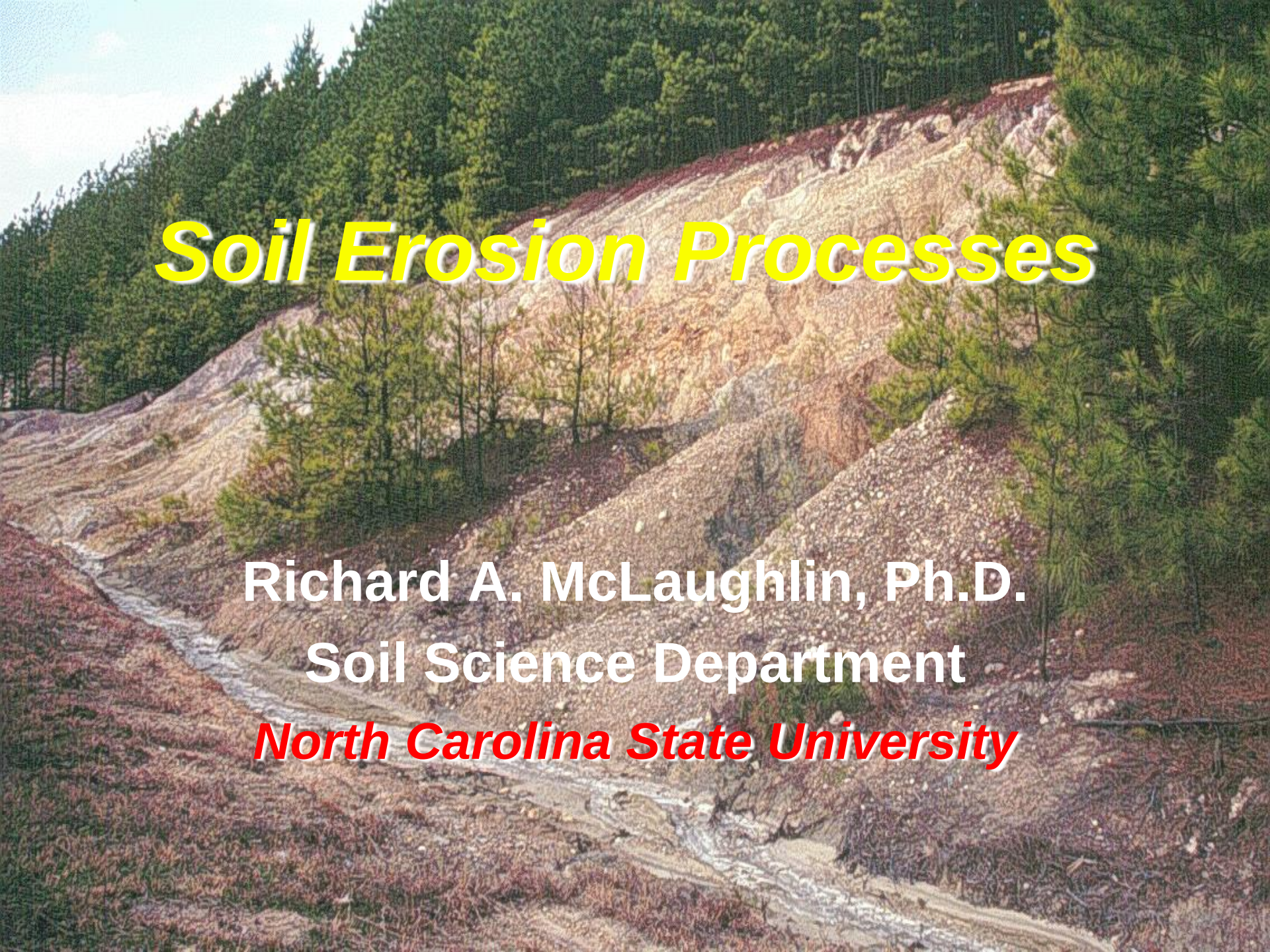


# Soil Erosion Processes

Richard A. McLaughlin, Ph.D.
Soil Science Department
North Carolina State University

# *Water Quality Problems: EPA Ranking*

***Sediment*: widespread problems in surface water. Ruins habitat, clogs waterways, fills lakes and reservoirs.**

***Nutrients*: cause algal blooms and ultimately oxygen depletion. Yuck.**

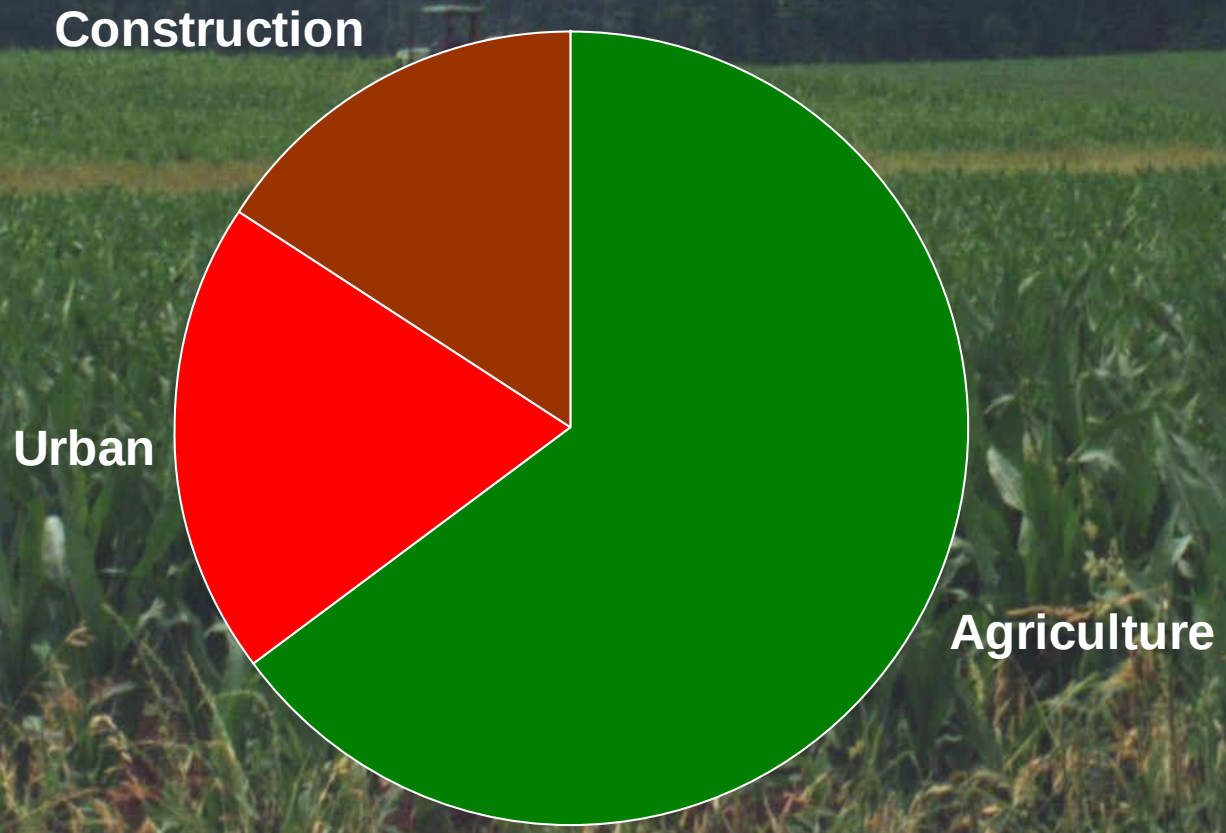
***Pathogens*: local problems especially on coast. Many sources and no way to tell them apart!**

***Organic Stuff*: degrades and robs oxygen.**

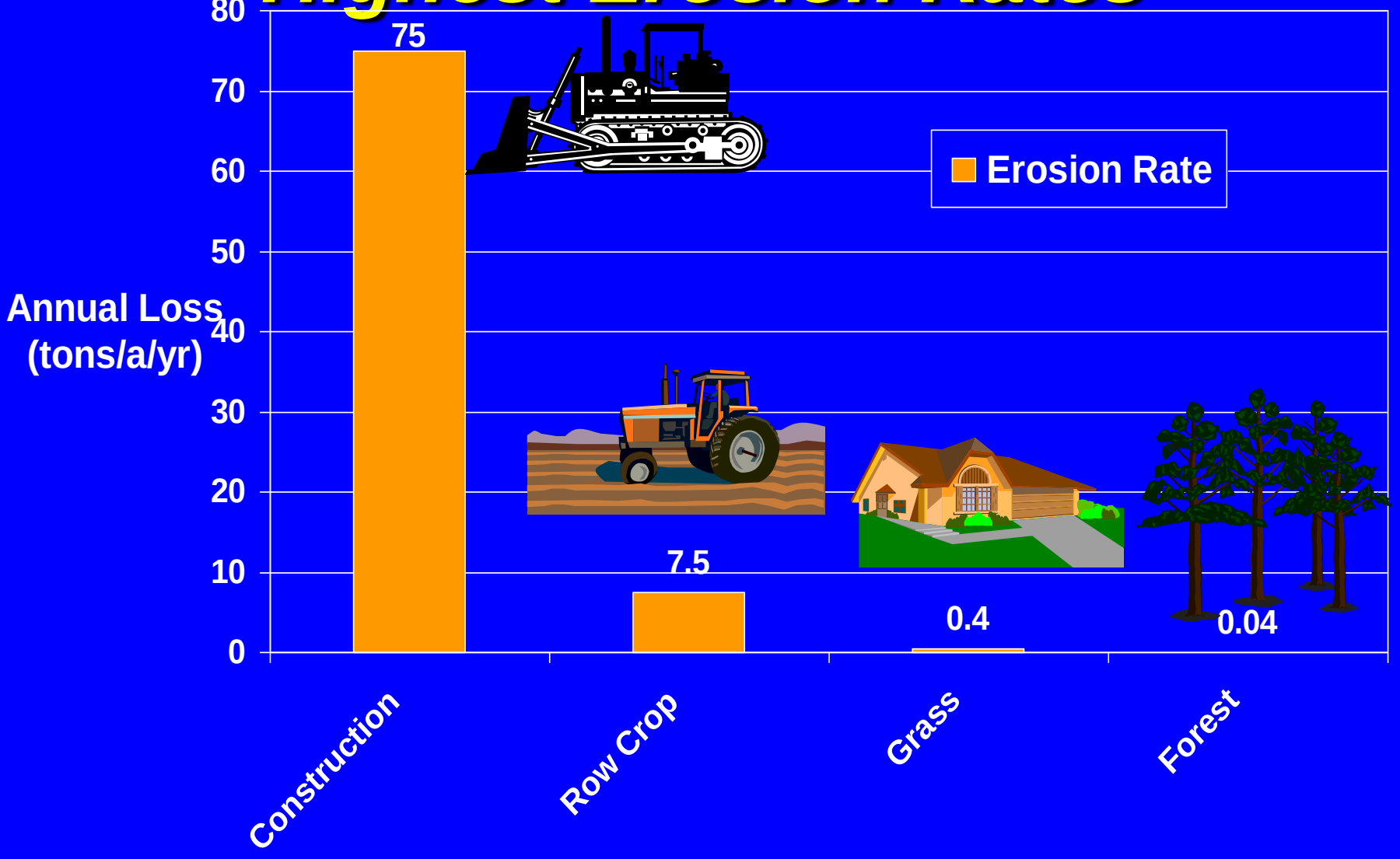
***Heavy Metals*: biological impacts**

***Pesticides*: mostly a private well problem.**

# Non-Point Pollutant Sources: North Carolina Rivers



# But…Construction Sites Have Highest Erosion Rates



# *Erosion: Two Phases*

- **Detachment: individual particles are loosened from the soil mass.**
  - **Rainsplash > running water > wind**
- **Transport: water or wind carries the detached particles downslope or downwind.**
  - **Flow in rills is the most important.**

# *Factors in Soil Losses*

- ***Rainfall***: intensity, duration, and energy.
- ***Soil erodibility***: texture, structure, organic matter content.
- ***Topography***: slope length, steepness.
- ***Surface Condition***: vegetation, mulch, bare, etc.
- ***Erosion Control Practices***: contours, terraces, silt fences, basins, etc.

