MANURE APPLICATION

THIS CHAPTER EXPLORES:

- which nutrients are in the manure, and what your crop needs
- how different nutrients "behave", once applied
- the effects of manure on soil life
- how to evaluate and minimize risks to water resources
- the value of testing manure, how to sample, and how to interpret results
- application rates and timing
- application technology
- implications for crops
- contingency measures
- economic analyses.

Nutrient management planning is not simply an accounting exercise. Although the paperwork of keeping records and calculating application rates is necessary, you also need to know where, how and when to apply nutrients for maximum benefit to crops and least impact on the environment. In other words, you need to ensure that what you planned is actually happening.

MANURE AND FERTILITY MANAGEMENT

Manure provides the same nutrients for crop production as commercial fertilizers. One of the main challenges with manure, however, is that we can't change the proportion of nutrients to meet the specific nutrient requirements of crops. We have to take the manure as it comes.

In terms of nutrient content, solid poultry manure is relatively concentrated, while liquid dairy manure is dilute.

MANURE AS A SOURCE OF NUTRIENTS

OPPORTUNITIES	CHALLENGES
• contains many required nutrients • provides nutrients for several years after application • supplies organic matter to soils, leading to improved soil health • may be available on-farm	• nutrient content is variable and relatively low • nutrients not always present in proportions needed by crop • odour • poor management can lead to water contamination • untimely application can lead to soil compaction

N, P AND K IN MANURE

Nitrogen (N)

Nitrogen in manure is present in **ammonium** and **organic** forms. The proportion of each depends on the type of manure, and the amount and type of bedding material added.

Any inorganic nitrogen in manure is usually in the ammonium form. This form of nitrogen is readily available to crops, but typically 30% of it, or more, is lost during application. Ammonia gas from decomposing manure may be harmful to fish if there is manure runoff to surface water.

Up to 30% of the organic nitrogen becomes available in the first cropping year, depending on the type of manure and the amount of bedding used.

At best, 50 to 60% of the total amount of nitrogen in manure is available in the first crop-year after application. Because a higher proportion of the nitrogen in poultry manure is present as ammonium–nitrogen, 75 to 85% of the nitrogen in liquid poultry manure can become available in the first year (60% in solid poultry manure).

As the organic portion from manure breaks down in the years following application, it continues to supply nitrogen to the soil. The amount can be estimated, but the more accurate measure of nitrogen release is obtained through the use of the soil test for nitrate-nitrogen.

To estimate the release of nitrogen from previous manure applications, refer to the NMAN computer program or the *Nutrient Management Workbook* from the Ontario Ministry of Agriculture, Food and Rural Affairs.

The soil test for nitrate-nitrogen can estimate the amount of available nitrate-nitrogen during the growing season. This can help to determine the need for and rate of sidedress applications.

Phosphorous (P)

Phosphorous is present in organic and inorganic forms in the solid fraction of the manure. In terms of availability to the crop, manure P differs considerably from fertilizer P, primarily because of placement. (Fertilizer P can be placed closer to the roots of growing crops.)

In the year of application, manure P from most manure types is only 40% as available as fertilizer P. That is, 100 lbs of phosphate (P_2O_5) from manure is equivalent to 40 lbs. of P_2O_5 from fertilizer. When it comes to the long-term change in soil-available P (soil test P), manure P does not differ as much from fertilizer P. Over time, 80% of the P in manure is available for crop uptake.

Potassium (K) and Other Nutrients

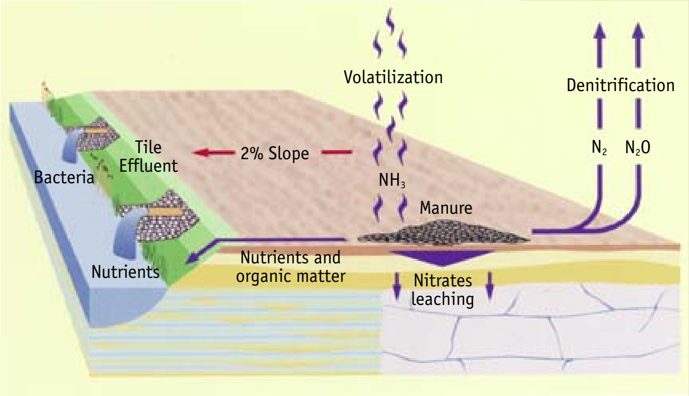
Manure contains significant quantities of potassium as well as micronutrients that can be excellent resources for crop production. When applied at levels to meet crop needs, these nutrients have not been identified as sources of environmental problems. In some instances, excess potassium applications to forages can lead to nutrient problems in cattle and sheep.

LOSSES FROM THE FIELD

The plant nutrients in manure that are of greatest environmental concern are nitrogen and phosphorous. Each behaves in a unique way once it's applied to the soil. As a result, nitrogen and phosphorous take different pathways to reach a water supply.

Nitrogen, when in nitrate (NO_3^-) form, moves quite easily with soil water. As a result, it can move through and below the root zone, and could eventually enter the groundwater.

Phosphorous, on the other hand, binds tightly to soil materials and does not move as readily with the soil water unless there are abnormally high phosphorous levels in the soil. As a result, the most common pathway for phosphorous to enter surface waters is through soil erosion.



Cropland nutrients can be lost by leaching (e.g., nitrates), runoff (e.g., phosphates), volatilization (e.g., ammonia) and gas (e.g., denitrification of N-compounds.). Some of these losses apply to all nutrients, regardless of source (e.g., nitrate leaching, P runoff). Other losses are specific to manure, or to a particular manure type – such as the preferential flow of liquid manure to tile drains.

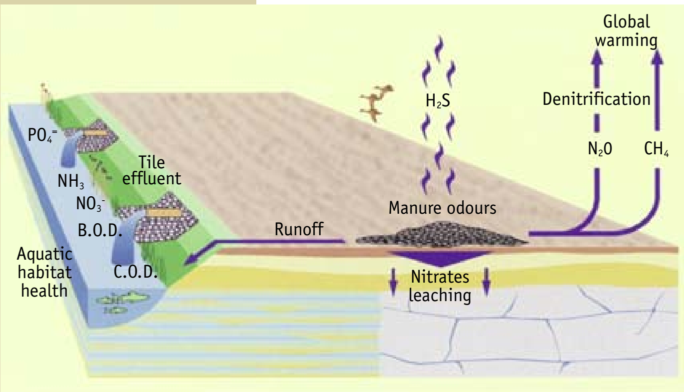
Many factors influence the potential movement of nitrogen and phosphorous to surface water and groundwater, including:

For more information on the fate of manure nutrients in the environment, see page 26.

- soil type/texture slope
- proximity of the surface water or groundwater
- fertility levels, and
- management practices.

Factors that influence nutrient movement off the field need to be assessed on a site-by-site basis to determine their relative importance. Factors are then weighed together to arrive at a risk "Index".

A Phosphorous Index (P Index) and a Nitrogen Index (N Index) have been developed for Ontario.



POORLY MANAGED manure can contribute to:

- **deterioration of aquatic habitats from manure-contaminated runoff and tile effluent containing nutrients, pathogens, and organic matter (measured by oxygen demand – biological and chemical, B.O.D. + C.O.D.)**
- **groundwater contamination from leached nitrates**
- **unwanted odours from manure gases, and**
- **release of greenhouse gases – nitrous oxide (N_2O) and methane (CH_4).**

THE PHOSPHOROUS-LOADING RISK INDEX (P INDEX)

The purpose of the P Index is to assign a value to the risk of surface water contamination through nutrient application to cropland. So, for example, on fields where soil phosphorous levels, as determined by soil tests, are high and erosion potential is high, the risk of phosphorous contamination of surface water from manure application is also high. Manure application to the field should be restricted to matching the amount of phosphorous that the crop removes.

The following chart lists the field and management practices that are considered when arriving at a P Index.

Even if the P Index calculated for a particular field is high, it's often not necessary to restrict manure application to the entire field. Only a portion of the field directly connected to the watercourse is likely to be "delivering" the phosphorous through periods of concentrated flow. As a result, only those areas adjacent to a watercourse or that have the highest risk of sediment delivery potential need to be avoided.

FACTORS CONSIDERED IN THE P INDEX TO ESTABLISH MINIMUM DISTANCE SEPARATIONS FOR MANURE-SPREADING ADJACENT TO WATERCOURSES	
INFLUENCING FACTOR	**FIELD MEASUREMENT OR INPUT NEEDED FOR DETERMINING THE P INDEX**
NATURAL FIELD CHARACTERISTICS – account for a field's soil erosion potential and water runoff potential	• soil texture/erodibility • slope length • slope gradient (adjacent to watercourse) • rainfall energy • distance to the watercourse
FIELD MANAGEMENT PRACTICES – adjust for a field's soil erosion potential	• tillage system (e.g., no-till) • cross-slope/contour farming
NUTRIENT MANAGEMENT PRACTICES – account for factors such as the current P levels in soil as well as how, and how much, P is being applied to a field	• soil fertility levels • manure type (liquid or solid) • manure application rates • method of manure and fertilizer application (e.g., incorporated vs. surface-applied)

The risk of P runoff increases with steepness and length of slope.

Nutrient management calculators in Ontario do not require you to consider the P Index if the soil test result is below 30. However, as a best management practice, you may want to complete the P Index to be assured that your field practices aren't resulting in a high movement of phosphorus to surface water.

THE NITROGEN-LOADING RISK INDEX (N INDEX)

The Nitrogen Index is a tool for reducing the risk of nitrate contamination of groundwater. It assesses the vulnerability of nutrient management practices with respect to the movement of nitrates.

DETERMINING RISK OF NITRATE MOVEMENT TO GROUNDWATER

For groundwater to be contaminated, there must be both:

- a **source** of nitrate in the soil – roughly defined as the net amount of nitrate in the soil following crop maturity
- the opportunity for nitrate to **transport** itself down into the groundwater – the net amount of infiltration, and the ease with which this water can move down through the soil to groundwater, being key factors.

The nitrogen cycle is complex, and factors contributing to both source and transport often interact. When manure-nitrogen converts to the nitrate form, it will move through the soil with water rather than bind to soil particles.

Source Factors

Nitrate present in the soil following harvest may have come from nitrogen applied for growing the current year's crop, or from nutrients applied after crop harvest. In the case of nitrogen applied for this year's crop, it is only the amount of N applied in excess of crop requirements that is of concern.

