

Clearing Alder Reservoir: Choose a Food-Web Fix and Plan the Test

Learning target: I can use a trophic pyramid model to predict how competing solutions would change a green, algae-choked reservoir, evaluate them against criteria and constraints, choose one, and plan how to test and improve it.

Transfer and design

About 55 min

Pairs

MS-ETS1-2 · assesses

MS-LS2-3 · practice

MS-ETS1-4 · supports

engineering design

data analysis

writing

Standards connections

MS-ETS1-2 (assesses, the systematic comparison of competing solutions against stated criteria and constraints): Students score four competing solutions in a decision matrix against the town's criteria and constraints and justify a choice. That is the systematic evaluation the PE describes; the scenario and cost figures are teaching estimates, which is acceptable for an engineering-practice task.

MS-LS2-3 (practice): Every prediction must come from the reservoir's trophic pyramid: how a change in one level moves matter and energy flow through the others. Students apply the chapter's model to a new system rather than building it from scratch.

MS-ETS1-4 (supports): The pyramid is used as a model to predict outcomes and to plan a test whose results would modify the solution; students plan the iteration but do not run a model that generates data, so this is background to the PE.

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

Answers with reasoning

The problem

Alder Reservoir is a 40-hectare lake that supplies drinking water to the town of Alder Springs and is used for swimming and fishing. For years a leaking sewer line fed nutrients into the lake. Algae grew so thickly that the water turned pea-green, and each late summer dead algae sinking to the bottom were broken down by decomposers that used up so much oxygen that fish died. The town repaired the sewer line in 2024, cutting the nutrients flowing in by about 70 percent. One year later the water is still green. Nutrients already stored in the bottom mud keep feeding the algae, and the lake's food web has not changed: it is full of small plankton-eating fish called shiners and has very few predatory fish.

Alder Reservoir surveys before and after the sewer repair (teaching dataset)

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

Measurement	2024 (sewer leaking)	2025 (sewer repaired)
Nutrient input from land (kg of phosphorus per year)	900	270
Algae cells per drop of water	1800	1500
Zooplankton per liter	12	15
Shiners (plankton-eating fish) per net haul	140	150
Largemouth bass (predatory fish) per net haul	2	2
Secchi depth in August (m)	0.3	0.4
Late-summer fish kill	yes	yes, smaller

Simulated data for teaching. Secchi depth is how deep a white disk can be seen; larger means clearer water. A Secchi depth of 1.5 m is the town's standard for safe swimming.

Alder Reservoir trophic pyramid (top to bottom)

Largemouth bass (predatory fish): very few	top
Shiners (plankton-eating fish): very many	
Zooplankton (tiny drifting animals): few	
Algae (producers): enormous	bottom

The reservoir's food web as a trophic pyramid. Each level eats the level below it. Arrows of matter and energy run upward; only a small fraction passes each step.

Criteria and constraints set by the town council — Criteria (what success looks like): (1) August Secchi depth of at least 1.5 m by the third summer; (2) no late-summer fish kills; (3) swimming and fishing stay open. Constraints (limits you must respect): (a) total cost no more than \$40,000 over three years; (b) no chemicals may be added, because the lake is a drinking-water source; (c) the reservoir cannot be drained; (d) the sewer repair stays in place.

Four options proposed at the town meeting

Options and the engineer's estimates (teaching dataset)

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

Option	What is done	Cost over 3 years	How fast it acts	Known side effects
A: Stock predatory fish	Release 20,000 young largemouth bass in year 1 and 10,000 in year 2	\$12,000	Bass need 2 to 3 years to grow large enough to eat many shiners	Fishing improves; bass also eat some zooplankton while small
B: Net out shiners	Hire a crew to net and remove about half the shiners each spring for three years	\$27,000 (\$9,000 per year)	Shiner numbers drop within weeks of each netting	Shiners breed back quickly if nothing eats them; nutrients leave the lake in the removed fish
C: Algaecide	Spray a copper-based algaecide twice each summer	\$18,000 (\$6,000 per year)	Algae die within days	Also kills zooplankton; dead algae sink and use up oxygen as they decay; copper is a chemical
D: Add zooplankton	Buy and release water fleas each spring	\$12,000 (\$4,000 per year)	Zooplankton rise for a few weeks	Shiners eat most of the added zooplankton within a month

Simulated estimates for teaching. Costs and timelines are invented to be realistic for a small reservoir.

Part A: Predict with the model

1. Use the pyramid to explain why the reservoir has so much algae even though it has a level of zooplankton that eats algae. Name the level that is out of balance and the arrow that is the problem.

Answer: The shiner level is far too large. Shiners eat zooplankton, so the zooplankton level stays small (15 per liter) and cannot graze the algae down. The problem arrow is shiners eating zooplankton; with almost no bass (2 per haul) nothing keeps the shiners in check, so the algae, fed by nutrients in the mud, go uneaten.

Why: The pyramid is inverted in the middle: a huge second-consumer level sits on a small first-consumer level. Students must connect the missing predator to the missing grazing.

