BMPs FOR APPLYING NUTRIENTS

"Nutrient use efficiency has many definitions. Several of them focus on a crop's ability to recover an applied nutrient. Short-term increases in such efficiencies are easily attained by reducing rates. But rates lower than optimum can reduce the long-term efficiency of cropping systems.

Sustainable efficiency focuses on:

- ensuring all nutrients are used, not wasted
- meeting crop needs
- maintaining soil fertility."

– Dr. Tom Bruulsema, International Plant Nutrition Institute

Put the right rate of each nutrient at the right time in the right place. In a nutshell, this is your BMP for applying nutrients.

The challenge, of course, is in reaching this goal for a wide range of crops, soils and weather conditions, and using a range of materials. The BMPs suggested here build on the basics, and try to account for the various conflicting forces to optimize profitability, practicality and environmental stewardship.

This chapter will guide you through:

- getting the right rate
  - accounting for nutrients from all sources
  - BMPs for application of liquid manure and biosolids
  - balancing nutrient input with removal in the long term
  - calibrating spreaders and planting equipment with fertilizer attachments
- at the right time
  - matching plant uptake
  - avoiding soil compaction
  - suiting the crop rotation
- in the right place
  - placing for maximum availability to crop
  - exercising extra care in areas at high risk of contaminating surface water or groundwater.

We'll begin with a brief outline of Nutrient Use Efficiency, since it is at the heart of improving profits and reducing environmental impacts from nutrient use.

NUTRIENT USE EFFICIENCY

Nutrient Use Efficiency (NUE) refers to how well a crop uses available soil nutrients. As more nutrients are taken up and used by the crop, fewer nutrients remain in the soil to be lost (i.e., leached, volatilized) or immobilized.

Nutrient management systems that strive to improve NUE incorporate practices will:

- provide the required amount of available forms of nutrients when the crop needs them
- place nutrients where the crop roots can access them
- reduce the amount of nutrients (e.g., nitrate) in the soil when the crop can't use it
- account for and manage all sources of plant-available nutrients
- follow good cultural, soil and water management practices to encourage vigorous crop growth.

BMPs FOR IMPROVING NUE

AREA	BMP
CROP ROTATIONS	✔ rotate crops because crop growth is improved by following a crop with any crop but itself in a rotation, therefore increasing nutrient uptake ✔ grow a legume or forage before a crop with high N requirements ○ legumes and forages fix N from the atmosphere, which can be used by subsequent crops
VARIETAL SELECTION	✔ consider choosing cultivars that produce the highest yield with the same inputs as they will have the highest nutrient and water use efficiency
TILLAGE	In reduced tillage systems: ✔ band in the root zone as it's more beneficial (compared to surface broadcast)
NUTRIENT SOURCE	✔ don't necessarily try to supply all of a crop's needs with manure-based N ✔ apply manure to meet part of the N requirements of the crop, and then add nitrogen fertilizer for the balance to prevent over-application of phosphorus, and compensate for uneven manure application
TIMING	✔ use split application for grains and oilseeds, so most of the N is applied just before maximum crop uptake
TRAP CROPS	✔ use trap crops in the off-season to recycle plant-available N

Trap crops such as oilseed radish are cover crops grown in the off-season that trap and release applied nutrients for next year's crop.

Legume cover crops provide nitrogen to the subsequent crop.

Cover crops help prevent soil erosion and build soil organic matter, retaining more nutrients in the field.

Improve NUE and you will:

- increase yields and improve product quality
- lower fertilizer input and application costs
- reduce the risk of runoff and groundwater contamination.

Achieving this goal is hampered by variability in crop requirements, and imprecision in determining needs and application rates.

RIGHT RATE

RIGHT RATE – SUMMARY OF BMPs

BMP	DETAILS
✔ Soil test (see pp. 56–61)	• test regularly, same point in rotation, same place in field
✔ Tissue test (see pp. 71–72)	• for perennial and high-value crops, verify nutrient content and adjust application program • for all crops, diagnose nutrient deficiencies
✔ Interpret fertility test results (see pp. 68–71)	• use only the information from the test that is relevant to your situation • look for trends in soil fertility levels over time • determine whether sufficiency or build-up and maintenance is appropriate for your situation • use OMAFRA recommendations as a starting point
✔ Account for nutrients from all sources	• account for the available nutrients from manure or previous crop • meet the N needs of the crop with a combination of manure and fertilizer
✔ Adjust for environmental limitations	• account for liquid loading and runoff risks as defined by depth to bedrock, depth to water table, slope and soil texture
✔ Balance nutrient input with removal in the long-term	• meet crop needs for N • build up soil test P and K to desired levels and maintain them by balancing nutrient input with removal in the long-term
✔ Calibrate application equipment	• use BMPs to calibrate solid manure spreaders • use BMPs to calibrate fertilizer attachments for planting equipment • use BMPs to calibrate liquid manure application equipment

Taking care to maximize nutrient availability from these sources, and accounting for these nutrients in your fertilizer program will turn "waste" into "resource."

ACCOUNT FOR NUTRIENTS FROM ALL SOURCES

Since the manure and legumes are already on the farm, it makes sense to use these nutrients before spending money on fertilizers.

Where manure is applied to meet all the nitrogen needs of a crop, the amount of P applied exceeds the amount removed by the crop. If this is continued for a number of years, the phosphorus soil test will build up to the point where there is no benefit to the crop from additional P, and the risk of contaminating adjacent surface water increases.

With annual manure applications, this P buildup can be avoided. Limit the manure application to provide no more than two-thirds to three-quarters of the N requirement of the crop. The remainder of the N requirement can be provided by mineral fertilizer. Where manure is applied only once every two or more years, it may be appropriate to use a higher rate of manure N, but be sure the manure rates do not exceed the requirements of the crop.

Including some nitrogen from mineral fertilizers is a good idea. Nitrogen release from organic materials is dependent on the weather, and in cool, damp seasons, the crop may not receive enough nitrogen from organic sources for optimum growth and yield. Also, manure application is often uneven, so parts of the field receive insufficient manure to meet crop requirements. A blanket application of mineral N fertilizer helps to increase overall yields by ensuring all parts of the field have received some N.

