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HOW WATER MOVES THROUGH SOIL

DISCLAIMER

The materials being presented here are the opinion of the presenter and do not reflect the opinions of NOWRA.

THE DIRECTION OF WATER FLOW THROUGH SOIL IS THE RESULT OF THREE FORCES: **SATURATED** FLOW, **UNSATURATED** FLOW, AND **VAPOR** FLOW. THIS SESSION WILL REVIEW THESE THREE BASICS FORCES OF WATER FLOW THROUGH SOIL AND WILL **DISCUSS** THEIR RELATIONSHIP TO WASTEWATER RENOVATION BY SOIL.

VADOSE ZONE

OUTLINE

1. Soil water characteristics and behavior
2. Types of soil water movement
3. Relationship to wastewater renovation
4. Structured vs Non-Structured Soils
5. Delaware Valley College Research.
6. NC State University Dye Tracer Study

SOIL WATER CHARACTERISTICS AND BEHAVIOR

Structure and Related Properties of Soil Water

- Polarity +H-O-H+
- Hydrogen Bonding
- Cohesive forces vs. Adhesive forces
- Surface tension

CAPILLARY FUNDAMENTALS AND SOIL WATER

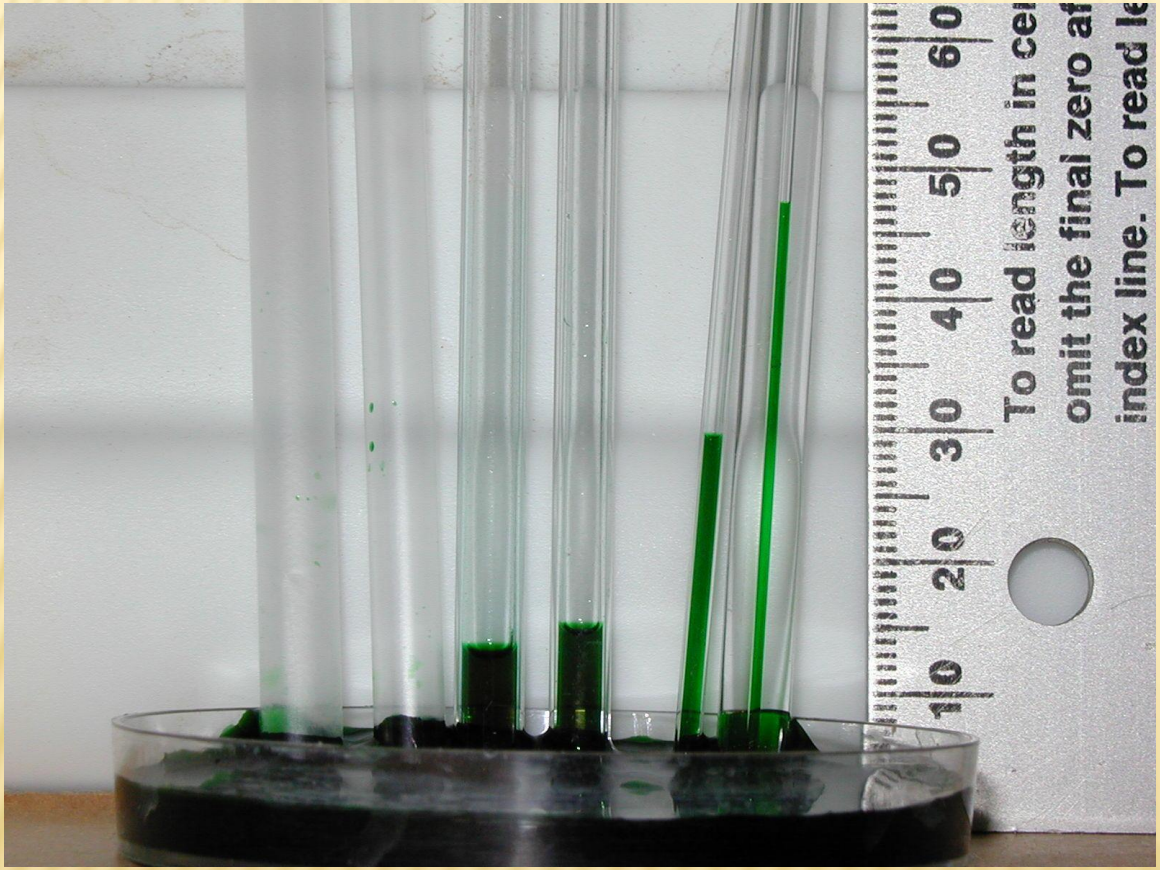
Capillarity is due to two forces:

1. The attractive force of water for solids on the pore linings or un-like surfaces= adhesion
2. The surface tension of water which is due to attraction of water molecules to each other=cohesion

Capillary force is due to big pores and little pores

Why does water rise higher in a small glass tube vs a large glass tube when place in the same bowel of water?

