

**Operation of the Tributary Loading Program
in Major Lake Erie Tributaries**

OLEC Project No. 1-11

Final Report
To

Gail Hesse
Executive Director

Ohio Lake Erie Commission
111 E. Shoreline Drive
Sandusky, Ohio 44870

Submitted by
Kenneth A. Krieger and David B. Baker
Project Co-directors

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For more information about the Lake Erie Protection Fund, visit www.lakeerie.ohio.gov

Executive Summary

This project provided for the continued operation of the Lake Erie tributary monitoring stations on the Maumee, Sandusky, Cuyahoga and Tiffin rivers in Ohio during Calendar Year 2011. Those stations are part of the long-term Heidelberg Tributary Loading Program (HTLP) operated by the National Center for Water Quality Research at Heidelberg University. The periods of record for the four tributaries date back to 1975 for the Sandusky River, 1976 for the Maumee River, 1983 for the Cuyahoga River, and to 2007 for the Tiffin River, and as such the data sets that have been generated through the HTLP are unique in the U.S. in terms of their duration and sampling intensity.

We analyzed 542 samples on average from the Maumee, Sandusky and Cuyahoga rivers and 264 samples from the Tiffin River in Calendar Year 2011 (the grant period). Sampling of these rivers in 2011 was especially valuable in that, because of record amounts of precipitation during the year, record loads of dissolved phosphorus and total phosphorus from the Maumee and Sandusky rivers were recorded and those loads appeared to be responsible for the most severe harmful algal bloom in Lake Erie in recent years. Dissolved phosphorus is readily taken up by algae and is usually the algal nutrient in shortest supply; therefore, an increased supply of dissolved phosphorus yields an increased production of algae and often results in harmful algal blooms.

Introduction

This project, which was supported through the targeted funding program of the Lake Erie Protection Fund, made possible the continuation of part of the multi-decade Heidelberg Tributary Loading Program operated by the National Center for Water Quality Research. The specific purpose of the project was to ensure an uninterrupted record of nutrient and sediment loadings in four tributaries in the Lake Erie Basin by providing operating funds for those sites during the period 1 January 2011 through 31 December 2011, after which funds from other sources would be applied. This grant completely funded the operation of the long-term stations on the Sandusky River above Fremont and the Cuyahoga River at Independence. It provided partial funding for the stations on the Maumee River at Waterville and the Tiffin River (a Maumee tributary) at Stryker.

The grant activities included (1) operation and maintenance of pumping systems and automatic samplers, (2) weekly servicing of the automatic samplers at each station or payment to a local observer to ship samples (Cuyahoga only), (3) analysis of up to 3 samples per day during storm runoff periods and otherwise 1 sample per day for a suite of analytes, (4) transfer of data to the NCWQR tributary data download web site, and (5) calculation of annual loading data, and dissemination of the concentration and loading data through public presentations, written reports, and summary fact sheets.

Description of the Heidelberg Tributary Loading Program (HTLP)

This description is adapted from our fact sheet for the HTLP, which is attached as **Appendix A**. The HTLP is a specialized water quality monitoring program designed to accurately measure the total amounts (loads) of pollutants exported from watersheds by rivers and creeks. Such studies require both stream flow and pollutant concentration data during storm runoff events. The sampling program utilizes automatic sampling equipment located at selected U.S. Geological Survey stream gaging stations across

Ohio and in southeastern Michigan. More than 50% of Ohio's land area is upstream from HTLP stations (**Figure 1**).

The HTLP traces its origin to 1969, when Heidelberg researchers recognized that accurate measurements of nutrient transport by rivers required detailed studies during storm runoff events. Our tributary loading studies began in the Sandusky River Watershed. In 1974, as part of the U.S. Army Corps of Engineers' Lake Erie Wastewater Management Study, we received contracts to expand our studies from the Sandusky Watershed to other major Ohio tributaries to Lake Erie. At the urging of the Ohio Farm Bureau Federation, the HTLP was extended to include the Ohio River Basin in 1996. The data set for the current network of 14 stations is unique within the United States in terms of its detail and duration.

The HTLP provides information to support the development of effective and efficient nonpoint source management programs. It also supports the application of adaptive management to water resource protection programs by assessing program effectiveness and identifying emerging problems. Over the years, funding has come from a combination of federal and state agencies, industries and foundations. Most State of Ohio support has been passed to the HTLP through the Division of Soil and Water Resources of the Ohio Department of Natural Resources. State funding was terminated in 2009. Subsequently, in fiscal years 2010 and 2011 we maintained the HTLP with grants and cooperative agreements from the Ohio Lake Erie Protection Fund (this grant), USDA's Natural Resources Conservation Service, the Ohio Water Development Authority, the Great Lakes Protection Fund, the Environmental Defense Fund, and the Michigan Department of Natural Resources. State of Ohio funding was restored as of July 2011 and presently accounts for almost one-half of the annual costs of the HTLP.

The data generated by the HTLP are used by many agencies, industries and universities. For example, the data are used to

- Provide a basis for calculations of annual phosphorus loading to Lake Erie since 1975.
- Help develop management plans for the restoration of Lake Erie.
- Quantify the magnitude of agricultural nonpoint pollution (more reliably than models).
- Help develop TMDL (Total Maximum Daily Load) plans.
- Develop agricultural pollution abatement plans for nutrient and sediment load reduction.
- Assess the effectiveness of agricultural pollution abatement programs.
- Identify trade-offs associated with nonpoint control measures. (Example: initiation of the Ohio Lake Erie Phosphorus Task Force to address the problem of increasing dissolved phosphorus loads.)
- Aid research through design of sampling programs, pesticide exposure assessment, water quality model calibration, climate change impact prediction, scale-effect studies, and nutrient trading.
- Assist education in uses ranging from classroom illustrations to master's and Ph.D. research throughout the U.S.

The "information infrastructure" provided by the HTLP gives Ohio agencies and institutions a competitive edge in gaining federal and foundation support for both Best Management Practice (BMP) implementation projects and related environmental research programs. Federal and state investments in this information have helped leverage millions of additional dollars that support farmers, soil and water

districts, agribusinesses and university researchers. Both agriculture and water resources are extremely important to our nation's economic vitality, both now and into the future. The HTLP serves both sectors.

The Present HTLP Station Network

A total of fourteen tributary stations in the Lake Erie and Ohio River basins were operated during all or part of Calendar Year 2011. Their geographic distribution and basins are shown in **Figure 1**. **Table 1** lists each station and the sources of funding for each station in Calendar Year 2011.

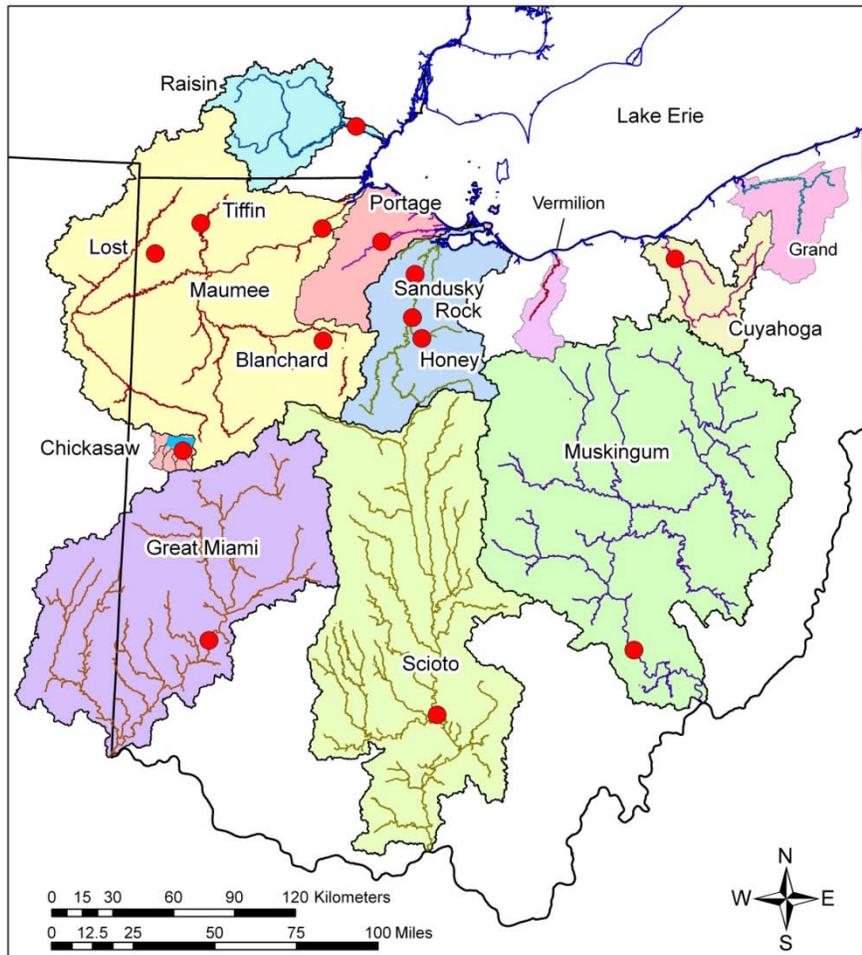


Figure 1. The fourteen stations (red dots) comprising the Heidelberg Tributary Loading Program in Calendar Year 2011.

Methods

We typically collect approximately 1,050 samples per year at each station and analyze approximately 500 to 550 of those samples. The exact number analyzed is dependent on weather conditions and the number of rainfall-runoff events. Sample collections and analyses for the four stations funded by the LEPF were performed according to our standard protocol for all of our stations. The Tiffin

River is an exception to the above pattern because the pumping system for that stream only collects storm runoff samples and low flow samples are collected once per week when the sampler bases are changed. Consequently we only have weekly rather than daily low flow samples at that station.

Table 1. Sources of funding for operating the 14 stations included in the HTLP in Calendar Year 2011. Stations in bold type were supported entirely or in part by the LEPF. Abbreviations: LEPF: Ohio Lake Erie Protection Fund; OWDA: Ohio Water Development Authority; EDF: Environmental Defense Fund; NRCS: U.S. Department of Agriculture Natural Resources Conservation Service.

