

Tilt, Soak, Slide: When Does a Model Hillside Fail?

Investigation question: How does the amount of water in sand change the slope angle at which a model hillside fails, and can keeping rain out of a slope or letting it drain away delay the failure?

Physical model

Groups of 4

2 sessions

Setup 8 · Activity 85 · Cleanup 12 min

MS-ESS3-2 · practice

MS-ESS2-2 · supports

MS-ETS1-2 · supports

Name _____

Group _____

Date _____

Your role today

- ☐ **Lifter:** Raises the upper end of the tray slowly and evenly, about 1 cm every 5 seconds, and holds it still when the Watcher calls.
- ☐ **Reader:** Holds the ruler upright at the raised end and reads the height of the tray's bottom edge at each call, to the nearest 0.5 cm.
- ☐ **Watcher and timer:** Counts the 5-second steps aloud, calls 'crack' at the first crack or rolling grains and 'fail' when sand passes the tape line, and describes the kind of movement.
- ☐ **Recorder:** Writes every reading, converts heights to angles with the table, computes the means and posts them on the class chart.

Safety

- Wet sand is heavy: a tray with a liter of saturated sand weighs about 2 kg, and the bucket of used sand much more. Keep trays low on the tabletop and carry buckets with two people.
- Wear goggles throughout. Sand can fly when a slope fails, and grit in the eyes is the most likely injury. Never blow on sand to clear it.
- Use washed play sand, not crushed silica, construction sand or sandblasting sand. Keep the sand damp where possible and do not pour dry level A sand from a height; fine dry dust can irritate lungs, so a student with asthma should handle only damp bags.
- Spilled sand and water make floors slippery. Work over paper towels and sweep or wipe spills at once.
- Do not pour sand or sandy water down a sink; it clogs drains. Let it settle in the bucket and pour the clear water off outside.
- Pushpins for the drains are sharp; only the student assigned the drain kit handles them, and they go back in a closed box. Wash hands after the lab; no eating or drinking at the trays.

Procedure

1. Session 1. Each student writes a prediction for q1. Then put on goggles, lay the liner in the tray, and set the tray flat with its lower end butted against a heavy book so it pivots without sliding.

2. Open your first bag, knead it, and spread the sand in the upper 20 cm of the tray. Level it with a straightedge to about 2.5 cm thick and press it flat with five light pats of an open hand. Build every bed the same way.
3. Tilt test: the Reader holds the ruler upright at the upper end. The Lifter raises that end about 1 cm every 5 seconds as the Watcher counts. The Watcher calls 'crack' at the first crack or rolling grains and 'fail' when sand crosses the tape line by 2 cm. The Reader reads the height at each call.
4. The Recorder converts both heights to angles with the height table and records how the sand moved: grains rolling down the surface, a block sliding, a slump that bulges at the toe, or a flow like wet cement.
5. Lower the tray, scoop the sand back into the zone, rebuild the bed and repeat for three trials. Then do three trials with your second bag. Reseal each bag between trials.
6. Compute the mean failure angle for each of your levels, post both on the class chart, and copy the class means into the class table. Plot the class means on the graph and answer q2.
7. Session 2. Time how long 50 mL takes to drain from your rain cup and record it. Build a bed from a fresh bag of level B sand and prop the upper end on books at 15.0 cm, which is 30 degrees.
8. Rain test, bare slope: hold the rain cup about 10 cm above the upper half of the bed and pour in 50 mL. When it has drained, that is one dose. Keep dosing, up to 10 doses. Record the dose number at the first crack, the first water seeping out at the toe, and failure (sand crossing the tape line by 2 cm).
9. Rebuild with your second bag of level B sand and add your assigned mitigation. Cover and gutter: lay plastic wrap over the upper two-thirds of the bed and fold the index card into a gutter along its uphill edge that carries water off to the side. Drains: poke holes every centimeter along three straws and push them into the base of the bed from the toe, sloping slightly downhill, with their ends sticking out. Toe wall: tape eight craft sticks side by side and push them upright into the sand along the toe.
10. Repeat the rain test on the mitigated slope. Post both results on the class chart, copy the class results, clean up as directed, and answer q3 through q10 individually.

Record your observations

Lab 1 recording sheet: Tilt, Soak, Slide

Your bed is a model hillside. The **failure angle** is the slope at which sand crosses the tape line by 2 cm. Find the angle from the height of the raised end with the table below. Water levels are mL of water mixed into 1,000 mL of dry sand: **A** 0, **B** 50, **C** 125, **D** 250, **E** saturated (amount written on the bag).

Height of the raised end for a 30 cm tray (height = 30 cm x sine of the angle)

Angle (degrees)	Sine of the angle	Height for a 30 cm tray (cm)
10	0.174	5.2
15	0.259	7.8
20	0.342	10.3
25	0.423	12.7
30	0.5	15.0

Angle (degrees)	Sine of the angle	Height for a 30 cm tray (cm)
35	0.574	17.2
40	0.643	19.3
45	0.707	21.2
50	0.766	23.0
55	0.819	24.6
60	0.866	26.0
65	0.906	27.2
70	0.94	28.2
80	0.985	29.5
90	1.0	30.0

1. Prediction before testing: rank the five water levels A to E from the steepest failure angle to the gentlest. Explain your ranking in one or two sentences.

