BEST MANAGEMENT PRACTICES

Manure Management

Canada

Ontario

Agricultural Adaptation Council

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▸ a proven, practical and affordable approach to conserving soil, water and other natural resources in rural areas

Who decides what qualifies as a BMP?

▸ a team that represents many facets of agriculture and rural land ownership in Ontario, including farmers, researchers, natural resource managers, regulatory agency staff, extension staff and agribusiness professionals

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Field Crop Production
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Manure Management
No-Till: Making It Work
Nutrient Management
Nutrient Management Planning
Pesticide Storage, Handling and Application
Soil Management
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Water Wells

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▸ please note that prices vary per title and with quantity ordered

CONTENTS

METRIC-IMPERIAL CONVERSION FORMULAS

Convert		To		Metric
%	►	kg/1000 L	multiply by	10
%	►	kg/tonne	multiply by	10
mg/L	►	%	divide by	10,000

Convert		To		imperial
%	►	lbs per 1000 gallons	multiply by	100
%	►	lbs per ton	multiply by	20
ppm	►	%	divide by	10,000

Note: 1 m^3 = 1000 L

CONVERSIONS – METRIC AND IMPERIAL

Common Conversions

1 gallon	=	4.546 litres	1 acre	=	0.405 hectare
1 gallon	=	1.201 US gallons	1 acre	=	43,560 $feet^2$
1 gallon	=	0.161 ft^3	1 lb/ac	=	1.12 kilogram/hectare
1 US gallon	=	3.785 litres	1 ton/ac	=	2.25 tonnes/hectare
1 US gallon	=	0.833 Imp gallons	1 gal/ac	=	11.2 litre/hectare
1 ton	=	0.907 tonne	1000 gal/ac	=	11200 litre/hectare
1 pound	=	0.454 kilogram	1000 gal/ac	=	11.2 $metre^3$/hectare
1 tonne	=	2205 pounds	1 metre	=	3.28 feet
1 $foot^3$	=	6.229 gallons	1 metre	=	39.4 inches

Application Rate Conversions

Metric to imperial (Approximate)			Imperial to Metric (Approximate)		
Litres per hectare x 0.09	=	gallons per acre	Gallons per acre x 11.23	=	litres per hectare (L/ha)
Litres per hectare x 0.36	=	quarts per acre	Quarts per acre x 2.8	=	litres per hectare (L/ha)
Litres per hectare x 0.71	=	pints per acre	Pints per acre x 1.4	=	litres per hectare (L/ha)
Millilitres per hectare x 0.015	=	fluid ounces per acre	Fluid ounces per acre x 70	=	millilitres per hectare (mL/ha)
Grams per hectare x 0.015	=	ounces per acre	Tons per acre x 2.24	=	tonnes per hectare (t/ha)
Kilograms per hectare x 0.89	=	pounds per acre	Pounds per acre x 1.12	=	kilograms per hectare (kg/ha)
Tonnes per hectare x 0.45	=	tons per acre	Ounces per acre x 70	=	grams per hectare (g/ha)
Kilograms per 1000 L x 10	=	lbs per 1000 gallons	Pounds per ton x .5	=	kilograms per tonne

Many measurements in this book will be presented in metric values with imperial equivalents in parentheses. However, where common usage, common sense, space limitations or regulatory concerns dictate, one or the other may appear exclusively.

INTRODUCTION

Manure has been spread as fertilizer for almost as long as animals have been raised for food. Over the past decade in Ontario, some important features of manure and how it's handled have come into sharp focus.

The first is **a keener appreciation of manure as a valuable resource, containing key nutrients for crop growth and soil conditioning.** By taking a full account of the nutrients in manure and what their crops and soils need, farmers can fine-tune what they apply on their fields, often reducing input and labour costs.

Livestock agriculture is fundamentally important to Ontario's agricultural economy, generating at least 50% – or $4 billion – of annual farm cash receipts.

There is **greater societal concern, shared by the farming sector, for protecting rural water sources.** For livestock producers, this means greater attention to (and possibly investment in) storage facilities and capacity, application calibration and timing, separation distances from wells and water bodies, and in-field practices to minimize soil erosion and runoff.

Livestock and poultry operations are increasing in size, and concurrently the non-farming population is quickly outnumbering farmers in rural areas. Odour complaints top the list of neighbour conflicts. Farmers must handle greater volumes of manure in ways that minimize odour.

As we better understand the value of manure and the importance of safe storage, handling and application, we are entering an era of nutrient management planning. Farmers adopting this "systems approach" benefit everyone – agriculture, soil and water, rural communities and society at large.

Taking a comprehensive "systems approach" to manure management will sharpen your understanding of the interplay among different components of your operation. In so doing, you'll be better able to foresee how a planned change to one component, e.g., bedding, could affect others, e.g., manure handling. We'll look at this concept more closely in the next chapter.

WHAT'S IN THIS BOOK

If you're a livestock producer, you're already living with the reality of accountability regarding nutrient management. This book will help you adapt and fine-tune your operation to get the most from your efforts.

THEMES

This book's intention is to help you select and implement the right best management practices for managing manure and other nutrient materials in your operation. You'll see some recurring themes, including:

the value of nutrient management planning

▶ accounting for all nutrients and thereby reducing input costs

the concept of a systems approach

▶ always considering the entire system, from animal to field, through planning and implementation

the importance of managing all liquids

▶ managing all liquids around facilities, storage areas, and handling equipment, and during application – regardless of whether you're set up for solid manure, liquid manure, and/or other organic materials

the need for due diligence

▶ as a producer, you'll be expected to match storage and handling systems to your needs, sample and test for all nutrients, calibrate application equipment, apply at calculated rates, keep separation distances, monitor storage sites, monitor application operations, develop contingency plans for spills, and keep accurate records.

Hard hoses and pipes carrying manure to fields should be monitored for leaks.

Please note that this book generally complements the **Nutrient Management Act** and **Regulation 267/03**. The precise requirements for the Nutrient Management Act can be found on the Ontario Ministry of Agriculture, Food and Rural Affairs website: http://www.omafra.gov.on.ca/english/agops/index.html

OUTLINE

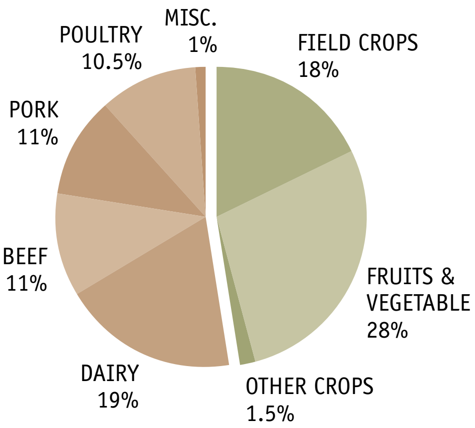
We'll begin by putting manure management in an Ontario context, then look at some facts and issues concerning manure, biosolids and agricultural washwaters.

In the next chapter, we'll cover the basics. These are the scientific principles related to the environmental and practical qualities of manure and other materials. An understanding of these will help you make informed choices among best management practices.

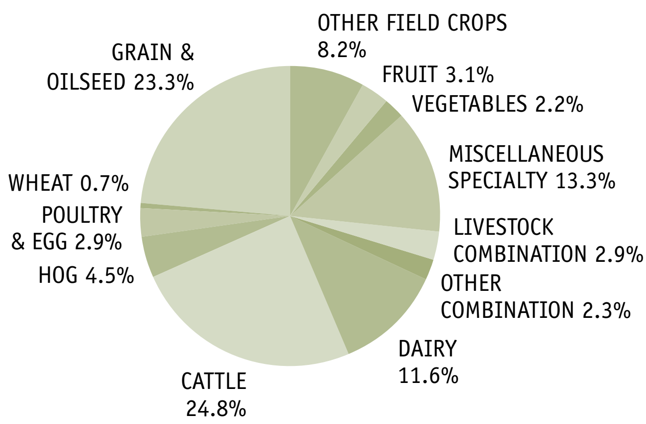
The balance of the book is devoted to describing best management practices in a systems approach context. This will cover: farmstead concerns – siting, odour and storage; field issues – planning, timing and application; and monitoring – storages, runoff and tile effluent.

ONTARIO'S LIVESTOCK SECTOR

FARM RECEIPTS BY TYPE OF OPERATION



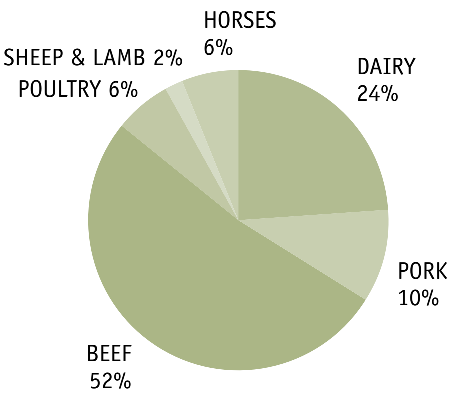
FARMS BY COMMODITY TYPES



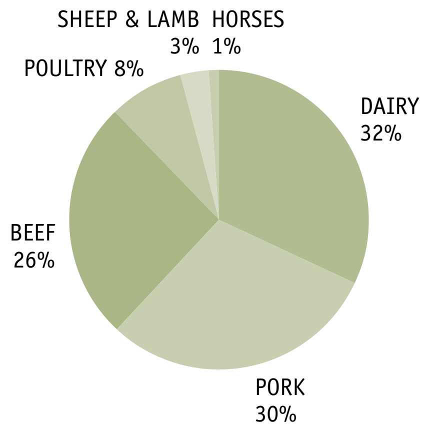
With over half of Canada's Class 1 agricultural land, Ontario boasts a diverse farming sector. The province's farms generate over $8.3 billion annually in farm cash receipts – about half of which comes from livestock and poultry operations.

Ontario's crop and livestock sectors are interdependent. Approximately 3.9 million hectares (9.6 million ac) are in crops, a significant portion of which is used to feed livestock and poultry. In turn, most of livestock manure is recycled on cropland as nutrients to promote plant growth and soil quality.

LIVESTOCK NUTRIENT UNITS IN ONTARIO



NUMBER OF LIVESTOCK FARMS BY COMMODITY



A head count of animals on Ontario farms reveals, in descending order, approximately 41.5 million chickens, 3.3 million hogs, 3.5 million turkeys, 1.2 million beef cattle, 800,000 dairy cattle, 230,000 sheep and goats, and 75,000 horses.

MANURE PRODUCTION AND DISTRIBUTION IN ONTARIO

Several states in the eastern U.S. have manure surpluses, i.e., more manure than cropland on which to spread it.

Animal agriculture in Ontario generates a considerable volume of manure and other by-products. These animals generate approximately 16 million cubic metres* (3.5 billion gal) of liquid manure and 22 tonnes (24.4 million tons) of solid manure.

If this manure were spread evenly over all the available cropland in Ontario, approximately 4375 litres (or 962 Imp gal) could be spread on each cropland acre – in other words, a very light application.

With the exception of a few localized imbalances in the distribution of manure, Ontario has a net deficit of manure nutrients, i.e., more cropland needing nutrients than available manure can supply. The imbalances in manure distribution can be attributed to:

farm size

- operations are becoming fewer in number but larger in size, and the average size (and manure volume/operation) continues to increase with time

uneven distribution across Ontario

- 60% of Ontario's livestock and poultry operations are found in southwestern Ontario

shift in the rural landscape from agricultural to residential and other land uses

- less locally available, suitable land on which to spread manure and other organic wastes (e.g., biosolids, farm-generated wastewaters).

Rural land use continues to change from farm to other applications. Growth in the number of rural non-farm residents increases the potential for conflicts about odour and other perceived environmental problems.

A small minority of livestock producers consider manure a waste, not a resource.

*1000 litres = 1 cubic metre

MANURE AS A RESOURCE

Manure has value both as a source of nutrients and as a soil conditioner – two good reasons for managing it as a resource.

Regular applications of manure help build soil's organic matter.

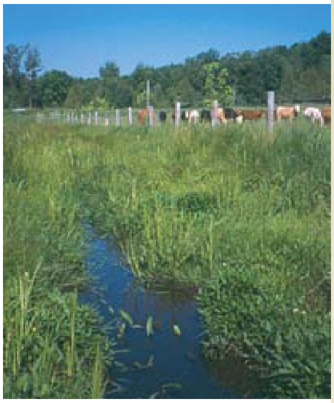
NUTRIENT VALUE OF DIFFERENT TYPES OF MANURE*

MANURE	NITROGEN	PHOSPHATE	POTASH	APPROXIMATE TOTAL VALUE
		kg/m³ (lb/1000 gal)		
DAIRY, LIQUID	1.4 (14)	0.7 (7)	3.0 (30)	$23.00/1000 gal
SWINE, LIQUID	2.4 (24)	1.1 (11)	2.0 (20)	$28.00/1000 gal
POULTRY, LIQUID	5.1 (51)	2.5 (25)	3.4 (34)	$60.00/1000 gal
		kg/tonne (lb/ton)		
DAIRY, SOLID	1.5 (3)	1.5 (3)	5.5 (11)	$8.00/ton
POULTRY, SOLID	9.5 (19)	10 (20)	12.5 (25)	$36.00/ton

* Values in this chart are based on the following assumptions:
- incorporated within 24 hours, spring application
- all nutrients are required by this year's or subsequent crops for long-term value
- nitrogen is $0.48/lb; phosphorus is $0.41/lb; potash is $0.26/lb

  1m³ = 1000 litres

To make the most of its potential, manure has to be stored, handled and applied in ways that retain its value, suit your operation, reduce the risk of environmental contamination and aren't cost-prohibitive.



With proper distribution of manure, most natural or intensive grazing systems don't require additional fertilizers.

OTHER ORGANIC MATERIALS

Manure is not the only organic nutrient material generated on farms or brought to farms that needs to be managed.

Examples of **on-farm source materials** include: milking centre washwaters, manure and yard runoff, silage leachate, and greenhouse wastewaters.

Examples of **off-farm source materials** include: municipal sewage biosolids, paper biosolids, food processing byproducts and abattoir wastewaters.

Like manure, these materials add plant nutrients and soil-conditioning organic matter. Likewise, these materials must be managed as a resource. Using these materials may require approval, e.g., Certificate of Approval from Ontario Ministry of the Environment.

MANURE ISSUES

Nutrient management of livestock and poultry manure and other organic materials is one of the most challenging issues facing agriculture in Ontario. It's complex, with dimensions ranging from environmental concerns at a societal level to nuisance concerns from neighbours, to health concerns for your family and farm animals. It's all about managing risk while conducting your farm business.

MANURE-RELATED ISSUE	CONCERNS	MANAGEMENT GOALS
ECONOMIC	• is generally a net cost to livestock operations	• improve soil quality and fertility • reduce dependency on off-farm inputs
ENVIRONMENTAL	• can lead to ground and surface water contamination	• increase soil water-holding capacity • increase soil biological diversity
NUISANCE	• produces offensive odours • can be a source of flies	• minimize odour, flies, and prevent neighbour complaints
HUMAN HEALTH	• contains pathogenic organisms	• minimize risks to human health

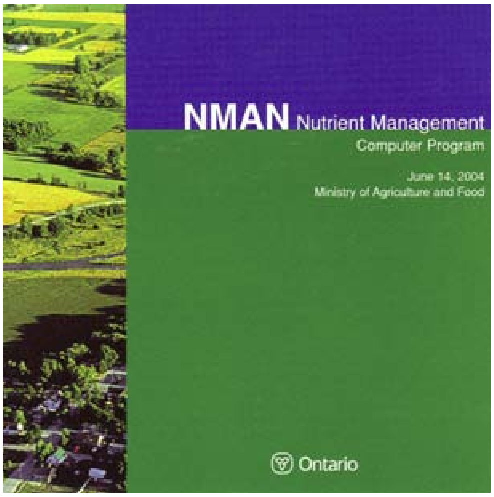
The proportion of large livestock farms is increasing in Ontario. Most intensive (or large) livestock operations are well-managed, as are their manure management systems.

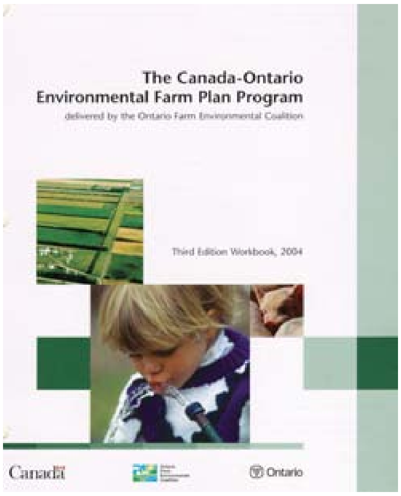
AGRICULTURE'S RESPONSE

Over the past decade, manure-related issues have been addressed head-on by many, often diverse, groups involved in Ontario agriculture. Farm organizations, government agencies, municipalities, environmental non-governmental organizations and other partners are continuing to work aggressively and collaboratively.

Here are some snapshots of recent successes.

In Ontario, we have the software to develop reliable, science-based nutrient management plans. This approach helps plan storages, calculate safe application rates for suitable acreage, identify optimal timing, and schedule monitoring.





The Environmental Farm Plan program focuses on soil, water, nutrient and pesticide issues. Each participating producer develops a semi-detailed site assessment by rating components of their farm's environmental management system and completing an action plan.

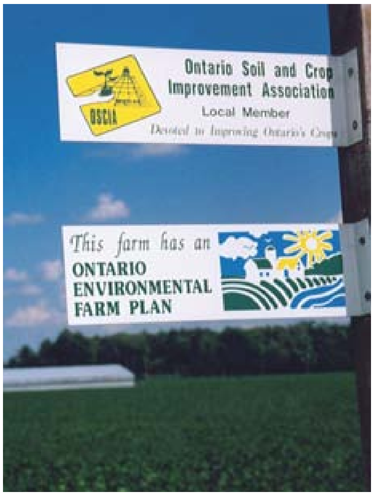
Sampling and testing manure for nutrient levels qualifies as a best management practice. Like all BMPs, it integrates production targets with environmental goals.

Ontario Ministry of Agriculture, Food and Rural Affairs engineers and commodity specialists have long advocated the systems approach to manure management. This involves comprehensive management of all liquid and solid byproducts from barn to seedbed.

Research and advisory staff are working with producers to reduce manure-nutrient levels through improved livestock nutrition and feed.

Many of farmers' questions have been answered with on-farm applied research and demonstration projects.

Improvements in manure-treatment technology may reduce the volume of material to be managed and help to provide on-farm energy.



The costs of some on-farm improvements to nutrient management practices and systems can be burdensome for individual farmers. In some cases, they can get assistance from local water quality programs (e.g., Remedial Action Plans, local Conservation Authority efforts, and municipal-based initiatives) that cost-share with government and industry partners.

MANURE AND OTHER ORGANIC WASTES – THE BASICS

THIS CHAPTER EXPLORES:

- **the physical properties of solid and liquid manure**
- **manure's odour and gaseous properties**
- **manure's chemical or nutrient properties**
- **the processes by which different chemicals or nutrients in manure will cycle through, and possibly be lost to, the environment**
- **manure's biological properties**
- **environmental risks**
- **nutrient management planning.**

Best management practices for manure and other organic wastes are based on scientific principles and real-world experience. Understanding the physical, chemical and biological properties of manure and other organic materials will help you manage these products safely and more effectively.

PHYSICAL PROPERTIES

Livestock manure has a variable composition. In other words, it has solid and liquid portions as well as organic and inorganic components. Manure's composition will vary with livestock type, age, size, nutrition, housing and bedding, as well as the nature and amount of materials (such as bedding and wastewaters) added to it.

Manure = fecal material + undigested feed + urine + bedding + uncontaminated water + wastewater + other wastes.

The key principle to manure management is to account for all materials – especially liquids.

MANURE COMPONENT	COMPOSITION	
FECES	• undigested feed • other bodily wastes	• organic forms of nutrients and organic acids • inorganic forms of nutrients and salts
URINE	• water • acids and salts	• nutrients (e.g., nitrates)
BEDDING	• straw, wood fibre	• wasted solid feed
UNCONTAMINATED WATER	• drinking water • leaking or spilled water	• eavestroughs, precipitation, snowmelt
WASHWATER AND RUNOFF	• facilities washwater • milking centre washwater	• runoff from yards, stored feed, and solid manure

Moisture content and total solids affect handling characteristics. When it's more liquid and less solid, it's easier to handle with pumps and gravity systems designed for liquids.

A typical 20,000-bird facility needs about 9 tonnes (9.25 tons) of wood shavings to provide a 10-cm (4-in.) depth on the floor.

SOLID MANURE

Worth noting: solid manure is typically 40–80% liquid by composition.

composition

- ▶ consists mostly of bedding and fecal material
- ▶ varies with livestock type, age, nutrition and bedding
- ▶ also changes with time and degree of decomposition

dry matter content

- ▶ usually ranges from <18% (e.g., solid dairy) to 60% dry matter (e.g., poultry manure with wood shavings)
- ▶ contains moisture primarily from animal urine and spillage from waterers

MANURE CHARACTERISTICS (SOLID MANURE SYSTEMS)					
ANIMAL TYPE	**AVERAGE WEIGHT (lbs)**	**ADDITIONAL BEDDING (average ft^3/day)**	**DENSITY (lbs/ft^3)**	**TOTAL VOLUME/ DAY (ft^3)**	**% DRY MATTER (average)**
SOWS AND LITTERS	400	0.58	60	0.624	14.6
FEEDER HOGS – solid scrape	117	0.013	60	0.158	13.2
WEANER HOGS SEW	26.7	.0076	60	0.066	13.5
HOLSTEIN MILKING-AGE COWS – freestall solid	1400	0.598	52	2.135	21.2
MATURE BEEF COWS (with calf)	1300	0.156	50	1.258	30
MATURE BEEF COWS (with calf) – deep bedded	1300	0.578	40	1.690	45
BEEF FEEDERS	683	0.082	52	0.661	21.9
BEEF FINISHERS	800	0.096	52	0.774	21.9
SHEEP – meat	175	0.060	45	0.156	30
GOATS – meat (including unweaned offspring)	160	0.012	50	0.096	30
GOATS – meat feeder kids (>45 lbs)	40	0.0029	50	0.024	30
GOATS – dairy does	170	0.016	50	0.123	30
GOATS – dairy kids	36.7	0.0033	50	0.027	30

All figures in this table are averages.

Liquid manure materials with low solid content (i.e., <8% dry matter) are easier to collect, transfer and handle.

LIQUID MANURE

composition

- consists mostly of facility washwater + milking centre washwaters (dairy) + added runoff + snow and rain + bedding + feces + urine bedding and fecal material

dry matter content

- usually ranges from <8% (e.g., dairy manure and milking centre) total solids to 12% (e.g., dairy manure with medium bedding)

Knowing species- and system-specific manure characteristics such as volume and dry matter is important when designing manure management systems.

