

Non-Point Source (NPS) Strategy for the Great Lakes

Abstract

Non-point source pollution in the Great Lakes chokes wetlands, fouls tributaries, embayments and the Lakes at large with eutrophication, closes beaches, causes fish-kills, makes water undrinkable, spreads human and animal pestilence, and destroys diversity. It encompasses four of the greatest manmade sources of stress and damage to the Lakes: nutrient loading, contaminants (toxic chemicals), land use practices (in consequences) and altered flow regimes (hydraulic alteration).

If untouched, these four alone could represent the beginning of a “slippery slope” toward ecosystem meltdown; this need not be so. In this strategy we, the Non-Point Source Task Force, outline a series of goals, objectives and action items, organized according to the five principal stressors. The actions are organized by category: administrative changes only, organization and focusing of information, full funding or completion of existing programs, and development or funding of new programs.

We ask Congress and the States initially (year 1) only for the amount of money needed for the administrative and informational actions, and possibly the administrative basis for new programs. This is unlikely to exceed \$8 million and will allow much more efficient and cost-effective approaches to existing and new programs. We are willing to promote these first efforts within our agencies, and among the general public. Having developed the proposals, we are willing to stand accountable within 18 months of funding, to be judged on our worthiness for actual program fund.

Note: users familiar with the problems and stakeholders of the Great Lakes may wish to proceed directly to Part II (Section Where To Go) for goals and objectives, and Part III (The Response to Non-Point Source Pollution in the Great Lakes) for action items

I. INTRODUCTION

Challenge and Response

The problem of non-point source pollution is present almost everywhere in the Great Lakes basin, in many forms and with many interactions. This strategy discusses first the challenge: the five aspects (“stressors”) of the problem with broad goals and objectives. It then outlines the response: specific actions steps mitigating the stressors. The complex air/water/soil connections require a full and complex coordination of responses.

In judging challenge and response we must remember that non-point source impacts vary greatly in frequency and severity from place to place. Impact has been particularly severe in the coastal wetlands and previously healthy tributaries that buffered the Lakes themselves from damage. Geographically, other prime impact areas may include western Lake Erie, Saginaw Bay, Green Bay, coastal Ohio (where sediment loads are high), selected Areas of Concern (AOCs), and selected tributaries or near-shore areas.

This geographic variation makes geographically responsive tools and coordination with geographically based Task Forces (habitat, coastal health) of this Great Lakes initiative particularly valuable. Similarly, issues like land use and smart growth have a major impact upon the control of non-point sources. Thus, this strategy should be reviewed again after Task Force members have seen the other Task Force strategies.

II. THE CHALLENGE OF GREAT LAKES NON-POINT SOURCE POLLUTION

The Web of Stressors

Under the principles of conceptual modeling, Stressors are the physical or chemical changes that occur within the ecosystem that are brought about by the drivers.¹ Stressors significantly impact the biological components, patterns, and relationships in the natural system. Great Lakes non-point source pollution can be broken down among: nutrients, contaminants, pathogens, sedimentation, and altered flow regimes.

These stressors enter the Great Lakes through three primary pathways: surface runoff, atmospheric deposition and groundwater infiltration. In these five forms non-point source pollution damages flora and fauna in the lakes, threatens human health, reduces recreational opportunities, and increases the cost of treating drinking water and dredging our harbors and marinas.

In varying ways the five stressors impose not just significant impediments to the protection and restoration of the Great Lakes, but a far-flung complex of collateral costs and impacts upon agriculture and public health in general. Actions against stressors have direct short-term costs, but often save money and sometimes make new sustainable growth possible. Thus, the Lakes ecosystem is rarely alone in experiencing harm from impact or benefit from relief.

