

Manitoba Soil Sustainability in the 21st Century

Afternoon Workshop on Soils
Manitoba Envirothon Workshop, 11th April, 2003, Fairholme Hutterite Colony.
Geoffrey Scott, University of Winnipeg (g.scott@uwinnipeg.ca)

Time permitting we will cover most of the following topics. Anything we do not complete today can be completed back at your local School!!

1. Observations on Soil Organic Matter (o.m.)
2. Soil Texture (apparent texture)
3. Soil Structure
4. Soil Profiles (horizons)
5. Vulnerability to Wind Erosion
6. Vulnerability to Water Erosion
7. Residue management (percentage straw cover)
8. Zero Till indicators
9. Percolation (Infiltration) - Field Method

1. Observations on Soil Organic Matter (o.m.)

As soil organic matter plays such an important role in many soil properties we need to “guesstimate” its presence in a soil sample. (A more accurate way to determine this is to incinerate an oven dry sample at 500 °C and determine weight loss.) Soil organic matter is primarily comprised of four components, a) soil humus, b) dead roots and plant/leaf parts, c) living roots and plant/leaf parts, and d) soil organisms. The very finely divided material is the soil humus which normally comprises > 75% of the organic matter content of a topsoil sample. Soil samples with large amounts of organic matter are generally quite high in organic matter. Generally, as the organic (humus) content declines, the soil colour becomes lighter.

Task: Separate out some of the aggregates on the four trays provided and classify each in terms of the two primary forms of non-living organic matter. Avoid materials which were likely living at soil sampling time (e.g. roots and earthworms).

Sample #	Soil Horizon	Verbal description of soil colour, and % Humus content	Verbal description of non-humus and non-living plant material.
1	Ap		
2	C		
3	Ap		
4	Ah		

2. Soil Texture (apparent texture)

Examine Module # 1 entitled “Apparent Texture”. Determine the apparent texture of the four samples provided. Note that this experiment could be performed more accurately in the laboratory, but this quick method produces good results.

Sample #	Soil Horizon	“Apparent texture”
1	Ap	
2	C	
3	Ap	
4	Ah	
5	Ap	

3. Soil Structure (Structural aggregates)

Examine the background material in Module# 2 entitled “Soil Structure - Soil Aggregates”, and then examine Table 1 in it depicting aggregate types and terms. Take special note of the “Spheroidal” group. While the module is designed for use in the field, you are now asked to examine the soil samples on the four trays and, based on the information in Table 1, describe the form and diameter of their aggregates.

Sample #	Soil Horizon	Aggregate type (From Table 1)	Diameter of aggregates (mm)
1	Ap		
2	C		
3	Ap		
4	Ah		
5	Ap		

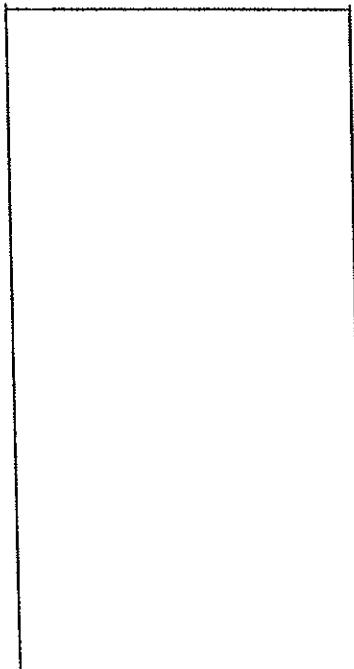
4. Soil Profiles (horizons)

All soils can be described using soil profile diagrams, with soil horizon details provided as a type of "short-hand". Examine the information on soil profile description provided in Module # 4. Typical examples of profile diagrams for the Black Chernozemic soils of the Fairholme region or for the Swan River town-site are given in Figure 2 of this module. In addition, typical profile diagrams for the Gray Luvisols of the type found in the Duck Mountains are presented along with a typical Humic Gleysol of the type common in poorly drained depressions are along the shores of lakes. Gleysolic soils are common in the Winnipeg region where the gumbo (clay-rich) soils on relatively level terrain do not promote good drainage.

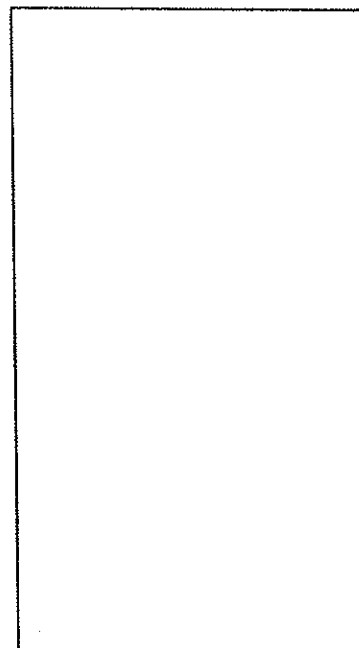
Practical Examples: Descriptive information is provide for two soil profiles from the Swan River region. Complete the two blank profile outlines below so as to convert these descriptive summaries to proper annotated profile diagrams.

