Wastewater System and Potable Water Supply Rules

# Soil Evaluation and Simplified Groundwater Mounding Analysis

**Facilitated by Graham Bradley**

**Drinking Water & Groundwater Protection Division**

VERMONT
AGENCY OF NATURAL RESOURCES
Department of Environmental Conservation

# This afternoon we'll take a look at …

## 1. Soil Description and Application Rates

- Soil description and percolation tests for application rates
- Using texture, structure, and consistence for application rates
- Determining the treatment zone: Munsell colors & redox features

## 2. Simplified Method of Groundwater Mounding

- What is Darcy's Law?
- How is Darcy's Law used in the Simplified Method?
- Examples of using the Simplified Method and how to use the simplified method when there are two soil layers

# Discussion

## What is the purpose of soil evaluation?

- Is an on-site soil-based wastewater system viable?
- Is the soil good habitat for aerobic microbes that treat effluent?
- Can wastewater infiltrate the soil at rate to facilitate design flow?

## What should we expect from a test pit log?

- Is the minimum permit requirement the same as good practice?
- Observation > Interpretation > Design
- Is 5 minutes enough time? As a young engineering geologist I was expected to take around 30 minutes to log each test pit.

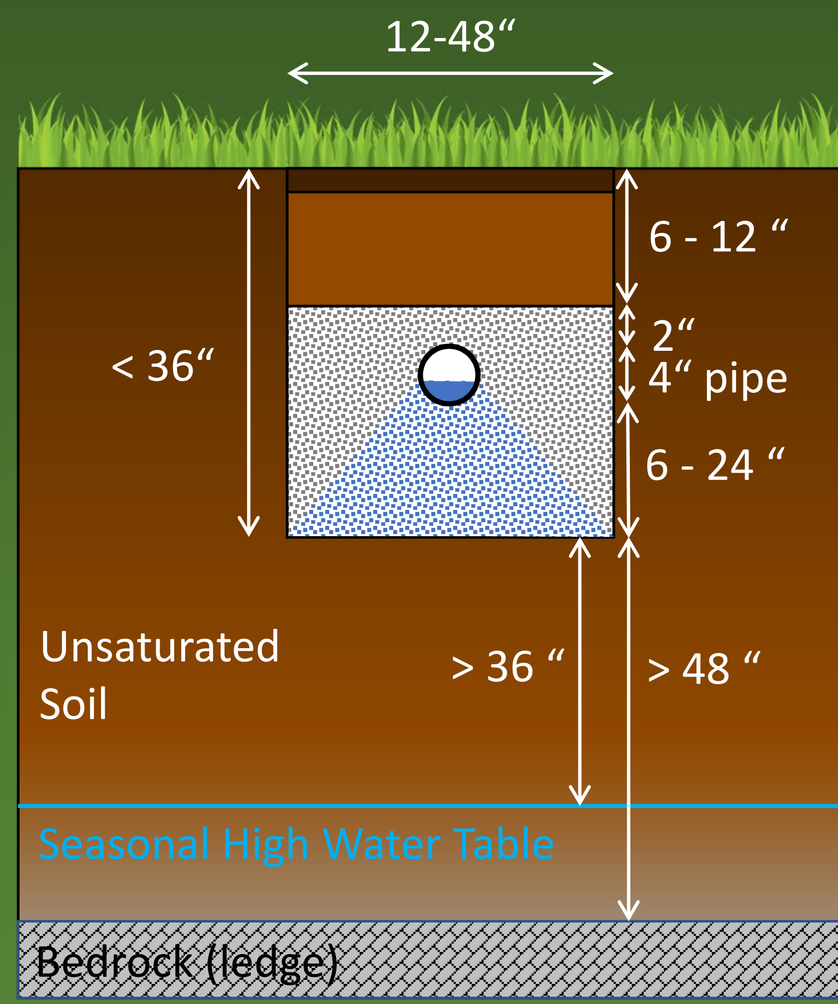
# Remember the purpose of the site investigation for a soil-based wastewater system

**1. Texture, structure, consistence:**
Application Rates

*Can you get wastewater in the ground?*

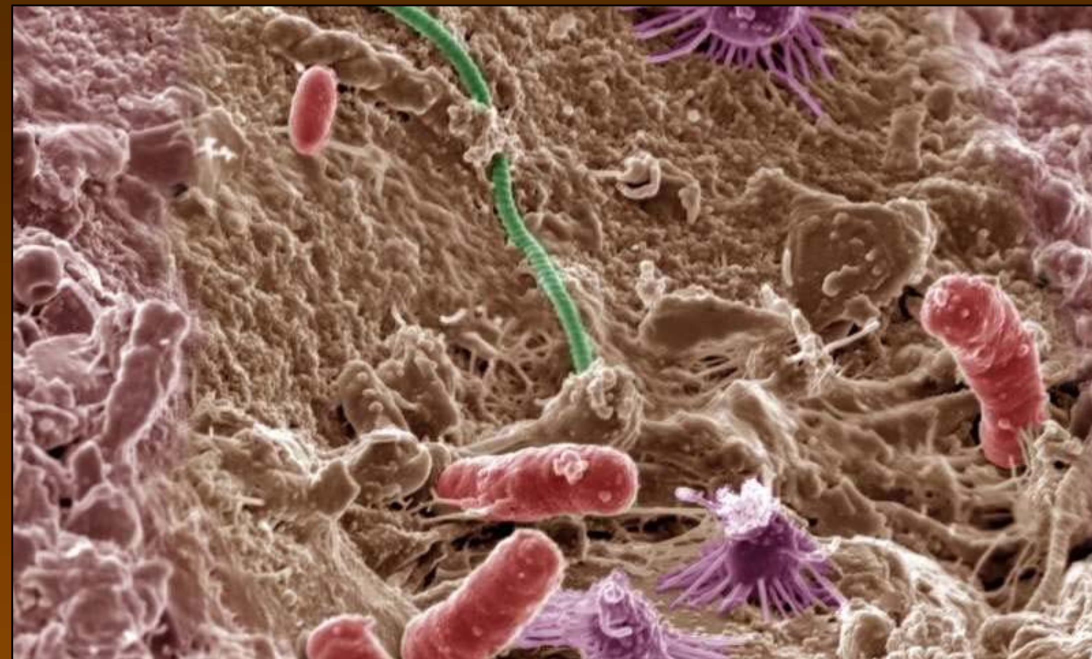
**2. Color / Redox Conditions:**
Seasonal High Water Table

*Is there aerobic habitat for the microbes that treat the wastewater once it is in the ground?*



# Teaming with microbes!

Bacteria (aerobic, anaerobic, facultative), actinomycetes, fungi, algae, protozoa, nematodes



Designers, engineers… and microbe farmers?

# §1-9 Specific Technical Standards for Wastewater Systems

## § 1-910 Soil Evaluation

- < 600 gpd - 2 excavations per in-ground leachfield & replacement area
- < 600 gpd - 3 excavations per mound or bottomless sand filter area
- Confirm soils under leachfield and 25 ft downslope
- Soil excavations shall be conducted using a backhoe unless authorized by the Secretary
- Secretary may allow fewer soil excavations if soils are uniform
- Secretary may require additional soil excavations to confirm complying soil conditions

# §1-9 Specific Technical Standards for Wastewater Systems

## § 1-911 Application Rates

- Maximum application rate for sizing leachfield in **mound** shall be 1.0 gpd
- Maximum application rate for **in-ground** or **at-grade** leachfield shall be determined using one of the following methods:
  - Using Table 9-3 for most limiting **soil texture and structure** identified within 0 to 3 feet below leachfield infiltrative surface
  - Using the results of the **percolation tests** in the most limiting soil texture and structure identified within 0 to 3 feet below leachfield infiltrative surface
- If percolation test gives a higher application rate than soil description (Table 9-3) then the application rate determined by the soil description shall be used – **use the lowest application rate**

*Both are tools in your tool box, but <u>you must give full soil descriptions</u>*

# §1-9 Specific Technical Standards for Wastewater Systems

## § 1-910 Soil Evaluation

- Soil described for each horizon according to **USDA-NRCS** Field Book
- Description shall include
  1. Color based on Munsell notation (and name), e.g. 10YR 4/3 (brown)
  2. Redoximorphic features (reductions and concentration, ‘mottles’)
  3. Texture as identified by full name and USDA-NRCS abbreviation
  4. Structure
  5. Consistence
- Evidence of SHWT: redoximorphic features, seepage, standing water
- Percolation testing **may** be conducted for establishing application rates

# § 1-911 Application Rates

**Table 9-3**
**Application Rates Established Using Soil Excavation**

| Soil Characteristics | | Application Rates (gallons per square foot per day) | | | |
|---|---|---|---|---|---|
| Texture | Structure Type[1] | In-Ground Trench | In-ground Bed | At-Grade Leachfield | Leachfield in a Bottomless Sand Filter |
| Very Coarse Sand or Coarser | SG | See § 1-919(b) | See § 1-919 (b) | See § 1-919(b) | 1.00 |
| Coarse Sand, Sand | SG | 1.50 | 1.20 | 1.00 | 1.00 |
| Loamy Coarse Sand, Loamy Sand | SG | 1.50 | 1.20 | 1.00 | 1.00 |
| Fine Sand, Very Fine Sand, Loamy Fine Sand, Loamy Very Fine Sand | SG | 1.00 | 0.80 | 0.80 | 0.80 |
| | MA/PL | 0.50 | 0.40 | 0.40 | 0.40 |
| | PR/ABK/ SBK/GR | 0.70 | 0.60 | 0.60 | 0.60 |
| Coarse Sandy Loam, Sandy Loam | MA/PL | 0.50 | 0.40 | 0.40 | 0.40 |
| | PR/ABK/ SBK/GR | 0.70 | 0.60 | 0.60 | 0.60 |
| Fine Sandy Loam, Very Fine Sandy Loam | MA/PL | 0.50 | 0.40 | 0.40 | 0.40 |
| | PR/ABK/ SBK/GR | 0.60 | 0.50 | 0.50 | 0.50 |
| Loam | MA/PL | 0.50 | 0.40 | 0.40 | 0.40 |
| | PR/ABK/ SBK/GR | 0.60 | 0.50 | 0.50 | 0.50 |
| Silt Loam, Silt | MA/PL | 0.30 | 0.20 | 0.20 | N/A |
| | PR/ABK/ SBK/GR | 0.40 | 0.30 | 0.30 | N/A |
| Sandy Clay Loam, Clay Loam, Silty Clay Loam | MA/PL | 0.25 | 0.20 | 0.20 | N/A |
| | PR/SBK/ GR | 0.30 | 0.20 | 0.20 | N/A |
| Sandy Clay, Clay, Silty Clay | N/A (See § 1-926) | | | | |

Adapted from J. Tyler, 2000.

[1] The abbreviations used for structure are: SG = single grain; GR = granular; MA = massive; PL = platy; PR = prismatic; ABK = angular blocky; SBK = subangular blocky.

# Percolation Rates back-calculated from Application Rates in Table 9-3 WW Rules

| Soil Characteristics | | Application Rates (gallons per square foot per day) | | | Percolation Rates (minutes per inch) | | |
|---|---|---|---|---|---|---|---|
| Texture | Structure Type[1] | In-Ground Trenches | In-ground Beds and At-Grade Leachfields | Leachfields in Bottomless Sand Filters | In-Ground Trenches | In-ground Beds and At-Grade Leachfields | Leachfields in Bottomless Sand Filters |
| Very Coarse Sand or Coarser | SG | See § 1-919(b) | See § 1-919(b) | 1 | See § 1-919(b) | See § 1-919(b) | 6 |
| Coarse Sand, Sand | SG | 1.5 | 1.2 | 1 | 4 | 4 | 6 |
| Fine Sand, Very Fine Sand, Loamy Fine Sand, Loamy Very Fine Sand | SG | 1 | 0.8 | 0.8 | 9 | 9 | 9 |
| | MA/PL | 0.5 | 0.4 | 0.4 | 36 | 36 | 36 |
| | PR/ABK/SBK/GR | 0.7 | 0.6 | 0.6 | 18 | 16 | 16 |
| Coarse Sandy Loam, Sandy Loam | MA/PL | 0.5 | 0.4 | 0.4 | 36 | 36 | 36 |
| | PR/ABK/SBK/GR | 0.7 | 0.6 | 0.6 | 18 | 16 | 16 |
| Fine Sandy Loam, Very Fine Sandy Loam | MA/PL | 0.5 | 0.4 | 0.4 | 36 | 36 | 36 |
| | PR/ABK/SBK/GR | 0.6 | 0.5 | 0.5 | 25 | 23 | 23 |
| Loam | MA/PL | 0.5 | 0.4 | 0.4 | 36 | 36 | 36 |
| | PR/ABK/SBK/GR | 0.6 | 0.5 | 0.5 | 25 | 23 | 23 |
| Silt Loam, Silt | MA/PL | 0.3 | 0.2 | N/A | 100 | 144 | N/A |
| | PR/ABK/SBK/GR | 0.4 | 0.3 | N/A | 56 | 64 | N/A |
| Sandy Clay Loam, Clay Loam, Silty Clay Loam | MA/PL | 0.25 | 0.2 | N/A | 144 | 144 | N/A |
| | PR/SBK/GR | 0.3 | 0.2 | N/A | 100 | 144 | N/A |
| Sandy Clay, Clay, Silty Clay | N/A (See § 1-926) | | | | N/A (See § 1-926) | | |

# Information to be recorded on a test pit log

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## Soil Test Pit Log

Project: ______________________ Date: ______________________ Test Pit #: ______________________

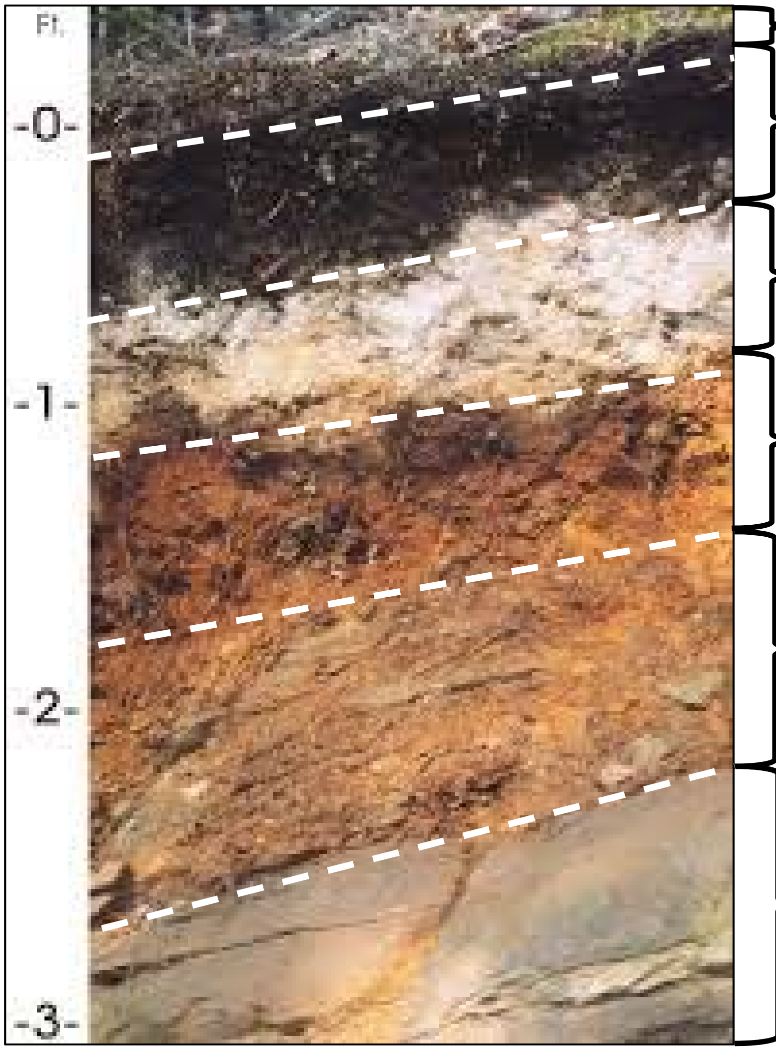
Logged by: ______________________ Location: ______________________ Time: ______________________

Excavation Method: ______________________ Weather: ______________________ Slope Shape, Position, %: ______________________

| Horizon (O, A, B, C, R) | DEPTH (inches) | MATRIX COLOR (Munsell code, name) | OTHER COLOR (RMF, conc/dep, % ) | TEXTURE (e.g. ART GRV LFS) | STRUCTURE (SG, GR, BK, PL, 1-3) | CONSISTENCE (Friable, firm etc.) | COMMENTS (seepage, SHWT etc.) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

# Diagnostic Soil Horizons

## e.g. Vermont State Soil -Tunbridge Series




**O** **Humus**: organic leaf litter

**A*** **Topsoil**: humus, minerals, organisms

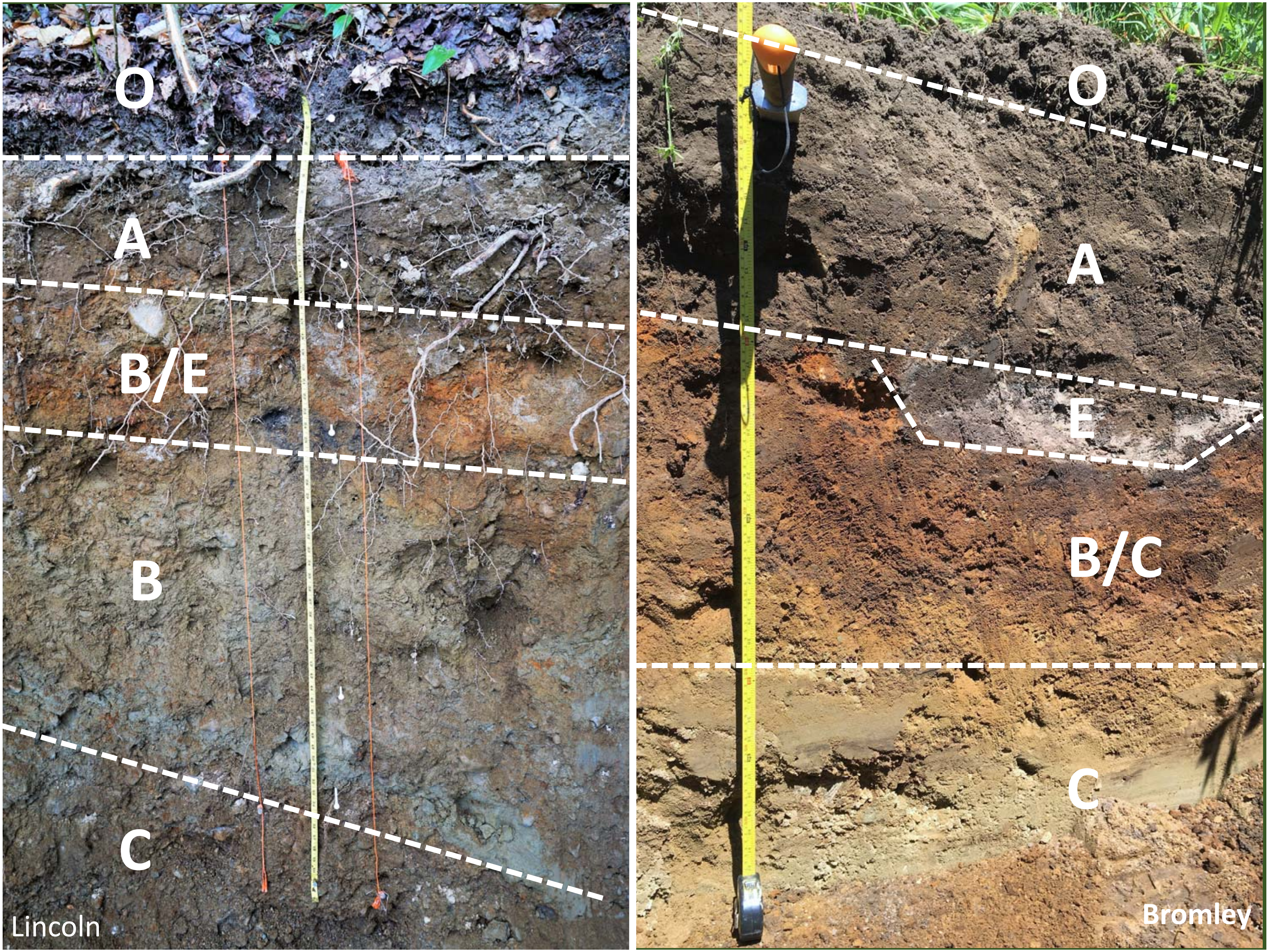
**E** **Leached by humic acid:** mineral soil (forest soils, not present in most soils)

