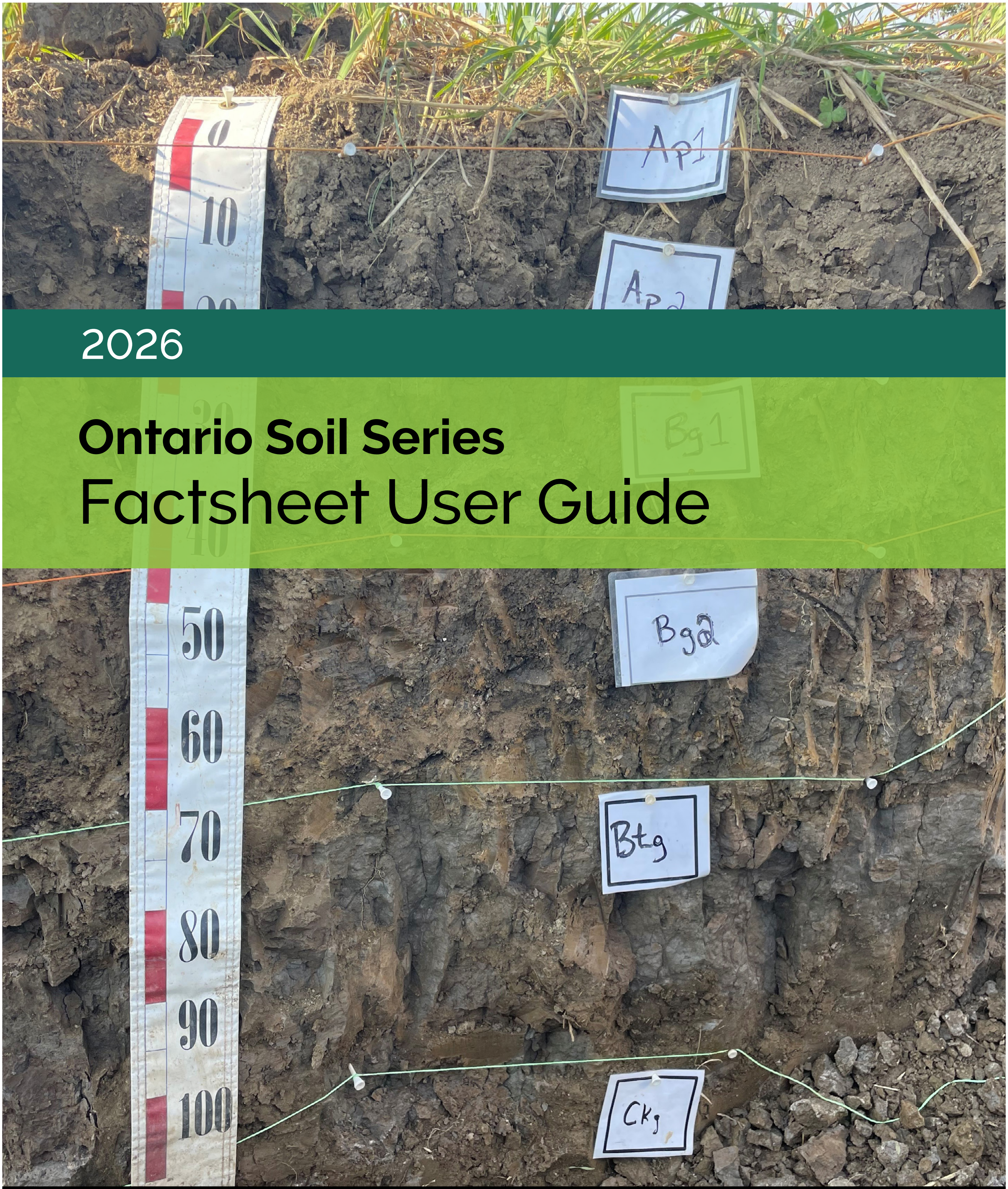

2026

Ontario Soil Series
Factsheet User Guide

Ministry of Agriculture,
Food and Agribusiness

Ontario

Acknowledgement

The development of this soil series factsheet user guide for Ontario farmers was inspired by the pioneering work of the Institute for Research and Development in Agri-Environment (IRDA) in Quebec. IRDA's groundbreaking *Soil Factsheets* and *Explanatory Guide Description and Interpretation Sheets for Quebec Soil Series, February 2022 (updated February 2023),* provided the conceptual and methodological framework for the creation of detailed soil series factsheets for use in Canadian agricultural extension services. The Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA) extends sincere appreciation to IRDA for establishing this model of knowledge transfer to bridge scientific research and practical farming applications. OMAFA has adapted the framework to serve Ontario's agricultural community while respecting the unique characteristics of our province's soil landscapes and farming systems.

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Front Cover: Vertical soil profile, in a field, showing distinct layers of compacted earth.

Summary

The Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA) has produced a set of soil series factsheets that describe various soil properties, management challenges, chemical and physical attributes and example soil profiles. These factsheets provide producers, agronomists, and other stakeholders with information to support sustainable farm management. The guide offers additional context and information for using and interpreting the factsheets. It explains how to interpret the OMAFA soil series factsheets, understand soil classification and identify management challenges. By using this guide, in combination with the soil series factsheets, users will gain additional insight to make informed decisions about farm management, drainage requirements and soil management practices specific to Ontario's diverse soil landscapes.

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1. Introduction

The soil series factsheets were developed to make Ontario's soil information more accessible and understandable for land use and farm management decisions. The factsheets are based on soil series with the greatest agricultural importance in Ontario. The Canadian System of Soil Classification (CSSC) provides a strong taxonomic foundation for Ontario's agricultural soils; however, the classification system does not always translate easily into practical soil and land management interpretations. The soil series factsheets provide a two-page summary that bridges the gap by offering standardized, user-friendly information to support learning, farm planning and land management. This soil series factsheet user guide will help readers understand the information provided in the factsheets. With a better understanding of soil properties and soil information available in the factsheets, producers, agronomists and other stakeholders will gain additional insights to consider when making decisions about farm management.

2. Overview of Soil Series Factsheet Content

Page 1: Key Soil Properties and Management Overview
The first page (Figure 1) offers a concise overview of the texture and mode of deposition of the parent material, soil profile photo and description of the series with a soil profile diagram, example landscape photo, key soil properties, management challenges and Canada Land Inventory (CLI) soil capability for agriculture rating.

Page 2: Soil Data and Geographic Context
The second page (Figure 1) explores deeper into analytical data, including chemical and physical properties, and provides the geographic distribution of the soil series. The page concludes with an agricultural production section offering insights into crop suitability and productivity potential.