- A. This soil site is located 25 km south of Swan River on the moderately steep slopes of the Duck Mountains under aspen forest. The soil surface has a 4-cm thick leaf litter layer, underlain by a dark, organic rich mineral horizon 6 cm thick. Below this the upper mineral layer has been eluviated of some of its' clay content, and this clay has been deposited in the 12-cm horizon below - this horizon is slightly darker that the horizon above and the horizon below. The horizon below is the unaltered, very light coloured, calcareous till parent material. The profile is well drained.
- B. This soil site is located in a farmers wheat field 2 km south of Swan River on a loamy soil that is drained by a ditch along the field boundary. The top layer is a relatively dark mineral layer 15 cm thick, with good aggregation. Directly below this is a lighter coloured layer some 12 cm thick - this is only slightly weathered and no deposition from above. Below this is the light coloured parent material which is made of calcareous (calcium carbonate rich) glacial till. While the profile is moderately well drained, in places this parent material takes on a grey colouration due to gleying caused by a high water table.

A.



B.



5. Vulnerability to Wind Erosion

A bare field surface (one with no residues or plant cover) can vary in its vulnerability to wind erosion due to the surface properties of the soil. Those factors most important in determining if a bare soil has a low or high potential risk for wind erosion are, the size of the mineral particles, and the way these particles are aggregated into crumb-like structures. The particle size most vulnerable to wind erosion is that of fine sand. Examine the three maps listed below.

Soil Landscapes of Canada - Manitoba. (1986) 1: 1,000,000

Wind Erosion Risk Map - Manitoba. (1989) 1: 1,000,000

Detailed Reconnaissance Survey of Swan River Area in Manitoba. 1:126,720

The Soils Landscapes map uses a polygon (mapping area) system for locating areas with similar soil types. Each polygon is assigned a number. To permit easy comparisons, the Wind Erosion Risk maps uses the same polygons shapes and numbers. Find polygons # 131 at Swan River town-site, and # 11 (the Duck Mountains).

1. Polygon unit 131 uses the mapping symbols **Hn**, polygon # 11 uses **Nf**. Explain what each of these mean:
 - a) Hn
 - b) Nf

2. Using both the **Wind Erosion Risk map** and the Soils Landscapes of Canada - Manitoba Map, compare Polygon # 131 to polygon # 130 (to the east of Swan River).
 - a) Which of these places/polygons has soils potentially most vulnerable to wind erosion?

 - b) After checking soil types and soil properties (on Manitoba Landscapes map), explain why this difference exists.

4. Find polygons # 100 and # 89 on both maps. The Fairholme Hutterite Colony is located in # 100 just east of the Assiniboine River, while Winnipeg is located in polygon # 89.
 1. Which of these two polygons exhibits the greatest potential for wind erosion if the surface is bare?
Polygon # _____
 2. If the soils around Winnipeg are primarily made of the finest of mineral material (clay) why then does it not have at least the same vulnerability for wind erosion that polygon # 100 has?

6. Vulnerability to Water Erosion

Water erosion on a bare surface (no residues or plant cover) results from overland flow, a problem greatly exacerbated if the soil surface is sloping. For these reasons, soils which permit good infiltration of rainfall are generally less prone to water erosion. Likewise, as the slope steepens, so does the effect of gravity on running water, and more water erosion is possible. Please examine the following maps:

Soil Landscapes of Canada - Manitoba. (1986)

Water Erosion Risk Map - Manitoba. (1989) 1:1,000,000

Note that these maps use the same polygon (mapping area) and numbering system.

1. Polygon unit 131 uses the mapping symbols **Nf**, polygon # 11 uses **Sm**. Explain what each of these mean:
 - a) Nf
 - b) Sm

2. Using both the **Water Erosion Risk map** and the **Soils Landscapes of Canada - Manitoba Map**, compare Polygon # 131 to polygon # 130 (to the east of Swan River).
 - a) Which of these places/polygons has soils potentially most vulnerable to water erosion?

 - b) After checking soil types and soil properties (On Manitoba Landscapes map), explain why this difference exists.