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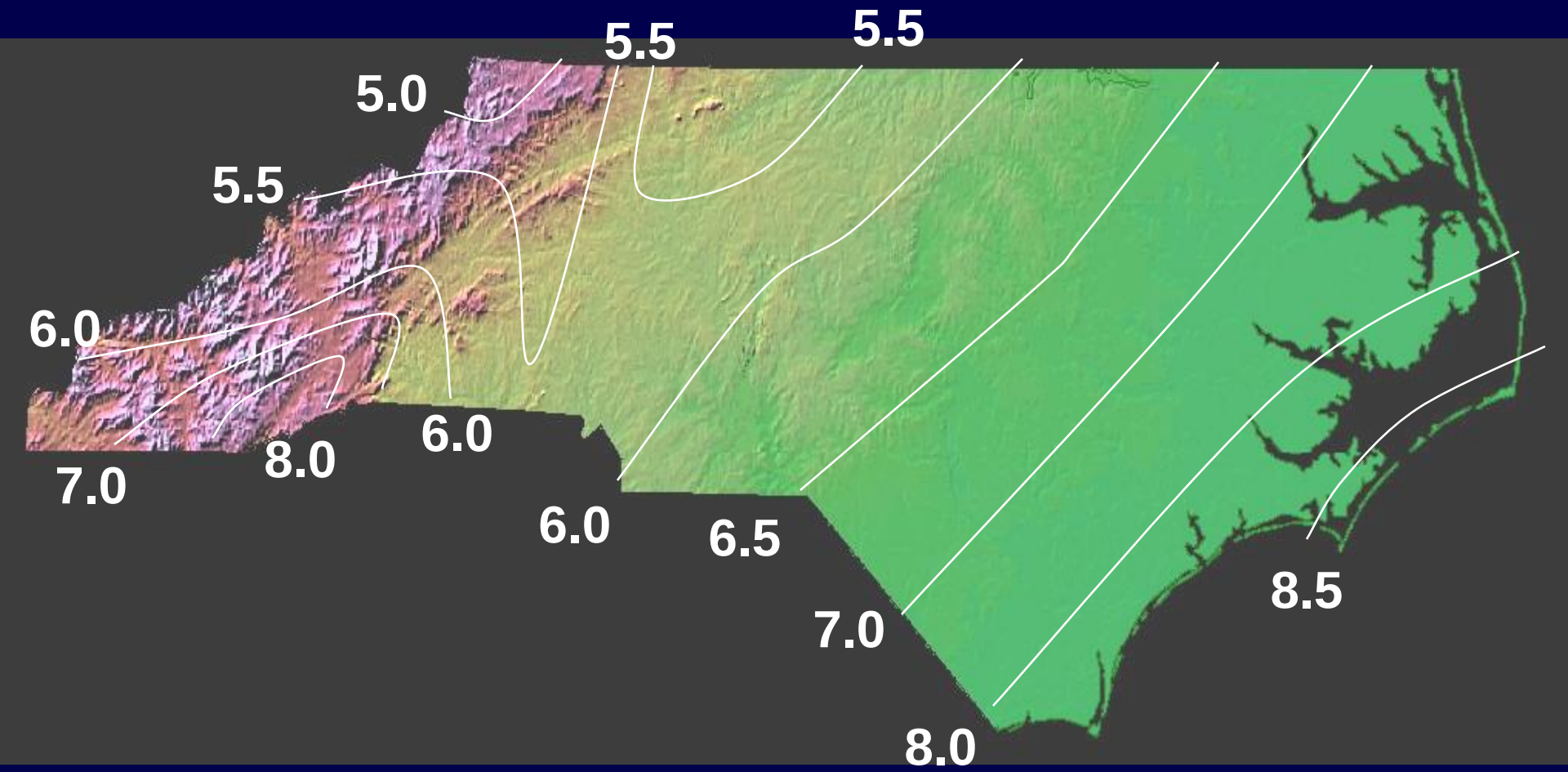
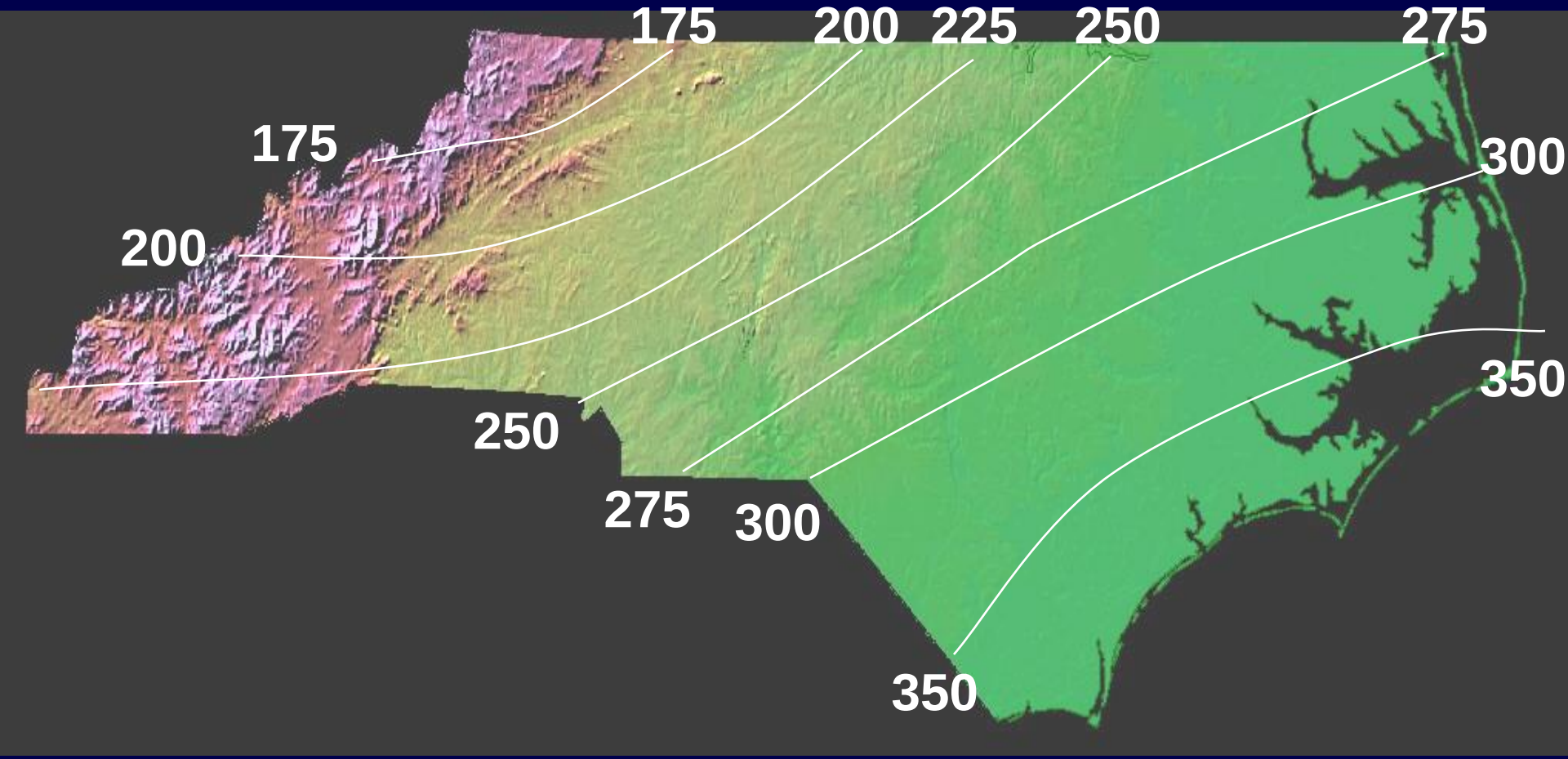
# Rainfall Factor

- Intensity: the volume of water per unit of time e.g. inches/hour.
  - Records: 1.23” in 1 minute (MD, 1956), 19” in two hours (WV, 1889), 45” in 3 days (FL, 1950).
- Duration: how long the storm lasts.
  - Norfolk has an average of 603 hours of precipitation/year, or 6.9% of the time. Of that, 12 hours exceed 0.5 in per hour.
- Energy: droplet size and velocity.
  - Heavy rain (0.6”/hr) has 30 times more energy than light rain (0.04”/hr).

