutrient management. Nutrient management starts with avoiding the leaching of fertilizers and ends with keeping the nutrient laden soil particles out of the stream. Due to a litany of changing variables related to farming, such as; crop selection, soil type, past practices, type of fertilizer used, weather and other factors, it is difficult to quantify the leaching of nutrients. For the purposes of discussion of nutrient leaching in this report, it is enough to say that nutrient management BMPs should be applied; take soil samples, apply only what is needed by the crop, apply under proper weather conditions, etc. Perhaps the more important source of nutrients to OWC is siltation, since nutrients enter waterways attached to soil particles during erosion. As such, the *Siltation Results and Methods* sections previously mentioned can be used to quantify the needed reduction and margin of safety for nutrient enrichment in Old Woman Creek.

Chappel Creek

Chappel Creek does not have the necessary flow and chemistry data needed to quantify the siltation or nutrient loads, however since its basin is adjacent to Old Woman

Creek and because it has similar attributes (see Table 2) the results and conclusions made for Old Woman Creek can be made for Chappel Creek.

Habitat Alteration

Habitat alteration was assessed to be a cause of impairment for two sites in the Old Woman Creek watershed and one site in the Chappel Ceek watershed. Habitat alteration includes the straightening, widening or deepening of the stream's natural channel. Habitat alteration can also include the degradation or complete removal of vegetated riparian areas that are essential to a healthy stream. Such activities can effectively transform the stream from a functioning ecosystem to a simple drainage conveyance.

Ohio EPA assesses habitat quality using the Qualitative Habitat Evaluation Index (QHEI). The QHEI is a visual assessment tool used to provide a measure of habitat that corresponds to those physical factors affecting fish communities and are generally important to other aquatic life (Rankin, 1989). The QHEI is a composite of six habitat categories: 1) substrate, 2) in-stream cover, 3) channel morphology, 4) riparian zone and bank erosion, 5) pool/glide and riffle/run quality, and 6) gradient. Each category is further divided into individual attributes that are assigned a weighted point-value reflective of the attribute's impact on aquatic life. The highest point-values are assigned to attributes correlated to streams with high biological diversity and integrity, while lower values are assigned to less desirable habitat features. An example QHEI score sheet is included as Appendix E. Habitat alteration, while a significant cause of impairment, is not a load-based chemical parameter for which a TMDL is traditionally developed. For this reason no loading capacity is calculated as part of the habitat TMDL. Rather, the QHEI is used as a surrogate for loading capacity in developing targets to achieve use attainment. In this context the QHEI serves as a measure of a quantitative non-chemical parameter as specified by EPA (EPA, 1991).

The QHEI target for the Warmwater Habitat use designation is 60. Since habitat is usually strongly correlated with the IBI (Index of Biotic Integrity, a fish index) biocriterion, the QHEI provides a quantitative way to evaluate how habitat issues affect the attainment of the aquatic use designations. Figure 11 shows a plot of QHEI versus IBI for 471 reference sites across the state to demonstrate the effect that improving QHEI scores has on IBI scores, (Rankin, 1989). Figure 12 shows the same relationship for headwater sites, which are more similar in size to the sites on Old Woman Creek.

The plot suggests that increasing the QHEI score is likely to result in an increase of the IBI score. The QHEI is being suggested not as a prescribed limit, but as a way to monitor effectiveness of management practices that aim to improve riparian habitat and reduce sediment loads. Positive results have been observed so far in other Ohio watersheds that have implemented conservation tillage and other conservation practices. These practices reduce sediment which allows for a higher substrate subscore and thus improves the overall QHEI score.

Comments received from the Ohio Farm Bureau on the Sugar Creek TMDL support the use of the QHEI as a tool to evaluate the quality of a stream's habitat. The Bureau suggests that an investigation of the scores for each of the QHEI's individual metrics can be a useful tool to help in the identification of the principal factors limiting habitat quality. The analysis would also lead to the identification of the types of possible remediation actions that could take place. For example, if the riparian/erosion metric score is low, then the proposed remediation actions should focus on stream bank erosion control and riparian buffer establishment (Ohio Farm Bureau, 2002). Ohio EPA will make the metric scores available to watershed groups to help them prioritize the implementation of management practices.

Channelization is the source of impairment in this basin and, since the act of channelizing a stream can affect most of the QHEI subcomponents, the QHEI score is a good measure of the effects of channelization for a specific reach of stream. To see the QHEI subscores for each site in the basin, see the 2002 stream survey QHEI results in Appendix B. The intent of the QHEI target of 60 is for it to be compared to the median value of QHEI scores performed at several sites in a given stream segment. Since QHEI data is limited for this project, QHEI scores for individual sites, not medians of multiple sites, were used for site evaluation.

The habitat quality of seven sites in the Old Woman Creek Watershed and six in the Chappel Creek Watershed were evaluated in the years 2000 and 2002. A habitat TMDL is developed for three sites for which habitat was determined to be a cause of impairment, and are presented in the following sections. QHEI assessment sites are specifically chosen to be representative of the stream segment on which they are assessed; therefore, the associated TMDLs are applicable to the entire stream segment, not just the assessment site.

Old Woman Creek

Two sites are considered to be in non or partial-attainment of their use designation due to siltation/habitat alteration. Those sites are located at RM 9.4 and the east tributary at RM 8.82/0.9. For each site, the source of impairment is listed as channelization-agricultural. These stream reaches do not support aquatic life to their potential because they have been straightened, riparian area has been removed, instream cover has been removed, and/or structures such as pools and riffles have been removed allowing the stream bottom to cover with siltation.

Chappel Creek

One site at RM 7.4 is impaired due to habitat alteration. The source is non-irrigated crop production.

Figure 11. Least Squares Exponential Regression Analysis of the QHEI and IBI for 471 Warmwater and Modified Reference Sites, All Site Types and All Ecoregions (Rankin, 1989)

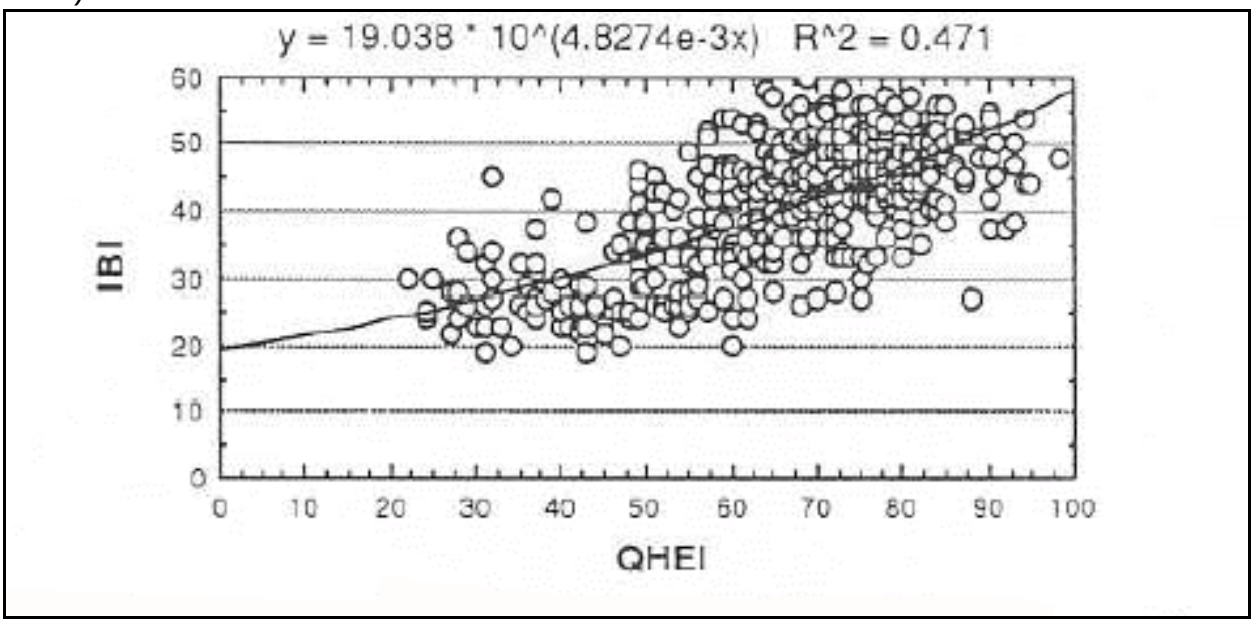
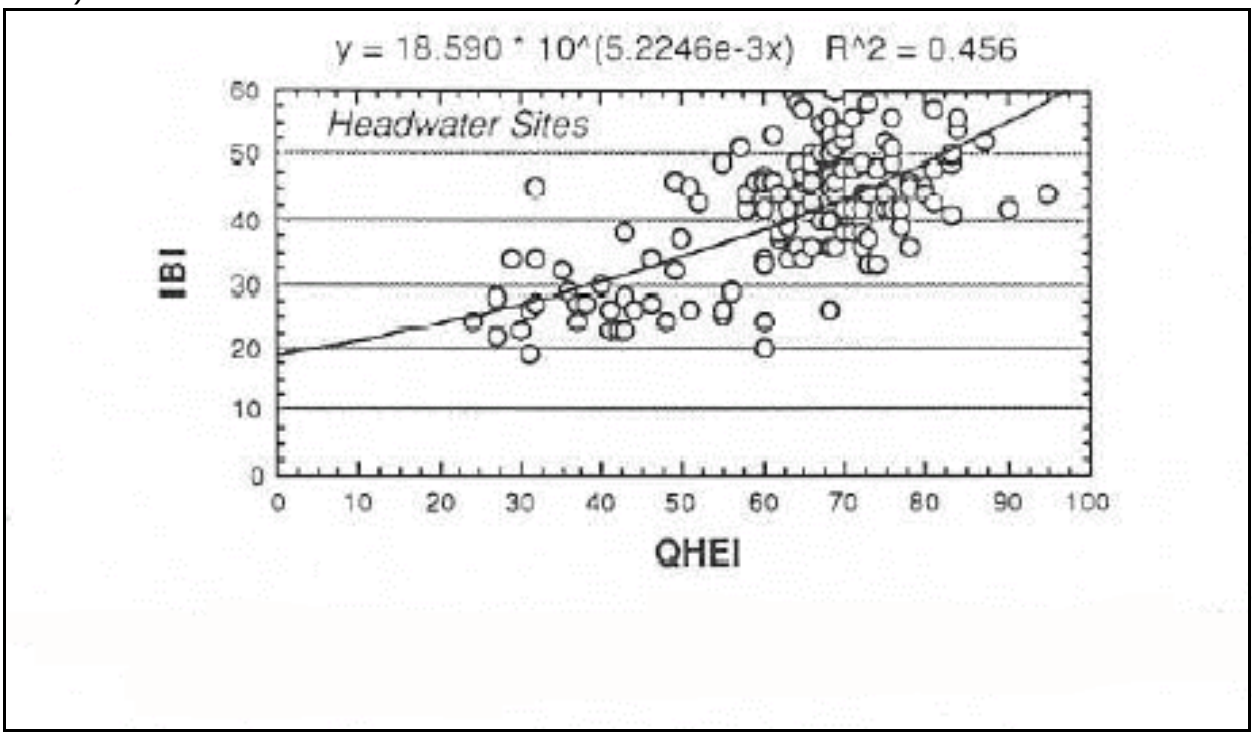


Figure 12. Least squares exponential regression analysis of the QHEI and IBI for warmwater and modified reference sites (all ecoregions) for headwater sites (Rankin, 1989)



Habitat Alteration Methods

For use in TMDL development, a target QHEI of 60 was selected. The target was determined by statistical analysis of a statewide database of paired QHEI and IBI scores. Linear and exponential regressions and frequency analyses of combined and individual components of the QHEI in relation to the IBI were examined (Ohio EPA, 1999). The regressions indicated the QHEI is significantly correlated with the IBI with the exponential model providing a better fit to the data than the linear. Sites with QHEI scores greater than or equal to 60 were generally associated with IBI scores supportive of a WWH use designation.

