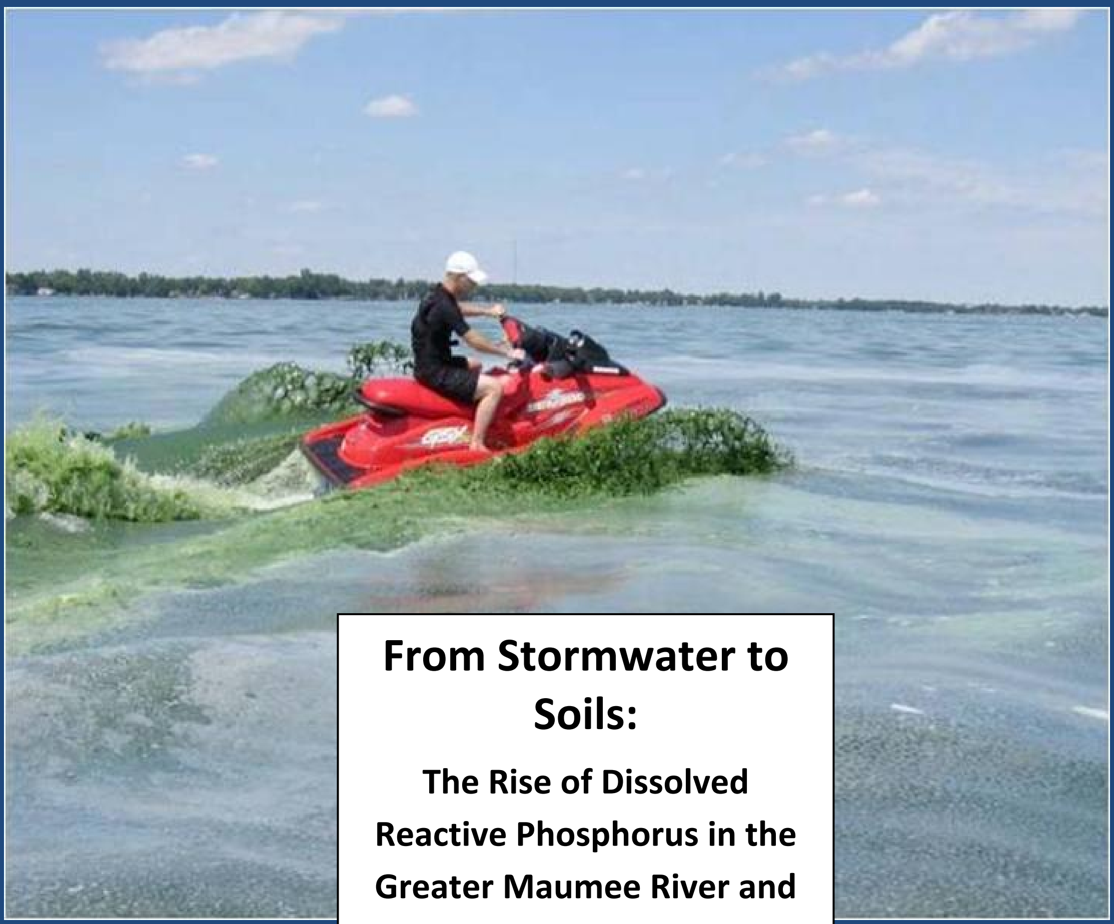

From Stormwater to Soils:

The Rise of Dissolved Reactive Phosphorus in the Greater Maumee River and Lake Erie Basin

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Introduction

Prior to the establishment of the U.S. E.P.A. "Clean Water Act," officially the Federal Water Pollution Control Act of 1972, there was little heed paid to what entered the waterways. Several separate instances of environmental degradation occurred and led to the enactment of this law.

Phosphorus is considered a limiting factor in the proliferation of algae. Of all the factors that impact the growth of algae, available phosphorus directly growth of algae (Braig, 2011). Early legislation and action called for the primary elimination of detergents containing phosphorus. This resulted in a marked change in the proliferation of algae in our waterways.

There were many waterways that made the news in the 1960's and 70's concerning pollution and the abundance of algae. Lake Erie and its tributaries received a lot of attention.

Amounts of phosphorus, in different forms, are still being used and are present in waterways. Lake Erie continues to suffer from historic levels of *anabaena* (Davis, 1964; Baker, 2011) resulting in many Harmful Algal Blooms (HABs). The result of these blooms has a direct effect on the other biota and habitats within Lake Erie and other impacted bodies of water. The proliferation of the HABs has diminished or ceased the recreation economies, impacting fishing, swimming and boating.

