

Where Should the Overlook Go? Siting a Deck on a Changing Coast

Learning target: I can use measured rates of cliff retreat and evidence of sudden events to evaluate three competing designs against criteria and constraints, and justify a siting decision for a structure that must last fifty years.

Transfer and design

About 55 min

Pairs

MS-ETS1-2 · assesses

MS-ESS2-2 · practice

MS-ETS1-1 · practice

engineering design

data analysis

writing

Standards connections

MS-ETS1-2 (assesses): Students score three competing overlook designs against stated criteria and constraints using a decision matrix and rate calculations, then recommend one with reasons. Evaluating competing solutions with a systematic process is the PE as written.

MS-ESS2-2 (practice): The decision depends on explaining how the coast changes at two time scales: gradual retreat measured in meters per year and a sudden landslide that removed 25 m in one night. Students apply that explanation to a design problem rather than constructing it from scratch.

MS-ETS1-1 (practice): Students restate the brief's criteria and constraints with numbers before scoring; the brief supplies most of the limits, so this is practice in precise definition rather than a full definition task.

Purpose: extend · **Time:** about 55 minutes · **Format:** pairs

Answers with reasoning

The brief from the park — 'We need a deck where visitors can see the three sea stacks. The deck must hold at least 20 people (at least 40 m²). It must stay at least 10 m back from the cliff edge for 50 years without being moved. The path from the parking lot must be accessible: no steeper than 1 in 12 (about 8 percent), and no longer than 150 m. The budget is \$60,000. Park rules forbid building within 30 m of a known landslide scar. The deck must open within one year.'

Distance from each site's survey marker to the cliff edge (teaching dataset)

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

Site	2015 (m)	2020 (m)	2025 (m)
A: Headland	60.0	58.4	57.0
B: Beach Bluff	45.0	41.2	37.0
C: Cove	30.0	29.6	29.0

Simulated survey data for a classroom scenario. Each marker stands at the edge of the parking area for that site, so the distance is also how far the parking lot is from the cliff.

Site notes from the survey team — Site A, Headland: hard bedrock cliff that waves undercut slowly; a grassy slope of about 4 percent from the parking area to the edge; all three sea stacks visible. **Site B, Beach Bluff:** soft sandy cliff; flat approach; closest to the stacks and the best view; chunks fall after most winter storms. **Site C, Cove:** sheltered; slope of about 10 percent from the parking area; two of the three stacks visible. In 1998, a section of this cliff 25 m deep slid into the sea in one night. The 1998 scar is 20 m from where a deck would stand.

Part A: Do the math before you design

1. Complete the table. Rate = change $\div$ 10 years. Expected retreat = rate $\times$ 50 years. Engineers double the expected retreat as a safety margin: setback = 2 $\times$ expected retreat. Show one full row of calculations below the table.

Answer: Site A: $60.0 - 57.0 = 3.0$ m; $3.0 \div 10 = 0.3$ m per year; $0.3 \times 50 = 15$ m; setback $2 \times 15 = 30$ m. Site B: $45.0 - 37.0 = 8.0$ m; 0.8 m per year; 40 m in 50 years; setback 80 m. Site C: $30.0 - 29.0 = 1.0$ m; 0.1 m per year; 5 m in 50 years; setback 10 m.

Why: Each row is a rate (change over ten years), a projection (times 50) and a doubling. Students who use 2020 to 2025 only get slightly different rates (A 0.28, B 0.84, C 0.12 m/yr); accept if the span is stated.

Also acceptable: Accept rates computed from the five-year span with the work shown.

2. Site C has the slowest measured rate. Explain why the rate calculation alone underestimates the danger at Site C, and propose a setback for Site C that accounts for the 1998 event. Show your reasoning.

Answer: The rate (0.1 m per year) describes gradual retreat between big events, but in 1998 the cliff lost 25 m in one night. A sudden event is not captured by an average of quiet years. A safer setback adds the sudden loss to the gradual one: 10 m (doubled gradual retreat) + 25 m (one slide like 1998) = 35 m, and since the marker is only 29 m from the edge, a 35 m setback puts the deck behind the parking area. Combined with the rule against building within 30 m of the scar, Site C cannot hold a deck that meets the brief.