MANURE CHARACTERISTICS (LIQUID MANURE SYSTEMS)

ANIMAL TYPE	AVERAGE WEIGHT (lbs)	TOTAL (ft^3/day)	% DRY MATTER (average)	ADDITIONAL BEDDING/WATER
SOWS AND LITTERS	400	0.722	2.9	–
FEEDER HOGS	117	0.245	5.0	–
WEANER HOGS	35	0.100	2.7	–
MILKING-AGE COWS	1400	2.613	9.1	0.017 ft^3/cow/day
DAIRY HEIFERS	650	0.744	11.0	0.016 ft^3/cow/day
DAIRY CALVES	200	0.240	11.0	0.005 ft^3/cow/day
WASHWATER – free-stall	–	–	–	0.6 ft^3/cow/day
WASHWATER – tie-stall – pipeline	–	–	–	0.5 ft^3/cow/day
WASHWATER – tie-stall – no pipeline	–	–	–	0.25 ft^3/cow/day
BEEF COW (with calf)	1300	1.508	9.0	–
BEEF FEEDERS	683	0.793	9.0	–
BEEF FINISHERS	800	0.928	9.0	–

SEMI-SOLID MANURE

Liquid manure can be pumped. However, if your system generates manure with a dry matter content in the 14–18% range, it becomes difficult to manage: too dry to pump and too wet to manage easily as a solid.

This material – often referred to as semi-solid manure – should be diluted with washwaters and runoff or mixed with additional bedding to be managed as a solid or liquid.

MANURE TYPES AND MANURE MANAGEMENT SYSTEM

MANURE TYPE AND SYSTEM	DRY MATTER CONTENT	FORM	STORAGE TYPE
SWINE – liquid manure DAIRY – minimal bedding, high dilution with milking centre washwater	• <8%	• liquid	• tank – concrete, steel, glass-lined • earthen – no tractor access
DAIRY – moderate bedding, medium dilution	• 8–12%	• liquid	• tank – concrete, steel, glass-lined • earthen – no tractor access
DAIRY – high bedding, medium dilution	• 21%	• solid portion	• concrete pad with managed runoff (e.g., separate runoff storage)
DAIRY – high bedding, no dilution BEEF – high bedding, no dilution	• >21%	• solid	• covered concrete storage with access • concrete pad with managed runoff (e.g., separate runoff storage)
SHEEP – high bedding, no dilution	• 35%	• solid	• in-barn (solid pack)
POULTRY – high bedding, no dilution, air-dried	• 60%	• solid	• covered concrete storage with tractor access • solid pack (in-situ)

ODOUR AND GASEOUS PROPERTIES

The human nose is capable of detecting a broad range of odorous compounds – many at extremely low concentrations. Researchers have identified more than 160 odourless and odour-producing compounds that can originate from manure. It's this wide range and mix of compounds combined with our keen ability to detect odours that result in the variety of manure smells we experience.

Some of the more common compounds in manure are described in the following chart.

PRIMARY MANURE GASES

COMPOUND	DESCRIPTION
CARBON DIOXIDE	• odourless • generated by microbial activity (anaerobic* and aerobic)
METHANE	• odourless • generated by anaerobic activity
AMMONIA	• sharp, pungent, irritating odour, only mildly toxic • generated by anaerobic and aerobic activity • water-soluble and less dense than air • readily disperses in open environment, resulting in it being more of an odour concern within barns than during land application
HYDROGEN SULPHIDE and RELATED SULPHUR-CONTAINING COMPOUNDS	• hydrogen sulphide gas has a powerful rotten-egg fragrance • produced during anaerobic decomposition of manure • water-soluble and heavier than air • humans can readily detect very low concentrations of such compounds • hydrogen sulphide can be very toxic if allowed to accumulate in enclosed spaces
VOLATILE ORGANIC ACIDS	• wide variety of types and characteristics • mostly produced under anaerobic conditions • important contributors to manure odour
PHENOLICS	• highly odorous compounds • found in raw manure and increase under anaerobic conditions

* "anaerobic" means oxygen-deficient
Chart adapted from: Koelsch, Rick, *FFPPA Reference Manual*

The amount and type of gases produced will depend on the type of manure and the way it's handled. Aerobic conditions will generate gases such as carbon dioxide and nitrous oxide. Anaerobic conditions (liquid manure, centre of solid piles) can generate hydrogen sulphide, ammonia and methane.

Some gases are often trapped within the bulk of the manure until the storage is disturbed for spreading. That's why the smell is much worse at spreading time.

Manure odour is strongest during application. For the most part, odour-causing gases are trapped in stored manure.

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CHEMICAL (NUTRIENT) PROPERTIES

Nutrients are found in all components of manure, be they organic or inorganic. For more information about their functions in growing crops, please see the textbox on the facing page. Their environmental implications are explored toward the end of this section.

MACRONUTRIENTS

Nitrogen (N)

In fresh feces, most of the nitrogen is in organic form, either as undigested feed or in a biological form within the bodies of bacteria and other microbes that make up the normal population of the digestive tract. In urine, a large part of the nitrogen is present as uric acid or urea, with a lesser amount as ammonium or organic salts. These compounds are transformed in storage and handling, so that what's applied to the field is much different from what comes from the animal.

Phosphorous (P)

Most of the phosphorous is excreted in the feces, primarily in organic compounds like phytin (from undigested feed), and also as ortho-phosphate. The organic compounds are readily degraded in storage or in soil, so that much of the P in manure becomes available to crops eventually.

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

Potassium (K)

Most of the potassium is excreted in the urine as soluble potassium salts. A small amount will be contained within the bacteria in the feces. Potassium doesn't get bound up in organic compounds in either animal or plant cells, so it's readily available for crop uptake. It's also subject to loss with any manure runoff.

AVAILABLE MANURE NUTRIENTS FROM VARIOUS LIVESTOCK TYPES – LIQUID MANURE

Animal Type	Ave DM	# Samples	Total N	NH_4-N	Usable N[1]	P_2O_5	K_2O	Year 1 Value[2,3]	Year 2-4 Value[2,3]	Total N	NH_4-N	NH_4-N	P	K
	%	lbs/1000 gal						$/1000 gal		%	ppm	%	%	%
HOG	3.8	924	40	26.5	26.5	12.0	18.4	22.35	6.00	0.40	2648	0.26	0.13	0.17
DAIRY	8.5	860	36	15.3	17.9	8.3	25.9	18.60	5.10	0.36	1527	0.15	0.09	0.24
BEEF	7.1	61	31	13.4	15.6	7.4	21.6	16.00	4.45	0.31	1337	0.13	0.08	0.20
POULTRY	10.6	137	83	55.8	58.4	27.6	32.4	47.65	13.50	0.83	5581	0.56	0.30	0.30
RUNOFF	0.6	41	5.2	3.2	3.5	1.5	9.6	4.60	0.75	0.052	321	0.03	0.02	0.09
MILK-FED VEAL	7.2	5	33	5.4	13.2	6.4	18.4	12.35	4.90	0.33	543	0.05	0.07	0.17
BIOSOLIDS AEROBIC	2.0	10	12	1.1	4.3	5.5	0.0	3.77	2.86	0.12	109	0.01	0.06	
BIOSOLIDS ANAEROBIC	4.4	39	28	7.8	13.1	12.9	0.0	11.55	6.90	0.28	776	0.08	0.14	0.00

1 Usable N = amount of nitrogen available in the year of application assuming spring application is incorporated within 24 hours.

2 Value of manure is based on purchase price of an equivalent amount of mineral fertilizer (N-P_2O_5-K_2O = 0.48-0.21-0.26 $/lb).

3 The actual immediate value for crop production will be less if all the nutrients applied are not required for growing the crop.

Source: Data from manure analysis provided by A&L Lab, Guelph Agri-Food Lab, Stratford Agri-Analysis and University of Guelph Analytical Services from 1991 to 2003

Nitrogen deficiency in corn shows up as yellowing in leaves.

Potassium deficiency will impede water uptake in alfalfa.

AVAILABLE NUTRIENTS FOR MANURE FROM VARIOUS LIVESTOCK TYPES – SOLID MANURE

Animal Type	Ave DM	# Samples	Total N	NH_4-N	Usable N[1]	P_2O_5	K_2O	Year 1 Value[2]	Year 2-4 Value[3]	Total N	NH_4-N	NH_4-N	P	K
	%	lbs/ton						$/ton		%	ppm	%	%	%
HOG	28.2	40	17.8	4.7	7.5	8.5	11.0	9.90	4.50	0.89	2324	0.23	0.46	0.51
DAIRY	24.2	150	12.2	2.6	3.7	3.1	10.8	5.85	2.05	0.61	1278	0.13	0.17	0.5
BEEF	28.6	155	14.6	1.6	3.4	4.2	12.3	6.50	2.80	0.73	812	0.08	0.23	0.57
SHEEP	31.3	35	14.4	3.4	4.7	4.8	14.5	7.95	2.85	0.72	1716	0.17	0.26	0.67
DAIRY GOATS	35.5	39	21.6	5.8	7.6	5.2	11.50	11.50	3.40	1.08	2878	0.29	0.28	1.04
COMPOSTED, CATTLE	38.3	29	17.2	1.1	5.8	5.2	23.8	11.00	3.40	0.86	543	0.05	0.28	1.1
GRAIN-FED VEAL	28.8	18	15.8	2.7	4.4	3.3	10.2	6.05	2.40	0.79	1328	0.13	0.18	0.47
HORSES	36.5	20	10.8	1.6	2.8	2.9	10.6	5.25	1.95	0.54	784	0.08	0.16	0.49
RABBIT	45.5	20	24.4	2.6	5.6	15.8	13.8	13.24	8.25	1.22	1281	0.13	0.86	0.64
POULTRY	52.6	623	47.4	11.0	20.8	20.4	25.3	24.85	11.30	2.37	5495	0.55	1.11	1.17
LAYERS	32.7	149	34.5	15.4	19.6	15.6	17.0	20.15	7.95	1.72	7719	0.77	0.85	0.79
PULLETS	36.2	47	42.0	12.4	20.0	16.6	19.4	21.40	9.20	2.1	6200	0.62	0.90	0.90
BROILERS	73.0	22	62.2	3.8	20.9	23.6	34.6	28.55	14.40	3.11	1881	0.19	1.28	1.6
BROILER BREEDERS	58.2	37	39.0	6.6	15.7	26.8	30.3	26.30	13.60	1.95	3300	0.33	1.46	1.40
TURKEYS	39.2	27	46.1	16.48	23.7	23.2	24.4	27.15	11.90	2.31	8239	.82	1.26	1.13

1 Usable N = amount of nitrogen available in the year of application assuming spring application is incorporated within 24 hours.

2 Value of manure is based on purchase price of an equivalent amount of mineral fertilizer (N-P_2O_5-K_2O = 0.48-0.41-0.26 $/lb)

3 The actual immediate value for crop production will be less if all the nutrients applied are not required for growing the crop.

PHYSIOLOGICAL FUNCTION OF MAJOR NUTRIENTS IN AGRICULTURE

Whether they involve livestock or crops, most production systems depend on ample supplies of available nutrients. **Macronutrients (nitrogen, phosphorous** and **potassium)** plus **secondary nutrients (calcium, magnesium** and **sulphur)** are considered essential for plant and animal life.

NUTRIENT	FUNCTION IN LIVESTOCK	FUNCTION IN PLANTS
NITROGEN (N)	• proteins for muscle, skin, internal organs • enzymes for metabolic processes	• proteins for tissue growth • enzymes for metabolic processes • photosynthesis and respiration
PHOSPHOROUS (P)	• bone growth • energy transfer • milk, meat or egg production	• photosynthesis and respiration • energy transfer • cell division
POTASSIUM (K)	• muscular activity • blood pressure regulation • pH buffering	• plant structure • photosynthesis and respiration • water uptake by roots
CALCIUM (Ca)	• bone growth and repair • milk or egg production • reproductive functions	• cell wall strength • cell formation • enzyme activation
MAGNESIUM (Mg)	• enzymes • muscle relaxant	• photosynthesis • protein and enzyme activation
SULPHUR (S)	• component of several amino acids in proteins and enzymes	• component of several amino acids in proteins and enzymes

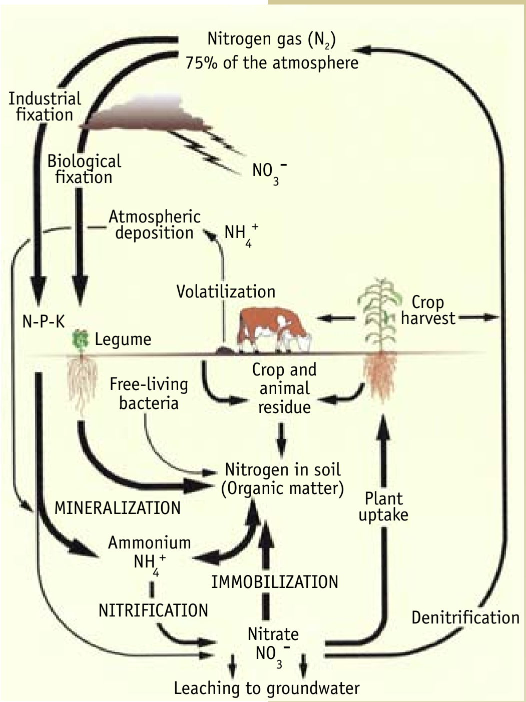
HOW KEY NUTRIENTS CYCLE THROUGH THE ENVIRONMENT

Nitrogen

In manure, nitrogen has two forms: inorganic and organic. The chief, inorganic form, **ammonium (NH_4^+)**, is available for plant growth, and also highly volatile as it can convert to ammonia gas under the right conditions. Ammonium can be a problem if raw manure runs off into surface water, where some of it converts to dissolved ammonia, which is very toxic to fish.

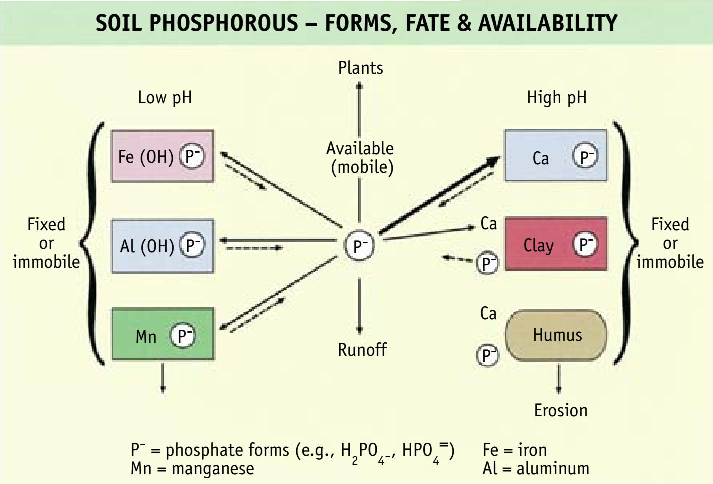
The organic N component in manure is quite stable and will eventually become converted to ammonium through a process known as mineralization. In soil, ammonium will stick to soil surfaces (clay and organic matter). It's available to plants and is subject to a process called nitrification, whereby soil microbes change ammonium to nitrite or nitrate NO_3^-.

Nitrate (NO_3^-) in soil is subject to several fates. It can be taken up by plants or absorbed by soil microbes (i.e., immobilized). It may leach through the soil beyond the root zone. It may be found in cropland runoff. In wet soils, nitrates can be transformed by soil microbes through denitrification to N gases such as N_2 and N_2O. N_2O is a greenhouse gas.



Phosphorous

Phosphorous has two forms in manure: organic P and inorganic P. Manure P is only 40% available as fertilizer phosphate in the first year following application. There are inorganic phosphates as minerals in soil (see illustration) and in solution – plus small amounts of organic P. In soils with low pH, P is bound in immobile forms as iron, manganese and aluminum compounds. In soils with a high pH, P can be found attached to clay and humus particles or tied up with calcium compounds. In solution, phosphates can be taken up by plants, lost in soil runoff or leached out of the root zone through soil cracks. Phosphate in surface water can promote algal blooms. As these aquatic plants die and decompose, and oxygen levels in the water drop, fish and other aquatic life are killed.



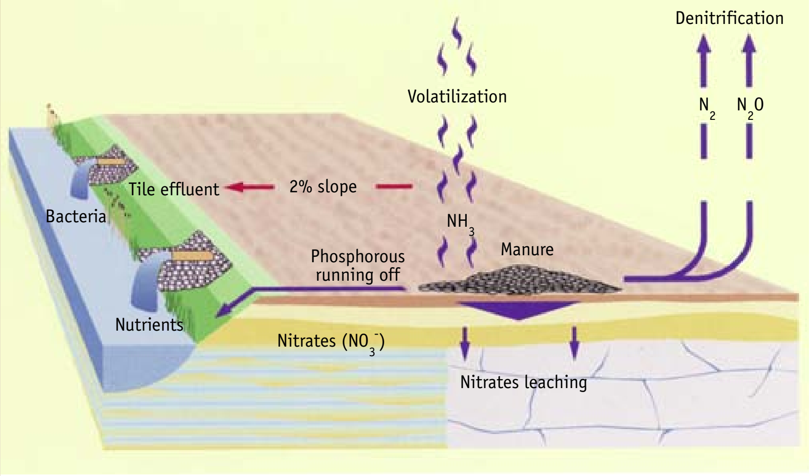
Potassium

Potassium does not form part of complex compounds within plants or animals, but remains almost exclusively as K ions in solution, either within cells or in the intra-cellular fluid. This means that most of the K in manure is in a readily available form – up to 90% as available as fertilizer K.

Once the manure is applied to the soil, the positively charged potassium ions are attracted to the negatively charged clay and humus particles. This adds to the pool of potassium that forms part of the soil minerals. From 90–98% of the total potassium in soil is bound in unavailable forms within the mineral structure, with up to 10% held in exchangeable form on clay minerals, and 1–2% in the soil solution. This dissolved K can leach from very sandy soils under heavy rainfall.

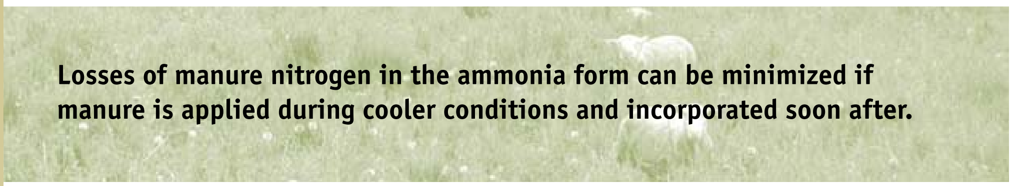
HOW NUTRIENTS IN MANURE ARE LOST

Some of the same macronutrients that are essential for sustaining animal, crop and soil life are, in excessive quantities, harmful to water and air quality. The processes by which nutrients are lost during manure storage, handling and application are summarized in the table on page 21.



It can be challenging to manage manure nutrients effectively and minimize loss. Manure nutrients, especially forms of manure nitrogen, are prone to manure loss as a gas – by volatilization of ammonia or through denitrification. Organic and inorganic forms of manure nitrogen can be lost from cropland with surface runoff or through cracks in the soil into tile drains. Inorganic nutrients can be immobilized by soil microbes or leached into shallow aquifers.

NUTRIENT LOSS DURING STORAGE, HANDLING AND APPLICATION	
PROCESS	**DETAILS**
VOLATILIZATION	• is the loss of free ammonia (NH_3) to the atmosphere • manure-based ammonium (NH_4^+) will readily convert to ammonia if left on the surface • manure with higher levels of NH_4^+ will more readily produce NH_3 • rate of loss depends on temperature, wind speed, soil moisture, pH, vegetative cover, rainfall and infiltration – loss is greatest in warm, sunny dry weather • loss is almost eliminated by incorporating manure into the soil
DENITRIFICATION	• manure-based nitrogen (ammonium) will convert to nitrate and nitrite (nitrification) • in saturated soils, nitrates will be converted by microbes to nitrogen gas (N_2) • in semi-saturated soils and storages, nitrates will be converted by microbes to N_2O
RUNOFF	• surface-applied manure is at risk of runoff • runoff increases with slope, low infiltration rates, compacted or frozen soils, low vegetative or crop cover, intense rainfall or rate of application and snowmelt
LEACHING	• leaching is the movement of soil solutions and their solutes out of the soil profile/rooting zone • for this to happen, there must be a high concentration of nitrates (and/or bacteria) in the rooting zone and a net movement of water through the soil profile • sandy and gravelly soils with high water tables are at the greatest risk • prime sources of nitrate are: ○ improperly stored manure (e.g., uncovered solid or composted manure on bare soil) ○ nitrogen fertilizers applied above crop requirements, and ○ manure and legumes with high ammonium concentrations
PREFERENTIAL FLOW	• preferential flow is mass flow of applied liquids directly into tile, where it's carried to tile outlets • all manure-based nutrients and bacteria can end up in surface waters, as effluent flows through cracks and continuous earthworm holes
IMMOBILIZATION	• immobilization occurs when nutrients are tied up by soil microbes in soil • soil microbial populations are large and diverse enough to trap available nitrates and phosphates from soil solutions before plants can use them • the rate of immobilization depends on the ratio of carbon:nitrogen of crop residues or manure added to the soil ○ if the high carbon: low nitrogen material such as straw or sawdust bedding is added to soil, the microbes will tie up any available nitrates ○ in time the microbes will run out of food and release the nitrogen following mineralization ○ see chart on page 25 for the C:N ratio of common soil management materials



Losses of manure nitrogen in the ammonia form can be minimized if manure is applied during cooler conditions and incorporated soon after.

AMMONIA NITROGEN LOSS* (percentage)

SEASON DETAILS			WEATHER CONDITIONS		
	AVERAGE	COOL, WET	COOL,DRY	WARM,WET	WARM,DRY
SPRING/SUMMER					
Incorporated within 1 day	25	<1	15	25	<5
Incorporated within 5 days	45	20	30	50	80
Not incorporated	66	40	50	75	100
Injected in season	5	5	5	5	5
FALL					
Early	66	40	50	75	100
Late	25	25	25	25	25**
Cover crop if grown after manure application	35	25	25	40	50

* An additional 10% ammonium loss should be calculated for manure irrigation systems.

** Spreading on forages, cover crops and residues will increase ammonia loss.

Use average weather conditions to estimate N loss value when projecting a future nutrient management plan.
(D. Hilborn, C. Brown, E. Beauchamp [1995])

BIOLOGICAL PROPERTIES

Manure is made up of animal wastes, bedding and wastewaters. It is a kind of ecosystem with all the necessities for biological habitat – namely space, cover, food and water. This can be a good thing, as healthy manure environments rapidly convert manure to soil organic matter and available nutrients. But this same environment can house pathogenic bacteria and unwanted pests such as rodents.

SOLID MANURE AND ITS DECOMPOSITION

Stacked solid manure provides:

▶ a protected environment for soil life
▶ food materials in the form of bedding and feces and inorganic nutrients
▶ water from moisture content of manure.

