

Dry Creek Decides: Aquifer Cups and a Twenty-Year Water Plan

Investigation question: Which of three competing water-supply plans should the town of Dry Creek adopt so that its wells still work in twenty years, and how do storage, recharge and pumping rates decide the answer?

Data-driven decision

Groups of 4

2 sessions

Setup 10 · Activity 85 · Cleanup 10 min

MS-ESS3-1 · assesses

MS-ETS1-2 · assesses

MS-ESS2-4 · supports

Scientific purpose

In session one, students measure how much water a cup of gravel, sand and clay-rich soil can hold and how fast each lets water through, which gives them a hands-on sense of why some underground layers make good aquifers and others do not. In session two they use a simulated data set for a fictional valley town with three aquifer zones, a seasonal creek and growing demand, score three competing plans in a decision matrix against stated criteria and constraints, compute how long each plan's water lasts, and write a recommendation. The lab is the groundwater half of the lesson's standard and the engineering strand in one package.

Why this helps students with this chapter

Students can recite that groundwater is in the ground, but the Central Valley's sinking floor and the textbook's 'most groundwater is nonrenewable' only make sense once storage, recharge and pumping are separate numbers in their hands. The cups make porosity and permeability physical; the Dry Creek data make the sustainability test arithmetic; the decision matrix makes them weigh cost against the future the way a real water board must. Choosing between a cheap plan that mines ancient water and a dearer plan that balances the budget is the lesson's big idea as a decision.

Standards connections

MS-ESS3-1 (assesses, the groundwater part: uneven distribution from porous rock and recharge, and change through pumping): Students explain why three zones under one town hold and give up water so differently (sediment type, depth, past climate) and use recharge-versus-pumping arithmetic to show how human removal changes the supply. That is an evidence-based explanation of groundwater distribution shaped by past and current processes.

MS-ETS1-2 (assesses, evaluating competing design solutions with a systematic process): Students score three plans in a matrix against four criteria and three constraints, reject any plan that breaks a constraint, and justify a recommendation with the scores and the calculations, which is the systematic evaluation this PE describes.

MS-ESS2-4 (supports, infiltration as the source of recharge): Recharge is rain, snowmelt and creek water soaking into porous ground, the water cycle seen from below. This is a Grade 6 PE in the California sequence; the lab uses it as background and does not assess the whole cycle.

Roles (rotate each session)

- **Hydrologist:** Runs the aquifer cups in session one: fills, pours, times and reads the cylinder. In session two, explains what each zone's sediment means for storage and well yield.
- **Data analyst:** Does the recharge-versus-pumping arithmetic for each plan and checks the years-of-supply calculations.
- **Engineer:** Leads the decision matrix: makes sure every plan is scored on every criterion and that any constraint violation is marked before scores are added.
- **Council reporter:** Writes the group's recommendation in the recording sheet and presents it to the class as a two-minute briefing to the 'town council'.

Materials

Item	Quantity	Per	Note
Clear plastic cups (about 300 mL), marked with a 200 mL line	6	group	Three for the storage test, three with five small holes punched in the bottom for the drain test.
Pea gravel or aquarium gravel, dry	about 500 mL	group	
Coarse play sand, dry	about 500 mL	group	
Clay-rich garden soil or potting soil sifted of sticks, dry	about 500 mL	group	Garden soil that holds a ball when squeezed damp works best; dry it on a tray for a day before the lab.
Graduated cylinder or measuring cup (100 mL or 250 mL)	1	group	
Coffee filters (to line the holed cups)	3	group	
Catch cup or beaker and a timer	1 each	group	
Tray or tub to contain spills, paper towels	1	group	
Printed Dry Creek data sheet and decision matrix (in the recording sheet) and a calculator	1	student	

Estimated cost: 12 to 20 per class (an estimate; Estimate. A small bag of pea gravel (about \$5), play sand (about \$5) and garden soil (about \$4) serve the whole class and can be dried and reused; cups, filters and towels are classroom stock or about \$4.)

Safety

- Dry sand, soil and gravel raise dust; pour gently, keep the tray under the cups and do not blow on the materials. Students with asthma may wear a mask or take the data-analyst role.
- Garden soil can carry bacteria and fungi; no eating or drinking in the lab, wash hands afterward, and use potting soil instead of garden soil if anyone has a weak immune system.