Station	Funding Sources in CY 2011
Maumee River at Waterville	LEPF (5.7 months) , National Science Foundation (6.3 months)
Sandusky River at Fremont	LEPF
Cuyahoga River at Independence	LEPF
Tiffin River (Maumee Basin) at Stryker	LEPF (6.5 months), OWDA (1.5 months), State of Ohio (4 months)
Unnamed tributary to Lost Creek (Maumee Basin) near Hicksville	EDF, State of Ohio
Blanchard River (Maumee Basin) at Findlay	EDF, State of Ohio
Portage River at Woodville	NRCS, State of Ohio
Honey Creek (Sandusky Basin) at Melmore	Great Lakes Protection Fund, State of Ohio
Rock Creek (Sandusky Basin) at Tiffin	Great Lakes Protection Fund, State of Ohio
Muskingum River at McConnelsville	OWDA
Scioto River at Chillicothe	OWDA
Great Miami River at Miamisburg	OWDA
Chickasaw Creek near Marysville (Grand Lake Saint Marys Basin)	NRCS, State of Ohio
River Raisin near Monroe, Michigan	Michigan Department of Natural Resources

Monitoring activities at each tributary station include the following:

1. Operation and maintenance of pumping system and refrigerated automatic sampler (3 samples/day) at each station, including payment of electric service charges for each station. Our sampling methodology is described in detail at <http://www.heidelberg.edu/sites/default/files/jfuller/images/1.b.%20Sampling%20Stations%20and%20Methods.pdf>.

2. Weekly servicing of automatic samplers at each station by NCWQR staff or payment to a local observer to ship samples to the NCWQR laboratory at weekly intervals and related shipping costs.
3. Analysis of all storm samples (up to 3/day) plus daily low flow samples for total phosphorus, dissolved reactive phosphorus (dissolved phosphorus), nitrate, nitrite, total Kjeldahl nitrogen, ammonia, dissolved silica, chloride, sulfate, fluoride, total suspended solids, and specific conductance. All analyses are completed within Ohio Environmental Protection Agency Level 3 (highest level) quality control operations and/or approved US EPA QAPP (quality assurance project plan) operations. The standard analytical method employed for each analysis can be found at our data download web site at <http://www.heidelberg.edu/sites/default/files/jfuller/images/1.c.%20Analytical%20Methods.pdf>
4. Calculation of annual loading data and transfer of final data to the NCWQR tributary loading website.

Results and Discussion

Tributary Loading Data

All of the river data resulting from this project can be downloaded at our Data Download web site: <http://www.heidelberg.edu/academiclife/distinctive/ncwqr/data/data>. The data have been applied to produce numerous graphs and summary tables that have been presented in many presentations during and following the project period. Examples of those graphs are included in **Appendix B**.

In Calendar Year 2011 (the grant period) we analyzed a total of 518 samples for the Maumee River, 610 for the Sandusky River, 497 for the Cuyahoga River, and 264 for the Tiffin River. Thus, for the Maumee, Sandusky and Cuyahoga rivers combined in Calendar Year 2011, we analyzed 542 samples on average, which is near the high end of the range of 500 to 550 samples per stations we had anticipated. The lower number of Tiffin River samples corresponds to the different sampling protocol at that station. In association with the samples collected from the four rivers, in keeping with our quality control (QC) protocol, we analyzed 972 QC samples and 180 blank samples. The high number of samples analyzed from the Maumee, Sandusky and Cuyahoga rivers in part reflects the wetter-than-average year experienced in those watersheds in 2011. As part of **Appendix B**, we have attached a summary of the unusually high amount of surface runoff and accompanying loadings of phosphorus, nitrogen and suspended solids at the Maumee and Sandusky monitoring stations during comparable periods in 2010 and 2011. The summary shows record dissolved phosphorus delivery from the Maumee to Lake Erie in the April through June period, which exceeded the record for that period established in 2010. The delivery of both total phosphorus and dissolved phosphorus in the 2011 Water Year (October 2010 through September 2011) in both the Maumee and Sandusky rivers by mid-June 2011 already far exceeded deliveries in the entire 2010 Water Year.

The 2011 Water Year was an excellent example of how every year is an "experiment." The Maumee and Sandusky rivers showed the effects of a dry fall, some large winter storms, a very wet spring and late planting, followed by a wet late summer-fall. Both rivers had the highest spring loads of dissolved phosphorus and total phosphorus for their entire periods of record (back to 1975). Several studies have now linked spring runoff and total phosphorus loads with algal bloom biomass in late summer and, this year, fall. For the Sandusky River, record discharge and loads occurred in the 2011 Water Year for total phosphorus, dissolved phosphorus and possibly nitrate (see the bar graphs of annual

loads through the 2011 Water Year). The rains then continued from October through January, already showing that the 2012 Water Year will have high dissolved phosphorus loads. The wet fall in 2011 provided a good opportunity to observe direct runoff of fall-broadcast phosphorus fertilizers. The above patterns were present at all of our northwest Ohio tributary sites.

Dissemination of Results

We have already disseminated the information resulting from our 2011 data in several ways and will continue to incorporate the data in future presentations, reports and peer-reviewed papers as the HTLP continues. Examples of our project dissemination efforts include:

- Presentations at conferences, symposia and meetings to a wide variety of audiences. The 43 presentations that made use of the results of this project in 2011 and early 2012 are presented in **Appendix C**.
- Manuscripts, reports and other written materials. Those produced thus far are listed below.
 - Baker, D. B. 2011. *Focus on Dissolved Phosphorus*. Web site devoted to presentation and interpretation of data preceding and included in this LEPF grant. <http://www.heidelberg.edu/academiclife/distinctive/nwqr/p>
 - Baker, D. B. 2011. *Dissolved Phosphorus from Cropland Runoff: Why is it a Big Problem?* NCWQR News & Notes Issue #6. (See **Appendix B**.)
 - Richards, R.P., I. Alameddine, J.D. Allan, D.B. Baker, N.S. Bosch, R. Confesor, J.V. DePinto, D.M. Dolan, J.M. Reutter, and D. Scavia. Submitted. The SPARROW Model and Lake Erie: A Commentary on the Great Lakes SPARROW Model. Submitted to *Journal of the American Water Resources Association*.
- All of the data from the Maumee, Sandusky and Cuyahoga rivers are loaded on our tributary data download site: <http://www.heidelberg.edu/academiclife/distinctive/nwqr/data/data>
- The data for the Tiffin River are available on request and we plan to add that site to the data download site in the future.

Conclusions

Lake Erie Protection Fund Project TG 1-11 made it possible to avoid interruption of the long-term Lake Erie tributary loading stations on the Maumee, Sandusky, Tiffin and Cuyahoga rivers in Ohio during Calendar Year 2011. Had these rivers not been sampled during that time period, there would be no knowledge of the record loads of dissolved phosphorus and total phosphorus from the Maumee and Sandusky rivers that appear to be related to the most severe harmful algal bloom in Lake Erie in recent years.

APPENDICES

Appendix A – Fact Sheet about the Heidelberg Tributary Loading Program

Appendix B – Examples of Informational Materials Disseminated through this Grant

Appendix C – Presentations That Disseminated the Results of this Project

Appendix A – Fact Sheet: The Heidelberg Tributary Loading Program



HEIDELBERG UNIVERSITY
www.ncwqr.heidelberg.edu
310 East Market Street
Tiffin, Ohio 44883-2462
Phone: 419.448.2198
Fax: 419.448.2345

The Heidelberg Tributary Loading Program

Information Infrastructure for Managing Agricultural Nonpoint Pollution

What is the Heidelberg Tributary Loading Program (HTLP)?

The HTLP is a specialized water quality monitoring program designed to accurately measure the total amounts (loads) of pollutants exported from watersheds. Such studies require both stream flow and pollutant concentration data during storm runoff events. The sampling program utilizes automatic sampling equipment located at selected U.S. Geological Survey stream gaging stations across Ohio and into Michigan. More than 50% of Ohio's land area is upstream from HTLP stations (see map).

How and when did the HTLP get started?

In 1969, Heidelberg researchers recognized that accurate measurements of nutrient transport by rivers required detailed studies during storm runoff events. In 1974, as part of the U.S. Army Corps of Engineers' Lake Erie Wastewater Management Study (LEWMS), we received contracts to expand our studies from the Sandusky Watershed to Ohio's major tributaries to Lake Erie. At the urging of the Ohio Farm Bureau Federation, the HTLP was extended to include the Ohio River Basin in 1996. The current network of 14 stations is unique within the United States in terms of its detail and duration.

Who funds the HTLP?

Over the years, funding has come from a combination of federal and state agencies, industries and foundations. Most State of Ohio support has been passed to the HTLP through ODNR's Division of Soil and Water Resources.

How are data from the HTLP used? (Some examples)

- Provide a basis for calculations of annual phosphorus loading to Lake Erie since 1975.
- Help develop management plans for the restoration of Lake Erie.
- Quantify the magnitude of agricultural nonpoint pollution (more reliably than models).
- Help develop TMDL (Total Maximum Daily Load) plans.
- Develop agricultural pollution abatement plans for nutrient and sediment load reduction.
- Assess the effectiveness of agricultural pollution abatement programs.
- Identify trade-offs associated with nonpoint control measures. (Example: initiation of the Ohio Lake Erie Phosphorus Task Force to address the problem of increasing dissolved phosphorus loads.)
- Aid research through design of sampling programs, pesticide exposure assessment, water quality model calibration, climate change impact prediction, scale-effect studies, and nutrient trading.
- Assist education in uses ranging from classroom illustrations to master's and Ph.D. research throughout the U.S.

What are the economic benefits of the HTLP to Ohio?

The "information infrastructure" provided by the HTLP gives Ohio agencies and institutions a competitive edge in gaining federal and foundation support for both Best Management Practice (BMP) implementation projects and related environmental research programs. Federal and state investments in this information have helped leverage millions of additional dollars that support farmers, soil and water districts, agribusinesses and university researchers. Both agriculture and water resources are extremely important to our nation's economic vitality, both now and into the future. The HTLP serves both sectors.

