

After the Fire: Choosing Debris-Flow Defenses for Sycamore Canyon

Learning target: I can use a debris-flow hazard assessment to evaluate competing defenses against criteria and constraints, combine the best features of several into one plan, and justify the plan with data and its remaining risks.

Transfer and design

About 55 min

Pairs

MS-ESS3-2 · assesses

MS-ETS1-2 · practice

MS-ETS1-3 · practice

engineering design

data analysis

writing

Name _____

Date _____

Period _____

Directions

You and a partner are advising the county on how to protect Sycamore Canyon before the first winter storm. Sycamore Canyon is a made-up town, and every number on this sheet is a teaching estimate, but the kinds of data and defenses are the ones California counties really use after wildfires. Read the problem, the hazard assessment and the options. Then follow Parts A to C in order. Show all calculations.

You will need: This worksheet, Pencil, Calculator

The problem

Last summer a wildfire burned 80 percent of the steep, 6 km² watershed above Sycamore Canyon, a foothill town of 140 homes, an elementary school and a stretch of state highway, all built on the fan of sediment where the canyon opens onto flatter ground. The fire burned away the chaparral whose roots held the soil and left much of the surface water-repellent. An old debris basin at the canyon mouth can hold 20,000 m³ of mud and rock. The rainy season usually begins in about four months.

Post-fire debris-flow hazard assessment for the Sycamore Canyon watershed (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Measure	Estimate
Design storm (rain burst used for planning)	15 minutes of rain falling at 24 mm per hour
Chance of a debris flow if the design storm hits	70 percent
Largest likely debris-flow volume	60,000 m ³
Time from the rain burst to the flow reaching homes	About 10 to 20 minutes
Years of higher danger	Highest in the first one or two rainy seasons, falling as plants regrow

Simulated assessment for teaching, modeled on the kinds of estimates USGS scientists produce for burned watersheds. The design storm is a short, intense burst of rain of the kind that triggered deadly debris flows in Southern California in the past.

Criteria and constraints — Criteria (what success looks like): (1) **Lives**: everyone below the canyon is out of harm's way during a design storm. (2) **Homes**: as many of the 140 homes as possible are protected from a 60,000 m³ flow. (3) **Ready in time**: the defense works before the rainy season. (4) **Upkeep**: the defense can be cleaned out or reset between storms. Constraints (limits that cannot be broken): the total cost must be no more than \$6.0 million, and every part of the plan must be finished within 4 months.

Six options proposed at the county meeting

Options and the county engineer's estimates (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Option	What it is	Cost (\$ million)	Months to finish	Debris held (m ³)	Engineer's notes
A	Enlarge the debris basin to hold 60,000 m ³ in all	5.5	6	40000	Would catch the whole design flow; needs heavy equipment to empty after each flow
B	Four steel ring nets strung across the canyon	2.0	2	20000	Lets water drain through; a flow bigger than the nets can hold spills over; emptied by crane
C	Rain-gauge warning and evacuation plan (six gauges, weather forecasts, phone alerts, door-to-door notice, drills)	0.4	1	none	Can get everyone out if people leave before the burst; protects no buildings; false alarms can wear down trust
D	Deflection walls that steer a flow away from the main neighborhood into the creek channel	2.5	3	none	Protects about 90 of the 140 homes; sends more debris toward the highway crossing; check for damage after storms
E	Mulch and seed the burned slopes from the air	1.0	1	none	Cuts runoff and erosion in light and moderate rain by about 20 percent; little effect in a short, intense burst
F	Buy out and remove 30 homes in the most dangerous zone	18.0	12	none	Removes those households from danger permanently

Simulated estimates for teaching. 'Debris held' is how much of a flow the option can trap; options without a number do not trap debris.

Part A: Use the hazard data

1. If the largest likely flow (60,000 m³) comes down the canyon, how much would the old debris basin fail to hold? What percent of the flow could the old basin hold by itself? Show your work.

2. The assessment says the flow could reach homes about 10 to 20 minutes after the rain burst. Explain what that means for **when** option C's evacuation must happen.

3. Which options break a constraint? Name the constraint each one breaks and explain whether it could still be useful in a later year.

Part B: Evaluate the remaining options

4. Score options B, C, D and E against each criterion: 2 = meets it well, 1 = partly, 0 = not at all. Add the totals. In the margin, write one reason for any score of 0 or 2.

Lives	Homes	Ready in time	Upkeep	Total (out of 8)
B: ring nets				
C: warning and evacuation				
D: deflection walls				
E: mulch and seed				

5. Does any single option meet all four criteria well? Use your matrix to explain what that tells you about how to protect Sycamore Canyon.

Part C: Design, justify and test

6. Choose a combination of options that stays within both constraints. Calculate its total cost and how much debris it could hold together with the old basin. Then explain how your plan meets each of the four criteria, using numbers from both datasets.

7. Pick two options in your plan. For each, name its best characteristic, and explain why the two together meet the criteria better than either one alone.

8. Write the rule that should trigger option C's evacuation order. Name the data it uses and when the order would go out.

9. What risk remains after your plan is built? Name at least two ways people or property could still be harmed.

10. After the first winter, the county will decide whether to pay for option A next summer. What measurements should crews take after each storm this winter to make that decision, and what result would support building option A?

Build the plan in layers

Think of protection in three layers and pick at least one option for each. Layer 1, keep people safe: which option gets everyone out before a flow? Layer 2, catch debris: which options trap mud and rock, and how much do they hold together with the old basin's 20,000 m³? Layer 3, steer what gets past: which option keeps the leftover flow away from homes? Add the costs as you go and stop if you pass \$6.0 million.

Who carries the leftover risk?

Option D protects about 90 homes by steering debris toward the highway crossing and the creek channel. Write a paragraph from the point of view of a family whose home is among the 50 not protected, or of a Caltrans engineer responsible for the highway. Then propose a change to the plan that spreads the remaining risk more fairly, and explain what it would cost in money, time or protection somewhere else.