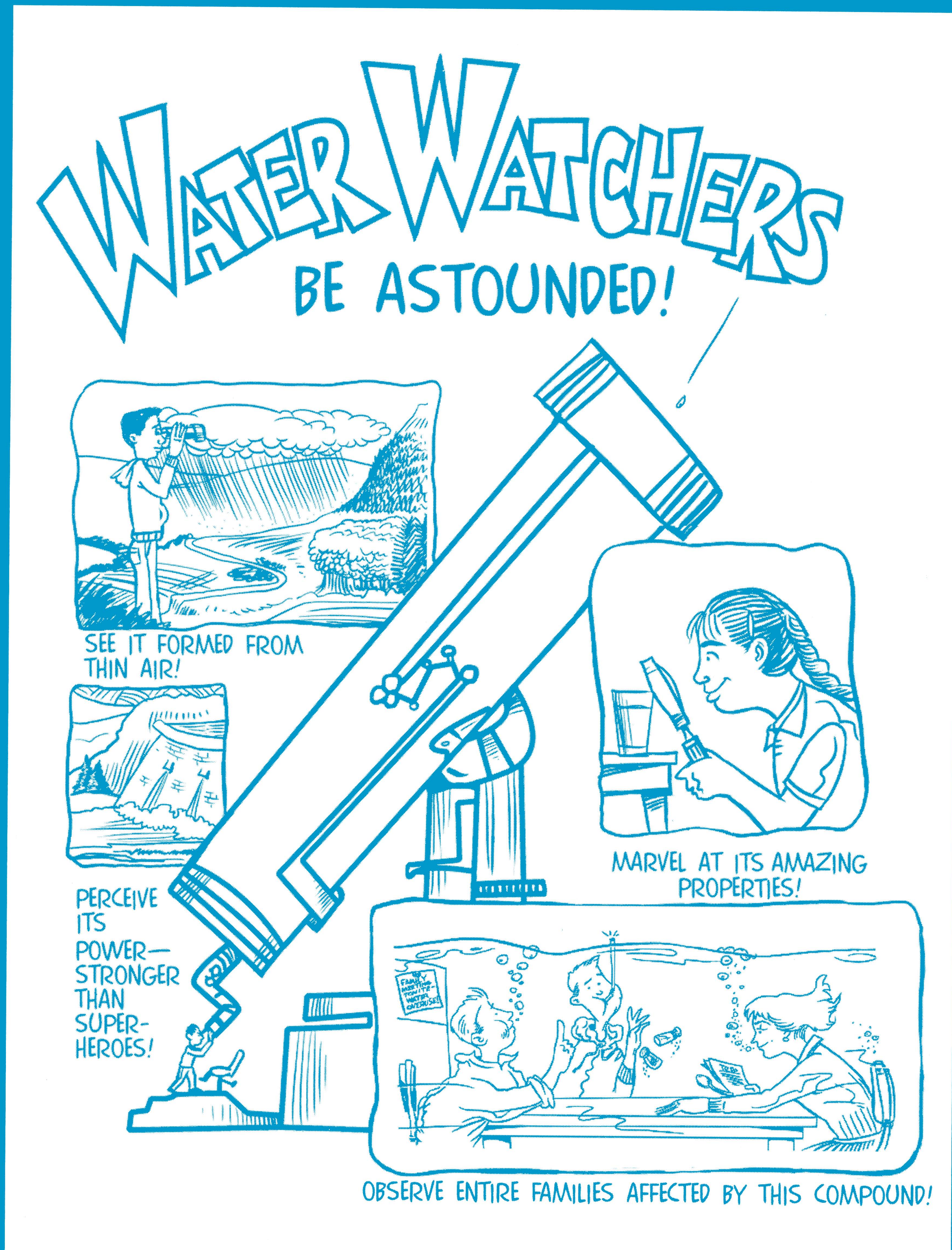
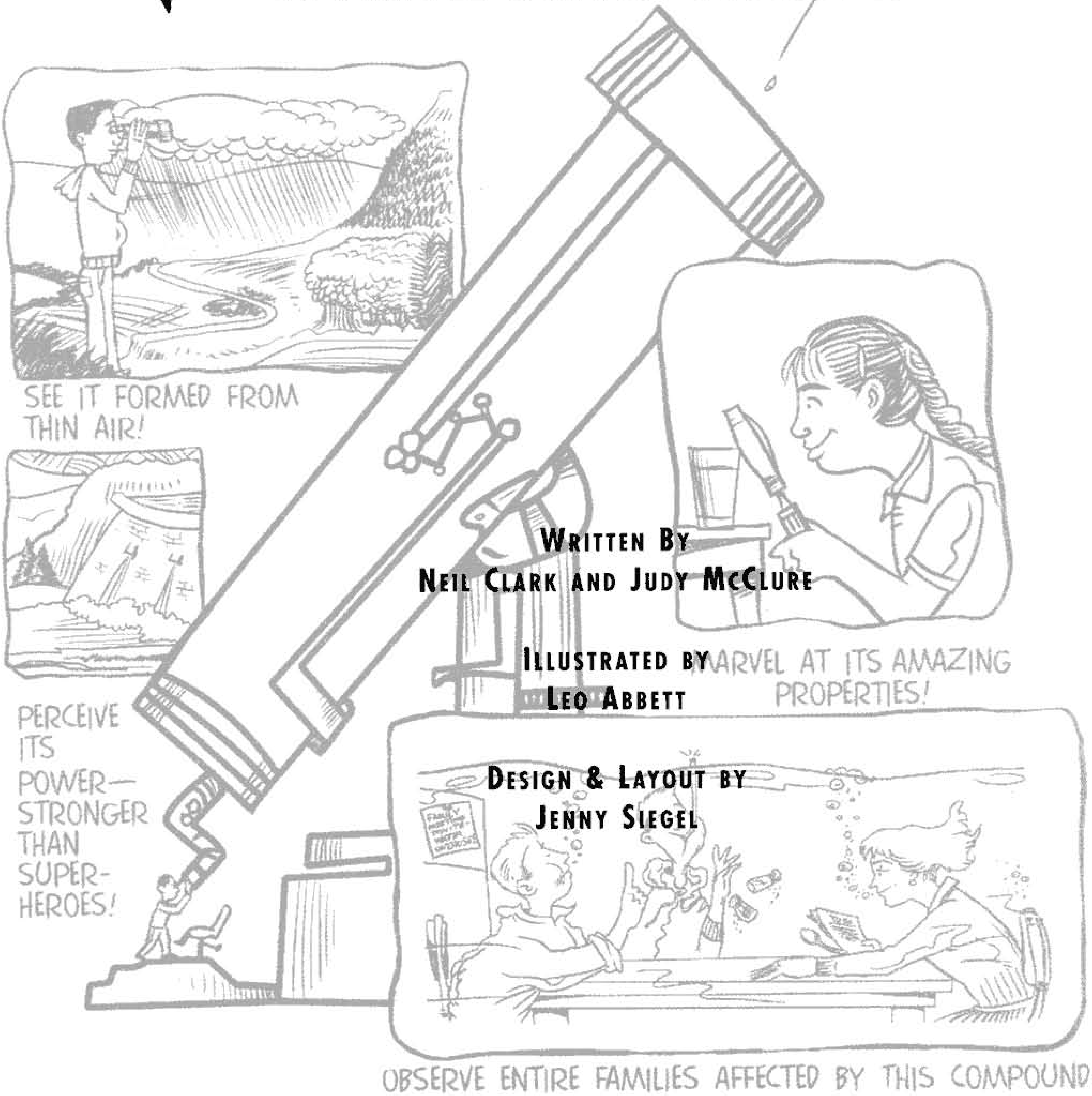


Classroom Activities for A Middle School Curriculum

Massachusetts Water Resources Authority

WATER WATCHERS

A MIDDLE SCHOOL CURRICULUM



WRITTEN BY
NEIL CLARK AND JUDY MCCLURE

ILLUSTRATED BY
LEO ABBETT

DESIGN & LAYOUT BY
JENNY SIEGEL

ACKNOWLEDGEMENTS

We would like to acknowledge the following teachers who piloted these activities in their classrooms. Their suggestions on implementing the curriculum were invaluable to us.

Sandra Fulmer	Stoneham Middle School, Stoneham
Ann McNamara	Lewenberg Middle School, Boston
Gwen Pozdena	Ottoson Middle School, Arlington
Janis Stevenson	Braintree Middle School, Braintree
June Thall	Remington Middle School, Franklin
Josephine Thomson	Stoneham Middle School, Stoneham

Our special thanks go to Nancy Seasholes for her help with Boston's water history in Activity 4-1, and to AnneMarie Desmarais for help with risk assessment in Activity 6-1. Thanks also to John Gregoire for his expertiese on watershed protection and advice on Activity 6-3.

We also acknowledge Carli Bertrand and Pat Hally Doherty for their contributions to editing this piece. Their attention to details was especially important.

TEACHING WATER IN MIDDLE SCHOOL

As long as there have been teachers, students have been asking, "Why are we learning this?"

We hope the lessons in *Water Watchers* answer this question themselves. In a culture that emphasizes fitness, well-being and longevity, water resources are a key element of public health. They are also a cornerstone of economic activity and security. By the time students have done an activity or two in "Everybody's Water" and "Valuing Water," these points should be abundantly clear. From there, questions about how water reaches consumers, how water suppliers plan and develop water resources, how resources are protected and what constitutes safe drinking water all have context.

Although there are many applications to physical, earth and life science in *Water Watchers*, this is an interdisciplinary curriculum. The science concepts in water resources are applied to the benefit of the community. The connection between science and social studies, between public health and decision-making, could hardly be more vivid. You will also find language arts, math, and art in several activities. Water lends itself handsomely to the goal of interdisciplinary studies, as we trust *Water Watchers* will demonstrate.

Water Watchers is designed with an active approach to learning. Some of these activities are messy, (keep the paper towels handy) but we hope by working with water students will come away with a deeper understanding of its importance. *Water Watchers* is intended to help students understand the dynamics of supplying water and the role that decision making and community involvement contribute to that process.

TEACHER'S NOTE: USING WATER WATCHERS

This curriculum is divided into six main lessons, each lesson containing two or three specific activities. The earlier lessons focus on the availability of water, on how much we use, how it is delivered and how it is valued. That theme takes on another dimension in later activities: water quality. What does it mean for drinking water to be safe? How is safety measured, and what steps are important in assuring clean drinking water?

What do teachers need to know to teach Water Watchers? You needn't be a water scientist or policy expert; knowing how to structure activities in a middle school classroom is far more important. If advanced questions arise, feel free to call the MWRA School Program for help. We are available for teacher workshops, to help you assemble materials or practice the activities, and we regularly visit classrooms in the MWRA service area to enhance students' experiences with water issues.

Each activity includes teacher and student pages. The teacher pages should give you all the information you need to teach the activity. The background sections in the teacher pages should enable you to answer student questions and guide the inquiries.

Many of the activities are structured so that students work in groups. You can determine what size group will work best for your teaching style. The time for each activity is listed as sessions. We estimate a session to be about 45 minutes. Some of the activities include "reflective" questions. These questions are meant to give students some time to think further about what they have learned. You may want to include reflective questions at the end of other activities in this curriculum.

The pockets in this manual contain some items that we hope will be useful to you. You will find a guide that links the activities to the goals of the Massachusetts Science Frameworks. We have also included a copy of "Water and Germs" which should enhance Lessons 5 and 6. You are welcome to copy any materials from this manual.

YOUR FEEDBACK

In many ways, these activities are only starting points. If you devise extensions or deeper applications, we would like to hear about them. A number of these activities have benefitted from the creativity of teachers. We see this curriculum as an ongoing project, always subject to expansion and improvement. Please share your ideas with us.

Finally, it is quite valuable to learn how students react to classroom activities, what difficulties they had, what insights they gained. Please tell us what went well or what didn't. Let us know what concepts came alive as a result of your water unit. That helps us develop our own program and will contribute to future editions of Water Watchers.

Call us at 617-788-4662 with your comments.

TABLE OF CONTENTS

LESSON 1 EVERYBODY'S WATER

LESSON 1 EVERYBODY'S WATER

We all depend on water in more ways than we realize, as individuals, families and communities. These three activities follow that progression. In the first, students first estimate, then calculate their personal use. In the second, they consider which uses are most important to their families. The final activity broadens the concept of water supply to its significance in the community. As they devise a community conservation plan, students learn that water supports not only themselves and their families, but hospitals, schools, stores and industries.

ACTIVITY 1-1 SHOWER MATH

SUMMARY Students will guess and then calculate an estimate of how much water they use during one day.

CONTENT AREAS environmental science, math, social studies

GOAL to help students become aware of their own water use

TIME two sessions

ADVANCE PREPARATION

- Create student working groups.
- Copy student pages.
- Make an overhead of the **Water Use Data Table**.

BACKGROUND INFORMATION

The average person uses about sixty gallons of water a day at home. This amount includes bathing, flushing the toilet, and washing dishes and clothes, but not washing the car, watering the lawn, or other outdoor use. We have included some average usage amounts in the **Water Information Chart**. These are accepted rates, but will not be the exact amount used in every case. They are certainly appropriate for this exercise. You will probably find that middle school students use more than 60 gallons each day due to the length of their showers. In the next activity there will be an opportunity for discussing how to conserve water.

During the first class discussion students will probably realize they need several pieces of information to calculate a daily water use estimate. Water use can be measured in two different ways: by number of gallons per minute (as in taking a shower), or by the number of gallons per use (as in flushing the toilet). There are two ways water is used in a home: by individuals (as in taking a shower) or by families (as in washing dishes). Therefore, students will need to use four different equations to calculate their estimates.

1. <u>Individual uses</u> by **flow rate** ("individual rate")

   individual volume = rate (gallons/min.) x time (min.)

2. <u>Individual uses</u> by **frequency** ("individual frequency")

   individual volume = amount (gallons/use) x number of uses

3. <u>Family uses</u> by **flow rate** ("family rate")

   student share = family volume (rate x time) ÷ # in family

4. <u>Family uses</u> by **frequency** ("family frequency")

   student share = family volume (number of uses x gallons/use) ÷ # in family

These equations are included in the four tables where students calculate their estimates. There are extra spaces on each table for water uses that students may think of on their own. They can use the **Water Information Chart** to determine the amounts for these uses.

TEACHER PROCEDURE

1. Ask student groups to consider how much water they use in one day.
2. Display the overhead **Water Use Data Table** (or create one on the board). Show only the column for guesses. You will uncover or create the other columns as you go through the activity. Record the students' guesses.
2. The class numbers should generate a discussion about individual water use. Some questions you might ask about the data are: what is the lowest guess? What is the highest? What is the difference between those two numbers?
3. Now you want the students to start thinking about water use. To generate this discussion you might ask: What are the different ways you use water during the day? What information would you need to know to calculate daily water use?
4. Distribute the **Water Information Chart** and **Calculating Your Water Use Estimate.** Students will use this information to calculate an estimate for their daily water use.
5. Explain to the students how to do the calculations. You might want to do some sample problems or write the equations on the board. (Note: sometimes after several copies are made, the division symbol looks like a plus sign. Make sure students know they are to divide in steps 3 and 4.)
6. Uncover the next five columns on the **Water Use Data Table**: individual rate, individual frequency, family frequency, family rate, and calculated estimate.
7. When students have completed the calculations they should be recorded on the **Water Use Data Table**.
8. Use the data for a class discussion on water use. Some questions you might use in the discussion are: In what category did students use the most water? In what category is there the most variability? Were there any surprises in these numbers?
9. Students should use their own data to complete the **Conclusion** questions.

ACTIVITY 1-1 SHOWER MATH

WATER USE DATA TABLE

Name	Guess	Individual rate	Individual frequency	Family rate	Family frequency	Calculated estimate

ACTIVITY 1-1 SHOWER MATH

NAME ______________________________

DATE ______________________________

INTRODUCTION

How much water do you use every day? You will make two estimates about this question. First, you will guess how much you use. Then you will calculate an estimate using standard water use information and your own water habits.