# 24-Hour Rainfall Amounts for a 25-Year Recurrence

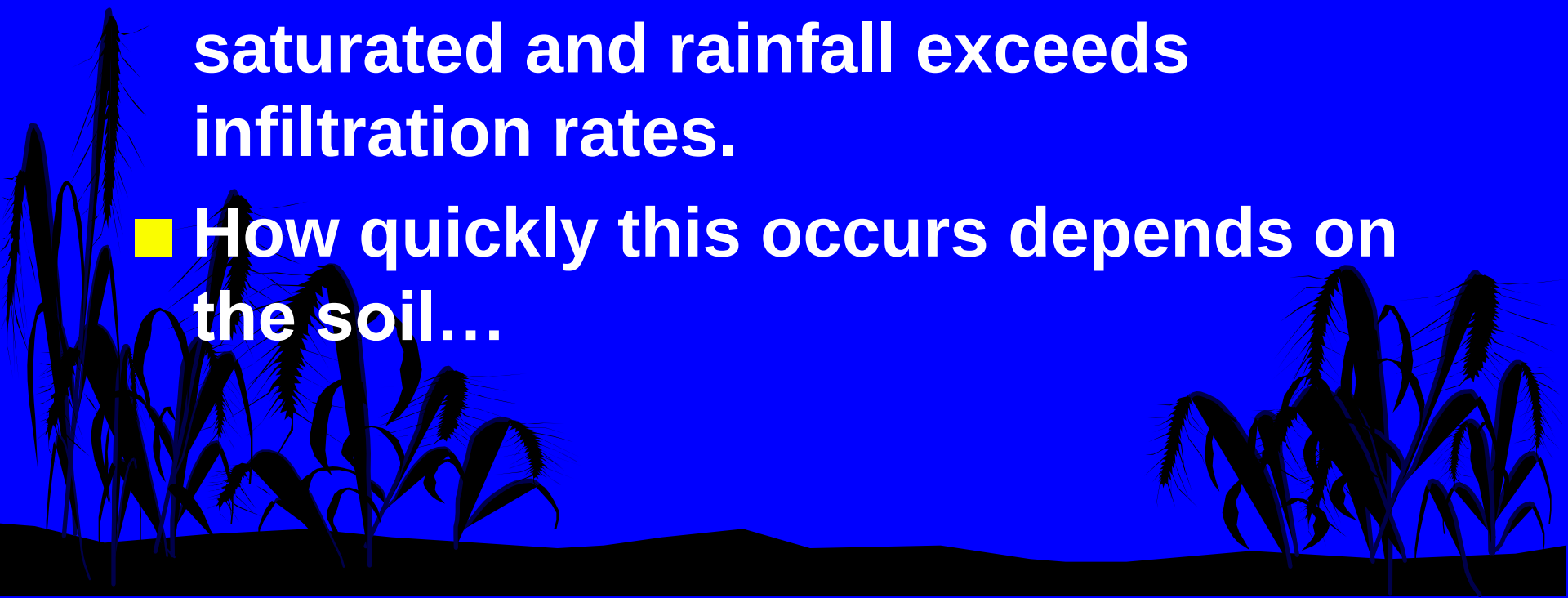


# *Rainfall Erosivity: Duration + Intensity*

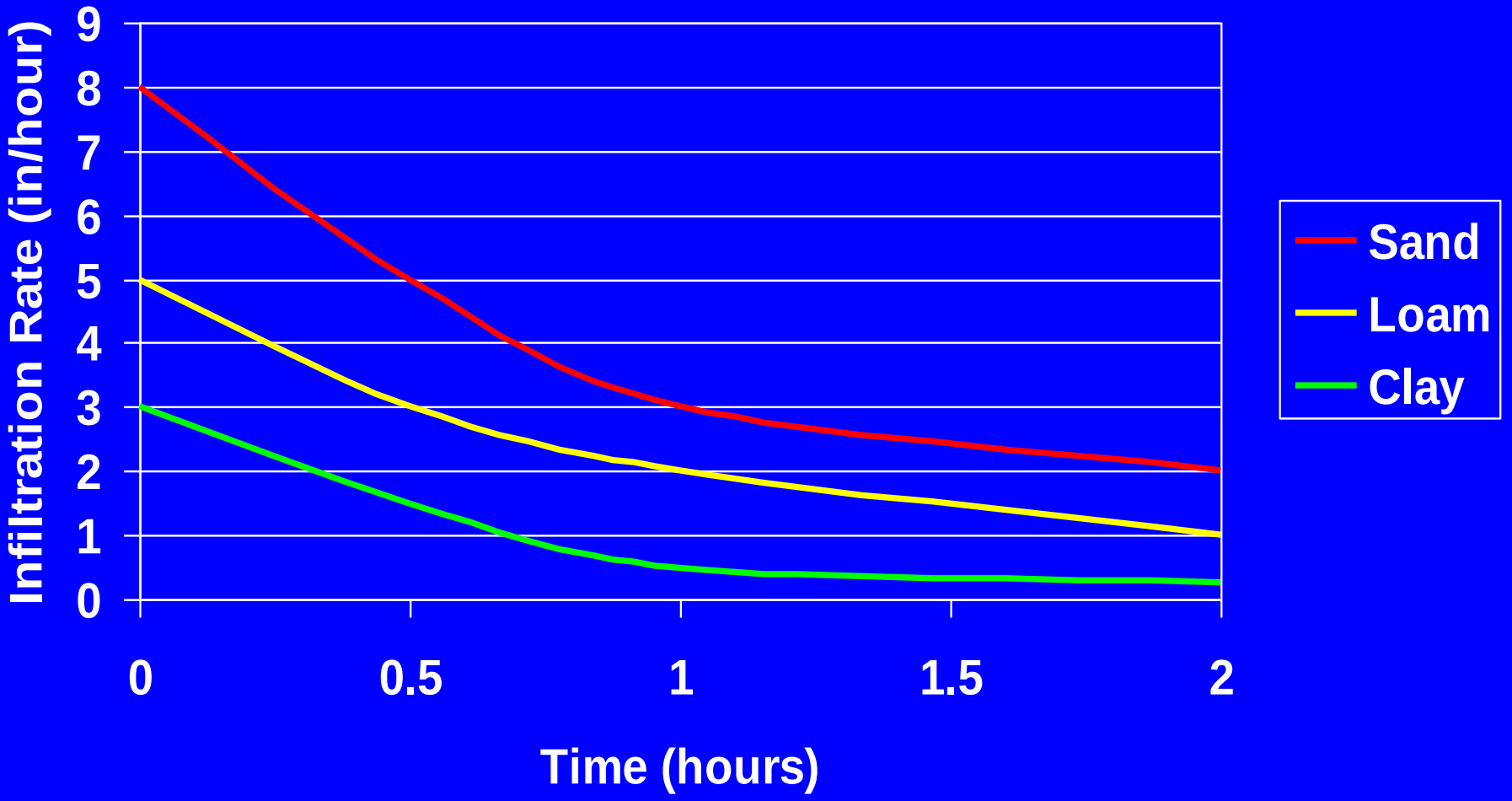


# *Saturated Soils Needed*

- **Water is initially drawn into soil by gravity and capillary forces.**
- **Runoff occurs once the soil is saturated and rainfall exceeds infiltration rates.**
- **How quickly this occurs depends on the soil…**