Reducing the N application rate from manure also reduces the amount of P being applied. In situations where soil test P isn't excessive, use manure P to furnish all P requirements – provided N requirements are not exceeded. Be sure to account for N from previous manure applications.

Only 40% of the manure P is considered to be available to crops in the year of application, but this is primarily because of uneven application or placement where crop roots cannot easily reach the P in the manure. At least 80% of the total applied P will eventually contribute to an increase in soil test P.

"I use the NMAN program as a tool to balance nutrient inputs from manure and commercial sources. Balancing the nutrient inputs has saved us significantly in fertilizer costs, is better for the environment, and allows us to achieve what we feel is an economic yield."

– Dave Biesenthal, Walkerton

Manure application is often uneven, so some parts of the field will fall short of crop requirements from manure. Reduce the manure application rate, and supply the balance with a uniform application of mineral N fertilizer to ensure all parts of the field have received some N.

ADJUST FOR ENVIRONMENTAL LIMITATIONS

Some sites are inherently more vulnerable to losses (particularly nitrate leaching) than others, and application rates should be adjusted to reflect this. Risk factors include soils with high runoff potential, shallow soils over bedrock, and soils with groundwater close to the surface.

Two factors contribute to the risk of nutrients moving away from where they are applied:

- ▶ the total amount of nutrient applied, and
- ▶ the volume of material used to carry those nutrients.

Where manure is applied only once every two or more years, it may be appropriate to use a higher rate of manure N. However, be sure the manure rates do not exceed the requirements of the crop.

Nutrients that are not utilized by the crop and not held tightly by the soil can be carried to surface water or groundwater. This type of loss will occur equally with nutrients from commercial fertilizer and organic sources, so the key management factor is to **keep application rates balanced with crop requirements.**

More dilute materials, such as manure or biosolids, may be applied at high volumes to meet crop requirements for nutrients. There is a risk that these materials, particularly the liquid materials, might move from where they are applied either at the time of application or during a subsequent rainfall or snowmelt.

Ensure Proper Closure of Trenches from Fertilizer Openers

Where manure or fertilizer has been applied in bands running up and down slope, the slots left by the opener can be a starting point for rill erosion during rainfall events.

Even worse than the soil movement in this circumstance is the movement of concentrated nutrients that could be carried directly into surface water.

Ensure that equipment is properly set to prevent this from happening, or invest in a different toolbar configuration for effective closure of the slot.

APPLYING LIQUID MANURE AND BIOSOLIDS

The risk of surface runoff is less on sandy soil than on clay soil, but the risk resulting from excessive infiltration is higher.

Surface Runoff

The risk of runoff increases with soils of low permeability, and with increasing slope. The risk of runoff is much greater from a sloping field than from a level one, and from a clay soil than from a gravelly soil.

✔ **Don’t apply liquid materials at rates where the material would run off the application site.**

Infiltration

Liquids applied at high volumes can move down through cracks, earthworm burrows and other large holes in the soil. This may increase the risk of contamination of groundwater, or of surface water if there is preferential flow to field tile. The risk of groundwater contamination is increased if there is fractured bedrock close to the soil surface, or if there is shallow groundwater.

Avoid preferential flow through large cracks or holes.

✔ **Keep application rates low enough that there is no ponding** on the surface.

✔ **Pre-till the soil** to break up any large cracks or earthworm burrows.

✔ **Avoid application when soils are wet.**

For more details on specific limits to manure application, refer to the *Manure Management* BMP book, or to the NMAN software and workbook.

Application of nutrients on exposed bedrock increases the risk of groundwater contamination, and will not provide any crop yield increase. Keep manure applications back at least 3 metres (10 ft).

Potential for Surface Water Contamination from Manure Runoff

Manure contains both nutrients and pathogens, which should stay out of water. Determining how far to keep manure applications from watercourses depends on many factors, including:

- soil moisture absorption capacity at the time of application
- slope near the watercourse
- soil texture, and
- manure type, application method and volume.

Where manure is incorporated a few days before planting, the separation distance may not need to be as wide as surface-applied manure (same slope and texture) in early spring. Where surface water enters a watercourse as a stream of concentrated flow, a separation distance that includes the path of flow would be more logical than a constant width along a watercourse.

BALANCING NUTRIENT INPUT WITH REMOVAL IN THE LONG TERM

Over the long term, the application of nutrients (particularly phosphorus) should balance fairly closely the removal of those nutrients by the harvested portion of crops. In low-testing soils, nutrient applications above crop removal are appropriate to produce profitable crops, and to build up the fertility of the soil.

For example, in a corn–soybean–wheat rotation, crop removal over the three years of the rotation would be about 400 lb/ac of N (190 from legume fixation), 145 of P_2O_5 and 140 of K_2O. Applying 7000 gallons/acre of liquid swine-finishing manure, split between the corn and the wheat, would supply 266 lb/ac of available N, 147 of P_2O_5 and 175 of K_2O. This balances the P removal very closely, and only slightly over-supplies N and K over the rotation.

If the manure were only applied to meet the N requirement of the corn, at about 4,000 gallons per acre, the phosphate and potash would be applied at less than crop removal, and the balance would have to come from either soil reserves or commercial fertilizer.

With commercial fertilizer application, sometimes the long-term view is appropriate. It's not uncommon, for example, to apply extra fertilizer to a corn crop, so there is more residual fertility in the soil to support the soybean crop to follow.

CALIBRATING FERTILIZER ATTACHMENTS ON SPREADERS AND PLANTING EQUIPMENT

Calibrate by following these steps.

1. **Assess the uniformity of spread pattern:**
   - ► drills/planters – rate delivered should be uniform across equipment width
   - ► broadcast equipment – typically, relative delivery rates should be higher immediately behind spreader, and drop steadily as the distance from point of spreading increases
   - ► where delivery rates are inconsistent, consult operator's manual for adjustment.