LIFE FORMS IN MANURE THAT PROMOTE DECOMPOSITION

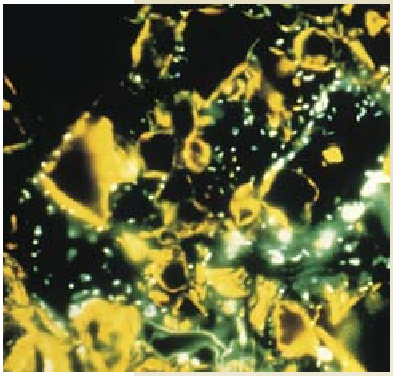
SOIL ORGANISM GROUP	TYPE OF ORGANISM	FUNCTION
DECOMPOSERS	• bacteria • fungi	• transform manure into materials that can be used by other life forms (e.g., shredded straw into humus) • retain (immobilize) nutrients in their tissue – some are pathogens
BACTERIA-FEEDERS	• protozoa • nematodes	• release inorganic nutrients (NH_4^+) • destroy some pathogens
FUNGUS-FEEDERS	• nematodes • insects	• release inorganic nutrients (NH_4^+) • destroy some pathogens
SHREDDERS	• earthworms • insects (springtails, dung beetles) • arthropods (centipedes, millipedes, pillbugs)	• shred bedding and waste feed into finer-sized materials • provide habitat and food for decomposers • accelerate decomposition rate when present
LARGER PREDATORS	• large insects, rodents, birds	• control populations of other manure life • aerate manure by burrowing

The rate at which solid manure decomposes is determined largely by:

▶ its composition – livestock type, bedding, feed, moisture content
▶ the method of storage and handling
▶ age (or state of decomposition)
▶ temperature, and
▶ method of application.

Solid manure with high N levels, such as poultry manure, will decompose thoroughly and quickly if kept moist and well-aerated. Conversely, semi-solid manure and solid manure at the bottom of an uncovered stack – where the manure can be saturated – will decompose more slowly. Most of the decomposers and shredders require aerobic conditions producing CO_2 gas, more microbial biomass and more stable carbon compounds in the remaining organic materials.

Solid manure will be subjected to aerobic and anaerobic decomposition.



Soil bacteria transform manure nutrients, making them usable by other soil life forms, such as protozoa, which in turn release inorganic N forms such as ammonium.

Fresh manure may be a better soil amendment than composted manure because it stimulates a more diverse soil ecosystem.

LIQUID MANURE AND ITS DECOMPOSITION

Stored liquid manure is mostly subjected to anaerobic decomposition, which produces methane (CH_4) and less stable compounds (e.g., volatile fatty acids). This process also leads to more odorous gases.

The number and diversity of life forms are lower in liquid manure than in solid manure.

MANURE AS A SOIL AMENDMENT

Organic matter from manure is an important soil amendment. Consistently manured soils have higher levels of soil organic matter.

Fresh manure may be a better amendment than composted manure because it's in a form that's readily used by soil fauna and, due to its complex nature, stimulates a more diverse soil ecosystem. When manure is composted before application, many of the processes that stabilize soil structure have occurred in the compost pile, not the soil.

MICROBIAL PROCESSES

Microbial processes are determined by the manure materials available, moisture content, exposure to air, and temperature. The decomposition process is more rapid when conditions are moist, warm, and aerobic, and when the manure materials have sufficient nitrogen content. There are several key microbial processes.

decomposition

- manure and soil microbes use available organic materials as a food source
- complex materials are broken down into simpler materials (e.g., proteins into amino acids)
- if the manure is solid and stored so that it's mostly aerobic (i.e., oxygen present), energy is released and the temperature of the stored manure increases – the products of decomposition are then available to further changes

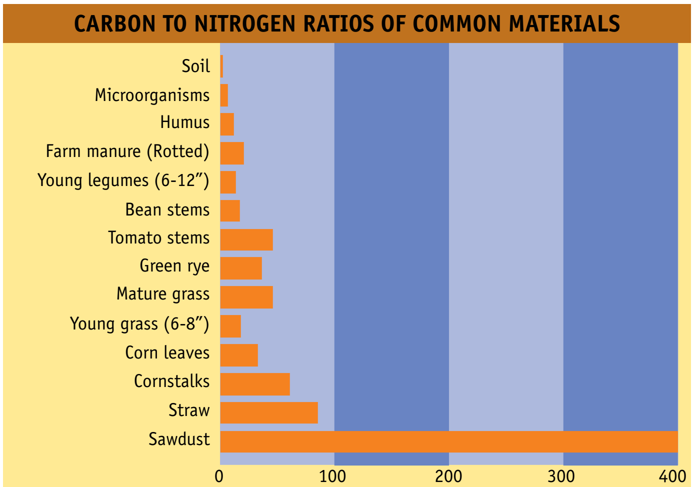
transformation

- manure and soil microbes can change the chemical nature of manure decomposition products
  - e.g., simple carbon compounds like sugars can be oxidized to release CO_2 + water + energy (for the microbes)
  - in liquid manure, carbon compounds are transformed to fatty acids and methane (CH_4) gas
  - nitrogen compounds can be transformed to ammonia (NH_3) gas, ammonium (NH_4^+) salts and nitrate (NO_3^-) nitrogen
- pathogens found in manure can be transformed into organic materials by high temperatures and a process known as denaturation (where protein compounds are broken down into components)

assimilation

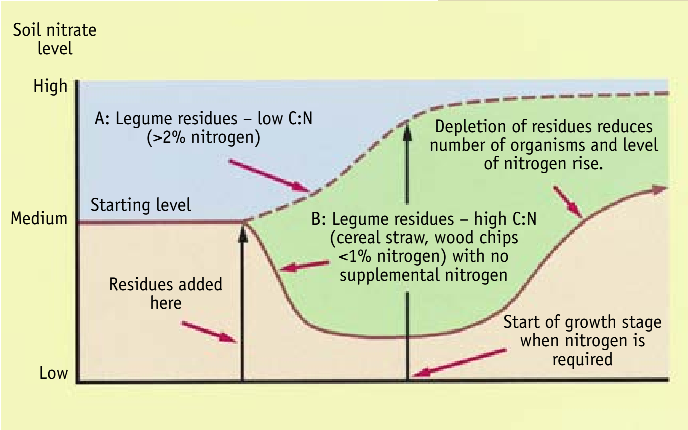
- just as simple carbon compounds are needed by microbes for energy, nitrogen compounds are required to build tissue
- if the N content of manure is limited, as in manure with a very high bedding content, decomposition will be rapid at first – then this N will be assimilated into the organisms themselves
- when this happens, the manure's N content can be immobilized and remain unavailable for plant growth when used as fertilizer
- manures with less bedding or higher N contents have a better balance between carbon and nitrogen compounds (C:N ratio) and will release more available nutrients when applied as fertilizer

Organic material with a chemical composition that's high in carbon relative to nitrogen content (C:N ratio) carries an increased risk. Much of the N content released during decomposition could be tied up (immobilized) by soil microbes, and therefore not readily available for crop growth.



Livestock diseases such as Johne's disease can be spread by contact with manure from infected cattle. Keeping livestock away from stored manure is a best management practice.

Much of the nitrogen released during manure decomposition will be tied up and later released by soil microbes – and not always when the crop requires it. The challenge is to account for this effect when determining nutrient application rates.



Livestock and poultry manure may harbour infectious diseases that can affect livestock and people. Their presence presents another good reason to manage manure with care.

PUT YOUR MANURE TO THE TEST

Having your operation's manure analyzed by a laboratory is the most accurate way of knowing what nutrients it contains. Livestock operations should sample and analyze manure for nitrogen, phosphorous, potassium and total solids during development of their nutrient management strategy and nutrient management plan. For more information on sampling and analysis procedures, see the Nutrient Management Act protocol or *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land*, available through the Ontario Ministry of Agriculture, Food and Rural Affairs.

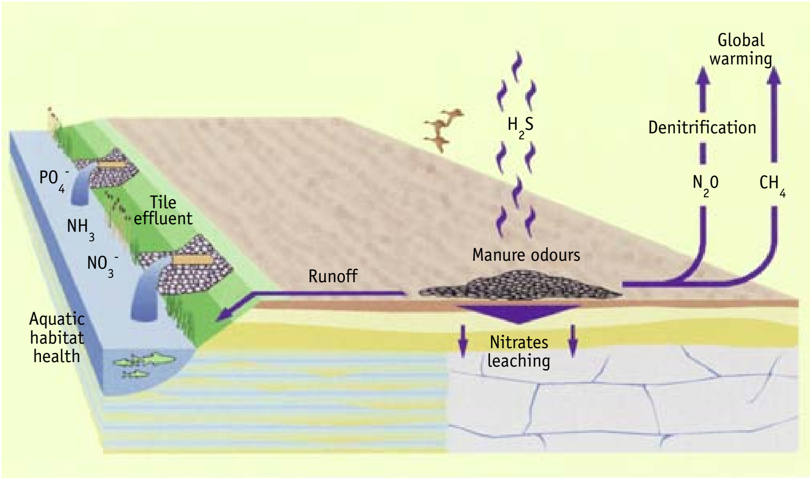
ENVIRONMENTAL RISKS OF MANURE AND OTHER ORGANIC MATERIALS

If not handled properly, farm-based nutrients can be a major pollution problem. Manure and other nutrient materials are assets when well-managed, but are pollution risks when poorly managed. The following chart summarizes how manure and other wastes can pollute or be nuisances.

RESOURCE	POLLUTANT AND ITS EFFECT
AIR	• ammonia (NH_3) gases from volatilized manure – cause odours • nitrogen gases (N_2, N_2O) from denitrification – N_2O adds to greenhouse gases • methane (CH_4) from decomposing manure in barns and in storage – adds to greenhouse gases • sulphide gases – are foul-smelling and add to the production of acid rain
SURFACE WATER AND AQUATIC HABITATS	• phosphates in solution or soil-attached from runoff or tile effluent – can cause excessive algae blooms since P is the limiting nutrient • ammonia (NH_3) from manure runoff to surface waters – is toxic to fish and other aquatic organisms • nitrates in solution – will reach surface waters from runoff or tile effluent and can cause excessive algae blooms • bacteria and pathogens from stored and applied manure – can reduce quality and safety of surface waters • biological debris – organic matter from manure creates in-water habitat for bacteria and pathogens
GROUNDWATER	• nitrates in solution – can leach into groundwater, making it unsuitable as drinking water for humans, livestock watering or cleaning facilities • bacteria and pathogens (disease-causing organisms and single-cell pathogens) – can contaminate where wells are improperly located, constructed, sealed, or in need of repair

To minimize these environmental risks, nutrient management planning is Ontario's tool of choice.

Manure and other nutrient materials are assets when well-managed, but are pollution risks when poorly managed.



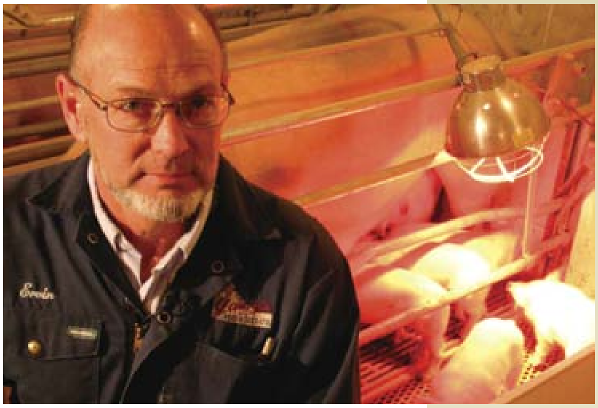
NUTRIENT MANAGEMENT PLANNING – AN OVERVIEW

Across the province, farmers are developing customized nutrient management plans, wherein:

- all nutrients are inventoried – organic, inorganic, those that a crop needs, those removed by a crop, and those already in the soil
- all nutrients are managed – according to land base, production goals, proximity to water resources, farmstead layout, equipment, and odour and safety concerns.

Since each farm is different, each plan is unique, but all plans are based on shared scientific principles.

A sound plan, when applied with related best management practices, is a win–win for the farm and non-farm population alike. The planning process results in valuable working documents for farmers that usually lead to reduced input costs and more efficient use of time and equipment. Water resources are better protected, and odour is kept to a minimum. The process also demonstrates due diligence to society at large and builds consumer confidence.



"There's a lot of negativity about nutrient management plans. I think most of it has to do with people not understanding it. But once you understand the purpose of it, how it helps you manage your manure better, and the safety for the environment - personally, I think it's good."

Erwin Horst, Perth County

TYPES OF MATERIALS APPLIED ON CROPLAND ("PRESCRIBED MATERIALS" IN THE NMA)

Agricultural Sources

- manure and bedding
- runoff from farm-animal yards and storages
- leachate from on-farm feed storages
- greenhouse and container nursery leachate
- washwaters from agricultural operations
- byproducts of on-farm processes (e.g., fruit and vegetable processing)
- other organic materials from agricultural sources (e.g., compost)

Non-Agricultural Sources

- pulp and paper biosolids
- sewage biosolids (e.g., municipal biosolids)
- organic materials that contain materials other than agricultural source materials (e.g., yard waste compost)

If nutrients are both generated on the farm and applied to the farmland, you may need to complete both a plan and a strategy. NMAN software or the associated workbook, both developed by the Ontario Ministry of Agriculture, Food and Rural Affairs, are tools to help you create your documents. You may wish to avail yourself of training opportunities, or hire a qualified consultant.

Yard compost from off-farm sources is considered a prescribed material.

For the NMA's purposes, plans and strategies are created for a **farm unit**. A farm unit includes the land and buildings (e.g., barns, greenhouses, etc.) that make up your farm. You have the option of dividing your farm into multiple farm units according to the limitations given in the regulations.

There are many sources for more information available from the Ontario Ministry of Agriculture, Food and Rural Affairs. Please see the back cover for references. One of the most comprehensive is another title in this Best Management Practices series, entitled *Nutrient Management Planning.*

To view current, legally correct compliance information for the Nutrient Management Act, look up: http://www.omafra.gov.on.ca/english/agops/index.html

MANURE MANAGEMENT AS A SYSTEM

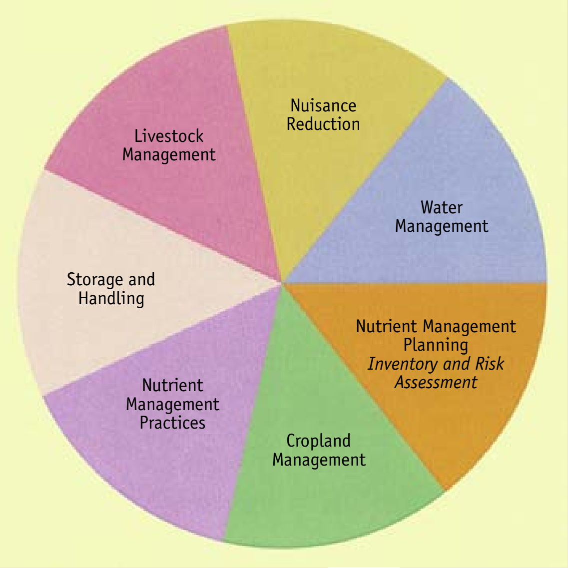
Manure management is a system. The scope of the system is strongly influenced by the type of livestock operation, the facilities, local site conditions and management practices. Some of these influences are given or not likely to change – such as the type of operation, soil type and proximity to environmentally sensitive areas. However, facilities and management practices can be changed and improved to meet both business and environmental goals.

The components of a "systems approach" to manure management are described below. Each component of the management system is distinct and interactive – a planned change will impact other components of the system as well as the system itself.

For example, a change in bedding practices will affect how manure is handled and applied. If you apply a systems approach when assessing your operation, you will have more success with selecting and implementing the BMPs for manure management presented in the remainder of the book

Manure Management System Components

1. ***Livestock Management:*** production system, facilities, nutrition and feeding, bedding, and sanitation
2. ***Storage and Handling:*** siting, site investigations, manure and other waste collection, transfer, storage and handling systems, and storage alternatives (treatment)
3. ***Nuisance Reduction:*** facilities and application practices that will reduce odours and prevent other nuisances
4. ***Nutrient Management – Inventory and Risk Assessment:*** accounting for all nutrient sources, testing levels in farm operation plus assessment of environmental risks and limitations
5. ***Water Management:*** proximity to surface waters, depth to water tables and aquifers, environmental protection and other surface water management practices
6. ***Nutrient Management Practices:*** selecting nutrient sources, scheduling applications, calibrating application and monitoring impact
7. ***Cropland Management:*** BMPs protecting soil and water plus practices to reduce nutrient loss, including cropping and tillage practices



SITING MANURE STORAGE FACILITIES

THIS CHAPTER EXPLORES:

- layout and location
- soil characteristics
- proximity to water
- separation distances
- legal requirements.

LAYOUT AND LOCATION

It pays to plan properly. Most conflicts between livestock operations and neighbours can be prevented if livestock facilities are located far enough away from other developments. Conversely, conflicts are reduced when new developments are located far enough away from livestock facilities.

Land use planning commonly groups together compatible land uses while separating incompatible ones. The same principle is applied in municipalities where an area within a municipal boundary is designated solely for industrial, commercial, agricultural or residential development.

MINIMUM DISTANCE SEPARATION FORMULAS

Early settlers established farmsteads near water sources. Today, the impact on surface waters and other environmentally sensitive areas must be considered when planning the construction of new livestock facilities.

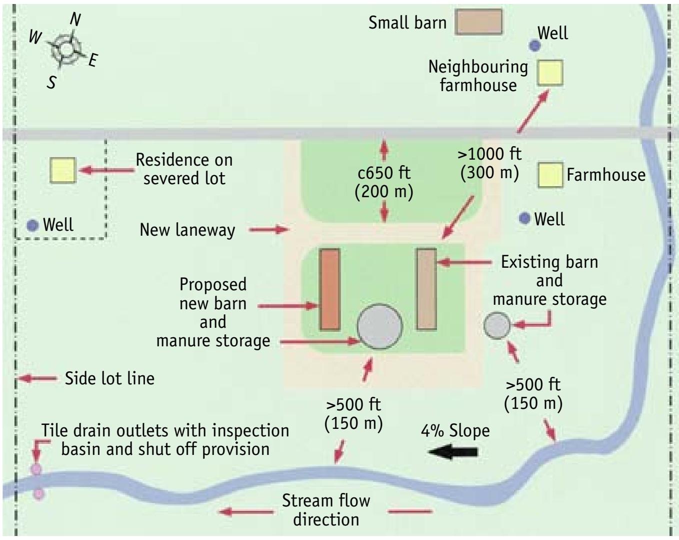
Ontario has established Minimum Distance Separation (MDS) formulas as a tool to determine the recommended separation distance between a livestock facility or manure storage and other land uses. The goal is to prevent land use conflicts and minimize nuisance complaints due to odour. Please note that MDS doesn't account for other types of nuisance complaints such as flies, dust, etc.

MDS varies with type of livestock, size of the farm operation, type of manure produced and the form of development present or proposed.

MDS I provides minimum distance separation for new non-farm development from existing or potential livestock facilities.

MDS II provides minimum distance separation for new or expanding livestock facilities and manure storages from existing or approved non-agricultural development.

Complying with minimum separation distances when choosing a site for livestock facilities can prevent nuisance complaints and lessen environmental risk. (Separation distances shown here are for illustration purposes, and pertain only to the particulars at this operation and site.)

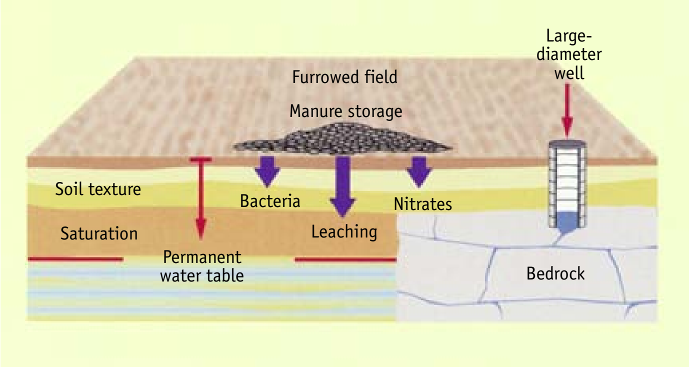


SOIL AND SITE FEATURES

The geology of a proposed site should be analyzed before constructing a livestock or manure storage facility. Synthetic liners may have to be installed in liquid manure storages to reduce the risk to groundwater. Livestock and manure storage facilities located on deep, well-drained, loamy soils on moderate slopes, far away from sensitive natural areas, pose few restrictions for siting livestock facilities. Conversely, a similar facility on a site where bedrock and/or water table are close to the surface may be at higher risk for contaminating groundwater.

SITE CHARACTERISTICS AFFECTING GROUNDWATER CONTAMINATION

Groundwater quality is degraded when inadequately filtered water carries contaminants downward through the soil to the groundwater. Once a groundwater aquifer is contaminated, all water wells drawing water from that aquifer are at risk of being polluted. Soil texture, depth to bedrock, and depth to groundwater significantly affect the degree of risk.



Raw manure and manure nutrients can leach to groundwater on sites with coarse-textured soils, shallow depths to bedrock, and/or high water tables.

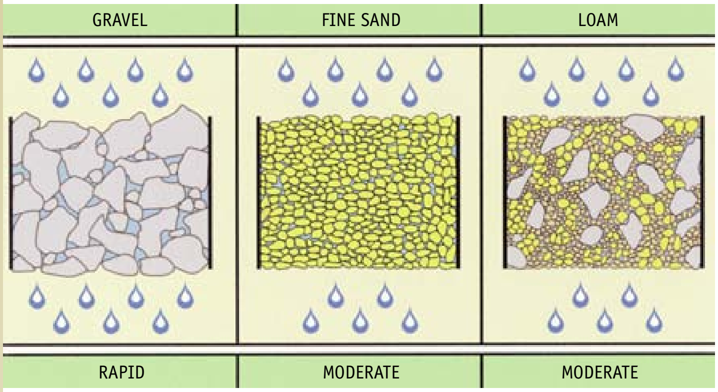
Coarse-textured soils may require concrete floors and/or synthetic liners or imported and compacted clay to seal the soil from the risk of groundwater contamination.

Soil Texture

Soil texture is the relative coarseness or fineness of soil particles. It's the most important determining factor in the ease and speed with which water and contaminants can move through soil to groundwater.

Coarse-textured soils such as gravels and sands have large pore spaces between the soil particles. This allows water to quickly percolate downward to groundwater.

Fine-textured soils provide better natural protection for groundwater. In these soils, such as clays and clay loams, the movement of water and contaminants through the soil is very slow. They act as a natural filter and allow for biological and chemical breakdown of contaminants before they reach groundwater.

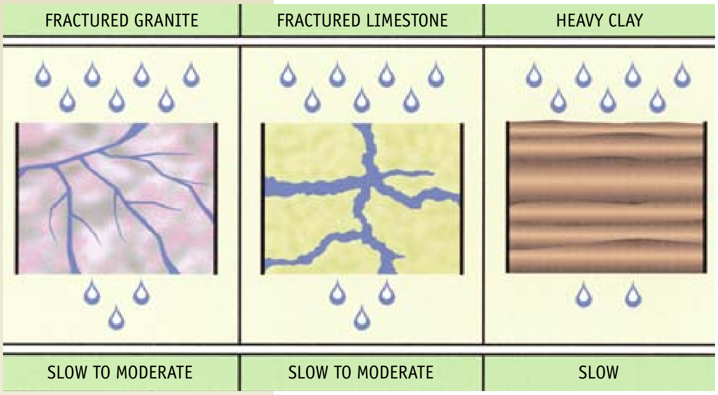


Soil texture can be assessed using hand-texturing methods or with laboratory particle-size analyses to describe the relative fineness or coarseness of the soil particles. Soil maps can provide an indication of the soil texture at the site.

Water moves slowly through uncracked clay soils and very quickly through gravelly and sandy soils.

Depth to Bedrock

Oftentimes where bedrock is close to the surface, so are shallow aquifers. This is particularly true with fractured-bedrock types such as limestone, dolomite, sandstone and weathered shales.



Groundwater can move quickly through fractured limestone and granite bedrock formations.