**B*** **Subsoil:** Mineral soil, weathered with accumulated iron, clay etc.

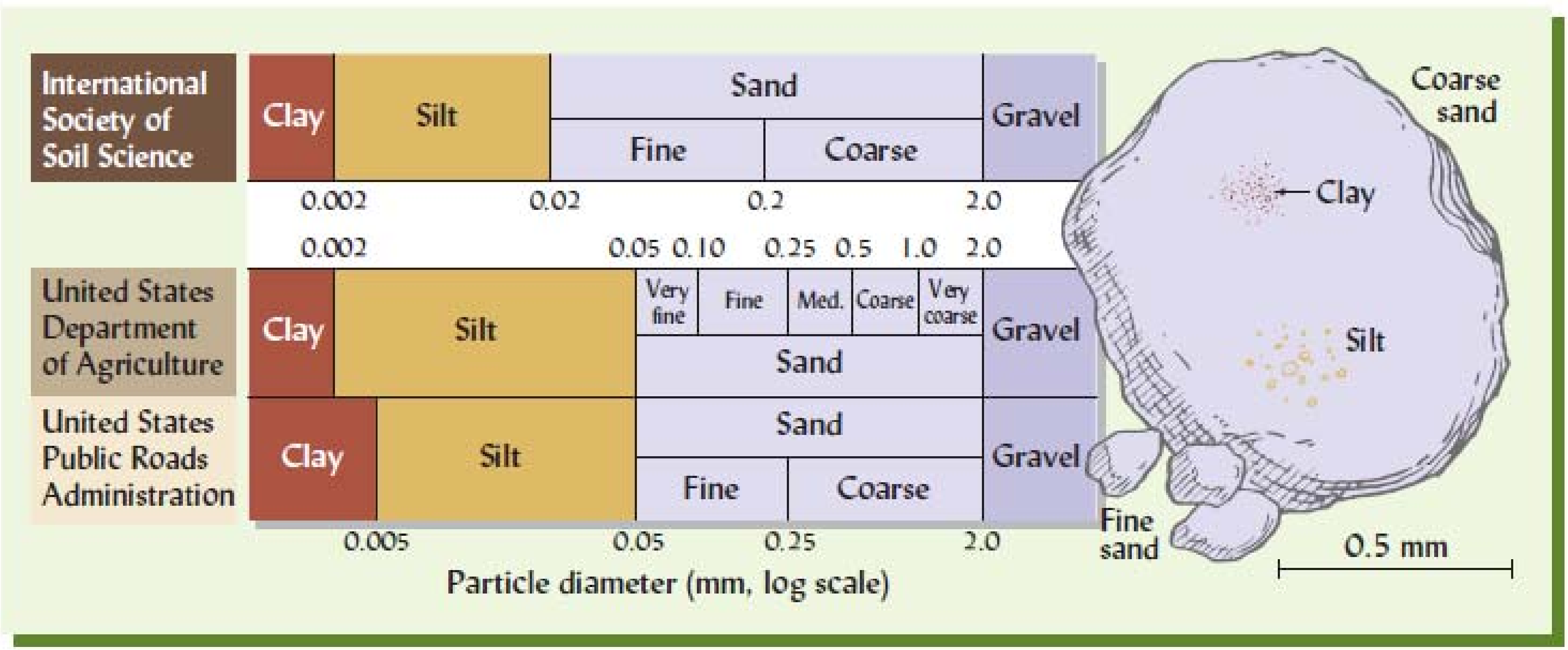
**C** **Parent material:** weathered rock, glacial till, alluvium, lacustrine etc. (Tunbridge is till)

**R** **Bedrock –** metamorphic

*** not always present in Tunbridge Series**


O
A
B/E
B
C
Lincoln
O
A
E
B/C
C
Bromley

# Soil Texture
# (particle size distribution)



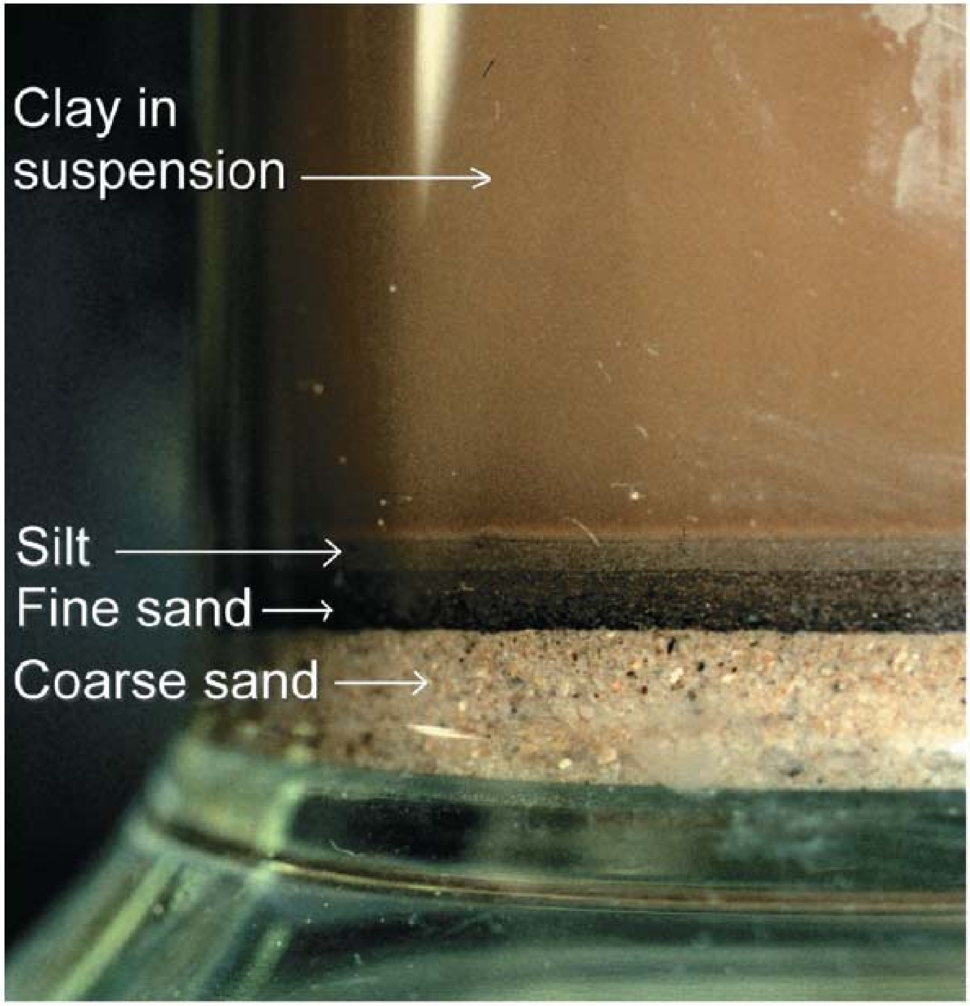
# Particle Size Analysis
# Sieve sand & gravel

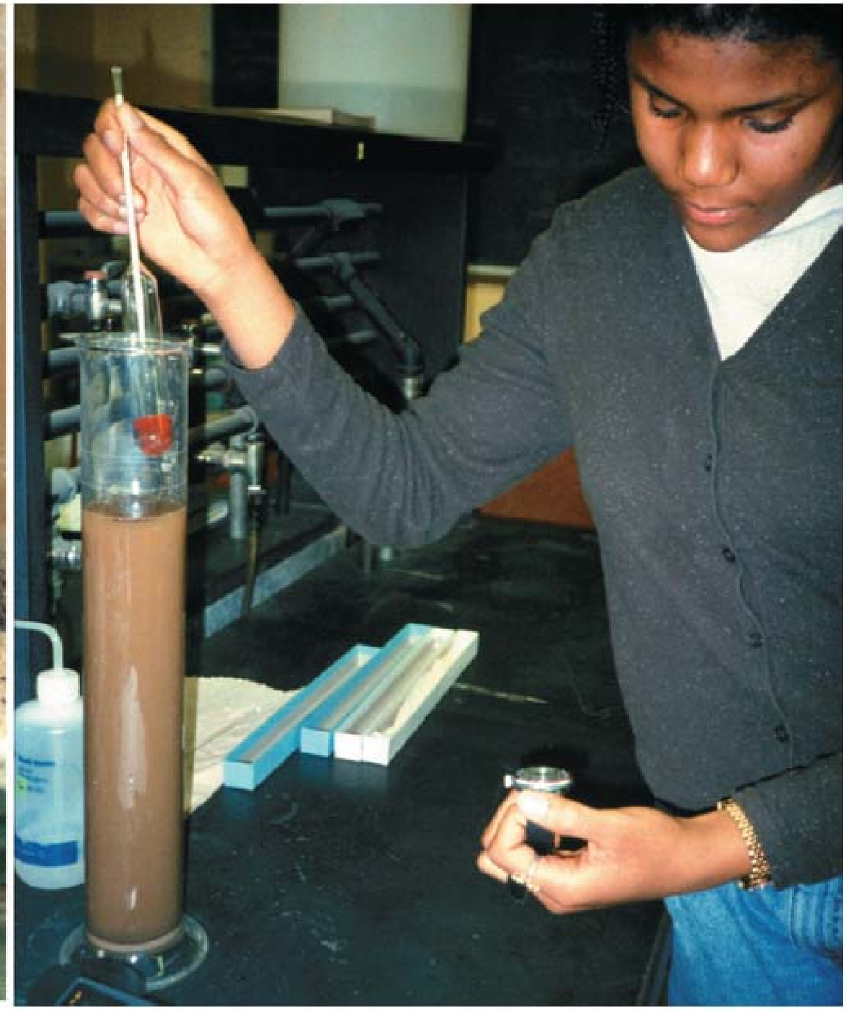

Sand

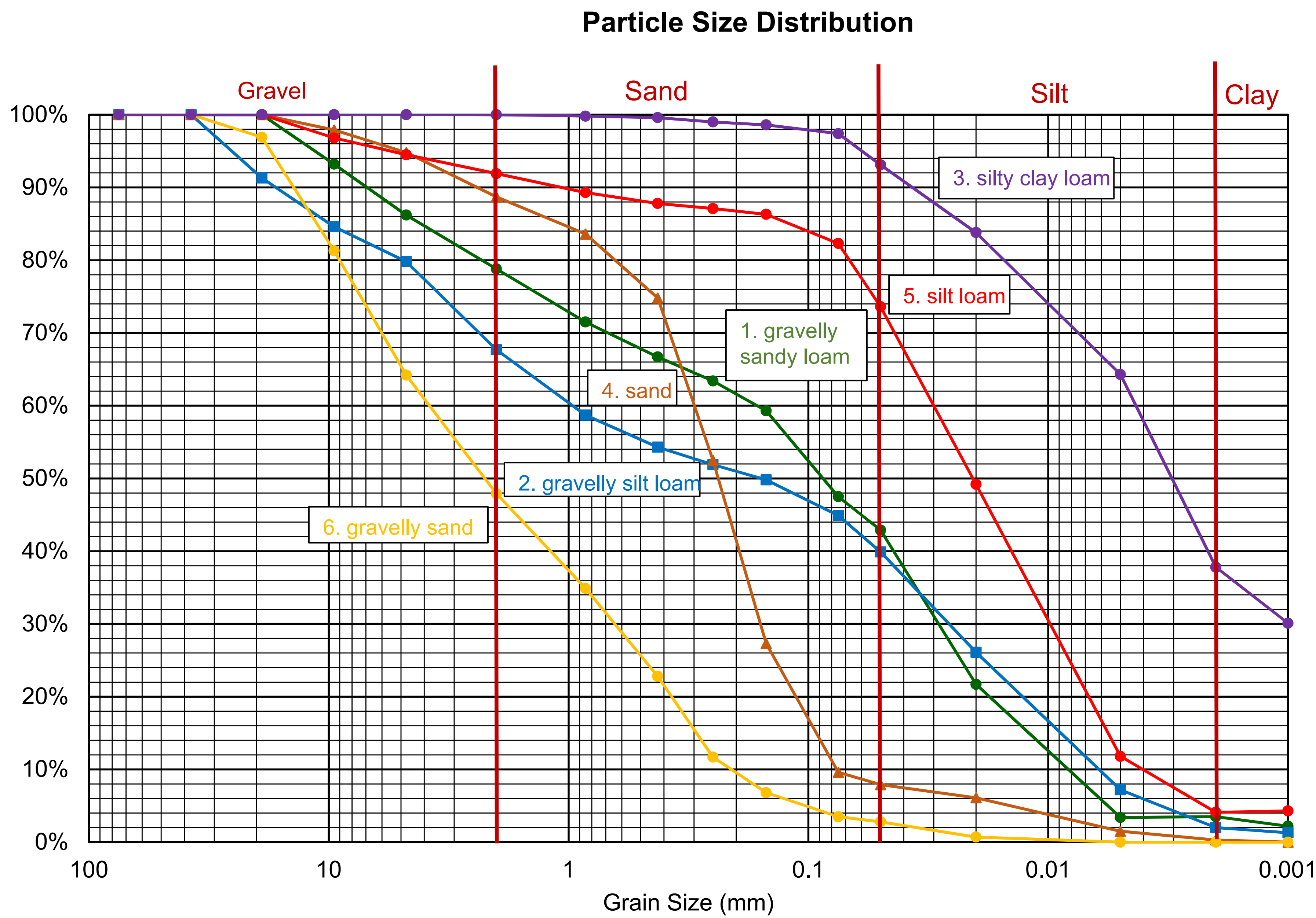
Silt

| Sieve size (mm) | BSS | Tyler (approx) | US (approx) |
|---|---|---|---|
| 4.75 | - | 4 | 4 |
| 3.35 | 5 | 6 | 6 |
| 2.81 | 6 | 7 | 7 |
| 2.38 | 7 | 8 | 8 |
| 2.00 | 8 | 9 | 10 |
| 1.68 | 10 | 10 | 12 |
| 1.40 | 12 | 12 | 14 |
| 1.20 | 14 | 14 | 16 |
| 1.00 | 16 | 16 | 18 |
| 0.853 | 18 | 20 | 20 |
| 0.710 | 22 | 24 | 25 |
| 0.599 | 25 | 28 | 30 |
| 0.500 | 30 | 32 | 35 |
| 0.422 | 36 | 35 | 40 |
| 0.354 | 44 | 42 | 45 |
| 0.297 | 52 | 48 | 50 |
| 0.251 | 60 | 60 | 60 |
| 0.211 | 72 | 65 | 70 |
| 0.178 | 85 | 80 | 80 |
| 0.152 | 100 | 100 | 100 |
| 0.125 | 120 | 115 | 120 |
| 0.104 | 150 | 150 | 140 |
| 0.089 | 170 | 170 | 170 |
| 0.075 | 200 | 200 | 200 |
| 0.066 | 240 | 250 | 230 |
| 0.053 | 300 | 270 | 270 |
| 0.044 | 350 | 325 | 325 |
| 0.037 | 440 | 400 | 400 |

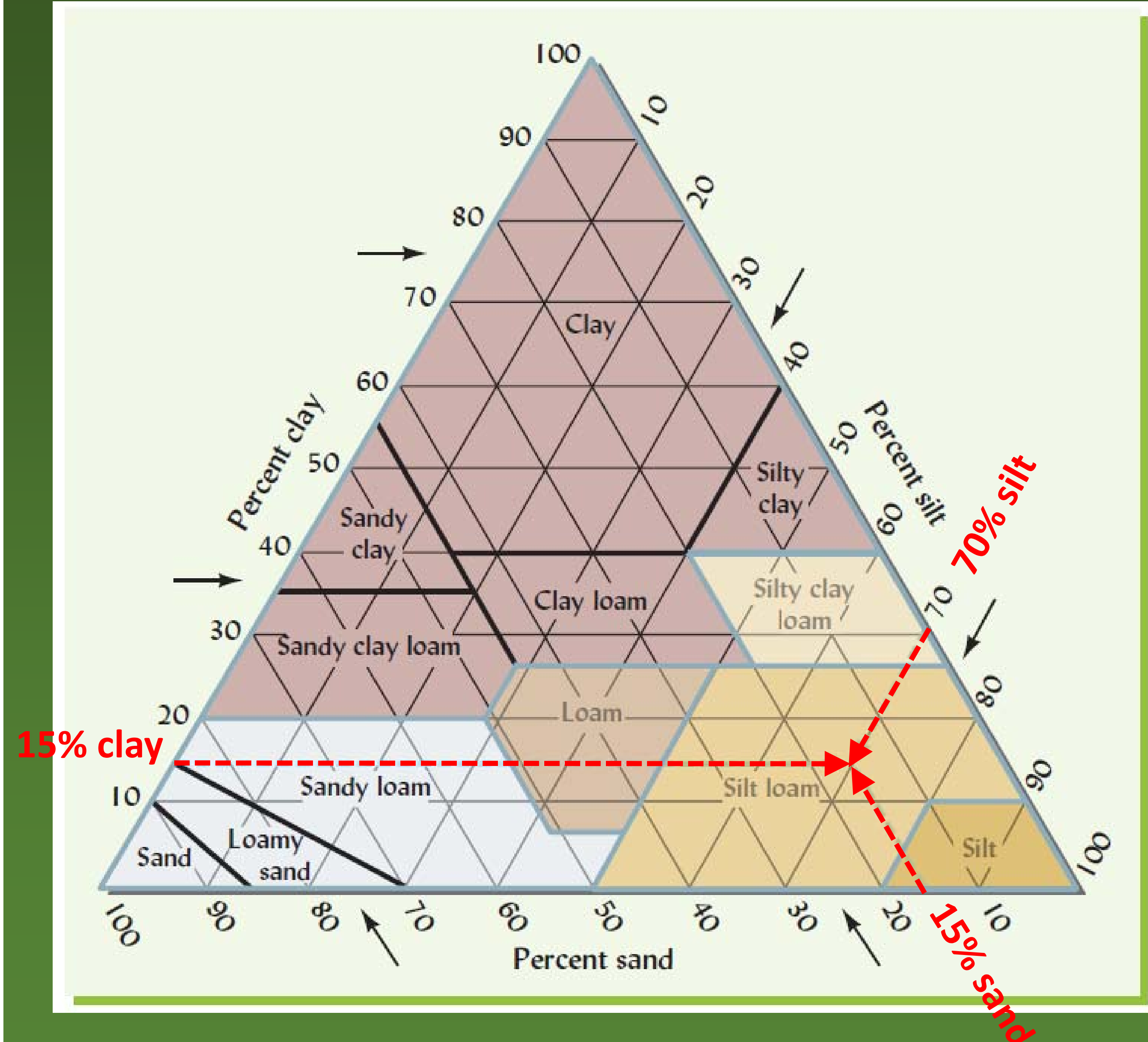
# Use hydrometer and Stokes Law to determine silt and clay fraction



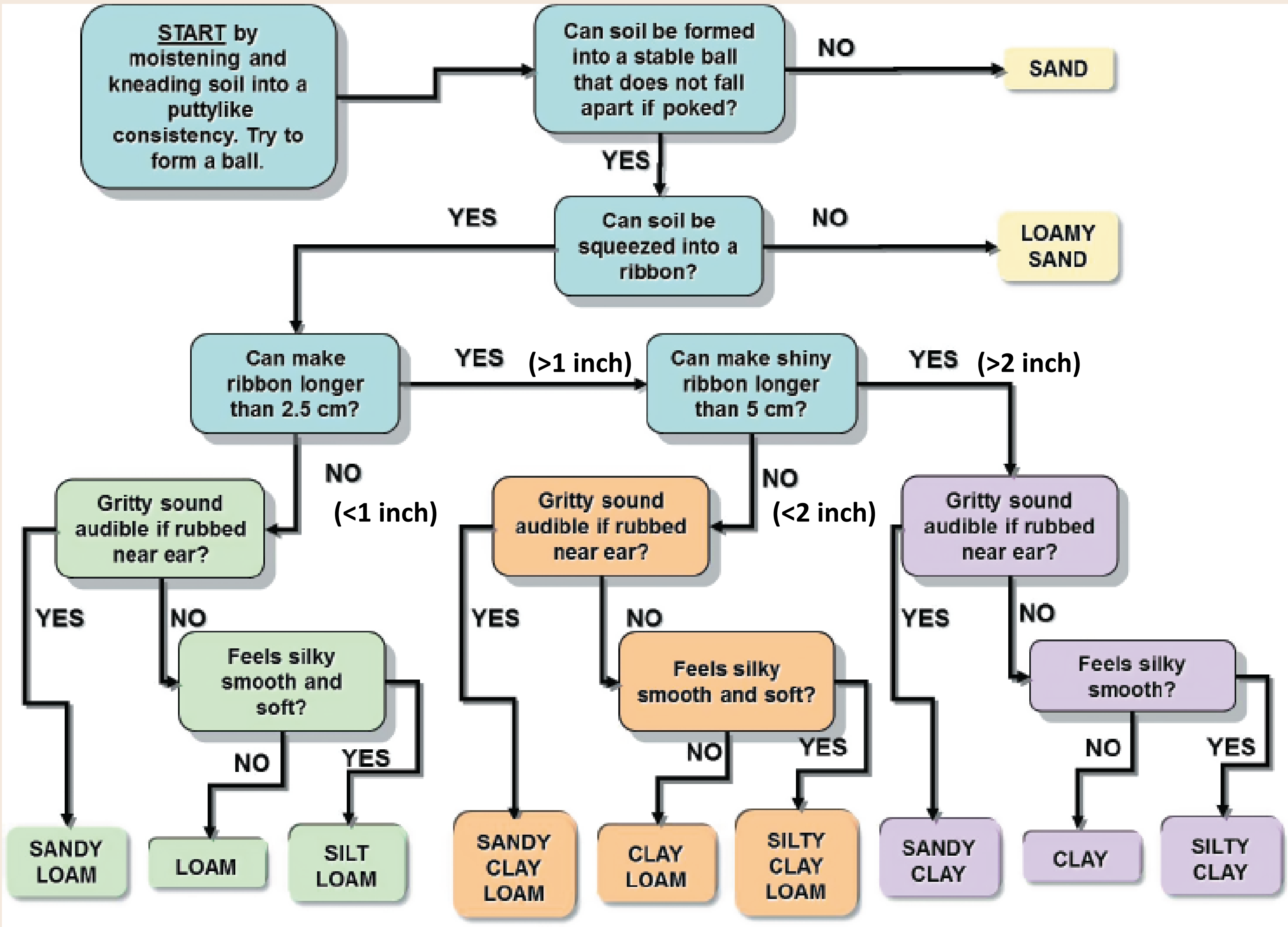




Particle Size Distribution
Gravel
Sand
Silt
Clay
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3. silty clay loam
5. silt loam
1. gravelly sandy loam
4. sand
2. gravelly silt loam
6. gravelly sand
100
10
1
0.1
0.01
0.001
Grain Size (mm)

