Land and people : Finding a Balance

Cape Cod

U.S. Department of the Interior
U.S. Geological Survey

The Cape Cod project in this curriculum packet asks students to consider the following Focus Question: Cape Cod has a serious problem with its ground water. During more than six decades, the activities at the Massachusetts Military Reservation (MMR) — formerly known as Camp Edwards, then Otis Air Force Base — on the Upper Cape have resulted in contamination of billions of gallons of underground water. (The Upper Cape is the western part of Cape Cod, including the following towns: Bourne, Sandwich, Barnstable, Mashpee, and Falmouth.)

You and your group are members of a blue-ribbon panel that has been formed to present a plan for providing safe, drinkable water to the Upper Cape for the next 10 years. You know of the contamination problem with the underground water supply. You also know how many Cape Cod residents will require water; your panel has been given data that describe the predicted increase in the region's population. Now, you and the members of your panel must figure out how the Upper Cape will meet its need for safe ground water in spite of the vulnerability of its water supply to contamination.

To develop an answer to this complex question, students will:

- learn about how Cape Cod's unique geology makes the ground-water supply vulnerable to contamination,
- create a working model of an aquifer, and
- discover how hydrogeologists gather data to describe the composition and movement of contaminated ground-water plumes.

At the end of this project, students should produce a presentation or paper to share with the class. Their presentation will discuss what they believe will be western Cape Cod's ground-water needs for the next decade, how well the existing water supply will meet those needs, and what other sources of uncontaminated ground water exist. Students will use what they have learned about how geology, water use, and wastewater disposal interact to develop a water-use plan. They will support their plan for supplying the area with safe, drinkable water with the information they received in the Student Packet, their understanding of the availability of ground water and human responsibility for maintaining its quality, and the lessons they learned as they completed the three activities in this packet.

An excerpt from Seth Rolbein's book, "The Enemy Within: The Struggle to Clean Up Cape Cod's Military Superfund Site," is included to demonstrate to your students that these environmental problems involve real people and real concerns. It is reprinted here with the permission of the Association for the Preservation of Cape Cod, a local environmental organization, and does not imply an endorsement of Rolbein's book by the U.S. Geological Survey.

Activity 1
A Model Aquifer

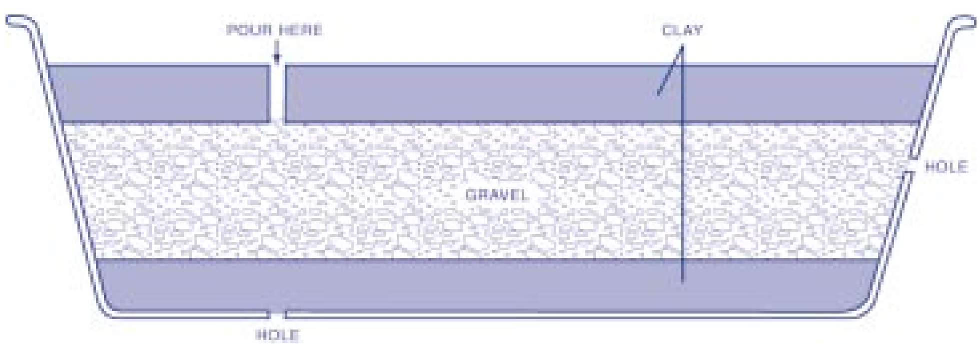
Purpose

This activity will help students understand how Cape Cod's ground-water system is unique and how contamination spreads easily underground. To do so, students will build a model of an aquifer. They will "recharge" the aquifer by pouring water into designated areas in the model and collecting water from holes they have made in the box holding the model. By doing this activity, students will determine how water moves through the aquifer and which materials make the "best" aquifer.

Materials

Each group of students will need:

- a clear rectangular 3-gallon-sized, plastic box or tub. Use the longest box you can find,
- potter's clay or natural clay soil,
- sand,
- gravel,



Model aquifer (Activity 1)

- measuring scoop made of a plastic gallon milk jug with the top cut off,
- graduated cylinder,
- two pie plates or petri dishes for catching water that flows out of the aquifer,
- a ten-penny nail for making holes in boxes,
- water, and
- a copy of the illustration of the model aquifer.

