Evaluation of Different Approaches for Controlling Phosphorus Pollution in the Maumee River Watershed

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Executive Summary

There is a growing consensus among scientists and natural resource managers that conservation efforts addressing nonpoint source pollution are most effective when coordinated at a watershed scale. In light of this understanding, the question is how to mobilize effective conservation strategies at the watershed scale in order to ensure desired water quality. With public resources limited, much of this question can be understood as a tension between seeking to put in place those actions that will assure the largest improvements in water quality while striving for the lowest costs to land owners, citizens, and agencies.

The Maumee River watershed, whose 8,316 square mile area is over 70% in agricultural land cover, presents an interesting and timely setting for tackling this challenge.[1] The Maumee's tri-state river watershed, spanning OH, IN, and MI, drains into the Western Lake Erie Basin and carries with it an excess load of dissolved reactive phosphorus (DRP), a nutrient that contributes significantly to the occurrence of harmful algal blooms (HABs). While HABs have been an increasing concern over the last decade, they came to the forefront of national news when in August 2014 the City of Toledo was forced to shut off its drinking water supply sourced from Western Lake Erie to approximately 500,000 metropolitan area residents due to microcystin contamination, a toxin produced by a HAB in Western Lake Erie.[2]

This report identifies a wide spectrum of conservation practices and policy approaches for reducing DRP at the watershed scale, including both voluntary and regulatory approaches. These are combined with model analysis of the physical watershed's landscape and an independently designed cost effectiveness analysis in order to create marginal cost of abatement curves that define a suite of possible watershed scale management scenarios structured to achieve optimum improvements to water quality.

Key Findings

Problem and Targets

While Lake Erie's total phosphorus load remains below 1970 levels, recent massive algal blooms in Lake Erie have been driven specifically by an increased load of DRP, a highly bioavailable form of phosphorus. This explains why even though total phosphorus entering Lake Erie has declined, algal blooms and hypoxia are increasing.

While a great deal of positive work around Lake Erie has been steered by the Great Lakes Interagency Taskforce, the Great Lakes Restoration Initiative, private landowner actions, and industrial innovation, the IJC's 2014 call for a 41% decrease in annual DRP loads from the Maumee River into Western Lake Erie from the 2007-2012 average makes clear there is pressing need for further coordinated and innovative action on this issue. [3]

Conservation Practices and Costs

In order to achieve the IJC's 41% DRP reduction target, it is important to establish an ecologically grounded understanding of which conservation practices, or best management practices (BMP), can be most beneficial to reducing DRP. Using a BMP Toolkit out of

Heidelberg University, we scanned the full suite of agricultural conservation practices and recognized the various tradeoffs presented by each practice in order to select 6 practices that rank highest within their category of practices in DRP reduction impact per acre of usage. These six agricultural conservation practices most applicable to DRP reduction in the Maumee River were determined to be:

- Subsurface injection phosphorus application
- Mulch till
- Strip cropping
- Cover crops
- Tree/shrub establishment
- Riparian forest buffers

Recognizing that cost is a vital component of implementing any conservation practice, we used Ohio's 2014 NRCS Environmental Quality Incentives Program Guide to assign a baseline $/acre cost to each conservation practice (noting that costs for each practice can increase exponentially for acquisition of additional benefits such as creation of pollinator habitat or market value of planting organic specialty crops).

NRCS Practice Code	**Conservation Practice**	**Cost Range ($/acre)**	**Cost floor ($/acre)**
590	**Nutrient management deep placement (subsurface injection)**	43.62	**43.62**
345	**Mulch till**	3.85	**3.85**
585	**Strip cropping**	3.38	**3.38**
340	**Cover cropping**	44.24	**44.24**
612	**Tree/shrub establishment**	491.36 (bare root)- 1282.34 (shrub establishment, bare root)	**491.36**
391	**Riparian forest buffer**	724.75 (direct seeding)	**724.75**

Policy Analysis

Historically, adoption of agricultural conservation practices has been largely voluntary in the Maumee River Basin and closely tied to federal cost share programs. Recognizing that policy approaches can act to increase implementation of these conservation practices at the watershed scale, policy change presents an avenue to achieving the DRP reduction target.

We examined a broad spectrum of possible policy tools or programs that might help reach the DRP reduction target set for the predominantly agricultural Maumee River Basin. Policies we examined ranged from voluntary programs to regulatory actions, and operate at different levels of government, from federal to state to local. They include land retirement, nutrient management planning, and water quality trading as well as approaches like Total Maximum Daily Loads (TMDLs) and litigation. The following table summarizes some key findings and recommendations that resulted from this policy analysis.

Federal	• Use Conservation Reserve Enhancement Program to implement selection indexes that prioritize high DRP runoff acres • Allocate funding to retire high-productivity acres
Interstate	• Transition MI, IN, and OH to using a common 590 Standard for nutrient management plans. • Conduct further research into potential for developing a Western Lake Erie basin wide point-nonpoint water quality trading program, ensuring that any water quality credits could reflect *reductions in DRP;* the work to incorporate water quality trading in any future efforts to place regulatory caps on nonpoint DRP runoff
State	• The State of Ohio could consider a state-wide phosphorus tax or solicit the federal government to pass a tax on phosphorus • Amend Ohio's anti-degradation policy to explicitly include DRP • Involve regional farmers directly in regulatory design • Ensure sufficient agency staff capacity exists for effective monitoring of on-the-ground efforts and that agencies are able to share enrollee information effectively across offices
Local	• Assure consistent and sufficient funding support for program enrollees • Local municipalities could challenge the Ohio EPA on the Ohio Revised code (ORC) chapter 611 exclusion of agricultural pollution from regulation

Comparison of Regional Modeling Tools

Despite obvious limitations in perfectly approximating reality, modeling is an effective way to interpret the complexity of nutrient application, uptake, and runoff from agricultural lands in a watershed and provides an attractive tool for individuals and decision makers seeking to address DRP loading from the Maumee River watershed into Western Lake Erie. With multiple models and tools available to simulate nutrient patterns and predict nutrient load changes based on implementation of conservation practices, we compared existing models of the Maumee River watershed in order to highlight their unique capabilities and limitations; these include Spatially Referenced Regression on Watershed Attributes (SPARROW), the Great Lakes Watershed Management System (GLWMS), the Soil and Water Assessment Tool (SWAT), and Soil Nutrient Application Planner (SNAP Plus). The report focuses on how these models handle the phosphorus transport pathway with additional discussion on erosion. We compare inputs, processes, and outputs but also the accessibility, ease of use, and how these factors made the various models practical for guiding decisions.

SPARROW is a tool created by the USGS that offers a decision support system that allows users to manipulate the sources of contaminants, such as total phosphorus and eroded sediments, in their watershed over an online interface. GLWMS can implement a suite of practices at a field scale that estimates reduction in phosphorus loading, but it is not possible to calculate changes in any form of phosphorus at a watershed scale. SWAT is well established as an accurate watershed model with increasing capabilities concerning nutrient runoff patterns; however, its technical nature makes it less accessible to potential users. Modeling DRP within SWAT is possible, but there still lies uncertainty in its accuracy of DRP loading. SNAP Plus is a field-based tool that estimates the phosphorus runoff risk of agricultural lands, and thus is very useful for generating nutrient management plans for specific farms.

Priority Mapping

While the models displayed a range of capabilities and flexibility, none were able to adequately address DRP in their computations. Thus, we developed a multi-criteria evaluation model (MCE) that could prove helpful to addressing this focal nutrient issue.

MCEs are a method of defining priorities within an environment like ArcGIS and using weights to visualize the results of that decision spatially. This specific model investigates the physical characteristics of the Maumee River watershed and how they influence DRP runoff from the landscape. The output of the MCE is a map that shows the spatial prioritization of our chosen conservation practices based upon their accepted ability to reduce DRP runoff from the fields. Through the creation of a MCE, individuals will have the tools necessary to designate the best regions for their own conservation practice implementation based on the best available knowledge, even when more complex tools are not at their disposal.

The primary output map of the MCE illustrated some interesting trends of conservation practice placement. Riparian forest buffers are best prioritized for regions closest to water, while cover crops appear to be suitable for a wide range of landscapes as they are seen across the map. Conversely, mulch tillage, a practice that is not effective at reducing DRP runoff, was not present on the map, demonstrating that the MCE was utilizing the defined spatial relationships accurately to assign conservation practices to certain pixels of land.

Marginal Costs of DRP Abatement

Since resources to implement agricultural conservation practices are limited, it is important to understand the relative cost-effectiveness of conservation practices in different locations across the watershed. By implementing practices in the locations where they will result in the greatest reduction in DRP runoff per dollar spent, programs can achieve the impact for a given budget or achieve a target loading reduction at the lowest possible cost.

While data limitations precluded a formal marginal cost analysis, a relative metric (ranging from 0 to 500) comparing the DRP abatement impacts of different conservation practices was created using the Heidelberg University toolkit. A similar, qualitative relative cost scale (ranging from 0 to 5) was created using estimates from the Natural Resource Conservation Service. The two relative scales were combined to provide a relative ranking of the marginal costs associated with implementing five key conservation practices across agricultural lands in the Maumee watershed. This information was used to simulate four scenarios covering a range in investment levels (low, medium, high and full investment) and DRP reduction goals. DRP abatement benefits were found to drop sharply after placing more than 46% of the watershed in recommended conservation practices.

Investment Scenario:	***Low***	***Medium***	***High***	***Full***
Willingness to Pay (relative cost/impact):	0.04738	0.07105	0.14193	4.26319
% of acres managed	9.63%	22.61%	46.72%	100.00%
% of possible expenditures	7.87%	20.36%	44.74%	100.00%
% of possible DRP abatement achieved	24.45%	49.57%	79.28%	100.00%

Investment Scenarios, totaling all conservation practices of interest

Due to the data limitations, this analysis is solely for the purposes of illustration and should not be used to guide policy recommendations.

Chapter 1:
Project Methodology

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1.1 Problem Statement

Conservation programs that control soil erosion, reduce sedimentation, and manage runoff from rural landscapes have been utilized in the United States for many decades. And yet, as development pressures continue to intensify across much of the country, water quality issues have grown steadily more complex and critical.

Today, a growing consensus among scientists and resource managers recognizes that nonpoint source (NPS) runoff plays a crucial role in determining the health of aquatic systems, and that conservation efforts addressing NPS pollution should align with the watershed scale. In light of this growing understanding, the question has thus become how to mobilize effective conservation strategies at the watershed scale in order to ensure desired water quality goals.

While there is a long tradition of conservation programs that address NPS runoff, they can be expensive, almost always require a long timeframe to show results, and require follow-up monitoring to assess progress. With public resources limited, much of the challenge to mobilize conservation strategies at the watershed scale can be understood as a tension between seeking the biggest improvements in water quality while striving for the lowest costs to land owners, citizens, and agencies.

This project takes on that challenge through a focused study of the Maumee River watershed, an over 8,000 square mile watershed that drains into the Western Lake Erie Basin and carries an excess load of dissolved reactive phosphorus (DRP). This project report identifies a wide spectrum of conservation practices and policy approaches for controlling DRP at the watershed scale, including both voluntary and regulatory approaches. These are combined with model analysis of the physical watershed landscape and an independently designed cost effectiveness analysis in order to create marginal cost of abatement curves that define a suite of possible watershed scale management scenarios structured to achieve target water quality improvement.

1.2 Project Methodology

While this project focused exclusively on the Maumee River Basin and the question of what policy recommendations might be most ecologically and economically effective at reducing harmful dissolved reactive phosphorus loads in that watershed, we recognize that many other watersheds face similar nonpoint source pollution management issues. The Integrated Assessment vision of this project is also novel in nonpoint source pollution management. This report attempts to follow an integrated assessment approach by combining the multiple of environmental, political, and economic variables into a multi-dimensional methodology for selecting the best approaches to control phosphorus pollution in a specific location, this one being the Maumee River watershed.

The following methodology is offered not as a hard and fast prescriptive method for assured success in formulating and assessing NPS pollution policies, but rather as a roadmap that may prove helpful in part or whole to others who seek to explore a set of NPS pollution management policy options at the watershed scale. This series of steps and considerations is flexible to a range of users, considering that each watershed presents different opportunities, resources, and spaces for action. This flexibility is meant to allow the future user the ability to manipulate the steps as they align with the goals of the user and the environment in which they work.

Some parts of the methodology may be more aligned than others. For instance, a multi-criteria evaluation tool (MCE) was used to determine suitable locations for select conservation practices in the watershed rather than relying on perhaps the best assessment tool available, the Soil and Water Tool, because of concerns for accessibility and replicability. It may be the next user of this methodology will be inclined towards using the best available technology because their organization has the expertise to utilize it. On the other hand, another user may not even have the expertise or ability to use an MCE and therefore may select a more qualitative approach to determining the best location for the conservation practices.

In constructing a methodology such as this, it is important to identify the audience in order to understand the various decisions, limitations, and intentions that will be considered. While the audience may vary – nongovernmental organizations, university researchers and students, local, regional, state, or federal government, and businesses – the process outlined below is meant to be a lowest common denominator methodology, recognizing that it may be different for each audience. The methodology closely follows the process used in this report and therefore serves as a roadmap to achieve the same level of analysis conducted here.

Step 1: Identify the Problem, Define the Goal(s), and Set the Target(s)

Identify the Problem: *What threat to water quality needs to be addressed?*

- Identify major stakeholder groups in the watershed in order to understand diverse priorities that may exist in relation to perceived water quality issues
- Build relationships with regional decision makers and stakeholders through attending meetings and workshops in order to ground project efforts in existing efforts and knowledge
- Utilize USDA Census data to determine predominant land uses in the watershed to understand environment and current ecological impacts
- Explicitly focus investigation on a specific problem of interest

Define the Goal(s): *What would a solution to the water quality problem look like?*

- Emphasize resiliency and longevity as primary concerns when defining watershed-scale goals

Set the Target(s): What specific accomplishment(s) will ensure achieving the stated goal?

- Strive for measurable targets, recognizing that this process can be iterative and that targets may be quantitative or qualitative depending on the nature of the water quality problem being addressed
- Assess degree of consensus on set targets through ongoing dialogue with regional water resource experts and professionals

Step 2: Create a Team and Build Foundation for an Integrated Assessment

Create a Multi-Disciplinary Team: This methodology requires a broad range of skills and expertise and continually supplements team knowledge with outreach to active local, regional, state, and federal land and water management agencies, nonprofit organizations, and academic experts.

- Ecological knowledge specific to the identified water quality problem and the efficacy of conservation practices is vital to ensuring the project promotes appropriate on-the-ground solutions
- Fluency in modeling is required to assess physical processes at the watershed scale and provide for coarse spatial prioritization in defining ecologically optimal siting distribution for conservation practices and for estimating their potential impacts
- Political analysis is required to assess the opportunities, challenges, and impacts of implementation for a variety of nonpoint source pollution management scenarios
- Economic analysis allows for valuing the costs associated with different nonpoint pollution management scenarios as well as consideration of the distribution of those costs

Develop a shared ecological understanding of the problem being addressed:

Assure that all team members first come to a shared understanding of the fundamental ecology behind the focal water quality issue in order to guide their work in building the foundation for the integrated assessment, whose components are listed below.

Build foundation for an integrated assessment of NPS pollution management:

1) Research applicable on-the-ground conservation practices (Ecology)

OBJECTIVE: Determine subset of practices to focus on in integrated assessment

- To the degree possible, build off of existing peer reviewed assessments of conservation practices rather than starting from scratch
- Look for regionally produced research tools that offer quantitative comparisons of numerous practices' efficacy as relating to the water quality parameter(s) relevant to your stated problem
- Align selected conservation practices with Federal Natural Resources Conservation Service (NRCS) codes or another authoritative source that is recognized and equally accessible to all land managers within the watershed of interest

2) Identify computer models that exist for the watershed region and are applicable to the identified water quality problem (Modeling)

OBJECTIVE: Select and use a model or models to distribute selected conservation practices across the watershed and tie to stated target(s)

- Compare models in order to understand the variety of existing tools
- Consider flexibility and limitations of models' inputs and outputs
- If a functionally useful model of your watershed exists, utilize what is available. When the models do not line up directly with the targets of your problem, consider using simple GIS tools for basic evaluation. In this project a multi-criteria evaluation tool was used to identify "best" acres for conservation practices and to estimate the benefits of implementing them.

3) Research the full spectrum of voluntary and regulatory policies that can drive nonpoint source pollution management (Policy)

OBJECTIVE: Identify policies that could be implemented to increase adoption of effective conservation practices within the watershed

- Research the cost dimensions, administrative components, and legal authority that underpin each policy of interest
- Identify and research case studies for policies of interest (regional case studies are preferable though may not be available)
- Recognize context of existing federal, state, and regional programs
- Forecast implementation considerations for the focus watershed

4) Assign per acre costs to each selected conservation practice (Economics)

OBJECTIVE: Begin building cost effectiveness curves

- Use regionally appropriate and up to date NRCS EQIP cost tables

Step 3: Conduct the Integrated Assessment

Build Marginal Cost of Abatement Curves:

- Use a modeling tool to determine ecological benefit of different levels of implementation of conservation practices. Ideally output the spatial location of the practices, even at a coarse scale.
- Use the per acre costs to develop marginal cost of abatement curves.

Step 4: Formulate and Communicate Recommendations

Formulate Regional Recommendations:

- Incorporate model output maps with policy understanding of the watershed in order to frame low cost, middle cost, and high cost implementation scenarios for achieving the set target(s) and obtaining the project's stated goal(s)

Communicate Recommendations:

- Identify and pursue opportunities to communicate findings with regional stakeholders and agencies who are engaged in addressing the focal problem

Conclusion

This Integrated Assessment skeleton provides a methodology for those addressing nonpoint source pollution in their own watersheds. We recommend the incorporation of most, if not all, of the steps as they truly achieve the crux of the integrated assessment, but this is dependent on the specific needs of each watershed. Hopefully, those utilizing this methodology are able to analyze their issue from each perspective: politically, economically, and scientifically. This methodology is illustrative of a process and should not viewed as a definitive process for making policy recommendations.

Chapter 2:
Environmental Scan of Western Lake Erie

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    Appendix 2A: 2012 Farm Census & Watershed Comparison

The excess nutrient pollution and subsequent harmful algae blooms (HABs) that have increasingly affected Western Lake Erie over the last decade are a critical watershed health issue of mounting concern. In order to effectively assess options for future management of nutrient pollution into Western Lake Erie, it is important to understand the ecological and historical context of nutrient pollution and pollution management efforts in the Great Lakes system, the legal context that has evolved in tandem with these efforts, and the composition of the Maumee River watershed's primarily agricultural landscape.

2.1 Lake Erie: Ecological Context

Lake Erie, one of the five Great Lakes, is located in the Upper Midwest region of the United States. Ontario, Canada borders the northern end of the lake, while the rest of the shoreline touches Michigan, Ohio, Pennsylvania, and New York. Lake Erie is the smallest of the Great Lakes by volume and is also the shallowest with an average depth of 19 meters and a maximum depth of only 64 meters.[4] These two qualities reveal why Erie is the warmest of the Great Lakes and often the first to freeze in winter. Lake Erie has the shortest residence time of all the Great Lakes, which indicates a quick turnover of water, nutrients, and other inputs to the lake.

Presently, inputs to the western basin of Lake Erie are dominated by nutrients from the heavily agricultural lands of the Maumee River watershed.[5] Incoming nutrients create an exceedingly productive environment for algae and other photosynthetic organisms. Generally, an increase in productivity of an ecosystem would be beneficial for species farther up the food chain, but too much algal production can lead to hypoxic areas, or dead zones, that lack life supporting levels of dissolved oxygen.

Figure 2.1 Maumee River watershed

In addition to excessive nutrient loading from both point and nonpoint sources, invasive species are another prominent concern in the management and health of the Great Lakes. Lake Erie in particular has become infested with invasive zebra and quagga mussels.[6] While these species initially improve water quality via filtration, excessive filtration by these mollusks leads to increased water transparency and more algae growth, thus exacerbating the influences of eutrophication in Lake Erie.

Climate change impacts are also influencing eutrophication as the Great Lakes region experiences higher temperatures as well as storms of greater intensity and higher frequency.[7] The combination of these climatic factors will continue to provide optimal conditions for increasing algal growth.

From a recreation and economics perspective, it is worth noting that Lake Erie is home to one of the largest freshwater fisheries in the world. The variety of species and the total number of fish caught each year are greater than that of any of the other Great Lakes.[8] Lake Erie's strong commercial and recreational fisheries bring in a plethora of species including walleye, steelhead, yellow perch, smallmouth bass, and rainbow smelt. The commercial fishery is mostly based in Canada, while the majority of the recreational fishery is American.

2.2 Western Lake Erie: Historical Context

For centuries, Lake Erie has been recognized as a valuable natural resource and transportation hub. While indigenous peoples lived along the lake for thousands of years, the Erie Native American tribe was the first recognized in the historical record and from whom the lake takes its name. By the 17th century, the Erie were conquered by the Iroquois and the region came to include Ottawa, Wyandot, and Mingo tribes.[9] French traders came to the region in the late 1700s and by the early 19th century, European settlers had moved into the area and begun developing agriculture, forestry, and mining operations. With the opening of the Erie Canal in 1825, which connected the Great Lakes to the Hudson River and high-demand East Coast markets, agricultural and economic activity expanded rapidly. Railroads proliferated, bringing resources down from the Upper Peninsula of Michigan and across the Ohio region. By the 20th century, the industrial cities of Detroit and Toledo were established along Western Lake Erie's shores.

When European settlers first arrived in northeast Ohio, the region was the site of the Great Black Swamp, a forested wetland of nearly 4,800 square miles that extended westward into modern day Indiana. As settlers moved into the area they cleared the forests and drained the swamp to make room for agriculture. In doing so, they destroyed the natural filtration system of Lake Erie's largest tributary, the Maumee River. This drained wetland area, rather than serving as a filtration system became the site of some of the most fertile soil in the country, which led to increasing agricultural activity and increasing runoff. Without the wetlands in place to capture this runoff, tile drainage systems were designed and expanded to move water away from agricultural areas as efficiently as possible. While tile drain systems prevented stagnation they also facilitated flows of applied fertilizers and pesticides off of fields and into waterways.[10]

By the late 1960s, decades of industrial pollution and intensified human settlement pressures began to show in the rapidly declining health of Lake Erie. Excess phosphorus from municipal sewage treatment plant runoff and other anthropogenic sources was driving the lake system to become eutrophic, as high nutrient loads fueled the growth of massive algal blooms. Those algal blooms compromised water quality and led to periods of hypoxia as bacteria decomposing dead algal cells consumed available oxygen in the water column.[11] Beaches lined with green algae called *Cladophora*, massive fish kills, and drinking water contamination by blue-green algae were among the dramatic symptoms of this ecological imbalance.[12] As subsequent research has revealed, average annual phosphorus loading for the years 1967-1972 was nearly 24,000 metric tons, whereas models showed the maximum allowable amount of phosphorus runoff that would not produce nuisance algae growth would have been just 11,000 metric tons.[13]

2.3 Great Lakes Water Quality: Legal Context

Lake Erie was not the only water body experiencing the ill-effects of excess pollution. National public concern over impaired waterways mounted throughout the 1960s, leading to Congress passing the Clean Water Act (CWA) on October 18, 1972. The CWA, a federal law governing pollution in navigable waters, set two definitive goals: “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters,” and “that the discharge of pollutants into the navigable waters be eliminated by 1985.”[14]

The CWA created a new approach for federal water quality management. Prior federal laws such as the Rivers and Harbors Appropriation Act of 1899 (which attempted to limit discharges of pollutants into the nation’s water bodies through prohibition) and the Water Pollution Control Act of 1948 (which adopted the principles of state and federal cooperative program development, limited federal enforcement authority, and limited federal financial assistance) had articulated a core vision for federal water protection but lacked the teeth to enforce action. Similarly, the federal Water Quality Act of 1965 had set water quality standards for water bodies as a whole but also had proven not strong enough to achieve measurable successes.[15] Thus, by enabling regulatory action against pollutant discharges into navigable waters from point sources, the CWA initiated an actionable approach to controlling pollution in navigable waterways.

The distinction between point and nonpoint sources of water pollution has proven central to the CWA’s implementation and impact. The Act defines point sources as “any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.”[16] Any source of water pollution that does not meet this definition is considered a “nonpoint source.” Of note, the CWA explicitly states that “agricultural stormwater discharges and return flows from irrigated agriculture” are not considered point sources.[17]

With the CWA redefining the legal scope of water quality management, and in light of the extent of phosphorus pollution in the Great Lakes, the US and Canada signed the Great Lakes Water Quality Agreement (GLWQA) in 1972 as an international agreement with a purpose to restore and maintain the chemical, physical, and biological integrity of the water of the Great Lakes Basin. This included seeking to limit phosphorus discharges into the Lakes. The GLWQA created a framework for joint management of the entire Great Lakes watershed by setting forth general objectives and regulatory aims, and directing programmatic planning.[18] Implementation of the Agreement is tracked by the International Joint Commission (IJC), a body created by the Boundary Waters Treaty of 1909.[19] The IJC advises the US and Canadian government who set phosphorus concentration and phosphorus load objectives for each of the Great Lakes and in their respective states and watersheds. The 2012 protocols of the GLWQA established ten Annexes to address water quality priorities for the Great Lakes. Under Annex 4, the nutrient annex of GLWQA, the IJC works with other parties to develop “regulatory and non-regulatory programs to reduce phosphorus loading from agricultural and rural non-farm point and nonpoint sources” though they lack regulatory authority to overturn CWA exemptions.[20]

Since 1972, the IJC has grown to include more than twenty boards and task forces and was most recently revised in 2012.[21] A 1978 amendment to the GLWQA provided the IJC with more detailed objectives, including ensuring that the future of the Great Lakes be “free from nutrients directly or indirectly entering the waters as a result of human activity in amounts that create growths of aquatic life that interfere with beneficial uses.”[22] GLWQA thus identifies and focuses efforts on areas of concern within the Great Lakes basin where beneficial uses--

including human uses, wildlife, and economic benefits derived from a water body-- have been compromised by water pollution.

Efforts initiated under the GLWQA helped achieve significant reductions in phosphorus loading into Lake Erie, from 24,000 metric tons annually for the years 1967-1972 down to around 11,000 metric tons.[23] Eight billion dollars (adjusted to 1990s dollars) has been invested in wastewater treatment improvements across the Great Lakes Basin, including numerous sewage treatment plant upgrades, and the amount of phosphate allowed in laundry detergents in both Canada and the US has been reduced.[24,25] The GLWQA was also instrumental to a regional mandate placed on a permitting process for industrial discharge of wastewater. As a result of these efforts and other initiatives, average algal biomass in Lake Erie was reduced by half and drinking water quality improved.[26]

2.4 Western Lake Erie Today

Total phosphorus loads have remained at or below the levels set by GLWQA in the 1970s. However, as the impacts of nonpoint source pollution have become more widely recognized, scientific understanding of lacustrine system response to phosphorus inputs has also evolved. It is now accepted in the scientific community that recent massive algal blooms in Lake Erie have been driven specifically by dissolved reactive phosphorus (DRP). DRP is a highly biologically available form of phosphorus which explains why even though less total phosphorus is entering Lake Erie than was the case before point source regulation under the CWA, algal blooms and hypoxia began reappearing in the late 1990s. Ongoing monitoring at the sub watershed level has shown that the DRP portion of total phosphorus has more than doubled from a mean of 11% in the 1990s to 24% in the 2000s.[27] A higher ratio of DRP in runoff causes more algal growth than occurs with traditionally tracked forms of phosphorus.

Lake Erie's water quality issues extend beyond just harmful algal bloom events. The central basin of Lake Erie experiences a worrisome depletion of oxygen during the summer, and in 2002 the U.S. EPA joined forces with regional universities and other agencies in the US and Canada to begin addressing this dead zone problem. A "dead zone" is the outcome of anoxic or hypoxic conditions that cause aquatic creatures to suffocate and typically occurs in the late summer.[28]

Research published January 2015 has shown that the relationship between harmful algal blooms and Lake Erie's central dead zone is more complicated than originally understood and that droughts contribute significantly to the prevalence of the Central Lake Erie Basin dead zone. It was found that the 2012 North American Drought, which caused low tributary discharge, was associated with a record-breaking hypoxic event while the 2011 harmful algal bloom was associated with only mild hypoxia. This suggests that more attention should be paid to meteorological factors when considering nutrient reduction strategies, particularly in light of the fact that climate change is likely to increase the volatility of regional weather patterns.[29]

The 2011 algal bloom in Western Lake Erie brought major public and political attention to the problems of HABs and hypoxia. Resulting from a combination of factors – including heavy spring rains and warmer spring and summer temperatures – phosphorus runoff fed a bloom that extended across more than 5,000 km^2 (1,930 mi^2) of Western Lake Erie, an area three times larger than the previously largest bloom on record.[30]

Figure 2.2 Western Lake Erie 2011bloom (NOAA)

In August 2014, harmful algal blooms came to the forefront of national news when the City of Toledo was forced to shut off its water supply to 500,000 metropolitan area residents. The drinking water, sourced out of Western Lake Erie through a near shore underwater intake, was found to be contaminated with microcystin, a toxin produced by the algal blooms in Western Lake Erie.[31] Ironically, the bloom that led to the shut off of the public water supply was much smaller than the 2011 bloom; however, its proximity to the water intake pipe meant once it was swept into the water treatment plant the public health repercussions were felt at a large scale.

Today, we see that while the regulation of point sources initially led to significantly cleaner water nationwide and in Lake Erie, the pace of water quality improvement has slowed as it becomes increasingly difficult to achieve further pollution abatement from point sources. Meanwhile, unregulated nonpoint source pollution has become the leading cause of water pollution.[32] In the Maumee River watershed, where over 80% of land is under cultivation, agricultural nonpoint sources account for the majority of phosphorus loading into Western Lake Erie, primarily from fertilizer application and manure use.

Agriculture in the Maumee River Watershed

According to the 2012 USDA Farm Census, there are 17,349 farms in the Maumee River watershed covering a total of 3,730,213 acres. Of these total farm acres, 86% are harvested cropland, and 14% are out of production. 50% of total harvested acres in the watershed are planted in soy, followed by 36% corn for grain, as well as 3% forage and 2% corn for silage.

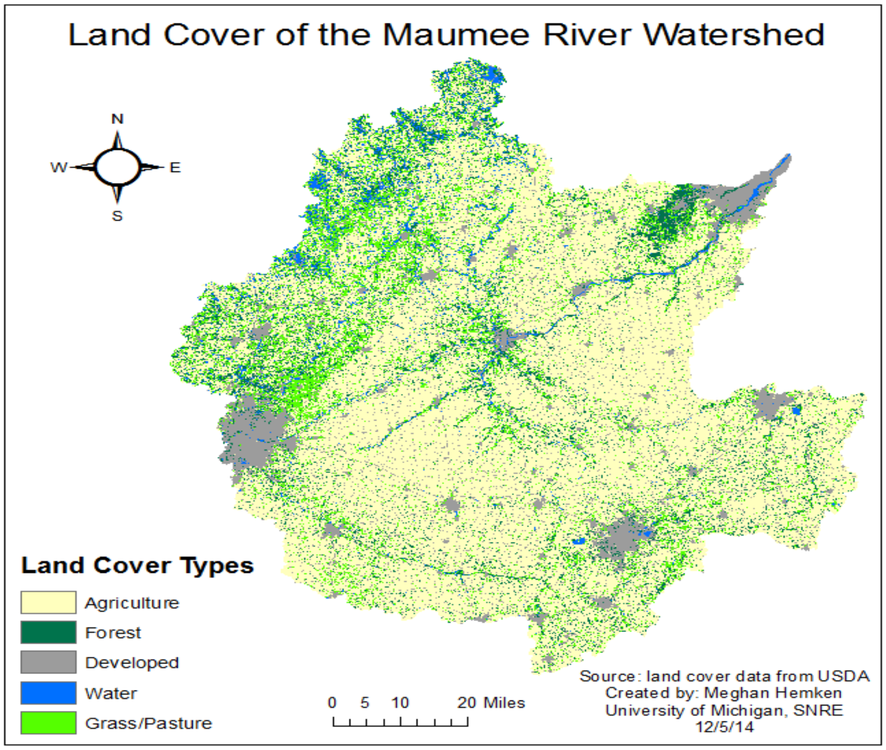
Farm ownership in the Maumee River watershed is dominated by part-time owners, who constitute 71.8% of total farm acres worked, while full-time owners constitute 21.6% and tenant farmers make up 6.7% of total farm acres worked. In the Maumee, commercial fertilizer, lime, and soil conditioners are used on 65% of total farm acres while manure is used on only 6% of total farm acres.

59.5% of farm acres in the Maumee are on farms that are greater than 500 acres in size. This trend is repeated across nearly all of the other watersheds in the region and the 2012 Farm Census data underscores the fact that while the number of farms and total acreage in production have declined across the Great Lakes Basin region since 2007, average farm size has increased.

In comparing the 2012 Farm Census statistics on the Maumee River watershed with nine other similar watersheds in the Great Lakes Basin [see Appendix 2A], the Maumee stands out for having the highest level of participation in federal land conservation programs,[1] with 5871 farms and 128,440 total acres enrolled in Conservation Reserve, Wetlands Reserve, Farmable Wetlands or Conservation Enhancement Programs. For comparison's sake, the second highest conservation enrollment is in the Saginaw watershed with 2,986 farms enrolling a total of 85,122 acres.

The Maumee River watershed is also a leader in total land enrolled in crop insurance programs, with 29% of farms enrolled in such programs (covering nearly 57% of the watersheds total farm acres) in 2012. It is interesting to note that enrollment in conservation programs, both in terms of number of farms and total acres, decreased from 2007 to 2012. At the same time, enrollment in crop insurance went up. These trends may signify a shift in farmer's interest away from conservation funding and towards crop insurance which can cover a farmer's losses in the event of natural disasters or a decline in crop price. This shift may further reflect volatility in the pricing of crops or increasing concern for damaging weather patterns and natural disasters.

The average farm size in the Maumee is greater than 500 acres, with 2,229,923 acres in farms of this size, out the total 3,750,213 acres. This trend is repeated in each other watersheds considered, with the marginal exception of the Menominee, which has 2,601 more farms in the 100-500 acre category than in the >500 acre category. In the Maumee, commercial fertilizers, lime, and soil conditioners are used on 2,442,762 acres while manure is used on 225,218 acres.



Source: land cover data from USDA
Created by: Meghan Hemken
University of Michigan, SNRE
12/5/14

Figure 2.3 Land cover in the Maumee River watershed

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[1] Watersheds included in the Appendix 2A analysis are Maumee, Sandusky, Huron-Vermillion, Saginaw, Muskegon, Kalamazoo, St. Joseph, Menominee, Fox, and Milwaukee.

Nonpoint Source Reduction Strategies

There are a variety of policies in Ohio that manage nonpoint source pollution. The Ohio EPA is the major body concerned with nonpoint source pollution in the state, and has recently formalized its action on nonpoint source pollution with an update to the Ohio Nonpoint Source (NPS) Management Plan approved by the U.S. Environmental Protection Agency in June 2014. This focused the Ohio EPA's actions towards hydro-modification, habitat alteration, polluted runoff, invasive species management and additional stormwater management demonstrations. The Nonpoint Source Management Plan has four sections: urban sediment and nutrient reduction strategies; altered stream and habitat restoration strategies; nonpoint source reduction strategies; and high quality waters protection strategies.

The Ohio EPA highlights the need to improve drainage water management as there is an increasing percentage of farmland that is using subsurface drainage, and this is contributing significantly to nutrient laden run-off. In addition to updates on the farmland, the Ohio EPA suggests the streams should also be managed to improve their capacity to assimilate existing pollutant loads.

The return of algal blooms to Lake Erie and other water bodies has underscored the limits of the CWA, for although the Act retains a system of water quality standards it fails to directly regulate nonpoint sources of water pollution, namely urban and agricultural runoff. Likewise, as an executive agreement, GLWQA has no legal basis for regulating nonpoint source pollution in the US. There has been intense ongoing debate over the question of whether to increase the regulatory strength of the CWA over nonpoint source pollution. Given the environmental health concerns posed by excess nonpoint source runoff, some parties engaged in this debate see possible changes to CWA authority as an opportunity to push innovative pollution management strategies while others see a potential threat to land owner decision-making, state authority, and the complex economics behind agricultural production. Other perspectives include a push for increased investment into existing programs in order to reap the full benefit of current conservation programs.

In 2004, the Great Lakes Interagency Taskforce was created by Executive Order 13340 under President Bush, "to establish a regional collaboration to address nationally significant environmental and natural resource issues involving the Great Lakes… ensur[ing] that their programs are funding effective, coordinated, and environmentally sound activities in the Great Lakes system."[33] While a great deal of positive and creative work has been steered by the Taskforce, the IJC's 2014 report calling for a 41% decrease in annual DRP loads from the 2007-2012 average makes clear there is still a pressing need for further coordinated and innovative action on this issue. [34]

With GLWQA's new offshore phosphorus concentration objectives, new nearshore phosphorus concentration objectives, and phosphorus loading targets for Lake Erie due out in 2016, the stage is being set for action.[35] Addressing DRP will require moving past the phosphorous reduction techniques of the 1970s and utilizing new strategies tailored to prevent the delivery of DRP into the aquatic system and to achieve these phosphorous objectives.