What are the environmental benefits of the HTLP to Ohio?

The HTLP provides information to support the development of effective and efficient nonpoint source management programs. It also supports the application of adaptive management to water resource protection programs by assessing program effectiveness and identifying emerging problems.

Appendix B

Examples of Informational Materials Disseminated through this Grant

Provisional Nutrient Loading Data
Heidelberg University, National Center for Water Quality Research
 Limited distribution for discussion purposes. Contact dbaker@heidelberg.edu

Note: Both 2010 and 2011 have had very large amounts of spring runoff that greatly affects nutrient losses. The runoff in 2011 has actually been considerably higher than for 2010.

Table 1. A comparison of spring (April-June) loading of sediments and nutrients for the Sandusky and Maumee rivers in 2010 and 2011. Note that for 2011, data are available only through June 12.

River	Period	Discharge Volume	Suspended Solids	Total Phosphorus	Dissolved Reactive Phosphorus	Nitrate-N
Sandusky		CFS-Days	Short Tons (2000 lbs)			
2010	04/01-06/30	199,758	127,757	257	53	3,823
2011	04/01-06/12	278,621	208,836	420	65	2,905
Sandusky			Flow Weighted Mean Concentration, mg/L			
2010	04/01-06/30		237	0.477	0.099	7.10
2011	04/01-06/12		278	0.559	0.087	3.87
Maumee		CFS-Days	Short Tons (2000 lbs)			
2010	04/01-06/30	985,027	414,311	1,008	260	15,845
2011	04/01-06/12	1,292,725	716,653	1,614	290	16,436
Maumee			Flow Weighted Mean Concentration, mg/L			
2010	04/01-06/30		156	0.380	0.098	5.97
2011	04/01-06/12		206	0.456	0.080	4.54

Table 2. A comparison of 2010 and partial 2011 Water Year loading of sediments and nutrients for the Sandusky and Maumee rivers. Note that Water Years begin October 1 of the preceding year and extend through September 30 of that year. Thus the 2011 water year will include loads delivered through September 30, 2011.

River	Period	Discharge Volume	Suspended Solids	Total Phosphorus	Dissolved Reactive Phosphorus	Nitrate-N
Sandusky		CFS-Days	Short Tons (2000 lbs)			
2010	10/1/09-09/30/10	396,334	168,926	391	88	6,839
2011	10/1/10-06/12/11	735,659	407,009	910	182	8,512
Sandusky			Flow Weighted Mean Concentration, mg/L			
2010	10/1/09-09/30/10		158	0.366	0.083	6.40
2011	10/1/10-06/12/11		205	0.456	0.091	4.26
Maumee		CFS-Days	Short Tons (2000 lbs)			
2010	10/1/09-09/30/10	1,919,402	627,132	1,683	445	27,689
2011	10/1/10-06/12/11	2,283,181	1,190,462	2,900	572	32,884
Maumee			Flow Weighted Mean Concentration, mg/L			
2010	10/1/09-09/30/10		121	0.325	0.086	5.35
2011	10/1/10-06/12/11		193	0.463	0.090	5.18

Special thanks to Ms. Barbara Merryfield for data handling and Dr. Aaron Roerdink for quality assurance review, allowing this early assessment of spring 2011 loading (June 17, 2011). Also thanks to the Ohio Division of the USGS for providing current provisional discharge data for these stations. June 17, 2011.

Dissolved Phosphorus From Cropland Runoff: Why is it a big problem?

What is dissolved phosphorus? Dissolved phosphorus is the phosphorus that remains in water after that water has been filtered to remove particulate matter (Figure 1). Phosphorus that remains on the filter with the particulate matter is called particulate phosphorus. Together these two forms of phosphorus make up the total phosphorus concentration in a water sample. In laboratories, water samples are typically analyzed for total phosphorus and dissolved phosphorus. Particulate phosphorus is calculated by subtracting dissolved phosphorus from total phosphorus, using the relationship shown in Figure 1.

Why is dissolved phosphorus a problem? Phosphorus is a common pollutant in surface waters because, when its concentrations are too high, it causes excessive growth of algae. Dissolved phosphorus is a special problem because (1) it is highly bioavailable to algae, (2) its loads to Lake Erie have been increasing dramatically in recent years, and (3) it does not settle out of the water column the way particulate phosphorus does.

Dissolved phosphorus is about 95% bioavailable to algae while only about 30% of the phosphorus attached to eroded sediments is bioavailable. Even though particulate phosphorus dominates total phosphorus loading to Lake Erie from the Maumee and other NW Ohio rivers, dissolved phosphorus contributes more bioavailable phosphorus (See Table 1). Over the past 5 years, dissolved phosphorus represented 26% of the total phosphorus and 52% of the bioavailable phosphorus entering Lake Erie from the Maumee.

Trends in dissolved phosphorus loads from the Maumee River are shown in Figure 2. Annual loads are highly variable from year to year, due to annual variability in weather conditions and river discharge. Figure 2 also shows 5-year running average annual loads of dissolved phosphorus. The increasing dissolved phosphorus loads are very evident from the 5-year running averages. Low points in 5-year averages occurred in 1987 (192 mtons) and 1994 (263 mtons), while the high 5-year average was in 2006 (726 mtons). Over this same time interval, the overall trend in particulate phosphorus and suspended solids loading has been downward. These downward trends reflect farmer adoption of BMPs. However, the upward trends in dissolved phosphorus have been linked to the return of serious algal bloom problems in Lake Erie.

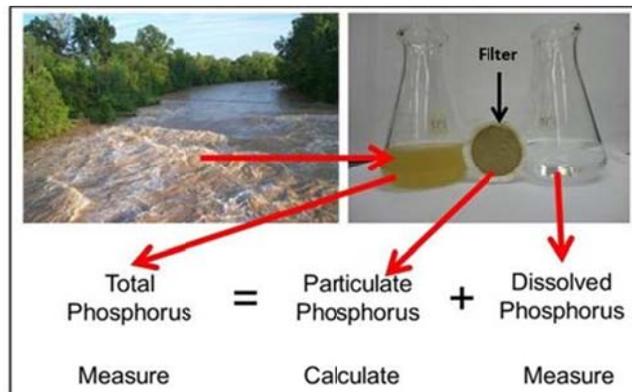


Figure 1. Illustration of the splitting of river samples into total, particulate and dissolved phosphorus.

Table 1. Annual average total and bioavailable phosphorus loads exported from the Maumee River at Waterville, 2006-2010.

Phosphorus Form	Total Phosphorus	Particulate Phosphorus	Dissolved Phosphorus
Total, metric tons	2,508	1,864	644
		74%	26%
Bioavailable, metric tons	1171	559	612
		48%	52%

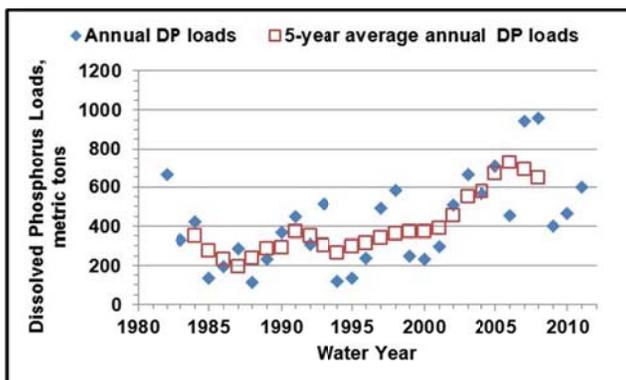


Figure 2. Annual and 5-year running average dissolved phosphorus (DP) export from the Maumee River at Waterville.

Dissolved Phosphorus From Cropland Runoff: Why is it a big problem?

National Center of Water Quality Research, Heidelberg University, News and Notes, Issue #6, 07/28/2011, page 2

During storm runoff events from the Maumee River, large volumes of river water move into the western basin of Lake Erie in a short amount of time. The sediment and particulate phosphorus settle out of the water column rather quickly as runoff waters enter the lower river and Maumee Bay. The dissolved phosphorus remains in the water column and supports the development of algal blooms such as that shown in Figure 3. Particulate phosphorus attached to eroded sediments not only has lower bioavailability to algae than dissolved phosphorus, but since it settles out of the water column so quickly, it also becomes “positionally” unavailable.



Figure 3. This satellite image of the western basin shows algal blooms forming in storm water runoff from the Maumee River. (August 19, 2003)

What has caused the increasing dissolved phosphorus export from northwestern Ohio rivers? Only about 7% of the total phosphorus exported from the Maumee River can be accounted for by municipal and industrial point sources entering the river upstream from the sampling station. Thus the increases in dissolved phosphorus loading have to be coming from nonpoint sources. Since cropland is the dominant source of nonpoint pollution in the watershed, cropland is now recognized as the source of the increases. The following changes in agriculture (and weather) have been identified as contributing to the upward trends in dissolved phosphorus export shown in Figure 2:

- Increased broadcasting of fertilizer especially in the fall and winter, without incorporation into the soil;
- Build-up of phosphorus concentrations at the soil surface due to broadcast fertilizer applications, crop residue breakdown on the soil surface, and the absence of inversion tillage (mold board plowing) associated with erosion control measures;
- Applications of maintenance level fertilizer rates when drawdown rates would be more appropriate;
- Soil compaction that increases surface runoff from fields;
- Excessive phosphorus concentrations and soil test levels on fields receiving animal manures;
- Increased tile drainage intensity coupled with preferential flow through macro-pores carrying water and sediments from the soil surface to tile lines and bypassing filter strips;
- Increased rainfall intensities giving rise to more surface runoff.