- Water on the floor is a slip hazard; keep all pouring over the tray and wipe spills at once. Teacher punches the cup holes, not students; a heated nail is a burn hazard, so use a push pin where possible.
- Do not pour sand, gravel or soil down the sink; dry and reuse them or discard in the trash.

Teacher preparation and setup

1. Dry the three materials on trays for at least a day; damp material already holds water and throws off the storage test.
2. Mark the 200 mL line on each cup (pour 200 mL of water into a sample cup, mark it, and use it as a template) and punch five small holes in the bottom of three cups per group with a push pin or hot nail (teacher only).
3. Run the drain test yourself once so you know roughly how long your soil takes; some garden soils take more than five minutes, which is itself the result.
4. Print the Dry Creek data sheet and decision matrix; write the criteria and constraints on the board so the whole class scores the same way.

Investigation design

Independent variable	Session 1: sediment type (gravel, sand, clay-rich soil). Session 2: the water-supply plan (A, B or C)
Dependent variable	Session 1: water stored (mL) and time for 25 mL to drain (s). Session 2: years of supply, constraint checks and matrix scores
Controlled	Same 200 mL volume of each material, settled the same way; Same 100 mL pour and the same 25 mL endpoint in the drain test; Same town data, criteria, constraints and scoring guide for every group
Trials	One run of each cup per group; the class pools porosity and drain times. One matrix per group; recommendations are compared in the council briefing.
Comparison	Gravel versus sand versus clay-rich soil; Plan A versus Plan B versus Plan C.

Student procedure

1. Session 1, storage test. Fill one plain cup with dry gravel to the 200 mL line, tapping gently to settle it. Fill the graduated cylinder with a known volume of water. Pour slowly into the gravel until the water surface just reaches the top of the gravel. Record the volume of water that went in: that is the pore space. Repeat with sand and with the clay-rich soil in their own cups.
2. Compute porosity for each material: water added divided by 200 mL, times 100, as a percent. Record it in the cup table.
3. Drain test. Line each holed cup with a coffee filter and fill it to the 200 mL line with dry material. Hold it over the catch cup, pour 100 mL of water onto the surface all at once, and start the timer. Record how many seconds it takes for the first 25 mL to collect in the catch cup. Stop at 300 seconds and write 'more than 300 s' if it has not arrived; also note how much, if any, collected.
4. Discuss and record: which material stores the most water, which lets water through fastest, and which would make the best aquifer for a well. Match each material to a Dry Creek zone (gravel to Zone G, sand

to the sandstone of Zone S, soil to the clay of Zone C) and note what the match leaves out (depth and the clay seal above Zone S).

5. Session 2, read the data. Study the Dry Creek data sheet and the three plans. For each zone, compute the sustainable pumping limit (the recharge) and the years the usable storage would last at the plan's pumping rate using $\text{years} = \text{usable storage} \div (\text{pumping} - \text{recharge})$; if pumping is no larger than recharge, write 'no decline'.
6. Check constraints first. For each plan, mark whether it stays within the \$32 million budget, diverts no more than 3 million cubic meters a year from the creek, and pumps Zone C no faster than its wells can give. A plan that breaks a constraint is marked 'fails' and is not scored further.
7. Score the surviving plans on each criterion from 1 (poor) to 4 (excellent) using the matrix guide, add the scores, and note any criterion on which a plan scores 1. Discuss whether a low score on sustainability should outweigh a high total.
8. Write the recommendation: the plan you choose, the two numbers that most support it, the strongest objection to it, and one change that would make it better. The council reporter presents it to the class.

Expected observations

- Storage test: roughly 60 to 80 mL for 200 mL of gravel (30 to 40 percent), 55 to 75 mL for sand, and a similar or higher value for clay-rich soil, which surprises students who expect clay to hold little.
- Drain test: first 25 mL in a few seconds for gravel, 15 to 60 seconds for sand, and more than 300 seconds (often nothing at all) for the clay-rich soil.
- Calculations: Plan A drains Zone S in about 47 years and uses about 42 percent of it in 20 years; Plan B declines 1 Mm³/yr in normal years (20 Mm³, a third of Zone G) and 14 Mm³ in a two-year drought; Plan C gains about 1 Mm³/yr in normal years and loses about 4 Mm³ from Zone G in a two-year drought, because the backup wells supply 3 of the 7 Mm³.
- Matrix totals typically favor Plan C (around 12, at most 13 because its \$31 million cost scores 1) over Plan A (around 10, with a 1 on sustainability and on ground sinking) and Plan B (around 9 to 10).