The factors and contributing sources leading to these algal blooms continues to be the foci of studies from colleges and universities within the region and abroad.

As of yet, there have been no definitive answers to the primary source of phosphorus or a single set of Best Management Practices (BMPs) to assist in reducing the impact.

Definition of Dissolved Reactive Phosphorus (DRP)

There are several forms of Phosphorus (P) being measured in water monitoring. Total Phosphorus (TP) is a reference to the entire loading of P in the waterways. This is then broken down into two other types; Particulate Phosphorus (PP) and Dissolved Phosphorus (DP).

PP settles to the bottom and is considered unavailable. DP, however, continues to be available due to its solubility. What this means is the likelihood of that contaminant contributing to the formation of harmful algal blooms.

Of these different types of phosphorus, DP is responsible for the Dissolved Reactive Phosphorus (DRP) form. DRP is important, in regards to Lake Erie and the Maumee, as it is more easily available to algae than the particulate form (Baker, 2011). The availability DRP becomes the limiting factor promoting the growth of algae meaning the more phosphorus available to algae, the more likely it will proliferate (Austin, 1996; Reutter, 2011).

Historic Trends

The Importance of Lake Erie-Lake Erie is a part of one-fifth of the world's surface freshwater system, the Great Lakes.

Of all the Great Lakes, it is Lake Erie that is the most biologically productive (Davis, 1964). There is a common rule, used in discussing the biological importance of Lake Erie, entitled the "70/5 Rule" (State of the Strait Conference, 2006). This rule states that Lake Superior represents 70% of the water in the Great Lakes and Lake Erie only 5%, these percentages are inverted when the discussion is framed around the relative bio-diversity of each lake.

Of all the commercial fishing in the Great Lakes, Lake Erie accounts for 75% of the production. Of that amount, the Western Lake Erie Basin produces 75% of that total (Western Lake Erie Basin conference, 2007).

In addition to the commercial fishing, sport fishing is very popular and brings millions of dollars to local communities. Boating is a billion dollar industry in the region. Thousands of people flock to the islands and shores of Lake Erie for swimming and camping as well.

Given the relative abundance Lake Erie provides, it has become the harbinger of future impacts to the other Great Lakes and fresh water-bodies in general (Ludsin, et al, 2001; Reutter, 2011).

The Lake Erie Phosphorus Legacy-Numerous studies leading up to the pronouncement of the "death" of Lake Erie (Time magazine, 1969) note the shifts, increases and decreases of certain organisms which would appear to be harbingers of more current trends (Vorce, 1882; Davis, 1964; Ludsin, et al, 2001). Even as early as the Vorce 1882 study, Lake Erie was facing challenges from anthropogenic sources of contamination. In the -Vorce study, there was an analysis of Lake Erie biota that led him to suspicions of the water quality due to the open-water dumping of "night-soil," or human and animal waste dumped onto the streets of Cleveland, Ohio.

Lake Erie, up to the middle of the last century and according to preliminary searches, had no history of regular recurring algae blooms of any real note (Vorce, 1882; Davis, 1964).

In the early days of our modern society, algae blooms were accepted as a fact of our modern society. It wasn't until scientists started investigating the negative impacts to the lake that they identified phosphorus as an early and major source to the proliferation of algae.

The presence of these compounds increased 75 times from their 1940 level. Phosphorus loading was up to 150,000 tons per year in 1970. Without any species to feed upon the algae, this led to the proliferation of harmful algal blooms (Outwater, 1996). During the course of eutrophication, the algae changes from increasing oxygen in the water during its growth stage to consuming far more of it upon its maturity and death (Outwater, 1996). With phosphorus identified as a source of unwanted nutrient loading, or eutrophication, phosphates were swiftly removed from many household detergents.

The phosphorus issue being addressed, along with other target projects, the lake was found to be a resilient survivor. Indeed, Lake Erie has not just survived but thrived. With the steady decline of Particulate Phosphorus (PP) over the past few decades, a positive response has been seen in the waterways and Lake Erie itself (Ludsin, et al, 2001).

Around 1995, the downward trend of PP continued. Even with the downward trend there started a rise, continuing to this day, of Dissolved Reactive Phosphorus (DRP) which has increased each year since.

Potential Sources of DRP

Ratio of P discharges into Lake Erie from non point-sources outweigh point-sources 3:1 (Baker, 2011)

Point-source (PS)- Point-sources are cited as contributing up to 22% of the total load to Lake Erie. This is not the largest source of P contributed in the water, however it does represent a chronic contribution with the loading of DRP and is considered highly available (Baker, 2011; Reutter , et al, 2011).

