Innovative In-Stream Control Methodologies for Reducing Nonpoint Source Pollution, Reducing Sediment and Abating Phosphorus Loadings to the Great Lakes

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Problem statement

Nonpoint source (NPS) pollution appears to be a major contributor to the recent increase in the frequency and severity of harmful algal blooms (HABs) in the Great Lakes and St. Lawrence River. HABs pose serious risks for human and animal health, water quality, and the vitality of aquatic ecosystems. As state and federal resources to mitigate HABs are often limited, additional information is needed to identify and compare best management practices (BMPs) that successfully reduce phosphorus and sediment loadings in streams.

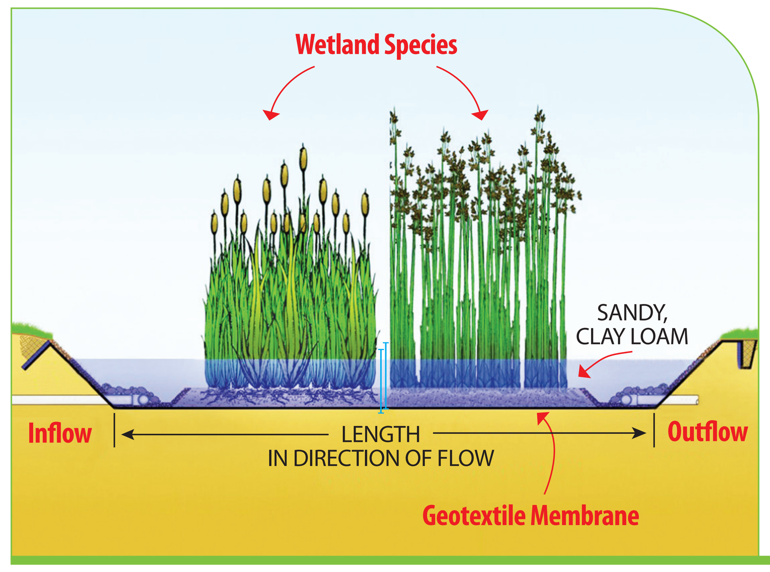
Objective

Through a review of the available literature, a series of efficient and innovative NPS control BMPs have been identified that can be implemented within stream bank boundaries, including the water channel and streambed, to reduce sediment and abate phosphorus loadings to the Great Lakes. A series of technical reports, peer-reviewed publications, government publications, books and academic dissertations were reviewed to outline BMP advantages and disadvantages, compare their efficiencies and estimate their implementation and maintenance costs.

Best Management Practices (BMPs)

Constructed wetlands

Constructed wetlands are ecologically-engineered marshes containing emergent vegetation and designed to receive and treat farmyard runoff or agricultural wastewater. The presence of plants decreases runoff velocities, which favors sediment deposition and water infiltration. Plants and associated micro-organisms will uptake dissolved phosphorus, while particulate phosphorus may be sorbed by soil or buried under accreting peat. However, their performances may fluctuate throughout the year, particularly when plants mature and nutrients may be released into the system.



EXAMPLE OF SUCCESSFUL IMPLEMENTATION

Two 100 m^3-wide (3,531 ft^3) basins were successfully used to filter effluents from a trout farm in Saint-Ferdinand, Québec, Canada. The two basins were, respectively, filled with coarse and finer limestone and planted with common reed. Their combined actions allowed for an impressive enhancement of the effluent's water quality, as 95% of the suspended solids and 80% of the total phosphorus load were retained in the basins.

Two-stage ditches

Two-stage ditches are designed to incorporate a floodplain to an existing stream. The presence of a vegetated floodplain enhances the stream's overall drainage capacity, thereby reducing the risk of flooding during large storm events, increasing channel stability and decreasing erosion. The decrease in flow velocity achieved by two-stage ditches also favors deposition of sediments and particulate phosphorus. While two-stage ditches require greater initial investment, they also require fewer maintenance efforts and costs over time than traditional trapezoidal ditches.

EXAMPLE OF SUCCESSFUL IMPLEMENTATION

The Nature Conservancy partnered with the University of Notre Dame to install a two-stage ditch on an 800 ft (243.8 m) section of an agricultural channel previously identified as a major contributor to the sediment load of a local chain of lakes. This construction improved the water quality in the ditch significantly, while annually trapping more than 105,000 pounds (47,627 kg) of sediment.

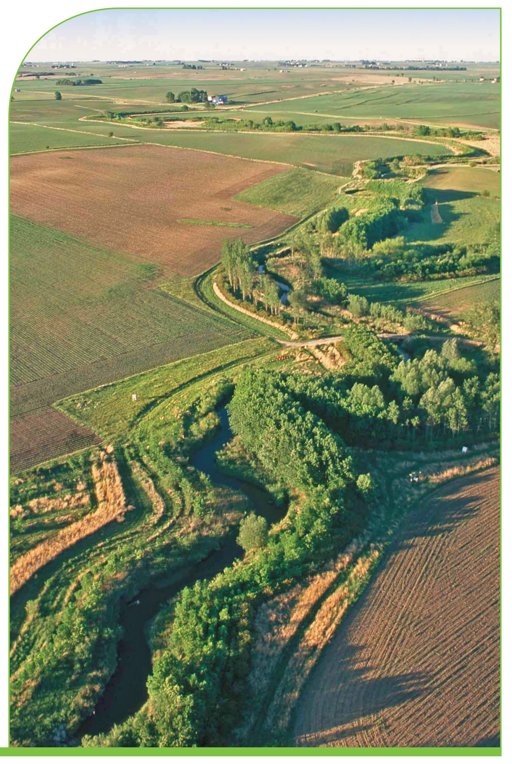
Two-stage ditch. Source: The Nature Conservancy.

