BEST MANAGEMENT PRACTICES

Cropland Drainage

Canada

Ontario

OFA Ontario Federation of Agriculture

What is a Best Management Practice or "BMP"?

- 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

What is the BMP Series?

- innovative, award-winning books presenting many options that can be tailored to meet your particular environmental concern and circumstances
- current BMP titles are:
  A Phosphorus Primer
  Application of Municipal Sewage Biosolids to Cropland
  Buffer Strips
  Controlling Soil Erosion on the Farm
  Cropland Drainage
  Deadstock Disposal
  Establishing Tree Cover
  Farm Forestry and Habitat Management
  Fish and Wildlife Habitat Management
  Greenhouse Gas Reduction in Livestock Production Systems
  Integrated Pest Management
  Irrigation Management
  Livestock and Poultry Waste Management
  Managing Crop Nutrients
  Manure Management
  No-Till: Making It Work
  Nutrient Management Planning
  Pesticide Storage, Handling and Application
  Soil Management
  Streamside Grazing
  Water Management
  Water Wells
  Woodlot Management

How do I obtain a BMP book?

- **Online** at www.publications.serviceontario.ca
- **By phone** through the ServiceOntario Contact Centre

  Monday to Friday, 8:30 am – 5:00 pm
  416-326-5300
  416-325-3408 (TTY)
  1-800-668-9938 Toll-free across Canada
  1-800-268-7095 TTY Toll-free across Ontario
- **In person** at ServiceOntario Centres located throughout the province or at any Ministry of Agriculture, Food and Rural Affairs Resource Centre

METRIC–IMPERIAL CONVERSION FACTORS

Convert		To		Metric
%	►	kg/1,000 L	multiply by	10
%	►	kg/tonne	multiply by	10
mg/L	►	%	divide by	10,000

Convert		To		Imperial
%	►	lbs per 1,000 gallons	multiply by	100
%	►	lbs per ton	multiply by	20
ppm	►	%	divide by	10,000

Note: 1 m^3 = 1000 L

UNITS OF MEASURE

While Canada "went metric" over 30 years ago, many commonly used measurements such as land area are still expressed using imperial units. Acres of land are a good example: landowners seldom, if ever, refer to the size of their property in hectares. For your convenience, most of the measurements used in this manual are provided in both metric and imperial units. However, where common usage, common sense, space limitations or regulatory concerns dictate, one or the other may appear exclusively.

CONVERSION FROM...	FACTOR	EXAMPLE
METRES TO FEET	1 metre = 3.281 ft	A 20.6-m tall tree is 67.6 ft (20.6 x 3.281)
FEET TO METRES	1 foot = 0.3048 m	A 100-ft buffer is 30.48 m (100 x .3048)
ACRES TO HECTARES	1 acre = 0.405 ha	A 35-acre field is 14.16 ha
HECTARES TO ACRES	1 ha = 2.47 ac	A 1.4-ha plot is 3.5 ac

CONVERSIONS – METRIC AND IMPERIAL

Common Conversions

1 imp gallon	=	4.546 litres	1 acre	=	0.405 hectare
1 imp gallon	=	1.201 US gallons	1 acre	=	43,560 $feet^2$
1 imp gallon	=	0.161 $foot^3$	1 pound per acre	=	1.12 kilograms per hectare
1 $foot^3$	=	6.229 gallons	1 ton per acre	=	2.25 tonnes per hectare
1 US gallon	=	3.785 litres	1 gallon per acre	=	11.2 litres per hectare
1 US gallon	=	0.833 imp gallon	1,000 gallons per acre	=	11,200 litres per hectare
1 ton	=	0.907 tonne	1,000 gallons per acre	=	11.2 $metres^3$ per hectare
1 pound	=	0.454 kilogram	1 metre	=	39.4 inches
1 tonne	=	2,205 pounds			

Application Rate Conversions

Metric to Imperial (Approximate)			Imperial to Metric (Approximate)		
Litres per hectare x 0.09	=	imp gallons per acre	Imp gallons per acre x 11.23	=	litres per hectare (L/ha)
Litres per hectare x 0.36	=	imp quarts per acre	Imp quarts per acre x 2.8	=	litres per hectare (L/ha)
Litres per hectare x 0.71	=	imp pints per acre	Imp pints per acre x 1.4	=	litres per hectare (L/ha)
Millilitres per hectare x 0.015	=	imp fluid ounces per acre	Imp fluid ounces per acre x 70	=	millilitres per hectare (mL/ha)
Grams per hectare x 0.015	=	imp 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	Imp ounces per acre x 70	=	grams per hectare (g/ha)
Kilograms per 1000 L x 10	=	lbs per 1000 imp gallons	Pounds per ton x 0.5	=	kilograms per tonne (kg/t)

CONTENTS

INTRODUCTION

Soils that get too much water and become saturated are vulnerable to erosion and can seriously impair crop growth. A drainage system removes this excess water from cropland – returning the soil to an unsaturated condition, and safely returning the water to the water cycle. This chapter outlines the basic principles of cropland water movement, and how drainage systems capture and move excess water.

Agricultural drainage systems are an essential infrastructure for Ontario food production. Proper drainage reduces the impact of excess water, conserves topsoil, and improves crop input efficiency. Because drainage contributes to higher productivity on our best land, more land can be maintained for natural areas and other uses.

Surface drainage removes excess surface water from cropland through drainage channels, land grading, and surface inlets. *Subsurface drainage* – also known as *tile drainage* – removes excess soil water from the soil profile using plastic tubing, or clay and/or concrete tile.

Water is a shared, essential resource, and agriculture is one of its many users. Farmers are responsible for managing drainage water properly – protecting its quality and quantity for downstream users.

The term *cropland drainage* refers to surface and subsurface components. *Agricultural drainage* refers to cropland drainage as well as outlets and drainage channels.

Today's drainage projects are well-designed, due to improvements in drainage technology and a greater understanding of:

- precisely what soils and crops need
- rural and agricultural water management concerns
- overall watershed management
- the value and functions of natural areas.

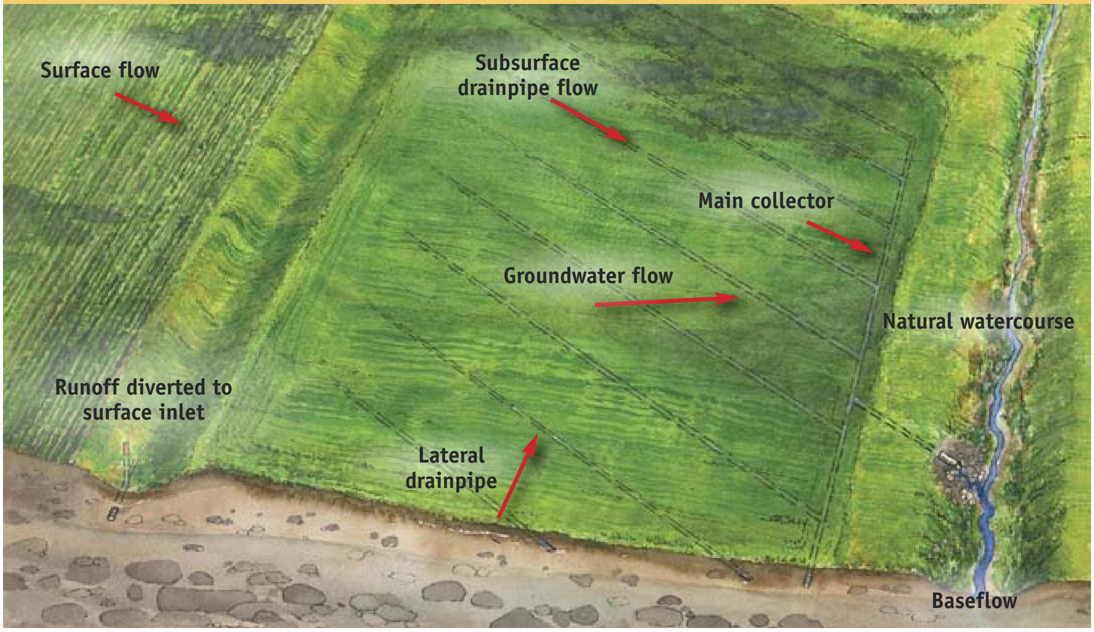
"The objective of cropland drainage is to remove enough water to facilitate good crop growth and not a drop more – because water conservation is critical to crop growth."
Dr. Richard Cooke, University of Illinois

When it comes to basic drainage terminology, there is some variation across Ontario and among farmers, contractors, engineers, and industry people. To keep it simple, we will use the terms *subsurface drainage* and *drainpipes* in lieu of *tile drainage* and *tiles*. A complete glossary appears on page 62.

Agricultural drainage has several components:

- ▶ surface drainage
- ▶ subsurface drainage
- ▶ drainage outlets
- ▶ natural watercourses and/or constructed drainage channels (ditches or pipe systems).

WATER MOVEMENT ON CROPLAND



Rain or snowmelt collects on the soil surface. At this point the water has several pathways it can take.

SURFACE FLOW – A large portion evaporates directly from the soil surface. Another portion will pond or flow across the surface as runoff, until it reaches a surface water body such as a natural watercourse or ditch. Some of the surface runoff may be directed to subsurface drainpipes via surface drainage components such as surface inlets.

SUBSURFACE FLOW – Some precipitation will infiltrate the soil surface where it's absorbed into the soil profile. Some of the infiltrated water will be taken up by plants and then transpired into the atmosphere. Once the soil is saturated, the excess (gravitational) water will continue to move downward to the soil water table. If subsurface drainpipes are in place, some of this water will move towards them.

Subsurface drainpipes provide a pathway for excess water to move from the upper soil profile near the drainpipe, and be conveyed to a larger-diameter collector drainpipe or "main" that controls the flow rate of drained water as it moves to an outlet. The water table is in constant flux, usually moving very slowly in the downgrade direction. Eventually this water returns to the surface, e.g., streams, lakes, rivers. When it reaches a stream, it is referred to as *baseflow*.

Drainage water will then exit to either a natural watercourse or more often to a constructed drainage channel – usually an open ditch or a buried larger-diameter drainpipe. Ultimately, drainage water is conveyed to larger bodies of surface water, including streams, creeks, rivers or lakes.

Too much water is as much a problem as not enough water. To imagine subsurface soil water, drop a sponge in a bucket of water, then remove the sponge. The water that freely flows from the full sponge is excess (gravitational) water. What remains in the sponge is similar to what remains in the soil.

Visual evidence of inadequate drainage includes: surface wetness, lack of vegetation or poor crop-stand density, crop stands of irregular colour and growth, and variations in soil colour on the ground surface.

Why drain cropland?

Without drainage, Ontario would have a much different and significantly less viable agricultural industry, and we would not enjoy the high quality, quantity and diversity of locally grown foods on our tables.

Overly wet soils are a major obstacle to crop production. Seasonally saturated soils become suitable for tillage and crop production after subsurface drainage has removed excess water from a portion of the upper soil profile above the drainpipe.

Drainage removes ponded water from the soil surface and facilitates the removal of excess water within the root zone in the soil profile.

Why do some soils benefit from drainage for cropland production?

Some soils benefit from subsurface drainage; others don't. Subsurface drainage will benefit soils with a naturally high water table, as well as soils with low permeability or soils with groundwater discharge. Soils such as those with high clay content most often benefit from surface and subsurface drainage.

Some soils do not benefit from subsurface drainage – including some sandy and loamy soils that are free of any water table activity in the rooting zone throughout the year. These soils contribute to more groundwater recharge than soils such as clay where the water movement is much slower.

THE BMP APPROACH: INTEGRATING BMPs ACROSS YOUR OPERATION

Throughout these pages, cropland drainage is considered part of an overall on-farm soil management system.

If you're a farmer, use this book to help you:

- ► better understand how drainage systems work
- ► see opportunities for improvements in existing systems
- ► integrate drainage-specific BMPs with other cropland BMPs to reduce runoff and flooding.

✔ This checkmark indicates a BMP. Every BMP improves a drainage system's effectiveness and reduces environmental impacts.

You'll find plenty of references to other BMP books for more in-depth information on related topics. The BMP series has a wealth of information to help you manage soil, nutrients, pesticides, and irrigation on agricultural land. A complete list appears on page i.

The BMPs in this book are intended to help landowners manage drainage systems more effectively, and reduce negative environmental impacts related to cropland drainage systems.

BENEFITS AND CHALLENGES OF SURFACE AND SUBSURFACE DRAINAGE

Among its benefits, drainage boosts productivity and helps manage erosive surface-water flow after rainfall events. However, it can also act as a conduit for inputs if cropland BMPs are not in place above ground. This chapter summarizes the benefits and challenges of cropland drainage.

KEY BENEFITS

SURFACE DRAINAGE AND EROSION CONTROL STRUCTURES

Properly managed, surface drainage and erosion control structures can do more than improve yields.

The potential on-farm benefits of surface drainage and erosion control include:

- reduced risk of drowned crops
- less soil compaction and erosion
- maintained soil infiltration rates
- improved functioning of subsurface drainage systems
- increased land values.

The potential off-farm benefits of surface drainage include:

- reduced flooding and sediment loading (due to reduced overland flow and erosion)
- reduced risk of phosphorus loading (as well as other crop inputs).

High-value crops are often more susceptible to damage or drowning (total crop failure) caused by ponding or prolonged wetness from storm events. Surface drainage reduces the risk of damage to crops.

Surface inlets move excess surface water on croplands to subsurface drainage systems. Intake rates are controlled when flow restrictors (orifices) are used in surface inlet structures.

SUBSURFACE DRAINAGE

The decision to install new or improve existing subsurface drainage is usually supported by evidence of some on-farm economic advantage.

By removing excess gravitational soil water in the plant root zone, subsurface drainage provides these potential on-farm benefits:

- improved field access and longer growing season
  - wet soil takes longer and much more heat than dry soil to warm up in the spring
- improved growing conditions – aeration, temperature, fertility and rooting depth
- increased production and crop quality
- greater protection from crop failure caused by excess water
- improved soil quality, e.g., reduced soil compaction
- reduced fuel consumption and wear and tear on equipment
- improved drought tolerance as root systems develop better
- improved soil conditions for harvest.

Subsurface drainage improves growing conditions for roots. Better root growth results in greater biomass above and below the ground. More organic matter is returned to the soil. Above-ground biomass improvements are measured as increased yields and reduced per-unit production costs. Increased root biomass improves soil life, improves subsurface soil structure, reduces soil density, and increases porosity.

Removing excess subsurface water allows soil to warm up sooner for earlier seed germination, and improves equipment access for field operations in the spring. Drier fields also extend the harvest period, and require less fuel for equipment operation. Spring tillage and fall harvest equipment cause less soil degradation.

The potential off-farm benefits of subsurface drainage include:

- ▶ reduced water quality impacts by reducing runoff and erosion
- ▶ reduced greenhouse gas (nitrous oxide and methane) emissions
- ▶ improved opportunity for soil and water conservation systems – conservation tillage needs cropland drainage to work effectively
- ▶ higher quality, greater yield of food products
- ▶ less need for irrigation water due to better root development
- ▶ may result in longer stream-flow duration after a rainfall event compared to undrained cropland in some watersheds
  - ▷ this assists with maintaining stream baseflow (groundwater discharge to watercourses), thus benefiting aquatic habitat
- ▶ may reduce peak watershed flow rates in some watersheds.

Cropland drainage systems enhance the soil's hydrologic ability to absorb water and transmit water downward during a rainfall event. It takes time for the soil to hydrate to a saturated condition, and it takes more time for the water to reach the cropland drainage system before being conveyed to a stream. Also, the volume of surface water runoff is reduced, and surface runoff is delayed.

These two functions have the overall impact of reducing peak flows in ditches and streams. In some cases, surface runoff is eliminated if the rainfall rate is slow enough to infiltrate completely into the soil. During fast or heavy rainfall rates, subsurface drainage systems have little or no impact as the rainfall comes too fast to infiltrate the soil regardless of the soil condition.

KEY CHALLENGES

CROP INPUTS

Surface water collected by surface drainage and erosion control structures can have the following materials in solution or attached to sediment in suspension:

- ▶ surface-applied nutrients
- ▶ manure and manure-based pathogens
- ▶ pesticides.

Further, some crop inputs are not completely assimilated by soils or used by the intended crop, and can leach with gravitational water to the drainpipe. These include:

- ▶ crop nutrients in solution
- ▶ manure and manure-based pathogens.

Nitrate-nitrogen, a soluble form of nitrogen, has great potential to move wherever water moves. Nitrates are readily taken up by plants. However, under certain conditions, nitrates will move beyond the root zone. Subsurface drains can provide a pathway for nitrates that have moved below (leached from) the root zone. Nutrient management BMPs – such as following recommendations for timing, placement and rates – will reduce nitrate loss.

Remember that drainage systems are a conduit, not a source. Use BMPs when applying nutrients, manure or pesticides to all fields, with or without subsurface drainage, and especially to fields with surface inlets. See other BMP books, and read on for more information.

RATE OF WATER REMOVAL

In the past, the sole goal for drainage was to provide a good growing environment by removing excess water. Now, drainage activities are finer-tuned to remove only water that is detrimental to crop growth and to minimize impacts to the overall water system.

Drainage system designs should consider cumulative impacts in a particular setting. For example, surface inlets are a very easy method of managing surface water problems. However, too many and/or too large inlets can increase peak flow rates in the receiving channel.

WET OR TEMPORARILY PONDED AREAS: TO DRAIN OR NOT TO DRAIN?

Removal of temporarily ponded surface water from croplands has potential benefits – not the least of which are increasing usable land area and improving access for field operations. On the other hand, some temporarily inundated sites, although not permanent, may function to provide water storage and temporary habitat for a variety of plant and wildlife species.

Small wet areas in croplands can be important habitat for migratory waterfowl and other wildlife. If these periodically wet areas have been cropped previously, it is likely that these areas do not meet the criteria to be classified as wetlands. If you are unsure, contact your local Conservation Authority or resource agency. You should carefully assess each site before deciding whether or not to drain it.

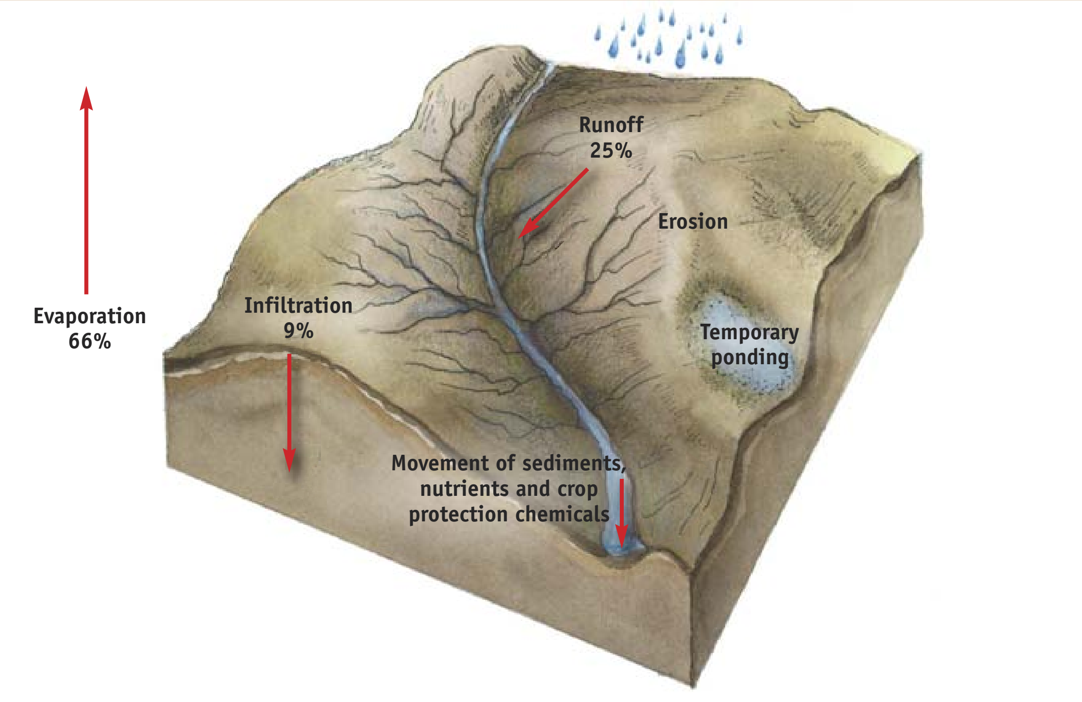
To guide your decision on whether to drain a temporarily ponded site, weigh the pros and cons first. Consider the history of water impact, crop flooding, the duration of ponded water, whether soil will be productive if drained (not all will be as good as hoped), use by wildlife, and other related factors.