Industry Discharge-Most factory discharges have been improved in the period following the passage of the Clean Water Act. In many communities, factory effluent is being treated alongside the regular waste stream in municipal wastewater plants. Allowances for spikes of various chemical loads are made and adjusted for within the means of the treatment facility.

Municipal Sewage Discharge-Most large urban centers, responsible for the largest amounts of effluent, treat their water to remove phosphorus loads before discharging . Untreated discharge containing phosphorus loads are considered highly bio-available. These are considered chronic sources of contamination but are reported to decrease in concentration as flow within a waterway increases. The net effect is that these sources cannot account for the wet-weather “pulse” of phosphorus into Lake Erie (Baker, 2011; Reutter, et al, 2011). There is always a likelihood of these communities contribute phosphorus through combined sewer outfalls under heavy loads or in wet weather.

It should be stated that Great Lakes Basin effluent standards are currently among the strictest in the country.

There is research of certain municipal sewage treatment plants actually harvesting the phosphorus and selling its crystallized form of it in the open market. This could be an effective means of recycling phosphorus from waste stream (Stratful, et al, 1999).

Non Point-source (NPS)-These sources abound within the region and are difficult to discern which contributes most heavily to the presence of bio-available phosphorus.

Baker, 2011 cites that for every ton of point-source contribution to Lake Erie, there are approximately 3 tons contributed through non point-sources. Most of this NPS load occurs during storm events (Kleinman, et al, 2011; Baker; 2011; Reutter, et al, 2011; Elsbury, et al, 2009).

Atmospheric deposition has been briefly discussed and ruled out through a short study. The same study eliminated the background contribution of P from bedrock as well (Elsbury, et al, 2009)

Agricultural Runoff /Cropping-Historically, agriculture has used phosphorus as an inorganic compound since 1927 (ref. “Odda” process), to assist with the starting of Spring crops. Since that time, composition, concentration and method of delivery have all drastically improved-thereby intensifying its effect on the land.

Before the advent of newer technologies and more efficient chemical management, the preferred technique was mold-board plow style tillage. There were many negative aspects to this technique but one benefit was the cycling and integration of residue and applications of P moved vertically throughout more of the soil horizons. This may have offset the availability of DP to stormwater runoff.

As the result of programs to reduce sediment and PP loss, producers have migrated away from conventional tillage and turned to no/low-till techniques. The reduction and management of PP creates a benefit resulting in lower erosion and sedimentation rates.

Instituting low/no-till strategies means that more of the surface-applied fertilizers, herbicides and pesticides remain in the upper-most layers of soil. The degradation of residue may now be releasing the chemical compounds that were once bound to them (Torstensson, et al, 1989). This could allow for the availability of these compounds, suspended in runoff events, to the organisms in the water column-specifically algae.

Amounts of DRP have climbed since 1995. This increase also seems to correlate with the release and popularity of genetically-modified crops. The advent of genetically modified crops-specifically glyphosate-resistant seeds, occurred around 1995. The popularity and adoption has only increased since that time. (Fernando-Cornejo, et al, 2006). There may appear a similarity between the glyphosate-resistant seed adoption rates and the rise of DRP in the region, however, the research supporting this is not apparent.

Research has recently revealed that algae native to Lake Erie are capable of using phosphonates, part of the composition of glyphosate, as the sole source of phosphorus (Brannan, 2009). Even glyphosate is suspect in the contribution to the creation of harmful algal blooms (McKay, et al, 2009; Brannan, et al, 2009).

In the Reutter 2011 study, it is mentioned that in a comparison between commercial synthetic fertilizer and manure, the solubility of manure is often lower. Given identical concentrations and rates, the synthetics contribute higher levels of DRP (Reutter, et al, 2011).

Currently, the best practice would likely seem to be low or no-till farming (Baker, 2011; Reutter, et al, 2011). Injection of nutrients into the soil appears to be better than broadcasting and particulate phosphorus reduction and management is still a valid strategy (Reutter, et al, 2011).

Agricultural Runoff /Livestock Management-The likelihood of nutrients from livestock production can be potentially quite high in a number of regards.

Primarily, it could be the presence and mismanagement of manure, concentrated in living conditions, from the livestock themselves. Improper livestock management and/or placement along with maintenance of waste lagoons create a rich nutrient mix that could infiltrate into waterways (Kleinman, et al, 2011).