PROCEDURE

1. How many gallons of water do you think you use every day? ______________
2. Using the **Water Information Chart** complete the four steps for calculating your estimate for your daily water use.
3. Be ready to share your information in a class discussion.
4. Complete the **Conclusion** questions using your information.

WATER INFORMATION CHART

Water Use	Gallons
flushing the toilet	1.6 gallons per flush (low flow) 3 gallons per flush (pre 1989)
showering	3 gallons per minute (low flow) 5 gallons per minute (less efficient)
bathtub faucet (6 minutes to fill the tub)	5 gallons per minute
bathroom faucet	2 gallons per minute
kitchen faucet	4 gallons per minute
dishwasher	20 gallons per use
washing machine	35 gallons per use

Water use can be measured in different ways in your home. For example, when you take a shower, water comes out at a certain rate and for a certain amount of time. We will call that type of use "rate use." However, when you flush the toilet you use a certain amount of water each time. We'll call that type of use "frequency use."

You will also need to calculate your share of water from your family's use. For example, when clothes are washed it is usually for the whole family and not an individual. Even if you are not responsible for washing dishes or your own clothes, you should still include those calculations.

You will not include any outdoor use in these calculations.

CALCULATING YOUR WATER USE ESTIMATE

Step 1: Calculating your individual rate use
Remember: rate x time = volume

Water use	Rate (gallons/min.)	Time (min.)	Volume (gallons)
showering			
taking a bath			
brushing teeth			

Total ____________

Step 2: Calculating your individual frequency use
Remember: number of uses x gallons per use = volume

Water use	Gallons per use	Number of uses	Volume (gallons)
flushing the toilet			

Total ____________

Calculating Your Water Use Estimate

Step 3: Calculating your share of family rate use.
Remember: your share = family volume(rate x time) ÷ number in family

Water use	Rate gal/min	Time min	Family volume gal	Number in family	Your share gal
washing dishes by hand					

Total ________________

Step 4: Calculating your share of family frequency use.
Remember: your share = family volume(frequency x gallons) ÷ number in family

Water use	Frequency	Gallons per use	Family volume gal	Number in family	Your share gal
dishwasher					
washing machine					

Total ________________

Add together your totals from step 1 through step 4 to calculate your daily water use estimate.

Daily Water Use Estimate ________________

CONCLUSION

1. What was your first daily water use estimate (guess)?

2. What was your calculated estimate?

3. Using your calculated estimate, determine your use for one week, one month, and one year.

Water Use	Gallons Used
one week	
one month	
one year	

4. In what category did you use the most water?

5. What are two conservation strategies you could use to save water?

6. If you used one of those strategies, how much water could you conserve in one day?

7. How much could you conserve in a week, a month, and a year?

Time	Water Saved
one week	
one month	
one year	

ACTIVITY 1-2 FAMILY WATER USE

SUMMARY Students will work in groups to prioritize water use.

CONTENT AREAS environmental science, social studies, math, reading

GOAL to evaluate family water use

TIME one session

ADVANCE PREPARATION

- Create student groups.
- Copy student pages.

BACKGROUND INFORMATION

Use the **Water Information Chart** from **Activity 1** (page 7) for the students to determine amounts of water used.

TEACHER PROCEDURE

1. Distribute student pages.
2. Explain that each student group is a family. There is a problem with the pump to the water tower and the water has been rationed. The problem will last for four days. The entire family will be allowed to use 100 gallons of water during the four day emergency. Each person must have one half-gallon of water to drink each day. The group's task is to decide how to use the water during the four days.
3. Each group should begin the task by listing all of the things that they might use water for. Then estimate how many gallons it would take for each.
4. Students should try to reduce or eliminate uses of water until each family is down to 100 gallons for four days.
5. Each group should present its plan to the rest of the class.

Activity 1-2 FAMILY WATER USE

There is a problem with the pump to the water tower in your neighborhood and the water has been rationed. Your family will be allowed to use 100 gallons of water (25 gallons per day) for the next four days. Each person must have one half gallon per day to drink in order to survive. How you use the rest of the water is up to your group.

Your challenge is to agree within your group how to use the water over the next four days. Be ready to present your results to the class.

Procedure

1. Make a list of all the ways that you might need to use water over the next four days.
2. Calculate how much water you would use for each of those activities.
3. Decide which of those activities is the most important. Put a "1" next to it.
4. Decide which activity is the second most important. Put a "2" next to it.
5. Continue with that process until you have put a number next to each water use.
6. Add up how the total number of gallons your group would use if they did all of the activities.
7. Reduce or eliminate water uses until you are down to 100 gallons for your family for the four days.
8. Prepare to present your results to the class.

NAME ____________________

GROUP MEMBERS ____________________

____

DATE ____________________

WATER USE DATA TABLE

Water use	Amount	Priority

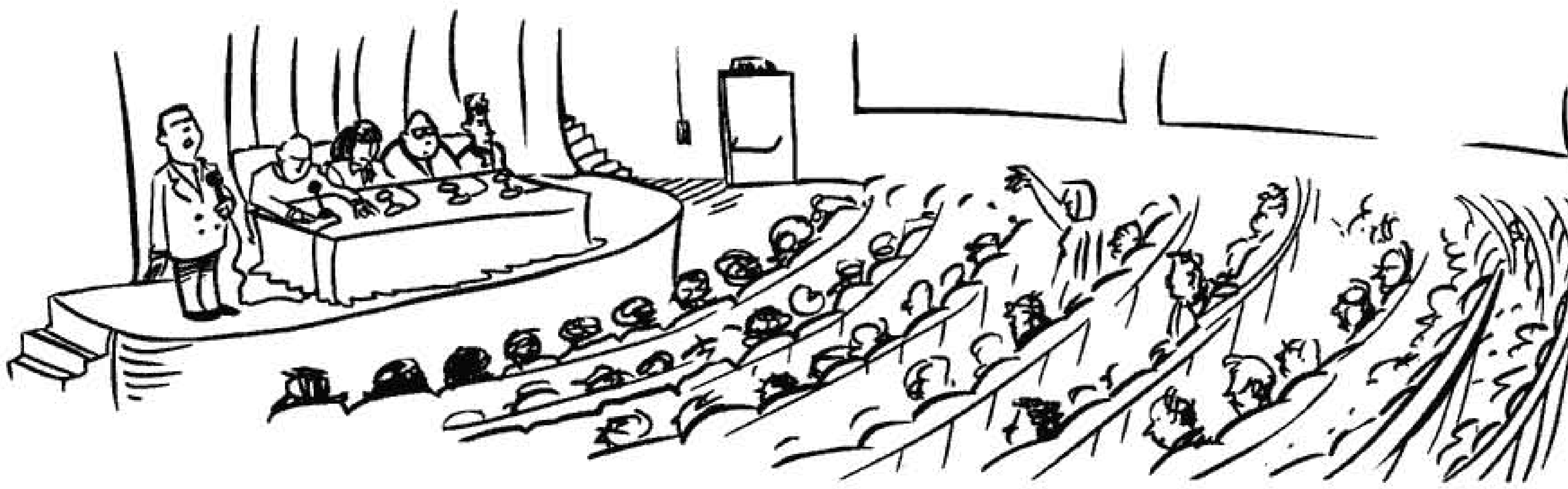
ACTIVITY 1-3 COMMUNITY WATER USE

SUMMARY Student groups will create water conservation plans for a community.

CONTENT AREAS social studies, language arts

GOAL to understand that water conservation affects entire communities

TIME two sessions



ADVANCE PREPARATION

- Create five student groups.
- Copy planning pages for each group.
- Copy four evaluation forms for each student.

TEACHER PROCEDURE

1. Describe the following situation to students:

   Your community's water supply is getting low. Several groups in the community will create water conservation plans for the next 25 years. Plans should include water conservation strategies, implementation methods, and ways to make sure people are following the plan. Each group will present its plan to everyone in the "community" (the rest of the class). Other community members will evaluate the plan presented. You may want to remind students that sometimes fines are imposed when people or corporations do not follow laws.

2. Divide your class into their five community groups.
3. Give each group the appropriate planning page.
4. Students will work together to create their group plans.
5. Each group will present its plan to the class. Other students in the class will complete the evaluation form as they listen to the presentation.

ACTIVITY 1-3 COMMUNITY WATER USE

NAME ______________________

GROUP MEMBERS ______________________

____

DATE ______________________

WATER CONSERVATION PLANNING PAGE

Community group: Residential

This group includes homeowners, renters, and landlords of apartment buildings and houses.

____

____

____

____

____

____

____

____

____

____

NAME ____________________

GROUP MEMBERS ____________________

____

DATE ____________________

WATER CONSERVATION PLANNING PAGE

Community group: Industry

This group includes factories and companies that use water for manufacturing.

____

____

____

____

____

____

____

____

____

____

NAME ____________________

GROUP MEMBERS ____________________

____

DATE ____________________

WATER CONSERVATION PLANNING PAGE

Community group: Small business

This group includes restaurants, grocery stores, banks, and other businesses.

____

____

____

____

____

____

____

____

____

____

NAME ____________________

GROUP MEMBERS ____________________

____

DATE ____________________

WATER CONSERVATION PLANNING PAGE

Community group: Institutions

This group includes hospitals, schools, and universities.

____

____

____

____

____

____

____

____

____

NAME ____________________

GROUP MEMBERS ____________________

____

DATE ____________________

WATER CONSERVATION PLANNING PAGE

Community group: The water company

This group is responsible for delivering the water through pipes, controlling water rates, taking care of pipes and reservoirs.

____

____

____

____

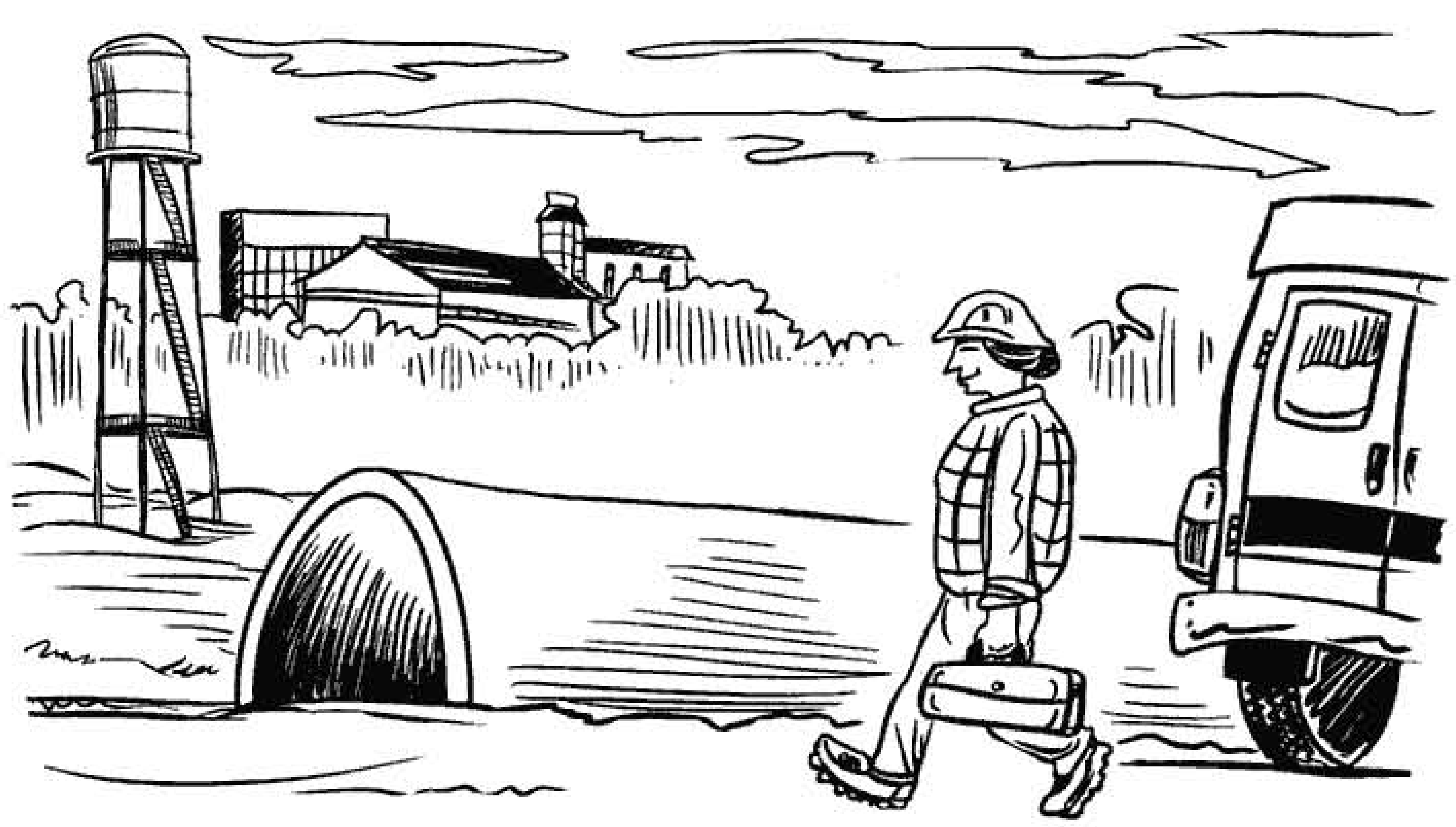
____

____

____

____

____



NAME ______________________________

DATE ______________________________

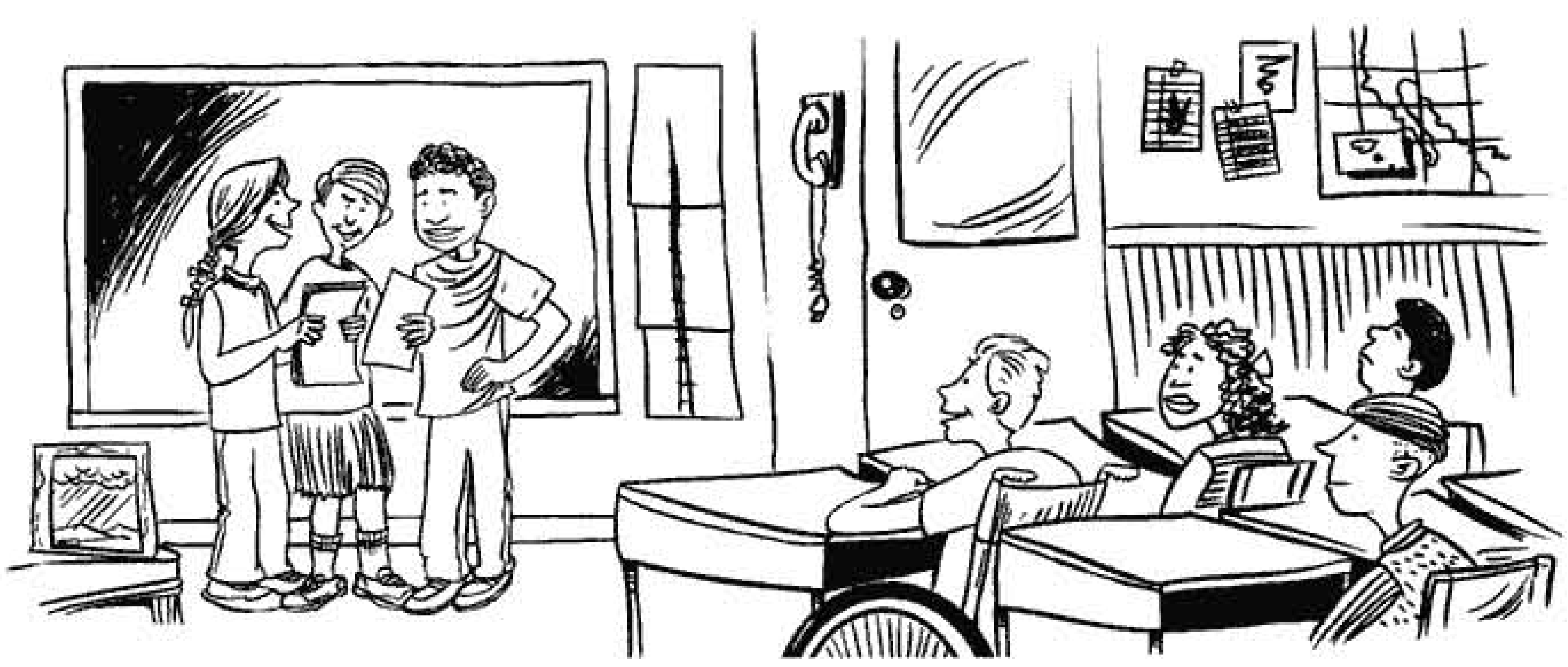
WATER CONSERVATION PLAN EVALUATION FORM

Use this form during the presentation of the plans.