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 1. Which of these two polygons exhibits the greatest potential for water erosion if the surface is bare?
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7. Residue management (using percentage straw cover values)

You are provided with a Satellite Images Showing "Erosion Risk" and Its Control for one of the Rural Municipalities of, Shell River, Thompson, Pembina, Hanover, and Arthur. Examine this satellite image carefully to appreciate the significance of both the cover on the ground and the rating for the percentage of ground residues that should be left in place in order to reduce/eliminate soil erosion. These images are not available for all the R. M's of southern Manitoba, but they serve as a good indicator of the conditions that require more careful residue management.

1. In terms of ground cover needed to control erosion, what percentage cover is needed on:
 - a) High Risk Land _____ %
 - b) Moderate Risk Land _____ %
2. Compare the areas of M, H and V on your satellite image and then find the same mapping area on the *Soil Landscapes of Canada - Manitoba*. (1986) . Do you note any relationships between the Residue Rating for an area and the type or textural characteristics of the soils found there?

8. Zero Till indicators in the field

As *zero till* indicates minimal interference with the soil surface we should find stalks or stubble of the previous crop still sticking out of the soil. The expression "minimal interference" is used because even though the soil may not be tilled, there is minor disruption as seeds/fertilizer are added in spring. When visiting a cropped field in early summer look between the new foliage for signs of stubble/stalks emerging from the soil.

Stubble from the previous year serves to not only reduce wind speed, and therefore wind erosion, but this should be aided by other straw/plant-part residues spread on the surface. Zero till also encourages the recycling of organic residues, and therefore a good "infiltration promoting" topsoil - this reduces the likelihood of surface water flow. Both stubble and residues will also physically reduce the speed of running water, and therefore water erosion is less likely.

Some "minimal tillage" operations leave many stalks/stubble standing but often at various angles to the horizontal. Make sure you can differentiate between undisturbed stubble and stubble moved around by some tillage. If a field does not show signs of zero tillage, at least note the degree which crop residues may or may not have been used as a conservation strategy.

9. Percolation (Infiltration) - Field Method only

The rate at which rainfall or melting snow enters the soil is important not only in terms of soil erosion, but in letting water escape from a septic tank into the septic field surrounding it. The method used to compare the percolation (infiltration) rates for different soils is outlined in Module # 4.

MODULE #1

APPARENT TEXTURE

Background:

Soil texture can be defined as, “*the relative proportions of the various soil separates (particle size range) in a soil*”. Texture is therefore a way of describing the combinations or proportions of sand (2.0 - 0.05 mm), silt (0.05 - 0.002 mm) and clay (< 0.002 mm) in a mineral soil. Based on the proportions of these particle sizes mineral soils can be classified into **textural classes** (see Figure 1 below). As used here, the term texture does not apply to organic soils, or to the organic matter in the top layers of mineral soils. As the simple field method detailed below (the *feel method*) does not exactly replicate the more rigorous laboratory technique we are really only approximating the textural class, and must therefore call it “apparent texture”.

Significance:

Texture greatly influences the amount of moisture and nutrients a soil can hold. It also greatly influences soil drainage. The sandier a soil, the lower the surface area provided in the soil to hold water against gravity, and the larger are the soil pores -- as a result a sandy soil retains little water but usually drains well. In addition it retains only small amounts of nutrients.

At the opposite end of the spectrum clays have large surface areas, generally provide micropores with poor drainage, and exhibit electrical properties. Clays therefore retain large amounts of water, and their electrical properties allow them to hold large amounts of positively charged cation nutrients such as calcium, potassium and magnesium (but also acids such as hydrogen) to their surfaces.

Ideally a soil that retains sufficient water for plant use, allows for drainage to allow air into the soil (with the important oxygen for root respiration) and retains nutrients, is best. Textural classes which best serve these objectives are called **loams**.

