

The Council Packet: Protect the Ecosystem or Pay to Replace It?

Investigation question: For three ecosystem services a fictional California town depends on, which mix of protecting, restoring or replacing best keeps the services and the biodiversity behind them, within a 30-year budget and with fair treatment of the people affected?

Data-driven decision

Groups of 4

2 sessions

Setup 5 · Activity 80 · Cleanup 2 min

MS-LS2-5 · assesses

MS-ETS1-2 · assesses

MS-ETS1-1 · practice

MS-ESS3-3 · supports

Scientific purpose

Groups act as the town council of Marisol Bay, a fictional coastal California town facing three decisions at once: whether to protect the forest that keeps its drinking water clean or build a filtration plant, whether to restore dunes and marsh or build a seawall, and whether to keep an oak woodland that feeds wild bees for valley farms or clear it for warehouses and rent more hives. Students calculate 30-year costs and cost per home, find packages that fit the budget, score every option on weighted criteria, hear stakeholder concerns, and defend a recommendation in a council hearing.

Why this helps students with this chapter

The PE asks students to evaluate competing solutions, which cannot be done with a single right answer. The packet gives three services with three different kinds of trade-off: one where protecting nature is far cheaper (water), one where the cheaper natural option is slower to work (flooding), and one where the human-made replacement brings money and jobs to the town (pollination). Calculating, scoring and arguing in front of the class shows students that science supplies the predictions and the costs, while people's values set the weights.

Standards connections

MS-LS2-5 (assesses, evaluating competing design solutions for maintaining ecosystem services and biodiversity against scientific, economic and social constraints): Students compare protect, restore and replace options for water purification, flood protection and pollination, weigh scientific evidence (how each option maintains the service and the habitat), economic constraints (30-year costs, the budget, who pays) and social constraints (housing, jobs, stakeholder concerns), and write an evidence-based recommendation. This is direct evidence toward the PE as written.

MS-ETS1-2 (assesses, a systematic weighted decision matrix): Each group sets criterion weights, scores all seven options on the same scale and computes weighted totals, then uses the totals and the budget to justify its choices.

MS-ETS1-1 (practice, stating constraints and turning concerns into testable criteria): Students identify the budget and stakeholder limits as constraints and, in q8, turn the goal of keeping a service into a measurable monitoring criterion with a trigger for action. Most criteria are supplied, so this is practice.

MS-ESS3-3 (supports, monitoring a human impact on an ecosystem service): MS-ESS3-3 is a Grade 6 performance expectation in the California integrated sequence; it is background here. The q8 monitoring plan revisits the Grade 6 idea of monitoring and minimizing a human impact.

Roles (rotate each session)

- **Water engineer:** Leads Decision 1: computes the costs for 1A and 1B, explains how the forest cleans the water, and reads the water district engineer's and housing advocate's statements.
- **Coastal scientist:** Leads Decision 2: computes the costs and cost per home for 2A, 2B and 2C, and reads the homeowner's and biologist's statements.
- **Farm advisor:** Leads Decision 3: computes the costs for 3A and 3B, tracks who pays and who gains, and reads the farmer's and company's statements.
- **Budget chair:** Checks every calculation, lists the packages that fit the budget, runs the decision matrix, keeps time and presents at the hearing.

Materials

Item	Quantity	Per	Note
Council packet (this recording sheet) with the option sheet, stakeholder statements and matrix	1	student	
Calculator	1	group	
Sticky notes in three colors for the hearing vote	3	student	
Timer for two-minute presentations	1	class	

Estimated cost: 2 to 4 per class (estimate) (an estimate; Printing only; calculators, sticky notes and the timer are classroom stock.)

Safety

- Paper and calculators only; no physical hazards.
- Marisol Bay, its people and its numbers are fictional. If students connect the lab to a real local decision, keep the discussion respectful of people who disagree and check facts before stating them.

Teacher preparation and setup

1. Solve the cost table and the budget packages yourself using the answer key so you can spot slips quickly; the most common error is multiplying a yearly cost by 3 instead of 30.
2. Decide how to run the hearing: each group presents its package in two minutes, or each of the four roles speaks for 30 seconds on its decision.
3. Draw a board table with the seven options down the side and space for each group's choice, so the class can see where groups agreed and disagreed.
4. If your community is debating a real development, dune or watershed decision, decide in advance whether to mention it, and keep the lab's numbers clearly fictional.

