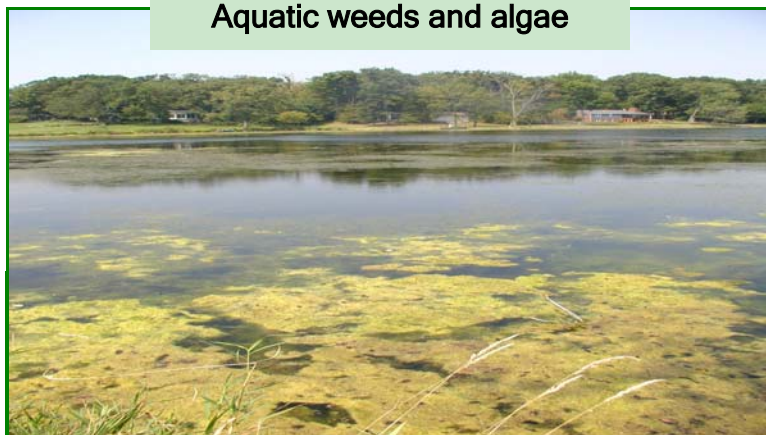


Phosphorus, Urban Runoff & Aquatic Weeds

Aquatic weeds and algae



Introduction

Phosphorus (P) has received much attention recently as the public has become increasingly curious about the role that this essential nutrient has on aquatic plant growth and water quality. In response to concerns over the nutrient loading of waterways, a few local municipalities and lake associations have sought to restrict or even ban the presence of P in lawn fertilizers on the assumption that such action will significantly reduce the growth of aquatic plants and algae in community ponds and lakes. In reality, these types of efforts are not based on sound science and misplace the blame.

This brochure will discuss the benefits of turf as well as the importance of phosphorus in healthy turf management. Further, the brochure explains “eutrophication” and discusses the myriad of other contributing sources of phosphorus in waterways. Finally, the brochure concludes with a brief introduction to a growing problem in waterways, “Eurasian watermilfoil” and its effects on water quality.

It is our hope that this brochure will assist local and state governments in making informed decisions as they consider options for turf management and water quality.

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The environmental benefits of a healthy lawn

A dense, healthy lawn provides many benefits toward protecting the water quality of lakes and streams.

- The leaves, stems and thatch layer of a dense lawn dissipate the energy of a falling raindrop before it can strike the surface and dislodge soil particles.
- A dense lawn reduces soil erosion by slowing the movement of water over the soil surface and reducing its ability to carry soil particles away in suspension.
- By slowing the movement of water over the soil surface, a dense

turf also provides much more time for rain to infiltrate the soil and reduce the total amount of runoff.

- Turfgrass roots add organic matter and improves the soil structure, which, in turn, enhances the infiltration and percolation of water through the soil and reduces runoff.

Most phosphorus reaches our lakes and streams attached to soil particles in surface runoff. However, numerous university studies have demonstrated that dense turf reduces the total amount of runoff and the amount of phosphorus in that runoff. Turf is so effective at reducing and filtering runoff that most state university extension programs recommend the use of grass buffer strips to protect streams and lakes from agricultural runoff.

Phosphorus is a critical component in fertilizers

Phosphorus (P) is critical to the growth of all living plants and is a part of nearly all chemical reactions that occur in the plant requiring or involving energy. P is needed for photosynthesis and plant metabolism. However, visual symptoms of P deficiency in lawns are often very difficult to observe. When P is in short supply, grass may first appear as a dark green color (the color of the older or more basal leaves) but the plant can appear spindly and stunted. Without adequate P, the general vigor of grass is diminished and the lawn will fail to thrive.

The use of lawn fertilizers is an essential part of any program to develop and maintain a dense, healthy turf and phosphorus is an essential part of any complete fertilizer program. Phosphorus is especially critical during the establishment of a new lawn. Because the very small roots of a germinating seedling can not obtain sufficient P from the soil, young turf will generally respond favorably to higher levels of soil P. Once a lawn is established and the small, undeveloped root system of young grass plants has been replaced by the extensive root system of an established turf, high rates of P are generally no longer

Without adequate P, the general vigor of grass is diminished and the lawn will fail to thrive.

needed nor beneficial and the applications of P should be reduced to meet the maintenance requirements of the lawn.

University research studies have determined that phosphorus from lawn fertilizer does not significantly contribute to nutrient runoff under natural conditions and normal situations.

When the fertilizer is properly applied, the fertilizer will not degrade water quality.