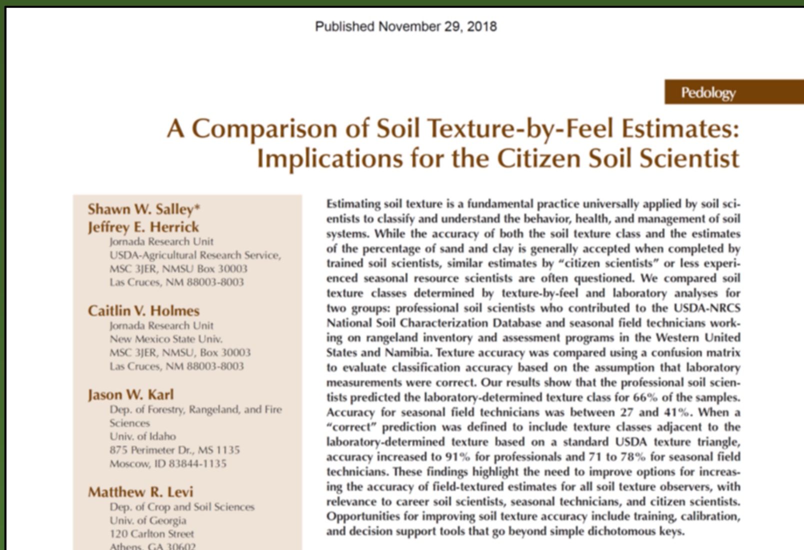
# USDA-NRCS Soil Texture Triangle




# Soil Texture: Field Determination



# Soil Textures … Stay Calibrated!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Pedology

A Comparison of Soil Texture-by-Feel Estimates: Implications for the Citizen Soil Scientist


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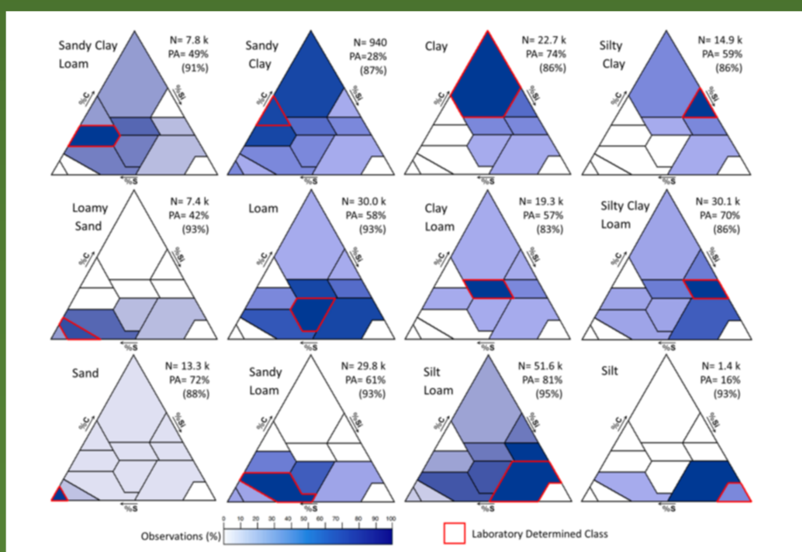
Estimating soil texture is a fundamental practice universally applied by soil scientists to classify and understand the behavior, health, and management of soil systems. While the accuracy of both the soil texture class and the estimates of the percentage of sand and clay is generally accepted when completed by trained soil scientists, similar estimates by "citizen scientists" or less experienced seasonal resource scientists are often questioned. We compared soil texture classes determined by texture-by-feel and laboratory analyses for two groups: professional soil scientists who contributed to the USDA-NRCS National Soil Characterization Database and seasonal field technicians working on rangeland inventory and assessment programs in the Western United States and Namibia. Texture accuracy was compared using a confusion matrix to evaluate classification accuracy based on the assumption that laboratory measurements were correct. Our results show that the professional soil scientists predicted the laboratory-determined texture class for 66% of the samples. Accuracy for seasonal field technicians was between 27 and 41%. When a "correct" prediction was defined to include texture classes adjacent to the laboratory-determined texture based on a standard USDA texture triangle, accuracy increased to 91% for professionals and 71 to 78% for seasonal field technicians. These findings highlight the need to improve options for increasing the accuracy of field-textured estimates for all soil texture observers, with relevance to career soil scientists, seasonal technicians, and citizen scientists. Opportunities for improving soil texture accuracy include training, calibration, and decision support tools that go beyond simple dichotomous keys.


## Professional Soil Scientists

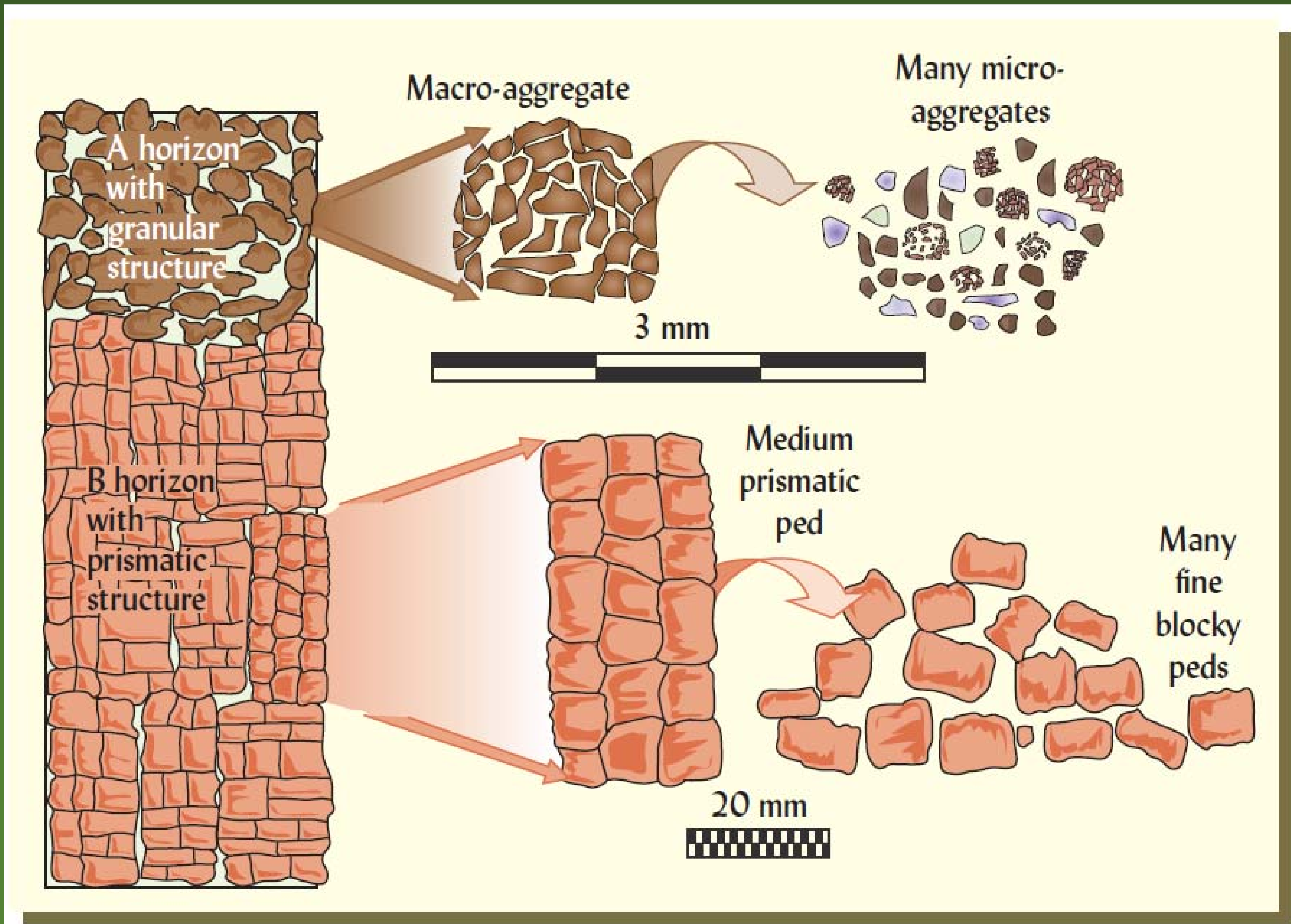
- 66% textures correct!
- 91% textures 'correct' when include adjacent classes
- Sand & clay classes good
- Silt & loam … not so much

## Seasonal Field Technicians?

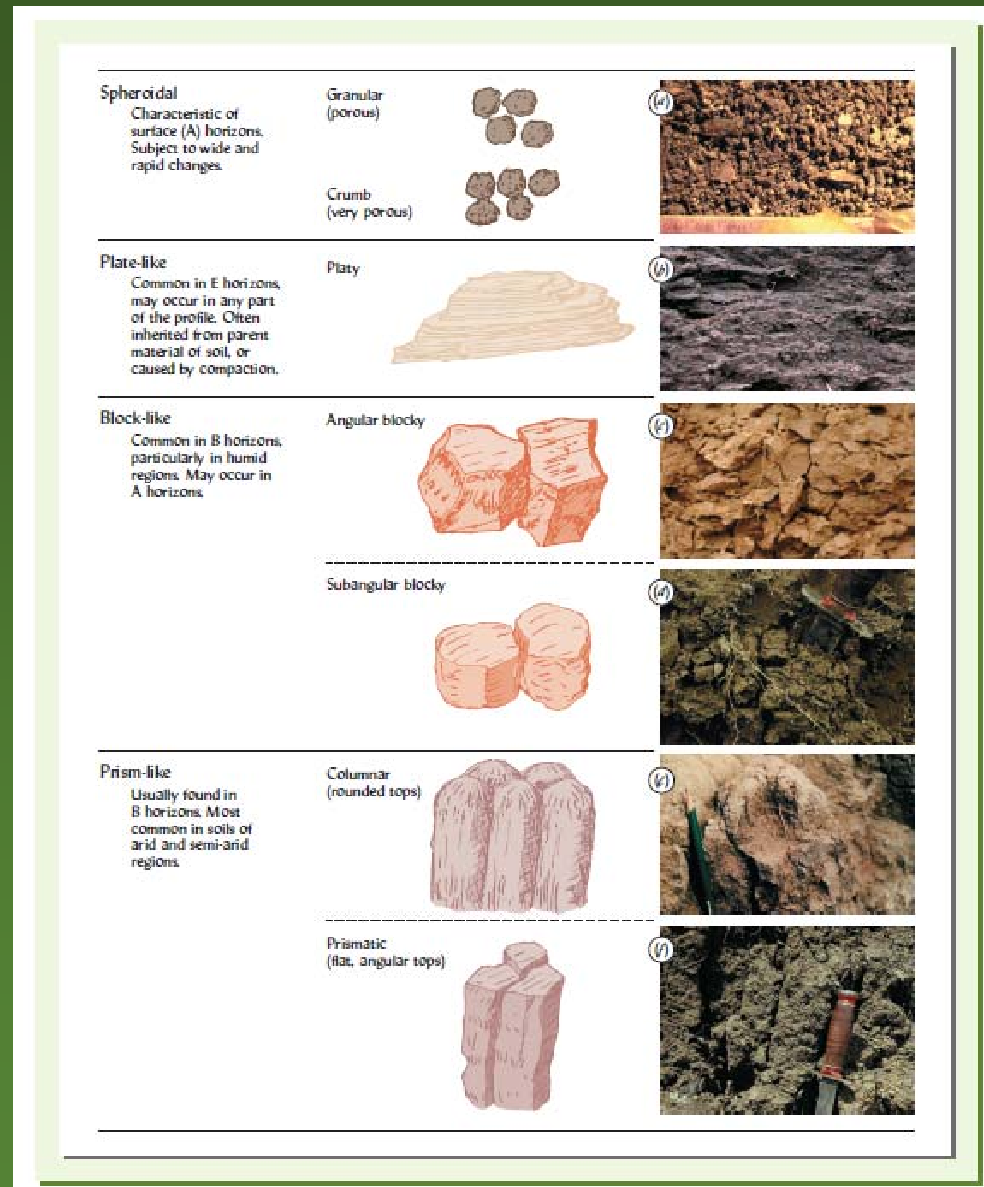
- 41% textures correct
- 78% textures 'correct' when include adjacent classes
- Silty classes most difficult
- Professionals: 59% Novice: 17%

# Soil Structure

## Arrangement of aggregated particles called peds



# Soil Structure: regular field calibration essential

# Soil Structure

- **Single Grain**
- **Granular**
- Crumb
- Angular blocky
- **Subangular blocky**
- Columnar
- Prismatic
- **Platy**
- Massive

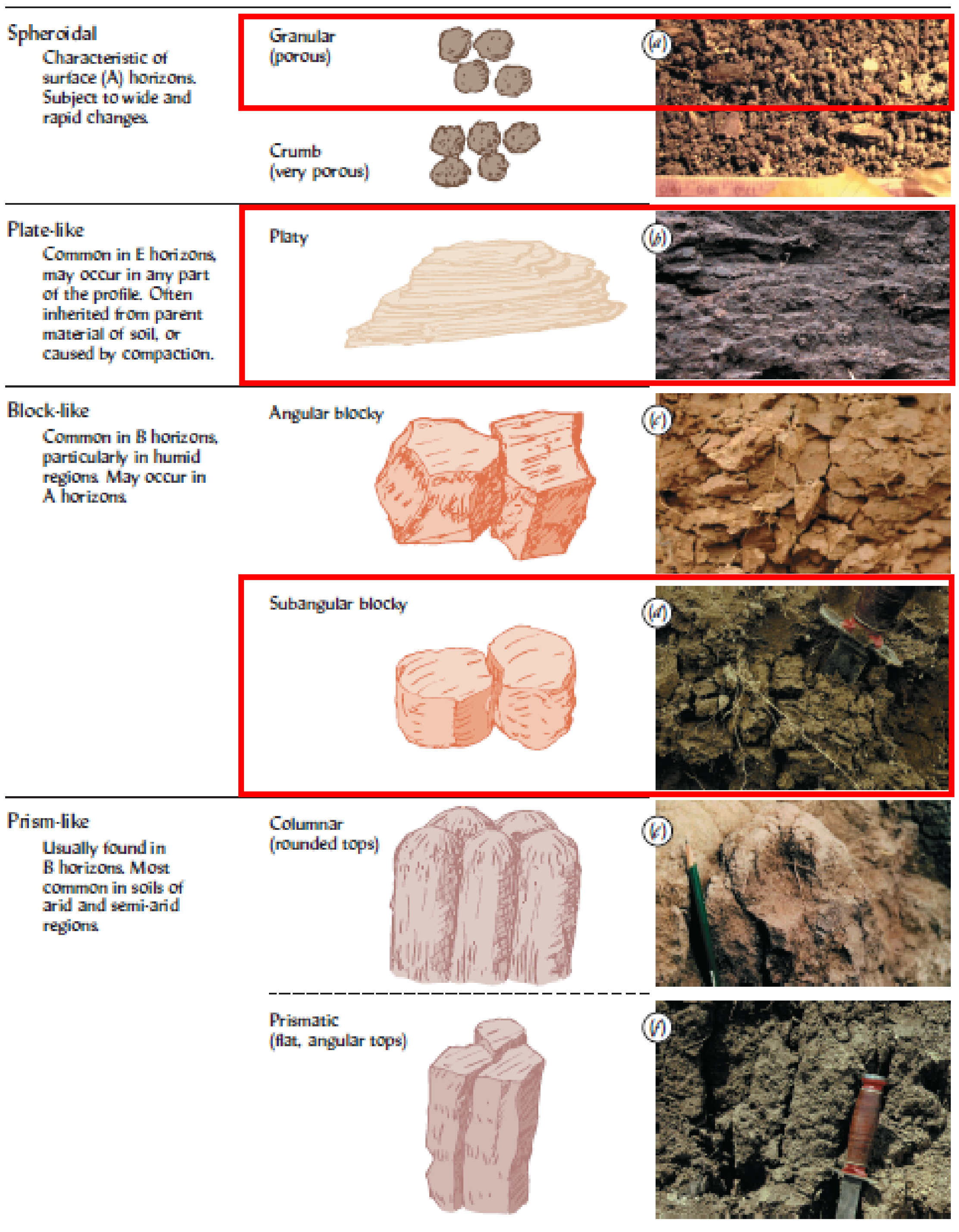
**Grade**

**0 = structureless**

**1 = weak**

**2 = moderate**

**3 = strong**



# "Consistence"= Ped resistance to deformation

| | Soil consistence[a] | | |
|---|---|---|---|
| Dry soil | Moist to wet soil | Soil dried then submerged in water | Field rupture (crushing) test |
| Loose | Loose | Not applicable | Specimen not obtainable |
| Soft | Very friable | Noncemented | Crumbles under very slight force between thumb and forefinger |
| Slightly hard | Friable | Extremely weakly cemented | Crumbles under slight force between thumb and forefinger |
| Hard | Firm | Weakly cemented | Crushes with difficulty between thumb and forefinger |
| Very hard | Extremely firm | Moderately cemented | Cannot be crushed between thumb and forefinger, but can be crushed slowly underfoot |

[a]Abstracted from USDA-NRCS (2005).

# McCarthy (1993) "Consistency"
# Uses field penetration test similar to designers

| | Soil consistence[a] | | | Soil consistency[b] | |
|---|---|---|---|---|---|
| Dry soil | Moist to wet soil | Soil dried then submerged in water | Field rupture (crushing) test | Soil at in situ moisture | Field penetration test |
| Loose | Loose | Not applicable | Specimen not obtainable | Soft | Blunt end of pencil penetrates deeply with ease |
| Soft | Very friable | Noncemented | Crumbles under very slight force between thumb and forefinger | Medium firm | Blunt end of pencil can penetrate about 1.25 cm with moderate effort |
| Slightly hard | Friable | Extremely weakly cemented | Crumbles under slight force between thumb and forefinger | Firm | Blunt end of pencil can penetrate about 0.5 cm |
| Hard | Firm | Weakly cemented | Crushes with difficulty between thumb and forefinger | Very firm | Blunt end of pencil makes slight indentation; thumbnail easily penetrates |
| Very hard | Extremely firm | Moderately cemented | Cannot be crushed between thumb and forefinger, but can be crushed slowly underfoot | Hard | Blunt end of pencil makes no indentation; thumbnail barely penetrates |

[a]Abstracted from USDA-NRCS (2005).
[b]Modified from McCarthy (1993).