Political Environment in Ohio and the Maumee Watershed

This research is focused directly on the Maumee Watershed to enable specific analysis and comparative evaluation on the efficacy of current programs and the potential for future program implementation for DRP reduction.

There are 17 counties in Ohio that drain into the Maumee River Watershed, as well as two Michigan counties and five Indiana counties. Most of the Maumee Watershed is in District 5, under Representative Bob Latta (R), with some tributary rivers in District 4, under Representative Jim Jordan (R), District 9 under Marcy Kaptur (D) and district 8 under John Boehner (R).[36] Nearly of the Districts of Ohio are registered and vote Republican, with the exception of those Districts around Columbus, Akron, and Cleveland.[37] The State of Ohio has been the site of controversial gerrymandering over the last several years.[38]

Ohio is a swing state and has had Republican and Democratic leaders in the state government and federal representatives. Currently, Republicans outnumber Democrats in the government, including the Governor, John Kasich, as well as all non-judicial statewide elected officials. Republicans also control the Ohio Congress, with 23-10 in the Senate and 65-34 in the House of Representatives. The majority of US Congressional Representatives are Republicans, 13 compared to 5 Democrats. One US Senator is a Republican, Rob Portman, while the other is a Democrat, Sherrod Brown, while most Ohio Mayors are Democrats.[39]

The Executive Branch includes many agencies that influence agricultural and its impact on the environment. This list includes the Department of Agriculture, Department of Commerce, Department of Health, and Department of Natural Resources. Other departments are included peripherally, such as the Department of Insurance, Department of Health, and Department of Job and Human Services.[40]

The State of Ohio is moving forward on these issues, as recent proposals have become bills and bills have become law. The Toledo water shut-off increased the pressure on the state government to regulate the pollution causing the harmful algal blooms. There have been several bills introduced in the past that make it out of the Ohio Congress. On April 2nd, 2015, Governor Kasich signed Senate Bill 1 for implementation beginning June 21, 2015. Among the new changes: the law will regulate fertilizer and manure application in the Western Lake Erie basin, certain publicly owned treatment works will be monitored for phosphorus, and establish research and mandate agency coordination on harmful algae response.[41] The law states that fertilizer, defined as nitrogen and phosphorus, may not be applied:

1. On snow-covered or frozen soil, or
2. When the top two inches of soil are saturated from precipitation, or
3. In a granular form when the local weather forecast for the application area contains greater than a 50% chance of precipitation exceeding one inch in a twelve-hour period, Unless the fertilizer is injected into the ground, incorporated within 24 hours of surface application or applied onto a growing crop.[42]

Chapter 3:
Conservation Practices

Contents

Related Appendixes:

As discussed in Chapter 2, the nutrient of concern in the Maumee River watershed is excess loads of dissolved reactive phosphorus (DRP), a nutrient that is scientifically proven to be the chief culprit fueling harmful algal blooms in Western Lake Erie. As over 80% of land in the Maumee River watershed is currently in farms, we recognize that reducing dissolved reactive phosphorus loads in runoff will require focusing on implementation of agricultural conservation practices on farmlands, specifically ensuring implementation of those conservation practices that are most effective at reducing DRP. Implementation of ecologically effective and economically cost-effective conservation practices across this agricultural watershed can move the system toward achieving the IJC's set target of a 41% reduction in DRP loads coming from the Maumee River Watershed.

3.1 What are Conservation Practices?

The term *conservation practices* refers to a wide range of different science-based land management approaches utilized to reduce runoff from both point and nonpoint sources. While some literature refers to these approaches as best management practices, or BMPs, it is important to note that the concept of BMPs was originally created in relation to storm water control under a 1987 amendment to the Clean Water Act while conservation practices have originated independent of any regulatory context.[43]

Conservation practices fall into two broad categories: structural and nonstructural. Structural conservation practices are built, long-term solutions to runoff from agricultural lands or urban storm water vectors, such as vegetated swales. Nonstructural conservation practices are those approaches that do not require a built component but a specific action, such as applying phosphorus fertilizer in the right amount at the right rate, place, and time.[44] The combination of structural and nonstructural conservation practices enables land use change that can reduce harmful nutrient runoff from both urban and agricultural lands.

Agricultural conservation practices include both structural and nonstructural approaches, with the latter falling into two categories: pre-application practices and post-application practices. Pre-application practices try to prevent phosphorus from entering the ecosystem in the first place while post-application practices attempt to remove or immobilize phosphorus that has already entered the biosphere through vegetative uptake or vegetative filtering.

Individual conservation practices generally attempt to mitigate multiple environmental harms; however, their effectiveness at addressing different environmental concerns varies.[45] As a result, selecting the most effective conservation practices for a parcel of land requires that the chief environmental objective for practice implementation be clearly identified and that tradeoffs be made among soil health, reducing erosion, increasing terrestrial nutrient retention, or other factors in order to achieve the stated management objective. This chapter assesses a range of structural and nonstructural, pre and post-application conservation practices in order to determine which are best suited to achieving desired reductions in Dissolved Reactive Phosphorus within the Maumee River Basin. The chapter then explores constructing per acre cost estimates for these conservation practices, a foundation that will help us consider the marginal costs of DRP abatement in Chapter 7.

3.2 Current Conservation Practice Usage in the Maumee Watershed

Voluntary conservation practice implementation by farmers is currently the leading approach to managing nonpoint agricultural nutrient runoff in the Maumee River watershed. With a wide variety of practices to choose from, implementation by stakeholders largely depends on their physical location, type of agricultural operations, financial circumstances, and attitude toward environmental stewardship.

Conservation districts are local government entities designated under state law to carry out conservation efforts at the county level. Conservation districts offer many forms of support to farmers, with agents regularly helping individual farmers develop conservation plans for their farms and/or advising landowners on appropriate conservation practices for their properties and goals.

Telephone interviews conducted in September 2014 with staff at each of the twenty conservation districts within the Maumee River Basin were used to collect baseline information on current conservation practice usage within the watershed [Figure 3.1], the primary services provided by each district,and their primary funding mechanisms [Figure 3.2].

These interviews gave us a baseline understanding of the broad range of conservation strategies already in place on private agricultural lands across the entire watershed. This baseline information highlights the suite of conservation practices that have been the most popular over the past ten years, chief among them being cover crops, filter strips, no-till/mulch-till, and nutrient management. Of these practices, cover crops and nutrient management were seeing the greatest gains in usage over this time period while filter strip usage was relatively stable across this same time period and tillage practices were in flux depending upon conservation district location. Additionally, by asking conservation districts about the type of assistance they most often provide and their chief funding streams for conservation practice implementation, we were able to confirm that the conservation districts do currently operate in the space of mobilizing federal dollars through combined financial and technical assistance to landowners, noting that state level funding is playing an increasing role in many districts as well. All of this information helped inform our consideration of which conservation practices to include in our later modeling efforts and policy recommendations, as this information comes directly from the frontline of agricultural conservation services in the region of interest.

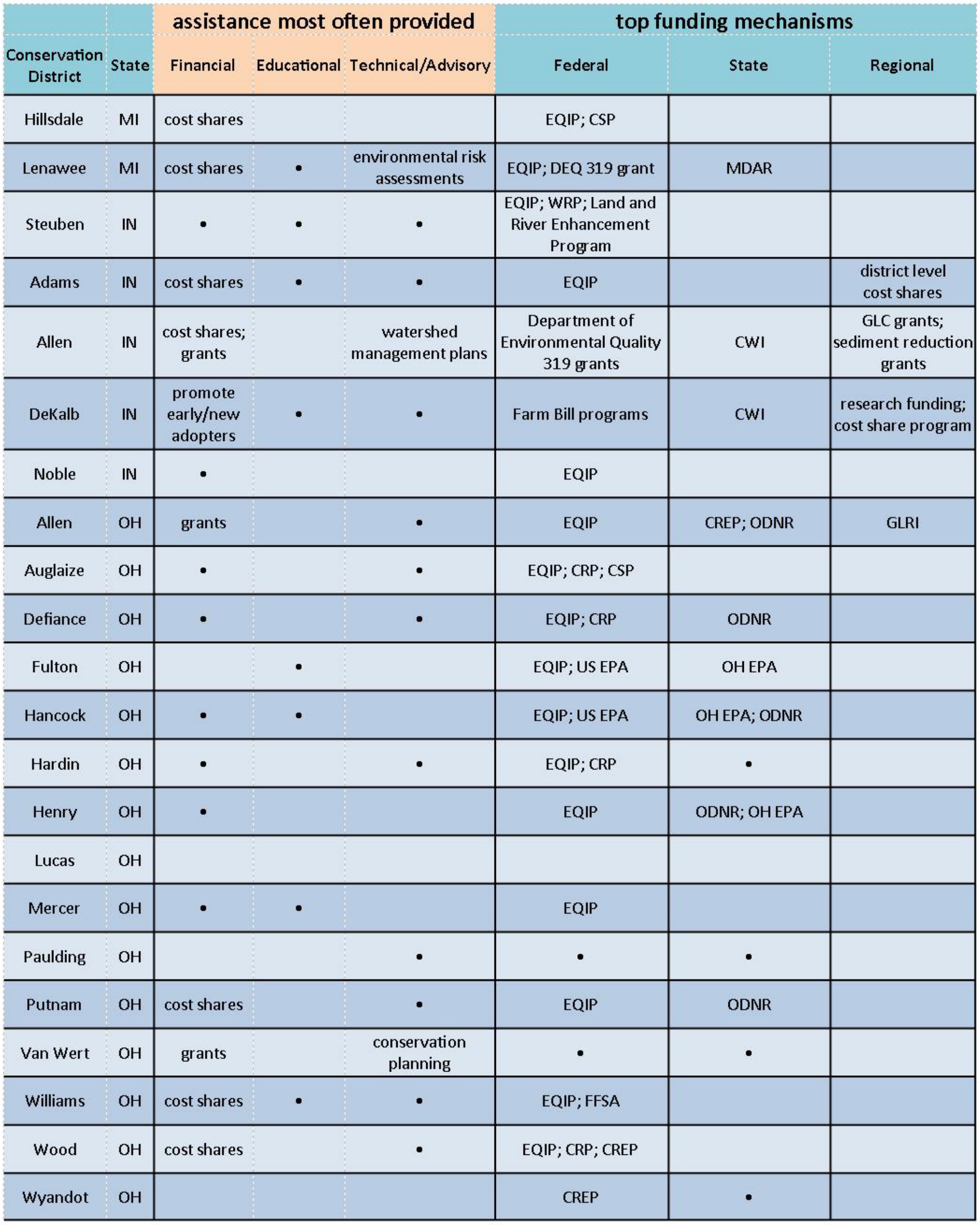
Conservation District	State	Most prevalent agricultural conservation practices (by NRCS code) with observed trends for 2004-2014									
		cover crop (340)	crop rotation (328)	drainage control (554)	filter strips (393)	grassed waterways (412)	no-till or mulch-till (329/345)	nutrient management (590)	pasture and hay planting (512)	tree planting (612)	windbreak/ shelterbelt (380)
Hillsdale	MI	↑				•					
Lenawee	MI	•	•		•			↑			
Steuben	IN	•			↓	↓			•	•	
Adams	IN	↑			↓		•	•			
Allen	IN	•				↓	•	↑			
DeKalb	IN	↑			•	•		↑			
Noble	IN	•					•	•			↓
Allen	OH	↑			•		↑				•
Auglaize	OH	•			•		↑			•	
Defiance	OH	↑			•		•	↑			
Fulton	OH	↑			↑		↑	↑			
Hancock	OH				↓		↓	↑			
Hardin	OH	•	•			•	↑				
Henry	OH	•			•		•	↑			
Lucas	OH										
Mercer	OH	↑									
Paulding	OH	•		•				•			
Putnam	OH	•	•				↑	•			
Van Wert	OH	↑			•	•					
Williams	OH	↑			•	•	↓				
Wood	OH	•		•			•				
Wyandot	OH			•	↑	•					

Figure 3.1: Most prevalent agricultural conservation practices with observed trends 2004-2014

• denotes conservation practice observed as most prevalent

↑ denotes observed increase in usage of a prevalent conservation practice

↓ denotes observed decrease in usage of a prevalent conservation practice



		assistance most often provided			top funding mechanisms		
Conservation District	State	Financial	Educational	Technical/Advisory	Federal	State	Regional
Hillsdale	MI	cost shares			EQIP; CSP		
Lenawee	MI	cost shares	•	environmental risk assessments	EQIP; DEQ 319 grant	MDAR	
Steuben	IN	•	•	•	EQIP; WRP; Land and River Enhancement Program		
Adams	IN	cost shares	•	•	EQIP		district level cost shares
Allen	IN	cost shares; grants		watershed management plans	Department of Environmental Quality 319 grants	CWI	GLC grants; sediment reduction grants
DeKalb	IN	promote early/new adopters	•	•	Farm Bill programs	CWI	research funding; cost share program
Noble	IN	•			EQIP		
Allen	OH	grants		•	EQIP	CREP; ODNR	GLRI
Auglaize	OH	•		•	EQIP; CRP; CSP		
Defiance	OH	•		•	EQIP; CRP	ODNR	
Fulton	OH		•		EQIP; US EPA	OH EPA	
Hancock	OH	•	•		EQIP; US EPA	OH EPA; ODNR	
Hardin	OH	•		•	EQIP; CRP	•	
Henry	OH	•			EQIP	ODNR; OH EPA	
Lucas	OH						
Mercer	OH	•	•		EQIP		
Paulding	OH			•	•	•	
Putnam	OH	cost shares		•	EQIP	ODNR	
Van Wert	OH	grants		conservation planning	•	•	
Williams	OH	cost shares	•	•	EQIP; FFSA		
Wood	OH	cost shares		•	EQIP; CRP; CREP		
Wyandot	OH				CREP	•	

Figure 3.2: Assistance most often provided by conservation district and top funding mechanisms

Acronyms

CREP: Conservation Reserve Enhancement Program	OH EPA: Ohio Environmental Protection Agency
CRP: Conservation Reserve Program	WRP: Wetlands Reserve Program
CSP: Conservation Stewardship Program	EQIP: Environmental Quality Incentives Program
CWI: Clean Water Indiana	FFSA: Fund for Financial Support of Agriculture
EPA: Environmental Protection Agency	GLC: Great Lakes Commission
ODNR: Ohio Department of Natural Resources	GLRI: Great Lakes Restoration Initiative
MDAR: Michigan Department of Agricultural Resources	

3.3 Selecting Conservation Practices for the Maumee River Watershed

As explained in Chapter II, scientific understanding of how land management techniques affect dissolved reactive phosphorus (DRP) loads in waterways has become increasingly vital as the linkages between DRP and eutrophication emerge. Thus, it is important to build understanding of how conservation practices affect DRP.

The sheer volume of available conservation practices made finding a research path based solely on our own assessment of each individual practice difficult. For guidance, we turned to a toolkit developed by Heidelberg University, which compares an array of conservation practices (referred to as BMPs by the toolkit) specifically by rating their DRP reduction potential [see Appendix 3A for the complete toolkit]. We used this toolkit to help us take a coarse look at which conservation practices have the greatest ecological capacity to reduce DRP.

The toolkit scores 30 conservation practices and sorts them into 5 categories: Phosphorus Application Method, Conservation Tillage, Conservation Cropping, Water Management, and Conservation Buffers. We dropped the Water Management category as it is beyond the scope of this investigation and regrouped several of the conservation cropping practices into a Land Retirement category to reflect conservation practices employed under the federal Conservation Reserve Program and Conservation Reserve Enhancement Programs [see Chapter 4 for further discussion of these programs].

Next, we selected a subset of these practices based on whether they are formalized NRCS conservation practices as well as if they can be built into the multi-criteria evaluation model that is part of our larger project methodology.*[2] Our aim is to use the practices' relative DRP reduction scores to select the most ecologically effective conservation practice from each category for inclusion in our multi-criteria evaluation model which we build and utilize for analysis in Chapters 6 and 7.

The toolkit assigns numeric values for the effect of each conservation practice on dissolved phosphorus and storm runoff from fields. The toolkit indicates resulting values should be interpreted as follows:

Field Reduction Rating Potential	
-2	somewhat moderate negative effect
-1	minor negative effect
0	little or no effect
+1	minor positive effect
+2	somewhat moderate positive effect
+3	moderate positive effect
+4	somewhat major positive effect
+5	major positive effect

---

*[2] Creation and utilization of a multi-criteria evaluation (MCE) model in ArcGIS is a critical component of this research project, allowing the incorporation of specific environmental and physical characteristics of the Maumee River Basin to inform prioritization of locations for conservation practice implementation. Slope, precipitation, distance to water, soil drainage class, and phosphorus loading are all incorporated into the model through a weighting scheme that determines the suitable conservation practice for each pixel of land.

The toolkit also ranks *Likelihood of Use* for each conservation practice on a scale of Low, Medium and High, assigning such values by "consider[ing] present cropland economics, current USDA incentive programs for the practice and continued Soil and Water Conservation District assistance with program delivery and practice application." This paper converts those qualitative rankings into numeric scores of Low = 1, Medium = 2, and High = 3.

The toolkit also ranks *Relative Costs* on a Low-High scale. However, Heidelberg provides limited explanation of how these cost ranges are assigned and so this report has dropped Heidelberg's *Relative Costs* and instead presents an original quantitative cost analysis based on Ohio's 2014 EQIP Payment Schedules. This analysis is presented in Sections 3.4 and 3.5.

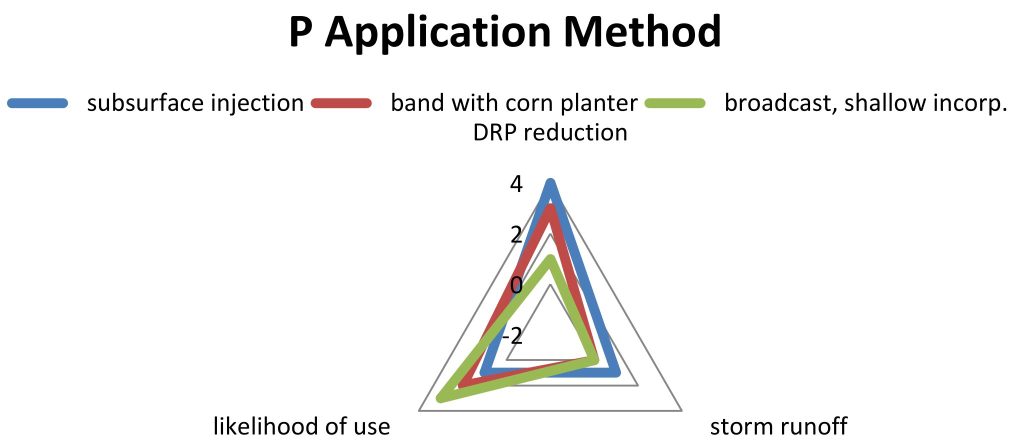
It is important for decision makers to realize that all conservation practices are not equally effective at reducing DRP, controlling storm water, and proving likely for adoption. Therefore, it is useful to help decision makers visualize the extent of tradeoffs by plotting the rankings for each conservation practice under consideration on a multi-axis radar graph.

How to read these radar graphs:

1) Rankings from the Heidelberg University Toolkit are placed in a table.
*note that higher numeric ratings signify a better score on that metric

P Application Method:	DRP reduction	storm runoff	likelihood of use
subsurface injection	4	1	low (1)

2) These rankings translate onto a graph with each axis representing one of the metrics of interest. Conservation practices are listed above the graph and color correspond to the triangles plotted on the graph.



3) Looking at this graph, the reader can conclude which practice ranks highest for DRP reduction (the focal concern for this study) while recognizing tradeoffs in relation to storm runoff reduction and likelihood of adoption.

4) The highest ranking practice from each category by DRP reduction is selected for inclusion in our MCE model (see Chapter 6 and 7).

Phosphorus Application Method

(NRCS Code 590 enhanced nutrient management with deep placement)

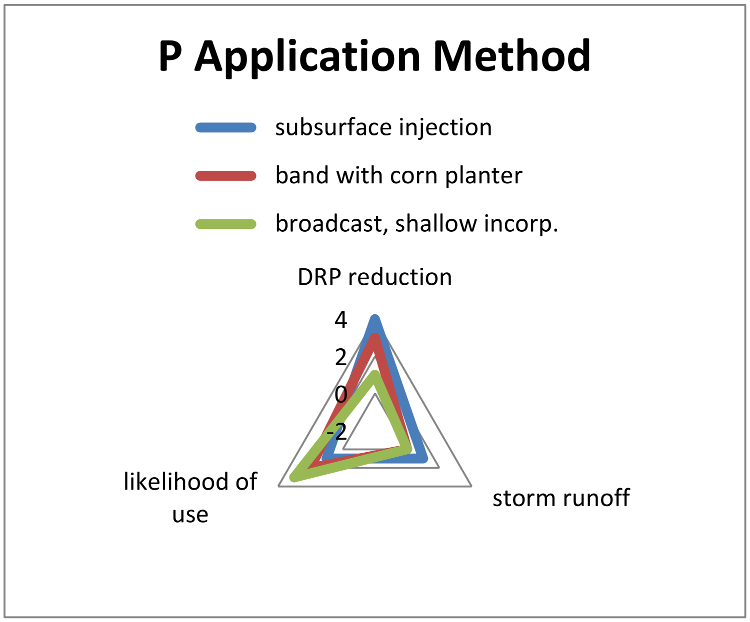


Figure 3.3: Comparison of P application methods

Figure 3.3 highlights an inverse relationship between likelihood of use and DRP reduction ability for a range of Phosphorus application methods. As this report is focused on achieving maximum reductions in DRP, we select the application method with the highest score for DRP reduction, subsurface injection, to include in our multi-criteria evaluation model.

Conservation Tillage

(NRCS Code 345 mulch till basic[3]*; 329 no-till/strip-till)*

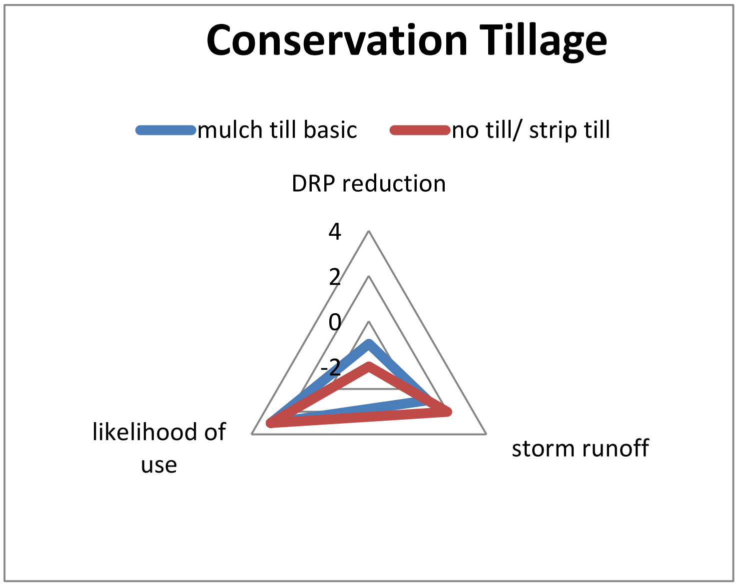


Figure 3.4: Comparison of conservation tillage practices

Figure 3.4 illustrates that conservation tillage practices can have no effect or a negative effect on DRP reduction. At the same time, these practices remain a major part of the dialogue around NPS pollution because of the complications and costs associated with sediment control at the mouth of the watershed. In order to recognize the role played by conservation tillage, we include the higher ranking DRP reduction practice of mulch till for our multi-criteria evaluation model.

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[3] Also referred to as *reduced till* in NRCS resources

Conservation Cropping

(NRCS Code 328 crop rotation; 340 cover crop; 585 strip cropping; 512 forage planting)

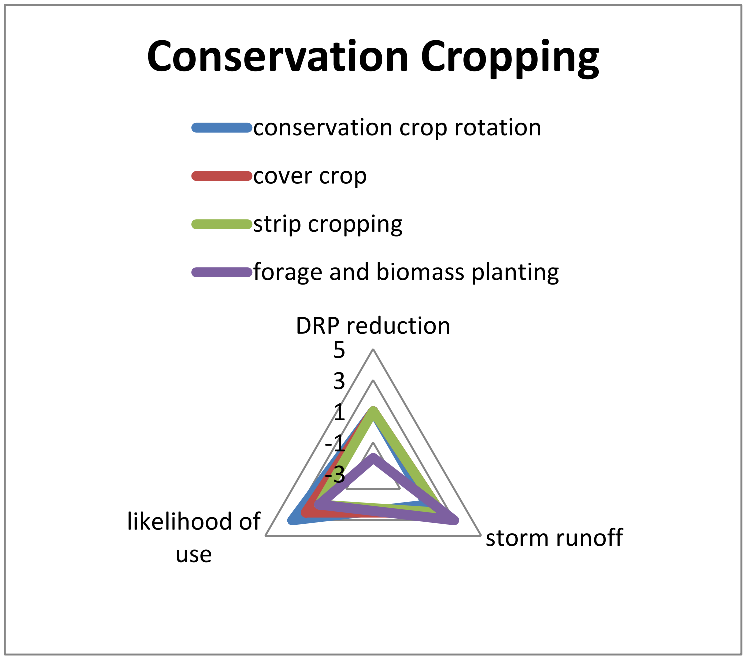

Figure 3.5: Comparison of conservation cropping practices

As three of the four conservation cropping practices show the same DRP reduction score in the graph, we are fundamentally equally interested in each of these 3 practices.

It is important to note, though, that all our analysis of these approaches is limited by the fact that we cannot define the crops that are planted under each approach at the parcel level. Of conservation crop rotation, cover crop, and strip cropping, the integrity of strip cropping and cover crop values is least compromised by this missing data, therefore these practice we select for inclusion in the MCE model.

Retired Land Cover

(NRCS Code 612 tree/shrub establishment, NRCS Code 327 conservation cover)

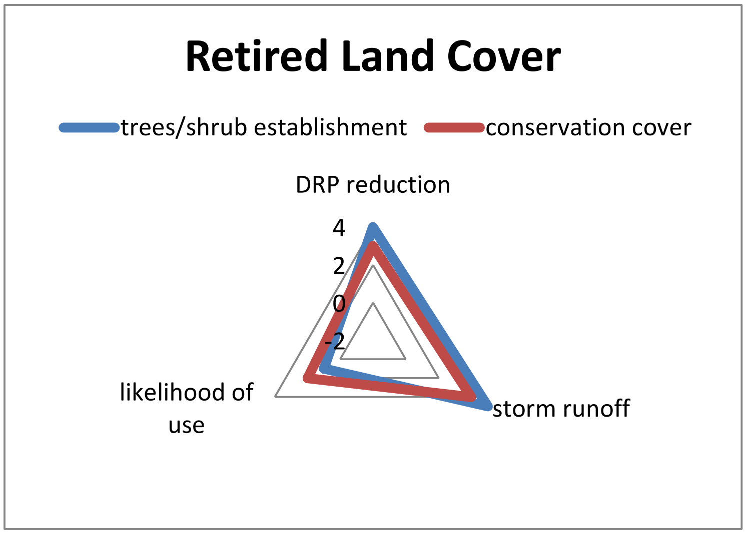

Figure 3.6: Comparison of retired land cover practices

Both tree/shrub establishment and grassy conservation cover are prevalent land retirement approaches that each align with a different strategic federal conservation program (CREP utilizes trees and CRP utilizes grasses). Therefore, our policy analysis in CH 4 and 7 will return to addressing how we parse out usage among these two practices, even though our MCE will only consider tree/shrub establishment as it has the higher DRP reduction score.

Conservation Buffers

(NRCS Code 391 riparian forest buffer; 393 filter strips; 386 field border)

In this figure, we see that riparian forest buffer achieves the highest DRP reduction score and therefore we select this conservation practice for inclusion in our multi criteria evaluation model.

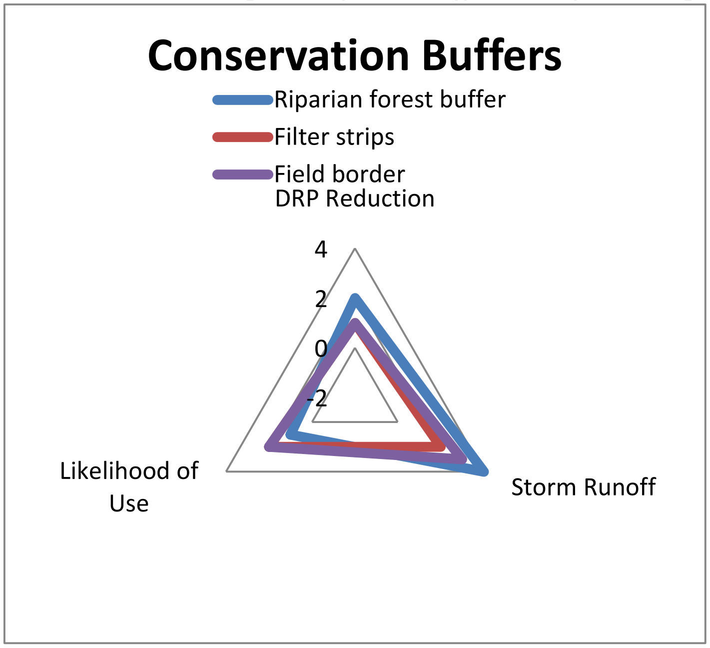

Figure 3.7: Comparison of conservation buffer practices

Looking across all five categories of conservation practices presented here, the five specific conservation practices that represent these categories and are the most effective at reducing DRP are identified to be:

- subsurface injection phosphorus application
- strip cropping
- cover crops
- tree/shrub establishment
- riparian forest buffers

These five practices are therefore included across the further work in this chapter and this report. Mulch tillage was also included as a sixth conservation practice in our analysis, despite a negative DRP reduction score, because of its pervasive use to control soil erosion.

3.4 The Need for Conservation Practice Cost Estimation

While the utilization of conservation practices can help improve local and regional water quality by targeting reductions to DRP runoff, the farm managers who implement these practices are constrained by the individual costs and benefits of such practices. As farm managers tend to favor the idea of implementing those practices that achieve the most positive impact for the least cost, systematic examination of conservation practices' cost-effectiveness is important to discussions of their implementation feasibility. In this study, cost effectiveness is considered a function of the total cost of implementing a conservation practice as well as that practice's efficacy in reducing DRP as shown in section 3.3. Thus, to examine cost effectiveness for conservation practices, we must first define Total Cost values for those practices of interest.

The Total Costs for a conservation practice's implementation and maintenance can vary at the unit, acre, or square foot scale due to site-specific ecological and economic factors. However, regionally-determined sets of Total Cost estimates can be used as proxies to estimate average site-specific values when considering implementation across large geographic scales.

NRCS's Field Office Technical Guides (FOTGs) publish cost values for conservation practices covered under USDA's Environmental Quality Incentives Program (EQIP). These FOTGs-- also known as Conservation Practice Payment Schedules-- set approximate Total Cost values for those conservation practices formalized under NRCS at the state level. This approach of approximating costs using a regionally modified national data set is a methodology found in current natural resource economics literature.[46]

3.5 Using EQIP Payment Schedules to Set Cost Estimates for Agricultural Conservation Practices

So how is a per unit cost figure built for a conservation practice? Since 2011, NRCS has used a standardized methodology to set Conservation Practice Payment Schedule prices for individual conservation practices. This NRCS effort started with building out implementation costs for 15 practices. Since 2012, NRCS has built costs and payment amounts for all conservation practices provided through EQIP.[4] In our quantitative models, we assign a $/acre cost value to each unit of conservation practice implementation in accordance with cost values taken from Ohio's 2014 NRCS FOTG. These values are determined by NRCS through a six-step process:[47]

1) Technical specialists identify all components of a conservation practice's installation and maintenance.
2) National Cost Team assigns incurred cost values for all identified components.
3) Twelve Regional Scenario Teams write scenario descriptions to evaluate if each conservation practice meets the intent of national practice standards.
4) Regional Scenario Teams finalize Payment Schedules using components and costs provided by National Cost Team.
5) Quality Assurance Team evaluates the results and makes any necessary modifications to ensure technical standards and programmatic policies are adhered to.
6) The National Cost Team collaborates with states to integrate payment percentages established by state conservationists and final payment rates for each practice.

The cost values used by EQIP are calculated as a function of six cost categories (nine categories prior to Dec 2013[5]) that account for the average total implementation cost of each particular conservation practice. [48]

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[4] This includes a total of 14 Conservation Activity Plans and 85 other conservation practices

[5] Due to revisions in the 2014 Farm Bill, cost components of *risk*, *operations & maintenance*, and *permitting* were removed from NRCS's BMP cost analysis.

Average conservation practice Total Implementation Cost =
Materials+ Equipment/Installation + Labor + Mobilization +
Acquisition of Technical Knowledge + Foregone Income [49]

(i) Materials: inputs used to make, develop, or implement a practice or activity.

(ii) Equipment: tools, machinery, or similar items needed to implement a practice or activity; calculated regardless of if owned, purchased, leased, or custom use by land user.

(iii) Labor: time and wage rate for hiring individuals or self-labor needed to implement the practice or activity; can be described as cost/hour or fixed contract price for a task.

(iv) Mobilization: cost of moving equipment, materials, and labor to and from the installed practice/activity site as well as site access costs.

(v) Acquisition of Technical Knowledge: cash expenditures to obtain direct technical assistance over and above what NRCS (or similar agency) would typically provide; cost to the land manager of acquiring technical knowledge needed to operate/manage new practice through personal study or educational course, time and other expenditures related to learning how to plan, oversee, and record new farm activities, or related to training; cost of hiring a private consultant or specialist to assist in implementing the practice.

(vi) Foregone Income: annual net income lost or gained from a change in land use, or land removed from production, or the opportunity cost of accepting less farm income in exchange for improved resource conditions due to the practice. Foregone income may be a one-time cost during the installation year or may be an annual cost occurring after the installation year, such as lands taken out of production.

NRCS calculates all of these costs using a wide array of data sources, including contract receipts, contractors, vendors, agricultural suppliers, conservation partners, external cost databases, Internet sources, published catalogs, agricultural statistics, cost estimating models or tools, contract payment records, discipline experts, and other reliable sources.[50] All cost data used by NRCS is documented to include data date, source, and how the cost was determined, with each category defined by NRCS.

While an NRCS code number is assigned to each conservation practice, many practices contain an array of variations and a corresponding range of different cost values. For example, NRCS Code 328 refers to conservation crop rotation, which can range from adding one year of planting perennials to crop rotation at a cost of $70.59/acre all the way up to adding 2 years of specialty crop perennials to crop rotation at $677.05/acre.

Upper price ranges for most conservation practices reflect the costs for obtaining added benefits such as use of organic varietals, native species, pollinator habitat creation, or options for managing specific conditions such as natural wet meadows. While such benefits may incentivize some farmers to absorb the associated additional costs, there is no literature showing if these practices increase uptake of dissolved reactive phosphorus. Without further data to define the feasibility of these variations on the basic practices, we bound our discussion of costs to the “cost floor”, or lowest per acre value option, for each of the conservation practices we examine [for cost data on all conservation practices in the Heidelberg Toolkit, see Appendix 3C].

NRCS Practice Code	Conservation Practice	Cost Range ($/acre)	Cost floor ($/acre)
590	**Nutrient management deep placement (subsurface injection)**	43.62	**43.62**
345	**Mulch till basic**	3.85	**3.85**
585	**Strip cropping**	3.38	**3.38**
340	**Cover cropping**	44.24	**44.24**
612	**Tree/shrub establishment**	491.36 (bare root)- 1282.34 (shrub establishment, bare root)	**491.36**
391	**Riparian forest buffer**	724.75 (direct seeding)	**724.75**

Figure 3.8: Conservation practice cost ranges and $/acre estimates (2014 Ohio EQIP data)

3.6 Normalizing Agricultural Conservation Practice Costs

The range in EQIP cost estimates for conservation practices of interest is over $720—over 140 times the five-point range in DRP reduction scores from the Heidelberg toolkit. As a final step, we normalized these cost to a scale of one (least cost) to five (highest cost). Normalizing costs to the same range as DRP reduction score will allow us to develop a clearer picture of the relative cost-effectiveness of different conservation practices in future chapters. By inverting cost scale values, we are also able to create a 4th axis on our radar graph to reflect cost considerations.

To translate our $/acre values onto a 1-5 scale, we take the natural log of the cost for each practice and normalized the result to a 1-5 scale based on the complete set of practices in the Heidelberg toolkit.