2. **Determine effective spreading width:**
   - ► drills/planters – the effective spreading width is the width of the equipment
   - ► equipment with spread patterns – where delivery rates drop off as the distance from the point of spreading increases
   - ► the spreading width is determined by the distance between the point on the right and left side of the swath, where the application rate is one-half the rate through the centre section of the swath.

3. **Calibrate:**
   - ► method #1
     - ▷ fill the equipment to a given level
     - ▷ travel a distance until area covered is equal to one acre
     - ▷ determine amount required to refill to the given level
   - ► method #2
     - ▷ weigh the equipment
     - ▷ spread several acres
     - ▷ reweigh the equipment
     - ▷ divide weight difference by number of acres covered.

Once the effective spreading width is determined, the overlap of the one-half rate swaths will result in a uniform application rate over the field.

Note: area covered is determined by multiplying the effective spreading width by the distance traveled.

For more detailed information on calibrating a liquid manure spreader, see the appropriate OMAFRA factsheet. It shows equations to calculate travel speed based on application rate required, width of application, and time it takes to empty a load.

For BMPs to calibrate solid manure spreaders or liquid manure application equipment, see the BMP book, *Manure Management*.

RIGHT TIME

RIGHT TIME – SUMMARY OF BMPs

BMP	DETAILS
✔ Plan point in crop rotation	• plan your crop rotation and nutrient applications to maximize nutrient use
✔ Schedule to avoid compaction	• watch for soil moisture conditions and weather patterns – plan accordingly
✔ Schedule to match operational concerns	• consider availability of equipment and labour • consider windows of opportunity (e.g, spring planting)
✔ Choose best time in growing season to match crop needs	• pre-plant, with planting, side-dress, split application, fertigation
✔ Consider season of application	• fall vs. late summer • late fall vs. winter • spring vs. fall
✔ Use cover crops	• manage residual N
✔ For manure – choose the right time to minimize losses and nuisance	• avoid rainfall events and hot, humid days • consider neighbours' needs and concerns

PLANNED POINT IN CROP ROTATION

Commercial fertilizer is generally applied immediately prior to the time a particular crop needs the nutrient, and the economics of fertilizer application are applied only to that crop. There are times, however, when a longer view is appropriate.

The timing of manure application is more complex, since considerations such as the need to empty out storage, or concerns about soil compaction, come into play. You need to balance maximized nutrient use from manure with the availability of suitable land to receive manure through the year.

Including a diverse mix of crops in the rotation allows for improved nutrient utilization and increased opportunities for nutrient application.

If your fields are wet, reschedule field operations.

SCHEDULE TO AVOID COMPACTION

✔ **When the field is wet, stay off** with all equipment.

✔ **Ensure soil is at proper moisture conditions at tillage depth** before applying nutrient materials.

✔ **Prevent compaction** with:
- ▶ good drainage – tile drainage should be installed in fields with variable drainage
- ▶ longer crop rotations that include forages/cereals for improved soil quality
- ▶ forage crops – leave in for longer than one year.

✔ **Limit the amount of traffic** across a field.

✔ **Restrict the area that will be compacted** – create a long, narrow "footprint" with tire arrangement, e.g., radials, large tires, tracks.

✔ **Reduce pressure on the soil by keeping tire pressures low** to increase the size of the footprint (radial tires only).

✔ **Keep axle loads as low as possible**, ideally less than 5 tonnes/axle.

SCHEDULE TO MATCH FIELD OPERATIONS

✔ **Plan and schedule all field operations** – especially for narrow windows of opportunity such as spring planting season.

✔ **Consider contingencies for nutrient application** when the situation (e.g., weather, available equipment and labour) prevents scheduled application operations (i.e., early surface broadcast of P+K or lime materials).

CHOOSE OPTIMAL TIME IN GROWING SEASON TO MATCH CROP NEEDS

To ensure full-season crops like corn get sufficient nitrogen when they need it, consider side-dressing nitrogen just prior to the time of maximum crop uptake.

In general, fertilizer should be applied as close to when the crop needs it as possible, particularly for nutrients that can move easily in the soil (e.g., nitrogen) or nutrients that are subject to tie-up in unavailable forms. This has to be balanced with the availability of time and equipment to apply the fertilizer at the optimum time.

With manure and biosolids, there are additional challenges from the nutrients in organic form, which need to break down before they are available to crops.

The nutrients showing the greatest response to time of application are nitrogen and phosphorus. Nitrogen that is not taken up by crops can be lost through leaching or denitrification, so should not be applied much before planting. With full-season crops like corn, there is significant opportunity for loss between planting and crop uptake. It's therefore advantageous to side-dress nitrogen just before the time of maximum crop uptake. Fertigation provides the opportunity to fine-tune nutrient applications even more, providing multiple doses of small amounts of nutrients to meet the demands of the crop.

Some crops have a high demand for phosphorus as seedlings, so these crops benefit from starter applications of P. Transplanted crops, like tomatoes, often respond to phosphorus in the transplant water to encourage rapid establishment of the transplant. Other crops, like soybeans, do not have a high demand until the crop's root system is well-established, and these are able to utilize residual fertility in the soil almost as efficiently as banded fertilizer.

Fertigation is a means of applying fertilizer materials in solution to micro-irrigation systems. It provides an opportunity for growers to add both nutrients and moisture to high-value crops in measured amounts where and when the crops require them.

Nutrient concentration can be changed to meet the changing nutrient and moisture requirements of growing crops. For more information, please see the BMP book, *Irrigation Management*.

Definitions of Fertilizer-Timing BMPs

Preplant	–	fertilizer applied prior to seeding
Side-dress	–	fertilizer applied in row adjacent to crop row
Split application	–	fertilizer applied at least twice per season
Starter	–	fertilizer applied at time of seeding, generally with/near the seed

CHOOSE THE BEST SEASON FOR APPLICATION

For Fertilizers

The best season to apply depends on seasonal climate patterns, local weather and field conditions, crop grown, and fertilizer material.

On horticultural crops, late-season application of N-fertilizers on sandy soils can increase the risk of N leaching, especially if the field is over-irrigated.

