A Phosphorus Primer

Best Management Practices for Reducing Phosphorus from Agricultural Sources

Canada

Ontario

OFA Ontario Federation of Agriculture

CONTENTS

INTRODUCTION

Phosphorus (P) is a naturally occurring element and is a key nutrient for the growth of crops, plants and algae. It occurs in many chemical forms.

In terrestrial ecosystems such as woodlands or croplands, phosphorus can be found on soil particle surfaces as well as in soil minerals, soil solution, plants and animals.

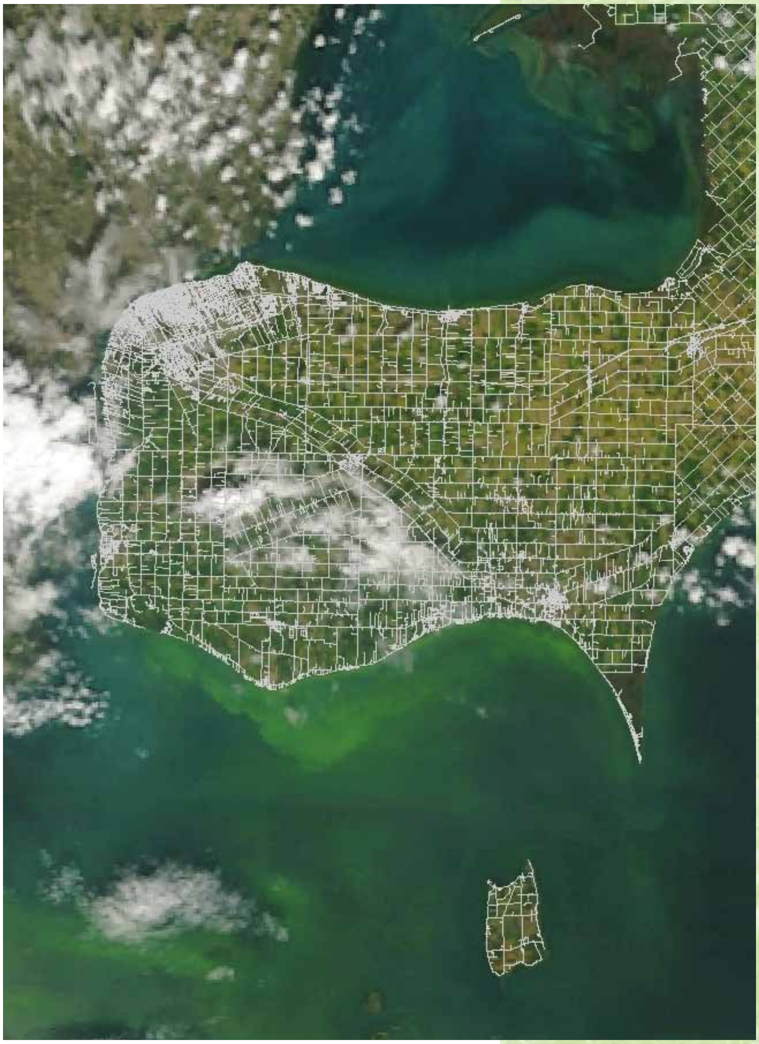
In aquatic ecosystems such as watercourses or lakes, phosphorus can be found in solution, attached to suspended or settled sediments, and in aquatic plants and animals.

Besides its natural presence in ecosystems, phosphorus appears in several forms as part of human-driven industrial, urban and agricultural activities. Excessive loss of phosphorus from these activities to the natural environment is harmful to aquatic ecosystems. In fresh waters, elevated phosphorus levels can:

- reduce oxygen in lakes, ponds and rivers – harming cold-water fish
- accelerate aquatic plant growth and create algal blooms – degrading the quality of irrigation water, contaminating livestock water, fouling beaches, impairing municipal and private drinking water supplies, and increasing the cost of treatment.

Everyone can take action to reduce phosphorus loss to the environment. This booklet is intended to help readers:

- understand the sources and forms of phosphorus created by agricultural activities
- learn about the impact of phosphorus on aquatic ecosystems
- recognize opportunities to implement sustainable agricultural practices (best management practices or BMPs) that can reduce phosphorus losses from agricultural sources.



Phosphorus contributes to excess algal and aquatic plant growth in parts of the Great Lakes. Note the green tones in Lake Erie and Lake St. Clair in this photo.

SOURCES OF PHOSPHORUS POLLUTION

POINT AND NON-POINT SOURCES

Phosphorus pollution comes from *point* and *non-point* sources. A point source means the pollutant enters the water body from a specific location. A non-point source is not so easily identifiable, as it comes from diffuse and variable points across the landscape.

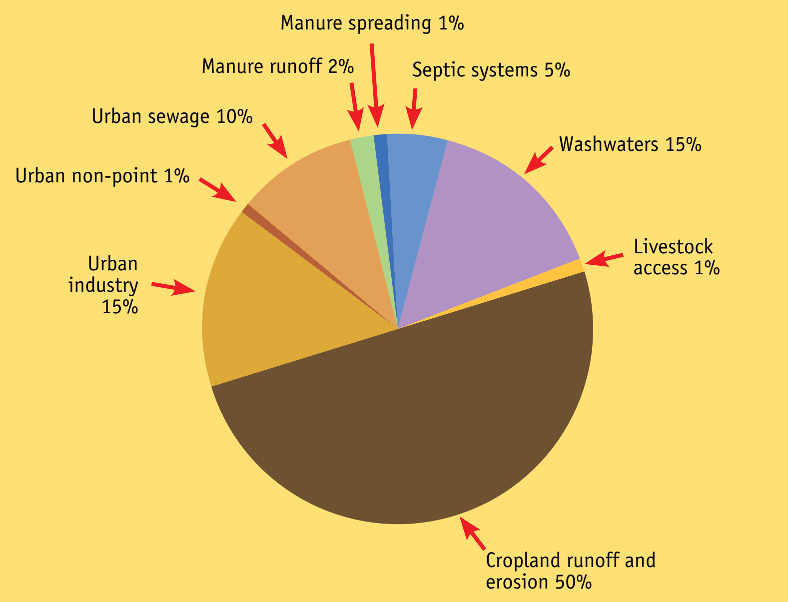
In urban areas, point sources of phosphorus pollution include industry and wastewater treatment plants. Urban stormwater runoff is considered a non-point urban source.

In rural areas, the majority of phosphorus loadings come from non-point sources, such as cropland erosion and runoff to surface waters – although this will vary from watershed to watershed. Potential agricultural point sources include poorly managed:

- washwaters from milking centres
- nutrient solutions from greenhouses
- runoff from livestock yards and stored manure.

Phosphorus is an essential nutrient in natural ecosystems, and is essential for crop growth and livestock production.

SOURCES OF PHOSPHORUS ENTERING RIVERS AND LAKES IN AN ONTARIO WATERSHED



Source: Fanshawe Reservoir Clean Up Rural Beaches Study

Every watershed is unique. This graph shows phosphorus contributions from different sources to a watershed in southwestern Ontario.

Soil erosion and nutrient runoff can promote algae and other aquatic plant growth, which decrease oxygen in surface waters. This degrades water quality for drinking, recreation, and fish habitat.

The risk of phosphorus pollution of surface water can be reduced with BMPs for applying manure, composted material, biosolids, and mineral fertilizers.

Greenhouse operations use nutrient solutions to fertilize flower and vegetable crops. Proper treatment and storage of used nutrient solutions will reduce the risk of phosphorus runoff to surface waters.

PHOSPHORUS ENRICHMENT IN SURFACE WATERS – LAKES, RIVERS AND STREAMS

There are two ways to look at phosphorus in the environment: phosphorus in surface waters and phosphorus in the soil. In unpolluted freshwaters, aquatic plant growth, including algae, is usually limited by the low level of phosphorus. When phosphorus is added to water, more algae and other plants are able to grow. In recent decades, abundant algal growth has made the water in some lakes and rivers in Ontario unpleasing or unsuitable for drinking or swimming.

Eutrophic is the term used to describe the condition of nutrient enrichment when aquatic plant growth becomes excessive. One of the key concerns of eutrophication is the impact on oxygen levels. High nutrient levels cause rapid growth of algae, which can form large blooms. Algae grow quickly, but each alga is short-lived. The dying mass of algae adds organic matter, which then decays. As the bacteria consume this glut of organic matter, they also consume dissolved oxygen in the water.

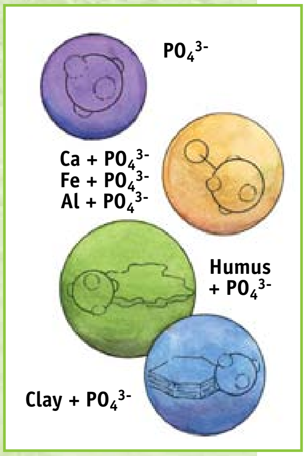
Like us, fish and other aquatic organisms require oxygen. Trout, salmon, and aquatic insects such as mayfly, stonefly and caddisfly are particularly sensitive to low oxygen levels.

Phosphate (PO_4^{3-})

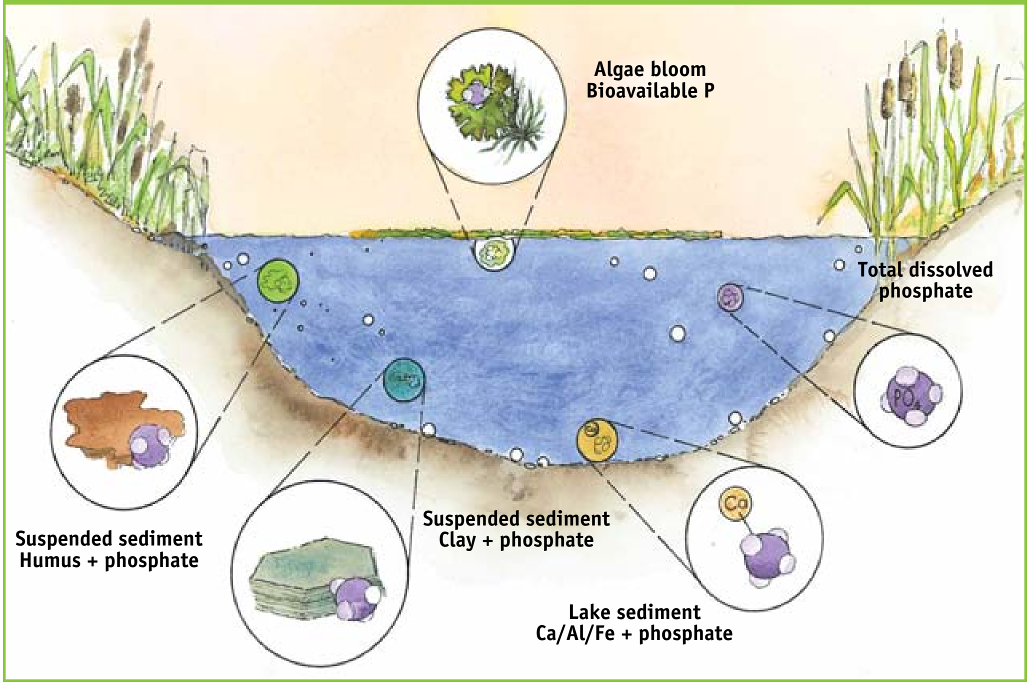
Calcium phosphates ($Ca + PO_4^{3-}$)
Iron phosphates ($Fe + PO_4^{3-}$)
Aluminum phosphates ($Al + PO_4^{3-}$)

Humus + phosphate (PO_4^{3-})

Clay + phosphate (PO_4^{3-})



FORMS OF PHOSPHORUS IN A LAKE ENVIRONMENT



Phosphorus is dynamic in surface water and constantly cycles among the various forms, unless trapped in deep sediments on the lake bottom.