Secondary, the management of pasture land would, through the growth of grazing crops, likely be subject to the same growth and chemical techniques as other food crops. Pastures have been cited in studies to have high values of DRP available in the initial runoff amounts ("first-flush") after rain events. Pasture mismanagement mimics the same effects as mismanagement of regular crop growth. Exposure of a chemically-treated surface to a rainfall fresh after application results in contamination much the same as any other crop. The net effects of over-application to initiate paddock or pasture crops create the same high nutrient load in the first runoff amounts ("first-flush") across a parcel of land as any other crops (Austin, et al, 1996). In the "first flush" of water over a superphosphate, the primary loss mechanism for P is through dissolution-not adsorption or sediment transport (Austin, et al, 1996).

Tertiary effects would be the mismanagement of herds as they progress across the landscape, particularly entering streams and rivers at will. The addition of fecal matter and urine directly into waterways is contributing to nutrient loads.

The majority of P in livestock feed is passed through in the manure. After collection, this manure tends to be applied locally. If the method of application is surficial, the incidence of P entering into waterways is very high (Reutter, et al, 2011). The areas where most of this manure application also tends to occur on lands with currently existing higher P soil levels (Kleinman, et al, 2011).

Best practices for this area include properly maintained lagoons and treatment of all pasture land feeds similar to any properly managed crop (Austin, et al, 1996). Improve paddocks and pastures to reduce the runoff and erosion. Restrict access of livestock to specific, hardened locations to reduce both manure and sediment contamination if the livestock are free-ranging and given access to a free-flowing stream. Incorporate any manure as fertilizer into the soil rather than on its surface (Reutter, et al, 2011).

<u>Septic Systems</u>-Septic systems range in effectiveness based, primarily, on the ability of surrounding soils to drain effectively, or "perk." If this drainage does not occur, the system is flawed and amendments or other strategies must be considered.

Maintenance of these systems must also be effective in order to circumvent failure. Working knowledge of effective septic system management is essential to rural homeowners.

There is also a disturbing trend of certain households using a bypass of the septic system altogether and installing an interceptor upon the failure of the system.

Some older discharge systems pass through sand filters and flow into drainages. These older systems are still in use in the region and do not treat for phosphorus removal (Allen County Health Dept., 2012).

Best Practices for septic systems would be to ensure the ability of the soils to "perk" or amend them until they do. Connect failing systems to sanitary sewer lines where possible. Educate the population on the causes, effects and responsibilities of owning a septic system. Investigating and addressing the known issue of septic system bypasses is also important.

<u>Urban/Suburban Storm Drains</u>-All drains lead ultimately to waterways. Storm drains are the most direct of these routes and carry a very high percentage of litter, yard and pet-waste to those waterways, often untreated.

Chemicals from inappropriate dumping of household solvents, debris from the street and sidewalk are problematic for water quality.

Degrading, chemical-laden grass clippings and pet waste from urban and suburban storm systems are of interest due to the very high nutrient load and the DRP issue.

Best practice is awareness for this type of contamination. Educating urban and suburban populations on the connection of these pipes to the rivers and the effects of allowing untreated waste into them is the most effective technique (U.S. EPA, 2009). Increasing visibility and civic

responsibility might be made by placing pet waste stations or signage pertinent to the problem. Regional detention systems, such as the Camp Scott Mitigation Wetland in Fort Wayne, IN also provide treatment and contaminant reduction for these systems.

Road Runoff-The runoff from the shoulders and gutters of all roads lead to storm drains and swales. Like the urban counterparts, this runoff rarely gets any treatment before entering the waterways. Land treatments used in maintaining swales, shoulders, easements, etc. are a risk of the very processes discussed. With the regular maintenance of highway medians and berms, high-P concentrations from years of continued application and the re-release of glyphosate in degrading biotic material after mowing are washed into the waterways and add potential to the nutrient load.

Coupled with chemicals and debris from vehicles, these added contributions increase the degradation of the water quality and disrupt any effective treatment of road runoff. With over 1300 miles of roadway (statistic: Allen County Highway Dept.) in Allen County, IN alone, there is a considerable amount of runoff from this hard surface.

Chloride, though not directly related to the topic of DRP, is readily traceable to the impact of roads on waterways. Levels of chloride are quite apparent at base flows, particularly during Winter (Tedesco, 2003). The delivery system for chloride is the snowmelt subsequent to its application on the roadways. This same snowmelt delivers any other surface contaminant with it.

Best practices would be roads with integrated stormwater measures and controls built into their design. Proper maintenance would be instrumental (U.S. EPA, 2009). Implement watershed boundary signage as reminders to the nexus of land and water.

Wildlife-The focus of this paper is primarily about the anthropogenic contributions of DRP sources. Rampant “nuisance” geese are major contributors to the nutrient load in waterways. Fecal matter from Canada Geese (Branta canadensis) are cited in DNA evidence (Ross, 2004) as prominent in the non-human contamination in the St. Joseph River (Maumee River watershed).