- **Nutrients** - Lake Erie and shallow embayments of the other Great Lakes display accelerated eutrophication including serious oxygen depletion and harmful algal blooms (such as the current Wisconsin *cladophora* outbreak). These stem in part from runoff carrying rural (especially agricultural) and urban non-point source nutrients. Much of this runoff is wasteful because it represents unused fertilizer from farms and lawns. Eutrophication caused the recent large-scale die-offs of fish and waterfowl in Lake Erie: deadly botulism is caused by powerful neurotoxin of the bacteria *C. botulinum*, produced in oxygen-deprived lake zones.
- **Contaminants** - The Great Lakes ecosystem exhibits many persistent bio-accumulative toxics (PBTs), including PCBs and mercury, at levels threatening human health and the environment. Health agencies have thus issued fish consumption advisories for broad areas of the Great Lakes basin. PBTs continue to enter the Great Lakes and tributaries through atmospheric deposition, sediment resuspension, as well as through urban and agricultural run-off. Parts of this runoff represent the costly waste of pesticides (insecticides, fungicides and herbicides) diverted from their proper function. The Great Lakes ecosystem and its beneficial uses may also be at risk due to non-point releases of new chemicals of concern. These include certain brominated flame-retardants and animal pharmaceuticals (e.g., hormones and antibiotics).
- **Pathogens Affecting Human Health** - Bacterial contamination in runoff from animal feeding operations, failing septic tanks and from diffuse sources in urban areas, limits the recreation use of tributaries and Great Lakes shoreline swimming beaches. Among animal feeding operations, this loss by runoff again represents a waste of a useful and valuable resource that might properly be used as fertilizer. Among septic tanks, it represents an annoyance and risk to the owner and neighbors. In 1993 a serious water supply contamination of *Cryptosporidium* occurred in the Great Lakes causing over 100 deaths and affecting an additional 400,000 residents causing severe diarrhea, nausea, stomach cramps and other symptoms.
- **Sediments** - These seriously impact aquatic habitats, choking riverine, coastal and near-coastal wetlands. Sedimentation results from storm water runoff from urban and rural developments that do not incorporate best management practices. It also comes from agricultural and forestry practices that do not employ conservation measures are adding excessive sediments as well as other pollutants to the Great Lakes and tributaries. Whatever manmade source it comes from, it is a directly function of erosion and a waste and diversion of good topsoil
- **Alteration of Flow Regimes** Both manmade and natural changes in flow regimes can cause significant harm. In the Great Lakes basin, we see manmade changes in the form of excessive flows from impermeable surfaces in developed areas and from drained agricultural wetlands. These may be exacerbated by the loss of wetlands and the removal of natural, riparian vegetative cover, altering natural groundwater and surface water flow regimes to the detriment of aquatic species.

Similar manmade flow alterations that reduce groundwater recharge and increase runoff also diminish base flows; increase flooding, bank erosion, and channel instability; and put cool water and cold water fisheries and ecosystems at risk. The flow alterations combine to increase the risks of flooding while reducing the quantity and quality of physical habitat available.

The Balance of Forces

Justifiably, billions of dollars have been spent over the last thirty-plus years to remedy major, obvious point source problems and discharges to the Great Lakes. We have seen large projects like the tunnel and reservoir programs of Chicago and Milwaukee and major cleanup or prevention efforts like those at Waukegan Harbor or Reserve Mining in Minnesota.

From the discussions above for the individual stressors, this great work has by no means secured the future or even the present security of the Lakes. By “ballpark” measurement, the total input of stressors from non-point source pollution today considerably exceeds that from point sources². It may compare in magnitude to the point source input thirty-five years ago, before the wave of sewage construction and remediation. Work on point sources approaches a point of diminishing returns; funding to move from 90 or 95 per cent control at point sources might reduce nutrients and contaminants by a factor of X, but by 10 or 20 X when applied to non-point sources.

Many large, powerful and effective governmental agencies and non-governmental organizations are already at work at, or with interests in, reducing non-point source pollution in the Great Lakes. These include the U.S. Environmental Protection Agency with its Regional Office Laboratories, and Great Lakes National Program Office. They include the Army Corps of Engineers with its vast experience and resources in construction. They include many USDA agricultural programs (NRCS, including EQIP, among many),

They include NOAA’s Centers of Human Health, especially the *Center of Excellence for Great Lakes and Human Health* and, its Coastal Zone Management Program. . There are all the Federal governmental bodies operating or acquiring special park or natural resource holdings within the basin, such as the National Park Service, the Forest Service and the Fish and Wildlife Service

Many State and local governments have also shown strong records of leadership, and have programs and initiative comparable to those the Federal government. Some of these have outstanding special initiatives, like the Wisconsin Department of Natural Resources. Other may include agricultural programs, including the Cooperative Extension Services with agents in every county. They may include State departments of forestry or natural Resources and range down to countless local park districts.