For the purposes of the radar graph in Figure 3.9, we invert all of the resulting scores so that a 5 means “least expensive”—putting our visual understanding of this graph axis in keeping with our visual understanding of the other axes where a higher numeric score is “better” in terms of attractiveness for adoption of that conservation practice. In the figure key, each conservation practice’s cost score is listed after its name in parentheses.

Due to data limitations on the part of information made available by NRCS, we were not able to account for detail within the long term maintenance costs of these conservation practices or accurately capture how the distribution of these costs over time relates to DRP reductions achieved by each conservation practice. As a result, longer term practices such as riparian buffer strips and tree and shrub establishment may appear less cost effective in this analysis than they really are due to our inability to quantitatively account for long term impacts

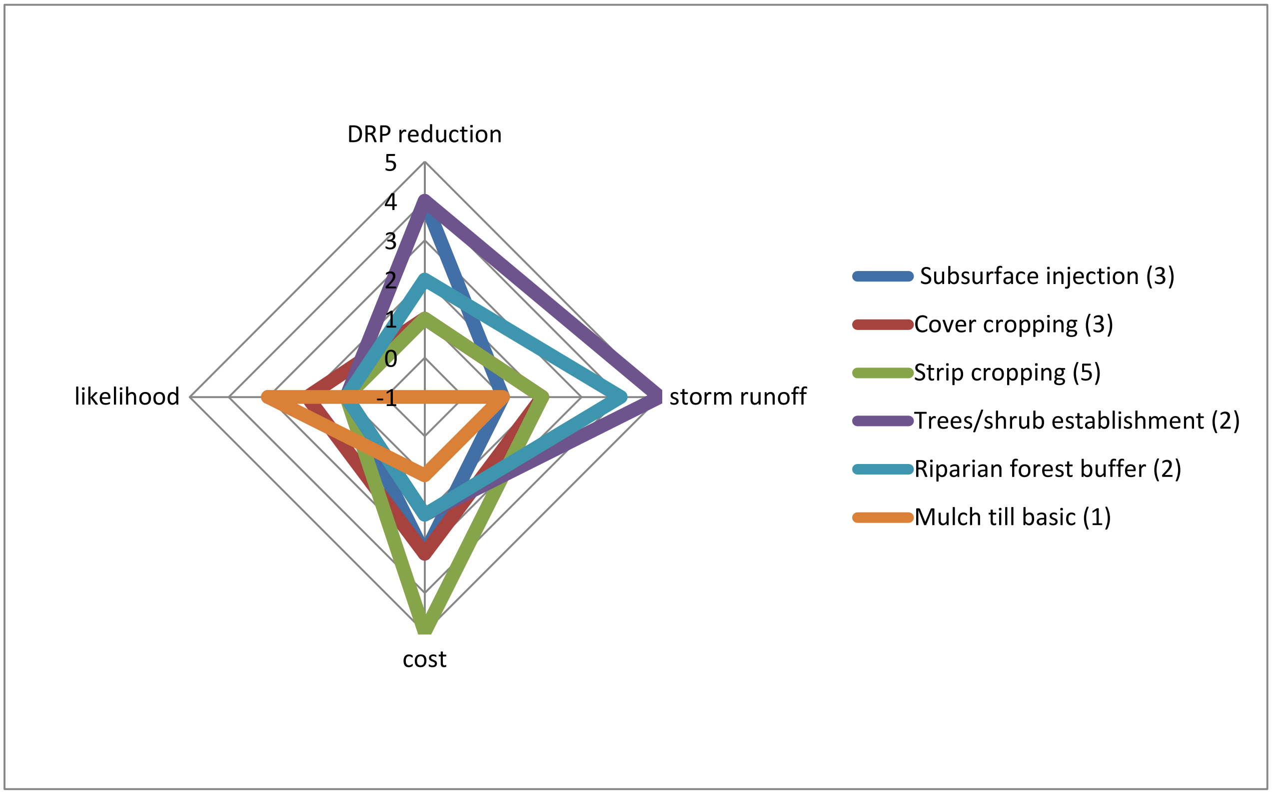

Figure 3.9: Agricultural conservation practices for inclusion in multi-criteria evaluation model
** numbers in parenthesis denote 1-5 cost score as described in this section.
1= most expensive, 5= least expensive

Chapter 4:
Policy Tools and Case Studies

Contents

A quantifiable target of 41% reduction in annual dissolved reactive phosphorus (DRP) loads has been set by the International Joint Commission for the Maumee River (see Chapter 2.4) and we have established a quantitative understanding of the composition of the Maumee River watershed as well as the agricultural conservation practices best suited to reducing DRP (see Chapter 3). Thus, the next question becomes what policy approaches can assure implementation of these conservation practices at the watershed scale in order to help in achieving the DRP reduction target. From voluntary programs to regulatory actions, we explore possible strategies and tools for increasing implementation of land management practices that can reduce DRP loads.

4.1 Introduction to the Spectrum of Policy Options

While decades of federal and state agricultural policies as well as market forces have contributed to existing environmental challenges in Western Lake Erie, policy change can be an avenue for advancing farmers' role as environmental stewards, conservationists and benefactors of a healthy regional future. Policy change can help ensure conservation land management behaviors occur at the scale necessary to achieve desired ecological health outcomes.

Policies that influence agricultural land management practices range from voluntary incentives to mandatory regulation, and has historically been largely voluntary in the Maumee River Basin where many federal and state programs leverage Farm Bill funding into environmentally protective landowner actions addressing erosion, sediment control, habitat creation, and drainage/runoff/water management. At the same time, regulation over specific activities such as animal feedlot sites has proved successful in instituting positive changes in management behaviors and achieving desired environmental outcomes.

Our challenge in this project is to determine what policy tools or programs can help generate desired ecological goals in the context of the predominantly agricultural Maumee River Watershed. The policies examined here range in how they incentivize and/or require land management actions that encourage long-term stewardship and reduced nutrient runoff into the Maumee River Basin, from voluntary to regulatory, and operate at a variety of levels of government, from federal to state to local.

Case boxes draw off of existing examples of policy implementation in other U.S. states, offering insights and considerations for utilizing approaches in the Maumee River Basin watershed. Two of these case studies, TMDLs and litigation, describe policies that can be used to set target limits on phosphorus loading. The remainder, land retirement, nutrient management planning, water quality trading, and phosphorus taxes, serve as mechanisms for achieving these targets once they have been set. Appendices provide additional information on possible program components and policy landscape considerations.

Figure 4.1: The spectrum of policy options

4.2 Land Retirement

Land retirement presents a conceptually simple approach to reducing nonpoint source pollution: simply remove the acres that are responsible for pollution from agricultural production. Federally supported land retirement programs originated in the mid-20th century with the dual goals of preventing the overproduction of agricultural commodities and reducing the cultivation of highly erodible soils. These "set-aside" programs required that farmers devote a portion of their land to conservation uses in exchange for direct payments or in order to qualify for federal or state benefits such as loans.[51] Increases in commodity prices led to the elimination of exclusively economically focused programs by the mid 1990's. However, two Farm Bill programs, the Conservation Reserve Program (CRP) and the Conservation Reserve Enhancement Program (CREP), persist as the most significant mechanism for land retirement in the US. Both are designed to achieve environmental quality, rather than commodity price, goals.

Case Box 1: LAND RETIREMET IN PRACTICE
Conservation Reserve Program and Conservation Reserve Enhancement Program

First authorized in the 1985 Farm Bill, the Conservation Reserve Program pays participating farmers to take highly erodible or otherwise environmentally sensitive land out of production for an extended period. The program is administered by the USDA's Farm Service Administration (FSA), with technical support provided by NRCS, state forestry agencies, local conservation districts, and others including non-federal parties. Farmers sign contracts with the FSA in which they agree to retire acres and institute certain basic conservation practices (generally maintaining or establishing vegetative cover) in exchange for a per-acre annual rental payment. Most of these are 10 year contracts.[52]

There are two avenues through which farmers can participate in CRP: general sign-ups and continuous sign-ups. Most participants enroll in CRP during general sign-ups, competitive bidding periods in which the FSA accepts offers from all eligible farmers who are interested in enrolling acres in the program. The FSA scores each offer using an Environmental Benefits Index (EBI) that takes into account the wildlife, water quality, air quality and erosion benefits of removing the land from production; the likelihood for conservation practices to remain in place after the contract period ends; and the size of the rental payment that the farmer has requested in order to participate (up to legislatively-defined maximum payments). At the conclusion of each general sign-up period the FSA sets an EBI threshold and accepts the offers with EBI scores above this threshold. Nation-wide, general sign-up rental payments averaged $51.09 per acre in 2014.[53]

CRP enrollment is highly influenced by commodity crop prices. The Farm Bill sets an annual cap on the maximum number of acres of farmland that can be enrolled in CRP in a given year, and authorizes the FSA to spend as much as is needed to enroll up to this level of acres in the program each year. In the most recent (2014) Farm Bill, this enrollment cap is set to decline from 32 million acres in 2014 to 24 million acres in 2018. However, since 2008, increasing commodity prices have reduced farmer's willingness to remove land from production, making it difficult to meet CRP enrollment goals. In 2014 the program enrolled a total of 25.4 million acres nationally, just 79% of the enrollment cap. This decline has occurred despite the fact that the FSA accepted a higher portion of the acres offered by farmers in the 2013 general sign up than in the 2012 sign up (88% as opposed to 85%), and that the enrolled acres had a lower average Environmental Benefits Index score (268 as opposed to 278 points).[54]

In contrast, the Conservation Reserve Enhancement Program (CREP) uses continuous sign-ups which allow farmers to enroll specific environmentally-sensitive land types in the program at any time. In CREP, the FSA partners with state governments to address specific environmental concerns within defined geographic areas. In contrast to CRP general sign-ups, CREP participants may be required to implement more extensive conservation practices designed to mitigate the relevant environmental impact. CREP rental payments are significantly higher, averaging $136.70 per acre nationally in 2014.[55]

Land retirement in the Maumee River Basin

CRP is currently the largest mechanism for land retirement in the Maumee River Basin. As of the end of 2014, 65,060 acres were enrolled in CRP programs in ten Ohio counties drained by the Basin.[56] Further acres are enrolled in the Lake Erie and Streams CREP agreement between the USDA and the state of Ohio, which is specifically designed to improve Lake Erie water quality through 14 and 15-year contracts requiring enrolled farmers to convert croplands to native grasses and trees.[57]

In its 2011 report "*Feast and Famine in the Great Lakes,*" the National Wildlife Federation recommended reversing this trend, arguing that an expansion of CRP enrollment would be a useful tool to address nutrient pollution in the Great Lakes.[58] However, market forces and existing program structures may limit future program enrolment and compromise the program's actual effectiveness at decreasing the chief nutrient pollution issue the Maumee River Basin faces, namely dissolved reactive phosphorus (DRP) runoff.

The overall efficacy of CRP and CREP are limited by decreasing enrollment. Paralleling national trends, the number of acres in CRP has dropped across the ten Ohio Maumee River Basin counties from a peak of 87,350 acres in 2007 to 65,060 acres in 2014. This represents a 25.5% decrease in enrolment over a seven-year period.

Most nonpoint source DRP in the Maumee Basin originates from intensively farmed low-slope farmlands in the center of the watershed. However, as it is currently structured, CRP disproportionately enrolls low-productivity high-slope lands.[59] Given high commodity prices, farmers tend to enroll in CRP the acres from which they expect the lowest yields and keep higher-yield lands in production. Surveys of Northwestern Ohio cropland cash rents prepared by Ohio State University Extension illustrate this point. Cash rents, which are highly correlated to commodity prices and input costs, averaged $140 per acre for "poor quality" farmland in 2013. This value came close to the national average CREP rental payments of $136.70 per acre. However "top quality" cropland rented for an average of $245 per acre, over $100 per acre more than the national average CREP rental payments.[60]

In addition, the Environmental Benefits Index used during CRP general sign-ups is structured to prioritize enrolling lands that are susceptible to soil erosion. The Lake Erie and Streams CREP lists reducing sediment runoff as its primary and only quantified goal. While the higher-slope acres on which most erosion occurs may be the point of origin for larger amounts of attached phosphorus, these acres are likely less responsible for DRP loading.

Recommendations

Use CREP to implement selection indexes that prioritize high DRP runoff acres. The FSA uses a single EBI nationally, making it at best a blunt instrument to further regional ecological goals. Adjusting the Index to better reflect conservation priorities in the Maumee River Basin by emphasizing water quality impacts could require significant compromise with priorities in other regions. As a result, efforts should focus on refining and expanding regional CREP programs to enroll more of the high-productivity, low slope acres from which a larger portion of the DRP in the basin originates, and providing the funding necessary to offer market-rate rents on those acres.

Allocate funding to retire high-productivity acres. The types of farmland with the highest per acre levels of DRP runoff are likely also highly productive. In order to secure enrollment of these "top quality" acres, rental payments would have to be sufficient to account for the additional income farmers would forgo by enrolling these lands in CREP.

4.3 Nutrient Management

Nutrient management plans (NMPs) define a site-specific conservation plan for nutrient use that optimizes economic benefits while minimizing environmental impacts.[61] Nutrient management planning ensures a reduction in the application of excess Nitrogen and Phosphorus to a land parcel through use of soil tests to determine soil nutrient deficiencies, attention to appropriate timing of nutrient application, and employment of site-appropriate best management practices.

The cornerstone for nutrient management in the U.S. is the NRCS 590 Nutrient Management Planning Standard, which is used by NRCS staff when providing technical assistance or implementing federal conservation programs. While the NRCS 590 Standard applies nationally, NRCS also works at the state level to supplement 590 guidance to local conditions, resulting in the majority of states issuing their own 590 Standard that supersedes the federal standard. Participation in NRCS nutrient management programs is currently voluntary for the majority of U.S. crop agriculture under cost share programs such as the Environmental Quality Incentives Program (EQIP), though notable examples of mandatory nutrient management programs are discussed below.[62]

Comprehensive Nutrient Management Plans (CNMPs) are conservation plans applying specifically to animal feeding operations (AFOs) laying out how an owner/operator will manage manure from production to application or disposal. [6] If an AFO discharges manure or wastewater into a natural or man-made ditch, stream, or other waterway, it is defined as a Concentrated Animal Feeding Operation (CAFO), regardless of its size. This is an important point as all CAFOs are defined as point source dischargers under the 2003 revisions to the Clean Water Act. As point sources, they are regulated under the state EPA and each owner/operator is required to hold a National Pollutant Discharge Elimination System (NPDES) permit under the state program. As of December 31, 2006 all CAFOs applying for and covered by a NPDES permit are required to develop and implement an up-to-date CNMP describing the practices and procedures that will be implemented to meet all of the production and land application requirements that apply to a specific operation. [63] CNMPs are updated every 5 years.

Components of CNMP	Issues addressed
Manure handling/storage plan	1. Diversion of clean water 2. Prevention of leakage storage plan 3. Adequate storage 4. Manure treatment 5. Management of mortality
Land application plan	1. Proper nutrient application rates to achieve a crop nutrient balance 2. Selection of timing and application methods to limit risk of runoff
Site management plan	Soil conservation practices that minimize movement of soil and manure components to surface and groundwater
Record keeping	Manure production, utilization, and export to off-farm users
Other utilization options	Alternative safe manure utilization strategies such as sale of manure, treatment technologies, or energy generation
Feed management plan	Alternative feed programs to minimize the nutrients in manure

Figure 4.1: Comprehensive Nutrient Management Planning (EPA)

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[55] Table from http://www.epa.gov/agriculture/ag101/impactcnmp.html

While broad adoption of nutrient management planning can help reduce agricultural nutrient runoff in a watershed, the upfront costs nutrient management planning places on farmers understandably presents a disincentive to voluntary development of such plans. Therefore, financial incentive structures must be clearly in farmers' economic best interest in order to secure participation. Leveraging county, state, or regional regulatory authority alongside a financial incentive is often an approach to ensuring timely and large scale enrollment in financial incentive programs, resulting in maximum participation at a minimum cost to farmers.

Case Box 2: MANDATORY COUNTY NUTRIENT MANAGEMENT IN PRACTICE
Wisconsin Programs

With the passage of a state law in 2005 and enforcement starting in 2008, Wisconsin requires all cropland to have a nutrient management program, though farmers can only be compelled to comply if their county government provides a cost share program under Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP). These cost share programs are designed to cover at least 70% of a farmer's annual nutrient management costs (90% if there is economic hardship) or alternatively offer up to $7/ac for 4 years, after which the state may require the farmer to continue practices at his or her own expense.[1]

Nutrient management may also be required outside of cost share counties if a farm is:

1. Causing a significant discharge
2. Regulated by local manure storage/livestock siting ordinance or DNR WPDES permit
3. Accepting nutrient management planning or manure storage cost share funds
4. Participating in the Farmland Preservation Program.

Wisconsin county governments apply annually to DATCP to access nutrient management planning cost-share dollars. When the program began in 2006, it was funded at half a million dollars; vocal lobbying by the environmental coalition during 2008-2009 state budget debates increased the program funding to $5 million.[1] Following this dramatic increase in funding, the national economic crash and subsequent state budget constraints have limited actual payouts to approximately $2 million/year as the other $3 million get annually reallocated to more immediate agency needs.

According to the 2014 annual report issued by DATC, 6,053 nutrient management plans were filed in 2014 across 2,583,737 acres, meaning 28% of Wisconsin's croplands are currently covered by nutrient management plans.[1] Considering that only 800,000 acres were covered in 2006, the cost-share program is clearly increasing agricultural acreages covered by nutrient management plans.[1] Over 80% of the nutrient management plans written in 2014 used Snap Plus, a software designed for use by farmers in preparing their plans in accordance with Wisconsin's 590 Nutrient Management Standard [see Chapter 5], suggesting the tool provides useful assistance to farmers in the development of nutrient management plans.[1]

As noted above, Wisconsin's Farmland Preservation Program (FPP) has also proven a major entry point for farmers' nutrient management planning. This program, founded in 1977 and housed under the WI Working Lands Initiative since 2010, pays farmers who keep lands in agricultural use an annual income tax credit ranging from $5-10/acre for all of their land, including both farmed and unfarmed acres.[1] As of 2009, FPP began requiring that enrollees also maintain compliance with soil and water conservation requirements, including nutrient management planning. FPP provides tax relief to nearly half of Wisconsin's total farmlands, specifically to acres located in state-designated "agricultural enterprise areas" or zoned for farmland preservation.

Looking at these programs side by side, there is some administrative confusion that must be addressed. The state DATCP says 28% of Wisconsin farms are under nutrient management plan, according to the records on current cost share programs reported by each participating county, but FPP makes income tax payments to half of Wisconsin's total farmlands. How to account for the missing 22%?

FPP has required nutrient management planning since 2009 for continued collection of income tax credits, but the Department of Revenue is the only state office with data on who is collecting income tax credits—and they are not legally allowed to share this data with the counties responsible for checking on landowner nutrient management planning. For landowners who have enrolled in FPP after 2009, this is not a problem as they must obtain a certificate of compliance from DATCP. But for those property owners grandfathered in under the old FPP program, it is very difficult to track which landowners are collecting income tax credits without having a nutrient management plan in place.

The income tax credit payments under the 2009 FPP are higher per acre, so it is in the economic best interest of participants to become compliant at the new tax credit values, and yet misunderstanding persists among many non-compliant program participants. DATCP is using their county level records to help identify and bridge this gap over time.

While the increasing enrollment statistics for Wisconsin are encouraging from a programmatic perspective, it must be recognized that the program does not provide for any edge of field monitoring structure to measurable changes in nutrient loads or overall water quality as a result of increased nutrient management planning.

Determining the appropriate level for instituting a mandatory nutrient management program is difficult and requires understanding of both the ecological scale of the nutrient issue being addressed as well as the landscape of political will and agency capacity for meaningful action.

Case Box 3: MANDATORY STATE NUTRIENT MANAGEMENT IN PRACTICE
Pennsylvania, Maryland, Delaware

The Chesapeake Bay estuary has long suffered the harmful effects of urban and agricultural runoff from its massive 64,000 square mile watershed which spans 6 states (MD, VA, DE, NY, WV, PA) and the District of Columbia. While nutrient loads into the Chesapeake Bay today are regulated under a watershed-wide TMDL [see Case Box 6], state-level regulation of agricultural nutrient management started back in the 1990s.

With passage of the Pennsylvania Nutrient Management Act (1993), PA became the first Bay state to regulate agricultural nutrients. Foreshadowing regulations that later emerged under 2003 CWA revisions, the Act required all CAFOs to file nutrient management plans with the state.[64] The Achilles heel of this Act was that it only applied to CAFOs with animal densities of 5 AEU ha, a *very high* value considering average animal density on CAFOs in the Bay was at 0.58 AEU ha.[65] Farms below this threshold were left with traditional voluntary measures and existing economic incentives, so the Act had no effect on the majority of manure production and application in the state.

The Maryland Water Quality Improvement Act (1998) mandated nitrogen and phosphorus nutrient management planning at more reasonable scales than the Pennsylvania Act, setting a minimum size of 8 AEU ha or nutrient applications >4 ha which thus affected nearly all of Maryland's commercial agricultural operations. This requirement dictated the use of a state phosphorus indexing tool (P Index) to determine potential P losses from affected agricultural land and was pushed through in response to the pfiesteria fish kills that dominated public attention in 1997. Implementation of the Act suffered from its impossibly ambitious timeline of seeking 100% compliance in only 3 years as well as the total lack of any reliable P index at the time of the Act's passage.

The Delaware Nutrient Management Act of 1998 was conceived alongside the Maryland Act but achieved more positive initial results. The Governor of Delaware formed an Agricultural Industry Advisory Committee on Nutrient Management, composed almost entirely of DE farmers, and charged them with developing recommendations for future state action. The resulting recommendations affected farms of the same sizes as the Maryland law, though DE went for a slower implementation schedule in order to encourage the majority of farmers to get voluntarily onboard. DE also offered cost-share funds for farmers to hire certified private sector planners, created a publically funded manure transport program, and required certification for nutrient users. These efforts were hailed by participants and the public as a success, though the government's subsequent enforcement efforts proved to be anemic as political will dissipated on assuring adequate enforcement or completing the enrollment process for program latecomers.[66]

Nutrient Management in the Maumee River Watershed

Since the mid-1980s, the Maumee River watershed has relied on a voluntary nutrient management paradigm to manage runoff, improve soil health, and reduce P loads from agricultural lands.[67] Each state in the Maumee River Basin (MI, IN, and OH) has developed a unique nutrient management policy and these are briefly reviewed below to ground our understanding of the current playing field and future options for furthering nutrient management.

Of the three states in the Maumee River Basin, Michigan is the only one to maintain only voluntary state nutrient management programs (other than those required for CAFOs). Michigan funds an income tax credit Farmland Preservation Program through the Michigan Department of Agriculture and Rural Development (MDARD). Participation in the Michigan program does *not* require conservation compliance on enrolled acres, though it could hypothetically imitate the Wisconsin FPP 2009 revision and add this requirement at a future date. At this time though, such a change seems unlikely. As noted by a Hillsdale Conservation District technician, "if you farm, you have to keep records, so in Michigan we are not pursuing ways to force [nutrient management planning] as some are in Indiana and Ohio…we are into rewarding preemptive actions as opposed to regulating."[68] This attitude is evident in the structuring of the Michigan

Agricultural Environmental Assurance Program (MAEAP) which encourages farmers to voluntarily identify risks on their farm, receive technical assistance in addressing that risk, and be recognized for their actions. While the program is a definite presence in Michigan (see Appendix 4B), it does not explicitly push formal nutrient management planning nor does it offer financial incentives for participation.

Ohio likewise points to existing CNMP measures as sufficient for addressing nutrient management concerns. Funding associated with Great Lakes initiatives including the Great Lakes Restoration Initiative has increased incentives for voluntary action at the state level over the past several years, though not expressly as a specific push for nutrient management plan filing. In June of 2014, Ohio moved into the arena of state-level regulation with the passage of Senate Bill 150 which mandates state certification for application of commercial fertilizers. This is a major shift from strictly voluntary programs, though the reach of the new law is limited by the fact that the final version of the law does NOT apply to manure applications. A former version of Ohio SB150 contained a measure that would have also required all certificate holders to file nutrient management plans but this measure was struck from the final version of the law. As noted by NRCS staff member Eric Shank, the issue was a lack of agency capacity to provide technical assistance in forming so many plans and monitoring their use, in spite of Ohio's ongoing efforts to get more certified crop advisors into position to be able to write those plans (currently approximately 20-30 people in a six county area).[69]

Indiana has gone the furthest of the three Maumee River Basin states in utilizing a more regulatory approach to nutrient management. In 2010, Indiana passed a law requiring all applicators of commercial fertilizers and manure to complete a training course and receive certification by the state. Indiana also maintains a state Nutrient Reduction Strategy (under Indiana State Department of Agriculture and Indiana Department of Environmental Management) that keeps tabs on all funding and efforts related to nutrient reductions across the state and prioritized watersheds.[70]

Case Box 4: MANDATORY NUTRIENT MANAGEMENT IN PRACTICE
Chesapeake Bay Watershed

With the passage of the Chesapeake Bay Total Maximum Daily Load (TMDL) on December 29th 2010, which established a strict "pollution diet" for the entire watershed, the Chesapeake Bay has become the nation's leader for crafting and implementing agricultural nutrient management regulations. The Bay TMDL is the product of more than 25 years of ongoing efforts to address the issues of nonpoint source pollution in the Chesapeake Bay and is the largest TMDL developed by the EPA.

By establishing legally-binding Bay-wide reduction targets for nitrogen and phosphorus, the EPA forced stronger nutrient regulations at the state level. Under the TMDL, EPA requires each of the states in the watershed to develop Watershed Implementation Plans (WIPs) that achieve allotted amounts of the total watershed-wide reduction requirements on a set Bay-wide timeline.[71]
This top-down approach has brought renewed vigor to states' existing nutrient management laws as well as driven creative new approaches to assuring that agricultural producers file and

adhere to nutrient management plans. Maryland, for example, expanded its standing laws from the 1990s to require all farmers grossing $2,500 a year of more or livestock producers with 8,000 pounds or more of live animal weight to follow nutrient management plans (NMPs) when fertilizing crops and managing animal manure. These plans specify how much manure, fertilizer, or chemical nutrient may be safely applied to crops to achieve yields and prevent excess nutrients from impacting waterways.

Because of their complexity, nutrient management plans must now be prepared by a certified University of Maryland specialist, certified private consultant for hire, or farmer who is trained and certified by the Maryland Department of Agriculture (MDA) to prepare his or own plan.[72] While MDA's frontline objective is to ensure farmer access to technical assistance, training programs, and certification programs, the department does hold legal enforcement authority and may levy fines and penalties, take administrative actions before the Office of Administrative Hearings, and file for civil or criminal proceedings in state court in the case of non-compliance.[73]

Recommendations

Transition MI, IN, and OH to using a common 590 Standard. In order to facilitate more rapid assessment of specific nutrient management practices and spatial distribution of participation at the full watershed scale, the Maumee River Basin states should develop and use one common 590 Standard. This Standard should be designed to be explicit as to the set of management behaviors needed to achieve desired reductions in DRP rather than soft balling the 590 Standard's language into a vague and non-committal standard that may prove politically easier to enact but incapable of achieving desired reductions in NPS nutrient pollution.

Give agricultural stakeholders' concerns and ideas a voice in policy making. A great deal of research has been conducted in the Maumee River Basin on farmers' perceptions of nutrient management issues. This body of knowledge on social acceptability, economic obstacles, and perceptions of risk should be communicated more effectively to state lawmakers in the case that legislation requiring stricter and more widespread nutrient management programs is prudent.

Involve regional farmers directly in regulatory design. Improve the transparency and palatability of any mandatory program by appointing a tri-state planning committee that places agricultural stakeholders in the position to craft a wise and functional management standard.

Assure consistent and sufficient funding support for program enrollees. Whether refining an existing voluntary program or developing a county/state/watershed mandatory nutrient management regulation, make financial benefits to farmers exceed the upfront costs of developing and implementing a nutrient management plan. Simultaneously, set costs for non-compliance high enough to encourage compliance.

Ensure sufficient agency staff capacity exists for effective monitoring of on the ground efforts. Any policy's efficacy is dependent upon the feasibility of implementing agencies enforcing and maintaining adequate monitoring of on the ground actions. Such efforts may require interagency coordination on data collection and management as well as careful consideration of how to avoid situations where privacy laws prevent one office from being able to share enrollee information with another office when both are instrumental to policy program execution.

4.4 Phosphorus Tax

A tax creates an incentive to reduce use of the taxed product. A state tax wouldn't significantly increase the cost of the corn throughout the country but could affect the use of phosphorus in the state of Ohio. The basic tenets of supply and demand suggest that as the input cost of phosphorus increases, the farmer will use it less.[74]

While a Phosphorus Tax has not yet been utilized in the United States, there is reason to consider a tax as a possible mechanism for reducing phosphorus runoff. Phosphorus is a limited resource with over 90% of minted phosphate going toward agricultural uses. Alarmingly, given the current inefficient nature of phosphorus use on farms, only about one-fifth of the total mined phosphorus becomes food.[75] This means there is a significant amount of phosphorus that leaves fields as runoff and therefore a large margin for reduction. This reduction could be effectively achieved through a tax because the increase in price to farmers of purchasing and using mineral phosphorus fertilizer could motivate them to purchase less and be more efficient utilizing only the minimum necessary amount of mineral phosphorus fertilizer application. Below is a review of how the implementation of such a tax might impact the Maumee River Basin and Sandusky watersheds in Ohio. This review is of the application of a national tax, but it is important to consider this as an option for state action.

Understanding the Impact of a Tax on Phosphorus Use

The challenge in discussing a tax on phosphorus use is determining how to implement a phosphorus tax, and what such a tax would look like. Using a Pigovian type tax, authors Shakramanyan et al evaluate the potential of internalizing the damages caused by phosphorus runoff into the price of phosphorus.[76] An internalization rate can range from zero to 100% of the cost of the externalities. If the external costs are not known, however, it can be challenging to justify a high internalization rate. In their model, the authors use a 50% internalization rate. Their model shows that at in an extreme implementation scenario, a 10 fold price increase in phosphorus and full taxation, U.S. production decreases 7% while prices increase by 8%. It is important to recognize that these numbers are an extrapolation about the impact of a national tax, the impact of a state tax would not include corn price increases. This is a valuable consideration however, in evaluating the potential impact of a phosphorus tax because it does demonstrate the impact it could have.[77]

Lower tax rates and phosphorus price increases would have smaller impacts on production and price. The relatively small impact may result from a complex set of agricultural production responses, such as growing different crops and using different crop rotation practices. Reducing the purchase of phosphorus by taxation then stimulates improved environmental stewardship as farmers are motivated to better conserve the nutrients they apply.

Potential Implementation in Ohio

A recent publication by Sei Jin Kim, Brent Sohngen, and Abdoud G. Sam used regression analysis to determine the impact of a variety of variables on the nutrient runoff of phosphorus. They included environmental, economic and policy factors, noting that this was the first time these variables had been combined. The analysis includes the price of corn, by the season, the price of phosphorus, temperature, precipitation, and flow; and dummy variables and interactions for periods of policy implementation. The authors suggest that while the price of inputs would increase, the price of food would not increase as many farmers already rely on stored phosphorus in the field. Rather, the authors assert that farmers would reduce their purchase of phosphorus instead of continuing to purchase the same quantity for an increased price. This would soften the impact of the tax on farmers and ease the transition of agricultural production to wiser and reduced use of phosphorus.[78]

By 1996, the Conservation Reserve Program had 34.1 million acres in its program, including 170,500 acres in the Maumee River Basin and Sandusky together. Since 1996, conservation tillage practice increased from 25% to 41% while reduced tillage adoption maintained its level at around 60-65% of active agricultural acres. The 1996 Farm Bill brought in the Environmental Quality Incentives Program (EQIP), which provides funding for farmers to implement cost-effective practices for improving the environment impact of their farms, through improved grazing, manure, nutrient, pest, or irrigation management. The EQIP program increased funding for conservation and working lands programs from $200 million per year before 2002 to more than $11 billion annually in 2011.[79] The post period also includes the impact of the EPA better regulating the large livestock facilities by requiring NPDES permits for their discharge.[80] All of these changes are expected to have caused a reduction in total phosphorus runoff, and ideally in both particulate and soluble phosphorus.

In the Sandusky, the one percent increase in corn prices is associated with an increase in the amount of soluble phosphorus runoff, and the authors suggest this is also possible because corn may be replacing less nutrient intensive crops.[81] The corn prices in fall also show a decrease in soluble phosphorus runoff of .257** percent and 0.089 in the Maumee River Basin and Sandusky, respectively.[82] The attached phosphorus, conversely, shows a statistically significant increase in runoff for the Maumee River Basin in all seasons, while there are no statistically significant impacts in the Sandusky.

Knowing the amount of soluble phosphorus concentration compared to attached phosphorus on a farm in the Maumee River Basin watershed would allow a calculation of the impact of a phosphorus tax. For example, the authors found a 1% increase in phosphorus tax is associated with a 0.425% decrease in soluble and a 0.14% decrease in attached phosphorus. If the total phosphorus in the runoff of the Maumee River Basin watershed is 75% soluble and 25% attached phosphorus, we would see a greater environmental impact from the tax on reducing DRP than if there was more attached phosphorus than soluble.

Recommendations

The State of Ohio could consider a state-wide phosphorus tax or solicit the federal government to pass a tax on phosphorus. It should be noted, however, there is significant resistance to taxing phosphorus at all levels of government.

4.5 Total Maximum Daily Load (TMDL)

Regulatory nutrient load caps, which set an upper limit on either or both acceptable concentrations within a water body or allowable discharges from a source of effluence, are a strategy available to states dealing with excess nutrient runoff. In the U.S., most nutrient caps have been set through Section 302 of the Clean Water Act which charges the EPA with setting "water quality related effluent limitations" in the form of Total Maximum Daily Loads, or TMDLs, of pollutants.[83] The Clean Water Act allows the EPA to this power to states' Environmental Protection Agencies, which it has done for most states. The state agencies follow a three-part process for developing these limitations, which are subject to EPA approval:

1) Describe designated uses of each water body and set water quality standards for each pollutant at levels that can maintain the water body's designated uses, which range from public water supply and protection of fish and wildlife to recreation, agriculture, industry, and navigation.[84]
2) Identify "impaired" water bodies that fail to meet water quality standards despite technology-based limitations on point sources of pollution.
3) Calculate the total amount of each regulated pollutant that each impaired water body can receive within a given day and still meet water quality standards, incorporating "seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." [85]

The Clean Water Act only requires permits for point source water pollution discharges. Nonpoint sources are not affected and the CWA specifically exempts certain nonpoint sources, including "normal farming, silviculture, and ranching activities" from regulation under CWA's National Pollution Discharge Elimination System (NPDES), though it is important to note that, since 2003 confined animal feeding operations are classified as point sources under CWA. [86,87] In setting TMDLs, states are required to aggregate both point and nonpoint source discharge effects and set TMDLs for all impaired waters within their borders, even if a water body is polluted entirely by nonpoint sources.[88] As a result, TMDL's can serve as a mechanism to address nonpoint source pollution.

The administrative rules that govern the NPDES program state that discharge permits cannot be issued if "the discharge from its construction or operation will cause or contribute to the violation of water quality standards," unless scheduled steps are being taken to bring the water body into compliance with water quality standards.[89] Agricultural waste, urban runoff and other nonpoint sources comprise the largest pollution source in many impaired water bodies—discharges that reduce the pollution load available for distribution among point sources via the NPDES permitting process. Since NPDES permits must be renewed at least once every five years, this can have significant consequences for major permit holders, most notably wastewater treatment plants.

This scarcity in water bodies' pollutant-adsorbing load has given rise to watershed nonpoint-point credit trading systems within watersheds. Under credit trading systems, point source polluters pay farmers and landowners to reduce nonpoint runoff, increasing the proportion of the TMDL available to NPDES permit holders. It can also result in political pressure to regulate nonpoint pollution sources at the state level. As a result, water quality standards have emerged as important legal mechanisms to address both point and nonpoint source pollution.

Case Box 5: TMDLs IN PRACTICE
<u>Chesapeake Bay TMDL</u>

Decades of persistent water quality issues in the Chesapeake Bay Watershed led to President Obama signing the Chesapeake Bay Protection and Restoration Executive Order on May 12, 2009. This Order called for an unprecedented level of interstate action on reducing NPS pollution, established a Federal Leadership Committee to oversee development of interagency Bay restoration efforts, and was a critical boost to years of increasingly forceful state and federal agency efforts to pave the road to a Bay-wide TMDL.