What can farmers do to reduce dissolved phosphorus loss from cropland? This question is currently at the forefront of many discussions involving groups such as: farmers; extension agents; fertilizer dealers and producers; local, state and federal agricultural and environmental agencies; implement manufacturers; nonprofit organizations; and university researchers. A partial list of the categories of BMPs under discussion is shown below:

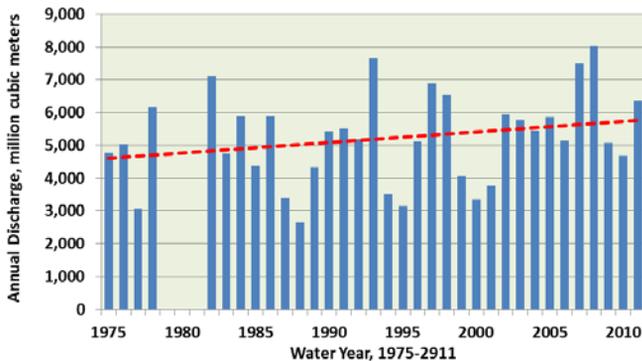
- Nutrient management (right amounts, timing, application methods, and forms);
- Tillage management aimed at reducing erosion and increasing water infiltration;
- Water management to allow timely field operations while maintaining appropriate soil moisture and minimizing nutrient loss;
- Conservation crop rotations and winter cover;
- Edge-of-field and/or end-of-tile treatment systems to remove nutrients.

As part of a grant from the Great Lakes Protection Fund, our laboratory has assembled a “Toolbox” of BMPs for reducing dissolved phosphorus export from cropland. The toolbox is now available for use by the various groups who are addressing the dissolved phosphorus problem. Copies of the “Toolbox,” which was compiled by Mr. John Crumrine, a retired NRCS District Conservationist, are available from David Baker (dbaker@heidelberg.edu).

This issue of NCWQR News and Notes was produced using support from Grant #833 from the Great Lakes Protection Fund and Grant # WS 00E39901-0 from the U.S Environmental Protection Agency.

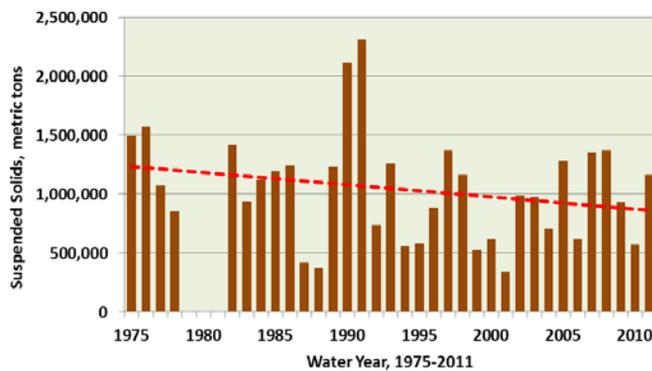
The Heidelberg Tributary Loading Program - Period of Record Summaries Maumee River at Waterville

Maumee at Waterville, Annual Discharge, 1975-2011

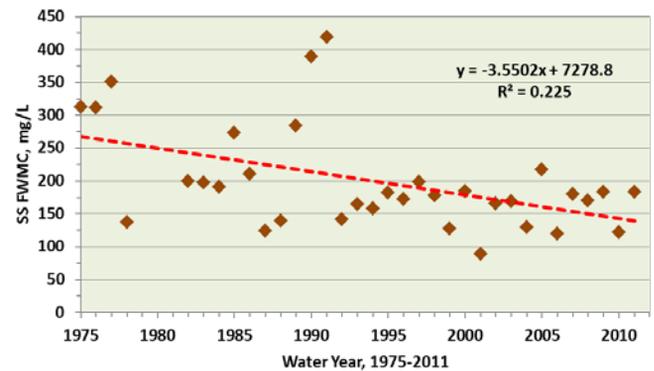


These bar graphs show the annual discharge of the Maumee River at Waterville, along with the annual loads of suspended solids (SS), total phosphorus (TP), and particulate phosphorus (PP). To the right of each bar graph is a graph showing the flow weighted-average concentration of each substance. Beginning in about 1990 efforts were launched to reduce particulate phosphorus loading to Lake Erie by programs to aid farmers adopt reduced till and no-till crop production efforts. The success of these efforts is indicated by the decreasing flow weighted concentrations of SS, TP and PP. Even though stream flow has increased, the loading of SS and PP has decreased. TP loads have changed little, due to increasing loads of DRP, as shown on the next page.

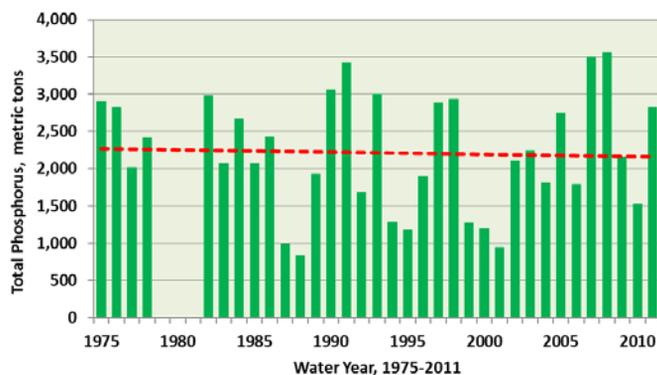
Maumee at Waterville, Annual Suspended Solids Loads



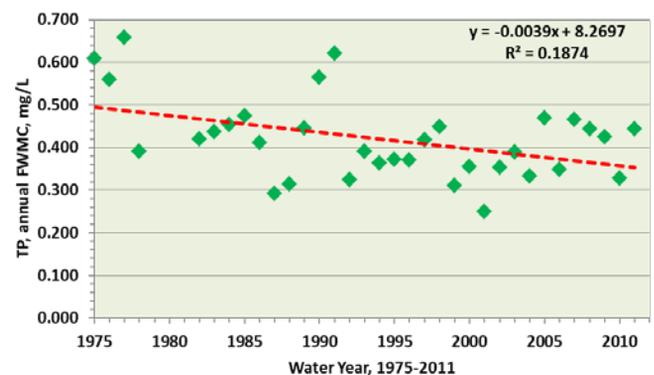
Maumee, Annual flow weighted mean conc., Suspended Solids



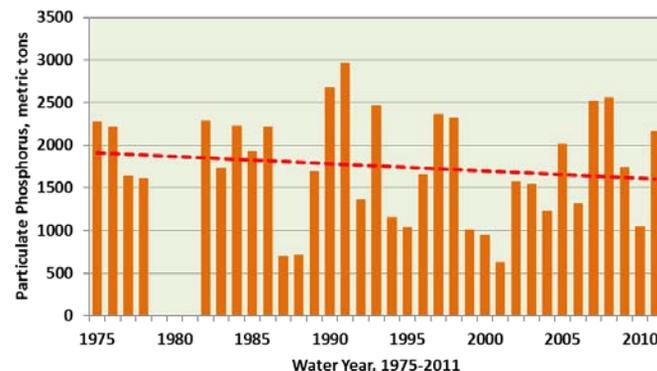
Maumee River at Waterville, Annual Total Phosphorus loads



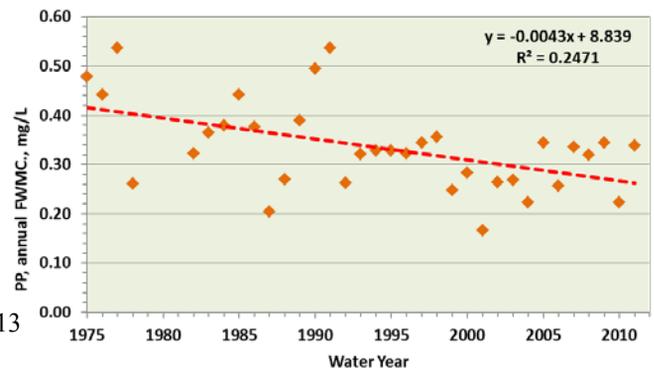
Maumee, Annual flow weighted mean conc, Total Phosphorus



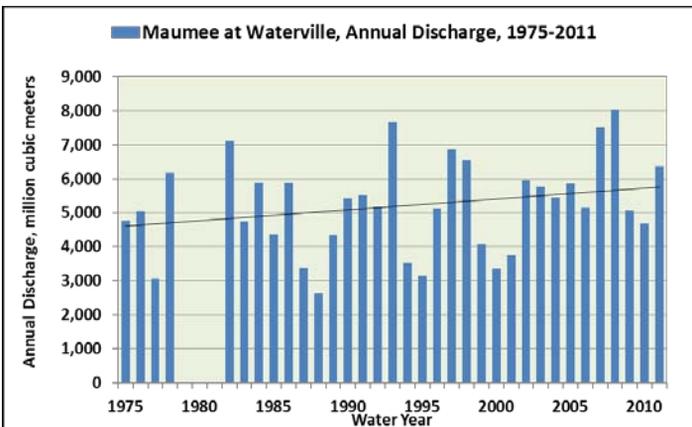
Maumee River at Waterville, Particulate Phosphorus loads