PRINCIPLES OF SOIL WATER AND CROPLAND DRAINAGE

How water passes through your cropland soils is determined by many factors. Key among them are the soils' properties, as well as time of year, topography, depth to water table, and your management. This chapter sets out the key principles of soil water and how it moves over and through cropland. Understanding these principles will help you manage cropland soil and water more effectively.

HOW WATER CYCLES THROUGH CROPLAND

WATER FALLING ON BARE CROPLAND



Best management practices for soil improve water infiltration rates. Keep reading for more information on BMP options.

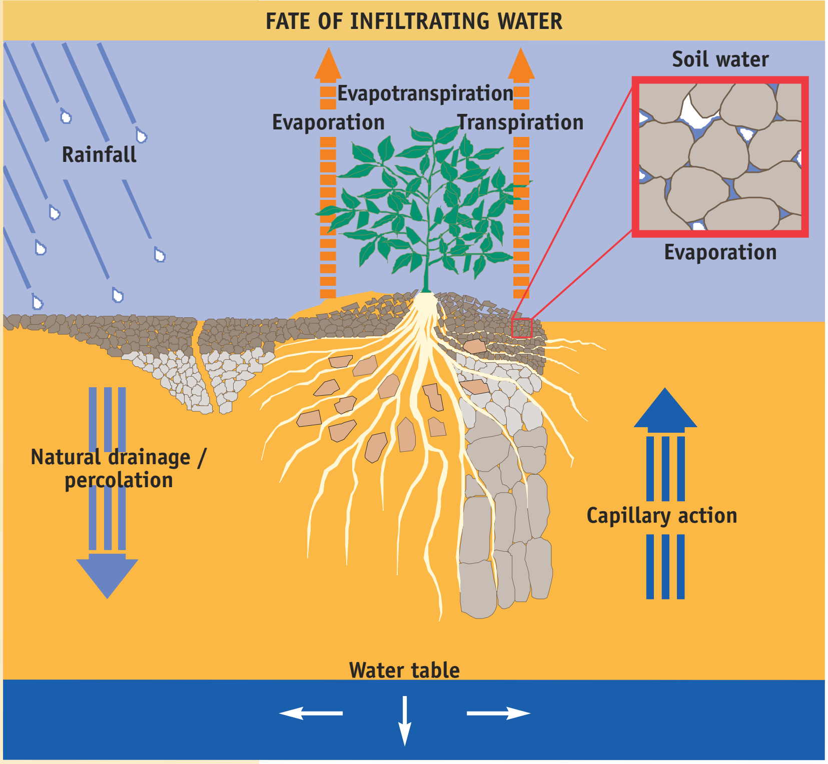
Most soil water in Ontario comes from precipitation and snowmelt. Some comes from groundwater discharge.

The amount of soil water is constantly fluctuating, closely reflecting the patterns of an annual water cycle. During the early part of the growing season, the soil is usually near saturation. Roughly 66% of water falling on cropland will evaporate, 25% becomes runoff, and 9% will infiltrate the ground surface.

In eastern North America, we have a humid temperate climate where precipitation will exceed evapotranspiration and soil storage capacities – resulting in excess water. When water supply exceeds the storage capacity of cropland soils, then precipitation, snowmelt and floodwaters will:

- keep soils saturated
- pond in depressional areas
- run off from sloping sites in sheets and rills – especially on bare soils or in frozen soil conditions, or
- follow natural drainage pathways, such as converging slopes, to run off as concentrated flow.

On frozen soils, considerably more water runs off than infiltrates. Runoff volumes often exceed infiltration by a 3:1 ratio during spring floods.



The portion of rainfall that infiltrates the soil will do one of the following:

- percolate through pores and cracks to the depth of saturation
  - the depth of saturation is the water table or the level of the groundwater in the soil
  - the water table is often in motion, moving laterally towards a lake, stream, river, drainage channel, ditch or low area where it will return to the surface as baseflow for streams (maintaining flow between rainfall events) or springs
- continue downward as deep percolation to recharge groundwater aquifers
- be held by soil particles or between the soil particles (in the soil pores)
- move back towards the soil surface by capillary action
  - water held in the soil pore spaces can be taken up by crop roots along with nutrients for plant growth
- reach the soil surface where it evaporates
- transpire to the atmosphere – some of the water taken up by crops returns to the atmosphere.

SOIL WATER AND GROUNDWATER

INFILTRATION

Infiltration is the process by which water enters the soil surface and displaces air. The rate of infiltration is directly related to local topography, surface soil properties, and site conditions. In most cases, soils with poor infiltration will benefit from a combination of soil management BMPs and subsurface drainage. However, in some extreme soil conditions, water does not infiltrate into the soil adequately to get the benefits of the subsurface drainage system – no matter how well-designed it may be.

Infiltration rates are higher in soils with large pores and aggregates, and soils covered with forage, crop residues, or a cover crop. Conversely, bare soils with small pores (fine materials) and poor seedbed conditions have low infiltration rates. Silty and clayey soils have inherently low infiltration rates.

Other soils subjected to compaction or excessive tillage may seal to the point of greatly reducing infiltration rates.

Lower infiltration rates caused by soil degradation are a soil management issue that should be corrected with BMPs such as adding organic matter (cover crops or green manures) – not by adding drainpipes.

HYDRAULIC CONDUCTIVITY

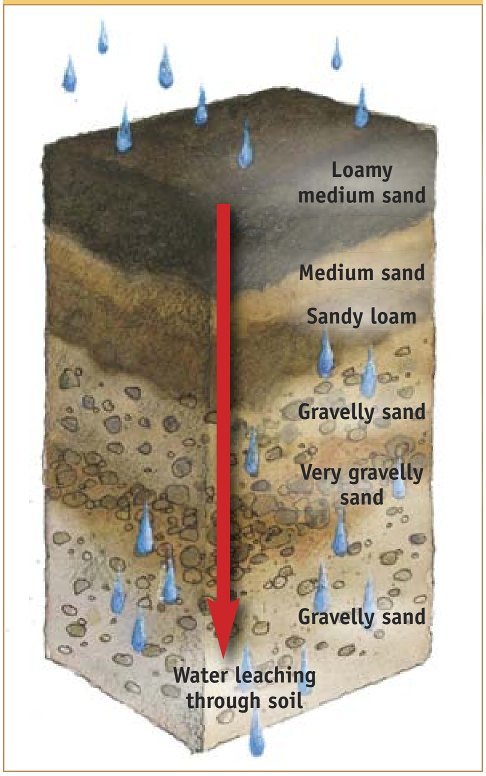
Once water moves into the soil, gravity helps it move from near the surface down through the soil profile.

Hydraulic conductivity is the rate at which water passes through (permeates) the soil. This rate is mostly linked to porosity, texture, structure, depth to restricting layer, and depth to water table. Soils with a lower hydraulic conductivity can benefit from subsurface drainage.

Soils with a high permeability are those with:

- continuous large pores (macropores)
- coarse or sandy soil materials (texture), or
- a high percentage (>33%) of coarse fragments (e.g., gravels, stones, etc.).

WATER MOVEMENT IN SOIL



Soils with a high hydraulic conductivity are sometimes described as permeable soils or having higher permeability.

Less permeable soils are more likely to benefit from subsurface drainage.

Soils with a low permeability are those with a restricting layer due to:

- ► no easy pathways such as cracks or macropores
- ► bedrock
- ► a naturally compacted layer (hardpan)
- ► a finer-textured (clayey) layer within the top metre or,
- ► a high water table – the water can only move with gravity to the depth of the water table.

Water movement in soil can be temporarily influenced by the presence of cracks and large pores such as worm holes. Many of these pathways close up once the soil becomes saturated.

Hydraulic conductivity also varies with moisture content. Water moves more quickly through moist soils than dry soils. In dry soils, the downward movement (by gravity) of the wetting front will be slowed by the counter-effect of suction by the soil materials. See Capillary Zone on page 17.

SOIL WATER

Not all soil water is equal. Some is held so tightly that it is virtually unavailable to plants; other soil water flows freely and isn't held in soil.

The amount of soil water is critical to crop uptake and crop needs, as well as temperature, workability, soil aeration, and crop root exploitation.

Soil water can be classified as *gravitational, capillary* or *hygroscopic.*

Gravitational water – water that moves through soil due to gravitational forces. It is the portion of soil water in excess of hygroscopic and capillary water.

Gravitational or drainage water fills cracks and large pores in the soil. The intent of cropland drainage is to remove this water – early in the growing season or after rain events at a predetermined rate – so that air and not water fills large pores and cracks in the root zone (top 60 cm or 2 ft) of the soil. Water will not drain (move by gravity) until the soil has reached a maximum capacity for capillary water – held by tension, much like a sponge.

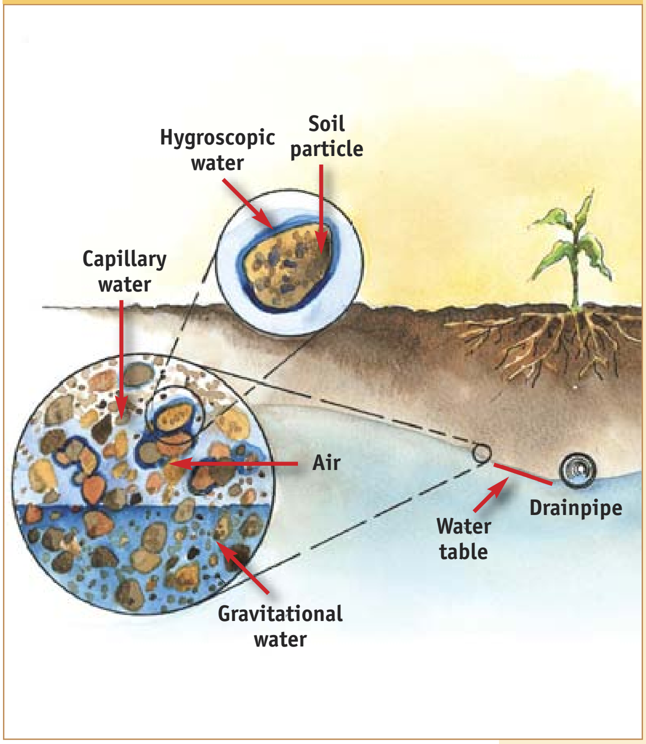
Gravitational water can be static, as is the case in a water table. However, a water table is an oxygen-free environment where crop roots cannot grow.

Capillary water – the part of soil water held cohesively as a continuous layer around particles and in spaces, most of it being available to plant roots.

Crops can only use soil moisture in a certain range of water volume and tension. By definition, only capillary water is available to crops.

Hygroscopic water – water held within 0.0002 mm of the surface of a soil particle. Hygroscopic water is held too tightly to be accessible to plants. This water is essentially non-mobile and can only be removed from the soil through heating.

SOIL WATER



There are three types of soil water: gravitational (excess water), capillary (available to plants), and hygroscopic (held tightly by soil particles).

Most fine- and medium-textured soils cannot be over-drained. However, some sandy soils have poor capillary action and can suffer if subsurface drains are placed too deep below the soil surface.

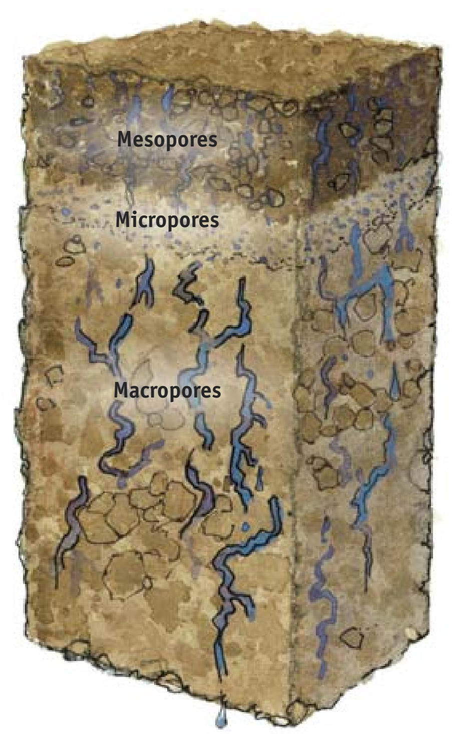
The amount of available soil water closely follows soil texture:

- ► loams, silt loams, and clay loams can hold the most available water
- ► clay soils have high surface areas and many fine pores, and therefore the highest proportion of hygroscopic water – but it is unavailable to plants.

From a drainage perspective, silty and clayey soils, because of their higher porosity and higher proportion of fine pores, contain more gravitational water at saturation but will not release it very quickly. While coarse soils (e.g., sandy) contain more large pores, they drain more quickly but don't contain as much water.

Gravity is the most important force in saturated soils.

MACROPORES



Pores can occupy up to 50% of soil volume between soil particles. Soil pores come in all shapes and sizes.

Micropores are the smallest and are usually filled with capillary water. Mesopores hold capillary and gravitational water. Macropores are most often cracks or worm channels.

Continuous macropores can transmit gravitational water through the soil to the water table or drainpipe.

WATER TABLE

The upper surface of groundwater is called the *water table.* Soils with a high water table will most often benefit from subsurface drainage.

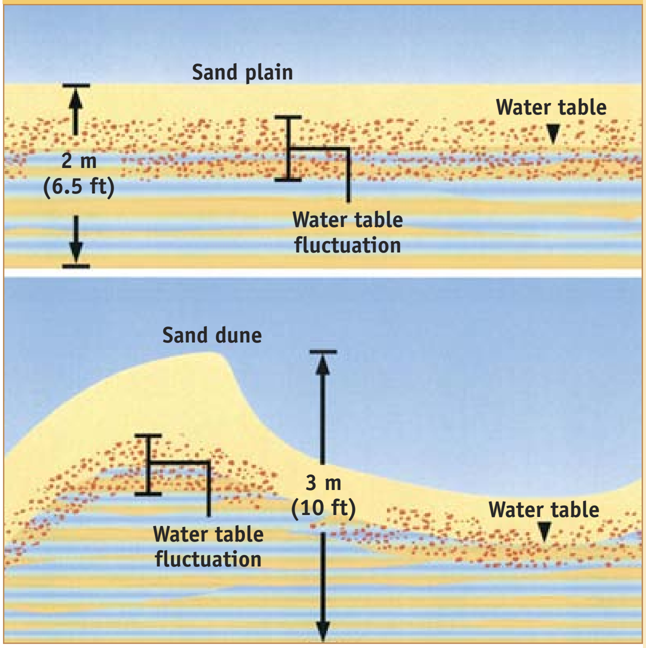
The water table's depth fluctuates over the year according to levels of precipitation, evapotranspiration, and deep percolation. In late fall, precipitation generally exceeds evapotranspiration rates, causing the water table to rise. The water table stays high and peaks in early spring following snowmelt and accumulated rainfall.

The water table drops throughout the growing season as crops mature, and precipitation falls off (normally) in July and August. Evapotranspiration rates are the highest during the summer months. In most cases, the water table is at its lowest (deepest) levels in early September.

One way to estimate the depth to water table is to excavate a posthole. After one day, measure the depth from the soil surface to the top of standing water in the posthole.

Water tables fluctuate up and down, and groundwater also moves laterally from areas of higher elevation to areas of lower elevation – the technical term is *hydraulic gradient.* This moving water can:

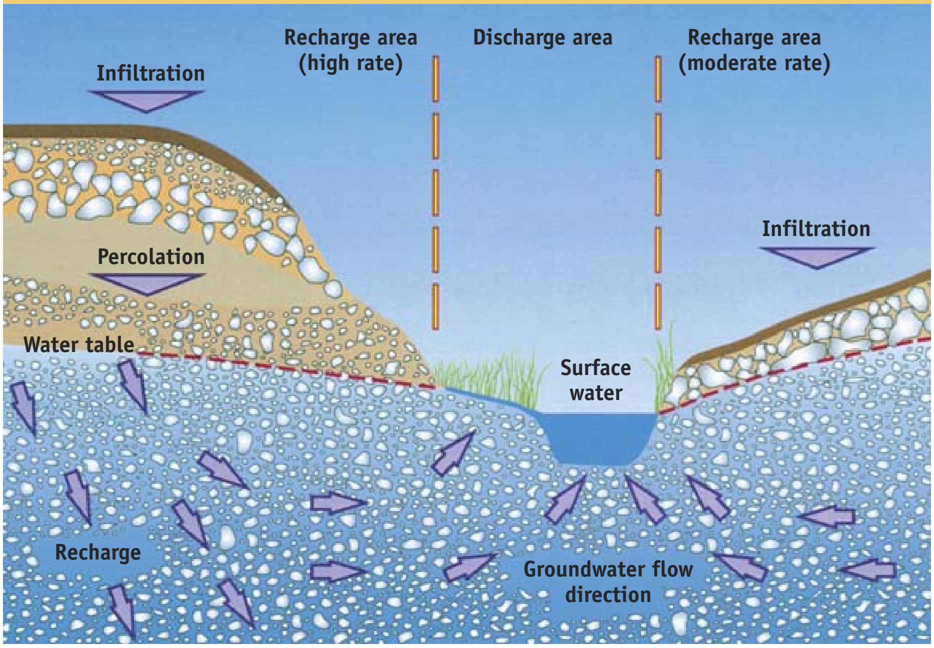
SOIL AND WATER TABLE PROFILE



By observing soil colours, you can get a good idea of the seasonal fluctuations of soil water tables. Dull, grey (gley) colours indicate zones or depths of permanent saturation, whereas layers in the soil with rust spots (mottles) indicate a fluctuating water table. Soil water tables normally mimic local topography, but tend to be deeper on hills and knolls and closer to the surface in depressional areas.

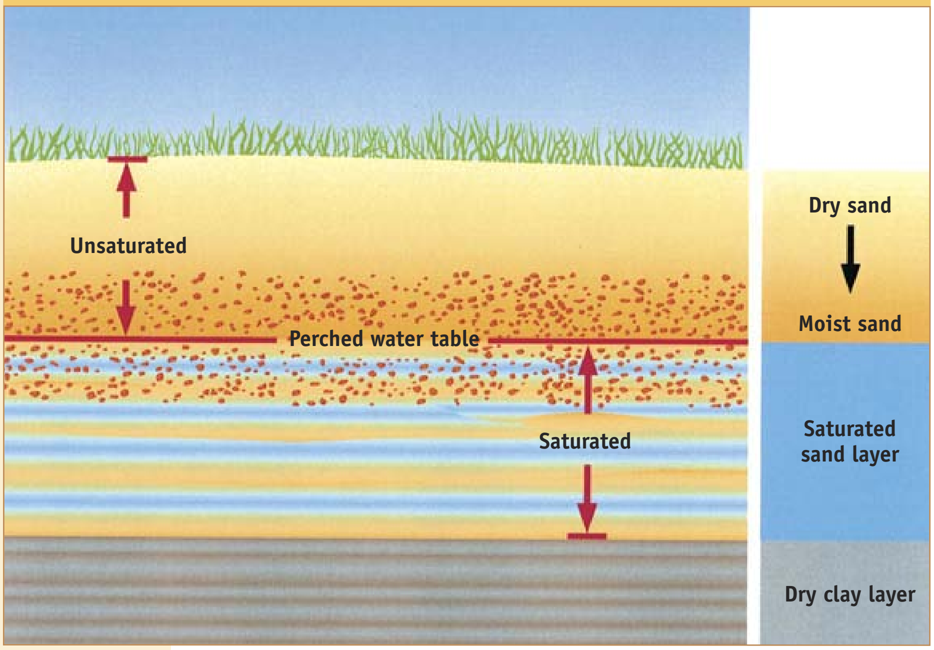
- ▶ increase moisture levels in lower areas (raise the water table)
- ▶ emerge along the slopes as side-hill seepage or springs, or
- ▶ replenish surface waters, rivers, streams, ditches, ponds and wetlands (baseflow).

GROUNDWATER RECHARGE



The excess portion of infiltrating water that isn't taken up by plants or absorbed by soil particles will move downward (percolate) through the unsaturated zone. When percolating water reaches the water table, it becomes groundwater recharge. Recharge replenishes water in aquifers, or is discharged in springs, streams, lakes or wetlands.

