The North American Lake Management Society calls for full implementation of the Clean Water Act with an Adaptive Systems Approach to Freshwater Management

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Abstract

A review of evidence concerning source water impairment and restoration by the North American Lake Management Society (NALMS) indicates that:

- The majority of lakes and reservoirs are eutrophic
- The prevalence of cyanobacterial harmful algal blooms (HABs) is increasing in spite of large expenditures of money and time
- HABs imperil health, aquatic ecosystems, water supplies, and economies
- Current federal policy does not implement within waterbody treatments as called for in the Clean Water Act

NALMS concludes that:

- Current federal policy is inadequate to restore water quality in lakes and reservoirs cost-effectively and over reasonable periods of time
- A whole-system approach to water quality protection and restoration that views waterbodies and watersheds as a system and does not a priori privilege intervention in one part of the system over another is needed

This talk describes an Adaptive Systems Approach to Freshwater Management that uses rigorous scientific and cost-benefit analyses to identify a suite of watershed and waterbody management tools that will restore water quality through an iterative process in the quickest, least expensive manner.

Background

It will take longer than 1,000 years to restore impaired freshwaters at current recovery and funding rates according to a U.S. Government Accountability Office (GAO) report to Congress. Moreover, the number of impaired freshwaters is increasing while few have recovered. NALMS asked why this is the case, and concluded that it is primarily because the Clean Water Act (CWA) is not fully implemented. In addition to requiring watershed management (WSM) to reduce new pollutant-input from point- and nonpoint-sources, the CWA prescribes treatments within waterbodies to reduce stress on impaired biological, chemical, and physical processes in freshwaters to help enable recovery. But the waterbody management (WBM) or "Clean Lakes" program was deemphasized and the Section 314 grant program was eliminated in the early 1990s. This decision was not based on scientific or economic analyses. It was based on the mistaken belief that input reductions alone would facilitate recovery in a timely and cost-effective manner. The CWA should be fully implemented by complementing the "preventive medicine" WSM approach of pollutant-input reduction with the "supportive therapy” WBM approach of treatments within waterbodies to form an Adaptive Systems Approach to Freshwater Management.

Current Policy

States followed current policy in developing over 68,000 pollutant-input reduction strategies for freshwaters designated as impaired pursuant to section 303(d) of the CWA. Over 43,000 await development. As shown in Figure 1, the process begins with the development of water quality standards that consider a waterbody’s designated uses in identifying water quality criteria for protecting health and the environment. Quantities and sources of impairment-causing pollutants in the watershed are assessed in developing total maximum daily loads (TMDLs). TMDLs are maximum amounts of pollutant inputs from surface waters considered to be below levels that will cause impairments. Rules that require point- and nonpoint-source input reductions to achieve TMDLs formalize implementation of WSM strategies. Long-term monitoring and assessments evaluate the effectiveness of the rules. When standards are not met, the typical response is to wait in anticipation that the standards will eventually be met. Rarely are strategies reassessed and altered.