PHOSPHORUS IN SURFACE WATERS

There are three forms commonly used to describe phosphorus in runoff, streams and lakes.

1. **Total dissolved P** (TDP), often called dissolved P, is defined as P that passes through a 0.45-micron filter. Total dissolved P is primarily orthophosphate (PO_4^{3-}) dissolved in water, but also may include some dissolved organic P. In some cases, only the orthophosphate component of total dissolved P is reported and is called dissolved reactive P (DRP).

2. **Particulate P** (PP) is also known as sediment P. This form of P can be in suspension or in lake sediments. It's the difference between total P (see below) and total dissolved P, and is defined as:

   - insoluble P compounds, formed by reactions between phosphate and minerals in solution – see gold spheres labelled calcium (Ca), iron (Fe), or aluminum (Al) phosphate (PO_4^{3-})
   - P attached to sediments – see blue spheres labelled clay + phosphate (PO_4^{3-}), and
   - organic P, attached to the surface of or incorporated into organic compounds, including living organisms – see green spheres labelled humus + phosphate (PO_4^{3-}).

3. **Bioavailable P** (BAP) is also known as algal-available P, and referred to as algae bloom/ bioavailable P in the illustration. It is defined as the portion of total P that is available to algae. It includes all of the total dissolved P and the portion of particulate P that algae are able to extract.

Bioavailable P is a measure of how much P from different sources will affect water quality.

Particulate P is less available in aquatic systems in the short term. In the long term, under conditions of low BAP concentration in the water, more of the particulate P can be released.

Total P (TP) is the total of dissolved P and particulate P in a water sample. (TP = TDP + PP).
Bioavailable P = TDP and some of PP

Phosphorus is dynamic in surface water and constantly cycles among the various forms, unless trapped in deep sediments on the lake bottom.

See the next page for a description of how these forms of phosphorus interact in surface waters.

While not all forms of phosphorus are equally available to aquatic life, they are all of concern for aquatic ecosystems. In general, the more soluble forms of phosphorus are immediately available to aquatic organisms, while phosphorus bound to sediment or precipitated as insoluble minerals has a slower, but longer term, impact on water quality.

Conversion of particulate P to a bioavailable form is affected by:

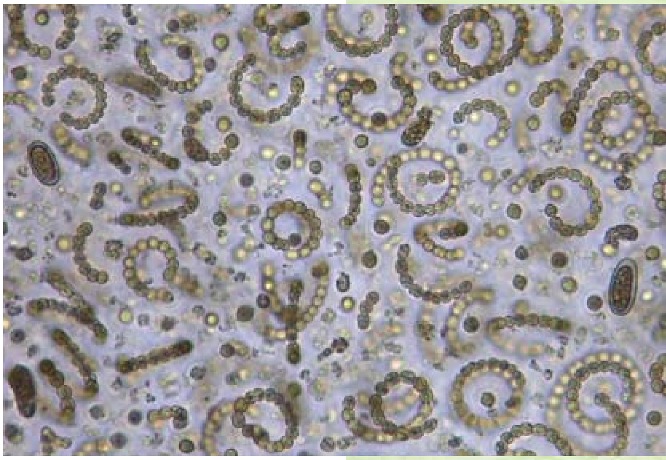
- phosphorus content of the particles and the surrounding water
- water pH and alkalinity
- size of the particles
- amount of sediment in the water – a greater proportion of P will detach from the sediment in clean water than muddy water.

When there is a shortage of dissolved P, algae can produce the enzyme *phosphatase*, which helps release more of the particulate P into forms the algae can use. This is why water quality does not always immediately improve after sources of P are reduced. The sediment-bound P continues to be released, until it is depleted or flushed downstream.

Molluscs and other aquatic life-forms filter water for nutrients. Shell tissue contains high levels of phosphorus and calcium. These organisms act like a living P-savings account, and can store large amounts of bioavailable P. As the shells break down slowly, P is recycled.

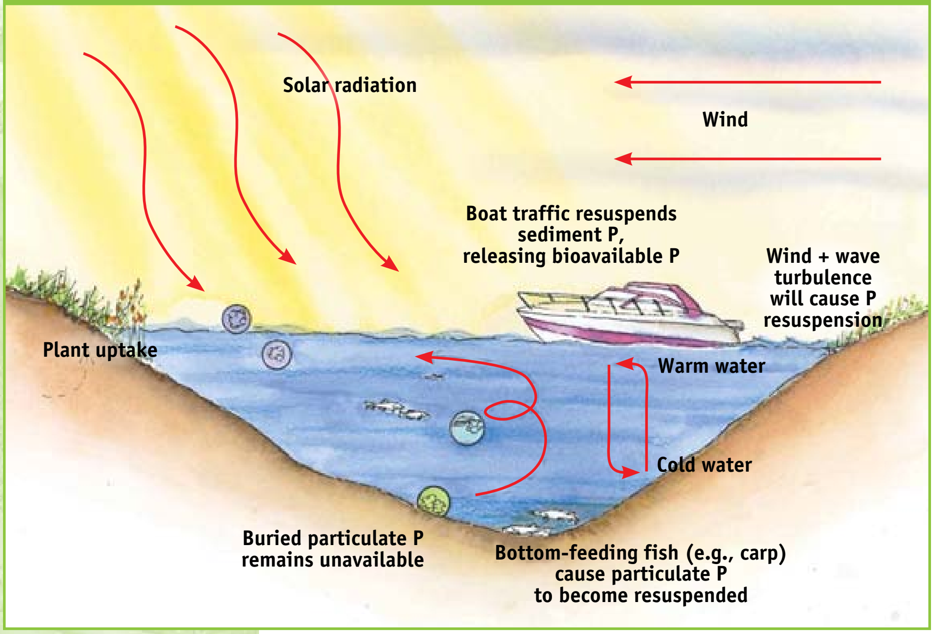
However, the mussels' feces, which break down quickly near-shore, are high in bioavailable P. Mussel feces can also be high in dissolved P. The invasion of exotic species like this zebra mussel has contributed to the reduction of P in the deep waters of the Great Lakes, while increasing P concentrations near the shore.

Excessive levels of phosphorus can lead to increases in levels of cyanobacteria (also known as blue-green algae) in surface waters. Blue-green algae produce a wide range of toxins that are harmful to animals and humans.



Available P for algae does not decline as quickly as reductions in P input, due to buffering by natural processes.

LIFE CYCLE OF PARTICULATE P IN SURFACE WATERS AND SEDIMENTS

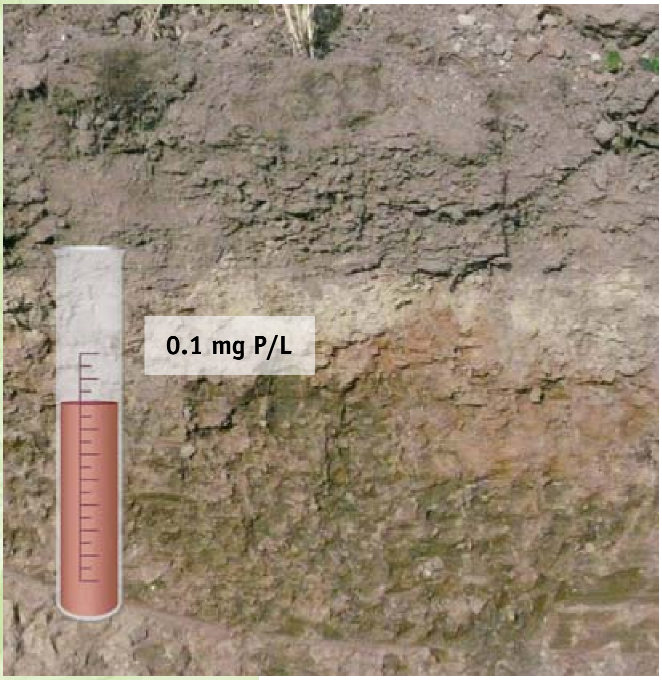


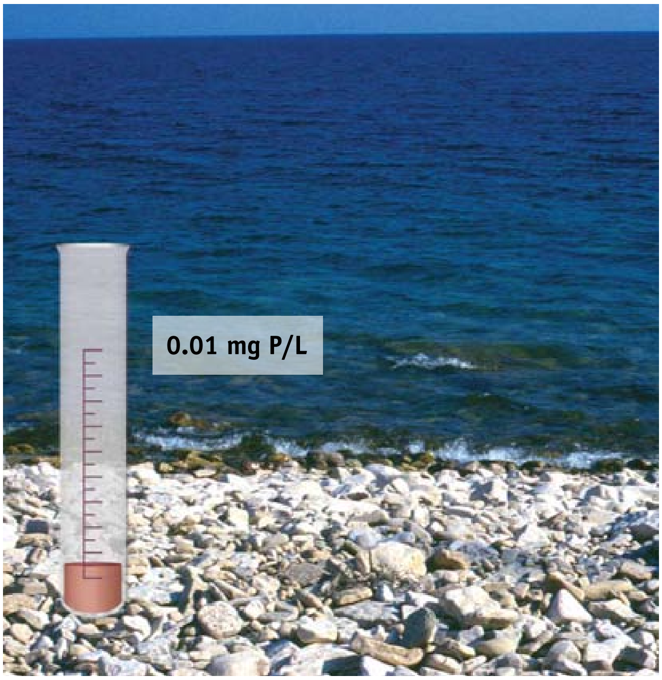
In some undisturbed aquatic ecosystems, particulate P will remain relatively unavailable. Particulate P is trapped in layers of buried sediment, or the chemical form may be relatively insoluble or not highly reactive with other aquatic chemicals.

This can change when aquatic ecosystems are disturbed. Wind and waves in shallow lakes, motorboat traffic, and bottom-feeding fish such as carp cause resuspension of particulate P, driving the reaction to release BAP. Typically lakes “turn over” or mix in the spring and fall. Turnover occurs when the water’s temperature and density are the same at all depths, which allows it to mix freely. P can then be brought up from deeper water.

Depletion of oxygen in the bottom waters can cause the release of dissolved P from iron phosphates in the sediments.

In the short term, dissolved P is of greatest concern because it’s immediately available to algae. However, because particulate P can transform into dissolved P under certain conditions over time, the larger amount of sediment-bound P can also cause excessive aquatic plant growth (eutrophication).





Concentration of phosphorus in soil solution of a fertile soil for plant growth is about 0.1 mg P/L. Acceptable concentrations in lake water are usually less than 0.01 or 0.02 mg P/L, depending on the natural phosphorus concentration of the system. Small losses from cropland can have large impacts on lake water quality.

UNDERSTANDING PHOSPHORUS IN RURAL AREAS

P = phosphorus

PO_4^{3-} = phosphate

For the most part, a discussion of phosphorus is really about phosphates. Phosphate is the form used in the metabolism of plants and animals, and most commonly found in minerals. Chemically, it has four oxygen atoms linked to the central P atom. Its charge and number of hydrogen atoms are a function of pH.