PERCHED WATER TABLE



Not all water tables are equal. In some cases, the depth to the water table is not the upper limit of groundwater. Soils that have a naturally compacted layer (hardpan) or strongly contrasting textures (e.g., sand over clay) can have a perched or temporary water table condition. A perched water table – or zone of saturation – will develop in the upper soil material just above the compacted or clay layer. The soil material below the compacted or clay layer is not saturated.

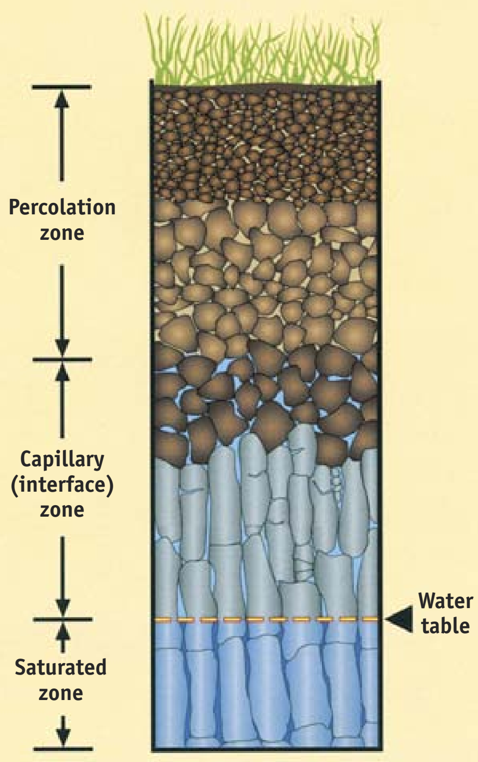
It's essential to know whether you have a perched or normal water table when designing a subsurface drainage system.

CAPILLARY ZONE

Soil above the water table is unsaturated, as all gravitational water has been moved out. But it's not dry. There is a zone above the water table that contains moist soil, known as the *capillary zone.* As crops use the available water, more water is drawn up from the water table. Subsurface drainage will not remove capillary water from cropland soils.

The thickness of the capillary zone will vary with overall soil texture and porosity, structural and textural changes in soil horizons, and rainfall.

CAPILLARY RISE



SOIL PROPERTIES AND SUBSURFACE DRAINAGE

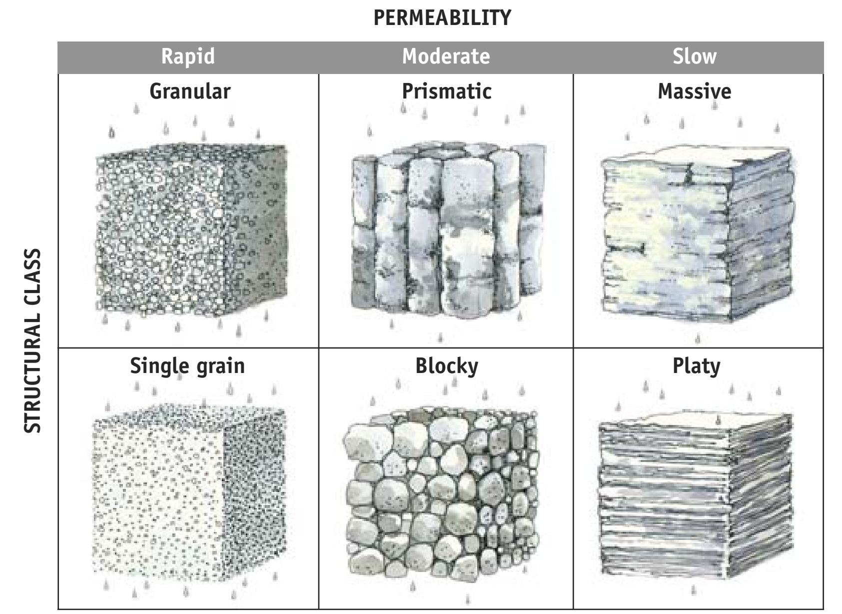
Soils have physical, chemical and biological properties. Historically, much attention has been paid to soil chemical properties when managing soil because they are central to soil fertility.

In recent years, attention has broadened to include soil biological properties such as organic matter content, and its fate as affected by soil flora and fauna.

Although very important to managing soils, soil chemical and biological properties are less important than physical properties (e.g., soil material, depth, depth to water table, etc.) in understanding soil water and drainage.

Soil texture is the relative coarseness or fineness of a soil based on the relative proportion of soil particle sizes. Sandy (coarse) soils have large pores, drain quickly, and don't retain much water. Clay (fine) soils have small pores, drain slowly, and retain lots of water in small pores.

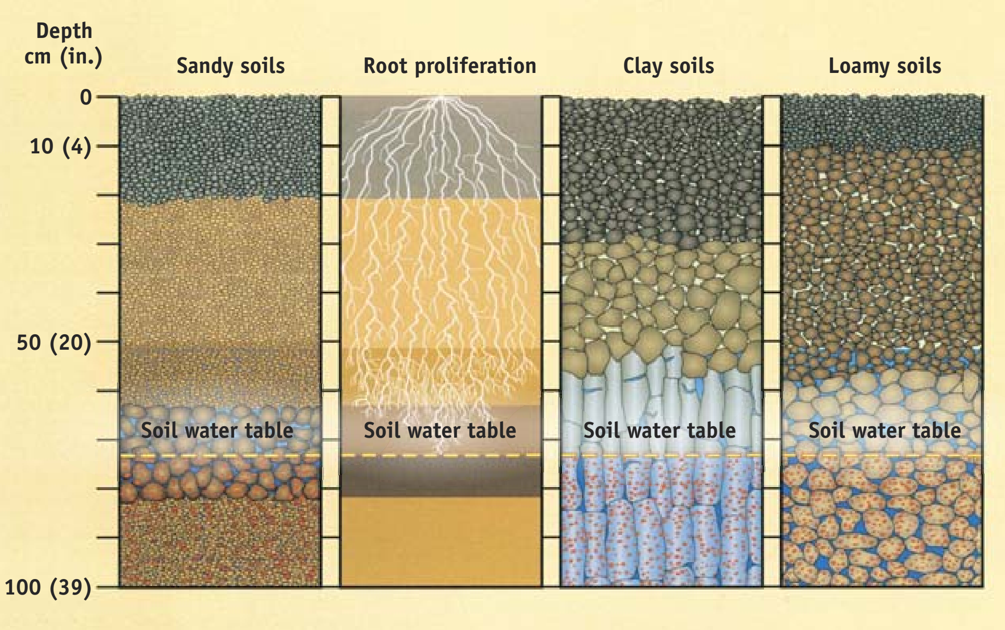
SOIL STRUCTURE AND DRAINAGE



Soil structure describes how soil particles are arranged and organized in the soil. Soil structure and its porosity greatly influence drainage, aeration and water retention. A well-formed and stable soil structure drains more quickly than a poorly formed structure (e.g., massive clays).

Granular structure is often associated with topsoil in loamy and clayey soils – especially those rotated with forage crops. Soils with a granular structure drain freely. Blocky and prismatic structures are normally found in clayey subsoils and parent materials, giving them large continuous macropores. These structures enhance the drainage from these soils. Platy structures are found in compacted soils with high silt and very fine sand contents. Platy structures can slow drainage substantially.

SOIL POROSITY AND DRAINAGE

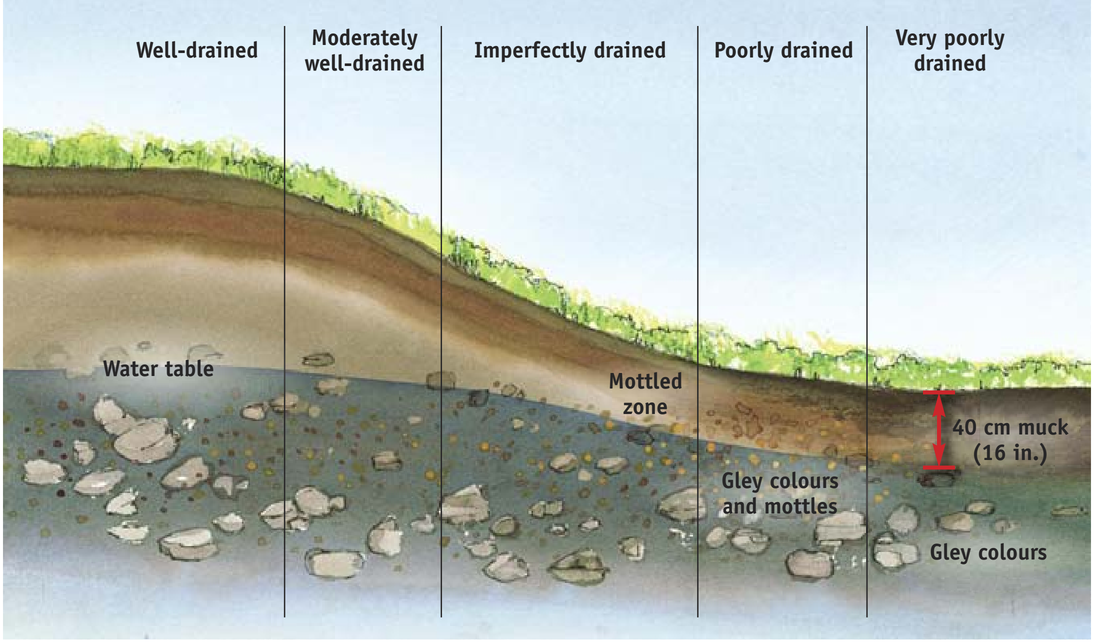


Soil porosity is the fraction of the soil volume filled with air. Soils with a high proportion of large pores, such as sands or well-structured clays, will drain more quickly. Subsurface drainage only removes gravitational water, which increases aeration. Porosity allows roots to breathe, thus improving crop growth. In this illustration, plant roots thrive in the moist pores above the soil water table.

Soil colour refers to the richness, intensity and brightness of soil colour. Dull, grey colours indicate depth to seasonal water table. The depth to a zone of rust spots (mottles) indicates the levels of a fluctuating water table.

For more information on soil biological and physical properties and soil management, see BMP *Soil Management*. For more information on soil chemical properties, refer to BMP *Managing Crop Nutrients*.

SLOPE POSITION AND SOIL DRAINAGE CLASS

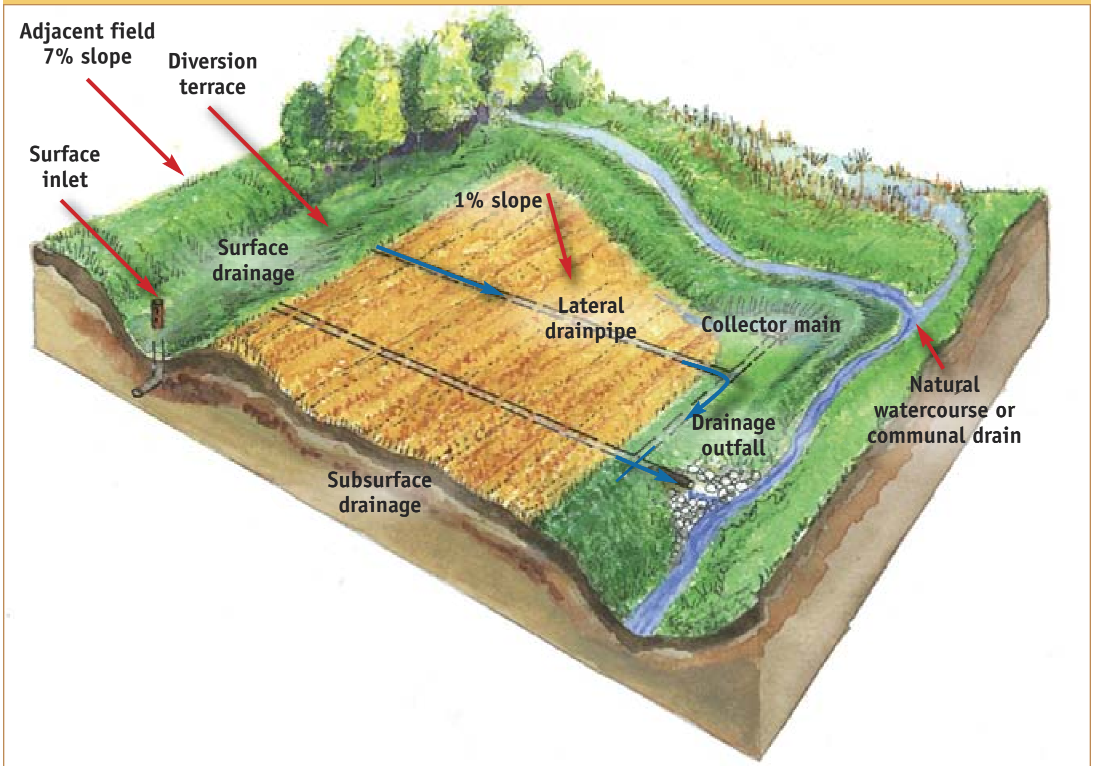


Texture is less important where water table activity close to the soil surface is evident. Soils that are permanently saturated with a very high water table are classed as *very poorly drained* – dull grey (gley) in colour and without spots or mottles. (In Ontario, mottles are often orange in colour due to iron.) Moving upslope, soils that have gley colours in the upper 50 cm (20 in.) of the soil profile and are often mottled throughout are classed as *poorly drained*. *Imperfectly drained soils* may have gley colours in the lower part of the profile and are often mottled throughout. *Moderately well-drained soils* have some mottling in the lower part of the profile or are fine-textured.

AGRICULTURAL DRAINAGE SYSTEM COMPONENTS

Agricultural drainage is a system with several components: surface drainage and erosion control, subsurface drainage, drainage outlets, and drainage channels. Subsurface drainage is usually made up of a network of smaller drainpipes (laterals) – typically 100 mm (4 in.) diameter. These are connected to a larger-diameter main collector pipe.

CROPLAND DRAINAGE SYSTEM



If surface and subsurface drainage components have been installed on cropland, only a portion of the water that infiltrates the soil surface is collected by the subsurface system.

The collected water is moved to the collector main by gravity, where the flow rate is metered by the diameter and slope of the collector main until it reaches the outfall (outlet point). That will almost always occur when the soil above the subsurface drainpipe is saturated (i.e., the water table is above the drainpipe). At all other times, no water is removed.

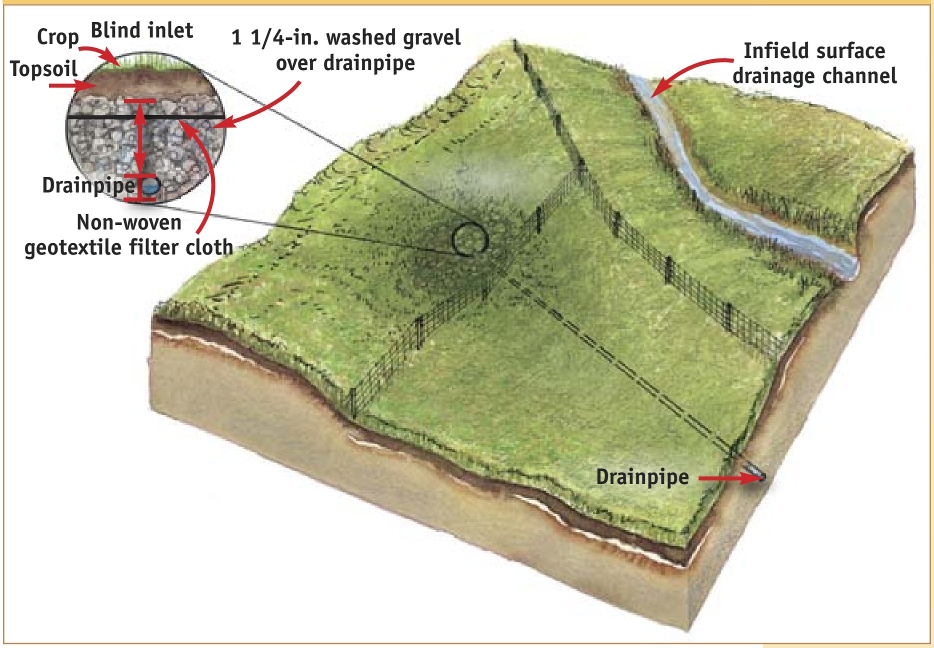
At the outfall, the water is introduced into open channels such as natural watercourses or drainage channel systems.

SURFACE WATER MANAGEMENT

Surface drainage helps move water from the surface of croplands, using various methods such as shallow open ditches, land grading, and surface inlets. If water is added to the soil surface faster than it can infiltrate into the soil, surface water will move and follow the slope of the land to a receiving point – which could be a drainage channel, creek, stream, pond, low spot, depressional area of a field, or constructed ponding area.

Water that is ponded in depressional areas will remain there until it evaporates, infiltrates the soil (eventually), or moves toward a surface water body due to a surface drainage BMP.

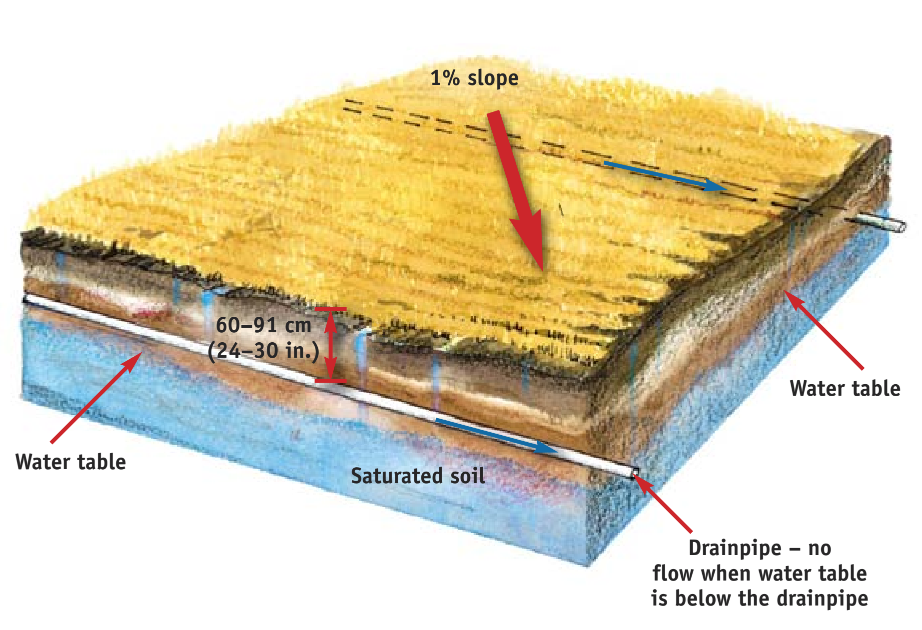
SURFACE DRAINAGE COMPONENT



Surface drainage often includes erosion control structures such as grassed waterways, water and sediment control basins (WASCoBs), terraces, and rock chutes. Erosion control structures take concentrated surface flow (runoff) and safely convey it to a proper outlet. Without such structures, surface water runoff can and does cause significant soil erosion.

SUBSURFACE DRAINAGE

SUBSURFACE COMPONENT

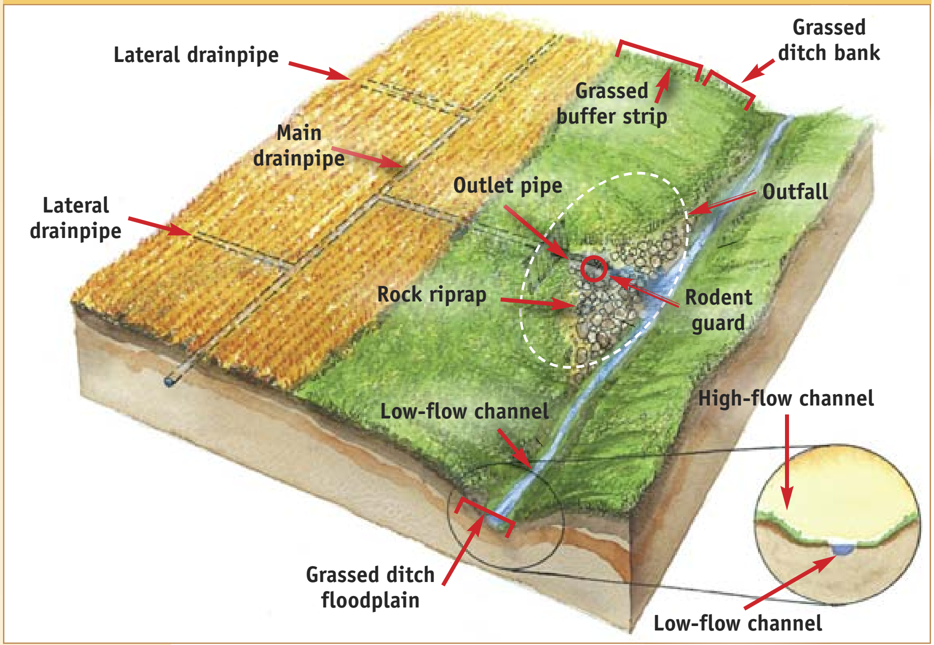


Subsurface drainage removes excess soil moisture (gravitational moisture) from the soil profile using plastic tubing, clay tile and concrete tile. Only excess water in the soil profile above the drainpipe (usually installed at 60–91 cm or 24–36 in. depth) is removed.