Further analysis of the QHEI components as they relate to IBI scores led to the development of a list of attributes that are associated with degraded communities. These attributes are modifications of natural habitat and were classified as high influence or moderate influence attributes based on the statistical strength of the relationships. The presence of these modified attributes can strongly influence aquatic biology to a degree that the QHEI score itself may not reflect. The analysis indicates that a stream with more than one high influence or more than four moderate influence attributes will not typically achieve WWH biocriteria (using an IBI of 40 as a representative WWH biocriterion). The implication of which is a stream segment can be impaired even with a QHEI score above 60. For example, the positive effects of a good riparian zone and high sinuosity may be overwhelmed by the negative impact of a thick muck substrate. In this hypothetical situation the QHEI may exceed 60 because some high quality habitat features are in place; however, the stream is impaired because it is limited by a very poor substrate. High and moderate influence attributes are presented in Table 9.

Table 9. Modified Habitat Attributes

High Influence	**Moderate Influence**
❶ Channelized with little to no recovery ❷ Silt or muck substrates ❸ Low sinuosity ❹ Sparse or no cover ❺ Max pool depth less than 40 cm	① Channelized, but recovering ② Sand substrate ③ Hardpan substrate origin ④ Fair or poor channel development ⑤ All cover types score < 3 ⑥ Intermittent or interstitial with poor pools ⑦ No fast current ⑧ High to moderate substrate embeddedness ⑨ Extensive to moderate riffle embeddedness ⑩ No riffle

The habitat TMDLs presented herein incorporate both the QHEI target of 60 and the targets for modified habitat attributes. The habitat TMDL equation presented in Table 10 reflects the relationship between the QHEI score, high influence modified habitat

attributes, and moderate influence modified habitat attributes. It is based upon a target of three (3), and is the sum of three component scores. Individual component scores exist for the observed QHEI score to target QHEI score ratio and for the presence or absence of high and moderate influence attributes. A QHEI score less than 60 or the presence of more than one high influence attribute or more than four moderate influence attributes will prevent a stream segment from achieving its TMDL target.

Table 10. Habitat TMDL Components

Component Measure	**Score**
QHEI score greater that 60 =	1
Less than 2 high influence modified habitat attributes =	1
Less than 5 moderate influence modified habitat attributes =	1
Total TMDL Score	3

Habitat Alteration Results

The habitat quality of seven sites in the Old Woman Creek Watershed and six in the Chappel Creek Watershed were evaluated in the years 2000 and 2002. One site from Old Woman Creek and one from Chappel Creek which were found to be impaired due to habitat alteration; results for the sites are presented in Table 11 . Table 11 also lists each site's observed modified habitat attributes, component scores, and habitat TMDL score. Modified habitat attribute codes correspond to Table 9.

Table 11. QHEI Assessment Results and Habitat TMDL Scores

Stream	**River Mile**	**QHEI**	**Modified Attributes**		**Component Scores**			**TMDL Score**	**Is TMDL Target Met?**
			High Influence	**Moderate Influence**	**QHEI**	**High Influence**	**Moderate Influence**		
WWH Targets		*≥60*	*<2*	*<5*	*1*	*1*	*1*	*3*	*Yes*
Old Woman Creek	9.4	44	❶❷❸❹	①②④⑤⑦	0	0	0	0	No
Trib. To Old Woman Creek*	0.7	34	❶❷❸❹	③④⑤⑧⑨	0	0	0	0	No
Chappel Creek	7.4	64	❷	②④⑤⑦⑧⑨	1	1	0	2	No

* East tributary crossing at S.R. 113, river mile 8.82/0.7.

Habitat Alteration Discussion, Critical Condition, and Margin of Safety

The QHEI is a macro scale approach that measures the emergent properties of habitat (sinuosity, pool/riffle development) rather than the individual factors that shape these properties (current velocity, depth, substrate size). The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar.

This method assumes that the significant variables that influence fish communities are included in the index, and that the index is able to distinguish between the relative effects of habitat versus water quality issues. The index is empirically derived and assumes that the empirical relationships remain similar for streams of similar size and type within an ecoregion. The evaluation is somewhat subjective and requires the evaluator to be experienced in the use of the index. The variability between evaluations from different trained investigators and the variability in time at a particular site have been determined to be minimal within the same season and if the investigators are experienced with the method (Rankin, 1989).

The QHEI provides a thorough evaluation of the physical habitat in a quantitative manner. Many of the metrics which comprise the QHEI are surrogate measures of load based stressors. Some of the metrics may also provide a measure of a cause of impairment, such as the substrate category as a measure of siltation, or the QHEI itself when habitat is listed as the cause of impairment. Because habitat is strongly correlated with the IBI biocriterion, the QHEI can be an indicator for pollutants such as sediment. Therefore, the QHEI can provide a numeric target and framework to help evaluate how habitat or surrogate issues affect attainment of the aquatic life use designations.

The use of the QHEI also assumes that the water courses being evaluated are typical riverine streams and rivers. The QHEI was not calibrated to low gradient wetland dominated streams and application of the QHEI to these habitat types may not be valid. The empirical nature of the QHEI and the data that underlie it provide measurable targets similar to a loading capacity for a pollutant. When used with biological indices, the numeric measurability of the index provides a means to monitor progress when implementing a TMDL and to validate that a target has been reached.

The deviations from target values for both QHEI and the high and moderate influence QHEI attributes are in Table 12. In order for the Old Woman Creek stream segments to not be impaired due to habitat alteration, improvements would need to be made in order to meet the QHEI target of 60 and the attribute target of 3 as detailed in Table 10.

Table 12. Habitat TMDL Deviation from Targets

Stream	River Mile	QHEI Score	QHEI Deviation from Target	TMDL Score	TMDL Deviation from Target
WWH Targets		*≥60*		*3*	
Old Woman Creek	9.4	44	16	0	3
Trib. To Old Woman Creek*	0.7	34	26	0	3
Chappel Creek	7.4	64	target met	2	1

* East tributary crossing at S.R. 113, river mile 8.82/0.7.

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

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

A degree of implicit margin of safety also exists because the same methods used to reduce siltation will improve habitat. Plus, reducing siltation will increase the QHEI substrate scores. Since siltation and habitat/QHEI are linked, the margin of safety used for siltation can be assumed to be an implicit margin of safety for habitat alteration.

Potential Existing and Future Impairment Sources for Bacteria and Siltation

Though Ohio EPA sampling didn't reveal any major bacteria problems in the Berlin Heights area (see Table 13), the staff at the Old Woman Creek NERR feel there is likely a bacteria problem there. Berlin Heights is an unsewered community situated on the Berea Escarpment with 674 residents (Berlin Heights, OH Houses and Residents). Ohio EPA's bacteria sampling consisted of one run in 2001 and one in 2002. Because of the inconsistent nature of bacteria, multiple samples taken in a short period of time, ideally under varying flow and weather conditions, are necessary to properly evaluate the magnitude of instream bacteria. The two sample runs performed by Ohio EPA are insufficient for comparison of bacteria to the bacteria Water Quality Recreation Use

Designation Standard. Therefore, with insufficient data, recognition should be given to the OWC NERR researchers opinion that at times bacteria is likely to be elevated in the vicinity of Berlin Heights, and that this potential problem should be evaluated.

Table 13. Comparison of Fecal Coliform Bacteria Upstream and Downstream of Berlin Heights

	8/14/2001			**5/16/2002**		
	Fecal coliform (cnts/100 ml)	**Flow at Berlin Rd. USGS gage (cfs)**	**Flow trend for previous 4 days (cfs)**	**Fecal coliform (cnts/100 ml)**	**Flow at Berlin Rd. USGS gage (cfs)**	**Flow trend for previous 4 days (cfs)**
upstream: Bellany Rd. RM 8.33	54	0	stable (all days < 0.2 cfs)	190	25	steady decrease from 299
downstream:Berlin Rd. RM 6.10	350			96		

Note: The statewide numerical and narrative criteria for primary contact recreational use designation requires that for each designation at least one of the two bacteriological standards (fecal coliform or e. coli) must be met. These criteria apply outside the mixing zone and for fecal coliform state; the geometric mean content (either MPN or MF), based on not less than five samples within a thirty-day period, shall not exceed 1,000 per 100 ml and shall not exceed 2,000 per 100 ml in more than 10 percent of the samples taken during any thirty-day period.

Spurred by an effort to provide county water throughout the basin, new housing will have the potential to result in more water quality impairments. Siltation during house and road construction can threaten water quality. Faster precipitation runoff from impervious areas increases stream hydraulic velocity which in turn increases siltation from bank erosion. More housing implies more failing septic systems in the future. In Erie County there is a 1.3 acre minimum lot size and no central sewage service. With county water will come houses and home sewage treatment systems (HSTS). Eventually the HSTSs will likely fail if not properly maintained, and if not repaired will add bacteria to Old Woman Creek and its tributaries. Local officials and developers should be aware of these potential future problems and plan now to avoid or prevent them.

Summary

Based on data collected by Ohio EPA in 2000, 2001 and 2002, Old Woman Creek does not meet its Warmwater Habitat Use Designation due to impairments from siltation/habitat alteration (source - agricultural related channelization), organic/nutrient enrichment (source - livestock and pasture), siltation/nutrient enrichment (source - non irrigated crop production), and flow alteration (source - drought). This section of the TMDL report quantifies the sources of impairments using data from existing studies in order to determine the needed reduction for each.

The source of siltation includes non-irrigated crop production and agricultural related channelization. Using the data from the eleven sampling dates in Woods' (1987) study, Ohio EPA determined the needed siltation load reduction from non-irrigated crop fields ranges from 50.6 kg/d to 11524 kg/d. The average needed load reduction is 2876 kg/d. The percent reductions needed to meet the target ranges from 37.7 to 91.6, with an average of 66.7.

The source of organic/nutrient enrichment is non-irrigated crop production and livestock. Crop production becomes a source when fertilized soil particles are washed off the field and into the stream or when fertilizer leaches out of the soil and to the stream. Therefore, reduction or elimination of erosion and leaching are essential for control of this source. Because phosphorus is a limiting nutrient for algal production in Ohio streams, emphasis is placed on it. Phosphorus enters streams attached to soil particles making soil erosion/siltation control important. Needed erosion reduction is quantified in the chapter on siltation. Manure from livestock contains nutrients and therefore manure control is essential in order to reduce or eliminate this source.

For Old Woman Creek, the source of habitat alteration is agricultural-related channelization. For the site at RM 9.4, the average QHEI score based on two scores is 44. Compared to the QHEI target of 60, there is a deficiency of 16 points. The high and moderate component score is 0 out of 3. For the East tributary site at RM 8.82/0.7 the QHEI target is met but the component score is 0 out of 3. To improve these two sites work should be concentrated on the high and moderate influence modification attributes to the stream listed in Table 10.

In Chappel Creek, the source of habitat alteration is non-irrigated crop production. Though the overall QHEI score exceeds the minimum for the warm water habitat use designation, there are certain aspects of this stream section which have been altered. The scores for these pertinent QHEI subcomponents (high and moderate modified attributes) are listed in Table 10. To improve habitat and thus biological scores, work should be focused on these attributes of the stream.

Much of the information on Old Woman Creek such as the work done by Ohio EPA, Old Woman Creek informational brochures, LEASEQ information, etc., shows the problem is clearly siltation and nutrients which come attached to the silt. Likely implementation will be in the form of BMPs to reduce siltation. Ohio EPA's survey results verified the findings of the Old Woman Creek NERR staff, the County Soil and Water Districts, and scientists from Heidelberg College, Ohio State University, and Case Western Reserve: that siltation needs to be reduced. Perhaps the greatest effect of the TMDL and its conclusions will be to open the door for more funding, possibly through the County Soil and Water Districts, to direct and implement siltation reduction BMPs.

3.0 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 their findings and recommendations. The Old Woman Creek TMDL has been completed using the process endorsed by the EAG.

Ohio EPA involved the partners and public stakeholders in the Old Woman Creek TMDL project by soliciting input and recommendations for action in a series of meetings during 2000 and 2001 and again in 2004 (see Table 14). Initially, Ohio EPA was interested in learning more about habitat problems at Old Woman Creek Estuary in relation to beneficial use impairments in the Lake Erie ecosystem. The Lake Erie Lakewide Management Plan (LaMP) document recognizes that habitat restoration is key to overall restoration of Lake Erie and chose to focus on coastal wetland habitat. As such, the LaMP was looking for a worthy restoration project that met the criteria and had some resources already available to impact habitat improvements. Old Woman Creek has one of the few remaining natural coastal wetlands along the Lake Erie shoreline in Ohio.