Modern lawn fertilizers have been formulated to provide the minimum amounts of P necessary to maintain healthy grass. University research studies have determined that phosphorus from lawn fertilizer does not significantly contribute to nutrient runoff under natural conditions and normal situations. When the fertilizer is properly applied, the fertilizer will not degrade water quality.



A dense turf protects against soil erosion and nutrient runoff

P is an essential component of the genetic materials of all living cells. Further, it functions in nearly all chemical reactions that occur in the plant that require or involve energy. Additionally, P is needed for photosynthesis, the conversion of sugars and plant metabolism.

P can move from older leaves and stems into younger tissues where metabolism and cell division are occurring at relatively high rates. Consequently, the reproductive parts of plants such as seeds, pollen and flowers are relatively high in phosphorus. Because P can move throughout the plant, nature has given it a limited ability to produce a new generation when P availability in the soil is low. However, P-deficient plants may exhibit sparse flowering, poor seed quality and delayed maturity. Therefore, applications of P are especially important when fertilizing vegetable and flower gardens where high yields and abundant flowers are desired.

How phosphorus acts in soils.

Phosphorus binds to soil particles and forms insoluble compounds in a series of chemical reactions commonly referred to as “phosphorus fixation.” As a result, of the total P present in a soil, most forms are chemically unavailable to plants.

Phosphorus binds to soil particles and forms insoluble compounds in a series of chemical reactions commonly referred to as “phosphorus fixation.”

The initial reactions that “fix” P are generally quite rapid and may begin within hours of application to the soil.

Slower reactions continue over months and even years to further reduce the solubility of P as these compounds age.

Soluble-P from traditional fertilizers reacts quickly with iron, aluminum, and manganese compounds and with calcium in soils to form insoluble compounds that bind to or coat soil particles such as clays or eventually form insoluble minerals. The initial reactions that “fix” P are generally quite rapid and may begin within hours of application to the soil. Slower reactions continue over months and even years to further reduce the solubility of P as these compounds age. (Note: Teeth are an example of such insoluble P compounds).

P also exists in soils in organic forms that result from the decomposition of plant and animal residues. As a general rule, plants take up P as soluble, inorganic ions in soil solution. Although studies have shown that some soluble organic forms of P can be taken up, these forms of P are generally of minor importance (other than acting as a storage reservoir) as under most soil conditions the nutrient must be converted to inorganic forms in order to be taken up by the plant.

What is “eutrophication”?

The process by which a barren lake, devoid of nutrients and aquatic organisms, is transformed into a highly productive lake with abundant fish and wildlife and finally into a body of water clogged with aquatic weeds and algae is referred to as “eutrophication.” Eutrophication is a process that describes the natural aging of lakes that can take thousands of years to complete if human activities do not intervene to speed up the process.

Lakes are classified by the degree of “eutrophication” that has taken place. According to the EPA, the “trophic states” of a lake are as follows:

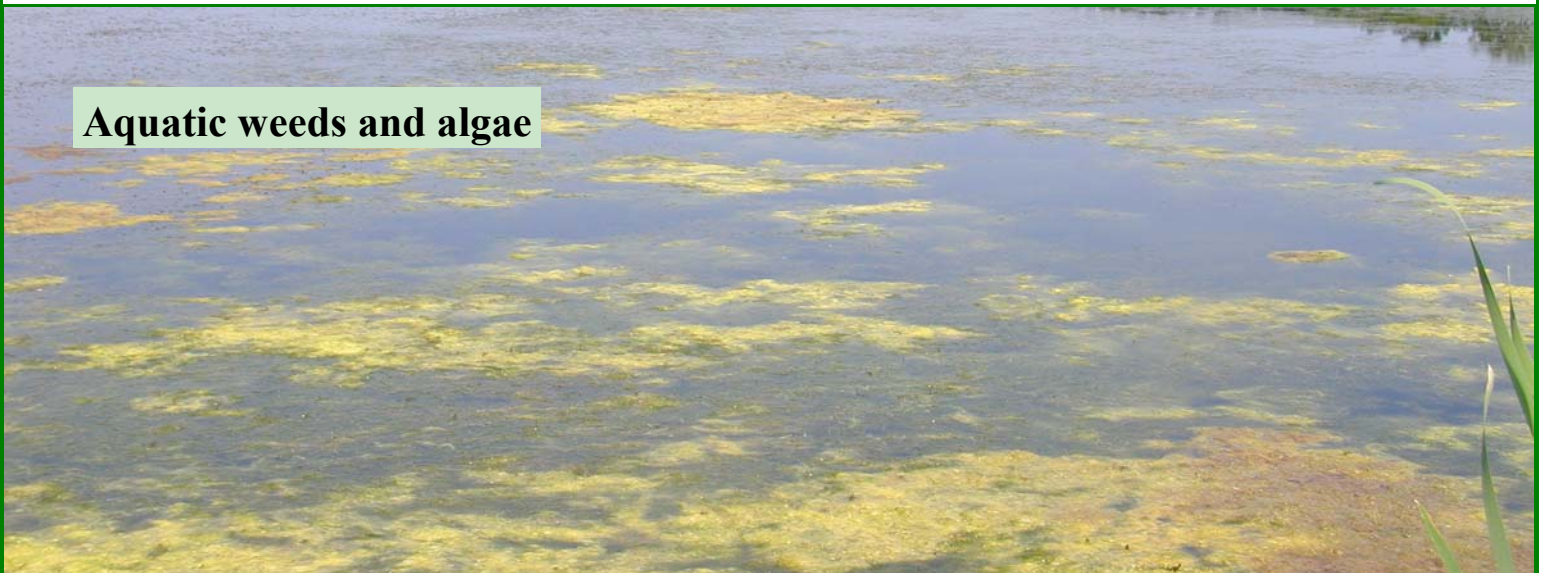
- Oligotrophic** Clear waters with little organic matter or sediment and minimum biological activity.
- Mesotrophic** Waters with more nutrients and therefore more biological productivity.
- Eutrophic** Waters extremely rich in nutrients, with high biological productivity. Some species may be choked out.