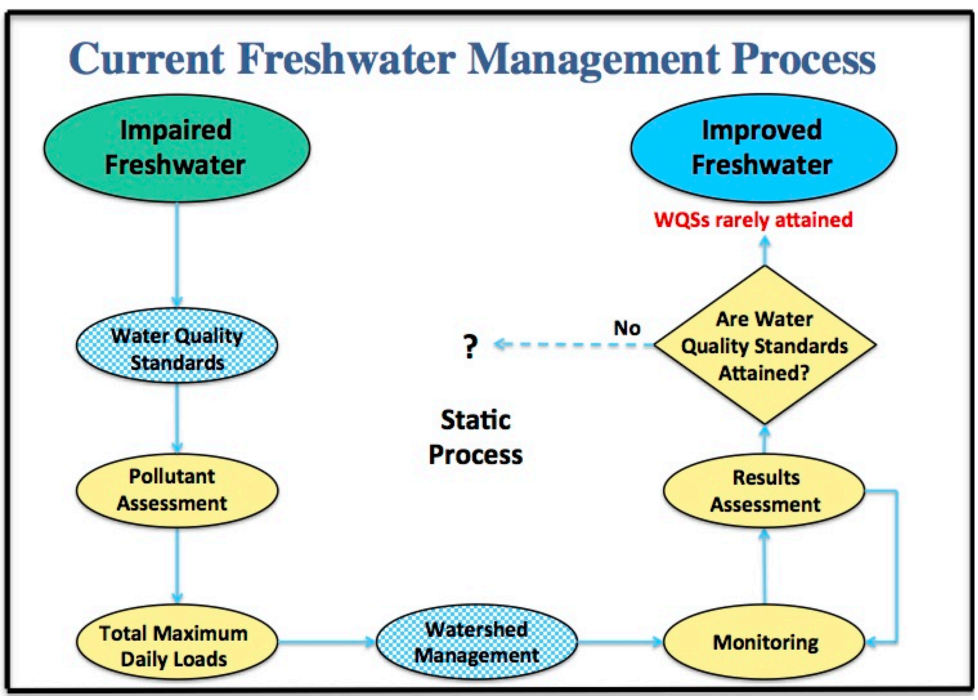

Figure 1. This diagram depicts the current EPA process for developing, implementing, and assessing strategies to restore impaired freshwaters. Waterbody management was removed from the process in the early 1990s. Watershed management rarely achieves water quality standards, and strategy is rarely adapted.

Current Policy Results

The evidence indicates that the current policy of WSM alone is not working well. Approximately 53% of assessed river and stream miles and 68% of assessed lake, reservoir, and pond acres are impaired. The Environmental Protection Agency (EPA) estimates that only 8 percent of about 40,000 waters listed as impaired prior to 2003 (to give time for recovery) now attain water quality standards. Most were small waterbodies dominated by point-source pollutant inputs. No impaired waterbody of at least 1,000 acres in size with at least 90 percent of pollutant input from nonpoint sources has ever attained water quality standards. Pathogens and toxigenic cyanobacteria are commonly found in nutrient over-enriched waters. EPA estimated in 1972 that 10 to 20 percent of lakes and reservoirs were nutrient over-enriched or eutrophic. About 50 percent were eutrophic or hypereutrophic in 2007. Rivers and streams with excessive phosphorus, usually the limiting nutrient for cyanobacteria, increased from 47 to 66 percent between 2004 and 2009. EPA estimated that the health risk from highly potent cyanotoxins was moderate to high in 27 to 41 percent of lakes and reservoirs. As in Toledo where almost 500,000 people were without public drinking water in early August 2014 due to cyanotoxins, about 80% of the U.S. population relies on treatment of surface water to provide safe drinking water.