AGRICULTURAL NON-POINT SOURCES OF PHOSPHORUS

PHOSPHORUS IN SOIL

Soil ecosystems are similar to water systems in that only a small portion of the total phosphorus is easily available to plants.

The soil P system is commonly described as having three pools of P:

- soluble P
- labile P
- stable P.

SOLUBLE PHOSPHORUS

A small fraction of soil P is dissolved in the soil solution in the orthophosphate form – the form that is taken up by plants.

LABILE PHOSPHORUS (ORGANIC AND INORGANIC FORMS)

As plants deplete orthophosphate in the soil solution, dissolved P is replenished from the second major soil P pool called *labile P*. Labile P is held loosely by soil particles and can move easily into solution.

STABLE PHOSPHORUS (ORGANIC AND INORGANIC FORMS)

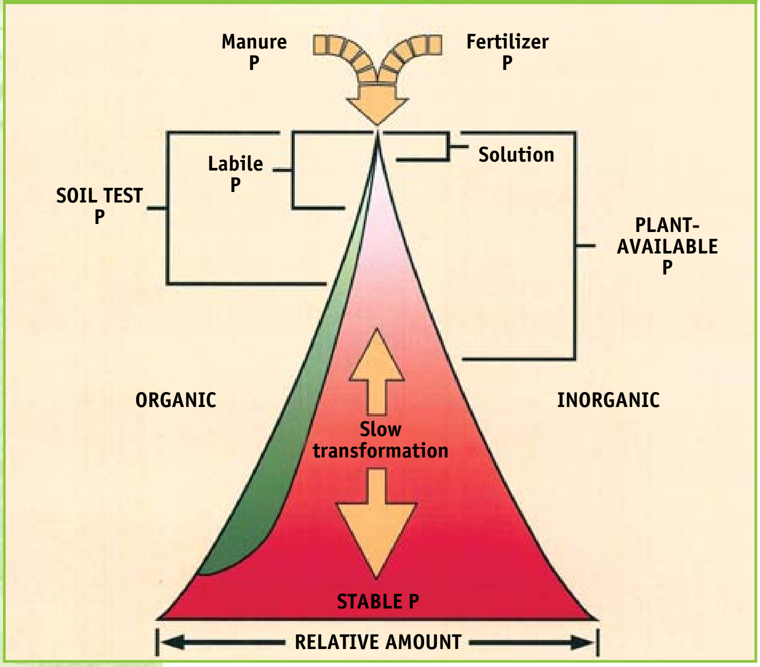
The third soil P pool, non-labile or *stable P*, is held strongly to soil particles in the form of iron and aluminum phosphates in acid soils, and calcium phosphates in calcareous soils. Some P is part of the molecular structure of soil organic matter. Stable P is unavailable to plants and is converted very slowly to labile and soluble P.

The total P in the top 15 centimetres (6 in.) of soil is equivalent to 3000–5000 kilograms per hectare (2700–4500 lb/ac) of phosphorus. However, less than 1% of the total P is available to crops.

What about P_2O_5 (fertilizer phosphate)?

This is a unit of measure used in fertilizer: plants do not absorb phosphorus in this form.

PHOSPHORUS TRANSFORMATIONS IN SOIL

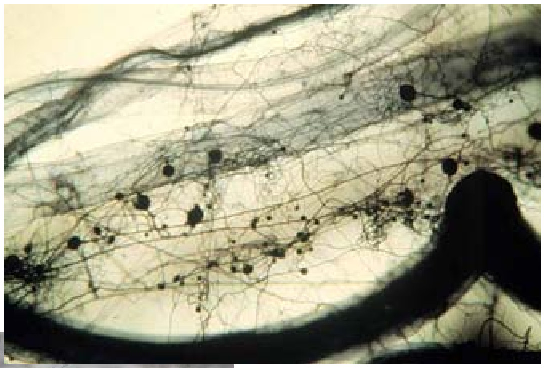


Phosphate reacts with so many different compounds and elements in the soil that only a small amount remains in solution at any time.

Most of the P is tied up in compounds with a range of solubility – as indicated by the *Solution* label in this illustration. When soluble P is added to the soil as fertilizer or manure (see top of illustration), most of it is rapidly converted first to labile forms. (Note: plant-available P is made of P in solution, labile P, and the less stable compound forms.) It then converts to progressively more stable forms, by reacting with iron, aluminum or calcium (see *Inorganic* label), by binding to clay particles or organic matter, or by forming part of the chemical structure of the humus (see *Organic* label).

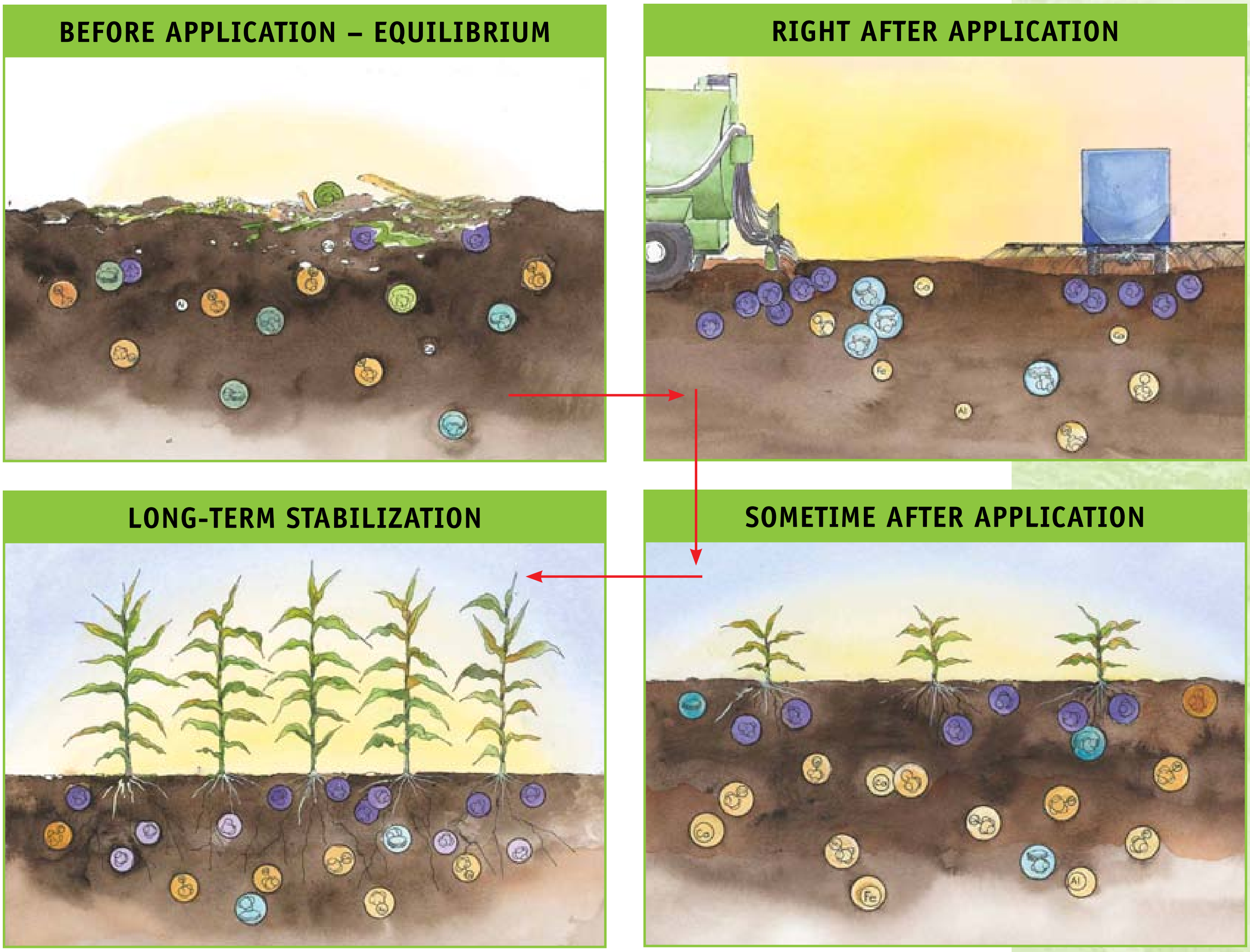
Over time, the P tends to accumulate in the most stable compounds (as represented by the area in the base of the triangle). However, some of the P will also be released into solution to replace the P taken up by plant roots – see arrows showing *Slow transformation* – with proportionally more P becoming stable and smaller amounts slowly released into solution.

Arbuscular mycorrhizae (AM) are fungi that help crops and most other plants increase nutrient and water uptake, especially phosphorus, in exchange for sugars. The very fine roots-like mycelia of the fungi are able to explore a greater volume of soil than the thicker plant roots could. Additionally they can excrete different chemicals to aid nutrient absorption.



The vast majority of phosphorus taken up by plants is due to plant roots, root hairs, and contact with P as they grow through the soil. Because low temperatures slow root growth and nutrient absorption, plants are often unable to obtain sufficient P during cold weather, especially when they are small.

Consequently, it's beneficial to place phosphorus fertilizer where roots can access it and to time fertilizer application to periods of higher use.



Phosphate (PO_4^{3-})

Calcium phosphates ($Ca + PO_4^{3-}$)
Iron phosphates ($Fe + PO_4^{3-}$)
Aluminum phosphates ($Al + PO_4^{3-}$)

Humus + PO_4^{3-}

Clay + PO_4^{3-}

Before Application – Equilibrium

P in soil is classed in three groups, although there is a gradation between labile and stable forms of P:

- soluble P: phosphate or PO_4^{3-} (purple spheres)
- labile P: held loosely by soil particles (blue spheres) and the surface of organic matter (green spheres), and
- stable P: phosphorus attached to calcium, iron or aluminum (gold spheres), or chemically bound within complex organic molecules.

Before planting, soil P is in a state of equilibrium with only a fraction of phosphorus in the soluble form.

Right After Application

This illustration shows what happens to this equilibrium when manure or fertilizer P is added before planting. Most P fertilizers are composed of water-soluble P compounds, and most manure P is water-soluble. Application of fertilizer or manure P causes an initial dramatic increase in soluble P in the soil at the point of contact – as indicated by the introduction of dark purple phosphate spheres.

Sometime After Application

Chemical equilibrium is rapidly re-established as much of the added P enters the labile P pool. See the humus (green) and clay attached (blue) P spheres – as well as fewer phosphates in solution (dark purple spheres) in the root zone.

Long-Term Stabilization

Over time, some of the P in the labile pool is converted into more stable organic and mineral forms. (Note the increase in the number of darker gold P spheres.) The immediate effect of P fertilization and manure P applications is to increase the capacity of the labile P pool to replenish solution P. The net long-term effect of P additions on labile and total P in a soil depends on soil properties, P removal by crops, and P loss by other processes (such as erosion and runoff).

PHOSPHORUS IN MANURE

About two-thirds of the phosphorus in manure is found in the feces (not the urine), primarily in the form of organic compounds and also as orthophosphate. The organic compounds are readily degraded in storage or in soil, so that much of the phosphorus in manure becomes available to crops eventually.

The best economic returns from manure generally come from applying rates to meet the nitrogen needs of crops like corn or cereals. However, this usually means that more phosphorus is applied than the crop removes, so phosphorus can accumulate to very high levels in the soil when this management is followed for a number of years.