Hypereutrophic

Murky, highly productive waters, closest to the wetland status. Many clearwater species can not survive

Lakes that are very low in nutrients (oligotrophic) are pristine but devoid of most wildlife. The lake is very clear, but without nutrients it cannot support much in the way of aquatic life. Insect and fish populations are relatively low. As nutrient levels increase (mesotrophic), populations of fish and plankton become more abundant and plants begin to thrive. As nutrient levels increase further (eutrophic), a point is reached where aquatic plants may begin to fill lakes resulting in impaired water bodies. As algae and other aquatic plant populations become excessive due to very high levels of nutrients, problems may occur as this vegetation dies and begins to decay. Microbes will decompose the dead plants and algae but will also reduce the amount of oxygen dissolved in the water in the process. As the oxygen levels drop, fish and other aquatic animals may also die. The lake is now filled with decaying, malodorous materials and its overall beneficial value has greatly diminished.

Aquatic weeds and algae



Why is it important to control phosphorus in lakes and streams?

P is the primary nutrient that has been linked to the productivity of fresh water aquatic ecosystems and is also considered the nutrient most responsible for excessive growth of algae in fresh water lakes and streams. It plays a major role in the overall process of eutrophication and is considered the factor that most often limits the growth of aquatic plants in fresh water.

Controlling the types and levels of P in water is critical to balancing the productivity of the lake with its recreational uses.

Controlling the types and levels of P in water is critical to balancing the productivity of the lake with its recreational uses. While an oligotrophic lake might be favored by boaters and water skiers, fisherman may favor a eutrophic lake which is capable of supporting higher fish populations.

P is a concern because it takes so little in water to cause a problem. Critical levels in water that can trigger algae growth have been reported to be as little as 20 parts per billion (ppb) of dissolved-P which is orders of magnitude lower than P concentrations found in the soil solution needed for crop/plant growth. Just a few decades ago, such low concentrations were below the minimum levels of detection of most laboratories.

Dissolved (or soluble) P is generally considered to be readily available for algae growth and was once considered the most environmentally significant source of this nutrient. However, recent studies have indicated that P attached to sediments (particulate-P) is also important and can act as a “phosphorus buffer” in aquatic systems. When the dissolved-P concentration of an aquatic system is relatively high, particulate-P will stay attached to suspended sediments and remain relatively unavailable. As algae reduces the concentration of dissolved-P in the water column, particulate-P will move off the sediment and replenish the dissolved-P in the system.

Controlling soil erosion and keeping particulate-P from reaching water is also a very important part of any effort to reduce the impact of P on many aquatic plants, as P in lake sediments is absorbed by roots in the sediments of shallow lakes. Plants, such as Eurasian watermilfoil, will utilize P absorbed from lake sediments by roots and recycle this nutrient back into the water column during the summer where it can stimulate nuisance algae blooms. There is even a growing body of evidence that indicates that Eurasian watermilfoil may actually leak P from its leaves and stems into the water column and help fuel the growth of algae (See “Eurasian watermilfoil discussion”).