Turf-grassed open spaces around ponds, lacking cover for predation, allow for the proliferation of year-round geese due to the creation of ideal habitat for the species. Design and maintenance issues have allowed geese to make homes of altered landscapes.

Best practices in regards to the prevalence and abundant nutrient contribution of “nuisance” geese would be better strategies regarding the choices of vegetation around retention/detention basins, yards and waterways in general. Denying geese unfettered easement to the water with the implementation of tall grasses along the edges provides ample deterrent for nesting geese (US EPA, 2009).

Potential Issues Impacting DRP Contribution

Failing Septic and Combined Sewer Outfall (CSO) effluent-Sewer and septic systems were prevalent during the settlement and early urban development phase in the Lake Erie Basin. During this time, most communities were unaware of the negative nutrient source potential of human waste and not using management practices (Vorce, 1882). Records of recurring, large-scale algae blooms seem a recent phenomena (Davis, 1964; Ludsin, et al, 2001).

Most sewage effluent is treated to remove phosphorus, however, smaller communities may have limited or no means to reduce the phosphorus load.

Municipal effluents are chronic point-sources and contribute DRP primarily at low flows (Baker, 2011). The addition of combined sewer discharge acts more like non point-sources with levels of untreated sewage entering waterways rising as flows increases. With Fort Wayne 2011 CSO levels reaching 1 billion gallons of discharge in the Maumee River (statistic: Fort Wayne City Utilities), this could have a severe impact locally during the relevant event and ramifications for the Western Lake Erie Basin, though as a percentage of the yearly flow of the Maumee River downstream it would seem inconsequential (>.365%).

<u>Glyphosate</u>**- G**lyphosate is designed to bond rapidly to particles as it comes into contact with soil particles and be rendered inert (US EPA, 1993). The half-life may vary from 3 to 141 days, depending on location (Andrea, 2003). There are, however, reports where the compound and its metabolite (aminomethylphosphonic acid or AMPA), are reported in soils up to two years after the application of glyphosate (Torstensson, 1989). The presence of glyphosate is impeding the bacterial ecology of soil, creating micronutrient deficiencies, and possibly impairing the beneficial nitrogen-fixing bacteria (Santos, 1995).

More recently, there is a study connecting glyphosate accessibility to phytoplankton, adding another nutrient source for algae (McKay, et al, 2009; Brannan, et al, 2009).

<u>Legacy Phosphorus (LP) Loading</u>-Several studies speak of the possibility of residual phosphorus recycling into the waterways (Elsbury, et al, 2009; Torstensson, et al, 1989; Kleinman, et al, 2011).

In the first study, there were various samples taken across Lake Erie and at the mouths of the various rivers across a period of time. The findings were such that the samples of phosphate isotopes reflected loads of phosphorus in the lake that could not be attributed to the rivers or point-sources along the lakeshore exclusively. There was another source contributing. This could be due to marine deposits of phosphorus, from decades past, becoming re-suspended due to turn-over of the lake. Also, the anoxic environment present in the hypolimnion, partly due to eutrophication, may be acting to release previously bound phosphates from benthic sediments (Elsbury, et al, 2009).

The second study reported the presence of glyphosate in soils between 1-3 years after application. This was also coupled with the presence of a metabolite of glyphosate, aminomethylphosphonic acid (AMPA) present in certain soils and other climatic conditions up to 4 years after application. The effect of these is attributed to the binding of the compound to the target plants, as expected, but the release of the compound and metabolite due to the degradation of the plant residue (Torstensson, et al, 1989). The effect of this degradation and release to DRP in Lake Erie is not known but must be entering the waterways in a soluble form.

The most recent of these studies cites the long-term over-application of phosphorus. Even when the limnic system would seem to be “in balance” there may be factors which promote accumulation, past the point of saturation and adhesion that allow for P in runoff. This study warns of conventional low/no-till conservation practices “exacerbating” dissolved P pollution by retaining the overload within the upper horizons of the soil (Kleinman, et al, 2011).

There is information is the possibility that wet-detention ponds may be, as a direct result of their function, accumulating phosphorus in the sediments within them. Every flood or rain event that is severe enough to flush these sediments from within, adds to the re-suspension of the contaminant-laden sediment or the concentration of DRP within the impounded waters (Renkenberger, 2012).

Climatic Variation

The variation in weather patterns should represent, all sources being considered, the cited research on the contributions of the major tributaries to Lake Erie and the presence of algal blooms.

