Integrated Stormwater & Lake Management **in the City of Eagan, Minnesota**

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Introduction

Throughout the U.S., stormwater managers are tasked with reducing flooding, improving water quality, and protecting the health of their communities' natural resources. Many of these services go unnoticed by residents who take for granted dry basements, roads clear of floodwaters and clean lakes for recreation. Residents are often shocked by the complexity and cost of managing local water resources to their expected level of service. In the U.S., communities spend over $1B annually to provide these stormwater services. Implementing the Chesapeake Bay Total Maximum Daily Load alone is estimated to cost over $8B and that doesn't address flooding that may occur as the frequency and intensity of storms increase because of climate change. Cost-effective stormwater management is critical to maintaining and improving our communities.

Many of the stormwater programs in the U.S. are funded through stormwater utilities that assess fees to implement stormwater practices in communities. These fees can range from as low as a few dollars a year for single family residences to thousands of dollars a year for highly impervious commercial and industrial areas. Local governments tap these utility funds to improve stormwater systems to address flooding and to improve water quality. Typical stormwater projects include pond maintenance, adding flood storage, runoff rate control, infiltration, and water quality practices. Significant funds are invested in Low Impact Development (LID) projects as communities redevelop or expand development in their jurisdictions. Overall, the job of managing stormwater utilities to provide expected services while being fiscally responsible to constituent ratepayers is a daunting task and not for the faint of heart.

The City of Eagan (city) recognizes the balancing act required to address stormwater regulations and needs with the most cost-effective solutions. Invariably, this balancing act is driven by a community's sense of place, regional economic forces, and willingness to deal with these issues head on. In Minnesota, lakes are so prevalent and cherished that they often represent the focal point of communities, providing an identity for residents. Recognizing the importance of lakes to its community, the City of Eagan's stormwater quality management program is molded around its neighborhood lakes, providing a management framework aimed at improving a natural resource that is central to the city's sense of place.

The City of Eagan's lake-based approach

The city is an outer ring suburb that covers 33 square miles in the southeast portion of the Twin Cities Metropolitan Area. Eagan boasts over 4,000 acres of parkland in 56 parks, and has 34 designated lakes, three designated trout streams, two calcareous fens, over 600 wetlands, and a portion of the Minnesota River (Figure 1). Eagan's lakes come in many shapes and sizes ranging from neighborhood "ponds" to shallow waters that easily could be defined as deep water wetlands. Eagan's diversity of lakes provides a unique management challenge because shallow lakes require a higher emphasis on managing fisheries and aquatic vegetation than the traditional approach of focusing primarily on phosphorus management in deep lakes. Adding to the challenge, the city supports sport fishing at 12 neighborhood fishing lakes, working with the Minnesota Department of Natural Resources' Fishing in the Neighborhood program to survey lakes, coordinate stocking efforts, and promote educational events. These diverse water resources are assets to Eagan residents and helps to define Eagan's character, making it a desirable place to live, work, and visit.

Balancing watershed restoration with in-lake management is one of the primary challenges in applying the city's lake-based approach. This balancing act is not unique to Eagan's lakes; the discussion surrounding restoration of the watershed versus in-lake management has been actively debated for years among water resources managers and regulators. In fact, since the implementation of the Total Maximum Daily Load program turned to nonpoint source pollution in the 1980s, the general focus shifted strongly to watershed restoration, limiting funding for in-lake management. For example, in Minnesota, Section 319 funding was historically prohibited from being used for in-lake management activities, an approach that has only recently been relaxed. Unfortunately, there remain few examples of lakes being restored through watershed practices alone, and recent studies suggest in-lake management is often the most cost-effective approach to lake management (Huser et al. 2016; Osgood 2017). Based on this understanding, the city selected a balanced approach to managing its lakes, recognizing the need for both watershed and in-lake management.