The other major source of nitrate in the soil during the fall and winter is the application of manure or other organic sources of nitrogen following crop harvest. There are many advantages to a late-summer or fall application of manure. They include: spreading out workload, reducing the storage requirements, and avoiding soil compaction. In some soils, however, this practice carries an increased risk of nitrate movement to groundwater. Timing and method of application also have an impact on potential loss.

Different types of manure vary in the proportion of ammonium and organic nitrogen. Ammonium-nitrogen can volatilize to the air as ammonia gas if the manure is surface-applied, but when incorporated into the soil it's converted to nitrate quickly in warm, well-aerated soils.

Manure applied in the fall following crop harvest can be a major source of nitrate-nitrogen in the soil.

Organic nitrogen must be mineralized to ammonium before it can be converted to nitrate, and this process generally proceeds more slowly. The rates of both processes depend on the temperature, so manure applied in summer is much more likely to be converted to nitrate than manure applied in late fall. Manure treatment such as anaerobic digesters will accelerate the conversion to ammonium.

Transport Factors

In Ontario, usually crops are removing more water from the soil during the growing season than is being added as precipitation, so normally there is no leaching during the growing season.

The fall and winter usually bring more precipitation than evaporation, so water can move down through the soil profile. This is the reason we're concerned with the amount of nitrate in the soil after the growing season, when there's no crop to absorb the nitrate and the risk of loss is high. Cover crops grown after crop harvest help reduce this risk of loss.

The rate of water movement down through the soil depends on the soil porosity. Gravel and sand soils are more porous than silt or clay soils. Shallow soils over bedrock provide less protection for groundwater, because contaminants aren't being filtered once they reach the fractures in bedrock.

Shallow soils provide minimal filtering protection for groundwater.

NUTRIENT USE EFFICIENCY

Nutrient use efficiency 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 nutrient use efficiency incorporate practices that:

- 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 them
- account for and manage all sources of plant-available nutrients
- manage other cultural practices and conditions (e.g., soil and water management).

One way to improve nutrient use efficiency is to vary your application rate to match the range of soil conditions found in the field.

Improve nutrient use efficiency from manure-based sources, and you will:

- increase yields and improve product quality
- lower fertilizer inputs
- reduce runoff and groundwater contamination.

Achieving these goals is hampered by variability in crop requirements and field conditions, and imprecision in determining exact needs and application rates.

BEST MANAGEMENT PRACTICES FOR IMPROVING NUTRIENT USE EFFICIENCY	
AREA	**DESCRIPTION**
CROP ROTATIONS	• grow a legume or forage before a high N-demanding crop ○ nitrogen fixation from legume/forage crops can replace nitrogen inputs for the following year
VARIETAL SELECTION	• select for more nutrient use efficiency and water-efficient varieties
TILLAGE	• ensure tillage reflects what's required to improve root zone fertilizer placement (as opposed to surface broadcast)
NUTRIENT SOURCE	• don't necessarily try to supply all of a crop's needs with manure-based N
TIMING	• use split application for crops with inefficient root systems or high value crops such as potatoes
COVER CROPS	• use cover crops in the off-season to trap and recycle plant-available N

Cover crops are grown in the off-season to trap and release applied nutrients for next year's crops.

Applying manure to meet all your crop's nitrogen needs may also mean that levels of phosphorous 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.

MICRONUTRIENTS AND TRACE ELEMENTS

Manures are rich in crop-required micronutrients such as boron, chlorine, iron molybdenum and zinc. They are also a source of micronutrients required for animal health, including selenium, zinc, copper, chromium, iodine and cobalt. Manure type and management have direct effects on plant and animal micronutrient levels. For example, zinc, copper, selenium and manganese levels from swine and poultry manure are often 10 to 100 times higher than from dairy manure.

For soil fertility, this means that annual manure applications aimed at meeting P and N needs may result in higher-than-expected soil levels of certain micronutrients.

Some international studies have shown a buildup of elements such as copper, zinc or arsenic in fields with a history of heavy manure application. Recent studies of manure nutrient contents have not shown this to be a problem in Ontario. However, the take-home message is to be aware that use of micronutrients in livestock feed that exceeds nutritional requirements could have a negative impact on soil quality in the long term.

The best practices for managing soil levels of micronutrients are:

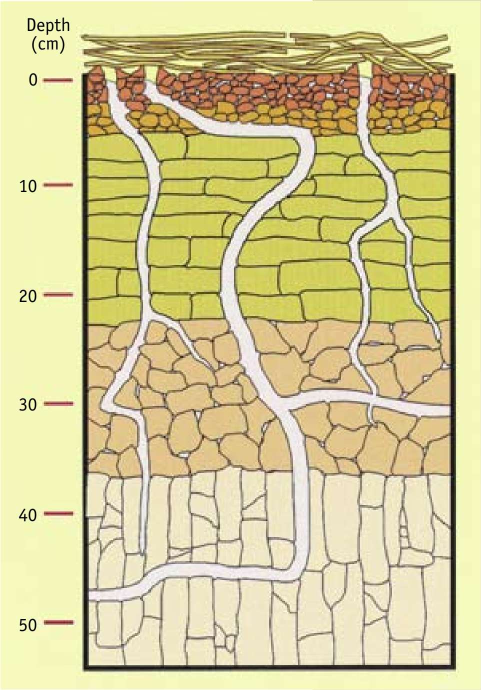
- manage sources of micronutrients in livestock feeds and treatments
- test manure and soil for micronutrient levels
- adjust your nutrient management plan and application operations if necessary to build up levels where needed and avoid excessive levels.

PATHOGENS

Manure contains a wide variety of bacteria, viruses and parasites. This variety of micro-organisms makes manure a beneficial soil amendment. But there are a few of these organisms that can infect other livestock and humans. These pathogens range from parasites such as roundworm and giardia to bacteria such as salmonella and *E. coli.*

The fate of most pathogens is species-specific and is related to the nature and duration of exposure. For example, giardia in cattle manure will not survive for a full day after being applied to cold soils. *E. coli* 0157:H7 may survive a full year on very cold to frozen soils, but is intolerant of hot and dry conditions during application.

Soil is generally considered to be a good filter to trap bacteria and other organisms. However, there can be movement of manure and associated microbes by preferential flow through cracks and wormholes. This can be a concern when high rates of liquid manure are applied to untilled soil over field tile. A portion of the manure can flow directly to the tile, resulting in contaminated tile flow. A secondary concern is the movement of manure, either surface-applied or incorporated, by preferential flow to tiles or shallow groundwater during heavy rains.



Pathogens from applied manure can travel in soils through cracks, worm channels and tile drainage systems. In some cases, in advance of applying liquid manure, pre-tilling soils that are prone to cracking can reduce risk.

Compared to foodborne diseases, waterborne outbreaks are rare. But when they do occur, people and animals can become ill, and even die.

Several management strategies can reduce the risk of pathogens moving off of cropland when manure is applied.

Schedule routine health visits by a veterinarian to prevent disease.

Treat manure. Manure storage and treatment reduce pathogen numbers by exposing the organisms to anaerobic, frozen or warm conditions.

Reduce movement and you'll reduce the opportunity for surface runoff.

- As you develop your nutrient management plan, identify timing and location opportunities to apply manure.
- Follow setbacks for application near wells, surface water and catch basins, and minimum depth requirements for saturated and shallow-to-bedrock soils.
- Increase surface roughness by leaving crop residues.
- Incorporate manure when and where there is minimal risk for soil erosion.
- Pre-till when applying liquid manure over tile drains, or keep application rates below 3600 gallons per acre. Ensure tiles are not flowing or about to flow, monitor them, and be prepared to shut off and deal with flow if contamination occurs (see the next point).
- Limit spills with preventive measures and contingency planning to reduce impact.

BIOLOGICAL IMPACT OF MANURE ON SOIL LIFE

The ecology of a solid manure pile is similar to that of a healthy, well-manured soil.

Many of the same fauna in soil can be found in manure. These creatures can be categorized by function:

- shredders – arthropods that break down residue into smaller forms
- decomposers – bacteria and fungi that digest and reduce complex compounds into simpler forms
- grazers and predators – fauna such as nematodes and protozoa that feed on decomposers.

For the most part, manure applications have a positive effect on soil life. Increased organic matter levels provide food for soil life. Increased soil fertility levels provide nutrients for soil life. Additions of solid and liquid manure improve a soil's physical properties, and therefore the quality of its habitat for soil life. This in turn encourages the presence of additional species and generally increases biodiversity.

Over-application of liquid manure can have negative effects, such as:

- ▶ increased saturation and decreased soil respiration
- ▶ accelerated rates of denitrification and methane production
- ▶ reduced soil life.

The effects are usually transitory, as the soil life rebounds once saturated conditions are replaced with aerobic conditions. But repeated over-application can have long-term effects.

BMPs to promote the positive effects of manure applications on soil life are to:

- ▶ apply rates to meet or to approach crop requirements
- ▶ distribute applications evenly over cropland acres
- ▶ apply heavier rates to areas requiring remediation (e.g., solid manure on eroded knolls)
- ▶ use application methods and techniques to minimize surface disturbance.

PLANNING FOR APPLICATION

NUTRIENT MANAGEMENT PLANNING PROCESS AND APPLICATION PRACTICES

The goal of a nutrient management plan is to determine the rate of application to meet crop needs or build up soil fertility levels, while protecting surface and ground water resources. When applying manure in sensitive areas, an acceptable NMP should identify an approach that will lower the risk of contamination.

There are areas in fields and along streambanks where manure should not be applied.

SAMPLING MANURE FOR ANALYSES

Sampling

Just like soil testing, proper sampling is critical. The composition of manure can vary significantly from one area or depth of a storage area to another. Thus, it's essential that the sample represents the entire volume of manure, not just the surface. Be sure to collect sub-samples from several areas of the storage and at different depths.

Liquid Manure

1 Agitate manure completely before taking samples.

2 Collect a minimum of five grab samples from different parts of the storage.

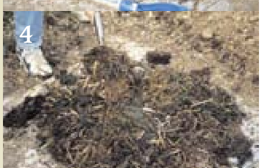
- for large storages, collect at least one additional sub-sample per 200 m^3 (18,000 gal) of material
- grab samples can be collected either directly from the storage, or as the storage is being emptied
- use a clean, non-metallic container (e.g., a 20-litre plastic pail) to collect the samples

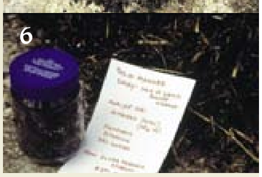
3 Place the grab samples in a larger non-metallic container with a lid (e.g., a plastic garbage can) and keep the container covered except when adding samples.