Soil test results that show high phosphorus levels indicate conditions at risk of phosphorus loss. Runoff and erosion from these areas can contribute high amounts of phosphorus to lakes and rivers.

Manure application often results in increased yield compared to use of fertilizer alone. This is likely due to the additions of organic matter, the proliferation of soil life, and the improvement in soil quality following manure applications.

Nutrient content of manures is highly variable and depends on species, size, age, feed, housing, manure type, and other management factors.

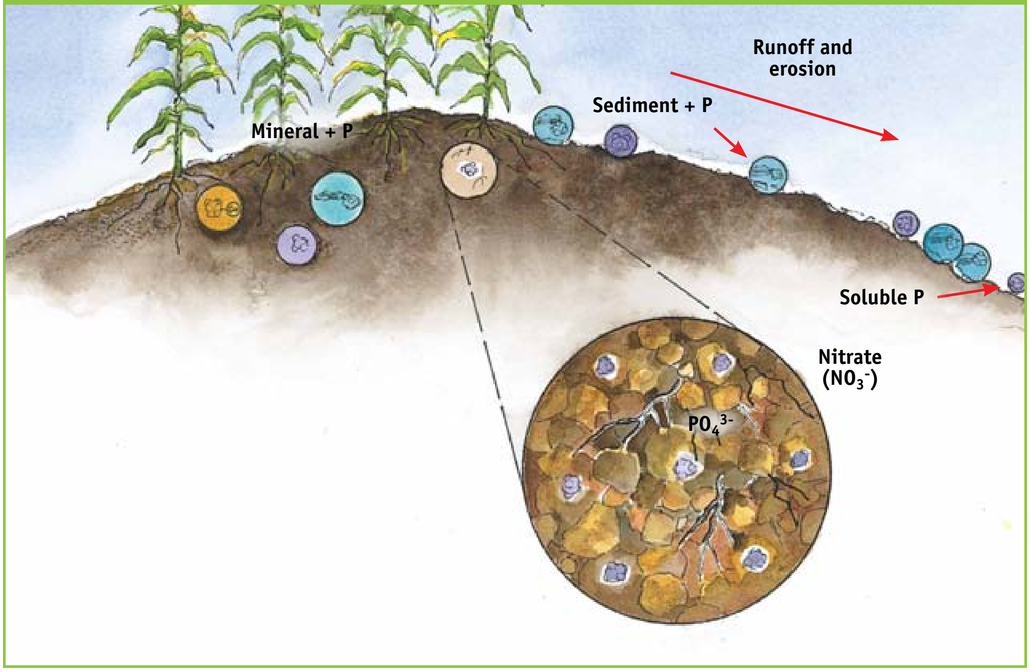
PHOSPHORUS IN FERTILIZERS

Rock phosphate is insoluble in water, and the phosphorus it contains becomes available to plants very slowly – taking 100 years or more.

To make the rock phosphate more available to plants, it is treated with various acids.

Rock phosphate, mined mainly in the southern United States, northern Africa and Russia, is the source of almost all of the phosphorus in fertilizers.

ROOT ZONE AND SOIL PHOSPHORUS



- Phosphate (PO_4^{3-})
- Calcium phosphates ($Ca + PO_4^{3-}$)
  Iron phosphates ($Fe + PO_4^{3-}$)
  Aluminum phosphates ($Al + PO_4^{3-}$)
- Clay + PO_4^{3-}

Phosphates in the soil are not easily lost. Most phosphates bind readily to soil particles (labile and stable forms) and are unlikely to leach – depicted by the blue, green and gold spheres positioned below the soil surface in the illustration and the inset.

Phosphorus is lost from the soil surface as surface runoff carries particulate P in eroded sediments and dissolved P – as shown by the sediment-bound and soluble P on the soil surface.

AGRICULTURAL POINT SOURCES OF PHOSPHORUS

Potential agricultural point sources for phosphorus loadings include:

- storage facilities for manure and other nutrients
- livestock yards
- milking centre washwaters
- faulty septic systems.

Unless properly managed, phosphorus from these sources can reach surface waters from overland flow and subsurface drainpipe (tile) outflow. In these circumstances, the risk of point source pollution is greatest following snowmelt and storm events.

Storm events and snowmelt can carry soil and manure from livestock yards to surface waters such as watercourses and lakes. Soil and manure can contain phosphorus, other nutrients, and bacteria.

Nutrients such as phosphorus in harvested crops are used by livestock and people. Returning their wastes to cropland closes the phosphorus cycle.

PHOSPHORUS TRANSPORT TO SURFACE WATERS

Phosphates from agricultural sources can reach surface waters from point sources and non-point sources. Here are some of the more common pathways for phosphorus transport to surface waters.

POINT SOURCE

In the event of a spill, work safely and quickly to stop and contain the spilled material. Then contact the MOE Spills Action Hotline at 1-800-268-6060. Provide the spill details, the action taken, and future intentions.

Spill

A spill occurs when phosphorus in a stored solution from a concentrated source (e.g., liquid manure, greenhouse solution) is discharged accidentally into the environment.

The spilled materials can run off directly to surface water from the spill source. In most cases, the liquid ponds on the soil or an impermeable surface. The ponded area breaches and forms concentrated flow. The concentrated flow can then move overland and follow the path of least resistance to the nearest body of surface water.

Spills can reach surface water indirectly as well. An adjacent surface inlet, cracked soil, or shallow bedrock formation can serve as direct conduits to subsurface drainage. The subsurface drainage system will outlet to adjacent bodies of surface water.

Leaks

In this context, leaks are the unintentional release of small volumes of contaminated liquids on an ongoing basis. Chronic leaks accumulate in the environment over time. For example, phosphorus can reach surface waters when in solution and suspension with organic sources such as solid manure stacks or livestock yards.

Leaked liquids can pond on the soil surface and follow the path of least resistance to surface waters.

Illegal Connections

There are a few isolated cases where sources of waste liquids are directly connected to subsurface drainage systems for discharge into surface waters. These deliberately bypass the natural treatment functions of soils – and are illegal.

NON-POINT SOURCE

Water Erosion

Particulate P can be eroded from the seedbed and upper layers by water moving over cropland. When a storm event causes soil to reach saturated surface conditions and/or when soils are semi-frozen, soil particles are readily detached. Attached P moves with sediment and runoff waters in sheets, rills and gullies. Eroded materials can be deposited on fields or into adjacent surface waters.

Exposed soil conditions can lead to the transport of particulate P with soil sediment by the erosive forces of wind.

Wind Erosion

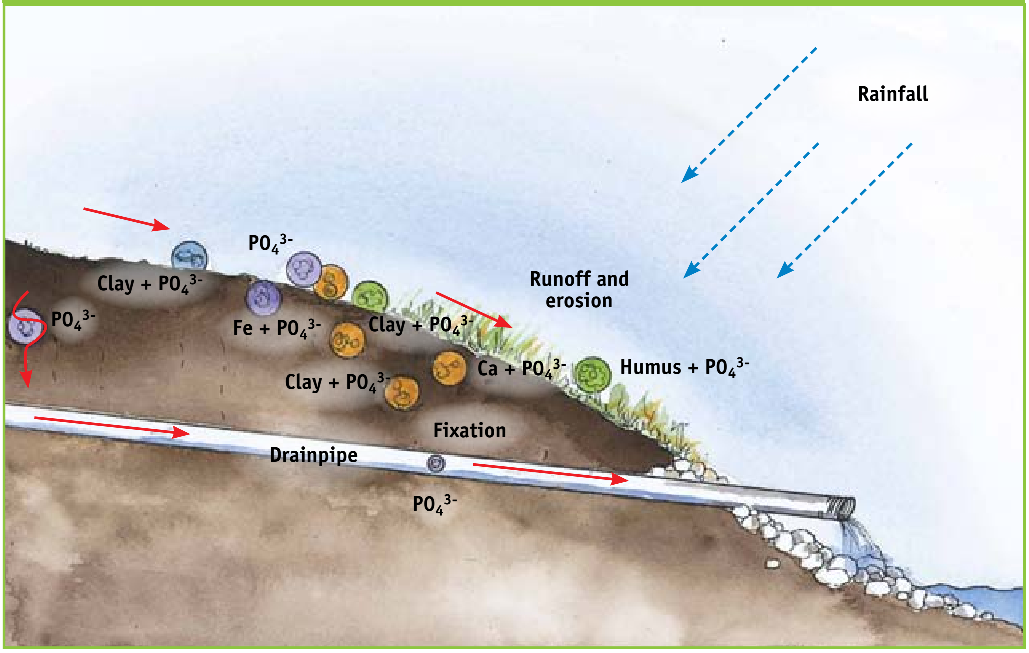
Dry and unprotected, exposed soil conditions can lead to the transport of particulate P with soil sediment by the erosive forces of wind. Most wind-borne particles are deposited on adjacent fields, fencerows or windbreaks. However, some material can reach adjacent surface waters such as lakes and watercourses.

DISSOLVED PHOSPHORUS FORMS

Runoff

Most phosphate in seedbeds and upper layers will remain attached to soil particles. But some will detach from the particles to move with water on the soil surface and be carried off the field with runoff – especially if there are saturated surface conditions and/or semi-frozen soil.

PHOSPHORUS LOSSES FROM A CROPLAND ECOSYSTEM



Phosphorus compounds can be lost from cropland root zones in the following ways.

- **Runoff and erosion**. Surface-applied nutrients in organic (e.g., manure) or inorganic (e.g., phosphate fertilizers) forms can run off directly during storm and snowmelt events – see purple P spheres on surface. Soil erosion can lead to the loss of sediment-bound phosphates – see blue and green P spheres on surface. The risk of erosion and runoff increases with slope, low infiltration rates, compacted or frozen soils, low vegetative or crop cover, and intense rainfall and snowmelt.
- **Drainpipe outflow**. Small quantities of phosphates from applied liquid manure or biosolids (see purple P spheres in pipe), or P attached to clay and organic matter can reach drainpipe systems in soils with large cracks and subsurface macropores.
- **Fixation**. Phosphate is very reactive in soil. It combines with calcium, magnesium, iron, manganese or aluminum to form insoluble compounds, or it binds to soil particles – see gold P spheres in soil profile. A small amount remains in solution at any given time. Much of the phosphate remains in a reserve form, and is slowly released into solution to replenish what's been removed by plants.

Subsurface Drainage

Phosphorus can reach subsurface drainage systems when the first condition below is joined by one or more of conditions 2, 3, and 4.

1 – soils with high soil P concentrations due to long-term application of P from organic or inorganic input sources

2 – deep sandy soils

3 – soils with continuous macropores – including cracks and worm burrows

4 – high organic matter soils (e.g., muck soils) with a low capacity to retain phosphorus.

Some of the dissolved P will follow continuous large pores in sandy and gravelly soils out of the root zone (i.e., the soil occupied by plant roots). Most of the gravitational water draining through the root zone above the subsurface drainpipe will reach the subsurface drainage system. However, this water will only carry some of the surface-dissolved P to drainpipes; most of it will be taken up by growing crops or fixed by soil minerals.

Phosphorus fixed to fine particles – such as clay and organic matter – may also follow macropores and enter subsurface drainage systems. In most cases, sediment and P loads are not high in outflow waters. However, there is a risk of higher levels in outfall (outlet) waters if the drained cropland:

- has a low infiltration rate
- is not protected by a crop cover or crop residues, and
- includes surface drainage components such as surface inlets, which connect directly to the subsurface drainage system.