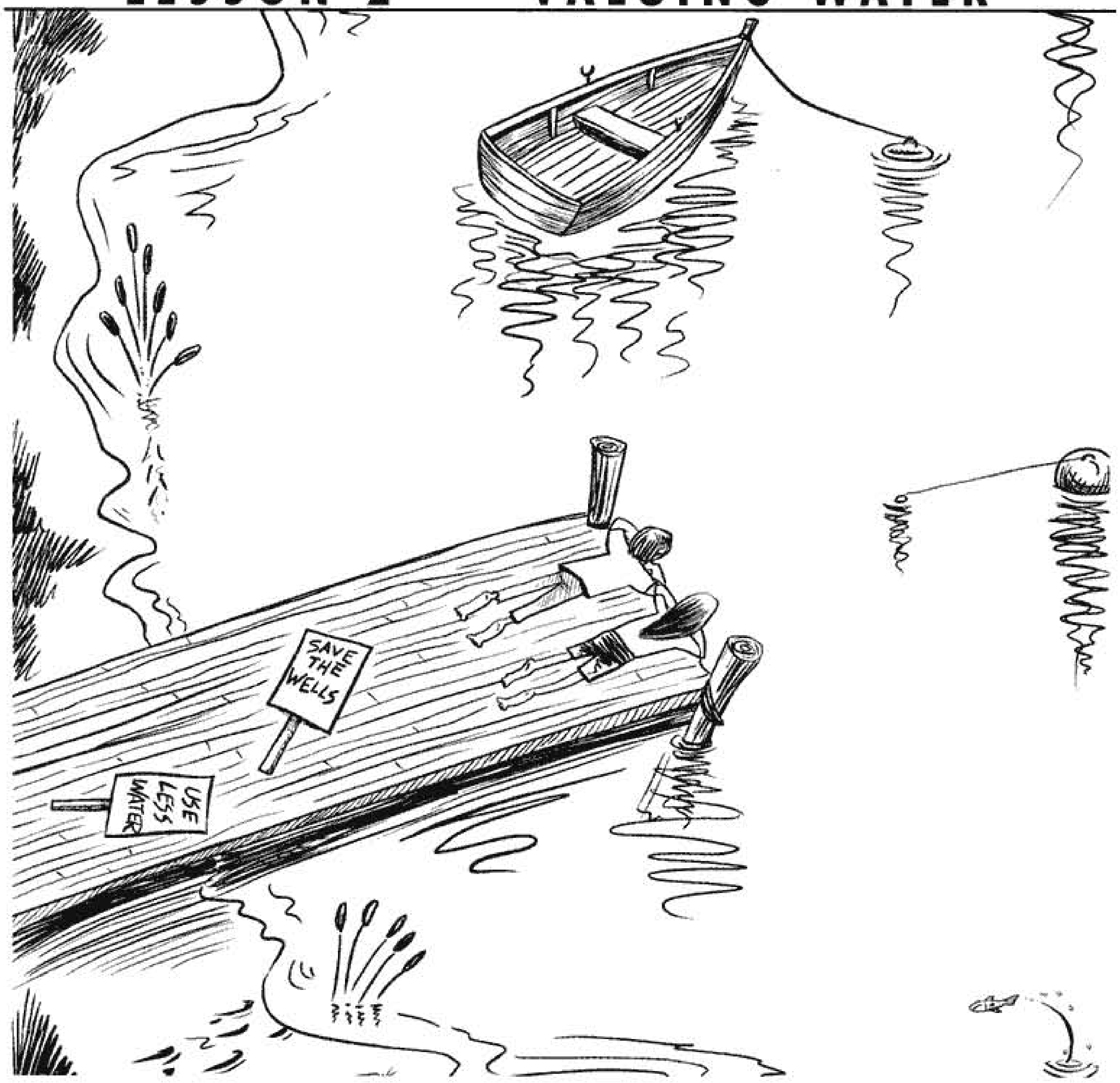
1. What were three of the main points of the plan?

2. What incentives did the plan include to help members of the community to conserve water?

3. Did the plan include ways to assess if members of the community are conserving water? What were they?



LESSON 2 VALUING WATER



LESSON 2 VALUING WATER

Students will explore several meanings of the word "value" as it applies to water. First, they will learn how monetary value is applied to a family's water service by examining a typical water bill. By designing a conservation slogan and bumper sticker, students express water's value to the community. The final activity, the water interview, brings reality to an experience few Americans ever have: daily life without plentiful running water. All these activities raise students' awareness of the importance of drinking water supply, the "silent service."

ACTIVITY 2-1 WATER RATES

SUMMARY Students will use a sample water bill to answer questions about water use and water rates.

CONTENT AREAS math, reading

GOAL to understand how water bills are determined

TIME one session

ADVANCE PREPARATION

- Copy student pages.

TEACHER PROCEDURE

1. Students will use the following water bill for a family of four to answer the questions.

WATER BILL

Period: January - June (water bill only-does not include sewer charge)

Meter Readings

Present 54,500

Previous 48,000

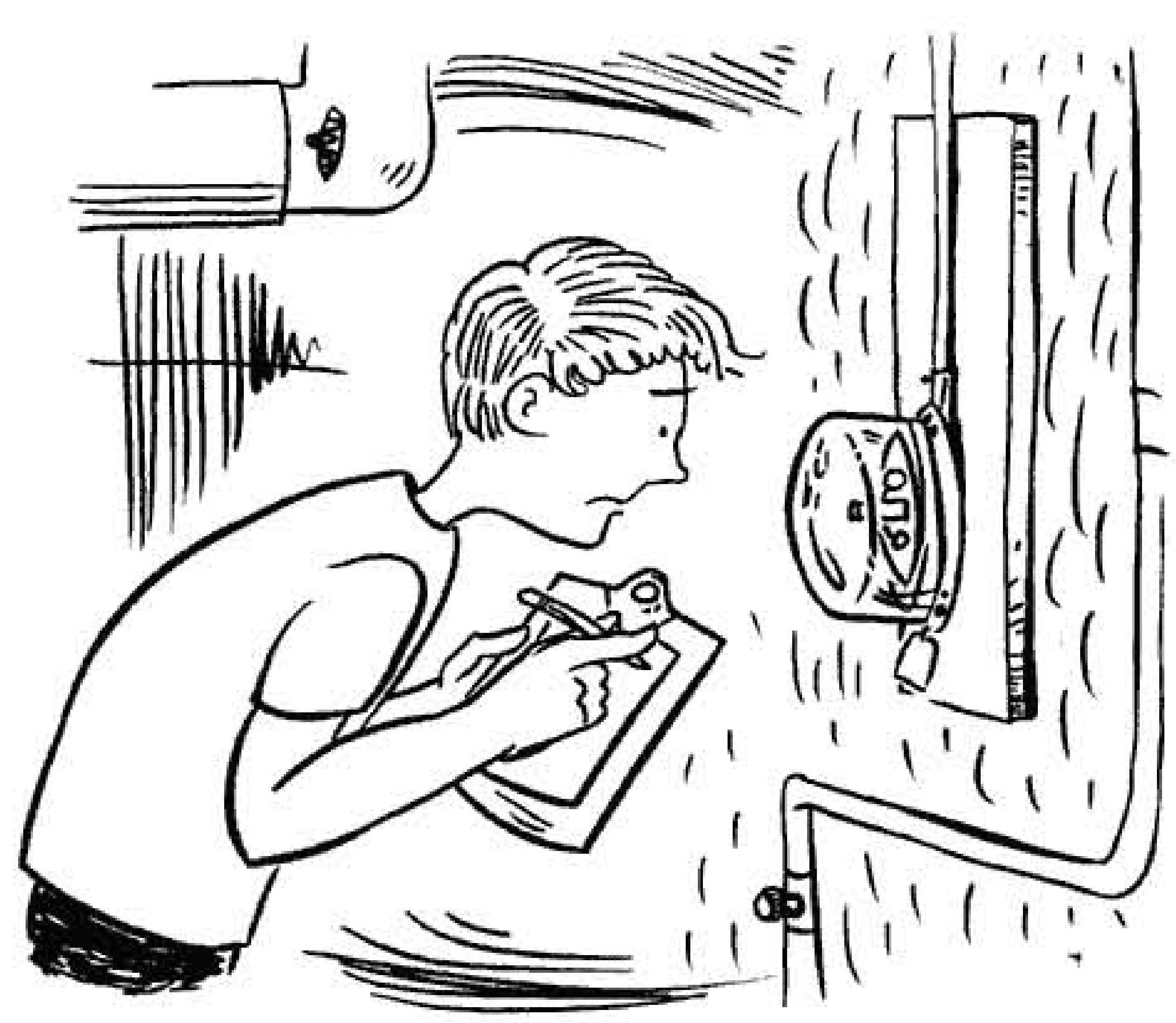
Total cubic feet used 6500

1 cubic foot = 7.48 gallons

Cost

100 cubic feet = $1.90

Total cost to customer = ____________



Answers to Student Questions

1. What was the total cost of the water to this family for six months?

   $123.50

2. How many gallons of water did this family use during the six months?

   48,620 gallons

3. How many gallons of water per day did they use?

   267 gallons per day

4. How many gallons did each person use per day?

   66.75 gallons per person

5. What is the cost per gallon of the water they used?

   $.0025/gallon

6. What would this family's cost for water be for one month?

   $20.58

7. What would this family's cost for water be for one year?

   $247.00

8. What would this family's water bill be if each person used 10 gallons per day less?

   $105.20

ACTIVITY 2-1 WATER RATES

NAME ______________________________

DATE ______________________________

WATER BILL

Use the water bill for a family of four to answer the following questions. Show all of your work and remember to include units.

WATER BILL

Period: January - June (water bill only-does not include sewer charge)

Meter Readings

Present 54,500
Previous 48,000

Total cubic feet used 6500
1 cubic foot = 7.48 gallons

Cost

100 cubic feet = $1.90
Total cost to customer = ____________

1. What was the total cost of the water to this family for six months?

2. How many gallons of water did this family use during the six months?

3. How many gallons of water per day did they use?

4. How many gallons did each person use per day?

5. What is the cost per gallon of the water they used?

6. What would this family's cost for water be for one month?

7. What would this family's cost for water be for one year?

8. What would this family's water bill be if each person used 10 gallons per day less?

ACTIVITY 2-2 WATER BUMPER STICKER

SUMMARY Students will create bumper stickers that encourage water conservation.

CONTENT AREAS social studies, language arts, art

GOAL to apply knowledge of water conservation

TIME two sessions

MATERIALS
- bumper sticker outline for each student
- one piece of paper (approximately 4" x 12") for each student (you may be able to get pieces with adhesive on the back)
- markers, crayons, and/or colored pencils
- optional: bumper stickers to show students

ADVANCE PREPARATION

- Cut paper to correct size.
- Copy "bumper sticker outline" for each student.

TEACHER PROCEDURE

1. Explain to students that they are going to create their own bumper stickers. The bumper sticker's message should encourage people to conserve water. Explain that different messages and styles will appeal to different groups. For example, a bumper sticker for young children will look different than one for people who work in restaurants. Explain to students that they will need to choose an "audience" for their message.
2. Discuss with the class the qualities that make a good bumper sticker. (Clear message, neatness, easy to read, catches the eye)
3. Give each student a **Bumper Sticker Outline** to prepare her/his ideas for the bumper sticker.
4. Each student should complete the outline and show it to you. Each student will then create a bumper sticker rough draft and get your approval.
5. Once you have approved a student's plan, s/he may create her/his bumper sticker.

Activity 2-2 WATER BUMPER STICKER

Name ______________________

Date ______________________

Bumper Sticker Outline

1. What is the "audience" for your bumper sticker?

2. What do you want the readers of your bumper sticker to understand?

3. How do you want the readers of your bumper sticker to feel?

4. What colors do you want to use on your bumper sticker?

5. Make a short list of words that might work well on your bumper sticker.

6. Write a message for your bumper sticker.

7. What type of background do you want for your words? (Drawings, patterns, shading, other?)

8. Show this outline to your teacher.

BUMPER STICKER

When your teacher has approved your outline, use pencil to create a rough draft in the space below. It is about one third of the size of your actual bumper sticker.

1. Show your rough draft to your teacher.
2. Decide on any changes you want to make.
3. Get your materials and create your bumper sticker.

ACTIVITY 2-3 WATER INTERVIEW

SUMMARY Students will interview a person who has had the experience of not having running water in their home. They will write an essay based on the interview.

CONTENT AREAS technology, language arts, and social studies

GOAL to appreciate the convenience of running water and to understand that not everyone has always had, or even today has, running water

TIME two sessions in class and one out of class

ADVANCE PREPARATION

- Copy student pages.
- Identify and contact possible sources of interview subjects. You may want to send a letter home to families, contact a senior center, and ask other staff members at the school. If students will be working with individuals they do not already know, you should make the first contact and see if people are interested.

BACKGROUND INFORMATION

We take running water for granted. During this interview students will discover what it was like for someone to live without running water. Perhaps you have students in your class or school who have moved here from other countries and might be good interview sources. In such a case the project could be the work of both students. Other interview sources might be adults or students in your school who have lived in other countries. There may be older people in the community who lived in the United States without running water. You could contact a local senior center or retirement home and see if there are people there who would be interested. Also, students' grandparents or great-grandparents may be good sources.

TEACHER PROCEDURE

1. Ask students what it might be to live without running water in their homes. Ask how it would change their lives and daily routines.

2. Tell students they are going to have a chance to hear how it is to live without running water by interviewing someone.

3. Give students a practice interview session. Partner them with another student in the class. Each student should ask their partner the interview questions and record the answers. This will help prepare them for the actual interview. (The student being interviewed will have to pretend they lived without running water to answer the questions.)