CAPILLARITY

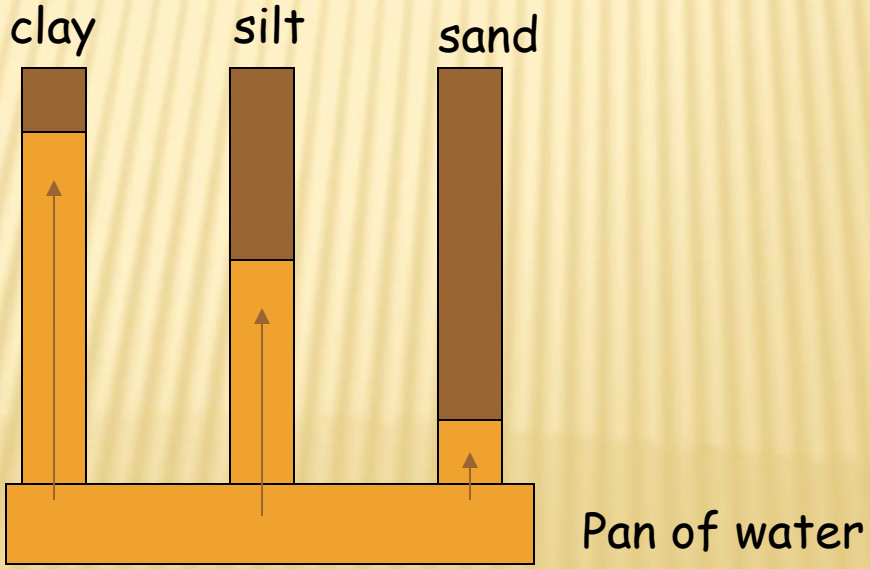


Plastic Glass

Height water will rise in cylinder depends on diameter of tube; due to adhesion of water and tube

CAPILLARITY

- the smaller the pore space, the higher capillary water will rise in profile
- Smaller pore space, tighter water is held to particle surfaces against gravity (i.e., higher field capacity)



TYPES OF SOIL WATER MOVEMENT

1. Saturated Flow
2. Unsaturated Flow
3. Vapor Flow

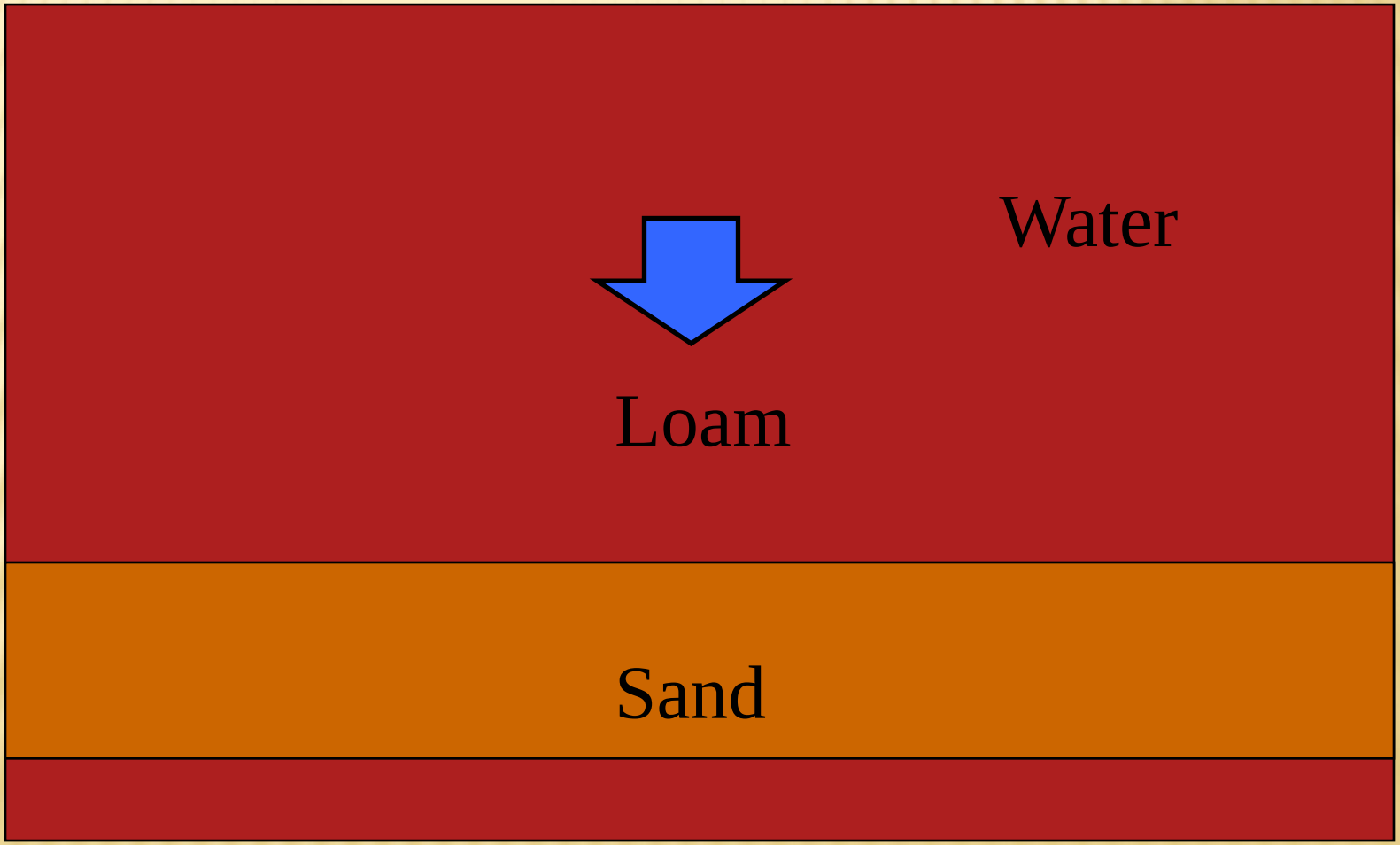
SATURATED FLOW

1. Occurs when all pore space is filled with water and gravity is the main directional force
2. Water flows downhill only under saturated flow
3. Is not conducive to wastewater treatment