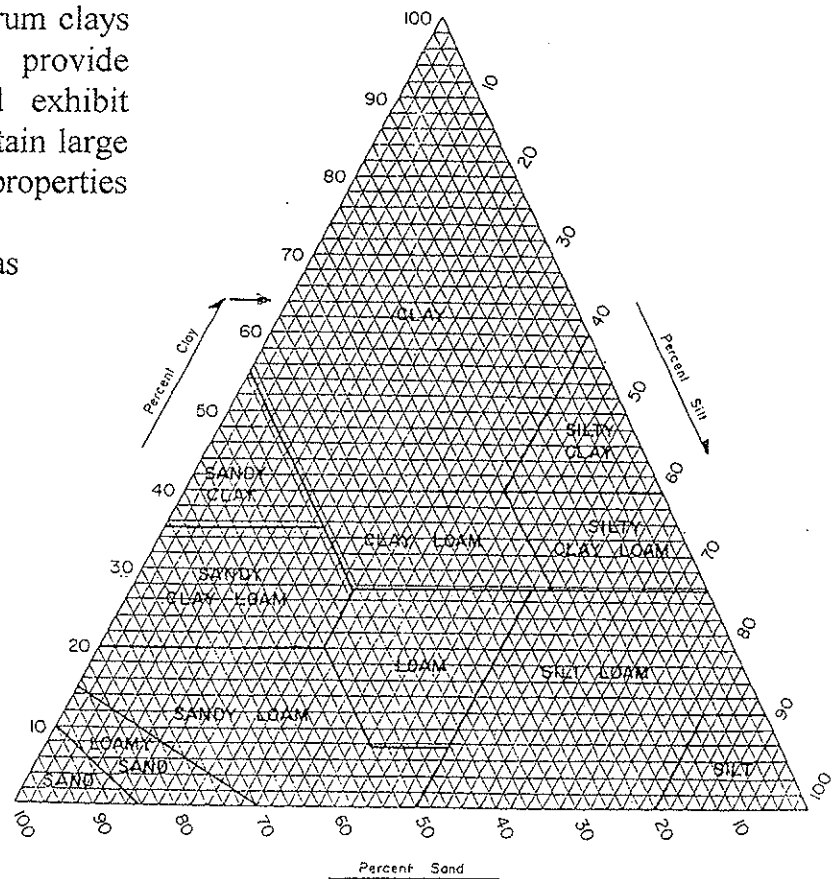


Figure 1.

Relationship between the textural class name of a soil sample and its particle size distribution. When using this diagram follow the lines which are parallel to the numbers representing percentages. For example, the textural class for a soil which has 10% sand, 55% silt and 35% clay, is a "silty clay loam".

Field Procedure: Follow the procedure provided graphically in Figure 2 below. Remember to bring a water bottle for use in mixing with soil. As this really is the *feel method*, make sure you have paper towels and extra water to wash your hands with. Hands-on techniques using soil can be rather messy!!