The universities and colleges may have specialized Great Lakes study centers, major research programs, or working affiliations with State or Federal programs. There are many governmental bodies at the local level, such as the local sanitarians who manage on-site wastewater treatment (septic tanks, etc), departments of public health, or simple local drainage districts.

There are national, regional and local non-governmental organizations with particular interests in the preservation or rehabilitation of the Great Lakes ecosystem, such as the National Wildlife Federation, Ducks Unlimited, the Nature Conservancy, the Izaak Walton League, Sierra Club and many “Friends of...” organizations. There are special local institutions like science museums, aquariums and botanic gardens. Any or all of these may educate the public, advocate policy changes and actions, carry on research, and acquire or maintain crucial land holdings.

Do These Pieces Fit?

Together these agencies and organizations represent a formidable block of knowledge and manpower, disposing of hundreds of millions of dollars annually. They, however, have not had anything like the impact upon non-point sources that the great municipal construction and remediation programs have had on the point sources.

There are many reasons for this, many of which are unintended. Stressors may have large impacts incidental to those upon the lakes ecosystem. The indicated agencies and organizations may focus upon the goals and objectives incidental to Great Lakes ecosystems, like agricultural productivity.

Similarly, agencies and organizations having broad national or state mandates may not all directly recognize the special significance of the Great Lakes basin; *thus a Department of Natural Resource may be strongly engaged with Lake problems, but many CES county agents within the basin may not. Excellent programs effective in one state may be entirely unknown in others.* Agencies specializing in construction may have mandates so sharply defined that they cannot respond to ready opportunities to better the ecosystem at little or no additional expense.

Organizations most familiar with particular areas or particular issues may not be recognized in law, so that they cannot act directly or receive public funds. Websites and clearinghouses may exist for at least passive interchanges of ideas among all these organizations, but not for consistent constant correlation of projects and opportunities. Databases that local officials and the public might use to understand day-to-day choices may be complex and arcane, accessible only through specialized GIS tools.

Where to Go

We, the Non-Point Source Task Force, represent the agencies and organizations described above. In exchanging ideas about the challenges or responses of the various stressors, we came to realize how much could be accomplished: by *greater* flexibility in the operation of our programs, *fuller* support for the tasks we have undertaken, and *fuller* marshalling of our information resources and managerial skill.

*In general, our agencies' programs need coordination at a higher level and focus on mitigating specific problem areas; such as Areas of Concern. These agencies may offer grants to states and local groups to address these concerns, but the grants are given without any overall, interagency focus strategy. Thus Federal agency budgets not only need enhancement to focus on a problem, but the effort must be **COORDINATED**, so that the Federal, State and local agencies will focus their energies on the same problems.*

We have blended and modified our insights to create the following lists of goals, primary and secondary objectives, and action steps. We strongly believe that the condition of the Great Lakes benefit as much by full, thoughtful attention to non-point source problems as it did by attention to the point sources. A much smaller amount than was spent on the point sources (especially when collateral benefits are reckoned) will complement and complete the progress made there.

I. Among **Nutrients**, two broad goals lead to logical objectives:

A. To **control eutrophication** (among embayments, open lake areas, and the rivers or tributaries):

Reduce the gross nutrient input that damages water quality to meet existing water quality criteria set by USEPA (Nitrogen, phosphorus, sediment loading).

- Make geographic information easily accessible to focus upon the varied targets.
- Rely or build upon existing programs like Section 303(d) of the Clean Water Act, the Great Lakes Water Quality Agreement, and state or local counterparts.
- Use non-regulatory and cooperative approaches too.
- Focus initially upon known problem areas.
- Coordinate standards, networking and enforcement among agencies and jurisdictions.

B. To reduce nutrient **loading from non-permitted agricultural operations** (feedlots, farms, etc.):

Assist **50% of non-permitted livestock operations to minimize nutrient loads** by 2015.
Rely or build upon existing Federal (USDA/NRCS), State and local programs.

II. Among **Contaminants**, two broad goals lead to logical objectives:

A. To **virtually eliminate persistent bioaccumulative toxic (PBT)**.contamination:

1. **Prevent the release of toxic substances** in toxic amounts
2. Place a **contaminant monitoring program** for PBT's and emerging toxics on a significant percentage of Great Lakes tributaries within the next decade.