With a subsurface drainage system in place, the excess (gravitational) water seeps into the drainpipe, either through small holes in the plastic tubing or through the small space between the ends of adjacent clay or concrete tile. Subsurface drainpipes convey this excess water from above the drainpipe, plus water collected from surface inlets, to a larger-diameter collector drainpipe or main. The drainpipe will continue to remove the gravitational water until the water table is lowered to the bottom of the drainpipe.

DRAINAGE OUTLET

DRAINAGE OUTLET



The larger-diameter collector drainpipe or main will control the flow rate of drained water before it moves to an outlet (outfall). The collector is installed deeper than the lateral drainpipe, and is there mainly to collect and convey water from the lateral drainpipe. It does not contribute much to drainage.

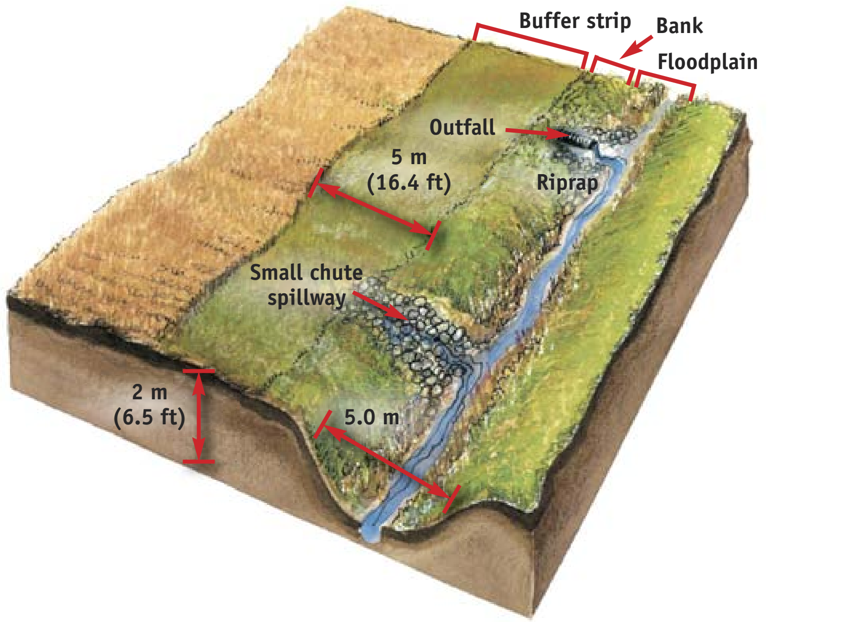
The outfall is the interface between the private subsurface drainage system and the receiving drainage channel system.

COMMUNAL DRAINAGE

Drainage water will pass from the subsurface drainpipe though the outlet pipe at the outfall location into a natural water body (e.g., stream, creek, river, lake) or a communal drainage (drainage channel) system.

A communal drainage system is one that has been constructed through a public body such as a municipality or road authority, or through the cooperation of a group of landowners. Communal drainage components are in the form of open channels or buried larger-diameter drainpipes. These drains are often called *municipal, mutual agreement, award*, or *private* drains.

COMMUNAL DRAINAGE COMPONENT



BMPs FOR CROPLAND SURFACE DRAINAGE

Accurate diagnosis of drainage problems and proper planning are essential before selecting BMPs. This chapter describes surface drainage methods, follows with planning tips, and concludes with brief descriptions of surface drainage BMPs.

SURFACE DRAINAGE METHODS

Unmanaged surface water runoff will cause serious topsoil erosion and sediment loading in open outlet drains and streams.

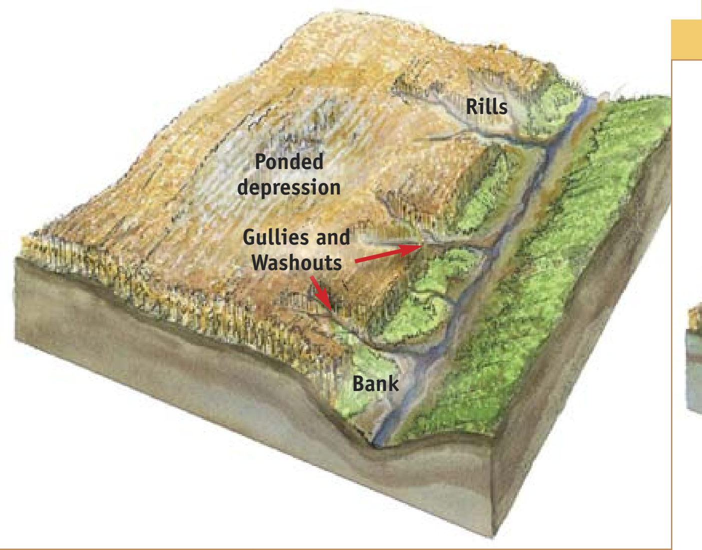
Surface drainage systems – including inlets, erosion control structures, and land-shaping – are designed to safely convey water on cropland to a proper outlet. Diverting surface runoff to managed drainage systems reduces the impact of cropland runoff on surface waters and natural habitats.

Surface drainage systems move water that is very slow to, or cannot, infiltrate. They don't lower the water table.

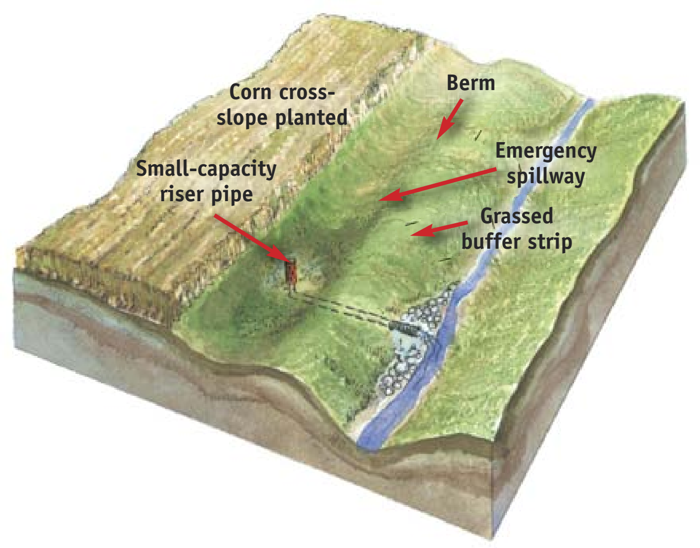
Most methods involve moving soil, creating shallow ditches that can be crossed by machinery, or diversions to subsurface drainage systems.

If not properly designed and constructed, surface inlets and other surface drainage systems can be direct conduits for contaminants to natural waterways. Runoff can carry sediment, nutrients, pesticides and pathogens.

BEFORE SURFACE DRAINAGE



AFTER SURFACE DRAINAGE



PLANNING SURFACE DRAINAGE PROJECTS

BMPs for surface drainage are intended to convey ponded surface waters or concentrated flow to proper outlets.

To be effective, structures require careful problem verification and planning before construction begins.

The soil problems addressed by surface drainage include:

- soils in channels or converging slopes
- soils in depressional areas
- soils with very low to low permeability, e.g., poorly structured (massive, heavy) clay soils, where subsurface drainage may not be feasible
- soils in floodplains of natural watercourses or spillover areas around ponds, lakes and wetlands.

Subsurface drainage may be ineffective for some heavy clays (>60% clay content) and some poorly structured clayey soils with very low permeability rates. Soils with these conditions may benefit most from surface drainage.

A professional contractor or drainage engineer should be consulted before any design or in-ground work begins. They will:

- verify the surface drainage problem – some infiltration problems are related to soil compaction
- estimate the hydrologic properties – size of area, volume of water and removal rates that should be considered
- evaluate alternative methods – in some cases, a less expensive grassed channel can adequately remove the ponded surface water
- evaluate the impact of various options to overall water movement.

✔ Properly design the option that has been selected before taking action on a surface drainage matter.

BMPs FOR SURFACE DRAINAGE

WHAT NOT TO DO

In some areas of the province, the conventional response to flooded or ponded areas has been to create surface features by shallow excavation to route ponded and flooded waters to the nearest drainage channel.

Drainage furrows should only be used to remove surface water in emergency situations or when there is no other drainage alternative. They should be designed and installed to minimize erosion.

Land-levelling is not considered a BMP. The practice removes the high spots, fills the low spots, and doesn't change the overall slope of a field. Water moves downslope with less resistance.

Land-levelling allows producers to access land more quickly in the spring and avoid crop damage from ponding during the growing season. However, it often leads to accelerated cropland erosion and runoff.

These practices, known as land-levelling, bedding, drainage furrows or shallow field ditches, are not BMPs. Here's why:

- flooded or ponded waters on bare fields are often sediment-laden
  - allowing a direct outlet from a surface ditch leads to soil loss and sediment plus nutrient loading of surface waters
- there are better choices available
  - sound soil and crop management practices will improve soil infiltration and percolation rates – reducing the incidence of flooding and ponding
  - depending on site features and conditions, erosion control structures may do the job better, e.g., water and sediment control basins – see BMP section for erosion control that starts on page 28.

BMP OPTIONS

A surface inlet can deliver water to subsurface drainage systems faster than water travelling through soils. The benefit is the effective prevention of erosion and runoff. Your goal – as a steward of land and water – is not to remove the water as fast as you can. Instead, you want to achieve a rate of water removal that will minimize crop damage and erosion.

Sizing and design of the main collector drain is very important to prevent overloading the subsurface drainage system with excessive volumes of surface water.

The following photos show the various types of surface or drop-pipe inlets.

✔ Riser (stand-pipe) inlets – used for small flows, especially for potential trash problems. To prevent trash from plugging the inlet, be sure the capacity of the holes isn't the limiting factor. Some are metered for erosion control purposes. Inspect surface inlets after storm events to ensure they're functioning properly and not blocked with debris.

✔ Blind inlets – are a type of surface water inlet. Soil is excavated over a length of drainpipe and backfilled with a granular material to within 30.5 cm (12 in.) of the surface. A geotextile filter is then laid and the remainder of the trench is filled with topsoil.

This type of structure allows surface water to enter the drain more easily than through the soil, but less efficiently than a direct surface inlet type. These are used in field locations where small surface drainage problems arise and no obstacle is wanted in the field. It's very important to keep records of where blind inlets are located. They are often not marked, and can be easily forgotten or overlooked when carrying out farming practices.

Blind inlets are direct pathways to the water system – the same as any other surface inlet – and activities and application of material (such as manure) should be managed accordingly.

✔ Catch basins – are covered by a grate, identified by markers, and located in low-lying areas. They intercept surface water and are connected to a subsurface drainpipe for transmitting water to an outlet. Inspect catch basin inlets after major storm events, and remove debris. They should be protected by a vegetative buffer. Take precautions to ensure that flowpaths from potential sources of contamination do not reach catch basins.

BMPs FOR CROPLAND EROSION CONTROL

Properly designed and located erosion control structures can safely convey excess water to an appropriate outlet. This chapter explains how to verify soil erosion issues, presents different types of erosion control structures, and shows how to plan for their implementation.

Some surface drainage structures are intended to remove ponded water from depressional areas on cropland. However, not all surface water is ponded. In fact, ponded water can become runoff if permitted to overflow into low runs (draws) in unevenly sloped fields.

On sloping cropland, runoff can lead to the erosion of soil particles. Cropland erosion in uniform layers is known as *sheet erosion.* Erosion caused by concentrated flow forms *rills.* When the rills develop into channels large enough to prevent crossing by farm machinery, these channels are known as *gullies.*

Subsurface drainage systems remove excess gravitational waters – making room for precipitation to infiltrate cropland soils. In this regard, subsurface drainage systems are an integral component of soil and water conservation systems.

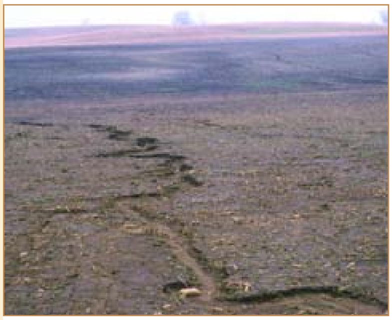
VERIFYING EROSION CONTROL PROBLEMS

Erosion can be verified on-site by looking for:

- ► eroded knolls ("white-caps") and shoulder slopes (usually the result of tillage erosion)
- ► washouts (rills)
- ► aprons of topsoil in depressional areas after a storm event
- ► off-site (or on-site) movement of runoff and sediment.

In a field with a 5% slope and loamy soils, the rate of soil loss and runoff would be even greater if there were small pathways for water to run downhill. Unchecked, these small pathways can lead to rills and gullies.

Soil erosion problems are more visible if soils are left bare.



Rill erosion can be a serious problem on complex slopes, even when no-till is practised. The remedy is to use erosion control structures to capture surface water and deliver it to the subsurface drainage system.

EROSION CONTROL STRUCTURES

Erosion control structures are designed to control erosion and safely convey surface water to an adequate outlet. Common examples include grassed waterways, terraces, and water and sediment control basins (WASCoBs). In many of these systems, the rate of water removal has been reduced.

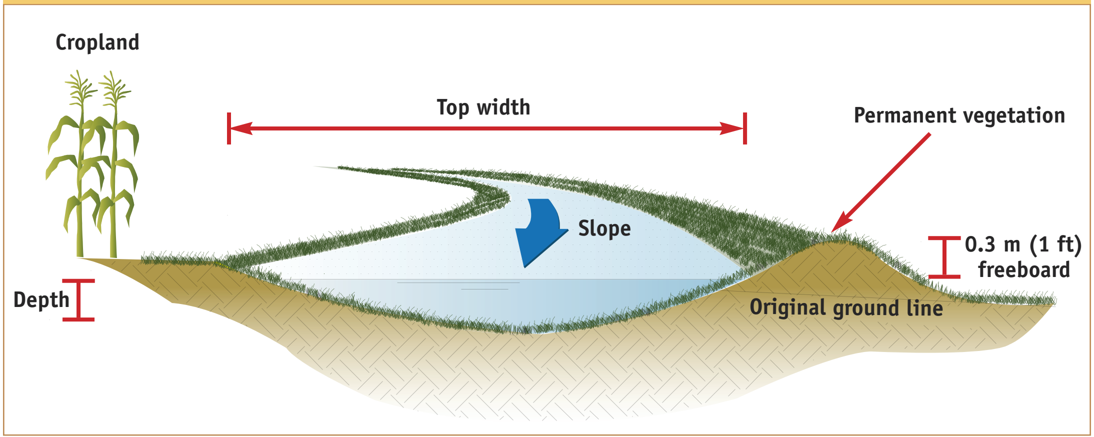
Calibrated stand-pipe inlets (e.g., Hickenbottom inlets) in WASCoBs will limit sediment loading from runoff events by allowing the water to pond for a short period of time and soil particles to settle out before entering the inlet.

Erosion control structures will move surface runoff to subsurface drainage systems and, by strategic placement, will limit the erosive forces of runoff events. This type of erosion control structure includes diversion terraces and narrow-based terraces.

Erosion control structures are designed and constructed to convey overland flow safely to a proper outlet.

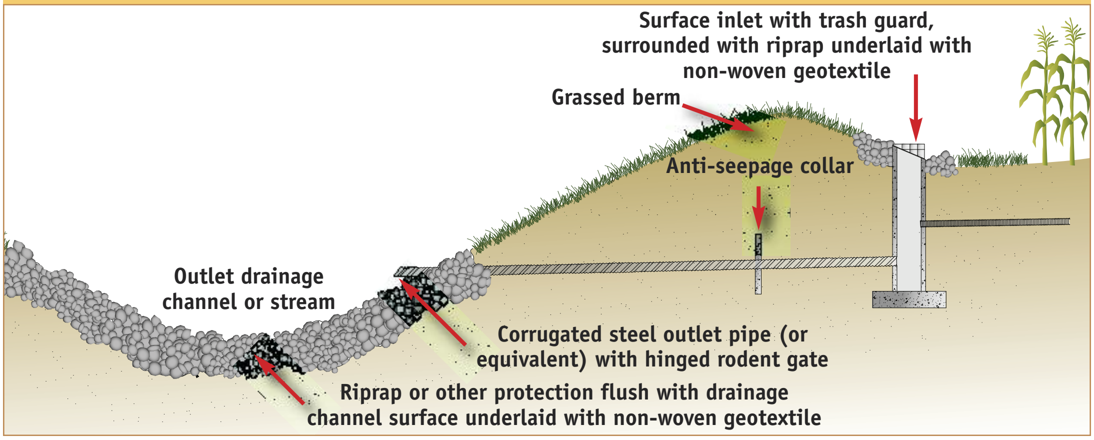
✔ **Grassed waterways are graded and grassed channels placed in low draws with subsurface drainpipe, intended to divert and transfer runoff to a properly protected outlet. They work best when established as part of an erosion control system that includes soil conservation BMPs such as no-till and mulch tillage.**

DIVERSION TERRACE CROSS-SECTION



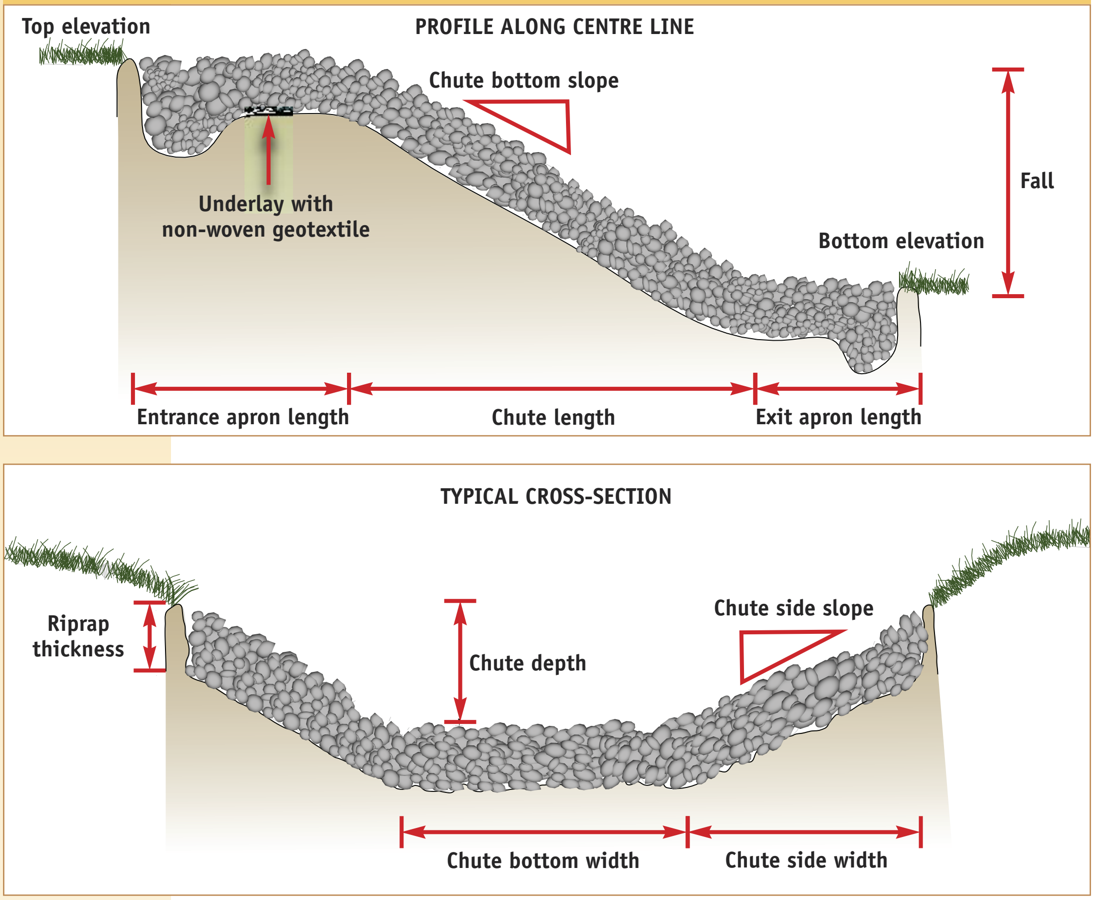
✔ **A diversion is a combination of channels and berms placed across slopes to slow down runoff and reduce erosion. The water is conveyed to a surface inlet where the water is then carried via an underground drainpipe to a proper outlet.**

DROP-PIPE INLET AND OUTLET FOR SUBSURFACE DRAINAGE SYSTEM



✔ A <u>large-diameter pipe (drop pipe)</u> is installed to convey water down steep slopes or high drops to prevent ponded water or concentrated flow from forming large rills or gullies.