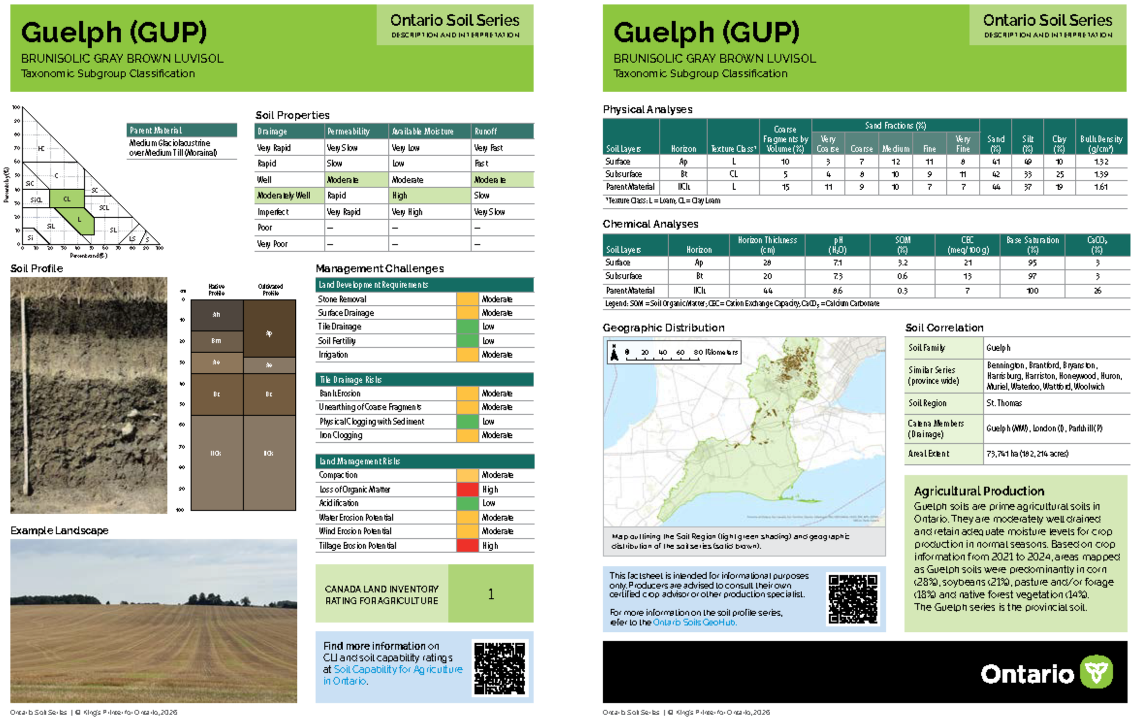

Figure 1. Detailed overview of page 1 (left) and page 2 (right) of the Guelph Soil Series Factsheet.

2.1. Soil Series Factsheet Header

The soil series factsheet header provides foundational information about the soil series, including:

- Soil Series: Name of the soil series
- Soil Series Code: A unique three-letter identifier for the series used in provincial and national soil databases
- Soil Subgroup: Classification of the soil to the subgroup level, based on the *Canadian System of Soil Classification (CSSC)*

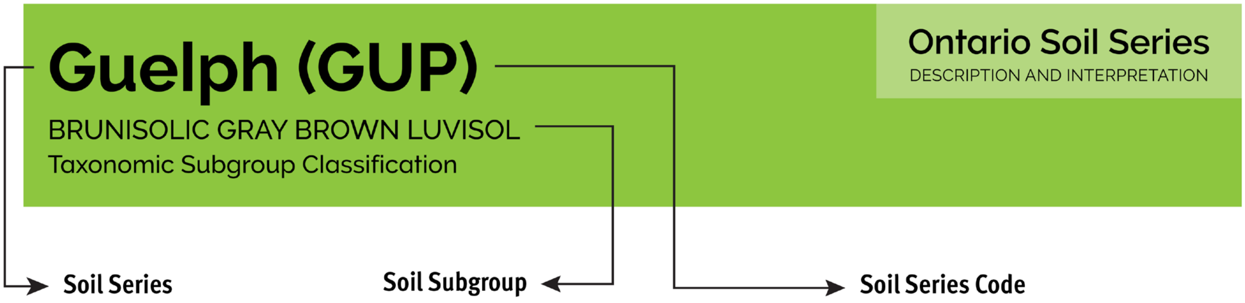

Figure 2. Overview of soil series factsheet header information

Soil classification is based on observable and measurable soil properties that reflect soil genesis processes and environmental factors. The Canadian System of Soil Classification (CSSC) is a hierarchical system with five levels. From broadest to most detailed, the levels are Order, Great Group, Subgroup, Family and Series (Figure 3). A soil series is the basic unit of soil classification and consists of soils that are essentially alike in all major profile characteristics. While no two soil profiles are identical, soils belonging to the same series have similar kinds and arrangements of horizons whose colour, texture, structure, consistence, thickness, reaction and composition fall within narrow ranges.

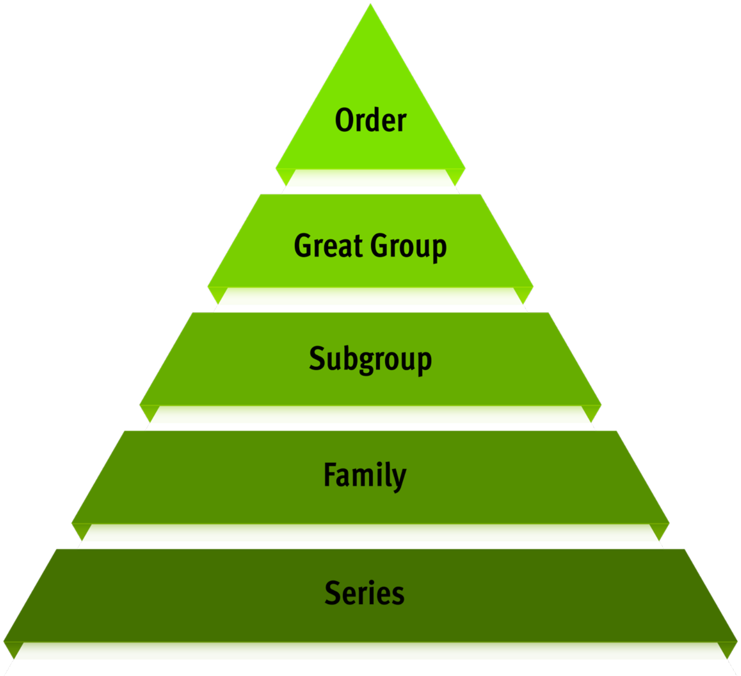

Figure 3. Hierarchical organization of the Canadian System of Soil Classification.

2.2. Soil Texture and the Soil Texture Triangle

Soil texture refers to the relative proportions of sand, silt and clay-sized particles in a mineral soil sample. It is a fundamental property that influences many aspects of soil behaviour, including water retention, drainage and nutrient availability. The soil texture triangle (Figure 4) provides the classification of the different combinations of sand, silt and clay into texture classes, which are used to communicate the relative proportions more easily.

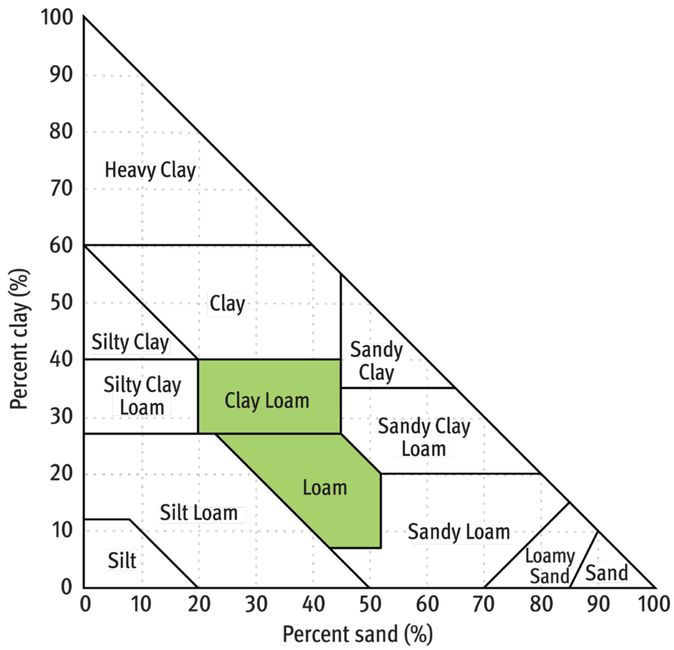

Figure 4. Soil texture triangle for determining soil texture class.

The soil texture class shaded in green on the soil series factsheet represents the soil texture class or range of texture classes of the parent material. The CSSC recognizes primary particle sizes ranging from clay (<0.002 mm) to stones (>250 mm) (Table 1). Thirteen soil texture classes are defined based on the percentages of sand (0.05–2 mm), silt (0.002–0.05 mm) and clay (<0.002 mm). The soil texture triangle is a tool used to determine the soil texture class of a soil based on the sand and clay content (Figure 4).

Table 1. Soil Particle Size Classes

Particle Size Class	Size (in diameter)
Stones	>250 mm
Cobbles	75–250 mm
Gravel	2–75 mm
Very Coarse Sand	2.0–1.0 mm
Coarse Sand	1.0–0.5 mm
Medium Sand	0.5–0.25 mm
Fine Sand	0.25–0.10 mm
Very Fine Sand	0.10–0.05 mm
Silt	0.05–0.002 mm
Clay	<0.002 mm

Note: Any materials larger than very coarse sand are not represented in the texture triangle.