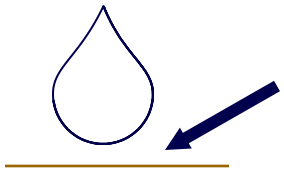


# Soil Infiltration Rates Decline Over Time



# *Raindrops: The Start of Erosion*

**TIME: 0 sec 1/1400 1/150 1/70**



**Rain droplet falls on saturated soil.**

**Crater formed**

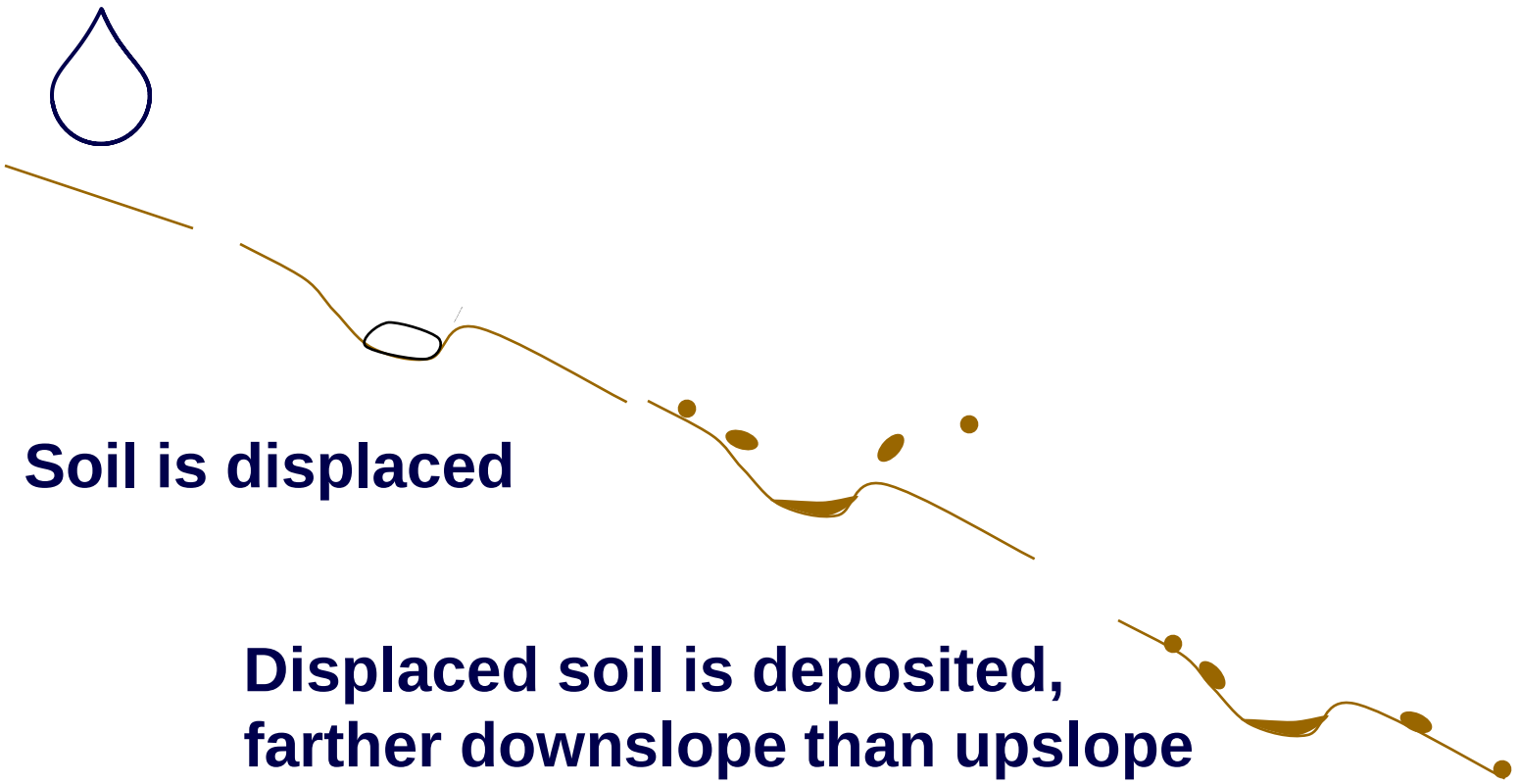
**Soil is displaced**

**Displaced soil is deposited**

From Hillel 1998

# *Slope Makes Big Difference*

**TIME:** **0 sec** **1/1400** **1/150** **1/70**

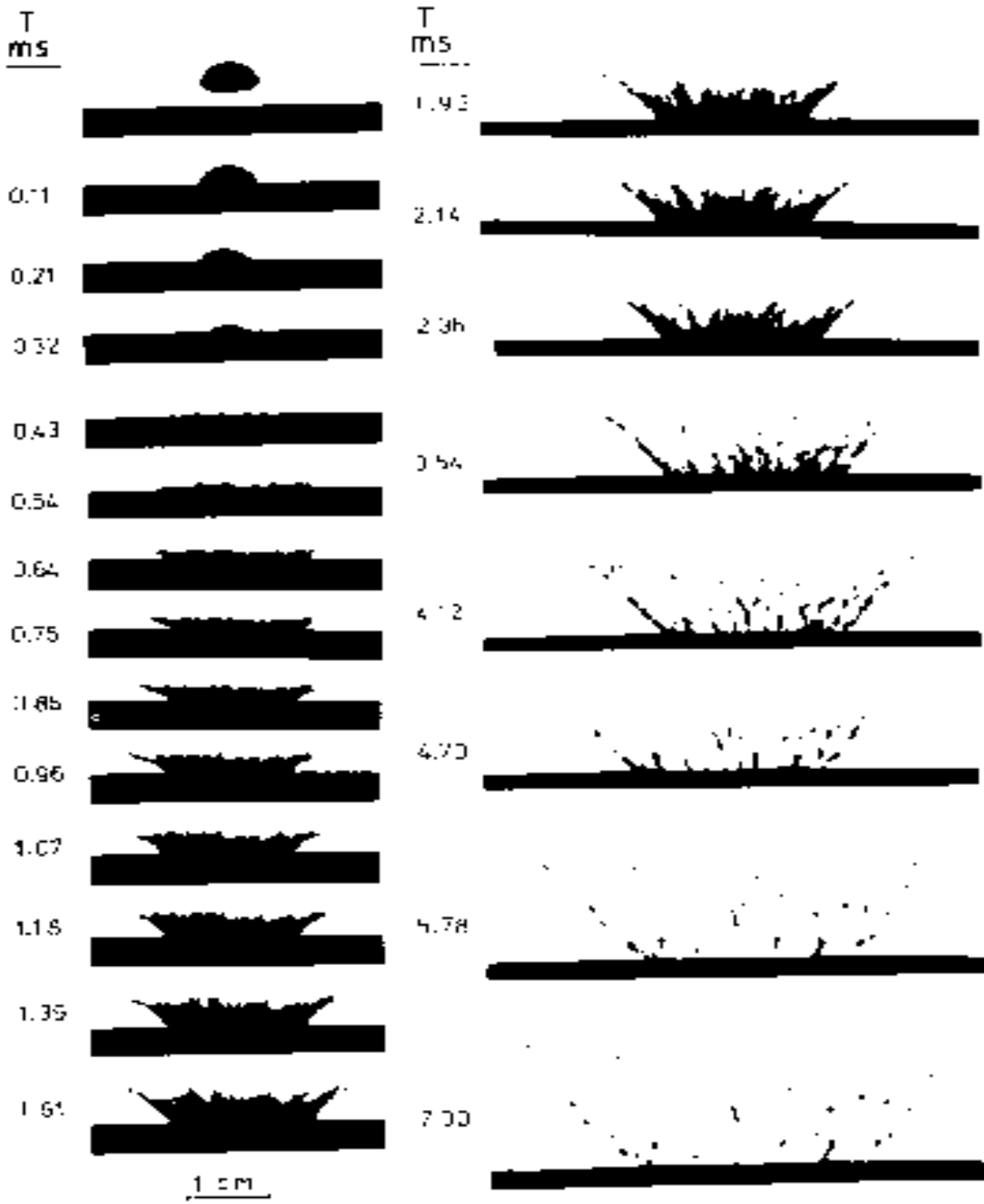


**Soil is displaced**

**Displaced soil is deposited,**
**farther downslope than upslope**

From Hillel 1998

# Actual Droplet Splash on Saturated Soil



# *Splash Has Removed Fine Materials, Left Rocks*

# *Surface Sealing and Crusting*

- **Rain droplets break down aggregates, sort the soil.**
- **Smallest particles form layer on surface.**
- **Infiltration rates decline *10X*, often after only one storm.**
- **A crust forms as the soil dries.**

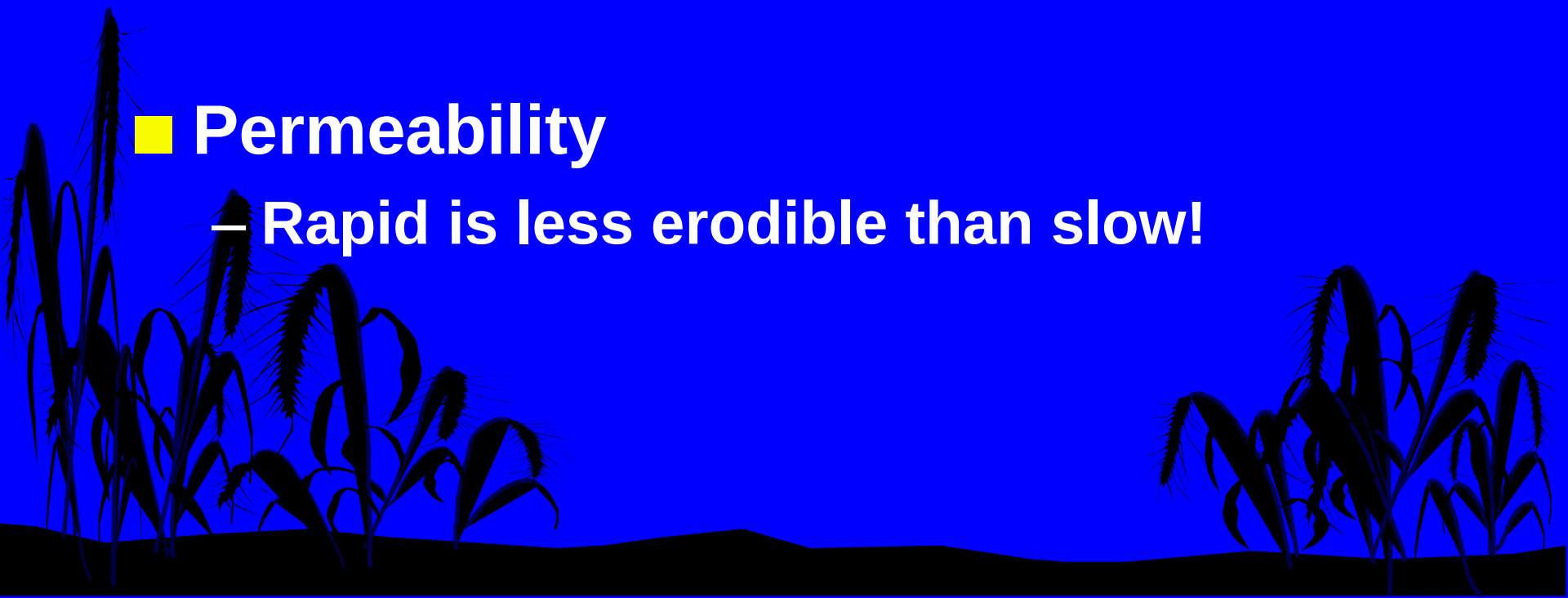
# *Soil Erodibility*

## *All Soils Are Not Created Equal*

- **Texture or Particle Size Distribution**
  - **Silt is the most easily eroded component.**
  - **Clay tends to remain bound in the soil structure. Once caught up in runoff, it is very difficult to settle out.**
  - **Sand promotes infiltration, reducing runoff volume, and tends to settle quickly.**
- **Organic Matter: increases infiltration so runoff volumes are lower.**

# *Soil Erodibility (cont.)*
## *All Soils Are Not Created Equal*

- **Structure**
  - **Blocky, platy, or massive are less erodible than granular.**
- **Permeability**
  - **Rapid is less erodible than slow!**