UNSATURATED FLOW

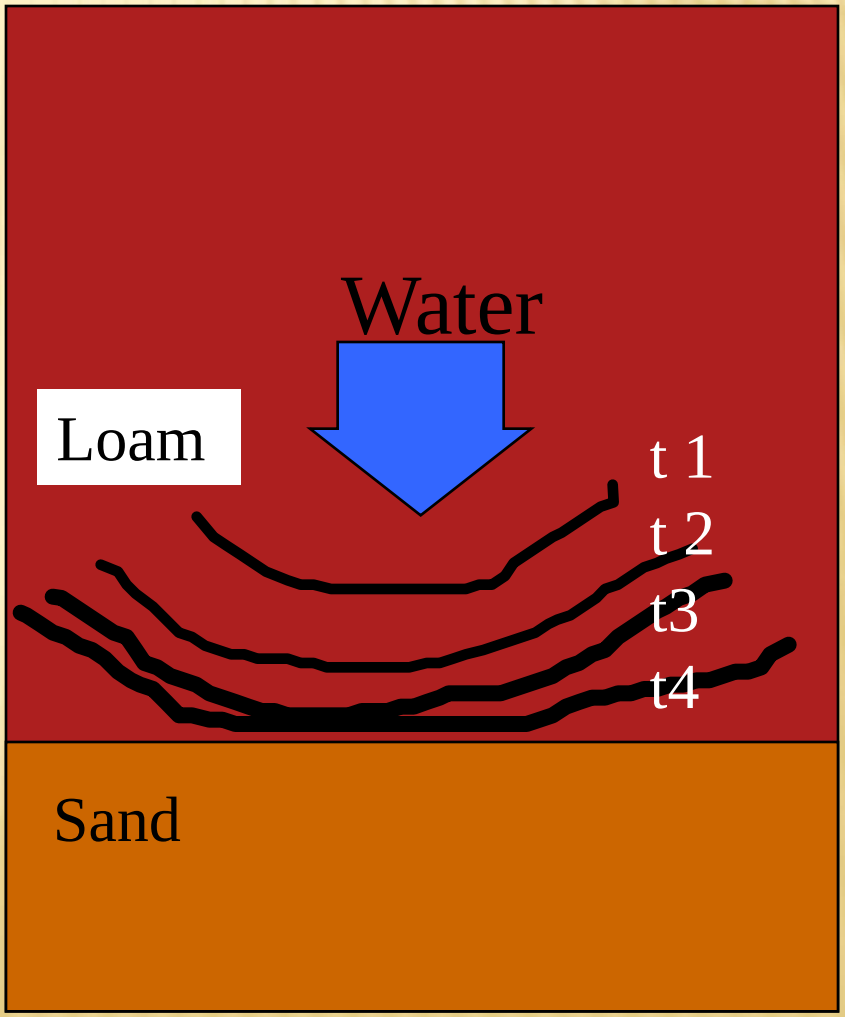
- Moves from low tension to high tension
- Moves from big pores to little pores
- Macro pore flow called by-pass flow or a “flush” event occurs in heavy rain events
- Micropore flow holds the water and contaminants in the soil for renovation by micro-organisms.
- Wastewater treatment requires unsaturated flow.
- Remember: Soils Suck… they hold water against the force of gravity by unsaturated flow.