The first meeting of agency partners and stakeholders on November 2, 1999, was hosted by staff at the Old Woman Creek National Estuary Research Reserve in Huron, Ohio. There was good participation and discussion included the challenges of managing the estuary, past conservation farming efforts, ongoing research by OWC Preserve, and other agency initiatives. It was agreed to continue to discuss a potential habitat restoration project in the Old Woman Creek watershed.

The Ohio EPA Division of Surface Water facilitated seven more meetings between February, 2000, and April, 2001, which invited broad representation from local agencies, conservation organizations, and academic researchers working in the watershed area. The public outreach activities included a watershed tour, discussions on water quality problem identification, gathering and review of existing data collected by OWC, Case Western Reserve University, Heidelberg College and others, highlights of current water quality improvement projects, and brainstorming new projects and potential funding sources.

A public stakeholders information meeting was held on February 23, 2001, attended by a total of thirty participants. A summary of water quality findings from studies along the Lake Erie shoreline and in the Old Woman Creek watershed was presented, as well as the TMDL process which would begin with a biological, chemical and physical water quality assessment in the summer of 2001.

On May 29, 2001, Ohio EPA held a TMDL study planning meeting at the Old Woman Creek Visitors Center. The field work was conducted in 2001 and 2002, and a follow up meeting was held with local agencies on April 15, 2004 to discuss potential solutions for the main causes of water quality impairment.

There is a local Friends of Old Woman Creek organization that is active with volunteer staffing and educational programs at the Reserve. Ohio EPA and ODNR offered support and information on the Ohio Watershed Coordinator Program during early 2002, and encouraged several local organizations to consider applying for 319 grant funding to employ a full time watershed coordinator. There also may be future funding through NOAA to have a watershed coordinator on staff at the Old Woman Creek Nature Reserve.

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report was available for public comment from February 7, 2005 through March 10, 2005. A copy of the draft report was posted on Ohio EPA's web page (www.epa.state.oh.us/dsw/tmdl/index.html), and copies of the report were distributed to local libraries. A summary of the comments received and the associated responses is included in Appendix C.

Public involvement is key to the success of any TMDL project. Ohio EPA will continue to support the implementation process and will facilitate to the fullest extent possiblerestoration actions that are acceptable to the communities and stakeholders in the study area and to Ohio EPA. Ohio EPA is reluctant to rely solely on regulatory actions and strongly upholds the need for voluntary actions facilitated by the local stakeholders and agency partners to bring the Old Woman Creek watershed into attainment.

Table 14. Old Woman Creek Watershed Public Involvement

Date	Time	Subject(s)
11/2/99	10:00	Potential Habitat Restoration Project planning meeting at Old Woman Creek Natural Estuary Research Reserve (NERR)
2/16/00	10:00-12:30	Watershed tour to learn about land use and discuss potential sites for a habitat restoration project
6/14/00	10:00 -3:00	Meeting to identify sources of data and land use information about watershed. Request for lists of permitted facilities including storm water construction sites
10/23/00	10:00 - 3:00	Review watershed inventory information. Begin planning for an outreach event in winter 2001.
1/11/01	10 -12:30	Discuss past or ongoing research projects and available funding sources; Continue planning for February stakeholders meeting
2/23/01	?	Local Stakeholders meeting
4/5/01	10-3:30	Proposed water quality projects and presentation by Ducks Unlimited
5/25/01	1:00 -2:30	Conference call to summarize needs and resources in the watershed in preparation for the upcoming TMDL process
6/28/01	10:00-2:00	TMDL study planning meeting at OWC Visitors Center
1/8/04	9:00-12:00	A discussion with Old Woman Creek NERR staff to explain TMDL, discuss TMDL report needs and to inquire about existing relevant studies.
4/15/04	10:00-12:30	Meeting at Old Woman Creek Visitors Center with local agency stakeholders to discuss potential solutions for TMDLs
1/21/05	9:30 - 12:00	Meeting to discuss Draft TMDL Report with local stakeholders
Feb 2005	-	Public notice of the Old Woman Creek TMDL Report

4.0 Implementation and Monitoring Recommendations

Restoration methods to bring an impaired water body into attainment with water quality standards generally involve an increase in the water body's capacity to assimilate pollutants, a reduction of pollutant loads, or some combination of both. The causes of impairment in the Old Woman Creek watershed are siltation, nutrient enrichment, and habitat alteration. Therefore, an effective restoration strategy would include habitat protection and improvements and reductions in pollutant loads, potentially combined with some additional means of increasing the assimilative capacity of the stream.

Potential restoration strategies used to achieve the TMDL restoration targets might include:

- Public education for awareness of watersheds and water quality
- Riparian buffer initiatives
- Natural stream management principles
- Corridor protection ordinances
- Flood plain management
- Sediment and erosion control practices in agricultural and urban areas
- Post-construction storm water management practices
- Reduced use of residential fertilizers and pesticides
- Proper use and storage of fertilizers and pesticides
- Conservation farming practices
- Comprehensive nutrient management plans
- Livestock waste management plans
- Home sewage treatment system management and maintenance
- Planned growth/development strategies
- Phase I and II Storm Water Pollution Prevention Plans (SWP3s) and Storm Water Management Programs (SWMPs)
- Centralized treatment for unsewered communities

TMDL Implementation Strategy

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

- a new discharge will not exceed the loading capacity of the receiving steam in relation to phosphorus, or ammonia.
- trends in in-stream concentrations will be tracked, and the NPDES permits will include an option for permit modifications should data indicate in-stream total phosphorus, ammonia and D.O. levels have achieved stable and desirable levels or that the use designations are being fully met.

Implementation of nonpoint source reduction measures will be achieved through a locally adopted implementation strategy built around non-regulatory and voluntary incentive programs. Local input to the implementation strategy will result in a planning

and decision process that leads to reasonable and sustainable actions that will be the most effective in restoring water resources in the watershed. Ohio EPA recommends an approach that directs resources to improve the overall habitat and physical stability of streams throughout the watershed. A two tiered approach that prescribes land management practices and promotes natural channel stability will be most effective in achieving nutrient and sediment load reductions. Traditional BMPs and barriers should be targeted at the stream segments most vulnerable to erosion during high flow storm events. Restoring stream habitat and maintaining channel stability will increase the nutrient and sediment assimilative capacity of streams during normal and lower flow conditions.

The local implementation strategy will evaluate existing conservation programs and seek opportunities for new funding sources for landowners willing to try innovative practices. Three potential funding sources from Ohio EPA are mentioned below.

Ohio's Water Pollution Control Loan Fund (WPCLF) has two funding sources for nonpoint source pollution control available through the Ohio EPA Division of Environmental and Financial Assistance (DEFA). The Linked Deposit Loan Program provides low interest loans through local banks to aid landowners in implementing nonpoint source reduction projects such as residential on-lot septic system repair or replacement, agricultural BMPs, stream corridor restoration, and sanitary sewer connections.

The other WPCLF funding mechanism, Water Resource Restoration Sponsor Program (WRRSP), is a unique opportunity for municipalities and local partners to work together on a stream restoration project. When a publically owned wastewater treatment system obtains a WPCLF loan for plant expansion or other improvements, the reduction in interest on the loan repayment can be used to "sponsor" a smaller local watershed project. There is an additional discounted loan rate for municipalities who enter these partnerships. Some uses of WRRSP could be to finance riparian easement purchase, stream channel and wetland restoration and protection, and match monies for other funding sources such as Section 319 grants. In a project sponsored by the City of Marion in 2000, Edison Woods was purchased and restored by Erie County Metroparks. More details are provided later in the Habitat Protection and Restoration section of this chapter.

Additional information on Linked Deposit loans and WRRSP is available on the Ohio EPA web site at http://www.epa.state.oh.us/defa/wpclf.html.

Clean Water Act Section 319 provides funding to Ohio EPA for grants to local sponsors to implement nonpoint source controls and stream restoration projects contained in TMDL reports or endorsed Watershed Action Plans. There have not been any Section 319 Nonpoint Source grant projects in this watershed, however Old Woman Creek may be considered a priority watershed for TMDL implementation funding in FY2006. Local partners will be encouraged to submit proposals that implement recommendations of the TMDL report.

Reasonable Assurances

As part of an implementation strategy, reasonable assurances provide a level of confidence that the 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 non-enforceable actions (certain nonpoint source activities) 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).

Minimum Elements of an Implementation Plan

Whether an implementation plan is for one TMDL or a group of TMDLs, it should include at a minimum the following eight elements:

- *Implementation actions/management measures*
- *Time line*
- *Reasonable assurances*
- *Legal or regulatory controls*
- *Time required to attain water quality standards*
- *Monitoring plan*
- *Milestones for attaining water quality standards*
- *TMDL revision procedures*

Reasonable Assurances Summary

This is a summary of the regulatory, non-regulatory and incentive based actions applicable to or recommended for the Old Woman Creek watershed. Some of these activities deal specifically with the point source discharge regulatory actions. Non-regulatory and incentive based programs are currently delivered through existing local conservation authorities and nonpoint source reduction activities:

Regulatory:

- Wastewater treatment facilities in unsewered village of Berlin Heights
- Statewide Rules for Home Sewage Treatment/Disposal
- Enforcement of Storm Water Phase I and II regulations
- Sediment and erosion control practices for construction projects

- Implementation of post-construction storm water controls on construction projects
- Implementation of the 208 Water Quality Plan in regards to development and sewer extensions

Non-regulatory:
- Locally developed watershed implementation plan which includes:
    - Watershed awareness education activities
    - Storm water management programs
    - Planned growth to manage impervious surface runoff
    - Source protection of ground and surface drinking water supplies (SWAP)
    - Fertilizer management in urban and residential areas
    - Septic system improvements
    - Inspection and Operation/Maintenance programs for home septic systems
    - Manure nutrient management plans
    - Agricultural conservation practices
    - Natural stream corridor management and bank stabilization practices
    - Riparian buffer initiatives
    - Recommendations for an updated drainage maintenance program
- Encourage local health departments to implement HSTS Plans in 2 counties.
- Periodic stream monitoring to measure progress

Incentive-based:
- Section 319 grant opportunities for implementation projects that support the goals of this TMDL
- Lake Erie Protection Fund and Great Lakes Commission grant opportunities
- Ohio Coastal Nonpoint Source Program grants
- USDA Farm Bill programs for agricultural BMPs (CRP, CSP, EQIP, WHIP)
- Lake Erie CREP for buffer practices throughout the Lake Erie watersheds
- Clean Ohio Grant Fund opportunities for natural resource protection and improvement and farmland BMPs
- Various loan opportunities for WWTP improvements
- Low interest loan opportunities through WPCLF Linked Deposit program
- Funding opportunities through WRRSP program for riparian/habitat improvements
- FmHA grants and WPCLF loan opportunities for centralized wastewater treatment in small communities
- Ohio Environmental Education Fund grants administered by Ohio EPA

Point Source Controls

Currently, there are no municipal waste water point sources which discharge into the watershed. However, there are a number of semi-public wastewater treatment plants that discharge to Chappel Creek which are monitored by NPDES permits. These facilities, with their design flow, can be found in Table 15 below.

Table 15. Semi-public Facilities Under NPDES Permit in the Chappel Creek Watershed

Entity Name	River Mile	Design Flow (GPD)
Beulah Beach Christian Community	0.21	30,000
Grand Harbour Condominiums	0.20	23,000
Shan Rod, Inc.	2.60	2,500
Berlin Milan Middle School	7.5	15,000

Grand Harbor Condominiums are scheduled in the near future to be tapped into the Erie County-operated Mittawanga-Ruggles wastewater treatment plant, which discharges outside the watershed. Beulah Beach will follow when commercial development warrants sewer extensions further east. All dischargers occur downstream of the most downstream nutrient impaired site in Chappel Creek (RM 9.1, see Table 1). The Berlin Milan Middle School is the closest discharging at RM 7.5. The next downstream site at RM 7.4 does not have a nutrient problem (see Table 1). For this reason waste load allocations are not addressed in this report.