4 Mix the resulting composite sample thoroughly.

5 Collect the sample to be submitted to the lab from this mixture.

6 Sample bottles should not be filled more than one-third to two-thirds full, so that there's enough headspace in the bottle to allow for the buildup of gas without bursting. Normally, one 500-mL sample bottle is sufficient.





Solid Manure

1 Obtain samples from different depths. This is most easily accomplished when the storage is being emptied. If a pile must be sampled at other times, then equipment to take cores from the entire depth of the pile will be necessary.

2 Collect at least 10 grab samples for piles of 100 m^3 (per ton) or less. For larger piles, take proportionately more. Or simply take a forkful from every third load and mix as described below.
NB: 1 m^3 = 1000 L = 220 Imp gal. 1 gal. weighs 10 lbs.

3 Place these grab samples in a larger non-metallic container with a lid (e.g., a plastic garbage can) and keep the container covered except when adding samples.

4 Once all the grab samples have been collected, empty them onto a large, clean surface for mixing.

5 Chop and mix the material with a clean shovel, then divide the pile into quarters.

6 Discard two opposite quarters and combine the remaining two. Repeat the process until a composite sample of approximately 1 kg remains.

SHIPPING

When the sub-samples have been mixed together thoroughly, follow these procedures for shipping.

1 Half fill a clean, plastic sample bottle and close the lid tightly

► sample bottles are available from the laboratories providing manure analysis.

2 Place the bottle in a strong plastic bag and tie bag securely.

3 Pack the bag, bottle, and completed information sheet into a box with sufficient packing to protect them from damage.

4 Keep the sample cool until it can be taken to the lab or shipped by courier

► gases produced in samples kept at warm temperatures can cause the bottle to burst
► biological activity in a warm sample can change the nutrient value of the sample before it reaches the lab.

4

5 Samples should arrive at the laboratory within two days of shipping

► time courier shipments so that there's no risk of the sample being held by the courier over a weekend.

INTERPRETING MANURE TEST RESULTS

Manure test results will provide nutrient levels using the same numerical values as a soil test, but will not provide recommended rates of application. Manure test results should be used to help determine total nutrient application rates.

NMAN incorporates soil and manure test results to calculate manure and other nutrient application rates.

The following principles should be addressed when interpreting manure test results:

- only a portion of the organic nitrogen is available for crop uptake in year of application
  - 20% for liquid manure
  - 15% for solid manure (<50% dry matter)
  - 5% for solid manure (>50% dry matter)
  - 30% for all poultry manure
  - 25% for solid swine
  - 30% for liquid and solid biosolids
- available ammonium is ammonium-nitrogen less the ammonium loss
- total nitrogen available for crop uptake is the sum of available ammonium and available organic nitrogen
- nitrogen will build up in the soil with repeated manure applications
  - residual N is derived from the organic fraction of manure, so there's a more significant contribution from solid manure
- in year of application, manure P_2O_5 is 40% as available as fertilizer P_2O_5 – at least 80% will become available over the longer term, and adds to the total available soil phosphorous pool
- about 90% of the potassium is available in the year of application.

Ammonium loss is based on the following chart.

The incorporation capabilities of the application system have a significant effect on nitrogen losses. Manure that is immediately incorporated will have very little ammonium loss. Hot, sunny conditions will give the highest losses, while cool, cloudy conditions will cause the least loss.

ESTIMATED AMMONIA LOSS (PERCENTAGE)					
DAYS AFTER APPLICATION	AVERAGE	COOL WET	COOL DRY	WARM WET	WARM DRY
INJECTED IN SEASON	0	0	0	0	0
INCORPORATED WITHIN 1 DAY	25	10	15	25	50
INCORPORATED WITHIN 2 DAYS	30	13	19	31	57
INCORPORATED WITHIN 3 DAYS	35	15	22	38	65
INCORPORATED WITHIN 4 DAYS	40	17	26	44	73
INCORPORATED WITHIN 5 DAYS	45	20	30	50	80
NOT INCORPORATED					
SPRING/SUMMER/EARLY FALL					
bare soil	66	40	50	75	90
crop residue	50	30	35	60	70
standing crop	33	20	25	40	50
LATE FALL (air temp <10 °C)	25	25	25	N/A	N/A

Adapted: Beauchamp, 1995

APPLICATION RATES

Application rates should be developed with two broad principles in mind.

1. Improve Nutrient Use Efficiencies (NUE) – see page 91.

2. Consider environmental limitations.

If your goal is to improve NUE:

- rates will be based on maximizing nutrient availability and uptake to meet crop needs
- application rates will be within environmental limits (of nutrient levels), except for setbacks and possibly liquid loading if the material is dilute (i.e., washwater)
- the key is to target a portion of crop-required nutrients from manure, sample manure at application time, determine actual nutrients applied, then balance with fertilizer to meet crop needs.

Pre-cultivation before applying liquid manure will ease absorption.

If your goal is to apply at a rate that is above-optimum for NUE, focus on environmental limits to determine the maximum rate to spread. Any one of the following can be used as limiting factors to keep the application rate low enough to prevent harm when setting a maximum rate:

- ▶ soil absorption capacity
  - ▷ liquid manure should be applied at rates that "stick" to the soil surface
  - ▷ when using very diluted liquids such as those from a runoff storage, soils will become saturated and manure will run off before desired nutrient application rates are reached
- ▶ phosphorous limits
- ▶ nitrogen limits.

Best management practices to assist absorption capacity include:

- **applying liquid manure 2–3 times a year provided odour is not a problem**
- **precultivating surface before application**
- **applying manure on forages, cover crops and residues to reduce runoff.**

To ensure that suitable volumes of liquid manure are applied:

- **consider crop needs**
- **calibrate equipment to ensure crop needs will be met**
- **monitor field surface following first 30 minutes of application – if you see surface movement or tile runoff, reduce amount.**

Applying liquid manure into heavy crop residue promotes absorption and reduces runoff.

APPLICATION RATES FOR LIQUID PRESCRIBED MATERIALS

Liquid materials (those with a dry matter content of less than 18%, and can be pumped) should not be applied at rates where the material would run off the application site.

The maximum application rate is defined by the runoff potential of the site, which in turn depends on the field slope and permeability of the soil. The risk of runoff is much greater from a sloping field than from a level one, and from a clay soil than a gravelly soil. These relations are described in the following charts.

RUNOFF POTENTIAL

HYDROLOGIC SOIL GROUP (DRAINAGE CLASS)	MAXIMUM FIELD SLOPE WITHIN 150 M OF SURFACE WATER			
	<3%	3 to <6%	6 to <9%	9 to 12%
A (RAPID)	very low	very low	low	high
B (MODERATE)	very low	low	moderate	high
C (SLOW)	low	moderate	high	no application
D (VERY SLOW)	moderate	high	high	no application

Group A is often associated with sand, Group B with loam, Group C with clay loam, and Group D with clay soil textures.

MAXIMUM APPLICATION RATE

RUNOFF POTENTIAL	SURFACE-APPLIED m^3/ha (gal/ac)	INCORPORATED OR PRE-TILLED m^3/ha (gal/ac)
HIGH	50 (4450)	75 (6700)
MODERATE	75 (6700)	100 (8900)
LOW	100 (8900)	130 (11600)
VERY LOW	130 (11600)	150 (13400)

The application rate must not exceed the numbers in this table.
Note: 1 m^3 = 1000 L

Phosphorous that is not used by crops remains in the soil. In areas prone to erosion, take care to avoid an accumulation of levels exceeding 60 ppm.

At extremely high soil test levels, phosphorous may be lost in its soluble form.

To determine the P Index for each field with a soil test result for P of >30 ppm, refer to the *NMP Workbook* (Publication 818). Use your P Index rating to determine the recommended separation distances from watercourses – as outlined in the following chart.

NUTRIENT APPLICATION LIMITATION AS DETERMINED BY P INDEX AND PROXIMITY OF TILLABLE LAND TO SURFACE WATER SOURCES

P INDEX	<3 m (<10 ft)	3–30.5 m (10–100 ft)	>30.5 – 61 m (>100–200 ft)	>61 m (>200 ft)
LOW <15	no application	crop removal	no restriction	no restriction
MEDIUM 15–30	no application	crop removal	no restriction	no restriction
HIGH 31–50	no application	crop removal	crop removal	no restriction
VERY HIGH >50	no application	no application	crop removal	crop removal

Note: Where separation distances, in combination with the P Index, restrict nutrient application, consider changing management practices (application rates, application methods, and soil and water conservation practices), so that your P Index will drop.

MEETING NITROGEN NEEDS

Nitrate is mobile. Unless quickly used by a crop, it could be lost to the air or groundwater. It's recommended that no more than 75% of a crop's need for nitrogen come from manure.

Include some nitrogen from mineral fertilizers, for the following reasons:

- 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
- manure application rate is not always uniform, 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 nitrogen.

Where nitrogen is the nutrient that determines application rate, keeping the rate to 75% of crop N needs will also help balance phosphorous and potassium buildup. Where phosphorous is the nutrient that determines application rate, additional nitrogen may be required for some crops (e.g., corn).

Manure application is often uneven, so parts of the field receive insufficient manure to meet crop requirements. Consider side-dress or a blanket application of mineral N fertilizer to ensure all parts of the field have received some N.

SEPARATION DISTANCES BASED ON P INDEX RESULTS

The following two methods provide recommended distances between manure application and surface water. Selection for the most appropriate method is dependent on the soil test P value.

If your soil P tests are less than 30 (P<30 ppm), follow the procedures on the next page to determine minimum separation distances.

If your soil P test results are greater than 30 (P>30 ppm), follow the procedure for the P Index as per the *NMAN Workbook*, NMAN 2004 software, or the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet on this topic.

Separation distances for manure application should take into account the presence of surface water inlets such as catchbasins.