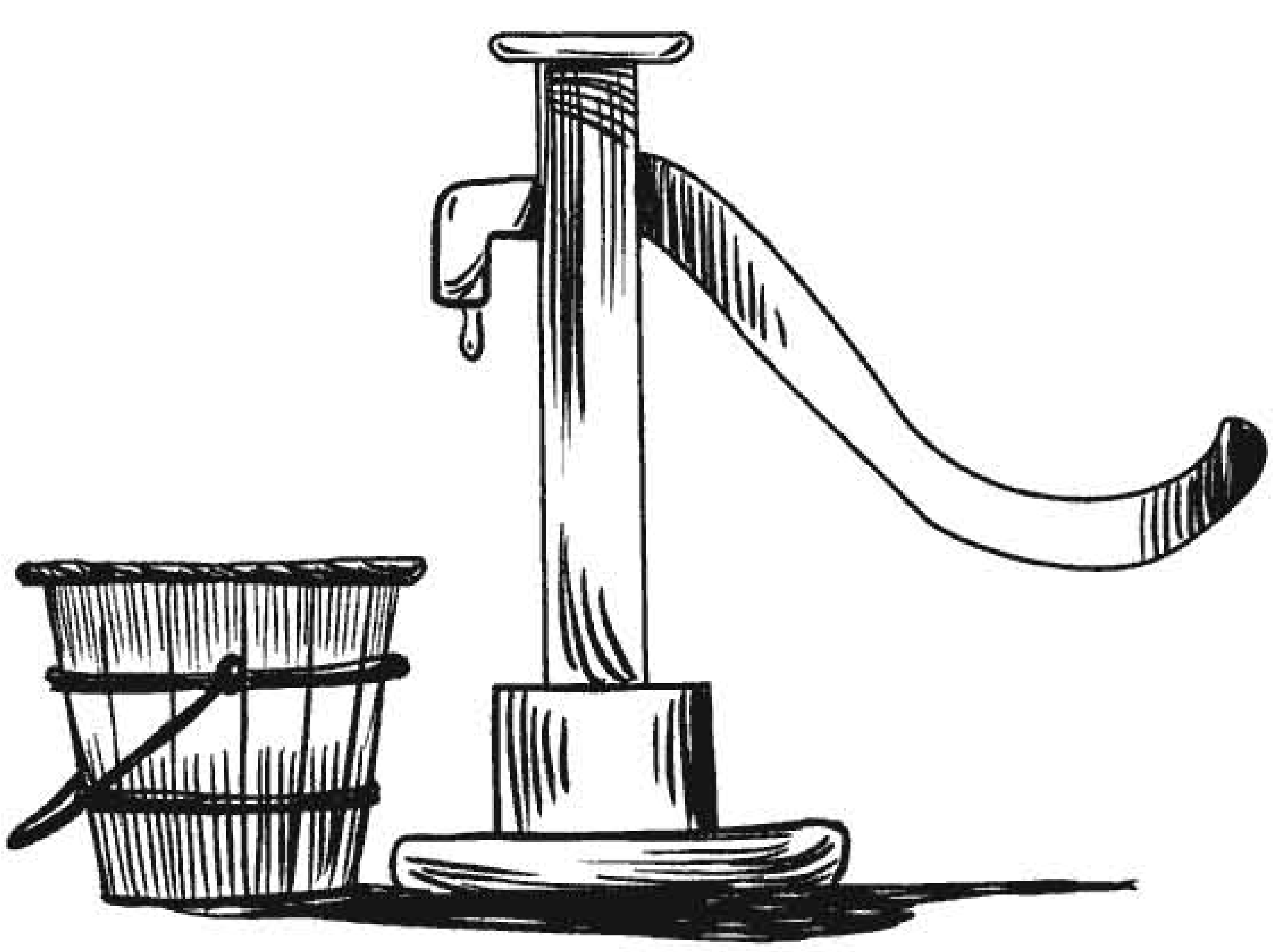
4. Explain to students how to contact interview subjects. If there are students in your class who would be good interview subjects, pair them with other students.

5. If students are interviewing classmates or people in the school, the interview can take place in class. If they are interviewing people outside of class, the interview process will be a homework assignment. Tell students to prepare to spend one hour with the person they are interviewing.

6. Give students a second copy of the interview questions for the actual interview. Encourage them to think of additional questions ahead of time.

7. When the interviews are complete students can use the information to write an essay about the individual they interviewed. They might want to include a picture of the person. Remind students to thank the person they interviewed and give her/him a copy of the essay.

8. There are many ways to share this information with your class or other people. Your class might want to create a book and include all the interviews. You might have students read their essays to the class. You could create a bulletin board in the hall with the essays. Your class could make a presentation at a senior center.



ACTIVITY 2-3 WATER INTERVIEW

LIVING WITHOUT RUNNING WATER

You may use the following questions for your interview. You should also create at least three questions of your own before the interview.

Name of person you are interviewing______________________________

1. When and where did you live in a home without running water?

____

____

____

2. Where did you get your water?

____

____

____

3. How did you get water to your home?

____

____

____

4. How did you use the water in your home?

5. How did clothes get washed?

6. How did people bathe?

7. What did you do with the water when you were done with it?

More Questions

8. ____

____

____

____

9. ____

____

____

____

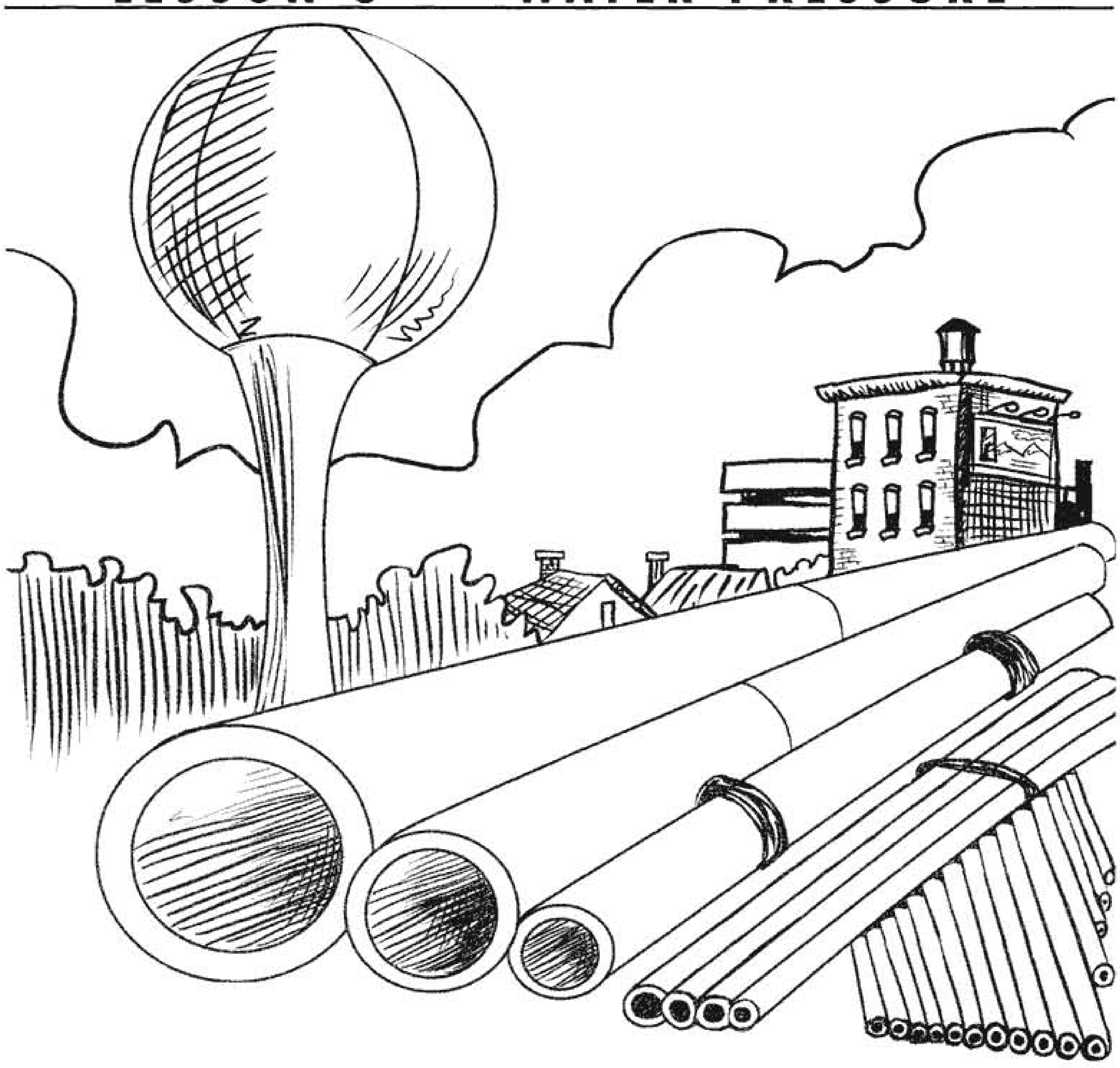
10. ____

____

____

____

LESSON 3 WATER PRESSURE



LESSON 3 WATER PRESSURE

Water flows freely in our bathrooms and kitchens at the turn of a faucet. Students know it arrives through pipes, and they will tell you that "water pressure" pushes it out. This lesson leads students to explore two variables in water flow: the diameter of pipes and the elevation difference between water's storage and its users.

Both activities use variations of the same apparatus. In the first, students measure flows through two different diameter tubes. In the second, they construct a system much like the one they use every day: elevated storage, delivery at ground level into buildings, and flow in upper stories. In both cases they are working in teams to manipulate an apparatus, collect data, answer questions, and draw conclusions. These activities will bring some basic laws of fluid mechanics to bear on their daily water use and the model will help them visualize aspects of water systems that are usually hidden from view.

ACTIVITY 3-1 HYDRAULICS - SIZE OF PIPES

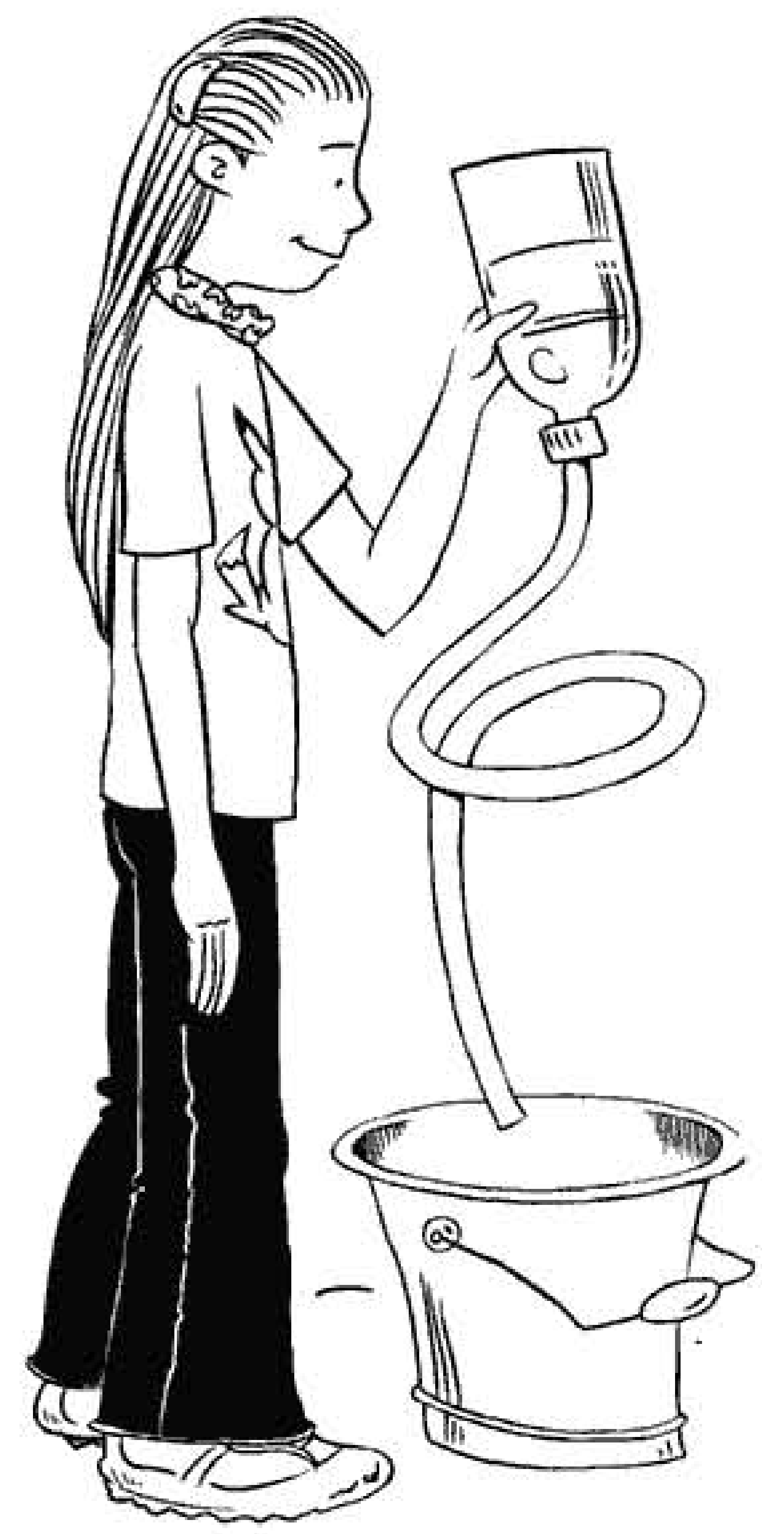
SUMMARY Students collect and analyze data on the time required for water to move through two different diameter tubes.

CONTENT AREAS physical science, math

GOAL to demonstrate the difference that pipe diameter makes to the amount of water delivered

TIME one session

MATERIALS For each group:
-water, paper towels
-a hydraulics apparatus (see construction procedure below)
-a bucket
-a .5 liter measuring cup
-a watch that can read seconds, or a wall clock with second hand
-student pages
-optional: calculators

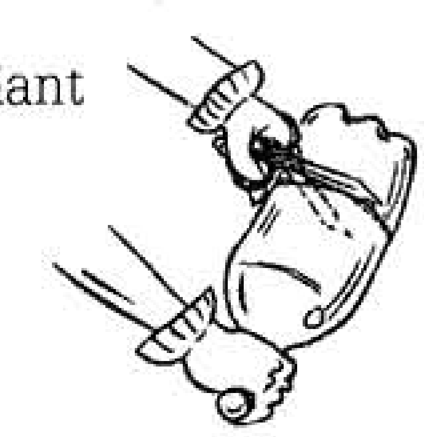


ADVANCE PREPARATION

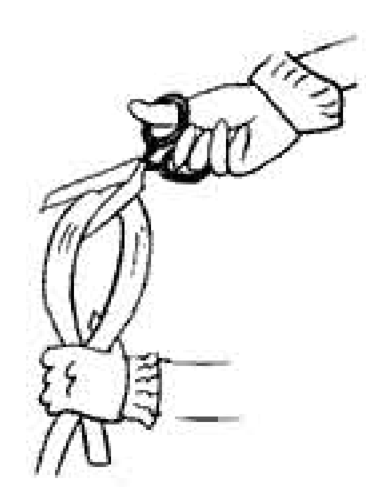
- Create student working groups.
- Copy student pages.
- To construct the student hydraulics apparatus, you will need:
  - plastic bottles; 1 liter bottles are best; bottles with wider caps are preferable but not necessary
  - 2 caps for each bottle
  - 3-foot lengths of vinyl tubing in two sizes:
    a. 3/16" inside diameter (5/16" outside diameter)
    b. 3/8" inside diameter (1/2" outside diameter)
  - electric drill
  - optional: plumber's adhesive sealant

CONSTRUCTION PROCEDURE

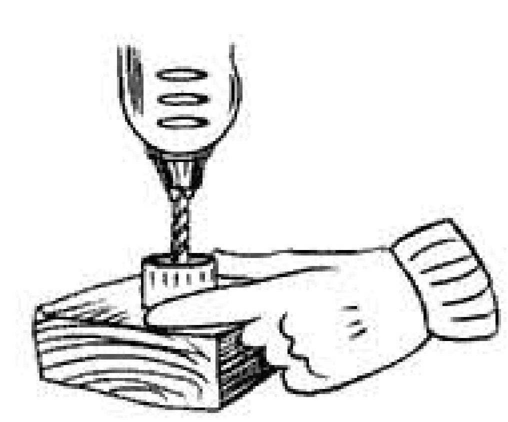
1. Cut off the bottom of each bottle.

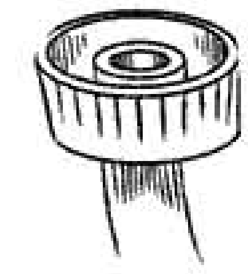


2. Cut 2 3-foot lengths of vinyl tubing, one 3/16" and one 3/8"



3. Remove any inside gasket from the inside of the cap and carefully drill either a 5/16" or 1/2" hole through it. Wear gloves, and place cap on a surface, such as a block of wood, to protect the work surface. Suggestion: hold cap right-side up, set drill to reverse, and apply pressure. You will effectively melt your way through, leaving a better hole in the cap.





4. Insert one end of each tube through the cap about 1/2". It should fit snugly.

5. Optional: Apply sealant to the tube on both sides of the cap, work the tube back and forth once or twice, and allow to dry.