Currently there are five regulated Municipal Separate Storm Sewer Systems (MS4s) in the TMDL area. Three have obtained permit coverage while two were granted waivers. This will be discussed further on page 46. There are also several sites with permit coverage under the NPDES General Permit for Storm Water Discharges Associated with Construction Activities (see Appendix D). There are no sites within the TMDL area which have coverage under the NPDES General Permit for Storm Water Discharges Associated with Industrial Activities.

Unsewered Areas Recommendations

Unsewered communities include the Village of Berlin Heights and Oberlin Beach. Berlin Heights does not have a central wastewater collection and treatment system. The collection system currently consists of storm sewers that also transport partially treated wastewater from septic tank-type systems that serve the 670+ residents. The discharges from these sewers contribute to water quality degradation in Old Woman Creek. It is recommended that this nutrient and bacteria source receive additional evaluation. Centralized wastewater treatment facilities may be recommended for this community. Berlin Heights is included in the Erie County Huron Basin Facility Planning area, but is not being considered for sanitary sewers in the near future. Oberlin Beach is a small private subdivision consisting of nineteen, primarily seasonal, homes/cottages located just east of Old Woman's Creek Preserve. The homes are served by a collection system and rock filter which discharges directly into Old Woman's Creek natural estuary. Erie County has indicated that Oberlin Beach will be included when sanitary sewers are extended east of Huron within approximately five years.

A future threat of impairment may occur as a result of continued rural development in Erie County which is spurred by installation of public water supply lines throughout the county. Because sewer lines are not being constructed concurrent with the water

supply, there will be an increase in failing septic systems that may impact Old Woman Creek and other streams in Erie County.

Nonpoint Source Controls

Agricultural Sedimentation and Nutrient Enrichment

The Old Woman Creek watershed is a predominately agricultural area used mostly for row crop production and, to a smaller degree, livestock production. In the past ten to fifteen years, conservation efforts by farmers, local partnerships and units of government have reduced non-point sources of pollution significantly, and efforts in this direction continue. However, agricultural contributions of sediment and nutrients are still problematic in the smaller tributary and headwater streams in the upper till plain area of Huron and southern Erie County. There is also a source of stream bank erosion and nutrient (animal waste) input in stream segments where livestock have direct access to the water.

Landowners can take advantage of several incentive programs that will cover significant costs of adopting Best Management Practices on farmland, while educational initiatives exist to boost participation in these programs. Livestock Environmental Assurance Program, CREP, and other 2002 Farm Bill programs are available through the Farm Service Agency and Soil and Water Conservation Districts in each county of the watershed. The watershed partners will be eligible for Section 319 grant funds beginning in FY 2006 to implement projects that address TMDLs. It is recommended that funds and incentive programs be prioritized by geomorphic region, beginning with the till plains in the headwaters, and small streams in the upper watershed.

Habitat Modification and Flow Alteration

A lack of instream and riparian habitat, and low water levels in small tributary streams and maintained channels caused multiple impairments in the Old Woman Creek watershed. In this study, the difference between small streams that were attaining their aquatic use designations and streams that were not, appeared to be related to the amount of nutrient enrichment and the presence or absence of riparian vegetative cover and continuous stream flow. In other words, the impacts of sediment and nutrients are magnified by poor physical habitat or intermittent flow. Conversely, good physical habitat and adequate flow can be effective in assimilating these pollutants.

Habitat improvements, especially to the quality of the substrate, stream channel, and riparian characteristics, are recommended throughout the watershed with special effort directed at the non-attaining stream segments located at RM 9.4 and RM 8.82 in Old Woman Creek and RM 7.4 on Chappel Creek. Restoration that yields an increase in the Habitat (QHEI) score to an average of 60 is desired. The target for the QHEI provides a means for evaluating success for any activities performed in terms of how likely it is for an aquatic life use to be restored. When QHEI values begin to exceed 60, the likelihood that a warmwater aquatic fauna will be supported is greater than when the scores are less than 60. In these stream segments, all aspects of the habitat; substrate,

instream cover, riparian and channel characteristics, and pool riffle quality need improvement.

Another practice that can lead to stream impairment is the attempt to stabilize steep banks at the east edge of Berlin Heights. Fill material such as contaminated soil, or construction and demolition waste may lead to cause of elevated levels of inorganic metals and sediment in the mainstem of Old Woman Creek.

Unlike the standard practices used to reduce sediment and nutrient runoff from crop land, the solutions for habitat and flow impaired streams will not be familiar agricultural BMPs that have well established incentive programs. Improved habitat will rely on long term land use changes and social acceptance of new trends in agricultural drainage practices. Implementation actions could include:

- Promote natural stream management and filter strips to reduce the frequency of maintenance on petition ditches.
- Promote physical stability in streams by restoring active flood plains
- Promote wetlands to provide flood water storage and enhance groundwater recharge.
- Research the feasibility of controlled drainage projects in selected areas.
- Adopt riparian protection ordinances that prevent flood plain encroachment and riparian removal.
- Implement site appropriate methods of stream bank stabilization.

Habitat Protection and Restoration

Preservation of natural habitat is key in maintaining the existing level of assimilative capacity of the watershed. Actions like preserving natural drainage features, maintaining riparian areas, disconnecting impervious surfaces, minimizing impervious areas, and installing post-construction structural storm water management practices are recommended. Restoration of natural habitat is also encouraged.

The purchase and restoration of Edison Woods Reserve in Erie County is an example of a successful Water Resource Restoration Sponsor Program (WRRSP) project. The City of Marion received a large low interest loan through the Ohio Water Pollution Control Loan Fund and was able to provide $6 million funding to Erie County Metroparks for the Edison Woods project. Nearly $4.7 million went to purchase the 1400 acre property from Ohio Edison. The remaining $1.3 million was used to preserve over 500 acres of wetlands located in the headwaters of Cranberry Creek, the protection and management of over 450 acres of forested habitat, and conversion of up to 400 acres of active agricultural land to native vegetation. In 2001 the farmland was planted to cool season native prairie vegetation. Ohio EPA worked with the County Metroparks and local prairie enthusiasts to develop a long term management plan of prescribed burns that will allow for a gradual return of trees to the prairie.

Home Sewage Treatment System Management

Septic systems impact water quality in the Old Woman Creek watershed through both

point and nonpoint discharges from failed, inadequately designed, or discharging systems in small unincorporated villages and rural areas. Individual sewage systems are used to treat household sanitary waste in areas where no municipal treatment facilities exist. When poorly designed or neglected, they contribute loads of organic matter, nutrients, and pathogens. Site limitations such as lot size, soil type and depth to bedrock or groundwater further reduce effectiveness and increase system failures leading to surface or groundwater contamination.

In small towns water quality and public health can be severely impacted when multiple homes bypass failed systems into the storm sewers or local streams. Sampling conducted during the 2001 TMDL assessment indicated unsanitary conditions due to sewage discharges from storm sewers in Berlin Heights.

Implementation actions to address these sources of pollution would include, identification and replacement of faulty septic systems, elimination of on-site septic systems through extension of municipal sanitary sewers or construction of community waste treatment facilities, and public education on septic system maintenance. Section 319 grant funds are available to assist homeowners with repair or replacement of failed septic systems in critical areas of the watershed. To be eligible for grant funding, a county health department must prepare and receive Ohio EPA approval of a county wide or watershed based Home Sewage Treatment System (HSTS) plan. HSTS Plans have been approved for Huron and Erie Counties.

Storm Water Management

In the Old Woman Creek watershed, sources of stream impairment may include discharges from urban storm runoff and storm water dischargers from both Phase I and II Industrial, Construction, and Municipal activities. Phase II Storm water rules now require prescribed management practices for construction activities in a Storm Water Pollution Prevention Plan (SWP3) that include:

- Installation and maintenance of sediment and erosion control practices for construction projects which, either by themselves or as part of a total common plan of development or sale, collectively disturb one acre or more
- Implementation of post-construction storm water controls on construction projects which, either by themselves or as part of a total common plan of development or sale, collectively disturb one acre or more

So that a receiving stream's physical, chemical, and biological characteristics are protected and stream functions are maintained, post-construction storm water practices shall provide perpetual management of runoff quality and quantity. To meet the post-construction requirements of this permit, the SWP3 must contain a description of the post-construction BMPs that will be installed during construction for the site and the rationale for their selection. The rationale must address the anticipated impacts on the channel and floodplain morphology, hydrology, and water quality. The post construction BMP(s) chosen must be able to detain storm water runoff for protection of the stream channels, stream erosion control, and improved water quality.

The formation of a stakeholder based advisory group to guide the development of a storm water program in a Watershed Implementation Plan would be an important first step. Implementation actions could include drafting ordinances for storm water and sediment and erosion control, planned growth initiatives, and expansion of existing programs (i.e., Soil and Water Conservation Districts (SWCDs)) to include storm water monitoring. Public education, such as developing an adult education program about storm water pollution would be an important and necessary part of the implementation plan.

The five regulated small MS4s in the OWC TMDL must either obtain NPDES permit coverage for their storm water discharges or request a waiver. The City of Huron and Erie County currently are Co-Permittees (Ohio EPA Number 2GQ00027) with coverage under the NPDES General Permit for Small MS4s. The Ohio Department of Transportation also has permit coverage (Ohio EPA Number 4GQ00000). Under this permit, entities are required to have a Storm Water Management Program (SWMP) implemented by March 2008 for all areas served by their MS4 within Elyria/Lorain and Sandusky Urbanized Areas (UA). The SWMP must address public outreach and education, public participation, illicit discharge detection and elimination, sediment and erosion controls (construction site program), municipal operations, and post construction storm water management. Under the Phase II Storm Water Regulations, those regulated small MS4s with populations less than 1000 inside a UA may be eligible for a waiver from NPDES MS4 permitting. Vermilion and Huron Townships were granted waivers in 2003. Such waivers must be re-evaluated every five years. It is recommended that Ohio EPA reconsider the waivers from NPDES Small MS4 General permit coverage currently granted to Huron and Vermilion Townships. As development progresses along the Lakeshore and these streams, it is important to have programs already in place to mitigate the impacts of development as it occurs.

Public Education

The local SWCDs and park districts may have nonpoint source education staff that deliver programs and information to help local landowners and public officials understand causes, sources and solutions to nonpoint pollution. The primary focus would be building public awareness about the value of a healthy watershed and the importance of reducing/eliminating these sources of pollution. Funding for NPS education in the Old Woman Creek watershed is available through grants from ODNR Division of Soil and Water Conservation, Ohio Coastal Management Assistance Grants Program, and the Ohio Environmental Education Fund administered by Ohio EPA.

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 in-stream 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 a local watershed group 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 a local watershed group work with the Ohio EPA to develop such a monitoring plan.

A biological and water quality study of Old Woman Creek, similar to that conducted by the Ohio EPA in 2002 will be scheduled when indications exist that major changes in the watershed have occurred. In addition, interim and/or surrogate measures that document progress in water quality improvement are recommended. 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 a local watershed 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 water bodies are still not attaining water quality standards after the implementation plan has been carried out, then a TMDL revision would be initiated. The Ohio EPA would initiate the revision if no other parties wish to do so.

References

Berlin Heights, OH Houses and Residents, www.city-data.com/housing/houses-Berlin-Heights-Ohio.html

Buchanan, D. B. 1983 Transport and Deposition of Sediment in Old Woman Creek Estuary, Erie County, Ohio. M.S. Thesis, Ohio State University, Columbus, Ohio. 198 pp.

Evans, J. E. and D. Erich Seamon 1997 A GIS Model to Calculate Sediment Yields from a Small Rural Watershed, Old Woman Creek, Erie and Huron Counties, Ohio, Department of Geology, Bowling Green University, Bowling Green, Ohio.

Gray, J. R., D. G. Glysson, L. M. Turcios, and G. E. Schwarz 2000 Comparability of Suspended -Sediment Concentration and Total Suspended Solids Data. USGS Water-Resources Investigations Report 00-4191, Reston, Virginia. 14 pp.