ROCK CHUTE SPILLWAY



✔ <u>A rock chute spillway</u> is a constructed chute using angular stone (riprap) and underlaid with filter cloth. Rock chutes are often placed in riparian areas to convey concentrated surface flows safely to watercourses. As with all erosion control structures, rock chute spillways are most effective when managed as part of a soil conservation system.

✔ **WASCoBs are earthen embankments across draws, with retention basins and calibrated stand-pipe inlets (drop-pipe inlets) to convey water to an adequate pipe outlet. These structures reduce downslope erosion. The duration of temporary ponding is carefully engineered to reduce the risk of damaging the crop. Inspect after major storm events and ensure that the inlet pipe is not blocked by sediment or crop debris.**

PLANNING FOR EROSION CONTROL STRUCTURES

✔ Seek technical advice for design and construction from professionals and trained contractors.

✔ Consider the following factors in the planning process:

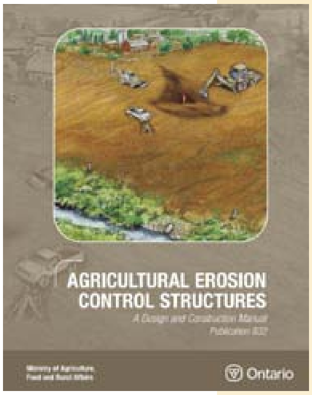
- **future land use** – whether the land will remain in its current land use
- **slope, slope length, soil type, upslope (in-field) watershed size** – must be considered when designing structures for size and safety
- **cropping and tillage practices** – how compatible a particular structure would be for current crop types, field operations
- **cost of options** – which option provides the most value for the investment required
- **potential improvements or changes to downstream water system.**

✔ To manage concentrated flow and reduce potential risks, you could:

- protect the low draw
- reduce the length of eroding section by segmenting into smaller units
- divert the flow below the surface.

In fact, most erosion control structures are designed to attain one or more of these goals. For example, WASCoBs reduce the length of eroding section and divert the flow below the surface. Multiple units can be installed.

For more on cropland conservation structures, see the Best Management Practices book, *Controlling Soil Erosion on the Farm.*



For more information, please see OMAFRA Publication 832, *Agricultural Erosion Control Structures – A Design and Construction Manual.*

BMPs FOR SUBSURFACE DRAINAGE

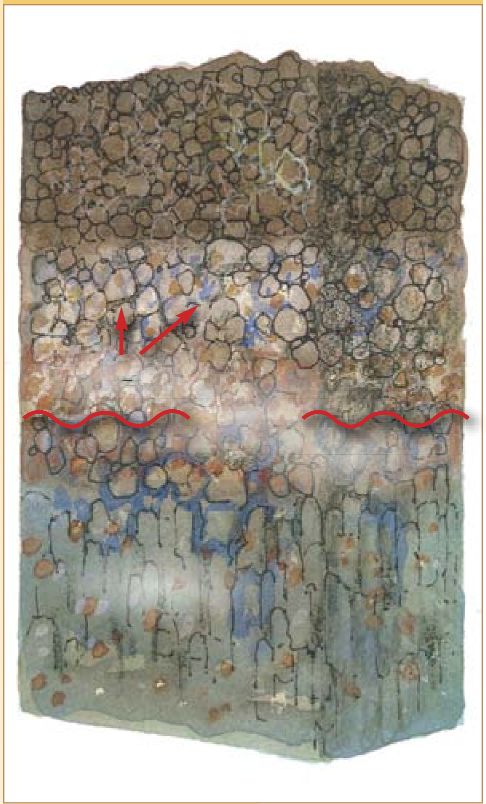
Accurately diagnosing drainage problems is the first task when planning an effective subsurface drainage system. This chapter opens with tips for diagnosing problems and sets out the planning steps for a drainage project. BMPs for design are explained, including drainage coefficient, depth and spacing, drainpipe sizing, layouts and systems, outfall (end pipes), and seepage control. Moving to the installation stage, handy checklists for contractors and landowners are presented for before, during, and after construction. The chapter closes with BMPs for system management, including maintenance and troubleshooting, as well as a brief look at controlled drainage and subirrigation.

The main challenges for subsurface drainage are:

- ► managing crop inputs and other contaminants
- ► removing excess water but also conserving water
- ► managing wet areas, and
- ► protecting adjacent wetlands.

DIAGNOSING SUBSURFACE DRAINAGE PROBLEMS

CONDITIONS THAT REQUIRE DRAINAGE



In many cases, drainage systems are established or improved due to the limitations of local soil and site conditions. Also, we have a humid climate in Ontario, which means that on average there is a seasonal net surplus of water on most croplands. The growing season (optimum temperatures) is limited, and there is a need to have the soil in a good hydrologic condition for the full growing season.

Soils may need drainage for one or more of the following reasons.

Uneven soil moisture conditions. Soil moisture conditions are not sufficiently uniform for efficient operations on fields with highly variable soil types and slope positions.

Inadequate natural drainage for the crop's sensitivity. Some crops are very sensitive to water ("wet feet"), and easily damaged if roots are in saturated soil – even for a short period of time. Some soils have average natural drainage, but are unsuitable for the crop's needs.

Soils with naturally high seasonal water tables. Found in level-to-depressional topography or where impermeable subsoils limit water infiltration, these soils will benefit from systematic drainage systems. Such soils are referred to as poorly and imperfectly drained soil types on soil maps and reports.

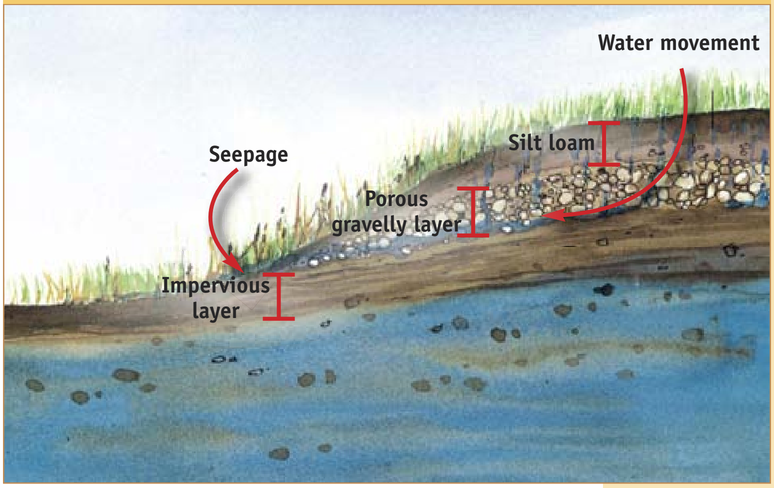
Cropland soils with a drainage class of "poor" require subsurface drainage. Poorly drained soils have a high water table for most of the year. To verify poor drainage, check for a zone of mottles and gley colours in the top 50 cm (20 in.) of the soil profile.

Water will not flow to outlet because land is too flat or natural surface barriers limit movement of water. Such sites are often in depressional areas.

Artificial barriers. Constructed barriers that obstruct or limit the flow of water include roads, fence rows, dams, dikes, bridges, and culverts of insufficient capacity and depth.

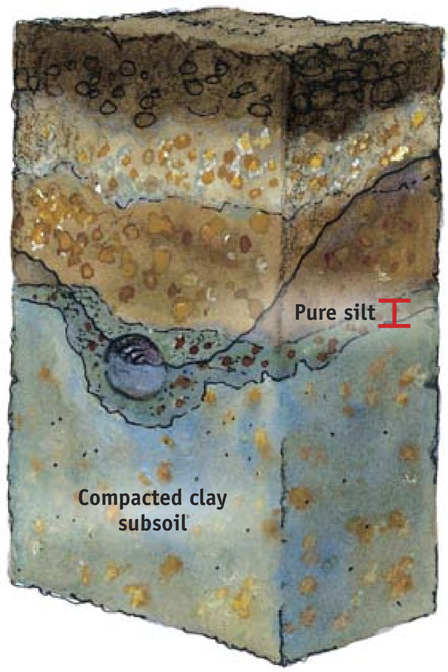
Seepage areas. When water table conditions cause groundwater to be discharged on a sloping field, the soil can be sufficiently saturated to require drainage. **A single seepage area can render a large area of cropland unfit for crop production.**

SIDE SLOPE SEEPAGE



Impermeable soil materials. Soil layers of low permeability that restrict the downward movement of water trapped in small surface depressions or held in the soil profile may benefit from drainage.

IMPERMEABLE SOIL

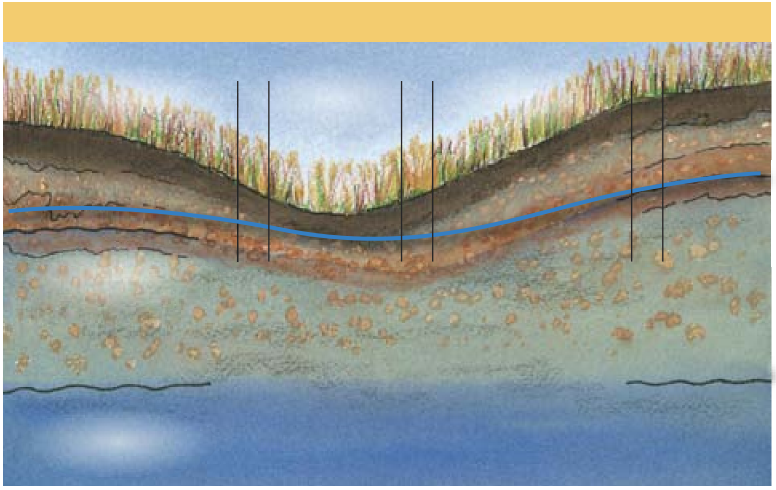


In some cases, subsurface drainage pipes are surrounded by impermeable soils such as heavy clay, pure silts or compacted subsoils.

Look for zones of mottles and gley colours around the existing drainpipe when identifying soil drainage problems.

Recharge areas don't normally require drainage improvements because water naturally moves rapidly to deeper levels.

VISUAL IDENTIFICATION OF DRAINAGE PROBLEMS



In April and May, on imperfectly drained and poorly drained soils, the water table is too high for seedbed preparation. These soils would benefit from subsurface drainage.

Indicators of poor drainage may include:

- uneven crop growth
- uneven crop colour
- water at or near the surface
- water-tolerant vegetation
- soil colours indicating a high water table
- soil colours indicating uneven or long drying period.

Locating Drainage Problems in the Soil Profile

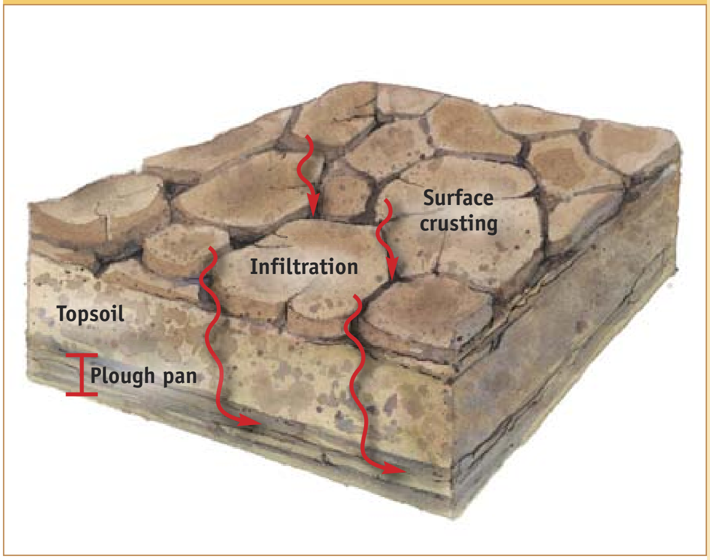
Drainage problems can be found in four places in the soil: at the surface, in the plough layer, in the subsoil, and around the drainpipe itself.

Most surface problems are associated with soil crusting – a sheet of soil that prevents infiltration. Following the rapid wetting and drying of an overworked seedbed, a solid sheet forms (0.2–5 cm or 0.8–2 in. thick) that is tight enough to prevent crop emergence. A track record of poor soil management and few organic matter inputs is most often the cause.

A similar impeding layer at the surface can result from "puddling" caused by a heavy rainfall of large rain droplets. Here the surface is compacted by the droplets, creating a barrier.

✔ Adopt farming practices that maintain good soil structure and organic matter/crop residue help to prevent crusting.

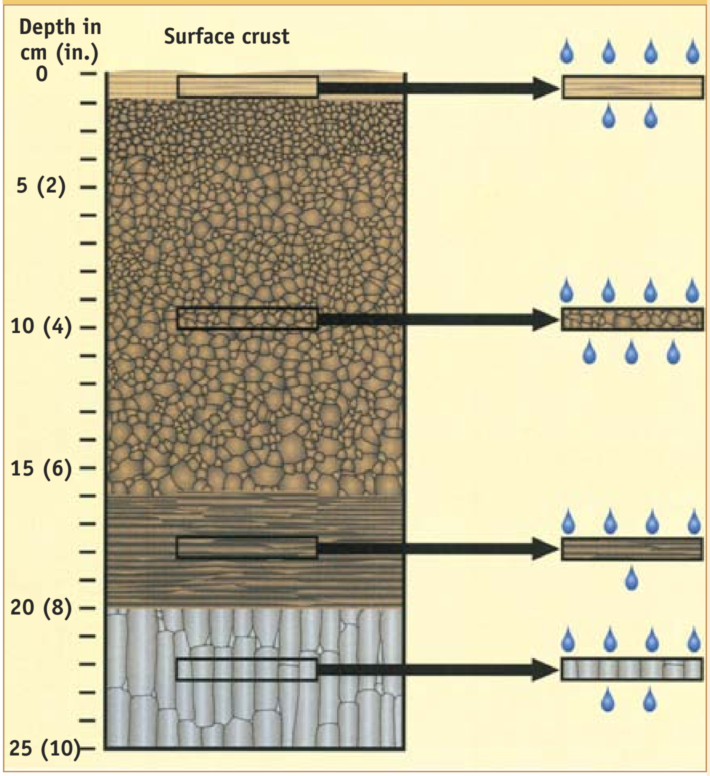
SURFACE STRUCTURE PROBLEMS



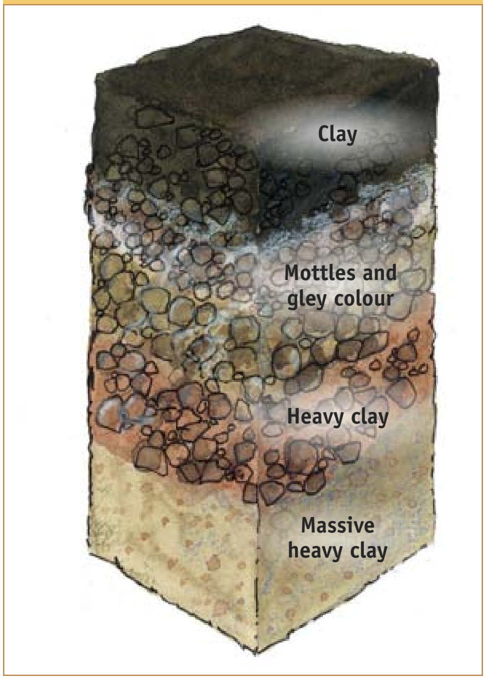
Most plough-layer drainage problems are actually compaction problems. Compaction is the process of increasing soil density by packing soil or smearing particles closer together. It can occur anywhere in the soil profile, but tends to be seen near the surface or at plough depth.

✔ Consider a range of BMPs, including tillage at proper soil moisture conditions, use of deep-rooted crops, and mulch tillage to reduce the impact of compaction on soil structure.

PLOUGH-LAYER PROBLEMS



SUBSOIL PROBLEMS



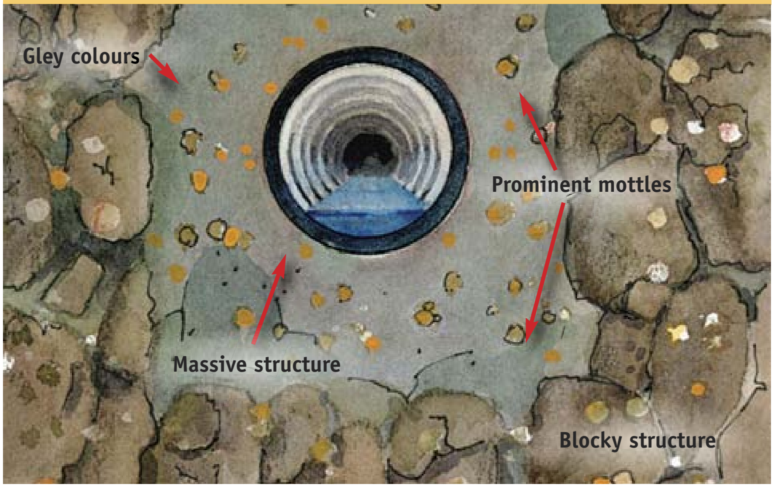
Subsoils can be impermeable and cause surface drainage problems. Impermeable subsoils are usually:

- **heavy clays – soils with high clay contents and low natural permeability**
- **massive soils – clay, usually poorly drained soils, with massive structure where there are few connected macropores to aid drainage**
- **compacted soils – some glacial till soils were smeared and compacted during deposition**
  - **more common near the Canadian Shield.**

Other soils have naturally high water tables, and so cannot store additional water.

✔ Have the problem properly evaluated by a licensed drainage contractor to determine course of action.

PROBLEMS AROUND THE DRAINPIPE



When water can neither permeate the soil around the drainpipe nor enter the drainpipe, it's known as *entrance resistance*. This can artificially elevate the water table. When operating in saturated soils, drainage equipment can sometimes smear soil. Gley colours and mottles around the drain indicate a problem.

✔ Avoid installing subsurface drainage in saturated soils if at all possible.

STEPS FOR PLANNING A SUBSURFACE DRAINAGE SYSTEM

Begin by determining the feasibility of the project. Your investigation should provide a clear understanding of the problem, the types of crops to be grown, which drainage designs will work, an estimate of the cost and value of expected benefits, and the impacts of the project. This information can often be obtained from a reconnaissance of a small problem area.

✔ Hire a professional licensed drainage contractor to conduct more detailed examinations and surveys that determine the size of the area, the drainage pattern, and special features where riparian vegetation, wetlands, or rock outcrops exist.

Environmental considerations must be a part of the cropland drainage planning process – including habitat enhancement or mitigation where needed.