COMPARISON OF SOILS WITH LOW AND HIGH SOIL TEST PHOSPHOROUS

CHARACTERISTIC / GOALS	LOW P LEVELS	HIGH P LEVELS
SOIL ADSORPTION OF P	higher	lower
FIELD VARIABILITY OF P	lower	higher
AGRONOMIC GOALS	apply P to optimize crop yields	limit P to crop removal, minimize environmental impact
CONCENTRATION OF P IN ERODIBLE SOILS	lower	higher

Generally, it's acceptable to maintain a narrower separation distance to watercourses where:

- P levels are lower, and
- the risk of erosion and runoff due to soil type, cropping and tillage practices, slope and distance to the watercourse is less.

Slope is measured as a percentage of elevation over distance. A rise in elevation of 0.5 metre (1.6 ft) over a distance of 100 metres (328 ft) in a field is a slope of 0.5% – or nearly flat. However, a rise of 5 metres (16.4 ft) in 100 metres is a 5% slope. The potential for surface water contamination increases with percent slope.

If your P soil test results are <30 ppm

These soils are limited to P applications to meet soil test recommendations (agronomic requirements) or 78 kg/ha (70 lbs/ac) above crop removal.

To determine a site's potential for surface water contamination from manure runoff, find the texture of your soil in the first column and move horizontally to the appropriate slope column in the upper chart on page 101.

Then, using the chart below, determine the recommended separation distance between surface water and manure application.

MINIMUM SEPARATION DISTANCES TO WATER SOURCES FOR SURFACE WATER CONTAMINATION POTENTIAL* FROM LIQUID & SOLID MANURE RUNOFF

	MINIMUM SEPARATION DISTANCE (with established buffer zone)			
RUNOFF POTENTIAL	SURFACE-APPLIED Liquid	Solid	IMMEDIATELY INCORPORATED OR PRE-TILLED Liquid	Solid
HIGH	30.5 m (100 ft)	15.2 m (50 ft)	18.3 m (60 ft)	9.1 m (30 ft)
MODERATE	22.9 m (75 ft)	13 m (43 ft)	13.7 m (45 ft)	6.1 m (20 ft)
LOW	15.2 m (50 ft)	13 m (43 ft)*	9.1 m (30 ft)	4.6 m (15 ft)
VERY LOW	13 m (43 ft)*	13 m (43 ft)*	3.0 m (10 ft)	3 .0 m (10 ft)

* Although the manure separation distance should be observed, commercial P sources can be applied. For commercial fertilizers, a minimum separation distance of 3 m (10 ft), composed of a vegetative buffer strip, should be established between the area of application and any watercourse. Where commercial fertilizer is surface-applied, a 13 m (43 ft) separation distance from surface water is recommended (unless applied to a living crop or >30% residue cover).

Soil and water conservation practices such as reduced tillage and strip cropping will reduce P Index values.

SEPARATION DISTANCES TO WELLS AND BUILDINGS

Surface water is not the only feature to consider when determining setback distances for manure application. Setback distances are also necessary for wells (private and municipal), residences, residential areas (four homes or more), healthcare facilities and schools.

The setback distance required varies, depending on the type of material being applied to land. Generally, the higher the risk of contamination, the larger the setback distance. Choose the combinations (nutrient type and building or well) from the chart below to find the setback distance required. For example, if you're applying manure on land with a private drilled well and single residence, the manure should not be applied within 15 metres (50 ft) of the drilled well or 30 metres (100 ft) of a dug or bored well, and no closer than 25 metres (82 ft) from the home.

If the nutrients are applied near residences, consider the odour of the nutrient material and appropriate setback distances.

Manure should not be applied within 30 metres (100 ft) of private large-diameter wells.

Soil and water conservation practices such as reduced tillage and strip cropping will reduce P Index values.

SETBACK DISTANCES* FROM WELLS FOR LAND APPLICATION OF NUTRIENTS

SETBACK FROM...	FERTILIZER	MANURE	BIOSOLIDS	OTHER NUTRIENTS GENERATED BY FARMS
PRIVATE WELLS	3 m (10 ft)	15 m (50 ft) drilled 30 m (100 ft) other	15 m (50 ft) drilled 90 m (300 ft) other	15 m (50 ft) drilled 30 m (300 ft) other
MUNICIPAL WELLS	100 m (330 ft)	100 m (330 ft)	not permitted in 2-yr. capture zone	100 m (330 ft)

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

Setback distances from water resources below the ground have also been established. What this means is there are minimum depth requirements to bedrock, water table or saturated soil when applying nutrients to land.

MINIMUM DEPTH TO UNDERGROUND FEATURES			
MINIMUM (VERTICAL) DISTANCE TO...	MANURE	BIOSOLIDS	OTHER NUTRIENTS GENERATED BY FARMS
BEDROCK	0.3 m (1 ft)	1.5 m (5 ft)	30 cm (1 ft)
PERMANENT WATER TABLE	0.9 m (3 ft)	0.9 m (3 ft)	0.9 m (3 ft)
SATURATED SOIL	0.3 m (1 ft)	0.3 m (1 ft)	0.3 m (1 ft)

CROP PRECAUTIONS FOR MANURE APPLICATIONS

Manure application can pose risks to certain crops.

MANURE APPLICATION	
RISK	DETAILS
LODGING (cereals + soybeans)	• nitrogen needs for some crops are low • high rates increase risk of lodging – use lower rates and apply as uniformly as possible • selected varieties should have strong (shorter) stalks and lodging resistance
WHITE MOULD	• risk to soybeans is highest in fertile fields with lush growth – choose varieties with resistance to white mould and lodging
NITROGEN BURN	• summer application of manure onto green tissue increases the risk of nitrogen burn or foliage burn ○ to prevent this, summertime liquid manure applications surface-applied onto crops should be kept below 4000 gal/ac and/or should be done using less concentrated manure

Lush growth on fertile soils poses a high risk of white mould for soybeans.

TIMING OF APPLICATION

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. Schedule your manure applications with the following in mind.

SEASON	BEST MANAGEMENT PRACTICES	WATCH FOR:
SPRING	• apply to crops with the highest nitrogen requirement – high-yielding crops will use the N more efficiently • pre-till strips (i.e., zone-till application) prior to injection to reduce tile effluent • incorporate solid-spread, liquid-broadcast or irrigated-liquid manure within 24 hours • adopt good neighbour practices • sidedress 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 moist, poorly drained soils • tile effluent – when tiles are running, monitor and cease application if effluent 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 • sidedress liquid manure on row crops • apply liquid manure on cereal stubble • apply liquid manure to forage crops as soon after harvest before regrowth	• risk of ammonia loss if not incorporated or without rain • rill erosion and runoff along injection strips • "smothering" of forages (mainly an issue with solid manures not spread uniformly and/or spread at high rates) • preferential flow (manure in tiles) when applied to dry or cracked soils at high rates without pre-tillage
FALL	• apply solid or liquid manure prior to establishing winter cereals or cover crops • apply manure after corn and soybean harvest and incorporate the manure within 24 hours of applicaton	• risk of ammonia loss if not incorporated, no rain and temperature is >10 °C • risk of leaching if not absorbed by actively growing cover crop – avoid application on sandy soils • risk of denitrification on wet, poorly drained soils • runoff and preferential flow (manure in tiles) • 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. Sometimes there are opportunities to apply and incorporate manure to unfrozen soils with no snow cover, but these conditions are rare. No crop is in place to absorb the surface-applied nutrients, and there's too great a risk of runoff to surface water, especially during snowmelt conditions combined with rain.

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.

When applying manure during the winter months:

- **apply only on level fields, and only when the fields are not snow-covered (5 cm or 2 in. average minimum snow depth) or frozen (2 in. of frozen soil in the top 15 cm or 6 in.)**
- **reduce application rates**
- **increase setbacks from surface water**
- **apply to heavy crop residue or to a living crop.**

A preferred approach is to have alternative storage pre-arranged in the event of premature filling.

SPRING APPLICATION – TIMING IS EVERYTHING

Spreading manure in the spring before planting crops should give the maximum use of nutrients, but there are some hazards associated with spring application as well. Driving over the field with a fully loaded manure tanker when the ground is moist could cause severe compaction, negating any benefit from the manure. The biggest mistake farmers make is heading to the field to spread manure "because it is too wet to cultivate." The effects of this compaction can last several (up to five) years.

Waiting until the ground is fit carries its own penalty, because of the limited number of field workdays in the spring before crop yields start to diminish from late planting. For maximum yields, corn in southwestern Ontario should be planted by May 10, but in central Ontario we only expect to get about five field workdays before this date, two years out of three. This means that within five days, you have to be able to get the manure spread and incorporated and the crop planted, or else sacrifice yield. The best option may be to target cornfields that will have manure applied, and plan to plant a shorter-day variety in those fields.

Compaction is one of the key risks to manage for when applying manure in the spring.

APPLICATION TECHNOLOGY

Manure is applied as a solid or a liquid. In Ontario, solid manure has been defined as having less than 82% liquids by weight, and liquid manure has been defined as having greater than 82% liquids.

All manure application technology should meet the criteria of practicality, durability, affordability, desirable distribution pattern, and minimal environmental impact.

In this section, we'll look at manure application equipment types with these criteria in mind.

SOLID MANURE

Box Spreaders

The box spreader is the most commonly used piece of solid manure spreading equipment. Although it can be truck-mounted, most producers use pull-type box spreaders. It has capacities from 2.5 to 18.4 m^3 (90–650 ft^3).

PTO-driven units are most common, although some hydraulic-driven units are also produced. Boxes are made of either wood or metal and should be watertight to avoid liquid leakage.

For solid manure of relatively high moisture content, manufacturers often offer the option of installing a hydraulically operated lift gate at the rear of the spreader to fully contain the liquids.

For solid manure with very low moisture content (e.g., poultry manure), side-delivery systems or side-slingers are a common option.

Box spreaders work best with cattle manure that has a 70–80% moisture content.

The spreader mechanisms at the rear of the unit:

- can take the form of paddles, beaters, flails or augers or combinations
- rotate on a shaft perpendicular to the load of manure and break up and discharge the manure as it passes through them
- can – in terms of their number and type – have a significant effect on how uniformly manure of certain consistencies is spread.

The feed apron, which moves the manure along the box length to the spreaders at the rear, is often variable speed. On some units, and for manure with a higher moisture content, a hydraulic push wall or front-end gate is sometimes used to push the manure to the rear.

Side-slinger box spreaders work best for poultry manure or other materials with a very low moisture content.