6. When screwing the cap back onto the bottle until it seals tightly, hold the cap steady and turn the bottle to minimize strain on the sealant.

BACKGROUND INFORMATION

This activity allows students to demonstrate for themselves the difference that pipe diameter makes to the amount of water delivered.

Municipal water systems and household plumbing use many different sizes of pipes. The pipes in the streets are larger than those leading into buildings, and those inside buildings are smaller still. Most students will recognize that larger pipes can carry more water, and that the pipe from the town well or reservoir must transport water for many people, while the pipe to a bathroom sink supplies just one user at a time.

By choosing two tube sizes, one exactly twice as large as the other, we also introduce an interesting geometric concept: that doubling the diameter of a cylinder quadruples its cross-sectional area. If students perform the experiment carefully and look at data from the whole group, they may discover that when tube diameter doubles, water moves four times as fast. Allow them to discover this relationship themselves; if they don't, simply accept "faster and slower." Hands-on guided learning gives students the opportunity to discover relationships for themselves when they are ready to see them. The teacher's job is to prompt them when they are close but not to supply them with answers too soon.

The size of the tube is only one variable that determines rate of flow; the other is the difference in elevation, which is the subject of the next activity, 3.2. For the purposes of this activity, be certain that the tables or desks from which students work are all the same height, or distance from the floor.

If data is inconsistent from one group to another, observe whether students are holding the end of the tube at the bottom of the bucket, as directed, or within the bucket but higher from the floor. You may suggest that students try keeping the bottle and bucket at the same elevations but raising the

end of the tube to see what effect that has on the time (flow rate).

TEACHER PROCEDURE

1. Ask students how water reaches their faucets. When they mention pipes, ask them where the pipes are and how big they are. Pipes are sized according to "inside diameter," or the distance from one inside wall to the other. After brief discussion, tell them they will be doing an activity with water moving through pipes.

2. Divide students into working groups. Groups of at least three students are recommended: one to hold the bottle, another to hold the tube in the bucket, and a third to act as timer and recorder. Students should trade responsibilities as they collect data.

3. Distribute student pages, hydraulics apparatus, paper towels and a measuring cup to each group.

4. Instruct students to familiarize themselves with the materials by following the instructions (steps 1-8) for a practice run. Remind them that when they attach tubes to bottles to hold the cap still and turn the bottle.

5. Instruct students to begin data collection by completing steps 1 through 4 on the **Data Collection Pages**. (Hint: Data will be more consistent if the end of the tube is very near the bottom of the bucket.)

6. Once they have completed step 4, instruct them to change to the larger tube and collect data as directed in Steps 5 through 8.

7. Construct a **Class Data Table** on the board (see below) and ask students to record their average times (from Steps 2 and 7).

8. Discuss the **Class Data Table.** Then instruct students to complete questions 9 through 13 of the **Analysis and Conclusion** section.

9. You may want to treat Questions 14 and 15 as optional.

CLASS DATA TABLE

GROUP #	3/16″ TUBE TIME	3/8″ TUBE TIME
1		
2		
3		
ETC.		

ANSWERS TO STUDENT QUESTIONS

Question 11: Most homes use 1/2" copper tubing for hot and cold water. The service pipe between the street and the building are probably 1" for single family, and larger for apartment buildings.

Question 12: Distribution pipes may be 4" to 6" on residential streets, but under main streets pipes are often 12" or larger.

Question 13: These aqueducts carry water for nearly two million people in more than 40 communities.

Question 14: Answers will vary. Suppose the average in Question 2 was 26 seconds. Then,

$$\frac{.5 \text{ ltrs}}{26 \text{ sec}} \times \frac{60 \text{ sec}}{1 \text{ min}} = \frac{30}{26} \frac{\text{ltrs}}{\text{min}} = 1.2 \text{ ltrs/min}$$

Question 15: Answers will vary. Suppose the average in Question 7 was 7 seconds. Then,

$$\frac{.5 \text{ ltrs}}{7 \text{ sec}} \times \frac{60 \text{ sec}}{1 \text{ min}} = \frac{30}{7} \frac{\text{ltrs}}{\text{min}} = 4.3 \text{ ltrs/min}$$

ACTIVITY 3-1 HYDRAULICS - SIZE OF PIPES

INTRODUCTION

Does the diameter of a pipe or tube affect how fast water can move through it? You will experiment with two different size tubes, a smaller one (3/16" inside diameter) and a larger one (3/8" inside diameter). You will use the same volume of water with each tube and observe how long it takes the water to empty from one container to another.

MATERIALS

Your teacher will give each group the following items:

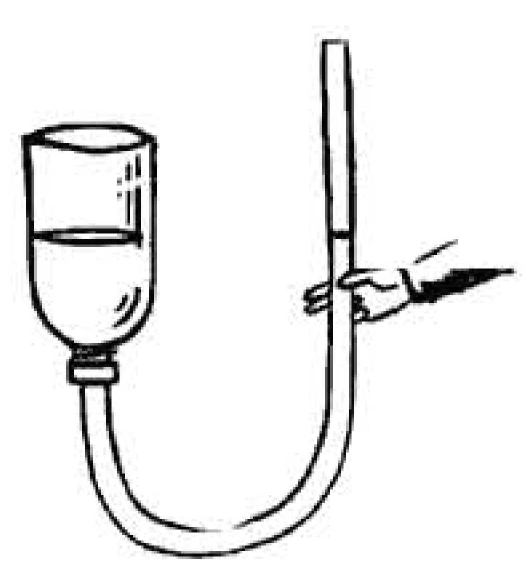
- -a plastic bottle with its bottom cut off
- -a measuring cup with markings to .5 liters
- -a plastic cap with a smaller tube through it
- -a plastic cap with a larger tube through it
- -a bucket to collect the water
- -student pages, including **Data Collection Pages**

PRACTICE RUN

First, make the following practice run with the apparatus.

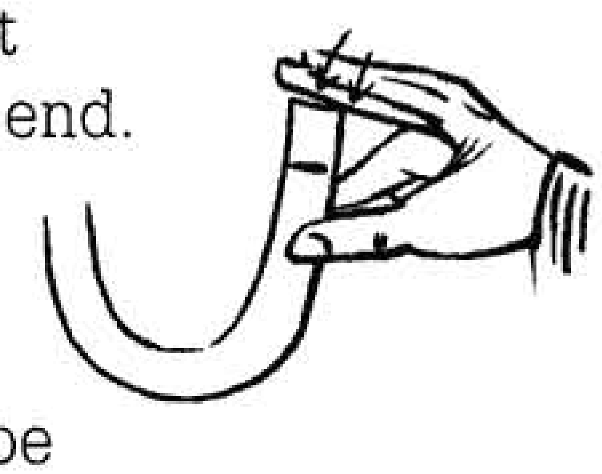
1. Attach the cap and smaller tube to the bottle. To protect the seal, it is best to hold the cap in place and turn the bottle until it is securely in place.

2. One student should hold the bottle so that the cap is at the edge of the table. Place the collecting bucket on the floor.



3. A second student should hold the end of the tube above the top of the bottle. Slowly pour .5 liters of water into the bottle.

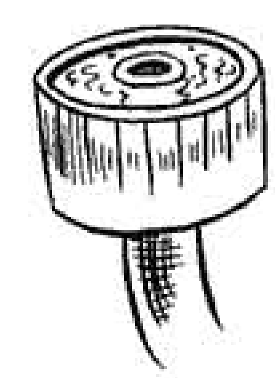
4. Slowly lower the end of the tube. When the water level just reaches the end of the tube, put your finger firmly over the end.



5. Keeping your finger firmly in place, lower the end of the tube to the bottom of the bucket.

6. When the timer says "go," the student holding the tube should release his/her finger and allow the water to flow. When the steady flow suddenly decreases to just a few drops, say "stop". The timer should then note the total elapsed time.

7. You will notice that a small amount of water remains in the bottle cap, beneath the top of the tube. Not all the .5 liters moved from the bottle to the bucket. Allow that water to stay in place; for subsequent trials, exactly .5 liters will pass through the tube.



Now you are ready to begin collecting data.

DATA COLLECTION PAGES

NAME ______________________

GROUP MEMBERS ______________________

____

DATE ______________________

1. Conduct three trials of the same experiment with the smaller (3/16") tube, recording times on the **Data Table** below. Record the elapsed time for each trial.

3/16" DATA TABLE

TRIAL #	VOLUME (LITERS)	TUBE SIZE	ELAPSED TIME (SEC)
1	.5	3/16"	
2	.5	3/16"	
3	.5	3/16"	

2. Compute the average time of your three trials. Record it below.

   Average time with smaller tube: ______________

3. How close were the three times to each other? From your three trials what do you think the time would be in a fourth or fifth trial?

4. Before conducting the same experiment with the larger (3/8") tube, predict how long you think it will take the bottle to empty through the larger tube.

   Prediction: __________ seconds

5. Now remove the small tube from the bottle (remember to hold the cap and turn the bottle) and attach the larger tube to the bottle.

6. Conduct three trials with the larger tube. Record the data.

3/8" DATA TABLE

TRIAL #	VOLUME (LITERS)	TUBE SIZE	ELAPSED TIME (SEC)
4	.5	3/8"	
5	.5	3/8"	
6	.5	3/8"	

7. Compute the average time for these three trials. Record it below.

   Average time with larger tube: ________________

8. How close were these three times to each other? Can you predict what time you would get if you ran more trials?

ANALYSIS & CONCLUSION

9. Put your data on the board with that of your classmates. Are all the averages consistent with each other? If not, what might account for the differences?

10. Do you see any patterns in the data? If so, what are they?

11. How large are the water pipes in your home? If they were larger, how would that affect the rate of flow?

12. Have you ever seen people installing water pipes in the streets? About how large do you think they were?

13. Tunnels and aqueducts from Quabbin and Wachusett Reservoirs into the Boston area are as large as 14 feet in diameter! Why do they need to be so large?

RATE OF FLOW

Sample problem:

If .5 liters of water moved through a tube in 12 seconds, what is its rate of flow in liters per minute?

You can convert your measured flow to standard units (liters per minute) in the following way:

$$\frac{.5 \text{ liters}}{12 \text{ ~~seconds~~}} \times \frac{60 \text{ ~~seconds~~}}{1 \text{ minute}} = \frac{.5 \times 60}{12} \frac{\text{liters}}{\text{minute}} = \frac{2.5 \text{ liters}}{1 \text{ minute}}$$

Note that because 60 seconds = 1 minute, the fraction $\frac{60 \text{ sec}}{1 \text{ min}} = 1$. Multiplying a quantity by 1 does not change its value, but by using this method we can convert from one set of units to another.

14. Convert your average from Question 2, the smaller tube, to a rate of flow in liters per minute. If necessary, round to the nearest tenth.

15. Convert your answer to Question 7 to liters per minute, rounding to the nearest tenth if necessary.

ACTIVITY 3-2 HYDRAULICS - CAN WATER FLOW UPHILL?

SUMMARY

Students experiment with water, containers and tubing to learn how water can move from the basement to an upstairs bathroom.

CONTENT AREAS

physical science, math

GOAL

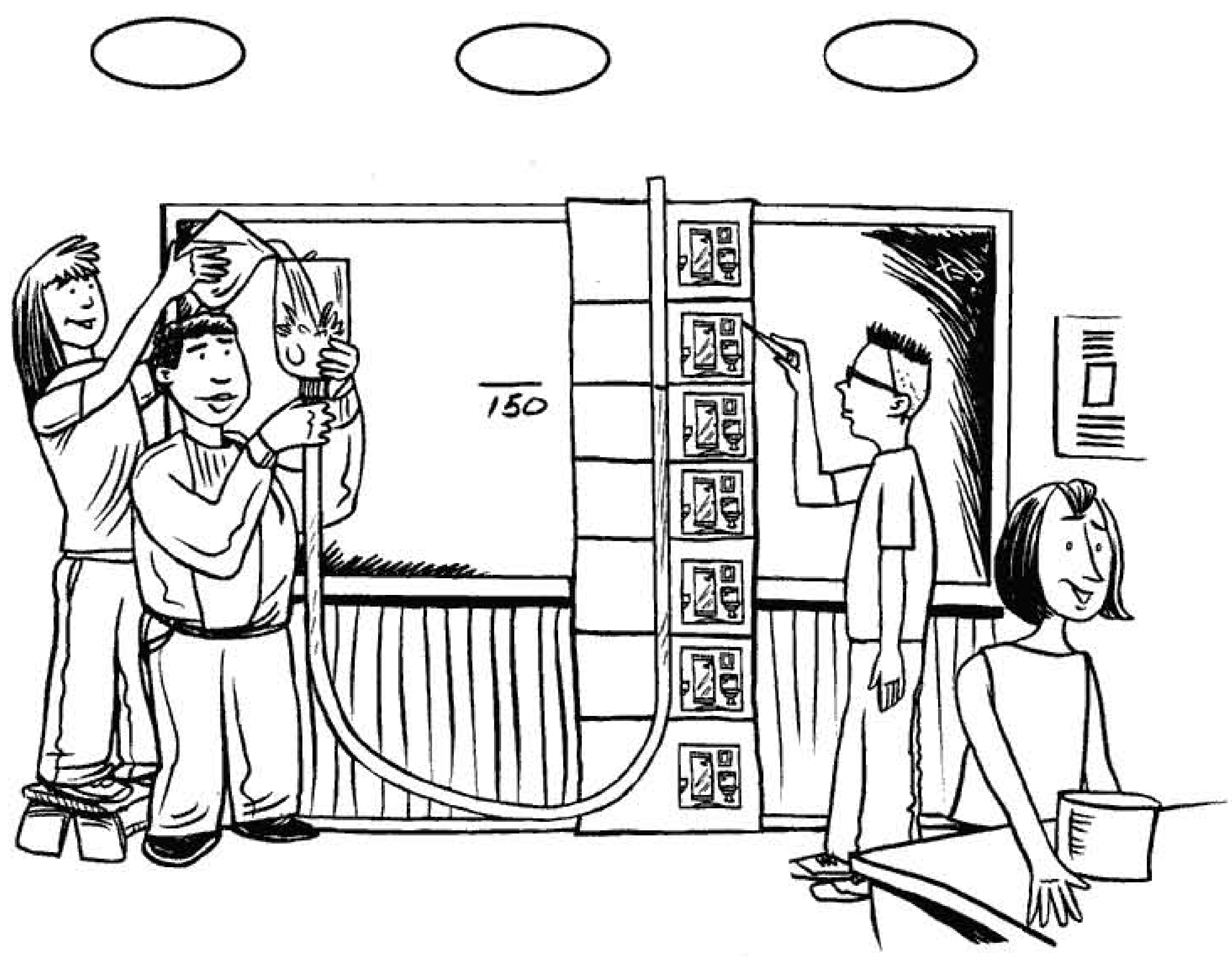
to understand the relationship between elevation and water pressure

TIME

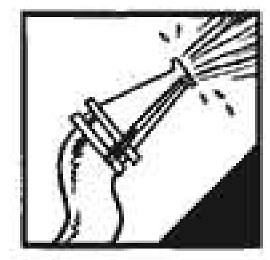
two sessions: one for the gathering data in the basic activity; a second for data analysis and discussion of problems

MATERIALS

For each group:
-water, paper towels
-a hydraulics apparatus (see construction procedure)
-a bucket
-a .5 liter measuring cup
-a meter stick
-a sheet of newsprint or other large paper, about 7 feet long
-a permanent marker
-a watch that can read seconds, or a wall clock with second hand
-copies of student pages
-optional: calculators



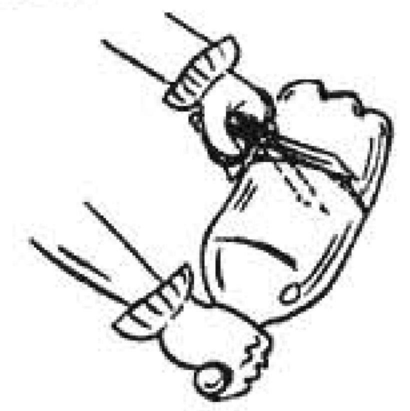
Activity 3-2 HYDRAULICS - CAN WATER FLOW UPHILL?