Algal bloom



Urbanization causes the replacement of permeable soils with impervious surfaces

How does phosphorus get into our urban streams and lakes?

Urbanization causes the replacement of permeable soils with impervious surfaces such as rooftops, sidewalks, parking lots, driveways, streets etc. Because the amount of porous land areas is reduced, rainfall now results in higher than normal runoff volumes that must be removed via storm systems to prevent damage from flooding. As runoff moves over new, hard, impervious surfaces, it carries with it soil, nutrients and other solids and dissolved materials that have collected on these surfaces that might not have otherwise reached the lake or stream previously.

Instead of being recycled into the new growth of trees and grasses, much of the P now finds its way into our lakes and streams via hard surfaces and urban storm water systems. Pristine lakes that were once very low in P now contain algae and other aquatic plants as a direct result of storm systems acting as conduits for many natural and man-made P sources including the following:

construction sites, waterfowl, pet waste, urban vegetation and deicing materials

Construction and soil erosion

Numerous studies have determined that soil erosion from construction serves as a major source of P in urban runoff.

- In 1999, the EPA estimated that sediment losses from large site construction areas ranged from 20 to 150 tons/acre/year.
- A study in the Baltimore-Washington, DC area noted that “the equivalent of many decades of natural or even agricultural erosion may take place during a single year from areas cleared for construction.” Sediment losses were reported in this study to range from 700 to 1800 tons per 1000 increase in the population.
- The Wisconsin Department of Natural Resources currently places sediment loss from the average construction site at 30 tons per acre.



One only needs to consider the processes involved during the development of a construction site to understand why so much sediment, and thus P, is deposited into urban storm systems. Land is cleared and vegetation that once prevented soil erosion is lost. Soils are compacted, which reduces infiltration and increases runoff volumes. Developers install impervious roads, gutters and storm systems that act very efficiently to transport any suspended solid to the streams and lakes where these conduits generally empty. Construction vehicles cause debris and mud to be deposited on the streets. Developers may even stockpile topsoil that generally contains relatively high levels of P which may be especially true when agricultural areas are developed. Without vegetative cover, these piles and building sites remain subject to erosion until vegetation is once again re-established to stabilize the region. Construction and the resulting urbanization contribute to higher levels of P in urban lakes and streams.

Waterfowl

Canada geese have become a recent problem in the urban environment as many no longer migrate. “Resident” populations, as they are now called, have thrived in many parts of the country as the suburban environment provides an ideal habitat, free of natural predators, with ample food and places to breed.



Feeding resident geese at local park.



Canada goose droppings are rich in phosphorus

According to recent estimates by the U.S. Fish and Wildlife Service (USFWS), there are over one million resident geese in the Atlantic Flyway alone and the average resident population of this flyway has grown at a rate of 8 % per year since 1981. In the spring of 2001, the Mississippi Flyway had an estimated 1,371,000 resident geese and an annual population growth rate of 6 % a year.

The droppings of geese are relatively rich in

phosphorus and under certain circumstances, may contribute significant amounts to the total phosphorus loading of lakes (guantrophy). One study of a small urban lake in the northeast USA found the phosphorus inputs from geese feeding on a nearby golf course and roosting on the lake to be nearly 5 X higher than storm drain contributions from surrounding residential/commercial areas during the same time frames. Further, in 2001, a study of the impact of waterfowl droppings on the water quality of an urban lake in Wilmington, NC estimated that waterfowl contributed 27 % of the total-P in the lake.

The waterfowl problem has grown to the point that the federal government has recently released a draft Environmental Impact Statement on a proposed program to address the issue. Unless action is taken, according to the USFWS, increasing numbers of resident geese will continue to harm water quality through increased erosion and sedimentation due to overgrazing along shorelines and excess nutrient additions to lawns and lakes from fecal droppings.



Pet waste

While pet waste is generally recognized as a source of phosphorus that finds its way into lakes and streams via urban storm systems, it is difficult to find studies relating to its relative impact on water quality. According to the North Carolina Cooperative Extension Service dog manure is approximately 10 % phosphate. In a study conducted to evaluate the impacts of various urban sources of nutrients on water quality of Four Mile Run near Washington, D.C, the Environmental Services Division of the Northern Virginia Regional Commission estimated that a population of 11,400 dogs in the area generated 5,000 pounds of solid waste every day or 1000 tons per year over a 20 square mile area. If we assume the waste was 15% dry matter, by using the above information from North Carolina and Virginia, it can be calculated that the aver-

age dog is responsible for approximately 2.6 pounds of phosphate per year. Where the animal “deposits” his annual phosphorus contribution is of significant importance to the water quality of the region. Proper pet sanitation must not be overlooked when seeking means to reduce phosphorus contributions from urban runoff.