Investigation design

Independent variable	The option chosen for each of the three decisions (protect or restore, replace, or do nothing).
Dependent variable	The 30-year cost to the town and to other people, the cost per home protected, each option's weighted matrix score, and how well the service and its habitat are kept.
Controlled	The same option sheet and numbers for every group; The same 30-year planning period; The same \$80 million town budget; The same 1-3 scoring scale and four criteria (weights chosen by each group before scoring)
Trials	Each group produces one recommended package; the class compares packages and votes across groups.
Comparison	Options compared within each decision on 30-year cost, cost per home and weighted score; packages compared across groups to see how different weights change the decision.

Student procedure

1. Session 1. Read the packet introduction, the option sheet and the stakeholder statements aloud; each role reads the statements for its decision.
2. Calculate the 30-year total for every option in the cost table (q1). Each role computes its own decision, and the Budget chair checks all seven.
3. Answer q2 (cost per home protected) and q3 (the replacement cost of the forest's water-cleaning service).
4. List the packages of one option per decision that fit the town's \$80 million budget (q4).
5. As a group, choose a weight from 1 to 3 for each of the four criteria and write the weights in the matrix headings before scoring anything. Then score every option from 1 to 3 on each criterion and compute the weighted totals.
6. Decide one option for each decision; you may propose a hybrid if you give its cost and show it fits the budget. Write the group's recommendation in the claim-evidence-reasoning box.
7. Session 2. Council hearing: each group presents its package, its strongest piece of evidence and one stakeholder concern it answers, in two minutes. The class records every group's choices on the board and votes on each decision with sticky notes.
8. Answer q5-q10 individually, in class or for homework.

Expected observations

- Every group should find that 1A cannot fit the \$80 million budget (it costs \$135 million by itself) and that every package containing 1B fits, so every valid package uses 1B unless a group proposes a costed hybrid.
- Decision 2 splits groups: 2B is cheaper (\$25.5 million, about \$72,857 per home, versus \$40 million, about \$114,286 per home, for 2A) and adds habitat, but 2A protects homes sooner. Several groups propose hybrids. Few choose 2C once they see \$54 million of expected damage falling on residents.

- Decision 3 is the most divided: groups that weight jobs, taxes or reliability heavily pick 3A; groups that weight biodiversity, the farmers' costs or long-term risk pick 3B.
- Changing the weights changes the winner in Decisions 2 and 3 but rarely in Decision 1, which shows students where the evidence decides and where values do.

Likely difficulties

- Multiplying a yearly cost by 3 or 10 instead of 30, or misplacing the decimal ($0.6 \times 30 = 18$, not 1.8).
- Charging the farmers' hive rent (3A) or the residents' flood damage (2C) to the town budget, or treating 2C as free.
- Forgetting 2B's one-time \$1.5 million of expected damage while plants establish.
- Choosing weights after scoring to make a favorite option win. Require weights in the headings before any scores.
- Giving every option the same scores, which makes the matrix useless; ask for at least one 1 and one 3 in every column.

Structured debrief

1. Show the board table of every group's choices. Decision 1 is settled by the budget: 1A alone (\$135 million) breaks it, so every package that fits uses 1B unless a group costs out a hybrid; tell students this is the same logic New York City used, with numbers a hundred times larger.
2. Spend the most time where groups split. On Decision 2, ask the 2A groups what they weighted most (usually reliability now, for the Lowlands homeowner) and the 2B groups (cost and habitat). Collect the hybrid ideas from q7; point out that real coastal towns often combine restored dunes or marsh with a structure, like the levees behind the restored South Bay marshes.
3. On Decision 3, show the q5 numbers: under 3A the town gains about \$12 million in taxes while farmers pay \$9 million in rent and the wild bees decline; under 3B the town spends \$3.9 million and keeps the woodland. Make the point that the replacement option is not always the expensive one, and that an honest analysis says so.
4. Close on q9: the class used the same evidence and still disagreed, because groups chose different weights. That is not a failure of science; it is the point where values and democratic decisions take over, which is why the evidence must be clear and the weights stated openly.

