

# Clear the Flood: Design, Test and Combine a Model Bridge

**Investigation question: Which bridge features keep a road open through a flood with floating logs, and can a bridge that combines the best features of several tested designs beat every one of them?**

Engineering design challenge

Groups of 4

2 sessions

Setup 10 · Activity 90 · Cleanup 10 min

MS-ETS1-2 · practice

MS-ETS1-3 · practice

MS-ESS3-2 · practice

Name \_\_\_\_\_

Group \_\_\_\_\_

Date \_\_\_\_\_

## Your role today

- ☐ **Project manager:** Keeps the budget sheet, checks that the design meets the constraints before building, and runs the 20-minute build clock.
- ☐ **Builder:** Leads construction from the sketch and places the bridge at the marked site with its footings set the same way for every test.
- ☐ **Flood operator:** Sets up the flood bottle, fills it to the 1.5 L line, peels the tape on the count, and drops the ten logs into the channel in the first 5 seconds.
- ☐ **Gauge reader and recorder:** Reads the peak water level on the upright ruler, measures scour at the footing pins and bridge movement, runs the load test and records every result.

## Safety

- Wear goggles while pouring floods and releasing logs; sandy water can splash into eyes.
- Water on the floor is a slip hazard. Keep a towel under each station, bail the lake into the bucket after every test, and wipe spills at once.
- A filled stream box weighs 20 kg or more. Never lift or carry a box with sand in it; set stations up where they will stay.
- Skewers have their points snipped off, and the cut bottle edges are taped, but handle both with care. Report any sharp edge to the teacher.
- Keep phones, laptops and electrical cords away from the water. Use a phone to film the peak only from outside the splash zone, in a plastic bag if possible.
- Do not pour sand or sandy water down sinks. Let the bucket settle, pour the clear water outside, and return the sand to the station. Wash hands after the lab.

## Procedure

1. Session 1. As a group, read the stream record and answer q1: the yearly chance of each flood size. Read your importance card and choose your design flood in q2, using the yearly chances and the number of floods expected in a 30-year bridge life.

2. Read the criteria and constraints on the recording sheet and write your group's targets in the criteria table. Then sketch your bridge in the drawing box, label every feature, and add up its cost. The project manager checks the budget (20 points or less), the deck height (underside no more than 7 cm above the channel bed) and the length (at least 16 cm).
3. Build version 1 in 20 minutes or less, using only kit materials.
4. At the station, smooth the channel with the template and set the bridge at your site. Push a toothpick into the sand beside each footing and mark the sand level on it. Push the clear ruler upright into the channel bed 5 cm upstream of the bridge as a water gauge. Tape a mark on the rim beside each end of the bridge.
5. Test 1, Small flood, no logs: tape the cap holes of the Small bottle, fill it to the 1.5 L line, hold it cap-down over the head of the channel, and peel the tape. The gauge reader reads the highest water level on the ruler (film it if you can) and watches for water touching the deck.
6. After the flow stops, record overtopping, scour (distance from each toothpick mark down to the new sand surface, in mm) and movement (distance each end moved from its rim mark). Place the 200 g bag at mid-span for 10 seconds: it passes if nothing breaks and the deck does not touch water or sand. Bail the lake, smooth the channel, refill any scour holes and reset the toothpicks.
7. Test 2, Design-size flood with logs: repeat with the Design-size bottle, and drop all ten logs into the channel about 10 cm upstream of the bridge in the first 5 seconds. Count the logs trapped against the bridge when the flow stops, then record everything else as in step 6.
8. Test 3, Record flood with logs: repeat with the Record bottle and the ten logs. Post your results on the class results chart.
9. Session 2. Copy the class results into the decision matrix. Score every design 0, 1 or 2 on each criterion (0 = misses the target, 1 = meets it, 2 = meets it with a clear margin) and total the scores. Write the best feature of each top design in the last column.
10. Answer q3: choose at least two features from other groups' designs to combine with your own. Redesign within the same constraints, sketch the changes, and build version 2.
11. Retest version 2 with Test 2 and Test 3 exactly as before and record the results in the version 2 table.
12. Post version 2 results, clean the station, and answer q4 through q10 individually.

## Record your observations

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### Lab 2 recording sheet: Clear the Flood

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Your bridge carries a road across Model Creek. Floods in the tray are made with flood bottles: more holes in the cap means a faster, higher flood. Logs are twigs released upstream. The tables below come from an imagined record of the creek.

## Model Creek: 40 years of yearly highest flows

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

| Flood size                            | Flood bottle | Years in which the year's highest flow reached at least this size (out of 40) |
|---------------------------------------|--------------|-------------------------------------------------------------------------------|
| Small: stays in the channel           | 2 holes      | 22                                                                            |
| Design-size: reaches the bank tops    | 4 holes      | 4                                                                             |
| Record: spreads across the floodplain | 6 holes      | 1                                                                             |

Teaching dataset for an imagined creek, invented for this lab; not a real stream record.