Urban vegetation

Concentrations of P in urban runoff are highest in the spring and in the fall of the year. In 1971, a study conducted in Madison, Wisc. found that high levels of soluble-P in the spring were attributed to tree flowers and seeds while high P levels observed in November were caused by piles of leaves in gutters and streets.



Tree flowers, pollen and seeds litter urban streets and walkways every spring.



In the fall and winter, leaves left on city streets can leach significant amounts of soluble P into storm sewers

To illustrate just how large the contribution these materials can represent, a study conducted by the University of Minnesota in the early 70's found that the act of sweeping the streets once a week could reduce the phosphorus concentrations of storm water runoff by up to 42 %. Leaves, clippings, pollen and seeds that accumulate on impervious surfaces are not inert materials and can make major contributions of P to enrich urban runoff.

A study in Minnesota demonstrated that sweeping streets once a week could reduce phosphorus concentrations of storm water by up to 42 percent.

Road sand and deicing materials

In the northern United States, the use of sand and de-icing materials is a very common practice in urban environments since hazardous road conditions due to ice and snow must be corrected or prevented for the safety of all highway users. A close examination of the nutrient contents of these materials is important since any nutrient applied to a road surface may still find its way into lakes and streams via local storm water systems.

Phosphorus from sand and deicing materials applied to highways must be reviewed by each and every municipality concerned with the quality of water in lakes and streams.

In 1987, a study of the P contribution of salt:sand mixtures used in the Twin Cities Metropolitan Area of Minnesota for deicing purposes found the materials used by seven local municipalities yielded an average of 0.62 ppm of P / liter of simulated runoff. The author concluded that “the high concentrations of phosphorus.... in snowmelt appear to be due in part to antiskid sand and deicing salts spread to improve winter driving conditions.”



Deicing materials storage bunker

A recent report from the New York State Attorney Generals Office found that new deicing technologies could contain up to 3700 ppm of P. In this report, only 6 of 25 deicing materials sampled were found to contain less than the recommended 50 ppm Total-P and 3 were road salt with less than 5 ppm Total-P. After considering the fact that increases measured in parts per billion (ppb) of P can effect the growth of algae, P from materials applied to highways must be reviewed by each and every municipality concerned with the quality of water in lakes and streams.

But what about lawns and lawn fertilizers?

Although some local governments have considered lawn fertilizers as a potential contributing source of P in urban waterways, this approach is not based upon sound science. In fact, numerous university research studies have shown that a dense, well-fertilized lawn significantly reduces runoff and off-site nutrient movement. After all, most university extension programs are recommending the use of sod buffer strips to protect streams and lakes from agricultural runoff because they are so effective.

It is noteworthy that the major mechanism by which P is transported is by erosion and, to a lesser extent, in surface runoff waters. Turf reduces the erosion of soil, in part, by absorbing the energy of moving water and reducing its ability to move soil particles (see “Benefits of turf” discussion). In addition, a growing turf also reduces soil moisture levels through evapotranspiration and thus increases the moisture storage capacity of the soil for future rainfall events. All of these factors function to reduce the amount of runoff and nutrient movement from a lawn.

Numerous university studies that measured both the quantity and the quality of runoff from a lawn, without artificially disturbing the turf-thatch-soil interface zone, have demonstrated that lawn fertilizers are not likely to be a direct source of phosphorus in runoff.

Numerous university studies that measure both the quantity and the quality of the runoff from a lawn, without artificially disturbing the turf-thatch-soil interface zone, have demonstrated that lawn fertilizers are not likely to be a direct source of P in runoff. Rapid fixation of phosphorus by the soil, the overall general lack of runoff and the nearly total elimination of soil erosion by a dense healthy lawn, all function to prevent P in lawn fertilizers from leaving the site of application. Where P losses in runoff from fertilizers have been observed, extremely harsh downpour conditions (4-6 inches/hour) immediately following the application of unusually high rates of P have been required before any significant movement of this nutrient from established turf has been measured in university studies.