Recording sheet: what students fill in

Lab 3 council packet: Marisol Bay decides

Marisol Bay is a **fictional** coastal California town of 38,000 people, and every number in this packet is a **teaching dataset**; real costs depend on place and year. The town gets three ecosystem services without paying for them. A forest of 2,500 acres above Alder Creek reservoir keeps the drinking water clear, so the town only disinfects it. Dunes and a salt marsh at Shell Point shield 350 homes in the Lowlands neighborhood from storm waves, but a parking lot and foot traffic have damaged them. An oak woodland of 1,200 acres in Arroyo Valley houses wild bees that help pollinate 4,000 acres of almond and apple orchards. Three proposals now threaten or depend on these ecosystems, and the council must choose a 30-year plan.

Option sheet (costs in millions of dollars)

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

Option	What the town would do	Up-front cost (\$ million)	Yearly cost (\$ million)	Who pays	Other information
1A	Approve 600 homes in the upper watershed and build a filtration plant	60	2.5	Town water customers	Very reliable once built (about 3 years); uses electricity and treatment chemicals; homes built where the developer prefers
1B	Buy conservation easements on 2,500 acres of forest; steer the 600 homes to an infill site downtown	18	0.6	Town water customers	Yearly cost covers wildfire-fuel work, trail upkeep and water testing; forest stays as habitat; a severe wildfire could still muddy the water for a few years; downtown neighbors worry about traffic
2A	Build a 1.5 km concrete seawall at Shell Point	28	0.4	Town	Full protection once finished (about 2 years); the beach in front is expected to narrow; little habitat
2B	Remove the beach parking lot, rebuild and replant the dunes, reconnect 60 acres of marsh	9	0.5	Town	Full protection in about 5 years, with about \$1.5 million of flood damage expected in total while plants establish (add it as a one-time cost); shorebird nesting habitat; a new trail
2C	Do nothing at Shell Point	0	0 to the town; about 1.8 a year in expected flood damage	Homeowners, insurers, disaster aid	350 homes at risk; damage likely to rise as sea level rises
3A	Approve clearing 400 acres of oak woodland for a warehouse park; farmers rent 1,500 extra honey bee hives a year	0	0.3	Valley farmers	300 jobs and about \$0.4 million a year in taxes for the town; hive supply and price can change; fewer wild bees

Option	What the town would do	Up-front cost (\$ million)	Yearly cost (\$ million)	Who pays	Other information
3B	Protect the woodland and plant 15 miles of flowering hedgerows along farm edges	0.9	0.1	Town	The company may build in another town; woodland keeps wild bees, birds and trails; hedgerows take about 3 years to flower well

Simulated values for a fictional town, built so that each decision has a real kind of trade-off. Up-front means paid once at the start; yearly costs repeat every year for 30 years.

Budget constraint: the town may spend at most **\$80 million over 30 years** on these three decisions combined. Costs paid by town water customers (1A, 1B) come through the town's water bills and count toward the budget. Costs paid by farmers, homeowners or insurers do not come out of the town budget, but the council must still weigh them. **30-year total** = up-front cost + (yearly cost x 30) + any other one-time cost.

30-year cost calculations

Option	Calculation	30-year total (\$ million)	Who pays
1A			
1B			
2A			
2B			
2C			
3A			
3B			

1. Complete the cost table. Show the full calculation for 1A and for 2B here.

Answer: 1A: $60 + (2.5 \times 30) = 60 + 75 = \$135$ million (town water customers). 1B: $18 + (0.6 \times 30) = 18 + 18 = \$36$ million (town water customers). 2A: $28 + (0.4 \times 30) = 28 + 12 = \$40$ million (town). 2B: $9 + (0.5 \times 30) + 1.5 = 9 + 15 + 1.5 = \$25.5$ million (town). 2C: \$0 to the town; $1.8 \times 30 = \$54$ million of expected damage to homeowners, insurers and disaster aid. 3A: $0 + (0.3 \times 30) = \$9$ million (farmers). 3B: $0.9 + (0.1 \times 30) = 0.9 + 3 = \$3.9$ million (town).

Why: Thirty-year total = up-front + yearly x 30 + any one-time cost; the 2B line includes the expected damage while plants establish.

- All seven totals correct
- Calculation shown for 1A and 2B
- Correct party named for 2C and 3A

2. Shell Point protects 350 homes. Find the 30-year cost per home for 2A and for 2B, and the expected flood damage per home over 30 years for 2C.