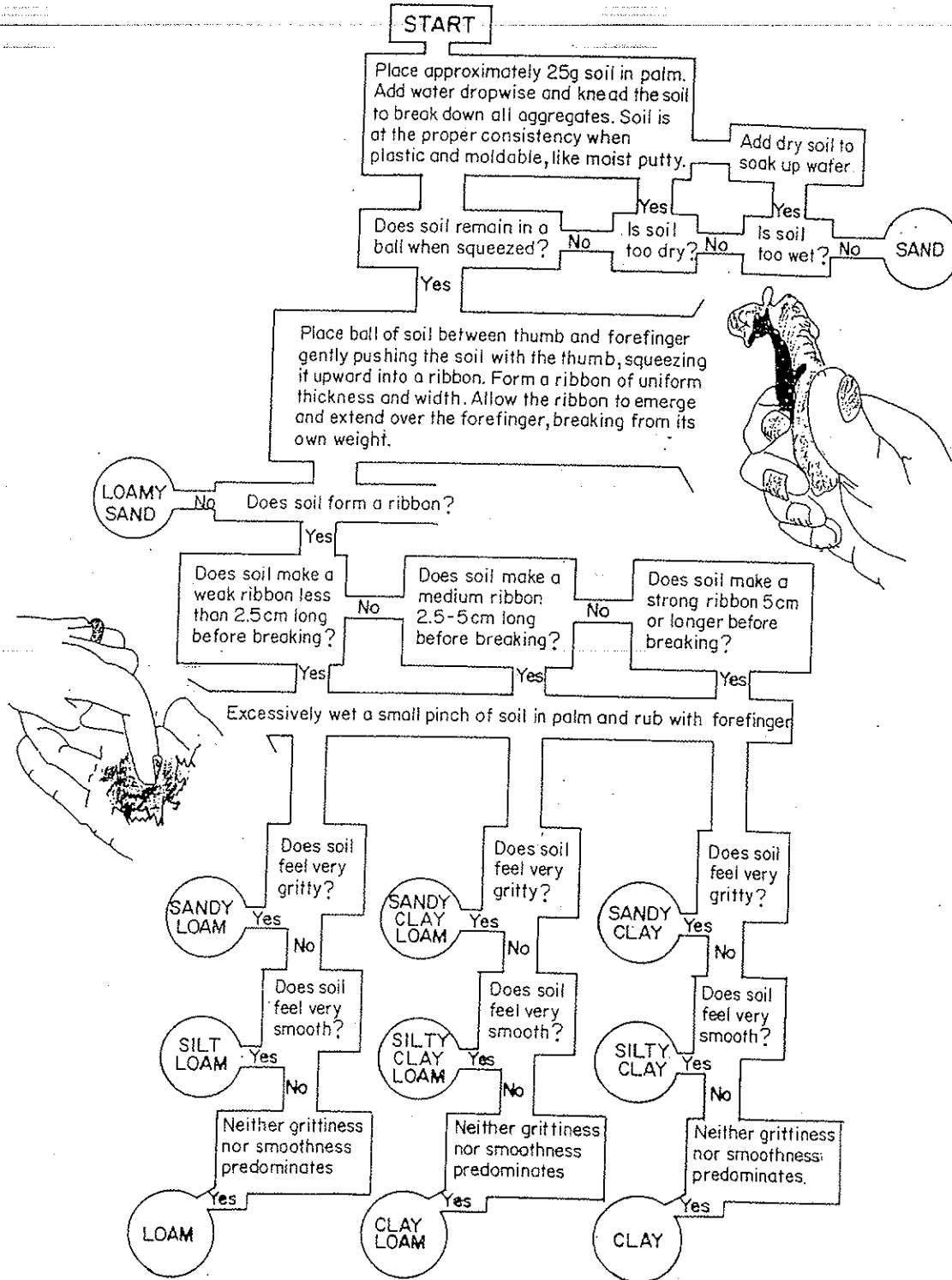


Figure 2. Flow chart for use in the field when determining apparent texture using the *feel method*.

MODULE # 2

SOIL STRUCTURE -- SOIL AGGREGATES

While it is best to perform this study in the field, it is possible to get good information directly from soil samples on the trays provided.

Background: One of the important physical characteristics of a soil is the way soil separates (sand, silt, and clay) and soil organic matter (if present) are grouped or clumped into aggregates (peds or structural aggregates). An aggregate is "*a group of two or more primary particles which cohere to each other more strongly than to surrounding particles*". Topsoils, especially those that contain 5-10% organic matter (humus), tend to form quite large aggregates that resemble large bread crumbs. In reality, many millions of individual mineral particles may combine to form one aggregate.

Significance: Non-aggregated clay soils have few macropores, drain poorly and are problematic for typical crop production because without a suitable soil atmosphere oxygen levels decline as will root respiration. If the clay soil is well aggregated into crumb-like structures the soil has the benefit of nutrient and water retention within the aggregates, while drainage and air-entry are promoted by the macropores between the peds. In your garden, or in a wheat field in southern Manitoba, it is therefore of critical importance to promote good aggregation, especially if the soils are clay-rich. The maintenance /promotion of good aggregation is best achieved by recycling organic residues as well as protecting the soil surface from erosion. The farmer will perhaps plow under cover crops, recycle straw residues, and/or add farmyard manure. The household approach is similar, but in addition to recycling residues (in the form of mulch/compost) you might add peat moss. The overall intent is to ensure good nutrient and water retention within the aggregates, while drainage and air result from the macropores between aggregates. If you allow the organic matter levels in your soil to decline, aggregates tend to decrease in size, fit together (compact) more readily, reduce macroporosity and infiltration rates and your plants tend to grow more slowly. It is important to note that it is not just the aggregate that gives benefits, but the increase in organic matter also helps in moisture and nutrient retention, and provides food for beneficial soil organisms. The farmer encourages the promotion of aggregates for other reasons as well. Larger aggregates increase infiltration thereby reducing runoff and water erosion. In addition, larger aggregates are less prone to wind erosion.


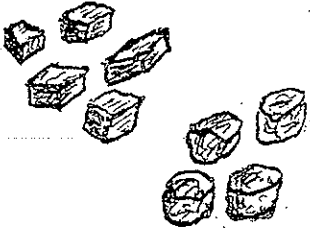
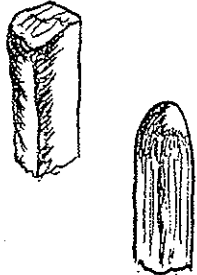

Aggregate Types: Table 1 summarizes the different aggregate forms possibly found in a soil. Some soils, such as sands with little or no organic are essentially structureless as the particles will not bind together. By adding organic residues the sandy soils are greatly improved for agricultural use.

Field Procedures: Basic equipment -- a trowel (or shovel), plastic collecting bags and the key given in Table 1. Be careful not to force soil aggregates together to form artificial *clods* -- they are larger than what was present before you started digging.

1. For a forested site clear the litter away and then collect a few hundred grams from both the topsoil and subsoil (say at a depth of 40-50 cm). Note how the surface aggregates are dark (organic rich) and well aggregated into **crumbs**, many of which "cling" to fibrous roots. Subsoil aggregates tend to be **massive** or **blocky** in shape.