# Creedmoor Sandy Loam

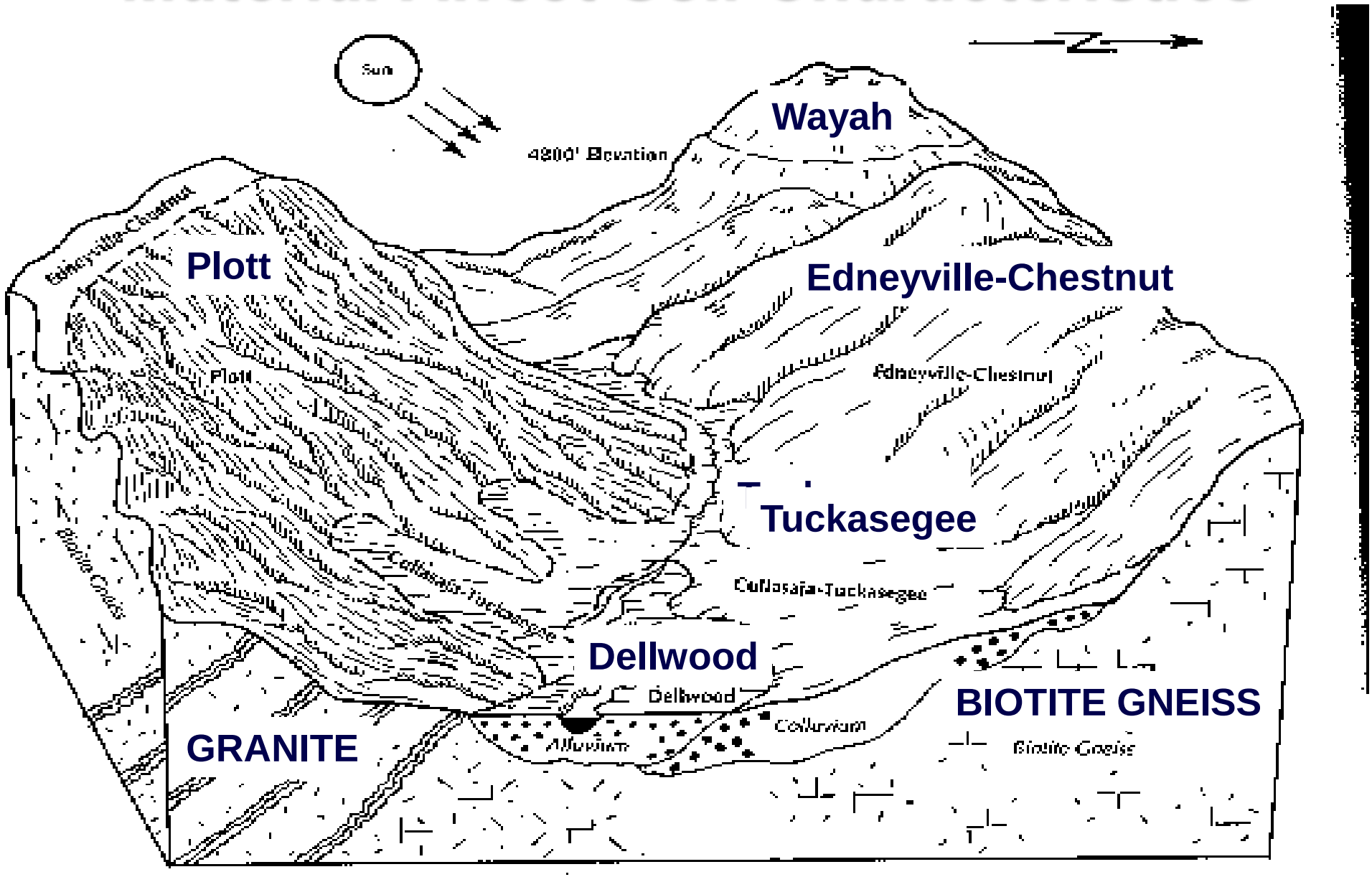
Sandy Loam

Sandy Clay Loam

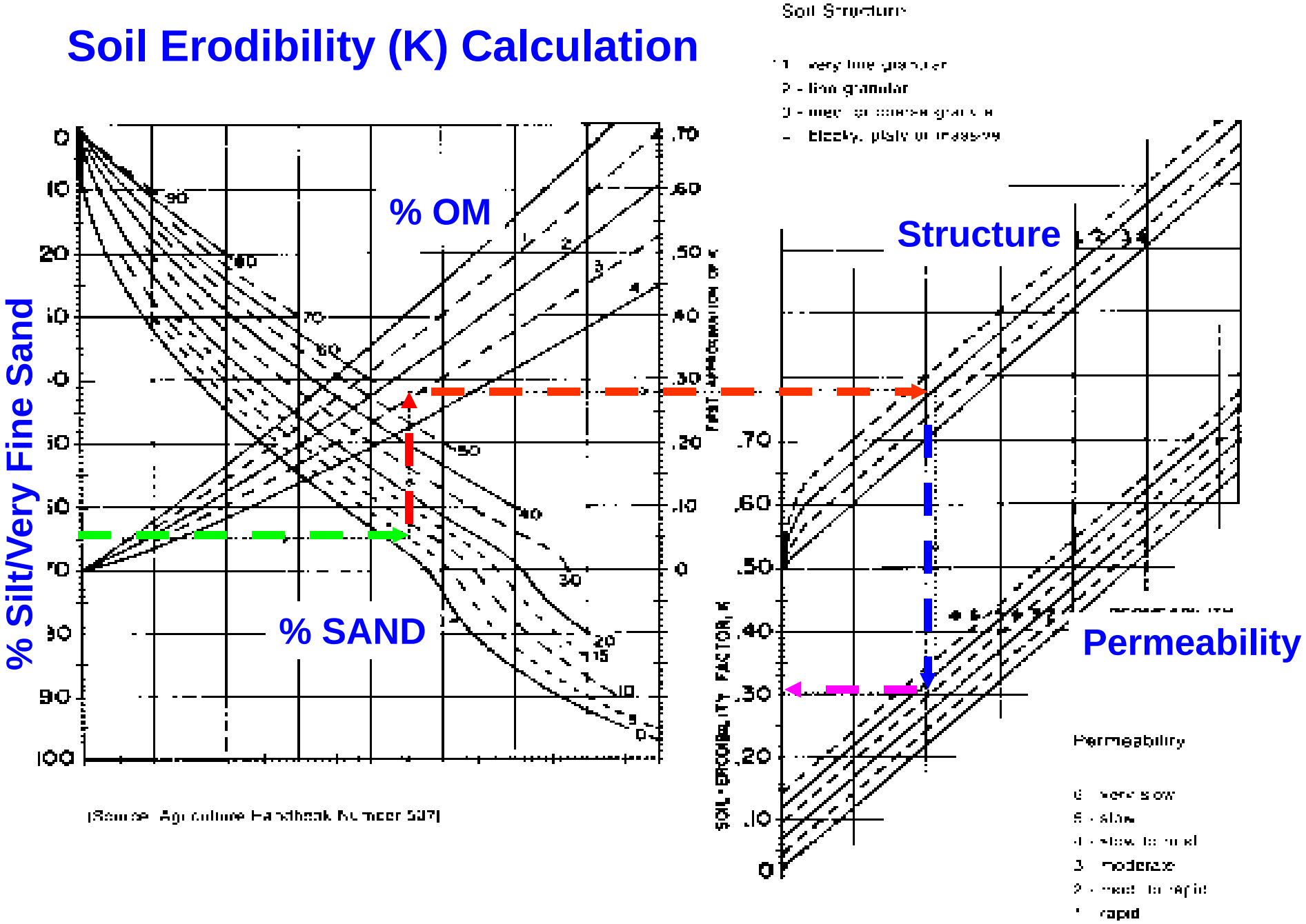
Clay

# Erodibility Changes With Depth

# Climate, Landscape Position and Parent Material Affect Soil Characteristics



# Soil Erodibility (K) Calculation

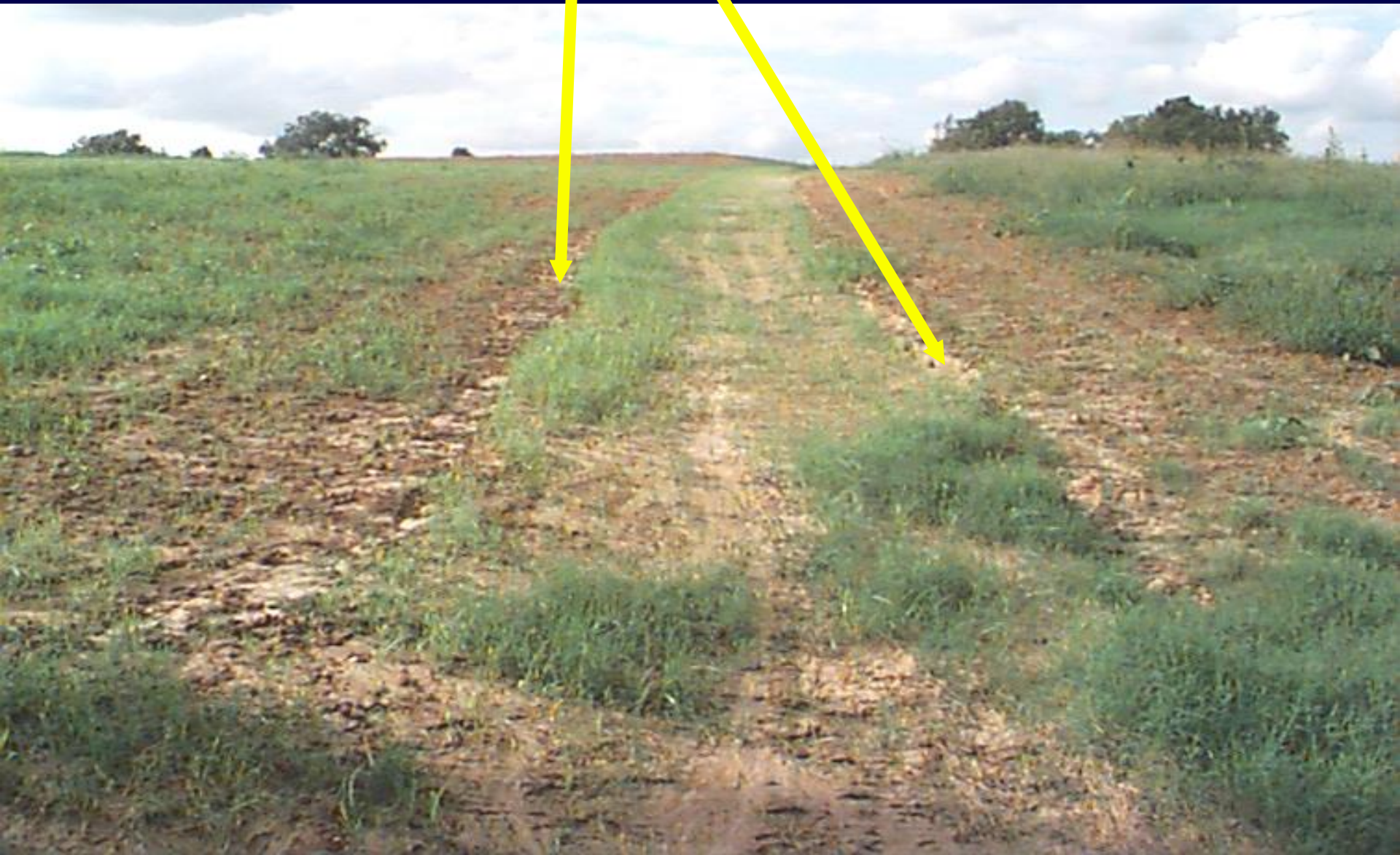


# *Overland Flow*

- **Once rainfall exceeds infiltration, water begins to flow.**
  - **Clay is hard to pick up due to cohesion.**
  - **Sand is hard to pick up due to size.**
- **Most of the sediment in sheet flow comes from rain detachment.**
- ***THIS IS WHY COVERING THE SOIL IS SO EFFECTIVE!***

# *Rills Starting…*

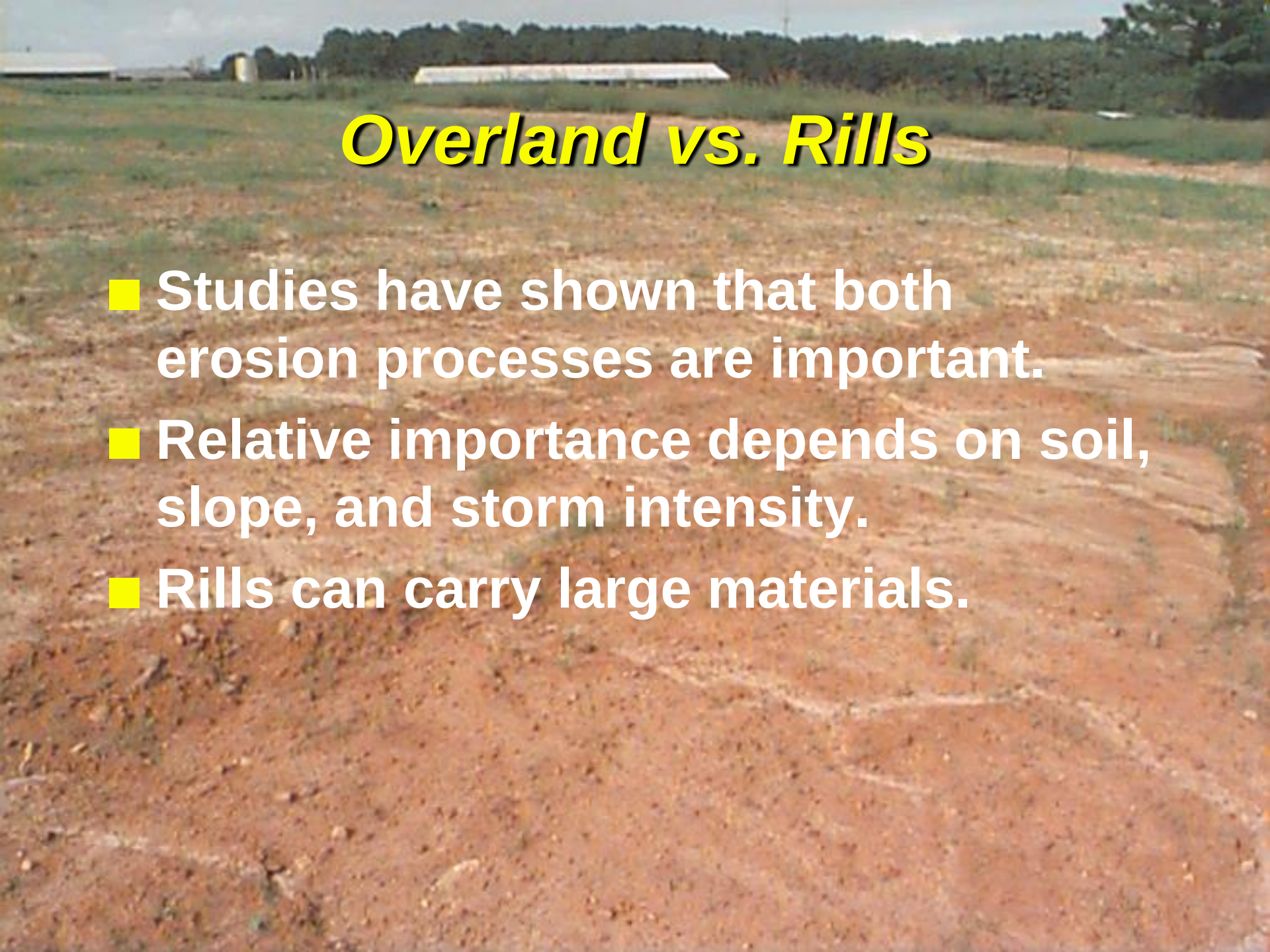
# *Flow Along Waterway*



# *Formation of Rills*

- Water begins to collect near the top of the slope.
- Rills generally deepen downslope.
  - Flow itself results in erosion.
  - Headcutting moves upslope.
- Sediment comes into the rill from overland flow.