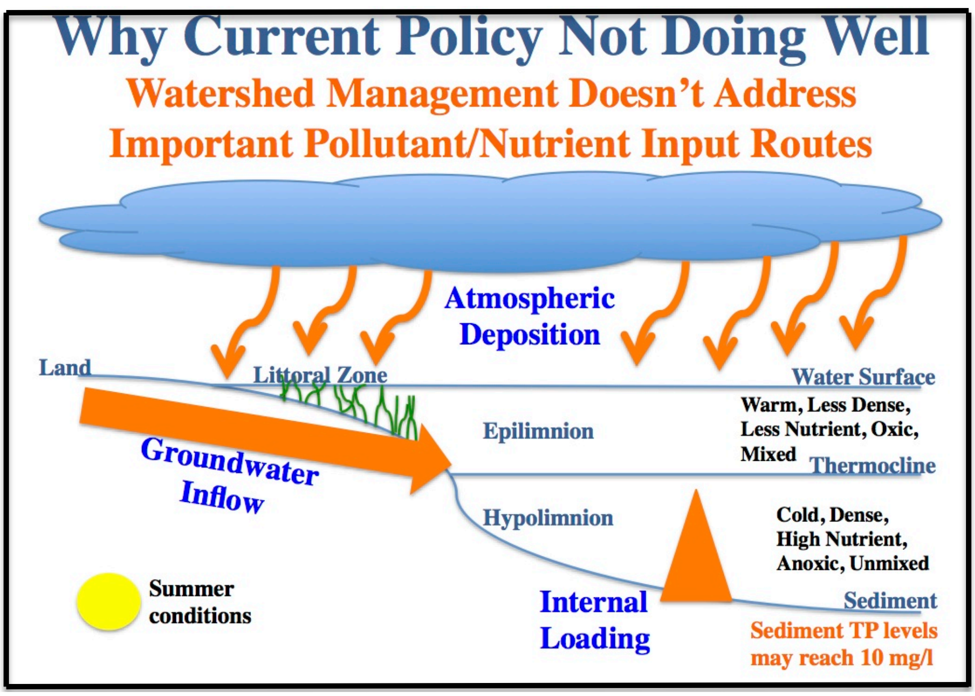

Figure 2. Current policy for restoring impaired freshwaters addresses only the reduction of new pollutant inputs from point-sources and nonpoint-source surface runoff through the watershed management program. It does not address the often-large pollutant inputs through atmospheric deposition and groundwater flow. Also unaddressed is the huge load of "legacy" pollutants such as

phosphorus that accumulated over decades and cycle between sediment and the water column.

Why Current Policy is Inadequate

Many factors contribute to the failure of current policy to protect and restore U.S. freshwaters. Although the WSM point-source program successfully reduced pollutant inputs from pipes and other pathways to 5-10 percent of total surface-water inputs nationally, the nonpoint-source program, contributing 90-95 percent, has been far less successful. Many nonpoint-source best-management practices lack cost-benefit analyses, are marginally effective, and are too expensive to implement over large areas. Furthermore, WSM does not address important routes through which pollutants enter the water column of lakes and reservoirs (Figure 2). Atmospheric deposition of nitrogen and phosphorus contribute to the nutrient loading of surface waters. Nitrogen deposition to surface water ranges from 10 to over 50 percent of total nitrogen inputs (Paerl, 1995). The EPA estimates that 34 percent of the nitrogen entering the Chesapeake Bay is from atmospheric deposition (EPA, 2010). Concentrated animal feeding operations contribute more than 40 percent of total nitrogen inputs to some large surface waters as ammonia nitrogen, a form preferred by algae (NCDENR, 1999). The ratio of nitrogen-to-phosphorus deposition usually exceeds the Redfield algal utilization ratio of 16:1, contributing to the increasing trend of phosphorus limitation on algal growth in freshwater. Shallow groundwater nitrogen inputs also contribute to this trend. Whereas phosphorus tends to bind with soil particles reducing flow, ammonia and nitrate are soluble in water and regularly flow from shallow groundwater to surface water (USGS, 1999). Groundwater and surface water are intimately linked through the hydrologic cycle, with groundwater inputs ranging between 0 and 100 percent on surface water inputs over time (ODNR, 1997). But most importantly, decades of pollutant inputs from all routes have accumulated huge “legacy” nutrient loads in sediment.

“Legacy” nutrient cycling between sediment and the water column is the primary phosphorus source in many freshwaters (Figure 3). The highest levels of phosphorus found in a freshwaters usually are in the sediment. Three primary processes enable the release of phosphorus from sediment to the water column. First, under oxic conditions, phosphate is bound to iron in the sediment, forming iron(III)phosphate. But anoxic conditions cause the chemical bonds between iron and phosphate to break, releasing soluble and reactive orthophosphate and ferrous iron into the water column. Cyanobacteria that regulate buoyancy with gas vesicles descend to the hypolimnion at night to uptake nutrients, and then ascend to the epilimnion in the morning to obtain sunlight for photosynthesis (Kromkamp and Walsby 1989). Second, even in oxic waters, phosphate in sediment releases from iron when $pH > 8$. Iron(III)phosphate reacts with three hydroxide ions, forming phosphate and ferric(III)iron hydroxide. Phosphate released from sediments above the thermocline is available for algal consumption in the epilimnion. A positive-feedback loop is formed when the phosphate triggers an algal “bloom” that further increases pH, causing more phosphate release. Third, shallow waters near shorelines cool more quickly than open, deeper waters when air temperatures are lower than surface-water temperatures. The cooler, denser shoreline waters descend laterally toward open waters, dragging along phosphate-enriched pore-waters. This process of convective mixing increases as the fall season progresses and solar irradiation and temperatures decrease. The thermocline rises as surface waters cool and descend, often until it is eliminated, resulting in “fall turnover” or the complete mixing of lake and reservoir water columns (EPA, 2000). The spread of the high-nutrient concentration waters from the bottom to the surface often stimulates fall algal “blooms.” The above entry pathways for nutrients into freshwater, and the cycling of nutrients within waterbodies, will continue to increase eutrophication prevalence and stimulate algal “blooms” even if WSM could eliminate most surface runoff and point-source inputs. Waterbody treatments are needed to transfer nutrients to top trophic levels, remove and recapture nutrients, suppress cyanobacteria, and address other impairment factors.