B. To establish and **secure healthy, diverse and sustainable biological communities**, free from toxics harming aquatic life or waterfowl:

Eliminate the need for fish consumption advisories within the next decade.

III. Among **Pathogens**, two broad goals lead to logical objectives:

- A. To bring **all Great Lakes beaches to swimmability** for at least 80 per cent of the swimming season by 2015.
- B. To reduce **annual closures by 20%** for beaches already 80 to 90 percent swimmable.

IV. Among **Sediments**, one broad goal leads to logical objectives:

To reduce sediment loadings to the Great Lakes by 30% by 2015:

(This includes both bays and coastal areas in urban and non-urban locations)

Existing programs include the Conservation Reserve Program, Clean Water Act, those of the NRCS (like EQIP) and more than a dozen others.

1. **Increase year-round cover in selected watersheds** by 30% by 2015.
(This cover may include plants, mulch, rip-rap, etc.)
2. Increase urban **areas without destructively erosive storm water rates** by 23 per cent by 2015. These are rates so excessive they degrade stream banks and beds.
3. **Increase porous surfaces** by 15 per cent nationwide.
Runoff from newly impervious areas adds to runoff and sedimentation.
Increasing infiltration will reduce runoff and thus sedimentation.

V. Within **Altered Flow Regimes** one broad goal leads to logical objectives:

To **protect, maintain and restore the natural flow regime** in all watersheds of the Great Lakes:

(This is vital to ensure the integrity of aquatic ecosystems):

1. **Reduce the causes of altered flows:** impervious surfaces, dams, channelization, agricultural runoff, stream bank and bed erosion (note link to sedimentation)
2. **Manage dams** to mirror natural flow and remove them where appropriate.
2. Increasingly **address multiple causes and stressors.**(wetland restoration, etc).
3. In all actions, **anticipate the impacts of altered flows** from manmade and natural sources, like climate change, extreme precipitations, etc.

III. The Response to Non-Point Source Pollution in the Great Lakes

A Big Picture- With A Thousand Strokes

Just as non-point source pollution consists of diffuse sources of many different kinds, a positive response proceeds not from one massive effort but from sum of hundreds of small things done well. Three principles to organize and prioritize these action items are **focus, severability, and concurrence**

Focus means bringing information and management resources together to bear upon a particular problem: to know its significance, the variety of factors present, problem magnitude, possible responses and their costs and impacts. Among goals and objectives we see this focus in conceptual models; among actions steps we see it in decision support tools.

Severability means that many of the action items in particular are not locked into an inflexible sequence. Those that can be done now with resources at hand should be done.

Concurrence means multimedia and multi-program inclusion. Goals and objectives that impact several stressors or the work of several task forces at once should have a higher priority, and calculations of costs and benefits should always include impacts beyond the Great Lakes ecosystems.

The following action items are organized according to a logical progression. This is, first, adjustment of programs & policies; second, orchestration and application of existing data (small \$); third, adequate execution of existing programs (\$); and fourth, new programs (more \$). Within each category every entry

is coded (NPCSF) for stressor issue areas, because one action may address many stressors at once. Those with multi-stressor impact come first.

The action steps are broadly aimed at averting ecosystem meltdown by reducing or eliminating new stressors and insults, and restoring the Lakes own capacity for healing and restoration. Particular action items tending in the same direction could be grouped into specific action “breadboxes.