Why: The key reasoning is that gradual rates and sudden events need separate treatment; the proposed setback must include the 25 m.

Also acceptable: Accept any setback of 30 m or more with reasoning that names the 1998 slide.

- Explains that an average rate misses sudden events
- Proposes a setback that includes the 25 m slide
- Concludes the site is too shallow or too close to the scar

Part B: Define the problem precisely

3. Write the three **criteria** from the brief (what the deck must do to succeed), each with its number or test. Then add one criterion of your own about visitor experience, with a way to test it.

Answer: Criteria from the brief: (1) visitors can see the three sea stacks (test: all three visible from the deck); (2) the deck holds at least 20 people, at least 40 m²; (3) the deck stays at least 10 m from the cliff edge for 50 years without being moved (test: setback minus 50-year retreat is 10 m or more). Added criterion examples: 'A visitor in a wheelchair can reach the railing' (test: path and deck surface meet the slope rule and have no steps); 'the deck is usable in wind' (test: wind speed on site compared with a threshold).

Why: Three brief criteria with numbers or tests plus one added, testable criterion about visitors.

Also acceptable: Any testable added criterion about visitor experience.

- Three brief criteria with numbers or tests
- One added criterion with a test

4. Write the five **constraints** from the brief (limits the design must stay within), each with its number. For two of them, name a design idea that the constraint rules out.

Answer: Constraints: budget \$60,000; path slope no steeper than 1 in 12 (about 8 percent); path no longer than 150 m; no building within 30 m of a known landslide scar; must open within one year. Examples of what they rule out: the budget rules out Design 3 (\$75,000); the scar rule rules out any deck at Site C within 30 m of the 1998 scar (Design 3 is 20 m away); the slope rule rules out a straight path up Site C's 10 percent slope; the one-year limit rules out a plan that waits for several more years of survey data.

Why: Five constraints with numbers and two eliminations tied to real designs.

Also acceptable: Accept 'retaining wall needs an extra permit' type additions if labeled as the student's own.

- Five constraints with numbers
- Two design ideas ruled out, each tied to the right constraint

Part C: Compare three candidate designs

Candidate designs

1 Design 1: Beach Bluff Deck (Site B)

A 45 m² deck 20 m back from the 2025 cliff edge, reached by a flat path 60 m long. Cost \$35,000. Plan: because the cliff retreats, the deck will be unbolted and moved back 15 m every 15 years. Full view of all three stacks from the closest site.

2 Design 2: Headland Deck (Site A)

A 42 m² deck 30 m back from the 2025 cliff edge, reached by a gravel path about 30 m long on the 4 percent grass slope. Cost \$52,000. View of all three stacks, somewhat farther away than at Site B.

3 Design 3: Cove Terrace (Site C)

A 48 m² deck 15 m back from the 2025 cliff edge, 20 m from the 1998 scar. The 10 percent slope is regraded into switchbacks at 7 percent with a retaining wall. Cost \$75,000. View of two of the three stacks; sheltered from wind.

5. Score each design against each criterion: 2 = fully meets, 1 = partly, 0 = fails. In the constraints row, write yes or name every constraint the design breaks. Add the criterion scores for the total, and circle any design that breaks a constraint.

Answer: Expected scoring: View: Design 1 = 2, Design 2 = 2, Design 3 = 1 (two of three stacks). Size: all three = 2 (45, 42 and 48 m²). 10 m for 50 years unmoved: Design 1 = 0 (plans to move; and fails even its own plan, see q6), Design 2 = 2 (30 – 15 = 15 m remains), Design 3 = 0 (15 m setback minus 5 m gradual retreat leaves 10 m, but one slide like 1998 would remove the deck). Added criterion: varies. Constraints: Design 1 yes on cost, slope, length and scar, but breaks 'unmoved for 50 years' by design; Design 2 yes on all; Design 3 breaks the budget (\$75,000) and the 30 m scar rule (20 m). Totals (before the added criterion): Design 1 = 4, Design 2 = 6, Design 3 = 3.