2.2.1. Parent Material Texture and Mode of Deposition

Parent material is the underlying geological material from which soil horizons develop. It significantly influences the soil's physical and chemical properties, including texture, structure, mineral content and fertility. The Parent Materials section in the soil series factsheet (Figure 6) describes the texture (Figure 5) and mode of deposition (Table 2) of the parent materials. Parent Material textures are grouped based on soil texture classes (Figure 4), and Mode of Deposition refers to how the materials were laid down by natural forces. Both are important factors when determining the soil series.

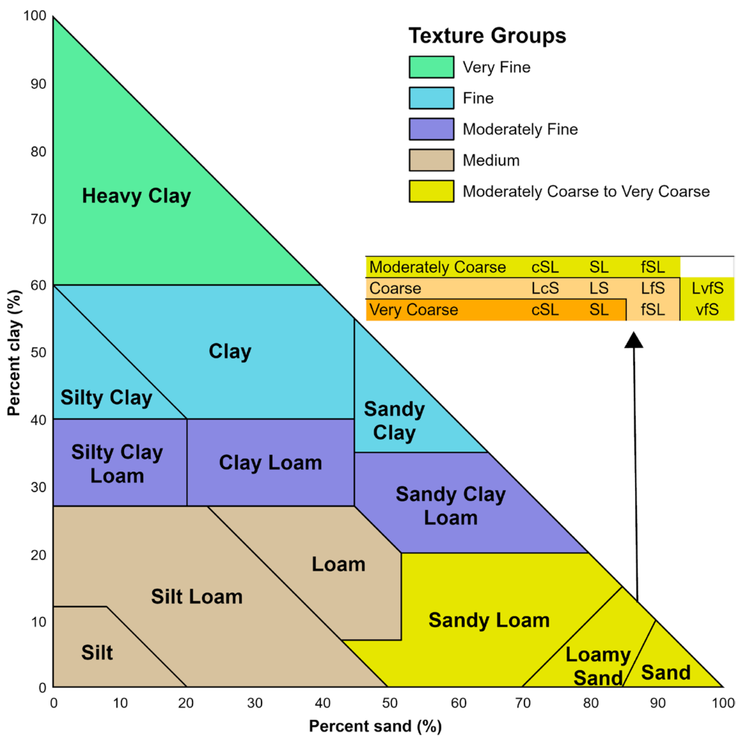

Figure 5. Textures of parent materials.

Parent Material
Medium Glaciolacustrine over Medium Till (Morainal)

Figure 6. Texture and mode of deposition of Parent Material.

Table 2. Classes and Descriptions of Various Modes of Deposition of Parent Material Recognized in Ontario

Mode of Deposition	Description
Residual	Materials formed from the weathering of bedrock in place.
Fluvial	Materials deposited by flowing water, such as rivers and streams.
Lacustrine	Materials deposited in lake environments.
Marine	Materials deposited in marine environments.
Glacial	Materials deposited by glaciers and ice sheets.
Till (Morainal)	Unsorted mixture of clay, silt, sand, gravel, and boulders deposited by glacial ice.
Glaciofluvial	Sorted and stratified materials deposited by glacial meltwater streams.
Glaciolacustrine	Materials deposited in glacial lakes.
Glaciomarine	Materials deposited in marine environments influenced by glacial activity.
Eolian (Aeolian)	Materials deposited by wind.

2.3. Soil Profile

A soil profile is a vertical section of the soil through all its horizons and layers extending into the parent material. These layers are known as soil horizons. Figure 7 shows a soil profile from the Guelph series.

Figure 7. Soil profile of the Guelph soil series.

Native and Cultivated Soil Profiles

The profile description in the factsheet represents the central concept of the series (typical profile). It is not specific to any one site but was created from an average of multiple profiles from the same soil series. A native soil profile refers to the natural, undisturbed layers of soil that have developed over time under natural vegetation. Whereas a cultivated soil profile is the result of human agricultural activities, such as plowing, planting and harvesting, which usually results in homogenized surface horizons forming an Ap (p = plowed) horizon. Figure 8 shows the native and cultivated soil profiles of the Guelph soil series along with the different soil horizons and their depths.

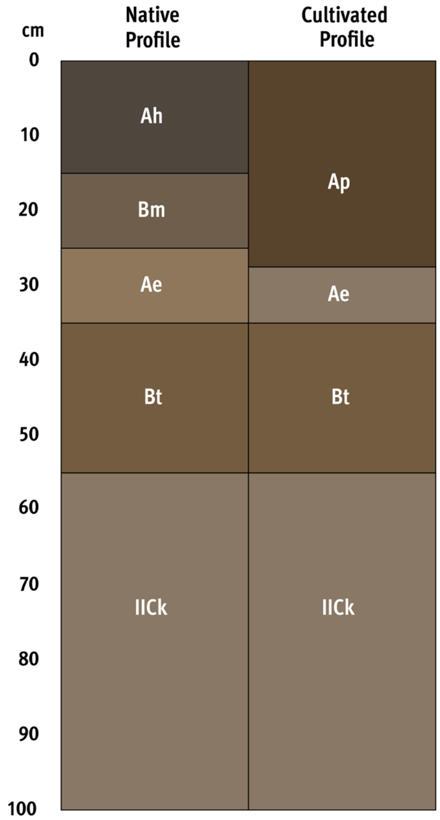

Figure 8. A typical Guelph soil series profile under native and cultivated land use. Note the surface horizons from the native land use are homogenized into an Ap (p = plowed) horizon under agricultural land use.

Soil Horizons

A soil horizon is a layer of mineral or organic soil material approximately parallel to the land surface. Different horizons have characteristics resulting from processes of soil deposition and/or soil formation. The major mineral horizons are designated A, B, C and R (Table 3).

Table 3. Major Mineral Horizons Used to Describe Soils

Horizon	Description
A	The uppermost horizon, zone of leaching or maximum accumulation of organic matter.
B	Subsurface horizon typically containing an accumulation of materials such as clay, iron, aluminum, or organic matter.
C	Horizon that is comparatively unaffected by soil-forming processes, it consists of weathered parent material.
R	Consolidated bedrock layer, too hard to break with hands or dig with a spade.

The major organic horizons are designated O, L, F and H (Table 4). Organic horizons can make up an entire profile or are found on the surface of mineral soils. They may also be present at various depths in buried soils or above geologic deposits. These horizons contain at least 17% organic carbon (approximately 30% organic matter) by weight. There are two main categories of these horizons: O horizons (peat materials) and L, F and H horizons (folic materials).

Table 4. Organic Horizon Suffixes and their Descriptions

Horizon	Description
O	Horizon developed mainly from mosses, rushes and woody materials. It is divided into the following sub-horizons: **Of** – This O horizon consists largely of fibric materials that are readily identifiable as to botanical origin. **Om** – This O horizon consists of mesic material, which is at a stage of decomposition intermediate between fibric and humic materials. **Oh** – This O horizon consists of humic material, which is at an advanced stage of decomposition.
L, F and H	Horizon formed from the accumulation of leaves, twigs, and woody materials, sometimes including a small component of mosses. They are typically found in upland forested soils that have imperfect drainage or are relatively dry. They are often used in combination (i.e., LFH) to describe thin forest floor materials. **L** – This organic horizon is characterized by an accumulation of organic matter in which the original structures are easily discernible. **F** – This organic horizon is characterized by an accumulation of partly decomposed organic matter. Some of the original structures are difficult to recognize. **H** – This organic horizon is characterized by an accumulation of decomposed organic matter in which the original structures are indiscernible.

Lowercase suffixes for mineral horizons are added to the major horizon symbols to provide more specific information about the characteristics of the horizon to better understand the processes occurring in the development of a particular soil horizon.