Major Action Steps

A. Adjustments of Programs, Policies and Guidance.

1. NCPSF: Coordinate control efforts for nutrients, contaminants, pathogens, and sediment among interested jurisdictions. These may be organized together or by stressor. Elements may include consistent standards, anti-degradation benchmarks, coordinated monitoring networks, and consistent enforcement.
2. NCPSF: Empower local and non-governmental “good actors” by opening funding for selected existing Federal and State programs to local drainage districts, public and private universities and established NGO’s with holdings or interests in the project area, such as National Wildlife Federation, Nature Conservancy, Izaak Walton League, Ducks Unlimited, etc. A special set of guidance will be needed to ensure permanency, access, etc.
2. NCPSF: Within existing programs, particularly USDA (EQIP, nutrient management plans, etc) create separate State priority lists for those area within the Great Lakes Basin.
3. NCPSF: Within existing programs, earmark funding for planning, design and implementation of practices in the most sensitive Great Lakes Watersheds, as determined by data or support tools.
4. NCPSF: Within existing programs, employ cost-effectiveness formulae that take into account all collateral benefits (reduced waste, etc).
5. NCPSF: Develop flexible alternatives to local matches within Federal and State grant/assistance programs. Some communities simply cannot afford current requirements. This might mean a reduced rate or extended payment schedule.
6. NCPSF: Apply the principles of **adaptive management** throughout the operation of existing Federal and State programs.
7. NCPSF: Within existing EPA programs like Section 319 of the Clean Water Act and the State Revolving Loan Fund, provide higher priorities for NPS projects that implement NPDES minimum measures.
8. NCSF: Develop concrete acreage goals with USDA’s Conservation Reserve Enhancement Program (CREP), especially for forested riparian areas in the northern Great Lakes Basin.
9. Identify and prioritize sites by cost and impact for the restoration of approximately one million acres of wetland within the US Great Lakes Basin: perhaps one tenth of the amount lost so far.
10. NPS: Expand the permitting threshold for confined animal feeding operations.
11. NCP: Develop basin-wide state mandated programs for household on-site wastewater treatment (septic systems). This could begin with the development of models codes and guidance to promote regulatory consistency, and the publicizing of sites and tools on optimum design.
12. PC: Evaluate the results of surveys on the effectiveness of fish consumption advisories, and make course corrections, particularly to improve communication with high-risk communities and populations.
13. SF: The FERC should incorporate dam management regimes mirroring natural flows into its licensing and re-licensing programs, at least as a major impact-mitigative measure. It should promote similar management of non-regulated dams, at least by offering model regulatory regimes on the Internet.
14. SF: Interested Federal and State agencies in concert should develop at least a model plan and procedure for planning and carrying out the removal of dams. This should balance advantages against harmful impacts viz. alien migrations, sediment release, etc.
15. SF: Replacement and modification of existing hardened channels and shorelines should be made at least an equal priority for Corps of Engineers and other projects. The Corps should

evaluate and rate biological engineering methods and use them in its projects where appropriate and cost-effective.

16. N: Develop outreach program on suburban lawn nutrients and investigate value of existing State or local limitations on Phosphorus in fertilizer

17. C: Expand the scope of regulations for land-applied sewage and manure to include emerging chemicals, like hormones, antibiotics and the most current pesticides.

18. S: Develop sediment control outreach and information for non-urban areas, if justified by data or support tools.

19 S: Encourage local drainage districts or other authorities to develop drainage codes that reflect sediment reduction packages. This may begin with the development of model codes and outreach.. 20. S: Promote the enforcement of existing sediment regulations by the development of web-based guidance, case studies, FAQs.

21. S: Develop a long term sediment monitoring network plan.

22. F: Through existing outreach and educational programs (like the Cooperative Extension Service) promote awareness of alternatives to respond to altered flow regimes, like storm-water detention, retrofitting detention basins, rain gardens, permeable pavements). This could also extend to providing technical assistance (model ordinances, legal drafting, GIS and decision support) to local governments to prevent flow regime alterations from new development.

B. Combining and Applying Data in Planning and Action

1. NCPSF: Develop Conceptual Models to view the problems on a systems level and identify significant data gaps and needs. These may be organized together or by stressor.
2. NCPSF: Develop and promote Decision Support tools to assess levels of need, appropriate responses and prioritize them by cost and impact. Examples include the Indiana EQIP tool, the Purdue Optimization Engine and the MSU Sedimentation tool.
3. NCPSF: Establish user-friendly web-based data bases for data, jointly or by stressor.
4. NPCSF: Created unified education/outreach strategies, jointly or by stressor
5. NCPSF: Create web-based administrative tools to ease the complexity of the **processes** associated with existing programs, such as TMDL's, nutrient management plans, etc.
6. SF: Within nutrient management plans for agriculture and public or private forestry, promote use of best management practices (BMP's) and generally accepted management practices that include considerations of natural flow regime.
7. F: Incorporate provisions for altered flow regimes into models and decision support systems.
8. F: Integrate consideration of flow regimes, particularly the critical 12-15% impervious "tipping point", into all non-point source watershed planning and voluntary assistance programs.
9. F: Make flow quantity and timing a consideration in storm water permits, TMDL's, and other discharge permits.