Watershed management

The city recognizes that phosphorus management is critical to restoring its lakes, and many of its efforts focus on reducing phosphorus loading from its urban watersheds. The city maintains

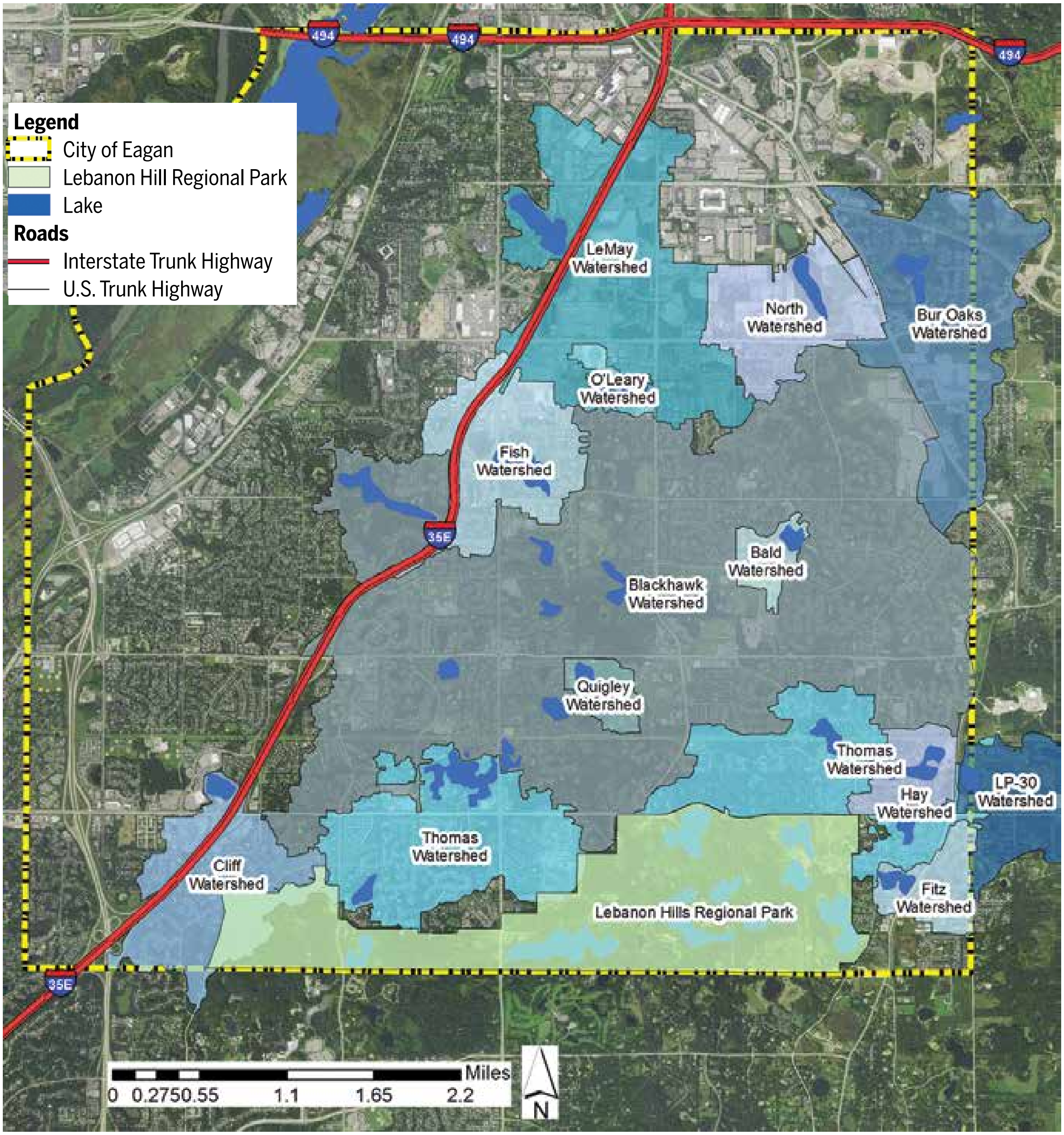

Figure 1. The City of Eagan, Minnesota, and its major lake watersheds.