# USDA "Excavation Difficulty" Field penetration test.

**EXCAVATION DIFFICULTY**—The relative force or energy required to dig soil out of place. Describe the **Excavation Difficulty Class** and the moisture condition (*moist* or *dry*, but not wet); use the "(Soil) Water State" table; e.g., *moderate*, *moist* or *M, M*. Estimates can be made for either the most limiting layer or for each horizon.

| Class | Code | Criteria |
|---|---|---|
| Low | L | Excavation by tile spade requires arm pressure only; impact energy or foot pressure is not needed. |
| Moderate | M | Excavation by tile spade requires impact energy or foot pressure; arm pressure is insufficient. |
| High | H | Excavation by tile spade is difficult but easily done by pick using over-the-head swing. |
| Very High | VH | Excavation by pick with over-the-head swing is moderately to markedly difficult. Backhoe excavation by a 50- to 80-hp tractor can be made in a moderate time. |
| Extremely High | EH | Excavation via pick is nearly impossible. Backhoe excavation by a 50- to 80-hp tractor cannot be made in a reasonable time. |

# Summary

| TEXTURE | STRUCTURE | CONSISTENCE |
| --- | --- | --- |
| Very Coarse Sand (VCOS) | Single Grain (SG) | Loose (L) |
| Coarse Sand (COS) , Sand (S) | Granular (GR) | Very Friable (VFR) |
| Loamy Coarse Sand (LCOS), Loamy Sand (LS) | Massive (MA) | Friable (FR) |
| Fine Sand (FS), Very Fine Sand (VFS),<br>Loamy Fine Sand (LFS), Loamy Very Fine Sand (LVFS) | Platy (PL) | Firm (FI) |
| Coarse Sandy Loam (COSL), Sandy Loam (SL) | Angular Blocky (ABK) | Very Firm (VFI) |
| Fine Sandy Loam (FSL), Very Fine Sandy Loam (VFSL) | Subangular Blocky (SBK) | |
| Loam (L) | 0 = structureless | |
| Silt Loam (SIL), Silt (SI) | 1 = weak | |
| Sandy Clay Loam (SCL), Silty Clay Loam (SICL),<br>Clay Loam (CL) | 2 = moderate | |
| Sandy Clay (SC), Silty Clay (SIC), Clay (C) | 3 = strong | |

**TAC Guidance on selecting “desk top” hydraulic conductivity for groundwater mounding calculations.**

**Soil logs must record:**

1. **texture**

2a. **structure**

2b. **grade of structure**

**If they do not then lowest K consistent with available description should be selected.**

# “TAC Table 1” TAC Report 2001

**Table 1. Hydraulic Loading Method for Detailed Soil Descriptions in Vermont**

| | | | | | Hydraulic Loading Rate (gpd/square foot) (Sorted by hydraulic gradient and % ground surface slope range as noted) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soil Texture[1] | Soil Structure[2] | | K[3] | 0.01 | 0.03 | 0.05 | 0.07 | 0.09 | 0.125 | 0.175 | 0.25 |
| | | Shape | Grade | (ft/day) | 0-2% | 2.1-4% | 4.1-6% | 6.1-8% | 8.1-10% | 10.1-15% | 15.1-20% | 20.1-30% |
| 1 | Coarse Sand, Sand, | | 0SG | 100 | 7.5 | 22.4 | 37.4 | 52.4 | 67.3 | 93.5 | 130.9 | 187.0 |
| | Loamy Coarse Sand, Loamy Sand | | | | | | | | | | | |
| 2 | Fine Sand, Very Fine Sand, | -- | 0SG | 50 | 3.7 | 11.2 | 18.7 | 26.2 | 33.7 | 46.8 | 65.5 | 93.5 |
| | Loamy Fine Sand, Loamy Very Fine Sand | | | | | | | | | | | |
| | Coarse Sandy Loam, Loamy Sand | | | | | | | | | | | |
| | | -- | 0M | 50 | 3.7 | 11.2 | 18.7 | 26.2 | 33.7 | 46.8 | 65.5 | 93.5 |
| | | PL | 1 | 25 | 1.9 | 5.6 | 9.4 | 13.1 | 16.8 | 23.4 | 32.7 | 46.8 |
| | | PL | 2,3 | 25 | 1.9 | 5.6 | 9.4 | 13.1 | 16.8 | 23.4 | 32.7 | 46.8 |
| | | PR/BK/GR | 1 | 40 | 3.0 | 9.0 | 15.0 | 20.9 | 26.9 | 37.4 | 52.4 | 74.8 |
| | | PR/BK/GR | 2,3 | 50 | 3.7 | 11.2 | 18.7 | 26.2 | 33.7 | 46.8 | 65.5 | 93.5 |
| 3 | Fine Sandy Loam, Very Fine Sandy Loam | -- | 0M | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |
| | | PL | 1,2,3 | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |
| | | PR/BK/GR | 1 | 20 | 1.5 | 4.5 | 7.5 | 10.5 | 13.5 | 18.7 | 26.2 | 37.4 |
| | | PR/BK/GR | 2,3 | 30 | 2.2 | 6.7 | 11.2 | 15.7 | 20.2 | 28.1 | 39.3 | 56.1 |
| 4 | Loam | -- | 0M | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |
| | | PL | 1,2,3 | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |
| | | PR/BK/GR | 1 | 15 | 1.1 | 3.4 | 5.6 | 7.9 | 10.1 | 14.0 | 19.6 | 28.1 |
| | | PR/BK/GR | 2,3 | 20 | 1.5 | 4.5 | 7.5 | 10.5 | 13.5 | 18.7 | 26.2 | 37.4 |
| 5 | Silt Loam | -- | 0M | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |
| | | PL | 1,2,3 | 5 | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 | 9.4 |
| | | PR/BK/GR | 1 | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |
| | | PR/BK/GR | 2,3 | 20 | 1.5 | 4.5 | 7.5 | 10.5 | 13.5 | 18.7 | 26.2 | 37.4 |
| 6 | Sandy Clay Loam, Clay Loam, Silty Clay Loam | -- | 0M | 5 | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 | 9.4 |
| | | PL | 1,2,3 | 5 | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 | 9.4 |
| | | PR/BK/GR | 1 | 8 | 0.6 | 1.8 | 3.0 | 4.2 | 5.4 | 7.5 | 10.5 | 15.0 |
| | | PR/BK/GR | 2,3 | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |
| 7 | Sandy Clay, Clay, Silty Clay | -- | 0M | 3 | 0.2 | 0.7 | 1.1 | 1.6 | 2.0 | 2.8 | 3.9 | 5.6 |
| | | PL | 1,2,3 | 3 | 0.2 | 0.7 | 1.1 | 1.6 | 2.0 | 2.8 | 3.9 | 5.6 |
| | | PR/BK/GR | 1 | 5 | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 | 9.4 |
| | | PR/BK/GR | 2,3 | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 | 18.7 |

Note: 1. Soil texture and structure columns are based on Tyler and Kuns (2000).

2. Structure Abbreviations: Shapes: PL = platy; BK = blocky; PR = prismatic; GR = granular

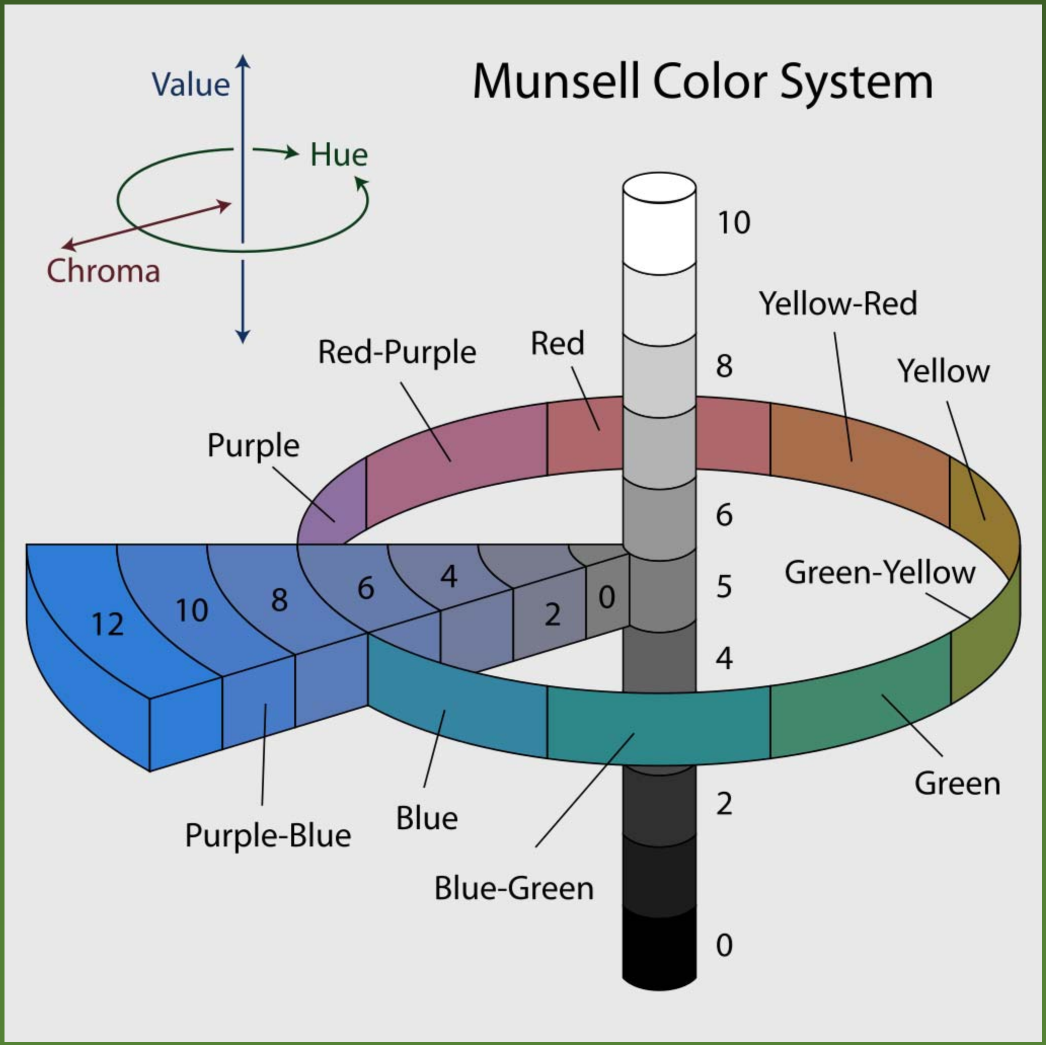
Grade: 0 = structureless; SG = single grain; M = massive; 1 = weak; 2 = moderate; 3 = strong

3. K = hydraulic conductivity (estimated)

# Munsell Colors, Redox Features, SHWT, and Aerobic Conditions

## Munsell Color System:

- hue
- value
- chroma



# Munsell color: hue, value/chroma (name)

**Example:**

**2.5YR 4/4 (reddish brown)**

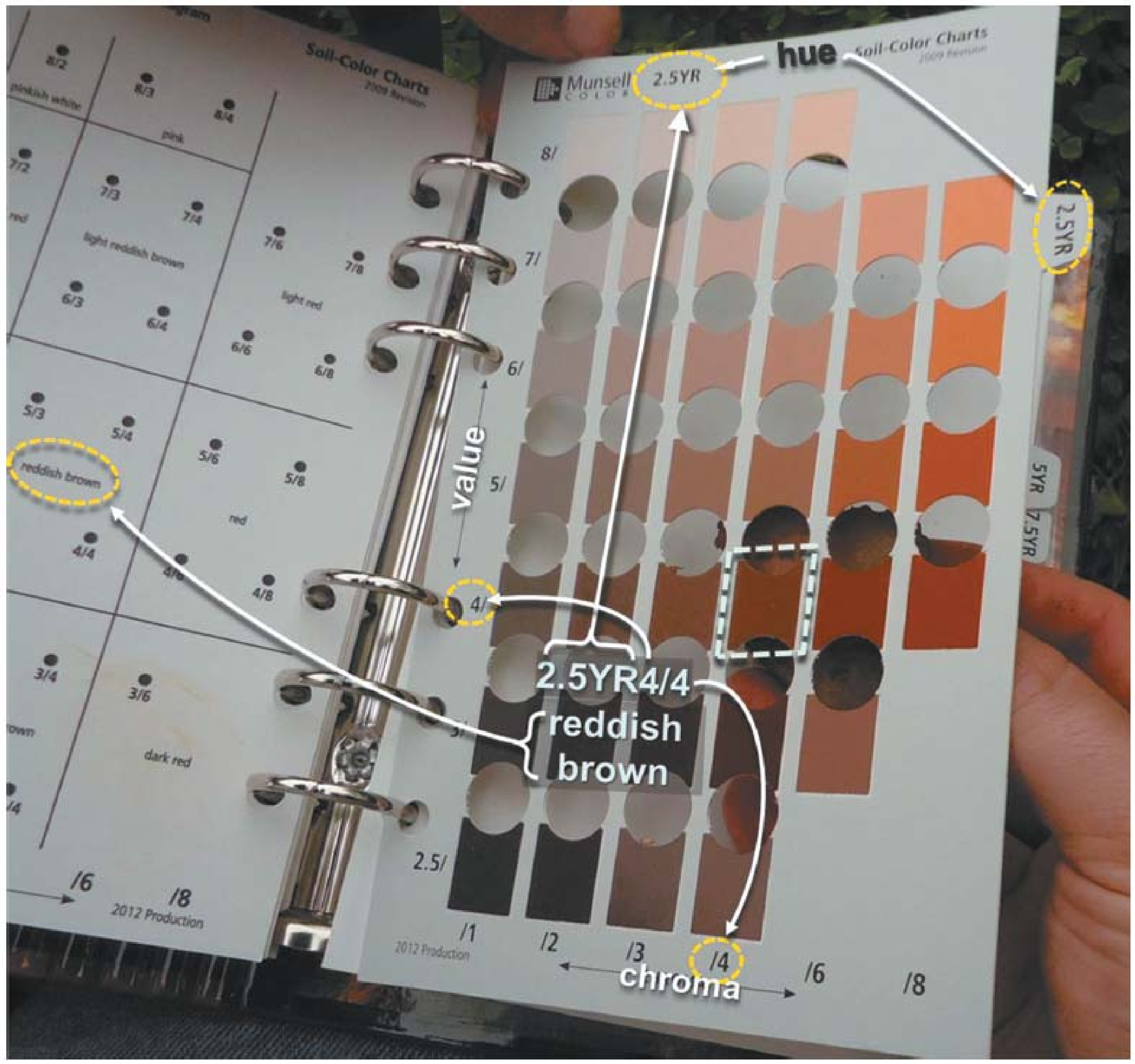
**Hue** (related to wavelength) **e.g. 2.5YR**

**Value** (lightness to darkness) **e.g. 4/**

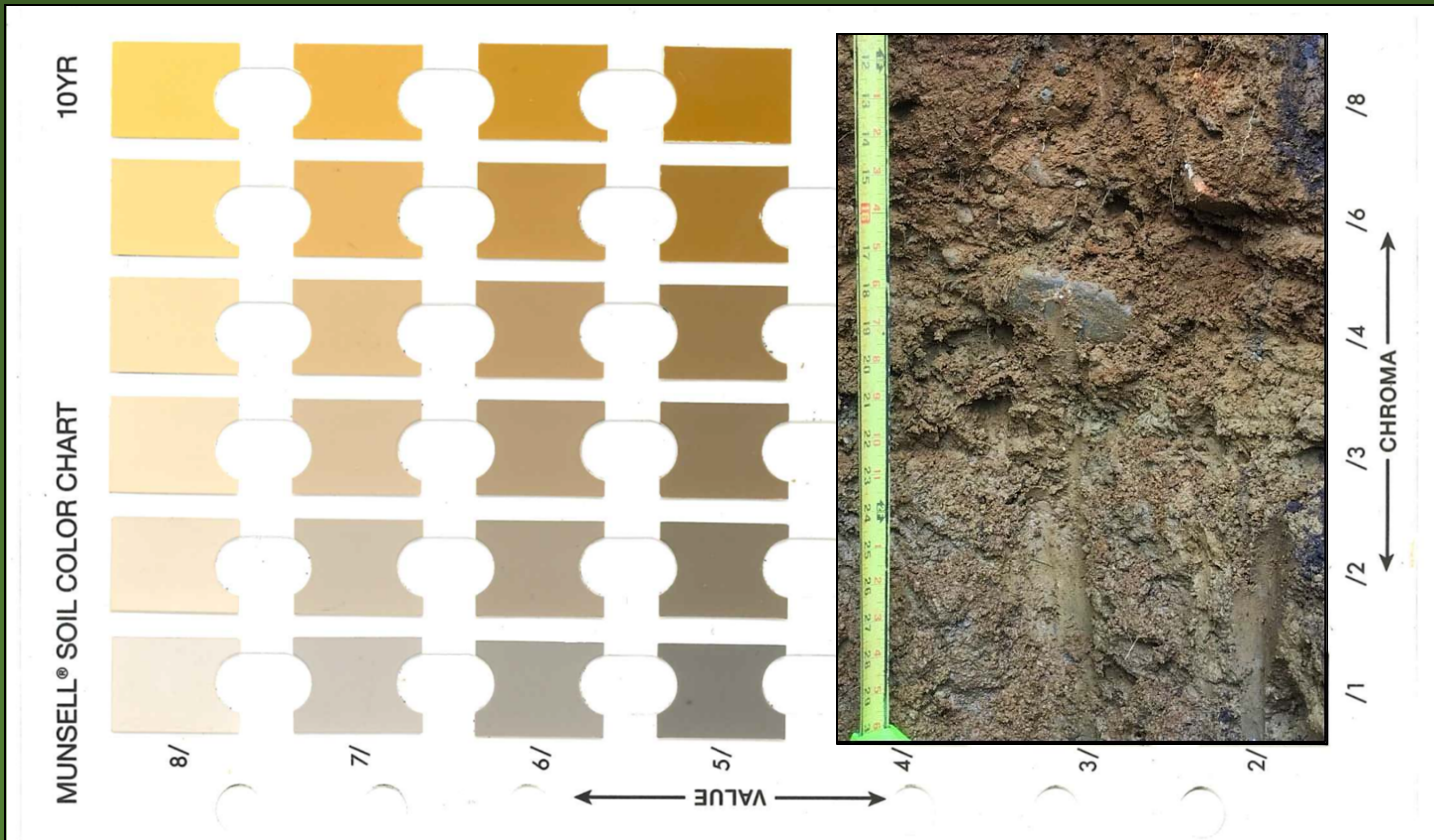
**Chroma** (related to saturation / degree washed out) **e.g.  /4**

**Name** (applied to a group of color chips on adjacent page) e.g. reddish brown

**Start on page 10YR!**



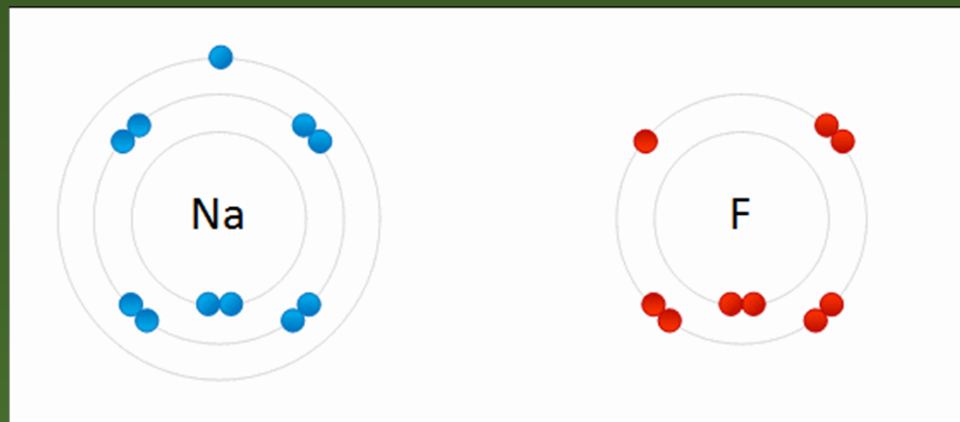
# Chroma is a key indicator!