Open fractures in the bedrock allow rapid movement of water and contaminants to groundwater. If the depth of soil over the bedrock is shallow, there is little opportunity for filtration or restricting the flow of contaminants to the bedrock layer. Once the water and contaminants reach fractured bedrock, the movement to groundwater is very rapid.

Depth to bedrock can be determined using hand or mechanical excavation equipment. Soil and geology maps can give a general indication of bedrock depth. Experience with local excavations, digging footings or post-holes, or seeing bedrock at the surface can also indicate bedrock depth.

Depth to Groundwater

Filtering and treatment of contaminated water by natural processes primarily take place in soil above the water table in the unsaturated zone of soil. In a naturally occurring, high water table, water and contaminants have little time to move through unsaturated soil before reaching shallow aquifers.

Water table depths can fluctuate significantly, depending on the season. In Ontario, the water table is usually highest in the spring or fall. Depth to water table can be assessed by:

- digging a hole in June or September and observing the depth to free water in the hole
- using soil colour features and the soil drainage method to assess drainage class – usually done by soil specialists and engineers
- referring to a local soil map to assess drainage class (e.g., imperfect or poor drainage).

Soils with grey-blue colours and rust blotches in the upper 50 cm (20 in.) from the soil surface indicate a high water table and poor drainage.

CONTAMINANTS AND RISK ASSESSMENT

Contaminants found in manure and other waste materials are mobile in surface water and groundwater. Key potential contaminants found in manure and other organic wastes include:

- phosphorus – in solution or attached to soil from runoff or tile effluent, can cause excessive algal blooms
- bacteria – in stored and applied manure, can reduce quality and safety of surface waters and can contaminate drinking water supplies
- pathogens – disease-causing organisms and single-cell pathogens from manure can travel with runoff to contaminate surface water and groundwater
- biological debris – organic matter from manure creates in-water habitat for bacteria and pathogens.

Keeping the potential source of contamination as far as possible from surface water is the most effective preventive strategy.

At any given site, there are two kinds of contamination sources. **Point sources** occur where potential contaminants are concentrated or stored in one spot, e.g., manure piles or fuel storages. A spill or a long-term leak is a point source, having the potential to contaminate groundwater. **Non-point sources** exist where potential contaminants are spread out over a greater area, e.g., pesticide or fertilizer applied to fields. Regardless of source, the primary consideration is the relative speed with which contaminants move through the soil.

A qualified person using on-site assessment, visual features and soil maps can assess site suitability. A study by a qualified specialist may be required to determine site characteristics.

For more information, see the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet on assessing ground water contamination potential on your farm.

POTENTIAL FOR GROUND WATER CONTAMINATION				
HYDROLOGIC SOIL GROUP	DEPTH TO WATER TABLE*			
	LESS THAN 1 M (3 FT)	1-4.5 M (3-15 FT)	5-14 M (16-45 FT)	GREATER THAN 14 M (45 FT)
BEDROCK (within 3 ft)	1–High	1–High	1–High	1–High
MUCK/ORGANIC	1–High	–	–	–
RAPID	1–High	1–High	1–High	2–Moderate
MODERATE	1–High	1–High	2–Moderate	3–Low
SLOW	1–High	2–Moderate	3–Low	4–Very low
VERY SLOW	1–High	3–Low	4–Very low	4–Very low

* If you do not know the depth to water table, use the highlighted depth column (1-4.5 m).

SUMMARY OF SITING RECOMMENDATIONS FOR MANURE STORAGE FACILITIES

Livestock and manure storage facilities are systems with many components. Whether you're planning to build a new facility, or fine-tune your current operation, you should account for all inputs, including solid and liquid materials, such as:

- manure
- bedding
- waste feed
- wastewater, including:
  - water spilled from drinkers and troughs
  - water from washing operations
  - water added for dilution
  - precipitation
  - yard runoff.

Manure = fecal material + undigested feed + urine + bedding + uncontaminated water + wastewater + other wastes.

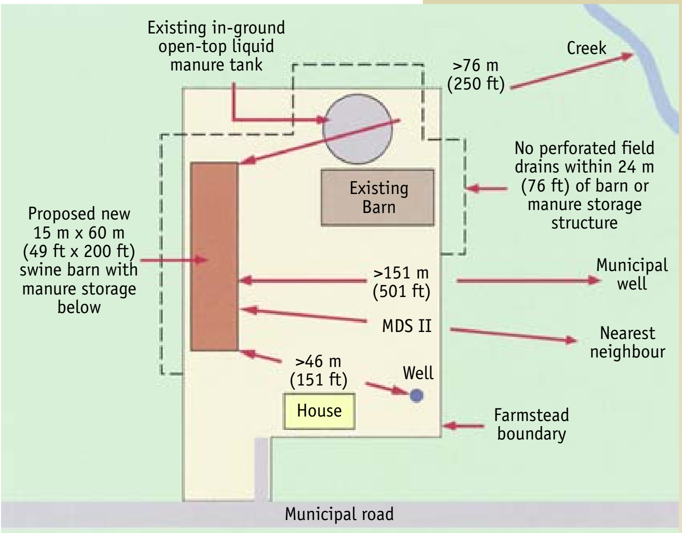
It bears repeating: when managing manure, account for all materials – especially liquids.

For Ontario farmers, a number of legal requirements (e.g., NMA and Building Code) may apply. These could include specific setbacks from wells, site investigations, observation stations for tile drains within 15 metres (49 ft) of a manure storage, and structural design.

New or Expanding Permanent Manure Storage Facilities

Should be located:

- at least 24 metres (76 ft) from a drainage tile, whether existing or to be constructed OR any tile within this distance or below the storage should be non-perforated and all joints properly sealed
  - this water could also be collected and stored or treated – see section on vegetative filter strip systems
  - some conditions, such as on clay soils where foundation drains are recommended, allow a third option: in this case, a perforated tile connected to an observation station should be adequate to verify that only uncontaminated (clear) drainage water is being removed from the site
- at least 151 metres (501 ft) from a municipal well
- at least 46 metres (151 ft) from any other well
- at least 24 metres (76 ft) from a drainage tile – whether existing or to be constructed, and
- with a flow-path that is at least 50 metres (164 ft) from the nearest surface water.

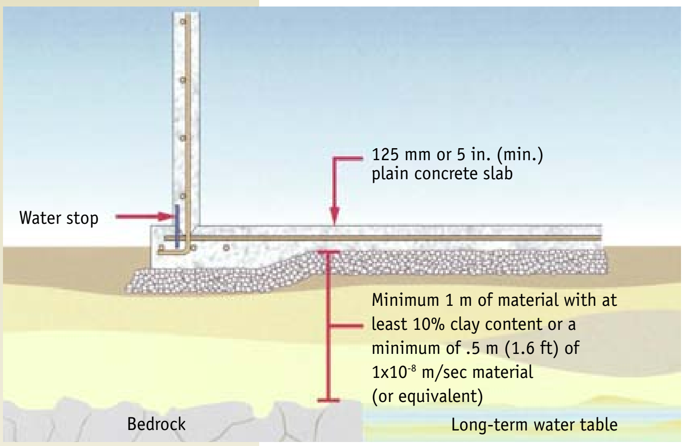


New or Expanding Permanent Liquid Manure Storage Facilities

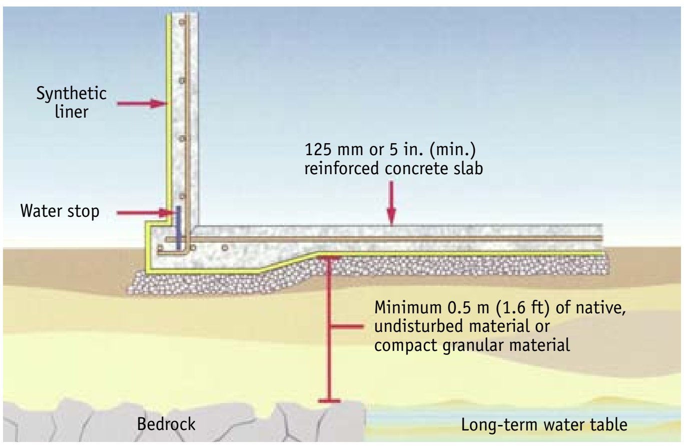
If you plan to construct a new or expanding liquid manure storage, you're required by law to have a site investigation by a professional engineer or geo-scientist. The table on page 36 specifies the site requirements for several types of liquid storages.

To view current, legally correct compliance information for the Nutrient Management Act, look up: http://www.omafra.gov.on.ca/english/agops/index.html

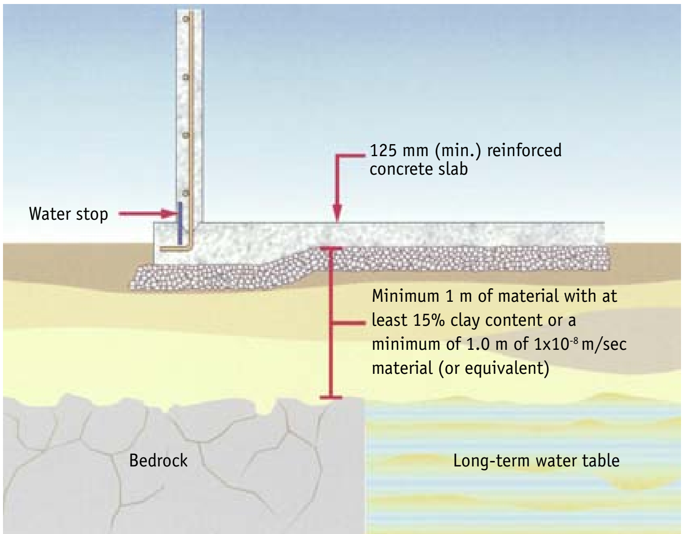
SITE REQUIREMENTS FOR PERMANENT LIQUID MANURE STORAGE FACILITIES	
LIQUID MANURE STORAGE TYPE	**REQUIREMENTS**
FOR STORAGES WITH REINFORCED CONCRETE FLOORS	
concrete or steel permanent storage facilities with UNLINED FLOORS	• a minimum thickness of 0.5 metre (1.6 ft) of a hydraulically secure soil over bedrock or a permanent water table, or • a minimum thickness of 1.0 metre (3.3 ft) of a soil material with a minimum clay content of 10%
concrete or steel permanent facilities with LINED FLOORS	• a minimum thickness of 0.5 metre (1.6 ft) of a native undisturbed soil over bedrock or a permanent water table
FOR STORAGES WITH UNREINFORCED CONCRETE FLOOR	
concrete or steel permanent facilities with UNLINED FLOORS	• a minimum thickness of 1.0 metre (3.3 ft) of a hydraulically secure soil over bedrock or a permanent water table, or • a minimum thickness of 1.0 metre (3.3 ft) of a soil material with a minimum clay content of 15%
concrete or steel permanent facilities with LINED FLOORS	• a minimum thickness of 1.0 metre (3.3 ft) of a native undisturbed soil over bedrock or a permanent water table
FOR EARTHEN MANURE STORAGES earthen, lined	• a minimum of 2.0 metres (6.5 ft) of hydraulically secure soil over bedrock or a permanent water table • the interior surface must be either of the following: ○ synthetic or geosynthetic liner or equivalent ○ engineered soil liner
FOR RUNOFF STORAGES (NOT MANURE) earthen, unlined	• a maximum storage depth of 3.0 metres (10 ft) and maximum storage volume capacity of 2,500 cubic metres (88,290 ft^3) • at least 2.0 metres (6.5 ft) of hydraulically secure soil over bedrock or an aquifer between the bottom and sides of the proposed facility • at least 150 mm (6 in.) of the interior surface material that is disked and recompacted to a specification that is equal to hydraulically secure soil



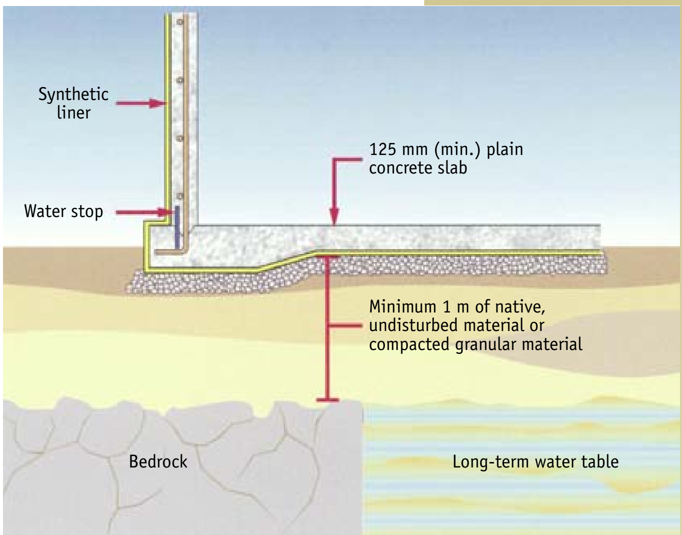
Unlined, reinforced floor



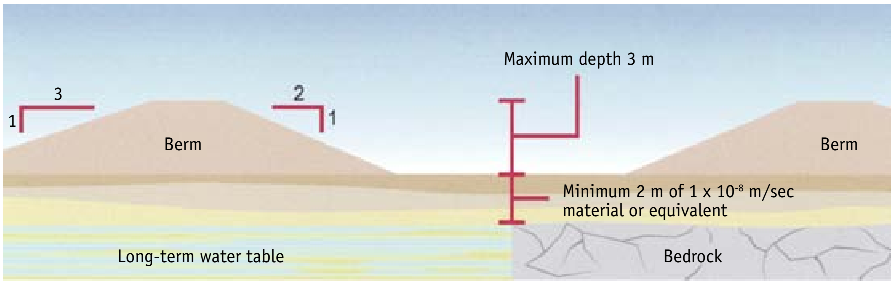
Lined, reinforced floor



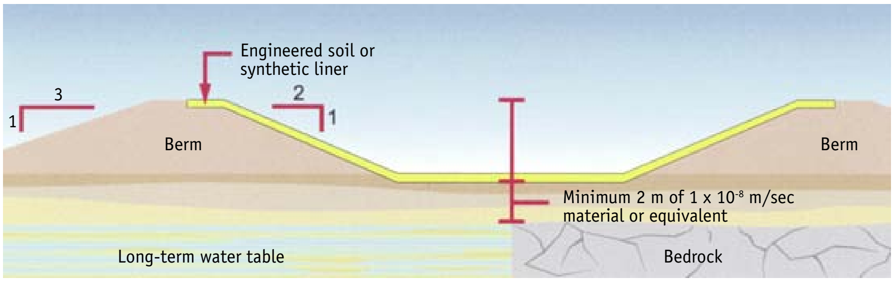
Unlined, unreinforced floor



Lined, unreinforced floor



Earthen runoff storage



Lined, earthen liquid manure storage

FARM ODOURS AND NEIGHBOURLY RELATIONS

THIS CHAPTER EXPLORES:

- **BMPs to minimize odours from manure storages**
- **BMPs to control odours during application**
- **common complaints by non-farming neighbours**
- **BMPs to maintain good relations with neighbours.**

To varying degrees, all livestock operations emit manure odours. It's generally accepted that operations with liquid manure systems are more odorous than those with solid manure systems.

In Ontario, more than half of the nuisance complaints regarding agriculture concern odours. Swine facilities tend to receive the greatest number of odour complaints. Dairy operations are typically next on the list. **Odour that is continuous and at excessive levels is atypical of normal farming practices.**

Addressing odour issues is an important component of a nutrient management plan and the management of organic nutrient-waste systems. An odour problem that may arise at a site can potentially attract attention to other environmental problems – real or perceived. Proactive manure odour control measures will help ward off other neighbourly conflicts.

More non-farm residents are moving to rural areas where large livestock farms operate.

BMPS TO CONTROL ODOURS FROM MANURE STORAGES

TECHNIQUE	LIQUID STORAGE CONSIDERATIONS	SOLID STORAGE CONSIDERATIONS
SITING	• meet MDS II distance formulas	• meet MDS II distance formulas
PROPER DESIGN	• properly size to accommodate expected liquid load • consider two-stage separation	• provide sufficient capacity for solid and liquid portions to avoid untimely spreading • divert roof water away to encourage aerobic conditions in manure pile
LANDSCAPING	• keep storage out of main view • plant trees to remove dust and aerosol particulates from air and increase dilution • ensure earthen walls are unaffected by tree roots	• plant trees to act as a visual barrier and provide considerable air movement • design with berms and side slopes to reduce visibility and airflow
NATURAL COVERS	• reduce surface area exposure to ambient air • act as biofilters on odours, but can be difficult to keep floating • depending on feed rations, dairy tanks can form a natural "crust", providing odour control	• don't apply, but pile shape affects runoff volumes
GEOTEXTILE COVERS	• add cost but allow for capture of gases • reduce volume of liquid to be spread	• reduce water content of manure (because of cover) and encourages aerobic conditions • don't have to deal with runoff
ROOFS	• reduce surface area exposure to ambient air • can be a high capital cost	• reduce water content of manure and encourage aerobic conditions • don't have to deal with runoff
CHEMICAL/ BIO ADDITIVES	• approach with caution – more failures than successes	• are similar to liquid systems
LIQUID/SOLID SEPARATION	• done often in conjunction with aerobic treatment • makes for increased labour and waste streams	• collect liquid runoff from solid systems to encourage aerobic conditions
AERATION	• preferably done in conjunction with liquid/solid separation • has high energy demands	• has high energy demands (composting) • can have "short-circuiting" of air flow through pile
AEROBIC TREATMENT (COMPOSTING)	• need a very large carbon supply (e.g., straw) liquid to solid	• increase area and equipment required • need to manage leachate
ANAEROBIC TREATMENT (DIGESTION)	• are costly to install and maintain – but revenue to convert generated may offset costs	• can mix solid manure with liquid manure and enter into the digester
BIOFILTERS	• involve blowing exhaust air from above liquid manure storage through biofilters to reduce odour, N-compounds and organic material • are costly to install and maintain – but revenue generated may offset costs	• not applicable

Changing livestock feedstuffs can reduce manure odours.

Treed shelterbelts can filter odorous gases from manure storages.

BMPS FOR ODOUR CONTROL DURING APPLICATION

Odour control needs particular attention during land application. This is the time when your manure handling practices are most apparent to neighbours. Fairly or otherwise, this may also be the time when your reputation for environmental safety is made – or destroyed.

Incorporate manure immediately following application to reduce odours.

ODOUR CONTROL DURING APPLICATION

APPLICATION BMP	BENEFITS	DRAWBACKS
INCREASE USE OF BEDDING	• reduces odours when wastes are handled as solids • keeps animals cleaner	• increases labour associated with solid systems and bedding • doesn't apply to liquid systems
INFORM NEIGHBOURS OF YOUR INTENTIONS	• shows your concern, improves relations • helps identify times when it may be inappropriate to spread for social reasons	• hard to satisfy everyone • requires planning ahead • may require adjustments of plans
PRE-TILL	• increases soil contact and infiltration • reduces odour	• may risk excessive tillage and soil degradation
REDUCE SPREADING FREQUENCY	• reduces the time in which there may be odour release from land application	• can have costs associated with providing required storage
REDUCE AMOUNT OF TIME SPENT SPREADING	• offers more time for manure to dry	• reduces time in day available for spreading
APPLY IN COOL WEATHER	• reduces volatilization	• may reduce opportunities to apply • don't apply to frozen soil
AVOID APPLICATION ON CALM HUMID DAYS, PARTICULARLY IF NOT INCORPORATING	• avoids climatic conditions most conducive for odour • preserves nutrients	• may restrict spreading in the summer months when soil conditions are ideal
APPLY WHEN CONDITIONS ARE DRY	• reduces anaerobic conditions	• may reduce opportunities to apply
MONITOR WIND DIRECTION WHEN HAULING MANURE TO FIELDS	• can take advantage of predominant wind directions to naturally direct odours away from sensitive areas	• may reduce opportunities to apply • unpredictable – wind direction can change during application
AVOID HIGH-TRAJECTORY MANURE-SPREADING EQUIPMENT	• reduces air/manure contact • increases control of spread	• may be more expensive and time-consuming with other technologies
USE DRIBBLE BAR APPLICATORS – TO KEEP MANURE CLOSE TO THE GROUND	• reduces air contact • applies to no-till systems • can potentially sidedress in row crops	• applies to liquid systems only • offers less effective odour control than injection
INJECT MANURE WITH A CONCENTRATED BAND	• prevents contact of manure with air • allows manure to be spread post-emerge in row crops such as corn, increasing period of manure application	• applies to liquid systems only • makes for slower application and requires more horsepower • may increase potential to contaminate tile drain flow at higher application rates
INCORPORATE AS SOON AS POSSIBLE AFTER APPLICATION	• reduces air/manure contact • preserves manure N	• can be more challenging for standing crops and in high crop-residue management system

COMPLAINTS FROM NEIGHBOURS

Odours comprise more than half of complaints from farmers' neighbours. Unfortunately, such conflicts are not always handled as constructively as possible. Conflict **can** be prevented: it takes a little know-how, a few skills and techniques, plus the right attitude and philosophy.

Livestock operations generate odours. This is a fact of life. It's unrealistic to expect them to be odour-free. It's equally unrealistic that people will accept excessive odours. Courtesy and understanding within rural communities will help to reduce conflict over the unique qualities of livestock agriculture.

Other topics of complaints include:

- a not-in-my-back-yard concern (particularly for proposed new operations)
- violations of environmental, health or safety legislation
- contraventions of local municipal bylaws
- whether a particular practice is a "normal farm practice"
- "nuisance" complaints as listed in the Farming and Food Production Protection Act: noise, dust, vibration, light, smoke and flies (as well as odour).

In the long run, it's often more effective to resolve local disputes locally, without official input.

As a farmer, unfortunately you may be unaware of complaints about your operation. Neighbours often go directly to authorities such as Ministry of the Environment, Ontario Ministry of Agriculture, Food and Rural Affairs' Agricultural Information Contact Centre, or their municipality. This step alone may set a negative tone to the conflict resolution process.

The good news is that problems can also be avoided. Read on to learn more!

BMPS FOR COMPLAINT AVOIDANCE

The keys to preventing problems are **site planning, careful management** and **fostering good, ongoing communication with your neighbours.**

SITE PLANNING

Considering potential odour concerns during the planning stage will yield an ounce of prevention, e.g.,

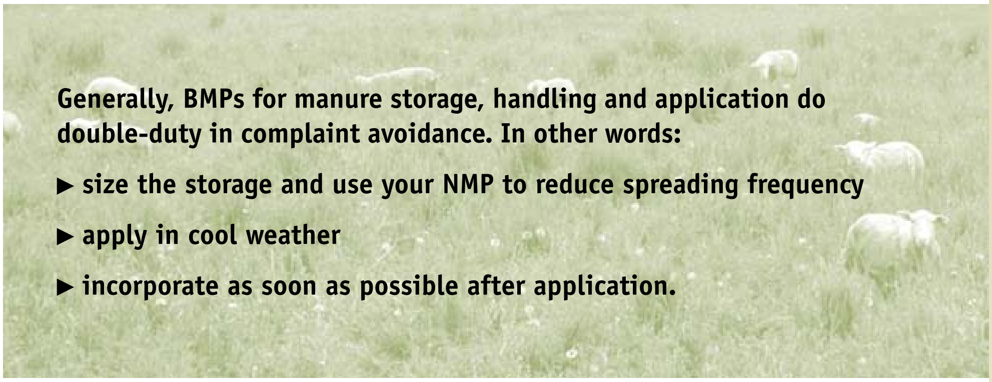
- meet MDS II distance formulas
- locate storage system and lanes downwind
- keep storage out of main view
- plant trees to remove dust and aerosol particulates from air and increase dilution.