almost 1,200 interconnected basins including constructed stormwater ponds and wetlands used primarily for flood storage and rate control with some assumed water quality benefits. This diverse network of over 220 miles of storm sewer pipes, over 400 constructed ponds and nearly 700 stormwater wetlands are distributed throughout the city, making individual maintenance practices difficult and expensive to implement. To prioritize activities, hydrologic and water quality models were developed and combined with city monitoring results to assess current conditions and identify watershed restoration opportunities (Wenck 2012; Wenck 2015). The two most cost-effective watershed management opportunities include improved stormwater maintenance and iron-enhanced sand filtration.

Advancements in Stormwater Pond Maintenance: Maintenance of stormwater ponds is one of the city's focal areas for managing phosphorus loading from watersheds. While the city continues to pursue pond cleanouts to maintain particulate settling efficiency, it has long surmised that stormwater ponds and wetlands may be transient rather than permanent sinks for phosphorus, recycling phosphorus back into the water column because of internal phosphorus loading. Internal phosphorus loading is a term used to describe phosphorus movement from lake or pond sediment to the water column caused by low oxygen (anaerobic) conditions at the sediment. The release of phosphorus can also occur in wetland sediments. While the drivers of pond sediment phosphorus release are well understood, wetland sediment release is much more complex and can be driven by microbial degradation of phosphorus bound in labile organic soils, shifts in pH, changes in oxygen dynamics and shifts in water level fluctuations. These processes not only reduce the water quality benefits of ponds and wetlands, they also transform particulate phosphorus to the more readily available soluble phosphorus, increasing the frequency and duration of algal blooms in downstream lakes. With over 1,000 stormwater ponds and wetlands distributed throughout the city, Eagan's stormwater ponds and wetlands represent a significant potential source of phosphorus to stormwater.

To better understand the severity and extent of phosphorus loading from stormwater ponds and wetlands, the city is strategically monitoring sediment phosphorus release and chemistry. Sediment phosphorus release is typically controlled by the reduction of iron under anaerobic conditions, releasing mobile phosphorus into the porewater. Release can also be a result of loosely bound porewater P diffusing to the surface or the breakdown of labile organic material containing phosphorus. These fractions of phosphorus (loosely bound, iron bound, and labile P) are generally termed redox-P or mobile-P because they are susceptible to release under anaerobic conditions. The city measured mobile-P in a number of stormwater ponds and wetlands to assess the potential pools of phosphorus that might be contributing to watershed loading. Mobile-P was relatively high in most ponds, ranging from 0.2 to 1.8 mg/g-dry weight (Figure 2). For reference, mobile-P concentrations above 0.2 mg/g-dry weight are often associated with higher sediment phosphorus release rates. Measured anaerobic sediment phosphorus release rates in three of the stormwater ponds ranged from 4.9 to 5.2 mg/m^2/day (Figure 3). Most of the ponds have large enough pools of mobile phosphorus to drive significant phosphorus loading from the watershed.

To address these sediment phosphorus pools in the watershed, the city applies aluminum sulfate (alum) to permanently bind mobile phosphorus in sediments to reduce internal phosphorus loading and improve their overall water quality benefits. Alum is applied to lakes and ponds as a liquid that subsequently forms aluminum hydroxide, a fine solid precipitate that settles to lake and pond sediments. Aluminum hydroxide attracts and permanently binds sediment phosphorus removing it from the internal phosphorus loading cycle.