Likely difficulties

- Students pour the storage-test water too fast and trap air, or read the cylinder before the water reaches the surface; pour slowly and read when the surface just glistens.
- The drain test for soil may never deliver 25 mL; students want to keep waiting. Cap at 300 seconds and treat 'did not drain' as the finding.
- The years-of-supply formula confuses students when recharge exceeds pumping; the recording sheet's 'no decline' option handles it, and the data analyst should check signs.
- Groups add matrix scores without checking constraints first, or let cost outweigh a sustainability score of 1; the engineer role and the 'any score of 1' row are there to force the discussion.
- Some students argue Plan A is fine because 47 years is 'a long time'; ask them to name who will be living in Dry Creek in year 48.

Structured debrief

1. Pool the cup data. Gravel and sand store similar amounts (often 30 to 40 percent) but gravel drains in seconds and sand in tens of seconds, while the clay-rich soil may store as much or more yet barely drains. Name the two ideas: porosity (how much) and permeability (how fast), and connect them to well yield in the data sheet.
2. Collect each group's recommendation. Most groups land on Plan C; some choose B for cost; a few defend A. Walk the arithmetic for A on the board ($400 \div 8.5 \approx 47$ years) and ask what happens in year 48, and what the town's grandchildren inherit: a dry, sunken valley or a working aquifer.
3. Make the sustainability test explicit: a zone is used sustainably when average pumping is no larger than recharge plus whatever is banked. Plan C passes in normal years ($7 \leq 8$); Plan B fails slightly ($9 > 8$); Plan A fails badly ($9 \gg 0.5$). Note that Zone S does get a little recharge, but at 0.5 Mm^3 a year refilling its 400 Mm^3 would take about 800 years, roughly ten human lifetimes, so its water is nonrenewable on a human timescale and any pumping much above 0.5 is unsustainable.
4. Connect to California. The Central Valley's water board problem is this lab with bigger numbers, and the 2014 law requires local plans to bring pumping into balance with recharge. Recharge basins that spread winter floodwater over gravel are a real tool there. Ask what Dry Creek's Plan C would need that the lab left out (land for the basin, flood years with water to spare, rules that farmers accept).

Recording sheet: what students fill in

Lab 3 recording sheet: Dry Creek decides

Session 1 asks a simple question with three cups: which material stores water, and which lets it flow?

Session 2 asks the town's question: three plans, one budget, twenty years. Keep the two parts connected: the cups are the zones under Dry Creek.

Session 1: aquifer cups

Material	Water added until full (mL)	Porosity (% of 200 mL)	Time for first 25 mL to drain (s)	Stores water? Flows to a well?	Dry Creek zone it stands for
Gravel					
Sand					
Clay-rich soil					

Dry Creek water data (teaching dataset)

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

Item	Zone G: river gravel, shallow, unconfined	Zone S: deep sandstone, under a clay seal	Zone C: clay-rich old lake beds	Dry Creek (surface water)
Usable stored water (Mm ³)	60	400	30	none in summer
Average yearly recharge (Mm ³ /yr)	5	0.5	0.5	winter flow 12
Recharge in a drought year (Mm ³ /yr)	2	0.5	0.3	winter flow 3
Most that wells can pump (Mm ³ /yr)	12	15	0.3	diversion limit 3
Depth to water (m)	20 to 60	300 to 500	10 to 40	surface
Age of the water	years to decades	more than 10,000 years	centuries	this winter
Ground sinks if overpumped?	slightly	yes: clay seal compacts	yes	no

Simulated data for a fictional town, invented for teaching. Volumes are in millions of cubic meters (Mm³); one Mm³ is about 400 Olympic swimming pools. Recharge values are long-term averages; drought years recharge less.

Demand and the three plans (teaching dataset)

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

Item	Plan A: Go deep	Plan B: Bank the winter	Plan C: Use less, bank, keep a backup
Town demand in 20 years (Mm ³ /yr)	9	9	7 after conservation (drip irrigation, lawn rules)
Main supply	4 deep wells in Zone S pump 9 Mm ³ /yr	Wells in Zone G pump 9 Mm ³ /yr	Wells in Zone G pump 7 Mm ³ /yr in normal years
Creek diversion	none	3 Mm ³ /yr of winter flow spread in a recharge basin, adding 3 to Zone G recharge in normal years (0 in drought years)	same recharge basin as Plan B
Drought backup	none needed; Zone S is unaffected by drought	none; keep pumping Zone G	2 small Zone S wells pump up to 3 Mm ³ /yr only in drought years, so Zone G wells pump 4
Cost (\$ millions)	18	28	31
Current demand today (Mm ³ /yr), for reference	6	6	6

Simulated plans for the fictional town of Dry Creek, invented for teaching; costs are totals for building and running each plan.