Also acceptable: Accept 'too few bass' as the level out of balance if the student then explains the shiner and zooplankton links.

- Names shiners as the level out of balance
- Names the shiner-to-zooplankton feeding link as the problem
- Connects low zooplankton to high algae

2. For each option, use the pyramid to predict whether each level goes up, down or stays about the same after two to three years, and whether the change would be lasting or temporary. Write up, down or same in each cell.

Answer: Option A: shiners down, zooplankton up, algae down; lasting (bass reproduce and keep eating shiners). Option B: shiners down, zooplankton up, algae down during the three years; temporary (shiners breed back once netting stops, since nothing eats them). Option C: shiners same, zooplankton down, algae down right after each spray then back; temporary (and zooplankton loss slows any recovery). Option D: shiners same or up (more food), zooplankton same after a few weeks, algae same; temporary.

Why: Each prediction follows the pyramid arrows: A and B act on shiners, C acts on algae and zooplankton directly, D adds food for shiners.

Also acceptable: Accept 'down then up' for C's algae; accept 'slightly down' for B's algae if the student notes the rebound.

- Option A and B cascades correct (shiners down, zooplankton up, algae down)
- Option C recognized as acting on algae directly and harming zooplankton
- Option D recognized as feeding shiners
- Lasting only for A

Part B: Evaluate against the criteria and constraints

3. Complete the decision matrix. Any option that fails a constraint (a 'no' in either of the first two columns) is eliminated no matter its score. Score the three criteria from 0 (no) to 2 (yes), then total.

Answer: Option A: cost yes (\$12,000), no chemicals yes, clear water by year 3: 1 to 2 (bass need 2-3 years), avoids fish kills: 1 to 2, lasting: 2; total 4-6. Option B: cost yes (\$27,000), no chemicals yes, clear water: 2 during netting, fish kills: 1, lasting: 0; total 3-4. Option C: cost yes (\$18,000) but no chemicals NO, eliminated; if scored, clear water 1 (temporary), fish kills 0 (decay uses oxygen), lasting 0. Option D: cost yes, no chemicals yes, clear water 0, fish kills 0, lasting 0; total 0-1.

Why: Scores can vary by a point; the ranking should be A highest, then B, then D, with C eliminated by the chemical constraint.

Also acceptable: Accept A and B tied if the student argues B's clear water is faster; the lasting-effect column should still favor A.

- C marked as failing the no-chemicals constraint
- A ranks highest
- D ranks lowest among the allowed options
- Totals computed

4. Which option is eliminated by a constraint before scoring, and which constraint does it break? Explain why that option could also make the fish kills worse, using the word *decomposers*.

Answer: Option C is eliminated because it adds a chemical (copper algicide) to a drinking-water source, breaking constraint (b). It could also worsen fish kills: the sprayed algae die all at once and sink, and decomposers breaking down that mass of dead algae use up oxygen in the water, which is exactly what killed fish in the past.

Why: This links the chapter's decomposer idea to the oxygen problem described in the scenario.

Also acceptable: Accept the added point that killing zooplankton removes the lake's own algae grazers.

- Names Option C and the chemical constraint
- Explains that decomposers consuming dead algae use oxygen

Part C: Decide and justify

5. State your recommendation (one option or a combination that stays within the \$40,000 limit). Justify it with the trophic pyramid: trace the chain of direct and indirect effects from what you change to the algae, and explain why your choice should last. Give the total cost.

Answer: Model answer: Recommend Option A plus one year of Option B (total \$12,000 + \$9,000 = \$21,000, within the \$40,000 limit). Netting in year 1 cuts shiners quickly (direct effect on shiners), which lets zooplankton rise (direct effect of fewer shiners on their prey), and more zooplankton graze the algae down (indirect effect of the netting on algae, through the zooplankton). Meanwhile the stocked bass grow; by years 2 and 3 they eat shiners continuously, so the shiner level stays low after netting stops. The fix lasts because bass reproduce and keep the top of the pyramid in place, unlike netting alone. Option A alone (\$12,000) is also acceptable with the justification that it is lasting even though it is slower.

Why: Any recommendation of A, or A combined with some B, is strong. The justification must trace the cascade through the pyramid with direct and indirect labels and address permanence and cost.

Also acceptable: B alone for three years (\$27,000) earns partial credit if the student admits it is temporary and proposes stocking later. D is not a defensible choice.

- Recommendation stays within \$40,000 and avoids chemicals
- Traces the chain from the change to the algae with direct and indirect effects
- Explains why the effect should last
- Total cost stated

6. Plan the test. Name three measurements the town should make each August, say what values after year 3 would show success, and explain why the Secchi depth alone is not enough.

Answer: Measure each August: Secchi depth, algae cells per drop, zooplankton per liter, shiners and bass per net haul, and whether a fish kill occurred. Success after year 3: Secchi depth at or above 1.5 m, algae well below 1,500 cells per drop, zooplankton well above 15 per liter, shiners far below 150 per haul, bass well above 2 per haul, and no fish kill. Secchi depth alone could improve for other reasons (a cool, cloudy summer) and would not tell the town whether the food web changed; the fish and zooplankton counts show whether the fix is working for the reason predicted.