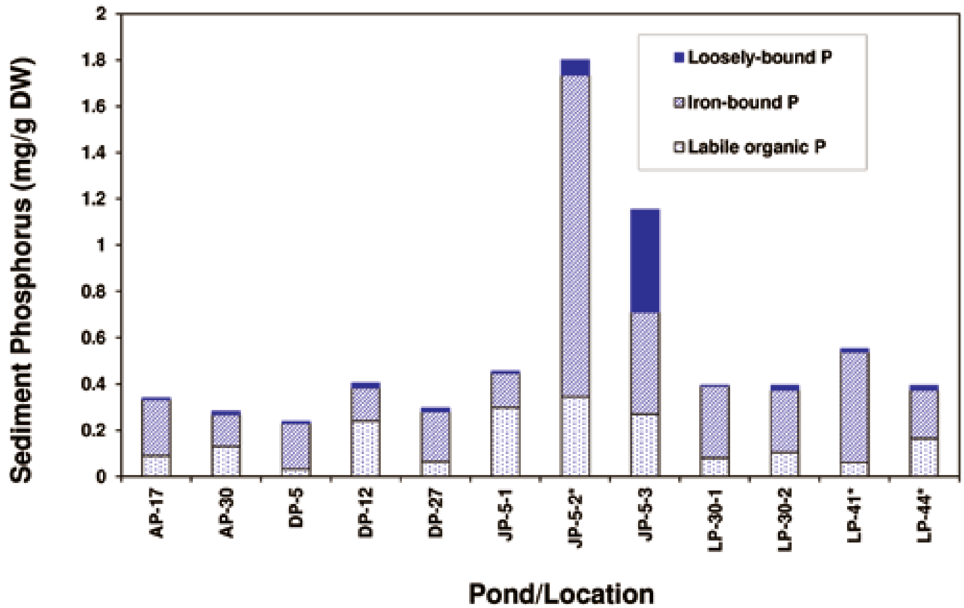

Figure 2. Mobile phosphorus concentration in select stormwater ponds in Eagan, MN.

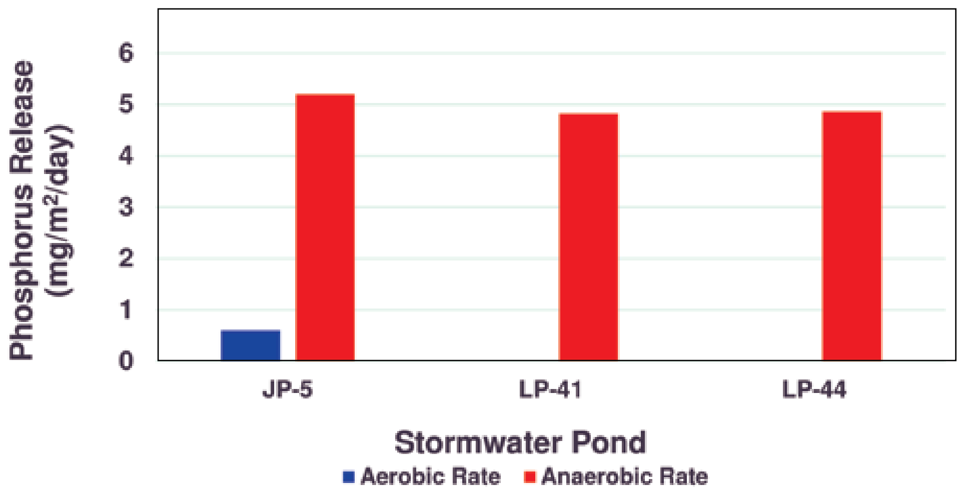

Figure 3. Sediment phosphorus release rates in three stormwater ponds in th City of Eagan, MN.

A missing link for quantifying the impacts of internal phosphorus loading in municipal stormwater networks are data that describe the extent and persistence of anoxia in these basins. Dissolved oxygen data for stormwater ponds are sparse throughout the Twin Cities Metropolitan Area although the data that do exist suggest anoxia is more common and persistent than originally expected. Collecting data from stormwater ponds is not a common or popular activity among municipalities since they often have hundreds of basins to assess, requiring significant effort from limited staff resources. Recognizing the difficulty of the task, these data are critical in assessing and ultimately controlling watershed phosphorus loading from municipal storm sewer systems.