Under the Order, Federal agencies began drafting reports and recommendations in consultation with each Bay state's government on all aspects of management of the water body. Compiling these agencies' reports led to the development and passage of the Chesapeake Bay TMDL in May 2010. Covering the entire 64,000 square mile watershed, this TMDL was the largest ever instituted by the EPA, setting a watershed-wide limit of 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorus, and 6.45 billion pounds of sediment per year-- a 25% reduction in nitrogen, 24% reduction in phosphorus and 20% reduction in sediment for the entire watershed.[90]

Under this top-down approach of a federally designated TMDL, a "pollution diet" was established and each of the Bay's seven major jurisdictions developed Phase I Watershed Implementation Plans (WIPs) in dialogue with the federal EPA.[7] Published in late 2010, these WIPs defined both how and when a state would achieve its required pollution reductions. The Bay-wide TMDL targets were thus parsed down via ninety-two smaller TMDLs that address the necessary reduction levels for individual Chesapeake Bay tidal segments and well as sector specific reductions, including agriculture.[91] This is how the watershed-wide TMDL translated into specific enforceable and accountable measures to drive mandatory participation of agricultural producers at state-defined production scales—as the states are legally bound to meet the reductions set by the EPA.

One critical aspect of the Bay TMDL is its two key deadlines across all jurisdictions: an interim deadline requiring that practices needed to achieve 60% of pollution reduction are in place by 2017 and a final deadline that all necessary pollution control measures are in place by 2025. To meet these deadlines, states developed Phase II WIPs by 2012 that increased involvement of local governments, conservation districts, citizens, watershed groups, and others on furthering efficacy of pollution reduction strategies.[8] By 2017, states will move into Phase III WIPs to provide additional detail of restoration actions beyond 2017 and to ensure that the 2025 goals are met. This timeline allows for an adaptive but continually enforceable process where WIPs and the publication of state "milestone reports" every 2 years assure both transparency and accountability for pollution reduction actions on the parts of sub watersheds.

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[84] The Chesapeake Bay includes the District of Columbia and six states (MD, VA, DE, PA, NY, WV)

[7] For further information on specific milestones achieved from 2012-2014 by each of the 7 Bay jurisdictions, visit http://www.epa.gov/reg3wapd/tmdl/2014Evaluations/factsheet_Overall.pdf

It is important to note that the Chesapeake Bay TMDL has faced numerous challengers throughout its development and passage, the most vocal being advocacy groups from the agricultural sector's American Farm Bureau Federation (AFBF). On January 10th, 2011 the AFBF filed suit against the EPA and its TMDL on January 10th, 2011 on three counts:

1. That the TMDL unlawfully "micromanages" state actions and the activities of farmers, homeowners and businesses within the six-state Chesapeake Bay watershed by imposing specific pollutant allocations on a range of activities without taking into account the economic and social impacts on businesses and communities in the states.
2. That the EPA violated the Administrative Procedures Act by taking "arbitrary and capricious" action in enacting a TMDL that was developed using a scientific model the agency itself admits had data discrepancies.
3. That EPA violated the Administrative Procedures Act by failing to provide "meaningful public participation on new rules." AFBF argues that a 45 day public comment period was insufficient for processing EPA's highly technical information and that the provided information was itself incomplete.[92]

While the case was brought in a Pennsylvania District that the plaintiffs believed would be sympathetic to their case, the District Court's September 2013 ruling upheld the legality of the TMDL and overturned all three challenges, deferring to EPA's "reasonable determinations" on interpretation of powers under the CWA.

AFBF then appealed this ruling to the US Court of Appeals Third Circuit Court, arguing that the federally designated TMDL infringes on states' land management decision making authority. As of February 2014, the list of co-plaintiffs had grown to include the National Association of Home Builders, national Corn growers Association, National Pork Producers Council, Pennsylvania Farm Bureau, The Fertilizer Institute and the U.S. Poultry & Egg Association. Additionally, 21 state attorney generals and eight counties joined AFBF and co-plaintiffs through an amicus brief to the court contending EPA authority violates states' authority*. The outcome of this case will have major repercussions far beyond the Chesapeake Bay.

*AL, AK, AR, FL, GA, IN, KY, LA, MI, MS, MT, NE, ND, OK, SC, SD, TX, UT, WV, WY

TMDLs in the Maumee River Basin

Currently, there are sixteen state-generated TMDLs in place on waters that flow into the Maumee River Basin; ten in Indiana, six in Ohio, and none in Michigan. These TMDLs address a host of water quality concerns from *e. coli* in the St Mary's River in Ohio to total suspended solids in the Maumee River Basin River's lower tributaries in Ohio. Each of these TMDLs is set at the subwatershed level and addresses pollution reduction in one portion of the Maumee River Basin watershed system. Of these, six set limits on total phosphorus but none specifically address soluble or dissolved reactive phosphorus. These phosphorus TMDLs have already guided allocation of GLRI funds toward properties and projects expected to achieve high impact reductions in total phosphorus as well as funding support for conservation land management activities under the Regional Conservation Partnership Program.[9] In addition, the Ohio Environmental Protection Agency uses the NPDES permitting process (which it administers within the state) to set a cap on the phosphorus discharges of large, publically-owned waste water treatment plants within the Lake Erie basin of 1.0 mg of phosphorus per liter, averaged over a 30-day period.[93]

While federal funding programs active in the Great Lakes such as the Great Lakes Restoration Initiative (GLRI) and the Regional Conservation Partnership Program (RCPP) seek to incentivize effective agricultural conservation practices, fragmented TMDLs have yet to move the system anywhere close to the desired phosphorus reduction. Ohio Lake Erie Task Force's goal of a 39% reduction in annual total phosphorus load at the mouth of the Maumee River Basin makes clear that actions are required at a larger scale.

On the chance that a watershed-wide TMDL should this come to pass for the Maumee River Basin, we explore several of the policy options facilitated by the existence of a TMDL in the following pages.

4.6 Water Quality Trading

Cap and trade programs provide a market-based mechanism for increasing the economic efficiency of regulations that place a cap on allowable nutrients from particular sources. As discussed in the TMDL section, nutrient caps set maximum allowable discharges from various sources of nutrient runoff. By allowing polluters for whom abatement is more expensive to "buy" pollution abatement credits from "sellers," or polluters for whom it is cheaper, cap and trade programs can reduce the overall cost of each unit of abatement[94].

Cap-and-trade schemes require a "market driver" in the form of enforceable standards setting caps on the amount of a pollutant that can be released from each source into a watershed or water body. Water quality trading can theoretically be viable whenever these regulatory caps force polluters to reduce discharges, and when some polluters face a higher cost of abatement than others—in other words, between any combination of regulated point sources, nonpoint sources, or point and nonpoint sources.[95] In the U.S., though, water quality caps are generally defined for point sources by water quality based limits specified in NPDES permits in response to Total Maximum Daily Loads (TMDLs) set for particular water bodies under section 303(d) of the Clean Water Act.[96] Due to nonpoint source and agricultural discharge exemptions, nonpoint source dischargers remain unregulated. As a result, demand in domestic water quality trading programs generally comes from point source dischargers, which purchase credits from either point or nonpoint sources. Other countries that actively regulate agricultural and other nonpoint source dischargers, most notably New Zealand, have successfully established trading programs between nonpoint sources.[97]

An economic incentive for point-nonpoint source trading is created because it is often cheaper for point sources to achieve the levels mandated in their NPDES permits by paying unregulated

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[88] OH EPA has prioritized 4 watersheds for the GLRI funding: Swan Creek, Lower Auglaize, Lower Sandusky, and South Turkey Foot

farmers to institute BMPs that reduce agricultural nonpoint source than to it is take further steps to mitigate their own point source pollution. Because of this, most water quality credit markets in the US engage farmers as sellers who generate credits by instituting BMP's that reduce nonpoint source runoff from their fields, and point source polluters as credit buyers, who purchase credits in order to offset regulatory pollution reduction requirements.

In order to support credible trades, water quality trading programs must be able to ensure that the pollution reduction credits that sellers generate by instituting BMPs actually result in the pollution reductions that the buyers are mandated to achieve. Most programs address this need in three forms:

- <u>Additionality:</u> Pollution abatement credits must reflect an additional reduction in effluence on the part of the seller—in other words, they must represent a reduction in pollution that would not have occurred without the trade. This principle prevents "double counting" effluence reductions that would have occurred even in the absence of a trading program. Most point-nonpoint source water quality trading programs ensure additionality by establishing a baseline nutrient discharge for each seller. This baseline may be set to discharges in a particular year, to discharges using the seller's current management practices, or to expected discharges using a set of baseline or standard management practices. Any reductions in nutrient discharges below this baseline are considered additional reductions, and are eligible for trading as credits.[98]
- <u>Equivalency:</u> The discharge reduction from the nonpoint source must have an equivalent impact on water quality at a set point of measurement in the basin as the reduction required from the point source. The actual pollution reduction achieved by instituted best management practices must be quantified and tracked, either through modeling or on-site measurements. [99]
- <u>Uncertainty:</u> Programs use trading ratios to address any remaining uncertainty about the additionality and equivalency of pollution abatement credits due to modeling limitations or ecological variability. These ratios create a buffer that ensures that trades result in water quality improvements by equating one unit of nutrient abatement on the part of a nonpoint source seller to less than one unit of required abatement on the part of a credit buyer. The most commonly used trading ratio is 2:1; in other words, two units of estimated phosphorus abatement on the part of a seller would generate a credit that would satisfy a buyer's regulatory requirement to achieve one unit of abatement.[100] Higher trading ratios bring the benefits of greater water quality impacts and more certainty that required nutrient reductions are met, but increases the cost of pollution credits and can reduce the number of transactions that occur.

A 2004 review identified over 70 water quality trading programs in the U.S., however, relatively few if any transactions had taken place in most of these markets[101]. The authors identified potential factors behind this lack of activity as insufficient demand on the part of point sources and high transaction costs due to the need to establish equivalency or the lack of effective brokering organizations.

Similarly, the Willamette Partnership identified five factors that can make a watershed suitable for water quality trading programs:[102]

- <u>Regulatory drivers</u>: there must be a regulatory driver such as limitations on discharges placed through NPDES permits in the context of a TMDL

- Demand: there must be enough demand on the part of buyers to purchase water quality abatement in order to justify program development
- Supply: there must be buy in and support from a group of sellers (generally farmers) with the organizational sophistication and the willingness to provide pollution reduction
- Intermediaries: there must be an intermediary organization with the "capacity and legitimacy to convene stakeholders, facilitate program design, and administer the program"
- Confidence: buyers must be confident that credits reflect actual pollution abatement and that regulatory agencies such as the EPA will support water quality trading as a strategy for meeting pollution reduction obligation.

Case Box 6: WATER QUALITY PERMIT TRADING IN PRACTICE
Ohio River Basin Trading Project

The Ohio River drains 204,000 square miles and is the largest tributary, by volume, of the Mississippi River.[103] As a result, phosphorus and nitrogen pollution from the heavily-farmed basin is an important driver of eutrophication in the Gulf of Mexico, at the Mississippi's mouth. In 2012, Ohio, Indiana and Kentucky signed an agreement to establish the Ohio River Basin Trading Project, a pilot point-nonpoint source water quality trading program targeting total phosphorus and nitrogen effluence within the basin. The program, which runs through 2015, conducted initial credit sales in March 2014, selling $90,000 worth of stewardship credits consisting of reductions of 6500 pounds of nitrogen and 2500 pounds of total phosphorus effluence over three years. The project will conduct its first public credit auction in 2015, and hopes to sell credits representing a total of 66,000 pounds of nitrogen and 30,000 pounds of phosphorus.[104] If successful, the project will serve as a model for further nutrient trading in the Ohio Basin and interstate nutrient trading programs elsewhere in the country.[105]

- Regulatory drivers: Although a basin-wide TMDL has been developed for dioxins in the Ohio, none exists for nutrients. The Ohio River Basin Trading Project is being developed "in anticipation of new or more stringent numeric water quality criteria, total maximum daily loads (TMDLs), and/or water quality-based National Pollutant Discharge Elimination System (NPDES) permit limits."[106]
- Demand: Sales during the pilot program will be for "stewardship credits," which do not count towards buyers' regulatory permitting requirements. Instead, program organizers envision demand being driven by point source dischargers' corporate sustainability goals.[107]
- Supply: The Trading Project will accept credits generated by point and nonpoint sources, but expects the majority of traded credits to originate from farmers. The Project sets a baseline for credit generation using current conditions and management practices on the farms based on the past three years of land management records.[108] The Electric Power Research Institute conducted a study of potential barriers to farmer participation in the market, issuing recommendations that include minimizing paperwork, including information on how BMPs might impact crop yields, and relying on trusted intermediaries to conduct outreach to producers and to monitor BMP implementation.[109] In the Project, local Conservation Districts will contract to farmers to institute approved credit-generating BMPs, and will conduct monitoring to ensure that contracted BMPs are implemented.

- Intermediaries: The Electric Power Research Institute (EPRI) has served as an intermediary throughout the development of the pilot program, by convening stakeholder groups and leading program design. EPRI also acts as a financial broker, assuming financial risk and conducting transactions with both credit sellers and buyers. It channels funding through state agencies and Conservation Districts to purchase credits from farmers through BMP implementation. It then sells those credits to buyers through online and in-person auctions. [110]
- Confidence: Regulatory confidence is provided by an agreement signed by the states of Ohio, Indiana and Kentucky agreeing to honor credits purchased through the program towards point sources' NPDES permitting requirements. The Project establishes ecologically equivalency through use of two models (the EPA's Watershed Analysis Risk Management Framework and spreadsheet model) and through trading ratios. Trading ratios are calculated dynamically, on a trade-by-trade basis. In addition to incorporating a margin of safety to discount for uncertainty, these ratios account for natural nutrient assimilation that would take place between the point in the watershed at which nutrient abatement occurred and the location of a credit buyer's point-source discharges.[111]

Water Quality Permit Trading in the Maumee River Basin

A careful analysis of potential demand for nutrient credits would be necessary before attempting to implement point-nonpoint source water quality trading as a strategy to reduce total or soluble reactive phosphorus loads in the Maumee River Basin.

As a first step, the caps on allowable phosphorus discharges set through NPDES permits would need to be lowered sufficiently to drive demand for abatement credits on the part of point sources. Setting a Total Maximum Daily Load for either total or soluble phosphorus would create a mechanism for reducing allowable discharges in new or renewed NPDES permits. The load targets at the mouth of the Maumee River Basin recommended by the Lake Erie Ecosystem Priority could serve as guidelines in setting this TMDL.

Ohio Administrative Code section 3745-33-06 currently uses the NPDES permitting process to set phosphorus caps for effluence from large, publicly-owned waste water treatment plants within the Lake Erie Basin. Under the regulation, the Ohio EPA (which is responsible for issuing NPDES permits in the state) includes a cap of 1.0 mg of total phosphorus per liter of discharge within these facilities NPDES permits, despite the absence of a TMDL mandating such limits. Reducing these caps, or broadening the range of facilities to which this regulation applies, could generate demand for phosphorus abatement credits.

Unlike nonpoint source agricultural runoff, which includes varying amounts of attached phosphorus and dissolved reactive phosphorus, the discharges from wastewater treatment plants consist almost entirely of dissolved reactive phosphorus. Because the bioavailability of DRP is much higher, any credit trading system would need to ensure that nonpoint source pollution reduction credits purchased by wastewater treatment plants would result in abatement of DRP equal or greater to the abatement that would have occurred had effluence been reduced at the point source; in other words, permits would need to be structured so phosphorus reductions by wastewater treatment plants, consisting largely of DRP, could not be offset by nonpoint source pollution reduction credits that largely reflect a reduction of attached phosphorus. This could be accomplished by setting effluence caps and trading credits specifically for DRP reductions, or mandating that only conservation practices known to effectively reduce DRP runoff count towards credit generation.

Point-nonpoint source water quality trading in the Maumee River Basin would also be facilitated by institutional capacities and a favorable regulatory climate. The Maumee River Basin is home to a highly-organized agricultural sector, with numerous governmental and civil society organizations (including Conservation Districts) that currently serve farmers and could act as trusted intermediaries to monitor conservation practice implementation and help farmers connect to credit markets. The Great Lakes Commission has built experience developing nutrient trading programs through work in the Lower Fox River Basin. Relevant regulatory agencies in Indiana, Ohio and Michigan have shown support for water quality trading. Programs exist in all three states, and Michigan and Ohio have adopted policies setting rules and guidelines for trading programs.[112]

However, analyses of the portion of phosphorus at the mouth of the Maumee River that can be attributed to point sources indicate that the water quality trading, on its own, would not be able to achieve the reductions in phosphorus loads needed to reduce harmful algal blooms if a program were to be implemented at a watershed-wide scale. As discussed above, the Lake Erie Ecosystem Priority recommended that annual total phosphorus loads at the mouth of the Maumee River Basin be reduced by 39%, to 1600 metric tons per year.[113] However according to Heidelberg University's Ohio Tributary Loading Program, only 7.5% of the total phosphorus export from the Maumee River Basin can be attributed to point source discharges.[114]

Even if phosphorus effluence caps on these point sources were reduced to 0 mg/l of discharge, and even if a trading ratio of 2:1 was used to increase water quality benefits, a point-nonpoint source water quality trading program could not be expected to achieve more than 15% reductions towards that 39% goal. Although it is unclear what price phosphorus reduction credits would trade at, this reduction would come at great cost to point source dischargers; more economically and politically feasible phosphorus caps would result in less progress towards water quality goals. Ultimately, the fact that phosphorus in the Maumee River Basin overwhelmingly originates from nonpoint sources appears to limit potential impacts of point-nonpoint source water quality trading.

This limitation could be addressed by expanding the geographic scope of a point-nonpoint source trading program. Across tributaries, point sources are responsible for 12.5% of the total phosphorus load entering the Western Lake Erie Basin. Allowing point sources that discharge into other Ohio tributaries of Western Lake Erie (most notably the Cuyahoga, where nearly 60% of phosphorus comes from point sources) to purchase DRP reduction credits from nonpoint sources in the Maumee could increase demand by up to 250%. However, while any cross-tributary credit transaction would reduce phosphorus pollution from the Maumee, it would result in an increase in loading in the credit-purchaser's tributary equal to the amount of the credit divided by the trading ratio. Potential negative environmental consequences resulting from this transfer would have to be studied and managed.

Finally, water quality trading could serve as a mechanism to allow agricultural producers to comply with any future regulatory caps on nonpoint sources phosphorus discharges in the most cost-effective way possible. This direct regulation of nonpoint sources has been successfully combined with water quality trading in New Zealand's Lake Taupo basin, where over 90% of nutrient pollution comes from nonpoint sources.[115] Caps on nonpoint source phosphorus pollution in the Maumee—at either the state or federal level—would face extensive opposition, and political barriers would have to be overcome. If caps were put in place, though, trading could provide a mechanism for newly-regulated producers to comply at the lowest possible cost.

Recommendations

Conduct further research into the potential for developing a Western Lake Erie basin wide point-nonpoint water quality trading program: Potential demand for water quality credits appears to be limited within the Maumee watershed. However, there may be enough demand throughout the Western Basin to support a trading program that would produce significant reductions in loading from the Maumee. Further research is needed to confirm that this demand exists, and to fully understand the ecological, economic and legal implications of reallocating pollution loads among tributaries through this type of a program.

Draw on the capacities of existing organizations to develop any future trading programs: The extensive network of government, nonprofit and research organizations working to address agricultural runoff and water quality issues in the Maumee form a rich pool of expertise and capacity that could be used to design and implement water quality trading programs.

Ensure that any water quality credits reflect reductions in DRP: Since it is recognized to drive Western Lake Erie's HAB's, credits must reflect reductions in DRP rather than total phosphorus loading. This can be accomplished through improved modeling, by focusing efforts on conservation practices known to reduce DRP runoff, and by the use of trading ratios.

Incorporate water quality trading in any future efforts to place regulatory caps on nonpoint DRP runoff: Water quality trading can reduce the costs of complying with any regulatory caps on nonpoint source DRP pollution. This may increase stakeholder support for caps should this regulatory approach ever be explored.

4.7 Litigation

Litigation is a mechanism that can be used to change a law, an interpretation, or the enforcement of the law. As law is based on precedent, challenging a law can be challenging, but it can also significantly shift the future execution of the law. The Clean Water Act has been challenged in court many times and these cases have sometimes led to the Supreme Court. Cases like *Carabell v. U.S. Army Corps* and *U.S. v. Rapanos* challenge the role of the federal government in interfering with local development on wetlands.[116]

Court cases can also be brought to put further pressure on the federal government to protect the environment. The EPA, under the Administrative Procedure Act, has been sued many times for this under both the CWA and other laws. The Clean Water Act, as one of the foundational environmental laws in our country, sets a standard for the role of the federal government and makes many exemptions in its enforcement, point versus nonpoint source pollution for example. Questions come up like whether or not to regulate the designated nonpoint sources or whether agriculture should be regulated as a point source or as a combination. These debates often find their way into the courthouse, and they can often have serious consequences.

Litigants can be citizens, municipalities, states, organizations, businesses, and each has a right to sue the government if they argue the government is not doing its due diligence in its responsibilities. This is an exciting consideration in the case of nonpoint source pollution because it provides a mechanism for disgruntled parties to circumvent the traditional legislative process at each level of government. There is precedent for environmental laws being improved through court cases, but certainly there are many cases where they have been weakened. The Clean Air Act has been bolstered through the years, most notably the Supreme Court's 2007 decision in *Massachusetts v. EPA* where the EPA was empowered to regulate greenhouse gases. On the other hand, the EPA has not won any cases in defense of the Clean Water Act since 1985, the *United States v. Riverside Bayview Holmes*, which bolstered the federal role to protect wetlands.[117]

There have been court cases on the nonpoint source aspect of the CWA, but they have not reached the Supreme Court. John Clemons, in "Addressing Nonpoint Source Pollution in the Fifth and Eleventh Circuits: Could Pronsolino Happen in Mississippi and Alabama?" highlights the potential for reasserting nonpoint source regulation in the Clean Water Act.[118] Section 303(d) of the CWA says that each state shall identify the waters in their state where limitations on point sources are not sufficient to ensure the waters meet the water quality standards have to be placed on a list and required to have formal total maximum daily loads.[119] Nonpoint sources are not mentioned explicitly here, so this leaves space for interpreting 303(d) as a mandate to place TMDLs on waters contaminated by nonpoint source pollution.

This is an example of how the law may be addressed in court to change the CWA to regulate nonpoint sources. Case Box 6 highlights a recent lawsuit filed by Des Moines Iowa Water Works to pressure the EPA to identify and regulate agricultural drainage districts as point sources. The court argues the tile drainage system replicates a municipal drainage utility and therefore should be under a similar standard for runoff as a point source. The case study is followed by a brief list of other possible mechanisms for litigating the enforcement of standards on nonpoint source pollution in Ohio and the Western Lake Erie Basin.

Case Box 7: LITIGATION IN PRACTICE
City of Des Moines, Iowa

The city of Des Moines, capital of Iowa, is a growing urban region with a population exceeding 200,000. [120] Positioned at the confluence of the Raccoon and Des Moines Rivers, the city's waterways and wastewater treatment facilities are significantly impacted by the runoff coming from upstream watersheds.

On January 8th, 2015, the Des Moines Water Works found nitrate levels at its facilities to be in excess of state water quality standards. When a city finds its water quality to be out of compliance with state standards, there are two possible courses of action: the city may update its water treatment system or it may seek to reduce the pollutants entering the water. Des Moines Water Works pursued the latter option and its commissioners voted to sue the county boards of three Northwest Iowa counties (Sac, Calhoun, and Buena Vista counties) under the Clean Water Act for negligence in controlling discharges into the Raccoon River.[121,122]

The Water Works is concerned about nitrate run off, which has been recorded at levels as high as 39.2 mg/L in groundwater discharged by drainage districts in the three sued counties, as compared to EPA's nitrate limit of 10 mg/L.[123] The Safe Drinking Water Act began regulating nitrate in 1992, with a contaminant threshold at 10 mg/L or 10 ppm.[124] Nitrate is dangerous to children and infants as it can cause shortness of breath and lead to "blue baby syndrome," in which an infant cannot take in enough oxygen.[125] The lawsuit will be filed on the basis of this contaminant level under the 1972 Clean Water Act, and challenge agriculture's exemption from the CWA as nonpoint source pollution. It is worth noting that there is precedent for changing exemption status for nonpoint source pollution as animal feedlots were brought into permitting compliance in the 1970s and in the 2000s due to evidence of their high nutrient runoff from animal waste..[126]

The lawsuit in Des Moines is the first time a city has challenged agricultural exemptions under CWA by suing upstream counties through a claim that their drainage districts are contaminating the ground water with unsafe levels of nitrates. While agricultural runoff is considered surface runoff, the Des Moines Water Works argues that deep tillage techniques used by farmers bypasses soil filtration, thus allowing pollution to enter groundwater and travel directly underground to the streams and rivers, thus making the agricultural runoff a subsurface flow issue.[127]

Ten predominantly agricultural drainage districts in the three sued counties are being highlighted as top polluters by the litigants.[128] The plaintiff's chief argument is that the drainage districts should be regulated like urban storm water districts, noting that the tile drainage systems underlying Midwestern agricultural land functionally act like urban piping systems. For this reason, the Water Works argues the districts should be treated as point-sources of pollution for how storm water runoff flows through them. Recognizing agricultural runoff as traveling through groundwater because of tile drainage infrastructure would change the way agricultural runoff is regulated in areas where tile-drainage is used, namely the Midwest.[129] The West has irrigation systems rather than tile drainage, and so it is not obvious how they would be affected should such a precedent be established.

Potential Litigation Strategies in the Maumee River Basin

Similar to the Des Moines case, there is a demonstrable public health angle to excess nutrient runoff in Western Lake Erie, namely the Toledo city water shutoffs of August 2nd and 3rd 2014. As mentioned in Chapter II of this report, an algal bloom that occurred in Western Lake Erie over a nearshore water intake pipe for the city's chief drinking water facility resulted in hazardous levels of toxic microcystin which forced temporary water shutoffs to the city's 500,000 residents. The ecological driver of this bloom event was excess phosphorus runoff coming from tributaries flowing into the Western Lake Erie Basin, including flows from the Maumee River Basin.

Recommendations

Possible litigation in Ohio targeting reduction in dissolved reactive phosphorus could take many different forms and can be targeted at the Federal government or the State government. Several possible angles that consider the regional context include:

The City of Toledo or the state of Ohio could sue the federal government to adjust statute 301 of the CWA to include "agricultural stormwater discharges and return flows from irrigated agriculture," which has been explicitly exempt from CWA regulation.[130] Stormwater runoff is considered a nonpoint source with some major exemptions: municipal stormwater, industrial, and construction discharges are all considered point sources and require NPDES permits.[131] The Des Moines, Iowa case argues that tile drainage replicates the municipal drainage system and therefore should also be considered a point source in spite of its current exemption under the CWA.

The City of Toledo could challenge the Ohio EPA on the Ohio Revised code (ORC) chapter 6111 exclusion of agricultural pollution from regulation. Ohio Revised code (ORC) chapter 611 governs pollutant discharge from point sources and it also excludes agricultural pollution, including stormwater runoff and animal waste.[132] According to ORC Section 61111.04, "no person may discharge any pollutant or cause, permit, or allow a discharge of any pollutant to waters of the state without applying for and obtaining a valid permit." This can be leveraged to push the OEPA to address nonpoint source polluters traditionally excluded.

Amending Ohio's anti-degradation policy to explicitly include dissolved reactive phosphorus would create another possible litigation tool in addition to the standard TMDL approach for excess nutrients of concern. The anti-degradation policy is designed to prevent states from allowing water quality below the national standard, which does not currently include phosphorus. [133]

The city of Toledo could request a change in the permitting structure of HSTS that requires evaluation of current HSTS and re-permitting if they are discharging above a certain phosphorus limit. Home Sewage Treatment Systems (HSTS) can produce significant amounts of phosphorus and have been identified as major contributors to Lake Erie. They are regulated by the Department of Health and require a NPDES permit from the Ohio EPA. While current NPDES permits do not contain a phosphorus limit, they do prohibit phosphorus levels that "are conducive to the growth of algae." There are no permit requirements for old HSTS and as of 2012, only 35 of HSTS had NPDES permits.[134]

4.8 Summary of Policy Recommendations for the Maumee River Watershed

Policy actions by their nature require interagency cooperation and participation across different scales, so placing policy recommendations in silos is fundamentally artificial. However, the following table divides policy recommendations for the Maumee River watershed across federal, interstate, state, and local in order to reflect the broad spectrum of actions that can be taken to address reducing DRP in the Maumee River watershed. As with all complex problems, there is no single "silver bullet" solution, rather a fluid opportunity space for diverse actions that may work to achieved desired ecological outcomes.

Federal	• Use CREP to implement selection indexes that prioritize high DRP runoff acres • Allocate funding to retire high-productivity acres
Interstate	• Transition MI, IN, and OH to using a common 590 Standard for NMPs • Conduct further research into potential for developing a Western Lake Erie basin wide point-nonpoint water quality trading program, ensuring that any water quality credits could reflect *reductions in DRP;* the work to incorporate water quality trading in any future efforts to place regulatory caps on nonpoint DRP runoff
State	• The State of Ohio could consider a state-wide phosphorus tax or solicit the federal government to pass a tax on phosphorus • Amend Ohio's anti-degradation policy to explicitly include DRP • Involve regional farmers directly in regulatory design • Ensure sufficient agency staff capacity exists for effective monitoring of on the ground efforts and that agencies are able to share enrollee information effectively across offices
Local	• Assure consistent and sufficient funding support for program enrollees • Local municipalities could challenge the Ohio EPA on the Ohio Revised code (ORC) chapter 6111 exclusion of agricultural pollution from regulation

Chapter 5:
Analysis of Models of Interest

Contents

5.1 Overview of Models of Interest

Models are utilized to better understand the environment, how human activities may affect it, and how the system may be better managed to achieve desired outcomes. Modeling provides scientists, policy makers, land managers, and the public a way to visualize an entire landscape and assess the possible ecological and economic impacts of different management options. Modeling is also a powerful way to communicate patterns of existing and anticipated environmental change. The utilization of modeling systems in science has become commonplace as the technology to build these tools grows. Interdisciplinary teams uniquely qualified to analyze each aspect of an environmental issue build models to simulate a specific environment. As a prominent limitation and tradeoff, it must be recognized that all models are a simplification of reality, no matter how complex the model.

For the purposes of this project, modeling is an effective way to interpret the complexity of nutrient pollution in an agricultural setting in terms of fertilizer application, nutrient uptake, physical characteristics of land, and conservation practice implementation. Approximately 7% of phosphorus loading to the western basin of Lake Erie is from point sources.[135] Therefore, the majority of phosphorus loading is from nonpoint sources, namely agricultural lands. Thus, prioritizing models that address nutrient runoff from croplands is a crucial use of resources for informing strategies to guide the most efficient application of conservation practices.

Multiple models and tools exist to simulate nutrient runoff patterns and to predict the nutrient load changes based on implementation of conservation practices. Here we chose to analyze existing models of the Maumee River Watershed in order to highlight their capabilities and limitations in light of current and potential future use of these models by individuals and decision makers seeking to address the issue of excess dissolved reactive phosphorus (DRP) loading into Western Lake Erie.

The models analyzed here include: SPARROW, SWAT, the Great Lakes Watershed Management System (GLWMS), and SNAP Plus. These models were chosen for our focused analysis as they exhibit a wide range of capabilities and outputs applicable to address nutrient pollution, one of the chief ecological concerns in the Maumee River watershed. The goal in analyzing these models is to understand the existing modeling abilities in the area and to use that knowledge to inform creation of a relevant and useful tool for use by other US watersheds that do not have such a multitude of premade models available.

	SPARROW - Spatially Referenced Regressions on Watershed Attributes	**GLWMS - Great Lakes Watershed Management System**	**SWAT - Soil and Water Assessment Tool**
Outputs	Total Nitrogen and Total Phosphorous Incremental Load (contribution from that reach) Accumulated Load (total upstream contribution)	HUC level Sediment, Erosion, Runoff, Total Nitrogen, Total Phosphorus, Suspended Solids, Lead, Zinc, and Copper	Outputs: Soluble and Particulate phosphorus, Nitrogen, Sediment, Erosion
Capabilities	Can display N, P loadings by source (farm, manure, point source, urban) for a specific reach. Can manually override loadings from each source Cannot predict changes due to conservation practices.	Can model No-Till, Mulch Till, grass cover on user chosen portion of worst sediment contributing area and 30 foot buffer on all streams. Only affects sediment and erosion.	Can model most common conservation practices.
Model	Takes many input layers to run regression to match measurements from observation data.	Takes few input layers and models physical processes in a simplified manner	Takes many input layers for detailed modelling of physical processes. Calibrated to observation data.
Ease of use	The “Mapper” is easy to use but it just displays pre calculated outputs. The “Decision Support System”, which allows user inputs, is harder to use. Easy to extract data, downloads ArcGIS shape file	Web based interface, easy to use Difficult to extract data from website	Hard to calibrate and requires extensive loading data. Runs in ArcGIS
Data Layers	Precipitation, temperature Bedrock geology, surficial geology, and STATSGO soil Land cover, percent impervious area, population density, percent canopy, areas of artificial drainage Digital elevation model (DEM): drainage area, basin shape, slope, stream density, stream length Base flow index, infiltration excess overland flow, saturation excess overland flow, and recharge of the soils. Chemical: either the average or the total of nutrients from fertilizers, manure, and atmospheric deposition.	Rainfall Intensity SSURGO soil data Cover management Factor (calculated from 5 year crop rotation & tillage data) Digital elevation model (DEM): slope length, steepness, stream network	Detailed user defined inputs that can be different from model to model. These can include: watershed dimensions, climate, hydrologic cycle, sediment, nutrients, pesticide, bacteria, water quality, plants, channel and impoundment processes, and land management
Link	Mapper, DSS	GLWMS	SWAT Website

Figure 5.1: Comparison chart for watershed scale models

	Snap Plus - Soil Nutrient Application Planner	**GLWMS - Great Lakes Watershed Management System**
Outputs	Generates user friendly reports on: Nutrient Management Plan, Farm Management, Soil Loss, and Water Quality	Outputs: Same as watershed scale
Capabilities	Detailed implementation of various tillage, crop rotations and fertilizer applications.	Can model 30 ft grass buffer, riparian buffer strip, detention basin, grass swale. close seeded legumes, cropland generalized, hay, row crops, small grain, Orchards, Tillage (reduces, conservation 30%, mulch, No 100%) and Land use change (Deciduous, Evergreen or Mixed Forest. Barren land, Grassland, Park, Shrub, Commercial, Industrial, Residential, Water, wetlands)
Model	Runs inputs against the point based Wisconsin Phosphorous index that classifies the risk of phosphorus runoff as low, medium or high.	Takes few input layers and models physical processes in a simplified manner
Ease of use	Requires user to input soil test and crop rotation data, making it harder to use. Training and support is available.	Web based interface and only requires field boundary makes it very easy to use.
Data Layers	Detailed field specific user defined inputs: Crop rotation, tillage, soil tests	Same as watershed scale. Model predicts outputs based on historical data.
Link	SnapPlus	GLWMS

Figure 5.2: Comparison chart for field scale models

SPARROW is a GIS-based online tool that assesses the origin, route, and result of nutrients across large watersheds in the United States, with no means of manipulation for conservation practice application's effect on nutrient runoff. SPARROW does not model for specific forms of nutrients, only total nitrogen and total phosphorus.

The SWAT model is much more intensive in data needs and requires expertise in coding to run, unlike SPARROW. Although, when created and calibrated correctly, SWAT has significantly more capabilities in analyzing how different forms of nutrients are released from the land and how conservation practice implementation on specific fields will reduce runoff in a given watershed. There does exist some uncertainty and questioning of the accuracy of SWAT's ability to measure and quantify DRP runoff baselines and how those concentrations change with BMP applications.

GLWMS is a web-based, easy to use tool for measuring differences in nutrient and sediment runoff before and after conservation practice implementation at the field scale, and differences in sediment runoff at the watershed scale.

SNAP Plus is a nutrient application planner utilized in Wisconsin that integrates a point system based off physical characteristics of the land to determine the phosphorus loss potential.

The Significance of Dissolved Reactive Phosphorus

Total phosphorus is primarily separated into *particulate phosphorus*, that which can be removed by a filter, and *dissolved* or *soluble phosphorus*, that which remains in solution after passing through a filter.[136] Particulate phosphorus has long been a key focus area when managing algal blooms, and only recently has scientific understanding emerged around the dramatic impacts dissolved phosphorus is having on driving algal blooms. Dissolved phosphorus is more bioavailable to aquatic photosynthetic organisms like phytoplankton than particulate phosphorus and it remains in the water for a longer duration than particulate phosphorus which settles out. Additionally, the load of dissolved phosphorus entering Lake Erie has been increasing over the last few decades (see Chapter 2).[137]

Phytoplankton species present in Lake Erie rely on nutrients and sunlight to create biomass and phosphorus is considered the limiting nutrient for their growth, as there is sufficient nitrogen in the water and some of these phytoplankton species are nitrogen fixing. Therefore, when there is excess bioavailable phosphorus in the system, it leads to growth of algal blooms provided all other environmental needs such as sunlight and water temperature are met.[138]

Due to these key ecological differences between particulate and dissolved phosphorus and the importance of DRP loads to harmful algal blooms (HABs), it is very important to explicitly identify the specific type of phosphorus (P) each model is capable of simulating.