Table 5. Mineral Horizon Suffixes and their Descriptions

Suffix	Description
b	A buried soil horizon
c	A cemented horizon
ca	A horizon enriched in secondary carbonates in which the concentration of calcium carbonate exceeds that of the primary carbonate in the unenriched parent material typically displaying nodules enriched in secondary carbonate precipitates.
e	A horizon characterized by the eluviation (loss) of clay, Fe, Al or organic matter alone or in combination. It is used with A (Ae or Ahe).
f	A horizon enriched with amorphous material, principally Al and Fe combined with organic matter.
g	A horizon characterized by gray colours, or prominent mottling, or both, indicating poor drainage.
h	A horizon enriched with organic matter. It is used with A alone (Ah), or with A and e (Ahe), or with B alone (Bh), or with B and f (Bhf).
j	A modifier for e, f, g, and t suffixes designating juvenile status. It is used to denote an expression of, but failure to meet, the specified limits of the suffix it modifies.
k	It denotes the presence of carbonate
m	A horizon slightly altered by hydrolysis, oxidation, or solution, or all three to give a change in colour or structure, or both.
p	A horizon disturbed by human activities such as cultivation, logging and habitation. It is used with A and O horizons.
t	An illuvial horizon enriched with silicate clay. It is used with B alone (Bt), or with B and g (Btg), etc.

Horizon Prefixes

In certain cases, prefixes are used to indicate lithological discontinuities or other significant changes in the soil profile. Horizon prefixes are Roman numerals (II, III, lV), and these indicate different parent materials or significant changes in the soil profile. For example, IICk indicates a carbonate-enriched horizon in a different parent material layer.

Example: Guelph Soil Series Horizons

Based on the Guelph soil series factsheet, these are the horizons and their characteristics:

- Ap: Cultivated or disturbed horizon
- Ae: Leached horizon, lighter in colour due to the removal of clay, iron, or organic matter.
- Bt: Horizon with accumulation of clay.
- IICk: This is a C horizon containing primary carbonates (k). The use of the prefix II indicates a different mode of parent material deposition compared to the material above it. The IICk is medium-textured till (morainal). The horizons (Ap, Ae and Bt) above the IICk in the Guelph soil profile are derived from a medium-textured glaciolacustrine parent material.

2.4. Example Landscape

This section of the factsheet provides a photo of a typical field view where a particular soil series is found. It provides a reference to the topography or land surface generally associated with the soil series.

2.5. Soil Properties

Soil properties are the physical, chemical and biological characteristics of soil that influence its function and suitability for various uses. There are four key properties described in the factsheet — drainage, permeability, available moisture and runoff. Below each soil property in the table are the possible classes, with the class representative of the soil highlighted in light green (Figure 9).

Soil Properties

Drainage	Permeability	Available Moisture	Runoff
Very Rapid	Very Slow	Very Low	Very Fast
Rapid	Slow	Low	Fast
Well	**Moderate**	Moderate	**Moderate**
Moderately Well	Rapid	**High**	Slow
Imperfect	Very Rapid	Very High	Very Slow
Poor	—	—	—
Very Poor	—	—	—

Figure 9. Soil properties table with applicable classes for the soil series shown in light green highlight.

2.5.1. Soil Drainage Class

Soil drainage refers to how quickly excess water is removed from the soil. Proper drainage is crucial for plant growth, root health and nutrient availability. Soil drainage is categorized into 7 classes in the Canadian System of Soil Classification (Table 6).

Table 6. Soil Drainage Classes and Descriptions as per the Canadian System of Soil Classification

Drainage Class	Description
Very Rapid (VR)	Water is removed from the soil very rapidly in relation to supply. Soils have very low available water storage capacity within the control section and are usually coarse textured, or shallow, or both. Water source is precipitation.
Rapid (R)	Water is removed from the soil rapidly in relation to supply. Soils have low available water storage capacity within the control section, and are usually coarse textured, or shallow, or both. Water source is precipitation.
Well (W)	Water is removed from the soil readily but not rapidly. Soils have intermediate available water storage capacity within the control section and are generally intermediate in texture and depth. Water source is precipitation.
Moderately Well (MW)	Water is removed from the soil somewhat slowly in relation to the supply. Soils have intermediate to high water storage capacity within the control section and are usually medium to fine-textured.
Imperfect (I)	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Soils have a wide range in available water supply, texture and depth, and are gleyed phases of well-drained subgroups.
Poor (P)	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Soils have a wide range in available water storage capacity, texture and depth, and are gleyed subgroups, Gleysols and Organic soils.
Very Poor (VP)	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Soils have a wide range in available water storage capacity, texture, and depth, and are either Gleysolic or Organic.

Source: Expert Committee on Soil Survey, 1982.

2.5.2. Permeability

Permeability refers to the speed with which gases and liquids penetrate or pass through a bulk mass of soil or a layer of soil. For the factsheets, soil permeability class was determined based on the saturated hydraulic conductivity (cm hr^{-1}) across all layers of the soil (Table 7).

Table 7. Permeability Classes and their Associated Range in Saturated Hydraulic Conductivity

Permeability Class	Hydraulic Conductivity (cm hr^{-1})
Very slow	<0.15
Slow	0.15–0.5
Moderate	0.5–15
Rapid	15–50
Very Rapid	≥50

Source: Scherer et al., 2022.

2.5.3. Available Moisture

Available moisture refers to the water that is available for plant growth. It is defined as the amount of water between the field capacity (FC) and the permanent wilting point (PWP) of the soil. FC is the maximum amount of water held in a soil, measured a few days after the soil has been thoroughly soaked and allowed to drain freely. PWP is the soil water that is not available to plants because it is held too tightly to soil particles. Once a soil has reached PWP, plants start to wilt because they cannot extract enough water to meet their physiological requirements. There are 5 classes of available moisture based on the soil's ability to retain water for plant use (Table 8). Available water was assessed for the full soil profile.

Table 8. Available Soil Moisture Classes and their Associated Range in Available Moisture

Available Moisture Class	Available Moisture% (by volume)
Very Low	<5%
Low	5–9.9%
Moderate	10–19.9%
High	20–24.9%
Very High	>25%

Source: McKeague et al., 1986.

2.5.4. Runoff

Runoff refers to the loss of water from an area by flow over the soil surface. It depends on many factors, acting independently or in combination, such as:

- the amount and intensity of rainfall
- the amount of water in the soil at the beginning of the reference period
- slope gradient
- infiltration capacity
- soil texture
- vegetation or land use

- soil management
- other factors that affect the surface or its cover, water control practices, etc.

Five runoff classes are recognized in the factsheets (Table 9).

Hydrologic Soil Groups (HSGs) can be used to estimate runoff potential. HSGs are grouped according to water intake rate after prolonged wetting. They are interpretations originally developed by the United States Department of Agriculture. The interpretation for each soil series is derived from data for soils in that series. There are four HSGs:

1. **Group A (Low runoff potential) —** Soils in this group have a high infiltration rate. They typically include deep sands with very little silt and clay.
2. **Group B (Moderately low runoff potential) —** These soils have a moderate infiltration rate when wet and are mostly sandy soils that are less deep than those in Group A. This group has above-average infiltration after thorough wetting.
3. **Group C (Moderately high runoff potential) —** Soils in this group have a slow infiltration rate when wet. They include shallow soils and soils containing considerable clay and colloids, though less than Group D. This group has below-average infiltration after thorough wetting.
4. **Group D (Highest runoff) —** These soils have a very slow infiltration rate when thoroughly wet. They include soils with high swelling clays and shallow soils with nearly impermeable horizons near the surface.

Table 9. Runoff Classes and their Associated Hydrologic Soil Group, Range in Hydraulic Conductivity and General Description

Surface Runoff Class	Hydrologic Soil Group	Hydraulic Conductivity *(cm hr^{-1})*	Description
Very Slow	A	>50	Surface water flows so slowly that free water remains on the surface for long periods or immediately penetrates the soil. Most of the water passes through the soil or evaporates into the atmosphere. Soils characterized by very slow surface runoff are generally flat.
Slow	A	15–50	Surface water flows so slowly that free water covers the soil for long periods, or penetrates rapidly into the soil, and a large proportion of the water passes through the profile or evaporates into the atmosphere. Soils in this class are either flat to gently sloping or absorb precipitation very rapidly. Normally, there is little or no danger of erosion.