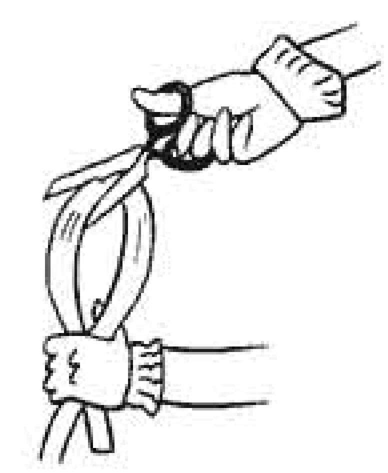
Advance Preparation

- Create student working groups.
- Copy student pages.
- Cut the necessary number of large sheets of paper.
- To construct the student apparatus, you will need:
  - plastic bottles; 1-liter bottles are best; bottles with wider caps are preferable but not necessary
  - a cap for each bottle
  - a 14-foot length of vinyl tubing 1/4" inside diameter (3/8" outside diameter)
  - electric drill
  - optional: plumber's adhesive sealant

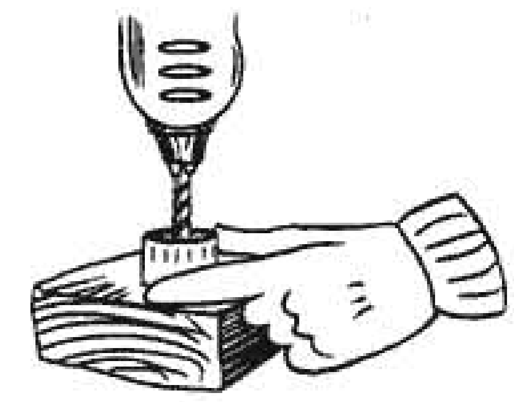
Construction procedure



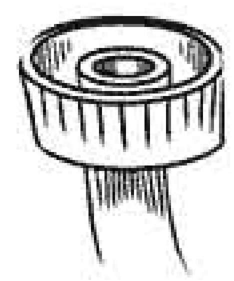
1. Cut off the bottom of each bottle.



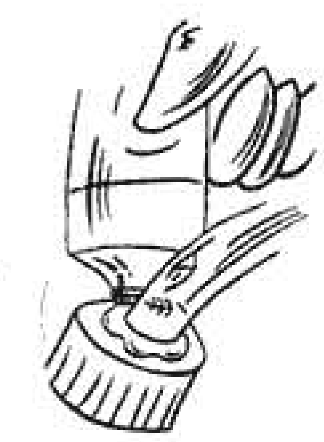
2. Cut a 14-foot length of vinyl tubing.



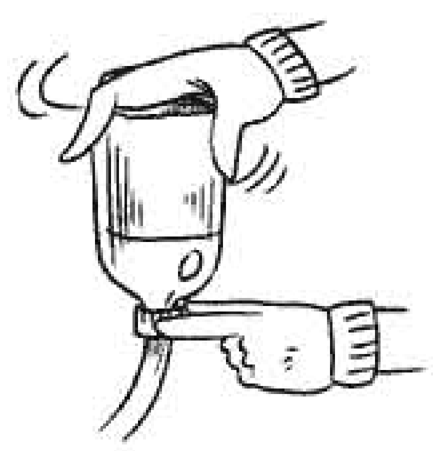
3. Remove any inside gasket from the inside of the cap and carefully drill a 3/8" hole through it. Wear gloves, and place cap on a surface, such as a block of wood, to protect the work surface. Suggestion: hold cap right-side up, set drill to reverse, and apply pressure. You will effectively melt your way through, leaving a better hole in the cap.



4. Insert one end of the tube through the cap about 1/2". It should fit snugly and should not leak.



5. Optional: For a better seal, apply sealant to the tube on both sides of the cap, work the tube back and forth once or twice, and allow to dry.



6. When screwing the cap back onto the bottle until it seats tightly, hold the cap steady and turn the bottle to minimize strain on the seal.

Background information

Students often ask how water gets from the pipes in the basement to kitchens and bathrooms on upper floors. This activity will explore that very question.

The water tower is a familiar landmark in many communities. If the terrain is naturally hilly, the tower will be located on one of the higher elevations in the area. In flat terrain, towers are constructed on long legs to stand well above the ground. The purpose in either case is to raise the elevation of the water storage (the bottle in our apparatus) in order to increase the pressure at people's faucets.

Metropolitan Boston, near sea level, is fortunate to collect its water in reservoirs west of the city at significantly higher elevations. Water collected at Quabbin Reservoir (530 feet above sea level) supplements supplies from Wachusett Reservoir (395 feet); then it's on to Norumbega Reservoir (272 feet), with gravity conveying water toward the city. The water in most of Metro Boston arrives entirely by gravity, though a few higher elevations do require pumping.

Another intriguing question is how water gets to the top of tall buildings. Some office towers in Boston are 700 feet high, much higher than the 272 foot elevation of Norumbega Reservoir in Weston. Such buildings must contain internal systems of pumps and storage tanks that raise water to the higher floors. Most houses, apartment buildings and schools don't require such complex systems, thanks to gravity-based water pressure.

If a community's water source is a river or well, the water must be pumped up to the water tower. If the pumps are electric, a power outage will deprive the community of not only the health and sanitation benefits of running water but of public safety as well, for without water at hydrants, fire fighters lose their primary weapon against destruction: a sufficient supply of water.

TEACHER PROCEDURE

1. Ask students how water enters their homes. Most will know that underground pipes lead into the basements of buildings. Then, how does the water reach kitchens and bathrooms on upper floors? Can water flow uphill? They will probably suggest the word "pressure," but what causes the pressure? Tell them they will be doing an activity to explore water pressure.
2. Divide students into working groups of at least three, and preferably four or five students. Encourage students to trade responsibilities as they proceed through the activity.
3. Give each group a large sheet of newsprint. Instruct the students to draw a seven-story apartment house with its ground floor at the bottom of the paper and its roof at the top. The building does not need much detail, but each floor should be 30 centimeters high and they should draw a bathroom at each level.
4. Have them tape the paper to the board or wall, with its ground floor at floor level. The top floor of the apartment should be higher than 150 cm.
5. Next tell them to tape a mark on the wall next to the apartment building at an elevation of 150 cm.
6. To fill the bottle, have one student hold the open end of the tube well above the bottle while another carefully pours .5 liters of water into the bottle. Then the student holding the tube should lower it slowly until the water level just reaches the end of the tube. That student should then place a finger firmly over the end of the tube.
7. The student holding the bottle should raise it until its cap is at the 150 cm. level.
8. Direct them to try to deliver water through the tube to all floors of the apartment house (catching the water in a bucket, of course). The tube should lie along the floor for a portion of its length, then rise to the floor in the apartment being tested. (This closely resembles the actual configuration of community water systems: a supply of water at a high elevation, pipes that carry water under ground, below the level of the buildings, and household plumbing that delivers water to kitchens and bathrooms.)
9. This activity includes the mathematical challenge of converting from one set of units to another. To explore conversion further, assign the problems on pages 55 and 56.

ANSWERS TO STUDENT QUESTIONS

Question 8: They should observe that they can deliver water to the lower floors, but not to the top floor (or floors).

Question 9: They should discover that the higher they move the tube, the more slowly the water moves. They may describe this as a difference in water pressure.

Question 10: asks students to devise their own procedure to measure rate of flow. If they have dificulty, you might suggest one of the following methods.

a. They may put a quantity of water (say, .5 liters) of water in the bottle and tube, and record the time it takes for the water to stop flowing. This method has a definite end point, the end of flow, but it will leave some water in the tube.

b. They may fill the tube and the bottom of the bottle, make a mark on the bottle at that level, then add .5 liters to the bottle. They can record the time it takes for the bottle to empty to the original line. This method requires students to judge when the line is reached, but it eliminates the issue of water remaining in the tube.

Question 11: To complete the third data column, students should report their rate of flow in the terms they measured it. For example, if they moved .6 liters of water in 21 seconds, their first rate of flow column would be .6 liters/21 seconds. No calculation is required.

Question 12: In order to compare data with others, the last column asks students to convert their data to standard units, in this case, liters per minute. Sample Problem 1 in the **Rate of Flow** section (page 56) will show them how to make the conversion.

Question 13: For class discussion, you will want to post a **Class Data Table** for students to display data. This will help them look for patterns and reach conclusions. A sample chart is included here (page 51); you may copy it as a transparency so students can enter their data onto an overhead, or you can create your own table on the board or on a flip chart.

ANSWERS TO STUDENT QUESTIONS

Question 14: Rates of flow will decrease at higher floors. Students may or may not see mathematical relationships.

Question 15: Water suppliers store water in elevated tanks to increase pressure in the distribution system. As long as the tank is higher than the highest kitchen or bathroom, water will enter the building through the basement and fill the pipes, escaping wherever anyone opens a faucet or valve.

CONVERSION PROBLEMS

1. $$\frac{15\text{ cm}}{1} \times \frac{1\text{ in}}{2.54\text{ cm}} = 5.9\text{ in}$$

2. $$\frac{1000\text{ ft}}{1\text{ min}} \times \frac{1\text{ mile}}{5280\text{ ft}} \times \frac{60\text{ min}}{1\text{ hr}} = \frac{1000 \times 60}{5280}\ \frac{\text{mi}}{\text{hr}}$$

$$= \frac{60{,}000}{5280}\ \frac{\text{mi}}{\text{hr}} \quad \text{(or mph, miles per hour)}$$

$$= 11.4\text{ mph}$$

3. a. $$\frac{60\text{ mi}}{1\text{ hr}} \times \frac{5280\text{ ft}}{1\text{ mi}} \times \frac{1\text{ hr}}{60\text{ min}} = \frac{5280\text{ ft}}{1\text{ min}}$$

b. $$\frac{5280\text{ ft}}{1\text{ min}} \times \frac{1\text{ min}}{60\text{ sec}} = \frac{5280}{60}\ \frac{\text{ft}}{\text{sec}} = 88\ \frac{\text{ft}}{\text{sec}}$$

4. $$\frac{100\text{ m}}{10\text{ sec}} \times \frac{60\text{ sec}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ hr}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{.625\text{ mi}}{1\text{ km}} = \frac{22.5\text{ mi}}{1\text{ hr}} = 22.5\text{ mph}$$

CLASS DATA TABLE

GROUP (names)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	

ACTIVITY 3-2 HYDRAULICS - CAN WATER FLOW UPHILL?

INTRODUCTION

How does water get to the top floor of an apartment house? In the previous activity, you experimented to learn whether the diameter of a pipe has an effect on the rate at which water moves through it. In this activity you will use only one size tube (1/4" inside diameter), but you will vary the vertical distance between the containers (bottle and bucket) to learn if that affects the rate of flow.

MATERIALS

Your teacher will give each group the following items:

- -a plastic bottle with its bottom cut off
- -a measuring cup with markings to .5 liters
- -a plastic cap with a tube through it
- -a bucket to collect the water
- -a meter stick
- -a large sheet of paper
- -a permanent marker
- -a data recording form

PROCEDURE

1. Draw a seven-story apartment house on the paper with its ground floor at the bottom and its roof at the top. Each story should be 30 cm high. Draw a bathroom at each level.

2. Tape the paper to the board or wall, with its lowest floor at ground level.

3. Tape a mark on the wall at an elevation of 150 cm. next to the apartment building. Your mark should be at the top of the 5th floor of your building.

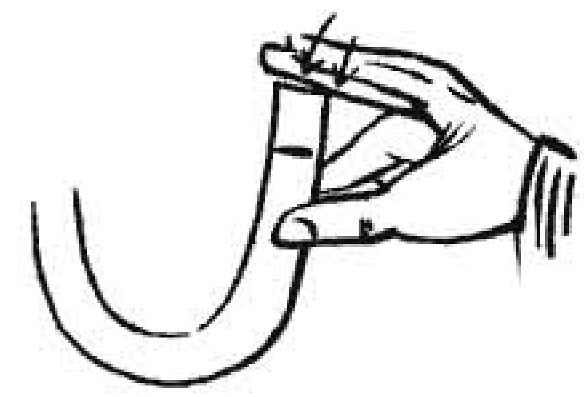
4. Holding the end of tube higher than the bottle, carefully pour .5 liters of water into the bottle.

NAME ______________________

GROUP MEMBERS ______________________

____

DATE ______________________



5. Slowly lower the tube until the water just reaches its end. Place your finger firmly over the end of the tube.

6. Hold the bottle with its cap at the 150 cm. level.

7. Try to make water come out of the tube at the first floor. (Be sure to have your bucket in place.)

8. Now move the end of the tube to the second floor, and the third, and the fourth. Does water reach all those floors? What about the top floor?

9. Can you observe any difference between how the water moves at the first floor and at the higher floors? What do you see?

10. Try to design a procedure to measure the rate of water flow at different levels of your building. Someone will need to act as timer, and you will need to work closely together to get consistent data. Try your procedure at least twice at each level, to be confident you have reliable data. Your measurement data will complete the first two columns on the **Group Data Table**.

GROUP DATA TABLE

FLOOR	Volume of Water (ltrs)	Time (sec)	Rate of Flow (Vol/Time)	Rate of Flow (Liters/min)*
1				
2				
3				
4				
5				
6				
7				

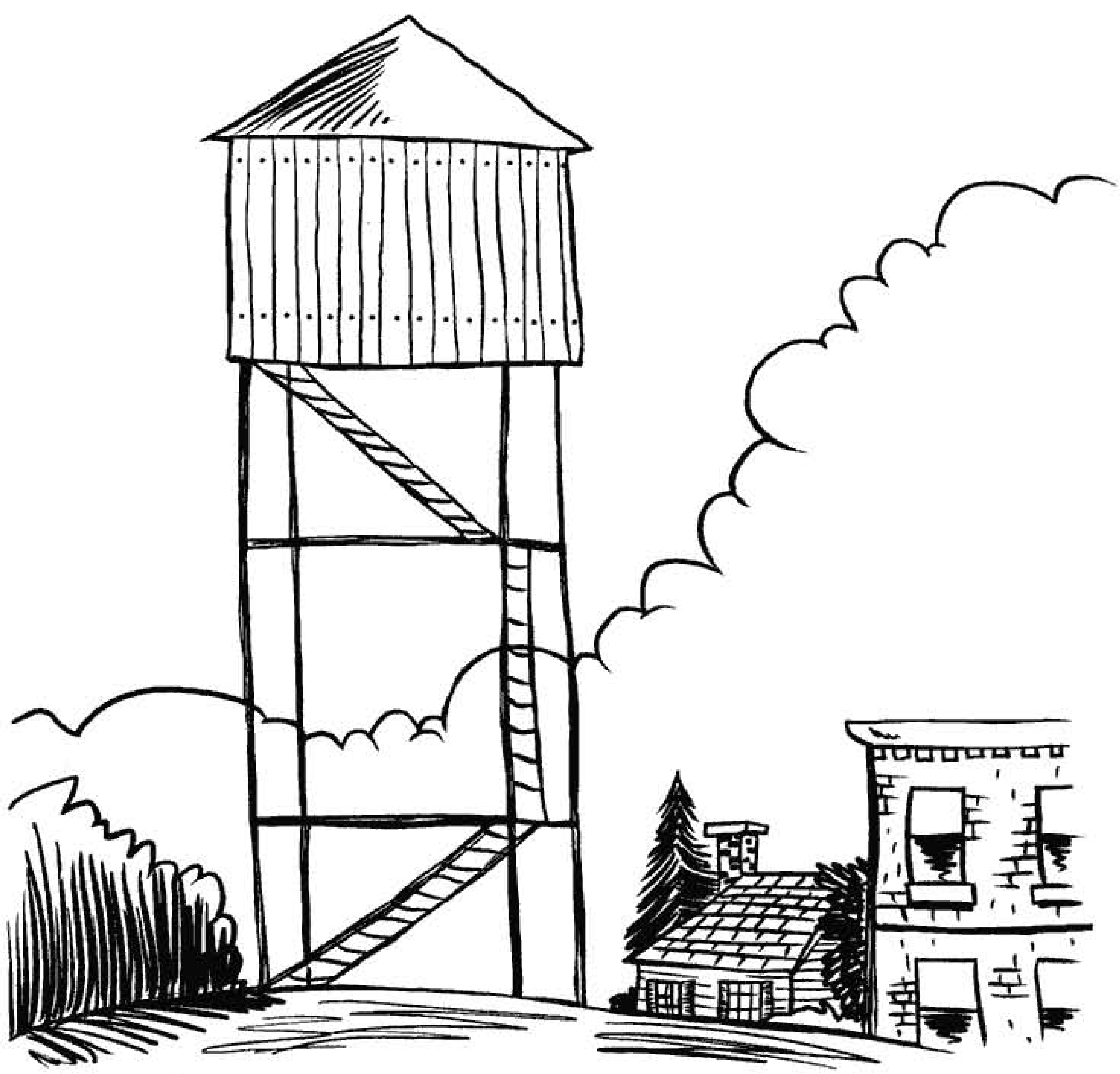
11. To complete the next column, express the rate of flow as your Volume column divided by your Time column. (Example: .6 ltrs/21 sec.)