PROCEDURE

1. Introduce students to the diagram of the aquifer. Tell students that they will be working in groups to build model aquifers. Explain that different groups will be using different mixes of materials in their aquifers. Some will be using all sand; some will be using all gravel; some will be using a mix of sand and gravel.

2. Instruct students to punch holes in the plastic tub. Holes should be no smaller than 1 mm and no larger than 2 mm.

3. Have students measure out the different aquifer materials using the measuring scoop. Make sure each group uses the same volume of material — sand, gravel, or half and half — for the aquifer. Have the students who are using the half-sand half-gravel mixture prepare the mixture before measuring it or packing the mixture into the aquifer.

4. Students should then pack the tubs with the "aquifer" materials. The bottom layer of clay should be very thin — 2 mm — and well packed. Students should then add the aquifer material — 2-3 scoops, depending on the size of the tub. The upper layer of clay — 1-2 cm thick — should also be well packed.

5. The next step is to elevate the tub or place it on the corner of a table so the holes where water will emerge are accessible. The tub could be elevated with coffee cans or blocks, or placed diagonally on a table corner. Students should position the two pie plates or petri dishes to catch the water that comes out of each hole.

6. To observe how the aquifer model works, students should pour water in the hole in the clay at the top, 10 mL at a time, until drops appear at the holes. After drops appear, students should pour in one final graduated cylinder full of water. Students should record the amount of water that is poured into the model. In the pie plates or petri dishes, they will collect the water that comes out of each hole, then measure the amount of water in an empty graduated cylinder.

7. When students have finished pouring water into their aquifer models, gather the class together. Have the students in different groups compare the water-holding capabilities of different materials.

8. Refer students to the section of the Student Packet that explains porosity and permeability. Review these concepts. Then hold a general discussion of what students expected to discover and what actually happened. Students are likely to be surprised to find that even a thin layer of impermeable material will not allow water through.

EXTENSION

1. Describe how a town built on top of this model could access and use the water in the aquifer for its water supply.

2. Invite a local well driller to class to discuss information related to local aquifers, drilling depth, and costs.

Activity 2
Cleaning Up A Contaminated Aquifer

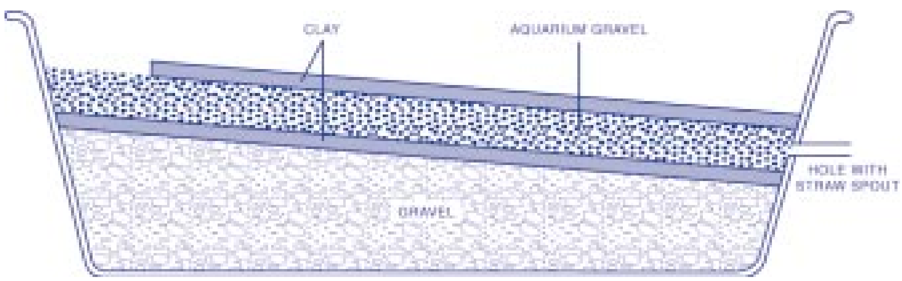
PURPOSE

Students will discover that once an aquifer is contaminated, cleaning it up is a long and difficult process.

MATERIALS

Each group of students will need:

- modeling or potter's clay,
- white aquarium gravel,
- gravel,
- food coloring,
- graduated cylinder,
- 2-3-inch-long eyedropper,
- a clear rectangular gallon-sized plastic box or tub. Use the longest box you can find,
- small drinking straw,
- spray pump from a household cleaner bottle,
- water, and
- a copy of the illustration of the "contaminated" aquifer.



Contaminated aquifer (Activity 2).

Procedure

1. Before beginning this activity, ask students the following questions:

- How does an aquifer get recharged? Where does the water come from?
- How does an aquifer become contaminated?
- How might an aquifer get cleaned up once it has been contaminated?