Why: Grade consistency between the student's criteria and scores; Design 2 should come out ahead on any reasonable matrix, and Designs 1 and 3 each break at least one constraint.

Also acceptable: A student who scores Design 3's safety as 1 (it meets 10 m against gradual retreat) is reasoning from the arithmetic; accept if the 1998 slide is discussed in q7.

- Every cell filled
- Scores follow from the stated criteria
- Constraint failures for Designs 1 and 3 identified

6. Check two designs' arithmetic. (a) Design 1 claims that moving the deck back 15 m every 15 years keeps it at least 10 m from the edge. Using Site B's rate, how far from the edge will the deck be just before the first move at year 15? Does the plan work? (b) Design 2 places the deck 30 m back at Site A. How far from the edge will it be after 50 years, and does that meet the 10 m rule? Show both calculations.

Answer: (a) Site B retreats 0.8 m per year, so in 15 years the edge moves $0.8 \times 15 = 12$ m. The deck starts 20 m back, so at year 15 it is $20 - 12 = 8$ m from the edge, less than the 10 m minimum. The plan fails before the first move (it would need moving about every 12 years: $(20 - 10) \div 0.8 = 12.5$ years). (b) Site A retreats 0.3 m per year, so in 50 years the edge moves $0.3 \times 50 = 15$ m. The deck starts 30 m back, so after 50 years it is $30 - 15 = 15$ m from the edge, which meets the 10 m rule with 5 m to spare.

Why: Both are rate $\times$ time subtracted from a starting distance; the point is that checking a design's numbers is part of evaluating it.

Also acceptable: Accept 8 m and 'fails' for (a), 15 m and 'passes' for (b); accept 12.5 years as the real moving interval.

Part D: Decide and justify

7. Which design do you recommend, or what change to one of them? Justify your decision using your matrix scores, at least one calculation from Part A or q6, the difference between gradual retreat and a sudden event, and at least one effect on visitors. Then state the strongest argument against your choice and answer it.

Answer: Model response: I recommend Design 2, the Headland Deck at Site A. It scores highest in the matrix (6 of 6 on the brief's criteria) and breaks no constraint: \$52,000 is under budget, the path is about 30 m at 4 percent, and the site has no landslide scar. The calculation decides it: Site A loses 0.3 m per year, so in 50 years the edge moves 15 m and the deck, built 30 m back, will still be 15 m from the edge (q6b). Site B's view is better, but its cliff retreats 0.8 m per year, so a deck would need an 80 m setback, which is farther than the parking lot itself, and Design 1's moving plan fails at year 15 with the deck only 8 m from the edge. Site C's slow average rate hides a sudden event: the 1998 slide took 25 m in one night, and gradual-rate math cannot protect against that, so the park's 30 m scar rule and the \$75,000 cost both rule Design 3 out. Visitors at Design 2 get all three stacks on an accessible path. Strongest argument against: the view is farther away than at Site B. Answer: a deck that must be moved every 12 years, or that stands 8 m from a crumbling sandy edge, is not a view the park can keep; the park could add a viewing scope at the Headland Deck to bring the stacks closer.

Why: Full credit requires a decision, use of the matrix, at least one calculation, the gradual-versus-sudden distinction, a visitor effect, and a counterargument answered.

Also acceptable: A modified Design 1 is acceptable only if the student moves it to a setback that works (80 m, which is behind the parking lot, so they must also move the parking); a modified Design 3 would need a cheaper path and a site more than 30 m from the scar with a 35 m setback, which the 29 m distance cannot provide. Students who show this arithmetic and still choose Design 2 have done the work.

- Clear recommendation (a design or a specified modification)
- Cites the decision matrix scores
- Uses at least one calculation from Part A or q6
- Distinguishes gradual retreat from the sudden 1998 event
- Names at least one effect on visitors
- States the strongest counterargument and answers it

8. Sketch your recommended site as a top view: the parking area, the survey marker, the 2025 cliff edge, the expected edge in 50 years, the deck, and the path. Label every distance in meters and the path's slope.