Iron Enhanced Sand Filtration: Eagan is essentially fully developed, creating significant challenges to finding opportunities for additional P load reduction from the watershed. To reduce soluble phosphorus loading from the

Figure 4. An iron-enhanced stormwater filter on a key stormwater pond draining to Bur Oaks Lake in Eagan, MN. Designed by Wenck Associates, Inc. Photo: Joe Bischoff.

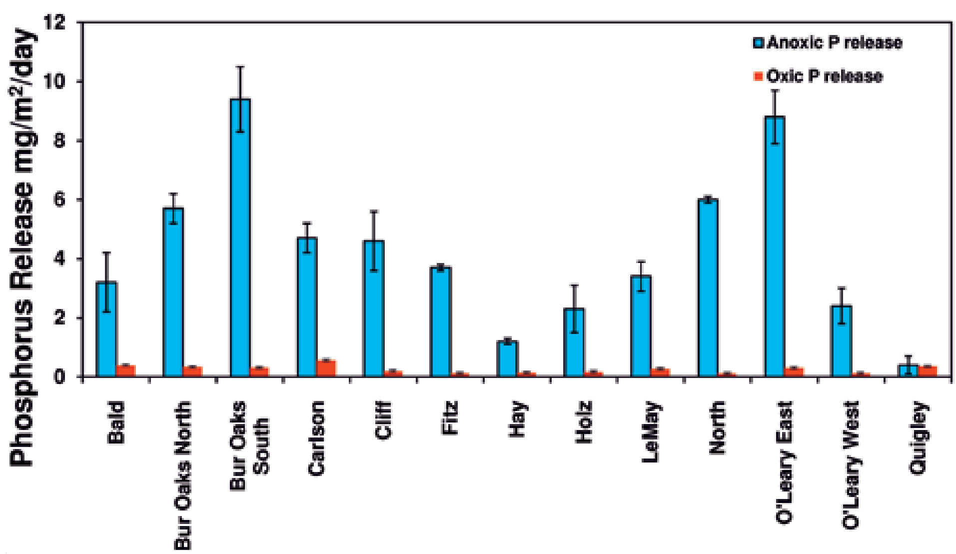

Figure 5. Measured aerobic and anaerobic sediment phosphorus release in key Eagan lakes.

extensive network of stormwater ponds and wetlands, the city is focusing on retrofitting its storm sewer system with iron-enhanced sand filtration practices (Figure 4). Iron-enhanced sand filters typically are installed as high-water benches in stormwater ponds or wetlands, where significant portions of drainage flow (Erickson 2007). The iron filings within the sand mixture strip soluble phosphorus from the drainage water, thereby reducing phosphorus export downstream. While relatively new, these practices demonstrate great promise in reducing watershed phosphorus loading, including the hard-to-capture soluble phosphorus fraction.

Lake management efforts

While iron-sand filters and management of sediment phosphorus release in stormwater ponds show great promise for cost effective watershed solutions, the city also actively monitors and manages sediment phosphorus release in lakes. As a part of a set of lake diagnostic studies, it measured sediment phosphorus release (Figure 5) which ranged from six percent to 68 percent of the phosphorus budgets in Eagan's lakes (Figure 6). The relatively broad range of importance for internal loading in Eagan's lakes requires an individually tailored restoration approach for each of the lakes. For example, internal phosphorus loading represented 63 percent and 68 percent of the phosphorus budget for Fitz and Bald lakes, suggesting that in-lake phosphorus management will be a primary management approach. In contrast, internal phosphorus loading was only eight percent of the phosphorus budget for Bur Oaks Lake, suggesting that watershed loading should be a priority. In cases where internal phosphorus loading was low, watershed phosphorus loading will be addressed through practices such as increased street sweeping, rain gardens, and Low Impact Development practices that reduce runoff.