Record their answers to these questions and refer to their answers after the activity is completed.

2. Students will build a model of an aquifer as illustrated in the diagram. (Students will notice that this aquifer looks different than the one they built in Activity 1. Explain that this model's slope simulates how ground water moves through the Cape Cod aquifer and shows the water-table slopes toward the sea.) They will "contaminate" this aquifer model with food coloring and then try to clean up the spill.

3. Have students fill the plastic box with clay and two kinds of gravel. Both clay layers should be well sealed against the sides of the plastic box.

4. Use an eyedropper pushed into the aquarium gravel to place 10 drops of food coloring deep into the aquifer to simulate underground leakage.

5. Have students slowly pour 50 mL of water on the gravel recharge area and collect it as it runs out of the straw. Repeat this process until all food coloring is washed out and the water is clear. (Note — be sure to use white gravel. If the gravel is colored, then students might think the color is coming from the gravel.) Collecting the liquid in white paper cups makes it easier for students to see faint coloration. Students may wish to transfer a portion of the liquid to a series of test tubes; looking down the length of the tubes will help students to see faint colors easily.

6. Have students record the number of flushings required for the water to run clear.

7. After the aquifer model has been flushed clean, have students use a clay plug to block the hole that had the straw spout in it. They should then recontaminate the model in two places: at the surface and at the same depth as they did before. Again, have them contaminate the aquifer using ten drops of food coloring. This time, however, have them use two different colors so they may track the effects of contamination at different levels.

8. Students should observe how the contamination spreads in the aquifer from the two different sources. Ask them to think about what might be the sources of contamination at the surface and at depth. Refer them to the sources of contamination at the MMR and at other places on Cape Cod.

9. Ask students "Could this contamination be cleaned out of the aquifer by drilling a well and pumping it out?" Have them discuss why they believe pumping will or will not draw the contamination out of the aquifer.

10. Students will try to pump the contamination out of the aquifer. They should begin by poking a hole in the clay in the center of the aquifer. Insert a straw 1-2 inches into the aquarium gravel to simulate a well. Place a spray pump (from a household cleaner bottle) into the straw and then pump the contamination from the aquifer. Students should record how well (and whether) pumping is able to clean up contamination. How many times did they have to pump to clean up the well?

11. Have students discuss which clean up method worked best, flushing or pumping. What would they do to improve the effectiveness of each method? Which method do they think works best on surface contamination? Which works best on contamination at depth?

Activity 3
Predicting the Path of Ground-Water Contamination

Purpose

In this activity, students will use different kinds of geologic information to predict the path of ground-water contamination from several toxic waste sources on the MMR. Once they have drawn possible plume paths, students will receive the actual contaminant plume traces for comparison.

Materials

Each group of students will need:

- map of MMR and water table configuration on March 23-25, 1993,
- map of surficial geology of area with location of hydrogeologic sections and explanation,
- figure showing hydrogeologic sections with explanations,
- map showing contaminant plumes at MMR,
- tracing paper, and
- colored pencils.

Procedure

1. Begin by defining the water table for the students. Explain that about half of the water that falls on the Cape Cod landscape — in the form of rain — or snow — percolates into the ground. It gathers in the saturated zone, where all the pores and crevices of the rock and soil are filled with water. The top of this zone is the water table. If one were to dig a well that just penetrates the top of the saturated zone, the water table would be the level at which water stands in the well.

2. Provide students with copies of the water-table map. As a class, have them identify the highest elevation of the water table and the lowest elevation.

Explain that the contours on the map indicate the surface of the aquifer, or the water table.

3. Ask students what direction(s) they think water is moving in the aquifer. (Water moves down the water-table slope in the aquifer. The MMR sits atop a round hill at the highest point of the water table.) To answer this question, ask them to remember how water moved in their model aquifers in Activities 1 and 2.

4. Now have students look at the hydrogeologic map and the sections. Explain that the sections are vertical slices that represent the distribution of rocks and sediments underlying the surface. These sections were constructed using materials brought to the surface during well drilling.