# What is Redox (reduction-oxidation)?

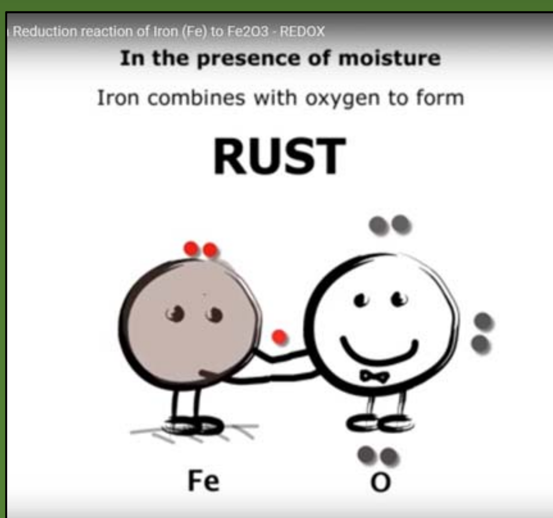
**Sodium**

**Oxidation = loss of electrons**




**Fluorine**

**Reduction = gain of electrons**

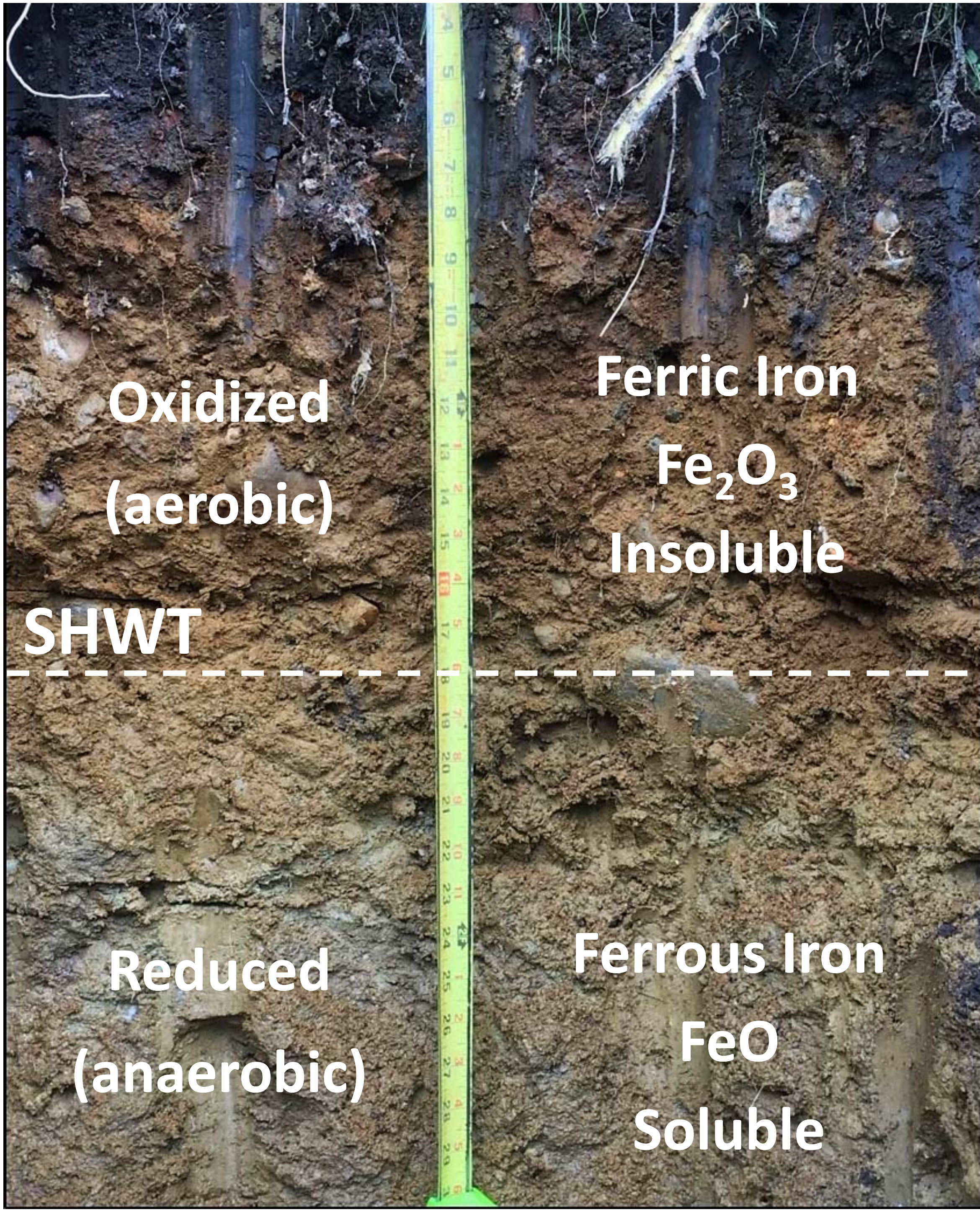



https://youtu.be/CMnkqKOTN-o

**Oxygen is an oxidizer. It is reduced by gaining electrons as it oxidizes metals**

**Iron$^{3+}$ oxide = ferric oxide**
**$Fe_2O_3$ is insoluble (rust)**

**Iron$^{2+}$ oxide = ferrous oxide**
**FeO dissolves in groundwater**



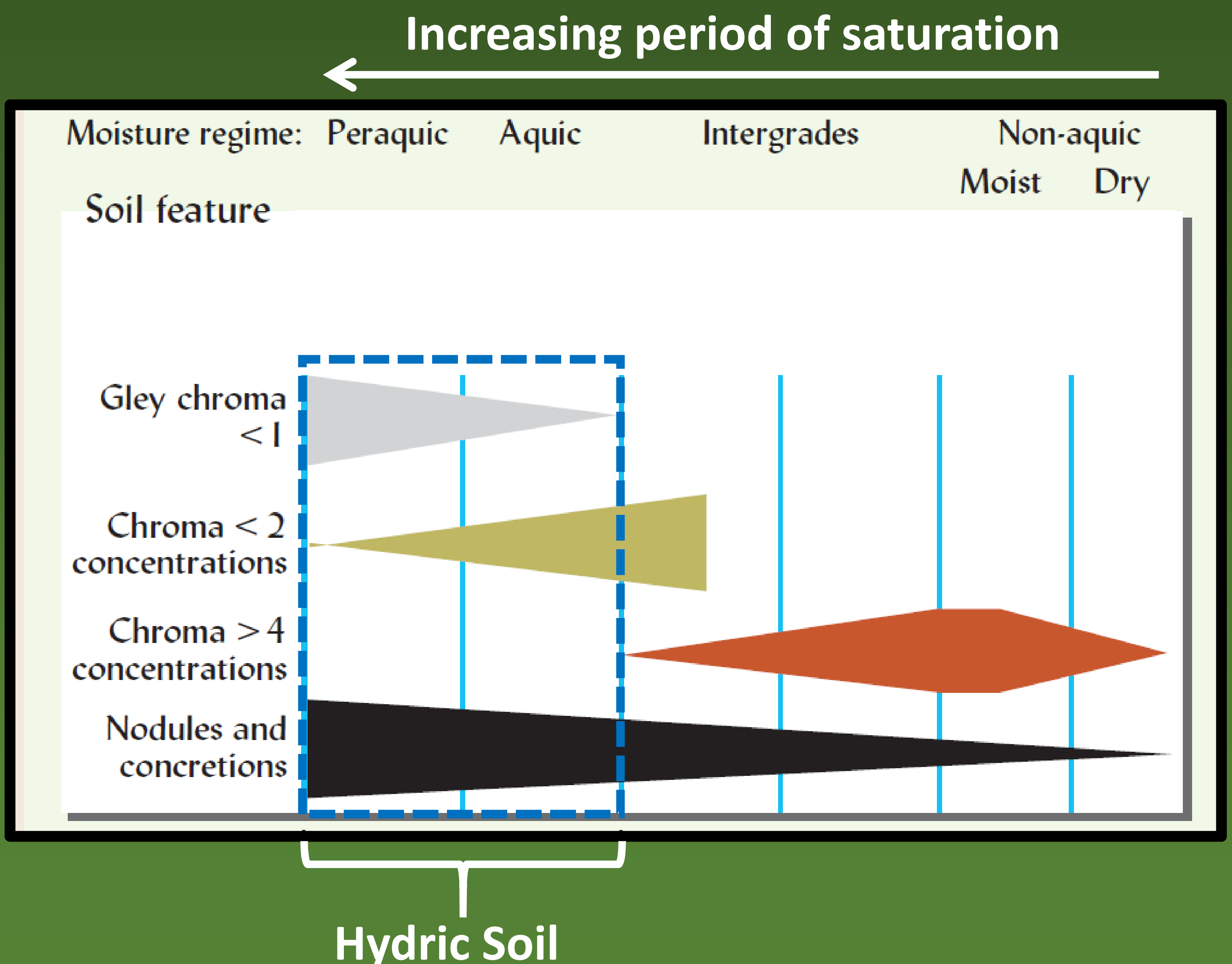

## Observations:

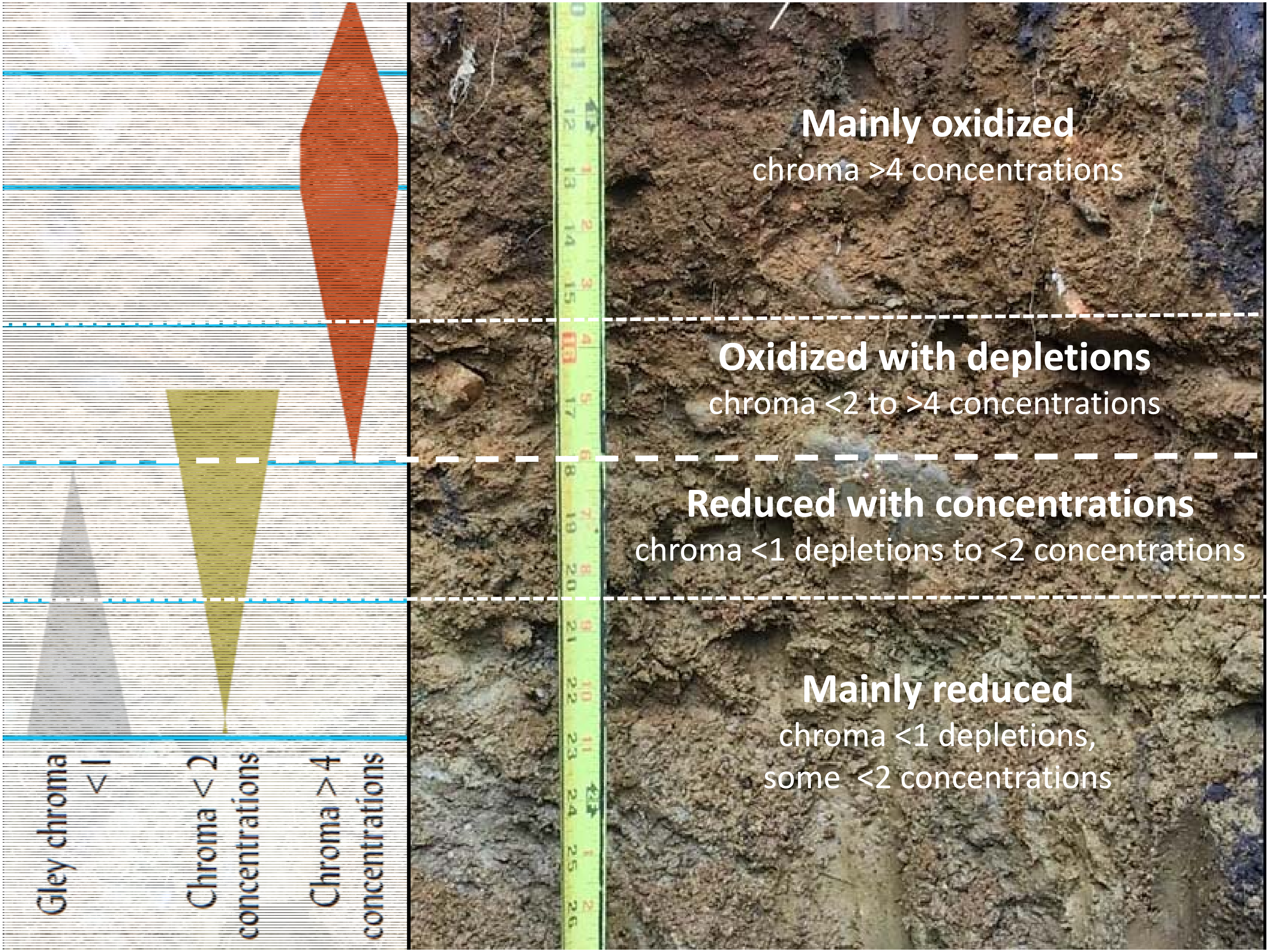
- What is the matrix color?
- Are there redox colors?
- Are they concentrations or depletions?

## Interpretation:

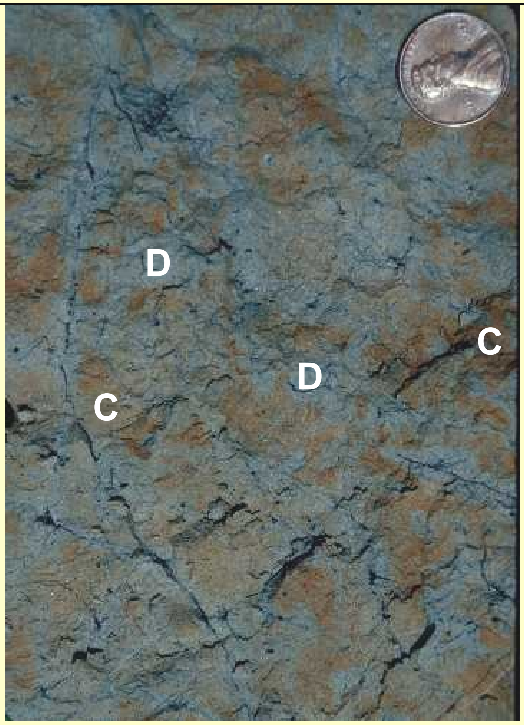
- Where is the Seasonal High Water Table?

# Soil Features & Duration of Water Saturation

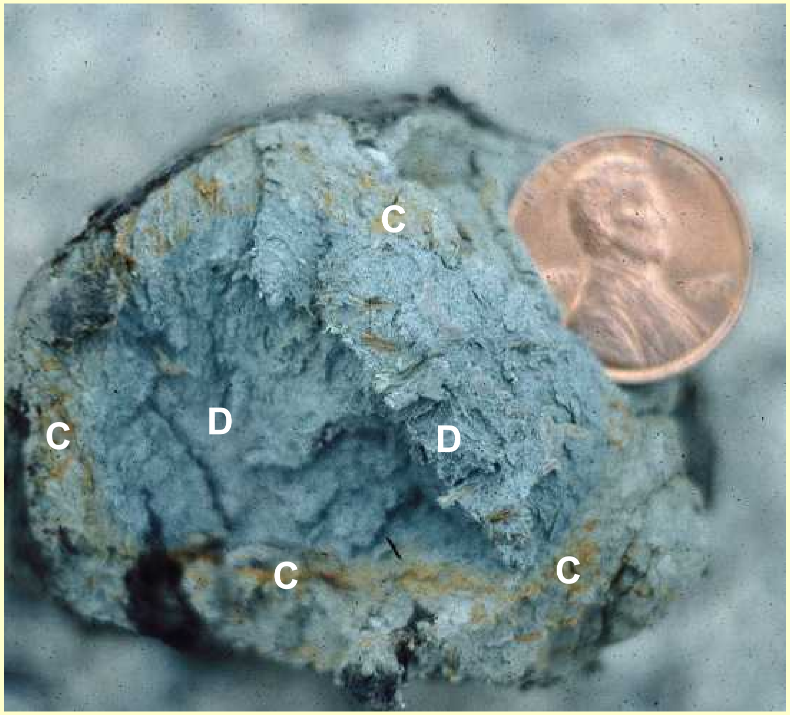



Mainly oxidized
chroma >4 concentrations
Oxidized with depletions
chroma <2 to >4 concentrations
Reduced with concentrations
chroma <1 depletions to <2 concentrations
Mainly reduced
chroma <1 depletions,
some <2 concentrations
Gley chroma <1
Chroma < 2 concentrations
Chroma > 4 concentrations

# Redoximorphic Features




This photo shows redox concentrations (bright yellowish-brown colors 10YR5/6 munsell color), redox depletions (gray colors - 2.5Y 6/1 colors) with a pale yellowish-brown matrix color (2.5Y 5/3 munsel color).



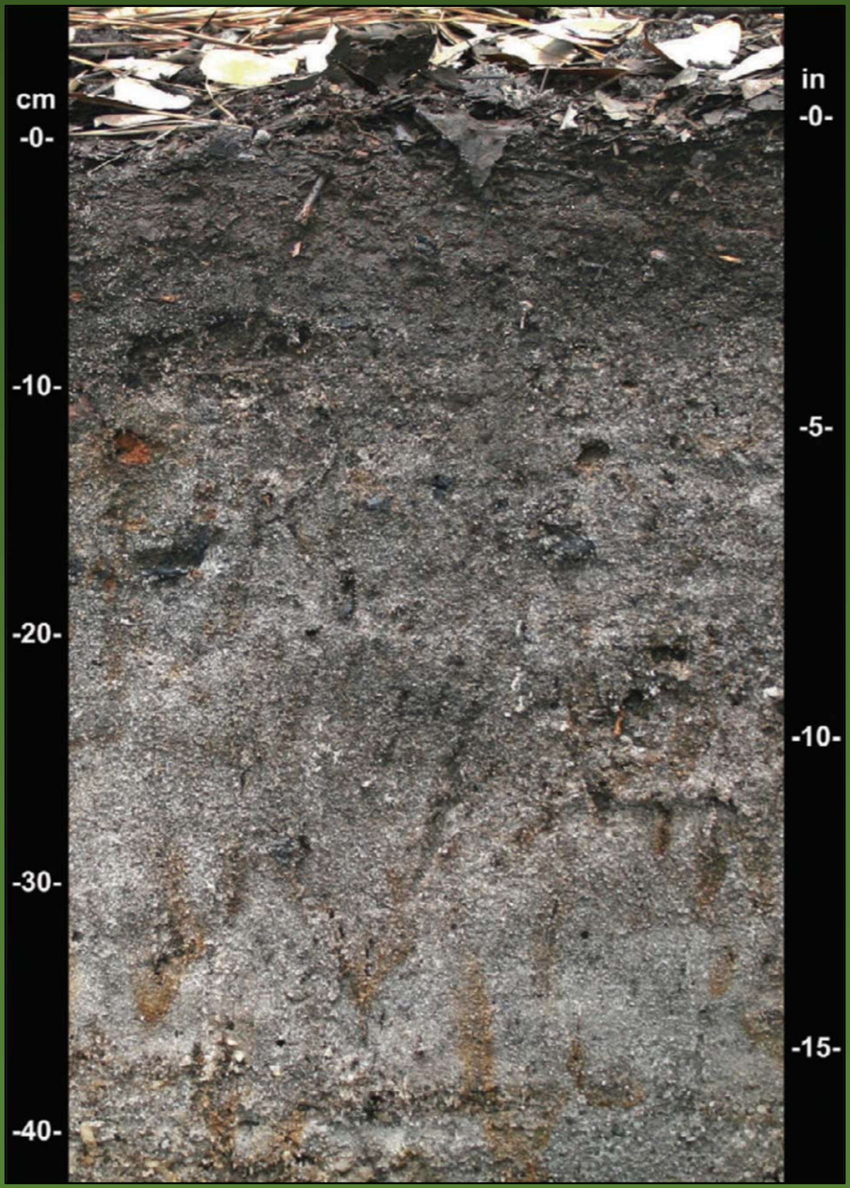

This photo shows a redox depletion (5BG 6/0 munsell color) along a dead root channel (visible in the center) with redox concentrations (10YR 5/6) around the depleteion.