It should be noted that percent loading from internal sources is not the only factor driving restoration decisions. In cases such as LeMay Lake, watershed reductions will be extremely difficult to achieve due to land use and ownership, so water quality benefits are most cost effectively achieved though routine in-lake phosphorus management. Based on these results, the city is implementing an adaptive alum treatment approach to provide immediate water quality benefits while targeting watershed load reductions for long term internal phosphorus load control.

Several lakes treated with alum in Eagan demonstrated reduced phosphorus concentrations for as many as 20 years after the alum was applied (Figure 7). As alum dosing and application techniques have improved, treated lakes have shown even more dramatic improvements in total phosphorus concentrations resulting in attainment of Minnesota's lake water quality standards for aquatic life and recreation (summer average total phosphorus concentration less that 60 µg/L for shallow lakes and 40 µg/L for deep lakes). These lakes also saw dramatic improvements in water clarity with Secchi depth measurements increasing by an average of 30 percent and chlorophyll-a concentrations less than half previously measured in the lakes. These reductions in internal phosphorus loading resulted fewer nuisance algal

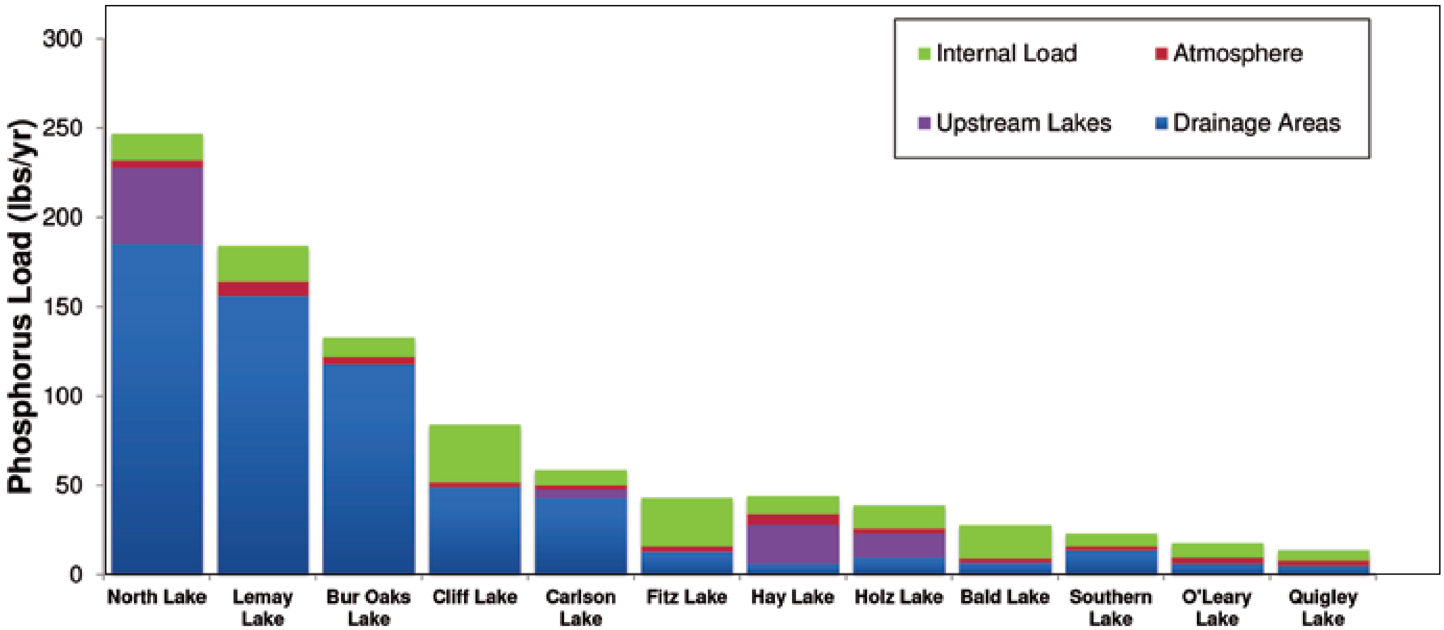

Figure 6. Phosphorus budgets for key lakes in Eagan, MN, showing the relative importance of internal phosphorus loading.