Hopper Spreaders

Hopper spreaders are another form of solid manure spreader. They have a V-shaped box with a large auger placed across the bottom of the spreader. This auger moves the manure to a point where impellers discharge the manure out a side opening.

Typically, solid manure nutrient contents are more variable than agitated liquid manure generated by the same animal type, given the variability among farms regarding bedding practices, and the amount of liquids allowed to drain from the pile. This adds to the complication of getting an even distribution of manure nutrients using solid manure spreaders that currently exist.

LIQUID MANURE

Liquid manure is transferred by pump to tankers, tractor-mounted systems or boom irrigation systems. In tanker and tractor-mounted systems, it's usually injected or broadcast – there's newer technology for low-trajectory broadcast and dribbling. Irrigation systems will broadcast by gun or a series of smaller nozzles.

From tankers, liquid manure can be broadcast, dribbled or injected.

Tanker Systems

Tanker systems – either tractor-pulled or tanker truck – are top-loading or vacuum-loading. Top-loading tankers tend to be more common. A liquid manure pump is needed to transfer the manure from the storage to a top-loading tanker. This same pump is often used to agitate the stored manure prior to loading. Vacuum tankers use differences in air pressure to load and unload the tank.

Tanker systems require high amounts of horsepower and energy, and many trips to and from storage – risking compaction. Some tankers will also have tillage or injection units mounted at the back. Nurse tanks will sometimes be used to transport manure from storage to field so that the tanker can spend maximum time in the field.

Irrigation Systems

Low-Trajectory Spray Irrigation Application

Spray irrigation guns are slowly being replaced by low-trajectory application. Spray irrigation is the biggest cause (over 60%) of manure spill charges. High-trajectory irrigation guns have been banned in Ontario under the Nutrient Management Act. They can still be used for application of very dilute liquid materials (<1% dry matter), such as yard runoff.

With low-trajectory application, manure is applied at less than 1.2 metres (4 ft) from the soil surface.

With low-trajectory application, where manure is applied at less than 1.2 metres (4 ft) from the soil surface, the following advantages are attained:

- decreased droplet size
- less wind movement
- less odour, and more uniform manure coverage (especially to field edges and along roads).

Direct-Flow Systems

Manure or other liquid nutrients are applied directly to land from the storage facility. This is a high-risk system that should be monitored closely and able to be shut down within one minute of a spill or accident. There are several operational setups that could allow this quick response, including radio communication between operators, remote control systems or a combination of these options.

USE A FLEX HOSE

Where hard-hose equipment is already on the farm, a flex hose between the soft hose and the tractor unit is an economical alternative to low-trajectory, without switching to a total soft drag-hose system. The flex hose allows manure application without restrictions when turning corners and moving through the field. In comparison, a hard hose attached directly to tractor-mounted application boom is rigid and short-lived.

Injection Systems

For most operations with liquid manure, injection of manure is considered a preferred application system, particularly if odour or runoff concerns exist. It does take some fine-tuning to make these systems work. Injectors that can spread manure in as broad a band as possible are much preferred over injectors that concentrate the manure application in a narrow band. Here's why:

- while an injection spreader may be set up to spread the correct rate of manure over the spreader's width of pass, with narrow band application, there are localized strips where extremely high manure applications have occurred – likewise, there are areas between the injectors where no manure has been applied
- areas receiving the high liquid manure loadings are more likely to have the liquid move through the soil profile and possibly enter any existing tile drains
- runoff potential along the narrow bands also increases
- regardless of the fate of manure in narrow strips, uneven nutrient application will result.

Some of the best-designed injection systems combine tillage and injection in one pass.

MANURE APPLICATION SYSTEMS				
METHOD	**TYPE**	**DESCRIPTION**	**ADVANTAGES**	**DISADVANTAGES**
SOLID SYSTEMS				
BOX SPREADER	PTO-driven	• common box spreader with aprons and paddles • tractors need to be >40 hp	• spreader is readily available and relatively inexpensive • handles a wide range of manure types • simple to operate	• many loads are required to empty a 200-day storage • risk of compaction • uneven broadcast
HOPPER SPREADER	PTO-driven	• V-bottom spreader • large auger across bottom of spreader • manure spreader via impeller on side	• wide, even manure application • leak-resistant	• risk of compaction • higher cost • high power requirements • may not work with very dry manure

METHOD	TYPES	DESCRIPTION	ADVANTAGES	DISADVANTAGES
LIQUID SYSTEMS				
TANKER	broadcast	• distributes manure in wide pattern – to one side, both sides or behind tanker	• simple to manage • less costly than injectors • less hp than injectors	• high risk of soil compaction • high hp to haul • significant travel time to fields • significant odour and volatilization • significant loss if windy and delay before incorporation
TANKER	injection	• consists of cultivator teeth or shoes on rigid shanks • soil is opened up so manure is deposited beneath surface • can be rear- or front-mounted	• odour is minimized • loss to atmosphere is minimal • nutrients can be placed in root zone	• high risk of soil compaction • high hp to haul and incorporate • poor distribution of manure in soil • significant travel time to fields • without pre-tillage, manure can enter tile drainage system
TANKER	dribble	• consists of fabric or rubber drape over nozzle to "dribble" low-volume applications – usually as sidedress	• low odour • can be combined with inter-row weed control cultivation	• high risk of soil compaction • high hp to haul • significant travel time to fields – moderate loss to volatilization if not incorporated
TRACTOR-MOUNTED (DRAG HOSE)	injection	• injector is mounted on tractor, hose dragged • draft increases with distance from the main line • rigid swing pipe prevents damage by tractor	• minimal odour and volatilization • lower power requirements than with tanker systems • low risk of soil compaction	• injectors must be lifted to turn • distance to field is a limitation • risk of spillage at end of runs
TRACTOR-MOUNTED (DRAG HOSE)	broadcast	• tractor-mounted unit consists of pipe, nozzle and deflector plate • similar spread pattern to broadcast tank spreaders	• simple design and operation • relatively inexpensive • relatively low hp requirements to pull hose • low risk of soil compaction	• significant odour and volatilization • significant loss if windy and incorporation is delayed • significant odour and volatilization
IRRIGATION	travelling boom	• either soft or hard systems • manure piped through rigid irrigation pipes to field • similar to irrigation technology for water – low-volume nozzles on travelling boom broadcast across strips on field	• low risk of over-application • fewer odour problems and loss due to volatilization • not as prone to loss if windy	• manure needs to have less than 4% solids • requires monitoring and regular calibration • moderately expensive • limited strip width • a risk of spills from pipes

NEW APPLICATION TECHNOLOGY

Solid Manure Application

Wet and clumped manure is spread more uniformly with aggressive paddle designs.

Spinner spreaders on box spreaders are designed to spread dry manure and composts more evenly in the field. Some spreaders are also designed to apply very low volumes.

Liquid Manure Application

The dilemma with liquid application equipment is the ability to spread a load quickly versus making the most economical use of nutrients by lowering rates or improving placement. New technology has focussed primarily on improving nutrient placement.

This system demonstrates variable-rate technology with GPS guidance, computer-guided rate control and a pneumatic pinch valve. All this helps producers pinpoint application where and when it's needed.

Low-disturbance injection systems can be used in NT systems, as a sidedress for cereals and between cuts in forages.

Coulter-injection systems have been developed to break macropores, inject to seedbed, and disturb enough soil to reduce odours and nutrient loss. This creates the opportunity to apply manure while establishing the zones in fall, then returning in spring with a no-till planter. These systems can be modified to also apply manure into a standing crop at sidedress time.

Aerator technology – designed to poke holes in the soil – will allow increased infiltration. This works well when modified for inter-row application into standing crops. One drawback of this application tool is that it will increase risk of compaction in fine-textured or wet soils.

MANURE TRANSFER AND HAULAGE

Manure transfer is the transfer of liquid manure from long-term storage to field site for land application (e.g., tanker systems, nurse tank systems, pipelines).

Manure haulage is the movement of solid or liquid manure from one unit to another, using manure-hauling equipment on roads and farm lanes. Human safety and environmental protection are primary concerns.

Manure transfer pipe.

BMPs for Tankers and Nurse Tanks

Tankers or nurse tanks are mobile, temporary storage devices used in the field to store liquid materials in the interim between hauling equipment and land-application equipment.

Tankers and nurse tanks should be:

- leak-proof
- equipped with emergency shut-off valves
- equipped with safety grills to prevent human entry.

In addition, nurse tanks should be located at a point in the field that meets the following separation distances:

- larger tanks (>45,400 L (10,000 gal) should be at least 150 metres (492 ft) from surface water
- smaller tanks should be at least 50 metres (164 ft) from surface water
- 125 metres (410 ft) from residences (could be difficult if nurse tank is using field entrance lane)
- 250 metres (820 ft) from residential area
- 15 metres (49 ft) from a drilled well
- 30 metres (98 ft) from a dug well.

Vacuum loading arms work well for unloading nurse tanks. Where appropriate, include them in your contingency plan, as they're also useful in case of a spill.

BMPs for Temporary or Portable Pipelines

Temporary or portable pipeline is usually rigid aluminum pipe or large-diameter hose material with threaded connectors. It can be dismantled and moved from field to field or farm to farm. While the capital cost is low, operating costs are high for labour to move equipment.

- ▶ Ensure pipe or hose can develop a flow velocity of 0.8–2.5 m/s
  - ▷ should be no less than 75 mm in diameter – 100–150 mm diameter pipes are most common.
- ▶ Ensure pipe or hose connections can withstand all likely loading conditions, such as head pressure from pump.
- ▶ Direct highway crossings through culverts:
  - ▷ set secondary containment berms parallel to the road to contain any spills or leaks
  - ▷ ideally any connections close to the culvert would be avoided (use a single length of flex).
- ▶ Flush the system with water or purge with air, or cap the single flex hose and drag it away from the culvert prior to disconnect:
  - ▷ caution: use proper equipment and be trained prior to using an air purge system, as the energy in the compressed air pipes can burst or the pipes become airborne if they improperly disconnect.

All systems should be operated by two trained staff, or one trained staff with an automatic, remote-control shutoff device.

- ▶ Use existing bridges or roadways to convey piped manure across watercourses.
- ▶ Operate all systems with two trained staff, or one trained staff with two-way communication capability at all times, or with an automatic, remote-control shutoff device.
- ▶ Use an air pressure blower to “blow” manure out of system (hoses/pipes) before moving to a different location.