INFORMATION REQUIRED TO PLAN A SUBSURFACE DRAINAGE PROJECT

STEP	INFORMATION NEEDED
1. RECONNAISSANCE	• nature and extent of drainage problem • location and condition of existing drainage system if one already exists • feasibility of outlet on neighbour's property – if necessary • whether activities or conditions on neighbouring property contribute to drainage problem • location of any utilities or pipelines
2. PROBLEM ANALYSIS	• watershed area • suitability of outlet • suitability of grades for mains • drainage system design
3. DETAILED SURVEY AND CHECKING FOR LEGAL OUTLET	• survey information to size watershed, to size field to drain, and to verify the presence of a legal outlet • estimate of surface runoff and water volumes/rates of subsurface flow through drains
4. DESIGN OPTIONS AND COSTS	• consideration and cost of any regulatory or municipal bylaw requirements (e.g., proper outlet, protection of wetlands, habitat, utilities and pipelines) • this step embraces all technical, environmental management, regulatory and economic information to help you make the best business decision
5. APPROVALS AND FUNDING	• compliance with any regulatory or municipal bylaw requirements

BMPs FOR SUBSURFACE DRAINAGE DESIGN

The intent of subsurface drainage is to remove only the necessary quantity of water that will ensure adequate cropland access and improved crop performance. Beyond that, it's important to conserve water to support crop growth during dry periods.

Drainage systems require proper planning, design, installation and maintenance. Design is critical. Improper design can lead to poor performance, failure, or repeated repair. Most drainage projects are designed by licensed professional contractors.

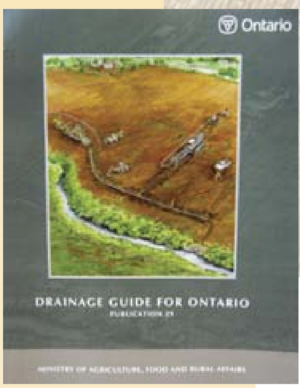
As a landowner, you will want to work closely with the contractor in the reconnaissance, surveying and design of your drainage project.

All subsurface drainage design should be conducted by trained and licensed professional drainage contractors.

Design factors include:

- ► drainpipe location
- ► spacing
- ► depth
- ► alignment
- ► materials
- ► outlets
- ► correct drainage coefficient for crops grown and soil type.

Design procedures must account for site factors (soil type, depth to water table, hydraulic conductivity) and the variability of soils and drainage requirements across the area to be drained.



For more detailed information on drainage design principles and practices, see OMAFRA Publication 29, *Drainage Guide for Ontario*. For more information on subsurface drainage and the Agricultural Tile Drainage Installation Act, check the Drainage page on the OMAFRA website, http://www.omafra.gov.on.ca/english/landuse/drainage.htm

DRAINAGE COEFFICIENT

The drainage coefficient or drainage rate is a design standard that reflects the amount of water that can be drained from a watershed in a 24-hour period. It is the physical capacity of the drainage system, and more specifically the main collectors. The coefficient is expressed in units of mm/24 hr (in./24 hr), i.e., surface equivalent. It does not reflect the soil's ability to transmit the water.

Part of the decision process is to ensure the soil and drainage system are balanced with the appropriate drainage coefficient needed for the crops to be grown. In some cases, expectations may have to be adjusted, as some soils will not allow gravitational water to move at the rate needed to protect the proposed crop.

The most common drainage coefficient used in Ontario is 12 mm/day (0.5 in./day) for cash crops on average soils. In other words, a drainage system designed to a 12 mm drainage coefficient would be capable of removing 12 mm of excess water from the entire subsurface-drained area over a 24-hour period.

If there is a heavier rain and more than 12 mm/24 hr needs to be removed, it would take longer to remove the excess water. Higher drainage coefficient rates are sometimes used for crops that are more susceptible to damage from excess moisture.

✔ Determine the drainage coefficient for your soil type and crop needs.

Check the *Drainage Guide for Ontario* for more information on drainage rate and other design ratings based on mapped soil series.

To protect crops, a subsurface drainage system must be able to remove excess water from the upper portion of the active root zone 24–48 hours after a rain.

DRAINAGE DEPTH AND SPACING

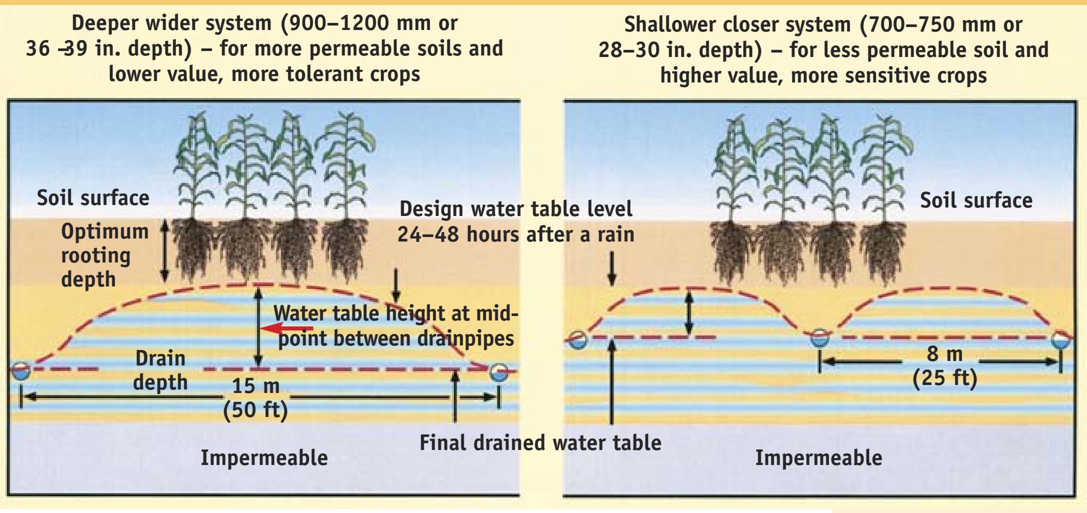
Place 100 mm (4 in.) laterals deep enough to prevent damage from tillage operations and from the weight of the equipment. A minimum cover depth of 600 mm (24 in.) is recommended. See the *Drainage Guide for Ontario* for more information.

Laterals' depth and spacing are linked, and should be selected jointly. Laterals must be shallow enough to provide timely drainage, deep enough to remove only excess water from the root zone, and spaced appropriately to get uniform drainage at the soil surface. The goal is to remove only the water that will impede proper crop growth.

Check the *Drainage Guide for Ontario* for recommended depth and spacing criteria related to the individual soil series as mapped and published in regional and county soil survey reports.

Main and sub-main drains must be deep enough to provide an easy connection point and a good outlet for lateral drains. Also, the maximum depth at which drains can be laid to withstand trench loading varies with the width of the trench and the crushing strength of the pipe to be used. Typical depths of header mains are 90–120 cm (36–48 in.) deep, but can be deeper as dictated by topography. A header main is there for the primary purpose of transporting water to the outlet.

SPACING AND DEPTH OPTIONS FOR DRAINPIPES



SIZING DRAINPIPE

The maximum amount of water a drainpipe can carry (its flow capacity) depends on the pipe's inside diameter, the installation grade, and the pipe surface roughness.

In the farm drainage industry, a more common way of reflecting drainpipe capacity is the area that can be drained through a particular diameter of drainpipe.

The following table shows how the capacity of a drainpipe to drain land is affected by size, material (roughness), and grade.

DRAINPIPE MATERIAL	GRADE OF DRAINPIPE	DRAINAGE COEFFICIENT	DESIGN CAPACITY
150 mm (6 in.) CORRUGATED PLASTIC PIPE	0.2% slope 0.2 m per 100 m slope (0.2 ft per 100 ft slope)	12 mm/day (1/2 in./day)	3.8 ha (9.3 ac)
The above row shows the capacity of a 150 mm diameter, corrugated plastic drainpipe with a grade of 0.2% to remove 12 mm of water from 3.8 ha of land in 24 hours.			
150 mm (6 in.) SMOOTH WALL e.g., clay, concrete	0.2% slope 0.2 m per 100 m slope (0.2 ft per 100 ft slope)	12 mm/day (1/2 in./day)	5.8 ha (14.3 ac)
The above row shows the capacity of a 150 mm diameter, smooth wall (clay, concrete) drainpipe with the same 0.2% grade. It has the capacity to remove 12 mm water from 5.8 ha of land in 24 hours – approximately 50% more capacity than a corrugated plastic tubing drainpipe of the same size and slope.			
150 mm (6 in.) CORRUGATED PLASTIC PIPE	0.4% slope 0.4 m per 100 m slope (0.4 ft per 100 ft slope)	12 mm/day (1/2 in./day)	5.3 ha (13.1 ac)
The above row shows the effect of increasing slope. While the pipe material and diameter are identical to the first row, the grade is now 0.4% instead of 0.2%. This changes the drainpipe's capacity to 5.3 ha. More slope, more capacity.			
200 mm (8 in.) CORRUGATED PLASTIC PIPE	0.2% slope 0.2 m per 100 m slope (0.2 ft per 100 ft slope)	12 mm/day (1/2 in./day)	7.6 ha (18.9 ac)
The above row shows the effect of increasing the diameter of the drainpipe. While the pipe material and grade are identical to the first row, the size is now 200 mm diameter instead of 150 mm. Capacity of the 200 mm corrugated plastic pipe is 7.6 ha – twice that of the 150 mm.			

Choosing the correct size of drainpipe is extremely important for main collector drains. Too small and the system does not function properly; too large adds cost to the system. A licensed drainage contractor can provide this information, or consult Publication 29, *Drainage Guide for Ontario* for the capacities of all sizes of drainpipe for different grades, drainage coefficients, and material.

Besides flow capacity, drainage systems should be designed to meet or exceed a certain minimum velocity of flow so that "self-cleaning" or "self-scouring" takes place.

LAYOUTS AND SYSTEMS

When selecting a layout pattern for a particular field or topography, there are a number of targets to aim for.

✔ Orient lateral drains nearly parallel to the field's contours, crossing the slope – not straight up and down. This way, water flowing downslope can be intercepted by laterals and the system will function more effectively and produce more uniform results.

✔ Orient lateral drains askew to tillage and planting pattern. This ensures that tracking of heavy equipment will be across the drainpipe and not lengthwise, thus reducing potential for damage and providing better traction for machinery. Also, tillage or row planting can alter the flow path of surface water. An askew pattern of drainage will ensure that gravitational water will be better intercepted by laterals and that drainage will be more uniform.

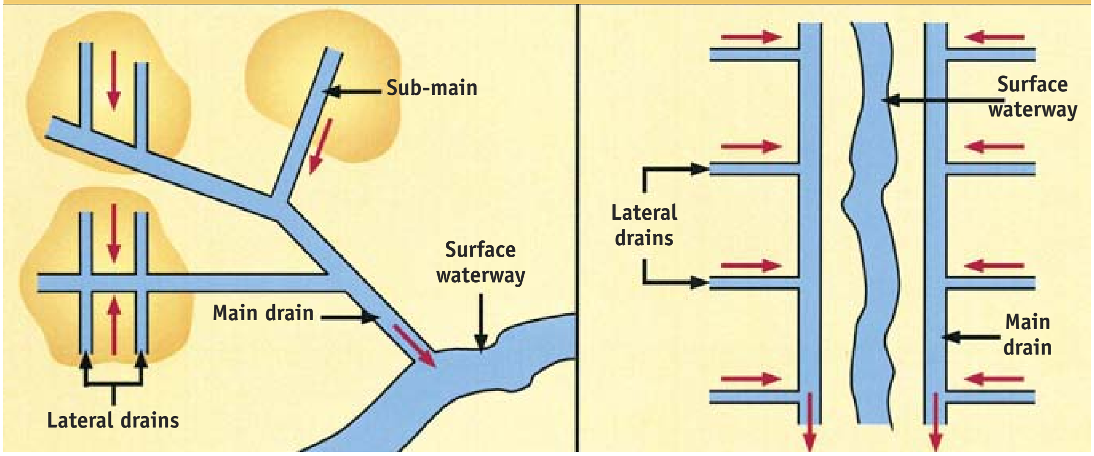
✔ Minimize the number of short lateral drains to reduce costs. Each lateral requires excavation to start installation and a connection to the header main.

✔ Balance the number and size of header mains for capacity and to reduce costs.

✔ Minimize number of outlets to reduce costs and maintenance.

Usually, not all of these objectives can be attained at the same time. A well-designed system will balance function with cost. Communication between the landowner and licensed drainage contractor is a must. Remember, a drainage system lasts a lifetime, and a little extra cost in the beginning is often an excellent investment in the long run.

RANDOM DRAINAGE SYSTEM

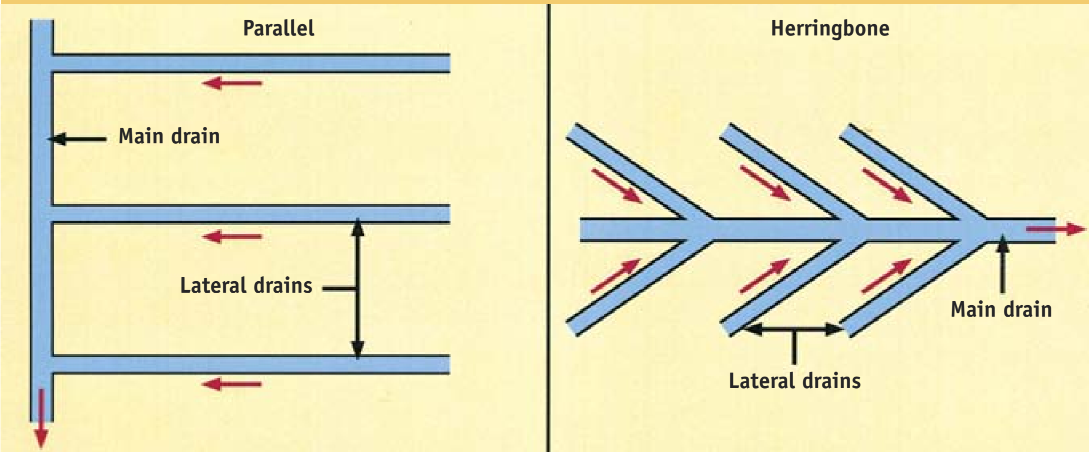


RANDOM SYSTEMS (SITE-SPECIFIC)

The main drain is generally placed near the lowest natural depression, and smaller drainpipes branch off to drain the wet areas.

Because such drains often become outlets for a more complete system established in the higher areas of the field, the depth, location, and capacity of the random lines should be considered as part of a complete drainage system.

SYSTEMATIC DRAINAGE SYSTEM



SYSTEMATIC SYSTEMS

Systematic patterns drain larger areas. There are two types: parallel and herringbone.

The parallel field drainage pattern consists of laterals that are perpendicular to the main drain or sub-main. In most cases, the laterals run parallel to a field boundary. Variations of this system are often used with other patterns.

The herringbone field drainage pattern consists of laterals that enter the main drain at an angle, generally from both sides. This system can be used in place of the parallel pattern. It can also be used where the main is located on the major slope and the lateral grade is obtained by angling the laterals across slope. This pattern may be used with other patterns in laying out a composite system in small or irregular areas.

The option of choosing the type of system layout is only available in new systems, or with complete system replacements.

✔ Align laterals across the slope and across the planting direction, which ensures that the general movement of both surface water and groundwater is across the lateral drainpipe.

This improves the potential to capture the water for drainage, and makes drainage more uniform. Herringbone systems can more easily achieve these objectives than parallel systems. However, in general, herringbone systems cost more to install, as usually there are more mains to install and more tap connections to be made to the main.

OUTFALL – END PIPE

The end pipe is a length of rigid non-perforated pipe that connects the main drain to a drainage channel or natural watercourse. It must be sufficiently large to:

- carry the water discharge from the main drain
- not cause any flow restrictions
- not cause any erosion
- remain stable in the bank.

End pipes are installed at the same elevation and slope as the main drain. They are simply a secure connection of the main drain to the surface water body.

The bottom of an end pipe should be located 300 mm (12 in.) above the normal water level in a receiving drainage channel or natural watercourse.

The discharging water may cause erosion in the receiving drainage channel or natural watercourse.

✔ Install an apron of rock riprap to prevent erosion.

✔ Equip all end pipes with rodent grates to prevent unwanted entry by animals.

✔ Inspect end pipes each spring to ensure proper functioning and that no debris is blocking them.

Proper placement and design of outfalls and end pipes are key drainage BMPs.

Drainage inlets are discussed in the previous chapter on page 26. For detailed information on sizing and construction, see the *Drainage Guide for Ontario*.

CONSTRUCTION CHALLENGES

Sedimentation – Drainpipe Plugging

Fine and very fine sands and silts are not sticky, which means it's easier for them to move through the orifices and into subsurface drainpipe.

✔ Evaluate whether special protection such as filters or envelopes may be required.

Consider different filter or envelope materials with specific pore sizes (e.g., very fine sands, 0.10–0.05 mm diameter) to ensure sediment or sand doesn't enter the drainpipe in these soils.

Filter materials known as non-woven geotextiles or woven filter cloth (sock) are widely used as pre-wrapped synthetic drain envelopes. These materials can be made from polyester, polypropylene, polyamide, polystyrene, and nylon. Filter materials may reduce sediment loading in drainpipe; however, no textile is suitable for all problem soils.

✔ Talk to manufacturers to see what envelopes may best suit your soil conditions. Consider providing them with a soil sample.

Ochre, an iron oxide, affects about 2% of cropland drainage systems in Ontario. It occurs in two soil conditions: acidic sands and poorly drained sands.

Ochre accumulates through chemical or microbiological processes, or both. It's a natural condition usually found where new land – sandy in nature with high organic matter – is cleared and drained. Recognized by brilliant red deposits at drain outfalls, iron ochre can seal drain openings very quickly.

At present there are no long-term solutions. If you encounter ochre:

► plan to replace or abandon the original system when it fails
► flush drainpipe with high-pressure water to provide temporary relief.

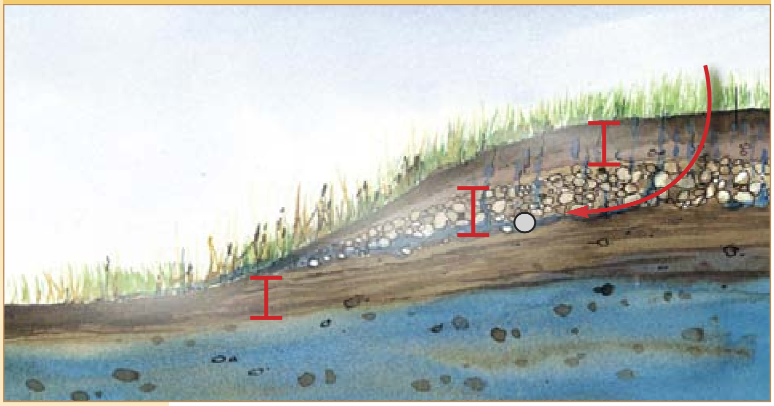
Connecting Old Drainage System to New System

If existing lateral drainpipes are relatively new, clean and not full of sediment, they are probably working. They can be hooked into the new subsurface drainage system.

However, if they are full of sediment, then relieve with crushed stone. Do not directly connect the two systems, as the old system may add excessive sediment.

SEEPAGE CONTROL

Interceptor drains are installed at right angles to the flow of groundwater to intercept subsurface flows. This drainage is applicable to broad, flat areas that are wet due to seepage from adjoining highlands, springs, seepage lines at two different layers of soil, etc.



Subsurface drains for interception of seepage must be located properly to correct wet areas usually found downslope from the seepage line. The seepage line can be located by digging test holes upslope from the wet area. The interceptor lines should be placed upslope from the wet area on the seepage line, and across the slope on grades slightly off-contour. Water is captured and drained away before it reaches the surface.

BMPs FOR INSTALLING SUBSURFACE DRAINAGE

BEFORE CONSTRUCTION

All agricultural subsurface drainage systems must be installed in accordance with the Agricultural Tile Drainage Installation Act. The act requires that each drainage contractor hold a valid business licence to install subsurface drainage systems on agricultural land, that each tile drainage machine be licensed, and that each operator of a drainage machine be licensed. These regulations do not apply to landowners installing subsurface drains on their own farm with their own equipment.

Review the Construction section of OMAFRA Publication 29, *Drainage Guide for Ontario.* It defines the minimum standard for workmanship, materials, and methods of construction acceptable for the installation of subsurface drains.

A list of drainage contractors is available from your nearest OMAFRA Resource Centre and the Land Improvement Contractors' of Ontario (LICO) website: www.drainage.org

BMP CHECKLIST FOR LANDOWNERS

Landowner Checklist – Before Construction

✔ Seek professional advice to verify that subsurface drainage will be a good investment.

✔ Have the soil examined if there's some doubt of its drainage properties – ensure soil is suitable for a subsurface drainage system.