WATER MOVEMENT

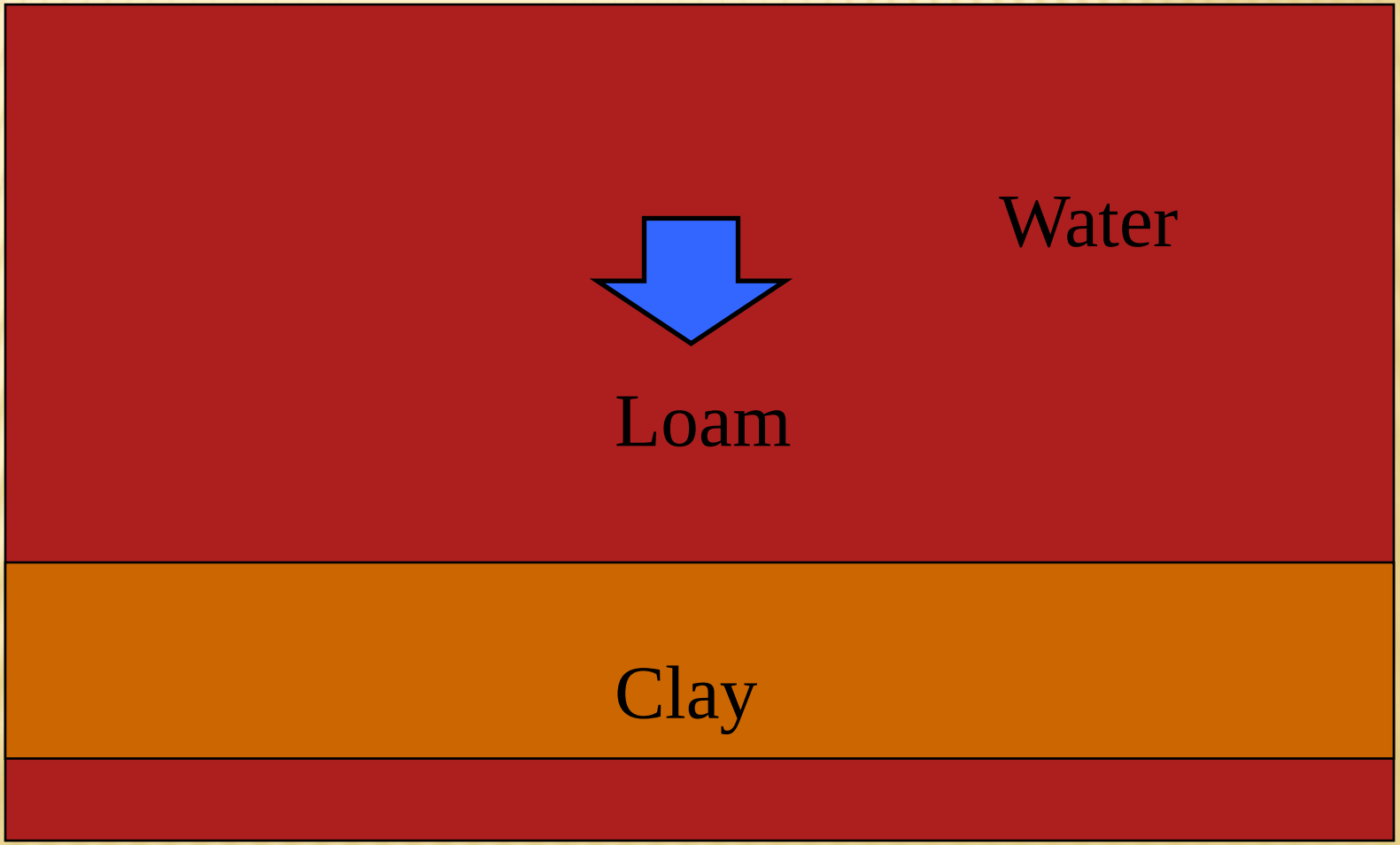


WATER MOVEMENT

Water-front does not move into sand until loam is ***saturated***. Is this a water table?

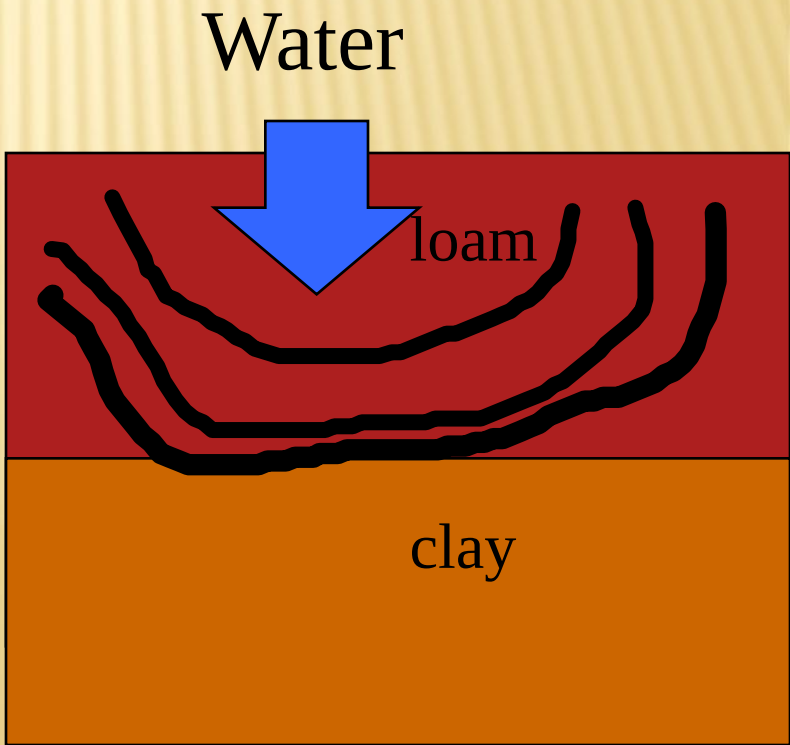


WATER MOVEMENT



WATER MOVEMENT

Water-front freely moves into clay upon contact with clay. This may create a perched water table because the clay slowly moves the water.