PHOSPHORUS-LOADING RISK INDEX (P INDEX)

The P Index assesses the risk of surface water contamination from a field, and identifies where measures to reduce phosphorus losses are needed.

The risk is highest when a source of phosphorus lies near a pathway to surface water. This means that the areas receiving the highest rates of phosphorus application, or with the highest phosphorus soil tests, will not always be the areas of greatest risk for phosphorus losses.

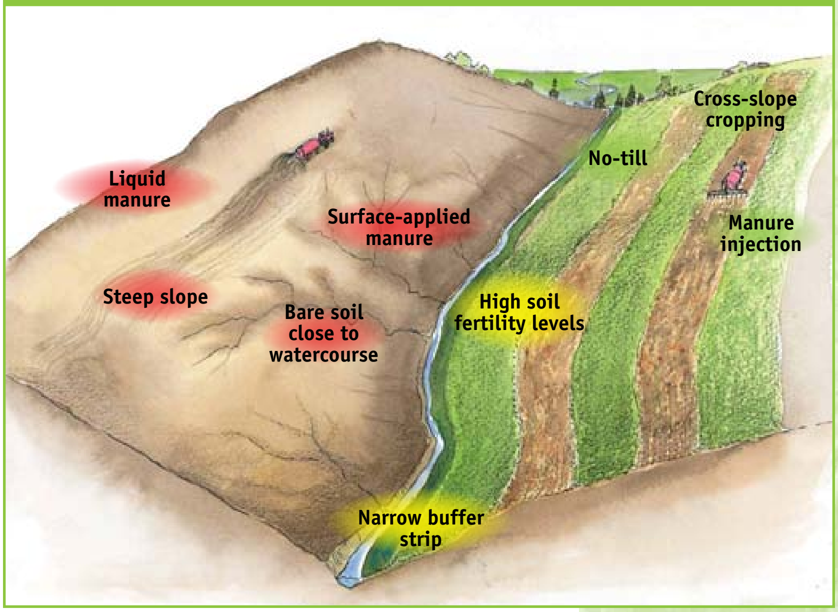
Phosphorus can move off of a field as particulate phosphorus on eroded soil particles, as dissolved phosphorus in surface runoff, or through drainpipe flow. Each of these will have separate source and transport factors, but the sum of each of these components represents the total risk from a particular field. As the risk increases, so do the restrictions on the amount, method and timing of phosphorus applications, to the point where some fields should not be receiving any additional phosphorus.

The following table lists the factors that are considered when assessing the inherent risk for phosphorus losses before the addition of any fertilizer or manure.

INFLUENCING FACTOR		FIELD MEASUREMENT OR INPUT NEEDED TO DETERMINE THE P INDEX
SOURCE	**TRANSPORT**	
PARTICULATE P IN SURFACE RUNOFF – soil erosion potential	– delivery of sediment from field to surface water	• soil texture and surface cover • slope length and gradient • rainfall intensity and duration (average) • distance to watercourse • roughness and cover of flow area
DISSOLVED P IN SURFACE RUNOFF – dissolved P concentration	– runoff potential	• P soil test • field slope • hydrologic soil group
P IN DRAINPIPES – sum of particulate and dissolved P loadings (since most P moves to drainpipes by preferential flow through cracks and worm channels)	– intensity of subsurface drainage network	• drainpipe spacing (systematic or random system) • area included in drainage system

- High P Index = high risk; no P application
- Moderate P Index = limits on rate, timing or method of P application
- Best P Index = low risk

P INDEX FACTORS



This illustration shows the impact of management on the risk of phosphorus losses, even though both fields are close to a stream, have similar slopes, and have highly erodible (silt loam) soils. The field on the left side of the illustration has few soil conservation measures in place, increasing the risk of particulate P losses. A history of high manure application rates has built up the P soil test to very high levels, so there is also a high risk of dissolved P runoff. This field should not be receiving any additional P because the risk of P loss is already so high.

The field on the right side has implemented no-till strip cropping to manage particulate P losses, and has applied phosphorus at much lower rates as guided by soil tests and a nutrient management plan. There is only a narrow strip adjacent to the stream where phosphorus application rates should be restricted, or the phosphorus should be subsurface-banded.

Here are management options where P Index is High.

✔ Implement soil conservation measures to reduce soil erosion, thus reducing inherent risk of phosphorus loss.

✔ Limit application rates of materials that contain phosphorus (e.g., fertilizer, manure, sewage biosolids).

✔ Apply materials containing phosphorus in subsurface bands rather than on the surface, or incorporate immediately.

✔ Eliminate phosphorus applications during the late fall and winter.

NON-AGRICULTURAL SOURCES OF PHOSPHORUS

Phosphorus in the form of phosphates was a common component of dishwasher detergents and industrial cleaners. Phosphate in detergent is being phased out of use in Ontario, reducing the P loading in grey water.

Wastewater (sewage) treatment plants discharge treated water into watercourses or lakes. Not all of the phosphate from treated sewage is removed in the process.

Septic systems can also be a source of phosphorus to lakes and rivers. The likelihood of phosphorus reaching surface water increases if a septic system fails, is close to shorelines, or is illegally discharging.

Recreational boats with facilities can be a source of P-rich water. Discharging sewage from boats into Canada's waterways is against the law, and discharging grey water is discouraged. Many marinas have pump-out facilities.

Urban-based phosphorus pollution includes effluent from wastewater (sewage) treatment plants, storm sewers, and industrial sources.

BEST MANAGEMENT PRACTICES FOR PHOSPHORUS

Practical and proven best management practices (BMPs) can reduce phosphorus pollution from agricultural sources. Most BMPs are site-specific, meaning that every BMP will not be suitable for every source and form of phosphorus, nor for every farm operation. This section is designed to help you select what will work for your circumstances.

BMPs are grouped by farm type on pages 18 and 19.

There are some guiding principles that apply to many of the phosphorus management challenges encountered in most agricultural operations. We'll start with these.

For all **on-farm point sources** of phosphorus:

✔ reduce the amount at the source – reduce volumes and concentrations where possible

✔ divert clean water – keep clean water clean with eavestroughs and berms

✔ manage all liquids – make sure that all contaminated liquids are managed

✔ manage concentrated sources differently from dilute sources

For *concentrated* sources of P on the farm:

✔ properly store, contain and use this nutrient-rich material – this applies to manure storages and handling, sewage biosolids, fertilizers, and concentrated nutrient solutions (e.g., greenhouses).

For *dilute* sources of P on the farm:

✔ collect and treat or re-use the material – this applies to manure runoff, livestock yards, runoff, greenhouse and container irrigation waters, and washwaters (including milking centre).

For **on-farm non-point sources**, the goals for field P management are to:

✔ know what you've got – using nutrient management planning, materials testing, P Index

✔ add what you need, when required, where required, and in the most suitable form

✔ keep what you've got – keep phosphorus in the soil and keep your soil on your cropland through soil management, soil erosion control, and the establishment of natural area BMPs.

Keep phosphorus in the soil and keep your soil on your cropland through soil management, soil erosion control, and the establishment of natural area BMPs.

BMP SUMMARY TABLE, BY FARM TYPE

The following table will show you which BMPs will likely best suit your operation. To use the table, look at the column headings for your type of farm operation and note the BMPs appropriate to it. The rest of this chapter contains brief outlines of BMPs, and links to resources for more detailed information.

BMPs	CONFINED LIVESTOCK	GRAZED LIVESTOCK	GRAIN & OILSEED CROPS	ANNUAL HORT. CROPS	MUCK CROPS	PERENNIAL HORT. CROPS[3]	GREENHOUSE & CONTAINER NURSERY	RURAL NON-FARM
POINT SOURCE BMPS								
NUTRIENT [1] STORAGE	✔		✔	✔	✔	✔	✔	✔
VEGETATED FILTER STRIPS	✔			✔	✔		✔	
CONSTRUCTED WETLANDS	✔				✔		✔	
TANK + TREATMENT TRENCH[2]	✔						✔	✔

Footnotes:

1. Nutrient Storage = for manure, fertilizers, solutions, biosolids, compost, nutrient-enriched irrigation water etc.
2. Tank + Treatment Trench = for septage, milking centre washwaters
3. Perennial Horticulture Crops = field nursery, ginseng, orchards, small fruit, etc.

BMPs	CONFINED LIVESTOCK	GRAZED LIVESTOCK	GRAIN & OILSEED CROPS	ANNUAL HORT. CROPS	MUCK CROPS	PERENNIAL HORT. CROPS[3]	GREENHOUSE & CONTAINER NURSERY	RURAL NON-FARM
NON-POINT SOURCE BMPS								
DO A NMP	✔	✔	✔	✔	✔	✔	✔	
SOIL + SOLUTIONS TEST	✔	✔	✔	✔	✔	✔	✔	✔
RIGHT SOURCE	✔	✔	✔	✔	✔	✔	✔	✔
RIGHT RATE	✔	✔	✔	✔	✔	✔	✔	✔
RIGHT TIME	✔	✔	✔	✔	✔	✔	✔	✔
RIGHT PLACE	✔	✔	✔	✔	✔	✔	✔	✔
MONITORING[4]	✔	✔	✔	✔	✔	✔	✔	
SOIL IMPROVEMENT[5]	✔	✔	✔	✔	✔	✔		✔
SOIL DRAINAGE	✔	✔	✔	✔	✔	✔	✔	
CONTROLLED DRAINAGE			✔	✔	✔			
RESIDUE MANAGEMENT[6]	✔		✔	✔				
EROSION CONTROL PRACTICES[7]	✔		✔	✔	✔	✔	✔	
EROSION CONTROL STRUCTURES[8]	✔	✔	✔	✔	✔	✔	✔	✔
RIPARIAN MANAGEMENT[9]	✔	✔	✔	✔	✔	✔	✔	✔

Footnotes continued:

3. Perennial Horticulture Crops = field nursery, ginseng, orchards, small fruit, etc.
4. Monitoring = there is a monitoring component to most environmental management systems
5. Soil Improvement = cover crops, add organic matter, crop rotation
6. Residue Management = no-till, mulch tillage
7. Erosion Control Practices = field buffers, strip cropping
8. Erosion Control Structures = grassed waterways, WASCoBs, diversion terraces, grade control structures, etc.
9. Riparian Management = buffer strips, livestock exclusion, streambank protection

BMPs FOR ON-FARM POINT SOURCES OF PHOSPHORUS

On-farm control of phosphorus at the source is possible by implementing BMPs from the following categories:

✔ nutrient storage – to contain liquid and solid nutrients

✔ vegetated filter strips – to treat agricultural washwaters

✔ constructed wetlands – to treat washwaters and crop inputs

✔ tank and treatment trench – for onsite treatment of domestic septage and milking centre wastewater

✔ phosphorus reduction at the source – through livestock feeding practices.

NUTRIENT STORAGE

Nutrient storages are constructed facilities designed to contain liquid and solid forms of nutrients used in agricultural operations. Phosphorus loss is reduced by complete containment of the concentrated form of nutrients until the material is applied or transferred to another location.

Nutrient storages are used for:

- liquid and solid manure – including yard runoff, milking centre and other washwaters
- sewage biosolids
- greenhouse and container-nursery nutrient solutions
- on-farm fertilizer storage.