2. Repeat for a field (bare or in crop). Topsoils tend to not be quite as dark, and many of the **crumb** aggregates are smaller. Subsoils will probably be similar to that under forest.
3. Compare samples in terms of aggregate properties both within one soil pit and between different soil pits. Why do they differ, and what could be done to change the properties of soils already modified by human activity?

Table 1. Aggregate structures (peds) and associated horizons.

Aggregate Types	Ped description	Common horizon	Form of occurrence
<p>A. Spheroidal</p> <p>1) crumb</p> <p>2) granular</p>	<p>small spheroid shaped peds which lie loosely and are separated from each other</p> <p>- very porous (soft)</p> <p>- less porous (firm)</p>	<p>A</p> <p>A</p>	
<p>B. Block-like</p> <p>3) angular blocky</p> <p>4) subangular blocky</p>	<p>larger blocky peds bounded by other peds - vertices sharply angular - pack closely together</p> <p>- rectangular faces</p> <p>- subrectangular and sub-rounded faces</p>	<p>B/Bt</p> <p>B/Bt</p>	
<p>C. Prismlike</p> <p>5) prismatic</p> <p>6) columnar</p>	<p>column-like peds arranged around a vertical axis -- relatively flat vertical surfaces</p> <p>- without rounded caps</p> <p>- with rounded caps</p>	<p>B</p> <p>Bnt</p>	
<p>D. Plate-like</p> <p>7) platy</p>	<p>particles arranged along horizontal planes and impair drainage</p> <p>- platy, platy-leafy, or flakey</p>	<p>Ae</p>	
<p>E. Structureless</p> <p>8) amorphous</p> <p>9) massive</p>	<p>without structure</p> <p>- sands low in organic matter</p> <p>- clay rich subsoils low in organic matter</p>	<p>A/B/C</p> <p>C</p>	<p>individual grains</p>

MODULE # 3

SOIL PROFILE DESCRIPTIONS FOR MINERAL SOILS

Background: The basic unit of the Canadian Soil Classification is the *pedon*, the smallest three-dimensional unit that is considered as a soil. This can be as little as one metre in diameter if horizons are regular/ordered, to 3.5 m in diameter where horizons vary laterally for whatever reason. When we dig a soil pit, while we may not have a complete pedon to examine, we can easily summarize what we see using a *soil profile diagram*. Figure 1 illustrates some of the possibilities for such a diagram, and to this has been added information on some of the physical processes involved in helping create distinct soil horizons.

We are all familiar with the every-day term, *leaching*. In Figure 1 the term *eluviation* is applied to horizons where material is removed and carried down the soil profile during the leaching process. *Illuviation* refers to any horizon where some of this eluviated material may be deposited. Leaching may also remove material (usually dissolved) farther down below the profile say to ground-water.

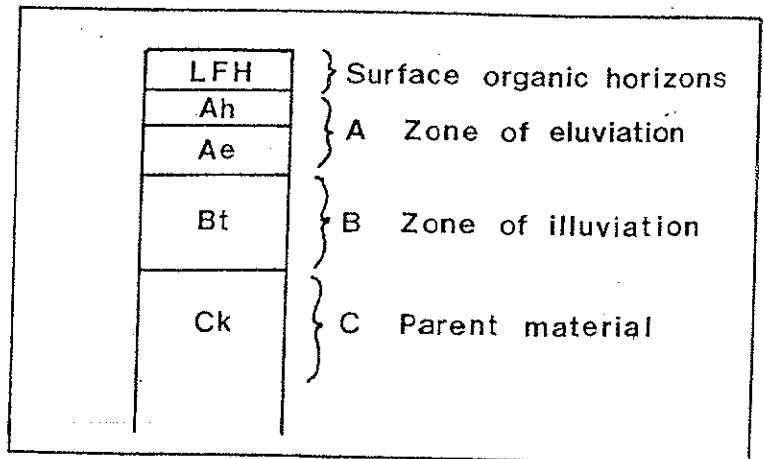


Figure 1. Typical soil profile under a mixed forest on calcareous till.

Figure 2 illustrates three soil profiles from southern Manitoba. Table 1 on the next page lists many of the abbreviations (capital letters for Master horizons, and suffixes) used to provide for greater detail. All soil profiles can be illustrated using this "short hand" approach to summarizing profile information. These letters are not used arbitrarily. Each letter tells a story.