For Manure

The goal of application is to get the manure to the desired crop when it needs it, in the right amount and with the least environmental impact. Notifying your neighbours of your intent to apply will ease concerns. The following chart summarizes application BMPs for each season.

For cool-season forages and cereals, spring is the time that growth and nutrient demand are greatest for nitrogen. P+K can be applied at any time – usually when they can be combined with another nutrient application.

For most field 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.

Forages can utilize nutrients from manure at times when other fields are unavailable for application.

SEASONAL BMPs FOR MANURE APPLICATION		
SEASON	**BMP**	**WATCH FOR:**
SPRING	✔ apply to crops with the highest nitrogen requirement – high-yielding crops will use the N more efficiently ✔ pretill strips prior to injection to reduce tile effluent ✔ incorporate solid-spread, liquid-broadcast or irrigated liquid manure within 24 hours ✔ adopt good neighbour practices ✔ side-dress in row crops, e.g., dribbling	• soil compaction from tanker loads and traffic • runoff from excessive rates or poor soil conservation practices • denitrification – loss of N-gases to atmosphere on wet soils • tile effluent – when tiles are running, monitor and cease application if effluent is observed • rill erosion along strips and runoff • spills in irrigated or tractor-mounted systems • excessive odours and drift • ammonia loss – incorporate within 24 hours
SUMMER	✔ apply liquid manure to grassy pastures and hayfields – land is dry and less prone to compaction ✔ apply liquid manure to forage and pastures to be reseeded/rotated ✔ side-dress liquid manure on row crops ✔ apply liquid manure on cereal stubble ✔ apply liquid manure after forage crop cuts before regrowth has started	• ammonia loss from surface-applied manure if not washed in by rain • N loss from denitrification • potential for nitrate leaching if N not utilized • rill erosion and runoff along injection strips • "smothering" of forages – low rates and even application will prevent this
FALL	✔ apply solid or liquid manure prior to establishing winter cereals or cover crops ✔ apply and incorporate manure following corn or soybean harvest – as late in the fall as possible so soil temperatures have cooled	• risk of ammonia loss from surface applications onto warm (>10 °C) soils • risk of leaching if not absorbed by actively growing cover crop – avoid application on sandy soils • risk of denitrification in early fall • runoff and water quality risks • soil compaction from tanker loads and traffic
WINTER	✔ don't spread manure on frozen or snow-covered ground – store it	• runoff and risks to water quality

Winter Application

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

There may be times, however, when winter application is necessary, and justified. If, for example, the storage has filled prematurely, it will be better to spread some manure in winter rather than face a spill when the storage overflows.

For more information about the limits on winter application, see the OMAFRA factsheet on applying manure and other agricultural source materials in winter.

USE COVER CROPS

Plant cover crops to reduce nutrient losses.

Some cover crops fix nitrogen, but all require nitrogen to grow. Grass cover crops (such as rye) and brassicas (such as oilseed radish) are excellent scavengers of nitrogen left behind by the main crop or from manure and fertilizer applications.

Cover crops can help to reduce nitrogen losses due to leaching. This reduces the potential for movement of nitrates to shallow aquifers. When the cover crop is killed, nutrients held in the plant tissues are returned to the soil and can be used by the following crops:

- **non-legume green manures** can serve as "catch crops" planted after harvest to absorb leftover inorganic nitrogen, thus minimizing losses
- **winter rye** grows anytime the temperature is above freezing, absorbing up to 60-lbs. soluble nitrogen during late fall and early spring
- **annual ryegrass**, while not as hardy as rye, is an excellent nitrogen scavenger if planted by September 15
- **spring cereals** planted in August will "catch" nitrogen in the fall, then winterkill, leaving an easy-to-till residue for early spring planting
- **overseeding a catch crop into vegetables** prior to harvest keeps the soil continuously covered by live plants, thus further conserving nitrogen
  - land that comes out of production during summer can be planted to a warm-season crop like **sudangrass or buckwheat** – since buckwheat is a light feeder, sudangrass may be the crop of choice for a really rich soil.

Undersown catch crops efficiently reduced nitrogen losses when mineral fertilizer or manure was applied at normal rates (90–110 kg N/ha). Undersown catch crops can reduce nitrogen leaching by up to 60%, when compared with soil that was conventionally tilled in August–September.

Nitrogen use by the succeeding crop has been inconsistent from non-legume cover crops, but some estimates have suggested that 20–30% of catch crop nitrogen is available to the following crop under ideal management.

Oats planted in late summer will catch nitrogen released from applied manure.

Don't let cover crops like rye get over-mature in the spring: otherwise, available soil N will actually be immobilized as the rye straw decomposes.

OFF-SITE IMPACTS

Producers applying manure face the challenge of balancing the goals of nutrient efficiency with other agronomic, environmental and social objectives. Manure management practices designed to provide the maximum amount of nutrients, along with balanced manure nutrient application at or near the time of optimum crop uptake can, in certain circumstances, conflict with BMPs aimed at preventing soil compaction, field work timeliness, reducing greenhouse gas emissions, lowering survival rates of manure pathogens, and reducing odours.

As a manure manager, you must take conflicting goals into consideration, and select the best approach based on the unique conditions specific to your farm at the time of application.

Applying manure when it will maximize the availability of nutrients will generally also avoid off-site impacts to water or air quality. So it's a win–win: doing the right thing will also improve the state of your wallet. There are, however, some other considerations in manure application to ensure your neighbours are not adversely affected.

Avoid denitrification. Don't add manure to soils that are already high in mineral nitrogen.

Weather

Weather conditions at, or shortly after, manure application will determine the impact you have on your neighbours or on the environment. A rain shower can help to incorporate manure into the soil, stopping odour and nitrogen loss, but a heavy rain will carry raw manure off the fields and into surface water. Warm, humid conditions will increase the volatile losses of both ammonia and odorous compounds from manure, and can create very intense odours. Windy conditions will dilute the smell, but will also carry it for long distances.