Herdendorf, C. E., Herdendorf, R. C., and Klarer, D. M. 2000 Bibliography of Research Publications for Old Woman Creek Estuary, Watershed, and Adjacent Waters of Lake Erie, Technical Report No. 14, Old Woman Creek State Nature Preserve.

Klarer, Dr. Dave, notes from the 4/15/2004 Ohio EPA, Old Woman Creek NERR and Erie County Soil and Water meeting.

Krieger, K. A. 2000 Effectiveness of a Coastal Wetland in Reducing the Movement of Agricultural Pollutants into Lake Erie. Old Woman Creek State Nature Preserve and National Estuarine Research Reserve Tech. Report No. 15. Ohio Dept. Natural Resources, Div. Natural Areas and Preserves, Columbus, Ohio. 60 pp. + app.

Lake Erie Agriculture Systems for Environmental Quality Project (LEASEQ) 1999 a collaborative research effort by Ohio State University, Heidelberg College and Case Western University.

Matisoff, G., P. J. Whiting, and E. C. Boniwell 1999 Transport of Fine Sediments from Agricultural Watersheds in Streams Tributary to Lake Erie, Department of Geological Sciences, Case Western University, Cleveland, Ohio.

Ohio Department of Natural Resources 2002 Old Woman Creek 2002 Annual Report. Division of Natural Areas and Preserves. 1889 Fountain Square Court, Columbus, Ohio. 43224. 36 pp.

Ohio Environmental Protection Agency 1999 Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams, Division of Surface Water, Monitoring and Assessment Section, Columbus, Ohio 43266.

Ohio Environmental Protection Agency 2004 Integrated Report, Columbus, Ohio.

Ohio Environmental Protection Agency 2004. Biological and Water Quality Study of the Vermilion River, Old Woman Creek, Chappel Creek, Sugar Creek, and Select Lake Erie Tributaries, 2002. Ashland, Huron, Erie, Richland and Lorain Counties, Ohio. Available at http://www.epa.state.oh.us/dsw/document_index/psdindx.html. October.

Ohio Farm Bureau, 2002 Review and Comment on Sugar Creek Basin TMDL Report, Larry Antosch/John Fisher, Ohio Farm Bureau Federation, January 14, 2002 (e mail).

Rankin, E. 1989 Qualitative Habitat Evaluation Index [QHEI]: Rational, Methods, and Application, Ohio EPA, Columbus, Ohio, (http://www.epa.state.oh.us/dsw/documents/BioCrit88_QHEIResDisA.pdf).

USEPA, 1991 Guidance for Water Quality-based Decisions: The TMDL Process, Watershed Branch Assessment and Watershed Protection Division (WH-553), U.S. Environmental Protection Agency, 401 M St. SW, Washington DC. 20460

USGS, 2000 Status and Trends in Suspended-Sediment Discharges, Soil Erosion, and Conservation Tillage in the Maumee River Basin—Ohio, Michigan, and Indiana, Water-Resources Investigations Report 00-4091.

Woods, A. J. C. 1987 Fluvial Erosion, Sedimentation, and Hydraulic Geometry in the Contributing Watershed of Old Woman Creek National Estuarine Research Reserve. NOAA Technical Memorandum, NOS MEMD 12, Washington DC. 140 pp.

Appendix A. General Overview of Ohio's Water Quality Standards and Assessments

What is a Biological and Water Quality Survey?
A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 4-5 watersheds study areas with an aggregate total of 250-300 sampling sites.

The Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.,* NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]).

Hierarchy of Indicators
A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Figure1). The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes

in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

Administrative → **True Environmental**

Level 1	***Actions by EPA and States***	NPDES Permit Issuance Compliance/Enforcement Pretreatment Programs Actual Funding CSO Requirements Storm Water Permits 319 NPS Projects 404/401 Certification Stream/Riparian Protection
Level 2	***Responses by the Regulated Community***	POTW Construction Local Limits Storm Water Controls BMPs for NPS Control Pollution Prevention Measures
Level 3	***Changes in Discharge Quantities***	Point Source Loadings: Effluent and Influent Whole Effluent Toxicity (WET) NPDES Violations Spills and Other Releases Fish Kills
Level 4	***Changes in Ambient Condition***	Water Column Chemistry Sediment Chemistry Habitat Quality Flow Regime
Level 5	***Changes in Uptake and/or Assimilation***	Assimilative Capacity: TMDL/WLA Biomarkers Tissue Contamination
Level 6	***Changes in Health and Ecology, or Other Effects***	Biota (Biocriteria) Bacterial Contamination Target Assemblages (Rare, Threatened and Endangered, Declining Species)

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.,* rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreation uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Use

The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. 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. *Cold-water 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 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/or 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 in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, 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 can be having a water depth of at least one meter over an area of at least 100

square feet or, lacking this, where frequent human contact is a reasonable expectation. If a water body does not meet either criterion, the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliform, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Attainment of recreation uses are evaluated based on monitored bacteria levels. The Ohio Water Quality Standards state that all waters should be free from any public health nuisance associated with raw or poorly treated sewage (Administrative Code 3745-1-04, Part F). Additional criteria (Administrative Code 3745-1-07) apply to waters that are designated as suitable for full body contact such as swimming (PCR- primary contact recreation) or for partial body contact such as wading (SCR- secondary contact recreation). These standards were developed to protect human health, because even though fecal coliform bacteria are relatively harmless in most cases, their presence indicates that the water has been contaminated with fecal matter.

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.

MECHANISMS FOR WATER QUALITY IMPAIRMENT

The following paragraphs are provided to present the varied causes of impairment that were encountered during the Vermilion and Old Woman Creek study. While the various perturbations are presented under separate headings, it is important to remember that they are often interrelated and cumulative in terms of the detrimental impact that can result.

Habitat and Flow Alterations

Habitat alteration, such as channelization, impacts biological communities directly by limiting the complexity of living spaces available to aquatic organisms. Consequently, fish and macroinvertebrate communities are not as diverse. Indirect impacts include the removal of riparian trees and field tiling to facilitate drainage. Following a rain event, most of the water is quickly removed from tiled fields rather than filtering through the soil, recharging groundwater, and reaching the stream at a lower volume and more sustained rate. As a result, small streams more frequently go dry or become intermittent.

Tree shade is important because it limits the energy input from the sun, moderates water temperature, and limits evaporation. Removal of the tree canopy further degrades conditions because it eliminates an important source of coarse organic matter essential for a balanced ecosystem. Erosion impacts channelized streams more severely due to the lack of a riparian buffer zone to slow runoff, trap sediment and stabilize banks. Additionally, deep trapezoidal channels lack a functioning flood plain and therefore cannot expel sediment as would occur during flood events along natural watercourses.

The lack of water movement under low flow conditions can exacerbate impacts from organic loading and nutrient enrichment by limiting reaeration of the stream. The amount of oxygen soluble in water decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion, but channelization eliminates turbulence produced by riffles, meanders, and debris snags. Plant photosynthesis produces oxygen, but at night, respiration reverses the process and consumes oxygen. Oxygen is also used by bacteria that decay dead organic matter. Nutrient enrichment can promote the growth of nuisance algae that subsequently dies and serves as food for bacteria. Under these conditions, oxygen can be depleted unless it is replenished from the air.

Siltation and Sedimentation

Whenever the natural flow regime is altered to facilitate drainage, increased amounts of sediment are likely to enter streams either by overland transport or increased bank erosion. The removal of wooded riparian areas furthers the erosional process. Channelization keeps all but the highest flow events confined within the artificially high banks. As a result, areas that were formerly flood plains and allowed for the removal of sediment from the primary stream channel no longer serve this function. As water levels fall following a rain event, interstitial spaces between larger rocks fill with sand and silt and the diversity of available habitat to support fish and macroinvertebrates is reduced. Silt also can clog the gills of both fish and macroinvertebrates, reduce visibility thereby excluding site feeding fish species, and smother the nests of lithophilic fishes. Lithophilic spawning fish require clean substrates with interstitial voids in which to deposit eggs. Conversely, pioneering species benefit. They are generalists and best suited for exploiting disturbed and less heterogeneous habitats. The net result is a lower diversity of aquatic species compared with a typical warmwater stream with natural habitats.

Sediment also impacts water quality, recreation, and drinking water. Nutrients absorbed to soil particles remain trapped in the watercourse. Likewise, bacteria, pathogens, and pesticides which also attach to suspended or bedload sediments become concentrated in waterways where the channel is functionally isolated from the landscape. Community drinking water systems address these issues with more costly advanced treatment technologies.

Nutrient Enrichment

The element of greatest concern is phosphorus because it is critical for plant growth and is often the limiting nutrient. The form that can be readily used by plants and therefore can stimulate nuisance algae blooms is orthophosphate (PO_4^{-3}). The amount of phosphorus tied up in the nucleic acids of food and waste is actually quite low. This organic material is eventually converted to orthophosphate by bacteria. The amount of orthophosphate contained in synthetic detergents is a great concern however. It was for this reason that the General Assembly of the State of Ohio enacted a law in 1990 to limit phosphorus content in household laundry detergents sold in the Lake Erie drainage basin to 0.5 % by weight. Inputs of phosphorus originate from both point and nonpoint sources. Most of the phosphorus discharged by point sources is soluble. Another characteristic of point sources is they have a continuous impact and are human in origin, for instance, effluents from municipal sewage treatment plants. The contribution from failed on-lot septic systems can also be significant, especially if they are concentrated in a small area. The phosphorus concentration in raw waste water is generally 8-10 mg/l and after secondary treatment is generally 4-6 mg/l. Further removal requires the added cost of chemical addition. The most common methods use the addition of lime or alum to form a precipitate, so most phosphorus (80%) ends up in the sludge.

A characteristic of phosphorus discharged by nonpoint sources is that the impact is intermittent and associated with stormwater runoff. Most of this phosphorus is bound tightly to soil particles and enters streams from erosion, although some comes from tile drainage. Urban stormwater is more of a concern if combined sewer overflows are involved. The impact from rural stormwater varies depending on land use and management practices and includes contributions from livestock feedlots and pastures and row crop agriculture. Crop fertilizer includes granular inorganic types and organic types such as manure or sewage sludge. Pasture land is especially a concern if the livestock have access to the stream. Large feedlots with manure storage lagoons create the potential for overflows and accidental spills. Land management is an issue because erosion is worse on streams without any riparian buffer zone to trap runoff. The impact is worse in streams that are channelized because they no longer have a functioning flood plain and cannot expel sediment during flooding. Oxygen levels must also be considered, because phosphorus is released from sediment at higher rates under anoxic conditions.

There is no numerical phosphorus criterion established in the Ohio Water Quality Standards, but there is a narrative criterion that states phosphorus should be limited to the extent necessary to prevent nuisance growths of algae and weeds (Administrative Code, 3745-1-04, Part E). Phosphorus loadings from large volume point source dischargers in the Lake Erie drainage basin are regulated by the National Pollutant Discharge Elimination System (NPDES). The permit limit is a concentration of 1.0 mg/l in final effluent. Research conducted by the Ohio EPA indicates that a significant correlation exists between phosphorus and the health of aquatic communities (Miltner and Rankin, 1998). It was concluded that biological community performance in headwater and wadeable streams was highest where phosphorus concentrations were

lowest. It was also determined that the lowest phosphorus concentrations were associated with the highest quality habitats, supporting the notion that habitat is a critical component of stream function. The report recommends WWH criteria of 0.08 mg/l in headwater streams (<20 mi^2 watershed size), 0.10 mg/l in wadeable streams (>20-200 mi^2) and 0.17 mg/l in small rivers (>200-1000 mi^2).

Organic Enrichment and Low Dissolved Oxygen
The amount of oxygen soluble in water is low and it decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion. Drainage practices such as channelization eliminate turbulence produced by riffles, meanders, and debris snags. Although plant photosynthesis produces oxygen by day, it is consumed by the reverse process of respiration at night. Oxygen is also consumed by bacteria that decay organic matter, so it can be easily depleted unless it is replenished from the air. Sources of organic matter include poorly treated waste water, livestock waste, sewage bypasses, and dead plants and algae.