5. When you are confident students understand the information provided by the geologic map and sections, ask them to predict what kind of materials make up the aquifer in this region. To make this prediction, students can refer to the sections.

6. Have students locate the four major contamination sites on the water-table map. Then, ask them to use the water-table contour map and the geologic information to predict the path of contamination movement. Remind the students to think about the kinds of sediments and rocks that are likely to be permeable and that are likely to be impermeable.

7. Have students place the tracing paper on top of the water-table contour map. Then have them sketch the paths they predict the contamination will take on the tracing paper.

8. When students have finished drawing what they believe will be the path of contamination movement on the tracing paper, have them show each other what they drew. Ask students to explain why they believe the contamination will follow the path they drew.

9. Distribute the map that shows the plumes. Have students compare the contamination paths they drew to the actual plumes. Point out that these maps were developed by geologists who sank a large number of test wells into the aquifer to measure the contamination levels in the ground water. Lead students in a discussion of how their predictions could have been used by geologists trying to decide where to put their initial test wells.

Extension

Since 1973, the MMR has been used primarily by the Massachusetts National Guard and the U.S. Coast Guard. In 1986, the National Guard Bureau's Installation Restoration Program (IRP) began investigating the contaminant plumes related to hazardous materials at the MMR. Since 1994, the IRP has published fact sheets that describe the history, size, and risks caused by each plume and what the IRP proposes to do about it. Call the IRP office at (508) 968-4678 to request copies of the 11 fact sheets published in 1994 and any others published since that time. Distribute copies of the IRP's Plume Response Fact Sheets to students as they answer these extension questions.

1. Are any of the local ponds in danger of contamination?

2. Are any of the town water supplies in danger of contamination?

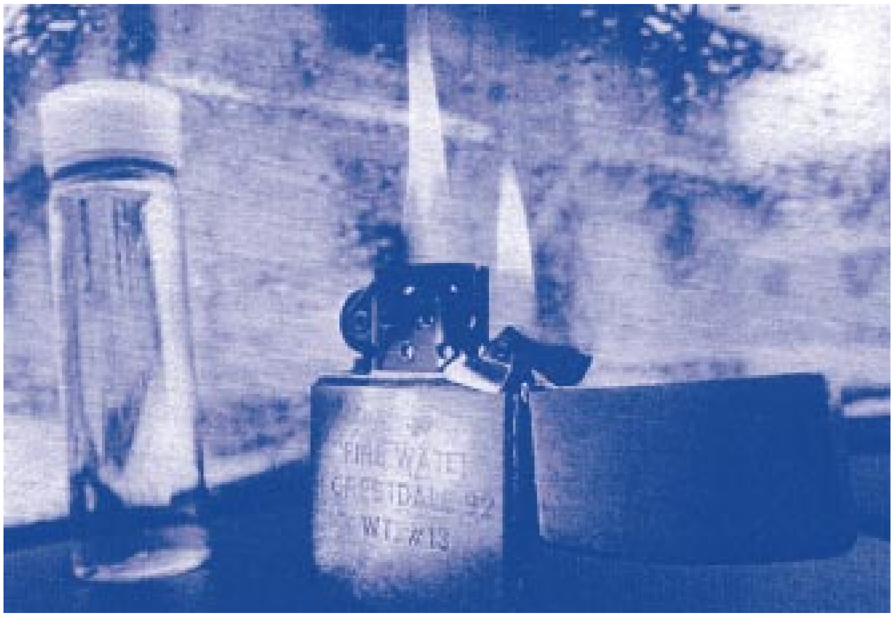
3. How can the movement of the contaminant plumes be slowed?