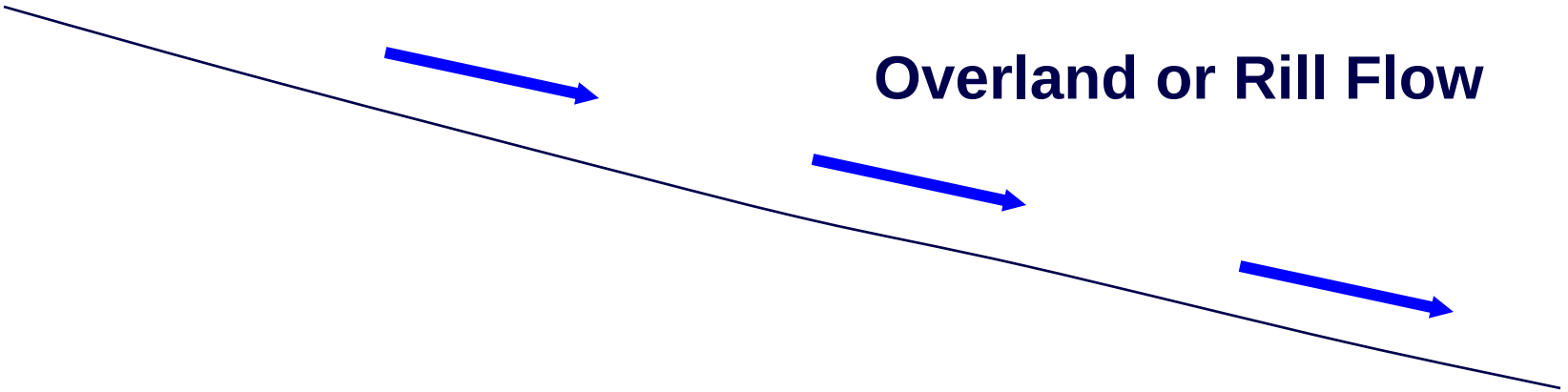
# Rills With Sandy Deposits



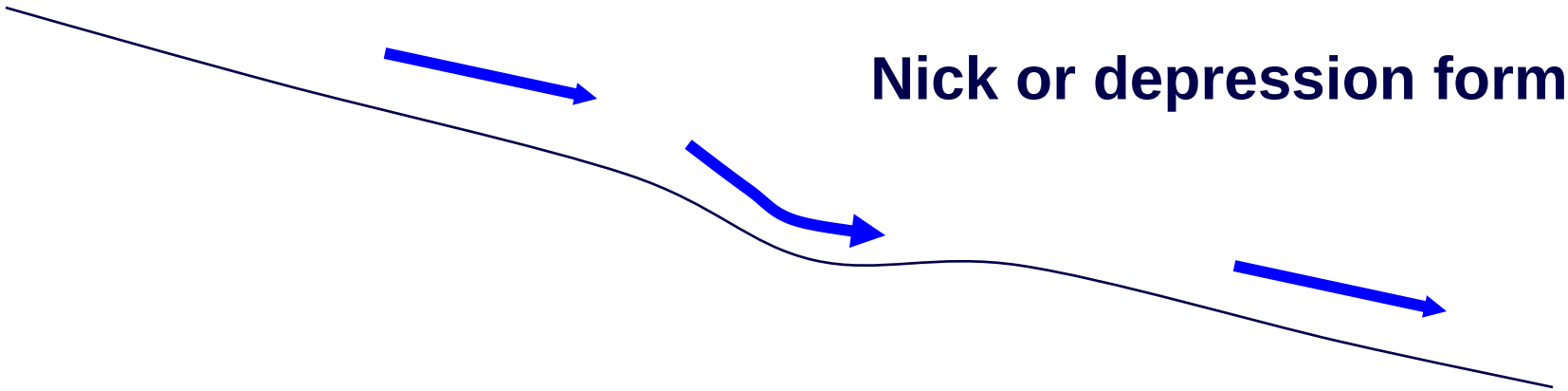
# *Overland vs. Rills*

- Studies have shown that both erosion processes are important.
- Relative importance depends on soil, slope, and storm intensity.
- Rills can carry large materials.

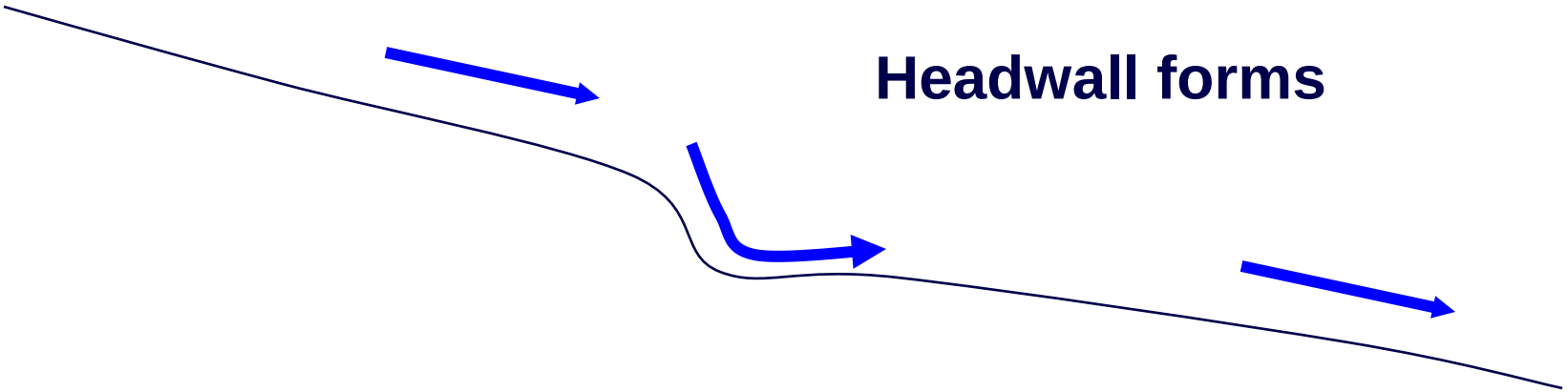
# *Gully Formation*



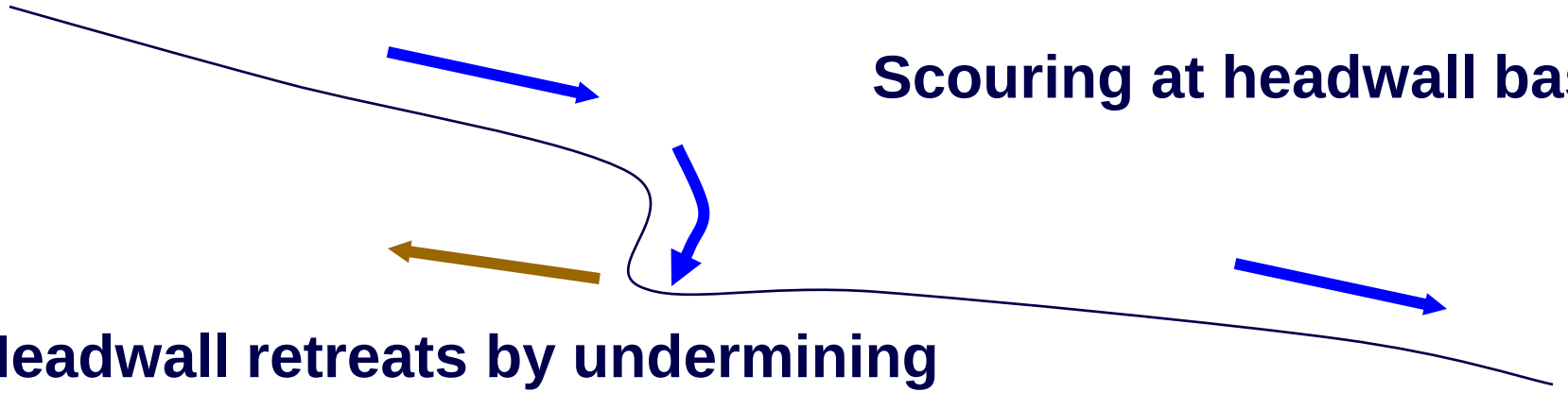
# Gully Formation



# Gully Formation



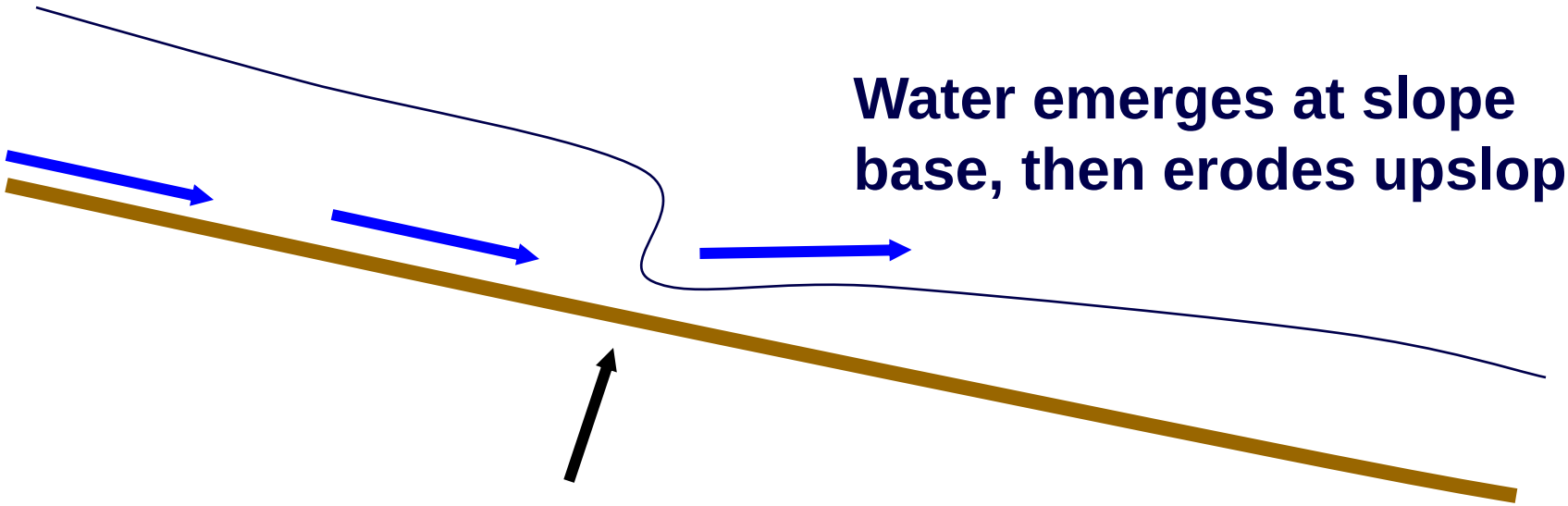
# Gully Formation



Scouring at headwall base

Headwall retreats by undermining and collapse.

# Gully Formation: Piping




Restricting layer forces percolating water along slope.