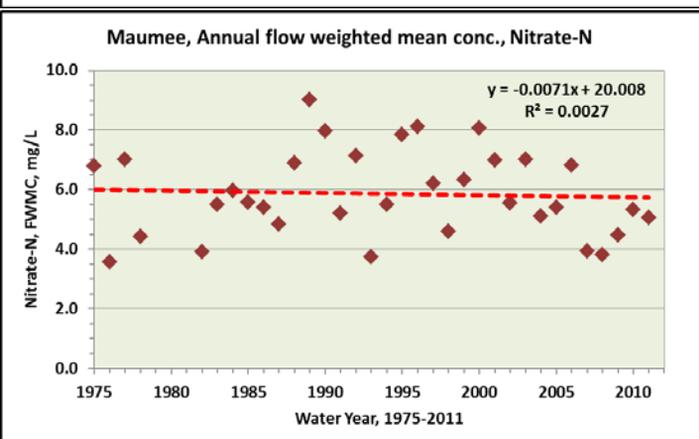
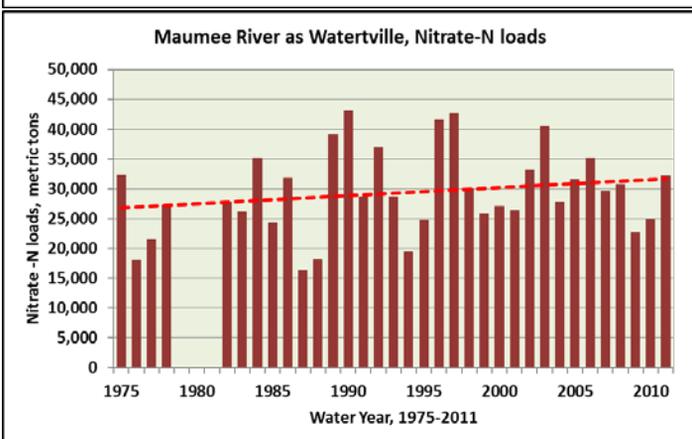
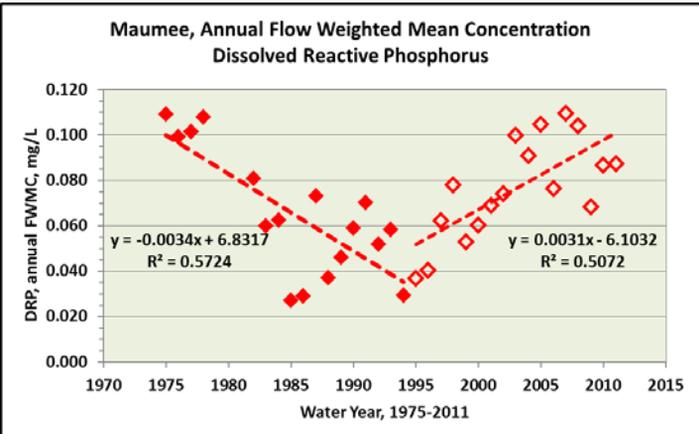
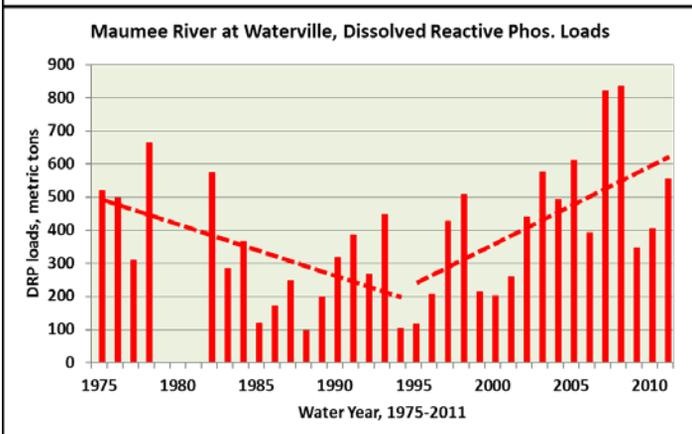
Maumee, Annual flow weighted mean conc., Particulate Phos.



Maumee River at Waterville (USGS Station # 04193500), continued.



Since annual stream discharge has a major impact on annual loading of sediments and nutrients, the annual discharge graph is repeated here. The trends in dissolved reactive phosphorus (DRP) is particularly important. DRP loads and concentrations dropped from 1975 to the mid-1990s but both have increased rapidly since that time. Because DRP is more available to support algal growth than PP, the increased loading of DRP in recent years has been linked to increasing problems of algal blooms in Lake Erie. Nitrate loads have increased slightly during the monitoring period in associated with the increased discharge. Nitrate concentrations have decreased slightly.



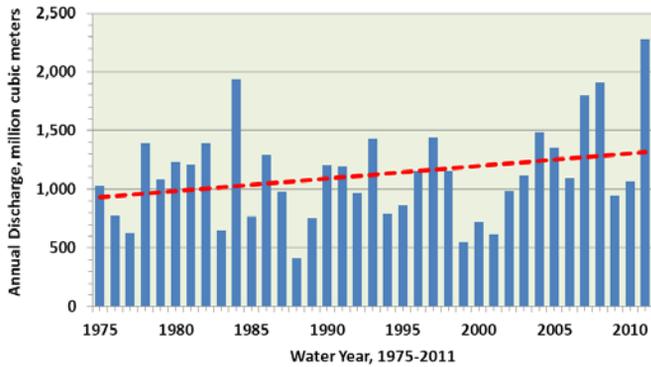
The nutrient and sediment loading data presented above are based on analyses of 16,043 samples collected from the Maumee River at the Bowling Green water treatment plant just upstream from the stream gage at Waterville. These data are available at the web site of Heidelberg University's National Center for Water Quality

Research: www.heidelberg.edu/NCWQR. Recent funding for the operation of this station has come from the USDA's Natural Resource Conservation Service, the Lake Erie Protection Fund, The Andersons, The Fertilizer Institute, and the U. of Michigan through a grant from the National Science Foundation.

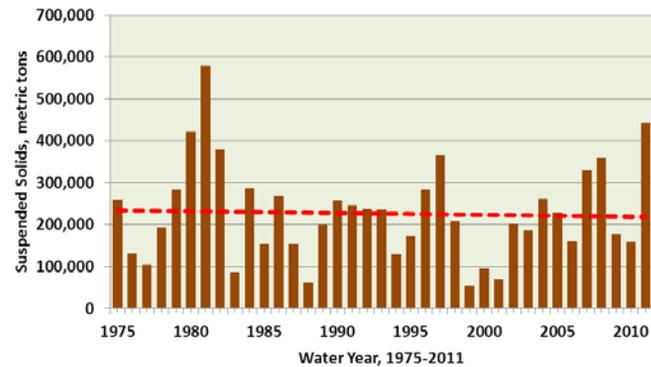
The Heidelberg Tributary Loading Program - Period of Record Summaries Sandusky River at Fremont

These bar graphs show the annual discharge of the Sandusky River at Fremont, along with the annual loads of suspended solids (SS), total phosphorus (TP), and particulate phosphorus (PP). To the right of each bar graph is a graph showing the flow weighted-average concentration of each substance. Beginning in about 1990 efforts were launched to reduce particulate phosphorus loading to Lake Erie through programs to aid farmers adopt reduced till and no-till crop production methods. The success of these efforts is indicated by the decreasing flow weighted concentrations of SS, TP and PP. Even though stream flow has increased, the loading of SS has decreased. However, loads of TP and PP have increased due to increased discharge and, for TP, increased DRP export.

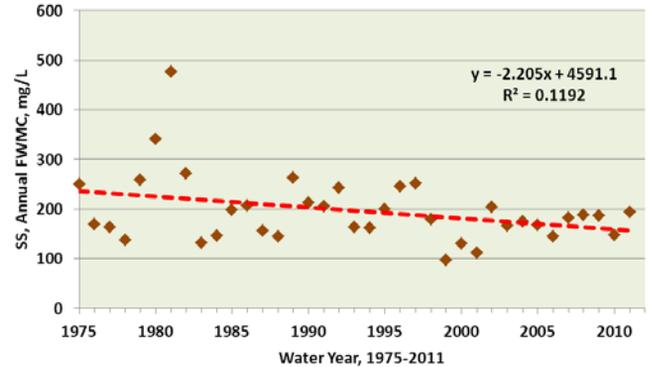
Sandusky River at Fremont, Annual Discharge, 1975-2011



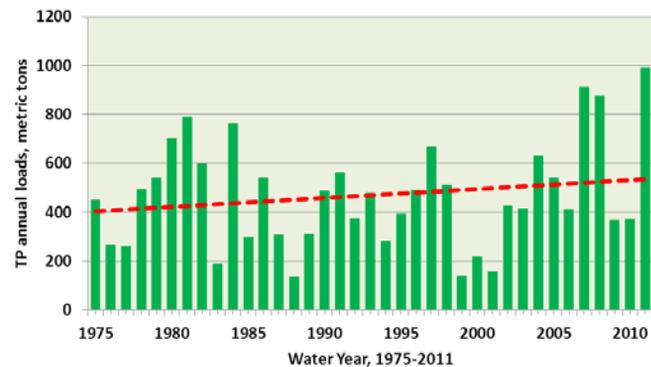
Sandusky River at Fremont, Annual Suspended Solids Loads



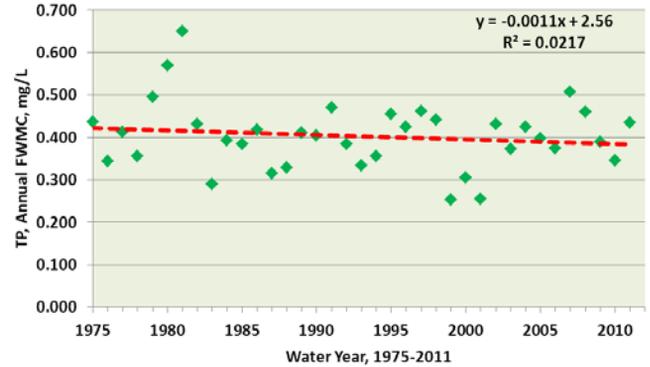
Sandusky, Annual Flow Weighted Mean Conc., Suspended Solids



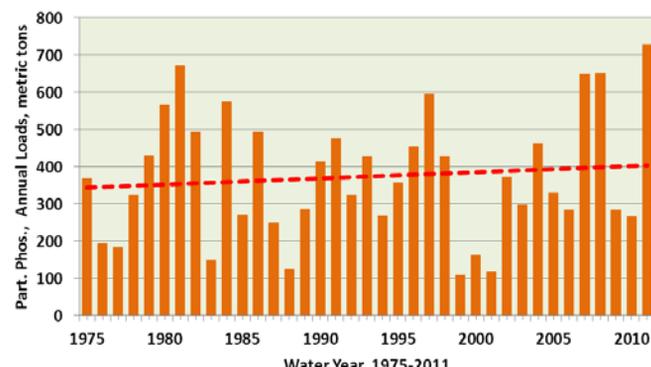
Sandusky River at Fremont, Annual Total Phosphorus Loads



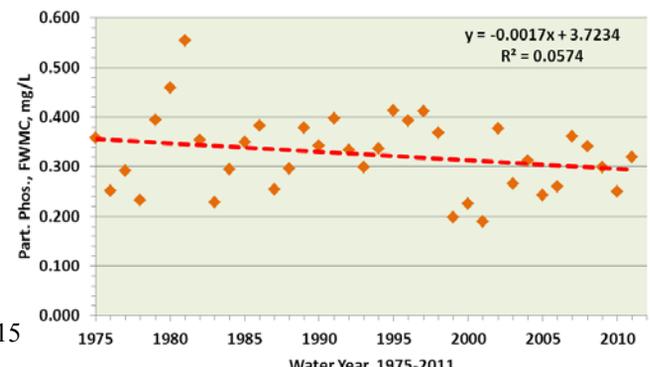
Sandusky, Annual Flow Weighted Mean Conc., Total Phosphorus