4. Where would students put in wells to remove contamination?

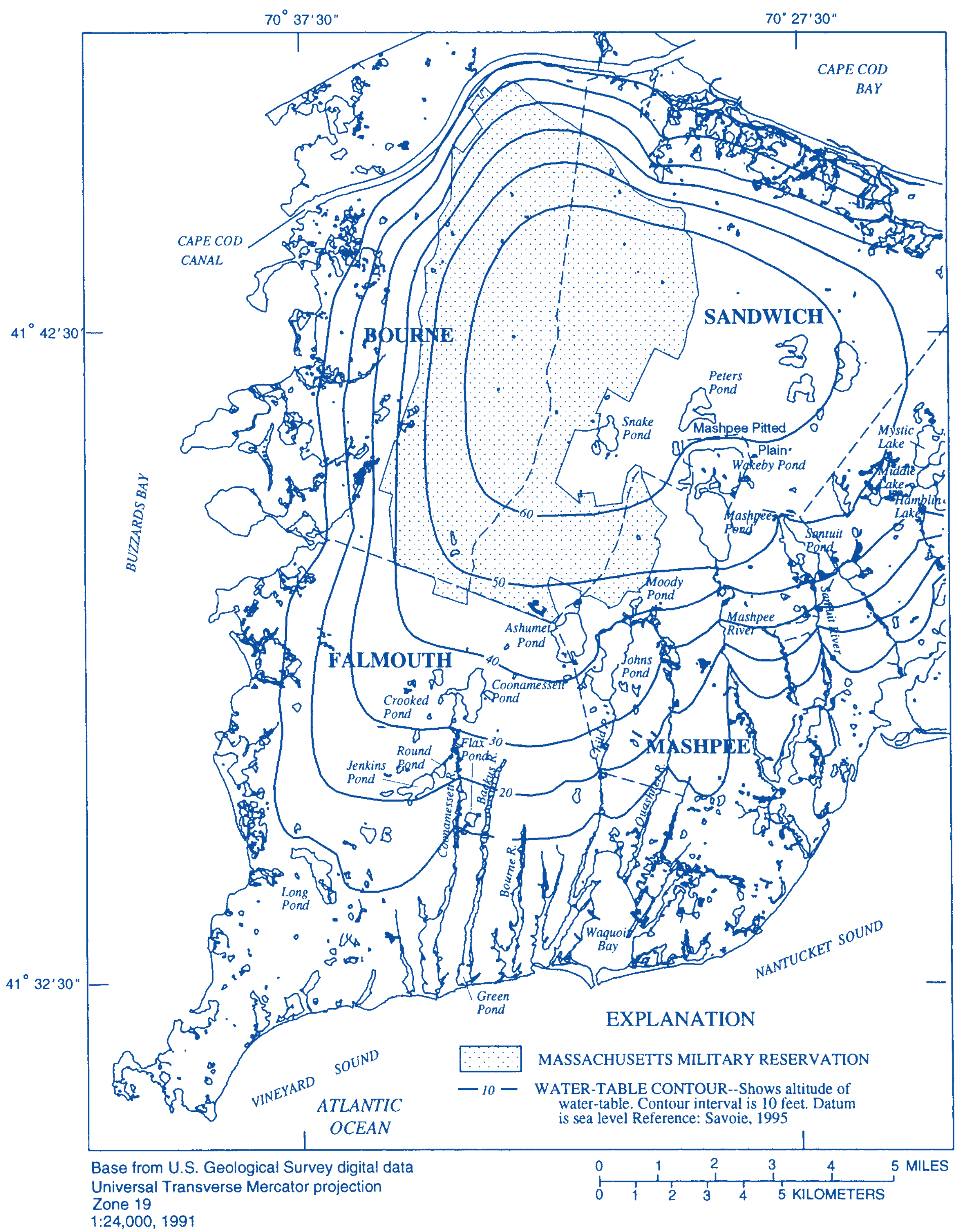
5. How else could the contaminated ground water be cleaned up?