BUILDING RELATIONSHIPS

Get to know your neighbours. Help them feel comfortable enough to talk to you directly about their concern. Simple courtesy will go a long way. This will help avoid third-party involvement. Here are some more ideas for nurturing positive relationships with your neighbours.

- Try to limit spreading to two or possibly three times a year – the less often odour is noticed, the less likely the concern.
- Avoid spreading manure on weekends, or the days just before the weekend.
- Notify neighbours (by telephone and/or through a note in their mailbox) to let them know in advance of your manure spreading plans, so they can plan around the event accordingly if they so wish.
- Consider conducting a farm tour to help in educating the rural non-farm public on today's farming practices.
- Participate in and even host special events in the neighbourhood (e.g., a summer barbecue).

With these considerations, many of today's livestock producers are building respect and unity within the rural community.



Generally, BMPs for manure storage, handling and application do double-duty in complaint avoidance. In other words:

- **size the storage and use your NMP to reduce spreading frequency**
- **apply in cool weather**
- **incorporate as soon as possible after application.**

BMPS FOR COMPLAINT RESOLUTION

Despite best intentions, it's not always possible to avoid complaints. When it happens, it can be difficult to accept the criticism, particularly if it comes from someone you don't know or is from someone who is unsympathetic to livestock agriculture.

Before you react defensively, remember: the concern was legitimate enough to the complainant to bring it to your attention. So, hear them out before presenting your perspective.

HOW TO HANDLE A COMPLAINT	
DO	**DO NOT**
Listen to the concern and try to understand the complainant's perspective.	Become argumentative.
Take the complaint seriously.	Be judgmental.
Ask questions to ensure you understand the concern.	Be defensive.
Consider independent advice if the concern seems unreasonable to you.	Immediately rely on outside help to solve the problem.
Identify common ground on which you can build a mutually satisfactory resolution.	Aggravate an already tenuous situation.
Follow up quickly on addressing a reasonable concern.	Ignore the request or otherwise be complacent.

By handling the complaint in a prompt and responsible manner, you can put an issue to rest quietly and efficiently.

ALTERNATIVE APPROACHES

There are some circumstances where personalities or situations are such that the problem cannot be fully resolved by the main parties. The parties may perceive that the conflict will need to be resolved through other, often more costly, avenues, such as tribunals or the courts of law.

There are, however, alternative approaches to resolving disputes that can be less costly and result in solutions that are more readily accepted by both parties. These alternative approaches include:

- negotiation
- mediation
- arbitration
- administrative tribunals.

Each approach has its application in a specific set of circumstances and is described briefly in the next chart.

Please note, however, that the opportunity for effective technical input decreases as the method more closely approximates court action – where the focus is on who's right and who's wrong, as opposed to the best remedial measure from a technical perspective.

APPROACH	DESCRIPTION	PROS	CONS
NEGOTIATION	parties meet either directly or through representatives	parties control the process – legal positioning avoided	personality conflicts may cause stalemate
MEDIATION	a neutral third person called a mediator facilitates the process that two or more people follow to arrive at a solution	mediator only assists parties in arriving at their solution – no legal advice given	more costly – may be difficult agreeing upon a suitable mediator
ARBITRATION	a binding process in which a third party decides issues between parties	solution process still within control of the party	arbitrator's decision is binding on the parties
ADMINISTRATIVE TRIBUNAL	example: the Normal Farm Practices Protection Board	solution arrived at outside of costly court proceedings	more formal procedures – parties have limited control of the process

The Normal Farm Practices Protection Board has legal authority through The Farming and Food Production Protection Act, 1997 (FFPPA). The act was designed to protect normal farm practices to the extent that it is reasonable to do so, even though they may cause some disturbance to nearby residents.

The FFPPA is not carte blanche for agriculture. It is subject to the Environmental Protection Act, the Ontario Water Resources Act, the Pesticides Act and the Health Protection and Promotion Act. Normal farm practices cannot be in violation of these acts. The FFPPA is intended to offer protection to farmers only in the cases where no provincial statute has been breached.

LOCAL ADVISORY COMMITTEES

Local advisory committees (LACs) may also be used to help resolve some nutrient management conflicts. These committees are formed with local (predominantly agricultural) membership by municipal bylaws. Their role is to educate the public and mediate local issues concerning nutrient management.

Local Advisory Committees are only permitted to mediate nutrient management complaints that do not violate regulations under the Nutrient Management Act, Environmental Protection Act or Ontario Water Resources Act. If the complaint reported to the municipality involves a spill or violation of a regulation, the matter must be referred to the Ministry of the Environment. Matters may be brought to the LAC by the municipality or by referral from the Ministry of the Environment.

MANURE TREATMENT

THIS CHAPTER EXPLORES:

the many benefits of manure treatment

the pros and cons of three Ontario-appropriate treatment technologies, namely mechanical solid-liquid separation, anaerobic digestion, and aerobic composting.

Raw manure should be managed to make it easier to store, handle, apply, and dispose of. You can do this by changing its physical, chemical and biological properties. That may sound challenging. But as best management practices, the on-farm manure-treatment technologies in these pages must also be simple, reliable, suit your operation, and be economically feasible.

Manure treatment can perform some combination of the following functions:

- ▶ reduce manure volume for land application
- ▶ reduce or increase nutrient content of manure for land application
- ▶ recycle a product for reuse (e.g., water for flushing systems)
- ▶ reduce environmental impact (e.g., surface water and groundwater contamination)
- ▶ reduce odours and other nuisances
- ▶ reduce pathogens
- ▶ produce useful byproducts for on-farm use or off-farm sales
- ▶ produce clean discharge
- ▶ produce renewable energy
- ▶ reduce emissions of greenhouse gases.

Unfortunately, no treatment developed to date can address all of the above functions. In fact, the challenge is to avoid a technology that reduces the impact of one potential pollutant (e.g., nitrate-nitrogen) only to cause a problem with another (e.g., manure phosphates).

There are dozens of technologies being developed for the treatment of manure. Many of them are simply unsuitable for Ontario conditions or require more practical research to resolve technical flaws.

The following technologies show promise for Ontario livestock farms:

- ▶ mechanical solid-liquid separation – particularly screw presses
- ▶ anaerobic digestion
- ▶ aerobic composting of manure.

MECHANICAL SOLID-LIQUID SEPARATION

The process mechanically divides manure into solid and liquid fractions. The solid component contains most of the fibre and some of the N + P.

The liquid component can be used for flushing the barn, land-applied, treated in a vegetated filter strip or stored with other dilute liquid wastes.

The screw press separates solids from liquid more efficiently than other technologies (e.g., belts and screens).

The process is more effective with fresh rather than stored manure.

Advantages

- less solids in liquid fraction makes handling, pumping and application easier
- phosphorous is concentrated in the solid fraction – improving the ability for more site-specific nutrient management or more valuable compost material
- more economical to transport the concentrated solids fraction offsite versus the raw liquid manure
- may reduce land base required for spreading manure onsite

Disadvantages

- creates two "streams" of manure to store, handle and apply
- increased capital cost, labour and maintenance

Solid-liquid separation makes the liquid fraction easier to pump and apply.

ANAEROBIC DIGESTION

The biogas produced by anaerobic digestion units can be burned for heat or used to generate electricity.

Liquid manure high in organic material is transformed by anaerobic bacteria into several end-products – including "biogas" (carbon dioxide and methane). Biogas can be burned for heat or used to generate electricity.

Digesters function over a range of operating temperatures. Most operate efficiently between 35 and 40 °C (35–104 °F). If operating temperatures exceed 48 °C (120 °F), more methane will be produced. However, the methane-producing microbes may shut down at these higher temperatures.

Components include storage tanks, manure-handling equipment, digester tank, gas-handling equipment and electrical generation equipment.

Remaining outputs may require further processing prior to disposal or application.

Generally speaking, there are two anaerobic digestion system configurations suitable for Canada.

Completely mixed

A completely mixed system, as the name implies, consists of a large tank in which new and old material is mixed. These systems are suitable for manure with lower dry matter content of 4–12%.

Plug flow

Typically a plug flow system consists of long channels in which the manure moves along as a plug. These systems are suitable for thicker liquid manure (11–13% dry matter).

Advantages

- odour reduction
- pathogen reduction
- energy production
- nutrient retention for fertilizer use

Disadvantages

- increased capital cost, labour and maintenance
- most suitable for very large operations
- utility connections may be difficult
- no decrease in the nutrient content of manure, so the same land base is required for spreading unless further treatment is done

AEROBIC COMPOSTING

This transforms solid manure and bedding materials into stable, soil-like material using accelerated aerobic decomposition by microbes. The process requires regular mixing and careful management of air flow, temperature, moisture, and C:N ratio.

Ideal conditions include a moisture content between 40–65% and a C:N ratio of 20:1–40:1.

Advantages

- pathogens and weed seeds are killed
- volumes are reduced
- material can be land-applied or sold
- land base for spreading reduced if compost sold

Disadvantages

- poor management can lead to runoff, offensive odours and greenhouse gas emissions
- improper site selection can lead to water contamination (field windrow composting in sensitive areas)
- most practical for large operations
- concentrates the nutrients in a reduced volume, and the same land base is required for spreading material

Windrow composters can be used to accelerate the composting process.

MANURE STORAGE AND HANDLING

THIS CHAPTER EXPLORES:

- the principles of manure storage and handling
- alternatives to manure storage
- types of manure storage systems
- sizing and safety requirements of manure storage designs
- best management practices.

Your manure storage system has impressive "reach" when you consider all its implications concerning:

timing and scheduling of application

- manure cannot be applied year-round
- storage capacity will directly affect when and how often manure needs to be applied
- net nutrient loss from leaching is reduced in properly stored and applied manure

quantity of manure

- net nutrient loss from leaching is reduced when manure is properly stored and applied

potential for groundwater contamination

- systems that store all contaminated liquids from the farmstead area – including silo effluent, milking-centre and housing-facility washwater, and yard and manure runoff – will reduce the risk of surface water or groundwater contamination

odours and loss of other gases

- storage conditions can reduce odour levels and the rate of release of manure gases to the atmosphere
- release of manure gases, particularly ammonia, affects the nitrogen content of the manure (and its value as a fertilizer)

potential for manure treatment and innovative technology trials

- solid manure systems are more compatible with composting treatments
- technologies such as energy co-generation, i.e., anaerobic digesters, and solid-liquid separation are intended for liquid manure systems or combination liquid/solid systems.

Manure piled behind the barn is NOT manure storage.

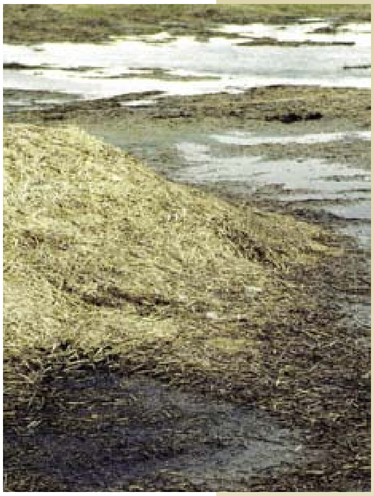
Manure can be treated to reduce storage volume requirements and to create useful end-products such as compost or energy.

Manure can be composted instead of stored as raw manure.

ALTERNATIVES TO PERMANENT LONG-TERM STORAGE ON YOUR FARM

Permanent manure storage is not the only legitimate way to manage manure materials. Here are three other approaches:

- temporary in-field storage – solid manure may be stored for up to several months in-field provided certain site and management conditions are met
- manure treatment – e.g., solid manure can be composted to reduce overall volume and create a more biologically stable product (NB: although storage is part of treatment systems)
- manure removal by a manure broker (e.g., solid sheep manure for commercial composting).



All temporary storage systems should be developed in ways that minimize nutrient loss.

To view current, legally correct compliance information for the Nutrient Management Act, look up: http://www.omafra.gov.on.ca/english/agops/index.html

HOW STORAGE AND HANDLING SYSTEMS AFFECT NUTRIENT MANAGEMENT PLANS

The selection and use of your manure storage and handling system will directly affect the development and implementation of your nutrient management plan.

A roofed storage system can reduce or eliminate the need to manage liquids.

SYSTEM FEATURE	IMPLICATIONS FOR YOUR NUTRIENT MANAGEMENT PLAN
FORM OF MANURE – SOLID OR LIQUID (OR BOTH)	• in many cases, unroofed liquid systems require larger volumes for storage • application rates for liquid manure are limited by soil type and are affected by the amount of nutrients lost during storage and handling • nutrient loss and residual content: solid manure will lose more nitrogen in the form of nitrous oxide than liquid manure, and liquid will lose more ammonia-N than will stored solid manure ○ nitrates, potassium and phosphorous can be lost with unmanaged runoff from solid manure stacks • in liquid manure storages, some N will be lost to the atmosphere ○ other forms of nutrients will not be lost unless there's a spill or leak in the system • application opportunities are fewer with solid systems, in most cases • options needed to reduce environmental risks: field runoff from winter spreading of solid manure, tile effluent from liquid applications • separation distances from sensitive areas are generally greater for liquid manure
MANURE SOURCE	• poultry manure nutrient levels are higher than swine and dairy manure • swine and dairy manure contains more washwater than poultry • manure nutrient content will affect application rates
MANURE VOLUME	• 240–250 days of storage is ideal to avoid spreading on frozen ground in Ontario • large volumes will require more acres for application (unless very dilute, or where multiple applications to the same land base are possible) • large volumes will require more opportunities for application and/or equipment capable of handling larger volumes per day • diversion of clean water or roofing the storage facility will help reduce volume stored • a roofing system for solid manure handling systems will reduce or eliminate the need for a secondary liquid storage system to handle runoff
STORAGE SITES – TEMPORARY AND/ OR PERMANENT	• use of temporary manure storage sites are limited to a certain length of time (120–300 days) • manure stored at temporary sites should be used on that farm unit for crop production • NB: temporary storage is not a BMP – it's recommended that you use a permanent storage that eliminates or contains all runoff
CROP ROTATION	• crop choice and sequence will affect crop needs, timing and application rates • cropping and tillage systems will affect the application methods and opportunities (e.g., sidedressing or early fall application can affect storage size)

A solid storage with a separate runoff system will contain all liquids – but will require two means of application.

DEFINING A MANURE STORAGE AND HANDLING MANAGEMENT SYSTEM

A management system for manure must take into account the following factors:

- **volumes of waste material or manure produced**
- **collection system (how the manure is collected from animals)**
- **transfer to storage facility (elevator or stacker, pump, etc.)**
- **approved storage structures, including roofed or concrete storage structures, runoff storages**
- **handling (transfer from storage location to application site)**
- **application scheduling and technology.**

COMMON HANDLING SYSTEMS

Livestock manure is handled and stored in a solid or liquid form. Manure form depends on the type of livestock manure and what's added – the amount of dilution water plus the type and volume of bedding used.

Most livestock operations in Ontario use either solid or liquid systems. Regardless of which system you have, it's critical that **all** liquids are managed. Clean water and eavestrough water should be diverted away from the barn or manure storage structure.

With the exception of poultry farms, larger livestock operations commonly use liquid manure systems. Washwater and milking centre washwater are often added to the manure storage facility.

Contaminated water such as yard runoff should be stored and managed separately. That's why some solid systems have separate liquid storage facilities.

CHOOSING A SYSTEM – WHY CONSIDER LIQUID?

When you think of manure storage and handling systems for beef operations, you normally think of solid manure systems. But should this always be the case?

Consider a large, unroofed feedlot that uses minimal bedding and needs to improve yard runoff management and manure storage. Without bedding and proper storage, a liquid manure system may be better suited to handle all the manure and yard runoff. This runoff can be land-applied to supply additional nutrients to growing crops.

SYSTEM	PROS	CONS
SOLID MANURE	• less expensive if currently in solid system • less odour • more application options • less concern regarding direct runoff or leaching	• manure runoff is not managed • yard runoff is not managed • more bedding needed • more labour required
LIQUID MANURE	• all liquids are managed • yard runoff can be contained • less labour	• more expensive system • more odours than with solid • higher risk for runoff and spills

Manure stacker and stable cleaners work well for tie-stall operations, when used in combination with a runoff tank.

SOLID MANURE HANDLING SYSTEMS IN ONTARIO

COLLECTION SYSTEM	TRANSFER SYSTEM TO STORAGE	COMMON STORAGE SYSTEM	APPLICATION SYSTEM	PROS + / CONS –	CAPITAL COSTS
BEDDED PACK with LOADER (e.g., beef, open-concept barn)	not required	bedded pack	box spreader	+ low labour until cleanout – runoff storage may be required if yard used – rodents/flies	low – combined with livestock housing
FRONT-END LOADER (e.g., broiler barn)	front-end loader, box spreader, hydraulic dump trailer or truck	roofed solid storage or open manure storage with a runoff storage facility	box spreader or hopper spreader	+ uses existing equipment – runoff storage facility may be required	moderate for roofed storage system – costs vary with choice of runoff system
STABLE CLEANER (e.g., tie-stall dairy barn)	stacker, front-end loader, or ram/ piston/air pump	roofed solid storage structure, or open manure storage structure and runoff storage facility	box spreader or hopper spreader	+ uses existing equipment + livestock don't have to be moved – runoff storage facility may be required – labour-intensive – stacker freezes/cannot handle wet manure	moderate to high for roofed storage system – costs vary with choice of runoff storage and transfer system

High-trajectory irrigation guns are not suitable replacements for insufficient storage volumes.

Concrete storages can be sized to hold all sources of contaminant liquids.

Earthen storages – with proper siting, site characterization and design – can be effective storages for liquid manure, runoff and washwaters.

LIQUID MANURE HANDLING SYSTEMS					
COLLECTION SYSTEM	**TRANSFER SYSTEM TO STORAGE**	**COMMON STORAGE SYSTEM**	**APPLICATION SYSTEM**	**PROS + / CONS –**	**CAPITAL COSTS**
TRACTOR SCRAPER (e.g., free-stall dairy)	liquid pump or gravity transfer	open or covered concrete, earthen, or steel	tanker, low-trajectory irrigation or drag hose	+ uses existing equipment – wear on concrete floors	moderate
MECHANICAL SCRAPER (e.g., layer barn)	direct to tank, cross auger, hydraulic/ mechanical/air pump, or gravity transfer	open or covered concrete, earthen, or steel	tanker, low-trajectory irrigation, or drag hose	– cannot irrigate gutter-scraped layer manure	moderate
ALLEY SCRAPERS (e.g., free-stall dairy)	direct to tank, liquid pump, or gravity transfer	open or covered concrete, earthen, or steel	tanker, low-trajectory irrigation, or drag hose	+ automatic manure removal – less bedding needed	moderate to high
GUTTERS – STOP-AND-FLOW, and CONTINUOUS GRAVITY-FLOW (swine)	liquid pump or gravity transfer	open or covered concrete, earthen, or steel	tanker, low-trajectory irrigation, or drag hose	– requires more management	moderate
SLATTED FLOOR (e.g., free-stall dairy, swine)	direct to tank below	in-barn concrete – storage below	tanker, low-trajectory irrigation, or drag hose	+ labour-efficient – manure gases and safety concerns	high to very high
SLATTED FLOOR / FLOW GUTTER BELOW (e.g., swine)	liquid pump or gravity transfer	open or covered concrete, earthen, or steel	tanker, low-trajectory irrigation, or drag hose	+ labour-efficient – requires good management	high to very high
FLUSHED ALLEYS (e.g., free-stall dairy)	liquid pump or gravity transfer	open or covered concrete, earthen, or steel	tanker, low-trajectory irrigation, or drag hose	+ labour-efficient – in-barn odours – possible difficulties in cold weather – new technology	moderate

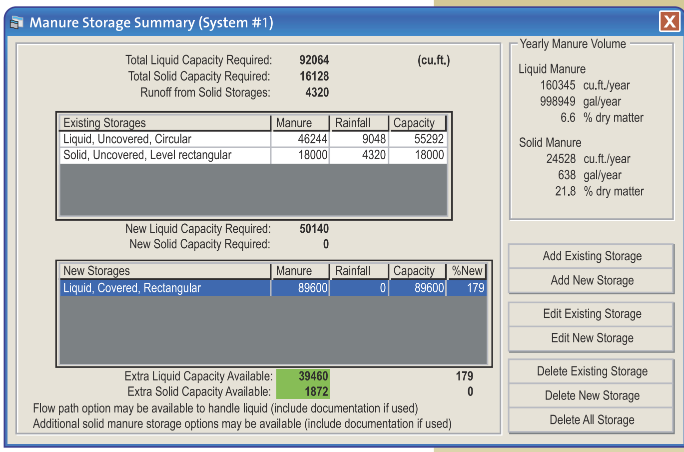
A manure storage system design that considers both manure production volumes and suitable times for cropland application simplifies the task of developing an effective NMP.

SIZING STORAGE SYSTEMS

To size a manure storage system properly, estimate the volumes of manure and washwater produced. Key factors to consider are as follows:

- ▶ type, size, age and numbers of livestock
- ▶ amount and type of bedding used
- ▶ volume of other washwaters generated, such as milking centre washwater, sanitation washwater, silage seepage
- ▶ volume of other inputs, such as roof water, yard runoff water, direct rain or snowfall, that can enter the storage system.

Menu-driven software named MSTOR, part of the NMAN software program, is available to assist in the sizing of manure storage facilities.



The MSTOR program has been developed to help properly size washwater storages.

DO YOU NEED MORE STORAGE CAPACITY?

Typically, storages are sized for a minimum of 240 days. But there are cases where having more than the minimum is justified, such as:

- ▶ you're spreading on land with a high Nitrogen Index (e.g., sandy, shallow to bedrock, etc.) – where you can only spread once a year (e.g., spring) – see page 89 for more information
- ▶ you're spreading on land with a high risk of compaction (e.g., poorly drained loamy soils – Parkhill loam)
- ▶ you're spreading on land with high runoff potential (e.g., steeply sloping clay soils such as Huron Clay Loams, Smithville Clays, Brantford Silty Clay Loams)
- ▶ you require more flexibility when scheduling the timing of manure applications
- ▶ you're planning for future expansion or systems change.

Farms that are phased-in under the Nutrient Management Act will have to provide manure storage capacity to meet the requirements of Regulation 267/03, as amended.

COLLECTION AND TRANSFER SYSTEMS FOR SOLID MANURE

FRONT-END LOADER

A tractor equipped with a front-end loader is an effective way of removing manure from livestock housed on a bedded pack. The manure can be loaded directly into a manure spreader, or moved to long-term storage.

TRACTOR SCRAPER

Tractors or loaders with rear-mounted scraper blades can be used to clean feed alleys and yard areas, as needed. This system is labour-intensive and requires removal of livestock during cleaning. Without precautions, it can wear concrete floors, creating a risk to livestock footing. To minimize this risk, concrete floors can be grooved. Rubber or wood can be attached to the edges of scraper blades to reduce wear on the concrete.