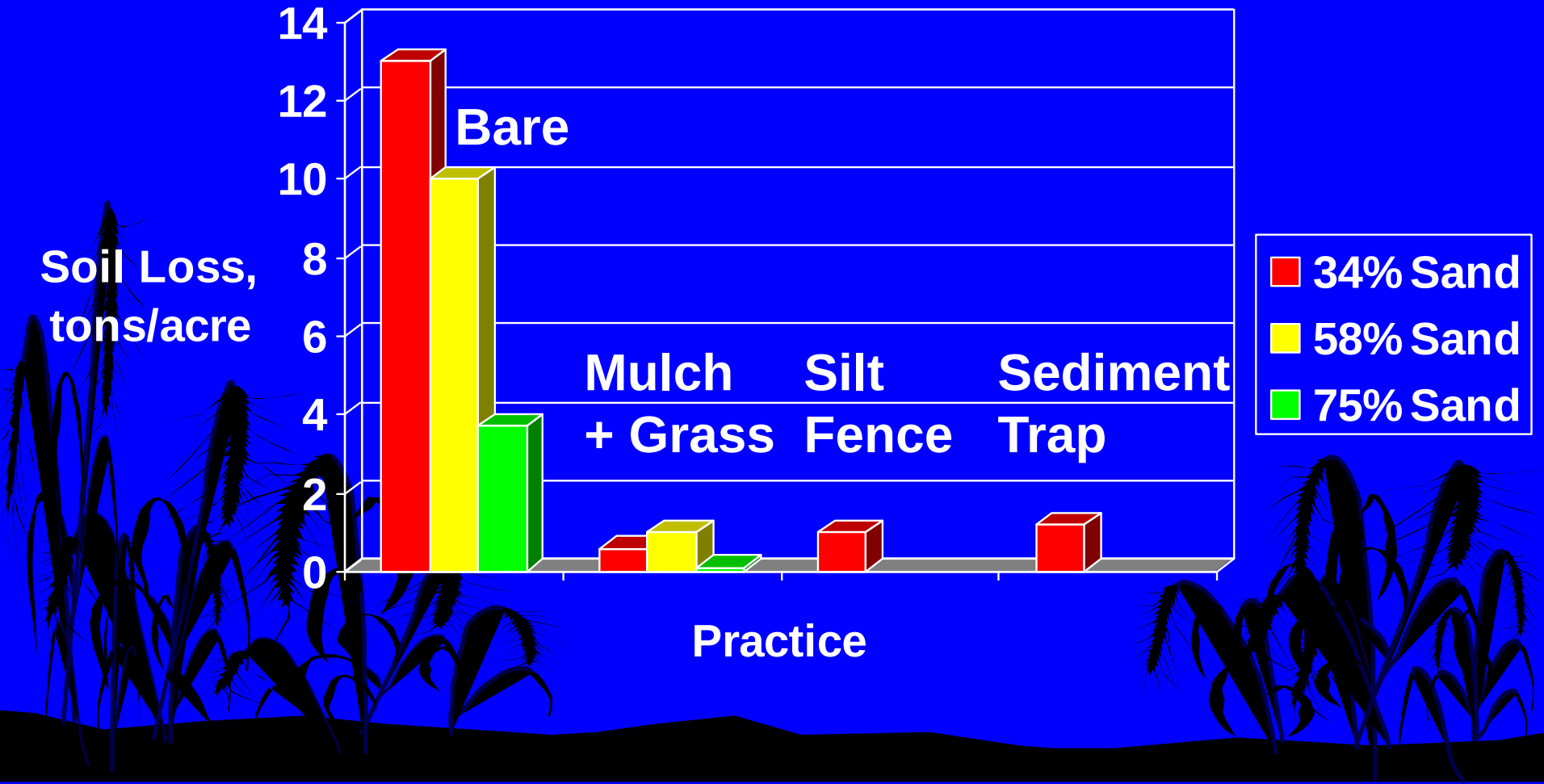
# Gully After One Storm

# Headwall retreat continues…

# Note Headwall Scouring…Nothing to Stop It!

# Gullies Form Even in Flat, Sandy Soil

# Soil and Practice Effects



# Ground Covers: Protect From Droplets

# Mulch Doesn't Work In Ditches

# Erosion – Even on Flat, Sandy Sites!

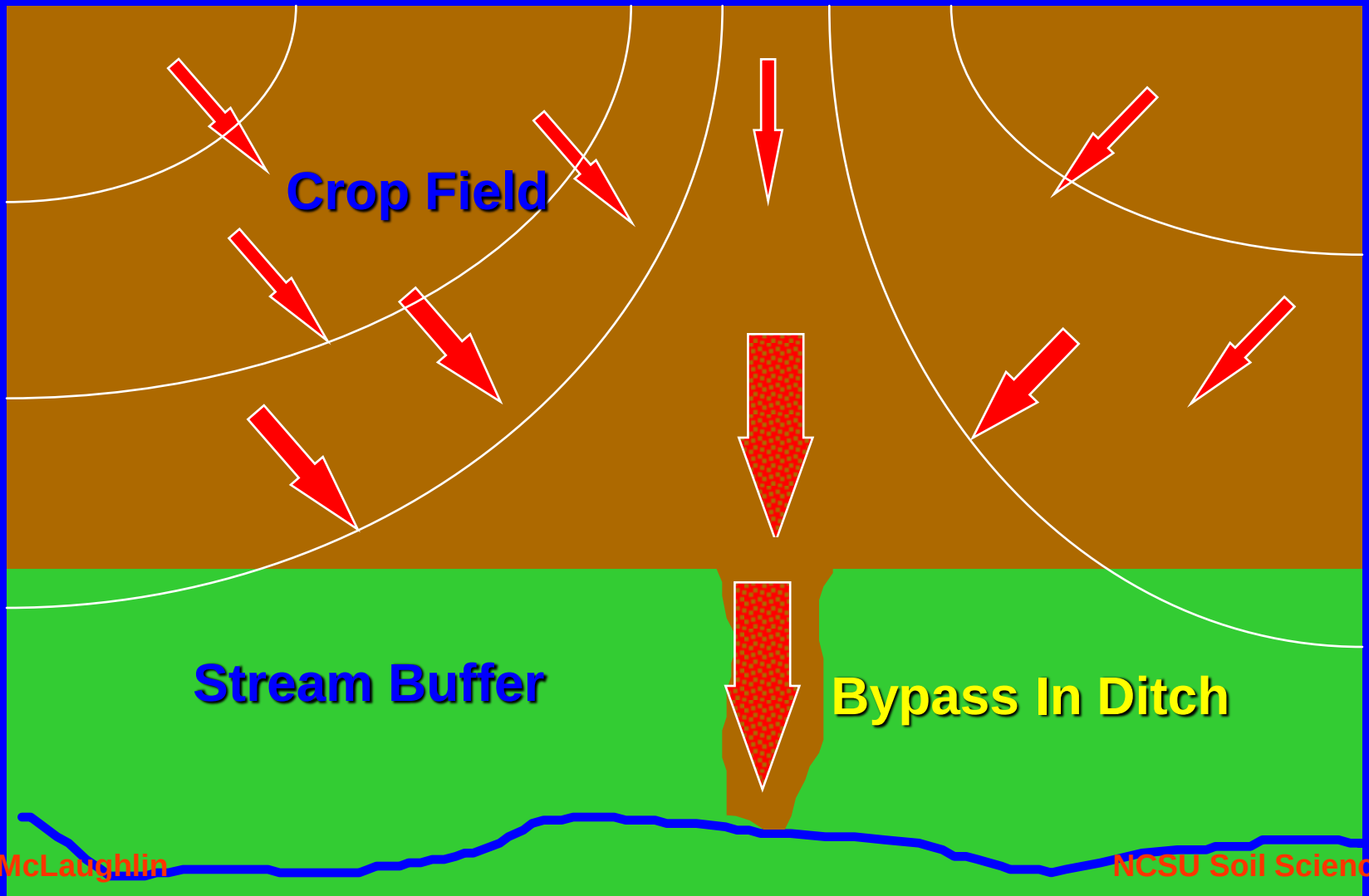
McLaughlin

NCSU Soil Science

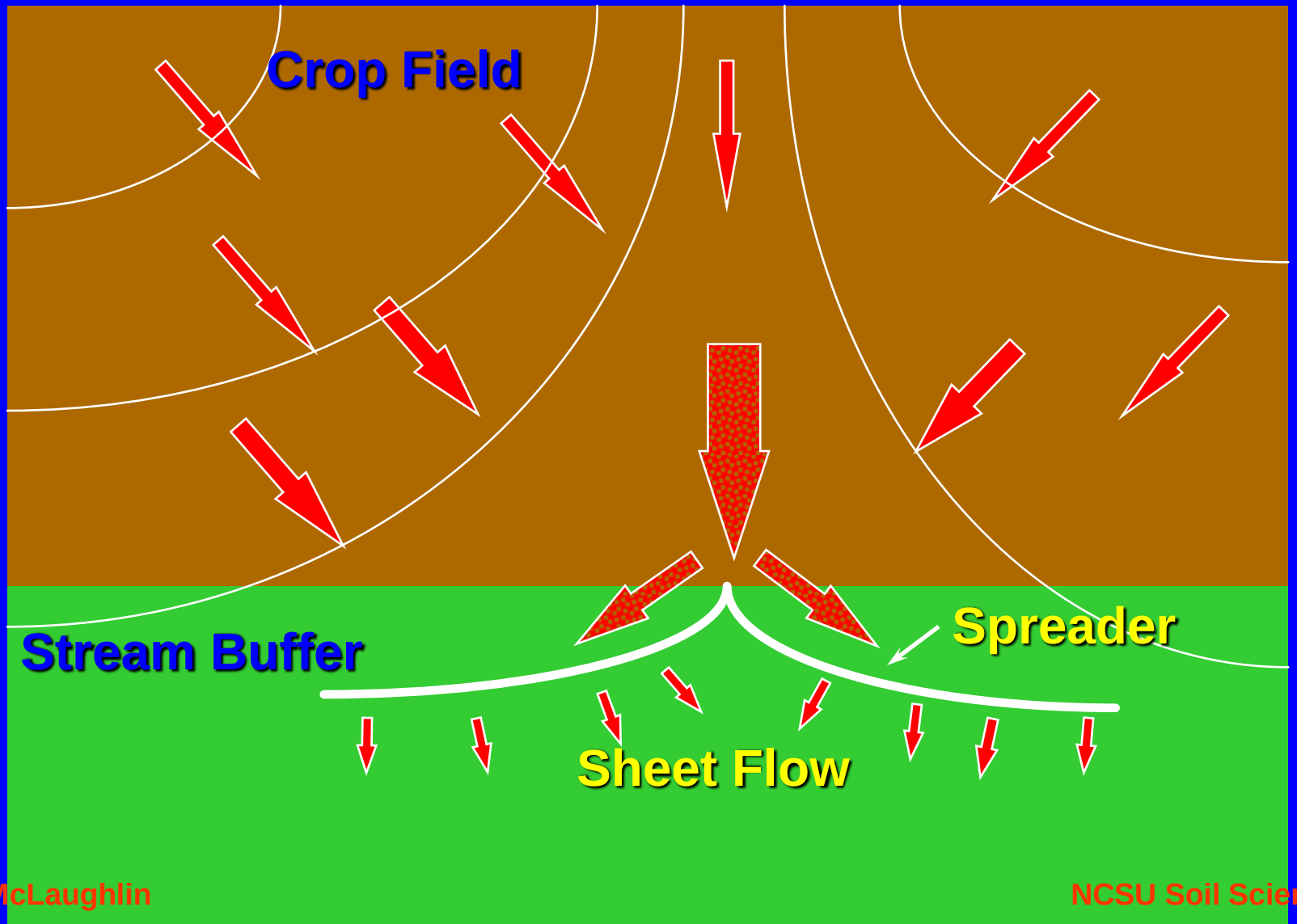
# Soft Armor for Gentle Slopes

# Hard Armor for Steep Slopes

# Field Runoff: Bypass Through Buffer



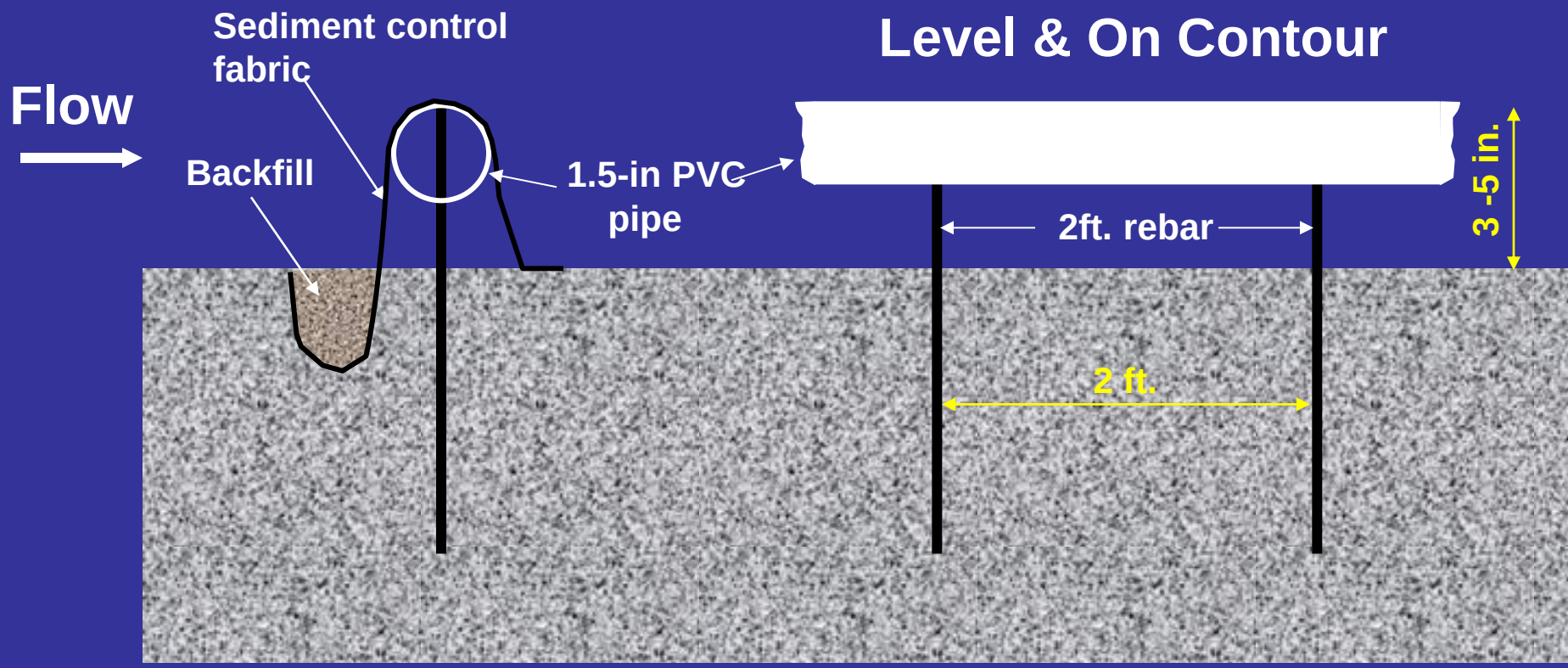
# Field Runoff: Spread Across Buffer For Treatment



# Silt Fence: Works but Needs Maintenance!

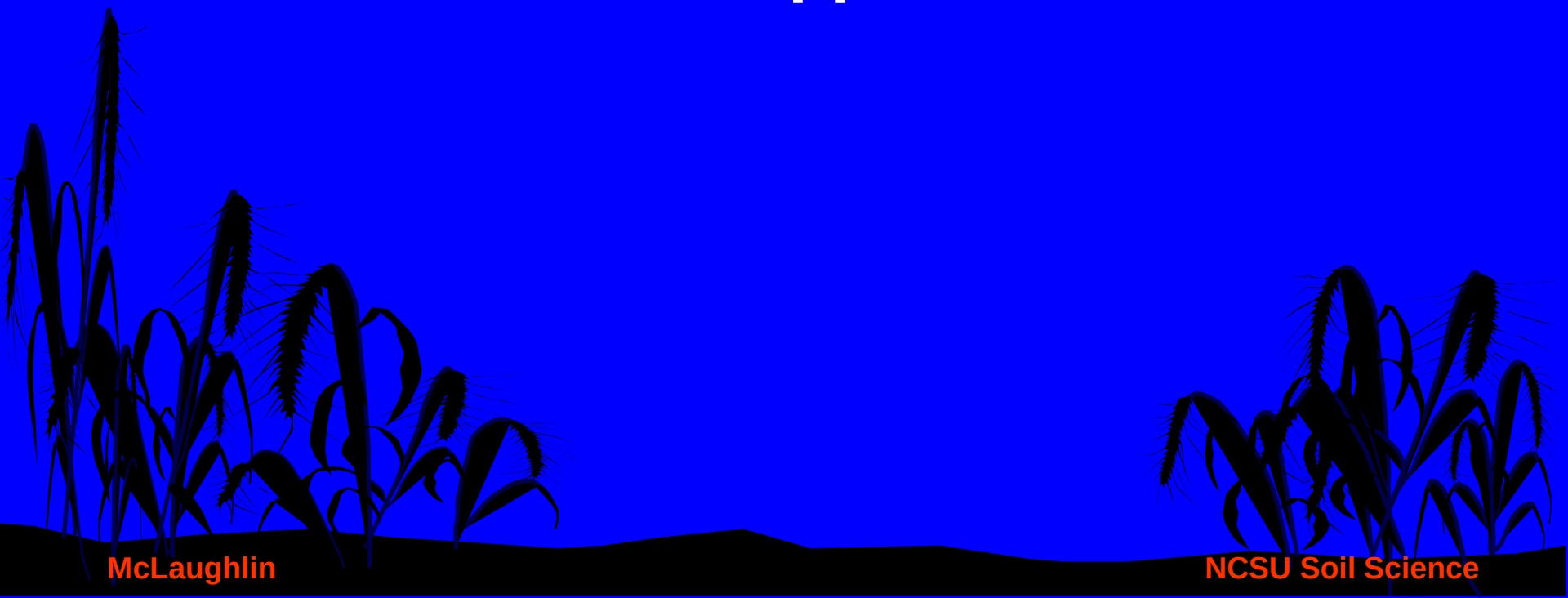