Answer: 2A: $\$40,000,000 / 350 =$ about \$114,286 per home. 2B: $\$25,500,000 / 350 =$ about \$72,857 per home. 2C: $\$54,000,000 / 350 =$ about \$154,286 of expected damage per home over 30 years.

Why: Dividing by the number of homes makes the options comparable from a homeowner's point of view; doing nothing is the most expensive for residents.

- All three values correct within rounding
- Work shown

3. Using option 1A, what is the replacement cost of the forest's water-cleaning service over 30 years? Give one reason this number is only an estimate of what the forest is worth.

Answer: About \$135 million over 30 years, the cost of the filtration plant that would replace the forest's water cleaning (or \$99 million more than protecting the forest with 1B). It is only an estimate because the plant's costs are predictions, the plant replaces only the water-cleaning job and none of the forest's other benefits (habitat, trails, carbon storage), and the town might choose not to build it.

Why: Replacement cost estimates a service's value by the price of a substitute; it can miss other services and overstate value if nobody would build the substitute.

Also acceptable: Accept \$99 million as 'what protecting the forest saves' if the student explains the difference.

- Gives \$135 million (or \$99 million with explanation)
- Gives a valid reason it is only an estimate

4. List at least three packages (one option from each decision) that fit the \$80 million town budget, with their totals. Which option can never fit, and why?

Answer: Packages within \$80 million of town spending (2C and 3A cost the town nothing): $1B + 2A + 3A = 36 + 40 + 0 = \$76$ million; $1B + 2A + 3B = 36 + 40 + 3.9 = \$79.9$ million; $1B + 2B + 3A = 36 + 25.5 + 0 = \$61.5$ million; $1B + 2B + 3B = 36 + 25.5 + 3.9 = \$65.4$ million; $1B + 2C + 3A = \$36$ million; $1B + 2C + 3B = \$39.9$ million. Option 1A can never fit, because by itself it costs \$135 million, more than the whole budget.

Why: Students add one option per decision and compare with \$80 million, counting only town costs.

- At least three valid packages with correct totals
- Explains that 1A alone exceeds the budget

Stakeholder statements heard by the council

Speaker	What they told the council
Water district engineer	A filtration plant would give us very reliable water, but customers would pay for it on every bill for decades.
Housing advocate	Marisol Bay is short of homes. If the 600 homes are not built upstream, where will they go, and how soon?
Lowlands homeowner	My street flooded twice in ten years. I need protection now, not in five years.
Shorebird biologist	The Shell Point dunes are one of the few places on this stretch of coast where shorebirds such as the western snowy plover nest.
Valley farmer	Hive rent goes up almost every year. The wild bees from the oak woodland cost me nothing, as long as the oaks are there.
Warehouse company	We offer 300 jobs. If the council says no, we will build in the next town.

How to score the options — First choose a **weight** for each criterion: 1 = matters some, 2 = matters a lot, 3 = matters most. Write the weights in the matrix headings before you score. Then give each option a **score** on each criterion: 1 = poor, 2 = fair, 3 = good. **Cost:** 30-year cost to the whole community, including what residents and farmers pay. **Reliability:** how surely the service will be delivered, and how soon. **Biodiversity and other services:** effects on habitat, wildlife and services such as recreation. **Fairness:** how well the option treats the people affected. Weighted total = (cost score x weight) + (reliability score x weight) + (biodiversity score x weight) + (fairness score x weight).

Decision matrix

Option	Cost (weight __)	Reliability (weight __)	Biodiversity and other services (weight __)	Fairness (weight __)	Weighted total
1A					
1B					
2A					
2B					
2C					
3A					
3B					

Answer: Open-ended. A strong example: Claim: 1B, 2B and 3B. Evidence: 1B costs \$36 million versus \$135 million for 1A, which cannot fit the budget; 2B costs \$25.5 million (about \$72,857 per home) versus \$40 million (about \$114,286 per home) for 2A; 3B costs the town \$3.9 million and keeps the wild bees; the package totals \$65.4 million; our matrix totals were 22 for 1B, 22 for 2B and 22 for 3B, the highest in each decision. Reasoning: protecting and restoring keeps each service working and also keeps habitat for wild bees and nesting shorebirds, which no substitute provides; we answer the Lowlands homeowner by using some of the remaining budget for temporary sandbag protection during the five years the dunes need.