Applying manure to meet all your crop's nitrogen needs may also mean that levels of phosphorus and potassium will rise. If this is repeated over several years, high soil-test levels can build up and increase the risk of environmental harm. This buildup occurs faster if the nutrient value of manure is ignored, and fertilizer is applied as well.

Plant field windbreaks to reduce odours during application.

Low-trajectory manure irrigation technology is designed to reduce odours and drift during application.

Injecting liquid manure below the surface almost eliminates odours.

Neighbours

Like it or not, we live within a community and that means having neighbours. Whenever possible, try to avoid manure application when your neighbours are likely to be outside and the breeze is carrying odour toward their houses.

Many nuisance complaints due to odour occur just after manure has been applied to cropland. Fortunately, there are a number of management practices that will reduce odour intensity and duration if conducted timely and properly.

RIGHT PLACE

RIGHT PLACE – SUMMARY OF BMPs

BMP	DETAILS
✔ Put nutrients in the right place	• place nutrients where crops can access them • band fertilizers with row crops • inject liquid manure or incorporate immediately • avoid salt injury • avoid ammonia toxicity • consider foliar where suitable, e.g., Mn on soybeans
✔ Keep nutrients away from surface waters and wells	• establish buffer strips • follow BMPs for separation distances from surface waters, wells, and other sensitive areas • close the slot properly when subsurface-applying manure or fertilizer • reduce erosion and runoff through contour cropping, no-till, and reduced tillage systems
✔ Reduce groundwater contamination	• know where your environmentally sensitive cropland areas are • follow BMPs for application in areas shallow to bedrock and with shallow aquifers

PROPER PLACEMENT – METHODS

The effective placement of fertilizers can maximize both yield and nutrient use efficiency, thereby increasing net profit for the producer and reducing environmental impact.

Granular fertilizer can be broadcast (surface-applied), broadcast-incorporated ("plowdown"), surface-banded, or deep-banded.

Liquid fertilizer can be broadcast, banded with either a shank or dribble applicator, or applied to the growing plants (foliar application or fertigation).

Banding can be performed prior to seeding, with/near the seed ("starter" or "pop-up"), or after planting.

Fertilizer Placement Definitions

Band –	any method where fertilizer is applied in concentrated strips, usually below the soil surface
Broadcast –	uniform application across soil surface
Deep band –	subsurface application, usually more than 10 cm (4 in.) below surface
Dribble –	surface bands of fertilizer
Dual –	simultaneous application of N and P
Fertigation –	fertilizer applied with irrigation water
Foliar –	liquid application to the leaf surface
Knife –	band application below the surface
Plowdown –	deep incorporation of broadcast fertilizer
Point injection –	liquid fertilizer applied at single points
Pop-up –	slang term for seed-placed fertilizer
Seed-placed fertilizer –	fertilizer placed with seed; some portion may be in direct seed contact
Side-dress –	subsurface application of fertilizer between the rows
Surface band –	concentrated band of fertilizer placed on the surface of the soil rather than below
Top-dress –	fertilizer broadcast on top of plants

Broadcasting is the most efficient way to apply large amounts of fertilizer quickly.

Broadcast

Broadcast fertilizer can be incorporated, which increases root contact and plant growth, especially for the more immobile nutrients such as P and K. Precision agricultural equipment can help the applicator avoid fertilizer distribution problems.

Banding

Fertilizer can be banded on the soil surface, or below the surface (subsurface banding).

Granular fertilizer can be subsurface-banded with either gravity-feed openers or air drills.

Fertilizer and seed can be applied simultaneously via air drills, which distribute the seed and fertilizer in a band up to 10 centimetres (4 in.) wide. Other designs use one line for seed, and one line for fertilizer, often 5 cm (2 in.) below and 5 cm to the side of the seed.

Liquid fertilizer, such as anhydrous ammonia and UAN, can be band-applied through knives mounted on shanks. It can also be surface-banded or "dribbled" over the row either beside or following a packer wheel.

Broadcast Versus Banding

It's hard to beat broadcast fertilizer for speed, convenience, crop safety and low cost of application. If there were no advantages to band placement of fertilizer, we could expect that all fertilizer would be broadcast. These advantages do exist, but we need to understand what advantages are provided for different nutrients, and manage accordingly.

Weed densities can be lower with banded nutrient applications compared to broadcast applications, because fewer nutrients are available to the weeds and more are available to the crop.

WHEN TO BAND

REASON FOR BANDING	WHERE IT FITS
REDUCING LOSSES TO THE ATMOSPHERE	• Nitrogen as anhydrous ammonia must be banded below the surface to avoid losses. • Urea or UAN solution is subject to volatilization if it's left on the surface, so subsurface banding prevents this loss without requiring tillage for incorporation. (Surface banding will have the same effect, but to a lesser extent.)
REDUCING LOSSES TO SURFACE WATER	• Concentration of both N and P in runoff water is reduced when these nutrients are placed below the surface rather than broadcast.
REDUCING IMMOBILIZATION IN THE SOIL	• Phosphate combines with many soil minerals to form insoluble compounds. Banding phosphate fertilizers, particularly in low-testing soils, reduces the contact between the soil and fertilizer, delaying the immobilization of the phosphate. • Some micronutrients are also subject to immobilization, so banding allows a longer time period before they are unavailable to crops.
INCREASING AVAILABILITY TO CROPS (STARTER OR SIDE-DRESS APPLICATIONS)	• Cereals and corn require high concentrations of phosphate at a seedling stage, when the root system is small. Placing a concentrated band of phosphorus fertilizer near the seed increases the availability to the plant when it needs it the most. • Some micronutrients (particularly zinc) are also required in highest concentrations by the seedling stage of the crop. • Availability of nitrogen and potassium can be reduced during dry weather. Banding places these nutrients into soil that is more likely to remain moist, enhancing availability to the crop. Care is needed that the bands of these nutrients are not too close to the roots. • Small amounts can be applied uniformly across the field.

Foliar Application

Due to the potential for leaf burn and the inability to supply sufficiently large amounts of required nutrients, macronutrients are generally not foliar-applied.

Conversely, micronutrients are sometimes foliar-applied because most are quite immobile in the soil, required in small amounts by crops, and produce positive growth responses.