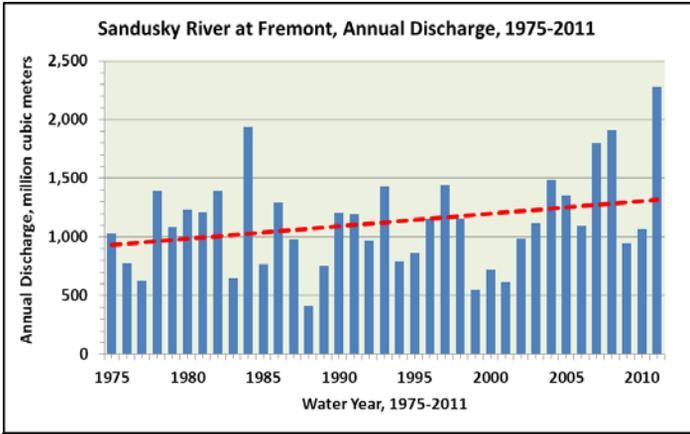


Sandusky River at Fremont, Annual Particulate Phosphorus Loads

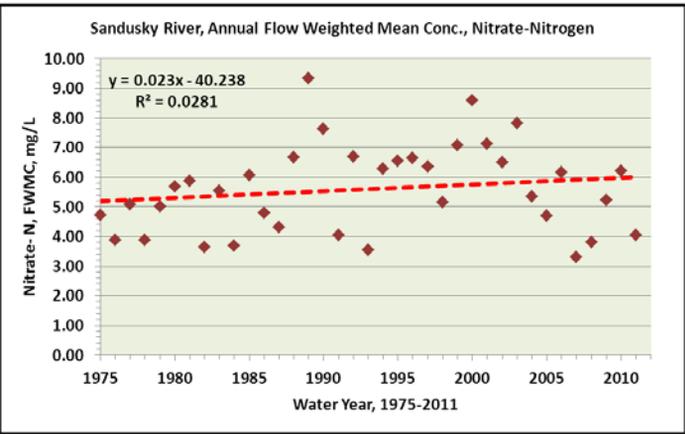
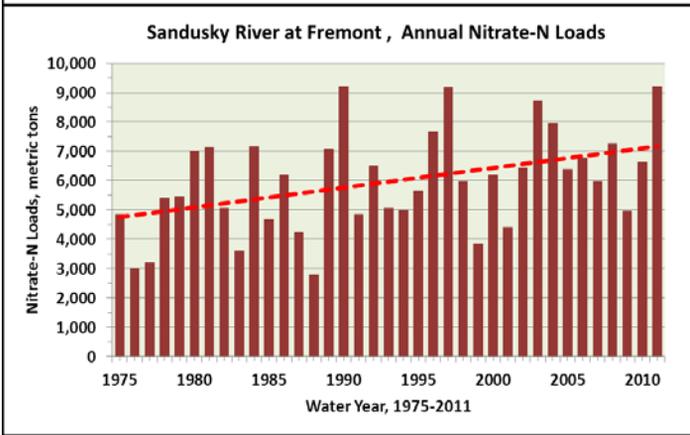
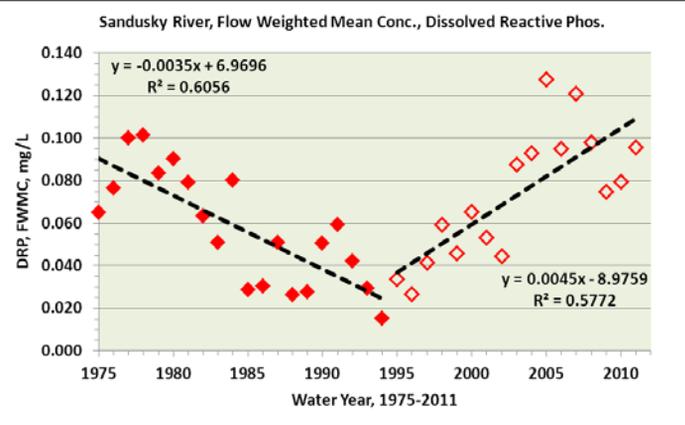
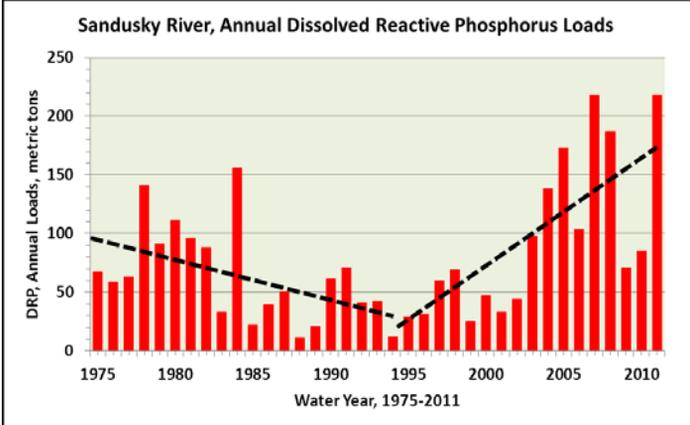


Sandusky River, Flow Weighted Mean Conc., Particulate Phosphorus





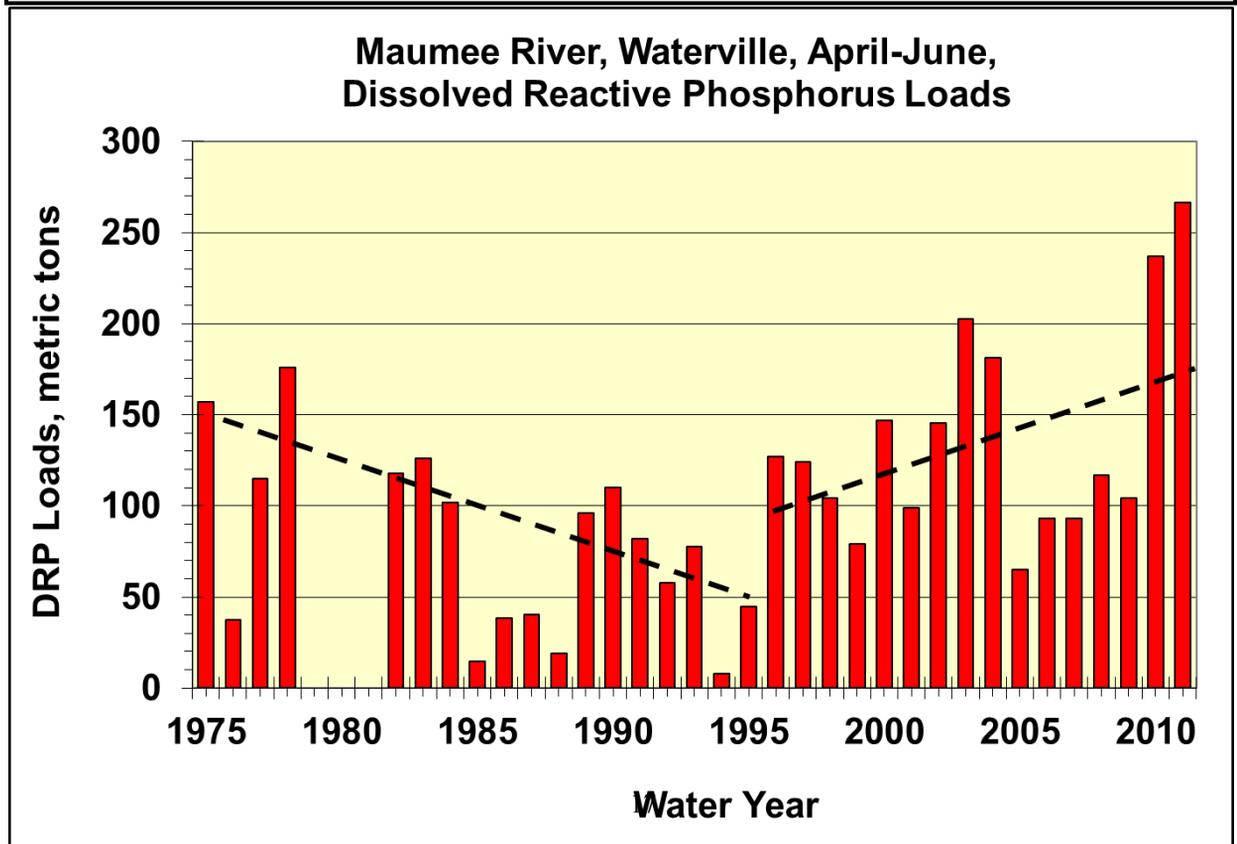
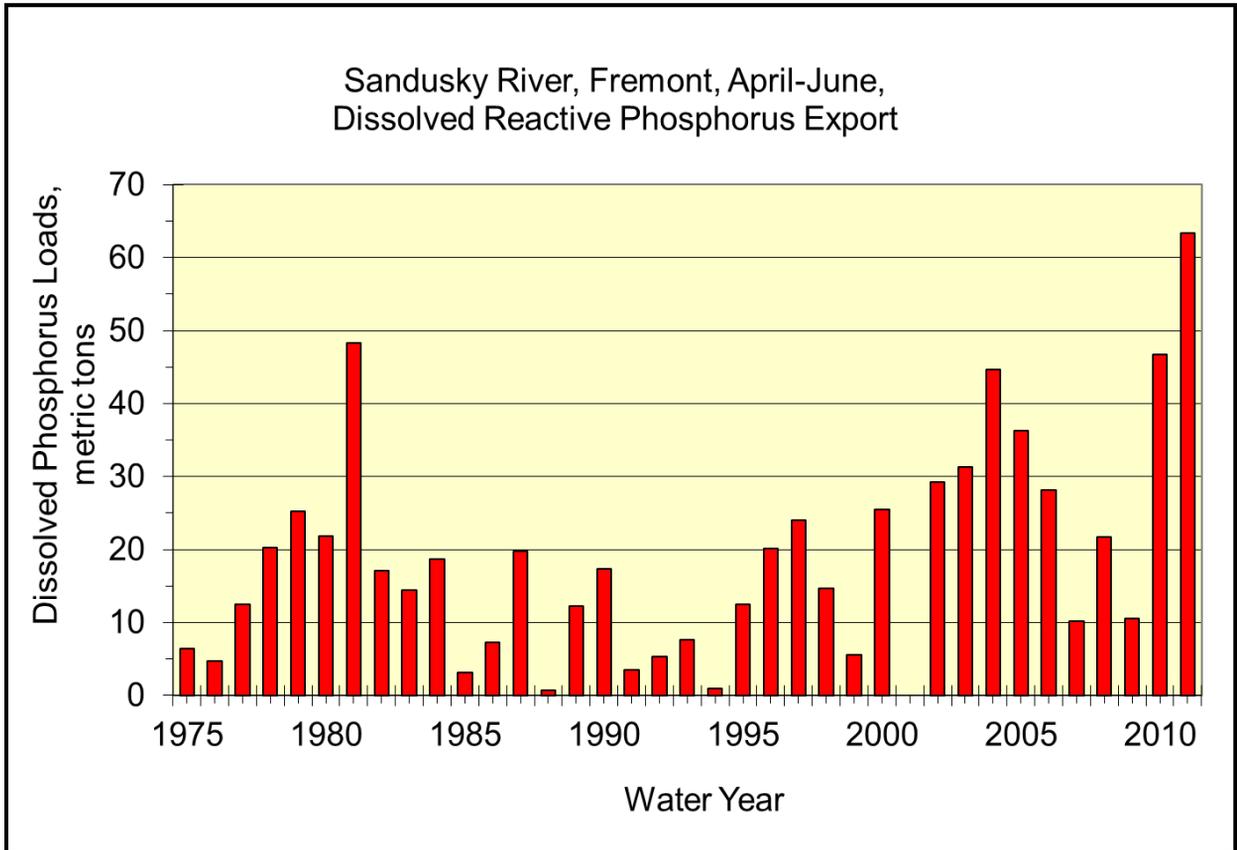
Since annual stream discharge has a major impact on annual loading of sediments and nutrients, the annual discharge graph is repeated here. The trends in dissolved reactive phosphorus (DRP) are particularly important. DRP loads and concentrations dropped from 1975 to the mid-1990s but both have increased rapidly since that time. Because DRP is more available to support algal growth than PP, the increased loading of DRP in recent years has been linked to increasing problems of algal blooms in Lake Erie. Nitrate loads have increased slightly during the monitoring period in association with the increased discharge and small increases in nitrate concentrations.