✔ Discharge water at a location where collected water can be legally discharged without adversely affecting downstream landowners, e.g., natural watercourses, agreement drains, municipal drains

- determine whether a satisfactory outlet is available for the proposed work on your property
- if not, negotiate agreements, in writing, with neighbours and other parties to obtain authority to enter their property
- if this does not work out, consider a petition for a municipal drain under the Drainage Act – see section 7.

✔ Check with your local Conservation Authority regarding regulatory requirements.

✔ Visit the municipal office to ensure municipal drain requirements will be met.

✔ Ensure financing is in place to complete the project.

✔ Locate existing drainage plans of the farm.

✔ Obtain a plan for the entire farm, even though only a part is to be drained.

Coordinating your crop rotation to allow subsurface drainage installation in the summer or early fall (e.g., after winter wheat) has many advantages. Most drainage is installed with plough machines. When soil is dry (not saturated), you'll have the least amount of compaction and the greatest amount of soil fracturing. At the same time, some topsoil will fall into the fractures. This will optimize your drainage system's potential in both the short and long term.

✔ Plan with consideration for drainage of upslope watersheds or neighbouring farms' drainage flow.

✔ Make the contractor aware of the location of telephone, gas and oil lines, water lines, septic beds, hydro lines, and other buried utilities. Remember to "call before you dig."

✔ Arrange mutual agreements and easements (hydro and other utilities) in advance.

✔ Ensure that the contractor is aware of the location of manure storages and transfer systems so that the requirements for distance separation under the Nutrient Management Act can be accounted for when designing the drainage system.

✔ Point out the location of existing subsurface drainage to the contractor.

✔ To avoid the risk of soil compaction, install subsurface drains in the summer or fall whenever possible

- crop damage can be as little as 10% when subsurface drains are constructed through crops with care
- make use of strategic crop rotation planning, e.g., field to be drained is planted in wheat or hay
- construction should be in reasonably dry soil so its structure is not destroyed and drainability is not impaired – if the field is dry enough to work, it's dry enough to install subsurface drains.

Landowners who are doing their own installations near wetlands or regulated areas should contact their local Conservation Authority to determine whether regulations apply or approvals are required.

✔ Remove obstructions to construction such as fences, trees, etc.

- check with local municipality regarding tree-cutting bylaw requirements before removing trees.

✔ Decide on the point of delivery of drainage materials ahead of time.

✔ Plan a rotation one or two years in advance for the field to be drained

- use soil and cropland BMPs to improve soil conditions that will assist cropland drainage performance.

✔ Ensure that the subsurface drainage contractor:

- holds the proper and relevant licences
- carries adequate insurance
- has checked with local Conservation Authority to determine whether any CA regulations apply
- has been provided with the necessary permits to do the work.

Landowners should know the exact location of subsurface drainpipes on their property. This will help with subsequent monitoring, maintenance, and new installations.

Landowner Checklist – During Construction

✔ Monitor and inspect the work to ensure it's proceeding according to the agreed-upon plan.

✔ Consult OMAFRA's drainage inspector for advice if needed – call your nearest OMAFRA Resource Centre or the Agricultural Information Call Centre. See back cover.

Landowner Checklist – After Construction

✔ Keep a record of the work done:

- obtain and retain a copy of the cropland drainage plan as constructed by contractor
- ensure the contractor has prepared a plan of the subsurface drainpipe locations with any changes and problem areas noted on it that may affect future maintenance
- in the absence of a proper plan, obtain an aerial photograph of the work area.

✔ File the plan at the municipal office where required. This creates a permanent record, which helps locate the lines for future subsurface drainage repair or improvements.

✔ Keep a copy of the drainage plan, aerial photograph and any mutual agreement under the Drainage Act, with the deed to the property

- keep copies of municipal drain reports and plans.

✔ Watch for erosion of the drainpipe trench following rain events over the first two years.

✔ Mark the outlets, and check them each spring for possible erosion, discharge volume and clarity.

BMP CHECKLIST FOR CONTRACTORS

Contractor Checklist – Before Construction

✔ Contact the local Conservation Authority or check their website to find out if any portion of the property is regulated. If it is regulated, find out if approval is required to install the subsurface drainage system.

✔ Ensure landowner has obtained all licences, permits and easements prior to moving onto the site.

✔ Ensure that the final plan has been agreed upon by landowner.

✔ Notify landowner where and when design changes may have to occur during construction.

✔ Inspect the site with the owner to ensure adequate outlets are available, utilities have been located, and possible problems identified (e.g., the soil is not drainable)

- inspect the soil profile to below drain depth
- advise the owner regarding necessary notices to third parties.

✔ Agree with the owner on the financial costs, and how and to whom the costs are to be paid.

✔ Determine whether there is an adequate outlet.

✔ Review Occupational Health and Safety Act requirements for health and safety on the job site, and remind workers of them.

Conservation Authority regulations may apply to some cropland, e.g., where wetlands or floodplains occur. Prior to undertaking any drainage work, contractors should contact the local CA or check the CA website to find out if any portion of the property is regulated, and if approvals are required.

Contractor Checklist – During Construction

✔ Comply with applicable legislation.

✔ Adhere to Occupational Health and Safety Act requirements on the job site.

✔ Follow all safety procedures.

✔ Keep casual observers away from construction operations.

✔ Erect safety barriers to prevent public access to the work.

✔ Restrict all machine and truck movement on the field to designated paths.

✔ Do not backtrack plough trenches to compress them: it may damage drainpipes and affect drainability.

✔ Inspect all cropland drainage materials before installation to ensure they're free from defects and meet approved quality standards for their intended purpose.

✔ Store drainage materials so they won't be damaged before installation.

✔ Check existing drainage systems for agronomic and hydraulic efficacy.

✔ Don't connect drainpipes that appear to be polluting.

✔ Minimize the number of outlets to reduce system maintenance.

✔ Maintain and operate the installation equipment so drainpipe is installed in accordance with the designed grade and depth.

Provide a copy of the plan to the landowner.

Contractor Checklist – After Construction

✔ Ensure the following information is on the plan to be left with the landowner:

- date of construction
- name of the contractor
- alterations to the original plan
- drainpipe type, size, footage, and materials
- details of construction problems
- location of utilities, sand pockets, springs, etc. that may affect future maintenance
- suggestions for future work additions.

BMPs FOR MANAGING SUBSURFACE DRAINAGE SYSTEMS

INSPECTION AND MAINTENANCE

Annual maintenance and good soil management practices are your best insurance for the successful long-term operation of your drainage system.

✔ Adopt soil management BMPs – cropland drainage system performance may be hindered by poor practices.

✔ Check outlets regularly

- make more thorough inspections in the spring or late fall when the soil is wet and the subsurface drainpipes are running
- mark locations in need of repair or maintenance
- make sure outlet marker is still in place and clearly visible.

✔ Schedule maintenance or repair work when field conditions are drier.

✔ Keep up a preventative maintenance program, including:

- keeping a plan of the cropland drainage system
- cleaning surface inlets and outlets
- repairing the outfall.

Cropland drainage systems require routine monitoring to ensure that the entire system is performing the expected function of safely conveying water to a proper outlet.

✔ Make routine, periodic inspections of drainage system components to ensure minimal environmental impact.

PROBLEM VERIFICATION

In practice, you will notice the inefficiency of a drainage system when water stands on the field for a long time, and in spring when the topsoil remains wet too long. Isolated wet spots in the field, surface wash-ins, and blowouts along the installed drainpipe are indications of drain problems.

The value of a proper drainage plan or aerial photograph of the system becomes very apparent when maintenance is needed.

For more information on drainage system maintenance and management, please refer to:

► OMAFRA factsheets, *Operating and Maintaining a Tile Drainage System*, Order no. 10-091, *Drain Problems*, Order no. 84-017, *Maintenance of the Drainage System,* Order no. 87-062 and *Management of Drained Fields,* Order no. 90-156

► the OMAFRA Drainage website http://www.omafra.gov.on.ca/english/landuse/drainage.htm

► your local Conservation Authority.

TROUBLESHOOTING

Diagnosing and troubleshooting drainage problems is an ongoing process that's both simple and complicated, and requires the landowner to pay attention to changes in the field drainage conditions.

Take note of changes to the wetness of a field or specific location, or to the uniformity of crop growth. After a rain, the soil will change colour as it dries and usually forms a pattern. Pay attention to these details. If the pattern changes, there may be a problem.

Some problems are very obvious in the form of easily visible wash-ins or washouts or water bubbling to the surface. These are abrupt changes. Other problems occur over time, e.g., iron ochre, tree roots, partial collapse of a plastic drainpipe. These are identified by changing conditions.

In most cases, a standard approach to fully identify and diagnose the problem is to expose the drainpipe on the downflow side of the wet area. Excavate the soil covering the drainpipe in the upstream direction until the problem is found. Diagnose and repair.

The following chart lists the most common drainage problems that you might encounter and what to look for.

TROUBLESHOOTING SUBSURFACE DRAINAGE

ITEM	WHAT TO LOOK FOR (SYMPTOM)	POSSIBLE CAUSES	PREVENTATIVE MEASURES	CORRECTIVE MEASURES
BLOCKED PIPE	• water bubbling to surface like a spring above the drainpipe • holes in soil above drainpipe • water not draining • trees close to drainpipes	• collapsed or crushed drainpipe • damaged or poorly installed drainpipe connection • sediment buildup or blockage in drainpipe • tree roots in drainpipe • dead animal blocking drainpipe	• ensure proper design, depth, location, and installation • avoid travelling over drainpipes with heavy equipment in wet conditions • do not plant water-loving trees within 30 m (100 ft) of drainpipe – all other trees, 15 m (50 ft) • install/repair rodent guards at outlets	• repair immediately, and replace damaged drainpipe • use rigid or double-wall drainpipes under high-traffic areas • relocate/resize drainpipe • remove problem tree(s) • use non-perforated drainpipe along problem tree • use high-pressure water system to clean out line • install/repair rodent guards at outlets
BLOWOUTS AND CAVE-INS	• similar to blocked drainpipe except water will go back down hole as well as come out	• poor design, inadequate grade, undersized drainpipes • drainpipe slope changes from steep to flatter, causing pressure buildup	• ensure drainpipe is properly sized to handle flows • use a relief well in the design or use larger-diameter drainpipe	• replace drainpipe with larger diameter • if high pressures persist, vent as necessary – relief well
		• partial collapse of drainpipe resulting in flow restriction and pressure buildup • faulty connections	• avoid travelling over drainpipes with heavy equipment in wet conditions • ensure proper installation	• replace damaged drainpipe • repair poor or damaged connections
		• too much surface water diverted to subsurface system		• make use of flow restrictors on surface inlets
HIGH TRAFFIC AREA	• drainpipes under laneways • water not draining	• compaction • crushed drainpipe	• use rigid drainpipe beneath traffic area	• replace drainpipe if necessary

TROUBLESHOOTING SUBSURFACE DRAINAGE				
ITEM	**WHAT TO LOOK FOR (SYMPTOM)**	**POSSIBLE CAUSES**	**PREVENTATIVE MEASURES**	**CORRECTIVE MEASURES**
SEDIMENT AND DEPOSITS FROM UNSTABLE SOILS	• decreased flow capacity causing areas of field to drain more slowly than normal • excess sediment in drainpipe	• no envelope on drainpipe	• verify presence of problem soils • use filter cloth • design with self-cleaning (steeper) grade	• replace with envelope-wrapped drainpipe • use high-pressure cleaning equipment to remove sediment
QUICKSAND	• soil is saturated at depth or near surface and will not settle	• upward pressure from groundwater in fine and very fine sand and silty soils	• install drainpipe when dry • install on solid bedding	• replace drainpipe in area of quicksand
IRON OCHRE	• reduced drainage each year in low area of field • reddish-orange slime at outlet • crusting around drainpipe when dug up • gelatinous growth in drainpipe	• natural condition of low-lying area of field triggered by installation of drainpipe and introducing oxygen	• very difficult to identify ahead of time • consider controlled drainage during growing season and flooding drainpipe in non-growing season to slow down action	• replace drainpipe • consider controlled drainage during growing season and flooding drainpipe in non-growing season to slow down action
DAMAGE TO SOIL STRUCTURE	• water ponding above drainpipe, yet soil somewhat dry underneath surface layer	• compaction layer • drainpipe installed in wet conditions	• stay off wet soils • modify axle weights • vary tillage depth • reduce tillage passes	• introduce deep-rooted crops into rotation • add organic matter
EROSION IN GRASSED WATERWAY CHANNEL	• drainpipe exposed in bottom of grassed waterway	• drainpipe too close to channel centre • prolonged flow in grassed waterway	• offset drainpipe from centre of grassed waterway	• install new drainpipe away from channel centre • install larger drainpipe to reduce length of time of overland flow
TREE ROOTS	• drainpipes near trees • water not draining • land wetter than other areas of the field	• some species more problematic than others • more acute in continuous flowing drainpipe	• route drainpipe 30 m (100 ft) from water-loving trees, and at least 15 m (50 ft) from all other trees <u>or</u> install sacrificial drainpipe next to tree • use non-perforated drainpipe within 15 m (50 ft) of tree	• reroute drainpipe beyond crown of trees • replace plugged areas • consider non-perforated drainpipe in problem areas • remove problem trees

TROUBLESHOOTING SUBSURFACE DRAINAGE

ITEM	WHAT TO LOOK FOR (SYMPTOM)	POSSIBLE CAUSES	PREVENTATIVE MEASURES	CORRECTIVE MEASURES
LOSS OF ORGANIC SOILS	• reduced depth of organic soil • mineral soil layer exposure • black and discoloured snow	• organic soils over-exposed to oxygen • drainpipe installed too close to an underlying impermeable mineral soils	• install subsurface drainpipes in organic soils and above mineral soils • manage high water levels in non-growing season to avoid wind erosion and oxidation of soil	• change cropping system or land use – less tillage, more vegetative cover
POOR QUALITY WATER (FARMSTEAD LOCATION)	• odours or solid waste in drainpipe at outfall • odours or solid waste in drainpipe dug up just downslope from farmstead	• manure storage, milking centre, septic or other wastes	• keep drainpipes away from source of contamination (vice-versa also true)	• take immediate action – locate source and eliminate connection • reroute drainpipe away from source
POOR QUALITY WATER AT OUTLET PIPE (FIELD LOCATION) – NON-POINT SOURCE	• odours, unusual brown discolouration, or manure in outflow • fish kills • excessive algae • excessive sediment	• poorly timed applications of crop inputs, e.g., manure, sewage biosolids, fertilizer, herbicides • untimely rainfall after application • excessive application rates • soil cracks or worm tunnels • accidental spill in field	• reduce application rates • pre-till to break flow-paths • split applications • improve application timing • apply manure when drainpipes not flowing • develop emergency response plan • consider installing in-line viewing stations for visual check of water quality flowing in drainpipe – same unit can also be used to stop flow in some instances if needed • check outlet pipe each spring, before and after major rain events, when applying manure etc.	• reduce application rates • pre-till to break flow-paths • split applications • improve application timing • apply manure when drainpipes not flowing

As with pipe outlets and surface inlets, regular inspections are an excellent early-warning system to help you troubleshoot.

Drainpipe blowout.

A 100 mm (4 in.) drainpipe containing 20 mm (3/4 in.) of sediment will have its discharge reduced to 80% of capacity. With 30 mm (1 in.) of sediment, the capacity is reduced to 65%.

Drainpipes near treed fencerows are at risk of being clogged by roots of fast-growing trees such as poplar, willow, elm and soft maple.

CONTROLLED DRAINAGE AND SUBIRRIGATION

In specific conditions, a subsurface drainage system can be used to maintain soil moisture at levels that meet crop requirements throughout the growing season.

Controlled drainage uses water table level-control devices and drainpipes to hold back some of the water that would normally drain to an outlet. By doing so, more water is made available for plant growth by capillary action and for a longer period of time. Under normal drainage conditions, the water table over time is lowered to the bottom of the drainpipe. With the control devices, the lowering of the water table is managed to a strategic depth conducive to root development and crop growth. Without additional rain, the water table will continue to lower because of evapotranspiration and normal deep percolation.

Controlled drainage may also be used to hold back soil water in non-cropping seasons (winter). It has been successfully used in muck soils to reduce soil loss in the non-growing season.

Subirrigation adds another dimension to the system. The water table is maintained at the optimum location for plants to use by adding water to the drainage system, usually with pumps, or in some instances by gravity. Hence, a water supply is required to make this system function. The water supply can be a separate source such as a river, stream or well, or it could be water that was captured from the drainage system and stored for irrigation.

For both practices, soil water contaminants may be withheld or allowed to be processed to other less environmentally harmful forms. (For example, nitrate is converted to nitrogen gas through denitrification.)

Research continues to evaluate the effectiveness and conditions under which these technologies may be used. Site conditions must be appropriate – such as flat terrain, proper drainpipe spacing, and an impermeable layer at or below but near the drainpipe depth – to make effective use of this emerging technology.

Controlled drainage has not been extensively tested in Ontario. Site requirements are often too limiting: there are few sites with the precise soil and slope requirements to make controlled drainage effective. Normal subsurface drainage design in Ontario – with shallow drainpipe depths – approximates the same intended effect of controlled drainage.

Controlled drainage and subirrigation show promise where soil and site conditions are suitable and the water supply is adequate.

BMPs THAT COMPLEMENT CROPLAND DRAINAGE

Not all drainage BMPs relate directly to the planning and management of drainage infrastructure. Soil health and management practices can help to reduce the need for drainage caused by soil degradation. Other practices, such as proper pesticide and nutrient application, can help reduce the concentration of soil sediment and crop inputs moving into and out of cropland drainage systems. This chapter introduces several of these BMPs, which are explored fully in other BMP books.

Soil organic matter is a very small part of the soil with a large role to play. Many soils used for crop production have soil organic matter levels between 2 and 4%. And yet, organic matter is second only to soil texture in importance.

BMPs FOR SOIL MANAGEMENT

Many problems with wet soil and drainage maintenance can be prevented or rectified with soil management BMPs.

Soil management BMPs include practices that:

- add organic matter
- reduce organic matter loss
- improve structure and porosity
- reduce the risk of compaction.

You will definitely find some overlap among the BMPs that address a particular problem. This is good news: adopting one measure can often help you on several fronts.

Organic Matter Additions

Growers can directly affect the organic content of their soils. Excessive tillage, soil erosion and poor crop rotation will accelerate the loss of organic matter. On the other hand, there are a number of BMPs that maintain and improve organic matter.

✔ **Forages in rotation such as grass or legume-based hay crops will add some organic matter and greatly improve seedbed structure in the short run. Suitable forages include: trefoil, red + alsike clover, orchardgrass, and timothy.**

✔ **Cover crops such as rye, oats and barley are suitable cereal cover crops for most soils. Others such as field peas, buckwheat, and oilseed radish can also be useful. Cover crops improve surface drainage conditions.**

Conservation Tillage Systems

Conservation tillage systems such as no-till involve very limited tillage and the management of residue left by the previous crop. Mulch tillage (e.g., chisel plough) mixes residue into the soil surface to reduce wind and water erosion. Vertical tillage leaves more residue on the soil surface than mulch tillage, and reduces the potential for tillage erosion.

- ✔ **Mulch tillage refers to any system where the soil is moderately disturbed between harvesting one crop and planting the next, and at least 30% of residue is left on the soil surface. Mulch tillage systems improve infiltration rates and reduce runoff.**

Reducing Surface Crusting

Following the rapid wetting and drying of an overworked seedbed, a solid sheet forms (0.2–5 cm or 0.07–2 in. thick) that is tight enough to prevent water infiltration and crop emergence. A track record of poor soil management (e.g., excessive tillage) and few organic matter inputs is most often the cause.

- ✔ **Adopt tillage options that maintain at least 50% of aggregates greater than 2 mm (0.07 in.) or use reduced secondary tillage, no-till or mulch tillage to reduce soil structure degradation and leave crop residue on the soil surface.**
- ✔ **Rotate crops to include soil-building crops such as grasses and legumes or cover crops.**
- ✔ **Manage manure to build soil organic matter.**
- ✔ **Use timely tillage. Prevent soil clodding by tilling only when soil moisture is suitable. Only use a rotary hoe to break up the crust if a crust has formed before the crop emerges: this is a remedial measure.**

Reducing Compaction

Compaction is the process of increasing soil density by packing soil particles closer together. It can occur anywhere in the soil profile, but tends to be seen near the surface or at plough depth. Soil compaction can impede the movement of water through soil by gravity. Soil management BMPs can lessen the impact of compaction on soil structure.