VAPOR FLOW

Two types of vapor flow

1. Internal: within the soil pores
2. External: loss of water to the soil surface by evaporation

SOIL WATER CAPACITY

Saturated soil: flow by gravity

Field capacity: point at which soil is still un-saturated but is almost saturated and gravity is not affecting the water flow

Wilting coefficient: water held so tightly that it is unavailable for plant uptake

Hygroscopic coefficient: down to water film of a few molecules

Air dry

Oven dry

Hydroscopic coefficient

Wilting point

Field capacity

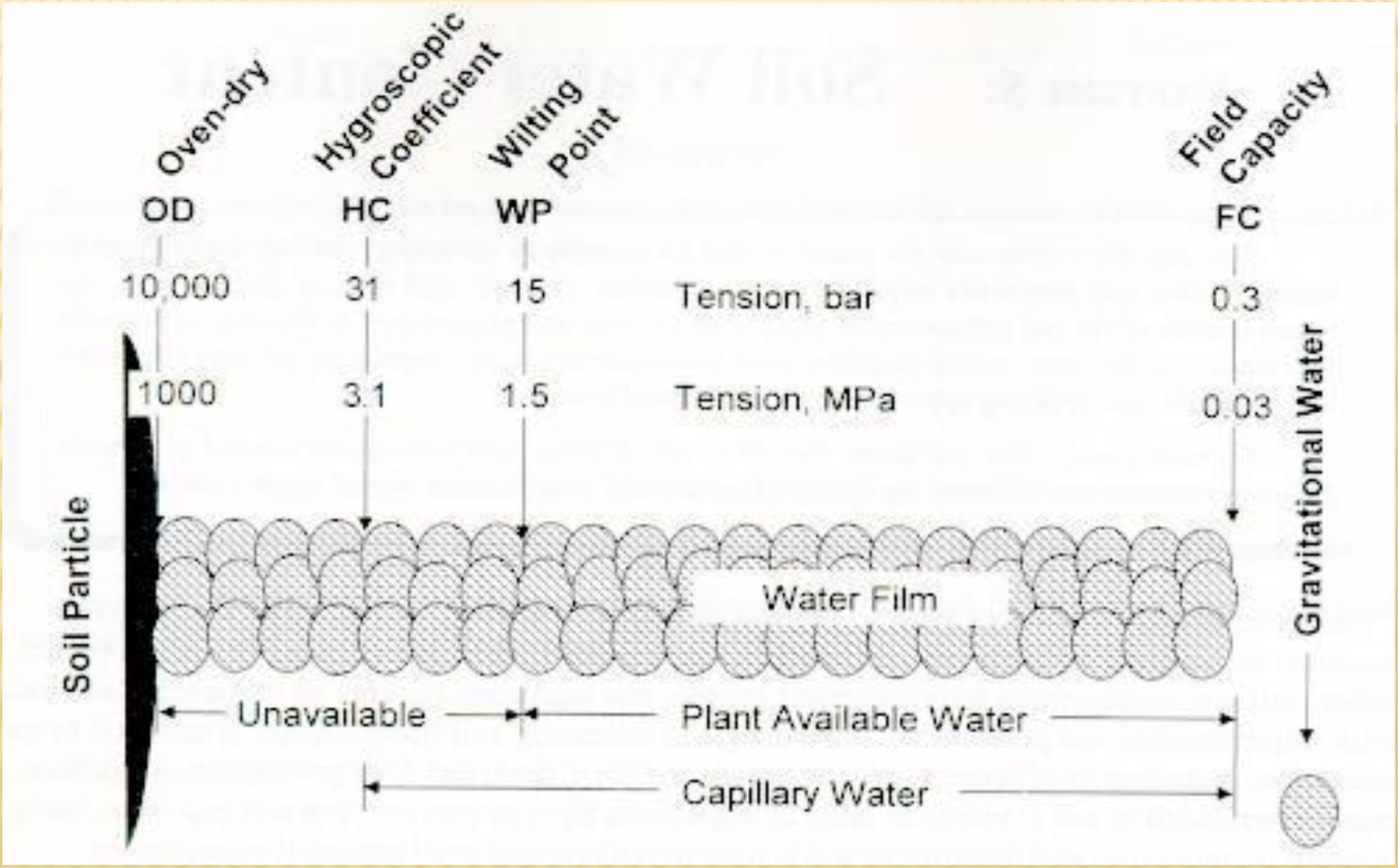
No water

Adhesion water

Plant-unavailable water (capillary)

Plant-available Water (capillary)

Gravitational water


Oven-dry
Hygroscopic Coefficient
Wilting Point
Field Capacity
OD
HC
WP
FC
10,000
31
15
Tension, bar
0.3
1000
3.1
1.5
Tension, MPa
0.03
Soil Particle
Water Film
Gravitational Water
Unavailable
Plant Available Water
Capillary Water

FACTORS AFFECTING PORE SIZES AND WATER MOVEMENT IN SOIL

- Texture
- Soil Structure
- Consistency
- Slope

RELATIONSHIP TO WASTEWATER RENOVATION

1. Saturated flow allows for transport of contaminates through the soil by macro pore flow
2. Flush events occur after a significant rainfall. This aspect was demonstrated by research at DVC
3. Unsaturated flow is what we try to achieve when siting an on-lot sewage disposal system. This allows for renovation of the wastewater in micro pores by physical, chemical and biological processes.
4. Sub-surface application of wastewater promotes macropore by-pass flow demonstrated by NC State dye test study.