Table 9. Runoff Classes and their Associated Hydrologic Soil Group, Range in Hydraulic Conductivity and General Description (continued)

Surface Runoff Class	Hydrologic Soil Group	Hydraulic Conductivity *(cm hr^{-1})*	Description
Moderate	B	0.5–15	Surface water flows at such a speed that a moderate proportion of it penetrates the soil profile and free water remains on the surface for only very short periods. A large proportion of precipitation is absorbed by the soil and used for plant growth, disappears through evaporation or circulates at depth. The loss of water at the surface does not greatly reduce the amount of water available for plant growth. The danger of erosion may be slight to moderate when soils in this class are cultivated.
Fast	C	0.15–0.5	A large proportion of precipitation moves rapidly over the soil surface and only a small proportion crosses the soil profile. Surface water runs off almost entirely as soon as it reaches the ground. Slopes are generally steep to fairly steep and infiltration capacity is low. The danger of erosion is generally moderate to high.
Very Fast	D	<0.15	Most of the water runs off quickly at the soil surface and very little crosses the profile. Water runs off the surface as soon as it falls. Slopes are generally steep to very steep and infiltration capacity is low. The danger of erosion is high to very high.

Sources: Expert Committee on Soil Survey, 1982, U.S. Department of Agriculture; Natural Resources Conservation Service, 2009.

2.6. Management Challenges

This section of the factsheet outlines various challenges and risks associated with the development and continued management of the soil for sustained agricultural production. The challenges are divided into three broad classes:

- land development requirements
- risk to/from tile drainage
- land management risks

Land development requirements are focused on activities that may be required to bring land into agricultural production. The tile drainage and land management risks provide additional details pertaining to risks associated with specific development activities which may already be implemented. The corresponding levels of required intervention, vulnerability and sensitivity are each categorized into three classes: low, moderate and high (Figure 10).

Management Challenges

Land Development Requirements		
Stone Removal		Moderate
Surface Drainage		Moderate
Tile Drainage		Low
Soil Fertility		Low
Irrigation		Moderate

Tile Drainage Risks		
Bank Erosion		Moderate
Unearthing of Coarse Fragments		Moderate
Physical Clogging with Sediment		Low
Iron Clogging		Moderate

Land Management Risks		
Compaction		Moderate
Loss of Organic Matter		High
Acidification		Low
Water Erosion Potential		Moderate
Wind Erosion Potential		Moderate
Tillage Erosion Potential		High

Figure 10. Management challenges outlining various land development requirements, risks to tile drainage and land management risks.

2.6.1. Land Development Requirements

Certain soils may benefit from various land development actions to improve their suitability for agriculture. Five categories of intervention are identified: stone removal, surface drainage, tile drainage, soil fertility requirements and irrigation. The required level of intervention is classified into three categories: low, moderate and high. These ratings reflect the severity of the limiting factor in a particular soil series. Different land development practices can mitigate the impacts of these soil limitations on agricultural production.

2.6.1.1. Stone Removal

Surface stoniness is an estimate of the percentage of the surface covered by stones 25 cm in diameter or greater. Soils with sufficient stones at the surface can hinder mechanical operations such as tillage, planting and harvesting. The descriptors in Table 10 indicate the amount of stone removal that may be required. The stone removal requirement class is linked directly to the surface stoniness class (percentage of the soil surface covered by stones) typical of the soil series. Surface stoniness can vary within a soil series and different areas with the same soil may not require as much stone removal.

Table 10. Stone Removal Requirement Classes

Stone Removal Requirement Class	Stoniness Class	% Surface Covered
Low	Non-stony	<0.01%
Low	Slightly stony	0.01–0.1%
Moderate	Moderately stony	0.1–3
Moderate	Very stony	3–15
High	Exceedingly stony	15–50
High	Excessively stony	>50

Source: Day, 1983.

2.6.1.2. Surface Drainage

Surface drainage refers to the requirement for the removal of excess surface water from cropland through various methods such as drainage channels, land grading and surface inlets. This process ensures the removal of excess water from the land surface. Three different soil characteristics (natural drainage class, saturated hydraulic conductivity and slope gradient) in combination or individually, are used to classify the need for surface drainage. Refer to *Cropland Drainage BMP Book* for more information.

Table 11. Soil Descriptors Used to Indicate the Degree of Need for Surface Drainage

Soil Descriptors	Surface Drainage Requirement Class		
	Low	**Moderate**	**High**
Drainage	Well to very rapid	Imperfect to moderately well	Poor to very poor
Hydraulic Conductivity (cm hr^{-1})	≥15	0.5–15	<0.5
Slope Gradient (%)	≥8	3-8	<3

Source: Martin and Nolin, 1991.

2.6.1.3. Tile Drainage

Tile drainage refers to the requirement for a network of perforated pipes installed below ground to prevent soil from becoming too wet for crop growth by removing excess water from the soil. All soils in Ontario are assigned a Soil Capability for Agriculture (CLI) rating. In this rating system, soils can be assigned a subclass limitation of “W”, which indicates a limitation to agricultural capability due to excess water. Excess water may result from inadequate soil drainage, a high-water table and seepage or runoff from surrounding areas. To assess the tile drainage requirement, the W subclass limitation is used. If the CLI Subclass W is high (classes 3W, 4W or 5W), there is a higher likelihood of a requirement for tile drainage to remove excess water from the soil to sustain better crop production (Table 12).

For more information, refer to the following resources:

- *Soil Capability for Agriculture in Ontario*
- *Best Management Practices: Cropland Drainage*
- *Publication 29: Drainage Guide for Ontario*

Table 12. Soil Descriptors Used to Indicate the Degree of Need for Tile Drainage

Soil Descriptors	**Tile Drainage Requirement Class**		
	Low	**Moderate**	**High**
CLI Rating	No excess water (W) limitation	2W	3W, 4W or 5W

2.6.1.4. Soil Fertility Requirement

Soil fertility refers to the ability of soil to support plant growth without human intervention. It depends on many soil chemical and physical parameters, including the texture of the soil and the reaction (pH) of the soil. For example, soils with high sand content tend to be naturally acidic, lower in organic matter, have lower cation exchange capacity, which limits their ability to cycle nutrients effectively. The natural fertility of the soil can be implied from the F subclass limitation (low natural fertility) of the CLI soil capability for agriculture rating. If the natural soil fertility class is low (4F or 5F), there is a higher requirement for improving soil fertility for better crop production. Specifically, the criteria for Subclass F, low natural fertility, are applied to determine the soil fertility requirements (Table 13). Additional information on soil fertility is available in the *Soil Fertility Handbook (Publication 611)*.

Table 13. Soil Descriptors Used to Indicate the Degree of Soil Fertility Requirement

Soil Descriptors	**Soil Fertility Requirement Class**		
	Low	**Moderate**	**High**
CLI Rating	2F or no fertility limitation	3F	4F or 5F

Note: F = Fertility.

2.6.1.5. Irrigation

Irrigation is the practice of adding water to moisture-deficient soils to improve production. Table 14 combines drainage class and useful water reserve (cm of water per 50 cm of soil) to determine the potential irrigation requirement.

An irrigation strategy should consider current crop stage, precipitation patterns and economic factors alongside these soil properties. For high-value crops, irrigation may be economically beneficial even in moderate irrigation requirement conditions. Find additional information on irrigation practices in the *Irrigation Management BMP Book* and at *Agricultural Irrigation*.

Table 14. Soil Descriptors used to Indicate the Degree of Need for Irrigation

Soil Descriptors	Irrigation Requirement Class		
	Low	Moderate	High
Drainage	Poor to very poor	Imperfect to moderately well	Well to very rapid
Useful Water Reserve (cm of water per 50 cm of soil)	High to very high (>9 cm)	Moderate (6–9 cm)	Low to very low (<6 cm)

Martin and Nolin, 1991.