5.2 SPARROW- Spatially Referenced Regressions on Watershed Attributes

Spatially Referenced Regressions on Watershed attributes (SPARROW) is a GIS-based watershed model created by the U.S. Geological Survey (USGS). This tool was designed to estimate the origin, route, and fate of point and nonpoint source pollution in seven large river networks within the conterminous United States. These seven networks span the Northeast, the South Atlantic, the Upper Mississippi and the Great Lakes, Missouri River, Lower Mississippi and Gulf of Mexico, Southwest, and the Pacific Northwest. The SPARROW models are all integrated into an online interface that water managers, researchers, and the general public can access as a decision support tool.

This tool has been used nationally to measure water quality conditions, estimate nutrient loading, and determine possible management paths. SPARROW simulates stream loads on the year through the integration of statistical methods into a model of watershed characteristics (climatic, landscape, and aquatic factors). The stream loadings are determined using data from monitoring sites as well as information on the source(s) of the pollution, be it urban (wastewater effluent and nonpoint source pollution from developed impervious surfaces), agricultural (fertilizers and animal manure), and/or natural processes (particulate phosphorus and atmospheric nitrogen deposition).

In addition to recognizing nutrient sources and loading quantities, SPARROW is built to illustrate the spatial patterns of how nutrients are delivered to downstream locations based on human activities and natural processes. SPARROW's results demonstrate the difference in magnitude of loading between the nutrients from anthropogenic sources and those from natural processes.[139] For example, in the Southwest SPARROW has been adapted as a salinity model to spatially simulate the total dissolved solids and anthropogenic factors influencing salinity.[140]

Information on the sources and amounts of nutrients reaching downstream sites can be used to determine priority areas within a watershed by comparing the nutrient sources so as to target for the best nutrient reduction practices. This use of SPARROW is of particular interest for sensitive bodies of water where algal growth and water quality are of high importance, such as the western basin of Lake Erie.

Model Framework

The USGS built SPARROW as a hybrid statistical, spatially explicit, and process based mass-balance model, meaning that the nutrient concentrations, fluxes, and yields in streams are calculated to evaluate the final quantity of nutrient entering downstream waters. The flux values are the product of the concentration and stream flow in units of mass, and the yield is calculated as the mass of nutrients per acre of land. Stream loading information was gathered from monitoring sites run by governmental agencies (see Figure 5.1), and wastewater effluent information from industrial and municipal facilities were compiled into a database. This data was screened by the USGS to ensure high quality before usage in calibrating the seven regional SPARROW models.

This data in combination with spatially explicit information of fertilizer application, manure, land-use, soils, topography, and stream locations were utilized to calibrate the regional models for locations without monitoring sites and data. The coefficient error and unexplained variability of observed data help to quantify the uncertainties within the model.

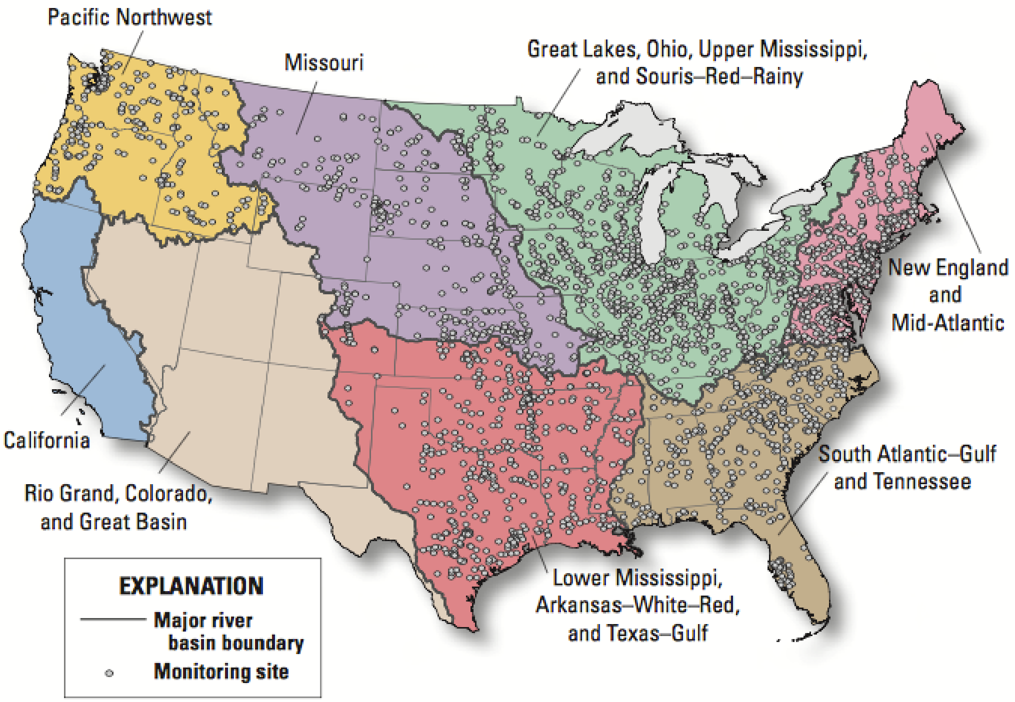

Figure 5.3: Seventy-three governmental agencies collected monitoring data from 2,700 stream sites[141]

The data layers include climate, geology/soils, land, hydrologic variables, physical measures, chemical, and stream network and catchments. Climate inputs cover annual precipitation and daily/annual temperatures (degrees C). Bedrock geology, surficial geology, and STATSGO soil data (all in square meters) contribute to the geology/soils class of data.

The land classification of data layers contains land cover, percent impervious, population density, percent canopy, areas of artificial drainage, and physiography. Hydrologic variables cover base flow index, infiltration excess overland flow, saturation excess overland flow, and recharge of the soils.

Physical measures include some data that can be acquired through a digital elevation model (DEM): drainage area, basin shape, slope, stream density, stream length, and road density. Chemical inputs are either the average or the total of nutrients from fertilizers, manure, and atmospheric deposition. All of the data input layers are in raster format.[142]

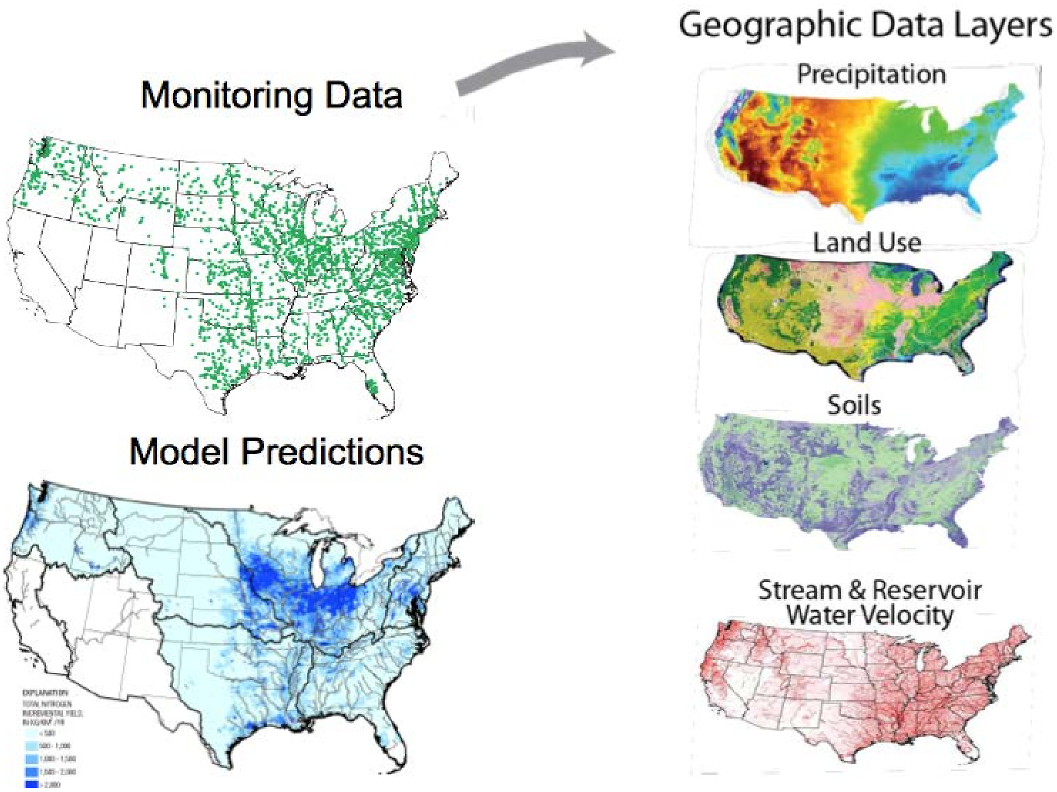

Figure 5.4: Integrating monitoring data with geospatial layers to make ecological predictions[143]

Discussion

The results from SPARROW are delineated as predictions of nutrient loading based upon the given parameters of nutrient sources and quantities. The predictions can be attained at multiple scales for streams, watersheds, and geographic areas. The EPA has created the Nitrogen and Phosphorus Pollution Data Access Tool (NPDAT), which is an easy method for displaying SPARROW results.

SPARROW can be utilized as a tool to describe the regional conditions by overcoming limitations of monitoring through its statistical extrapolation methods. SPARROW also allows the user to identify which sources they would like to model, while the model links conditions in each stream reach to individual sources in each upstream reach. For many cases, these capabilities will be enough, but it is important to note the limitation that SPARROW does not allow for the manipulation of phosphorus loading based upon conservation practice application. Nutrient loading is based strictly upon the loading sources like fertilizer and manure, but there exists no means to add in conservation practices in order to see how phosphorus loading would decrease. Furthermore, SPARROW can only model the total phosphorus concentrations passing through the lands, and is *unable to delineate between particulate and dissolved phosphorus*.

The results from SPARROW are only the temporal and spatial average, meaning that the equations describe only the average rate of movement of nutrients through the watershed. Additionally, since SPARROW analyzes such large areas of land, the resolution is very coarse. Individuals who choose to utilize this tool are able to search for the reach of their interest, but when extracting data only the sub-watershed SPARROW offers up all data from the current zoomed in page.

SPARROW possesses the capability to aggregate the delivered load of a specific nutrient to the mouth of the watershed. This gives the user the ability to analyze upstream regions that are contributing various amounts to the total delivered load of the river system. SPARROW first identifies all the reaches upstream of the selected mouth or downstream reach (we selected the mouth of the Maumee as the downstream reach of interest). Next, incremental delivered loads for each upstream reach are summed to provide aggregated delivered load. Unfortunately for our purposes the delivered load is specified as total phosphorus, not fractionated out to only the dissolved reactive phosphorus. Nonetheless, it was important to utilize the output from this function to produce marginal cost curves in Chapter 7.

5.3 SWAT - Soil and Water Assessment Tool[10]

The Soil and Water Assessment Tool (SWAT) is a publicly available computer program created and run through a joint effort of the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) and Texas A&M AgriLife Research. Like SPARROW, it is integrated with the ArcGIS so that many different scenarios can be run on the same geographic area. Unlike SPARROW, it requires a great deal of information from the user including the geographic area of interest, climate, and land cover in order to function effectively. This allows the program to be tailored to any region for which the requisite data exists without needing to change the fundamental governing algorithms. This program only functions with an ArcGIS program and license so it can only be used by individuals with considerable skills in spatial analysis and access to ArcGIS, thereby limiting the number of individuals and organizations that can effectively use the system.

SWAT was initially created in the early 1990s largely by Dr. Jeff Arnold at the USDA to predict the impact of land management on water quality, sediments, and agricultural chemical yields in complex watersheds. It incorporates elements of previous tools such as GLEAMS, CREAMS, EPIC, and is seen as a direct successor of the earlier Simulator for Water Resources in Rural Basins (SWRRB). It is widely agreed to be one of the most effective modeling tools for agricultural constituents in large watersheds.

This tool has been successfully used across the world to pinpoint the sources of constituent loading for various water bodies. SWAT incorporates land cover, the climate, as well as the types of conservation practices that are being employed to manage the runoff and loading to model constituent movement. The program uses standard governing equations to combine all of these factors and create a spatial map that shows what areas are contributing to the total constituent loads. These equations combine constituent movements within the soils, the amount of runoff and how that changes over distance to produce the final load map.

Base data for the model can come from two separate sources: on the ground measurements of water quality, soil, and other factors or estimates conducted within the model using generalized

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[10] All information is from the SWAT theoretical documentation 2009

datasets maintained by national or regional organizations. This model accounts for decomposition of organic materials, nutrient uptake, and remobilization of the nutrients making it a fairly comprehensive way to assess nutrient movements.

Model Framework

SWAT, unlike many other models, does not use regression equations to determine the relationships between inputs and outputs. This model instead relies on the specific base data such as climate and soil type and then uses them to calculate constituent movement through the hydrologic systems. This allows for different factors to be altered to model land use management changes as well as changing climactic conditions which would allow scientists and planners to create "scenarios" that model watershed or regional policy actions and management decisions.

The vital first step in using SWAT is to delineate the various watersheds into hydrologic response units (HRUs) that will make up the model. The next step is to enter precipitation data, followed by solar radiation data and other air factors. Finally, the soil temperature and snowmelt layers are added and then the model is ready to be run.

SWAT is excellent for tracking water movement as well as the constituents water picks up along the way. The first calculation in SWAT computes runoff volume as well as infiltration rate in order to determine how much water is moving through the system and where it is moving. The second calculation produces the systems sediment yields, nutrient yields, and any other factors that are a result of the water moving through the system. The final calculation produces a physical map of soil and water routing, evapotranspiration, crop growth, and water balances throughout the system.

Discussion

SWAT is a highly flexible tool that is widely applicable to many different systems and is only fundamentally limited by the accuracy of the basic information being fed into the program. Unlike many other tools, SWAT allows even its base assumptions to be altered in order to more accurately represent a specific watershed.

While all of this flexibility is a built-in model "feature," it can make it difficult for individuals without a background in computer modeling to use the program. The nature of the program also requires extensive calibration, which can take several months to produce a viable model of the modeled area. SWAT is also limited by the governing equations, which are largely representative of general water movement and may be somewhat inaccurate on a case-by-case basis.

With all of these limitations, SWAT can take several days to run an analysis on larger watersheds, the very systems to which it is most likely going to be applied. Despite these limitations SWAT is an incredibly useful program with wide applications for a number of different watershed scales. It can make scientific data easier to incorporate into management decisions and help policy makers visualize the impacts that a variety of policies and management practices can have on constituents.

While SWAT models several different forms of phosphorus and the transfers between the various phosphorus pools, <u>soluble reactive phosphorus is not directly modeled</u>. The model relies on modeling the bulk movement of phosphorus through different soil layers and stages rather than the dynamics associated with chemical sorption or other more complex interactions. The phosphorus dynamics in the shallow aquifer beneath the first 10 cm of soil are not actively modeled but are set as a value by the user. The end result is that while bulk phosphorus dynamics are effectively modeled using this program the fine scale dynamics may require alternative models.

5.4 GLWMS - Great Lakes Watershed Management System

The Great Lakes Watershed Management System (GLWMS) is a web-based, easy to use, spatial implementation of the High Impact Targeting (HIT) and Long Term Hydrologic Impact Analysis (LTHIA) models for the Great Lakes's four priority watersheds: the Maumee, Saginaw, Fox, and Genesee river basins. It was jointly developed by The Nature Conservancy, the U.S. Army Corps of Engineers (USACE) Chicago District, The Institute of Water Research at Michigan State University, and the Department of Agricultural and Biological Engineering at Purdue University.

The USACE has previously focused on developing detailed tools that answered specific watershed specific questions and required training for their use after development. It is now promoting the GWLMS as a general purpose, easy to use web tool to guide field and watershed level agricultural decisions and to allow more people to become involved in decision making. For example, the field scale tool is used by The Nature Conservancy in the Saginaw Bay region to prescreen projects that they help support using the tool. There RCPP proposal states that: "While we request that NRCS allow us to provide cost share funding for any nutrient management plans (104) and/or drainage water management plans (CAP 130) automatically, we propose to evaluate all other proposed implementation projects using the scoring rubric." Details of their scoring rubric are shown in Appendix 5C.[144]

Model Framework

HIT models erosion using the revised universal soil loss equation (RULSE) and calculates sediment contributions by looking at distance to streams as well as the slope and roughness across the distances required to get to them.

LTHIA calculates nonpoint source pollution contributions of different land uses and is based on looking up data from tables. It first uses the Curve Number Method to calculate the runoff from each pixel, a method that is flexible to different combinations of soil type and land use. It then multiplies this calculated amount of runoff by EPA loading concentrations. Again, loading concentrations are expressed in a table which contains values for contributions of constituents depending on land use.

Both of the models can be run at the field and watershed level. Used together in the GLWMS, the user can evaluate changes in nonpoint pollution and erosion based on the implementation of a few select conservation practices at both the field and watershed level.

Discussion

GLWMS has several benefits, chief being its comparative ease of use and accessibility as a web based tool. Most importantly, GLWMS allows the user to implement certain conservation practices at field and watershed levels to see the change in pollutant loadings.

During our team's analysis, significant coding errors were found during testing of the HIT segment of GLWMS, including cases where increasing conservation practice applications *reduced* benefits. These were reported by our team to the Institute of Water Research and have been corrected but we cannot be certain the code has been fully debugged. The source code was requested but not made available for review so no further comment can be made. See Appendix 5B for outputs before and after correction.

While the tool has seen positive results for public consumption it is difficult to perform academic analysis, such as optimization, using the platform. Each query must be submitted individually for multiple scenarios and data copied into a processor. There is no bulk data export capabilities for multiple scenarios – even though they are all possibly present in a spreadsheet in the backend. Moreover, base layers are not directly or easily available, especially the Crop Management factor, which was put together by the GLWMS developers.

HIT claims that it optimizes conservation practice placement on those acres contributing the highest sediment loads. However, this optimization only occurs at the HUC 12 level. For larger sub watershed delineations (HUC 10 and 8), the tool simply adds the reduction from the selected placement for each HUC 12 area under the larger watershed and does not re-optimize.

Poor and outdated documentation compounded by lack of response from the Department of Agricultural and Biological Engineering at Purdue University for LTHIA makes it hard to comment on specifics for this component of the model. This is unfortunate as it is the basis for NPS pollution, the focus of this study. The documentation gives an explanation of the watershed scale implementation present in GLWMS but LTHIA does not have watershed scale implementation of conservation practices. The model does allow for easy field scale implementation of several conservation practices but there is no documentation to explain the processing. While field scale conservation practice application is useful for land managers, it is not useful for informing large-scale policy decisions, apart from serving as a potential tool to evaluate impacts on individual farms.

<u>LTHIA, and thus GLWMS, does not model dissolved or soluble phosphorus and only deals with total phosphorus runoff.</u>

5.5 Snap Plus - Soil Nutrient Application Planner Plus

The Soil Nutrient Application Planner, is Wisconsin's Nutrient Management planning software and was developed for use by farmers to help them make the best use of on-farm nutrients. SNAP Plus is supported by the Department of Soil Science at the University of Wisconsin-Madison, USDA NRCS, University of Wisconsin Extension, the Wisconsin Department of Natural Resources, and the Wisconsin Department of Agriculture. Nutrient management planning with Snap Plus addresses the 4 Rs: the right source; right rate; right time; and right place. [145]

Model Framework

Snap Plus uses the Revised Soil Loss Equation 2 (RUSLE2) to assess soil loss and the Phosphorus Index to calculate phosphorus related calculations. The Phosphorus Index is a simple point based system that assigns points to various factors. [146] A combination of slope and field soil quality determine base points in the tool and fields get additional points for connectivity to water, phosphorus fertilizer application rate and method, soil erosion from the field, and the current amount of phosphorus in the soil. Points are then subtracted for the presence of buffer strips.

The Phosphorus Index qualitatively ranks field vulnerability for phosphorus loss to surface water as low, medium, high or very high based on the total points scored. As the Phosphorus Index is the core of Snap Plus, its governing equations are presented in full in Appendix 5A.

Discussion

For a field scale tool, Snap Plus is very effective though this also means it is not well suited to modeling management strategies at the watershed scale. Currently, a $2 million grant is funding research in improving the Ohio P index which could be used in lieu of the Wisconsin P Index should Snap Plus be utilized in the Maumee River watershed. [147]

In 2012, Snap Plus was used for 87% of the nutrient management plans developed in Wisconsin.[148] Furthermore, farmers can use Snap Plus to calculate the change in phosphorus run off based on their practices and use its output to qualify for credits in the Wisconsin water quality trading program.[149]

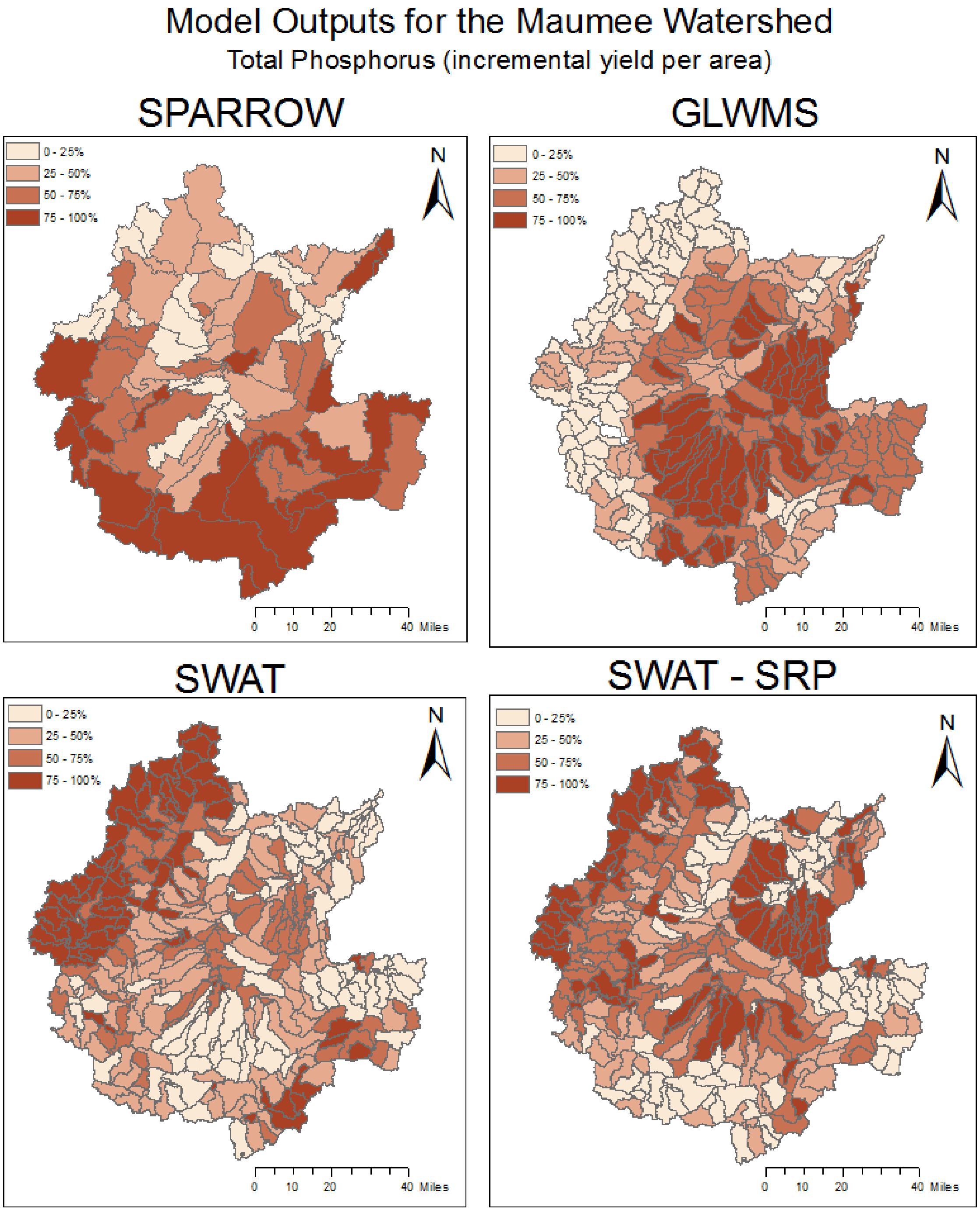
Using Snap Plus is challenging because it requires detailed inputs and not just the field boundary as in the web based programs. However, the benefit is it produces is a much more accurate result as it uses the actual on-the-ground conditions instead of having to approximate tillage and crop rotations based on historical trends. There are very regular training opportunities available for farmers (9 scheduled for March 2015).[150] Online support is also available with prompt and helpful response to questions.

Snap Plus calculates soluble phosphorus along with particulate phosphorus to evaluate the phosphorus runoff risk potential. However, as the output is focused on a runoff risk rating, the model does not output its intermediate calculations on soluble phosphorus.

Output Maps

Figure 5.5 displays outputs of three of the models we compared and shows the total phosphorus loading per acre from each of the parcels delineated in the map. Per acre loading is displayed instead of total so that it is possible to compare between the different sized parcels. The parcels are grouped into four quantiles for comparison between models. For example, being in the 0-25% bucket means that the parcel is in the lowest 25% bracket of phosphorus contributing parcels. The bottom right map is not total phosphorus but soluble reactive phosphorus output from SWAT, the closest approximation to dissolved reactive phosphorus.

Total phosphorus results are completely different between models. SPARROW ranks the southern periphery, the GLWMS ranks the central area, and SWAT ranks the northern periphery as the highest phosphorus contributing parcels. The lack of overlap between three models is surprising. Snap Plus is not a watershed scale model and is calibrated for Wisconsin and so does not have an output for comparison.



Created by Hassan Bukhari, 2/26/2015
Data from SPARROW, GLWMS
SWAT model by Margaret Kalcic

Figure 5.5: Comparison across model outputs for the Maumee watershed.

Chapter 6:
Priority Mapping

Contents

6.1 Overview of Multi-criteria Evaluation Models

Multi-criteria evaluation models (MCE) are a method of defining priorities within an environment like ArcGIS and using weights to visualize the results of that decision spatially. MCEs are also known as multi-criteria analysis models and multi-criteria decision making models. These are tools that utilize a weighting scheme of criteria to compare alternatives in a decision making process. Each determining criteria, or factor, is given a weight based on its importance to the decision and applied through this tool to provide a solution. Multiple weight regimes can be chosen to see how alternative priorities can affect the final spatial distribution of the target of interest and thus can optimize the decision. MCEs can be integrated with Geographic Information Systems (GIS) to utilize spatial information as factors.[151] The incorporation of spatial data allows for physical characteristics of the landscape to be criteria in the decision tool.

This model investigates these physical characteristics and how they influence dissolved phosphorus found in runoff, rather than simply the particulate nutrients that are normally lost through erosion of the region, which other modeling tools use as a proxy for dissolved phosphorus. Total phosphorus has been the common metric when monitoring for phosphorus runoff, but in recent years, it has been determined that dissolved reactive phosphorus (DRP) is a major concern for phytoplankton blooms. The ability to model DRP has been shown to be almost non-existent through our analysis in CH V, which is why our team chose to create an MCE for the spatial prioritization of conservation practices based upon their accepted ability to reduce DRP runoff from the fields.

Prioritization of locations for conservation practice implementation is critical in the efficient mitigation of nutrient pollution because it can conserve financial resources and also limit farmer fatigue from participating in too many practices, particularly if they are not seeing a benefit from the practices. Determining the most suitable management practices is dependent upon the physical characteristics of the land and the forms of nutrients being released. Additionally, prioritizing these practices for erosion or nutrient control can vary greatly. For example, regions with steeper slopes experience a higher rate of erosion and runoff of particulate nutrients; whereas areas that have soils with very low infiltration rates will need practices targeted towards controlling dissolved nutrient runoff.

Assessing the impact of each factor on the placement of each conservation practice requires an understanding of how these practices are implemented on the ground. For instance, Nutrient Management Planning is one of the most effective practices for controlling runoff; however it is very difficult to model spatially since there are no environmental conditions that would restrict its use. Riparian buffers, in contrast, are closely related to areas that are near water bodies, thus making it easier to define the relationship between this conservation practice and the physical environment. Each chosen conservation practice's relationship with the spatial environment is correlated to each input factor of the MCE.

Many efficient conservation practices are expensive or difficult to apply, so ascertaining the areas in most need of phosphorus control implementation is critical. MCEs can be very useful in locating the most suitable areas for conservation practice implementation based on singular prioritization of criteria. Prioritizing areas that will be most physically suitable for certain conservation practice applications will increase their efficiency and, ideally, their implementation and maintenance.

The inclusion of the multi-criteria evaluation model is to provide a methodology for decision makers, Conservation Districts, and other individuals to demonstrate the applicability of a tool for priority mapping within their watershed and the impacts that their decisions could have on impacting conservation practices within the watershed.

Currently, as highlighted in Chapter V, there is an inverse relationship between accessibility and accuracy in the models available to model agricultural runoff. Accessibility is defined with level of expertise needed and the cost or proprietary requirements to use it. Smaller watersheds that do not have those resources or the federal attention of the western basin of Lake Erie need feasible and practical methods for distinguishing the best locations for application of conservation practices. Tools like SWAT have extensive data and knowledge requirements, while the GLWMS is not suitable for watersheds outside defined surveyed regions. Through the creation of a MCE, individuals will have the tools necessary to designate the best regions for their own conservation practice implementation based on the best available knowledge, even when more complex tools are not at their disposal.

For these land managers, Conservation Districts, and individuals to produce their own MCE, a team member skilled in ArcGIS is necessary to manage the spatially explicit factors and to create the necessary maps for further analysis. Additionally the ‘spatial analyst’ toolbox is required for some of the tool we utilized in the model. Unfortunately, this toolbox may come at a cost outside of the regular ArcGIS license.

6.2 Methodology

Objective

Develop a ranking system that encompasses the physical characteristics and environmental considerations of nutrient losses from agricultural lands and defines the relationships between the physical environment and the success of conservation practices. The second objective is to utilize the GIS integrated MCE to apply this model to the Maumee River Watershed.

ArcGIS Tools Used:
Clip
Conversion (raster to shapefile)
Raster Calculator
Project
Spatial Join
Weighted Sum
Highest Position

Factors

The following data layers were given weights per parameters outlined below:

1. Slope
2. Distance to Water
3. Precipitation
4. Soil Drainage Class
5. Phosphorus Remediation

Data Sources

1. Land cover from the United States Department of Agriculture
2. Annual precipitation (in mm) from Dr. Kevin Czajkowski at the University of Toledo
3. Digital Elevation Model from the National Elevation Dataset
4. SSURGO data distributed by the Natural Resource Conservation Service
    a. Drainage Class
5. Water bodies and watershed boundaries from the United States Geological Survey's National Hydrologic Dataset
6. A dissolved phosphorus export model developed by Dr. Donald Scavia and Dr. Margaret Kalcic of the University of Michigan Graham Institute of Sustainability built using the SWAT model.
7. "A BMP Toolbox for Reducing Dissolved Phosphorus Runoff From Cropland to Lake Erie" phosphorus reduction index from Heidelberg University. Conservation practices were rated on a 5 to -5 scale. For the purposes of our MCE the reduction benefit was assumed to scale linearly rather than exponentially.

Data Specific Information

Drainage Class refers to the frequency and duration of wet periods under the most natural conditions of the soil, as much removed from anthropogenic influences as possible. Seven classes of natural soil drainage are identified, with their reclassified values in parenthesis:

(1) Excessively drained,
(2) Somewhat excessively drained,
(3) Well drained,
(4) Moderately well drained,
(5) Somewhat poorly drained,
(6) Poorly drained,
(7) Very poorly drained.

Excessively drained soils have high infiltration rates and low runoff rates, so was reclassified to 1; whereas the very poorly drained soils result in water buildup at the surface and high runoff rate, hence the higher value of 7.

Distance to water was calculated to determine the cost path of water from the field to surface water constrained by the slope. Instead of simply measuring the distance from each pixel of field to the closest water body, the cost path includes the influence of slope. If the water is moving down slope to the water body, it will move faster and thus the cost of this distance will be greater. This criterion illustrates the inverse effect of a smaller travel time on the increase of nutrient runoff. It estimates the total cost associated with traveling through that cell, including calculating the exponential costs of nutrient loss at a higher slope.

Phosphorus remediation was used to correlate the conservation practice distributions with the ability of that practice to reduce phosphorus. Conservation practice reduction coefficients are very difficult to assess due to the relatively new focus on dissolved reactive phosphorus and the dearth of data to base any firm conclusions on. Heidelberg University has created an excellent toolkit with a qualitative ranking of the dissolved reactive phosphorus reduction potential of many different conservation practices. This toolbox was relied on heavily for correlating the conservation practices with the phosphorus layer. Heidelberg University in Tiffin, Ohio, has maintained a sterling reputation for high quality water science since the founding of the river laboratory in 1969. The long term monitoring studies produced by the university have been integral in research on Lake Erie and formed a major part of our master's project. [152]

Overlay Analysis

Conservation practices were originally chosen for their effectiveness at reducing DRP runoff and for their availability for manipulation within watershed management tools analyzed in Chapter V. We used the conservation practice toolkit from Heidelberg University as the source for practices and their ability to reduce DRP runoff. We chose one or two most effective practices from the different groupings of conservation practices delineated by Heidelberg University.

Chosen conservation practices as delineated by NRCS title, NRCS code, and group:

1. Mulch till/reduced till (NRCS 345) is under the tillage group
2. Tree/shrub establishment (NRCS 612) is type of land retirement
3. Strip cropping (NRCS 585) is a method under conservation cropping
4. Cover crops (NRCS 340) is a type of conservation cropping
5. Subsurface injection (NRCS 590) is a form of nutrient management
6. Riparian forest buffer (NRCS 391) is a buffer

The weights for each conservation practice were assigned on a scale of .11-9 with numbers less than 1 indicating a negative correlation with the feature. The weights (see Table 1) are dimensionless figures representing the relative scale of influence each factor has on a given conservation practice. This scaling is somewhat subjective and is a representation of the relationships our group has tried to establish between various conservation practices and the physical landscape.

Weights for each conservation practice were ascertained based on their effectiveness in DRP reduction. Using each of the environmental and physical conditions of the watershed, weights were used in a pairwise comparison matrix. This method compares each factor to every other factor in sequence and in pairs to determine the importance of one over the other, then receiving a score on how much more suitable the factor is over the other.

