

Where Should Pine Ridge Drill? A Geothermal Data Decision

Investigation question: Using temperature-with-depth data from four test holes, which site should a small town choose for a geothermal power plant, and what does each site's data reveal about how energy moves up through the crust?

Data-driven decision

Groups of 4

1 session

Setup 5 · Activity 42 · Cleanup 3 min

MS-ESS2-1 · practice

MS-ESS3-1 · supports

MS-ETS1-2 · practice

Name _____

Group _____

Date _____

Your role today

- ☐ **Data analyst:** Computes the temperature change and gradient for each site and the depth needed to reach 120 °C, and checks the arithmetic with the calculator.
- ☐ **Grapher:** Plots all four profiles on one graph in four colors, labels each line, and marks the 120 °C level.
- ☐ **Cost accountant:** Fills in the decision matrix: drilling cost, power-line cost, total cost, and whether each site meets every criterion and constraint.
- ☐ **Spokesperson:** Leads the group to a decision, drafts the recommendation, and presents it to the class with the strongest objection and the group's reply.

Safety

- No hazards; this is a paper-and-calculator investigation. Remind students that real boreholes and geothermal fluids are dangerous and that the scenario is a model.

Procedure

1. Read the scenario and the site notes as a group. Underline the one criterion (fluid at 120 °C or hotter), the two constraints (no deeper than 2,500 m; total cost no more than \$5.0 million) and the two cost rates (drilling \$1,000 per meter; power line \$100,000 per kilometer).
2. The grapher plots temperature against depth for all four sites on one grid, one color per site, and draws a horizontal line at 120 °C. Everyone copies the finished graph.
3. The data analyst computes, for each site, the temperature change from 0 m to 2,000 m, then the gradient in °C per km (divide the change by 2 km). Record both in the gradient table.
4. For each site with a straight-line profile, use the gradient to find the depth at which the rock reaches 120 °C: subtract the surface temperature from 120, divide by the gradient, and convert to meters. For Site C, read the depth from the graph instead, because its line bends.
5. The cost accountant computes drilling cost (depth to 120 °C in meters × \$1,000) and power-line cost (distance to town × \$100,000 per km) and adds them. Mark whether each site meets the criterion and both constraints.

6. Discuss the site notes. Which sites already have water in the rock? Which would need water pumped in? Record this in the matrix as a risk.
7. Decide on a site. Write the recommendation in the box: the site, the three numbers that support it (depth, temperature, total cost), and one reason the science of the site makes it reliable.
8. Write the strongest objection a town council member could raise and your group's reply.
9. Present for one minute to another group or the class. Then answer the analysis questions individually.

Record your observations

Lab 3 recording sheet: Where should Pine Ridge drill?

The scenario (a teaching case; the town and the numbers are invented) — Pine Ridge is a small town in the northern California mountains that wants to build a small geothermal power plant. The plant's turbines need underground fluid at **120 °C or hotter**. The town can afford to drill **no deeper than 2,500 m** and has a **total budget of \$5.0 million** for the well plus the power line to town. Drilling costs **\$1,000 per meter**; the power line costs **\$100,000 per kilometer**. Engineers drilled a 2,000 m test hole at four candidate sites and measured the rock temperature every 500 m.

Borehole temperatures at the four candidate sites (teaching dataset)