2.6.2. Tile Drainage Risks

Tile drainage risks refer to potential impacts associated with the use of subsurface drainage systems in agricultural fields. These risks include bank erosion, unearthing of coarse fragments, physical clogging with sediments and iron clogging. Additional resources on tile drainage are available in *Drainage Guide for Ontario (Pub 29)* and in the *Cropland Drainage BMP Book*.

2.6.2.1. Bank Erosion

Natural streams and constructed drainage channels act as outlets for surface water runoff and subsurface drainage systems. Bank erosion is the progressive undercutting, scouring and slumping or collapsing of these drainageways. Poor construction practices and inadequate maintenance can lead to bank erosion problems. Table 15 evaluates bank erosion risk for fields with drains or outlets by combining several descriptors such as drainage class, consistency of wet mineral material, clay content and abundance of coarse fragments.

Table 15. Degree of Soil Vulnerability to Bank Erosion

Soil Descriptors	Risk of Bank Erosion		
	Low	Moderate	High
Drainage	Well to very rapid	Imperfect to moderately well	Poor to very poor
Soil Profile			
Consistency of Mineral Material in the Wet State	Firm to very firm (compact till)	Friable to very friable	Loose consistency
Clay (%)	≥20	10–20	<10
Coarse Fragments by Shape			
Angular (%)	≥35	20–35	<20
Rounded (%)	≥50	20–50	<20

Source: Martin and Nolin, 1991.

2.6.2.2. Unearthing of Coarse Fragments

During the installation of tile drainage systems, the soil is disturbed, which can lead to the unearthing of coarse fragments such as stones. These fragments may interfere with the proper functioning of the drainage system. Table 16 assigns risk classes for the unearthing of coarse fragments during tile installation based on depth to bedrock (cm), abundance of coarse fragments (%) in the subsoil and the dominant fragment size (cm).

Table 16. Degree of Soil Vulnerability to Unearthing of Coarse Fragments

Soil Descriptors	Risk of Unearthing Coarse Fragments		
	Low	**Moderate**	**High**
Depth to Bedrock (cm)	≥150	100–150	<100
Coarse Fragments of Subsoil			
Abundance (%)	<20	20–50	≥50
Dominant Dimension (cm)	<7.5	7.5–25	≥25

2.6.2.3. Physical Clogging with Sediments

Physical clogging in tile drainage systems occurs when sediments accumulate within the drainage pipes, obstructing water flow. This type of clogging can significantly reduce the efficiency of the drainage system and lead to waterlogging and other related issues. The extent of clogging is primarily influenced by particle size. Table 17 links the degree of vulnerability of soils to physical clogging of drainage pipes with clay % and the proportion of sand in specific size classes.

Table 17. Degree of Vulnerability of Soils to Physical Clogging of Drainage Pipes with Sediments

Soil Descriptors	Risk of Clogging with Sediment		
	Low	**Moderate**	**High**
Clay (%)	≥20	10–20	<10
Particles <0.5 mm (%) (very fine, fine, and medium sand)	<85	85–90	≥90
Particles ≥0.5 mm (%) (coarse and very coarse sand)	≥15	10–15	<10
Source: Martin and Nolin, 1991.			

2.6.2.4. Iron Clogging

Iron clogging in tile drainage systems, also known as iron ochre, is a significant risk leading to the underperformance or failure of subsurface drainage systems. Iron ochre is composed of many compounds, but mostly iron deposits mixed with bacterial slime. It is this slime that causes failure of subsurface drainage systems by clogging the pipe perforations, sealing the filter material and filling the internal volumes of the drains. Iron clogging is a result of ochre buildup in the drainage pipes. Table 18 evaluates iron clogging risk by using information on drainage class, soil order, subsoil organic carbon (OC) content, iron and aluminum content (extracted by pyrophosphate), the ratio of OC to iron, soil pH in the subsoil and parent material, and sand and clay content of parent material. All these soil descriptors can be used individually to assess the degree of vulnerability of soils to iron clogging of drainage pipes.

Table 18. Degree of Vulnerability of Soils to Iron Clogging of Drainage Pipes

Soil Descriptors	Risk of Iron Clogging		
	Low	**Moderate**	**High**
Drainage	Well to very rapid	Imperfect to moderately well	Poor to very poor
Order	Gleysolic* or Regosolic	Brunisolic	Podzolic
Subsoil			
Organic C (%)	<0.25	0.25–0.50	≥0.50
Fe-pyro + Al-pyro (%)	<0.15	0.15–0.40	≥0.40
C organic/Fe-pyro	<2	2–10	≥10
pH-water	≥6.5	5.5–6.5	<5.5
Parent Material			
Clay (%)	≥28	10–28	<10
Sand (%)	<70	<70	≥70
pH-water	≥7.0	6.0–7.0	<6.0

*Note: *Ndayegamíye and Nolin (1990) demonstrated that ferric clogging of drains can also affect all geographically associated soils with acidic, poorly drained and podzolized sandy soils. However, the "ferric" subgroups of the Gleysolic order show moderate vulnerability.*

Sources: Martin and Nolin, 1991; Ndayegamiye and Nolin, 1990.

2.6.3. Land Management Risks

Land management risk refers to the potential for agricultural practices to cause adverse effects on soil health, productivity and environmental quality. It includes threats to physical properties, chemical attributes and biological functions resulting from management decisions on the farm. The level of risk varies based on soil type, climate conditions and management intensity which requires appropriate mitigation strategies.

2.6.3.1. Compaction

Soil compaction is the squeezing together of soil particles which reduces the space available for air and water. Compaction increases the density of the soil, which hampers infiltration of water, soil and air movement, seedling emergence, root growth and ultimately reducing yield. Clay content, OC concentration of the surface layer and drainage class are used to assign the degree of vulnerability of the surface layer of soil to compaction (Table 19). Note that each factor is considered individually when interpreting the risk of compaction. Additional resources are available on *soil compaction* and at *Field Crop News*.

Table 19. Soil Descriptors of the Surface Layer Indicating the Degree of Vulnerability of Soils to Compaction

Soil Descriptors	Risk of Compaction		
	Low	**Moderate**	**High**
Clay (%)	<20	20–35	≥35
Organic C (%)	≥4.0	1.7–4.0	<1.7
Drainage	Well to very rapid	Imperfect to moderately well	Poor to very poor

Source: Martin and Nolin, 1991.

2.6.3.2. Loss of Organic Matter

Organic matter is the carbon-containing materials in soil derived from living organisms, including decomposing plant and animal residues, living microorganisms and stable humus. Soil carbon content declines when the removal or decomposition of organic material exceeds additions. The causes may include intensive tillage, continuous row cropping without residue return, erosion, and inadequate organic matter inputs leading to reduced soil quality and function. Each row in Table 20 shows a different soil property (OC, clay and slope), that affects the risk of loss of soil organic matter. Each factor is considered individually to assess the risk of organic matter loss. For example, even if high OC and heavy clay are categorized under low risk, a steep slope can result in high risk of loss of soil organic matter.

Table 20. Loss of Soil Organic Matter Risks for Various Soil Textures

Soil Descriptors	Risk of Loss of Soil Organic Matter		
	Low	**Moderate**	**High**
Organic C (%)	≥4.0	1.7–4.0	<1.7
Clay (%)	≥35	20–35	<20
Slope (%)	<3	3–8	≥8

Source: Martin and Nolin, 1991.

2.6.3.3. Acidification

Soil acidification is the process of reducing soil pH, making the soil more acidic. It is typically caused by nitrogen fertilization, crop removal of base cations, leaching from precipitation and natural weathering processes. Table 21 uses surface layer descriptors such as cation exchange capacity (CEC, meq/100g), texture, clay content, sand content and soil pH according to texture to estimate the vulnerability of the surface layer of soil to acidification. Learn more about *soil pH and pH extremes*.