Foliar application involves spraying liquid fertilizer directly on leaf surfaces.

Fertigation

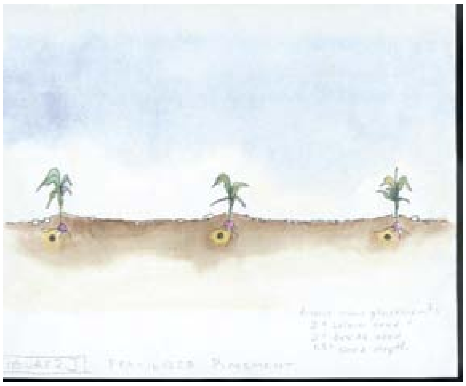
Fertigation is the application of fertilizer through an irrigation system. It can be an attractive alternative to traditional fertilization methods for some nutrients on particular crops (e.g., N) because fertilizer can be applied throughout the growing season.

PROPER PLACEMENT – FINE-TUNING

Roots and Placement

A goal of fertilizer placement is to maximize root–nutrient contact, without causing emergence or establishment problems from excess salt. This is especially important at the early stages of crop/root development.

Placing fertilizer in the region that will have the highest density of fine roots, or in a location that the fertilizer will move to this region, is needed to optimize yield. The impact of this placement will be greatest with nutrients that the crop requires in high concentrations during early growth (e.g., P and Zn on corn).



Proper fertilizer placement will avoid seedling damage.

This seedling has suffered salt burn.

Salt Effect

Placing fertilizer with the seed raises the possibility of poor germination and delayed emergence due to high salts.

The effect is highly dependent on the specific fertilizer's salt index. For example, KCl (0-0-60) and urea (46-0-0) have the two highest salt indices, and therefore have a high potential to negatively impact seed germination if placed with the seed.

Conversely, MAP (11-52-0) has a low salt index and causes only minimal germination problems.

Urea (46-0-0) and DAP (18-46-0) can both release free ammonia in the soil when banded, which can cause emergence problems.

These reductions depend on the concentration of fertilizer in the band, and its proximity to the row. Wide rows, narrow fertilizer bands, and placement with the seed all reduce the safe rates of fertilizer that can be banded.

Ammonia Toxicity

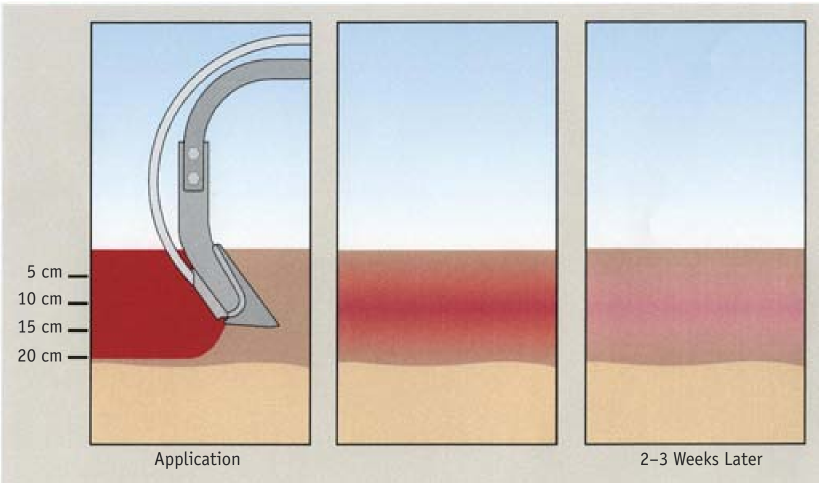
Roots are very sensitive to damage from ammonia. Side-dressed anhydrous ammonia must be placed well away from the row. Preplant ammonia must be applied in such a way that seedlings are not exposed to it.

The risk of injury from pre-plant anhydrous ammonia can be reduced by:

- ▶ applying several days before planting
- ▶ applying at least 15 centimetres (6 in.) deep
- ▶ using a narrow spacing between the outlets (to reduce the concentration in each band).

Ammonia can be released from urea or DAP (18-46-0). Use of either of these materials in starter fertilizer can greatly reduce the amount that can be applied safely.

Reduce volatilization losses by incorporating soon after application.



Ammonia concentration in the soil is reduced over time as the ammonia is converted to nitrate.

More complete guidelines for maximum safe application rates can be found in the OMAFRA production recommendations. See the back cover for more information.

✔ **Incorporate manure**.

The ammonium portion of manure can volatilize rapidly, particularly when the manure is applied in warm, breezy conditions. The rate of ammonia loss will be highest immediately after manure application, and decline as the ammonium in the manure is depleted. Injection, or incorporation as soon after application as possible, will stop ammonia volatilization and improve the availability of nitrogen from manure.

Where manure is incorporated, available nitrogen for the following spring's crop is predicted to be near 50% of the total nitrogen content of the sample.

Ammonia released by fertilizers can be toxic to plants.

KEEPING NUTRIENTS AWAY FROM SURFACE WATER AND WELLS

Crop nutrients are best kept close to crop roots. Use soil and water conservation BMPs and keep separation distances to help soil and applied nutrients remain in place.

✔ **Establish buffer strips.**

✔ **Keep soil and nutrients in place** with soil conservation BMPs and structures.

✔ **Keep your distance** – follow BMPs for separation distances from surface waters, wells and other sensitive areas.

Buffer Strips

Buffers are designed to keep crop operations away from surface waters and to reduce the likelihood that cropland soil and nutrients leave the field. They also help manage many other environmental concerns, such as soil erosion, flooding, and fish and wildlife habitat.

Buffer strips are strips of land that have permanent vegetation located next to bodies of water (streams, rivers, etc.). These small strips of land can have a big impact in protecting surface water.