GUTTER CLEANERS

Gutter cleaners are commonly used in tie-stall dairy operations. Tie-stalls should be sized to accommodate cow size and for proper collection of manure. Stalls that are too short or too long will result in manure missing the gutter or dirty stalls. Electric trainers are helpful to keep the cows clean.

Bedding keepers and gutter grates reduce the amount of straw required, although they're not essential for the proper operation of the manure system. Bedding keepers can be constructed from 25–50 mm (1–2 in.) pipe or purchased commercially. Grates work best with softer manure. Manure that is drier will not fall through the grate into the gutter.

HIGHRISE (CAGES OVER A DEEP PIT)

For poultry operations, highrise barns provide long-term storage for dry manure in the storey below the bird level. No mechanical equipment is needed to transfer manure to a separate storage structure. Manure is air-dried as it accumulates in the storage structure. Fans in the storage area are used to circulate the air over the manure. The fans are spaced 24 metres (80 ft) apart, directing their flow to one side of the barn length and returning on the other side.

In-barn storage is sufficient for highrise broiler operations.

The manure has a high moisture content during hot, humid weather, due to poor drying conditions and increased water consumption by the birds. In extreme cases, the manure is so moist that the development of cone-shaped manure piles on the barn floor doesn't take place, increasing odours and flies.

To keep the manure dry, use the following construction measures:

- ▶ storage completely above the original grade
- ▶ footings protected by fill
- ▶ concrete floor.

Salt content of the water and feedstuffs should not exceed dietary requirements.

MANURE BELT

Belts are located under layer cages or slatted floor and act as conveyors, moving manure to the end of the barn for collection.

For optimal handling and minimal odour, good ventilation is key.

In poultry layer-cage systems, a plastic belt is located under each tier (row) of cages. In order to produce dry, stackable and relatively odour-free manure, airflow must be directed across the manure belt to promote rapid drying. The barn ventilation system must be designed to accommodate the increased humidity from this moisture. The manure is sent to a cross-conveyor and onto a covered solid manure storage.

STORING AND HANDLING SAND-LADEN DAIRY MANURE

Sand provides greater cushioning and surface drainage than other materials to enhance stall use and cow cleanliness. Many veterinarians recommend sand bedding to reduce mastitis risk, but the benefits must be weighed against difficulties experienced when handling sand-laden manure.

CHALLENGES

Composition

- sand is dense, adding considerable weight to the manure mixture
- sand doesn't absorb moisture
- compared to raw dairy manure, a sand-laden manure system must handle, on average, 43% more material by weight and 18% greater total volume

Handling

- increased weight – the increased density can have especially serious implications for equipment used to haul sand-laden manure
  - while a gallon of raw manure or manure with organic bedding weighs about 8 lbs, sand-laden manure can easily weigh 10 lbs, or more, per gallon
- very abrasive material that can cause wear of moving parts and even surfaces

Undiluted vs. Diluted

Undiluted – sand-laden manure is best handled with a tire scraper or bucket loader

Diluted – handling characteristics of sand-laden manure and the performance of selected handling systems are greatly affected by dilution, in the following ways:

- excess water can quickly settle out sand from freshly loaded manure
- sand can build up and develop a large mass of solids similar to those seen when top-loading frozen or dry manure, making it difficult to load more manure into the storage
- settled sand and manure solids can build up to 2 ft on the bottom of liquid manure storages – this requires an intricate balance of dilution, agitation and pumping to handle
- often farmers and custom operators replace pump bearings on an annual basis
- agitation of sand-laden manure in storage must take place below the surface
- sand walls form when sand is propelled horizontally

STORAGE REQUIREMENTS FOR DILUTED SAND-LADEN MANURE

- alternative loading access is generally desirable for other storage loading options in the event that sand builds up and blocks the intended path of manure into the storage
- a concrete floor is highly recommended for the manure pit in any sand-laden manure storage
  - pour a level floor or gently slope the floor (normally no more than 1–2%) to direct the flow of liquids toward a sump or pumping area, and away from any areas where solids are to collect and drain
  - a flat surface prevents undesired ponding
- access ramp, concrete bottom and buckwalls are distinct features of sand-laden manure storages
  - this allows convenient removal of solids that may otherwise build up over time – the ramp provides access for a front-end loader and spreader

HANDLING STRATEGIES FOR DILUTED SAND-LADEN MANURE

Skim off water and haul solids – skim the liquid off the top of the storage and haul the remainder out as solid material. In long-term storage, liquids are typically removed two or three times a year while the bulk of the solids is hauled out each fall.

Stir-and-pump approach – uses agitation to mix solids into the liquid and the resulting manure slurry is pumped for application. Washwaters are used to dilute the manure when it becomes too thick to agitate and pump. The remaining sand-laden material is stirred by driving a tractor-loader or payloader around in the storage.

Fully agitate and pump out slurry – this method won't work due to an inability to properly agitate solids off the bottom of the storage. Also, solids quickly settle once agitation is reduced or stopped

Transfer methods

Tractor scraper – works best

Mechanical conveyor – extensive damage to all moving parts

Positive displacement pumps – wear is accelerated by abrasive action of sands

Gravity-flow cross-channels – require more elevation for gravity to work

HANDLING AND APPLICATION METHODS FOR UNDILUTED SAND-LADEN MANURE

Front-end loader – not efficient

Auger – special augers for sand-laden manure are effective with undiluted manure

V-spreader – suitable for undiluted sand manure

Box-spreader – less suitable, hard-to-contain liquids and easy to overload spreader

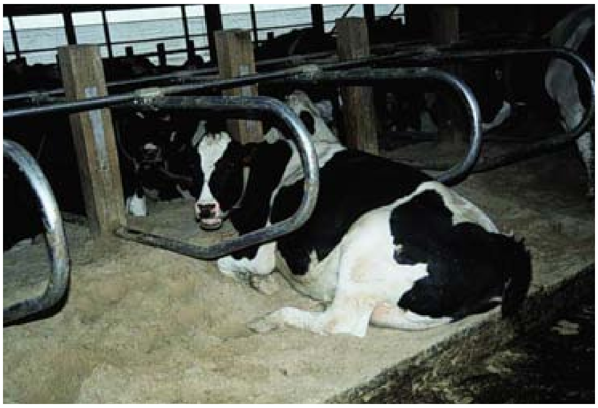
HANDLING AND APPLICATION METHODS FOR DILUTED SAND-LADEN MANURE

Tank methods – will work if baffles are replaced with simpler structure and if heavy-duty tires and suspension systems are used

Irrigation equipment – unsuitable for sand-laden diluted manure

Toolbar injection – reasonably compatible

Information on managing sand-laden manure is expanding rapidly. Before you make any planning decision, talk to someone knowledgeable (e.g., provincial agricultural engineer or dairy specialist) to get the latest information.



Sand-laden dairy manure poses unique challenges for manure handling.

Augers have been developed for sand-laden manure.

SOLID MANURE STORAGE SYSTEMS

There are several options for the storage of solid manure:

- in-barn manure pack
- roofed storage
- solid storage with separate runoff storage system.

SPECIAL FEATURES OF SOLID MANURE STORAGES			
FEATURE	**MANURE PACK BARN**	**ROOFED STORAGE**	**OPEN STORAGE WITH SEPARATE LIQUID RUNOFF**
SIZE OF STORAGE	• floor area large enough for all livestock and poultry • headroom to allow 1–1.2 m (3–4 ft) depth of manure pack above floor	• floor area large enough to store all manure produced at depth of 1.8–2.5 m (6–8 ft) depth	• pad area large enough to store all manure produced at 1.2–2.5 m (4–8 ft) depth above the walled pad • runoff storage sized to hold liquid runoff plus any contaminated runoff from yards, washwater and milking centre
CONTROL OF CONTAMINATED LIQUIDS	• does not handle external sources of contaminated water effectively	• does not handle external sources of contaminated water effectively	• runoff from stacked manure and any other contaminated water collected and stored as a liquid in runoff storage
EASE OF EXPANSION	• can be expanded if space available; demolition of concrete walls required	• can be expanded if space available; demolition of concrete walls required	• both pad and runoff storage can be expanded; demolition of concrete walls and safety fence required
CONSTRUCTION	• concrete floor and partial sidewalls plus standard woodframe construction	• concrete floor and partial sidewalls plus standard woodframe construction • open walls and ridge for ventilation	• concrete pad plus walls for solids; earthen or concrete for liquids
COST OF CONSTRUCTION	• cost-effective since one building used to house livestock and store manure • extra storage for contaminated water needed	• higher cost as separate building • a separate liquid storage may be needed	• cost-effective system since all manure and contaminated water can be stored
PRODUCTION OF ODOURS	• odours confined to building	• odours confined to building	• odours may be present from open liquid storage runoff
SAFETY OF PEOPLE AND LIVESTOCK	• minimal safety problems related to storage		• runoff storage must include all safety measures as in a liquid storage – including safety fence and lockable gates

ROOFED RECTANGULAR STORAGE

Advantages

- ▶ no liquid storage component
- ▶ only solid manure handling equipment is required
- ▶ manure volume doesn't include precipitation and the manure may partially dry with time
- ▶ moderate cost

Disadvantages

- ▶ may be difficult to keep manure solid
  - ▷ high levels of bedding may be required
  - ▷ cannot add liquids such as milking centre washwater or runoff from paved areas

Roofed rectangular storages are more commonly used in dairy, beef and poultry operations.

OPEN RECTANGULAR STORAGE WITH SEPARATE LIQUID RUNOFF STORAGE

Advantages

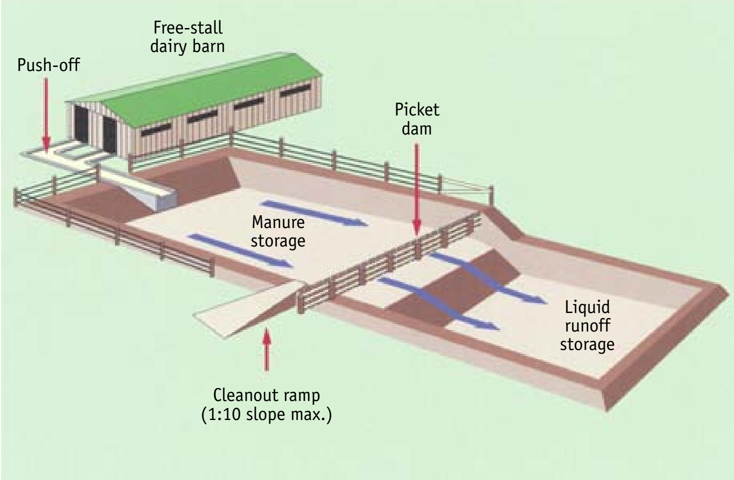
- ▶ high volumes of bedding can be handled in this system
- ▶ can cost less if an earthen liquid storage is used
- ▶ can handle liquids, such as milking centre washwater

Disadvantages

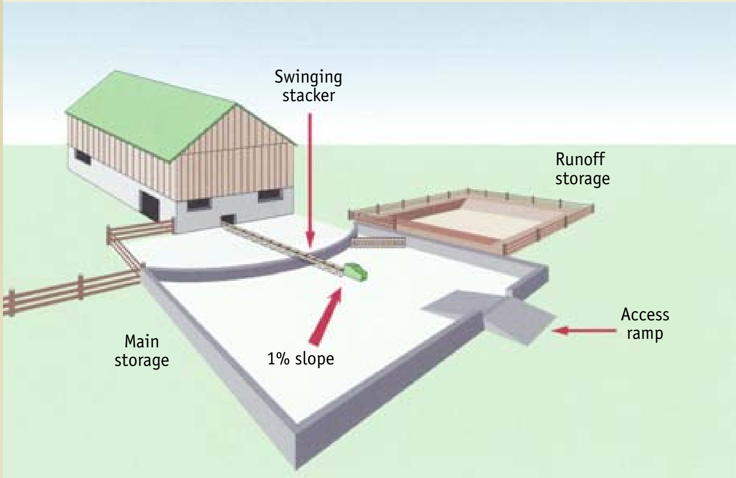
- ▶ two manure handling systems are required
- ▶ can be expensive if concrete liquid storages are used

Solid manure systems with separate liquid runoff storages can handle large volumes of bedding and liquids.

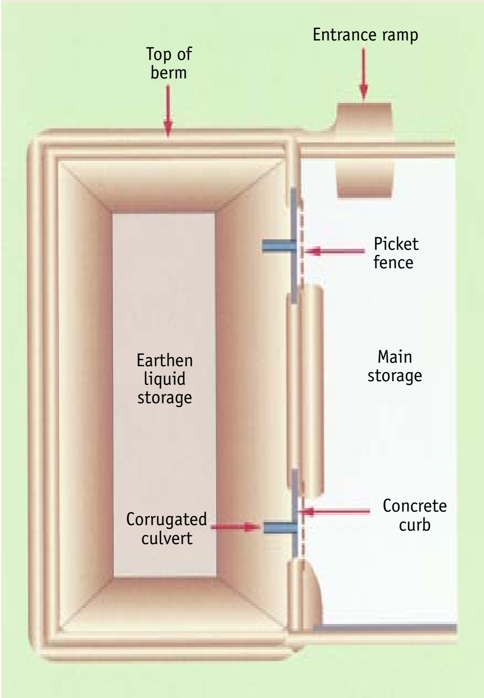
DAIRY FREE-STALL



DAIRY TIE-STALL



LARGE BEEF FEEDLOT



Open rectangular storage with separate storage for liquid runoff is a system used in dairy, beef, poultry and swine operations. The liquid storage may include any of the liquid manure options discussed previously. Solid storage can be sized using a level surface or a cone-shaped surface, depending on how manure is loaded into storage.

COLLECTION AND TRANSFER SYSTEMS FOR LIQUID MANURE

CONTINUOUS GRAVITY-FLOW GUTTERS

Continuous gravity-flow gutters consist of a flat, level gutter with a lip at the outlet. The lip is important in retaining liquids in the gutter, allowing the solids to flow or float along the gutter. Manure in a continuous-flow gutter must be prevented from becoming too dry. The gutter flow must be level along its length and flat across its width.

Continuous gravity-flow gutter systems are used successfully in tie-stall barns with grated gutters, and also under slatted-floor transfer gutters in free-stall barns. Their success depends greatly on bedding management. Excessive use of bedding will result in a buildup of solids. Parlour and milking centre washwater may be discharged into the upper end of the gutter to provide additional water.

Continuous-flow gutters work best with minimal bedding.

SLATTED FLOORS

By the action of animals' feet, manure is forced through the slats to a storage structure below. The slat design must not hurt the animals' feet, and must allow the manure to enter the storage structure freely.

Long-straw bedding will not move through the slats and should not be used. It may be necessary to add washwater to the manure under the slats for proper agitation.

Explosive, noxious, and deadly gases may be released when manure under the slats is agitated prior to manure removal. Since livestock may be in the barn during this process, the barn must be well-ventilated. If the barn is naturally ventilated, ensure you have adequate ventilation during agitation and pumping of manure.

Partially slatted floor areas may be used with a continuous-flow gutter underneath to collect and transport the manure to a separate, long-term storage.

Manure is transferred to an in-barn storage by the action of animals' hooves.

RACEWAY OR CIRCULATORY SYSTEMS (ONE TYPE OF SLATTED-FLOOR SYSTEM)

Raceway systems consist of two or more interconnected channels that lead back to one circulation or agitation point.

These systems consist of two or more interconnected channels that lead back to one circulation or agitation point. The channel walls commonly support the slats above. Raceway manure systems are agitated with a propeller-type agitator, forcing manure around the raceway until it completes the circuit. This breaks up crust, and dislodges solids that have settled to the bottom.

Be careful when agitating manure in this type of system. When pumping begins, the manure should circulate immediately. Otherwise, a blockage may develop, causing the manure level to rise and lift the slats. Since the slats provide lateral support for the dividing wall, when the support is removed, the wall can move, leading to a structural failure. As a result, the slats and livestock may fall into the storage area below.

The manure storage should be fully agitated when the storage tank is about half-full and then again when full. Start the agitator at a very low speed and pump out enough to lower the level so that it can be safely agitated. Start slowly and increase speed as manure starts to circulate around the track. Be careful that a blockage does not develop.

ALLEY SCRAPERS

Free-stall dairy barns often use a chain- or cable-driven alley scraper. They usually have one blade per alley and shuttle back and forth periodically. Blades fold back or are raised on the return stroke.

The cable- and chain-driven scrapers work in pairs, so while one scraper is cleaning one alley, another is on the return part of its cycle. Both alleys must be the same length. A hydraulic motor drives a second type of scraper. It can operate single scrapers, with different lengths of alleys. Cows are able to step over the slow-moving scraper blade. The collected manure may drop directly into long-term storage or into a transfer pump or gravity-transfer system.

Mechanical alley scrapers have the advantage of providing automatic, mechanized removal of manure. Frequent cleaning results in less bedding being used and cleaner cows. Maintenance and repair costs may be high because of the severe conditions that they operate in. During cold weather, alley scrapers may need to run more frequently to prevent manure from freezing to the alley floors. Over time, they can cause wear, making the floor slippery.

One advantage of alley scrapers is that they can keep cows clean with minimal bedding.

TRACTOR SCRAPERS

Free-stall alleys can also be cleaned with a tractor and front-end loader or rear-mounted scraper blade. Alleys are scraped when the cows are out of the barn and being milked. The tractor-scraping system is more labour-intensive and requires cattle to be relocated during cleaning. Cattle may be dirtier since the barn may not be scraped as often as in automated systems.

Adding a wood or rubber edge on the scraper blade can reduce wear.

Another problem is wear on the concrete floor. After several years of scraping, the concrete may become slippery, and cattle may be in danger of falling. Grooving or grinding the concrete surface will improve traction.

Using a wood or rubber edge on the scraper blade will reduce the polishing effect. Some operators use scraper blades made from large used tires. The tires are cut in half and split down the centre to form the scraper.

FLUSH MANURE

Free-stall barns can be cleaned with a flush-manure system. In a flush system, a large volume of water flows down a sloped alley and carries manure to an outside storage. Flushing can be used in free-stall alleys, holding areas, and milking parlours.

Typically, 546 litres/day (120 gal/day) per 454 kg (1000 lb) of cow is needed for adequate manure flushing. Flush with at least 1350 litres/m (90 gal/ft) of alley width. All flush water should be released in 10–20 seconds. Actual flush water volumes and the frequency of flushing are management decisions and will be based on experience with the overall system. The solids must be separated from the flush water to be most effective. Consider using a liquid-solid separator or multi-stage earthen storages for separation.

If the barn temperature is below freezing, a flushing system may require additional protection or an alternative manure handling system may need to be used.

For several reasons, including high odour levels, flush systems are currently not being installed on typical dairy barns in Ontario.

Washwaters can be reused to reduce the large volume of water required to make flush systems work effectively.

LIQUID MANURE STORAGE SYSTEMS

SPECIAL FEATURES OF LIQUID MANURE STORAGES

FEATURE	EARTHEN	OPEN CONCRETE OR STEEL	COVERED CONCRETE
SIZE OF STORAGE	• must also store rainwater and snow that falls into it • must be larger than covered storages as they collect more snow and rain because of sloped walls	• must also store rainwater and snow that falls into it • must be larger than covered storages	• sized only for manure and manure-contaminated liquids to be stored
HEIGHT OF STORAGE ABOVEGROUND	• in-ground, or partially in-ground	• in-ground, aboveground or partially in-ground	• totally in-ground if top reinforced for heavy loads • minimum .6 m (2 ft) aboveground warning signs installed if top is not designed for heavy loads
EASE OF EXPANSION	• possible to excavate larger area at low cost if area is available	• difficult to expand – often requires building a complete new storage	• requires additional storage
CONSTRUCTION	• plastic or clay lined • proper soil type and construction required to ensure proper sealing	• reinforced concrete or glass-lined steel (aboveground only)	• usually reinforced concrete • covers of reinforced concrete or wood frame/metal roofing • cover must be constructed of reinforced concrete capable of withstanding heavy vehicle loading if less than 0.6 m (2 ft) aboveground and not properly signed
COST OF CONSTRUCTION	• lower initial costs may be offset by higher maintenance and manure application costs	• approximately half the cost of same tank with reinforced concrete top	• can be twice the cost of similar open concrete storage – concrete covers are expensive
PRODUCTION OF ODOURS	• persistent odours more evident at a distance than for covered storage • floating crust (dairy cattle manure) reduces odour	• persistent odours more evident at a distance than for covered storage • floating crust (dairy cattle manure) reduces odour	• covers reduce odours during storage period, but strong odours produced during agitation, removal and spreading
SAFETY OF PEOPLE AND LIVESTOCK	• must be properly fenced • all access points must have proper safety signs	• must be properly fenced (or tank wall must extend) to minimum of 1.5 m (5 ft) aboveground • all access points must have proper safety signs	• access opening covers must be locked and secured with safety chain • cover must be constructed of reinforced concrete if less than .6 m (2 ft) aboveground • all access points must have proper safety signs and all staff and family fully aware of the dangers

COVERED RECTANGULAR

Covered liquid manure storages emit fewer odours.

- cover must be made of reinforced concrete
- commonly used for swine, dairy and beef
- often barn is built directly over the storage structure

Advantages

- helps to control odour
- walls are used as foundation for barn
- keeps precipitation out of storage structure

Disadvantages

- potential manure gas hazard if barn located over storage structure
- difficult to agitate
- higher cost – especially if the top must carry vehicles

COVERED CIRCULAR STORAGE

- commonly used for swine
- covered storages are no longer common – occasionally you see floating covers or air-inflated covers

Advantages

- helps to control odour
- easy to agitate

Disadvantages

- higher cost – especially if the top needs to support vehicles
- not easy to expand

Floating covers can be effective alternatives for circular storages.

OPEN CIRCULAR STORAGE

Open circular storages can be used on most soil types and conditions.

- commonly used in swine, dairy, and layer-hen operations
- available in concrete and steel

Advantages

- lower cost than a covered system
- structurally adequate without a top
- usable on most soil types
- easy to agitate
- can be retrofitted with a cover

Disadvantages

- provides limited odour control
- difficult to expand
- precipitation adds to volume

OPEN EARTHEN STORAGE

Although less expensive than concrete storage, open earthen storages require a thorough site investigation and may require liners to protect ground-water from contamination.

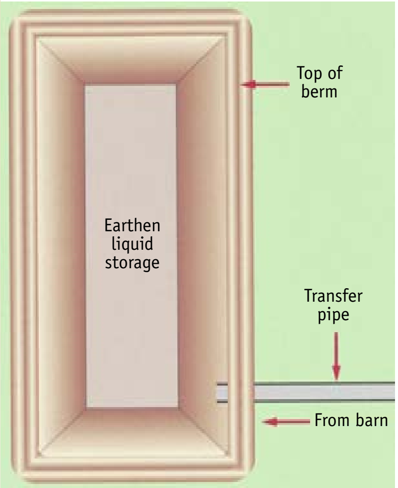
- commonly used for swine, dairy and layer

Advantages

- lower initial capital cost

Disadvantages

- poor odour control due to large surface area
- high volume of precipitation entering large surface area due to sloping sides
- installation requirements dependent on soil type – most conditions require a liner
- liners require considerable maintenance



Earthen storage

PERMANENT STORAGE SITES

The manure storage systems we've outlined should follow the requirements for permanent manure storages as set out by the Nutrient Management Act and its associated regulation and protocols. These requirements ensure that manure storage facilities won't create a risk to surface water and groundwater.