12. To complete the last column, convert your rate of flow to standard units, liters per minute. If you don't know how to convert to liters per minute, see **Sample Problem 1** on page 56. Round your answer to the nearest tenth.

13. Compare your results with those of other groups on the **Class Data Table** that your teacher provides. Did you all use the same procedure?

14. Do you see any patterns in the data? If so, what are they?

15. How do water suppliers make use of this phenomenon to assure water pressure for their customers?



CONVERTING RATE OF FLOW

Sample Problem 1: If .5 liters flows through a tube in 16 seconds, how many liters (to the nearest tenth) would flow through in one minute?

Solution:

$$\frac{.5 \text{ liters}}{16 \text{ ~~seconds~~}} \times \frac{60 \text{ ~~seconds~~}}{1 \text{ minute}} = 1.9 \ \frac{\text{ltrs}}{\text{min}}$$

Note that because 1 minute = 60 seconds, the fraction $\frac{60 \text{ seconds}}{1 \text{ minute}} = 1$. Multiplying a quantity (such as $\frac{.5 \text{ liters}}{16 \text{ seconds}}$) by 1 does not change its value. It does allow us to change the units in which the value (rate of flow, in this case) is reported.

Sample Problem 2: If .5 liters of water moved through a tube in 20 seconds, how many gallons (to the nearest tenth) would flow in one minute?

Solution: You can convert liters to gallons and seconds to minutes in the following way:

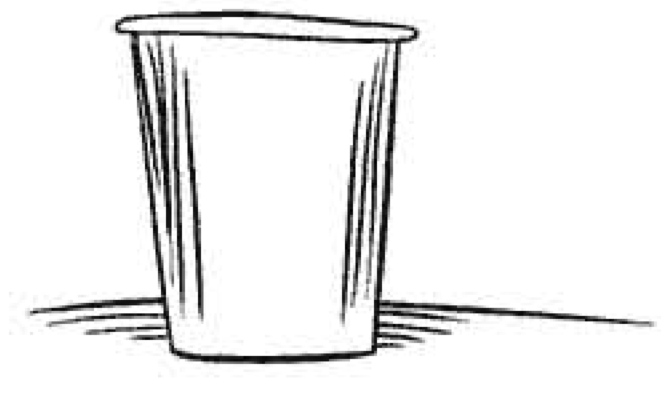
$$\frac{.5 \text{ ~~liters~~}}{20 \text{ ~~seconds~~}} \times \frac{1.06 \text{ ~~quarts~~}}{1 \text{ ~~liter~~}} \times \frac{1 \text{ gallon}}{4 \text{ ~~quarts~~}} \times \frac{60 \text{ ~~seconds~~}}{1 \text{ minute}} = \frac{.5 \times 1.06 \times 60}{20 \times 4} \ \frac{\text{gallons}}{\text{minute}}$$

= .4 gallons per minute

Note two things: 1) Because 1 liter = 1.06 quarts, 1 gallon = 4 quarts, and 1 minute = 60 seconds, each of those three fractions equals 1. Multiplying a quantity by 1 does not change its value.

2) Similar units on the tops and bottoms of fractions cancel each other. Thus, liters, quarts, and seconds all cancel, leaving the flow rate expressed in gallons and minutes.

Now try these conversion problems.



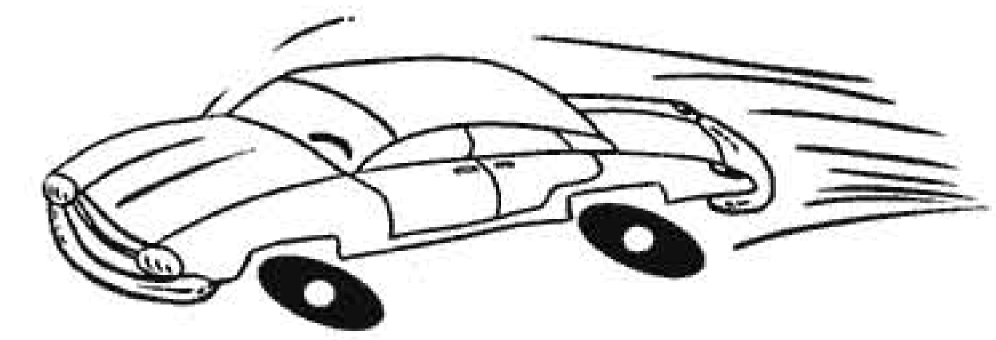
1. You know a container is 15 cm deep. How deep is that in inches?

   You need to know that 1 inch = 2.54 cm.

Hint: For this problem, remember that the fractions $\frac{2.54 \text{ cm}}{1 \text{ in}}$ and $\frac{1 \text{ in}}{2.54 \text{ cm}}$ both equal 1. Which way will you use the fraction? (Round your answer to the nearest tenth of an inch.)

2. Can you run 1000 feet in one minute? If you can, you traveled at the rate of $\frac{1000 \text{ feet}}{1 \text{ minute}}$.

   But how fast is that in miles per hour(to the nearest tenth)? You know that 1 hr = 60 minutes, and 1 mile = 5280 feet.



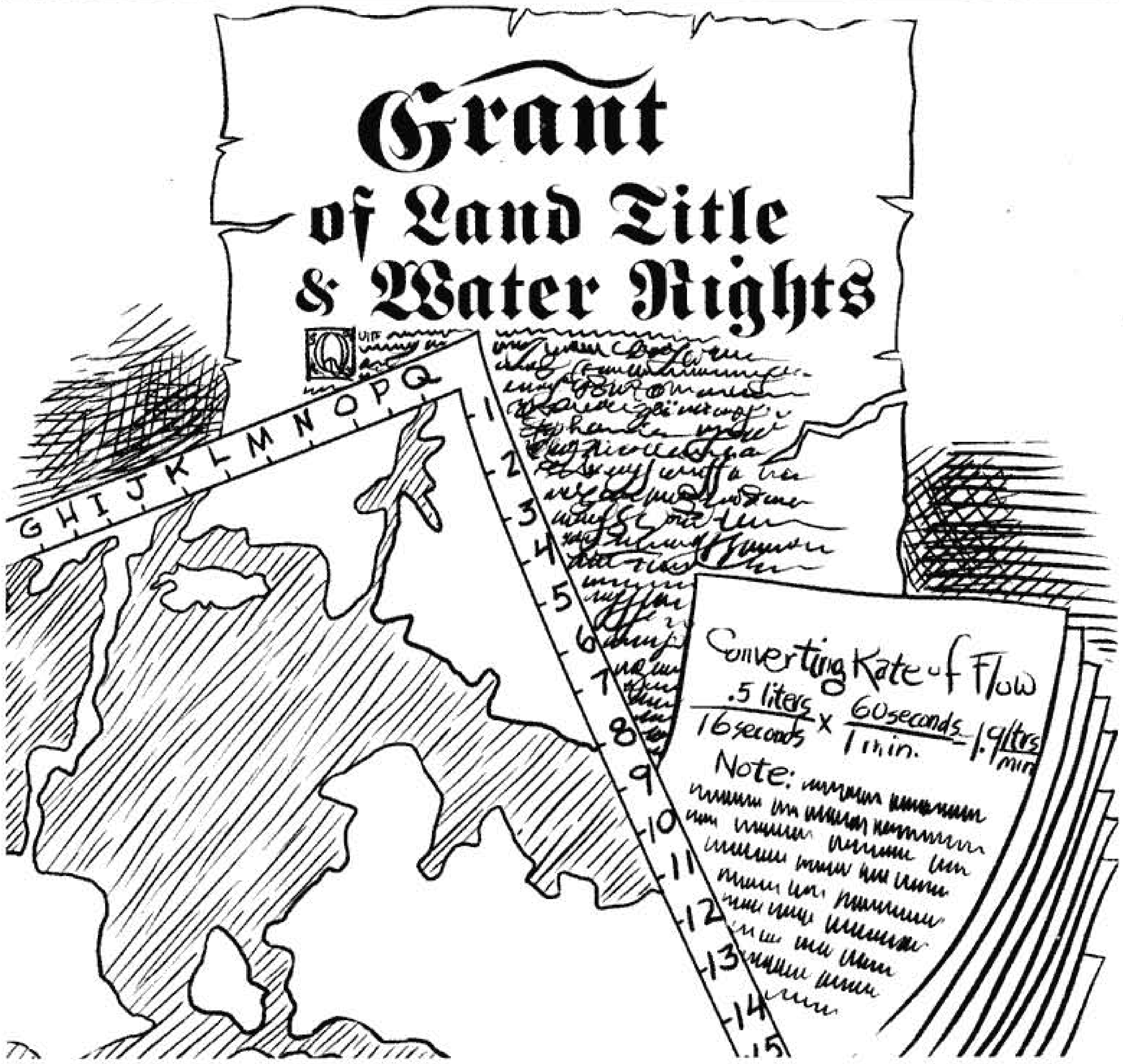
3. a. A car is traveling 60 mph. How far does it move (in feet) in 1 minute?

b. How far does the same car travel in 1 second?

4. Optional: (And harder.) World class sprinters run 100 meters in about 10 seconds. What is their average speed in miles per hour?

Facts: 1000 meters = 1 kilometer
1 kilometer = .625 miles (= 5/8 mile)

LESSON 4 BOSTON'S WATER HISTORY



LESSON 4 BOSTON'S WATER HISTORY

Water supply in Boston was a simple matter three hundred years ago, when no one had indoor plumbing and relatively few people lived in the colonial city. In the first activity, students will learn how Boston grew, not only in population but geographically. Filling tidal areas added land for houses and businesses, but it didn't increase the available fresh water. The creation of South Boston, the Back Bay and the South End eventually forced Boston to look inland for clean, fresh water. Using coordinates on a map, students will locate familiar landmarks to learn just how much Boston has grown.

Many Bostonians know vaguely that much of their water comes from a place called Quabbin Reservoir. Fewer know of the sacrifices made several generations ago to create this vast and precious resource. A second map activity honors the towns that were taken in the 1930s so that we could have a dependable water supply far into the future.

ACTIVITY 4-1 WET HISTORY OF BOSTON

SUMMARY Students will learn about the growth of Boston since colonial times.

CONTENT AREAS history, social studies, math

GOAL to understand the growth of Metropolitan Boston and the corresponding planning and building required to meet its water needs

TIME one session, plus homework

MATERIALS two one-foot rulers or other straight edges for each student

ADVANCE PREPARATION

- Copy student pages and maps for each student.
- Collect necessary straight edges.

BACKGROUND INFORMATION

Boston began as a small settlement of colonists in the 1600s and has grown to be one of the world's major cities. In earlier days, the Shawmut Peninsula (original Boston) was isolated from most neighboring areas by rivers and tidal flats. Filling of tidal areas, building of dams and tide mills, construction of bridges and extension of roadways have changed Boston's geography dramatically. Today, the original footprint of Boston has been obscured by a greatly expanded metropolis.

The few wells, springs, and streams on the peninsula that supplied water to the early settlers eventually proved inadequate for the growing population. As people and animals crowded together, the water sources became polluted. In 1795, a wooden pipeline was constructed from Jamaica Pond, far from the city in those days, to supply plentiful, clean water to the growing city.

Filling the Back Bay, East and South Boston, and other areas greatly increased the land available for homes and businesses, but it didn't increase the available water. The inadequacy of the Jamaica Pond system was demonstrated by a large fire in 1825, and city officials struggled to devise a plan for Boston's water future. Finally, in 1848, water from Lake Cochituate in Natick was brought to Boston, setting the precedent of westward expansion for the water system.

In the late 1860s and early 1870s, Boston annexed a number of communities, such as Dorchester, Roxbury, Brighton and Charlestown. One incentive for these communities to join Boston was connection to its water system. Then, in 1895, the Metropolitan Water District was formed, inviting membership from any community within a ten mile radius of the State House. Wachusett Reservoir at the turn of the century and Quabbin Reservoir in the 1930s were built to meet the needs of the new, larger district; they comprise the water sources we depend upon today.

Notes about the maps: The original Boston Harbor shoreline was not as distinct as the map in this exercise suggests. Large areas were shallow water at high tide and mud flats at low tide. Some areas that appear as islands here may have been connected to the mainland at low tide. Even sections of the Shawmut Neck could be covered with water at high tides during storms.

Due to limitations of the grid system, some landmark locations may not be exact, but they will work well for the purposes of the activity

TEACHER PROCEDURE

1. Give each student (or pair of students) a copy of the student pages, including **Map One - Original Boston** and **Map Two - Water Resources.**
2. Read the procedure with them, to be sure they understand the use of coordinates on a map and to clarify that if a point lies between two letters, say C and D, we label it as CD. Similarly, 8.5 is half way between 8 and 9.
3. The activity itself can be done as classwork or homework. If students are doing it in class, circulate to be sure they understand the concept of coordinates.
4. As a follow-up when students have completed their work, you may show them an overhead transparency of **Original Boston With Current Shoreline**, or distribute copies of it. Discuss with students what large sections of today's city (Logan Airport, South Boston, Back Bay and the South End) were created by filling marshes and tidal areas.
5. Conclude the activity by asking the students to answer some reflection questions. These might include but not be limited to:

   a. What two or three things most surprised you in this activity?

   b. Why do you think we no longer use Jamaica Pond or Lake Cochituate for water supply?

   c. Why are fires important to the development of Boston's water supply?

   d. Why don't we use Boston Harbor as a water source?