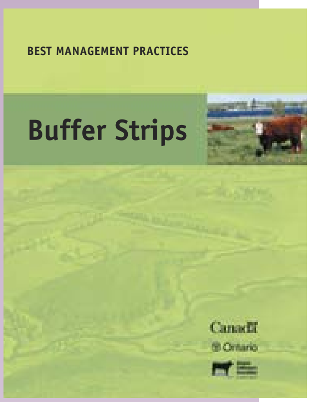
Buffers can reduce pollutants from reaching the water source through:

- ► sediment filtration
- ► infiltration
- ► plant uptake.

Sediment is trapped by dense vegetation in the buffer, keeping it out of the stream. This is particularly important for filtering out phosphorus that's often trapped on soil particles. The vegetation in the buffer area improves soil structure, and creates plant-root channels in the soil that improve soil infiltration. Infiltration slows down surface runoff and incorporates water-containing nutrients into the soil, where they can be used by plants growing in the buffer area.

Buffers also provide a physical separation of field activities from surface water, reducing the likelihood of spills or improper application having a direct impact on the stream or pond.

For a great deal more information about buffer strips, see the BMP book devoted to them.



REDUCING CROPLAND EROSION AND RUNOFF WITH EROSION CONTROL STRUCTURES AND SOIL CONSERVATION BMPS

As valuable as they are, even well-managed buffer strips cannot control erosion and runoff from cropland by themselves. Much of the risk of surface runoff and concentrated flow from cropland can and should be managed in the field by soil and water conservation structures and practices. Buffer strips are one part of this soil and water conservation system – in other words, they are the last line of defence.

Erosion control structures are in-field, constructed features designed to reduce soil loss and safely convey surface water to a properly protected outlet.

Soil conservation options range from reduced tillage practices (e.g., no-till, residue management) to slope management (e.g., strip cropping), to soil management practices that improve soil quality and reduce runoff.

Good artificial drainage may be the key to successful implementation of other BMPs. It can reduce surface runoff during some seasons by allowing more water to soak into the soil.

Erosion Control Structures – Water and Sediment Control Basins (WaSCoBs) for Concentrated Flow

In any given field, the rate of soil loss and runoff will be even greater if the runoff can collect in draws or convergent pathways, concentrating the flow as it runs downhill. Unchecked, these draws can lead to rills and gullies. To prevent or reduce the risk of gully erosion, you must:

- ► provide some form of cover to protect the floor of the draw
- ► reduce the steepness of the slope
- ► reduce the length of run, or
- ► divert the flow below the surface.

In fact, most erosion control structures are designed to attain one or more of these goals. For example, water and sediment control basins reduce the slope length and divert the flow below the surface.

You should seek technical advice for design and construction. Common examples include grassed waterways, drop pipe structures, terraces, and water and sediment control basins.

This is a well-constructed WaSCoB with established forage cover.

WaSCoBs are earthen embankments across draws, with retention basins and drop pipe structures to convey water to an adequate tile outlet. The duration of temporary ponding is carefully engineered to reduce the risk of damaging the crop.

Erosion control structures are designed to control erosion and safely convey surface water to an adequate outlet. You should always seek technical advice for design.

Soil Conservation Practices

Don't underestimate the value of healthy soils near riparian areas. Soil management BMPs improve soil quality and build resistance to erosive forces by adding organic matter, improving soil structure and increasing infiltration rates.

Soil management BMPs include cover crops, crop rotation and reduced tillage systems.

Grassed waterways are dish-shaped, graded and grassed channels placed in draws with subsurface drainage tile, intended to divert and transfer runoff to a properly protected outlet.

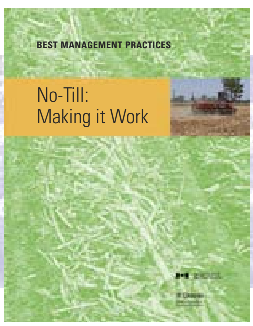
Cover crops such as fall-planted rye, oats and barley will tie up nutrients and protect the soil between crops.

Crop rotations that include annual and perennial crops will add organic matter, help maintain soil quality, and keep soils covered longer.

Reduced tillage systems, including no-till, help maintain soil quality and will reduce erosion and runoff rates.

Where conventional tillage is used, it will take many years of using a good crop rotation to build up organic matter. In conservation cropping systems, organic matter levels may increase more quickly.

For more details, see the Best Management Practices books, *Soil Management* and *No-Till: Making it Work*.



Cropland Conservation Practices

Conservation practices are non-tillage practices intended to control erosion by reducing the effect of slope and increasing soil cover. Two examples are shown below.

Contour strip cropping – alternate strips of row crops, cereals and forages on the contour level to slow surface flow and increases infiltration rates.

Field strip cropping – strips of row crops, cereals and forages at uniform widths across the main, simple slope. On complex slopes, this makes it easier to manage than contour strip cropping.

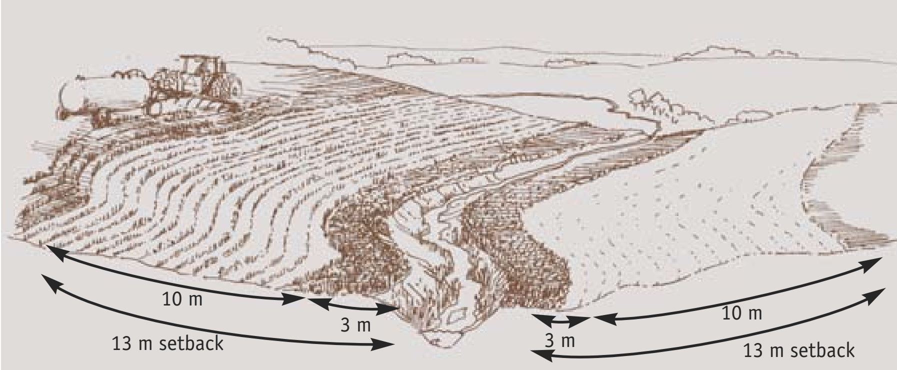
Separation Distances

Application of nutrients should be kept far enough away from surface water and groundwater to prevent contamination by runoff.

Separation distances are measured horizontally across the field to surface water and wells, and vertically to underground water features. The minimum distance required between water resources and nutrients vary with the risk associated of the material being applied.