The nutrient and sediment loading data presented above are based on analyses of 16,900 samples collected from the Sandusky River near Fremont. These data are available at the web site of Heidelberg University's National Center for Water Quality Research at

www.heidelberg.edu/NCWQR. Recent funding for the operation of this station has come from the USDA's Natural Resource Conservation Service and the Lake Erie Protection Fund.

Spring DRP Loads for the Maumee and Sandusky Rivers through the 2011 Water Year, Heidelberg University Data



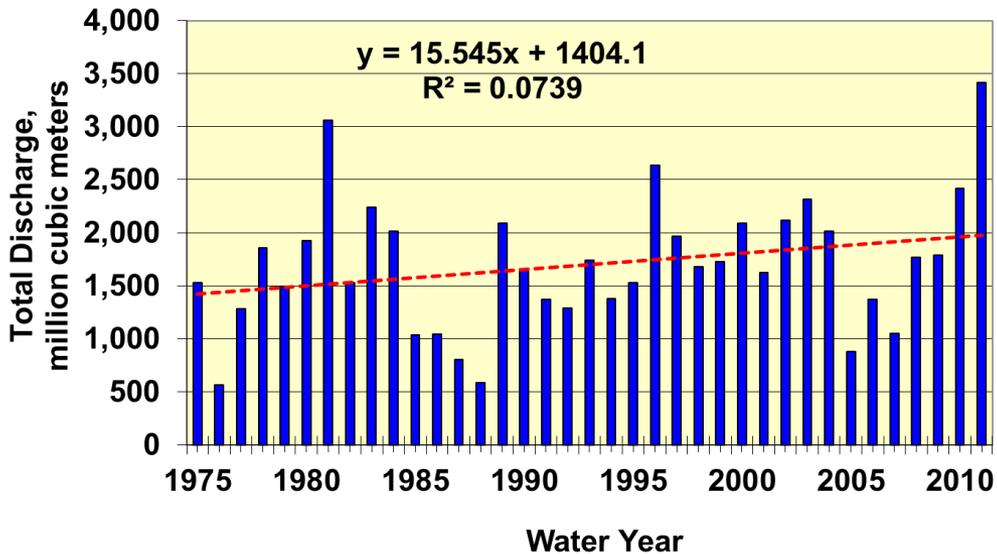
Trends in Spring Discharge and Loads for the Maumee River at Waterville

Graphs and Tabular Summaries for:

1. Discharge
2. Dissolved Reactive Phosphorus
3. Total Phosphorus
4. Suspended Sediments

Unpublished data from Heidelberg University,
Compiled by D. Baker

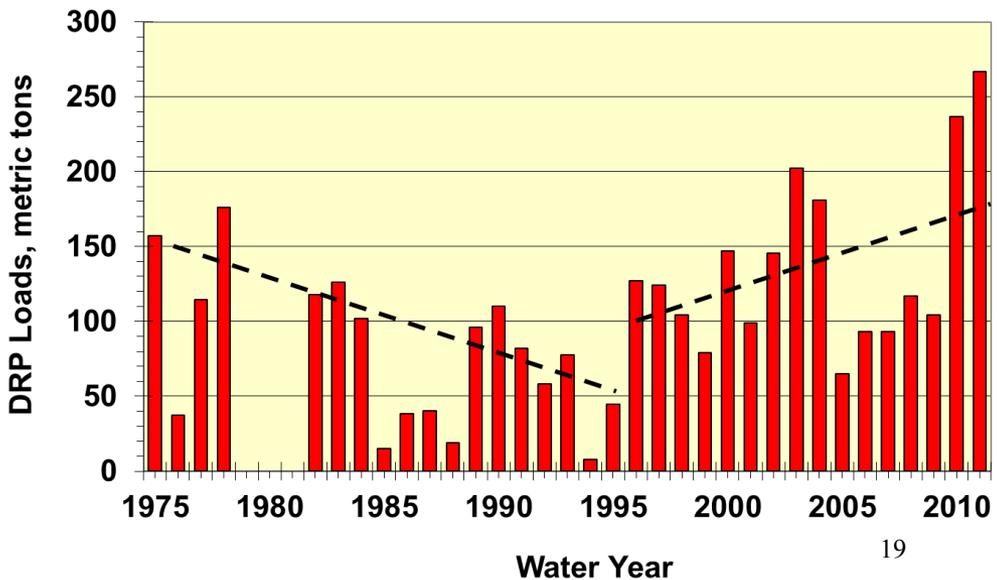
Maumee, Spring, Volume of water (discharge)



April 1- June 30, Discharge, Km³

1975-2009	2010	2011
Average		
1.63	2.42	3.42

Maumee, Spring, Dissolved Reactive Phosphorus



April 1- June 30, DRP loads

Metric tons

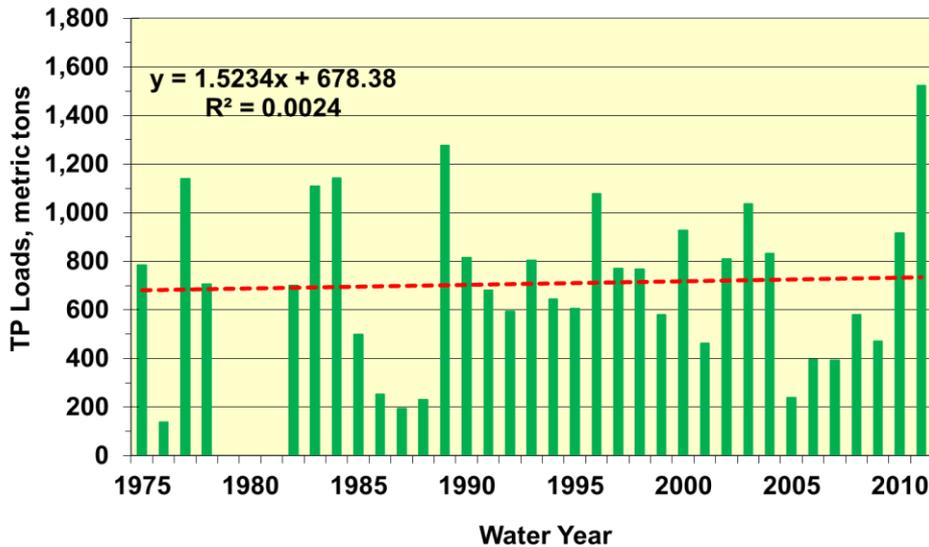
1975-2009	2010	2011
Average		
97	237	267