6. Where would it be safe to drill wells for drinking water?

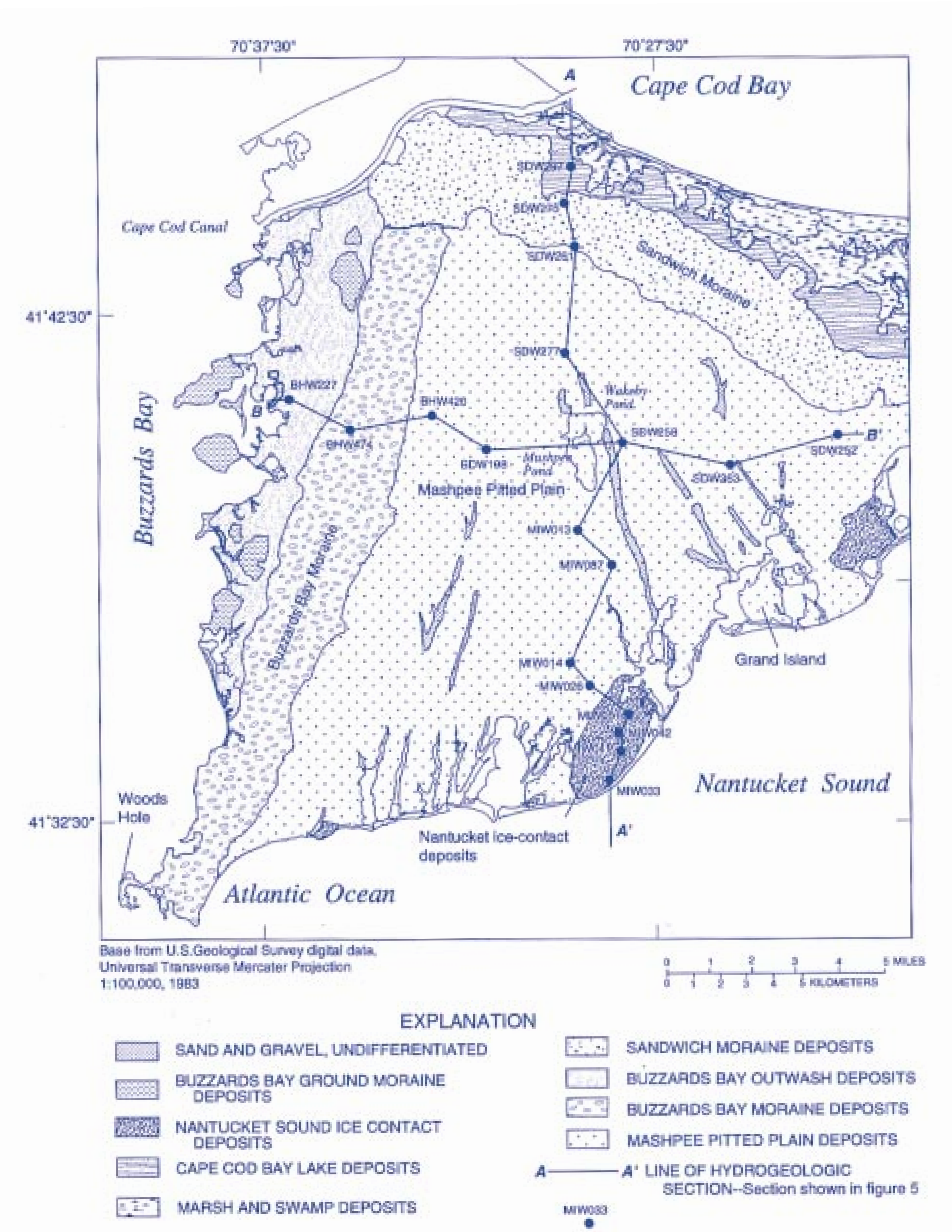
Note: In 1996, the U.S. Air Force's Center for Environmental Excellence assumed responsibility for containment, cleanup, and remediation of contaminated ground water within and emanating beyond the boundaries of the MMR.