These pictures will give you some general ideas about storage issues and management. There is much more detailed information in companion BMP books.

Manure runoff can contain phosphorus, ammonium, organic matter and pathogens.

✔ Keep clean water clean: divert clean water from system.

✔ Collect and store manure runoff in liquid manure storage systems, or treat in vegetated filter strip systems.

The solid fraction (portion) of liquid manure contains phosphorus.

✔ Design and size liquid manure storages to contain all manure solids and contaminant liquids from livestock operations.

Greenhouse or container-nursery operations may be able to collect and store irrigation and nutrient solutions, which can subsequently be “fertigated” on existing crops or adjacent alternative crops (e.g., orchards, lawns).

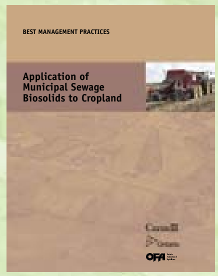
✔ Ensure holding ponds are properly designed.

Organic phosphorus compounds are found in the solid fraction of sewage biosolids.

✔ Make sure temporary storage – such as this liquid sewage biosolid bladder – is properly designed and managed to reduce the potential risk of runoff of liquid and dewatered biosolids before they are used for application.

Chemical fertilizers, which can come in granular, liquid solution or gaseous forms, contain concentrated forms of phosphorus and other crop nutrients. There is a risk of phosphorus contamination of surface water if fertilizers are stored too close to watercourses and lakes.

✔ Prevent runoff from spills or leaks with proper containment and curbed, impervious floors.



BMPi

See these BMP books for more info.

Manure Management

Application of Municipal Sewage Biosolids

VEGETATED FILTER STRIPS

Vegetated filter strips (VFS) are used for treatment of agricultural wastewaters. They are designed to remove contaminants such as phosphorus from wastewater as it is spread out over a wide area on a gentle downslope.

VFS can be used to treat greenhouse and container-nursery nutrient solutions, fruit and vegetable washwaters, and livestock yard runoff.

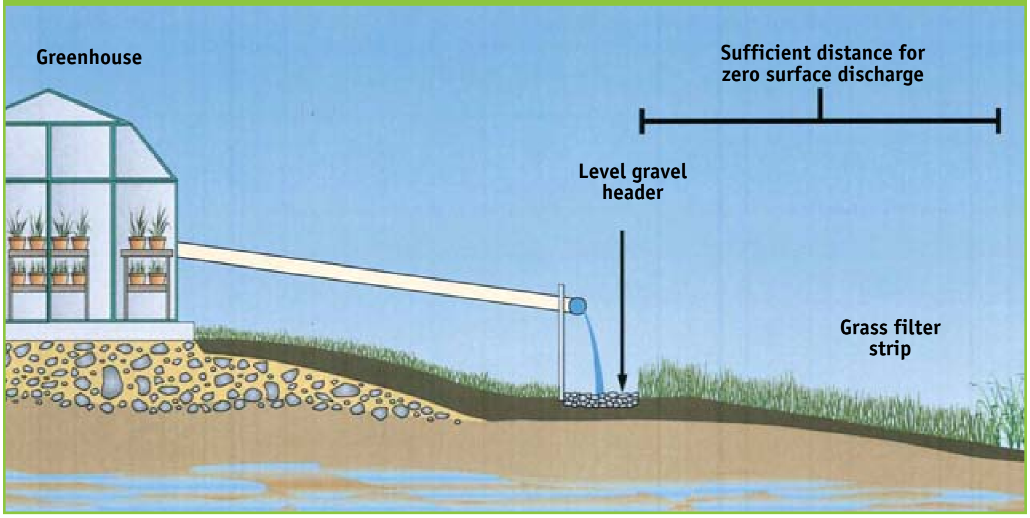
These need a Ministry of the Environment Certificate of Approval.

For design factsheets and manuals, please check the OMAFRA website or contact an OMAFRA resource centre.

www.omafra.gov.on.ca/english/engineer/facts/vfss_manual/vfsmantc.htm

Yard runoff containing both inorganic and organic sources of phosphorus, other nutrients, and enteric bacteria can be a problem for dairy, beef, sheep, horse and goat operations. VFS can be designed to manage and treat yard runoff flows and nutrients.

VEGETATED FILTER STRIP SYSTEM



A VFS system has the following components:

- collection and temporary storage in holding/storage tanks – in this case, in the greenhouse building
- screens for removal of solids in runoff in holding/storage tanks
- a distribution system, either gravity-fed or pump-fed, designed to provide uniform flow across the width of the infiltration area – see pipe and gravel header area
- an infiltration bed of sufficient size and design to allow for uniform and complete infiltration of applied wastewater, i.e., zero discharge under worst-case scenario – see grass filter strip.

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See this BMP book for more info.

Manure Management

CONSTRUCTED WETLANDS

Constructed wetlands are low-cost alternatives to many of the conventional treatment systems for the removal of nutrients, pesticides, and pathogens. Nutrients passing through a constructed wetland are removed by:

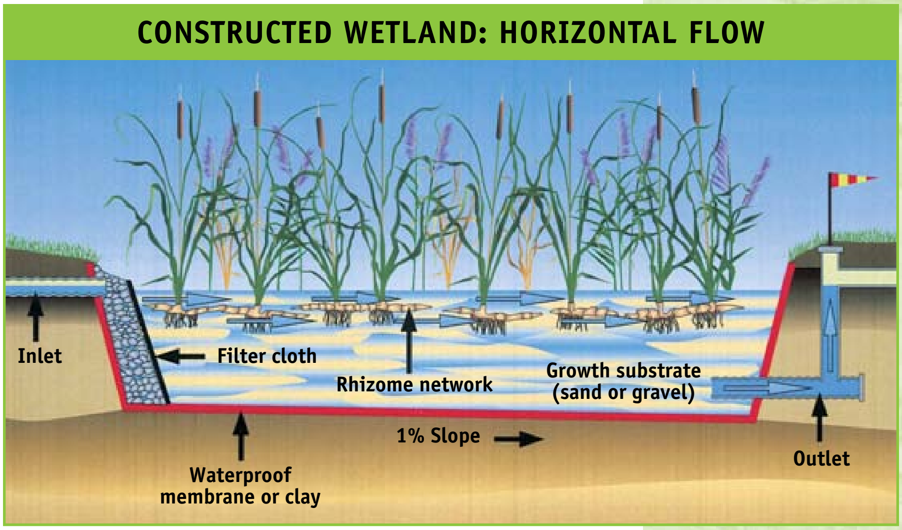
- filtering through the media
- binding to the media
- uptake by plants
- uptake or conversion by attached micro-organisms on plant roots and on media itself.

Constructed wetlands have been used to treat:

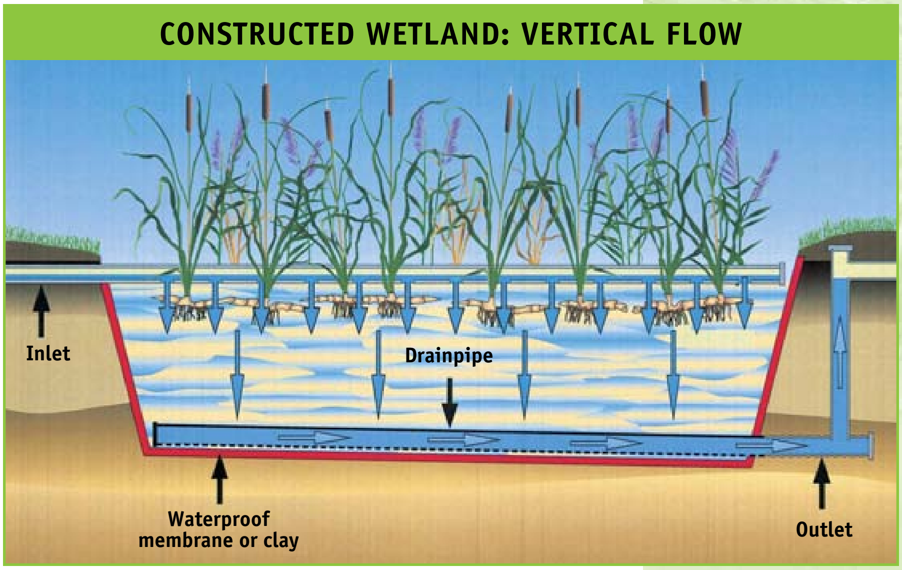
- greenhouse and container-nursery nutrient solutions
- fruit and vegetable washwaters
- livestock yard runoff and milking centre washwaters.

Note: Constructed wetlands require professional design by a qualified engineer. These projects also require approval by the Ministry of the Environment or the local building department.

There are two forms of constructed wetlands: horizontal flow and vertical flow. In horizontal flow, wastewater flows over the top of the system, and nutrients are removed largely by plant uptake and associated microflora.



A vertical-flow wetland directs the flow downward through the substrate. Depending on the nature of the contaminants to be removed, it can be run aerobically or anaerobically.



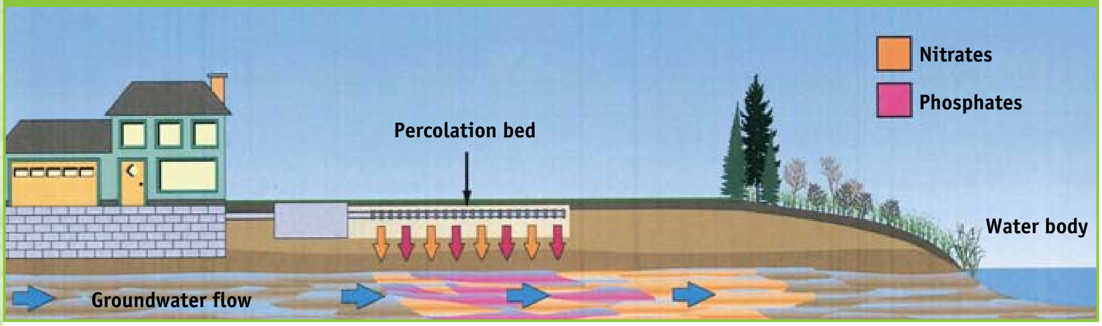
ON-SITE WASTEWATER TREATMENT SYSTEMS

Tank and treatment trench systems are onsite treatment units that eliminate the need for storage or transfer to wastewater treatment plants in rural areas. These systems use the filtering and biological action of soils to remove phosphorus and other contaminants.

There are two key applications of this BMP in rural areas:

- domestic septic systems – for the treatment of household black and grey waters that contain phosphorus compounds
- milking centre washwaters – usually from smaller, tie-stall operations producing solid manure.

SEPTIC SYSTEM



Septic systems have a tank, a network of pipes, and billions of organisms that break down household wastewater. The tank prevents the solids and fats from damaging the tile bed. Soil bacteria in the tile bed and surrounding soil treat pathogens, nitrates and phosphates in the septic effluent. However, some nitrates and phosphates will move through the soil profile. Risks to surface water and groundwater can be reduced with proper attention to soil suitability, separation distances, and regular cleanouts.

Grey water from domestic laundry, kitchens and bathrooms contains soap and detergent-based phosphorus. Black water from toilets is a source of organic P. Improperly functioning systems or illegal systems hooked up to pipes that discharge to rivers, ponds or lakes are a point source of phosphorus for surface water.