Conservation Practice	***Slope***	***Distance to water***	***Precipitation***	***Soil drainage class***	***Dissolved reactive phosphorus***
Mulch till	2	2	0.25	7	0.33
Tree/shrub establishment	6	0.11	6	0.11	9
Strip cropping	7	0.33	4	4	3
Cover crops	7	0.17	5	8	3
Subsurface injection	0.25	4	2	5	5

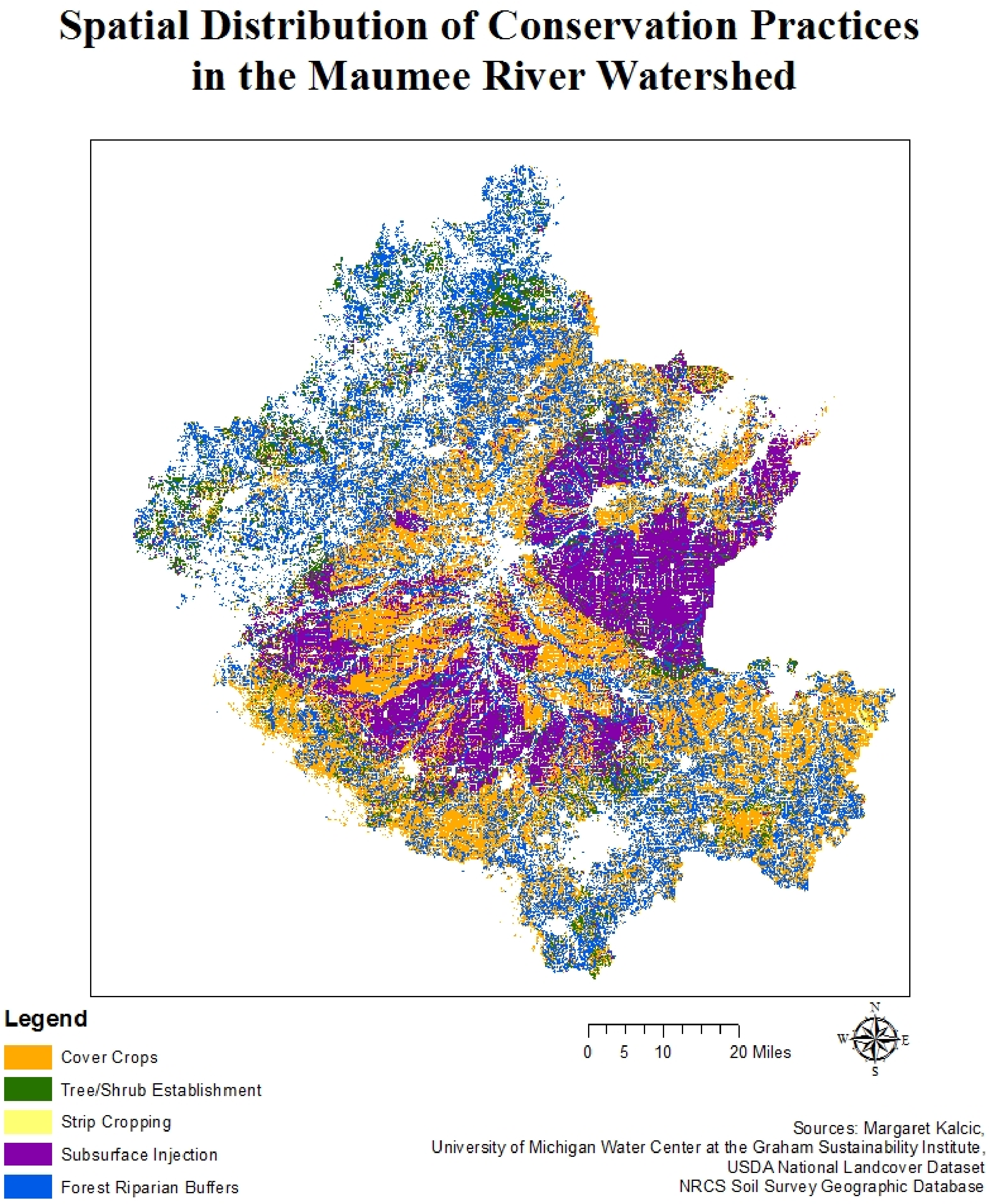
Table 6.1: Weights assigned to factors determining success of conservation practice

The Table 6.1 matrix takes into account several factors that could influence success including personal farmer preferences as well as physical characteristics associated with conservation practice implementation. For instance, the tree/shrub establishment scores high on the slope metric because it would be ideal to have slopes covered in well-developed plant communities, which reduce erosion and particulate phosphorus transport. After the model is run, the results would delineate areas with steep slopes as a high score for tree/shrub establishment and would be more likely to be assigned for this use. Areas that are low lying, far from water, and on a shallow slope are much more likely to be assigned a practice such as mulch till as this practice is likely to be implemented on productive farmland. This matrix is an assessment of our inputs and will change based on a review of this information by scientists from Heidelberg University.

In order to use an MCE the data must be in the form of a raster layer. Raster data is a geometric representation of information where cells are divided into blocks and assigned one value per block. The resolution for all of our input datasets was 30 by 30 meters so the maximum resolution that can be expected from the data set is quite large (900 square meters). The data layers were clipped to only represent the area available for cultivation (the farmland in the Maumee River watershed). With the area clipped to the spatial extents of the farmland in the watershed we used the spatial analyst toolbox of ArcGIS to calculate the spatial statistics incorporating our weighting scheme and finally displayed the "Highest Position" data for each pixel. "Highest Position" assigns the pixel to the conservation practice that got the highest score based on our input factors.

To get the information for the response curves require the calculation of an impact coefficient, or how much benefit was achieved per acre as a result of the specific conservation practice. We used the qualitative ranking system created by Heidelberg and multiplied these rankings by the dissolved reactive phosphorus export coefficients. The highest values would show where the most "effective" conservation practices were being applied, but to tease out these values we divided the product by the highest value possible to create percent scale, with 100 being the highest impact and 1 being the lowest impact.

6.3 Results



Spatial Distribution of Conservation Practices in the Maumee River Watershed

Sources: Margaret Kalcic,
University of Michigan Water Center at the Graham Sustainability Institute,
USDA National Landcover Dataset
NRCS Soil Survey Geographic Database

Figure 6.1: MCE output

Figure 6.1 is a direct output of our MCE. The map illustrates the spatially explicit prioritization of specific conservation practices within the watershed. It is interesting to see how the model prioritizes the conservation practices based on the weight regime. For example, forest riparian buffers are most suitable right next to waterways and thus by following the blue within the map, can easily delineate some of the tributaries of the Maumee River. Additionally it is intriguing to see that cover crops are so ubiquitous, thus considered favorable across different landscape types. Subsurface injection, as one of the most effect conservation practices, is seen prioritized in the center basin where there is low slope and the soils are very poorly drained and a higher rate of runoff. Strip cropping is only seen within a few locations, explicating that the other chosen practices are more suitable across the landscape for implementation.

Percent of Agricultural Land by Conservation Practice		
Conservation Practice	Total Area (ha)	Total Percent of Agricultural Land
Cover Crops	342,793	34.51
Tree/Shrub Establishment	91,804	9.24
Strip Cropping	1,860	0.19
Subsurface Injection	215,810	21.73
Forest Riparian Buffers	340,994	34.33

Table 6.2: MCE Output for % Agricultural Land by Conservation Practice

Unsurprisingly, even though mulch till was integrated into the model, its inability to reduce DRP prevented it from being displayed in our output map. Demonstrating that our weight regime prioritized the other practices above it, the model deemed those other practices more suitable and more effective at these locations.

6.4 Limitations

It must be recognized that MCEs are most useful in comparing the overall performance of each alternative and do not provide absolute solutions. The simplicity and high-efficiency for spatial prioritization of MCEs are the major drivers of their utilization. The weights used within our MCE were initially created by our team members, and then vetted by experts at Heidelberg University in Ohio. One of the commonly discussed disadvantages of MCEs is the ranking and rating method for the factors and the difficulty in justifying their weights. Our weighting criteria are based on the best understanding our team members have of how these conservation practices are affected by landscape scale factors. There is a significant deficiency in that our team members are neither farmers nor agronomists and the experiences of our team with the specific cropland in Ohio are limited. Were these techniques to be replicated our team would suggest focused workshops to broaden the community engagement and leverage the experience of the community. This would help to create a more comprehensive model framework and maximize the value of this technique. Furthermore, some critical factors in nutrient loss from agricultural lands, livestock waste, crop types, fertilizer application, irrigation practices, temperature, and wind speed, have been overlooked either due to the lack of data availability or to maintain model simplicity. A more stringent data validation process would be favorable, but with time and labor constraints, on-the-ground assessment, implementation of conservation practices, and follow-up monitoring are simply not feasible.

Chapter 7:
Marginal Costs Analysis

Contents

7. 1 Overview

In discussing various approaches for controlling nonpoint source pollution and dissolved reactive phosphorus (DRP) specifically, it is important to recognize that at any given level of abatement, the cost may differ. Put simply, the marginal cost of abatement describes the change in the cost of abating each additional unit of pollution as total abatement increases. The concept of "low-hanging fruit" demonstrates the idea of marginal costs – for the lowest hanging fruit, or the most cost-effective actions, lower expenditures will result in higher pollution abatement. As these "low hanging fruit" are captured, the "higher fruit," will be attained only at a higher cost per fruit, or per unit. As more pollution is addressed, the cost to reduce the subsequent units of pollution generally increases.

The research in this chapter is limited to marginal costs rather than a complete cost-benefit analysis because, although the qualitative benefits of reducing DRP runoff, including less eutrophication and smaller algal blooms, are clear, they have yet to be quantified. While a complete picture of marginal costs and marginal benefits, the benefit of producing or abating one more unit, can reveal the ideal level of action, marginal costs can still help in decision making.

In planning for abating DRP pollution, it is important to understand the varying practices that can be used to reduce the runoff and to understand that the cost effectiveness of these practices varies, both among practices and for a single practice in different locations in the watershed. This arises from both variation among the cost of the conservation practices themselves (discussed in Chapter 3) and variations in the DRP abatement that will result from implementing a practice across different locations.

A marginal cost analysis provides a point of comparison in selecting the most cost-effective combination of conservation practices to use given the amount of pollution to be abated, or the set of conservation practices that will lead to the most pollution abatement for a given budget. This analysis significantly contributes to the selection of conservation practices and policies to reduce DRP because an integrated assessment requires an evaluation of not just the efficacy of conservation practices but the ease of implementation. Marginal cost curves provide an economic reasoning for selecting specific practices, at specific quantities, in order to achieve abatement goals in the most cost-effective way.

This chapter illustrates the use of marginal costs with an example from sediment runoff in the Maumee. While data limitations precluded a full marginal cost analysis of DRP abatement, the conservation practices that have been highlighted in previous chapters are interpreted on a relative marginal cost curve. This is used to develop low, medium and high-investment scenarios for DRP abatement.

7.2 Marginal Cost Example for Sediment

The following example shows a possible use of Marginal Cost (MC) curves to decide the level of implementation of selected conservation practices.

Recent developments have resulted in public pushback from the open dumping in Lake Erie of sediment dredged by the Army Corps in Toledo Harbor. Proposals to transport dredged sediment elsewhere, rather than dumping it in the lake, will possibly increase the cost of sediment disposal from $65 per ton to $227.5 per ton for various alternate disposal scenarios[153]. For the purposes of this example, we will assume that the Army Corps' cost for sediment transport will be $100 per ton.

The Great Lakes Watershed Management System (GLWMS), a nutrient modeling tool analyzed in Chapter V, allows the user to calculate the reduction in sediment loading by implementing select conservation practices: no-till, mulch till, and grass cover on a user defined proportion of the watershed.[154] This allows us to create marginal cost curves for reduction in sediment due the implementation of these conservation practices. Comparing the cost of avoiding sedimentation through conservation practices with the cost incurred by the Army Corps in dredging sediment can help guide policy decisions. Conservation practices can prove a good investment if their cost per ton of avoided sediment is cheaper than the cost of dredging that sediment, were it to erode into the river.

The GLWMS prescribes the cost of no till as $24 per acre, mulch till as $31 per acre, and grass cover as $393 per acre. The tool states that these are based on 2013 EQIP data, and the tool was developed under the auspices of several credible institutions. Therefore, we keep these costs intact so that the results of the tool reflect the inputs of the creators.

We ran the tool at the HUC 8 level for a coarse result. The tool optimally puts the first acres of practices where they will result in maximum sediment reduction and slowly this reduction decreases. Running the tool outputs the marginal cost of abatement curves graphed in Figure 7.1. The horizontal lines indicate a marginal cost of abatement of $100 per ton, equal to the disposal costs incurred by the Army Corps. No till reduces sediment considerably at a marginal cost of $100/ton.

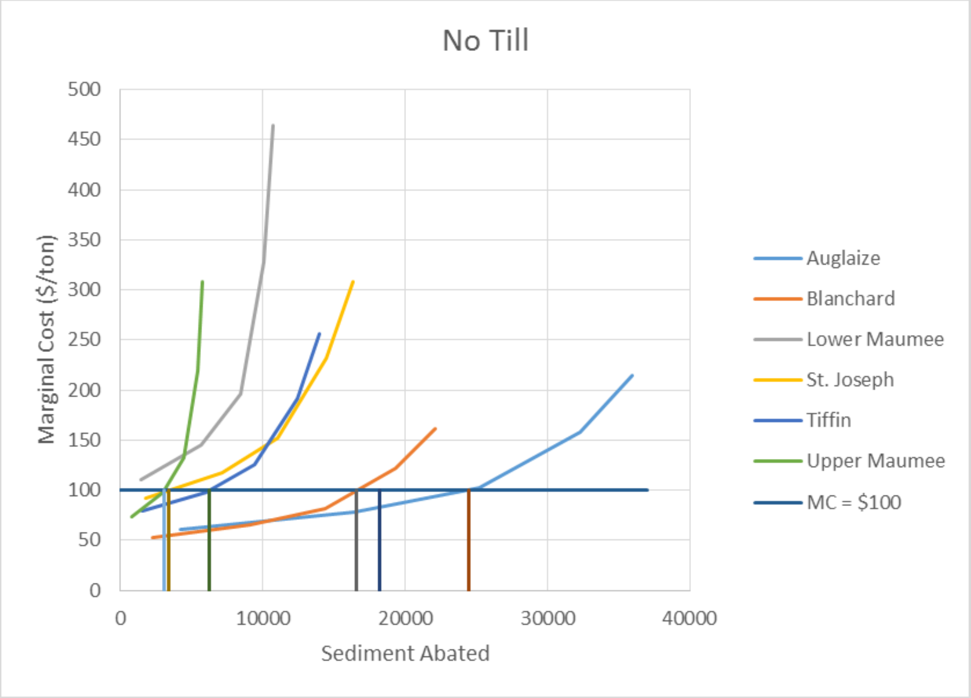


Figure 7.1: Marginal cost curves for implementation of no till at the HUC 8 level

There is a very small contribution from mulch till, Figure 7.2. As is visible the maximum reduction for marginal costs up to $100 is only about 450 tons compared to thousands of tons for no-till.

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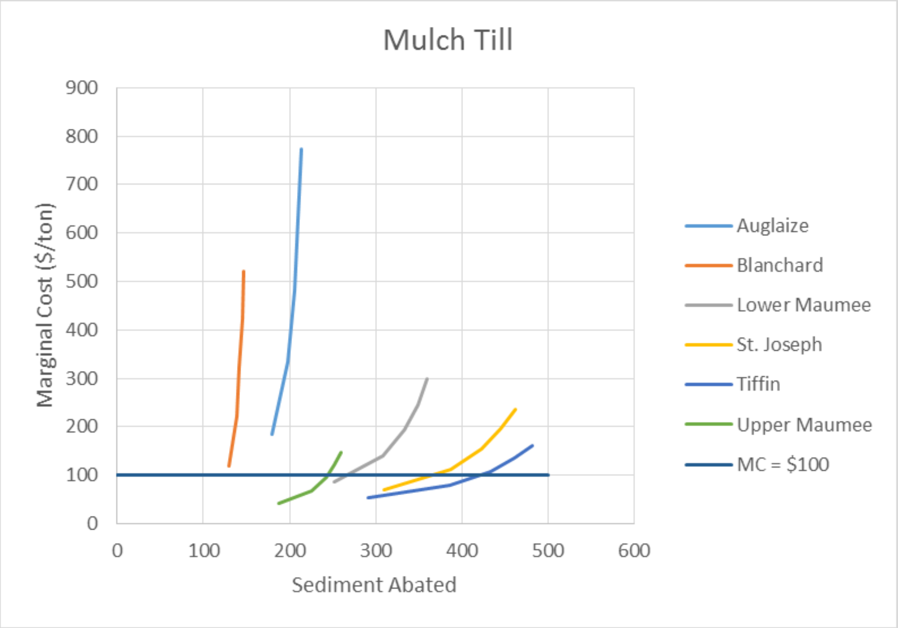

Figure 7.2: Marginal cost curves for implementation of mulch till at the HUC 8 level

At no point does the marginal cost of abatement by grass cover go as low as $100 per ton at the HUC 8 level.

No Till

A more in-depth examination of the no-till curves reveals the abatement impact of implementing the practice at points across the Maumee River watershed where the resulting marginal cost of abatement will be bellow $100. The values in Table 7.1 are obtained from the results by interpolating between the points at where the marginal cost of sediment abatement is $100. The total cost of implementing this program will be the area under the curves up to the point at which they intersect the MC = $100 line.

HUC 8 sub watershed	Total Sediment Abated (tons)
Auglaize	24467.58
Blanchard	16624.45
St. Joseph	3464.923
St. Marys	18212.69
Tiffin	6304.5
Upper Maumee	3121.588
Total	72195.73

Table 7.1: Sediment abatement potential at costs lower than $100 per ton by sub watershed

7.3 Marginal Cost of Abatement for Dissolved Reactive Phosphorus

The multi-criteria evaluation (MCE) model, described in Chapter VI, matches each location within the watershed with the conservation practice that is most suitable for reducing or abating DRP runoff in that location. However, resource limitations may make it unrealistic to implement conservation across every acre of agricultural land in the watershed. Furthermore, the actual reduction in loading resulting from implementing these conservation practices will vary from location to location across the watershed based on ecological characteristics and on the nature of the conservation practice recommended. The cost-effectiveness of implementing the recommended conservation practice in a given location similarly varies across the watershed. In some locations, the expense of implementing conservation practices may exceed what policy-makers deem worthwhile for the DRP abatement that would result.

A marginal cost analysis provides a mechanism to understand the relative cost-effectiveness of conservation practices in different locations across the watershed. Understanding these differences in the cost-effectiveness of pollution abatement allows policy-makers to use limited resources strategically. By implementing conservation practices in the locations where they will result in the greatest DRP reduction per dollar spent, programs can achieve the greatest reducing in DRP loading for a given budget or achieving a target loading reduction at the lowest possible cost.

Understanding Delivery Fractions

Nutrient loading can be measured at multiple locations in river or other water body. Nutrients carried by a river are removed from the flow through sedimentation, plant uptake, and other processes. As a result, a percentage of the nutrient loading entering a river arrives in the water body into which the river empties. This percentage is called “delivery fraction,” and varies by nutrient and by the point in the watershed from which the loading originates:

Delivery Fraction = Loading at mouth of river/Loading at edge of field
Or
Loading at mouth of river = Loading at edge of field * Delivery fraction

While the multi-criteria evaluation examines the suitability and relative impact of conservation practices on DRP runoff at the field scale, algal growth is shaped by the fraction of that runoff that is delivered into western Lake Erie. This delivery fraction will vary from field to field based on the length and characteristics of the stream network through which the DRP must travel to reach the lake. Understanding and incorporating these delivery fractions is important to developing an accurate understanding the impact of conservation practices on mouth-of-river DRP loading and of the associated marginal costs of abatement.

Current modeling tools (notably SWAT and SPARROW) incorporate delivery fractions to understand the relationship between edge of field and mouth of river total phosphorus loading. According to SPARROW, total phosphorus delivery fractions within the Maumee watershed range from 80% to 100% at the HUC-12 level. Because DRP is not attached to and does not settle out with sediment, we expect DRP delivery fractions to be higher than those of total phosphorus. However, DRP delivery fractions are not well understood and were not included in this analysis. Better defining these fractions should be a focus for further research.

Developing marginal cost curves

Developing a marginal cost of abatement curve for the five conservation practices examined in this study requires understanding both the reduction in DRP runoff, and the associated expenses that would result from implementing the practices in different locations across the watershed. The five practices focused on were subsurface injection, strip cropping, cover crops, riparian forest buffer, tree/shrub establishment, and mulch tillage. The conservation practice of mulch tillage was not included in the economic analysis because it was not deemed suitable for any area of land by the MCE. Unfortunately, the impact of various conservation practices on DRP runoff has not been quantified, and unlike sediment erosion, there are no easy to use modeling tools that can estimate the reductions in dissolved reactive phosphorous due to the implementation of conservation practices across a watershed scale. SWAT can model this, but an accurate SWAT model of large watershed is beyond the reach of most policy makers.

As a proxy, we developed a unitless DRP abatement score that provides insight into the relative reductions, if not the absolute abatement, achieved by each conservation practice across the locations in the Maumee Watershed. We assumed the DRP abatement achieved by instituting a conservation practice in a location to be the product of the potential of that practice to reduce DRP runoff and the amount of DRP loading that originated from that location before the practice was put in place. We multiplied qualitative DRP reduction score (from 1 to 5; see Chapter 3) of the conservation practice assigned by the MCE (Chapter 6) to each 30 by 30 meter pixel in the watershed by a normalized (1 to 100) scale of DRP loading from each HUC-12 subwatershed provided by Dr. Margaret Kalcic of the University of Michigan’s Graham Sustainability Institute. This assigned a relative abatement score, ranging from one (least abatement) to 500 (greatest abatement) to each 30 by 30 meter pixel of agricultural land in the watershed.

Next, we estimated the marginal normalized cost per unit of relative abatement (the marginal cost of abatement) achieved by implementing the assigned management practice on each 30 by 30 meter pixel by dividing the pixel’s DRP abatement score by the normalized cost of the practice assigned to that pixel. We used the unitless normalized conservation practice cost estimates developed in Chapter 3 in because of the large difference in range between the five conservation practices’ absolute per acre costs (which ranged over $720) and DRP reduction score (ranging from 1 to 5) made comparing costs of abatement across practices impractical. Normalizing costs to the same range as DRP reduction scores will allow us to develop a clearer picture of the relative abatement costs and cost-effectiveness. The relative abatement achieved per unit of cost (the marginal impact per expenditure) equals one divided by the marginal cost of abatement. Lower marginal relative costs of abatement or higher marginal relative impact coefficients associated with a pixel indicate that implementing the recommended practice on that pixel would be relatively more cost-effective.

Figure 7.4 graphs the changes in the marginal normalized cost of abatement (left) and marginal relative impact of expenditures (right) as the implementation level of the conservation practices in the MCE increases. In developing these graphs, we assume that practices will be implemented in locations in order of most to least cost-effective (lowest to highest marginal cost or highest to lowest marginal impacts).

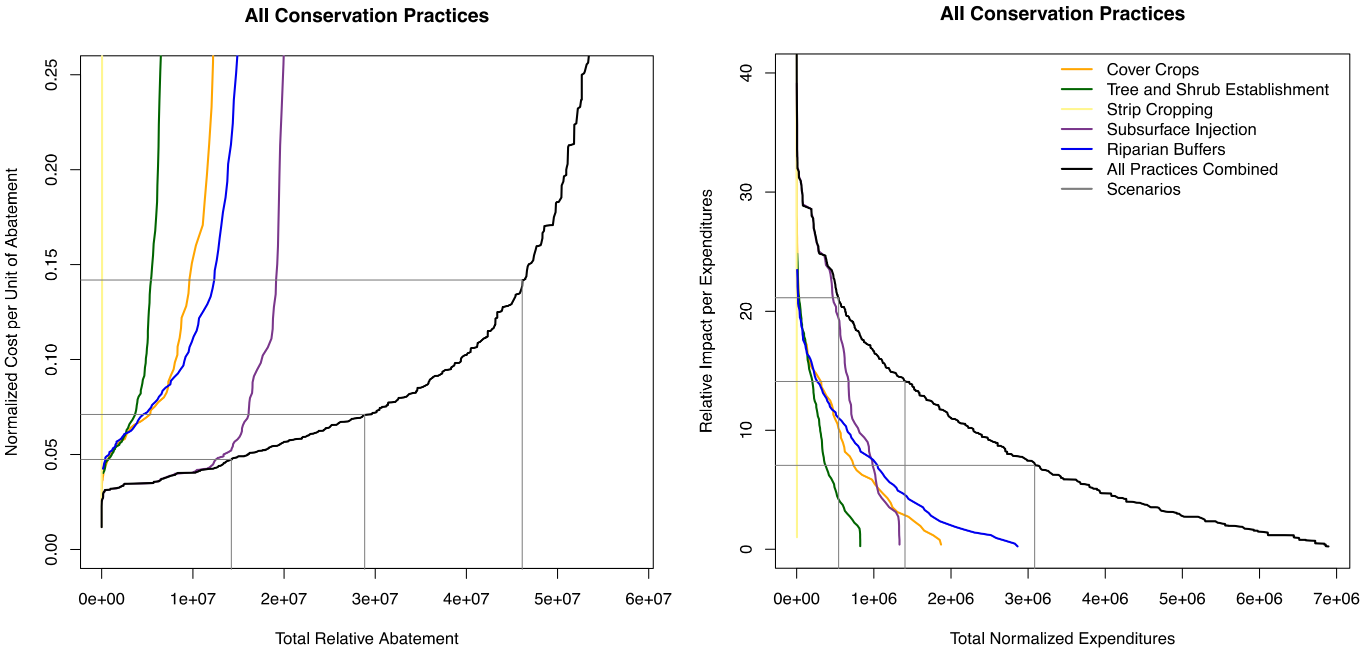

Figure 7.4: Marginal costs and impacts of conservation practices in Maumee watershed

Developing implementation scenarios

As a last step, we drew on these marginal cost curves to model four implementation scenarios:

- A whole-watershed scenario implementing recommended management practices on all agricultural lands in the watershed. This corresponds to a maximum expenditure to impact ratio, or maximum marginal willingness to pay, of 4.26.
- A high relative abatement, high normalized expenditure scenario that results in 75% of the relative abatement achieved in the whole-watershed scenario. This corresponds to a maximum expenditure to impact ratio, or maximum marginal willingness to pay, of about 0.142.
- A medium relative abatement, medium normalized expenditure scenario that results in 50% of the relative abatement achieved in the whole-watershed scenario. This corresponds to a maximum expenditure to impact ratio, or maximum marginal willingness to pay, of about 0.071.
- A low relative abatement, low normalized expenditure scenario that results in 25% of the relative abatement achieved in the whole-watershed scenario. This corresponds to a maximum expenditure to impact ratio, or maximum marginal willingness to pay, of about 0.047.

The acres in conservation practices, expenditures, and DRP abatement under these scenarios are presented in Table 7.2 and Table 7.3. Table 7.2 gives the values in terms of acres, unitless normalized expenditures and unitless relative abatement scores. Table 7.3 presents these values as percentages for easier interpretation. The low, medium, and high scenarios are represented graphically by the grey lines in figure 7.5.

Of the five conservation practices, subsurface injection provides the greatest portion of DRP abatement and would be implemented on the greatest number of acres across the low, medium and high scenarios. Cover crops and riparian buffers also become increasingly important as managed acreage and expenditures increase, while strip cropping plays a minor role across scenarios. The low-investment scenario achieves nearly 25% of possible relative DRP abatement at just under 8% of the normalized cost of the whole-watershed scenario, while the high-investment scenario achieves nearly 80% of the possible relative abatement at 47% of the cost. This indicates that moving from the high-investment to whole watershed scenarios results in relatively little increase in abatement at a high increase in cost.

Scenario:	Low	Medium	High	Whole Watershed
All Practices				
Acres Managed	205,380.68	482,013.62	996,100.82	2,131,837.06
Relative Expenditures	542,900.10	1,403,830.00	3,084,833.00	6,895,457.00
Relative DRP Abatement	14,226,110.0	28,840,046.0	46,121,976.0	58,176,829.00
Cover Crops				
Acres Managed	10,190.82	109,547.40	281,208.10	729,794.80
Relative Expenditures	26,122.92	280,811.10	720,842.00	1,870,738.00
Total Relative DRP Abatement	623,521.49	4,813,009.00	9,511,627.00	13,499,223.00
Tree/Shrub Establishment				
Acres Managed	7,905.57	50,156.68	90,089.52	204,554.50
Relative Expenditures	31,835.18	201,977.50	362784.3	823,726.80
Relative DRP Abatement	724,404.00	3,624,599.00	5,330,207.00	7,106,947.00
Strip Cropping				
Acres Managed	177.25	1,110.23	2,601.90	3,962.66
Relative Expenditures	177.25	1,110.23	2,601.90	3,962.66
Relative DRP Abatement	4,197.00	21,011.54	38,429.93	43,850.62
Subsurface Injection				
Acres Managed	183,159.28	263,055.70	382,791.40	521,657.60
Relative Expenditures	467,934.68	672,053.70	977,954.10	1,332,729.00
Relative DRP Abatement	12,495,389.40	16,109,591.00	19,081,967.00	20,488,970.00
Riparian Buffers				
Acres Managed	3,947.76	58,143.61	239,409.90	671,867.50
Relative Expenditures	16,830.04	247,877.40	1,020,650.00	2,864,300.00
Relative DRP Abatement	378,599.70	4,271,835.00	12,159,744.00	17,037,839.00

Table 7.2: Conservation practice implementation scenarios

Scenario:	Low	Medium	High	Whole Watershed
All Practices (amount in scenario as a percentage of the corresponding amount in whole watershed scenario)				
% possible acres managed	9.63%	22.61%	46.72%	100.00%
% possible expenditures	7.87%	20.36%	44.74%	100.00%
% possible DRP abatement	24.45%	49.57%	79.28%	100.00%
Individual Practices (amount in individual practice as a percentage of the total amount in the scenario)				
Cover Crops				
% acres managed	4.96%	22.73%	28.23%	34.23%
% expenditures	4.81%	20.00%	23.37%	27.13%
% DRP abatement	4.38%	16.69%	20.62%	23.20%
Tree/Shrub Establishment				
% acres managed	3.85%	10.41%	9.04%	9.60%
% expenditures	5.86%	14.39%	11.76%	11.95%
% DRP abatement	5.09%	12.57%	11.56%	12.22%
Strip Cropping				
% acres managed	0.09%	0.23%	0.26%	0.19%
% expenditures	0.03%	0.08%	0.08%	0.06%
% DRP abatement	0.03%	0.07%	0.08%	0.08%
Subsurface Injection				
% acres managed	89.18%	54.57%	38.43%	24.47%
% expenditures	86.19%	47.87%	31.70%	19.33%
% DRP abatement	87.83%	55.86%	41.37%	35.22%
Riparian Buffers				
% acres managed	1.92%	12.06%	24.03%	31.52%
% expenditures	3.10%	17.66%	33.09%	41.54%
% DRP abatement	2.66%	14.81%	26.36%	29.29%

Table 7.3: Conservation practice implementation scenarios

Assumptions and Limitations

Ultimately, conservation investments should be made at a level that will achieve quantitatively defined goals, based on the ecological and social costs of DRP runoff. These goals can take the form of an abatement target, such as that outlined in the IJC’s Lake Erie Ecosystem Priority Report, or an understanding of the social cost of each unit of DRP runoff. Developing these goals is beyond the scope of this project. In this analysis, our assumptions about the abatement achieved by different conservation practices, the lack of concrete data about DRP delivery fractions, and our reliance on relative, unitless metrics precludes its use in determining the investments in overall DRP abatement or in particular conservation practices that will achieve a specific goal.

However, this analysis does begin to indicate the most efficient sequence in which to implement management practices in the watershed. Our hope is that, once the relationships between land management and DRP runoff are better understood, this analysis can form a foundation for a formal marginal cost analysis that will relate the true costs (in dollars) of conservation practices with actual marginal changes in DRP abatement.

Chapter 8:
Synthesis and Recommendations

Contents

8.1 Introduction

This project uses an integrated assessment to evaluate approaches for controlling nonpoint source pollution runoff from the Maumee watershed into the Western Lake Erie Basin. As a team, we chose to highlight the ecological characteristics that determine the ideal conservation management practices for each unit of agricultural land in the watershed. We evaluated several modeling tools in order to do this, but found that all have limitations. A multi-criteria evaluation was developed as a method that enables a non-expert to utilize available data to help make these determinations. Based on this analysis, we assessed the marginal costs of conservation practices so that the most cost effective combination can be chosen. Since this information is all acted upon on in a policy environment, it is important to understand which policies would most effectively lead to the implementation of these varied conservation practices. These policies range from voluntary participation on behalf of the farmers to more stringent mandatory practices and end of pipe standards.

8.2 Methodology

Chapter 1 outlines a methodology that a broad range of stakeholders with varied resources and expertise may be able to use to make these distinctions. In this section, we will outline our attempt to employ this methodology to analyze strategies for reducing DRP runoff in the Maumee. We discuss our findings as well as limitations we faced.

Data collection and landscape scan

The quality of data is one of the most important aspects of making informed decisions for a watershed as large as the Maumee. Obtaining highly localized data over this watershed proved quite difficult so our group focused on large national and regional datasets for the spatial data we incorporated into our model. These datasets were taken from federal programs such as the National Land Cover Dataset, and were supplemented with regional datasets from Ohio and Indiana. Data on the relationship between crops and nutrient exports were obtained from papers published by Heidelberg University and models created at the University of Michigan Water Center Graham Sustainability Institute. Data on conservation practice costs was obtained from the US Department of Agriculture’s Natural Resource Conservation Service. With this data we attempted to characterize the complex environmental, policy, and economic interactions at play within the Maumee watershed.

Limitations

While the data we received was excellent at the national level, the low resolution of this data limits the applicability of our analysis. A significantly more accurate assessment and characterization of the watershed could have been achieved with data that had a more focused scope. This was most prevalent in farm areas where our knowledge of cropping strategies, tile drains, and conservation practices currently in place is restricted by federal law.

Develop spatially explicit modeling

Our analysis examined several pre-built models such as SWAT and SPARROW and came to the conclusion that, while these models are well-suited to a range of purposes, a lack of transparency, limitations on ability to model DRP, and incomplete representation of the full scope of conservation practices available made them inadequate for our purposes. SPARROW is an example of a model that lacks the ability to model DRP and also lacks a comprehensive package of conservation practices, which makes modeling impacts in the watershed difficult. SWAT, while a flexible program that could have been used to model any number of conservation practices looking at DRP, required a degree of skill beyond our group members and often requires many months to use effectively

Limitations

To overcome these limitations our group was able to produce a multi-criteria evaluation model that explicitly located suitable lands for the implementation of conservation practices that effectively reduce DRP. Unfortunately, this model is not able to explicitly represent how nutrients, specifically DRP, is leaving the landscape as the other models attempt, but it does allow us to model the most effective spatial distribution of conservation practices across the watershed for reducing DRP.

Analyze marginal costs

Low, medium, high and whole watershed investment scenarios were developed based on marginal costs. Of the conservation practices examined, subsurface injection was found to provide the greatest portion of DRP abatement and would be implemented on the greatest number of acres across the low, medium and high scenarios. Cover crops and riparian buffers also were found to be increasingly important as managed acreage and expenditures increase, while strip cropping plays a minor role across scenarios. The low-investment scenario achieves nearly 25% of possible relative DRP abatement at just under 8% of the normalized cost of the whole-watershed scenario, while the high-investment scenario achieves nearly 80% of the possible relative abatement at 47% of the cost. This indicates that moving from the high-investment to whole watershed scenarios results in relatively little increase in abatement at a high increase in cost.

Limitations

A full analysis of the marginal costs of abating DRP pollution was precluded by limited data on the DRP runoff reduction achieved by different agricultural management practices. As an alternative to actual abatement, a unit-less relative abatement scale was developed based on qualitative estimates of different management practices' impacts on runoff.

Evaluate policies

The intention in evaluating policies was to create a process that is accessible and transferable to other watersheds and impaired water bodies. This methodology was designed to ask questions that any stakeholder may ask in making determinations for the most appropriate policies in their watershed or impaired water body. In doing so, the stakeholder can identify the defining characteristics of their watershed that can contribute to the viability of various policy options. These questions then contributed to a series of recommendations for managing the phosphorus pollution runoff in the watershed based on what agency or stakeholder group is in the position to take action.

Questions used to achieve this were are follows:

1. What are the necessary components for implementation of a policy?
2. What is the authority responsible for implementation and enforcement?
3. What would the Maumee River watershed policy environment need in order to adopt this policy?
4. How might the policy fit into the existing policy framework?
5. What level of authority may be most appropriate for implementation of the policy?

Limitations

The policy evaluation portion of this research was limited by the amount of information available on the efficacy and benefit of these policies. Without proper cost-benefit analyses for each policy, it is hard to explain deliberately the benefit of each policy's use. This project tried to relieve this problem by doing marginal cost analysis to understand the costs of implementing the various conservation practices, but this does not reach the CBA that would be needed.
There are additional challenges in determining the applicability of a policy for a specific location based on the results of its application elsewhere. While evaluating the success of policies to manage the Chesapeake Bay, for instance, there are only so many similarities between the Maumee Watershed and the WLEB and the Chesapeake Bay, with differences ranging from the ecological, social and political environments.

8.2 Recommendations

Addressing modeling and data needs

Determining the best conservation practices and policy approaches requires extensive data. Specifically, in addressing such a complex problem, with many stakeholders, many cumulative causes and serious impacts, it is important to understand what the science is saying and how the science is being articulated and translated into action.

A large amount of the discussion on models has been the 'things' they can model and less about the modeling process. Our review attempted to broaden this discussion beyond capabilities by comparing the inputs and processes as well. However, there is a much larger conversation to be had beyond the technical aspects of inputs, processes and outputs. The modeling process should be a conversation undertaken by all the stakeholders together. Sometimes the questions asked and insights gained during the modeling process are more valuable than the final pounds of phosphorus runoff offset by the additional implementation of a buffer strip.

Data Needs

1. *Recommendation*: Our research informed us of the many available monitoring sites within the watershed maintained by governmental agencies, universities, and non-profits, but not all are currently testing for DRP concentrations in their samples. We propose that the current monitoring locations are assessed for the possible incorporation of DRP monitoring.
    a. *Usefulness*: Once this knowledge has been accumulated, it should be extremely practical for targeting of conservation practices to areas that are releasing the most DRP to the watershed. This type of targeted approach can decrease later costs in implementation and still achieving the highest effective DRP runoff reduction.
    b. *Limitations*: Understandably some monitoring locations will not be able to accommodate DRP monitoring due to the higher monetary costs required to install and maintain such additional monitoring technologies.

2. *Recommendation*: We recommend that additional research be performed so as to quantify the impact of conservation practices on the effect of DRP runoff. Our research on conservation practices and DRP specifically, informed us that the currently available data

is slim, and there exists a need for DRP research. In part to amend this uncertainty, we recommend tests performed in-field, edge of field, and various constructed tests.

  a. *Usefulness:* Understanding the true reduction in DRP release before and after various conservation practice implementation will allow land managers to utilize the most applicable and, most importantly, effective conservation practice for their fields.
  b. *Limitations:* This data need is already accepted in the region, and so the main limitations include securing the necessary resources like time, money, and labor to perform this additional research.