Case In point, the combined research of the National Center for Water Quality Research (NCWQR) released studies and reports that seasonal increases of DRP correlate with seasonal increases in flows of the Sandusky and Maumee Rivers and their primary non point-source contributions of Total Phosphorus (TP). Chronic point-sources, primarily contributed at low flow by the Cuyahoga River and considered highly bio-available, decrease as flows increase (Baker, 2009 and 2011, respectively).

Regionally speaking, the wet Spring of 2010 reported the largest amount of Phosphorus since 1975 in an April-June period (D. Baker, 2010), resulting in algal blooms by late Spring and early Summer. Compared with the drought period of 2012, with the effect of reduced or non-existent runoff, Lake Erie was predominantly free of the large algal blooms. The observation of these comparisons would indicate the amount of DRP entering Lake Erie is most likely from stormwater runoff and not the chronic, low-flow sources.

If there are overall trends of higher precipitation (Appendix 1), the overall trend does not correlate strongly with the continued upward trend of DRP in the area. Overall trends do not account for individual storm events, their respective severity or regional variances. It would be prudent to refrain from any real conclusion about gross climatic changes accounting for increases in DRP but at first glance it does not seem to correlate.

The research that Legacy Phosphorus (LP) might be re-suspended from the marine soils under certain limnic conditions (Elsbury, et al, 2009) would seem to make the re-emergence of algal blooms more probable. The likelihood of blooms would be affected in size by climate and phosphorus loading from other sources.

Flooding-There is more severe flooding in the recent years (period 1995-present) than there has been in the decades preceding the rise of DRP in the waterways. Historic crests records of the Maumee River (NOAA, 2012) hold values of the highest flood levels at each monitoring station. The record shows 37.5% of the top 10 levels at each station during the period 1995-2012. What this means in regards to the rise of DRP is that almost all of the major flood events happened within the period during or between Fall and Spring fertilizer application seasons (Renkenberger, 2012; Appendix 2). There is a strong correlation between periods of inundation and the probability of high DRP loading (Kreiger, et al, 2010).

Summary

The rise of phosphorus and the onset of algae, specifically Harmful Algal Blooms (HABs), is the direct inheritance to a heritage of anthropogenic contributions and a culture of intensification of cultural practices in communities, industry, transportation and agriculture. It is not the presence of any of these, but the proliferation and impact of improper or impartial strategies and ambiguous enforcement of regulations. The net result of DRP loading is probably the culmination of detrimental and synergistic effects of all of the issues discussed here.

Without the benefit of oversight, political and social will and the ability to enforce regulations, Lake Erie and the region will likely enter into another phase of diminished water quality and impaired biological habitat.

The continual unchecked use of compounds and strategies for relatively short-term returns and a "business-as-usual" attitude toward water and our waterways will result in the degradation of this resource. The net result of cultural stasis compromises the economic interests and drastically impairs the ability of the region to compete globally in agriculture, industry and commercial fishing markets. The viability of our communities and of one of the largest bodies of freshwater will be compromised.

The point-sources of contamination are relatively apparent and easy to address. The nonpoint-sources are more difficult and must remain the focus in order to limit contamination. Until singular behavioral patterns are identified and addressed, we are all responsible.

To comment on the statement made earlier in the "Lake Erie Phosphorus Legacy" section, what was different in the early days of Lake Erie and the apparent absence of large, noxious algae blooms?

Before the drastic transformation of the landscape we had riparian vegetation in abundance on most all waterways. Wetland complexes had not been drained and broken up. Major damming projects had not created large areas of still water. Farms were managed in smaller units with biologically diverse cropping, with the presence of beneficial insects and separation of fields. Agriculture did not push production to the margins of the waterways due to the potential loss to flooding. Urban centers were smaller and the impact of that life was far less intense or concentrated.

We cannot go back to the way things were without compromising our current way of life. Obviously, forward is the only momentum we have, holding all the real options. The Greater Maumee River and the Lake Erie Watershed are suffering due to the general indifference and/or the lack of understanding of the issues and concerns poisoning it. A healthy watershed leads to a healthy and vital region, economically and environmentally.

Best course of action for the watershed? Most likely all of the following: continued phosphorus and nutrient reduction programs; cover crops; better riparian habitat creating cooler, darker waterways; continued sediment and erosion controls (Reutter, et al, 2011); comprehensive and effective land-use planning and development for urban/suburban/rural communities; better sewage and septic treatment and maintenance; stricter adherence to rules, regulations and enforcement concerning all the pertinent laws governing these issues; continued studies for potential sources and solutions of the issues.

The design and placement of highways is as important as sediment management in development, pet waste and refuse in urban settings or the utilization of cover crops and nutrient management in agriculture. Until we have better information leading to the primary causes of DRP, all strategies are on the "table" and should be implemented accordingly.