Dissolved oxygen criteria are established in the Ohio Water Quality Standards to protect aquatic life. The minimum and average limits are tiered values and linked to use designations (Administrative Code 3745-1-07, Table 7-1).

Ammonia
Ammonia enters streams as a component of fertilizer and manure run-off and wastewater effluent. Ammonia gas (NH_3) readily dissolves in water to form the compound ammonium hydroxide (NH_4OH). In aquatic ecosystems an equilibrium is established as ammonia shifts from a gas to undissociated ammonium hydroxide to the dissociated ammonium ion (NH_4^{+1}). Under normal conditions (neutral pH 7 and 25°C) almost none of the total ammonia is present as gas, only 0.55% is present as ammonium hydroxide, and the rest is ammonium ion. Alkaline pH shifts the equation toward gaseous ammonia production, so the amount of ammonium hydroxide increases. This is important because while the ammonium ion is almost harmless to aquatic life, ammonium hydroxide is very toxic and can reduce growth and reproduction or cause mortality.

The concentration of ammonia in raw sewage is high, sometimes as much as 20-30 mg/l. Treatment to remove ammonia involves gaseous stripping to the atmosphere, biological nitrification and de-nitrification, and assimilation into plant and animal biomass. The nitrification process requires a long detention time and aerobic conditions like that provided in extended aeration treatment plants. Under these conditions, bacteria first convert ammonia to nitrite and then to nitrate. Nitrate can then be reduced by bacteria through the de-nitrification process and nitrogen gas and carbon dioxide are produced as by-products.

Ammonia criteria are established in the Ohio Water Quality Standards to protect aquatic life. The maximum and average limits are tiered values based on sample pH and

temperature and linked to use designations (Administrative Code 3745-1-07, Tables 7-2 through 7-8).

Metals

Metals can be toxic to aquatic life and hazardous to human health. Although they are naturally occurring elements many are extensively used in manufacturing and are by-products of human activity. Certain metals like copper and zinc are essential in the human diet, but excessive levels are usually detrimental. Lead and mercury are of particular concern because they often trigger fish consumption advisories. Mercury is used in the production of chlorine gas and caustic soda and in the manufacture of batteries and fluorescent light bulbs. In the environment it forms inorganic salts, but bacteria convert these to methyl-mercury and this organic form builds up in the tissues of fish. Extended exposure can damage the brain, kidneys, and developing fetus. The Ohio Department of Health (ODH) issued a statewide fish consumption advisory in 1997 advising women of child bearing age and children six and under not to eat more than one meal per week of any species of fish from waters of the state because of mercury. Lead is used in batteries, pipes, and paints and is emitted from burning fossil fuels. It affects the central nervous system and damages the kidneys and reproductive system. Copper is mined extensively and used to manufacture wire, sheet metal, and pipes. Ingesting large amounts can cause liver and kidney damage. Zinc is a by-product of mining, steel production, and coal burning and used in alloys such as brass and bronze. Ingesting large amounts can cause stomach cramps, nausea, and vomiting.

Metals criteria are established in the Ohio Water Quality Standards to protect human health, wildlife, and aquatic life. Three levels of aquatic life standards are established (Administrative Code 3745-1-07, Table 7-1) and limits for some elements are based on water hardness (Administrative Code 3745-1-07, Table 7-9). Human health and wildlife standards are linked to either the Lake Erie (Administrative Code 3745-1-33, Table 33-2) or Ohio River (Administrative Code 3745-1-34, Table 34-1) drainage basins. The drainage basins also have limits for additional elements not established elsewhere that are identified as Tier I and Tier II values.

Bacteria

High concentrations of either fecal coliform bacteria or Escherichia coli (E. coli) in a lake or stream may indicate contamination with human pathogens. People can be exposed to contaminated water while wading, swimming, and fishing. Fecal coliform bacteria are relatively harmless in most cases, but their presence indicates that the water has been contaminated with feces from a warm-blooded animal. Although intestinal organisms eventually die off outside the body, some will remain virulent for a period of time and may be dangerous sources of infection. This is especially a problem if the feces contained pathogens or disease producing bacteria and viruses. Reactions to exposure can range from an isolated illness such as skin rash, sore throat, or ear infection to a more serious wide spread epidemic. Some types of bacteria that are a concern include *Escherichia*, which cause diarrhea and urinary tract infections, *Salmonella*, which cause typhoid fever and gastroenteritis (food poisoning), and *Shigella*, which cause severe gastroenteritis or bacterial dysentery. Some types of viruses that are a concern include

polio, hepatitis A, and encephalitis. Disease causing microorganisms such as cryptosporidium and giardia are also a concern.

Since fecal coliform bacteria are associated with warm-blooded animals, there are both human and animal sources. Human sources, including effluent from sewage treatment plants or discharges by on-lot septic systems, are a more continuous problem. Bacterial contamination from combined sewer overflows are associated with wet weather events. Animal sources are usually more intermittent and are also associated with rainfall, except when domestic livestock have access to the water. Large livestock farms store manure in holding lagoons and this creates the potential for an accidental spill. Liquid manure applied as fertilizer is a runoff problem if not managed properly and it sometimes seeps into field tiles.

Bacteria criteria are established in the Ohio Water Quality Standards to protect human health. The maximum and average limits are tiered values and linked to use designation, but only apply during the May 1-October 15 recreation season (Administrative Code 3745-1-07, Table 7-13). The standards also state that streams must be free of any public health nuisance associated with raw or poorly treated sewage during dry weather conditions (Administrative Code 3745-1-04, Part F).

Sediment Contamination

Chemical quality of sediment is a concern because many pollutants bind strongly to soil particles and are persistent in the environment. Some of these compounds accumulate in the aquatic food chain and trigger fish consumption advisories, but others are simply a contact hazard because they cause skin cancer and tumors. The physical and chemical nature of sediment is determined by local geology, land use, and contribution from manmade sources. As some materials enter the water column they are attracted to the surface electrical charges associated with suspended silt and clay particles. Others simply sink to the bottom due to their high specific gravity. Sediment layers form as suspended particles settle, accumulate, and combine with other organic and inorganic materials. Sediment is the most physically, chemically, and biologically reactive at the water interface because this is where it is affected by sunlight, current, wave action, and benthic organisms. Assessment of the chemical nature of this layer can be used to predict ecological impact.

The Ohio EPA evaluation of sediment chemistry results are evaluated using a dual approach, first by ranking relative concentrations based on a system developed by Ohio EPA (1996) and then by determining the potential for toxicity based on guidelines developed by MacDonald et al (2000). The Ohio EPA system was derived from samples collected at ecoregional reference sites. Classes are grouped in ranges that are based on the median analytical value (non-elevated) plus 1 (slightly elevated), 2 (elevated), 4 (highly elevated), and 8 (extremely elevated) inter-quartile values. The MacDonald guidelines are consensus based using previously developed values. The system predicts that sediments below the threshold effect concentration (TEC) are absent of toxicity and those greater than the probable effect concentration (PEC) are toxic.

Sediment samples collected by the Ohio EPA are measured for a number of physical and chemical properties. Physical attributes included % particle size distribution (sand $\geq$60 µ, silt 5-59 µ, clay $\leq$4 µ), % solids, and % organic carbon. Due to the dynamics of flowing water, most streams do not contain a lot of sediment and samples often consist mostly of inert sand. This scenario changes if the stream is impounded by a dam or channelized. Chemical attributes included metals, volatile and semi-volatile organic compounds, pesticides, and poly-chlorinated biphenyls (PCBs).

NONPOINT SOURCE POLLUTION IMPACTS AND REMEDIATION PROJECTS

Nonpoint sources of pollution to a water resource are a direct function of surrounding land use. All land use contributes to nonpoint sources of pollution that impair Ohio watersheds. Land use impacts water resources by affecting stream flow, stream habitat, nutrient enrichment, and siltation. Since agriculture occupies about 71% of the land area in the Vermilion River watershed and over 66% of the land use in the Old Woman Creek basin, agricultural land uses are responsible for much of the nonpoint source pollution in area streams (Huron SWCD, 2004 and Erie SWCD, 2004). Agricultural land use is a source of nonpoint source pollution as it may increase habitat alteration, nutrient enrichment, siltation and flow alteration. Nonpoint source pollution and land use impacts on water resources in the Vermilion River and Old Woman Creek watersheds include the following.

A. Impacts on Drinking Water
- Nitrate concentrations often exceed drinking water standards
- Seasonally elevated herbicide levels
- High concentrations of suspended solids during runoff events

B. Impacts to Aquatic Life
- Failure to attain aquatic life uses set by Ohio Water Quality Standards
- Fish and wildlife kills due to spills
- Sedimentation impairment to in-stream habitat for fish and macroinvertebrates

C. Impacts to Recreational Water Use
- Primary and Secondary Contact Recreation Uses limited by high bacteria events
- Fish consumption advisory for the entire Vermilion River watershed
- Aesthetic impairment from sediment and algal blooms

D. Impacts on Lake Erie through pollutant loading
- Phosphorus loading to Old Woman Creek and Lake Erie
- Suspended sediment degradation to Vermilion River, Old Woman Creek, and Lake Erie habitat
- Pesticides, nitrates, and other organic chemical pollutants transported by sediment

E. Impacts from Urban Land Use
- Impervious surfaces cause accelerated runoff volume to the river

- Failing septic systems
- Contaminated storm runoff

Over the past fifteen years many programs for reducing nonpoint source pollution have been introduced within the Vermilion River watershed, including the Continuous Conservation Reserve Program (CCRP), the Conservation Reserve Enhancement Program (CREP), Upper Vermilion Nutrient Management Program, Vermilion River Water Quality 319 project and the USDA Agricultural Stabilization and Conservation Service Best Management Practices (HWSCD, 2004).
The high amount of agricultural practices affecting water quality throughout the study area indicates that increased participation in these and similar programs is needed. Additional educational and outreach activities may help boost involvement in these programs and thereby reduce the impacts of agricultural practices on water quality.

Appendix B. Aquatic Life Use Attainment for OWC Basin

Aquatic life use attainment status for stations sampled in the Old Woman Creek basin, and select Lake Erie tributaries based on data collected July-September, 2002. Sampling results from 2000 and 2001 (noted in **bold**) were included in the table where sampling could not be completed in 2002. 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.

Stream Name	River Mile	Drainage Area	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes[d]	Sources[e]
Old Woman Creek			*WWH - ECBP Ecoregion*						
	11.4^{H}/11.3	2.4	24*	NA	P*		NON	Flow alteration	Natural (drought)
	9.4^{H}/9.4	3.4	36^{NS}	NA	F*	41.0	PARTIAL	Siltation/habitat alteration	Channelization -Ag.
			WWH - EOLP Ecoregion						
	8.4^{H}/8.4	7.8	32*	NA	P*	74.5	NON	Organic/nutrient enrichment	Livestock
	5.4^{H}/5.2	11.8	38^{NS}	NA	G	66.0	FULL		
	3.5^{H}/3.6	21.0	38^{NS}	NA	MG^{NS}	73.5	FULL		
	1.8^{O}/1.9^{L}	29.0	24*	NA	16*		NON	Siltation/nutrient enrichment	Non-irrigated crop production
	0.2^{O}/0.2^{L}	30.0	19*	5.4*	P*	36.5	NON	Siltation/nutrient enrichment	Non-irrigated crop production
Trib. to Old Woman Creek (8.82)			*Undesignated/WWH recommended - ECBP Ecoregion*						
	--/**0.9**	1.8			VP*		NON	Siltation/habitat alteration	Channelization -Ag.
Trib. to Old Woman Creek (3.7)			*Undesignated/WWH recommended - EOLP Ecoregion*						
	3.1^{H}/**4.9**	4.5	28*	NA	F*	67.5	NON	Flow alteration	Natural (drought)
	0.7^{H}/0.9	7.9	26*	NA	P*		NON	Flow alteration	Natural (drought)