A recent Wisconsin study was conducted over a 6-year period and measured the P content and the amount of runoff from turf under natural precipitation conditions. In this study, an average of only 0.36 pounds of P per acre per year was collected in runoff which averaged only 1.3 inches per year. Nearly 80 % of the annual runoff and the P collected occurred when soils were frozen. The P in runoff samples leached out of desiccated frozen turf. Runoff from unfertilized plots was found to be 78 % higher than fertilized plots and the P losses from the unfertilized turf were nearly 147 % higher than fertilized turf. Unfertilized grass had thinned so much that runoff increased, which, in turn, reduced the time available for infiltration into the soil.

So, while P is indeed found in lawn fertilizers, it is there for an important nutritional reason. Further, persons concerned about P in urban waterways need to remember and understand that the benefits of a healthy turf in preventing erosion and other contributing factors caused by

urbanization far outweigh any alleged *de minimus* contribution of P from lawn fertilizers.

A brief discussion regarding Eurasian watermilfoil

A common problem found in many lakes and streams is an invasive aquatic weed known as Eurasian watermilfoil (EWM). Since its introduction into this country back in the 1940's, this noxious weed has infested lakes in 44 states. Eurasian watermilfoil spreads from lake to lake as plant fragments that attach to boats and trailers. These fragments root in nutrient-rich sediments and quickly form dense canopies at the surface of the water, shading out beneficial native aquatic plants and significantly curtailing many recreational uses of these lakes.

According to the U.S. Army Corps of Engineers, the growth of this devastating weed is not phosphorus-limited, as it can generally obtain adequate P from existing lake sediments. Research conducted at the University of California-Davis found that EWM actually leaks phosphorus back into the water through its leaves and stems at higher levels than native species. However the amount of P released back into the water column in this fashion needs further study to quantify the potential impact on water quality.

Eurasian watermilfoil is an invasive aquatic plant that can quickly disrupt the natural ecology of a lake.



Photo courtesy of Robert L. Johnson, Cornell University, www.invasive.org

Research conducted at the University of Wisconsin-Madison has shown EWM to be an important vector of P from the sediments back into the water column for a different reason. Because EWM establishes perennial root systems within existing nutrient-rich sediments, it is very capable of mobilizing significant amounts of sediment-P and redistributing this nutrient back into the water column to fuel the growth of algal blooms that require the more soluble forms of P. Phosphorus is taken up from sediments by EWM and is released into the water column when the vast amount leaves and stems produced by this fast-growing weed dieback and are degraded via microbial decomposition.

It is a mistake to make the assumption that a community's EWM problem will simply go away if, for example, phosphorus in lawn fertilizer is banned. The growth of this invasive weed is not limited by a lack of soluble-P in the water column. The source of P that this plant generally uses is the same source

of P that a dense, healthy lawn is best at removing from urban runoff: particulate-P from soil erosion.

As communities consider water quality problems associated with urban lakes and streams, such as heavy algal growth and Eurasian watermilfoil, it is imperative they base any actions on readily available science. While it may be tempting to try a presumed "quick fix" by banning lawn fertilizers that contain phosphorous (P), numerous studies indicate that heavy phosphorous loadings are attributable to a myriad of more important sources including soil erosion, urban run-off from leaves, water fowl waste and de-icing materials. Furthermore, if EMF is a principal problem, studies of this invasive plant indicate that it self-perpetuates its own P source and heavily relies on P-laden soil sediments from erosion. One of the most effective ways to ensure water quality is by establishing and maintaining healthy turf around urban lakes and streams. Healthy turf requires phosphorus.

KEY POINTS TO REMEMBER ABOUT PHOSPHOROUS

- Phosphorus (P) is a vital nutrient that is critical for all plant life.
- When limited, phosphorus inhibits the plant's ability to grow, thrive and reproduce.
- Lawns grown in soils that are low in phosphorus take longer to establish and are far less vigorous and dense.
- A dense, healthy turf significantly reduces the amount of nutrients and precipitation that runs off of a lawn.
- University research indicates that phosphorous found in fertilizer does not significantly contribute to nutrient runoff unless inappropriately applied at very high rates to turf just prior to an unusually harsh precipitation event.
- Much of the phosphorus in urban storm water runoff can be attributed to soil erosion from construction sites, natural sources such as pollen, flowers and decaying plant material such as leaves and grass clippings left along curbs and in rain gutters, pet and waterfowl wastes and highway deicing materials.
- Restricting phosphorus in lawn fertilizers will do little or nothing to solve Eurasian watermilfoil (EWM) problems. This invasive aquatic weed utilizes phosphorus in existing sediments and re-distributes this nutrient back into the water column in a soluble form that can fuel nuisance algal blooms.

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