Note: permanent pipelines are buried below-grade with risers/hydrants at specific locations on the farm. They are usually constructed with PVC (polyvinyl chloride) or equivalent – high capital cost to build but low operating cost if properly maintained.

PREPARATION

CALIBRATING MANURE APPLICATION EQUIPMENT

Like many farmers, you might estimate how much manure is spread by counting the number of loads being applied to a field, based on the spreader capacity. Although this may seem to work well, it doesn't take into account the different densities of the manure, or whether your spreader is being filled to meet the manufacturer's specifications.

You can use several methods to measure your spreading rates. One quick method for solid manure involves weighing the manure to be applied on a plastic sheet placed in the path of the spreader. A method for liquid manure uses a straight-walled pail/jar to measure depth of application. The following chart shows how to convert the measurements to application.

New methods are being introduced to quickly and accurately determine what's being applied. An on-line flow-meter is available, which can instantly give you an application rate in gallons per hour. Another method being developed combines flow-meter data with application width and groundspeed information to give an instant gallons-per-acre readout.

To calibrate liquid manure spreaders:

1. Set a series of straight-walled pails/jars in the application path of a liquid manure spreader.
2. Measure depth of liquid in pails/jars. Take an average.
3. See the chart on the next page to estimate application rate.

To calibrate solid manure spreaders:

1. Spread several plastic sheets (40 x 48 in.) within spread pattern of spreader.
2. Drive by the plastic sheets at normal speed.
3. Collect the sheets and weigh them. Note the average.
4. Use the chart on the next page to determine the application rate.

CALIBRATING MANURE SPREADERS			
SOLID MANURE Calibrations Using a 40 x 48 in. Sheet (Opened Feedbag)		**LIQUID MANURE** Calibrations Using a Straight-Walled Pail/Jar	
MANURE PER SHEET lb (kg)	**APPLICATION RATE tons/acre (t/ha)**	**DEPTH OF MANURE IN PAIL inches (cm)**	**APPLICATION RATE gallons/acre (L/ha)**
1 (.45)	1.6 (3.6)	1/10 (.25)	2,250 (25,200)
2 (.91)	3.2 (7.2)	1/8 (.3)	3,000 (33,600)
3 (1.4)	4.8 (10.7)	– –	5,500 (616,000)
4 (1.8)	6.4 (14.3)	3/8 (.9)	8,500 (952,000)
5 (2.3)	8.0 (17.9)	– –	11,250 (126,000)
7 (3.2)	11.2 (25)	5/8 (1.6)	14,000 (156,000)
10 (4.5)	16 (35.9)	– –	17,000 (190,400)
15 (6.7)	24 (53.8)	1 (2.5)	22,500 (252,000)

An alternative method for liquid manure is to weigh the manure and follow the sheet method used for solid. If you're using a straight-walled container, calculate the area from the inside rim diameter. The formula for area is 3.14 x square of radius, and assumes that a gallon of liquid manure weighs 10 lbs.

TYPE OF MANURE	WEIGHT PER CUBIC FOOT (LBS)	WEIGHT PER BUSHEL (LBS)
LIQUID	62.4	80
SEMI-SOLID	60	76
THICK SOLID MANURE	50	64
LIGHT SOLID MANURE	20–35 lbs/ft^3	25–45 lbs/bu

1 bushel = approx. 1.25 ft^3

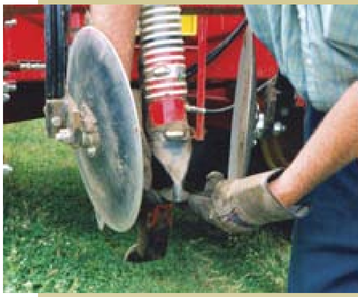
For more detailed information, see the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet on how to calibrate a liquid manure spreader. It shows equations to calculate travel speed based on application rate required, width of application and time it takes to empty a load.

Please note that manure tankers are sold in US gallon capacity. All gallons listed in this book are Imperial, unless otherwise noted. To convert Imperial gallons to US gallons, multiply Imperial gallons by 1.2.

EQUIPMENT MAINTENANCE

With the exception of tractors, most farm implements and equipment are used heavily, but for a short period of time. Manure application equipment is no different. And like all farm equipment, it should be ready to use and reliable when needed.

Preventive maintenance is essential to reduce the risk of down-time and serious malfunction – the kind that could cause personal injury or environmental damage. When preparing manure application equipment for storage, you want to ensure the equipment will be in good working condition the next time you need it. Cleanup should be done as soon after application as possible (within hours), since dried-up manure is difficult to clean and high salt content in liquid manure can cause rapid rusting.



Flush pipelines with clean water and empty contents into manure or runoff storage.

Pumps

✔ run clean water through it, then drain to protect from freezing
✔ cover metal with protective lubricant
✔ loosen V-belt to reduce tension (if belt-driven)

Electric motors

✔ lubricate bearings
✔ cover motor to protect from dust and moisture
✔ lock control box

Clean all nozzles and pipe connections.

Combustion engines

✔ drain and replace oil when not in use
✔ remove spark plugs and place clean oil in spark plug holes, crank engine, and replace plugs
✔ drain cooling system
✔ drain all fuel from engine and tank
✔ lubricate all moving parts
✔ remove battery

Pipelines

✔ flush with clean water and empty into manure or runoff storage OR collect and land-apply the washwater

✔ **be very careful when using an air system, as compressed air can cause pipes to explode or be rapidly displaced – proper equipment and operator training are necessary before an air system is utilized**

✔ check for and repair leaks and verify that repair worked

✔ keep valves open

✔ clean all pipe connections

✔ store portable units in a clean dry place

Some tankers come equipped with intake washing units, which prolong tanker life and reduce the risk of deadly gas buildup.

Hoses

✔ flush with clean water to prevent crusting
✔ store on reels under roof

Tankers

✔ flush tanks and pumps with clean water
✔ drain tanks and hoses
✔ lubricate wheels and all moving parts
✔ **never enter tanker without proper safety precautions**
✔ prevent liquid manure from spilling onto roadways at take-off from storage or stop signs by using risers (chimney) to extend the loading opening
✔ ensure PTO guards always cover PTO shafts

Note: Many farmers use automatic oil pressure and water temperature switches that cause the pumping unit to shut down if low oil pressure or high water temperature is detected. These switches often work in conjunction with the automatic radio-controlled shutdown system.

Some tankers have an access cleanout door (tray) near the bottom to help "bleed out" dangerous gases.

PRE-PLANNING OF APPLICATION – TRAFFIC PATTERNS

Make fewer passes by modifying application/ incorporation equipment.

Applying manure when it's necessary or when the crop requires it is often a time when conditions are favourable for soil compaction.

There are several planning and operational measures that can help to reduce the incidence of compaction:

- ► increase the volume of manure storage to provide for more application opportunities
- ► modify cropping and tillage practices to provide more application windows – this will reduce the necessity to spread total volume at one time (e.g., in spring)
- ► use high flotation tires on farm implements
- ► modify traffic patterns – direction, path and frequency, or use tramlines to minimize location of compaction
- ► reduce axle weights to less than 10 tons/axle – use systems with more axles and tires
- ► note that crop rotation and reduced tillage may be more effective than deep tillage to lessen the impact of soil compaction.

SAFETY

Safe operating procedures are the best way to prevent farm accidents related to manure handling.

- ✔ Keep people, pets and livestock out of any confined space or area storing liquid manure by using locked and signed entrances.
- ✔ Keep storage area ventilation systems working and functional.
- ✔ Never fill a storage or tank completely.
- ✔ Evacuate livestock facilities when agitating or removing liquid manure from an in-barn storage.
- ✔ Watch for all moving parts, such as PTO shafts and impellers.
- ✔ Handle transfer equipment with caution – there are high pressures in hoses and pipe. Before using an air system in pipelines, be very careful to ensure you have the proper equipment and adequate operator training.
- ✔ Sign all vehicles and equipment used on public roads.
- ✔ Keep brakes in good working order if any equipment is used on sloping land or is transported on inclines.
- ✔ Have emergency plans and post them.
- ✔ Train all staff and family members.

Train all staff and family members regarding manure-related safety hazards and features on your farm.

BMPS FOR MANURE APPLICATION – PUTTING IT TOGETHER

Manure application is a system, one that is full of small uncertainties. To maximize the Nutrient Use Efficiency from manure (which will also maximize profit and minimize environmental impact), a systems approach is needed that's sensitive to the unique attributes of manure.

One of the key limitations to maximizing nutrient use is that the best time for sampling is when manure is agitated for application to the field. Thus, the value of the manure isn't known until after it has been applied. Also, despite the best calibration, there's always some variation in the actual application rates of the manure.

This is a suggestion for a system that can overcome these limitations:

1. Determine which fields can get greatest benefit from manure application. These will generally be the fields with the lowest soil tests for P and K, and growing crops with the highest N demand.
2. Determine average nutrient contents for the manure from past manure analyses, or from chart values.
3. Calculate a target application rate that supplies $^2/_3$–$^3/_4$ of the N requirement for the crop, based on the estimated nutrient values.
4. Calibrate the application equipment.
5. Collect samples from the manure storage as it's being emptied, following agitation. If manure is applied to more than one field, keep samples separate for each field.
6. Record the actual manure application rate on each field.
7. Submit the manure samples for analysis.
8. From the analyzed value of the manure, and the application rate, calculate the actual amount of available nutrients applied to each field.
9. Determine the amount of fertilizer required to make up the difference between total crop requirements, and the amount applied with the manure. Apply that fertilizer as a sidedress or topdress application if required.

CROPS

TIPS FOR APPLYING MANURE AFTER CEREAL HARVEST

If you have spring and winter cereals in rotation – often deployed in nutrient management planning – you have the opportunity to apply manure when risk of compaction is lowest, and when there are fewer demands on your time.

Whether from an on-farm storage or a manure agreement, manure should be applied at this time of year with the goal of maximizing nutrient value while minimizing risk to the environment and minimizing odours.

This is the highest risk period for nitrogen losses. On soils sensitive to nitrogen losses, you should use a cover crop or delay application to later in the year. This is especially true with manures with high ammonium levels, such as swine and poultry manure.

Cracked, bone-dry soils should be pre-tilled prior to liquid manure application.