In addition to these, sharing the successes and the continued education of the general public could only improve the relationship of the stakeholders to the water resources of the region. Elaborate the

societal values of cleaner communities and water quality treatment. Improve the cohesion, transparency and leadership of all the relevant organizations, departments and agencies as to make clear to the public the responsibilities and hierarchy of the respective organizations.

Questions for Further Investigation

What kept L. Erie from Algal Blooms in the Settlement/Early Development phase of the Maumee River Basin past (period mid-1800s to 1940's)?

Is there a trend of increased flooding during the period 1995-2012 and how might this correlate to the rise of DRP?

Are the many wet detention ponds and dams on the rivers acting as concentration and loading areas for phosphorus? Might these also be feeding and/or incubating Blue-green algae and HABs?

Is it a coincidence that the Introduction of first GMO crops (1995) correlates with the rise of dissolved reactive phosphorus (DRP) after particulate phosphorus (PP) is recorded as decreasing in runoff in the same period?

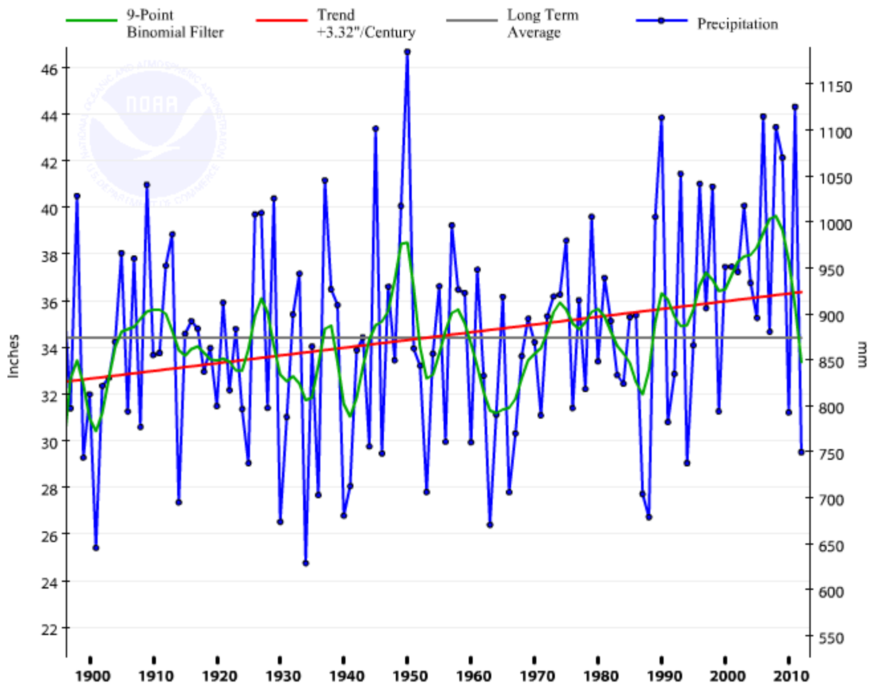
Is there a correlation between the rise of DRP and the advent of glyphosate as herbicide?

Though phosphorus has decreased in particulate form, are genetically-modified, glyphosate-resistant plants building a resistance to phosphorus overall? Are new crops not utilizing the full amount of applied phosphorus?

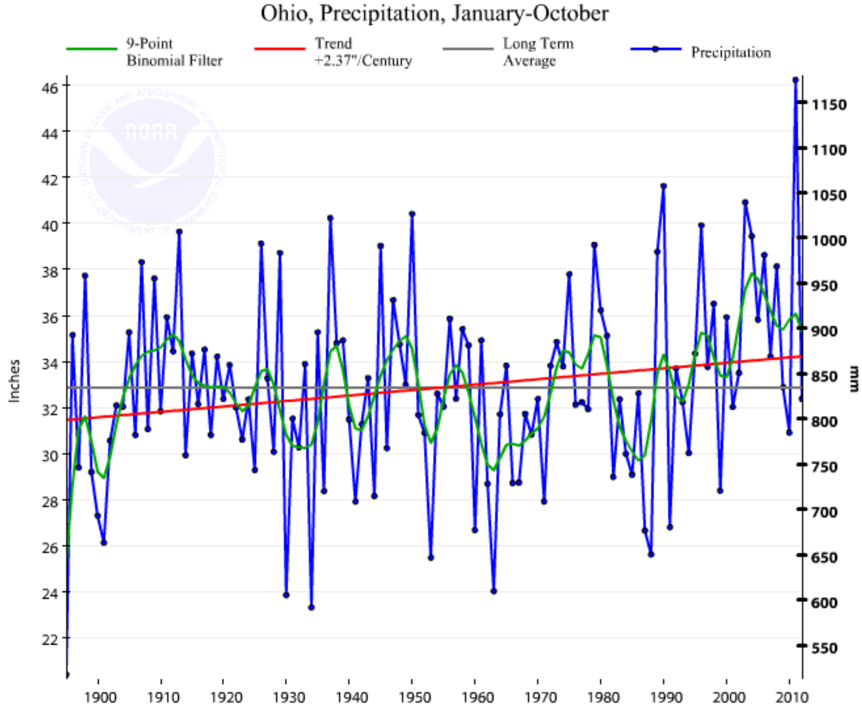
Could synergistic factors of soil biology and phosphorus/phosphate compounds impact the amount of DRP in the longer term?