# Dissipated Flow Deposits Sediment

# Level Spreaders Can Dissipate Flow: Example

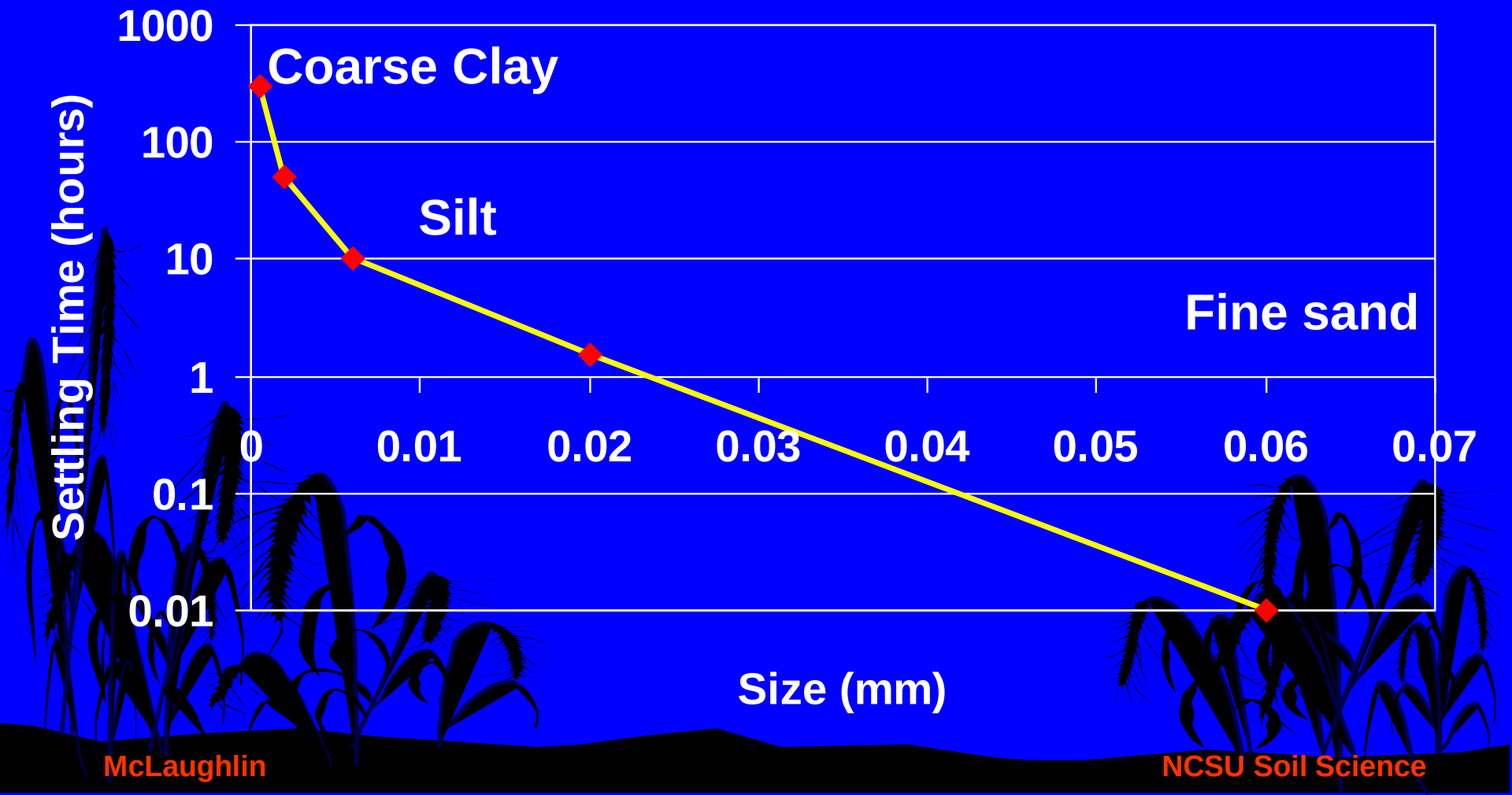


# *Simple Math for Sedimentation*

- $V=((4/3)pi(r^3)*(d_1-d_2)*g)/(2pirz^3)$
- OR…larger particles fall faster once flow is slowed/stopped.



# Sedimentation: Size Matters



# Sediment Trap (full)

# Sediment Deposit at Basin Inlet

# *In Conclusion...*

- Sediment is the #1 cause of surface water degradation.
- Soil has to become detached to erode: cover it up!
- Water always gathers and becomes more erosive: protect those waterways!
- Slow water holds less sediment than fast water: keep the flows low and ponded wherever possible!