Criteria, constraints and the scoring guide — Constraints (must pass): budget no more than \$32 million; creek diversion no more than 3 Mm³/yr; Zone C pumping no more than 0.3 Mm³/yr. Criteria (score 1 to 4): (1) Meets demand for 20 years, including two drought years in a row. (2) Sustainable: average pumping from each zone no larger than that zone's recharge, so storage does not decline over 20 years; 4 = no decline, 3 = less than 10 percent decline, 2 = 10 to 30 percent, 1 = more than 30 percent. (3) Low risk of the ground sinking. (4) Cost: 4 = under \$20 million, 3 = \$20 to 25, 2 = \$25 to 30, 1 = over \$30.

Session 2: calculations

Quantity	Plan A	Plan B	Plan C
Zone pumped most, and its recharge in a normal year (with any banking)			
Normal-year change in that zone's storage per year (recharge – pumping)			
Years until usable storage is gone (storage ÷ yearly decline), or 'no decline'			
Storage change after 20 normal years (Mm ³) and as a percent			
Change in Zone G storage during two drought years in a row (Mm ³)			
Constraints: budget / diversion / Zone C (pass or fail)			

Decision matrix

Criterion	Plan A score (1-4)	Plan B score (1-4)	Plan C score (1-4)
1. Meets demand for 20 years, incl. two drought years			
2. Sustainable (storage does not decline)			
3. Low risk of the ground sinking			
4. Cost			
Total			
Any score of 1? (criterion number)			

- From the cups: which material stored the most water, which drained fastest, and which would you drill a well into? Use your numbers.

Answer: Group-specific. Typical: clay-rich soil or gravel stored the most (about 60 to 80 mL per 200 mL), gravel drained fastest (seconds), and the well should go into the gravel because it both stores water and releases it quickly; the soil stores water but will not give it up.

Why: The point is that storage and flow are different properties and a well needs both.

- Uses the group's own numbers
- Distinguishes storing from releasing water
- Chooses gravel (or sand) for the well with that reason

2. Our recommendation to the council: the plan, the two numbers that most support it, the strongest objection, and one change that would improve it.

Answer: Expected: Plan C. Supporting numbers: in a normal year pumping 7 is less than recharge 8 (5 plus 3 banked), so Zone G storage holds or grows by about 1 Mm^3 a year; in a two-year drought the Zone S backup supplies 3 of the 7, so Zone G is pumped 4 against recharge of 2 and loses only about 4 Mm^3 ; and the cost of \$31 million passes the budget. Strongest objection: it costs the most and depends on people cutting water use by about 20 percent. Improvement: add a rule that the Zone S backup wells run only when Zone G drops below a set level, or build the basin first and the wells later to spread the cost.

Why: Drought arithmetic for Plan C: Zone G recharge 2, no banking; demand 7, of which 3 comes from the Zone S backup, so Zone G is pumped 4; change = $2 - 4 = -2 \text{ Mm}^3$ per year, -4 over two years, with 6 Mm^3 taken from Zone S (storage 400, so a negligible share). If a group reads the backup as extra to 7 Mm^3 of Zone G pumping, they will get -5 per year (-10 over two years); accept that if stated, but point to the data-sheet cell. Accept Plan B with a clear argument that a 20 Mm^3 decline over 20 years is acceptable and the cost saving is worth it, or Plan A only if the student acknowledges the 47-year limit and subsidence and argues explicitly for the trade-off; a recommendation with no numbers does not earn full credit.

- Names a plan and passes all constraints
- Cites two correct numbers from the calculations
- States a genuine objection
- Proposes a specific improvement

Analysis questions: answer key

3. Plan A pumps $9 \text{ Mm}^3/\text{yr}$ from Zone S, which recharges $0.5 \text{ Mm}^3/\text{yr}$ and holds 400 Mm^3 . How many years until the usable storage is gone, and what fraction is used in 20 years? Show the calculation.