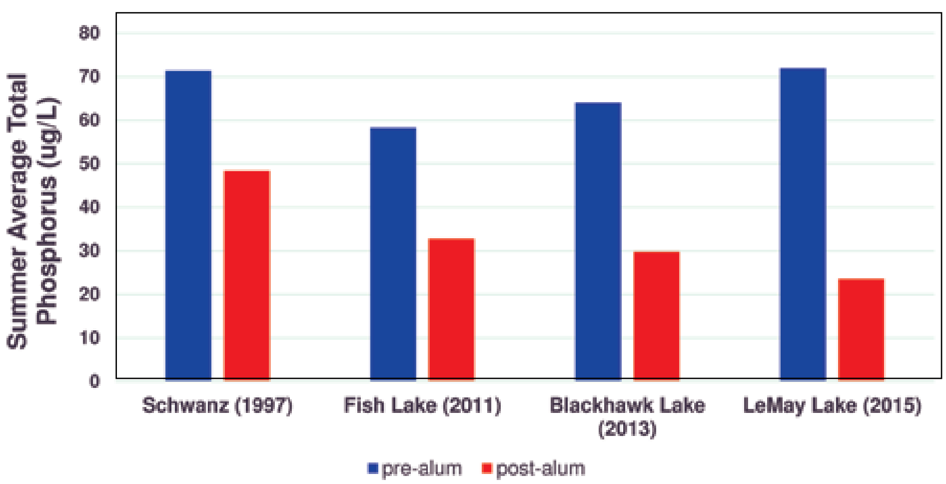

Figure 7. Total phosphorus concentrations before and after alum treatments for four lakes in Eagan.

blooms throughout the summer and clearer water often commented on by local residents and lake users.

Balancing cost, feasibility, and water quality benefits

A desire to sustain high quality lakes at the lowest possible cost is at the heart of Eagan's stormwater program. Eagan uses a forward-thinking approach to focus on the most cost-effective approaches first (iron enhanced sand filtration and alum treatments), using the more costly approaches only when all other options are determined infeasible. A comparison of estimated costs and removal efficiencies for a variety of project types supports Eagan's approach of targeted filtration in the watershed balanced with alum treatments in key ponds and lakes (Figure 8).

While implementation cost is important, the city is also willing to pursue necessary monitoring efforts to support successful stormwater management. For example, the city's foresight in identifying sediment phosphorus release in stormwater ponds and developing a monitoring approach to validate its suspicions led to a pond maintenance program that has a high probability of making meaningful reductions in watershed loading where others have failed or given up.

Ultimately, Eagan is challenged with improving lakes and natural resources at the heart of its identity, while remaining vigilant in its stewardship of the taxpayer's dollars. The average citizen is not often well-versed in the complexity and expense that is involved with providing the numerous societal benefits of clean lakes and flood-free streets and residences.

Increased taxes and stormwater utility fees are never popular but are critical to successful management of municipal stormwater. In 2015, the Eagan City Council made the unusual decision to increase the stormwater utility fee by 66 percent to raise more than $12M to make a significant investment in meeting water quality goals for its lakes. The council clearly expressed its desire to take responsibly for implementing these water quality projects and not leave it to future decision makers to answer for the expenditures. Eagan's City Council should be applauded for its willingness to take action now and stand for the values of the community. It is now incumbent on the city's staff and contractors to demonstrate that such a large investment can make a real difference in the quality of life in Eagan.