Modeling Needs

1. *Recommendation*: The most apparent limitation of models in our study was that none of the accessible tools effectively modeled DRP. We partially attribute this lack of modeling capability based on the lack of data on how effective specific conservation practices are at reducing DRP runoff. We recommend additional efforts be placed in the production of models that are accessible and accurately model DRP.
    a. *Usefulness*: As DRP is recognized as one of the primary factors driving harmful algal blooms, the ability to model its amount and route from field to lake are crucial management needs. Effectively modeling the effect on DRP runoff of conservation practices would play an important role in land management decisions and be a beneficial tool for recommending policy decisions.
    b. *Limitations*: As with the data recommendations, the main limitations for this step are obtaining the necessary resources. This includes utilizing experts in the field of nutrient pollution and modeling to integrate DRP data and trends within previously made models, or the creation of a new DRP targeted model for the region.

2. *Recommendation*: During our comparison of the four models, we analyzed their baseline output of total phosphorus per acre, and found that they did not coincide. The output maps showed varied phosphorus loadings from different locations within the watershed. This is possibly due to the difference in inputs and processes but also potentially due to errors. During our review we found coding errors in GLWMS, and a fellow modeler has found issues with the much awaited tile drain add on in SWAT. As the SWAT code is openly available, a community of SWAT users has arisen, which has developed tools useful to the whole community. We strongly suggest that the code and base layers for the two components of GLWMS (HIT and L-THIA) as well as any model being promoted for greater adoption, to be made open for public review. We recommend increased transparency and validation of models by making the methods explicit to the public.
    a. *Usefulness:* This will aid with the previous suggestion of allowing stakeholders to engage with the model at multiple levels and also let people help with correcting any possible errors in the models. This may seem incriminating for the organizations involved in the development, but it will bring benefit to the model users in the long run.
    b. *Limitations:* It can be expected that some model developers would be hesitant about releasing their code as it is their own individual work.

Policy Recommendations

The policy recommendations collected from this project range based on actor (federal to local authority) and level of regulation (voluntary to regulatory). Some of the recommendations are dramatic, while others are more modest proposals for incremental improvements. For instance, the ultimate boon in attempts to reduce eutrophication and phosphorus run-off may be to directly regulate nonpoint source runoff, currently exempt from the CWA. Other significant changes to the CWA would be a requirement for a total maximum daily load for all impaired water bodies even if the cause of the pollution is a nonpoint source.

These federal-level changes could lead to a cascade of subsequent action by the state and local governing bodies and would increase their ability to manage agricultural runoff. The following list includes the recommendations from Chapter 4 organized by the level of government at which it would be implemented. For instance, the State of Ohio could implement a phosphorus tax if the federal government has not addressed nonpoint source pollution. The recommendations are also designed to stimulate future action, such as once CREP implements selection indexes that prioritize high DRP runoff acres, Ohio can implement better support programs to assist farmers in managing these high impact acres.

1. Federal
    a. Use CREP to implement selection indexes that prioritize high DRP runoff acres.
    b. Increase CREP payments to encourage farmers to retire higher-productivity acres.

2. Interstate
    a. Transition MI, IN, and OH to using a common 590 Standard for nutrient management planning.
    b. Place TMDLs or other regulatory caps on DRP loads in the Western Lake Erie basin.
    c. Explore strategies for placing regulatory caps on nonpoint source DRP runoff.
    d. Conduct further research into potential for developing a Western Lake Erie basin wide point-nonpoint water quality trading program.

3. State
    a. The State of Ohio could consider a state-wide phosphorus tax.
    b. Amend Ohio’s anti-degradation policy to explicitly include DRP.
    c. Involve regional farmers directly in regulatory design.
    d. Ensure sufficient agency staff capacity exists for effective monitoring of on-the-ground efforts and that agencies are able to share enrollee information effectively across offices.

4. Local
    a. Assure consistent and sufficient funding support for program enrollees.
    b. Local municipalities could challenge the Ohio EPA on the Ohio Revised code (ORC) chapter 6111 exclusion of agricultural pollution from regulation.

8.3 Conclusion

All of these recommendations, from management practices, data and modeling tools, and policy options can contribute to improved water quality in the Western Lake Erie Basin. This methodology can be used in other watersheds with water quality issues, and more specifically, this research can contribute to other regions concerned about agricultural runoff and harmful algal blooms. Future research should incorporate climate change scenarios as it has become increasing clear that priorities and management may have to change in the face of a changing climate. Inevitably, the modeling tools and data will improve over time and increase the level of accuracy in the science that can contribute to improved management planning. Adaptive management is an effective model for managing nutrient runoff and harmful algal blooms and this integrated assessment can serve as a brief model for the beginning of this process.

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Appendix 2A: 2012 Farm Census & Watershed Comparison

Ten watersheds were selected to provide context and comparison to the data on the Maumee. The counties included in each watershed can be seen in Figure 2A.1. Data for these counties was taken from the USDA Agricultural Census of 2012 and 2007 and then summed to get totals for each watershed. We hope this appendix can help provide a quantitative base for comparative discussions between watersheds. The county level data can also be displayed on a map for a more detailed view. The explanatory comments for each table are taken from "Appendix B. General Explanation and Census of Agriculture Report Form."

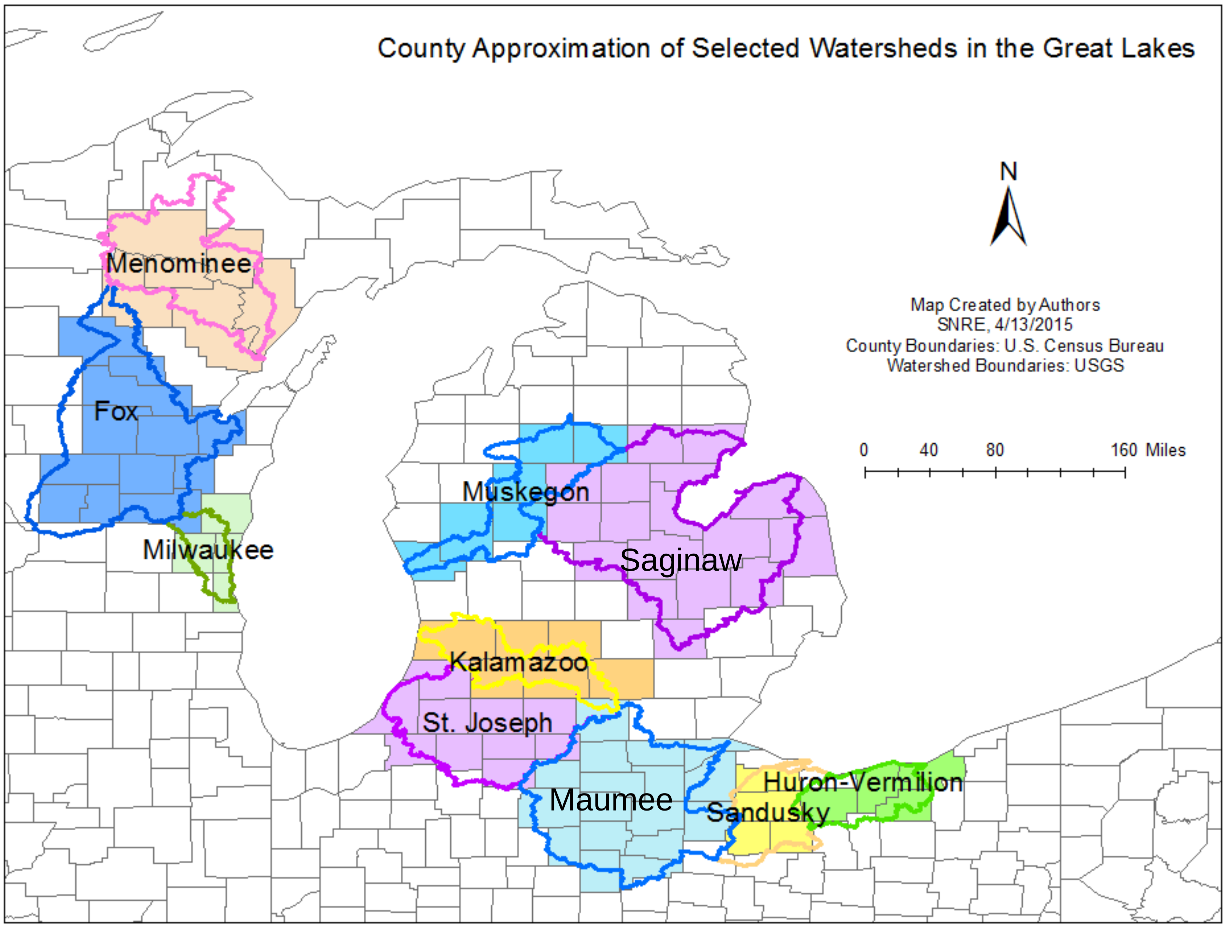

Figure 2A.1. County approximation of selected watersheds. Similarly colored counties assumed part of that watersheds boundary**.**

1. Number of Farms and Land in Farms

The acreage designated as land in farms consists primarily of agricultural land used for crops, pasture, or grazing. It also includes woodland and wasteland not actually under cultivation or used for pasture or grazing, provided it was part of the farm operator's total operation. Large acreages of woodland or wasteland held for nonagricultural purposes were deleted from individual reports during the edit process. Land in farms includes CRP, WRP, FWP, and CREP acres.

Harvested cropland includes land from which crops were harvested and hay was cut, of all types (alfalfa and all other).

	Land in farms				Harvested cropland	
	Number of Farms		Acres		Acres	
	2012	2007	2012	2007	2012	2007
Maumee	17349	18219	3750213	3814891	3214088	3229413
Sandusky	3077	3242	932814	889905	818158	776432
HVB	2667	2744	458569	441872	368480	343675
Saginaw	14151	15624	3231297	3252868	2535749	2468654
Muskegon	3457	3592	540419	543070	315937	298388
Kalmazoo	6420	7206	1210234	1220719	881213	852205
St. Joseph	11554	11256	1801157	1780179	1339940	1311731
Menominee	1429	1725	319177	354628	159721	160567
Fox	10018	11088	2056295	2143030	1485070	1484423
Milwaukee	2196	2499	393137	397656	302271	293181

2. Distribution by Farm Size, 2012

The census lists farms in smaller size buckets that have been aggregated.

	Small (< 100 acres)		Medium (100-500 acres)		Large (>500 acres)	
	Acres	Percent	Acres	Percent	Acres	Percent
Maumee	379084	10	1141206	30	2229923	59
Sandusky	55871	6	251674	27	625269	67
HVB	56547	12	136684	30	264414	58
Saginaw	330652	10	846706	27	2013595	63
Muskegon	88186	17	207869	39	231738	44
Kalmazoo	161031	13	319421	26	729782	60
St. Joseph	291984	16	473058	26	1036115	58
Menominee	28840	10	136951	46	134351	45
Fox	205626	10	838492	41	1011616	49
Milwaukee	45281	12	152148	39	188084	49

3. Distribution by Operator Type, 2012

Full owners operated only land they owned, part owners operated land they owned and also land they rented from others. Tenants operated only land they rented from others or worked on shares for others. Farms with hired managers are classified according to the land ownership characteristics reported. For example, a corporation owns all the land used on the farm and hires a manager to run the farm. The hired manager is considered the farm operator, and the farm is classified with a tenure type of “full owner” even though the hired manager owns none of the land he/she operates.

	Full owners		Part owners		Tenants	
	2012	2007	2012	2007	2012	2007
Maumee	21.6	22.1	71.8	71.1	6.7	6.7
Sandusky	17.0	20.4	72.7	71.6	10.3	8.0
HVB	21.7	26.4	71.2	67.8	7.1	5.8
Saginaw	23.6	24.7	70.3	68.6	6.1	6.7
Muskegon	37.1	37.7	61.2	60.3	1.7	2.0
Kalmazoo	25.9	29.4	69.6	66.7	4.5	4.0
St. Joseph	28.8	29.5	63.0	63.7	8.2	6.8
Menominee	38.9	32.4	60.4	66.5	0.7	1.1
Fox	27.0	30.1	69.2	66.0	3.8	3.8
Milwaukee	21.2	24.4	75.4	70.2	3.5	5.5

3. Number of Livestock

	Cattle and calves		Hogs and pigs		Poultry	
	2012	2007	2012	2007	2012	2007
Maumee	298404	279389	884527	900641	12083523	13902501
Sandusky	24864	26295	184414	148380	80897	5681
HVB	32807	29809	39028	20254	323239	300619
Saginaw	413706	368415	148355	145401	373382	61402
Muskegon	109672	100765	87233	46148	28879	28971
Kalmazoo	140114	125341	350989	295712	7010827	4446715
St. Joseph	212067	186579	458880	457787	4313738	2533731
Menominee	62949	57200	1308	1134	8264	10005
Fox	663045	598982	12092	31071	82218	152934
Milwaukee	130409	113095	1551	4698	9469	8654

4. Conservation Programs (CRP, CREP, WRP & FWP) and Crop Insurance

CRP is a program established by the USDA in 1985 that takes land prone to erosion out of production for 10 to 15 years and devotes it to conservation uses. In return, farmers receive an annual rental payment for carrying out approved conservation practices on the conservation acreage. The Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP), Farmable Wetlands Program (FWP), or Conservation Reserve Enhancement Program (CREP) programs are included under the Conservation Reserve Program and offers landowners financial incentives for conservation. Operations with land enrolled in the CRP, WRP, FWP, or CREP were counted as farms, given they received $1,000 or more in government payments, even if they had no sales and otherwise lacked the potential to have $1,000 or more in sales.

The crop insurance data are for all land enrolled in any Federal, private or other crop insurance program.

	Land enrolled in CRP, CREP, WRP & FWP				Land enrolled in crop insurance programs			
	Farms		Acres		Farms		Acres	
	2012	2007	2012	2007	2012	2007	2012	2007
Maumee	5871	6603	128440	175770	5057	4428	2116031	1734074
Sandusky	1072	1098	19775	23579	1164	1028	618977	494372
HVB	363	449	7556	11929	479	411	242608	196864
Saginaw	2986	3631	85122	116151	2979	3120	1649988	1520655
Muskegon	129	235	5277	8484	325	333	122172	91935
Kalmazoo	624	922	23286	38471	938	815	533869	450680
St. Joseph	1323	1907	41002	65003	1378	1385	649609	604667
Menominee	20	70	412	1788	168	240	69093	75246
Fox	1382	2160	37519	70248	2233	2439	804720	752875
Milwaukee	227	456	4217	13866	351	409	130409	120009

6. Fertilizer Usage

	Commercial fertilizer, lime, and soil conditioners	Manure
	Acres Treated	Acres Treated
Maumee	2442762	225218
Sandusky	649150	23697
HVB	275113	27924
Saginaw	1993702	246656
Muskegon	213536	76583
Kalmazoo	689600	105750
St. Joseph	1115559	137112
Menominee	104221	37395
Fox	1163599	321576
Milwaukee	227128	71902

7. Selected Crops by Harvested Acres

	Corn for grain	Soy	Forage	Corn for Silage	Beans	Oats	Wheat	Vegetables	Orchards	Total Harvested land
Maumee	1168418	1595418	105152	65312		4996	248567	8597	630	3214088
Sandusky	333296	415623	12827	3812		1289	47265	2997	354	818158
HVB	126280	181796	30031	7901		2228	11894	5238	807	368480
Saginaw	786766	741686	249941	93471	169374	9648	282800	30037	1864	2535749
Muskegon	77983	19479	128632	41075	1370	2762	8463	14139	4108	315937
Kalmazoo	368418	294141	99999	43046	70	1495	50156	8653	2529	881213
St. Joseph	656681	420488	111304	45228	204	1787	26740	36228	24695	1339940
Menominee	36644	6841	82276	19242		3354	2010	3863	174	159721
Fox	450123	266708	374494	202775		21547	71646	83802	825	1485070
Milwaukee	73280	62651	84267	40426		5812	24582	7578	473	302271

8. Selected Crops by Percent of Total Harvested Acres

	Corn for grain	Soy	Forage	Corn for Silage	Beans	Oats	Wheat	Vegetables	Orchards	Total
Maumee	36	50	3	2	0	0	8	0	0	99
Sandusky	41	51	2	0	0	0	6	0	0	100
HVB	34	49	8	2	0	1	3	1	0	99
Saginaw	31	29	10	4	7	0	11	1	0	93
Muskegon	25	6	41	13	0	1	3	4	1	94
Kalmazoo	42	33	11	5	0	0	6	1	0	99
St. Joseph	49	31	8	3	0	0	2	3	2	99
Menominee	23	4	52	12	0	2	1	2	0	97
Fox	30	18	25	14	0	1	5	6	0	99
Milwaukee	24	21	28	13	0	2	8	3	0	99

Appendix 3A: Heidelberg University Toolkit

Figure adapted from Crumrine, J. *A BMP Toolbox for Reducing Dissolved Phosphorus Runoff From Cropland to Lake Erie*. July 29, 2011.

	FIELD REDUCTION RATING POTENTIAL				
	DRP CONC. (-2-5)	**STORM RUNOFF (0-5)**	**RELATIVE COSTS (Low-High)**	**LIKELIHOOD OF USE (Low-High)**	**HOW THE PRACTICE WORKS**
Nutrient Management:					
P application rate	5	0	Low	High	Key component of all P Indexes. Main determinant of DP availability.
time of P application	4	0	Low	Medium	Considers: rain forecast; saturated, frozen or snow covered soils; growing crops.
variable rate P application	3	0	Medium	High	Results in Improved spatial placement of P fertilizers for crop utilization.
soil testing – environmental (slope and erosion risk)	2	0	Low	Medium	Measures potential for DP losses in surface flow or, at times, in sub soil leaching.
vegetative mining	2	0	Low	Low	Uses cropping system to drawdown high soil test levels. May take 15 plus years.
P application location	3	0	Low	Medium	Setbacks from watercourses, surface tile inlets, sinkholes, tile blow outs. Avoidance of flood plains, steep slopes or poorly drained soils.
soil testing – agronomic (nutrient testing)	1	0	Low	High	Measures phosphorus requirements for optimal crop growth.
P application method:					
subsurface injection	4	1	Medium	Low	Placed typically in a band more than 5 inches deep. Improved short term infiltration.
band with corn planter	3	0	Low	Medium	Placed at corn planting time in a band at least 2 to 3 inches deep.
broadcast, shallow incorp.	1	0	Low	High	Incorporated 2 to 3 inches within 24 hours of application using full width tillage.
broadcast, AerWay incorp.	1	2	Low	Medium	Can allow DP to infiltrate 6 to 8 inches while maintaining residue cover to slow runoff. Including tillage - vertical tillage
Conservation Tillage:					
mulch tillage/ residue mgt.	-1	1	Low	High	P can stratify. Slows runoff, increases infiltration and soil organic matter.
no tillage/ residue mgt.	-2	2	Low	High	P can stratify and enter macropores. Increases infiltration, builds organic matter.
non inversion tillage	-2	2	Medium	Medium	Reduces compaction and retains residue to promote infiltration. P can stratify.
Conservation Cropping:					
CRP cover (trees)	4	5	High	Low	P nutrients not applied. Permanently increases percolation and retards runoff.

CRP cover (grass)	3	4	Medium	Medium	P nutrients not applied. Significant increase in percolation. Retards runoff.
crop rotation	1	1	Low	High	Basis for P nutrient uptake, slowing of runoff and increased organic matter.
cover crops	1	2	Medium	Medium	P uptake seasonally. Increases infiltration and adds organic matter.
strip cropping	1	2	Medium	Low	Wheat or hay with row crops. Disperses P application. Diversifies cover.
hayland planting	-2	3	Medium	Low	Permanent cover. Slows runoff and increases organic matter. P can stratify.
Conservation Buffers:					
riparian strips (trees)	2	4	High	Low	P nutrients not applied. P uptake permanent. Greater percolation, runoff dispersal.
filter strips (grass) (*grassed waterways*)	1	2	Medium	Medium	P not applied. Need proper design. DP reduction less with time. More infiltration.
filter/recharge areas (*filter strip*)	1	2	Medium	Medium	
in field buffers (grass) (*buffer strips*)	1	3	Medium	Medium	P nutrients not applied. Slows runoff across landscape. Greater infiltration.
field windbreaks (trees)	1	3	High	Low	P not applied. P uptake is permanent. Slows overland flow. Greater infiltration. With Atmospheric deposition (env'l impact assm't)
Water Management:					
controlled traffic	1	2	Low	Medium	Reduces wheel traffic compaction. Improves infiltration. Improves crop P uptake.
tile drain outlet control	1	1	Medium	Low	Reduces some storm runoff in soils with preferential flow. Greater P uptake by crops.
tile drain inlet control	1	3	Medium	Low	Blind inlets permit greater infiltration and halt direct delivery of water to channel.
tile main repair	1	3	Medium	Medium	Repair permits greater soil infiltration and halts direct delivery of water to channel.
wetland construction	1	2	High	Low	Reductions in DP are less with time. Slows/disperses runoff. Groundwater recharge.

Appendix 3B: Definitions of Conservation Practice

From NRCS Conservation Practice Standard Handbook

NRCS Practice Code	Conservation Practice Name	Definition
590	nutrient management	Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments.
329	no till/strip till	Limiting soil disturbance to manage the amount, orientation and distribution of crop and plant residue on soil surface year round.
345	mulch till	Managing the amount, orientation and distribution of crop and other plant residue on the soil surface year round while limiting the soil disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.
585	strip cropping	Growing planned rotations of row crops, forages, small grains, or fallow in a systematic arrangement of equal width strips across a field
328	conservation crop rotation	A planned sequence of crops grown on the same ground over a period of time (i.e. the rotation cycle).
340	cover crop	Grasses, legumes, and forbs planted for seasonal vegetative cover.
612	tree/shrub establishment	Establishing woody plants by planting seedlings or cuttings, direct seeding, or natural regeneration.
327	conservation cover	Establishing and maintaining permanent vegetative cover
391	riparian forest buffer	An area predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies
393	filter strips	A strip or area of herbaceous vegetation that removes contaminants from overland flow.
386	field border	A strip of permanent vegetation established at the edge or around the perimeter of a field.
380	windbreak/shelterbelt establishment	Single or multiple rows of trees or shrubs in linear configurations
412	grassed waterway	A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross section to a stable outlet.

Appendix 3C: Conservation Practice Costs Table

Based on 2014 USDA NRCS Ohio EQIP data

NRCS Practice Code	Conservation Practice	Cost Range ($/acre)
590	nutrient management deep placement	43.62
329	no till/strip till	13.9
345	mulch till	3.85
585	strip cropping	3.38
328	conservation crop rotation	70.59 (*1 year of perennials*)- 677.05 (*2 years of perennial specialty crop*)
340	cover crop	44.24 (*winter kill species*)- 128.18 (*organic cover crop*)
612	tree/shrub establishment	491.36 (*hardwood, bare root, free seedlings*)- 724.75 (*hardwood, direct seeding*)
327	conservation cover	575.4 (*introduced grass*)- 3709.82 (*sedge meadow*)
391	riparian forest buffer	724.75 (*direct seeding*)
393	filter strips	502.07 (*introduced species*)- 622.33 (*organic native species*)
386	field border	486.27 (*introduced grass*)- 727.62(*organic pollinator habitat*)
412	grassed waterway	2435.72 *(<35 foot top width*)- 3801.03 *(>35 foot top width with checks*)

Appendix 4A: Environmental Quality Incentives Program (EQIP)

Summary

The Environmental Quality Incentives Program (EQIP) is a voluntary federal program under USDA's Natural Resource Conservation Service that provides financial and technical assistance to eligible agricultural producers for the planning and/or implementation of approved conservation practices addressing natural resources concerns on farmers' lands. Projects under EQIP can provide an array of environmental benefits including improvements to air and water quality, conservation of surface and groundwater, reductions to soil erosion and sedimentation, and improvements to wildlife habitat.

EQIP is a programmatic umbrella that houses and funds multiple specific National EQIP Initiatives. These include the Air Quality Initiative, On-Farm Energy Initiative, Organic Initiative, Colorado River Basin Salinity Project, Seasonal High Tunnel Initiative, National Water Quality Initiative, National Landscape Initiative, and the Conservation Innovation Grants Program.[1] Distribution of funds under EQIP is a function of national priorities, legislative requirements, and annual appropriations.

Eligibility

Agricultural producers, owners of non-industrial private forestland, and Tribes are eligible to apply for EQIP provided participants lease or own eligible land and comply with adjusted gross income (AGI) provisions.[2] Eligible lands include cropland, rangeland, pastureland, non-industrial private forestland and other farm or ranch lands. Land enrolled in other conservation programs remains eligible for EQIP *provided that*:

- EQIP does not pay for the same practice on the same land as any other USDA conservation program.
- Lands enrolled in CRP and CREP may only enroll in EQIP during the last year of their contract and no EQIP practice shall be applied on that land until after such a contract has expired or been terminated.
- The EQIP practices do not defeat the purpose of the other conservation program.

Implementation

Eligible agricultural producers can apply at their local USDA Service Center or use the NRCS website. NRCS provides free consultation to applicants for identify specific conservation practices and activities in the drafting of an EQIP plan of operations, which then becomes the basis of the EQIP contract between the agricultural producer and NRCS. Producers may also apply for financial support to hire Technical Service Providers (TSP) who can assist with the development of certain Conservation Activity Plans.[3]

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[1] Natural Resources Conservation Service (nd) *Environmental Quality Incentives Program.* Retrieved June 23, 2014 http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=stelprdb1044009

[2] The **Adjusted Gross Income** (AGI) of eligible applicants must be $900,000/year or less, unless two-thirds of that income is derived from agriculture, ranching, or forestry operations. That limit is based on the 3 tax years preceding the year of the original contract obligation.

[3] **Technical Service Providers** (TSPs) are individuals or businesses with technical expertise in conservation planning and design of conservation activities. TSPs are hired by farmers, ranchers, private businesses, nonprofit organizations, or public agencies to provide services on behalf of Natural Resources Conservation Service (NRCS), and all certified TSPs are listed on the NRCS's online registry, TechReg.

NCRS ranks applications according to local resource concerns, amount of conservation benefit the proposed activity will provide, and applicant need.[4] Accepted participants receive payments from the Program after their plan is implemented. Contracts under EQIP can last up to ten years with payments spread over up to six years.

Under the 2014 Farm Bill, EQIP was refunded at $8,000,000,000 through 2018. Significant changes to EQIP under the new Farm Bill include:[5]

- Inclusion of the former Wildlife Habitat Incentive Program under EQIP
- Advance payments are now available for veteran agricultural producers,
- Advance payments for socially disadvantaged, beginning and limited resource farmers, Indian tribes, and veterans have increased from 30% to 50% of project material and contracting service costs
- Payment limitations are set at $450,000 with no ability to waive
- Decrease of AGI limitation from $1 million/year to $900,000/year

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[4] Natural Resources Conservation Service (nd) *Get Started with NRCS: 5 Steps to Assistance*. Retrieved on June 23, 2014 from http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/home/?cid=stelprdb1193811

[5] Natural Resources Conservation Service (nd) *Environmental Quality Incentives Program.* Retrieved June 23, 2014 http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=stelprdb1044009

Appendix 4B: Regulatory Certainty Programs (RCPs)

Regulatory Certainty Programs enable farmers to follow clear standards of environmental stewardship, putting them into a compliant category that excuses them from further certification requirements for a specified period of time. A variety of such programs across the country and while they differ in some regards, there are common elements across all such programs. Regulatory Certainty Programs help achieve water quality goals, enhanced public perceptions of agriculture, enable potential ecosystem services payments and other benefits.[6] Their shared long term goal is to enroll enough farmland that future regulation becomes unnecessary, except to recertify enrolled fields on periodic time intervals.

Voluntary programs that RCPs act to promote are attractive in that they increase implementation of conservation practices while avoiding the challenges of mandated compliance. EPA Administrator Lisa P. Jackson has said on the record, "I believe that local conservation efforts, like those supported through this [RCP program], are among the most effective means for improving water quality in our nation."[7]

Existing State-Level Regulatory Certainty Programs:

- Louisiana Master Farmer Program
- Michigan Agriculture Environmental Assessment Program
- New York Agricultural Environmental Management Program
- Texas Water Quality Management Plan Program
- Minnesota's State/Federal Partnership

Developing State-Level Regulatory Certainty Programs:

- Arkansas: Discussions under way
- Maryland: Developing program with help of Conservation Innovation Grants (CIG)
- Vermont: Developing program with help of Conservation Innovation Grants (CIG)
- Virginia: Developing program, near completion[8]

Common elements of regulatory certainty programs:

- Voluntary participation
- Support State water quality agency objectives
- Education components (often requiring education credits to maintain certification)
- Process to evaluate pollution risk(s) and putting plan(s) in place to address risk(s)
- Formal verification or recognition process to affirm the risks have been addressed.

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[6] Berry, B. (Director) (2013, January 1). State Certainty Programs for Agricultural Producers: A Formula for a Positive Future? 2014 NACD Annual Meeting. Lecture conducted from National Association of Conservation Districts, San Antonio.

[7] Berry, B. (Director) (2013, January 1). State Certainty Programs for Agricultural Producers: A Formula for a Positive Future? 2014 NACD Annual Meeting. Lecture conducted from National Association of Conservation Districts, San Antonio.

[8] Berry, B. (Director) (2013, January 1). State Certainty Programs for Agricultural Producers: A Formula for a Positive Future? 2014 NACD Annual Meeting. Lecture conducted from National Association of Conservation Districts, San Antonio.

- Verification provides regulatory certainty
- Regulatory certainty is defined in legal statute.
- Expiration date is clearly set for verification and there is a process for re-verification.
- Statutes guarantee participant confidentiality[9]

Variations in the programs:

- Paths to certification
- Time length of certification
- Specific program participation requirements
- BMPs vs. FOTG and state-approved practices
- Some programs (LA) seek to achieve other conservation goals.[10]

Example: Michigan Agricultural Environmental Assurance Program (MAEAP)

The MAEAP program started in 1997 and is led by the Michigan Department of Agriculture and Resource Development. The program works in a three-phase process similar to the Louisiana program: education, farm-specific risk assessment, and on-farm verification. More than 1,200 farms have been verified and more than 10,000 producers have begun the process. The program is split into three systems: Farmstead, Cropping, and Livestock. The farmers agree to a plan of Generally Accepted Agricultural and Management Practices (GAAMPs) for compliance. Michigan farmers are also eligible for EQIP funding, and more if they pursue risk assessments and apply extra practices. Participation in MEAP is often used in marketing by the participating farmers, although the specifics of the plan are kept confidential.[11]

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[9] Certainty Programs for Landowners and Producers. (2012, January 1). . Retrieved July 20, 2014, from http://www.nacdnet.org/resources/reports/Certainty_Programs.pdf

[10] Berry, B. (Director) (2013, January 1). State Certainty Programs for Agricultural Producers: A Formula for a Positive Future? 2014 NACD Annual Meeting. Lecture conducted from National Association of Conservation Districts, San Antonio.

[11] Michigan Agriculture Environmental Assurance Program. (2014, June 26). Michigan Agriculture Environmental Assurance Program. Retrieved July 20, 2014, from http://www.maeap.org/

Appendix 4C: Federal Microsystin Standard

Many states have their own microcystin level, such as the state of Ohio which using the WHO recommendations of 1 microgram of microcystin per liter, but there currently is no federal microsystin standard or existing federal guidelines for the management of harmful algal blooms in the Safe Drinking Water Act or the Clean Water Act.[12] In light of the ill effects experienced by the public due to HABs in recent years, there have been increasing efforts to standardize the regulation surrounding microcystin as it relates to safe drinking water.

In June 2014, President Obama signed the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act, a mandate for information gathering and delineating jurisdictions, an action some have regarded as a motion toward creating such federal guidelines.

The original Senate bill behind this action, which had18 cosponsors including senators from Arkansas, Louisiana, and Minnesota, reauthorized the 1998 Harmful Algal Bloom and Hypoxia Research and Control Act of 1998. This Act requires the Under Secretary of Commerce for Oceans and Atmosphere to

> “(1) Maintain, enhance, and periodically review a national harmful algal bloom and hypoxia program, and (2) develop and submit to Congress a comprehensive research plan and action strategy to address marine and freshwater harmful algal blooms and hypoxia.”[13]

The Act also puts NOAA in charge of administering the program and adds that EPA will contribute research and monitoring with a focus on new approaches to addressing freshwater harmful algal blooms that haven’t already been investigated.

Lastly, the law requires the Task Force under the Under Secretary to

> (1) Submit within 18 months to Congress and the President an integrated assessment that examines the causes, consequences, and approaches to reduce hypoxia and harmful algal blooms in the Great Lakes and (2) develop and submit to Congress a plan, based on the assessment, for reducing, mitigating, and controlling hypoxia and harmful algal blooms.[14]

The federal government must begin with information gathering to move forward with these plans, which are due at the end of 2015.

The bipartisan “Safe and Secure Drinking Water Act of 2014,” was then introduced in September 2014 in direct response to the Toledo Water Crisis, directing the EPA to produce a

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[12] "Policies and Guidelines" Nutrient Policy and Data. US Environmental Protection Agency, 3 Feb. 2015. Web. 10 Feb. 2015. <http%3A%2F%2Fwww2.epa.gov%2Fnutrient-policy-data%2Fpolicies-and-guidelines>.

[13] "Summaries for the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014." GovTrack.us. United States Congress, July 2014. Web. 09 Feb. 2015. <https://www.govtrack.us/congress/bills/113/s1254/summary>.

[14] "Summaries for the Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014." GovTrack.us. United States Congress, July 2014. Web. 09 Feb. 2015. <https://www.govtrack.us/congress/bills/113/s1254/summary>.

health advisory for microcystin in drinking water.[15] The legislation was introduced in the House by the U.S. Rep. Marcy Kaptur from Toledo and was introduced in the Senate by Senators from Cleveland and Cincinnati, a Democrat and Republican, respectively. Despite this bipartisan support, the bill ultimately died in both houses. In the House, it died in committee while in the Senate its companion bill, the S. 2785 passed with unanimous consent. This sent it over to the House, but on the eve of the vote the bill died by way of objections.[16]

Federal legislature is a strong option for furthering these goals because it can change the role of the regulating bodies, the laws that guide their actions, and the financial support for their efforts. Ohio legislators recognize this and have continued to introduce similar bills into Congress. The H.R. 5753 bill died in the 113th Congress in November, 2014 and as soon as the new 114th Congress began, the Ohio Representative Robert Latta (R-OH5) had reintroduced the bill.[17] Representative Latta was joined by Representative Marcy Kaptur (D-OH9) and Representative David Joyce (D-OH14) couple days later. The bill is cosponsored by 3 additional Representatives. The bill passed on February 24, 2015 with 375 supporting and 37 opposed. It was a nearly perfectly bipartisan vote, with 199 Republicans and 176 Democrats supporting the bill.[18] The bill has such surety of being passed it was taken under the “suspension of rules” procedure, in which non-controversial bills are sped to the vote but need a 2/3rds majority to pass. This bill received an 87% support rate.[19] The bill text is the same as the previous bill and is similar to the bill being introduced in the Senate.

On February 11th, 2015, Senator Robert Portman (R-OH) and Senator Sherrod Brown (D-OH) introduced S. 460 into the US Senate and it was referred to the Senate Environment and Public Works committee that same day. Like H.R. 212, S. 460 is a repeat of a bill introduced in the last Congress by Senator Sherrod Brown (D-OH) with Representatives Robert Portman (R-OH) and Debbie Stabenow (D-MI) as cosponsors. Senate Bill 2785 passed unanimously in the Senate but its companion bill H.R. 5723 died in the House without going to vote. The roles of the bills are reversed now that the House bill has passed and the Senate bill is stuck in Committee. This switch may be a good sign, however, given the strong support in the previous Senate and the current support in the House of Representatives.

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[15] "Safe and Secure Drinking Water Act of 2014 (2014 - H.R. 5439)." GovTrack.us. US Congress, 15 Dec. 2014. Web. 10 Feb. 2015. <https://www.govtrack.us/congress/bills/113/hr5439>.

[16] Board, Editorial. "Lake Erie Safe Drinking Water Bill Dies Mysterious Death in 2014 Congress: Editorial." Cleveland.com. Plain Dealer Publishing Co. and Northeast Ohio Media Group, 09 Jan. 2015. Web. 10 Feb. 2015. <http://www.cleveland.com/opinion/index.ssf/2015/01/lake_erie_safe_drinking_water_bill_dies_mysterious_death_in_2014_congress_editorial.html>.

[17] "Drinking Water Protection Act (H.R. 212)." GovTrack.us. The Library of Congress, 25 Feb. 2015. Web. 26 Feb. 2015.