Answer: Yearly decline = $9 - 0.5 = 8.5 \text{ Mm}^3/\text{yr}$. Years until gone = $400 \div 8.5 \approx 47$ years. In 20 years: $20 \times 8.5 = 170 \text{ Mm}^3$, which is $170 \div 400 = 0.425$, about 42 percent of the usable storage.

Why: Checks the storage $\div$ (pumping – recharge) formula and the percent. The 20-year figure is what scores a 1 on sustainability (more than 30 percent decline).

Also acceptable: Accept 47 or 'about 47'; accept 42 or 43 percent.

4. In a normal year under Plan B, Zone G recharge is 5 plus 3 banked = 8 Mm^3 and pumping is 9. Compute the yearly change, the change over 20 normal years, and the change during two drought years in a row (recharge 2, no banking). Is Plan B sustainable by the scoring guide?

Answer: Normal year: $8 - 9 = -1 \text{ Mm}^3/\text{yr}$. Over 20 normal years: -20 Mm^3 , which is $20 \div 60 = 33$ percent of Zone G's usable storage. Two drought years: recharge 2, banking 0, pumping 9: $2 - 9 = -7$ per year, -14 Mm^3 over the two years. By the guide, a 33 percent decline is more than 30 percent, so Plan B scores 1 on sustainability (a student who argues that droughts are already in the average and scores it 2 for a 'typical' mix of years should show that reasoning).

Why: The small normal-year deficit looks harmless until it is multiplied by 20 and combined with a drought; that is the lesson of the Central Valley.

Also acceptable: Accept a sustainability score of 2 if the student explicitly treats 20 Mm^3 as roughly a third and argues the boundary; the calculation must be correct.

5. Explain why Zone S holds far more water than Zone G yet cannot be pumped sustainably at the town's demand, using the words recharge, storage and age of the water.

Answer: Zone S has huge storage (400 Mm^3) because its thick sandstone is porous and was filled during a wetter climate long ago; the water is more than 10,000 years old. But its recharge today is only $0.5 \text{ Mm}^3/\text{yr}$ because a clay seal and the dry climate let almost no new water in. Refilling 400 Mm^3 at 0.5 a year would take about 800 years, roughly ten human lifetimes, so Zone S's water is nonrenewable on a human timescale. Sustainable pumping is limited by recharge, not storage, so Zone S can give only about $0.5 \text{ Mm}^3/\text{yr}$ forever; pumping 9 is like spending savings that will not be replaced. Zone G stores far less but is refilled every year by the creek and rain, so it can supply several Mm^3/yr for as long as pumping stays under recharge.

Why: This is the fossil-water idea from the accuracy notes in arithmetic form; all three words should appear with the right meaning.

- Distinguishes storage from recharge
- Uses the water's age to explain the low recharge
- States that the sustainable rate is set by recharge

6. Use your cup results to explain why Zone C stores 30 Mm^3 but its wells can give only $0.3 \text{ Mm}^3/\text{yr}$, and why the ground above Zone C and Zone S can sink when they are overpumped.

Answer: In the cups the clay-rich soil held as much water as the gravel (high porosity) but let almost none drain (low permeability), because its pores are tiny and poorly connected. Zone C is the same: 30 Mm^3 sits in the clay, but water moves through it so slowly that wells get only a trickle ($0.3 \text{ Mm}^3/\text{yr}$). When water is pumped out of clay layers, or out of the sandstone beneath the clay seal, the water that was holding the clay grains apart is removed, the grains pack closer and the layer gets thinner, so the ground above sinks. Gravel grains already touch each other, so pumping Zone G barely changes the surface.

Why: Links the cup results to well yield and to subsidence; the Central Valley slide gives the real case.

- Explains the storage/flow difference with porosity and permeability
- Connects to Zone C's small well yield
- Explains sinking as compaction of fine-grained layers when water is removed

7. Plan A is the cheapest and scores well on cost and on surviving a drought. Give the strongest argument for choosing it anyway and the strongest argument against, and say which should win for a town planning for its grandchildren.

Answer: For: it is the cheapest by \$10 million or more, it needs no creek diversion or conservation rules, and because Zone S is deep and sealed, a drought does not touch it, so the taps never run short in the 20-year window. Against: it spends 42 percent of ancient water that will never be replaced on a human timescale, leaves the aquifer empty in about 47 years, and the clay seal above it will compact, so the ground sinks and canals, roads and the creek bed crack; the savings today become a far bigger bill later. For a town planning for its grandchildren the argument against should win, because the plan passes the problem to people who had no vote; a sustainable plan costs more now but still works in year 48.