New or expanding permanent manure storage facilities should be designed and inspected by a professional engineer.

GENERAL SITING RECOMMENDATIONS FOR A PERMANENT MANURE STORAGE FACILITY

- not be located within a regional or 1 in 100-year flood line unless a permit for the facility is issued under section 28 of the Conservation Authorities Act
- at least a 50-metre (164 ft) flow path to the nearest surface water (unless it's an artificial facility intended to collect runoff)
- type and depth of soil material to meet requirements of the type of storage facility (e.g., earthen, concrete)
- located at least 15 metres (49 ft) from a drilled well, 100 metres (328 ft) from a well supplying water to a municipal water system and at least 30 metres (98 ft) from any other type of well
- Minimum Distance Separation II distances between the manure storage facility and neighbouring land uses (e.g. residence, school)

When permanent manure storage sites are taken out of operation, they should be decommissioned. This involves disposing of any manure left in the facility.

Decommissioning

As the owner of a manure storage structure, you should ensure the facility is in good repair and in safe working condition. When permanent manure storage sites are taken out of operation, they should be decommissioned by disposing of any manure left in the facility. The site should then be rehabilitated.

When rehabilitating a decommissioned nutrient storage facility:

1. fill the hole with layers of clean soil or fill material with similar infiltration rate of the surrounding soil
2. crown topsoil to allow for settlement
3. establish vegetation
4. prevent water from accumulating on the area.

To view current, legally correct compliance information for the Nutrient Management Act, look up: http://www.omafra.gov.on.ca/english/agops/index.html

Professional engineers should be hired to supervise the construction of new liquid manure storages.

DESIGN AND CONSTRUCTION CHECKLIST

Construction of a New Manure Storage or Expansion of an Existing Storage

✓ a professional engineer to design the structure, monitoring and nutrient transfer system for liquid system

✓ a professional engineer to supervise construction and ensure that the structure is built according to the design

✓ facility designed to minimize leakage and corrosion and be structurally sound

✓ a professional engineer to follow construction procedures and standards that comply with NMA Regulation 267/03, as amended

Concrete Quality

✓ to construct a permanent nutrient storage facility, where concrete is required, the concrete must meet the specifications as outlined in NMA Regulation 267/03, as amended

LINERS

✓ where liners are proposed or required, the synthetic liners must follow the standards in NMA Regulation 267/03, as amended

✓ all liners must be continuous under the floor and must extend up the wall to ground-surface level

✓ compacted soil liners must follow the standards as outlined in NMA Regulation 267/03, as amended

Synthetic liners must be anchored or bonded to the facility. Any discontinuity or perforations must be repaired according to the engineer's instructions.

To view current, legally correct compliance information for the Nutrient Management Act, look up: http://www.omafra.gov.on.ca/english/agops/index.html.

For regulated farms, the maximum time that a temporary storage site should be used is determined by using the table in Regulation 267/03, as amended. Complete the table in this reference to determine the maximum number of days of temporary storage.

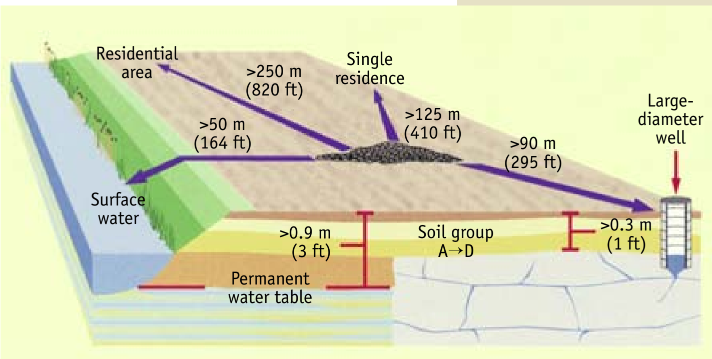
TEMPORARY STORAGE SITES

Temporary in-field manure storage sites are used for solid manure. The amount of manure stored at the temporary site should not exceed the quantity needed for crop production on that farm unit, as outlined in the nutrient management plan.

When determining the location of a temporary manure storage site, the site should have the following features:

- ▶ slope less than 3%
- ▶ Hydrological Soil Group A–D; not AA, soil with a rapid infiltration rate
- ▶ not located in a regional or 1 in 100-year flood line
- ▶ at least 0.3 metre (1 ft) of soil above the bedrock and at least 0.9 metre (3 ft) of unsaturated soil above the permanent water table
- ▶ a flow path that is at least 50 metres (164 ft) from the nearest surface water and is located at least 0.3 metre (1 ft) above bedrock
- ▶ at least 45 metres (148 ft) from a drilled well having a depth of at least 6 metres (20 ft) and a watertight casing extending to a depth of at least 6 metres below ground level, 90 metres (295 ft) from any other well except a municipal well and at least 100 metres (330 ft) from a municipal well
- ▶ at least 125 metres (410 ft) from a single residence and 250 metres (820 ft) from a residential area if it is NOT used for storing dewatered municipal sewage bio-solids
- ▶ at least 200 metres (656 ft) from a single residence and 450 metres (1,476 yds) from a residential area for dewatered municipal sewage biosolids.

Keep records of the location and dates of pile establishment, turning and removal.



Temporary manure storage sites must be selected carefully to reduce the risk of contaminating ground and surface water.

RUNOFF MANAGEMENT FROM YARDS AND STORED FEEDS

THIS CHAPTER EXPLORES:

runoff – what it is, its risks, and how to estimate volume

management options – roofed yards, runoff collection and storage systems, vegetated filter strips, and constructed wetlands

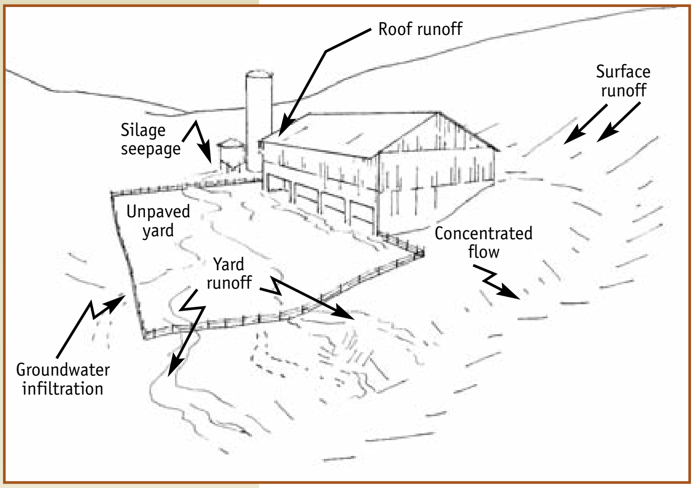
seepage from stored feeds as another form of runoff, and specific means of controlling it.

Livestock **yards and feedlots** provide confined outdoor space for feeding, exercising or loafing. They're a common sight in dairy, beef, sheep and goat operations.

Livestock **confinement areas** are considered yards or feedlots in facilities where grazing and foraging provide less than 50% of the livestock's feed requirements.

Runoff can be a problem. Runoff is a liquid that has come into contact with manure in a concrete yard or feedlot, and may contain components of manure in solution or suspension. The source of the water can be:

- direct rain
- snow and snowmelt
- eavestrough water
- excess water from waterers
- water from stored or deposited manure, and
- surface water flow.



Without proper management, runoff can flow over the ground and contaminate surface water such as streams. This in turn can leach to groundwater, potentially degrading drinking water quality.

Many operations have large yards that are not designed to manage wastes, or are not maintained to reduce runoff.

The constituents that may be found in runoff can be divided into liquid and solid portions. Typically, urine, washwater and contaminated water make up the liquid portion while the solid portion consists of manure, bedding, feed and soil.

Many of the same contaminants found in runoff can be found in liquid manure. Typically, runoff has a very low solids content (often referred to as dry matter content), resulting in considerably lower constituent levels than liquid manure.

RUNOFF VOLUME

Solid manure storages, concrete livestock yards and permanent outdoor confinement areas should be equipped with a runoff management system that handles all the runoff generated by the facility. Runoff should not be allowed to negatively affect surface water.

Current versions of the Ontario Ministry of Agriculture, Food and Rural Affairs's NMAN software can be used to calculate the volume of runoff. This volume is dependent on the factors outlined in the following chart.

"This eavestrough system directs clean water away from the outside yard." – Bob Stone, Agricultural Engineer, Ontario Ministry of Agriculture, Food and Rural Affairs

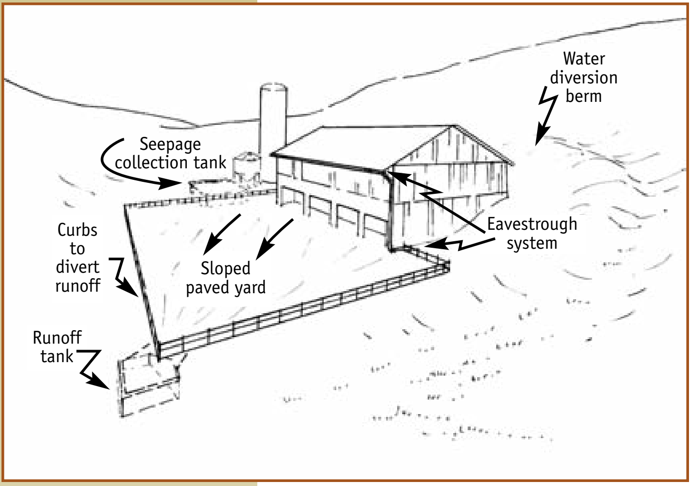
FACTORS USED TO CALCULATE RUNOFF VOLUME

DESIGN FACTOR	EXPLANATION
RAINFALL INTENSITY, DURATION AND FREQUENCY	NMAN uses a standard annual rainfall value for the province
LOT OR MANURE STORAGE SURFACE AREA	a smaller surface area reduces the runoff volume, which reduces the size of the runoff treatment or storage system
DRY MATTER CONTENT OF SOLID MANURE	depends on the type of livestock, amount of bedding or water added

In general, runoff volumes from outside lots and solid manure storages are much higher than most farmers anticipate. For example, an outdoor lot can produce up to 36.6 cm (1.2 ft) of depth of runoff water per square foot of feedlot area over a 240-day period.

This amount of runoff depends on the dry matter content of the manure and manure quantity on the feedlot during this period. A significant percentage of the liquid that falls on the outside lot can be absorbed by solid manure. However, when there's a small amount of solid manure on the outside lot, more runoff will result.

Before considering a runoff management system, divert all clean water away from the solid manure storage, livestock yard or permanent outdoor confinement area. Clean water is rain, snowmelt or other water that has not come in contact with manure. Directing clean water away from the facility will reduce the volume of contaminated runoff that has to be handled.



BMPs for diverting water include: earthen berms and diversions; drop-pipe inlet structures upslope from yard; grassed waterways; and gutter and eavestrough systems on roofs of livestock facilities.

A runoff management system capable of handing all runoff generated for a 240-day period (with some exceptions) should be part of all outdoor confinement areas, concrete yards and permanent solid manure storages.

There are four general best management practices for runoff management that we'll look at here. One, or better yet a combination, of the following may work for you:

- roofed yards
- runoff collection and storage systems
- vegetated filter strip systems
- constructed wetlands.

ROOFED STORAGE OR ROOFED OUTSIDE YARDS

Constructing a roof over a livestock yard or solid manure storage prevents rain and snow from entering the facility. Rain and snowmelt increase the runoff volume that needs to be stored or treated. Additional water may also change the dry matter content of the manure, which may change the type of treatment system used.

RUNOFF COLLECTION AND STORAGE SYSTEMS

You have two options:

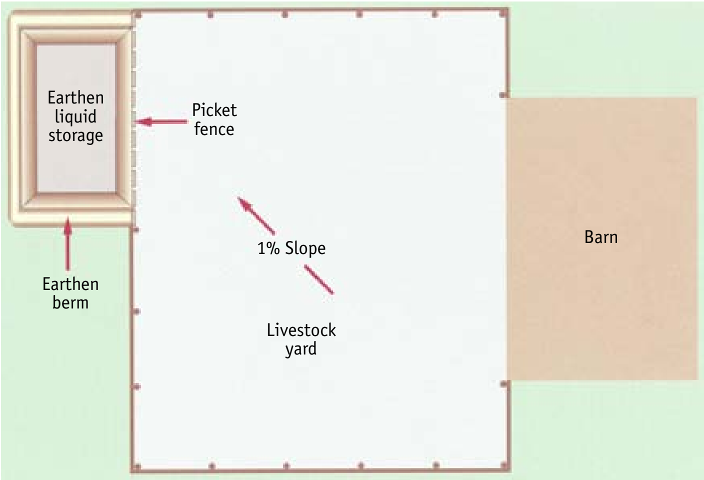
- ▶ divert to existing liquid manure storage (suitable for paved yards and some dry lots), or
- ▶ divert to separate storage.

DIVERSION TO LIQUID MANURE STORAGE

- ▶ existing storage should be sized to meet additional storage requirements from runoff
- ▶ yards should be designed to convey contaminated water and all precipitation (including storm events) to the liquid storage
- ▶ concrete curbs, gutters, and a picket-fence outlet to storage may be part of the paved yard design
- ▶ these systems work best with regular scraping of manure, bedding and wasted feed, plus unplugging the picket-fence outlet area

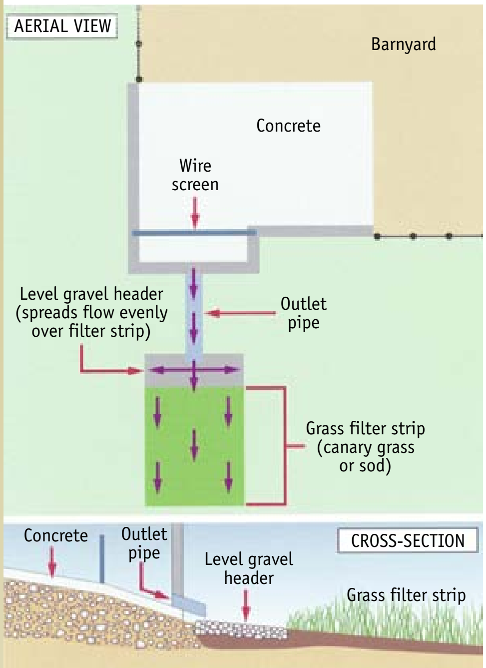
DIVERSION TO SEPARATE STORAGE

- ▶ yards need to be shaped to channel contaminated water and all precipitation (including storm events) to the designated storage
- ▶ properly designed concrete curbs, concrete gutters or grassed diversions and a picket-fence outlet may be part of the paved yard design
- ▶ these systems will only work effectively with scraping of manure, bedding and wasted feed, plus unplugging the picket-fence outlet area



Separate storage systems for yard runoff are more effective if some of the solids are prevented from entering the storage.

VEGETATED FILTER STRIP SYSTEMS



Vegetated filter strip systems are designed and constructed to intercept and treat runoff by settling, filtration, dilution and absorption of pollutants, and infiltration into the soil.

Runoff can be collected and transferred by diversions, curbs, gutters, lot paving, and, in some cases, by pumping.

The runoff is controlled in two stages – one for solids and one for liquids. A settling basin/storage is needed to remove solids. Liquids go to a vegetated area where the liquid is filtered and infiltrates the soil.

Vegetated filter strip systems are designed, vegetated areas constructed to intercept and treat runoff by settling, filtration, dilution, absorption of pollutants, and infiltration into the soil.

SETTLING BASIN/STORAGE

A settling basin/storage provides a method to retain runoff and reduce the flow rate for settling out solids. The liquids are transferred to a vegetated infiltration area, and the solids remain in the basin/storage for drying and later removal and spreading. The settling basin/storage keeps solids out of the infiltration area and prevents clogging of the pump, pipes, etc.

There are two types of settling basins/storages.

Settling Basin/Storage on Paved Yard

A concrete curb is constructed around the lower part of the paved yard to a height adequate to hold a 25-year 24-hour storm. The runoff may be ponded in this area during a 4–10 hour period, during which the heavier sediment-type material settles out. This settled material can be scraped up with the solid manure. A screening system at the outlet of the curbed area further assists in retaining the settled portion on the paved yard. The liquid portion moves to a sump from where it's transferred by gravity or by pump to the infiltration area.

External Settling Basin/Storage

An external basin/storage may better suit your operation, although it's considerably more expensive to construct than locating a settling area on the paved yard. The liquid runoff moves off the paved yard through a picket-fence area for coarse screening to the external basin/storage. The basin/storage is large enough to slow the flow rate to allow settling of the solid material. The solids are removed for later field application. The settling basin/storage prevents solids from moving to the infiltration area and prevents clogging of the pump, pipes, etc.

The best basin/storage shape is a relatively large surface area that's shallow – usually less than 1 metre (3 ft) deep. The settling basin/storage should be concrete or at least have a concrete bottom for solids removal. Typically, runoff solids will settle out in about 30 minutes, so design the basin/storage accordingly. The basin/storage will require a properly screened outlet to prevent solids from moving to the sump, pump, pipes and infiltration area. Several types of outlet pipes are available to drain liquids from the full depth of the basin/storage and dewater the solids, including perforated pipes and slotted pipes. The basin/storage should be cleaned after every runoff event and frequent unplugging of the outlets is necessary. Typically more maintenance is required with the external basin/storage than with the basin/storage located on the paved yard.

Perforated pipes can be used to transfer liquids to the vegetative filter area.

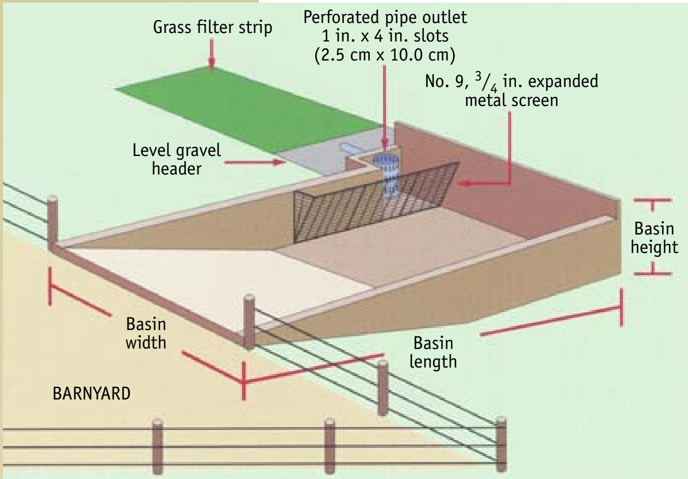
VEGETATED INFILTRATION AREA

From the settling basin/storage, the runoff either flows by gravity or is pumped to the vegetated infiltration area. Treatment occurs as runoff moves down the grass strip and infiltrates the soil.

It's essential that solids be settled out before runoff enters the infiltration area. To be effective, a vegetated infiltration area must be designed, constructed, vegetated, and adequately maintained. Generally, this area is grassed with a slope away from the point where runoff enters the infiltration area. The infiltration strip is surrounded by a berm that diverts all outside surface water so that only lot runoff and direct precipitation enter the vegetated infiltration area.

Approval under the Ontario Water Resources Act may be required from Ontario Ministry of the Environment for installation of a vegetated filter strip system.

Prepare a construction plan for each site. The success of the infiltration area depends on good planning and consideration of site characteristics (e.g., soil infiltration, hydraulic conductivity). Vegetated infiltration areas need to be properly established and maintained with a good stand of vegetation.



A well-designed vegetated infiltration area will take into account liquid volumes and site features, and will divert clean water away from the system.

A CONSTRUCTED FLOW PATH – <u>NOT</u> A BEST MANAGEMENT PRACTICE

A constructed flow path provides minimal treatment and does not contain yard runoff. A surface pathway, channel or depression, it conducts liquid away from yards and outdoor confinement areas.

The flow path is a permanently vegetated area that is not tiled, and runs between the facility and surface water and/or tile inlets. Some treatment occurs as the runoff moves down the length of the flow path. Flow paths may be suitable for areas with low livestock density and located at a distance of greater than 300 metres (984 ft) to surface water.

CONSTRUCTED WETLANDS

Natural wetlands have long been known to treat contaminated waters, which move through them by a combination of physical, chemical and biological activities. These natural processes can be duplicated in constructed wetlands.

Constructed wetlands are manmade systems that are designed, built and operated to emulate natural wetlands or their functions for human desires and needs. They create optimal conditions for natural organisms to do their work.

Constructed wetlands are essentially wastewater treatment systems that are designed to transform many pollutants into gaseous forms for release to the atmosphere or to trap other pollutants in the substrate. They effectively treat contaminated waters high in nitrogen, phosphorous, bacteria, organic matter and suspended sediment.

This bioengineering technique uses aquatic vegetation to purify wastewater. Oxygen is transported down to the plant root zone through the aquatic vegetation where an aerobic region supports various microbiological activities. This aerobic zone allows for bacterial decomposition and the breakdown of various pollutants containing nitrogen, sulphur and other organic material from human activities (BOD).

Wetlands constructed for wastewater treatment are classified as either:

- ▶ surface-flow or free-water surface systems, or
- ▶ subsurface-flow systems.

With surface-flow systems, the incoming wastewater flows across and largely above the surface of the substrate materials, i.e., native soils and clay. In subsurface-flow systems, wastewater flows through the system passing entirely within the substrate, i.e., gravel, crushed rock, soil, and free water is not visible. Most of the constructed wetlands installed in Ontario to date have been the surface-flow or free-water surface systems.

Constructed wetlands will occupy 0.4–0.8 hectares (1–2 ac) on the farmstead. During the planning stages, a complete site investigation has to be made to determine the soil condition and depth to groundwater. It's important to minimize environmental impacts on groundwater.

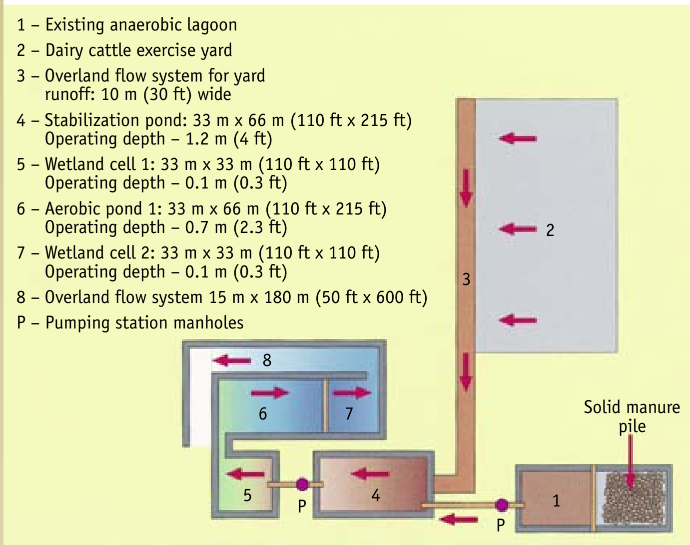
Properly constructed wetlands designed to treat runoff and washwater (e.g., milking centre washwater) are expensive to install. Several constructed wetlands have been installed on Ontario farms on an experimental basis. A proper design for the constructed wetland is essential.

Check with Ministry of the Environment regarding approval to install a constructed wetland.

SYSTEM COMPONENTS

The components outlined in this chart are typical of a surface-flow constructed wetland system. Refer to the illustration on the next page.