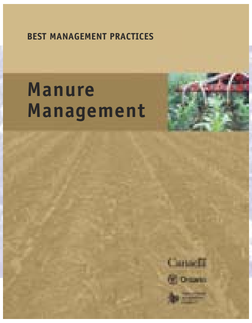
Separation Distance to Surface Water

In most cases, protecting surface water means a zone immediately adjacent to the surface water where nothing is applied, and a wider zone outside of this where extra care should be taken to keep nutrients from moving, by reduced rates, immediate incorporation, improved erosion control, or a combination.



For commercial fertilizers, a minimum separation distance of 3 metres (10 ft) should be established between the area of application and any watercourse.

For organic materials, the setback distances should be increased as the runoff potential from the field increases. On permeable soils in good condition, there may not be a large risk of runoff at the time of application, but movement during a subsequent rainfall can carry nutrients and other contaminants into surface water.



More information regarding setbacks from surface water can be found in the *Manure Management BMP*.

Separation Distances to Wells

Since any well is a potential conduit from the surface to groundwater, one of the most effective ways to protect water resources is to keep nutrients at a safe distance. This has led to the development of minimum separation distances to wells and groundwater when applying nutrients. The next chart outlines the setback distances required from wells.

SETBACK DISTANCES FROM WELLS FOR LAND APPLICATION OF NUTRIENTS*

SETBACK FROM...	FERTILIZER	MANURE	BIOSOLIDS	OTHER NUTRIENTS GENERATED BY FARMS (e.g., washwaters, silage leachate)
PRIVATE WELLS (Drilled)	3 m (10 ft)	15 m (49 ft)	15 m (49 ft)	15 m (49 ft)
PRIVATE WELLS (Other type)	3 m (10 ft)	30 m (98 ft)	90 m (295 ft)	30 m (98 ft)
MUNICIPAL WELLS	100 m (328 ft)	100 m (328 ft)	100 m (328 ft)	100 m (328 ft)

*All of the distances listed are measured horizontally across the surface of the ground.

Nutrient Leaching

Nutrients in solution will move with soil water. Leaching occurs when these nutrients (e.g., nitrates [NO_3^-]) move through soil pores below the root zone. The amount of leaching is related to:

- the concentration of nutrients in the soil solution
- the permeability of the soil, influenced by the texture (sandy or gravelly soils are more permeable than clays) and structure (presence of large cracks and pores) of the soil
- the amount of excess water available to carry nutrients down through the profile (greatest from late fall through spring)
- soil depth to bedrock or water table – less soil depth means quicker travel time.

Groundwater Protection

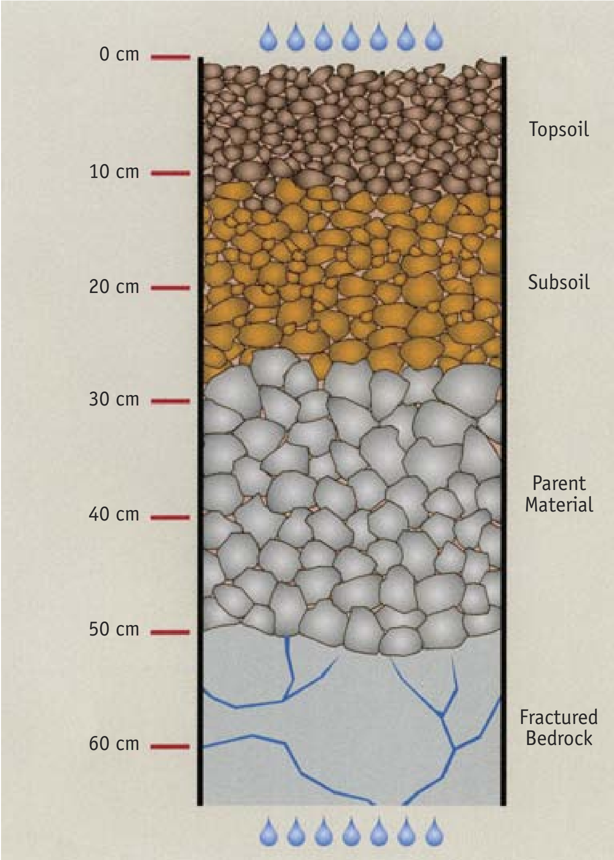
Most of the bedrock underlying Ontario's agricultural areas is extensively fractured. This is an advantage when it comes to providing water-bearing strata for wells to tap into, but it is a concern where the bedrock is close to the surface. Contaminants that enter this fractured bedrock can travel directly into an aquifer with little or no filtering,

Extra care needs to be taken with nutrient applications on areas with shallow bedrock. These areas are generally lower-yielding than deep soils, so the nutrient removal by crops will be less, and the ability of the soil to hang onto nutrients will be reduced.

✔ **Do not apply manure on or within 3 metres (10 ft) of exposed bedrock.**

For more details about limits to manure application on shallow soils, see the aforementioned BMP *Manure Management*.

Know where your environmentally sensitive cropland areas lie. Follow BMPs for application for areas shallow to bedrock and with shallow aquifers.



Shallow soils over bedrock provide less protection for groundwater because there's less opportunity for filtering or breakdown of contaminants prior to reaching fractured bedrock.

AND NOW IT'S UP TO YOU

It's time to put the theory and advice into practice. Both science and on-farm experience attest to the many good reasons for developing a nutrient management plan for your operation, not to mention the due diligence you demonstrate to your community.

Underlying any well-conceived plan is an understanding of the basics:

- ► knowing what nutrients do for crops and how they behave in soil will help you better predict crop needs
- ► understanding the cycles of these nutrients helps prevent losses to the system
- ► knowing the pros and cons of inorganic and organic nutrient sources helps you choose the right combination for your operation.

Use this book as a constant companion before you plan, as you plan, and as you adjust your plan in the coming years.

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For More Information

A number of books in the Best Management Practices series pertain to facets of crop nutrients. They include:

Buffer Strips
Field Crop Production
Manure Management
Nutrient Management Planning
No-Till: Making It Work
Soil Management

For information on how to get copies, please see page i.

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