Why: This is the main evidence for MS-LS2-5: an evaluation of competing solutions with scientific, economic and social constraints. Other packages earn full credit if argued with the same quality of evidence.

Also acceptable: 1B + 2A + 3B (reliability now for Lowlands homes, at \$79.9 million) or 1B + 2B + 3A (valuing jobs and taxes, accepting fewer wild bees) are fully acceptable if the trade-off is named and the budget total is correct.

- Claim names one option or a costed hybrid for each decision
- Evidence cites at least three correct numbers, including the package total within budget
- Reasoning explains how each service and its biodiversity are maintained
- Reasoning answers at least one stakeholder concern
- Acknowledges at least one trade-off or uncertainty

Analysis questions: answer key

5. Decision 3 is the one where the replace option might look better to the town treasury. Over 30 years, who pays and who gains under 3A and under 3B? Use numbers (hive rent paid by farmers, taxes gained by the town).

Answer: Under 3A, farmers pay $0.3 \times 30 = \$9$ million in hive rent over 30 years, while the town gains $0.4 \times 30 = \$12$ million in taxes plus 300 jobs; the woodland and many wild bees are lost, and farmers depend on the hive market. Under 3B, the town pays \$3.9 million and gives up the warehouse taxes, while farmers keep free pollination from wild bees and everyone keeps the woodland's habitat and trails. Counting only money for the whole community, 3A comes out about \$3 million ahead ($12 - 9$) while 3B costs \$3.9 million, so 3B's case rests on reliability, biodiversity and fairness to farmers rather than on price.

Why: Shows that the replace option can win on money for some parties, so the decision depends on who pays, risks and values.

- Correct \$9 million and \$12 million figures
- Names who pays and who gains for each option
- Recognizes that money alone may favor 3A and names what else matters

6. Name two benefits of the forest, the dunes or the woodland that appear nowhere in the cost columns. Why do replacement costs leave them out?

Answer: Examples: habitat for wildlife (oak woodland birds, nesting shorebirds, native bees), recreation and trails, scenic beauty, carbon stored in trees, cooler air and shade, places for scientific study, cultural or spiritual value. Replacement costs leave them out because they count only the single job a substitute would do, and many of these benefits have no market price or no human-made substitute at all.

Why: Replacement cost is a partial measure of value.

- Two benefits not in the cost columns
- Explains that replacement cost counts only the replaced job or that these benefits have no price

7. Option 2B is cheaper than the seawall but takes about five years to reach full strength. Describe a hybrid plan for Shell Point, estimate whether it fits your budget, and say what the council would need to know to judge it.

Answer: Example: restore the dunes and marsh (2B, \$25.5 million) and, for the first five years, protect the most exposed Lowlands streets with removable barriers or a short rock section at the worst spot, for an estimated few million dollars, keeping the package under \$80 million with 1B and 3B. The council would need the cost and lifespan of the temporary protection, how much flood risk remains during the five years, whether the structure would harm the beach or the plover nesting area, and sea-level projections for the site.

Why: Hybrid designs combine the strengths of competing solutions; judging them requires costs, risks and side effects.

- A specific hybrid
- A cost estimate and a budget check
- At least two things the council would need to know

8. Choose one option your group recommended. Write a monitoring plan: what to measure, how often, and what result would make the town take action.

Answer: Example for 1B: measure turbidity at the reservoir intake weekly and within a day after every large storm, and survey the forest for fire fuel and erosion each year; if turbidity stays above an agreed limit for a week, or erosion gullies appear, repair the damaged slopes and review land use upstream. Example for 2B: survey dune height and width and plant cover each spring and after every major storm; if the dune falls below a set height, add sand and replant before the next storm season. Example for 3B: count bee visits on almond blossoms near and far from the hedgerows each bloom and compare nut set; if counts fall for two years, add plantings or nesting sites.

Why: A monitoring plan turns 'keep the service' into a measurable criterion with a trigger, the ETS1-1 idea and the Grade 6 ESS3-3 idea.

- Names a measurable quantity
- Gives how often or when
- Gives a specific result that triggers action and the action

9. Science can tell the council what each option is likely to do and cost, but it cannot make the decision. Explain this using one place where your group disagreed or where two stakeholders wanted different things.