Table 21. Soil Descriptors of the Surface Layer Indicating the Degree of Soil Vulnerability to Soil Acidification

Soil Descriptors	Risk of Acidification		
	Low	**Moderate**	**High**
CEC (meq/100 g)	≥15	6–15	<6
Texture	Clay	Loamy	Sandy
Clay (%)	>20	≤20	≤20
Sand (%)	<70	<70	≥70
Estimated pH as a Function of Soil Texture			
Clay	≥5.0	4.5–5.0	<4.5
Loamy	≥5.5	5.0–5.5	<5.0
Sandy	Not relevant	≥5.5	<5.5

Source: Wang and Coote, 1981.

2.6.3.4. Soil Erosion

Soil erosion refers to the wearing away of a field's soil by physical forces. It is categorized based on the nature of the force (water, wind, tillage) and the amount of erosion that has occurred. Erosion problems are most obvious on the highest risk soils — loamy, steeply sloping and with complex topography. Table 22 provides information about degree of soil vulnerability to erodibility, as it is an important factor to identify the water erosion potential. Tables 23–25 each link a specific erosion potential risk to different soil descriptors such as texture, erodibility, slope gradient, drainage and organic C, etc.

Water Erosion: The detachment, movement and removal of soil from the land surface by precipitation or snowmelt, leaving the landscape as runoff. It occurs naturally, without human intervention, but is accelerated through human activities such as insufficient residue cover on soils prone to runoff. Soil erosion by water increases as the slope length increases due to the greater accumulation and energy associated with runoff. Consolidation of small fields into larger ones often results in longer slope lengths, increasing erosion potential due to increased velocity of water, which permits a greater degree of scouring (carrying capacity for sediment).

Soil erodibility is affected by surface texture, organic matter content, size and shape of soil aggregates and the permeability of the least permeable horizon. Refer to the *Soil Management Guide* for more information.

Susceptibility to soil erosion by texture: clays or loams > sands

Susceptibility to soil erosion by structure: single-grained (structureless) > crumbly or cloddy

Learn more about *soil erosion by water*. To estimate soil erosion at the farm level, refer to the Inherent Water Erosion Potential ("Risk") Map available through *AgMaps*. Refer to *Estimating Soil Erosion by Water in Ontario* for step-by-step guidance on how to access and use this tool.

Table 22. Soil Descriptors of the Surface Layer Indicating the Degree of Soil Vulnerability to Erodibility

Soil Descriptors	Risk of Soil Erosion		
	Low	Moderate	High
Hydraulic Conductivity (cm hr^{-1})	≥15	0.5–15	<0.5
Silt + Very Fine Sand (%)	<40	40–80	≥80
Organic C (%)	≥2.0	1.0–2.0	<1.0
Structure	Granular	Polyhedral	Amorphous

Source: Presant and Acton, 1984.

Table 23. Soil Descriptors of the Surface Layer Indicating the Degree of Soil Vulnerability to Water Erosion

Soil Descriptors	Risk of Water Erosion		
	Low	Moderate	High
Erodibility	Low	Moderate	High
Slope (%)	<3	3–8	≥8
Landscape Dissection	Imperceptible	Presence of gullies or shallow ravines	Presence of several deep ravines

Source: Martin and Nolin, 1991.

Wind Erosion: The detachment, movement and removal of soil from the land surface by wind. It occurs naturally, without human intervention, or is accelerated through human activities such as excessive tillage.

Soils most susceptible to wind erosion by texture: sands > clays > loams

Soils most susceptible to wind erosion by structure: single-grained (structureless) > crumbly or cloddy

Learn more information about *soil erosion by wind*.

Table 24. Soil Descriptors of the Surface Layer Indicating the Degree of Soil Vulnerability to Wind Erosion

Soil Descriptors	Risk of Wind Erosion		
	Low	Moderate	High
Drainage	Poor to very poor	Imperfect to moderately well	Well to very rapid
Organic C (%)	≥2.0 and <17.0	1.0–2.0	<1.0 and >17.0
Medium + Fine + Very Fine Sand (%)	<40	40-80	≥80

Source: Martin and Nolin, 1991.

Tillage Erosion: Occurs when tillage redistributes soil from high slope positions to lower slope positions. It is aided by gravity, which moves soil particles downslope and takes place gradually over many years. Tillage erosion moves topsoil off the very tops of knolls, where it is more susceptible to water erosion. This form of erosion is especially common on fields with complex topography.

The amount of tillage erosion is influenced by the type of tillage equipment, direction of tillage, speed and depth of tillage, slope gradient of the field and number of tillage passes. Tillage equipment that lifts and carries soil, operates up and down slope, moves at fast speeds and at depth, and performs multiple passes tends to cause more erosion. Learn more about *tillage erosion*.

Table 25. Soil Descriptors of the Surface Layer Indicating the Degree of Soil Vulnerability to Tillage Erosion

Tillage Erosion Potential	Slope Class	Percent Slope	Approximate Degrees	Terminology
Low	A to B	0–2%	0–1.1	Level to nearly level
Moderate	C	2–5%	1.1–3	Very gentle slopes
High	D to J	>5%	>3	Gentle slopes to very steep slopes

Expert Committee on Soil Survey, 1982.

2.7. Canada Land Inventory (CLI) Soil Capability for Agriculture Rating

The Soil Capability for Agriculture is a comprehensive land classification system that evaluates the capability of land for agricultural use based on climate, soils and landscape characteristics. The Soil Capability for Agriculture ratings include a class (Table 26) and one or more subclasses (Table 27). There are 7 capability classes; soils descend in quality from Class 1, which is highest, to Class 7 soils, which have no agricultural capability for common field crops (Figure 11).

Capability subclasses indicate the kinds of limitations present for agricultural use. Eleven subclasses have been adopted for interpreting soils in Ontario (Table 27).

The soil capability for agriculture ratings are used to guide land use planning and agricultural management. They assist in making decisions on land improvement, farm consolidation and developing land use plans. The ratings assume the soils will be well managed and cropped under a largely mechanized system. This system does not classify land for horticultural or other specialty-type crops. Get more details about *Soil Capability for Agriculture in Ontario*.

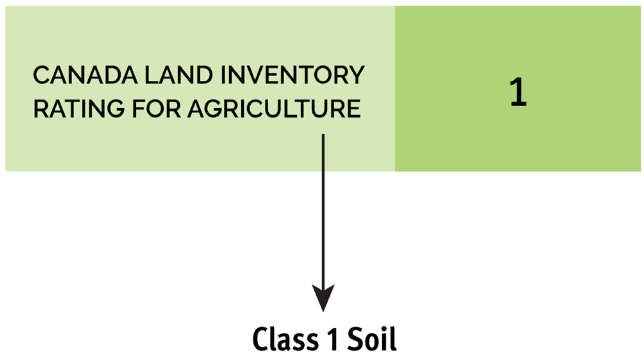

Figure 11. Canada Land Inventory (CLI) Rating for Agriculture.

Soil Capability for Agriculture in Ontario
The CLI Soil Capability for Agriculture system classifies land into seven classes based on the degree of limitation imposed by the soil in its use for agriculture (Table 26).

Table 26. Soil Capability Classes

Capability Class	Description
Class 1	No significant limitations: level to nearly level, deep, well to imperfectly drained; highly productive and versatile.
Class 2	Moderate limitations: restricts crop range or requires moderate conservation; moderately high to high productivity.
Class 3	Moderately severe limitations: reduces crop choice or requires moderate conservation; affects tillage, planting, and harvesting.
Class 4	Severe limitations: restricts crop choice or requires special conservation and careful management; low to medium productivity.
Class 5	Very severe limitations: suitable for perennial forage crops; not for sustained annual crop production; can be improved with machinery.
Class 6	Unsuitable for cultivation: suitable for unimproved permanent pasture; severe limitations make machinery improvement impractical.
Class 7	No capability for arable culture or permanent pasture; includes marsh, rockland, very steep slopes.

Soil Capability Subclasses
Capability classes 2 to 7 are further refined according to 11 subclasses that identify specific limiting factors affecting agricultural use (Table 27).