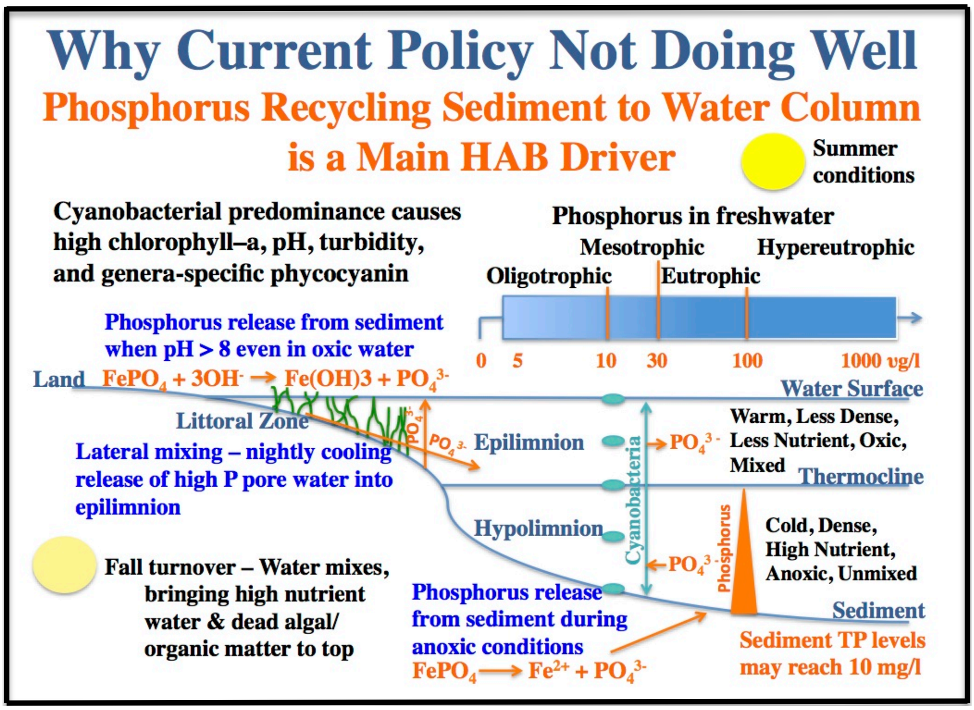

Figure 3. Phosphorus moves from sediment into the water column during anoxic conditions. Second, phosphate releases from iron when pH > 8 even during oxic conditions. Third, when air above the water surface is cooler than the surface water, thin surface layers cool, become denser, and fall through the water column while deeper, warmer layers rise. This process causes both lateral mixing and “fall turnover.”

Improving Policy

The solution to restoring and protecting freshwaters is having a more holistic approach to freshwater science and management. Physical, chemical, and biological factors, and their interactions, must be addressed when trying to establish a balanced aquatic ecosystem. For example, even freshwaters with moderate nutrient load may exhibit excessive chlorophyll-a levels when the transfer of nutrients from primary producers to higher trophic levels is disrupted. Grazing pressure on algae by zooplankton may be insufficient to prevent an “algal bloom” when planktivorous fish decimate zooplankton populations. No amount of WSM can rebalance the aquatic assemblage. WBM is required to reduce the planktivorous fish population. This may be as simple as curtailing a juvenile-fish stocking program meant to supply food for piscivorous fish to improve the fishery. This cause of impairment would not even be recognized through the WSM process.