LANDSCAPE LOADING

Landscape loading uses soil morphology and the principals of soil water movement to determine the length and width of an absorption area (Tyler 2000).

5-gallon bucket of water tipped over and measure the distance for infiltration vs. a long rain gutter with 5 gallons of water

Which one will infiltrate in the shortest distance?

This is landscape loading!

REVIEW OF SOIL WATER MOVEMENT

- Saturated vs unsaturated flow
- Saturated flow by gravity
- Unsaturated flow from low to high tension
- Saturated flow uses the macro pores
- Unsaturated flow uses the micro pores

CONCLUSION

Saturated water flow is by gravity

Unsaturated flow moves by tension…from low to high

Soils Suck!

Field capacity is the amount of water held by a given soil against the force of gravity…that point right before saturated flow

Wastewater renovation is best at unsaturated flow

RESEARCH AND DEMONSTRATION CENTER
ON-LOT SYSTEMS AND SMALL FLOW TECHNOLOGIES
DELAWARE VALLEY COLLEGE
DOYLESTOWN, PA

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CONCLUSIONS

- Loading rates well below measured saturated HC is needed to promote unsaturated flow and maximize effluent renovation.
- Placement of effluent near the soil surface vs. subsurface avoids macro pore flow when loading rates are well below measurable K_{sat} promoting unsaturated flow.
- Flush events may transport FC through the soil profile regardless of soil drainage class and the depth of system installation.