Table 27. Soil Capability Subclasses

Subclasses	Description
C	Adverse climate
D	Undesirable soil structure and/or low permeability
E	Erosion
F	Low fertility
I	Inundation by streams or lakes
M	Moisture deficiency
P	Stoniness
R	Consolidated bedrock
S	Adverse soil characteristics
T	Topography
W	Excess water

2.8. Physical Analyses

Physical soil properties play an important role in making on-farm decisions and impact land management strategies. Soils are not only a 2-dimensional feature in our landscapes changing across the field; they also show important variability with depth. For this reason, physical analyses for each soil series are provided for three separate depths or layers within the soil profile: surface, subsurface, and parent material (Figure 12). Analytical data was retrieved from the *Ontario Soil Survey Reports*.

Physical Analyses

Soil Layers	Horizon	Texture Class[1]	Coarse Fragments by Volume (%)	Sand Fractions (%)					Sand (%)	Silt (%)	Clay (%)	Bulk Density (g/cm^3)
				Very Coarse	Coarse	Medium	Fine	Very Fine				
Surface	Ap	L	10	3	7	12	11	8	41	49	10	1.32
Subsurface	Bt	CL	5	4	8	10	9	11	42	33	25	1.39
Parent Material	IICk	L	15	11	9	10	7	7	44	37	19	1.61

[1] Texture Class: L = Loam; CL = Clay Loam

Figure 12. Physical analyses of soil properties for the Guelph soil series.

Surface (Topsoil): The uppermost layer of soil, rich in organic matter and microorganisms. It is crucial for plant growth as it contains the highest concentration of nutrients and supports most root systems. This layer is usually called Ap or Ah horizon by soil scientists.

Subsurface (Subsoil): Located beneath the topsoil, this layer has less organic material but is rich in minerals leached from the topsoil. It is denser and often contains more clay, making it important for storing and filtering water. This is usually called the B horizon by soil scientists.

Parent Material: This layer consists of weathered rock and minerals from which the soil is formed. It lies beneath the subsoil, is relatively unaltered compared to the topsoil and subsoil and influences the soil texture, structure, and mineral content. This is usually called the C horizon by soil scientists.

For each layer, a series of key soil physical parameters are provided in each factsheet, including:

Texture Class
Refer to the Soil Texture and Soil Texture Triangle (Section 2.2).

Coarse Fragments
Coarse fragments are particles >2 mm in diameter described according to abundance, shape, and type. The Coarse Fragments by Volume column provides an estimate of the percentage of coarse fragments by volume.

Particle Size Analysis
Particle size analysis includes a breakdown of the proportions of the sand fractions, plus the total sand, silt and clay contents. Combined, this information permits the assignment of a soil texture class.

Bulk Density
Bulk density is an indirect measure of soil compaction and a key indicator of soil health. It is the weight of oven-dried soil per unit of volume, usually expressed in grams per cubic centimetre (g/cm^3). Soil compaction occurs when soil particles are pressed together, reducing the pore space between them. Generally, the bulk density of mineral soils ranges from 1.0 to 1.8 g/cm^3.

2.9. Chemical Analyses

The same three layers are used to report soil chemical properties for each soil series. Soil chemical properties are important for understanding how soils may function within the agricultural context (e.g., CEC influences nutrient cycling, SOM increased soil aggregation, etc.). Figure 13 provides an example of soil chemical properties across different soil layers or soil horizons of the Guelph Soil Series. Analytical data was taken from the *Ontario Soil Survey Reports*.

Chemical Analyses

Soil Layers	Horizon	Horizon Thickness (cm)	pH (H_2O)	SOM (%)	CEC (meq/100 g)	Base Saturation (%)	$CaCO_3$ (%)
Surface	Ap	28	7.1	3.2	21	95	3
Subsurface	Bt	20	7.3	0.6	13	97	3
Parent Material	IICk	44	8.6	0.3	7	100	26
Legend: SOM = Soil Organic Matter; CEC = Cation Exchange Capacity; $CaCO_3$ = Calcium Carbonate							

Figure 13. Chemical analyses of soil properties.

Soil pH

Soil pH is a measure of the acidity or hydrogen ion activity of a soil. It is used as an indicator of the acidity or alkalinity of soils. Soil pH is measured on a 14-point scale, with pH 7 being neutral. Lower pH values indicate increasing acidity; higher pH values indicate increasing alkalinity.

Soil Organic Matter

Soil organic matter is any material derived originally from living organisms that is returned to the soil and goes through the decomposition process.

Cation Exchange Capacity

Cation exchange capacity (CEC) is a measure of the soil's ability to hold and exchange positively charged nutrients (cations). It depends on the negative charge of soil colloids (clay and organic matter). Higher CEC means better nutrient retention and availability of nutrients for plants.

Base Saturation

Base saturation is the extent to which the adsorption complex of a soil is saturated with exchangeable cations other than hydrogen and aluminum. It is expressed as a percentage of the total cation exchange capacity.

Calcium Carbonate

Calcium carbonate is a naturally occurring mineral in soil derived from limestone which neutralizes soil acidity and supplies calcium for plant nutrition. Calcium carbonate is the primary ingredient in agricultural lime which is used to correct acidity through land application.

2.10. Soil Correlation

Soil correlation is a scientific method that compares the characteristics of a soil to those of other soils in a classification system. The Soil Correlation section provides detailed information, (soil family, similar soil series in Ontario, soil region, catena and areal extent) related to the soil series which belong to various taxonomic subgroups and are widely distributed across different regions (Figure 14).

Soil Correlation

Soil Family	Guelph
Similar Series (province wide)	Bennington, Brantford, Bryanston, Harrisburg, Harriston, Honeywood, Huron, Muriel, Waterloo, Wattford, Woolwich
Soil Region	St. Thomas
Catena Members (Drainage)	Guelph (MW), London (I), Parkhill (P)
Areal Extent	73,741 ha (182,214 acres)

Figure 14. Soil Correlation.

Soil Family: The soil family category is a subdivision of the subgroup category of the CSSC based on soil chemical, physical and other properties that reflect the environmental factors in which a soil has developed. The soil family is intended to provide a basis for interpretations for land use and management. Soil families are assigned a name, usually from one of the soil series that belongs to the family.

Similar Soil Series: This section provides details about other soil series in Ontario that are similar to the series described in the factsheet. A group of similar soil series often make up a soil family.

Soil Region: Each soil series belongs to a specific Soil Region, such as the St. Thomas, which includes Guelph, among other areas. Soil Regions roughly parallel established ecoregion and/or ecodistrict boundaries with particular attention given to differences in quaternary geology.

Catena: The catena refers to a non-taxonomic grouping of a sequence of soils derived from similar parent materials and occurring under similar climatic conditions but having unlike characteristics because of variations in relief and in drainage. For example, the Guelph (well drained), London (imperfectly drained) and Parkhill (poorly drained) soils make up a catena.

Areal Extent: This provides an estimate of the areal extent of the soil series based on the Ontario Soil Survey Complex database.

2.11. Agricultural Production and Geographic Distribution

The Agricultural Production section provides a general description of the soil series, including some key soil properties or characteristics and management considerations important to agricultural production and common crops grown in the specific soil.

The Geographic Distribution section provides a map which shows the distribution of the soil series in Ontario.

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Resources

Agriculture and Agri-Food Canada
Canadian System of Soil Classification (CSSC)

Manitoba Agriculture
Soil Management Guide

Ontario Ministry of Agriculture, Food and Agribusiness
Best Management Practices
Best Management Practices Resources
Cropland Drainage BMP Book
Irrigation Management BMP Book
pH extremes
Soil Compaction
Soil Erosion by Wind
Tillage Erosion

Publications
Drainage Guide for Ontario (Pub. 29)
Soil Fertility Handbook (Pub 611)

Factsheets
Estimating Soil Erosion by Water in Ontario
Soil Capability for Agriculture in Ontario
Soil Erosion: Causes and Effects

Websites
Agricultural Irrigation
Field Crop News
Information Atlas (AgMaps) for soil and other agricultural data
Ontario Soils GeoHub
Soil Resources in Ontario