Stream Name	River Mile	Drainage Area	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes[d]	Sources[e]
Chappel Creek			*WWH - ECBP Ecoregion*						
	16.6[H]/--	5.5	24*	NA		67.5	**(NON)**	Nutrient/organic enrichment	Pasture/non-irrigated crop production
	14.1[H]/--	9.9	30*	NA		64.0	**(NON)**	Nutrient/organic enrichment	Pasture
	9.1[H]/--	14.5	18*	NA		64.0	**(NON)**	Nutrient/organic enrichment	Pasture/non-irrigated crop
			WWH - EOLP Ecoregion						
	7.4[H]/7.4	18.2	34*	NA	F*	64.0	**NON**	Habitat alteration	Non-irrigated crop production
	1.3[W]/1.1	23.0	49	7.7[NS]	G	59.0	FULL		
Sugar Creek			*WWH - EOLP Ecoregion*						
	3.5[H]/--	5.7	32*	NA		69.0	**(NON)**	Flow alteration	Natural (drought)
	1.5[H]/--	6.4	36[NS]	NA		61.0	(FULL)		

Ecoregion Biocriteria: Eastern Corn Belt Plain

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				36	46	22
Wading	40	50	24	8.3	9.4	4.0	36	46	22
Boat	42	48	24	8.5	9.6	4.0	36	46	22

Lacustuary Scoring Benchmarks

Site Type	IBI	MIwb	ICI
WWH	42	8.6	42

Ecoregion Biocriteria: Eastern-Ontario Lake Plain

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				34	46	22
Wading	38	50	24	7.9	9.4	6.2	34	46	22
Boat	40	48	24	8.7	9.6	5.8	34	46	22

a - MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.

b - A qualitative narrative evaluation based on best professional judgement and sampling attributes such as community composition, EPT taxa richness, and QCTV scores was used when quantitative data were not available or considered unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates.

c - Attainment status is given for both existing and recommended use designations.

d - Causes listed are considered to be a primary influence on water quality, but may not be the only issue leading to impairment. See text for discussion of additional causes that cumulatively have led to impairment.

e - Sources listed are considered to be a primary influence on water quality, but may not be the only source leading to impairment. See text for discussion of additional sources that cumulatively have led to impairment.

f - Ag. refers to agricultural impacts while Dev. refers to impacts associated through urbanization and development.

H -Headwater site.

W -Wading site.

B - Boat site.

O - Fish Lacustuary site. Scores have been compared to lacustuary scoring method.

L - Macroinvertebrate Lacustuary site. Scores have been compared to lacustuary scoring method.

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

* - 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.

Appendix C. Responses to Public Comments

One organization, the Ohio Farm Bureau Federation, provided written comments on the draft Old Woman Creek TMDL report, as follows:

- Letter received 3/09/2005 from Mr. John C. Fisher
- Follow-up email on 3/22/2005 from Dr. Larry Antosch.

The comments were reviewed by the Ohio Environmental Protection Agency (Ohio EPA). Page number references in the comments refer to the draft report available for public comment and may not apply to the final report.

1. **Comment:** The future target suspended sediment load at station 8 was determined by using the stream flow values measured at station 8 multiplied by the suspended sediment concentrations measured at station 2. There is a large increase in drainage area between the two sampling locations. In fact, a large tributary enters from the east just above station 8. It is not logical to assume that with such a large increase in drainage area that the suspended sediment contribution will not change between station 2 and station 8. Some allowance for increased suspended sediment delivery needs to be incorporated into the calculation of the future target suspended sediment load.

   Response: The statement, "It is not logical to assume that with such a large increase in drainage area that the suspended sediment contribution will not change between station 2 and station 8" is true when referring to load, but not true for concentration. Hypothetically, if 1 acre of land produces a concentration of 20 mg/l of parameter X and the only variable that changes is size, then from 2000 acres the concentration would still be 20 mg/l. The concept on which the TMDL analysis is based was this: site two has good land use practices, so if we apply it to the rest of the drainage we should be able to get the same concentration. The concentration from site 2 was simply multiplied by the area from site 8 to account for the increase in area when developing the target.

2. **Comment:** One way to overcome this error would be to calculate a unit area load (pounds of suspended sediment per square mile of drainage area) for suspended sediment at the upstream site (station 2). The unit area load could be assumed to remain constant throughout the basin and used to calculate a future load at the downstream site (station 8). The use of a unit area load will provide a reasonable allowance of increased suspended sediment due to natural conditions and increased drainage area. The difference between the current suspended sediment load at station 8 and the one calculated using the determined unit area load would be the amount that should be reduced by the TMDL.

   Response: The suggested method yields a very similar result. By using a drainage-area-derived yield for load, the commenter is assuming the same flow and

concentration per unit area from both basins. In the TMDL, the concentration from site 2 (the target basin) is applied at site 8 using the measured flows from site 8. Thus only one variable, concentration, is assumed to change. By reducing the number of variables that are assumed the potential error is minimized.

Using the commenter's method, the flow yield from site 2 would be applied to site 8. With the TMDL method, the measured flow for site 8 was used, but since the flows were measured on the same day for both sites and since they are in the same area the drainage yields should be very similar.

3. **Comment:** Page 21. Discussion in the first paragraph establishes an implementation process for sediment reduction that is prioritized by geomorphic region and land use. This focused approach to implementation is a departure from the usual "cookie cutter" implementation scenario found in past draft TMDL documents. It is a positive change and greatly enhances the document.

   Response: We appreciate the comment and will try to incorporate this improvement in future TMDLs.

4. **Comment:** Habitat Alteration Results Pages 26 and 27. The use of the QHEI subcomponent scores in the habitat alteration discussion helps to identify the principal factors limiting habitat quality. Investigation of the individual metric scores will help watershed managers identify those management practices that can make a difference. This also is a positive improvement to a TMDL addressing habitat alteration.

   Response: We appreciate the comment and will try to incorporate this improvement in future TMDLs.

5. **Comment:** Thank you for your prompt reply to my comments on the Draft Old Woman Creek TMDL. After reviewing them I can see that we were both going in the same direction just following slightly different paths [referring to comments 1 and 2, see above].

   I think it is curious that when I reviewed the math on Table 3 (page 13) the values for G^c under the Mean column do not equal the product of $Q^a * C^b$ in the Mean column. Assuming slight rounding errors, the values for G^c under the individual column do equal the product of $Q^a * C^b$ under the individual columns. The calculations to obtain the Mean values appear correct.

   Response: The value for G^c under the Mean column does not equal the product of $Q^a * C^b$ in the Mean column because it is the mean of the G^c values in the individual "date" columns. A footnote explaining that the mean column was calculated differently than the other columns is included in the final report. *[Table 3 in the draft report is Table 4 in the final report.]*

Appendix D. Facilities with Coverage under the NPDES General Permit for Storm Water Discharges Associated with Construction Activities

Number	Name	Phone	Contact Name	County	Address	City	Zip	Latitude	Longitude	Section	Township	Quadname	Recwater	Muniswownr	Acreage	Startdate	Enddate
OHR100362	G Herchler Builders Inc		Gregory S. Herchler	Sassafras West Subdivision	Erie				412356	822220			Vermilion East	Lake Erie		15.49	01-Oct-92	31-Dec-95
OHR100842	ODOT - District 3		Stan Hunt	Mason Road Project	Erie											14	07-Aug-92	23-Nov-92
OHR101547	City of Vermillion	216-967-0123	Lynn S. Miggins	West Lake Watermain replacement	Erie	Vermillion Township			41-25-00	88-23-00				Lake Erie	ODOT	6	01-Sep-93	01-Mar-94
OHR105206	Park & Fun, Ltd.	216 835 1199	Zack Hoty	Fun Drive Phase 1	Erie			44870	41 24 15	82 39 30				Plum Brook		2	15-Jan-97	15-Jun-97
OHR105991	GLH, Inc. Resort Properties	419 433 2376	Tom Bleile	Turtle Bay Condominiums	Erie	Cleveland / Liberty / Brunswick	Huron	44839	41 24 00	82 33 45				Lake Erie		12.14	17-Sep-97	30-Sep-98
OHR108718	District Petroleum Products, Inc.	419 625 8373	Mike Stipp	Rye Beach and Cleveland Roads	Erie	Rye Beach and Cleveland Roads	Huron	44839			2			Rye Beach Ditch	City of Huron/ Erie County	13	30-Aug-99	30-Jun-00
OHR107377	East Ridge Development LTD	419 667 8661	Joe Bersche	Chappel Creek Village and Resort Phase I	Erie	East of Joppa Road	Vermilion Twp.	44089			3	6N		Chappel Creek		16	01-Nov-98	01-May-99
OHR107884	East Ridge Development Ltd.	419 667 8661	Joe Bersche	Chappel Creek Village and Resort Phase 2	Erie	Joppa Road	Vermilion Twp.	44089			3	6N		Chappel Creek		32	01-May-99	01-Sep-99
OHR110285	Tahoma & Co.	419 433 0217	Norman Hura	Huron Green Subdivision 3	Erie	Snowy Egret Dr.	Huron	44839				Huron		Lake Erie	Erie County	8	01-Jul-01	01-Oct-01
OHR105967	Westport Development, LTD	419 433 2630	David Dreffer	Eagle Crest Subdivision	Erie		Huron	44839	41 23 11	82 31 59		Huron		Winkler Ditch	Huron	13.8	01-Sep-97	01-Dec-97
OHR108027	Westport Developm	419 433 2630	David Dreffer	Eagle Crest Subdivision	Erie		Huron	44839	41 23 04	82 31 59		Huron		Winkler Ditch	Huron City	30	15-Jun-99	15-Oct-99

Number	Name	Phone	Contact	Name	County	Address	City	Zip	Latitude	Longitude	Section	Township	Quadname	Recwater	Muniswownr	Acreage	Startdate	Enddate
	ent, Ltd.			No. 2														
OHR109 463	Zimmerm an Remodeli ng & Constructi on, Inc.	419 483 7250	Greg Zimmerm an	Zimmerman Remodeling/ Construction Improvement Plan	Erie	E. of Huron on Cleveland Rd. E.			41 23 00	82 31 45		Huron		Old Woman's Creek		5.1	25-Sep-00	31-Oct-01
OHR111 191	Eagle Concern, Ltd.	419 433 2630	David Dreffer	Eagle Crest Subdivision # 3	Erie		Huron	44839	41 23 04	82 31 56		Huron		Hoffman	Erie County	14.4	15-Jun-02	15-Oct-02
OHR111 347	Prete Builders Inc.	419 636 8352	Todd Roth	Pine Lake Condominiu ms	Erie	Bogard Rd	Huron	44839	41 23 37	82 38 26	4	Huron		Boos Ditch		29	01-Jun-02	01-Oct-02
OHR104 956	Dennis Galloway	419 626 4193	Dennis Galloway	Riverwood Estates Subdivison No. 1	Erie				41 21 30	82 32 45	2	Milan		Huron River		5	01-Nov-96	30-Jun-97
OHR103 427	East Ridge Developm ent, LTD.	216 967 4352	Joseph E. Bershe	Chappel Creek Resort	Erie	S. of US6 - W. of Poorman Rd.	Vermili on	44089	41 23 25	82 25 20		Vermilion		Chappel Creek		11	01-Jun-95	01-Oct-95
OHR104 887	Elden Properties LTD Part. / Elden Motels LTD	216 967 0521	John A. Elden	Elden Prop. LTD -Elden Motels LTD	Erie						1	Vermilion		Unnamed Tributary	Erie County	8	15-Sep-96	30-Jun-97
OHR109 655	Western Reserve School District	440 839 2066	John Charville	Western Reserve Elementary School	Huron	3841 US Rte 20E	Collins	44826			1	Townsend		Chappel Creek		11	01-Nov-00	30-Aug-01

NPDES General Permit for Storm Water Discharges Associated with Construction Activities
Entities obtaining permit coverage via Individual Lot Notice Of Intent