C. Commitment of Resources for Existing Programs

1. NCPSF: Accelerate the work of established programs for each stressor. These may include TMDL's water management plans, nutrient management plans, etc.
2. NCPSF: Expand the Riparian Buffer Initiative in sensitive watershed. Establish many more buffer strips to limit erosion and withhold nutrients, contaminants, pathogens and sediment from streams, **especially in priority areas based on nutrient loads, slope, and critical habitat**. To preserve ecosystems, native shade trees are a preferred alternative.
3. NCPSF: Accelerate wetland restoration to maximize capture of nutrients, contaminants, pathogens and sediment, and stabilize flows. **Such programs almost always impact all stressors**.
4. NCPSF: Eliminate the current backlog in the Wetland Reserve Program for the Great Lakes.
5. NCPSF: Provide adequate technical assistance dollars within existing programs to ensure that prudent, cost-effective technologies and methods are used, that collateral benefits are understood, and that the relation to the Great Lakes is well understood.
6. NCPSF: Increase funding for USDA's Conservation Reserve Enhancement Program, with funding and implementation targeted to the Great Lakes Basin.

7. NCPSF: Increase incentives in existing programs for the use of Best Management Practices (BMP's) and Generally Accepted Management Practices (GAMP)
8. NCPSF: Increase funding for NPDES storm water regulation, implementation and enforcement.
9. NCPCSF Through existing Federal, State and Local programs provide funding sufficient to restore one million acres of wetlands: one tenth of the amount lost so far in the US Great Lakes Basin. These should be prioritized and costed using decision support tools.
10. NCPS: Through existing programs (GLNPO, Beach Act), provide additional funds to local governments and NGO's for pollutant tracking and real-time monitoring.
11. NCPS: Through existing programs (GLNPO, Beach Act) provide additional funds to local governments and NGO's for public education and immediate implementation of BMP's in beach areas.
12. NCPS: Provide additional funding to local governments for NPS needs through EPA programs like Section 319 of the Clean Water Act, the State Revolving Loan Fund or others.
13. C: Accelerate implementation of the Clean Air Act Section 112 regulations in the Great Lakes basin
14. P: Complete TMDL's for *E. coli* (or another adopted indicator) at all beaches with more than a 20 per cent annual closure rate.
15. S: Accelerate the TMDL development process for non-point sources.

D. Creation of New Programs and Commitment of Resources

1. NCPSF: Provide actual funding to support the National Association of Conservation Districts' Great Lakes Buffer/No-Till Program.
2. NCPSF: Fund research to fill specific identified gaps identified in conceptual models
3. NPS: Regulate the storm water runoff and facility wastewater from concentrated animal feeding operations. First, develop decision support and self-evaluation tools to assist and educate operators
4. NCP: Create new Federal or State programs to fund the evaluation and upgrade of on-site wastewater treatment systems. This could begin with a "lending library "of survey and data tools, such as septic leachate detectors, groundwater flow meters, etc.
5. C: Identify and model the presence and distribution of emerging contaminants of concern (hormones, antibiotics, most current pesticides). This should allow prioritization by storm water, tributaries, air deposition, and land- applied sewage sludge.
6. C: Reduce the mercury contamination of the Great Lakes by reducing the release of mercury into the air from coal-fired power plants within 150 miles of the Great Lakes. This should rise to 90 per cent reduction from 1990 levels by 2015.
7. S: Within the long-term sediment monitoring program, provide 100 per cent Federal funding for NPS load monitoring for selected sensitive watersheds

Endnotes:

¹ Structurally, conceptual models often include five major components:

a. Drivers are the major external forces, either natural (e.g., water level fluctuation) or anthropogenic (e.g., regional land-use programs) that have large-scale influences on natural systems

b. Stressors are the physical or chemical changes that occur within the ecosystem that are brought about by the drivers. Stressors cause significant changes in the biological components, patterns, and relationships in the natural system

c. Ecological effects are the biological responses to the stressors

d. Attributes, or indicators, are typically populations (e.g., number of lake trout), species (e.g., *Diporeia*), guilds (e.g., number of waterfowl), communities (e.g., coastal wetlands), or processes (e.g., primary productivity)

e. Measures are the specific feature(s) of each attribute that must be monitored to determine the attribute response to changes in the stressors

² Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications* 8: 559-568.