Why: This is the engineering judgment the PE asks for: the cheapest plan that meets the criteria for 20 years is not the best if a criterion is scored 1. Credit a well-argued Plan A choice that accepts the trade-off openly.

- A genuine argument for Plan A using cost or drought resilience
- A genuine argument against using the 47-year limit or subsidence
- A reasoned verdict that refers to the future

8. The data show what geologic history put under Dry Creek: river gravel, deep sandstone filled in a wetter past, and old lake clay. Explain in two or three sentences how past processes made the three zones so different, and how the town's choice is a current process that will change them.

Answer: Rivers from the mountains spent thousands of years dumping gravel and sand in the valley, making Zone G porous and connected to the creek, so rain and snowmelt refill it every year. Far deeper, sandstone laid down long before was filled with water in a wetter climate more than 10,000 years ago and then sealed under clay, so Zone S holds a great deal of water that is barely being replaced. An old lake left fine clay, which holds water but will not give it up. The town's choice is a current process: pumping faster than recharge lowers the water table, can dry the creek in summer, compacts clay layers so the ground sinks, and shrinks the supply, so the map of where usable water is will change depending on which plan is chosen.

Why: This is the lab's statement of MS-ESS3-1: past processes made the distribution, current removal changes it.

- Names a past process for at least two zones
- Explains why that history sets each zone's storage or recharge
- Describes pumping as a current process with a specific effect

Individual evidence of learning

Each student submits their own cup table, calculations table, decision matrix and answers to q1 through q8. The calculations table and q3 to q5 are the evidence for the recharge-versus-pumping explanation (MS-ESS3-1); the matrix and q2 and q7 are the evidence for systematic evaluation of competing solutions (MS-ETS1-2).

Assessment criteria

Criterion	Proficient looks like
Porosity and permeability from the cups	Correctly computes porosity, records drain times, and distinguishes storing water from releasing it to a well, matching each material to a zone with a stated limitation.
Recharge versus pumping arithmetic	Computes yearly change and years of supply correctly for all three plans, including the 'no decline' case and the drought case.
Systematic evaluation	Checks all three constraints before scoring, scores every criterion for every surviving plan using the guide, and explains how a score of 1 was weighed.
Explanation of distribution and change	q5 and q8 explain the zones by sediment type, depth and past climate, and describe pumping as a current process that changes storage and the land surface.

Accessibility adaptations

- Provide the calculations table with Plan A already worked as an example for students who need more support, and a calculator for everyone; the formula is written on the sheet.
- Let students who need movement run the cups while others do the arithmetic, then switch for the matrix; the council briefing can be spoken rather than written for q2.
- Offer a labeled cross-section sketch of the three zones (from the slide 9 diagram) with the data sheet, and a glossary card for recharge, storage, porosity, permeability and subsidence in the student's home language.

- For students with dust or soil sensitivities, assign the data-analyst or engineer role and have them read the pooled cup data instead of handling material.

Low-cost alternative

Skip the drain cups and run only the storage test with three clear cups, or run the cups once as a teacher demonstration and give every group the class data. The decision matrix needs only the printed data sheet and a calculator, so session two costs nothing.

Model limitations

A cup of loose, dry material is not an aquifer under pressure: real sandstone is cemented, real recharge arrives over months, and a confined aquifer's clay seal and depth are not modeled by a cup of soil. The Dry Creek numbers are invented and simplified; real recharge varies year to year, real plans have environmental reviews, land costs and water rights, and real aquifers do not have a single 'usable storage' number. The scoring guide is one reasonable way to compare plans, not the only one. This activity has not been physically tested by the authors; the porosity and drain-time ranges in expectedObservations are estimates for typical pea gravel, play sand and garden soil.

Teacher notes

Insist on the order: constraints first, then scores. Every plan here passes the constraints, so the matrix decides, but the habit matters for W9. Expected matrix: Plan A about 4/1/1/4 (total 10), Plan B about 3/1/3/2 (total 9) or 3/2/3/2 (10), Plan C about 4/4/3/1 (total 12); the exact numbers will vary and the discussion of the sustainability 1 is the point. If groups finish early, ask them to design a Plan D that combines the best parts of B and C (for example conservation plus the basin without the backup wells, about \$22 million) and to find its weakness (a two-year drought with no backup). Reuse the gravel and sand after drying; the soil is best discarded.