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

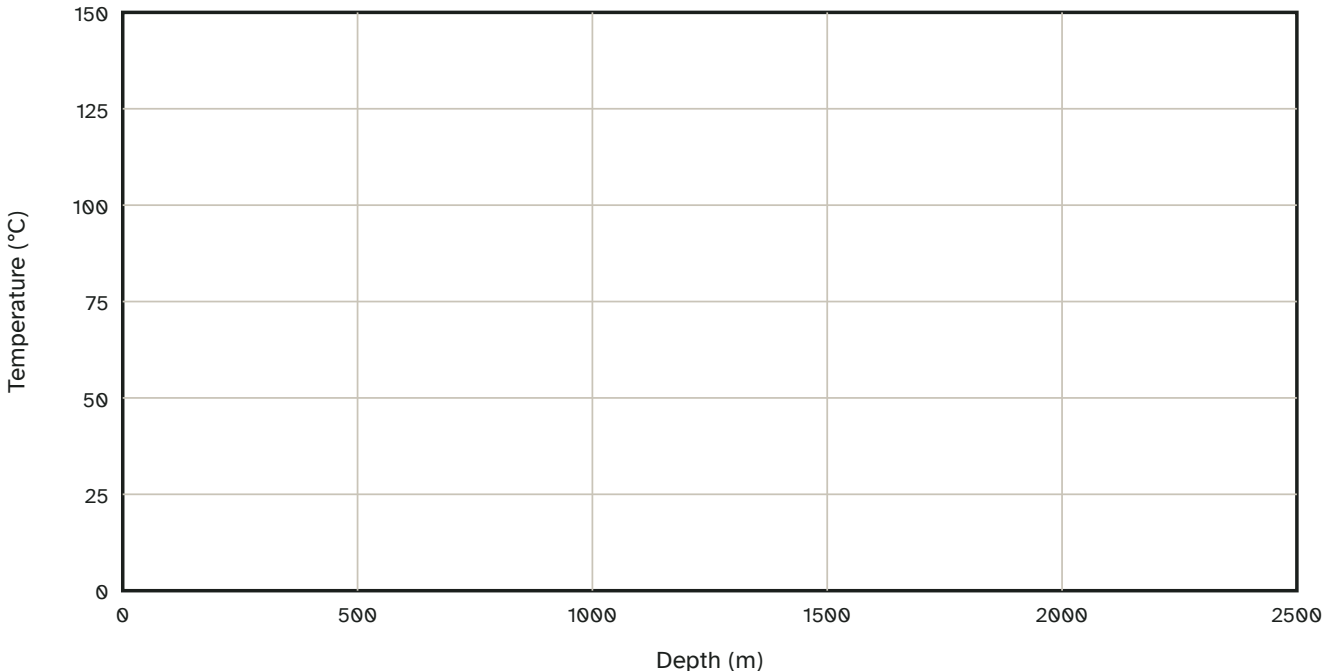
Depth (m)	Site A: valley basin (°C)	Site B: near a young volcanic field (°C)	Site C: hot-spring area, cracked rock (°C)	Site D: coastal plain (°C)
0	15	14	16	17
500	27	45	70	30
1000	40	76	118	44
1500	52	106	126	57
2000	65	137	131	70

Simulated data for teaching. The gradients are realistic for the settings described; the sites are invented.

Site notes from the field team

Site	Distance to town (km)	Water in the rock	Other notes
A	5	Plenty, in a cool shallow aquifer	Flat farmland; easy road access
B	30	Very little; water would have to be pumped in	Lava flows about 10,000 years old nearby
C	12	Plenty; hot springs at the surface bubble at 60 °C	Rock is heavily cracked; steam seen on cold mornings
D	3	Plenty, cool groundwater	Soft sediment; drilling is easy

Temperature versus depth at the four sites



Gradient and depth calculations

Site	Temperature at 0 m (°C)	Temperature at 2,000 m (°C)	Change (°C)	Gradient (°C per km) = change ÷ 2	Depth to reach 120 °C (m)	Is the line straight or does it bend?
A						
B						
C						
D						

Decision matrix

Site	Reaches 120 °C within 2,500 m? (yes/no)	Drilling cost (\$)	Power-line cost (\$)	Total cost (\$)	Under \$5.0 million? (yes/no)	Water risk (low/high)
A						
B						
C						
D						

1. Our recommendation: which site, and the three numbers (depth to 120 °C, temperature available, total cost) that support it. Add one sentence about why the science of this site makes it reliable.

2. The strongest objection a council member could raise, and your group's reply.

Analysis questions

3. Compute the gradient for Site A and Site B in °C per km. Show the subtraction and the division. Which site is losing energy from the interior faster, and how do you know?

4. At Site B, how deep would the town have to drill to reach 120 °C, and how deep to reach 150 °C? Show the calculation for each and give the drilling cost for the 120 °C well.

5. Site C's line climbs steeply and then flattens, while the other three are nearly straight. Explain what is happening to energy in the rock at each kind of site, using the words conduction and convection.

- 6.** A classmate argues for Site B because it is the hottest at 2,000 m. Using the criterion, both constraints and the site notes, explain whether that argument holds up.

- 7.** Every site gets warmer with depth, even the ones far from any volcano. Where is that energy coming from, and how is it reaching the surface at Site A?

- 8.** Before the town spends \$5 million, what one extra measurement or test hole would you ask the engineers for, and what result would change your recommendation?