Pre-till

If you have bone-dry soils that may be cracked, pre-till before applying liquid manure. A light cultivation increases infiltration while reducing the risk of runoff through cracks to tile or groundwater sources. Pre-tillage will also reduce odour and nitrogen loss, although not to the same degree as post-application incorporation.

Where application rates are above 5000 gal/ac on a moderately sloping loam soil, or, on a gently sloping clay or clay-loam soil type, pre-tillage is strongly recommended.

Incorporate within 24 hours

When manure is applied shortly after wheat or spring-grain harvest, temperatures are usually warm and rainfall limited. Volatilization losses can be high if manure isn't incorporated within a day or two of application.

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

Reduce volatilization losses by incorporating soon after application.

Plant cover crops to reduce nutrient losses

Some cover crops fix nitrogen, but many more 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 applications.

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

- **non-legume green manures** (oilseed radish) 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 lb 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
- **oats** planted in August will "catch" nitrogen in the fall, then winterkill, leaving an easy-to-till residue for early spring planting
- **legume green manures** (i.e., red clover) can absorb residual inorganic nitrogen or will fix nitrogen
  - planted in early spring
  - growth can be variable depending on thickness of the cereal stand and summer moisture
- **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 such as **sudangrass or buckwheat** – since buckwheat is a light feeder, sudangrass may be the crop of choice for a really rich soil

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

Undersown cover crops have been shown to reduce nitrogen losses when mineral fertilizer or manure has been applied at normal rates (90–110 kg N/ha). Research suggests that undersown cover crops can reduce nitrogen leaching by up to 60%, when compared with soil that was conventionally tilled in August–September.

Incorporating cover crops will affect nitrogen mineralization, mainly during the first growing season following incorporation, when approximately 20–30% of cover crop nitrogen is released. In spring, following the incorporation of cover crops, an early onset of nitrogen mineralization is necessary to overcome the soil-depleting effect of nitrogen uptake induced by the cover crop.

MANURE APPLICATION ON FORAGES

Productive forage fields have high fertility needs, so nutrient levels need to stay high. Manure nutrients can work as well as commercial fertilizer and save you money. Consider your options for manure application, both for fields to which manure can be applied and for timing of application.

Consider applying manure to the oldest and/or grassiest forage stands first.

BEST MANAGEMENT PRACTICES FOR APPLYING MANURE TO FORAGES

BMP	DETAILS
ANALYZE MANURE	Use a manure analysis that indicates ammonium–nitrogen content of the manure to help determine most appropriate application rate. • the ammonium–nitrogen content of manure changes with livestock types and from farm to farm • applying at a rate too high of ammonium–nitrogen could cause burn damage to regrowth • when an analysis isn't available, a rate of 4000 gallons (with the exception of liquid poultry manure and highly concentrated liquid finisher hog manure) is safe for an alfalfa stand • since the NH_4^+–N content in solid manure is relatively low, nitrogen burn to new growth is not a concern (with the exception of high rates of poultry manure)
USE MANURE TO ESTABLISH FORAGE STAND	Manure can be used at relatively high rates before seeding a new forage crop. However, there are a few precautions. • manure should be applied and incorporated at least 5 days before planting • high nitrogen and/or salt content in manure can lead to severe root injury in new seedlings, which will reduce plant stand • new seedlings may also have higher weed pressure when manure is used prior to planting
APPLY MANURE TO GRASSY HAY FIRST	Applying to the oldest and/or grassiest forage stands first will provide stands with needed nitrogen and potash.
APPLY RIGHT AFTER HARVEST	Applying before regrowth will prevent manure contact and potential nitrogen burn on new growth.
APPLY TO FORAGES DURING THE SUMMER	In sunny hot weather, applying manure during late afternoon or early evening will help to minimize nitrogen loss and reduce potential nitrogen burn. Twelve to 18 hours without direct sunshine and with potential dew will reduce manure volatilization. An application rate of less than 4000 gal/ac when water is not flowing from tile drains will help prevent manure preferential flow (macropore movement) to tile drains.
WATCH FOR RAIN	A gentle rainfall – 10–12 mm – will help incorporate the nitrogen from manure. An erosive rain will increase risk of surface water contamination. Since manure spread on forages is surface-applied without incorporation, odour can be an issue, especially if there are neighbours in the vicinity.

BMP	DETAILS
AVOID APPLYING MANURE WHEN SOIL CONDITIONS ARE WET	Wheel traffic from a heavy tanker will cause some crown damage and potentially some compaction – another reason to apply to older stands. Irrigating watery manure (<1% DM) will cause less damage to crowns. The benefit of washwaters for forage yields may be as much from the water as from the nutrients.
MODIFY APPLICATION EQUIPMENT	Applying manure uniformly is difficult. Rates under 3000 gal/ac are hard to apply without applicator modification due to high tractor-speed requirement.
WATCH FOR CLUMPING	Where solid manure is being applied to forages, exercise extra caution. • in most cases, the manure is not applied uniformly enough • when manure "clumps", it can cause a significant reduction in the crown stand
AVOID APPLICATION TO HAY FOR ROUND BALE SILAGE	Take precautions for manure applied to forages that will be used for wrapped, long-hay silage. • in some cases where manure was applied to regrowth, the bacteria from manure caused improper fermentation, which could lead to problems (spoiled areas) in silage
WATCH FOR MANURE-BORNE DISEASES	Disease transmission from manure in forages has not been reported as an issue, but the question is raised periodically. • if you have a concern about a particular disease being carried in the manure, question your local veterinarian about how the disease is transmitted • if the disease is carried in manure, then question how long can the organisms survive in the soil under normal weather conditions
DO NOT APPLY BIOSOLIDS ON LEGUME FORAGES	Biosolids, specifically sewage sludge, have almost no potash. Forage crops have high nitrogen and potash needs. Since legume crops naturally produce nitrogen, legume forages have traditionally not been the best economic targets for the nitrogen from manure and biosolids. Livestock manure is a good source for replacing commercial potash; in contrast, biosolids are a poor choice for replacing potash needs of the crop.
MANAGE POTASSIUM (K) LEVELS FOR DRY COWS	Precaution: high soil test levels of potash and high potash levels in manure can lead to high potassium (K) levels in forages, resulting in milk fever problems in dairy cows. • alternatives to high K forages include off-farm sources of low K hay and/or dilution with low K forages such as corn silage, or anion/cation balancing
REDUCE FERTILIZER APPLICATIONS	When applying manure to forages, additional commercial fertilizer (particularly potash) applications should be reduced to compensate for nutrients applied from manure.
MANAGE COPPER LEVELS	Precaution: manure containing high levels of copper (i.e., from farms using hog rations high in copper and/or cattle footbaths containing copper sulphate) should never be applied to sheep pasture. • sheep have a low requirement for copper; their maximum tolerable level is close to their requirement • a 5000-gal application rate containing a copper level of 5 ppm applied regularly to pastures could kill sheep • manure applied to sheep pastures should have been analysed for copper in addition to the common nutrients

Wheel traffic from a heavy tanker can cause compaction and alfalfa crown damage.

High soil test levels of potash and high potash levels in manure can lead to high potassium (K) levels in forages, resulting in reproductive problems in dairy cows.

NO-TILL AND MANURE: MAKING IT WORK

Livestock producers – particularly those with solid manure systems – think twice about no-till. Livestock producers who practise no-till have to modify their tillage and application practices to make it work. Manure management should always be well-planned, taking crop rotation into consideration, but this is even more important in a no-till system.

Here are the most popular options to date.

Apply manure to wheat fields after harvest, followed by shallow tillage.

- this allows faster breakdown of the wheat residue, and alleviates risk of allelopathic interference for the planned corn crop, while also allowing minimal soil disturbance and reduced risk of compaction
- also makes good use of manure nutrients, especially if combined with a fall cover crop
- on sandy soils prone to leaching, application rates should reflect nitrogen quantity and type being applied
- in most cases, solid manure containing a higher percentage of organic nitrogen will have less risk of loss through leaching

Use liquid manure on forages.

- although not the most economical use of manure nitrogen, alfalfa does utilize the phosphorous and potassium from manure

Sidedress liquid manure into a standing corn crop by injection.

- the manure will reach the crop when the nutrients are most needed, and when the risk of compaction is often lower than at planting time
- the biggest drawback is the greater time requirement as well as increased risk of reducing plant population
- some sidedress application is accomplished by irrigating manure into standing corn
  - the drawback to this system is that risk of nitrogen loss due to volatilization is higher due to warmer temperatures
  - also, there's an increased risk of nitrogen burn to the crop if concentrated manure is applied, especially in the heat of the day

Manure management in a no-till system must be well-planned to minimize soil disturbance.

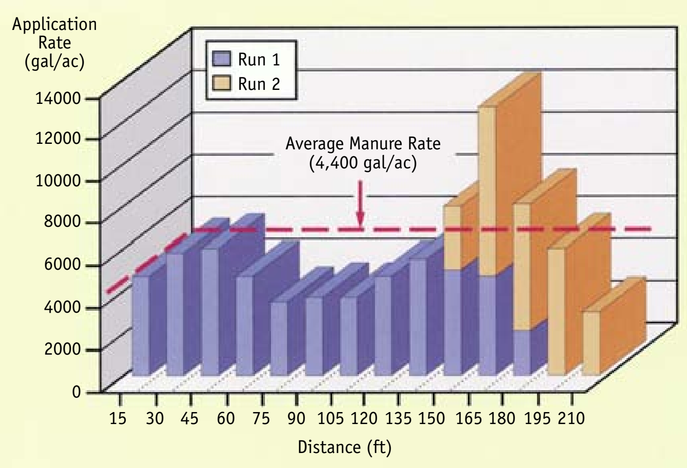
Manure can be dribbled as a sidedress application to a standing row crop and incorporated when combined as a scuffling or weed control pass.

FINE-TUNING MANURE APPLICATION

Using manure can decrease the fertilizer bill, but getting uniform application is difficult. In this section are some factors that will help you get more constant application rates at a volume suitable to your crop needs.

As we've already discussed, to maximize the benefits of manure application onto cropland, manure must be spread evenly and at an appropriate density. Variable manure application rates within a field can cause variations in crop yield.