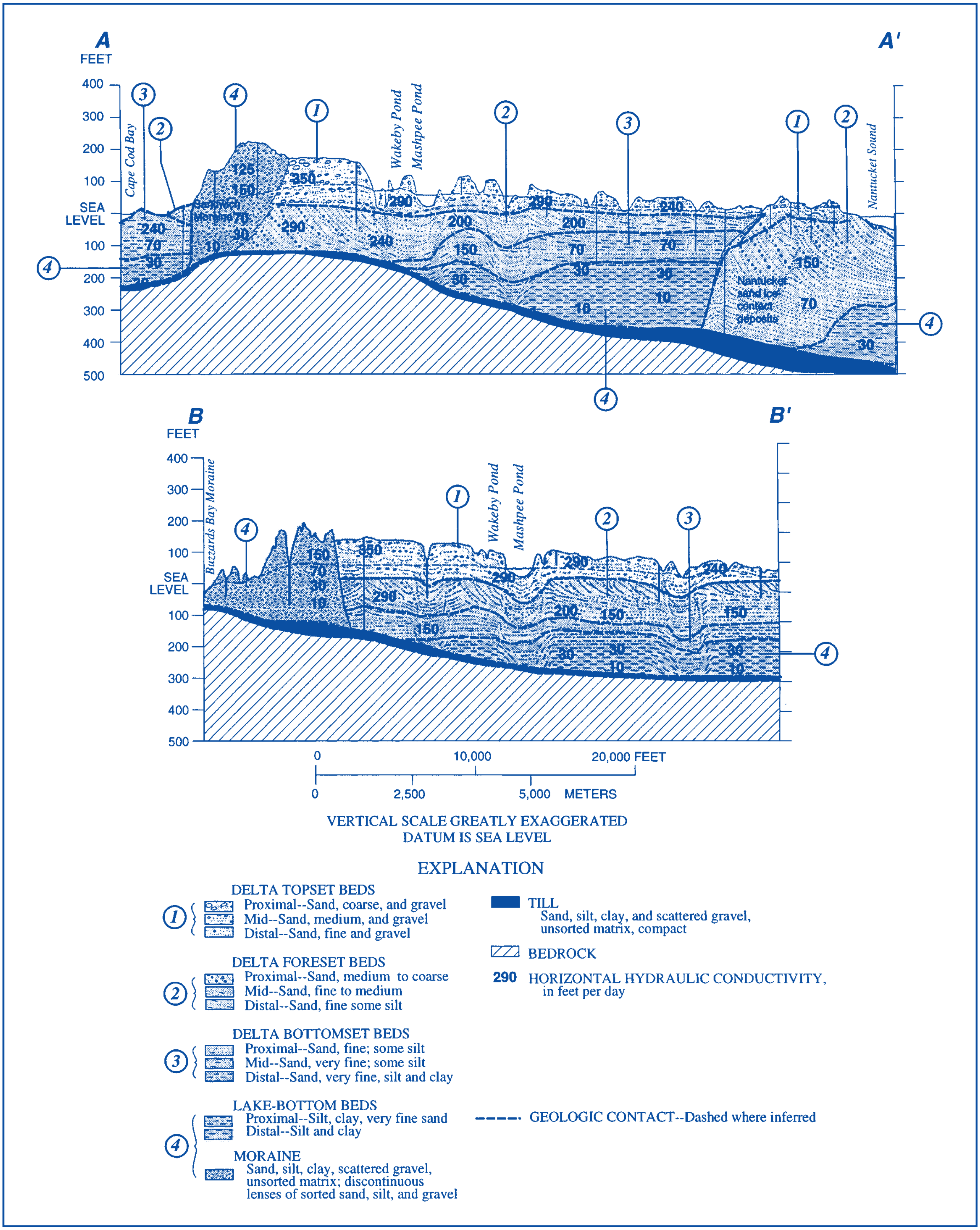
Firewater: a ground-water sample from one site on the MMR contained enough jet fuel to burn.



Location of Massachusetts Military Reservation and water-table configuration on March 23-25, 1993 (Masterson and others, 1996).



Surficial geology and lines of hydrogeologic sections, western Cape Cod, Massachusetts (Masterson and others, 1996).



Hydrogeologic sections A-A' and B-B' showing glacial drift of western Cape Cod, Massachusetts (Masterson and others, 1996).

