Laboratory #5
ABE 325
Erosion Processes Laboratory

Objective: To better understand the process of rill erosion and to understand the interaction between flow rate, sediment yield, slope, and a soil additive.
Theory: Shear stress is the primary means of calculating soil detachment because of its physical basis in the momentum equation. Considering the control volume shown below, the change in momentum flux in the stream wise direction is equal to the sum of the forces in that direction. There are three principal forces: gravity, pressure, and bottom resistance, or shear.

The momentum equation can then be written by setting the change in momentum flux equal to the sum of the forces in the stream wise direction, as follows:

$$\rho A \left( V + \frac{dV}{dx} - V \right) = \left( \gamma y A \right) - \left( \gamma y A + \gamma A \frac{dV}{dx} \right) + \gamma A \Delta x \sin \theta - \tau_o P \Delta x$$

where,
\( \rho \) is the density of water,
\( V \) is the average velocity
\( A \) is the cross sectional area
\( \gamma \) is the specific weight of water
\( g \) is the acceleration of gravity,
\( \theta \) is the slope angle,
\( \hat{y} \) is the centroid of the channel measured from the surface, 
P is the wetted perimeter, 
\( \Delta x \) is the length of the control volume, 
and, \( \tau_0 \) is the shear force.
Simplifying, the equation can be rewritten as:
\[
\rho VA \left( \frac{dV}{dx} \right) = -\left( \gamma A \frac{dy}{dx} + \gamma A \Delta x \frac{dz}{dx} + \tau_0 P \Delta x \right)
\]
Using the definition of head, \( \tau_0 = R_{bf} \frac{dH}{dx} \) and the fact that \( dH/dx \) is equal to the friction slope and the energy grade line if the only losses are from skin friction.
\( \tau_0 = R_{bf} \delta_f \) and if uniform flow is assumed, then \( S_f = S_0 \), so \( \tau_0 = R_f \delta_0 \).
For a particle subjected to this force to stay at rest it must oppose the shearing action of the water. The point at which motion begins, or soil begins to detach, is referred to as the critical shear stress, \( \tau_c \).
The boxes you will be using are 15 cm wide. Assuming this constant width, the depth of flow can be solved for using the continuity equation. The continuity equation is \( Q = VA \), where \( Q \) is the flow rate, \( V \) is the velocity, and \( A \) is the area of flow.

**Treatments (may vary):**
Slope: 5% and 10%
Rainfall Rate: Low (M2) = 50 mm/hr, High (M3) = 75 mm/hr
Soil Condition: Amendments may vary (straw, gypsum, etc.)

**Materials:**
- 24 1-L bottles
- Stopwatch
- Data sheets (appended to this document)

**Procedure:**
You will work in assigned groups for this experiment.

One student should be in charge of keeping track of time. Another student should record data and be in charge of overall experiment management. The third student should collect the runoff samples and make observations about rill development.
- Record the empty (tare) weights of your bottles
- Record the slope of your box
- Set rainfall to low (remember to keep track of the time)
- Keep track of and note rill development
- Record the runoff start time
• Take a flow sample using the bottles for 15 minutes (replace bottles every 3 minutes, or when bottle is full)
• Repeat the procedure with high intensity rainfall
• After data collection record the weight of the bottles with water/sediment mixture
• Decant excess water from bottle, per directions given in lab
• On Friday, at least one member from each group will need to come back to the erosion lab, weigh the dry bottles and clean them out. Failure to clean your bottles will result in point deduction.
• Email your data to the TA by 5:30pm on Friday.

Assignment:
1. Work with your groups of 5 from previous labs for this assignment.
2. Draw a diagram of the experimental setup and describe the procedure you followed.
3. Describe for each combination of flow rate and slope what you observe in terms of rill development and erosion rate with time.
4. Plot sediment yield rate in kg/s versus flow rate (L/min). You should have two groups of points (one for each slope).
5. Plot sediment yield rate in kg/s versus depth of flow (cm). Estimate flow depth using flow and the box dimensions. Again, you should have two groups of points.
6. Now plot the sediment yield rate versus the product of flow depth and slope.
7. Sediment yield rate is heavily dependent on flow rate. Why isn't flow rate by itself a good predictor of sediment yield rate?
8. What is the effect of the roughness on the lag time to runoff, total runoff, and sediment load?
9. In this lab we have neglected the effects of infiltration on sediment yield. In other words, we assume the flow rate at the top of the soil box is what is coming off at the bottom. Is this a valid assumption? When might it not be?
10. We have also assumed a rectangular channel cross section that does not change. Is this a valid assumption?
11. The product of slope and flow depth is directly related to the shear stress of the flowing water. Is there a critical shear stress for this particular soil? What is that value (in kg/s/cm)? How would this value change if the bulk density of the soil were increased?
12. How would you apply the knowledge you gained in class to soil conservation design applications?

Last updated: Thursday, June 18, 2009
# ABE 325 - Erosion Processes Laboratory

**Soil Type/Treatment:**

**Slope:**

## LOW INTENSITY

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<th>Diameter</th>
<th>Runoff Start Time</th>
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**Containment Basin Dimensions**

**Potential Sources of Error**