Riparian buffers

Riparian buffers, also known as buffer strips and vegetative filter strips, are strips of vegetation planted between a waterbody and cropland or grazing lands. Riparian buffers are particularly efficient at trapping sediment, but may also contribute to the abatement of phosphorus, nitrogen and pesticides. They also enhance drainage and filtration capacities of cropland, thus reducing the velocity and volume of runoff.

EXAMPLE OF SUCCESSFUL IMPLEMENTATION

Canada's Prince Edward Island adopted legislation in 2000 that prescribes the installation of 10 m-wide (32 ft) buffer strips along moderately sloped agricultural ditches. Efficacy assessments conducted by Environment Canada on more than 40 ditches showed significant reductions in soluble phosphorus (30%), nitrate-nitrogen (38%), and suspended sediment (64%).



Large forested riparian buffer along a creek in Iowa. Source: U.S. Department of Agriculture.

Scrubber box

Algae scrubber boxes are composed of a combination of algae and micro-organisms attached to a screen through which wastewater flows. Algae can uptake nitrogen and phosphorus and transform it into organic compounds through respiration. Algae turf scrubbers have been successfully used in both large- and small-scale projects to filter agricultural runoff, domestic sewage and industrial wastewater.

EXAMPLE OF SUCCESSFUL IMPLEMENTATION

A series of small-scale algal turf scrubbers were installed on the stream bank of three tributaries of the Chesapeake Bay. Results varied greatly among the tributaries, but a single scrubber was shown to be able to remove the equivalent of 380 kg (837.8 lbs) of nitrates and 70 kg (154.3 lbs) of phosphorus per hectare. Larger algal turf scrubbers are now being constructed throughout the bay, and research teams are studying the possibility of producing biofuel with harvested algae.

The Egret Marsh Algal Turf Scrubber in Indian River County, Florida. Source: AlgaeIndustryMagazine.com.

Reactive material

Reactive materials have been mixed with animal manure and litter to decrease phosphorus solubility, with topsoil rich in phosphorus to minimize the release of phosphorus, and integrated in barriers and installed directly in ditches to sorb phosphorus in agricultural runoff. Materials used can range from natural materials to industrial waste and byproducts (e.g. steel slag, gypsum).

EXAMPLE OF SUCCESSFUL IMPLEMENTATION

A research team at the University of Michigan has designed structures that use flue gas desulfurization gypsum and steel slag as phosphorus sorbing components. These filters were tested in an attempt to improve water quality of residential and agricultural watersheds and were shown to achieve an average removal of 25% of the dissolved phosphorus load.

Pile of gypsum ready to be used as a soil amendment. Source: Great Lakes Commission.

Comparison of BMP costs, maintenance, lifespan, and area requirements

	Contruction cost and effort	Maintenance cost and effort	Lifespan	Land surface requirement
Constructed wetland	High	High	25-50 years	Large
Two-stage ditch	High	Low	Over 30 years	Medium
Riparian buffer	High	Medium	30 years	Medium to High
Scrubber-box	High	High	Unknown	None
Reactive material	Medium	Medium	Unknown	None

Comparison of NPS removal capacities

	High Efficiency	Good Efficiency	Poor Efficiency
Constructed wetland	Total phosphorus Dissolved phosphorus Suspended sediment Chemical oxygen demand Biochemical oxygen demand Pathogens	Nitrogen Heavy metal	
Two-stage ditch	Total nitrogen Suspended sediment	Particulate phosphorus	Dissolved phosphorus
Riparian buffer	Suspended sediment Particulate phosphorus Sorbed pesticides	Total phosphorus Total nitrogen	Dissolved phosphorus
Scrubber-box	Total nitrogen	Total phosphorus Dissolved phosphorus	
Reactive material	Total phosphorus	Dissolved phosphorus Heavy metal	

Preliminary Conclusions

1. Construction and maintenance costs and complexity in implementation vary greatly among NPS control technologies and should be considered when selecting an appropriate BMP.
2. Most NPS control technologies show good to high efficiencies for nitrogen, phosphorus or sediment removal; however, only constructed wetlands demonstrate these capabilities for all three pollutant types. NPS control technologies should be selected as a function of runoff or wastewater type and the type and/or amount of pollutant.
3. Constructed NPS control technologies that show the highest efficiencies are generally more costly and require more land area to be effective.

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Header photo: Algae in Lake Erie, Ottawa County, Ohio. Source: Ohio Sea Grant and Stone Laboratory.

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