Waste milk contains organic P, and milking centre washwaters can contain detergents with P compounds.

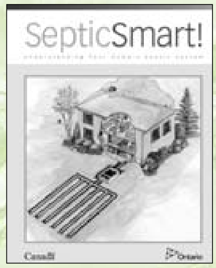
✔ To reduce P from washwaters, remove milk from the pipelines (and feed to calves), and use phosphate-free detergents.

Septic systems don't last forever – all systems need to be replaced eventually.

✔ Have your tank inspected for sludge and scum buildup on a regular basis (3–5 years).

✔ Clean it out when a third of the depth of your tank is full of sludge and scum.

✔ Look for signs of septic failure: slow drainage, septic smells, spongy beds, and sewage backups and breakouts.



See **Septic Smart!**, a 12-page booklet available from OMAFRA.

BMPi

See this BMP book for more info.

Manure Management

REDUCTION OF PHOSPHORUS AT THE SOURCE

REDUCE P CONTENT IN MANURE

There are BMPs for livestock nutrition and feeding practices that reduce phosphorus intake or reduce phosphorus in excrement.

✔ Don't overfeed phosphorus in livestock rations or supplements.

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See this BMP book for more info.

Manure Management

"Green Lawn, Green Lake… Break the Link!" Poorly timed applications, excessive rates, and poor storage practices can lead to P runoff.

Feed supplements can reduce phosphorus in manure. Most of the phosphorus in grains fed to livestock (i.e., corn and soybeans) is phytate-P – which is not readily available to animals, particularly monogastric animals like poultry and swine. Phytase-supplemented diets will result in 15–25% less manure P than conventional diets.

✔ Feed livestock phytase-supplemented diets to reduce manure P.

✔ Choose low-phosphorus protein supplements for dairy cattle to reduce manure P levels. Feed a balanced ration to dairy cattle.

PHOSPHATES AND WATERFRONT ACTIVITIES

Cottages, estate properties, marinas and other waterfront private properties can be sources of phosphate pollution.

Manicured lawns and ornamental plants require considerable annual additions of fertilizers to maintain strong root growth and vigour. Shoreline alterations can lead to increased erosion, contributing particulate P to the near-shore zone.

Poor waste management at marinas can lead directly to phosphate loading at shoreline waters. This is especially true with poor plumbing-sanitation practices from large pleasure craft. Grey and black water discharged directly from boats into lakes is also a source of phosphorus pollution. Preventative measures include adding a tank for grey water, and using phosphate-free detergents while boating.

✔ Plant naturalized vegetated buffers along the shore to stabilize shorelines and to reduce the requirement for fertilization near shoreline areas and aquatic ecosystems. Naturalized vegetation is also less attractive to geese and other waterfowl, reducing the P loading from bird feces.

✔ Plant naturalized vegetated buffers between intensively managed lawns and shorelines. Buffers trap P fertilizer runoff before it reaches lakefront aquatic ecosystems.

BMPs FOR ON-FARM NON-POINT SOURCES OF PHOSPHORUS

While many of the BMPs in this section benefit multiple areas of the farm, for our immediate purpose they are grouped as follows:

- nutrient management planning – knowing what you've got, and testing materials for nutrient levels
- crop nutrient management – focussing on the 4 Rs of nutrient management: right product, right rate, right time, and right place
- keeping P in the soil, on the field, and out of natural areas with BMPs for:
    - cropland drainage to remove excess soil water and reduce P loss from erosion and runoff
    - soil management to improve soil quality and resilience
    - soil conservation to reduce soil erodibility
    - field structures to reduce cropland erosion and runoff
    - riparian areas to prevent P from entering surface waters.

NUTRIENT MANAGEMENT PLANNING – KNOWING WHAT YOU'VE GOT

Building a nutrient management plan (NMP) is a 10-step process that helps you achieve a sustainable on-farm crop and manure nutrient management program.

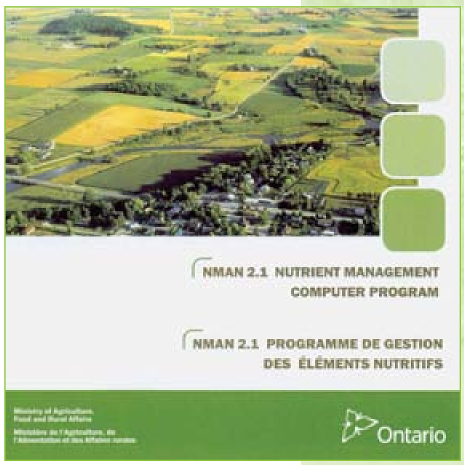
A NMP accounts for soil fertility levels, all nutrient sources, site features, management practices, and risk factors. The key outputs of this program are:

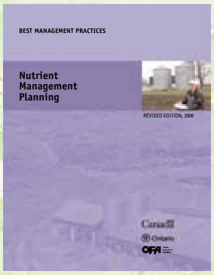
- optimized application rates and timing
- analysis of any need for additional crop nutrients
- identification of appropriate setback distances
- establishment of application setback values.

A NMP will also indicate environmental limitations, land-base requirements, and annual manure volumes.

The P Index is a critical component of this analysis.

A NMP accounts for fertility levels, all nutrient sources (including phosphorus), site features, management practices, and risk factors.





BMP*i*

See these BMP books for more info.

Nutrient Management Planning

Manure Management

Managing Crop Nutrients

Steeply sloping cropland is at a greater risk for erosion and runoff. The P Index is higher on steeply sloping fields.

Many components of your NMP will help you protect surface water from phosphorus loading. It will specify N and P application rates, liquid-loading limits, application separation distances, setbacks, and land-base requirements.

NUTRIENT LEVEL TEST

Nutrient level tests will tell you the fertility levels of a given growth medium, nutrient source, or crop tissue. Knowing the level of fertility can help make nutrient applications more effective and less wasteful, which can prevent the risk of phosphorus loss.

There are several types of nutrient level tests for:

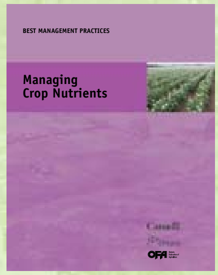
- soil
- manure
- sewage biosolids
- nutrient solution
- tissue
- soil-less media.

✔ Frequent and regular nutrient solution analyses will help you maintain proper phosphorus levels and reduce P concentrations in used nutrient solutions.

"Applying fertilizer every year without taking a soil test is like adding a litre of oil to the crankcase before you start the tractor each time. At best, you'll waste some dollars... at worst, you'll damage the engine (your soil), or spill the excess somewhere we don't want it. Don't guess – soil test!" – Keith Reid, OMAFRA Soil Fertility Specialist

In the year of application, manure P is considered 40% as available as fertilizer P. And at least 80% will become available over the longer term, adding to the total available phosphorus pool. Combine soil test results with manure test information. This will help prevent the buildup of soil P to levels that would restrict application rates in subsequent years.

✔ Test manure for phosphorus (nutrient) levels.



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See these BMP books for more info.

Manure Management

Managing Crop Nutrients

Nutrient Management Planning

CROP NUTRIENT MANAGEMENT

These BMPs help growers maximize the effectiveness of applied nutrients and reduce phosphorus loss.

RIGHT PRODUCT OR SOURCE OF CROP NUTRIENTS

✔ Match the nutrient source and product to crop needs and soil properties. Be aware of nutrient interactions: balance nitrogen, phosphorus, potassium, and other nutrients according to soil analysis and crop needs.

Don't try to meet all of your nitrogen requirements with manure. The nitrogen won't be available at the right rate and right time, and you risk over-applying phosphorus. It's better to use manure to supply the right rate of phosphorus, using timing and placement to capture as much of its nitrogen as possible, and then supply the remainder of the crop's nitrogen need with fertilizer.

RIGHT RATE FOR APPLYING CROP NUTRIENTS

The right rate meets crop needs and minimizes environmental risk. The key principles for right rate are:

- know what you've got in your soil – soil test
- account for all sources of nutrients
- apply according to science-based recommendations – see your soil test results.

The "right rate" approach is an attempt to balance crop needs with reduced environmental risk.

✔ Calibrate all nutrient application equipment to ensure actual rate is being applied.

To turn "waste" into "resource," maximize nutrient availability from organic sources (manure and sewage biosolids), and account for these nutrients in your fertilizer program.

RIGHT TIME FOR APPLYING CROP NUTRIENTS

Apply crop nutrients when the actively growing crop requires them and at a time when the risk of loss is minimal. Applying phosphorus when there is no crop, no cover, or just before a forecasted storm event risks the loss of phosphorus from erosion and runoff.

✔ Apply fertilizer at the time the crop needs it. Some nutrients such as nitrogen can move easily in the soil. Other nutrients such as phosphorus tend to get bound to soil particles, and are relatively immobile in the soil.

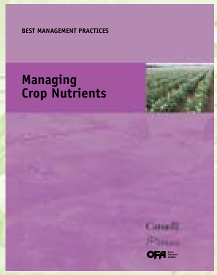
For most crops, the best season to apply most fertilizers is at planting time for early season growth and, if necessary, in late spring for the remainder of the requirement.

✔ Apply most fertilizers at planting time.

Winter application is not a best management practice. There is no crop to absorb the nutrients, and too great a risk of manure or sewage biosolid runoff to surface water.

✔ Avoid winter application.

For more information on requirements for winter application, please see BMP *Manure Management*.



BMPi

See these BMP books for more info.

Manure Management

Managing Crop Nutrients

Soil is a good filter and soil flora compete with many potentially harmful bacteria and pathogens. However, there are conditions when the risk is higher for liquid manure/biosolid to reach the subsurface drainpipe. Risk is elevated when high rates are applied to crack-prone soils during a dry summer or on moist soils in the spring or fall, and when water is running in the drainpipe.

RIGHT PLACEMENT FOR CROP NUTRIENT APPLICATION

Fertilizers and manures can be broadcast, side-dressed, injected or dribbled. P fertilizer or manure on the surface is subject to rapid loss as dissolved reactive P (DRP) with runoff. Subsurface banding or incorporation reduces this risk.

✔ Incorporate surface-applied solid or liquid manure soon after application. Otherwise it can run off from steeply sloping cropland to surface inlets.

The right source, right rate, right time, and right place help you meet your goals for sustainable production: optimum yields with minimal risk to the environment.

Methods that place P fertilizer below ground make the compounds more available and less prone to loss caused by erosion and runoff.

✔ Band phosphate fertilizer to place it where the crop can access it.

✔ Inject or incorporate manure immediately after application to reduce the risk of nutrient loss.

CROPLAND DRAINAGE

These BMPs reduce phosphorus loss from runoff by improving cropland soils' ability to store water.

SUBSURFACE DRAINAGE

Subsurface drainage – also known as tile drainage – involves plastic perforated pipe placed below the soil surface to remove excess water from the root zone. Drained croplands are at a lower risk of erosion, surface runoff of contaminated water, and soil compaction.

Some of the nutrients applied for crop growth can reach tile outlets. What goes on, can go through.

BMPs such as nutrient management planning and crop nutrient management should be in place to reduce this risk.

Rain and snowmelt will not readily soak into (infiltrate) saturated soils. Saturated soils are prone to runoff and P loss. Subsurface drainage systems remove enough soil water to alleviate saturated soils. Drained soils are less prone to erosion and runoff.