Applicant Name	Site Name	County	Site Address	City	State	Zip	Lat.	Long.	Township	Lot No.	Start Date	End Date	Acres	OHR#	Original Owner
ANGELA KUHL	HURON GREEN SUBDIVISION	ERIE	1722 SHEARWATER CIRCLE EAST	HURON	OH	44839			HURON	8	01-Dec-98	01-May-99	0.33	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	38	26-Oct-00	01-Mar-00	0.42	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	24	03-Jan-00	10-Jun-00	0.33	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	25	03-Feb-00	15-Jun-00	0.29	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	7	28-Feb-00	21-Jun-00	0.34	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	19	08-Mar-00	25-Jun-00	0.31	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	26	15-Mar-00	01-Jul-00	0.27	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	23	21-Mar-00	05-Jul-00	0.33	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE	CLEVELAND SANDUSKY ROAD		OH	44839	41 23 00	82 31 26	HURON	16	28-Mar-00	10-Jul-00	0.25	105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION NO 1	ERIE			OH	44839	41 23 00	82 31 26	HURON	37	15-May-00	15-Sep-00	0.5	105975	TAHOMA & CO
PERIDIA INC	HURON	ERIE			OH	44839	41 23 00	82 31 26	HURON	2	08-May-00	09-Sep-00	0.41	105975	TAHOMA & CO

Applicant Name	Site Name	County	Site Address	City	State	Zip	Lat.	Long.	Township	Lot No.	Start Date	End Date	Acres	OHR#	Original Owner
	GREEN SUBDIVISION NO 1														
MAJOY BUILDERS	HURON GREEN SUBDIVISION NO 1 LLC	ERIE	CLEVELAND-SANDUSKY ROAD	HURON	OH				HURON	22				105975	TAHOMA & CO
MAJOY BUILDERS	HURON GREEN SUBDIVISION NO 1 LLC	ERIE	CLEVELAND-SANDUSKY ROAD	HURON	OH				HURON	21				105975	TAHOMA & CO
WILLIAM J THOMAS	HURON GREEN SUBDIVISION 1	ERIE	6 SHEARWATER CIRCLE	HURON	OH	44839	41 23 00	82 31 26	HURON	6				105975	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION #1	ERIE			OH	44839	41 23 00	82 31 26	HURON	15	25-May-00	25-Aug-00	0.48	105975	TAHOMA & CO
EDGE WATER CONSTRUCTION	SCOTT SACHS (HURON GREEN SUB)	ERIE	509 LIBERTY DR	HURON	OH	44839				20	01-Jun-01	01-Dec-01		105975	SHOW BUILDERS
PERIDIA INC	HURON GREEN SUBDIVISION II	ERIE	CLEVELAND RD		OH	44839	41 23 00	82 31 26	HURON	50	21-Aug-01			110285	TAHOMA & CO
MICHAEL E MOSER	HURON GREEN SUB 3	ERIE	502 MERGANZER DR		OH	44839	41 23 00	82 31 26	HURON	64	01-Nov-01	01-Apr-02		110285	TAHOMA & CO
MAJOY BUILDERS	HURON GREEN SUB # 1 LLC	ERIE	CLEVELAND-SANDUSKY RD	HURON	OH	44839	41 23 00	82 31 26	HURON	21	01-Sep-01	01-Apr-02	0.54	110285	TOHOMA & CO
MAJOY BUILDERS	HURON GREEN SUB # 2 LLC	ERIE	CLEVELAND-SANDUSKY RD	HURON	OH	44839	41 23 00	82 31 26	HURON	45	01-Sep-01	01-Apr-02	0.5	110285	TOHOMA & CO
MAJOY BUILDERS	HURON GREEN SUB # 2 LLC	ERIE	CLEVELAND-SANDUSKY RD	HURON	OH	44839	41 23 00	82 31 26	HURON	46			0.57	110285	TOHOMA & CO
PERIDIA INC	HURON GREEN PHASE 2	ERIE			OH	44839	412300	823126	HURON	49	25-Mar-02	31-Jul-02	0.36	109428	HURON GREEN LLC
PERIDIA INC	HURON GREEN	ERIE			OH	44839	412300	823126	HURON	54	10-Jun-02	30-Oct-02	0.36	109428	HURON GREEN LLC

Applicant Name	Site Name	County	Site Address	City	State	Zip	Lat.	Long.	Township	Lot No.	Start Date	End Date	Acres	OHR#	Original Owner
	PHASE 2														
PERIDIA INC	HURON GREEN PHASE 2	ERIE			OH	44839	412300	823126	HURON	65	17-Jun-02	31-Oct-02	0.36	109428	HURON GREEN LLC
PERIDIA INC	HURON GREEN PHASE 2	ERIE		HURON TWP	OH	44839	41 23 00	82 31 26	HURON	42	12-Aug-02	23-Dec-02	0.36	109428	TAHOMA & CO
PERIDIA INC	HURON GREEN PHASE 3	ERIE	521 SNOWY EGRET	HURON	OH	44839	41 22 51	82 31 23	HURON	86	08-Apr-04	31-Aug-04	0.26	110285	TAHOMA & CO
MICHAEL SAVULAK	HURON GREEN SUBDIVISION II	ERIE	1730 SHEARWATER CIR E	HURON	OH	44839	41 22 51	82 31 23	HURON	12	05-Apr-04	05-Jun-04	366	110285	TAHOMA & CO
PERIDIA INC	HURON GREEN PHASE 3	ERIE	536 SNOWY EGRET		OH	44839	412300	823126	HURON	75	06-Jun-04	31-Oct-04	0.31	110285	TAHOMA & CO
PERIDIA INC	HURON GREEN PHASE 3	ERIE	534 KELLEY LN		OH	44839	412300	823126	HURON	74	03-May-04	30-Sep-04	0.27	109428	TAHOMA & CO
PERIDIA INC	HURON GREEN SUBDIVISION PH 2	ERIE	505 SNOWY EGRET		OH	44839	41 23 00	82 31 26	HURON	62	01-Sep-04	31-Jan-04	0.31	110285	TAHOMA & CO

Appendix E. Example QHEI Score Sheet

The example QHEI sheet has been transposed (rows to columns, columns to rows) to faciliate publication. The original sheet contains 131 columns (rows, in this format).

HU11	04100012 040	04100012 040	04100012 040	04100012 040	04100012 040	04100012 040	04100012 040	04100012 040	04100012 040	04100012 040	04100012 040
BASIN	12	12	12	12	12	12	12	12	12	12	12
STREAM	005	005	005	005	005	005	005	005	015	015	015
RIVER	Old Woman Creek	Old Woman Creek	Old Woman Creek	Old Woman Creek	Old Woman Creek	Old Woman Creek	Old Woman Creek	Old Woman Creek	Trib. to Old Woman Creek (RM 3.70)	Trib. to Old Woman Creek (RM 3.70)	Trib. to Old Woman Creek (RM 3.70)
RM	3.50	5.40	5.40	8.40	8.40	9.40	9.40	11.40	0.70	3.10	3.10
YEAR	2000	2000	2002	2000	2002	2000	2002	2000	2000	2000	2002
QHEI	73.5	71.5	66.0	81.0	74.5	47.0	41.0	21.0	34.0	92.0	67.5
SUBSTRATE	9.0	16.0	17.0	20.0	17.5	16.0	11.5	1.0	5.0	16.0	17.0
BLDR_SLAB											
BOULDER				Y	X						
COBBLE			X			Y					X
HARDPAN	Y								Y		
SILT								X			
MUCK								X			
GRAVEL		Y	X		X		X			Y	X
SAND							X				
BEDROCK											
DETRITUS											
ARTIFICIAL											
NUM_TYPES	X	X	X	X	X					X	X
LIMESTONE					Y						
TILLS	X	Y	Y	Y		X	Y	X	X	Y	Y
WETLAND											
LACUSTRINE					Y		Y				
SANDSTONE											
SHALE		Y	Y	Y						Y	Y
RIPRAP											

HARDPAN_O											
COAL_FINES											
SILT_HEAVY								X	X		
SILT_MOD	X					X	X				
SILT_NORML		X	X	X	X					X	X
SILT_FREE											
MWH_H_ATTR	0	0	0	0	0	3	3	5	3	0	1
EMBED_XTEN								X	X		
EMBED_MOD	X				X		X				
EMBED_LOW		X	X	X		X				X	X
EMBED_NONE											
COVER	13.0	10.0	13.0	14.0	16.0	4.0	6.0	3.0	5.0	20.0	13.0
UNDERCUT	X			X	X					X	X
OVERHANG			X		X	X	X	X		X	X
SHALLOWS	X		X	X	X		X		X	X	X
DEEP_POOLS	X	X		X	X					X	
ROOTWADS				X	X					X	
ROOTMATS	X		X	X	X					X	X
BOULD_COV		X	X	X	X					X	X
OXBOW											
AQ_PLANTS			X				X				
LOGS	X		X		X				X	X	X
UNDERCUT2					1						1
OVERHANG2			2		1		2				2
SHALLOWS2			1		1		1				1
DEEP_POOL2					1						
ROOTWADS2					1						
ROOTMATS2			1		2						1
BOULD_COV2			2		2						1
OXBOW2											
AQ_PLANTS2			1				1				
LOGS2			1		1						1
EXT_COV										X	
MOD_COV	X	X	X	X	X						X
SPARSE_COV						X	X	Y	X		
NO_COV								Y			
CHANNEL	16.0	20.0	17.0	20.0	17.0	4.0	8.0	4.0	5.0	20.0	16.0

H_SINUOS		X		X						X	
M_SINUOS	X		X		X						X
L_SINUOS							X		X		
N_SINUOS						X		X			
E_DEVELOP		X		X						X	
G_DEVELOP	X		X		X						Y
F_DEVELOP							Y				Y
P_DEVELOP						X	Y	X	X		
CH_NONE	X	X	X	X	X					X	X
RECOVERED											
RECOVERING							Y				
RECENT						X	Y	X	X		
H_STABLE		X	X	X	X					X	X
M_STABLE	X						X				
L_STABLE						X		X	X		
RIPARIAN	9.5	6.5	5.0	5.0	5.0	2.0	2.5	1.0	9.0	10.0	6.5
RIP_WIDE	Y	X							Y	Y	
RIP_MOD		X									Y
RIP_NAR			X	X	X						
RIP_V_NAR			X	X	X						
RIP_NONE						Y	Y	Y			
FOREST	Y								Y	Y	
OP_PAST_RW		Y	X	X	X	Y	Y	Y			X
OLD_FLD_SH											
PARK			X	X	X						X
CONS_TILL											
FENCE_PAST											
URBAN_INDS											
MINING_CON											
EROSION_NL	X	Y	Y	Y	Y		X			Y	Y
EROSION_M	X					Y	X		Y		
EROSION_HS								Y			
POOL	12.0	9.0	7.0	9.0	8.0	10.0	5.0	5.0	6.0	11.0	4.0
CM_100	X					X				X	
CM_70_100		X		X	X						
CM_40_70			X				X		X		
CM_20_40								X			X

CM_20											
TORRENT											
FAST	X	X	X	X						X	
MODERATE	X	X	X	X	X	X	X	X	X	X	X
SLOW	X	X	X	X	X	X	X	X	X	X	X
EDDIES	X										
INTERSTIT											X
INTERMITT											
WIDER	X	X	X	X	X	X		X	X	X	X
NARROWER											
EQUAL							X				
RIFFLE	4.0	6.0	3.0	5.0	3.0	3.0	0.0	-1.0	0.0	7.0	3.0
RIF_Z_VLOW						X		X			Y
RIF_Z_LOW			X	X	X				X		Y
RIF_Z_MOD	X	X								X	
RIF_Z_HIGH											
RIF_STABLE			Y	X	Y	X				X	Y
RIF_MOD	X	X	Y		Y						Y
RIF_UNSTBL								X	X		
RIFEMBED_E								X	X		
RIFEMBED_M	X		Y		Y						
RIFEMBED_L			Y		Y	X					X
RIFEMBED_N		X		X						X	
GRADIENT_S	10	4	4	8	8	8	8	8	4	8	8
GRADIENT_V	8.70	43.48	43.48	31.25	31.25	14.71	14.71	12.35	4.59	12.50	12.50
MWH_ATTRIB	3	1	1	0	3	4	6	6	7	0	2
INITIALS	XRFT	XRFT	XBM	XRFT	XBM	XRFT	XBM	XRFT	XRFT	XRFT	XBM
COV_TYPES	5	2	6	6	8	1	3	1	2	8	6
DRNAREA	21.1	11.8	11.8	7.8	7.8	3.4	3.4	2.4	7.9	4.5	4.5
WWH_ATTRIB	6	9	9	9	7	4	2	0	1	9	7