April 1- June 30, DRP FWMC

mg/L

1975-2009	2010	2011
Average		
0.060	0.098	0.078

Maumee, April - June, Total Phosphorus Loads



April 1- June 30, TP loads

Metric tons

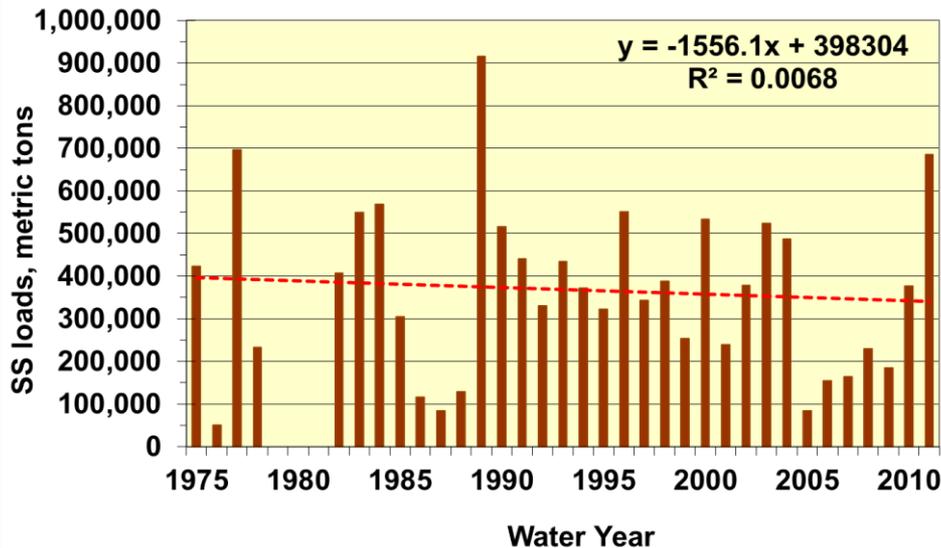
1975-2009	2010	2011
Average		
677	917	1,554

April 1- June 30, TP FWMC

mg/L

1975-2009	2010	2011
Average		
0.418	0.380	0.446

Maumee River, Spring, Suspended Sediment



April 1- June 30, SS loads

Metric tons

1975-2009	2010	2011
Average		
356,707	376,838	684,917

April 1- June 30, SS FWMC

mg/L

1975-2009	2010	2011
Average		
219	156	200

Appendix C – Presentations That Disseminated the Results of this Project

Listed below are talks presented by NCWQR staff members that included information derived directly from the data generated through this LEPF grant and/or from data that directly preceded the current grant.

- 2 February 2012. **Heidelberg’s National Center for Water Quality Research: history and current programs.** Heidelberg University Faculty Research Symposium. (Krieger)
- 2 February 2012. **Modeling pollutant exports from Lake Erie watersheds.** Heidelberg University Faculty Research Symposium. (Confesor)
- 16 December 2011. **Chickasaw Creek Nutrient and Sediment Export Studies, 2009-2011 Water Years.** Briefing for NRCS chief scientists. Celina, OH. (Richards and Baker)
- 15 December 2011. **Maumee Trends.** Briefing for NRCS Chief and chief scientists. Oregon, OH. (Richards)
- 15 December 2011. **Observations of 2010 and 2011 Watershed Loadings of Dissolved Phosphorus.** USDA/NRCS tour of Western Lake Erie Basin Issues. Lake Erie Center, Maumee, OH. (Baker)
- 14 December 2011. **Trends in Temperature, Precipitation, and Storm Runoff.** NSF WSC Team Meeting, Ann Arbor, MI. (Richards)
- 12 December 2011. **The Great Lakes SPARROW Model from a Lake Erie Perspective.** Western Lake Erie Basin Partnership Meeting. Perrysburg, OH. (Richards)
- 12 December 2011. **It starts in the watershed: Observations of 2010 and 2011 watershed loadings of dissolved phosphorus.** Western Lake Erie Leadership Team. Perrysburg, OH. (Baker)
- 1 December 2011. **Lagrangian Analysis of Storm Runoff Water from the Maumee River into the Western Basin of Lake Erie.** Lake Erie Researchers Meeting. Lake Erie Center, U. of Toledo. (Baker)
- 1 December 2011. **Maumee Trends.** Maumee River Researchers’ Meeting. Oregon, OH. (Richards)
- 11 November 2011. **The Great Lakes SPARROW Model from a Lake Erie Perspective.** NOAA-EcoFore Project Meeting. Ann Arbor, MI. (Richards)
- 8 November 2011. **Chickasaw Creek Nutrient and Sediment Export Studies, 2009-2011 Water Years.** Project report to NRCS. Columbus, OH. (Richards and Baker.)
- 20 September 2011. **Increasing Trends in Dissolved Phosphorus in Lake Erie Tributaries: The Role of Agriculture.** American Water Works Association Ohio Meeting. Cincinnati, OH. (Richards)
- 25 August 2011. **Loads and Concentrations in Ohio Rivers and Streams.** Agriculture, Nutrients, and Water Quality Workshop. Columbus, OH. (Richards, Baker, and Kramer.)
- 23 August 2011. **Perspectives on the Dissolved Phosphorus Problem.** Crop Production Services/IPM/Sandusky Watershed Coalition. Upper Sandusky, OH. (Baker)
- 15 August 2011. **Lessons from the Rivers: The Links between Cropland and Lake Erie.** Ohio Environmental Council. Maumee Bay State Park. (Baker)
- 26 July 2011. **Loads and Concentrations in Rivers and Streams.** EPA RARE Workshop. Celina, OH. (Richards, Baker, and Kramer.)

- 18 July 2011. **From Soils to Rivers to the Lake Erie Western Basin: Connecting the (Phosphorus) Dots.** Lake Erie Environmental Challenges. Lakeside Association, Lakeside, OH. (Baker)
- 12-13 July /2011. **The Dissolved Phosphorus Problem: A Viewpoint from the Rivers.** Consultation on Dissolved Reactive Phosphorus Loading from Agricultural Sources. Dearborn, MI (Jointly sponsored by the IJC, NRCS and Heidelberg University. (Baker)
- 8 July 2011. **Perspectives on the Dissolved Phosphorus Problem.** County Commissioners Association of Ohio, Agriculture and Rural Affairs Committee. Columbus, OH. (Baker)
- 24 June 2011. **Water Quality in Western Lake Erie.** 10th Annual Forum on Environmental Health. Sponsored by Toledo-Lucas County Health Department at St. Luke's Hospital, Maumee, OH. (Krieger)
- 17 June 2011. **P and N Trends in the Maumee and Sandusky Rivers, Major Lake Erie Tributaries.** Annual meeting of the International Association for Great Lakes Research, Duluth, MN. (Richards)
- 8 June 2011. **Land-Lake Connections: The Maumee River Watershed and Western Lake Erie.** Lake Erie Improvement Forum, Camp Perry, Port Clinton, OH. (Baker)
- 1 June 2011. **A Comparison of Mixing Zones between Storm and Base Flows for Major Ions, a Dissolved and Particulate Nutrients: A Case Study in the Lower Maumee River, Maumee Bay and Nearshore Waters of the Western Basin of Lake Erie.** Annual meeting of the International Association for Great Lakes Research. Duluth, MN. (Baker, Kramer, Ewing, Merryfield, Confesor, and Richards)
- 22 April 2011. **On the Care and Feeding of Lake Erie.** University of Cincinnati, Cincinnati, OH. (Richards)
- 20 April 2011. **The Heidelberg Tributary Loading Program.** Ohio Water Resources Council, Water Resources Monitoring Meeting, Columbus, OH. (Krieger)
- 13 April 2011. **Phosphorus Management for Lake Erie: Round Three.** The Andersons, Maumee, OH. (Baker)
- 8 April 2011. **Phosphorus: From Cropland to the Maumee River to the Western Basin: Connecting the Dots.** Lake Erie Waterkeeper Conference, LaSalle, MI. (Baker)
- 2 April 2011. **Phosphorus: From Cropland to the Western Basin of Lake Erie- A Quick Tour.** Heidelberg University Science Reunion, Tiffin, OH (Baker)
- 28 March 2011. **The Sources and Transport of Bioavailable Phosphorus to Lake Erie.** University of Toledo, Lake Erie Center, Toledo, OH. (Baker)
- 15 March 2011. **On the Care and Feeding of Lake Erie.** Tri-state Conservation Expo, Montpelier, OH. (Richards)
- 15 March 2011. **On the Care and Feeding of Lake Erie.** Huron County GLRI Workshop, Huron, OH. (Richards)
- 9 March 2011. **The Heidelberg Tributary Loading Program.** Great Lakes Science Advisory Board, International Joint Commission, Windsor, ON, Canada. (Krieger)
- 25 February 2011. **Increases in Dissolved Phosphorus Runoff: Is No-till Responsible?** Conservation Tillage and Technology Conference, Ada, OH. (Baker)

- 23 February 2011. **The Sources and Transport of Bioavailable Phosphorus to Lake Erie.** Ohio Coastal Management Program Office, Sandusky, OH. (Baker)
 - 19 February 2011. **Lakes and Watersheds: A Quick Walk to the Limits of my Knowledge and Beyond.** Aquatic Sciences Meeting, American Society of Limnology and Oceanography, San Juan, PR. (Richards)
 - 18 February 2011. **Application of Analytical Methods for Water Samples Directly to Soils: Lessons Learned.** Aquatic Sciences Meeting, American Society of Limnology and Oceanography, San Juan, PR. (Baker, Ewing, Kramer, and Richards)
 - 18 February 2011. **Exploring Phosphorus Retention and Release in Rivers and Watersheds Using Extended Endmember Mixing Analysis.** American Society of Limnology and Oceanography, San Juan, PR. (H.P. Jarvie, C. Neal, J.P. Withers, D.B. Baker, R.P. Richards, and A.N. Sharpley)
 - 18 February 2011. **Re-eutrophication of Lake Erie: Insights from the Maumee and Sandusky Systems.** American Society of Limnology and Oceanography, San Juan, PR. (D.D. Kane, J.D. Conroy, D.A. Culver, T.B. Bridgeman, J.D. Chaffin, D.L. Bade, W.J. Edwards, R.M. McKay, R.P. Richards, and D.B. Baker)
 - 18 February 2011. **Increasing Trends in Dissolved Phosphorus in Lake Erie Tributaries: The Role of Agricultural Practices.** American Society of Limnology and Oceanography, San Juan, PR. (Richards and Baker)
 - 27 January 2011. **The Great Lakes Watershed and Agriculture.** Michigan Agriculture's Conference on the Environment, Lansing, MI. (Richards and D. Scavia)
 - 12 January 2011. **Sediment Concentrations and Loads to Lake Erie, 1975-2009.** Army Corps Workshop: Managing and Understanding Sediments, Cleveland, OH (Richards)
 - 8 January 2011. **P and N Trends in the Maumee and Sandusky Rivers, Major Lake Erie Tributaries.** Winter Gala, Bowling Green, OH. (Richards)
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