CONTROLLED DRAINAGE

The water table can be controlled by keeping water in drainpipes at times of year when the soil doesn't need to be dry for planting or harvest. This reduces the volume of drainage water, and also the amount of phosphorus and other nutrients that leave the field and enter surface water. It also provides water to the roots of the crop (which is less expensive than overhead irrigation), and reduces the risk of spreading leaf diseases.

Organic soils such as muck or peat are very high – 30–98% – in organic matter content. The organic matter begins to break down as soon as soils are exposed to air by drainage. This process is known as *subsidence*. Nitrogen, phosphorus, and other nutrients are released through mineralization as the organic matter breaks down, and can be lost through the subsurface drains. By keeping as much of the soil profile as possible under water, mineralization decreases.

Controlled Drainage

By using water table management devices (pictured) and the ditches and pipes of the existing drainage system, water table levels can be kept at depths that will supply water and reduce subsidence rates. Soils must have an impermeable layer at depth, and grades must be very level for controlled drainage to be an option.

DRAINPIPE OUTLET PROTECTION

Ditchbank scouring and erosion are controlled by placing erosion-resistant materials around subsurface drainage outlet pipes.

✔ Inspect pipe outlets. Look for bank erosion and take measures to correct and prevent further loss.

Drainpipe Outlet Protection

Soils around drainpipe outlets are prone to erosion and sediment P loss. This is due to the combined effects of outfall waters on the soil below the outfall and the scouring effects of high-flow conditions along ditch and stream banks.

✔ Replace end pipes with corrugated metal (rigid) pipe to prevent breakage.

✔ Place angular rock (riprap) underlaid by erosion-resistant fabric in an apron-shaped configuration to prevent scouring from high-flow conditions.

Constructed Wetlands

Subsurface drainage systems with many surface inlets may lead to sediment-bound P loss. By discharging subsurface drainage outflow into a constructed wetland, the wetland plants will help to remove most of the sediments and phosphates in the drainpipe outflow.

MONITORING DRAINPIPE OUTLETS AND SURFACE INLETS

Unless precautions are taken, high application rates of liquid manure can enter subsurface drainage systems.

✔ Pre-till to break up cracks, and apply lower rates.

✔ Monitor drainage inlets and outlets to prevent manure P from entering surface water systems.

Monitoring studies have shown that in certain conditions, manure can reach outflow subsurface drainpipes in spring and fall, when the pipe is running. If manure in the outflow is observed (as shown in the sample bottles on the right), cease operations and reschedule when drainpipe is not running.

BMPi

See these BMP books for more info.

Buffer Strips

Streamside Grazing

Cropland Drainage

Soil Management

Water Management

Fish and Wildlife Habitat Management

SOIL MANAGEMENT

The following BMPs improve soil quality, water infiltration, and resilience to degradation caused by erosion or compaction.

COVER CROPS

Cover crops are used to cover the soil when a crop is not being grown.

Most horticultural and field crops provide reasonable protection from wind and water erosion when mature. However, cropland soils can be exposed and vulnerable to erosive forces after harvest in the fall, throughout the winter (especially if there is minimal snow cover), and in the spring before there is full crop canopy.

✔ Sow cover crops such as spring cereals, broadleaf non-legumes or legumes to keep soils covered. Consider over-seeding cover crops following tillage, aerial seeding before harvest, or planting as soon as possible after harvest.

Cover Crops

Cover crops such as spring cereals, broadleaf non-legumes, or legumes can be sown to keep soils covered. Early establishment in the fall will provide better cover over winter.

CROP ROTATION

Growing the same annual crop year in, year out degrades the soil and decreases yields. A combination of tillage practices, minimal organic matter input, and exposed soil will lead to poor seedbed quality and erosion.

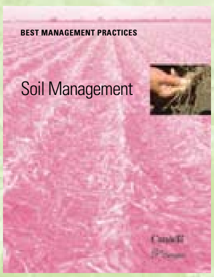
Crop rotation is the practice of alternating crop families – in some cases annually – on field and horticultural cropland. Crop rotations can:

- increase soil organic matter – especially if forages are used

- improve seedbed structure – with varied root systems
- protect soil – narrow-seeded cereals plus pasture and hay crops will cover the soil more effectively than regular row crops.

Crop Rotation

✔ Alternate crop families each year (e.g., cereals then broadleaves) to reduce soil degradation.



BMPi

See these BMP books for more info.

Soil Management

Cover Crops (2012)

SOIL CONSERVATION

The following BMPs help reduce phosphorus loss and soil erosion from cropland.

RESIDUE MANAGEMENT

Managing residues from the previous crop can provide soil cover after harvest and until the canopy development of the next crop.

Some grains and oilseeds leave tons of unused biomass on the soil surface.

In conventional systems, crop residues are chopped up and buried. But in conservation tillage systems, they are left on the surface or only partially buried.

The material acts like a mulch to protect the soil, and as it breaks down, it adds organic matter to the soil.

✔ Practise mulch tillage or no-till to minimize soil disturbance, enrich soil, and reduce erosion and runoff.

Bare Soil

Conventional tillage leaves no residue on the surface – increasing the risk of erosion and runoff (with phosphorus attached).

No-Till

In a no-till cropping and tillage system, the soil is undisturbed prior to planting, and well-protected from erosion and runoff. Adding soil conservation structures and surface water management practices will further reduce the risk of erosion, runoff, and loss of phosphorus.

FIELD BUFFERS AND WINDBREAKS

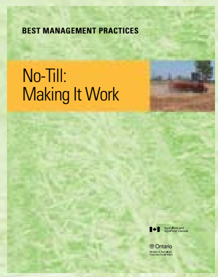
Grassed borders slow down runoff and can filter some sediment and soil-attached P at the edge of fields.

Field Buffers

Cropland perimeters, headlands and fencerows can be converted to buffer strips of permanent sod.

Windbreaks

Wind erosion can transport soil and attached nutrients off site. In some watersheds, windblown sediments can be a source of phosphorus to rivers, lakes and streams. BMPs such as field windbreaks will reduce cropland wind erosion.



BMPi

See these BMP books for more info.

Soil Management

No-Till: Making it Work

CONTOUR STRIP CROPPING

Contour strip cropping involves crops grown in a systematic arrangement of strips across a field along contours. The intent is to reduce soil erosion from water, and therefore reduce the transport of sediment and attached inputs such as phosphates.

Contour Strip Cropping

Strip combinations include alternate rows of:

- forage and row crops
- cereals and row crops.

Crop choice and strip width will depend on field slope, soil erodibility, and machinery widths.

EROSION CONTROL

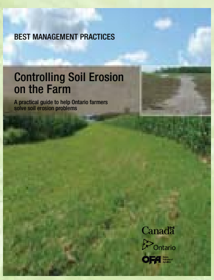
These BMPs are professionally designed structures that help to reduce phosphorus loss caused by cropland runoff and soil erosion.

GRASSED WATERWAYS

Grassed waterways are broad, shallow, vegetated channels. They are designed and constructed to transport the concentrated flow of surface water (runoff) at safe velocities.

Grassed Waterways

When properly constructed, grassed waterways can safely transport large water flows downslope. They decrease flow velocity, thereby minimizing erosion. The vegetation helps remove inputs such as nitrogen, phosphorus, herbicides and pesticides through plant uptake and sorption by soil. Soil is better aerated, and water quality and aquatic habitat are improved.



BMPi

See this BMP book for more info.

Controlling Soil Erosion on the Farm

DIVERSION TERRACES AND WATER AND SEDIMENT CONTROL BASINS (WASCoBs)

Diversion terraces are constructed across field slopes. They reduce erosion and runoff by intercepting, detaining, and safely conveying runoff to an outlet.

Water and sediment control basins are erosion control structures commonly installed to prevent bank and gully erosion on farmland. These structures control erosion caused by concentrated water flows, but are not effective in combatting sheet erosion.

Diversion Terraces

Narrow-base terraces have 2:1 slopes on both the front slope and back slope. Both front and back slopes are seeded to perennial grasses.

Water and Sediment Control Basins

A WASCoB consists of a berm and ponded area. The runoff water is temporarily stored behind the berm, eliminating its erosive capabilities further downslope. This ponded water is slowly released through an inlet riser pipe to an underground drainpipe exiting at an adequate outlet.

RIPARIAN AREAS

Riparian areas are the transitional zones between bodies of surface water and upland areas. Think of river and stream banks, floodplains, and ravine slopes. Among their many important functions, well-vegetated riparian areas protect natural areas from the cumulative effects of upland activities.

The BMPs on the next page help to prevent phosphorus from entering directly into watercourses and other surface waters.

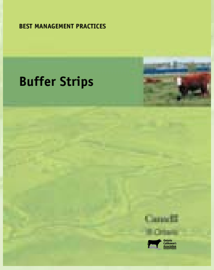
See OMAFRA Factsheet *Grassed Waterways,* Order no. 05-2009.

BMP*i*

See these BMP books for more info.

Water Management

Buffer Strips



BUFFER STRIPS

Buffer strips are strips of planted permanent vegetation – grass, herbaceous shrubs, trees or a workable combination of any of these – alongside watercourses, ponds, lakes or wetlands.

Buffer Strips

Buffer strips are placed strategically along sensitive natural areas to reduce the impact of cropland runoff. Generally, wider buffers are best. Diversely vegetated buffers are the most effective and provide better habitat value as well.

Narrow Buffers

Narrow buffers filter runoff from flat landscapes, and also help stabilize the ditchbanks. They are often complemented by erosion control structures such as rock chute spillways. These structures prevent gullies from forming when concentrated flow spills into drainage channels.

STREAMBANK PROTECTION

The banks of watercourses can be protected from erosion and slumping by "hard" structures and bioengineering features. Check with your local Conservation Authority for permission and approvals before proceeding with streambank protection projects.

Bioengineering Features

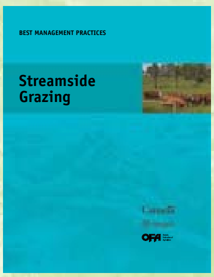
Live, rootable cuttings are planted along eroded banks of small streams to create a living root mass that will stabilize and bind the soil.

LIVESTOCK EXCLUSION FROM STREAMS

In some cases, livestock access to watercourses and other natural aquatic habitats can degrade water quality and destroy habitats. A suite of grazing and streamside BMPs can limit access.

Livestock Exclusion

The nature and extent of the problem depend on the number and type of animals per unit riparian area (density), the time of year, the area's sensitivity, and the grazing BMPs in place. High-risk situations require more permanent solutions. Fencing is the best option to exclude livestock in yards from watercourses.



BMP*i*

See these BMP books for more info.

Buffer Strips

Streamside Grazing

For More Information

BEST MANAGEMENT PRACTICES

For more detailed information on closely related BMPs, we urge you to see several other BMP books, including:

Buffer Strips
Controlling Soil Erosion on the Farm
Cropland Drainage
Managing Crop Nutrients
Manure Management
Nutrient Management Planning
No-Till: Making It Work
Soil Management.

ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

OMAFRA offers many publications on related topics. Of particular relevance:

Soil Fertility Handbook, OMAFRA Publication 611

A complete listing of all OMAFRA products and services is available at www.ontario.ca/omafra

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If you have a question regarding farming, agri-business, or rural business, call the Agricultural Information Contact Centre at 1-877-424-1300 or e-mail ag.info.omafra@ontario.ca

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