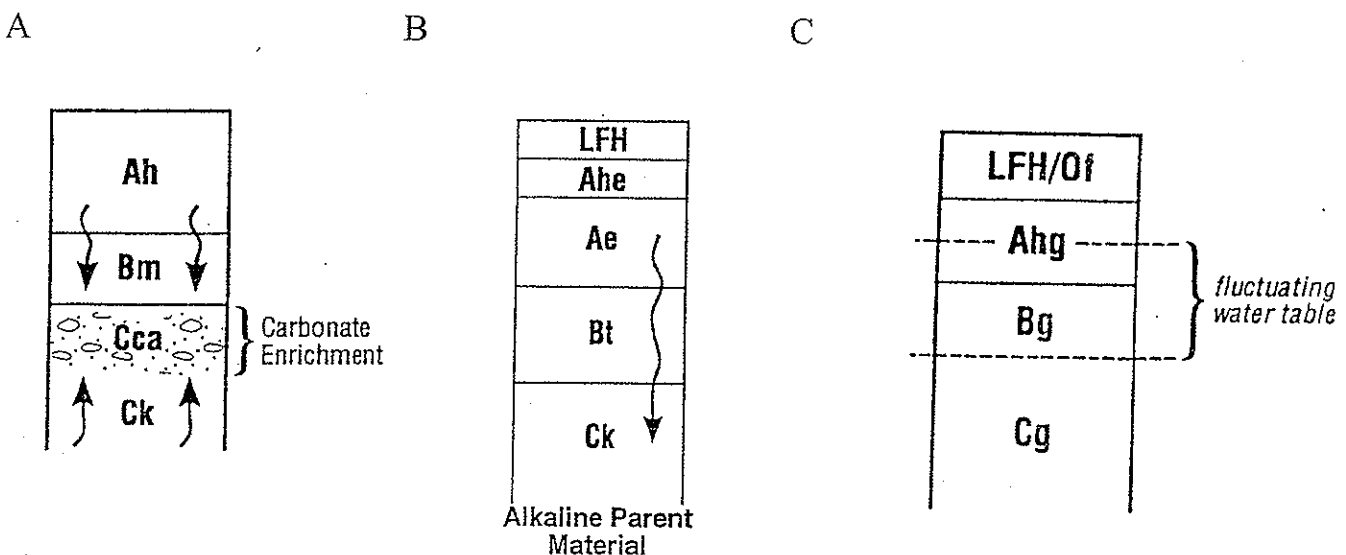


Figure 2. Typical Manitoba soil profiles. A = Black Chernozem from the semi-arid prairie grasslands, B = a typical Gray Luvisol from the sub-humid mixed forests (aspen and spruce), and C = a Humic Gleysol from an area in the prairie grasslands where the water table is close to the surface.

Table 1. Definition of Selected Soil Horizon Designations for Mineral Soil Profiles. See Soil Classification Working Group (1998: 11-22) for fuller details.

ORGANIC HORIZONS

- L Horizon**—An organic layer characterized by the accumulation of organic matter in which the original structures are easily discernible.
- F Horizon**—An organic layer characterized by the accumulation of partly decomposed organic matter. The original structures are discernible with difficulty. Fungi mycelia often present.
- H Horizon**—An organic layer characterized by an accumulation of decomposed organic matter in which the original structures are undiscernible.

MASTER MINERAL HORIZONS

- A Horizon**—A mineral horizon or horizons formed at or near the surface in the zone of maximum removal of materials in solution and suspension and/or maximum in situ accumulation of organic matter. It includes: (1) horizons in which organic matter has accumulated as a result of biological activity (Ah); (2) horizons that have been eluviated of clay, iron, aluminum and/or organic matter (Ae); (3) horizons dominated by 1 and 2 above, but transitional to underlying B or C (AB or A and B); (4) horizons markedly disturbed by cultivation or pasture (Ap).

- B Horizon**—A mineral horizon or horizons characterized by one or more of the following: (1) an enrichment (exclusive of dolomite or salts more soluble in water) in silicate clay, iron, aluminum and/or illuvial organic matter (Bt, Bf, Bh, Bfh); (2) a prismatic or columnar structure which exhibits pronounced coatings or stainings and characterized by the presence of significant amounts of exchangeable sodium and/or magnesium (Bn); (3) an alteration by hydrolysis or oxidation to give a change in color and/or structure and does not meet the requirements of (1) and (2) above (Bm).

- C Horizon**—A mineral horizon or horizons comparatively unaffected by the pedogenic processes operative in A and B, excepting (1) the process of gleying and (2) the accumulation of dolomite and salts more soluble in water (Cca, Csa and C).