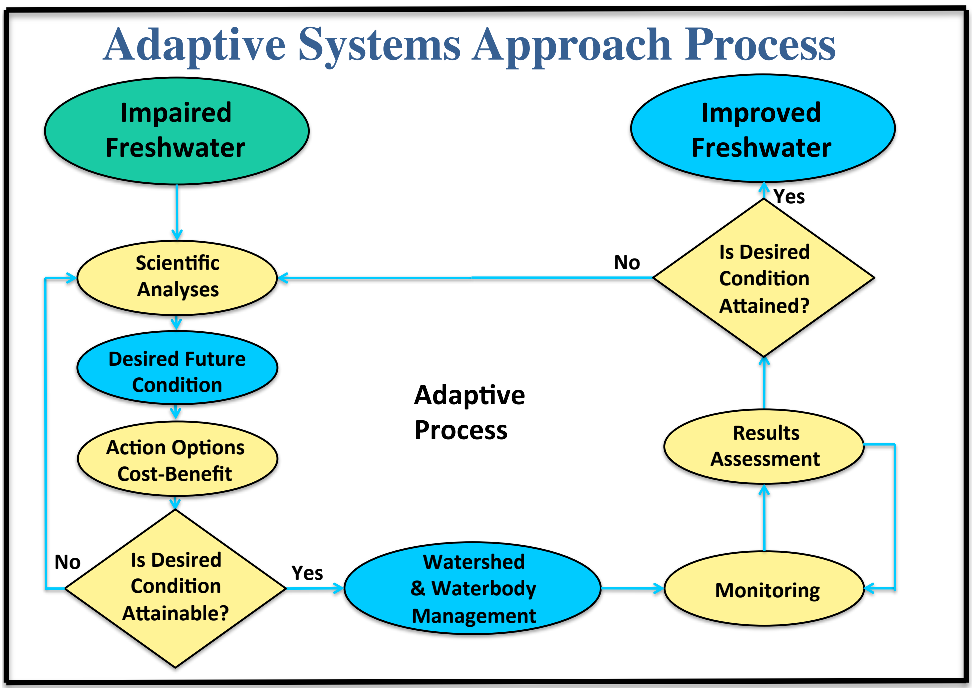

Figure 4. This diagram depicts an Adaptive Systems Approach to Freshwater Management that fully implements the Clean Water Act by complementing watershed management with waterbody management. An ASA takes a holistic view of the impaired waterbody and watershed as a single system. Rigorous scientific assessments identify the direct and contributing causes of impairment. Interventions to improve water quality can be made anywhere within the system. The desired water-quality condition and the selection of interventions to improve water quality are determined using cost-benefit analyses of designated uses and interventions. A feasible strategy is implemented to achieve realistic goals, and can be adapted over time if needed to increase progress.

An Adaptive Systems Approach to Freshwater Management

NALMS believes that full implementation of the CWA with an Adaptive Systems Approach to Freshwater Management will protect and restore freshwaters more quickly and less expensively than current policy. Ecologically sustainable WBM treatments are needed to suppress cyanobacteria, remove or deactivate nutrients from inlets and lakes where they are concentrated and accessible, deactivate pathogens, degrade toxic substances, and establish a balanced ecological community that can help enhance water quality.

As shown in Figure 4, the Adaptive Systems Approach process begins with comprehensive scientific analyses of the greatest risks to health and the environment, and of the direct and contributing causes of impairments posing those risks. Determining the desired future condition entails analyses of the benefits of designated uses, the technological feasibility of reducing risks to acceptable levels, and designating water quality standards that will attain those risk levels in a specific waterbody. Cost-benefit analyses of every viable WSM and WBM tool characterize options for improving water quality across economic, degree-of-impact, and time-to-impact scales. A set of tools is selected that optimizes attainment of the water quality standards. A water quality strategy is implemented only if the standards are both technologically and economically feasible. If the strategy cannot attain the standards, or the cost is prohibitive, the above process is repeated to determine whether or not all designated uses are warranted, scientific or technological advancements can improve strategies, or acceptable risk levels can be achieved with lower standards. A feasible strategy and associated rules are implemented to achieve realistic goals. Progress is monitored to determine whether the goals are being achieved or the strategy should be adapted to improve progress.

NALMS position is that an Adaptive Systems Approach to Freshwater Management is needed to reverse the trend of increasing water impairment and improve water quality in the near term at an affordable cost.

For additional information or to help bring about improved freshwater management policy, contact one of the following people.

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