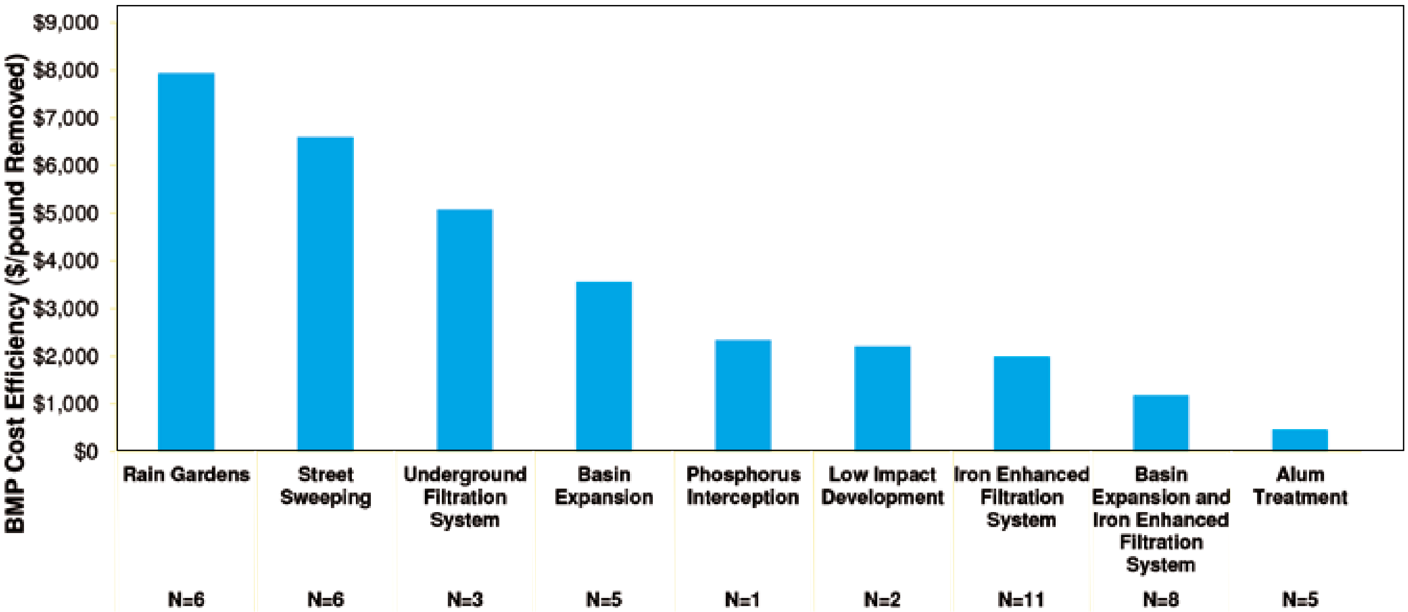

Figure 8. Cost efficiency of selected practices applied in Eagan, MN. Phosphorus removal efficiencies are based on model results. Costs are based on 30 percent design estimates.

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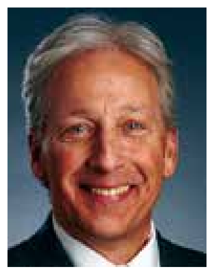

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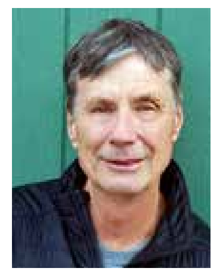

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Upcoming – *LakeLine* Winter 2018:

The winter issue of *LakeLine* will focus on highlighting case studies of lake and watershed projects that did not originally go as planned, for one or multiple reasons.

LakeLine Spring 2019:

NALMS student member issue! Graduate students are invited to submit articles outlining their ongoing studies on lakes and watersheds.

LakeLine Summer 2019:

The summer issue will focus on updates on cyanobacteria and harmful algal bloom concerns, so articles are being requested to support this theme.