- ✔ Time operations with care. Stay off wet fields. Check that soil has proper moisture conditions for working at (and below) tillage depth.
- ✔ Use longer crop rotations that include forages/cereals. Soils with subsurface drainage can grow a wider range of deep-rooted crops (e.g., alfalfa).
- ✔ Limit the amount of traffic, including tillage, across a field.
- ✔ Use controlled traffic strategies such as tramlines or strip tillage.

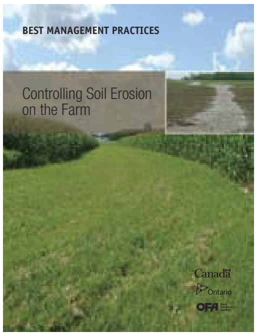
✔ Adjust tillage equipment. Ensure it lifts and shatters soil (coulter chisel, cultivator) as opposed to pulverizing and grinding (disk). Alternate tillage depth so that tillage pans aren't created, or try no-till.

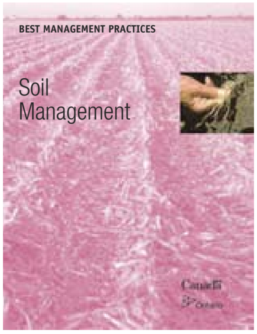
Non-Tillage BMPs for Cropland Conservation

Non-tillage practices can help to control erosion by reducing the effect of steep slopes and increasing soil cover. Conservation practices include cropland buffers and contour farming.

- ✔ In areas of extreme erosion, consider retiring the land with tree plantings.

✔ Contour strip cropping involves alternate strips of row crops, cereals and forages on the contour level, which slow surface flow and increase infiltration rates.





BMPs TO MINIMIZE CROP INPUT RUNOFF

Without careful consideration and management, crop inputs applied to cropland can find their way to drainage channels and natural watercourses.

Implement BMPs on the land adjacent to the surface channels or surface inlets (including blind inlets) to reduce the risk of these materials entering the cropland drainage system. Take special care when applying nutrients, manure, or pesticides in fields where surface inlets have been installed.

By combining the BMPs in the previous section with BMPs for nutrient and pesticide application, you'll drastically reduce the potential for contaminated drainage outflow.

Nutrient Application

Crop nutrients are applied to soil in the form of inorganic fertilizers, manure and biosolids. The following BMPs are suitable for the application of all forms of crop nutrients.

✔ Test soil regularly. Follow soil test results. In this way you'll apply what's needed – reducing risk of loss from the soil system.

✔ Calibrate crop nutrient (e.g., manure) application equipment. Accurate application rates and uniformity will reduce the risk of loss from cropland.

✔ Prepare and follow a nutrient management plan for your operation. It will help balance crop nutrient requirements with nutrient applications, and will set out effective separation distances.

To reduce the risk of manure in outflow, follow these BMPs.

✔ Reduce manure application rates if there's a chance for manure in outflow, i.e., when soils are too wet, in early spring and late fall, and following several consecutive days of rain

- always consider reducing rates instead of pre-tilling on highly erodible, fragile soil.

✔ Spread manure when the ground is dry and no water is flowing from the drainpipe.

✔ Pre-till land before applying liquid manure.

✔ Don't spread if any one of the following conditions is present:

- rainfall occurs shortly before application
- heavy rains are forecast within 12–24 hours of spreading on subsurface-drained lands
- ground is frozen and/or snow-covered.

✔ Incorporate manure when and where there is minimal risk for soil erosion.

✔ Develop a monitoring and contingency plan for manure application. React to spills and leaks. This will reduce the risk of manure entering the drainage system.

Check flow from end pipe at outfalls for discolouration and odour after applying liquid manure.

For more information on nutrient management, please see the Best Management Practices books, *Managing Crop Nutrients, Manure Management* and *Nutrient Management Planning.*

Pesticide Application

Herbicides and other pesticides are very expensive, and must be applied judiciously in crop production systems to help you reach goals for crop yield and quality.

✔ Employ integrated pest management strategies. Identify, monitor, and determine critical pest and economic thresholds – before selecting pest control methods.

✔ Read and follow the label instructions before making application. Do not exceed recommended rate and frequency of pesticide use.

✔ Select nozzles to attain the droplet size spectrum that will give you proper coverage and deposition. This will reduce the risk of pesticide drift.

✔ Calibrate your application equipment before using it.

✔ Don't spray pesticides if weather is inappropriate, e.g., rain or high wind. Washed-off insecticides and fungicides can cause off-site damage and reapplication is expensive.

When applying pesticides, follow label directions for separation distances from environmentally sensitive areas.

For more information on pest management, see the BMP books, *Integrated Pest Management* and *Pesticide Storage, Handling and Application.*

LEGAL ASPECTS OF CROPLAND DRAINAGE

Federal, provincial and municipal legislation is in place to help ensure that everyone working in or around water is giving due consideration to all users, including private landowners and the general public, as well as aquatic life. The following table lists legislation that can directly affect the design, construction, and maintenance of cropland drainage and erosion control structures.

LAW /GUIDELINE	GOVERNMENT AGENCY	GOAL	RELEVANCE TO LANDOWNER
Agricultural Tile Drainage Installation Act	OMAFRA	• to provide for the licensing of contractors engaged in the business of installation of agricultural drainage systems ○ each contractor, each of their drainage machines, and each of their operators must be licensed • to regulate the quality of work by licensed drainage contractors	• the Act does not apply to contractors working under the Drainage Act nor to individuals installing drains on their own property with their own equipment
Common Law	Provincial Courts	• generally, to protect the rights of the people	Potential civil liability if: • blocking or interfering with the flow in a natural watercourse, causing damage to others • collecting and discharging water onto a lower property, causing damage
For more information, see the OMAFRA factsheet, *Top 10 Common Law Drainage Problems Between Rural Neighbours*, Order no. 98-015.			
Conservation Authorities Act	MNR, delivered by local CA	• to manage and conserve natural resources within watershed jurisdiction • to ensure that the control of flooding, erosion, dynamic beaches, pollution or the conservation of land is not affected • to ensure that development and land management activities do not have a negative hydrologic impact on wetlands	Conservation Authorities regulate and require permission for: • proposed development and activities in or adjacent to any surface waters, stream valleys, shorelines, hazardous lands and wetlands • proposed modification or interfering in any way with the existing channel of a watercourse or a wetland • proposed development adjacent to wetlands – this could include lands 30 m or 120 m from the wetland boundary, depending on the individual policy adopted by the CA

LAW /GUIDELINE	GOVERNMENT AGENCY	GOAL	RELEVANCE TO LANDOWNER
Drainage Act	Local municipality, OMAFRA	• to provide landowners with a procedure to resolve outlet drainage problems through the establishment of communal systems called *municipal drains* • to provide for the subsequent improvement, repair and maintenance of municipal drains by the municipality	• can be used to obtain an outlet for subsurface drainage systems • costs are shared among property owners who contribute water or benefit from the drain • municipality is responsible for future maintenance • grants are available towards share of cost assessed on agricultural land
Environmental Protection Act	MOE	• to protect Ontario's land, water, and air resources from pollution	• persons are not allowed to discharge contaminants into the natural environment, if the discharge may cause an adverse effect
Fisheries Act	DFO and Environment Canada CAs have partnership agreements with DFO to review projects	• to protect fish and fisheries habitat	• persons are not allowed to discharge contaminants into the natural environment, if the discharge may cause an adverse effect • general prohibitions against stream alterations that would harm fish habitat
Nutrient Management Act	OMAFRA	• to provide for the management of materials containing nutrients in ways that will enhance protection of the natural environment and provide a sustainable future for agricultural operations and rural development	• livestock producers are required to develop and follow Nutrient Management Strategies/Plans and manage manure according to regulatory requirements
Ontario Water Resources Act	MOE	• to protect the quality and quantity of Ontario's surface water and groundwater resources	• general prohibitions against discharging pollutants to surface water or groundwater • permits are required for taking of large amounts of surface water or groundwater, i.e., for irrigation
Pesticides Act	MOE	• to protect surface water and groundwater resources from damage due to improper use of pesticides	• farmers buying and/or applying pesticides are required to take a Grower Pesticide Safety Course • standards are established for pesticide storage, handling and application

CA – Conservation Authority; DFO – Fisheries and Oceans Canada; MNR – Ontario Ministry of Natural Resources; MOE – Ontario Ministry of the Environment; OMAFRA – Ontario Ministry of Agriculture, Food and Rural Affairs

Note: The information provided in this table and within this document is not to be used by persons with drainage or water problems as a substitute for competent legal advice. The application of the law usually depends upon the circumstances of each case and laws may be changed by court decisions or legislation.

GLOSSARY

Aquifer	A geologic formation that holds and yields usable amounts of water. Aquifers can be classified as confined or unconfined.
Artesian pressure	This is the confining internal pressure of groundwater in an artesian aquifer. The pressure is sufficiently greater than atmospheric pressure to cause groundwater to rise above its natural level in soil.
Baseflow	The portion of watercourse flow that is not attributable to direct runoff, precipitation or melting snow. That part of the stream flow that is derived from groundwater.
Berm	A raised strip or area of land, usually level, between the edge of a spoil bank and edge of a drainage channel or canal, or a small embankment or ridge for controlling surface water flow.
Best management practice (BMP)	Any structural, non-structural and/or managerial technique recognized to be the most effective and practical means to reduce surface water and groundwater contamination while still allowing the productive use of resources.
Blind inlet	Surface water inlet to a subsurface drainpipe in which water enters by percolation through placed granular material, rather than through open-flow conduits. Does not obstruct tillage and often not visible.
Buffer strip	A permanently vegetated strip of land adjacent to a watercourse that filters runoff and stabilizes the bank.
Capillary rise	Height that water will rise by surface tension above a free water surface in the soil, expressed as length unit of water.
Collector main	A main drain that collects the water from lateral drains on one or both sides of the drainpipe.
Controlled drainage	Conserving water in a subsurface drainage system by means of control dams, check drains, or a combination of these. At the end of a drainage event, the drainage system is stopped to make more water available at a depth favourable to crop growth. Similar to subirrigation, except no water is added to the system to maintain the water table level.
Diversion	A channel or berm constructed across a slope to intercept surface runoff and divert it to a safe or convenient discharge point. Usually placed above the area to be protected.
Drain	Any closed conduit (perforated pipe or tile) or open channel used for removal of excess groundwater or surface water.
Drain envelope	A synthetic material placed around subsurface drainpipe to restrain the entry of soil particles with the drainage water.
Drainage	Process of removing surface or subsurface water from a soil or a specified area.
Drainage system	Collection of surface ditches or subsurface drainpipes, together with structures and pumps used to collect and remove excess surface and subsurface water from an area.
Drainpipe	Any product such as corrugated plastic tubing, clay or concrete drain tile, or other type of conduit used for drainage.
Draw	A natural depression across a field where water collects (converges) and flows. In most cases, the slopes of draws are sufficiently gradual to be cropped.
Drop structure	Hydraulic structure for safely transferring water from a higher level to a lower level safely, without causing erosion.
Envelope	Generic name for materials placed on or around a drainage conduit, irrespective of whether used for mechanical support, hydraulic purposes (hydraulic envelope), or to stabilize surrounding soil material (filter envelope).
Evapotranspiration	The combination of water transpired from vegetation and evaporated from the soil and plant surfaces.
Field capacity	Amount of water remaining in a soil when the downward water flow caused by gravity becomes negligible.
Field ditch	An open channel with two sides and a bottom constructed to convey water within a field either for irrigation or drainage.
Gley	Refers to the dull grey to bluish-grey colour of soil when subjected to prolonged saturation, i.e., oxygen-deprived environment.
Grade	Slope of a channel or natural ground. In field drainage, it is often expressed in metres per 100 metres (feet per 100 feet) or per cent.

Grade control	Process of maintaining constant and correct slope of a predetermined trench, ditch, terrace, canal, etc., using optical, laser, or GPS-based surveying equipment.
Gravitational water	Soil water that moves into, through, or out of the soil under the influence of gravity.
Groundwater	Water occurring in the zone of saturation in an aquifer or soil.
Groundwater flow	Flow of water in an aquifer or soil.
Hardpan	A hardened soil layer caused by cementation of soil particles.
Header main	A main usually parallel to drainage channel to capture water from a series of laterals and reduce the number of exit points (outfalls) at the drainage channel. Term is sometimes used when main drain runs along field boundary. Laterals only enter from one side.
Heavy soil	Soils with a high clay content; soils requiring higher draught power requirements to plough.
Herringbone system	Arrangement of a pipe drainage system where laterals enter a main from both sides at angles less than 90 degrees.
Hydraulic conductivity	The rate at which water moves through a soil.
Hygroscopic water	Soil water that is held so tightly to soil particles that it is unavailable to growing plants.
Impermeable layer	A layer of soil that significantly restricts the flow of water. If the permeability of a layer in the soil profile is about one-tenth that of the soil above it, the soil can be considered impermeable.
Infiltration	The process by which water on the ground surface enters the soil.
Inlet	A device to deliver water directly from the ground surface to a subsurface drainpipe.
Iron ochre	A reddish or yellowish brown gelatinous deposit formed by iron-fixing bacteria when exposed to air. With time the gelatinous material hardens into a scale deposit.
Land grading	The shaping of the land surface by cutting, filling and smoothing to continuous planned grades so that each row or surface slopes to a drain without ponding.
Lateral drain	Secondary subsurface drainpipe that collects excess water from a field, and conveys water to a header main/main drain for conveyance to a proper outlet.
Main drain	Principal subsurface drainpipe that conducts drainage water from the lateral drains and sub-mains to an outlet. See also Header main and Sub-main.
Municipal drain	Constructed channels or large-diameter pipes created under the authority of the Drainage Act.
Outfall	Point where water flows from a conduit, stream, or drain.
Outlet / end pipe	A pipe (usually steel or rigid plastic) that connects a subsurface drainage system to a surface water system without causing erosion.
Perched water table	A localized condition of free water held in a pervious layer because of an underlying impervious layer and separated from deeper aquifers.
Percolation	Downward movement of water through the soil profile.
Perforated pipe	Pipe designed to discharge or accept water through small, multiple, closely spaced orifices placed in its circumference.
Permeability	The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil or porous media.
Porosity	The volume of pores in a soil.
Random drainage	Surface or subsurface drainage system of irregular pattern used mainly in depressional sites.
Recharge area	Land area over which water infiltrates and percolates to replenish an aquifer.
Riparian area	The land adjacent to bodies of surface waters – including shores, banks, floodplains and ravine slopes.
Root zone	Depth of soil that plant roots readily penetrate and in which the predominant root activity occurs.
Runoff	The portion of precipitation or snowmelt that flows over the soil surface.
Sand	A soil particle with a diameter between 0.05 and 2.0 mm.

Seepage	The movement of water through the soil into or out of unlined canals, drainage channels, and water storage facilities.
Silt	A soil particle with a diameter between 0.002 and 0.05 mm.
Soil aeration	Process by which air and other gases enter the soil or are exchanged.
Soil compaction	Consolidation, reduction in porosity, and structure collapse of soil when subjected to surface loads.
Soil conservation	Protection of soil against physical loss by erosion and chemical deterioration through the application of management and land use methods.
Soil erodibility	A measure of the soil's susceptibility to erosion processes.
Soil erosion	The movement of soil by natural or mechanical means.
Soil horizon	A layer of soil differing from adjacent layers in physical, chemical, and biological properties or characteristics.
Soil organic matter	Organic fraction of the soil, including plant and animal residue in various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil populations.
Soil profile	Vertical section of the soil from the surface through all its horizons into the parent material.
Soil series	A conceptualized class of soil bodies having similar characteristics and arrangement in the soil profile.
Soil structure	The arrangement of primary soil particles into secondary particles, units, or peds that make up the soil mass. Soil structure has a major influence on water and air movement, biological activity, root growth, and seedling emergence.
Soil texture	Classification of soil by its relative proportions of sand, silt, and clay.
Soil water	All forms of water in the soil.
Spillway	Conduit through or around a dam or dike for the passage of excess water.
Subirrigation	Regulation of the water table by means of control dams, check drains, or a combination of these, and addition of water by means of the subsurface drainage system to maintain the water table at a depth favourable to crop growth.
Sub-main	Collects water from laterals and delivers it to main drain.
Subsoiling	Tillage operation to loosen the soil below the tillage zone.
Subsurface drainage	The removal of excess water from below the soil surface by means of drainpipe.
Surface drainage	The diversion or orderly removal of excess water from the surface of the land by means of improved natural or constructed channels, supplemented when necessary by sloping and grading of land surfaces to these channels.
Surface inlet	Structure for diverting surface water underground and into an open drainage channel, subsurface drain, or pipeline.
Surface water	1. Water found on the surface of the earth – e.g., ponds, lakes, streams and rivers. 2. Water on cropland soil surface.
Tile	Drainpipe made of burned clay, concrete, or similar material, in short length usually laid with open joints to collect and carry excess water from the soil. Sometimes also refers to plastic drainpipe.
Transpiration	The absorption of soil water by plants and its release into the atmosphere in the form of water vapour. This process regulates plant temperatures.
Vent	A device fitted to a pipeline that permits the passage of air to or from the pipe. Also called a breather.
Watershed	Total land area above a given point on a stream or waterway that contributes runoff to that point.
Water table	The upper surface of a saturated zone within the soil.
Wetland	Lands that are seasonally or permanently covered by shallow water, have very poorly drained soils, and are dominated by water-tolerant plants.

Agencies and Offices

ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

For questions regarding farming, agri-business, or rural business:

Agricultural Information Contact Centre
1 Stone Road West
Guelph, ON N1G 4Y2
ph: 1-877-424-1300
email: ag.info.omafra@ontario.ca
web: www.omafra.gov.on.ca

CONSERVATION ONTARIO

Box 11, 120 Bayview Parkway
Newmarket, ON L3Y 4W3
ph: 905-895-0716
email: info@conservationontario.ca
web: www.conservationontario.ca

ONTARIO MINISTRY OF THE ENVIRONMENT

Public Information Centre
1st floor,135 St. Clair Avenue West
Toronto, ON M4V 1P5
ph: 1-800-565-4923
email: picemail.moe@ontario.ca
web: www.ene.gov.on.ca/environment/en/index.htm

ONTARIO FEDERATION OF AGRICULTURE

Ontario Agricentre
100 Stone Road West, Suite 206
Guelph, ON N1G 5L3
ph: 1-800-668-3276
email: info@ofa.on.ca
web: www.ofa.on.ca

LAND IMPROVEMENT CONTRACTORS OF ONTARIO

For a list of licensed drainage contractors in your area, visit the LICO website: www.drainage.org

Canada

Ontario

OFA Ontario Federation of Agriculture

For More Information

ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

The Ontario Ministry of Agriculture, Food and Rural Affairs has numerous factsheets and other information pertaining to cropland drainage. Here is a sampling:

FACTSHEETS

Operating and Maintaining a Tile Drainage System
Order no. 10-091

Drain Problems
Order no. 84-017

Maintenance of the Drainage System
Order no. 87-062

Management of Drained Fields
Order no. 90-156

PUBLICATIONS

Publication 29, *Drainage Guide for Ontario*

Publication 832, *Agricultural Erosion Control Structures: A Design and Construction Manual*

See www.omafra.gov.on.ca/english/landuse/drainage.htm for a complete list. To obtain your copies, please see below.

BEST MANAGEMENT PRACTICES SERIES

A number of BMP books concern on-farm soil and water management, and are strongly recommended to help you make the most of your drainage system. See page i for a complete list.

HOW TO OBTAIN COPIES OF BMP AND OMAFRA PUBLICATIONS

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

To obtain copies of OMAFRA and Best Management Practices publications, please order:

Online at www.publications.serviceontario.ca

By phone through the ServiceOntario Contact Centre
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Acknowledgements

The Best Management Practices Program is a partnership of Agriculture and Agri-Food Canada, the Ontario Ministry of Agriculture, Food and Rural Affairs, and the Ontario Federation of Agriculture.

FUNDING

Funding for this publication has been provided by Agriculture and Agri-Food Canada and the Ontario Ministry of Agriculture, Food and Rural Affairs.

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Printed 2011