1. For each flood size, calculate the chance that it happens in any one year (years reached divided by 40, as a percent). Show your work.

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2. Our importance card: \_\_\_\_\_. Which flood will our bridge be designed to survive, and why? Use the yearly chances and what the road serves.

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### Criteria and constraints: our targets

| Criterion or constraint       | Requirement                                                                                  | Our target or plan | How we will measure it |
|-------------------------------|----------------------------------------------------------------------------------------------|--------------------|------------------------|
| C1 Overtopping                | Deck not overtopped in our design flood                                                      |                    |                        |
| C2 Stays put and carries load | Moves less than 5 mm and holds 200 g after our design flood                                  |                    |                        |
| C3 Debris                     | Traps no more than 3 of 10 logs                                                              |                    |                        |
| C4 Scour                      | Deepest scour beside any footing less than 5 mm                                              |                    |                        |
| Budget                        | 20 points or less (stick, straw, skewer or 10 cm tape = 1; clay ball or scoop of gravel = 2) |                    |                        |
| Deck height                   | Underside no more than 7 cm above the channel bed                                            |                    |                        |
| Length                        | At least 16 cm, so both ends rest on the banks                                               |                    |                        |

-  Sketch version 1 from the side and from above. Label the deck height, any piers, the footings and any armor, and write the cost of each part and the total.

#### Version 1 test results

| Test                       | Peak water at gauge (cm) | Overtopped? (Y/N) | Logs trapped (of 10) | Deepest scour (mm) | Bridge moved (mm) | Held 200 g? (Y/N) |
|----------------------------|--------------------------|-------------------|----------------------|--------------------|-------------------|-------------------|
| 1 Small flood, no logs     |                          |                   |                      |                    |                   |                   |
| 2 Design-size flood + logs |                          |                   |                      |                    |                   |                   |
| 3 Record flood + logs      |                          |                   |                      |                    |                   |                   |

#### Class decision matrix (score each criterion 0, 1 or 2; use Tests 2 and 3)

| Group and design | C1 Overtopping | C2 Stays put and load | C3 Debris | C4 Scour | Within budget? (Y/N) | Total | Best feature |
|------------------|----------------|-----------------------|-----------|----------|----------------------|-------|--------------|
| 1                |                |                       |           |          |                      |       |              |
| 2                |                |                       |           |          |                      |       |              |
| 3                |                |                       |           |          |                      |       |              |
| 4                |                |                       |           |          |                      |       |              |
| 5                |                |                       |           |          |                      |       |              |
| 6                |                |                       |           |          |                      |       |              |
| 7                |                |                       |           |          |                      |       |              |
| 8                |                |                       |           |          |                      |       |              |

3. Name at least two features from other groups' designs that you will combine with your own in version 2. For each, give the evidence from the matrix that it works and the cost it adds.

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#### Version 2 test results

| Test                       | Peak water at gauge (cm) | Overtopped? (Y/N) | Logs trapped (of 10) | Deepest scour (mm) | Bridge moved (mm) | Held 200 g? (Y/N) | Cost (points) |
|----------------------------|--------------------------|-------------------|----------------------|--------------------|-------------------|-------------------|---------------|
| 2 Design-size flood + logs |                          |                   |                      |                    |                   |                   |               |
| 3 Record flood + logs      |                          |                   |                      |                    |                   |                   |               |

#### Analysis questions

4. Which design feature made the biggest difference to the number of logs trapped? Support your answer with class data from at least two designs.

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5. Where was scour deepest in the class tests, and why? Use the idea of how water speeds up as it squeezes past an obstacle or through a narrow opening.

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6. A real bridge is expected to last about 30 years. Using your answers to q1, about how many design-size floods and how many record-size floods should it expect in that time? Show the calculations. Does 'record flood' mean it will not happen during the bridge's life?

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7. Compare your version 1 and version 2 results. Which criteria improved, which stayed the same or got worse, and did the combined design beat every version 1 design on every criterion? Use numbers.

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8. Describe one trade-off the class found, for example between deck height, cost and the length of approach ramps, or between piers that support the deck and piers that catch logs. How would you decide which side of the trade-off to choose?

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9. In December 1964, huge logs carried by the flooding Klamath River battered the Highway 101 bridge until spans on its south end washed out. Using your class data, describe two design changes that would have lowered that risk, and one reason your tray results cannot predict exactly what a real river would do.

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- 10.** Explain why engineers would design the only road to a hospital for a rarer, larger flood than a park footbridge. Use the words criteria, risk and cost.

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