Subhorizons; Lowercase Suffixes

- b** Buried soil horizon.
- c** Cemented (irreversible) pedogenic horizon.
- ca** Horizon of secondary carbonate enrichment in which the concentration of lime exceeds that in the unenriched parent material.
- e** Horizon characterized by the eluviation of clay, Fe, Al, or organic matter alone or in combination.
- f** Horizon enriched with amorphous material, principally Al and Fe combined with organic matter; reddish near upper boundary, becoming yellower at depth.
- g** Horizon characterized by gray colors, or prominent mottling, or both, indicative of permanent or intense reduction.
- h** Horizon enriched with organic matter.
- j** Used as a modifier of suffixes e, f, g, n, and t to denote an expression of, but failure to meet, the specified limits of a suffix it modifies.
- k** Denotes presence of carbonate as indicated by visible effervescence when dilute HCl is added.
- m** Horizon slightly altered by hydrolysis, oxidation, or solution, or all three to give a change in color or structure, or both.
- n** Horizon in which the ratio of exchangeable Ca to exchangeable Na is 10 or less. It must also have following distinctive morphological characteristics: prismatic or columnar structure, dark coatings on ped surfaces, and hard to very hard consistency when dry.
- p** Horizon disturbed by human activities such as cultivation, logging, and habitation.
- s** Horizon of salts, including gypsum, which may be detected as crystals or veins or as surface crusts of salt crystals.
- sa** Horizon with secondary enrichment of salts more soluble than Ca and Mg carbonates; the concentration of salts exceeds that in the unenriched parent material.
- t** Illuvial horizon enriched with silicate clay.
- u** Horizon that is markedly disrupted by physical or faunal processes other than cryoturbation.
- x** Horizon of fragipan character. (A fragipan is a loamy subsurface horizon of high bulk density and very low organic matter content. When dry it is hard and seems to be cemented.)
- y** Horizon affected by cryoturbation as manifested by disrupted or broken horizons, incorporation of materials from other horizons, and mechanical sorting.
- z** A frozen layer.

MODULE # 4

THE 'PERC' TEST -- INFILTRATION

Background: Percolation is the movement of water down through a soil profile. Infiltration is a measure of the rate that this surface water (e.g. rainfall or snow melt) enters the soil. During a rainstorm water is able to enter the soil via pores and animal burrows -- collectively we can call these *macropores*. The rate at which this rainfall enters the soil macropores is called the *infiltration rate*, and this dictates the percolation of water down the profile.

Significance: Percolation rates vary depending on soil properties. If the rate of rainfall is greater than the infiltration rate then some water collects on the surface, begins to form run-off, and may contribute to soil erosion and flooding. Those soil properties which influence infiltration should therefore be managed so as to reduce these potential problems. The greater the percentage of rainfall we get to enter the soil then less run-off occurs and this in turn helps reduce the rapid rise in river levels during and following storms. Needless to say infiltrating water does not just disappear, but if we can get it to enter the soil it percolates to the ground water and is discharged less rapidly and over a longer period of time into rivers and lakes. The secret to good watershed management is therefore to carry out land use practices which encourage infiltration and percolation.

Promoting Percolation: Those properties which significantly influence percolation include: 1) the size and numbers of the surface pores, 2) the degree to which the topsoil is well aggregated, 3) the loosening of topsoil promoted by a vegetation cover and/or crop residues, 4) the degree to which the soil is already moistened by previous rainfall, and 5) soil compaction.

Comparing Infiltration/Percolation rates in the Field (the 'perc' test):

Equipment:

1. Five equal-sized tins, four of which have both tops and bottoms removed, while the other has only the top removed.
2. A four-litre jug of tap water.
3. A square piece of plywood (of sufficient size to completely cover a tin opening).
4. A hammer or rubber mallet

5. A centimetre ruler.
6. A watch with seconds.

Procedure:

1. Seek out four different soil surfaces that are relatively close to each other. Soils should be selected on the basis of cover and compaction differences. Record site/soil conditions in Table 1 below.
2. Place the plywood over each open-ended tin before hammering/pushing into the soil. Ensuring you do not hit rocks or large roots, hammer/push each of the tins into the ground to a depth of 4 cm. If penetration of the soil is hindered by tough objects remove and try elsewhere.
3. Using the tin that is only open at one end as a measuring device pour a full tin of water into each of the tins that are inserted into the ground. Measure the time it takes for the water in the tin to infiltrate the soil (the last millimetre or two can be ignored).

Table 1. Field data on infiltrations sites and infiltration rates.

	Site 1	Site 2	Site 3	Site 4
Desdription of Soil condition				
Time for water to infiltrate				

Follow-up:

Draw a graph of the results so that time is on the y ordinate and soil condition/vegetation cover is on the x ordinate. If your time data differ, why do they differ? Extrapolate results to the watershed level so as to anticipate the effects on the hydrologic cycle of altering large areas. Is this study related to flooding possibilities in Manitoba? To soil erosion?