Answer: Example: our group agreed on the costs, but two members ranked jobs (3A) above wild bees and two ranked wild bees (3B) higher; the numbers did not settle it, because the choice depended on how much we valued each. Science predicted what each option would do and cost; deciding what matters most is a value judgment that the council, and voters, have to make.

Why: The California framework and the MS-ESS3 clarification note that science describes consequences but does not decide society's actions.

- Gives a specific disagreement or stakeholder conflict
- Separates what the evidence shows from what people value
- States that values or people make the final decision

10. New York City faced a choice like Decision 1. What did it choose, and which number in your packet plays the role of New York's estimated filtration-plant cost?

Answer: New York City chose to protect its Catskill and Delaware watersheds (buying land and easements, upgrading upstate sewage and septic systems, and working with farmers) instead of building a filtration plant for that water, and it still disinfects. Option 1A's filtration plant (\$60 million up front and \$2.5 million a year) plays the role of New York's estimated plant, which the city put at up to about \$6 billion to build and more than \$300 million a year to run, though an EPA-appointed expert panel argued filtration could cost as little as half that.

Why: Connects the fictional decision to the lesson's engineering case.

- States New York protected its watershed instead of filtering
- Identifies 1A's plant costs as the parallel number

Individual evidence of learning

Each student submits the completed cost table, answers to q1-q4, the group's matrix and recommendation, and individual answers to q5-q10. The recommendation (cer) with q5, q6 and q7 is the main evidence for MS-LS2-5; the matrix is the evidence for MS-ETS1-2; q8 shows a measurable monitoring criterion; q9 shows understanding that values, not only data, decide.

Assessment criteria

Criterion	Proficient looks like
Calculations	All seven 30-year totals and the per-home costs are correct, with the right party named as paying.
Budget reasoning	Lists at least three packages that fit with correct totals and explains why 1A never fits.
Systematic evaluation	Weights stated before scoring, every option scored on every criterion, weighted totals correct and used in the recommendation.
Evidence-based recommendation	Chooses one option or a costed hybrid per decision, cites costs and matrix totals, explains how the package keeps each service and its habitat, and answers at least one stakeholder concern.
Limits of replacement cost and of science	Names benefits missing from the cost columns and why (q6), and explains with an example that the evidence informs but values decide (q9).

Accessibility adaptations

- Provide a version of the cost table with the setup printed (up-front + yearly x 30 + other = __) and a multiplication strip for x 30.
- Let each role complete only its own decision's calculations first, then teach them to the group; the Budget chair role suits a student who likes checking.
- Read the stakeholder statements aloud and offer picture icons for each speaker; allow a spoken or recorded recommendation in place of the written one.

- Give sentence frames: 'We chose ___ over ___ because it costs ___ less over 30 years and ___' and 'This answers the ___'s concern by ___.'

Low-cost alternative

The lab needs only printing. If printing is limited, project the option sheet and statements and have groups copy only the cost table and the matrix into notebooks; the hearing can become a gallery walk of posted recommendations.

Model limitations

This lab has not been tested with a class by the authors. Marisol Bay, its people and every number are invented teaching values, built so each decision has a real kind of trade-off; they are not estimates for any real place. Real decisions use ranges instead of single numbers, treat money spent decades from now as worth less than money spent today, must follow laws and permit rules, may include grants, and take months of public hearings. Replacement-cost estimates are themselves disputed, as New York City's was. The 1-3 matrix compresses complex trade-offs into a few numbers, and the weights express values, not science.

Teacher notes

All numbers are fictional and labeled simulated. Check every group's cost table before the matrix: a single multiplication slip (3 instead of 30) will distort the whole decision. Grade the recommendation with the cer criteria; there is no single correct package, but every package must fit the budget and be argued with correct numbers. The sample matrix in the cer key used weights cost 2, reliability 3, biodiversity 2, fairness 2 and scores 1A 1-3-1-2, 1B 3-2-3-2, 2A 2-3-1-2, 2B 3-2-3-2, 2C 1-1-2-1, 3A 2-2-1-2, 3B 3-2-3-2, giving totals 17, 22, 19, 22, 11, 16 and 22. Different weights or scores are fine if applied consistently.