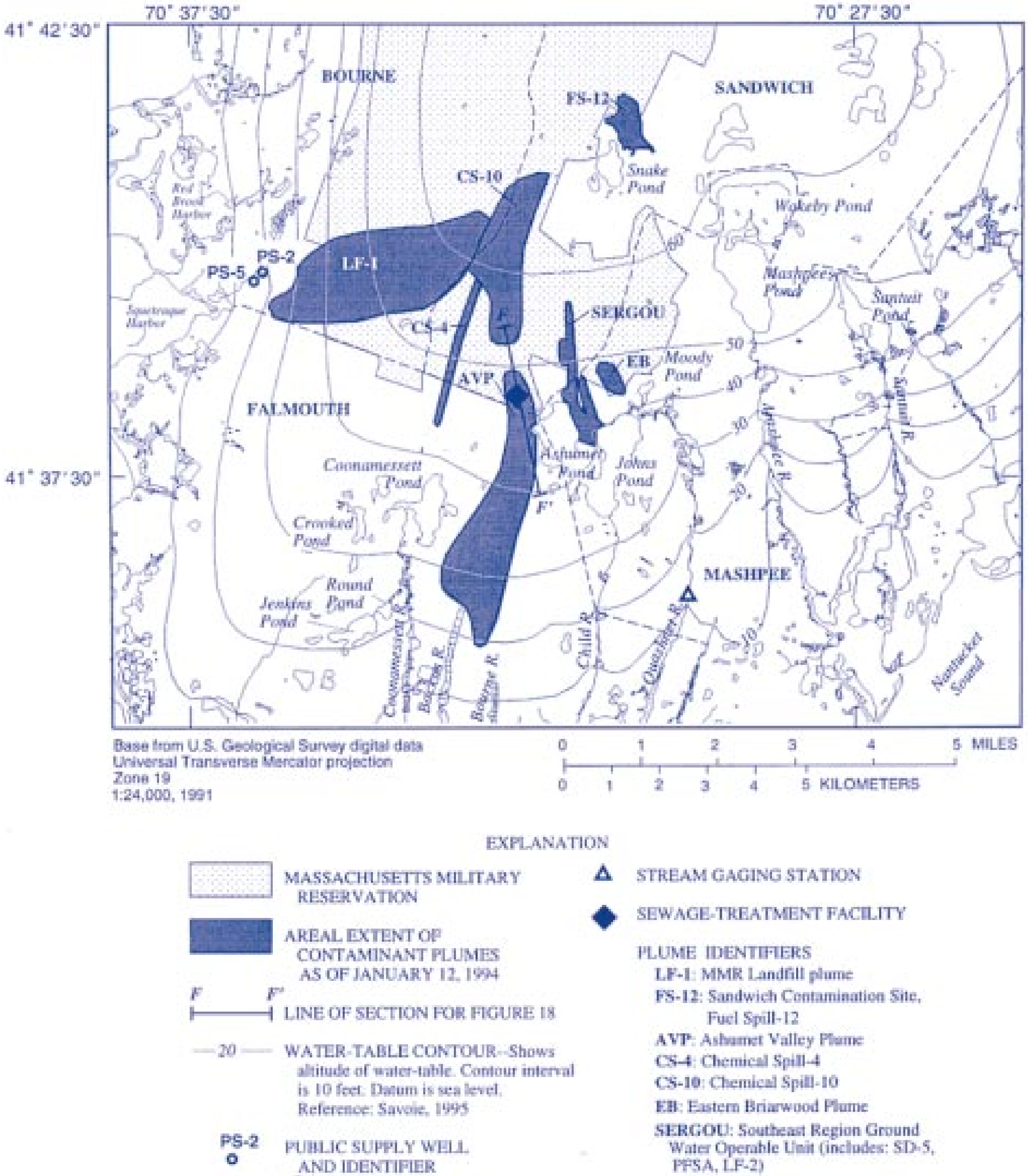


Figure 2. Location of contaminant plumes at Massachusetts Military Reservation, western Cape Cod, Massachusetts.

(Masterson and others, 1996).

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