# Redoximorphic Features

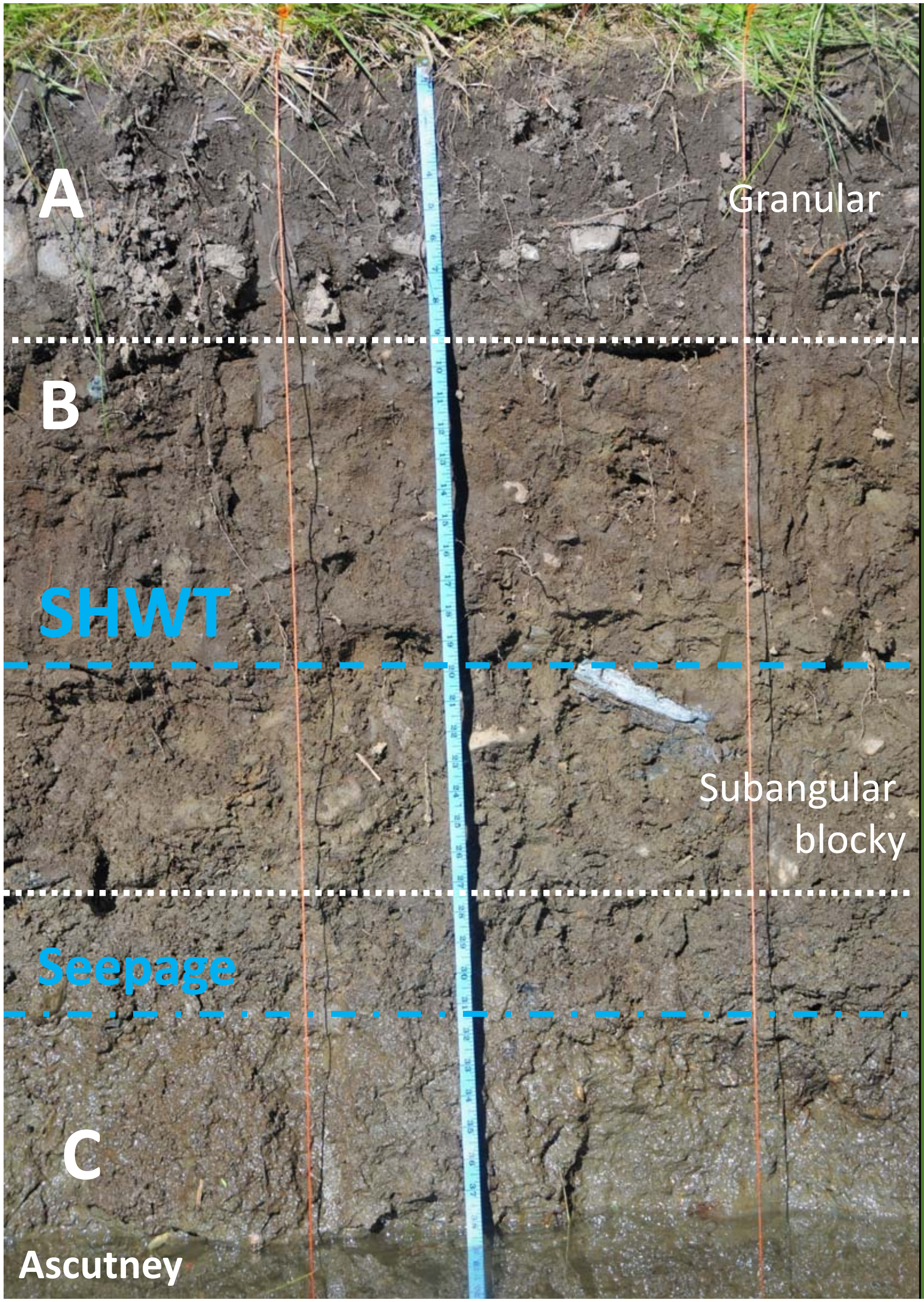
e.g. 1: Depletions in macropores & concentrations in matrix - water is infiltrating along macropores, matrix is unsaturated

e.g. 2: Concentration in macropores & depletions in matrix - matrix is saturated for long periods, macropores are drained

# Redoximorphic Features



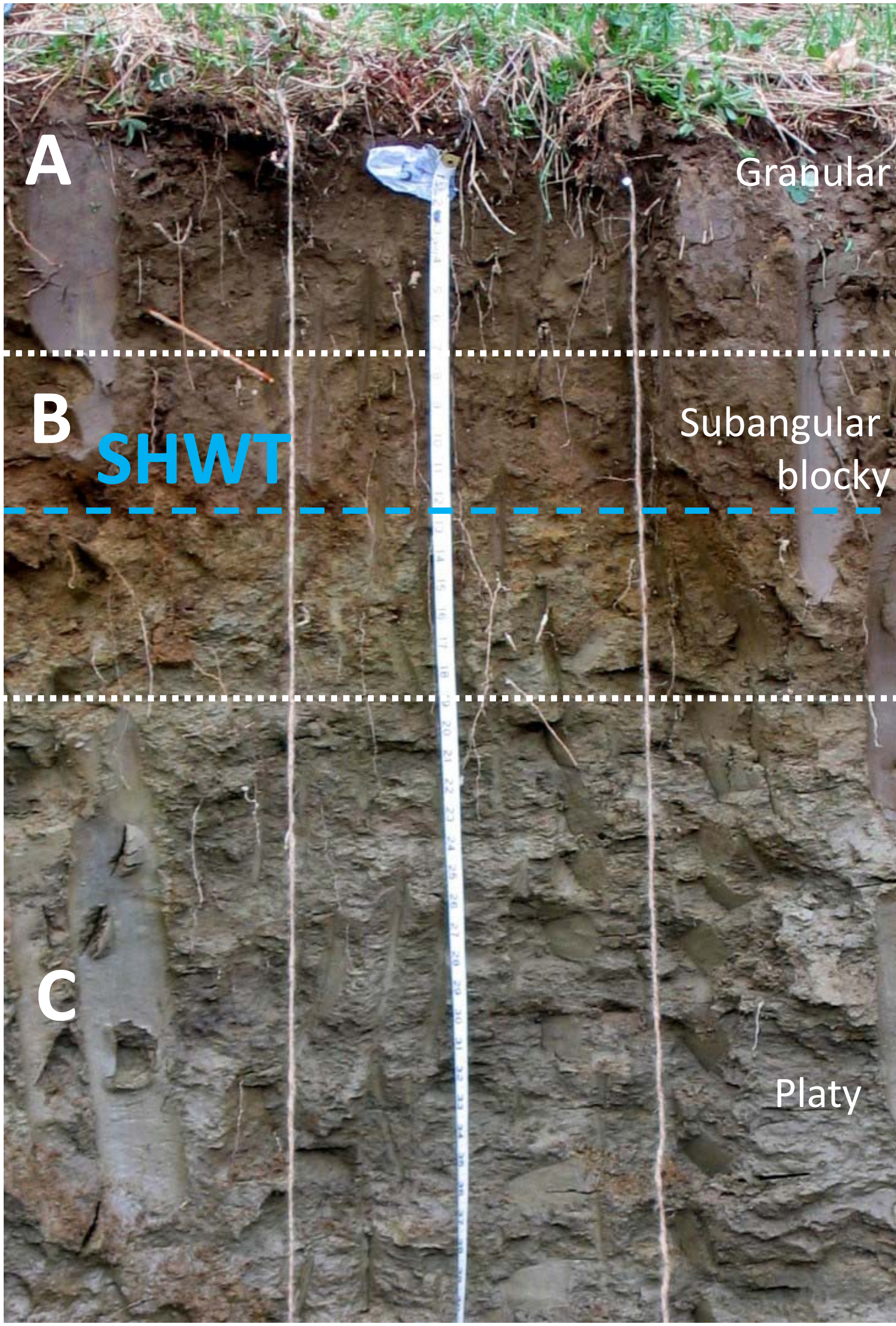

e.g. 3:  Depletions and concentrations have no consistent relationship to macropores – common indicator in sandy soils. This example show iron-manganese concentrations




# What can you see?

- Horizons
- Structure
- Seepage
- Redox colors
- Seasonal High Water Table

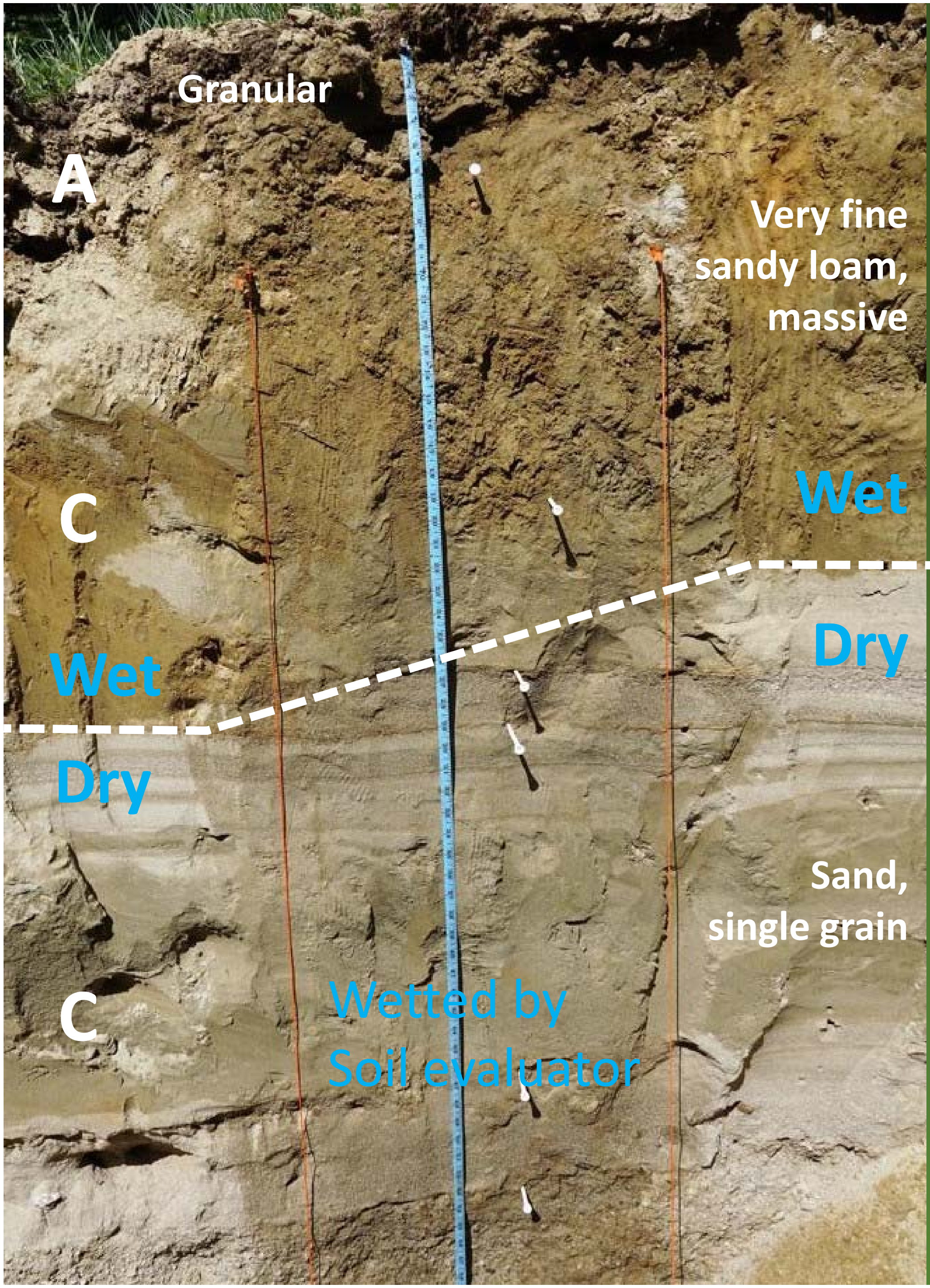

SHWT
Seepage Flowing in
Flowing out

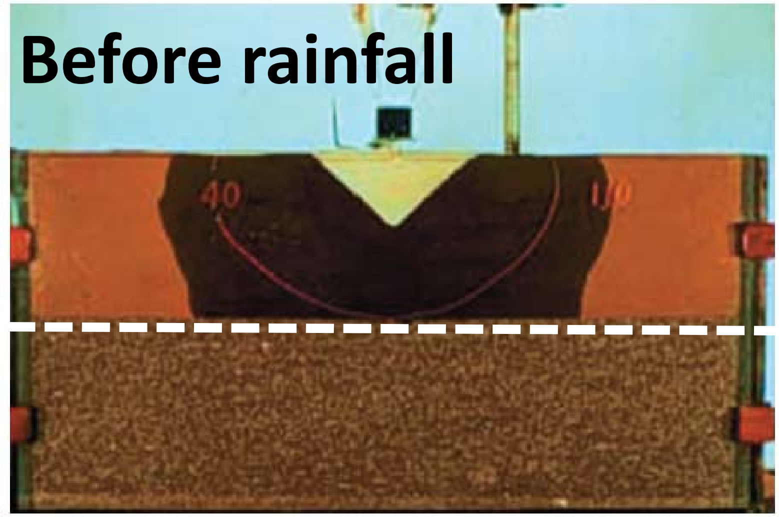


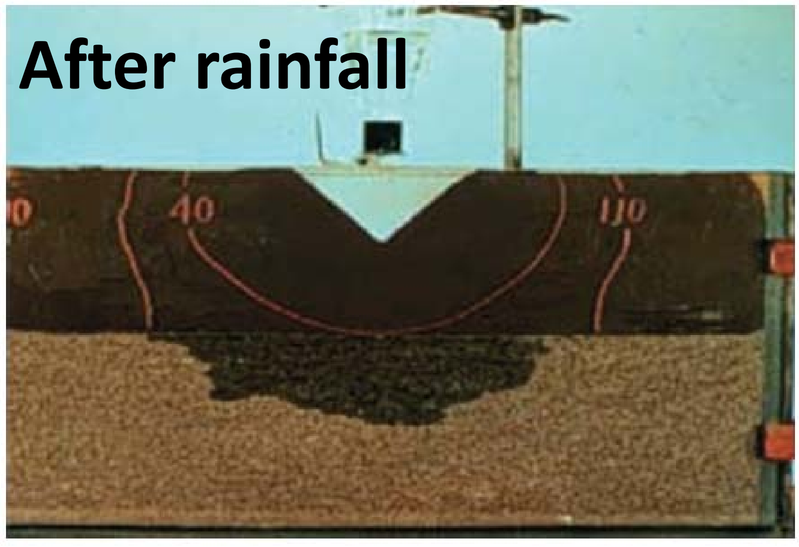

# What can you see?

- **Horizons**
- **Structure**
- **Seepage**
- **Redox colors**
- **Seasonal High Water Table**

# Example of infiltration through stratified soil kame terrace, Lincoln, VT



# Training Exercise
# Color and Texture

VERMONT
AGENCY OF NATURAL RESOURCES
Department of Environmental Conservation

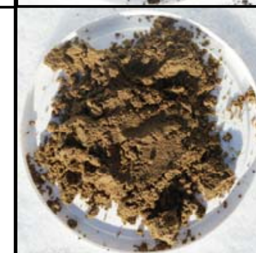
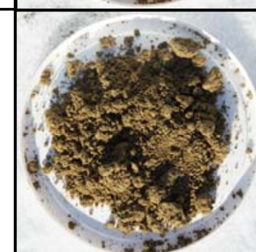
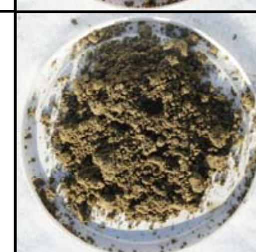
## Soil Test Pit Log

**Project:** ______________________ **Date:** ______________________ **Test Pit #:** ______________________

**Logged by:** ______________________ **Location:** ______________________ **Time:** ______________________

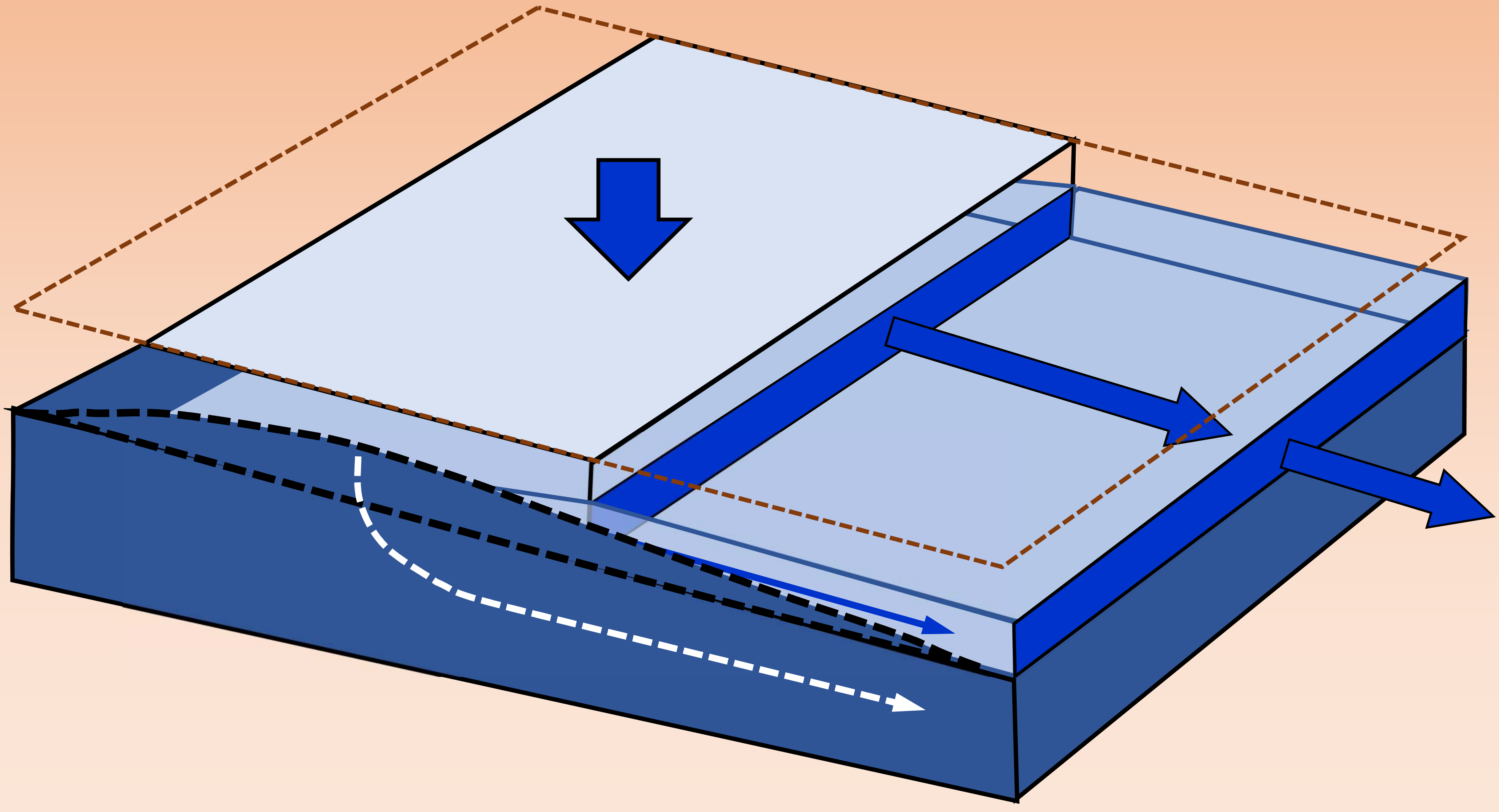
**Excavation Method:** ______________________ **Weather:** ______________________ **Slope Shape, Position, %:**______________________

| **Horizon** (O, A, B, C, R) | **DEPTH** (inches) | **MATRIX COLOR** (Munsell code, name) | **OTHER COLOR** (RMF, conc/dep, % ) | **TEXTURE** (e.g. ART GRV LFS) | **STRUCTURE** (SG, GR, BK, PL, 1-3) | **CONSISTENCE** (Friable, firm etc.) | **COMMENTS** (seepage, SHWT etc.) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

| Texture | Selected Munsell Colors | | | | | | | Average Value | Average Chroma | |
|---|---|---|---|---|---|---|---|---|---|---|
| organic sandy loam | 10YR 3/2 | 10YR 3/2 | 10YR 2/2 | 10YR 2/1 | 10YR 3/2 | 10YR 2/2 | 10YR 3/3 | 2.6 | 2.0 |  |
| sand | 10YR 4/6 | 10YR 5/6 | 10 YR 5/6 | 10YR 3/4 | 10YR 5/6 | 7.5YR 4/4 | 10YR 4/4 | 4.3 | 5.1 |  |
| gravelly sandy loam | 10YR 5/6 | 2.5Y 5/3 | 10YR 4/4 | 10YR 4/4 | 10YR 4/4 | 7.5YR 4/6 | 10YR 5/4 | 4.6 | 4.4 |  |
| silt loam | 2.5Y 6/4 | 2.5Y 6/4 | 10YR 4/2 | 10 YR 5/3 | 2.5Y 4/3 | 10YR 4/4 | 10YR 5/2 | 4.9 | 3.1 |  |
| silty clay loam | 2.5Y 6/2 | 5Y 6/2 | 10YR 3/1 | 2.5Y 5/2 | 5Y 4/2 | 5Y 6/2 | 2.5Y 6/2 | 5.7 | 1.9 |  |

# Simplified Method

*for Groundwater Mounding Analysis*



## § 1-903 General Requirements for Soil-Based Wastewater Systems

**(j)** (1)(A) Minimum depth to Seasonal High Water Table shall be **24 inches** of natural soil for a leachfield **in-mound**

**(k)** Notwithstanding Subsection (j) when a 'hydrogeological analysis' (*i.e. groundwater mounding*) is performed

(1) Minimum depth to bedrock shall be 24 inches

(2) Minimum depth of natural soil to induced water table shall be

(A) 6 inches anywhere beneath mound*

(B) **or** (at least) 6 inches at the limit of the fill**

**When SHWT less than 24 inches below ground surface a groundwater mounding analysis is required. The Simplified Method can be used if induced water table never rises to less than 6 inches from ground surface.**

*can be demonstrated using the Simplified Method

** cannot use demonstrated using the Simplified Method

## § 1-903 General Requirements for Soil-Based Wastewater Systems

(n) A groundwater mounding analysis must be completed for:

1) All bottomless sand filters
2) Leachfields in-mound more than 1000 gpd (*or when SHWT <24”*)
3) Leachfields in-ground or at-grade more than 2000 gpd
4) When groundwater mounding created by two leachfields is likely to overlap because
   - A. new upslope leachfield or replacement area is less than 25 feet upslope of existing leachfield or replacement area
   - B. new leachfield or replacement area is down gradient of existing leachfield or replacement area and
   - i. downslope leachfield is a bottomless sand filter
   - ii. combined > 1000 gpd when downslope leachfield is in a mound
   - iii. combined > 2000 gpd when downslope leachfield is in-ground or at-grade
   - iv. downslope leachfield unable to comply with the depth of natural soil

## § 1-903 General Requirements for Soil-Based Wastewater Systems

(r) When groundwater mounding analysis is required it should

1) Be completed using one of the following methods:

**A. Designers – "Simplified Method"**

i. All bottomless sand filters

ii. Leachfields in-mound more than 1000 gpd (*or when SHWT <24"*)

iii. Leachfields in-ground or at-grade more than 2000 gpd

**B. Hydrogeologists – other methods approved by the Secretary**

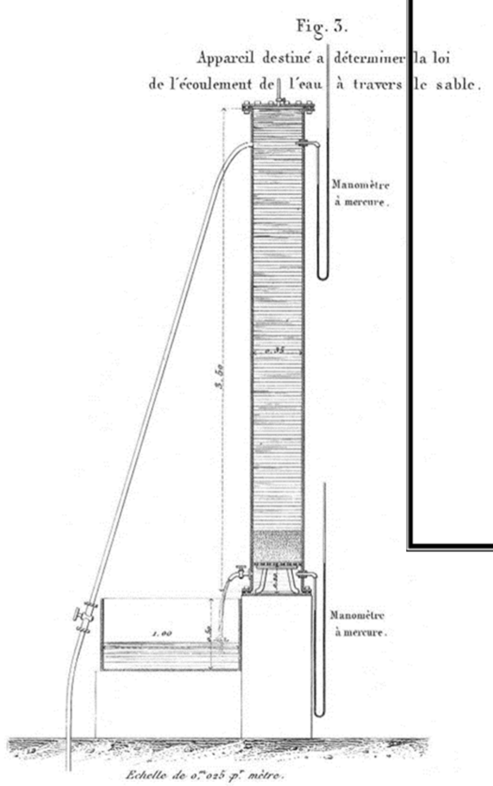
- e.g. Darcy (1856), (Hantush (1967), Zlotnik et al. (2017) etc.
- based on ***site-specific soil descriptions*** and conservative assumed hydraulic conductivities from literature (e.g. TAC 2001, Table 1)

**C. Hydrogeologists – other methods approved by the Secretary**

- e.g. Darcy (1856), (Hantush (1967), Zlotnik et al. (2017) etc.
- based on ***site-specific hydraulic conductivity testing***

2) Calculate leachfield length based on height of raised water table

# Monsieur Henry Philibert Gaspard Darcy




THE

PUBLIC FOUNTAINS

OF THE CITY OF DIJON

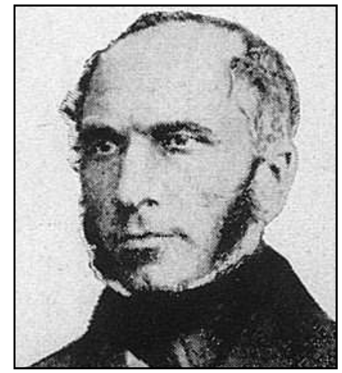
EXPERIENCE AND APPLICATION

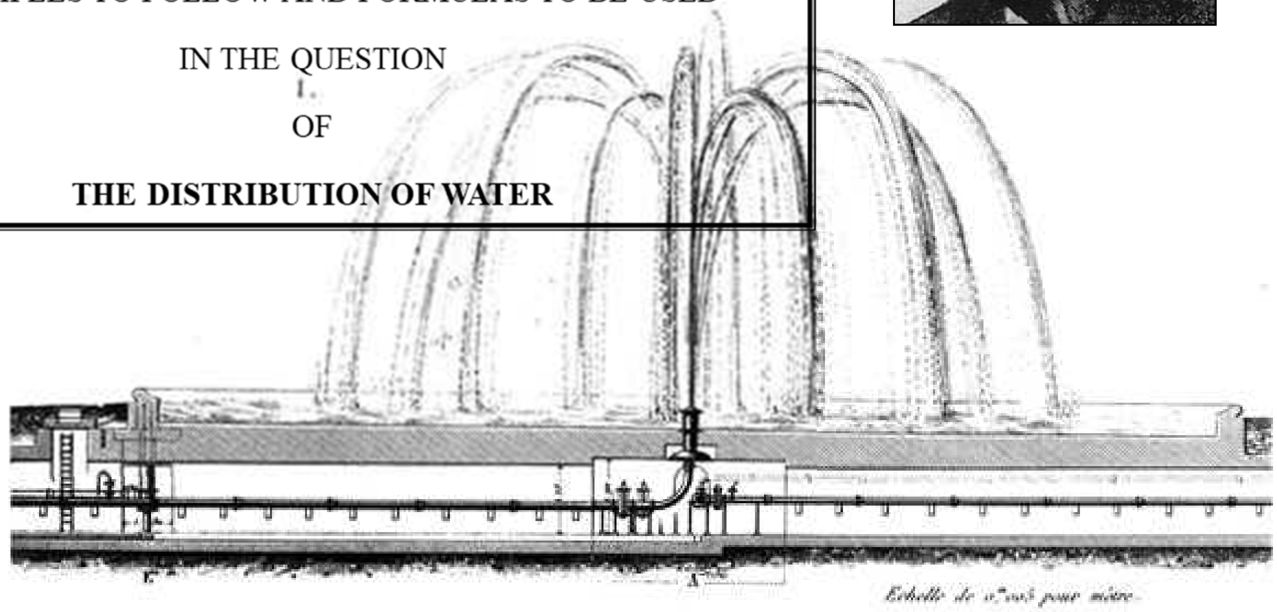
PRINCIPLES TO FOLLOW AND FORMULAS TO BE USED

IN THE QUESTION

OF

**THE DISTRIBUTION OF WATER**





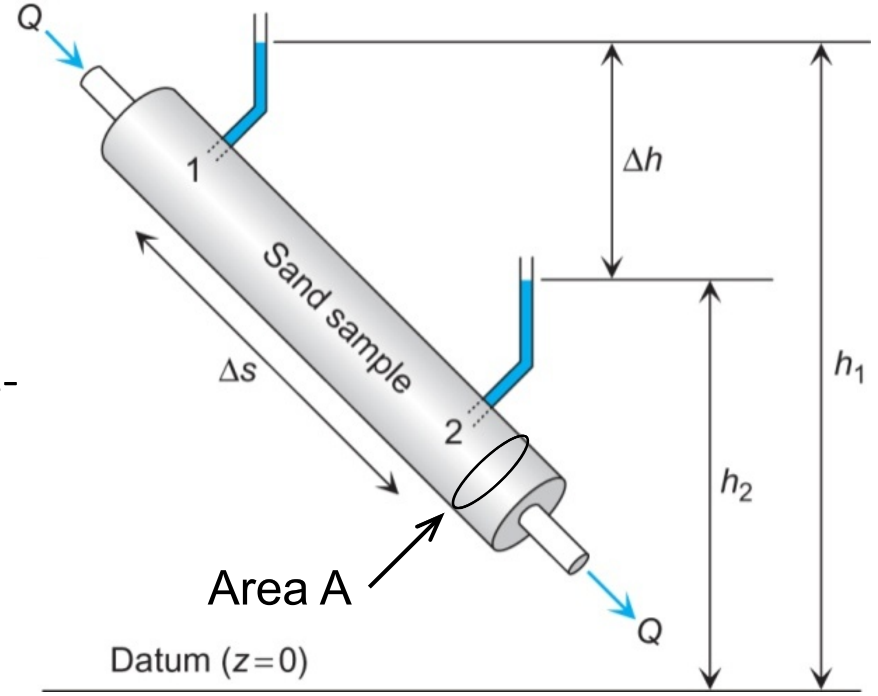

1857

# Darcy's Experiment

Darcy found through experiments with the same cylinder and a given sand, that:

a) Flow rate (Q) is proportional to head difference ($\Delta$h) between manometers
b) Flow rate (Q) is inversely proportional to the distance ($\frac{1}{\Delta s}$) between manometers
c) Flow rate (Q) is proportional to the cross-sectional area (A) of the cylinder.

$$Q \propto \frac{\Delta h}{\Delta s} A$$

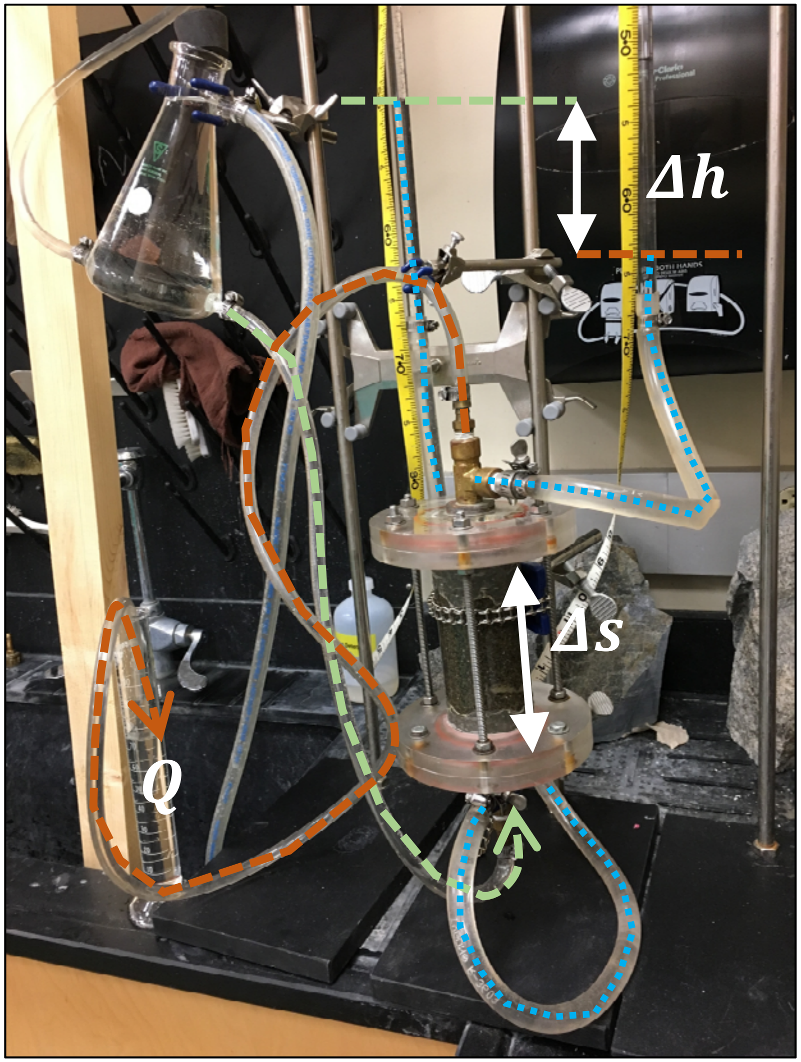


# Darcy Lab at NVU- Johnson

Darcy found through experiments with the same cylinder and a given sand, that:

a) Flow rate (Q) is proportional to head difference (Δh) between manometers
b) Flow rate (Q) is inversely proportional to the distance ($\frac{1}{\Delta s}$) between manometers
c) Flow rate (Q) is proportional to the cross-sectional area (A) of the cylinder.

$$Q \propto \frac{\Delta h}{\Delta s} A$$

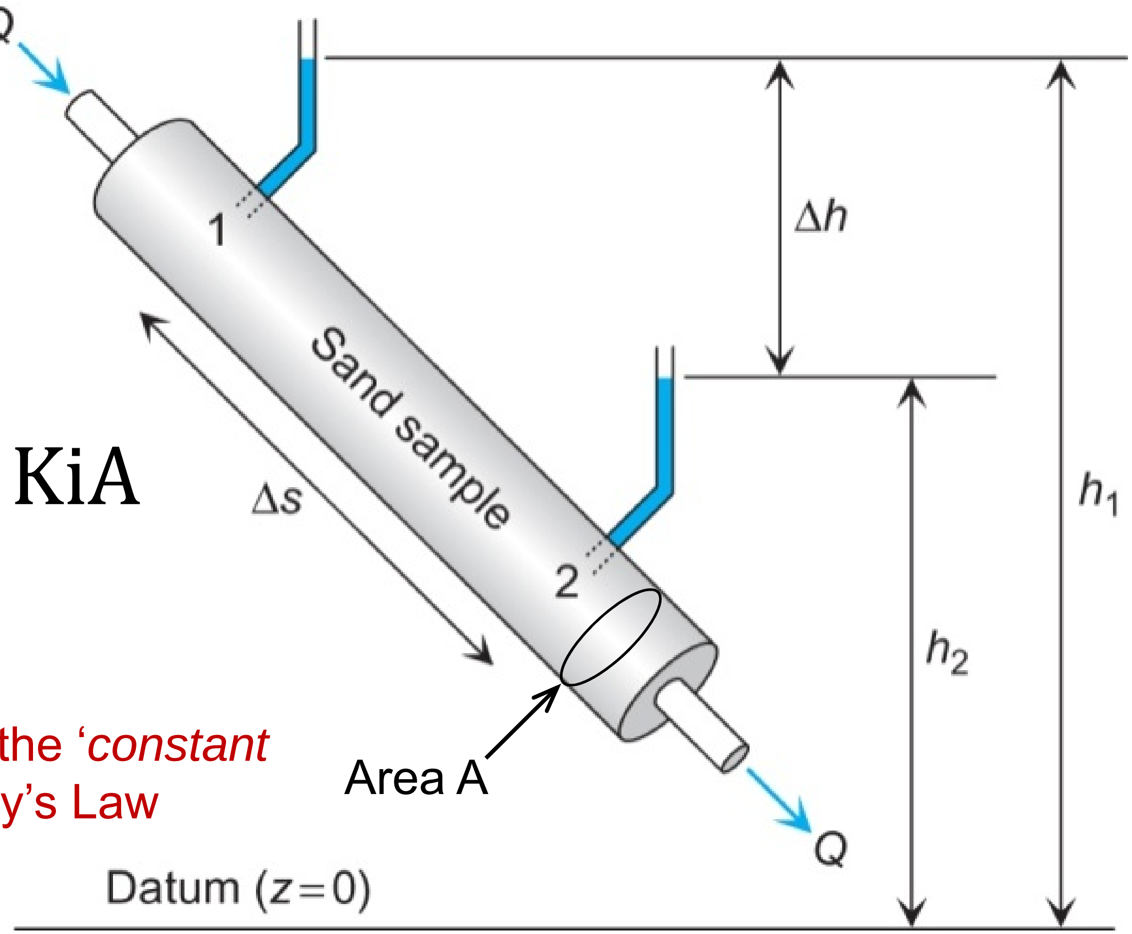


# Darcy's Law and Hydraulic Conductivity

$$Q \propto \frac{\Delta h}{\Delta s} A$$

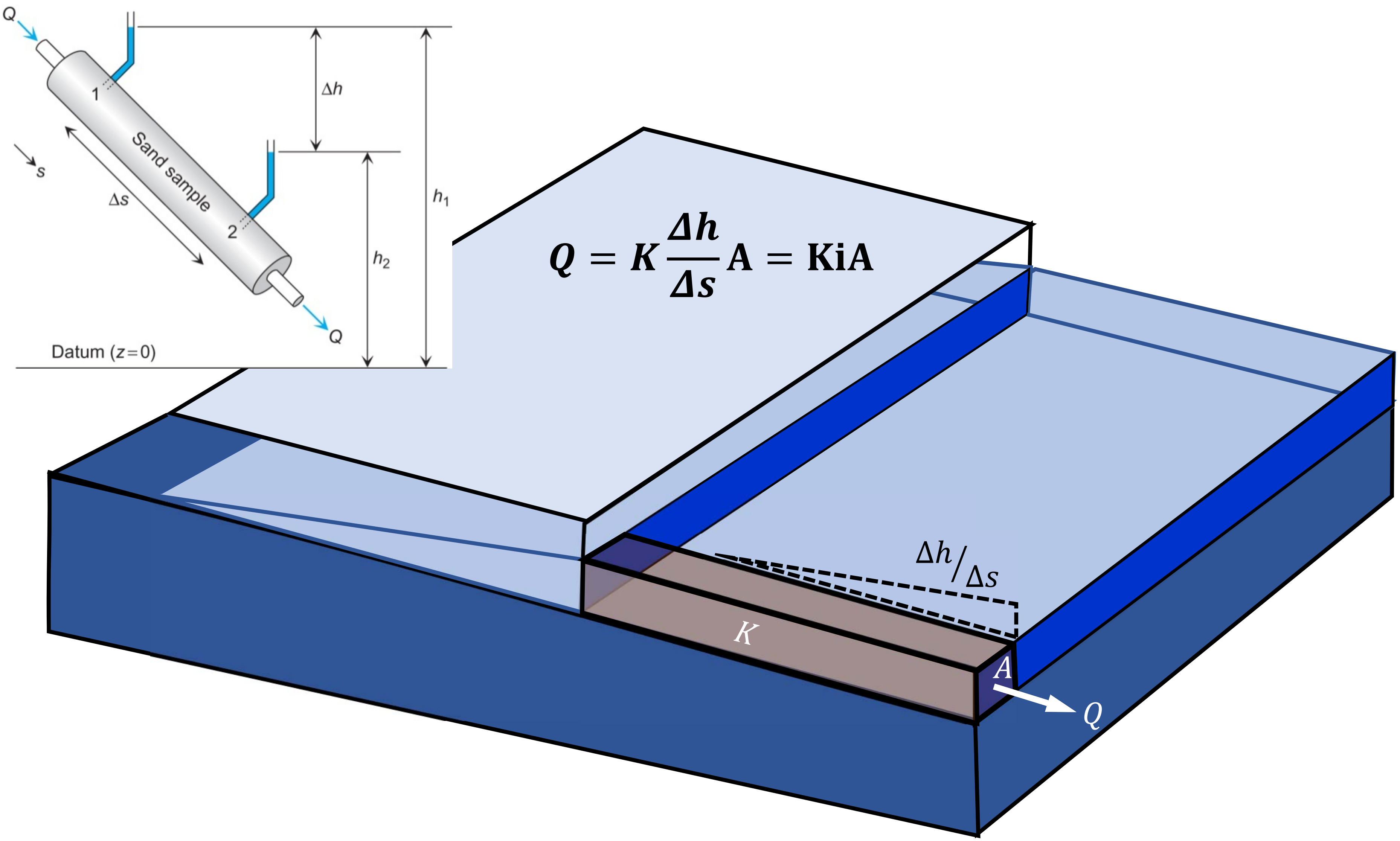
$$Q = K \frac{\Delta h}{\Delta s} \mathrm{A} = \mathrm{KiA}$$