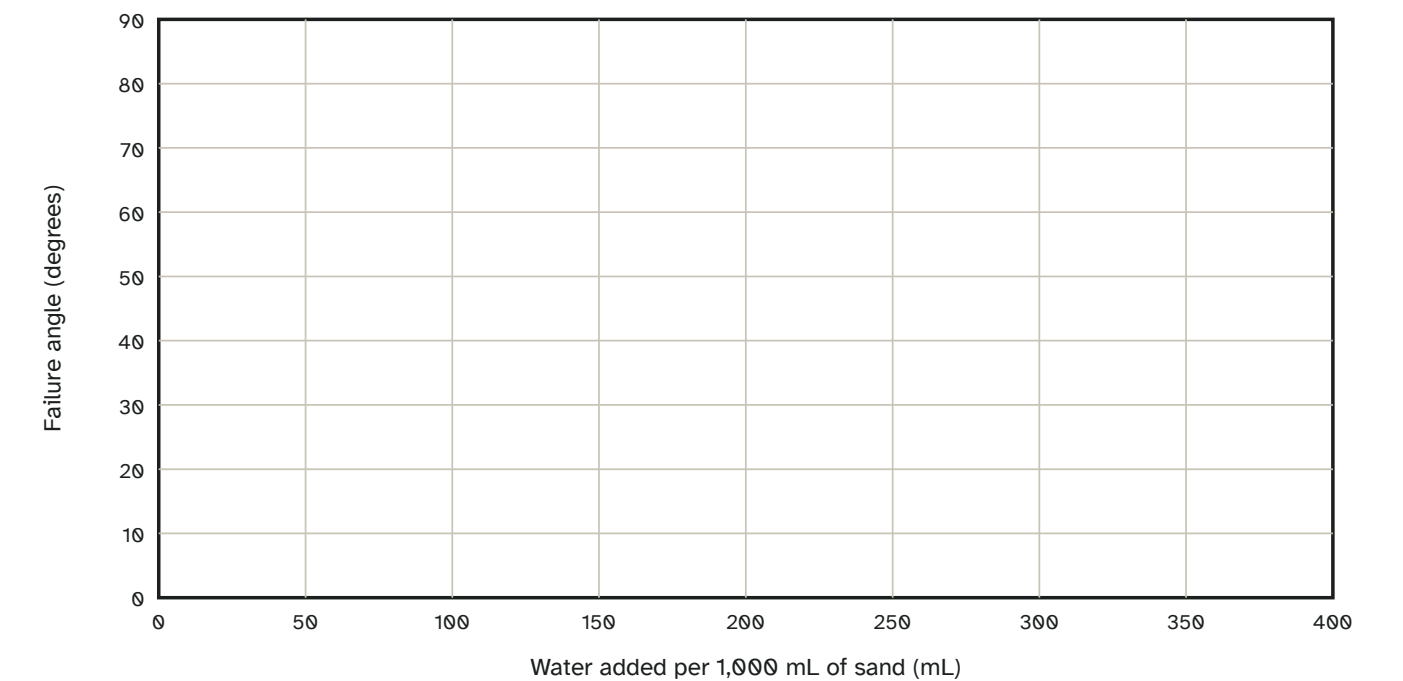
Session 1: our tilt trials

Water level	Trial	Height at first crack (cm)	Angle at first crack (degrees)	Height at failure (cm)	Angle at failure (degrees)	How the sand moved
	1					
	2					
	3					
	Mean					
	1					
	2					
	3					
	Mean					

Class results: mean failure angle at each water level

Level	Water per 1,000 mL sand (mL)	Group means (degrees)	Class mean (degrees)	Most common kind of movement
A	0			
B	50			
C	125			
D	250			
E	saturated: ____			

Class mean failure angle against water added



2. Describe what you saw at the moment of failure for your two levels. Which kind of real mass wasting did each one look most like: creep, a slide, a slump or a debris flow?

Session 2: rain on a 30-degree slope (one dose = 50 mL; rain cup drains in ___ seconds)

Slope	Dose at first crack	Dose at first seep at toe	Dose at failure (or 'none by 10')	Rain at failure (mL)	What failed first
Bare slope					
With mitigation: _____					

Session 2: class results

Mitigation	Number of groups	Mean doses to failure, bare slopes	Mean doses to failure, mitigated slopes	Difference (doses)
Cover and gutter				
Drains				
Toe wall				

3. Compare your bare and mitigated slopes. How many more doses of rain did the mitigated slope take, and where did the water go in each case?

Analysis questions

4. Describe the pattern in the class graph. At which water level was the failure angle highest, and at which was it lowest? Is the pattern a straight line? Use numbers from the class table.

5. Explain the pattern using what happens between sand grains. Why did damp sand stand steeper than dry sand, and why did saturated sand fail at the gentlest angle?

6. Use your class means for level A (dry) and level E (saturated); if your class data are incomplete, use A = 34 degrees and E = 18 degrees. By how many degrees did saturation lower the failure angle? What percent of the dry failure angle is the saturated failure angle? Show your work.

7. Which mitigation delayed failure the most in the class results? Explain how it works in terms of water, and name one problem it would have on a real hillside.

8. The La Conchita bluff is about 180 m high with slopes of about 35 degrees, and its 2005 slide came at the end of about 15 days of heavy rain, not after the first storm. Use your session 1 and session 2 results to explain why failure came at the end of the wet spell.

- 9.** Name three ways the tray is different from a real hillside, and say for each one whether it would make a real slope fail more easily or less easily than the model.

- 10.** You are setting up a landslide watch for a steep slope above a road that burned last summer. Which two measurements would you monitor, and what reading would make you warn the road crew? Use evidence from this lab and from the lesson.