[18] "H.R. 212: Drinking Water Protection Act -- House Vote #84 -- Feb 24, 2015." GovTrack.us. The Library of Congress, 25 Feb. 2015. Web. 26 Feb. 2015

[19] "H.R. 212: Drinking Water Protection Act -- House Vote #84 -- Feb 24, 2015." GovTrack.us. The Library of Congress, 25 Feb. 2015. Web. 26 Feb. 2015

Appendix 4D: Agricultural Performance Bonds

Summary

Agricultural Performance Bonds encourage farmers to adopt NPS pollution-reducing conservation practices by providing fiscal protections that offset farmers' concerns around conservation practice implementation (i.e. the perceived risks of lost yield or the strain of high cost conservation practices). Broadly speaking, a performance bond program is successful when savings from pounds of nutrient not delivered into the aquatic system outweighs the sum of program administration costs and payments made to farmers.

Payment to Incentivize Conservation Practice Implementation

Performance bonds can incentivize conservation practice implementation by agreeing to pay farmers for any yield they lose as a result of implementing nutrient reducing practices.

One example of such an agricultural performance bond program is the American Farmland Trust's ongoing BMP Challenge Program. Begun in 1998, the BMP Challenge currently operates on 9,200 acres in 7 states across the Midwest and mid-Atlantic.[20] This program simultaneously asks farmers to adopt a conservation practice and keep an area of their production acreage under their standard management practice. This setup provides farmers with a baseline for comparing traditional yield with yield under the practice. In this program, the administrating body of the BMP Challenge compensated farmers for any yield losses that result from implementing a conservation practice that reduced N application to 15% below university-recommended rates.[21]

Over its 16 year history, the BMP Challenge has been found to successfully reduce Nitrogen applications on participating lands, thus lowering Nitrogen delivered into local aquatic systems. The payments made to farmers under the program for lost yield and direct program costs came out to a cost-effective sum of $2.84 per pound of Nitrogen not applied.

One of the significant outcomes of the BMP Challenge was captured in the result of a follow-up survey which found that 59% of participants nationally said they would lower their nutrient application rates as a result of being involved with the program. In effect, the BMP Challenge program improved the attitudes of farmers nationally towards BMP implementation by providing a mechanism that reduces risk to farmers.

> *Eligibility:* Farmers in California, Delaware, Idaho, Iowa, Illinois, Indiana, Maryland, Michigan, Minnesota, Missouri, New York, North Carolina, Nebraska, Ohio, Pennsylvania, South Dakota, Vermont Virginia or Wisconsin who grow corn for grain

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[20] American Farmland Trust (2013) *AFT's Environmental Solutions: AFT's BMP Challenge*. Retrieved on July 13, 2014 from http://www.farmland.org/programs/environment/solutions/conservation practice-challenge.asp

[21] Wainger, L., Shortle, J. (3rd Quarter 2013) *Local Innovations in Water Protection Experiments with Economic Incentives.* Choices: The Magazine of Food, Farm, and Resource Issues. Retrieved on July 13, 2013 from http://www.choicesmagazine.org/choices-magazine/theme-articles/innovations-in-nonpoint-source-pollution-policy/local-innovations-in-water-protection-experiments-with-economic-incentives

and silage are eligible for the BMP Challenge program.[22]

Payment for Environmental Services

A different style of agricultural performance bond provides fiscal compensation for measurable environmental improvements resulting from farmer implementation of conservation practices.

The Florida Ranchlands Environmental Services Project (FRESP) is an example of a Payment for Environmental Services program, as FRESP pays farmers according to the measured performance of their conservation practices. In this program, the South Florida Water Management District state agency is the "buyer" and ranchers willing to modify existing water control devices and management approaches on their production lands are the "sellers".[23] Structural modifications by ranchers that prove to retain more water on fields and wetlands, and thus reduce Phosphorous runoff, are financially rewarded by the buyer. [24]

By linking payments directly to results, the program incentivizes effective implementation rather than just rewarding practice implementation that may or may not be effective. A key strength of this program is its flexibility, allowing ranchers to make structural changes at any scale.

Institutionally, this program requires cooperation and development of cost-effective monitoring approaches for assessing practice results. Also, the payment mechanism has to assure payment certainty for ranchers while still making payment contingent on the actual provision of environmental services. To this end, the contract between buyer and seller covers a wide time range, averaging between 10-20 years.

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[22] American Farmland Trust (2013) *AFT's Environmental Solutions: AFT's BMP Challenge*. Retrieved on July 13, 2014 from http://www.farmland.org/programs/environment/solutions/bmp-challenge.asp

[23] Florida Ranchlands Environmental Services Project (2014) *Florida Ranchlands Environmental Services Project*. Retrieved on July 13, 2014 from http://www.fresp.org/

[24] Shabman, L. (2008) *Designing Pay-for Environmental Services Programs and the Florida Ranchlands Environmental Services Project*. Retrieved on July 13, 2014 from http://waterinstitute.ufl.edu/events/downloads/shabmanseminar-08.pdf

Appendix 4E: Fertilizer Applicator Certification

Summary

Fertilizer Applicator Certification requirements ensure that nutrient applicators receive training in best management techniques for the use of Nitrogen and Phosphorus rich substances that, when occurring in excess, contribute to eutrophication. Specific best management techniques for fertilizer use change from landscape to landscape but consistently address right time, right place, right amount, and right rate of application.

Implementation

Fertilizer applicator certification requirements are set by legal mandate and focus on four key components:

1. Definition of fertilizer (synthetic chemical compounds and/or organics or manure)
2. Specific type of application (turf, urban, or agricultural)
3. Size of application area (ex. contiguous parcels larger than x acres)
4. Affected applicators (government, private landowners, professional landscapers,etc.)

In the US, a county or state may hold the legal authority to pass such a mandate. County levels programs may be administered through local extension offices while state mandated programs may be administered through state DNR, across regional extension offices, or other agencies. At either scale, the certification requirement must be clearly communicated and accessible to all affected individuals.

Statewide Fertilizer Applicator Certification Programs

While statewide pesticide applicator certification programs have long been required in many states, fertilizer applicator certifications are a more recent development. Over the past four years, requisite statewide fertilizer applicator certification programs have been enacted in numerous states including Indiana (2010), Virginia (2012), New Jersey (2012), and Ohio (2014). Each program addresses the 4 key components differently, resulting in differing effects from the programs.

Appendix 5A: Governing Equations

SPARROW

As a statistically built model, SPARROW has a multitude of governing equations, but most importantly for our purposes, the equation below calculates the nutrient loading (L) at a downstream water quality monitoring station (i). It takes into account the # of upstream reaches, the losses versus sinks and a multiplicative error term, [25]

where
L = load in reach *i*
n, *N* = source index where *N* is the total number of considered sources
J(i) = the set of all reaches upstream and including reach *i*, except those containing or upstream of monitoring stations upstream of reach *i*
B_n = estimated source parameter
$s_{n,j}$ = contaminant mass from source *n* in drainage to reach *j*
α = estimated vector of land to water delivery parameters
Z_j = land surface characteristics associated with drainage to reach *j*
Δ = estimated vector of instream-loss parameters, and
$T_{i,j}$ = channel transport characteristics
ε_i = error term to account for unknown variations in data

$$\log(L_l) = \log\,(\sum_{n=1}^{N} \sum_{j \epsilon J(i)} \beta_n S_{n,j} e^{-\alpha Z_j} e^{-\delta T_{i,j}}) + \epsilon_i$$

GLWMS

The Great Lakes Watershed Management System is a combination of two models: HIT and LTHIA.

High Impact Targeting (HIT)

HIT uses the Revised Universal Soil Loss Equation (RUSLE)[26] shown below for calculating erosion. It uses spatial data and calculates the contribution based on RUSLE for each pixel.

$$A = R \times K \times L\,S \times C \times P$$

A: Estimated average soil loss in tons per acre per year
R: Intensity of rainfall events. The model uses estimates of R-factor generated by the PRISM Climate Group at Oregon State University.
K: The soil erodibility factor represents how prone specific soils are to erosion. SSURGO soil data is used to extract K factor.
LS: This is calculated based on the steepness and length of slopes. The model uses the 10 meter DEM from USGS National Elevation Dataset.
C: The Cover Management Factor is influenced by crop type in the previous year and crop

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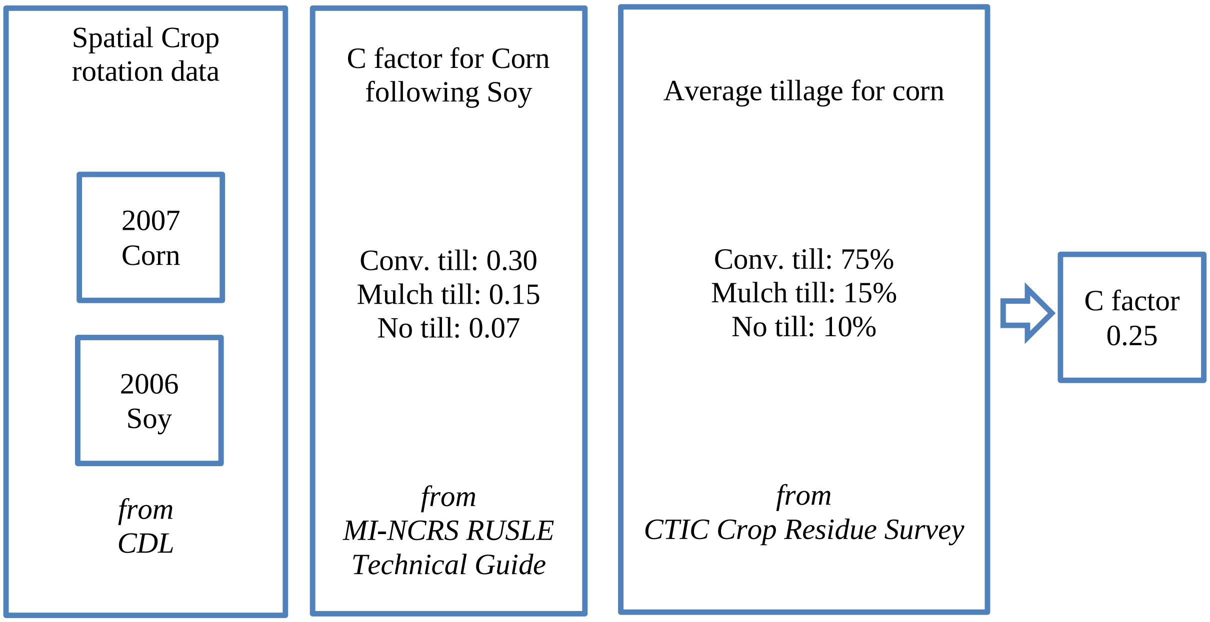
[25] http://md.water.usgs.gov/publications/wrir-99-4054/html/
[26] http://35.8.121.139/rusle/about.htm

type and tillage in the current year as outlined by the MI-NCRS RUSLE Technical Guide. The model does not use current crop rotation and tillage data. Instead it uses the USDA Cropland Data Layer (CDL) 2006-2010 for crop rotation data and the Purdue CTIC crop residue surveys for tillage data to create an average C factor based on these historic data sets. Figure X displays a sample calculation for the C factor.

Figure 1: *Sample calculation for the C-factor in GLWMS for a single pixel. The CDL data shows a specific pixel was under soy in 2006 and corn in 2007. The MI NRCS technical guide says the C-factor for corn following soy is 0.07 if corn is under no-till, 0.15 if it is under mulch till and 0.30 if it is under conventional tillage. The Purdue CTIC crop Residue Survey says that between 2000 and 2004 on average corn was under conventional till 75%, mulch till 15% and no-till 10%. Multiplying tillage by till specific C-factor for this pixel for this year: 75 x 0.30 + 15 x 0.15 + 10 x 0.07 = 0.25. This process is repeated for year pairs between 2006 and 2010 for each pixel in the target watershed, and their average is used.*



HIT uses the Spatially Explicit Delivery Model (SEDMOD) to calculate the fraction of the eroded soil that reaches the stream network i.e. Sedimentation. SEDMOD takes the erosion output from RUSLE and does not model in stream dynamics such as routing or deposition.

SEDMOD first finds the path to the stream from the cell using the DEM and stream location. It then sees the surface roughness (from land cover) and soil texture (from the clay content) combined with a user defined weighting for each of these factors (not given for this model in documentation) to calculate what fraction of the eroded soil will reach the stream. It uses the same input files used for RUSLE.

Long Term Hydrologic Impact Assessment (L-THIA)

The model uses the curve number method to calculate runoff and uses empirical data for pollutants running off different land uses. Unlike the documentation for HIT, which is specific for the GLWMS, the link to LTHIA documentation references back to the core model website. It explains how the model calculates the long term averages based on long term land use and average rainfall. The model gives estimates for: Runoff, Total Nitrogen, Total Phosphorus, Total Suspended Solids, Total Lead, Total Copper and Total Zinc.

The model uses MRLC's National Land Cover Dataset[27] and USDA SSURGO soil classification as base inputs. Each land use and soil type combination is assigned a curve number[28] based on a table an extract of which is shown in Table 1. Depending on the curve number and the annual average rainfall a runoff amount is assigned to the cell. Once the cell specific runoff is calculated it is multiplied by the Event Mean Concentration depending on the land use of the pixel to get the amount of NPS pollutant in that cell.

Table 1. Sample curve numbers for different soil and land uses from the Urban Hydrology for Small Watersheds, Technical Report 55

Land Cover	**Curve Number for Hydrologic Soil Group**			
	A	B	C	D
Crops, Straight Rows, Crop Residue Cover	64	75	82	85
Urban Districts: Commercial and Business	89	92	94	95

Table 2. Example of NPS pollution calculation, 2012 EPA pollutant concentrations[29]

NPS Pollutant (mg/L)	Land use classification						
	Residen-tial	Commer-cial	Indu-strial	Transi-tion	Mixed	Agricul-tural	Range
Total Nitrogen	1.82	1.34	1.26	1.86	1.57	4.4	0.7
Total Phosphorus		0.32	0.28	0.22	0.35	1.3	0.01

SWAT

While SWAT has the ability to model numerous parameters, of the ones of most interest to our project is how phosphorus and erosion are calculated. To look at this information more in depth, we can look at the theoretical underpinnings of the 2009 SWAT model which lists the governing equations the model uses[30]. For this constituent, SWAT considers six pools of phosphorus both mineral and organic. Mineral P is divided into stable, active, and solution P which is the

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[27] http://35.8.121.111/glwms/docs/LTHIA_Uncertainty.pdf

[28] USDA Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds. Technical Release 55, 2nd ed., NTIS PB87-101580, Springfield, VA.

[29] http://www.epa.state.oh.us/portals/35/tmdl/GrandLowerAppF_Final.pdf

[30] http://swat.tamu.edu/media/99192/swat2009-theory.pdf

bioavailable form that is analogous to soluble reactive phosphorus. Organic P is divided into active, stable, and fresh P, which is organic fertilizer that can transform into mineralized P.

The only phosphorus pool that is not modeled is solution phosphorus which instead of an equation set to 5 mg/kg and 25 mg/kg in cropland. For this model each pool has an equation to define the initial conditions within the watershed.

For the **active mineral pool** the equation is:

$$mineral\ P_{act,ly} = P_{solution,ly} \cdot \frac{1 - pai}{pai}$$

The equation states that the amount of phosphorus in the active mineral pool ($mineral\ P_{act,ly}$) soil layer is equal to P in solution ($P_{solution,ly}$) in the soil layer multiplied by the phosphorus availability index (pai).

The concentration in the **stable mineral phosphorus pool** is represented by:

$$\min P_{sta,ly} = 4 \, . \min P_{act,ly}$$

This equation states that the concentration in the stable mineral pool ($minP_{sta,ly}$) in the soil layer is four times greater than the concentration in the active mineral phosphorus pool($P_{act,ly}$) in the soil layer.

Organic phosphorus levels in humic soils are assumed to be based on a 1:8 ration of Nitrogen to Phosphorus. The **humic organic phosphorus** is represented by:

$$org\ P_{hum,ly} = 0.125 \, . \, org\ N_{hum,ly}$$

Humic organic phosphorus ($org\ P_{hum,ly}$) is 1/8th of humic organic nitrogen ($org\ N_{hum,ly}$) concentration.

For **fresh organic Phosphorus (**$org\ P_{frsh,surf}$) the equation is based on the assumption that fresh organic P is .03% of the initial residue on the surface (rsd_{surf}). This equation is represented by:

$$org\ P_{frsh,surf} = 0.0003 \, . \, rsd_{surf}$$

Finally the initialization requires turning a concentration into a mass, which is represented by this equation, which multiplies the concentration ($conc_p$) by the bulk density (ρ_b) and the depth of the layer ($depth_{ly}$) leading to a kg per hectare concentration.

$$\frac{conc_p . \rho_b . depth_{ly}}{100} = \frac{kg\ P}{ha}$$

Mineralization, Decomposition, Immobilization

Decomposition in this context is the breakdown of organic material into organic phosphorus components. Mineralization is the conversion of organic phosphorus components to inorganic phosphorus, which is plant available phosphorus. Immobilization is the process of transferring from available inorganic phosphorus to organic unavailable phosphorus.

The mineralization equations in SWAT factor in immobilization to produce a net mineralization equation. The two pools that are subject to these equations are the fresh organic phosphorus pool (crop residues) and the humic microbial biomass and active organic phosphorus pools. These two processes are assumed to occur only if the soil layer is above 0 Celsius.

The two factors that affect these processes are water availability and temperature. The temperature equation is

$$\gamma_{tmp,ly} = 0.9 \, . \frac{T_{soil,ly}}{T_{soil,ly} + \exp\left[9.93 - 0.312 \, . T_{soil,ly}\right]} + 0.1$$

In this equation the temperature of the soil layer is the only variable on the right side of the equation and is equal to the nutrient cycling temperature factor ($T_{soil,ly}$). The nutrient cycling water factor equation is

$$\gamma_{(sw,ly)} = \frac{SW_{ly}}{FC_{ly}}$$

which states that the water factor ($T_{soil,ly}$)is equal to the water content of the layer (SW_{ly}) on any given day divided by the field capacity of that layer (FC_{ly}).

Humus Mineralization

The humus fraction of phosphorus is assumed to be related to the nitrogen phases within the humus layer. It is thus divided into the stable and active organic phosphorus pools similar to the nitrogen divisions.

$$orgP_{act,ly} = orgP_{hum,ly} \cdot \frac{orgN_{act,ly}}{orgN_{act,ly} + orgN_{sta,ly}}$$

$$orgP_{sta,ly} = orgP_{hum,ly} \cdot \frac{orgN_{sta,ly}}{orgN_{act,ly} + orgN_{sta,ly}}$$

These two equations are very similar and are simply stating that the organic phosphorus ($orgP_{X,ly}$) in each respective pool is equal to the total organic phosphorus ($orgP_{hum,ly}$) multiplied by the analogous nitrogen fraction. The actual equation for mineralization is

$$P_{mina,ly} = 1.4 \cdot \beta_{min} \cdot \left(\gamma_{tmp,ly} \cdot \gamma_{sw,ly}\right)^{1/2} \cdot orgP_{act,ly}$$

which states that the phosphorus mineralization ($P_{mina,ly}$) is a function of the rate coefficient of mineralization (1.4) of the humus active organic nutrients, the product of the water factor and the temperature factor($\gamma_{(sw,ly)}$*$\gamma_{tmp,ly}$), and finally the active organic phosphorus in the layer ($orgP_{hum,ly}$). This result is then added to the phosphorus solution pool

Residue decomposition and mineralization

The decay rate constant controls decomposition and mineralization and is a function of the C:N and C:P ratios. C:N residue is represented by

$$\varepsilon_{C:N} = \frac{0.58 \cdot rsd_{ly}}{orgN_{frsh,ly} + NO3_{ly}}$$

which states that the C:N ($\varepsilon_{C:N}$) ratio is equal to the residue in layer (rsd_{surf}) multiplied by .58 to produce the carbon fraction, over the product of the nitrate in the layer ($NO3_{ly}$), added to the fresh organic nitrogen pool $orgN_{(frsh,ly)}$. The C:P ratio is the exact same equation with the solution phosphorus substituted for the nitrate.

$$\varepsilon_{C:P} = \frac{0.58 \cdot rsd_{ly}}{orgP_{frsh,ly} + P_{solutionly}}$$

The decay rate constant, or how quickly the residue decays is represented by

$$\delta_{ntr,ly} = \beta_{rsd} \cdot \gamma_{ntr,ly} \cdot \left(\gamma_{tmp,ly} \cdot \gamma_{sw,ly}\right)^{1/2}$$

which states that the decay rate constant in the soil layer ($\delta_{ntr,ly}$) is a product of the mineralization εcoefficient multiplied by the temperature and water factors ($\gamma_{(sw,ly)}$*$\gamma_{tmp,ly}$), and the residue composition factor for the layer ($y_{ntr,ly}$). This term is represented by the equation

$$\gamma_{ntr,ly} = \min \begin{cases} \exp\left[-0.693 \cdot \frac{(\varepsilon_{C:N} - 25)}{25}\right] \\ \exp\left[-0.693 \cdot \frac{(\varepsilon_{C:P} - 200)}{200}\right] \\ 1.0 \end{cases}$$

which only includes the $\varepsilon_{C:N}$ and $\varepsilon_{C:P}$ ratios as variables.

Once these equations are combined, the results can be used to calculate the mineralization from the fresh organic phosphorus pool. The relevant equation is

$$P_{minf,ly} = 0.8 \cdot \delta_{ntr,ly} \cdot orgP_{frsh,ly}$$

So that the product of the fresh organic p layer ($orgP_{frsh,ly}$)and the decay rate constant ($\delta_{ntr,ly}$) is multiplied by .8 to produce the amount of phosphorus mineralized ($P_{minf,ly}$)from the fresh phosphorus layers. This is added to the solution phosphorus in the layer.

The decomposition rate($P_{dec,ly}$) is the same equation with .2 substituted for .8 and then added to humic phosphorus pool.

$$P_{dec,ly} = 0.2 \cdot \delta_{ntr,ly} \cdot orgP_{frsh,ly}$$

Sorption of Inorganic Phosphorus

SWAT assumes that there is a rapid equilibrium between the active mineral pool and the solution phosphorus pool and a slow reverse reaction. To represent the phosphorus availability index the equation

$$pai = \frac{P_{solution f} - P_{solution i}}{fert_{minP}}$$

the phosphorus availability index is equal to the phosphorus in solution after a fertilization and incubation period of 6 months ($P_{solutionf}$), minus the phosphorus in solution before fertilization($P_{solutioni}$), divided by the amount of fertilizer added($fert_{minP}$).

The equilibrium between the two pools is represented by

$$P_{sol|act,ly} = 0.1\left(P_{solutionly} - \min P_{act,ly} \cdot \left(\frac{pai}{1-pai} \right) \right)$$

$$\text{if } P_{solutionly} > minP_{act,ly} \cdot \left(\frac{pai}{1-pai} \right)$$

$$P_{sol|act,ly} = 0.6 \cdot \left(P_{solutionly} - minP_{act,ly} \cdot \left(\frac{pai}{1-pai} \right) \right)$$

$$\text{if } P_{solutionly} < minP_{act,ly} \cdot \left(\frac{pai}{1-pai} \right)$$

the phosphorus transferred between the two pools is thus a product of the P in solution($P_{solution,ly}$), the phosphorus in the active mineral pool($minP_{act,ly}$), each equation is used depending on the relationship between the phosphorus in solution ($P_{solution,ly}$) and the active mineral pool of phosphorus($P_{act,ly}$). If the answer is positive then phosphorus is being transferred from solution to the mineral pool. If it is negative then it is going the opposite direction. The rate of flow from the active mineral pool is 1/10th the rate of flow in the opposite direction to the mineral pool. It is assumed that at equilibrium the stable mineral pool is 4 times greater than the active mineral pool. The non-equilibrium equation is

$$P_{act|sta,ly} = \beta_{eqP} \cdot \left(4 \cdot minP_{act,ly} - minP_{sta,ly} \right)$$

$$\text{if } minP_{sta,ly} < 4 \cdot minP_{act,ly}$$

$$P_{act|sta,ly} = 0.1 \cdot \beta_{eqP} \cdot \left(4 \cdot minP_{act,ly} - minP_{sta,ly} \right)$$

$$\text{if } minP_{sta,ly} > 4 \cdot minP_{act,ly}$$

where the transfer from the active to mineral P is governed by the slow equilibrium constant of (.0006) (β_{eqP}), the phosphorus in the mineral active pool($minP_{act,ly}$), and the phosphorus in stable mineral pool($minP_{sta,ly}$). If positive then the equation means that phosphorus is transferring to the active mineral pool, if negative then the phosphorus is moving into the stable mineral phosphorus pool.

Leaching

SWAT only allows phosphorus to leach from the top 10mm of soil into the first layer of soil due to assumed low mobility. The equation is

$$P_{perc} = \frac{P_{solutionsurf} \cdot w_{perc,surf}}{10 \cdot \rho_b \cdot depth_{surf} \cdot k_{d,perc}}$$

where the amount of phosphorus percolating (P_{perc}) through the soil is equal to the amount of phosphorus in solution in the top 10mm of the soil($P_{solution,surf}$) multiplied by the amount of water in the top 10mm of soil($w_{perc,surf}$) divided by the bulk density of the soil ρ_b, the depth of the surface layer (10mm) ($depth_{surf}$) multiplied by the percolation coefficient ($k_{d,perc}$).

Erosion

The erosion in SWAT is calculated using the modified universal soil loss equation which is

$$sed = 11.8 \cdot (Q_{surf} \cdot q_{peak} \cdot area_{hru})^{0.56} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG$$

The equation states that the sediment yield (sed) is equal to the surface runoff volume (Q_{surf}, q_{peak}, $area_{hru}$) multiplied by the peak runoff rate and the hydrologic response unit area. This term is then multiplied by the soil erodibility factor (K_{USLE}), the cover and management factor (C_{USLE}), the support practice factor (P_{USLE}), the topographic factor (LS_{USLE}), and the coarse fragment factor ($CFRG$).

Soil Erodibility Factor

The soil erodibility factor is represented by the equation

$$K_{USLE} = \frac{0.00021 \cdot M^{1.14} \cdot (12 - OM) + 3.25 \cdot (c_{soilstr} - 2) + 2.5 \cdot (c_{perm} - 3)}{100}$$

which is a function of the particle size(M), the organic matter percentage(OM), the soil structure code($c_{soilstr}$), and the soil profile permeability class (c_{perm}).

Cover Management Factor

The cover management factor takes into consideration the soil loss on cropped lands versus the soil loss on clean tilled continuous fallow lands. The equation is

$$C_{USLE} = \exp\left([\ln(0.8) - \ln(C_{USLE,mn})] \cdot \exp[-0.00115 \cdot rsd_{surf}] + \ln[C_{USLE,mn}]\right)$$

which makes the cover management factor a function of the minimum cover management value ($C_{USLE,mn}$) and the amount of residue on the surface(rsd_{surf}). The minimum cover management value can be calculated through

$$C_{USLE,mn} = 1.463 \ln[C_{USLE,aa}] + 0.1034$$

which makes it a function of the average cover management factor ($C_{USLE,aa}$).

Support Practice Factor

Support Practice Factor is the ratio of soil loss with a practice to the ratio of soil loss in a straight up and down slope culture.

Topographic Factor

The topographic factor is represented by the equation

$$LS_{USLE} = \left(\frac{L_{hill}}{22.1}\right)^{m} \cdot \left(65.41 \cdot \sin^{2}(\alpha_{hill}) + 4.56 \cdot \sin\alpha_{hill} + 0.065\right)$$

which says that the factor is a function of the slope length (L_{hill}), the angle of the slope (α_{hill}), and the exponential factor represented by the equation

$$m = 0.6\,.\,(1 - \exp[-35.835\,.\,slp])$$

which makes m a function of slope (slp) calculated through simple rise over run equation.

Coarse Fragment Factor

The coarse fragment factor is expressed through the equation

$$CFRG = \exp(-0.053 \cdot rock)$$

which makes the coarse factor($CFRG$) a function of the percent rock($rock$) in the upper soil layer.

SnapPlus

Erosion

Erosion is calculated using the Revised Universal Soil Loss Equation 2 (RUSLE2). RUSLE 2 is a significantly more advanced equation than RUSLE or MUSLE as used by GLWMS and SWAT respectively. Detailed documentation can be found on its website[31]

Phosphorus Runoff Risk

Snap plus uses the Wisconsin Phosphorus Index (PI) to determine the potential of phosphorus runoff. It is important to note that several states have their own phosphorus indexes which have differing levels of complexity. The Wisconsin PI is very complex[32] and is calculated within Snap plus with the use of RUSLE2.

Total Risk Index for Phosphorus (lb /acre / year) =
[Particulate P losses from the edge of the field + Dissolved P losses from edge of field,]
x Total P Delivery Ratio (TPDR)

Particulate losses depend on soil composition (clay, silt, large particles and the corresponding phosphorus related to these soil groups.

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[31] http://fargo.nserl.purdue.edu/rusle2_dataweb/About_RUSLE2_Technology.htm

[32] http://wpindex.soils.wisc.edu/wp-content/uploads/2011/10/PIndexdocumentforwebNov-182010final.pdf

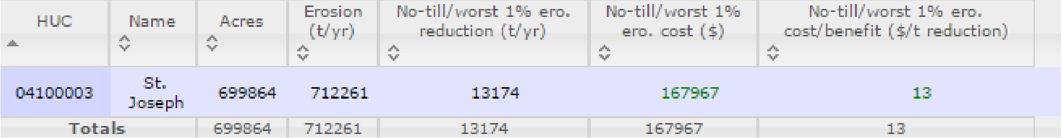
The dissolved P disaggregates winter frozen runoff and non-frozen runoff during calculation and takes a large number of inputs, including fertilizer applied (amount and time), tillage / incorporation method, soil P tests among others.

The Delivery Ratio is determined by the distance from the stream and the dominant slope. For example, for streams less than 300 feet the Delivery Ratio is 1. The lowest delivery ratio is 0.45 for streams more than 20,000 feet away at a slope of 0-2%.

Appendix 5B: Sample Errors in GLWMS

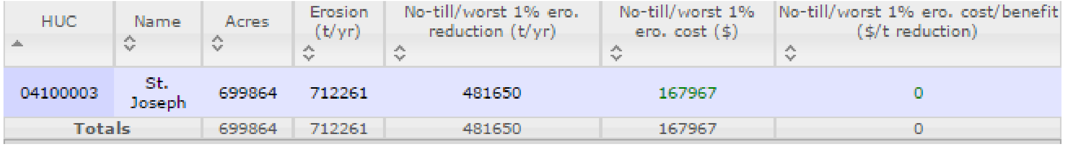
<u>Coding error in HIT</u>

After correction 1% no till on St. Joseph HUC 8 reduces erosion by 13,174 tons / year



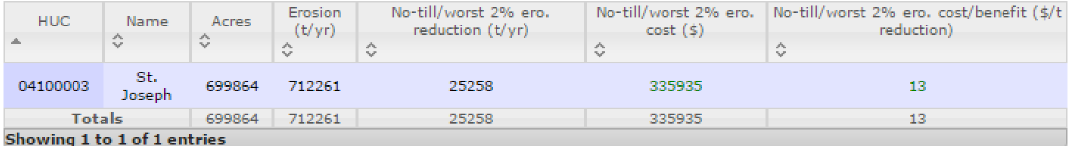
HUC	Name	Acres	Erosion (t/yr)	No-till/worst 1% ero. reduction (t/yr)	No-till/worst 1% ero. cost ($)	No-till/worst 1% ero. cost/benefit ($/t reduction)
04100003	St. Joseph	699864	712261	13174	167967	13
Totals		699864	712261	13174	167967	13

Before correction 1% no till on St. Joseph HUC 8 reduces erosion by 481,650 tons / year



HUC	Name	Acres	Erosion (t/yr)	No-till/worst 1% ero. reduction (t/yr)	No-till/worst 1% ero. cost ($)	No-till/worst 1% ero. cost/benefit ($/t reduction)
04100003	St. Joseph	699864	712261	481650	167967	0
Totals		699864	712261	481650	167967	0

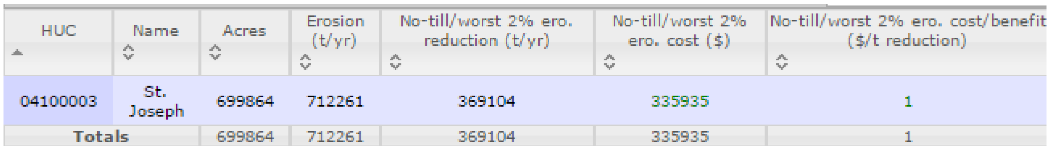
After correction 2% no till on St. Joseph HUC 8 – 25,256 tons / year



HUC	Name	Acres	Erosion (t/yr)	No-till/worst 2% ero. reduction (t/yr)	No-till/worst 2% ero. cost ($)	No-till/worst 2% ero. cost/benefit ($/t reduction)
04100003	St. Joseph	699864	712261	25258	335935	13
Totals		699864	712261	25258	335935	13

Showing 1 to 1 of 1 entries

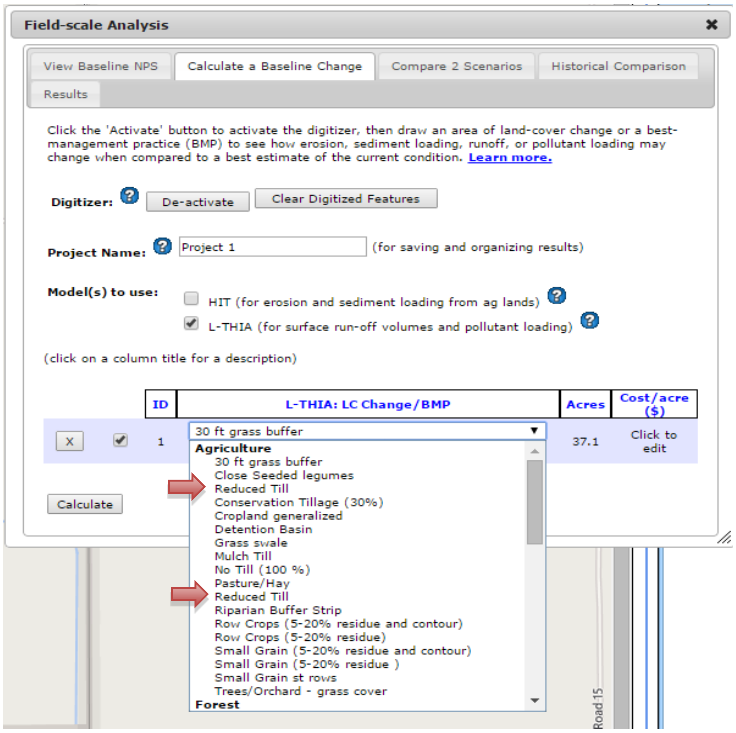
Before correction 2% no till on St. Joseph HUC 8 – 369,104 tons / year



HUC	Name	Acres	Erosion (t/yr)	No-till/worst 2% ero. reduction (t/yr)	No-till/worst 2% ero. cost ($)	No-till/worst 2% ero. cost/benefit ($/t reduction)
04100003	St. Joseph	699864	712261	369104	335935	1
Totals		699864	712261	369104	335935	1

<u>Display error in LTHIA</u>

There are two instances of *reduced till* and implementing them gives different results.



Click the 'Activate' button to activate the digitizer, then draw an area of land-cover change or a best-management practice (BMP) to see how erosion, sediment loading, runoff, or pollutant loading may change when compared to a best estimate of the current condition. Learn more.

Digitizer:

Project Name: Project 1 (for saving and organizing results)

Model(s) to use:

☐ HIT (for erosion and sediment loading from ag lands)

☑ L-THIA (for surface run-off volumes and pollutant loading)

(click on a column title for a description)

		ID	L-THIA: LC Change/BMP	Acres	Cost/acre ($)
X	☑	1	30 ft grass buffer	37.1	Click to edit

Appendix 5C: GLWMS Scoring Rubric

Draft rubric presented in the RCPP proposal for Saginaw Bay

	Category	Points
Implementation acres	0-100	1
	101-500	2
	501 – 1000	3
	1001 – 3000	4
	More than 3000	5
Conservation practices implemented	1 practice	1
	2 practices	2
	3 or more practices	3
% of parcel at high risk for sedimentation (GLWMS)	0 – 10%	1
	11 – 30%	2
	31 – 50%	3
	51 – 70%	4
	71 – 90%	5
	Over 90%	6
Sediment removal OR phosphorus removal (GLWMS)	0-10 tons / 0-20 lbs	1
	10-20 tons / 21 – 30 lbs	3
	21-30 tons / 31 – 40 lbs	5
	31-40 tons / 41-50 lbs	7
	40 – 50 tons / 51 -60 lbs	9
	Over 51 tons / over 61 lbs	11
Current Fish Community Health	Not impacted	1
	Moderately impacted	3
	Impacted	5
	Poor	6
	Very Poor	9
Total Available Points		**34**