Hydraulic conductivity is the '*constant of proportionality*' in Darcy's Law



# **Simplified Method**

## *for Groundwater Mounding Analysis*



# **Simplified Method** *for Groundwater Mounding Analysis*

$$\textbf{Darcy's Law } Q = K.i.A$$

$$Q = K.i.h.L$$

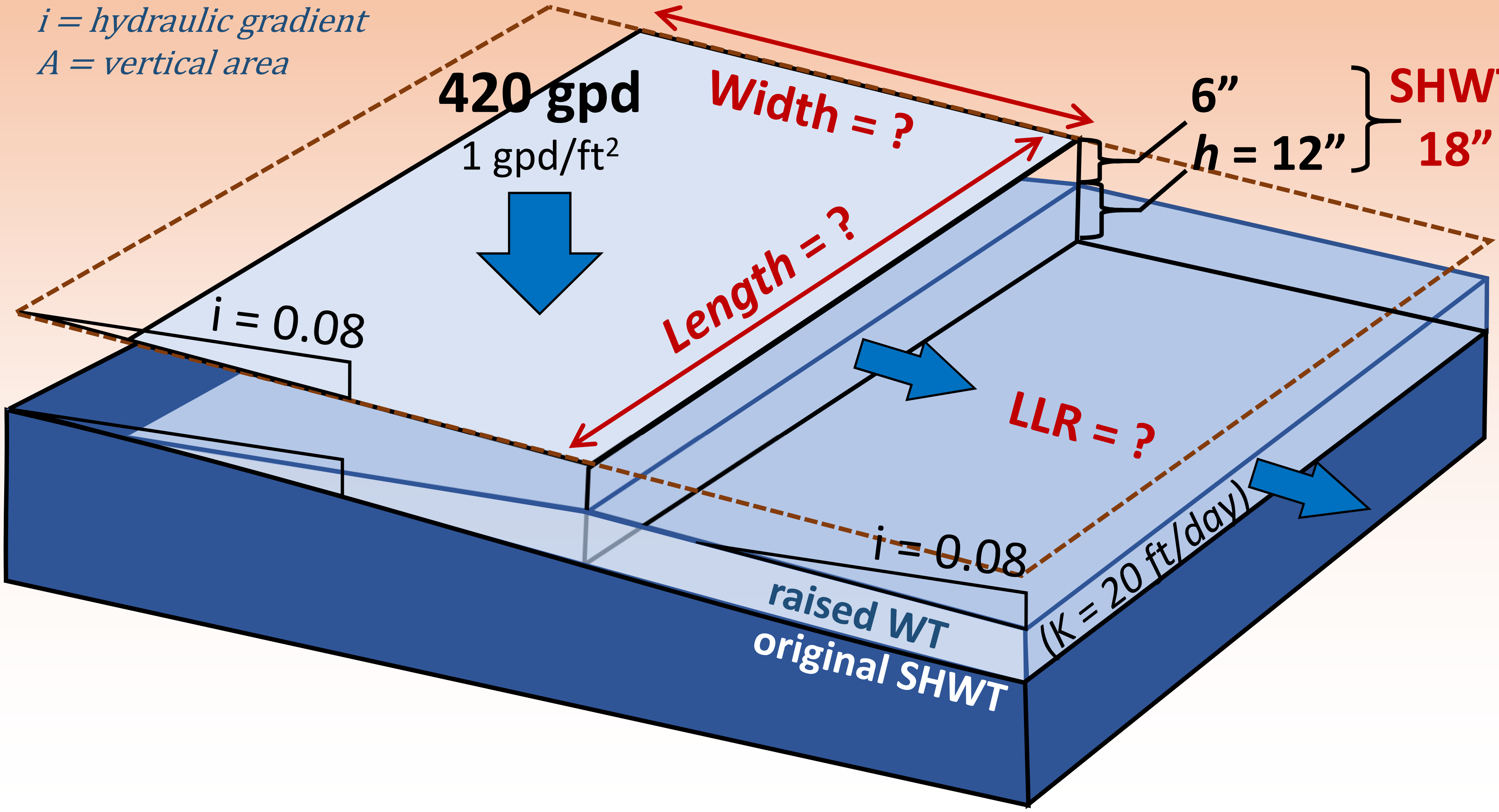
*Q = flow rate,*
*K = hydraulic conductivity*
*i = hydraulic gradient*
*A = vertical area*

$$\textit{For each foot}$$

$$LLR = K.i.h.1$$

$$f = K.i.\textit{conversion}$$

$$LLR = f.h$$



# LLR = h × f

**LLR = Linear loading rate (gpd/ft)**

**h = thickness of available soil for water table rise (ft)**

**f = LLR factor from Table 1**

| Soil Texture | LINEAR LOADING RATE FACTORS (f) Natural Ground Slope 0 - 2% | 2.1 - 4% | 4.1 - 6% | 6.1 - 8% | 8.1 - 10% | 10.1 - 15% | 15.1 - 20% |
|---|---|---|---|---|---|---|---|
| Coarse Sand, Sand, Loamy Coarse Sand, Loamy Sand | 7.5 | 22.4 | 37.4 | 52.4 | 52.4 | 52.4 | 52.4 |
| Coarse Sandy Loam, Sandy Loam, Fine Sand, Very Fine Sand, Loamy Fine Sand, Loamy Very Fine Sand | 3.7 | 11.2 | 18.7 | 26.2 | 33.7 | 33.7 | 33.7 |
| Fine Sandy Loam, Very Fine Sandy Loam | 1.5 | 4.4 | 7.5 | 10.5 | 13.5 | 18.7 | 26.2 |
| Loam | 1.1 | 3.4 | 5.6 | 7.9 | 10.1 | 14.0 | 19.6 |
| Silt Loam | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 |
| Sandy Clay Loam, Silty Clay Loam, Clay Loam | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 |
| Sandy Clay, Silty Clay, Clay | 0.2 | 0.7 | 1.1 | 1.6 | 2.0 | 2.8 | 3.9 |

**Example:** Using the Simplified Method, calculate the length of a leachfield in a mound for three bedroom house with a Design Flow of **420 gpd**, **fine sandy loam** to **36",** and seasonal high water table at **17",** on a ground slope of **8%.** Assume maximum mound Application Rate = **1 gpd/ft$^2$**

1. Calculate thickness of available soil for water table rise — **h = 17 – 6 = 11" = 0.92 ft**
2. Determine LLR factor from table — **f = 10.5**
3. Calculate Linear Loading Rate — **LLR = 0.92 × 10.5 = 9.7 gpd/ft**
4. Calculate system length = Design Flow / LLR — **Length = 420 / 9.7 = 43.3 ft**
5. Calculate MINIMUM system width = Minimum Area / Length — **Width = 420 / 43.3 = 9.7 ft**
6. Check 2:1 length/width ratio for mounds — **Build 44 long/10 wide**
7. For **septic effluent** vertical separation = 36" — **2.5 ft sand beneath leachfield**
8. For **filtrate effluent** vertical separation = 18" — **1.0 ft sand beneath leachfield**

# LLR = h × f

**LLR = Linear loading rate (gpd/ft)**

**h = thickness of available soil for water table rise (ft)**

**f = LLR factor from Table 1**

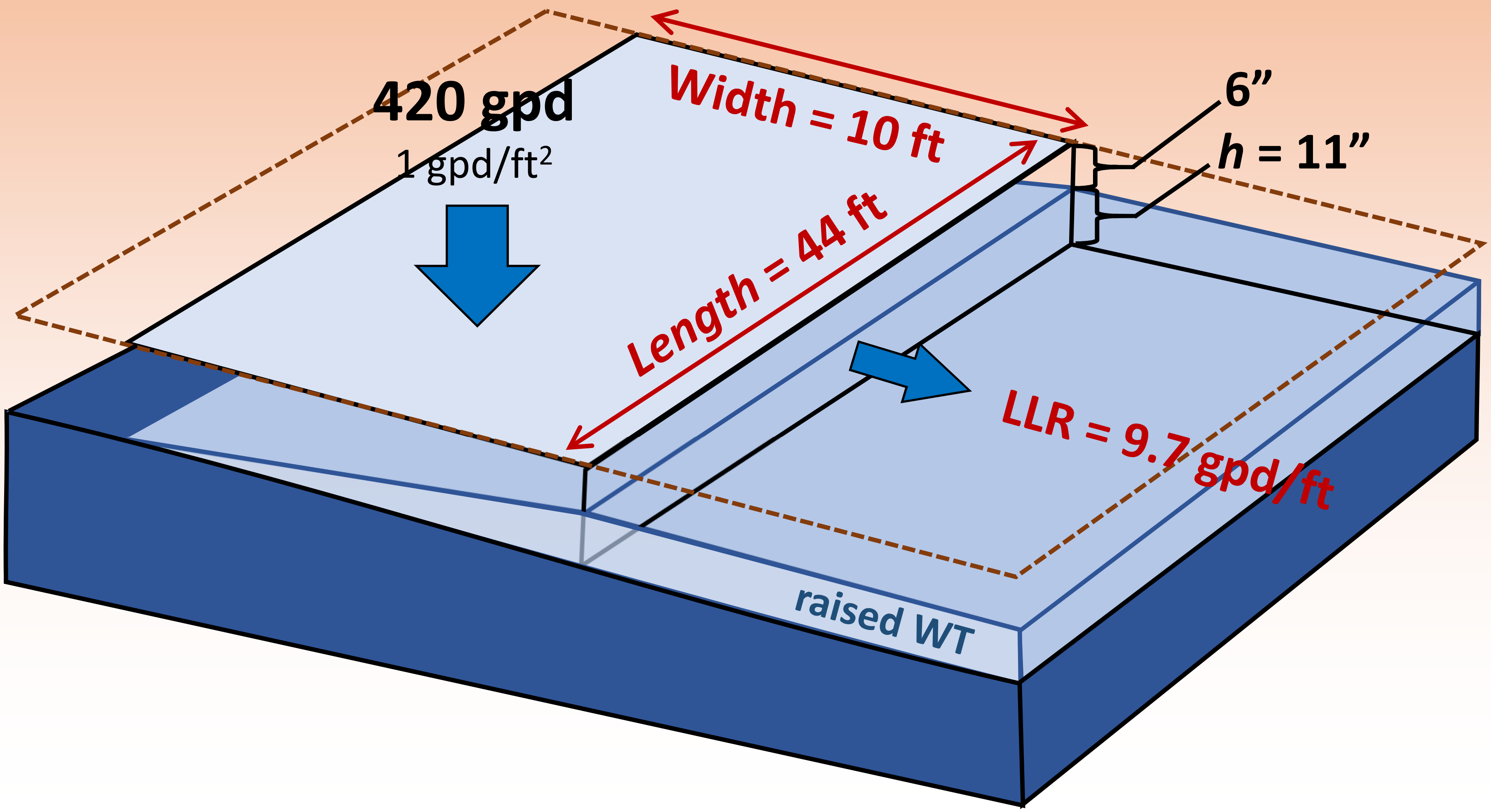
| Soil Texture | LINEAR LOADING RATE FACTORS (f) Natural Ground Slope | | | | | | |
|---|---|---|---|---|---|---|---|
| | **0 - 2%** | **2.1 - 4%** | **4.1 - 6%** | **6.1 - 8%** | **8.1 - 10%** | **10.1 - 15%** | **15.1 - 20%** |
| Coarse Sand, Sand, Loamy Coarse Sand, Loamy Sand | 7.5 | 22.4 | 37.4 | 52.4 | 52.4 | 52.4 | 52.4 |
| Coarse Sandy Loam, Sandy Loam, Fine Sand, Very Fine Sand, Loamy Fine Sand, Loamy Very Fine Sand | 3.7 | 11.2 | 18.7 | 26.2 | 33.7 | 33.7 | 33.7 |
| Fine Sandy Loam, Very Fine Sandy Loam | 1.5 | 4.4 | 7.5 | 10.5 | 13.5 | 18.7 | 26.2 |
| Loam | 1.1 | 3.4 | 5.6 | 7.9 | 10.1 | 14.0 | 19.6 |
| Silt Loam | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 |
| Sandy Clay Loam, Silty Clay Loam, Clay Loam | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 |
| Sandy Clay, Silty Clay, Clay | 0.2 | 0.7 | 1.1 | 1.6 | 2.0 | 2.8 | 3.9 |

**Example:** Using the Simplified Method, calculate the length of a leachfield in a mound for a Design Flow of **1,120 gpd** (2 × 5 bedroom), **loam** to **36”,** and seasonal high water table at **18”,** on a ground slope of **4%.** Assume maximum mound Application Rate = **1 gpd/ft$^2$**

1. Calculate thickness of available soil for water table rise — **h = 18 – 6 = 12” = 1.0 ft**
2. Determine LLR factor from table — **f = 5.6**
3. Calculate **Linear Loading Rate** — **LLR =1.0 × 5.6 = 5.6 gpd/ft**
4. Calculate system length = Design Flow / LLR — **Length = 560 / 5.6 = 100 ft long**
5. Calculate MINIMUM system width = Minimum Area / Length — **Width = 560 / 100 = 5.6 ft wide**
6. Check 2:1 length/width ratio for mounds — **Build 100 ft long / 6 ft wide**
7. For **septic effluent** vertical separation = 36” — **2.5 ft sand beneath leachfield**
8. For **filtrate effluent** vertical separation = 18” — **1.0 ft sand beneath leachfield**

# **Simplified Method** *for Desktop Mounding Analysis*

$LLR = f.h$



# Simplified Method … *the hidden numbers!*

| SOIL TEXTURE | K (ft/day) | LINEAR LOADING RATE FACTORS (f) Natural Ground Slope | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1% | 3% | 5% | 7% | 9% | 12.5% | 17.5% |
| | | 0 to 2% | 2.1 to 4% | 4.1 to 6% | 6.1 to 8% | 8.1 to 10% | 10.1 to 15% | 15.1 to 20% |
| Coarse Sand, Sand, Loamy Coarse Sand, Loamy Sand | 100 | 7.5 | 22.4 | 37.4 | 52.4 | 52.4 | 52.4 | 52.4 |
| Coarse Sandy Loam, Sandy Loam, Fine Sand, Very Fine Sand, Loamy Fine Sand, Loamy Very Fine Sand | 50 | 3.7 | 11.2 | 18.7 | 26.2 | 33.7 | 33.7 | 33.7 |
| Fine Sandy Loam, Very Fine Sandy Loam | 20 | 1.5 | 4.5 | 7.5 | 10.5 | 13.5 | 18.7 | 26.2 |
| Loam | 15 | 1.1 | 3.4 | 5.6 | 7.9 | 10.1 | 14.0 | 19.6 |
| Silt Loam | 10 | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 |
| Sandy Clay Loam, Silty Clay Loam, Clay Loam | 5 | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 |
| Sandy Clay, Silty Clay, Clay | 3 | 0.2 | 0.7 | 1.1 | 1.6 | 2.0 | 2.8 | 3.9 |

$$f = K \times i \times conversion\ factor\ (gallons\ per\ cubic\ foot)$$

$$Example\ f = 15\ \times 0.05 \times 7.48 = 5.6$$

$$From\ Darcy's\ Law\ (Q = K.i.A)\ \ LLR = K \times i \times h\ \ or\ LLR = f \times h$$

$Example\ \ LLR = (15 \times 0.05 \times 7.48) \times 1.0$ = 5.6 gpd/ft

# §1-9 Specific Technical Standards for Wastewater Systems

## § § 1-927 Simplified Method

- When an overlying soil layer within groundwater mounding zone has a smaller f-factor (lower K) than underlying layer, use the smallest f-factor (lower K) to calculate Linear Loading Rate
- When an overlying soil layer within the groundwater mounding zone has as larger f-factor (higher K) than underlying layer, the Linear Loading Rate may be calculated for the overlying soil layer AND underlying soil layer separately, and the two numbers ADDED to obtain the total Linear Loading Rate
- **Wait...what?**

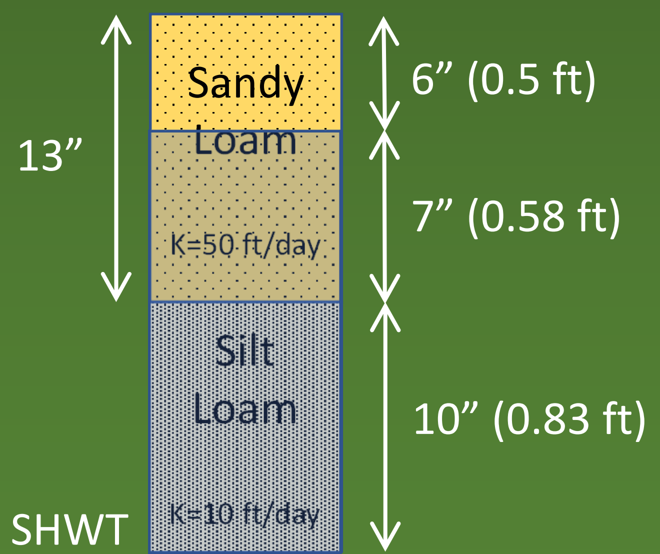
# How to Add Linear Loading Rates?

Slope = 5%

Sandy loam, f = 18.7

Silt loam, f = 3.7

| Soil Texture | LINEAR LOADING RATE FACTORS (f) Natural Ground Slope | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 - 2% | 2.1 - 4% | 4.1 - 6% | 6.1 - 8% | 8.1 - 10% | 10.1 - 15% | 15.1 - 20% |
| Coarse Sand, Sand, Loamy Coarse Sand, Loamy Sand | 7.5 | 22.4 | 37.4 | 52.4 | 52.4 | 52.4 | 52.4 |
| Coarse Sandy Loam, Sandy Loam, Fine Sand, Very Fine Sand, Loamy Fine Sand, Loamy Very Fine Sand | 3.7 | 11.2 | 18.7 | 26.2 | 33.7 | 33.7 | 33.7 |
| Fine Sandy Loam, Very Fine Sandy Loam | 1.5 | 4.4 | 7.5 | 10.5 | 13.5 | 18.7 | 26.2 |
| Loam | 1.1 | 3.4 | 5.6 | 7.9 | 10.1 | 14.0 | 19.6 |
| Silt Loam | 0.7 | 2.2 | 3.7 | 5.2 | 6.7 | 9.4 | 13.1 |
| Sandy Clay Loam, Silty Clay Loam, Clay Loam | 0.4 | 1.1 | 1.9 | 2.6 | 3.4 | 4.7 | 6.5 |
| Sandy Clay, Silty Clay, Clay | 0.2 | 0.7 | 1.1 | 1.6 | 2.0 | 2.8 | 3.9 |

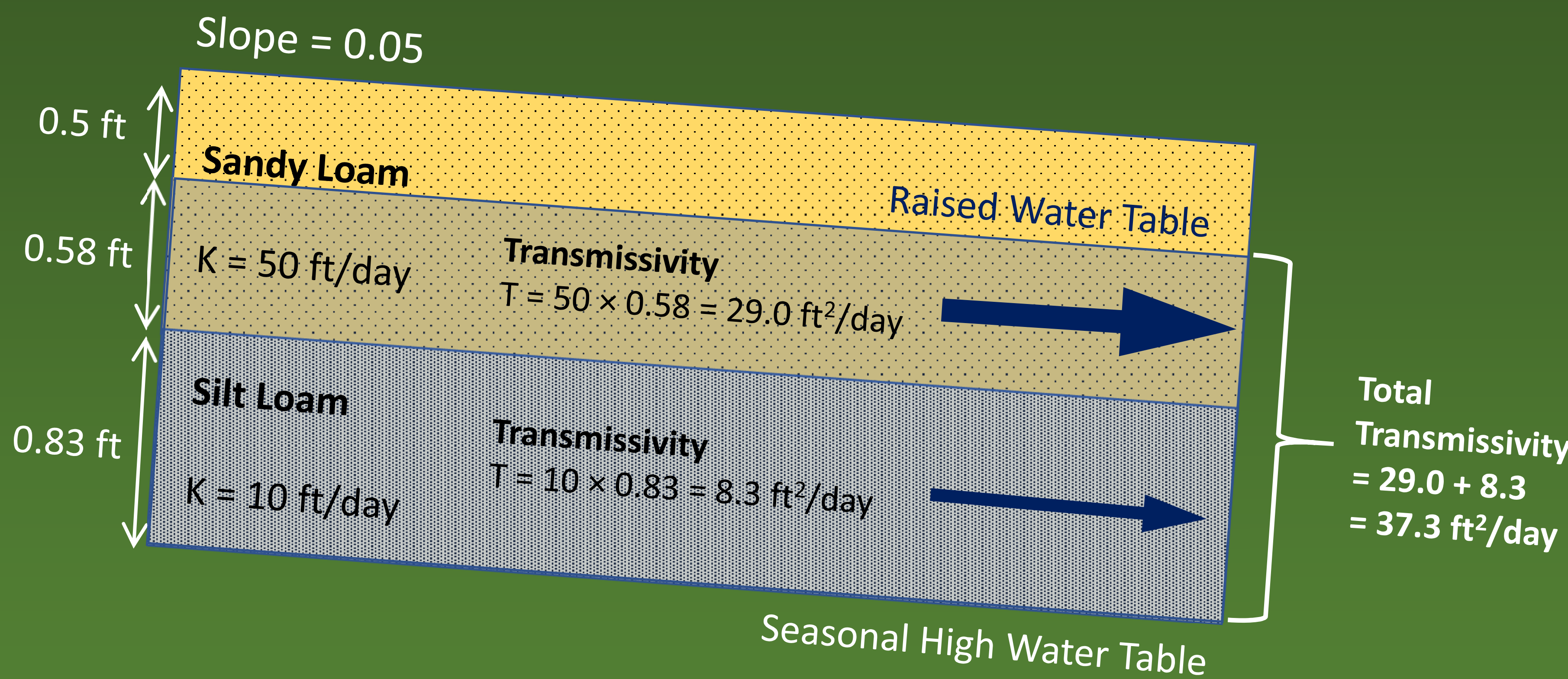



Sandy loam LLR = f × h = 18.7 × 0.58 = 10.85 gpd/ft

Silt loam LLR = f × h = 3.7 × 0.83 = 3.07 gpd/ft

**Total LLR = 10.85 + 3.07 = 13.92 gpd/ft**

# Why Add Linear Loading Rates?



# “Take home” message: <u>simplified</u> method is based on flow downhill (not downward) flow