Answer: A top view of Site A: parking area with the survey marker at its edge; the 2025 cliff edge drawn 57 m from the marker; the expected 2075 edge drawn 15 m closer (42 m from the marker); the deck drawn 30 m back from the 2025 edge (27 m from the marker), with its 42 m² size noted; a path about 30 m long labeled 4 percent; the three sea stacks offshore.

Why: The sketch should match the recommended design and show that the 50-year edge stays at least 10 m from the deck.

Also acceptable: A sketch of a modified design is fine if its labels match the student's recommendation.

- Parking, marker, 2025 edge and 50-year edge shown
- Deck and path placed with distances in meters
- Path slope labeled
- Distances consistent with the student's calculations

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Rates and projections	All three rates, 50-year retreats and setbacks correct with units; Site C's sudden event is added to its setback with reasoning.	Calculations correct with one unit or rounding slip; the 1998 slide is mentioned but not added to a setback.	Rates computed but projections or safety factor missing; the sudden event is ignored.	Calculations missing or incorrect throughout.
Criteria and constraints	Three criteria and five constraints restated with their numbers, one testable criterion added, and two constraints linked to designs they rule out.	All restated with numbers; the added criterion lacks a test or the rule-outs are missing.	Criteria and constraints mixed, or several numbers missing.	Not attempted or copied without numbers.
Systematic evaluation	Matrix complete and consistent; both arithmetic checks in q6 correct; constraint failures for Designs 1 and 3 identified.	Matrix complete; one q6 check has an error, or one constraint failure missed.	Matrix partly filled or scores not tied to the criteria.	No systematic comparison.
Decision and justification	Decision follows from the matrix, cites a calculation, distinguishes gradual from sudden change, names a visitor effect, and answers the strongest counterargument.	Decision follows from the matrix with a calculation and the gradual/sudden distinction, but the counterargument or visitor effect is weak or missing.	Decision stated with general reasons not tied to the scores or the numbers.	No decision, or a decision that contradicts the student's own matrix.

Teacher notes

The park, sites and survey data are fictional; rates of 0.1 to 0.8 m per year are realistic for sea cliffs of different rock types, and a 25 m single-night loss is realistic for a slide in weak coastal material. The scenario is built so that the arithmetic alone would favor Site C (slowest rate) and the view alone would favor Site B, while the full analysis (rate, safety factor, sudden event, constraints) favors Site A. The key numbers: A 0.3 m/yr, 15 m in 50 years, 30 m setback (deck ends 15 m from the edge); B 0.8 m/yr, 40 m in 50 years, 80 m setback, which exceeds the 37 m available; C 0.1 m/yr, but 25 m in 1998, and the scar rule. The accessible-slope figure (1 in 12, about 8.3 percent) is the common ramp standard. In the debrief, name the two reasoning moves the lesson supplies: rates measured today project gradual change (uniformitarianism as a tool), and sudden events must be treated as separate evidence, not averaged away.

Scaffold offered to students: Setback in three lines

For each site, write three lines: (1) rate = (2015 distance – 2025 distance) ÷ 10 years; (2) 50-year retreat = rate × 50; (3) setback = 2 × the 50-year retreat. Then ask one more question the arithmetic cannot answer: has this cliff ever changed suddenly? If yes, add that sudden loss to the setback. A criterion says what the deck must DO (hold 20 people, keep its view, stay 10 m from the edge); a constraint says what the design CANNOT exceed (money, slope, length, distance from a scar, time).

Extension: The 100-year version

The park's director asks what changes if the deck must last 100 years instead of 50. Recalculate the setback for each site, decide whether any site still works within 150 m of parking, and write a short memo explaining whether the park should change the site, shorten the design life, or accept a plan to move the deck once. Include one sentence on why an average rate from ten years of data becomes less trustworthy the farther into the future you project it, and what a sudden event like the 1998 slide does to that trust.