Appendix 1

Indiana, Precipitation, January-October



Ohio, Precipitation, January-October



Appendix 2

Maumee River Historic Crests (highlight indicate period 1995-2012)

Fort Wayne

(1) 26.10 ft on 03/26/1913
(2) 25.93 ft on 03/17/1982
(3) 24.55 ft on 02/27/1985
(4) 23.90 ft on 01/01/1991
(5) 23.76 ft on 03/24/1978
(6) 23.58 ft on 03/13/2009
(7) 22.93 ft on 02/08/2008
(8) 22.50 ft on 03/08/1908
(9) 22.44 ft on 01/14/2005
(10) 22.40 ft on 01/15/1930

Coliseum

(1) 23.72 ft on 03/13/2009
(2) 23.21 ft on 02/08/2008
(3) 22.84 ft on 01/14/2005
(4) 22.32 ft on 12/01/2011
(5) 21.69 ft on 05/27/2011
(6) 20.86 ft on 02/12/2009
(7) 20.38 ft on 05/22/2010
(8) 19.95 ft on 03/06/2011
(9) 19.47 ft on 01/16/2007
(10) 19.34 ft on 04/29/2011

New Haven

(1) 25.49 ft on 03/17/1982
(2) 23.76 ft on 01/01/1991
(3) 23.68 ft on 03/13/2009
(4) 23.20 ft on 02/08/2008
(5) 22.69 ft on 01/14/2005
(6) 22.29 ft on 12/01/2011
(7) 22.07 ft on 05/27/2011
(8) 22.05 ft on 01/06/1993
(9) 21.60 ft on 07/10/2003
(10) 21.51 ft on 01/25/1999

Defiance

(1) 26.00 ft on 03/26/1913
(2) 20.50 ft on 03/15/1982
(3) 18.50 ft on 02/25/1985
(4) 17.97 ft on 02/08/2008
(5) 17.65 ft on 03/12/2009
(6) 17.50 ft on 02/16/1950
(7) 17.44 ft on 12/01/2011
(8) 17.36 ft on 05/27/2011
(9) 17.20 ft on 01/01/1991
(10) 16.90 ft on 03/23/1978

Independence Dam

(1) 15.87 ft on 03/15/1982
(2) 9.55 ft on 06/15/2004

Napoleon

(1) 25.00 ft on 03/27/1913
(2) 19.50 ft on 02/11/1959
(3) 19.50 ft on 02/14/1918
(4) 18.80 ft on 03/02/1910
(5) 18.00 ft on 03/20/1912
(6) 17.54 ft on 03/15/1982
(7) 17.13 ft on 01/01/1991
(8) 16.70 ft on 03/11/2009
(9) 16.65 ft on 01/14/2005
(10) 16.58 ft on 12/31/1990

Grand Rapids

(1) 20.81 ft on 03/15/1982
(2) 19.96 ft on 03/23/1978
(3) 19.50 ft on 03/11/2009
(4) 19.33 ft on 02/08/2008
(5) 19.15 ft on 01/14/2005
(6) 19.04 ft on 01/01/1991
(7) 18.30 ft on 01/30/1969
(8) 18.12 ft on 12/31/1990
(9) 17.50 ft on 02/15/1950
(10) 16.85 ft on 02/20/1981

Waterville

(1) 19.90 ft on 03/28/1913
(2) 16.17 ft on 02/12/1959
(3) 15.31 ft on 01/01/1991
(4) 15.21 ft on 02/26/1985
(5) 15.00 ft on 02/29/1936
(6) 14.96 ft on 03/14/1982
(7) 14.92 ft on 03/20/1978
(8) 14.60 ft on 01/25/1999
(9) 14.52 ft on 02/16/1950
(10) 14.16 ft on 03/11/2009

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