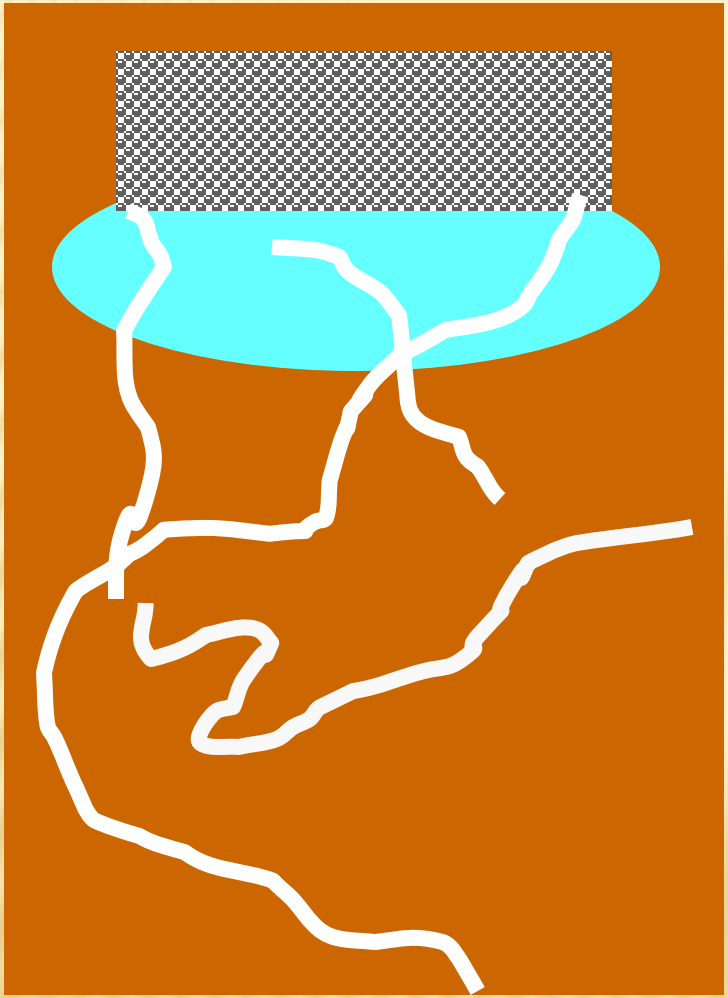
WASTEWATER FLOW FIELD STUDY

NC Carolina State University

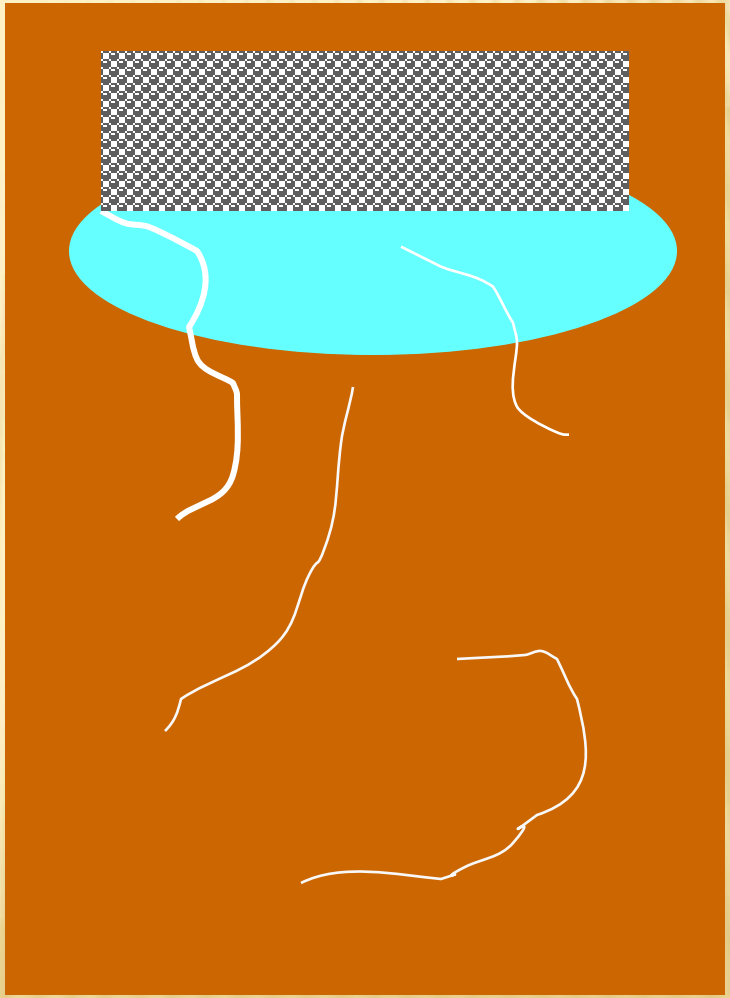
Dye Tracer Study

2000

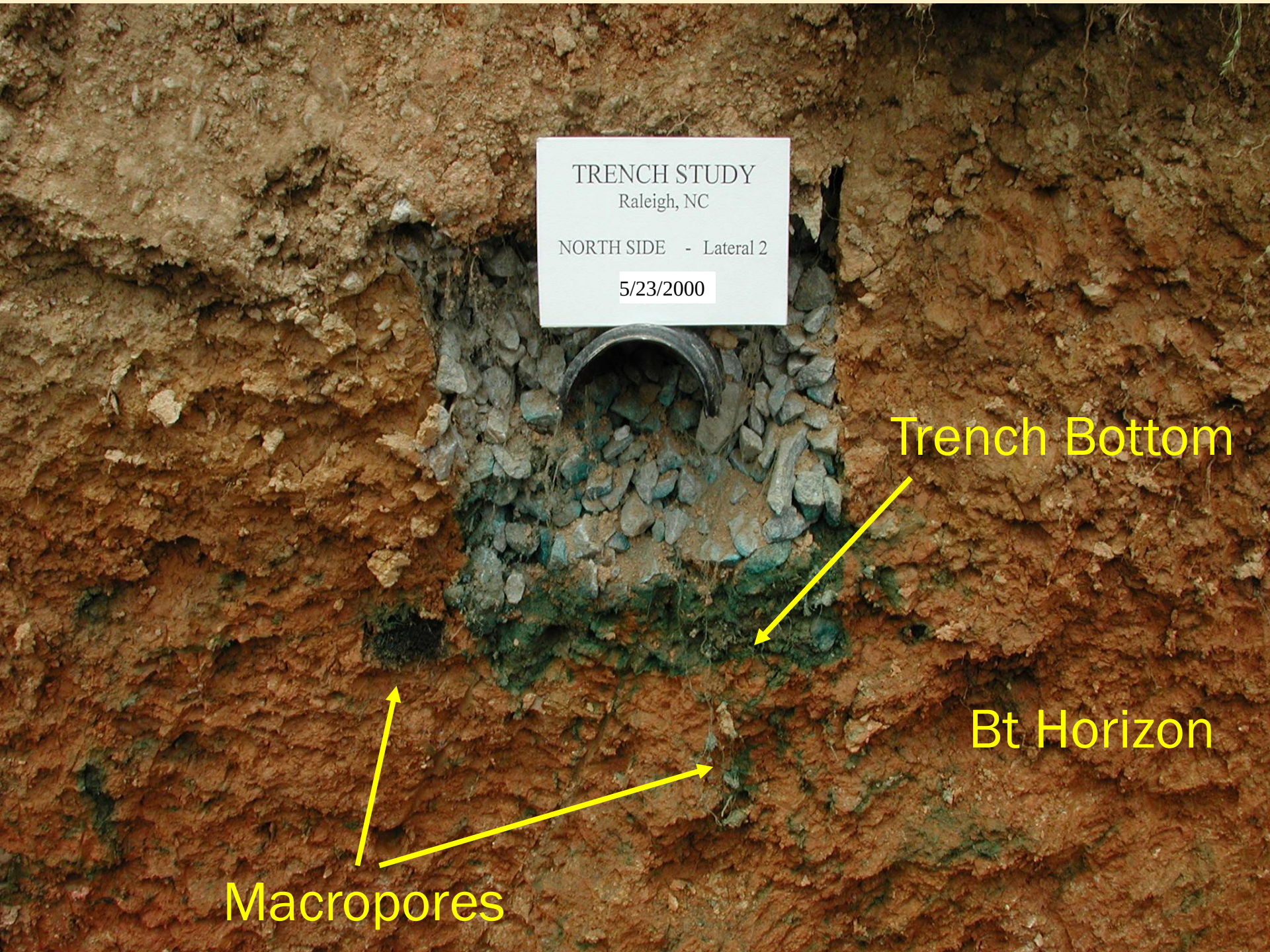
DETAIL OF FLOW AWAY FROM TRENCH

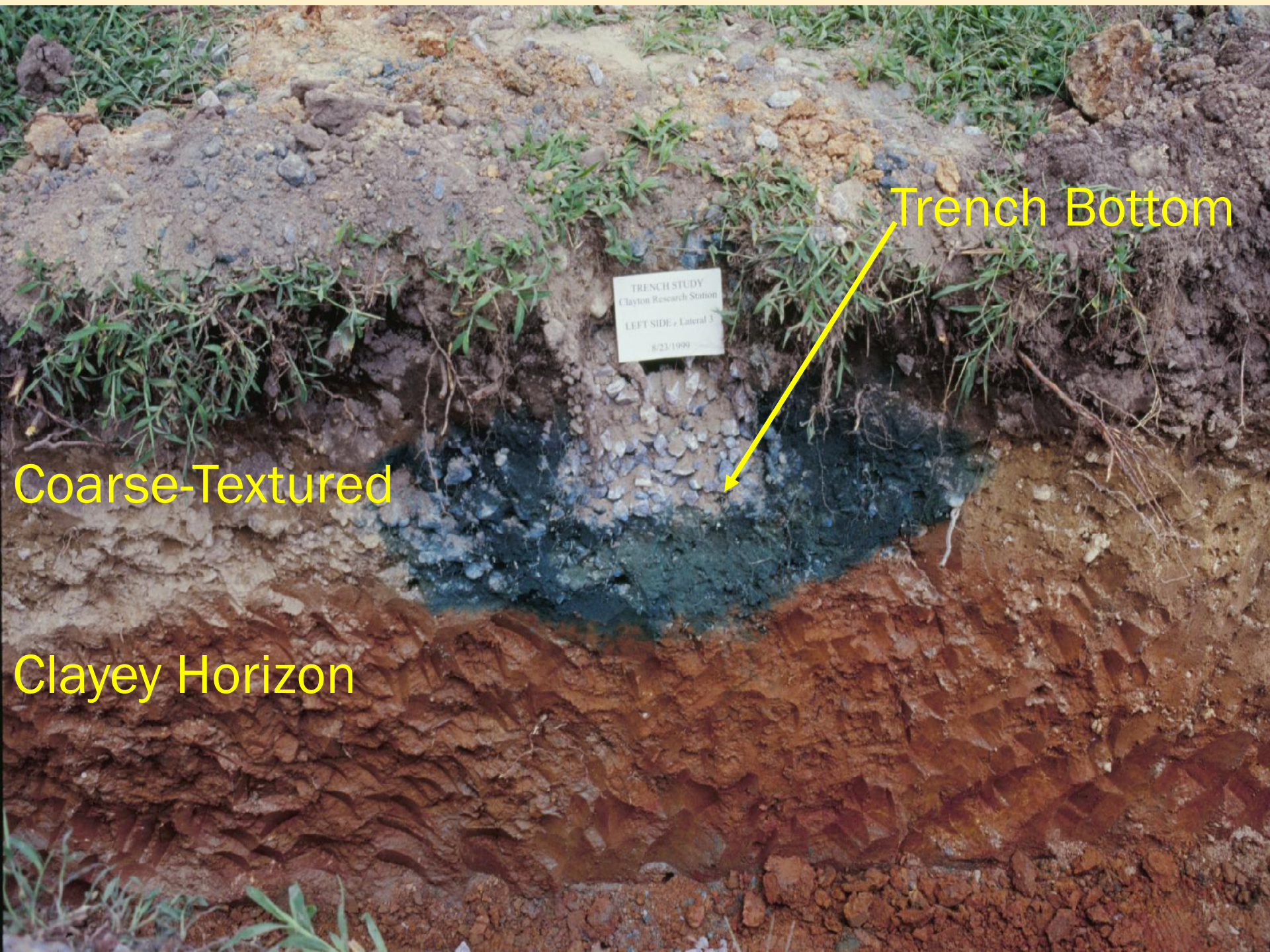


Faster flow away from trench



Slower flow away from trench


TRENCH STUDY
Raleigh, NC
NORTH SIDE - Lateral 2
5/23/2000
Trench Bottom
Bt Horizon
Macropores


Trench Bottom
TRENCH STUDY
Clayton Research Station
LEFT SIDE - Lateral 3
8/23/1999
Coarse-Textured
Clayey Horizon


TRENCH STUDY
Lake Wheeler
EAST SIDE - Lateral 3
11-28-2000


LIBERTY
IN GOD WE TRUST
1967


TRENCH STUDY
Raleigh, NC
NORTH SIDE - Lateral 3
5-23-20000
A
B
C
D
E
F
G
H

SUMMARY OF SOIL WATER FLOW AND THE EFFECT ON SEWAGE RENOVATION

- Saturated vs. unsaturated flow
- Macropore vs micropore flow
- Structured vs non-structured soils
- Vertical vs horizontal flow
- Surface vs sub-surface installations and preferential flow patterns (exception drip)
- Flush events and by-pass macropore flow
- It is not a simple process

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- Dr. David Lindbo, USDA-NRCS
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- *The Nature and Properties of Soils 15th ed.* by Weil (2017)

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QUESTIONS

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