Why: A good test measures the mechanism, not only the outcome; this is the iterative-testing idea in the chapter's engineering strand.

Also acceptable: Accept a dissolved-oxygen measurement in August as one of the three.

- Three or more measurements named
- Success values stated relative to the 2025 data and the 1.5 m criterion
- Explains why Secchi depth alone is insufficient

7. Suppose that after two summers the shiners are down but the algae are still high. Name one thing the model may have left out, and describe one specific change you would make to your plan.

Answer: The model leaves out the nutrients stored in the bottom mud, which can keep feeding algae for years even with fewer grazers; it also leaves out other algae eaters, water temperature, and the possibility that the algae shift to kinds that zooplankton cannot eat. A specific change: add a measurement of nutrients released from the mud, and if they are high, add a year of netting (removing more nutrients in fish bodies) or extend the timeline before judging the fix; alternatively stock more bass to push zooplankton higher.

Why: The scenario itself names the mud nutrients; the strongest answers use it and propose a change that follows from it.

Also acceptable: Accept 'the bass are not eating enough shiners yet, so wait one more year and stock more' as a modification.

- Names a plausible missing factor
- Proposes one concrete modification tied to that factor

8. Explain why repairing the sewer line was necessary but not sufficient, and why any food-web fix would likely fail if the sewer were still leaking.

Answer: Repairing the sewer was necessary because it cut the supply of nutrients that let algae grow so fast; without that, any amount of grazing would be overwhelmed by new growth. It was not sufficient because the nutrients already in the mud and the unbalanced food web (many shiners, few zooplankton, few bass) still let algae dominate. If the sewer were still leaking, more zooplankton would eat more algae but the extra nutrients would grow algae back just as fast, so the pyramid fix would be fighting a constant new supply.

Why: This separates the nonliving input (nutrients) from the living structure (the pyramid); both must be addressed, which matches what scientists found in real lake restorations.

Also acceptable: Accept 'you have to fix the input and the web' with reasons for each.

- Explains why cutting nutrients was needed
- Explains why it was not enough (mud nutrients, food web unchanged)
- Explains why a web fix fails with a continuing nutrient supply

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Use of the trophic pyramid model	Predictions for all four options follow the arrows level by level, with direct and indirect effects correctly labeled and permanence explained.	Predictions mostly correct; one option's cascade is incomplete or one label is wrong.	Predictions given for some options without tracing the levels in between.	Predictions guessed or contradict the pyramid.
Evaluation against criteria and constraints	Matrix complete; the chemical option is eliminated by a constraint; scores are justified and totaled; ranking follows the scores.	Matrix complete with one scoring inconsistency; constraint handled correctly.	Matrix partly complete or the eliminated option is scored as if allowed.	No systematic comparison.
Decision and justification	A clear recommendation within budget, justified by a traced cascade to the algae, with cost and permanence addressed.	A sound recommendation with a partial cascade or a missing cost total.	A recommendation with a reason that does not use the model.	No recommendation or one that breaks a constraint.

Test plan and iteration	Names at least three August measurements with success values, explains why outcome alone is not enough, and proposes a specific modification tied to a named missing factor.	Three measurements with success values; the modification is general.	Measurements named without success values or without a modification.	No test plan.
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Teacher notes

The scenario is fictional and all numbers are simulated. It is modeled on real restorations of nutrient-polluted lakes, including the textbook's Lake Vesijärvi example, where published reviews credit cutting off sewage, removing plankton-eating fish (which also carried nutrients out of the lake) and stocking predatory fish, and where nutrients stored in sediments delayed recovery; do not teach the fictional numbers as a real case. The option set is designed so that one option (C) fails a constraint, one (D) fails on the model, one (B) is fast but temporary and one (A) is slow but lasting; most strong answers combine A with some B. Keep the chemistry of oxygen use by decomposers at the level of 'decomposers use oxygen as they break down dead algae'. The pyramid figure is drawn with shiners as a wide middle layer on purpose, to show the imbalance; remind students that a pyramid of stored energy is never inverted in the long run, but a count at one moment can be.

Scaffold offered to students: Follow the arrows one level at a time

To predict an option, write the four levels in a column: bass, shiners, zooplankton, algae. Mark the level the option changes first with a big arrow. Then move one level at a time: if a level goes down, the level it eats goes up (less eating) and the level that eats it goes down (less food). The first step is a direct effect; every step after that is indirect. Stop when you reach the algae.

Extension: Pitch it in one page

Write a one-page proposal to the town council for your recommendation. Include a labeled pyramid showing the lake now and the lake after your fix, a three-year budget, the August measurements you will report, and the single result that would make you change the plan. Then add a paragraph on one risk the model cannot predict, such as a warm summer, a new fish species arriving, or nutrients still stored in the mud, and how you would watch for it.