The amount of manure a field should receive depends upon the soil fertility level, the nutrient requirements of the crop, and on the nutrient value of the manure itself. Application rates from almost all systems have been measured during the past few years and reveal that **most farmers underestimate how much is being applied.** Application goals of 8,000 gal/ac sometimes end up over 20,000 gal/ac when the manure is on the field. This is both uneconomical and potentially harmful to the environment.



The graph illustrates the variability that can occur from an irrigation gun system where overlap has not been accounted for. In this example, the average application rate is about 4,400 gal/ac, with a range from 2,000 to 13,000 gal/ac.

TIPS TO IMPROVE UNIFORMITY

Solid manure spreaders vary considerably. However, once calculated, the spread pattern is relatively constant.

The consistency of the manure used has a tremendous influence on spread pattern. Hard, tightly packed manure often passes through the beaters intact, thus creating large chunks (usually less than 10 lbs) and an unpredictable spread pattern.

For **back spreaders**, the areas behind the spreader generally receive two to three times more manure than do the areas to either side of the spreader.

For **side spreaders**, the application density decreases with increasing distance from the spreader.

Tightly packed or compacted manure can pass through the beaters intact – leaving an irregular clumpy spread pattern.

To improve solid manure uniformity:

- heap manure evenly on the spreader
- determine width of spread pattern and determine amount of overlap required
- incorporate perpendicular or at an angle to direction of application
- determine difference between beginning and end of the load and adjust speed accordingly.

Liquid manure is spread both by tanker and irrigation systems. Wind speed and direction often determine liquid manure variation. It is also influenced by consistency of the manure. Seemingly random fluctuations are often due to changes in manure thickness. These are difficult to adjust for.

High-trajectory irrigation guns have been banned in Ontario under the Nutrient Management Act. They can still be used for application of very dilute liquid materials (<1% dry matter), such as yard runoff.

Irrigation systems cover a large area in relatively little time. This system also creates the most problems in non-uniform application.

Factors affecting liquid manure application uniformity include:

- from current uniformity tests, the volume of manure applied when a tanker is three-quarters full vs. one-quarter full is not different than when the manure is being pumped to spread from an 8-ft. height
- tractor speed varies the application rate – in one trial, the application rate changed by 60% when going from 5 mph to 2 mph (4300–7500 gal/ac)
- the area covered is not equal on both sides of the irrigation gun
- the application pattern narrows from the fully extended reel to the rolled-in reel
  - this is caused by friction and constriction as manure flows through a rolled-up hose
  - speed increases as the drum rolls up.

To improve application uniformity for side-spreaders, determine the amount of overlap required and adjust distances between application "lanes" accordingly.

A compensator comes with some irrigation systems. Most are not functioning, however. A compensator can change the motor speed so that it is constant during the entire pull.

A flow meter, a device that attaches to the hard hose near the manure storage, helps to measure pumping rate and the velocity of flow.

BMPS FOR VARIABLE-RATE TECHNOLOGY

Fields that have been soil-sampled using site-specific technology (GPS) often demonstrate variable fertility levels, especially as fields have increased in size. Fields closest to the barn often display excessive fertility.

Modification of application equipment to allow variable rate application is being developed with the use of flow meters, GPS monitors, maps etc. However, for the average farm this is still beyond economic or equipment potential.

INCORPORATION METHODS

Pre-injection tillage – pre-tillage to reduce risk of tile flow will also loosen soil for improved soil-applied manure contact.

Secondary tillage practices – discs, cultivators and light harrows are sufficient for most soil and residue cover conditions to adequately incorporate manure.

One-pass systems – for the application of liquid manure

- injection systems with tillage implements, or
- tanker/tractor-mounted broadcast application techniques with knives or discs, which are considered superior to two-pass systems as the material is mixed with the topsoil as it is applied.

A tanker-based broadcast application with discs is one example of a one-pass system that reduces manure loss.

APPLICATION ON LAND WITH TILE DRAINAGE

When liquid manure or other prescribed nutrients are applied to land with tile drainage, the tile outlets should be monitored for visual signs of contamination. New installation of tile drains in fields should have a drainage system that can be monitored, and is capable of isolating contaminated tile lines.

Tile outlets should be monitored for early detection of contaminated tile effluent.

In many existing tile drainage systems, it may not be possible to monitor the outlet. If this is the case, assess the field before application to determine whether severe crevices or other means of preferential flow to the tiles exist. If crevices are detected in the field, then choose one of the following options.

- Pre-till the land (e.g., cultivate or tamdem disc) within seven days before application.
- Reduce the application rate to less than 40 m^3/ha (<3600 gal/ac / 4300 US gal/ac).
- Apply when:
  - there's no water flowng from tiles
  - tiles are blocked
  - tiles discharge to holding pond, or monitor tile outflow and stop application if discoloration of tile water is observed
  - intended rate from one load has been applied to a representative tile with monitoring of tile outlet

Guide for Monitoring Tile Outlets

Look for discoloration of tile flow, relative to pre-application condition.

The suggested schedule for observation is as follows:

- 10-20 minutes after start of application
- once each hour, if rate >20,000 gal/hr (24,000 US gal/hr)
- once each 20,000 gallons applied, if rate is less.

You could use automated continuous monitors.

Stop application immediately if discoloration in tile water is observed. Activate your contingency plan (for more information see the final chapter).

Another means of reducing odours and drift is low-trajectory manure irrigation technology.

Plant field windbreaks to reduce odours generated during application.

ECONOMIC ANALYSES

ECONOMICS OF APPLICATION OPTIONS

The handling of manure is a cost associated with the livestock portion of the farm. Handling manure has many costs connected with it, including:

- equipment purchase and maintenance
- application to fields, and
- liability when something goes wrong and there's a spill.

You can incur more costs if you have to rent additional land, or in situations where manure agreements must be established.

Manure has value. Although mainly credited for its nitrogen, phosphorous and potassium value, manure is valuable for the organic matter additions to the soil – more so with solid manure and higher dry matter liquid manures – and for the micronutrients added.

The nitrogen, phosphorous and potassium content of manure has the most value when used in areas where soil fertility levels are lower. In these situations, there's actually a cost saving from not having to add commercial fertilizer. In fields where soil test levels are already excessive, building additional soil fertility with manure will increase environmental risk. With the exception of nitrogen, it will take many years before the nutrients added by the manure will be utilized.

The organic matter component of manure adds raw plant residues and microorganisms to the soil, which serves as a "revolving nutrient bank account" as well as an agent to improve soil structure and maintain soil tilth. Adding manure helps maintain soil organic matter levels, which improves soil moisture-holding capacity and nutrient uptake by the crop.

Most soils in Ontario have a soil organic matter level in the 2–5% range. Decomposition and mineralization of nutrients from that range will release an estimated 40–80 lbs of nitrogen per acre per year. By maintaining the soil organic matter level with the long-term use of manure, soil health is improved, and the potential for lowering crop nitrogen requirement is increased ($12–24/ac reduction in nitrogen cost).

AVERAGE APPLICATION COST OF COMMERCIAL FERTILIZER

FERTILIZER APPLICATION METHOD	# OF QUOTES	COST ($/ACRE)
CUSTOM-SPREAD DRY FERTILIZER	119	$ 6.00
RENTAL OF DRY BULK APPLICATOR	13	$ 8.50
ANHYDROUS APPLICATION	54	$ 11.50
LIQUID SIDEDRESS APPLICATION	30	$ 8.50

Source: OMAFRA 1997 and 2000 Custom Farmwork Rates in Ontario

Biological activity from regular manure applications improves the soil health and nutrient cycling.

AVERAGE COST OF MANURE APPLICATION		
SPREADER TYPE	**NUMBER OF QUOTES**	**AVERAGE COST**
LOADER ONLY – SOLID MANURE	28	$ 44/hour
SPREADING ONLY – SOLID MANURE	59	$ 57/hour
SPREADING & LOADING – SOLID MANURE	34	$ 82/hour
LIQUID MANURE – SURFACE-IRRIGATED	16	$ 7.90/1000 gal
LIQUID MANURE – SURFACE-IRRIGATED	3	$ 167/hour
DRAG HOSE-LIQUID INJECTION	2	$ 8/1000 gal
DRAG HOSE-LIQUID INJECTION	1	$ 145/hour
LIQUID TANKER – SURFACE-APPLIED	9	$ 8/1000 gal
LIQUID TANKER – SURFACE-APPLIED	34	$ 102/hour
LIQUID TANKER - INJECTION	1	$ 165/hour
TRUCKING MANURE	3	$ 62/hour
MANURE SPREADER - RENTAL	3	$ 150/day

Source: 1997 and 2000 Custom Farmwork Rates Charged in Ontario

- custom rates of liquid manure application range from $6 to $15 per 1000 gallons, depending on equipment, distance, volume and conditions
- approximate fertilizer cost (November 2005): nitrogen $0.48/lb; phosphorus $0.41/lb; potash $0.26/lb

Custom rates of manure application used in the nutrient management computer program range between $6 and $15 per 1000 gallons for liquid manure and are approximately $3/ton for solid manure.

SUMMARY OF BEST MANAGEMENT PRACTICES FOR APPLICATION

Pre-till to reduce manure loss.

- ✔ Remember that odours are more intense and ammonia loss increases with rises in temperature, humidity and wind.
- ✔ Have regard for neighbours' concerns when spreading near their homes.
- ✔ If irrigating, use low-trajectory technology.
- ✔ Where suitable, pre-till tile-drained lands before applying liquid manure. This will break up large pores and reduce infiltration to tiles. Conserve soil as you go: maintain as much residue cover as possible.
  Note: Pre-tillage may not be necessary if a visual system for outlet monitoring exists and if you've seen no past evidence of tile drainage effluent.
- ✔ Incorporate manure as quickly as possible (24 hours) following application.
- ✔ Where liquid loading is a concern due to soil type, use split applications. Wait until soil is dry before the second application.
- ✔ Avoid wet soils and wet weather, and you'll avoid nutrient loss, runoff, soil compaction and tile effluent. More precisely, avoid spreading manure if:
  - ▸ rainfall occurs shortly before application or
  - ▸ heavy rains are forecast within 12–24 hours of spreading on tile-drained lands.
- ✔ Avoid applying liquid manure when tiles are running.
- ✔ Avoid surface application on steeply sloping lands adjacent to watercourses, lakes, ponds and wetlands.
- ✔ Monitor for, and be prepared to react to, any spills.

High-trajectory guns are banned in Ontario for manure with >1% dry matter.