COMPONENT	FUNCTION
PRE-TREATMENT POND/TANK (#1)	• a pre-treatment or sediment pond/tank situated at the entry to the constructed wetland removes solids, debris, etc. and acts as an inlet control to the next component of the system • washwaters will have to be stored during the seasons of the year when the wetland is not able to provide the desired level of treatment • storage will also be required in this pond to contain any precipitation or runoff generated by precipitation
FACULTATIVE STABILIZATION POND (#4)	• the facultative stabilization pond reduces the organic content of the wastes to a level acceptable for wetland vegetation • solids that can settle will also be removed in this pond • the liquid depth in this pond is approximately 1.2 m (4 ft) • the facultative stabilization pond also provides flow equalization and acts as a wastewater reserve in dry season, i.e., July, August
WETLAND / AEROBIC POND / WETLAND SYSTEM (#5, 6, 7)	• the wetland / aerobic pond / wetland system further reduces the BOD and nutrient levels • the wetland vegetation, i.e., cattails, which carry the biomass, degrade the soluble organic matter • oxygen is transferred to the soil surrounding the roots, creating sites favourable to aerobic digestion and nitrification
INFILTRATION / EVAPORATION FIELD (#8)	• the infiltration / evaporation field completes the treatment system • phosphorous is removed by adsorption in the soil while other nutrients are removed as the hay is harvested



MANAGING MANURE FROM YARDS AND PERMANENT OUTDOOR CONFINEMENT AREAS

Manure can be mounded to make for easier movement and handling of livestock in the confinement area. Unless it's mounded, manure should be removed from an outdoor confinement area.

Manage all solids. Scrape them to the solid manure storage system (see section on solid manure systems). Clean frequently. Clean yards are less prone to contaminated runoff, methane and nitrous oxide emissions (greenhouse gases), and less likely to cause livestock injury and spread livestock diseases.

MANAGING SNOW THAT CONTAINS MANURE

Snow that contains manure removed from livestock yards or outdoor feedlots is known as "feedlot snow", "winter yard scrapings" or "brown sugar". This material is bulky and low in nutrient content.

Your best management approach is to:

- prevent – by roofing the outdoor confinement area
- reduce – with windbreaks and frequent maintenance
- contain – store with liquid manure storage or separate runoff storage, or
- apply – apply manure to field, but with the following restrictions.

To apply brown sugar to a field, you should ensure that:

- the field has a maximum sustained slope of less than 3%
- the snow is applied no closer than 40 metres (130 ft) from the top of the nearest bank of any surface water in the field
- there is a 6-metre (20-ft) vegetated buffer zone along all surface water in the field and downslope edges of the field, and
- the application rate is one-half of the maximum rate of application for nutrients otherwise established for the field.

MANAGING SEEPAGE FROM STORED FEEDS

Silage can be made from corn, cereal grains, alfalfa, and canning company wastes such as processed sweet corn waste.

Under good harvesting and storage conditions, silage should be of little risk to your water supply. However, without proper containment, excess silage juices can contaminate groundwater and surface water. Too much water or pressure in the silo will cause these liquids to seep out.

Any silage stored at over 65% moisture content will produce a leachate. Most leaching will occur in the first three weeks of storage. Grass silage can produce a trickle of leachate at 75% moisture and 353 litres per tonne (79 gal/ton) at 85% moisture.

The liquids from this silage contain high amounts of:

- nitrates
- ammonia
- iron
- acidity
- organic compounds.

These nutrient-rich liquids, if allowed to reach a stream, can decrease the oxygen content in water, affecting fish and other stream life.

In terms of moisture, tower silos less than 12 metres (40 ft) in depth should have a moisture content below 65%. Above this depth, the moisture content should be below 60%. Moisture content should be less than 70% for horizontal silos.

Before considering a silage seepage management system, divert all clean water away from the silage storage area. As with manure and yard runoff, directing clean water away from the facility will reduce the volume of contaminated fluid to be handled.

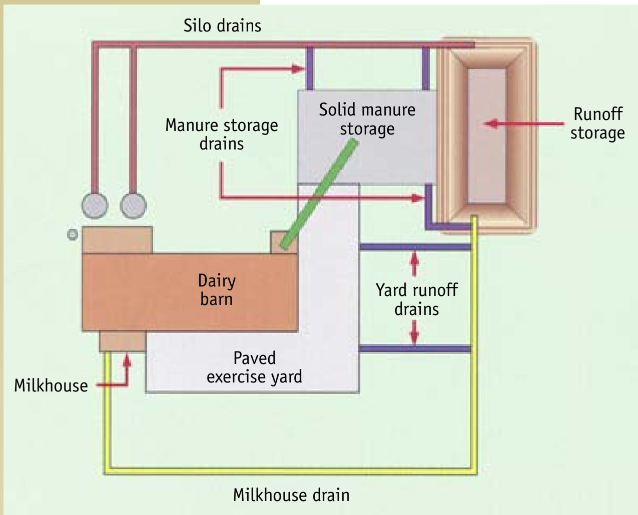
To divert water, use the following approaches:

- silo cover
- earthen berms and diversions
- drop pipe inlet structures upslope from yard, and
- grassed waterways.

Best management options should be linked with yard and feedlot runoff management and include:

- reducing seepage with a physical barrier, i.e., diversion berm
- seepage storage in a separate tank
- storage with runoff or liquid manure storage, and/or
- concentrated seepage to storage tank and diluted high flows to approved vegetated filter strip system.

REDUCING SEEPAGE



One method for managing silage liquids is to store them with liquid manure or yard runoff.

Silage/haylage should be harvested at proper moisture content (i.e., below 60%) for tower silos and below 70% for horizontal silos. Planting shorter-season varieties of corn will result in a drier crop and therefore lower seepage production.

Adding absorbents designed to take up excess moisture will result in low or no seepage production. Material that can be used includes straw, oatmeal, dried sugar, beet pulp, dried corncobs, ground corn, and hay cubes. To be effective, enough material must be added to absorb the anticipated seepage.

On many occasions it may not be possible to wilt the forage adequately or harvest at the desired dry matter content. If the forage is too wet, then seepage is likely. Absorbent materials can be added to "absorb" this seepage.

SEEPAGE COLLECTION AND STORAGE SYSTEM

Whether vertical or horizontal, all silos should have a silage seepage collection and storage system. This seepage system would link to the runoff system used for stored solid manure and/or yard runoff.

Locate seepage collection tanks a safe distance from water wells and surface water (streams, ditches, ponds) to reduce the risk of contamination. See the section on siting storages on page 30.

Likewise, storage sites for bagged, wrapped or tubed haylage should be located a safe distance from water wells and surface water (streams, ditches, ponds) to reduce the risk of contamination.

Storage tanks for seepage should be sized according to the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet on how to handle seepage from farm silos.

Flow will occur throughout the total storage period as the silo is emptied. Where proper silo drainage exists, most of the volume is excreted within the first 30 days after loading. Separate tanks should be sized according to Ontario Ministry of Agriculture, Food and Rural Affairs factsheet on how to handle seepage from farm silos.

Beyond this 30-day period, the dilute seepage can be directed to an outside liquid manure or runoff storage. If there's no liquid storage on the farm, consider building a storage to contain runoff and seepage for a minimum storage period of 240 days. Another option is to treat this dilute liquid on an approved vegetated filter strip system.

Caution: Never mix silage effluent in enclosed tanks, especially tanks within barns, because silage effluent mixed with manure slurry will accelerate the release of hydrogen sulphide gas. Add seepage only to uncovered outdoor storages.

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

- 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

CHALLENGES

- 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

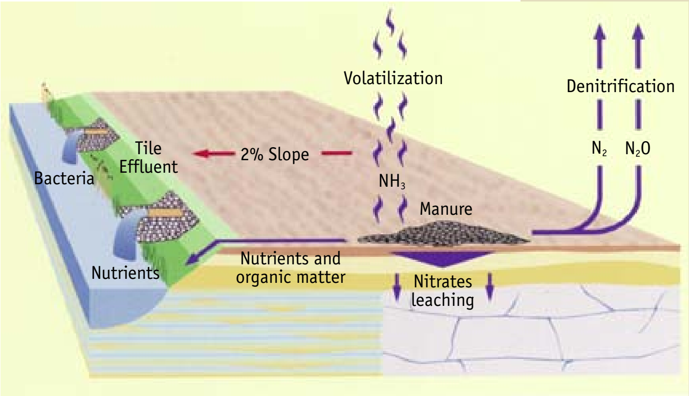
Manure contains significant quantities of potassium as well as micronutrients that can be excellent resources for crop production. When applied at levels to meet crop needs, these nutrients have not been identified as sources of environmental problems. In some instances, excess potassium applications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

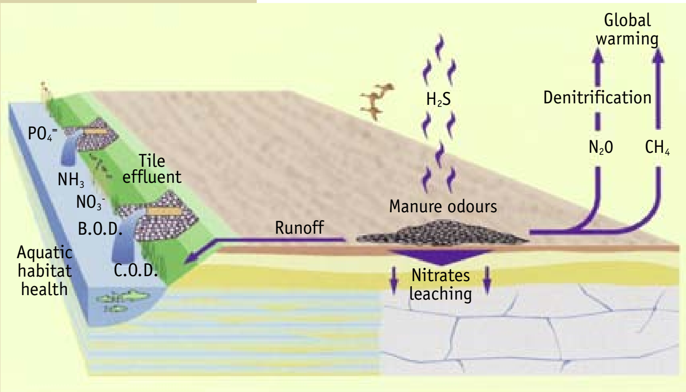
Many factors influence the potential movement of nitrogen and phosphorous to surface water and groundwater, including:

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

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

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.

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

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).

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

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.

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

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:

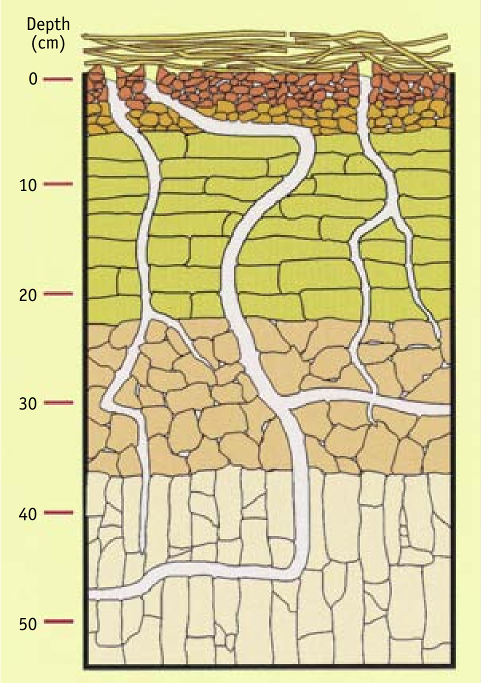
- manage sources of micronutrients in livestock feeds and treatments
- test manure and soil for micronutrient levels
- adjust your nutrient management plan and application operations if necessary to build up levels where needed and avoid excessive levels.

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.

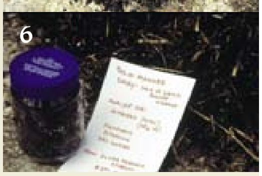
- ▶ for large storages, collect at least one additional sub-sample per 200 m^3 (18,000 gal) of material
- ▶ grab samples can be collected either directly from the storage, or as the storage is being emptied
- ▶ use a clean, non-metallic container (e.g., a 20-litre plastic pail) to collect the samples

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.

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.

4

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 ^{o}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		IMMEDIATELY INCORPORATED OR PRE-TILLED	
	Liquid	Solid	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 ^{o}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.

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

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

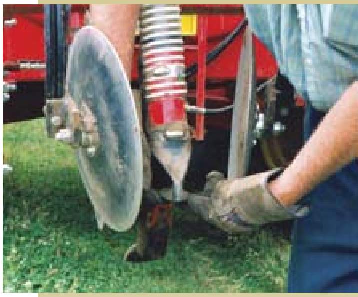
✔ **be very careful when using an air system, as compressed air can cause pipes to explode or be rapidly displaced – proper equipment and operator training are necessary before an air system is utilized**

✔ 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



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

Clean all nozzles and pipe connections.

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.

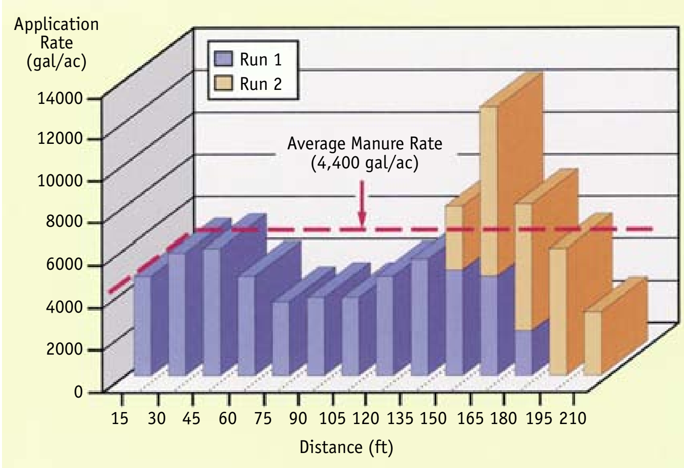
Manure can be dribbled as a sidedress application to a standing row crop and incorporated when combined as a scuffling or weed control pass.

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.

MONITORING, RECORD-KEEPING AND CONTINGENCY PLANNING

MONITORING

You should monitor whenever nutrients are applied. In most cases, monitoring can be as simple as a visual inspection to make sure things are going as planned.

For example, when spreading manure on cropland, check to make sure that the manure is spread evenly and that tile drains show no evidence of liquid nutrients entering the tile drainage system. If you find manure entering the tile drainage system, the contaminated portion of the drainage system should be isolated and the contingency plan should be put in place.

Monitoring doesn't take much effort, and it can help head off significant problems and allow you to respond quickly in case of an accident.

RECORD-KEEPING

There are two main reasons for record-keeping.

The first is that it provides the information required to fine-tune your manure and nutrient management plan and helps to record how closely the plan fits with reality.

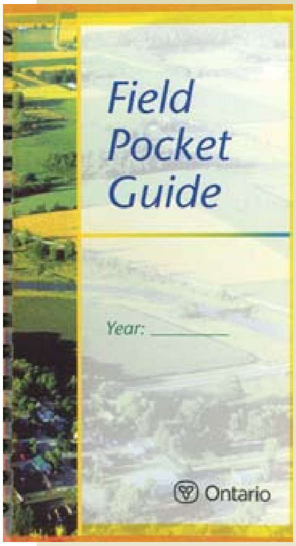
The second is that it helps demonstrate accountability and diligence. In the small chance that something goes wrong, or if someone questions what was done (i.e., odour or water complaint from neighbour), having the records of what was done, and when, will help resolve conflicts.

Keep the nutrient management plan as simple as possible, but have the details in the record-keeping.

Records could itemize the following.

Cropping Practices

- ▶ nutrient types applied and application dates, rates, and methods
- ▶ manure analysis records if manure is being managed differently at different levels in the storage
- ▶ incorporation method and date
- ▶ weather conditions around application and incorporation dates
- ▶ rainfall records to determine water content changes from the norm
- ▶ for spreading: date, time, location, quantity, setbacks
- ▶ date and times of tile outlet monitoring including observations
- ▶ commercial fertilizer bills showing volume and timing of application
- ▶ crop type and planting date
- ▶ tillage method and date
- ▶ harvest date and yield



These days, farmers have many options – high-tech and low – for storing records.

Livestock Information

- feed records, especially to justify or monitor manure nutrient reductions
- inventory of livestock on the farm (monthly basis)
- inventory of feed
- record of livestock groupings and batch feeding
- biosecurity protocols for the operation
- manure volume generated – an accurate measurement of the nutrients generated on a farm is an important aspect of manure storage planning
- manure analysis results

Other Information

- documentation of any other time/conditions when a contingency plan is utilized, including location, estimated volumes and remediation measures
- what was done to resolve any complaints
- imported nutrient-containing materials, date, tons or volume, description of the material (i.e., agreements)
- biosecurity protocols for the operation

Your record-keeping efforts can result in a lot of information. That's why it's worth the effort to organize your records so that it can be readily accessed. There are many different systems for record-keeping, including: software options, GPS-type systems, hand-held palm pilots, and the old-fashioned field books.

Record-keeping demonstrates farm stewardship to society.

CONTINGENCY PLANNING

A contingency plan is a document that sets out actions to be taken in the event that a nutrient management strategy or nutrient management plan cannot be followed.

For example, manure in the storage facility described in your nutrient management strategy may become filled with rainwater. Another example is a "spill" or unanticipated release of nutrients. Preparing contingency plans in advance simplifies the implementation of corrective action on short notice.

1 **Identify potential contingencies.** The contingency is the answer to questions such as:

- ► What procedure will I follow if a spill occurs?
- ► What steps will I take to contain, eliminate and clean up a spill? (at the storage, at the transfer site, in the field)
- ► What will I do if my operation has more nutrients than planned? (i.e., livestock must be held for longer than planned, thus increasing the volume of manure)
- ► If wet weather delays application of nutrients and storage is nearing capacity, where will I transport the nutrients?
- ► If excess rainfall fills the nutrient storage to capacity, where will I transfer or spread the nutrients/manure?
- ► If soil conditions are not compatible with planned spreading operations, how will I compensate or what are my alternatives?

2 **Identify the resources required** in case the contingency must be put in place. Some of these resources could include:

- ► finding a local custom applicator with a vacuum tanker
- ► locating tile outlets for monitoring
- ► making a list of the telephone numbers required and remembering the list's location.

3 **Communicate the contingency plan** to those involved in the operation. It's important that all farm help, family members, custom applicators etc. are aware of the details of the contingency plan and the location of the emergency list(s), and are able to follow through on the required actions.

4 **Post contact phone numbers by all phones** for immediate access in case of a spill:

- ► Spills Action Centre (1-800-268-6060)
- ► other phone numbers that should be readily accessible:
  - ▷ local Ontario Ministry of the Environment office
  - ▷ bulldozer or backhoe operator
  - ▷ custom applicator (preferably one that has a vacuum tanker)
  - ▷ municipality
  - ▷ neighbours

In the event of a spill, call the Spills Action Centre.

5 **Document what was done when an emergency occurred.** Detailed reports of what was done, when, who was called and what was discussed will help in case of complaint or spills followup.

If you ever need to put your contingency plan into effect, evaluate and fine-tune it.

Why have a contingency plan?

- to protect the environment, your family, your business and your livestock
- accidents can, and will, happen
- to demonstrate "due diligence"
- so that you can react when there's an emergency – do not panic!

SOME CONTINGENCY SCENARIOS

If you have more manure than planned

If the application rates for nutrients in a nutrient management plan are at the maximum, you should be prepared to set up alternative uses for the nutrient. Some possibilities include:

- find a broker who can take the excess nutrients
- find a neighbour (e.g., cash cropper) who will accept the excess nutrients.

If you have more nutrient than the storage design capacity

In some cases, usually due to adverse weather conditions, manure storages may be in danger of overflowing. The preferred solution is to land-apply the manure where doing so will not result in an adverse effect. Other options include:

- transfer the nutrients to another available storage
- find a broker who can take the excess nutrients
- acquire more land.

If you have to change the timing of manure application

- adjust nutrient amounts to reflect the change in timing
- don't exceed the maximum annual nutrient application rate or the maximum rate per application
- adjust subsequent applications of nutrients to accommodate the change in timing of the nutrient application
- record the change in your nutrient management plan.

Contingency plans should address the impact of probable changes to annual crop choices.

If you change crops

Nutrient amounts and formulation should be adjusted (where possible) to account for a change in crop. If the nutrients have already been applied, the amount and formulation should be adjusted for the next crop where possible, to account for the previous crop change.

If you have a spill

This is an important issue. Your contingency plan should outline the required equipment, contacts and safety precautions. The idea is to minimize the potential for a spill, and if one does occur, to ensure that the operator and the employees know what actions to implement.

SPILLS

To avoid a spill

Spread the nutrient according to your nutrient management plan or put it in an adequate nutrient storage for later application. In addition:

- calibrate your manure application equipment regularly so that you can follow the rate specified in your plan
- follow setbacks to surface water required by the nutrient management plan for the site
- mark all tile outlets and catchbasins for nutrient application and inspection purposes
- for a direct-flow system, use two people with a radio link or an automatic shutdown system
- follow your nutrient management plan for the appropriate tillage practices
- avoid spreading before rain events.

To stop a spill

1. Immediately stop the cause of the spill if possible.
2. Shut down the appropriate pumps and valves.
3. Ensure the system cannot be restarted.
4. Contact the 24-hour Spills Action Centre at 1-800-268-6060 or your local Ontario Ministry of the Environment office.

To stop a spill, shut down pumps and valves.

To contain a spill

1. Minimize opportunity for manure to enter tile drains or plug the tiles in the event that flow appears to be contaminating the tile drains.
2. If the spill is moving over the ground surface, build an earthen berm using farm or commercial equipment, such as backhoes or dump trucks.
3. Notify downstream users.

Contain spills. Prevent entry into ditches, culverts and tile drain systems.

It is an offence under the provincial Environmental Protection Act and the federal Fisheries Act to pollute a stream and kill fish.

When a manure spill occurs, call the Spills Action Centre, 1-800-268-6060.

CHECKLIST FOR A CONTINGENCY PLAN FOR SPILLS

A properly developed contingency plan has the following components.

- ✔ A mission statement – your objective(s)
- ✔ A list of preventative BMPs and routine equipment inspection
- ✔ A list of contingency measures
- ✔ A step-by-step procedures list for eliminating the source
- ✔ A list – near each phone – of all essential emergency call numbers
- ✔ A map of the facilities indicating areas of risk and location of cleanup equipment and supplies – you should have a secure location for the map and your contingency plan (such as the Ontario Soil and Crop Improvement Association emergency tube)
- ✔ A list of who's responsible for what
- ✔ Documented proof of staff and family training, plus any preventative measures taken
- ✔ An account of how the spill will be cleaned up
- ✔ A formatted blank form to be completed after a spill was properly dealt with

For More Information

PUBLICATIONS

The Ontario Ministry of Agriculture, Food and Rural Affairs has extensive information on manure management. You can find factsheets on composting, livestock watering, manure storage and application, soil testing, odour control, manure agreements, and much more. Many helpful publications on specific aspects of the Nutrient Management Act, its regulation and protocols are also available.

For a full list of titles and information on how to obtain copies, please visit the ministry's website:

Ministry website:
www.omafra.gov.on.ca

Publications:
www.omafra.gov.on.ca/english/products/product.html

Nutrient Management Act:
www.omafra.gov.on.ca/english/agops/index.html

If you do not have access to the Internet, please visit your nearest ministry office or call the ministry toll-free (see below).

ONTARIO GOVERNMENT CONTACTS

Ontario Ministry of Agriculture, Food and Rural Affairs
Agricultural Information Contact Centre
1-877-424-1300
www.omafra.gov.on.ca
ag.info@omafra.gov.on.ca

Ontario Ministry of the Environment
Public Information Centre
1-800-565-4923
www.ene.gov.on.ca
picemail@ene.gov.on.ca

DISCLAIMER

This publication reflects the opinions of the contributing writers and/or editors, and is based on information available as of the publication date. It may not reflect the programs and policies of the supporting agencies. References to particular products should not be regarded as endorsements.

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