ANSWERS TO STUDENT QUESTIONS

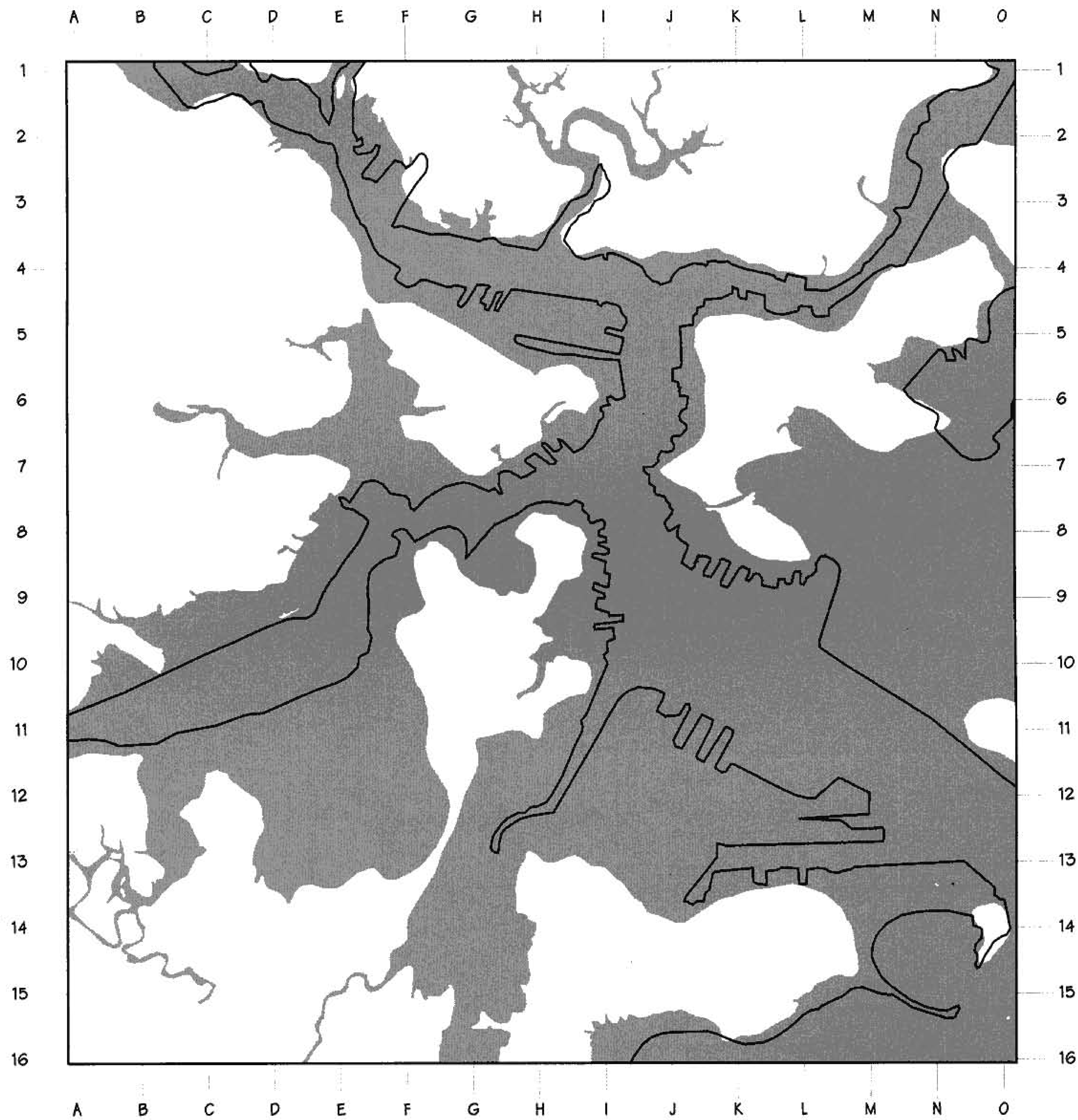
b. Too many people now live close by Jamaica Pond and Lake Cochituate, so the water is no longer as clean.

c. Firefighting requires large quantities of water in a short time. Inadequate sources are quickly depleted. At least once in Boston's history, Boston Harbor water was used to fight fires, but the salt water caused rapid corrosion of pipes, pumps and valves.

d. Boston Harbor contains salt water, not fresh water. Even if the harbor were as clean as possible, treating salt water to convert it to fresh water would be hugely expensive.

ACTIVITY 4-1 WET HISTORY OF BOSTON

ORIGINAL BOSTON WITH CURRENT SHORELINE



ACTIVITY 4-1 WET HISTORY OF BOSTON

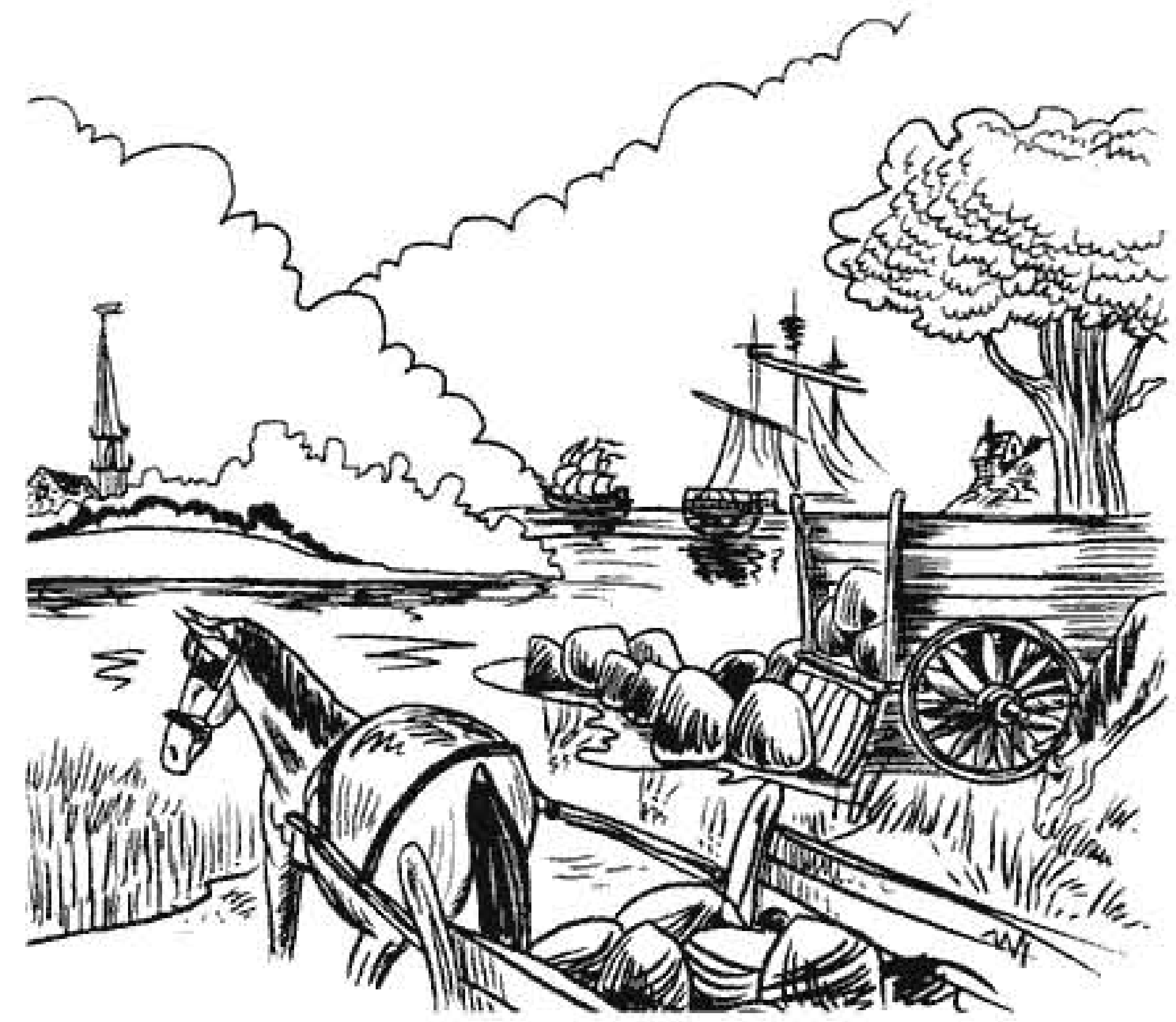
INTRODUCTION: THE STORY OF EARLY BOSTON

Boston, in Ben Franklin's boyhood, was a very different community from the city we know today. It was a peninsula of hills, fields, and marshy shores, very much a port and sea-faring place, inhabited by merchants, shopkeepers and shipbuilders. Yet as simple as it sounds, by 1743, when Franklin was 37 years old, Boston was the largest town in British North America, larger than Philadelphia or New York, with a population of 16,382.

The center of town was the present intersection of State and Washington Streets. To the east, State Street ran down to Long Wharf, the sea, and the rest of the world. The high ground to the north, which we call Beacon Hill, was mostly fields and a few poorer neighborhoods. To the south and west, a main road we now call Washington Street was Boston's only link to the mainland, running along a narrow neck of exposed land that connected to Roxbury. A fortified gate there protected the town by land; gun emplacements on the hilltops and in shoreline batteries controlled access by sea.

Residents of Dorchester and Cambridge did not visit Boston often, for travel by foot or horseback was time consuming at best and wet and muddy in stormy weather. Jamaica Pond was far out in the country. The first bridge that linked Boston and the mainland was built to Charlestown in 1786. Boston was no longer quite so isolated.

The greatest geographical differences between Boston in 1776 and today are its shoreline and its lowered hills. Large areas we know as the central waterfront, South Cove, the South End, South Boston, East Boston and Back Bay were simply tidal flats -- that is, shallow water at high tide and marshy ground at low tide. Early ships unloaded by anchoring in the harbor and transferring cargo to lighter boats. Only when docks and wharves were extended to deeper water could ships unload directly onto land.



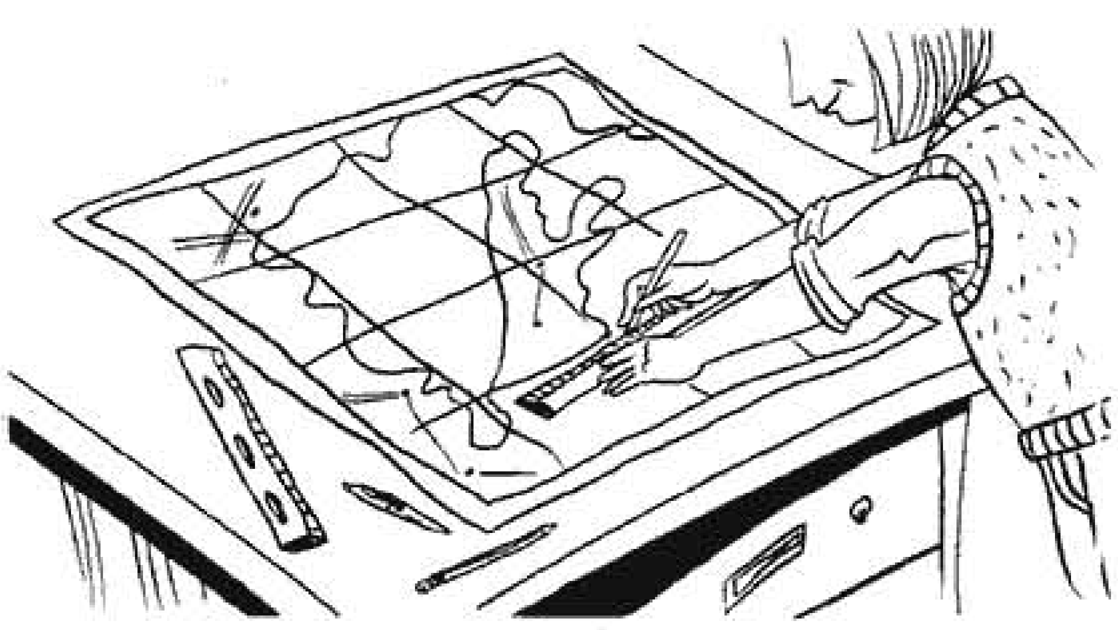
How did tidal flats become neighborhoods? Beginning around 1800, several of Boston's tall hills were cut down, and their gravel and soil were hauled to the shore and dumped there. This raised the ground high enough that new buildings would not flood at high tide. Beacon Hill was 60 feet taller than it is today, and two other hills on either side of it (the three together were called Trimountain) were cut down completely. Much of this work was done by hand, with only horses to help. Later, beginning in the 1850s, when most of the hills had been moved, gravel was dug by steam shovels in Needham and brought by railroad to fill the Back Bay and South End. The land for the neighborhoods from Washington Street to the Charles River on the northwest, and from Washington to the Fort Point Channel on the east, was all "created" by filling tidal flats.

Map One in this exercise will show you just how much Boston has changed. The white area is land; the gray is water.

PROCEDURE

A. Using small, neat lettering, label the following features of the 1775 Boston area. Example:

1. Castle Island O - 14



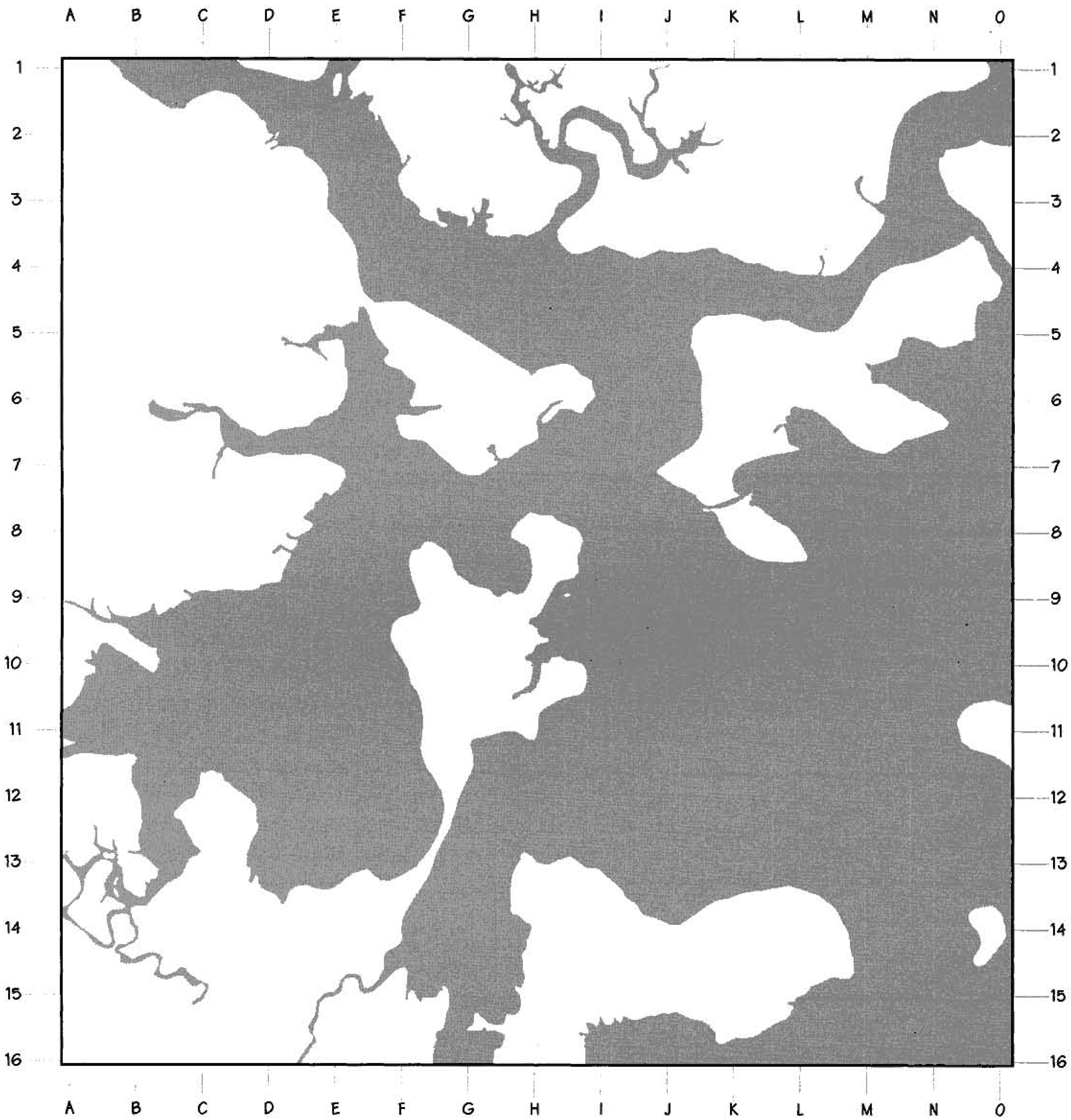
First line up one straight edge along the two "Os" at the top and bottom of the page. Then line up the other straight edge along the "14s" on the sides. The two lines cross on Castle Island.

Note: If a point is between two letters, say C and D, we will give its location as CD. If it is between 8 and 9, we will call that 8.5.

NAME ________________________

DATE ________________________

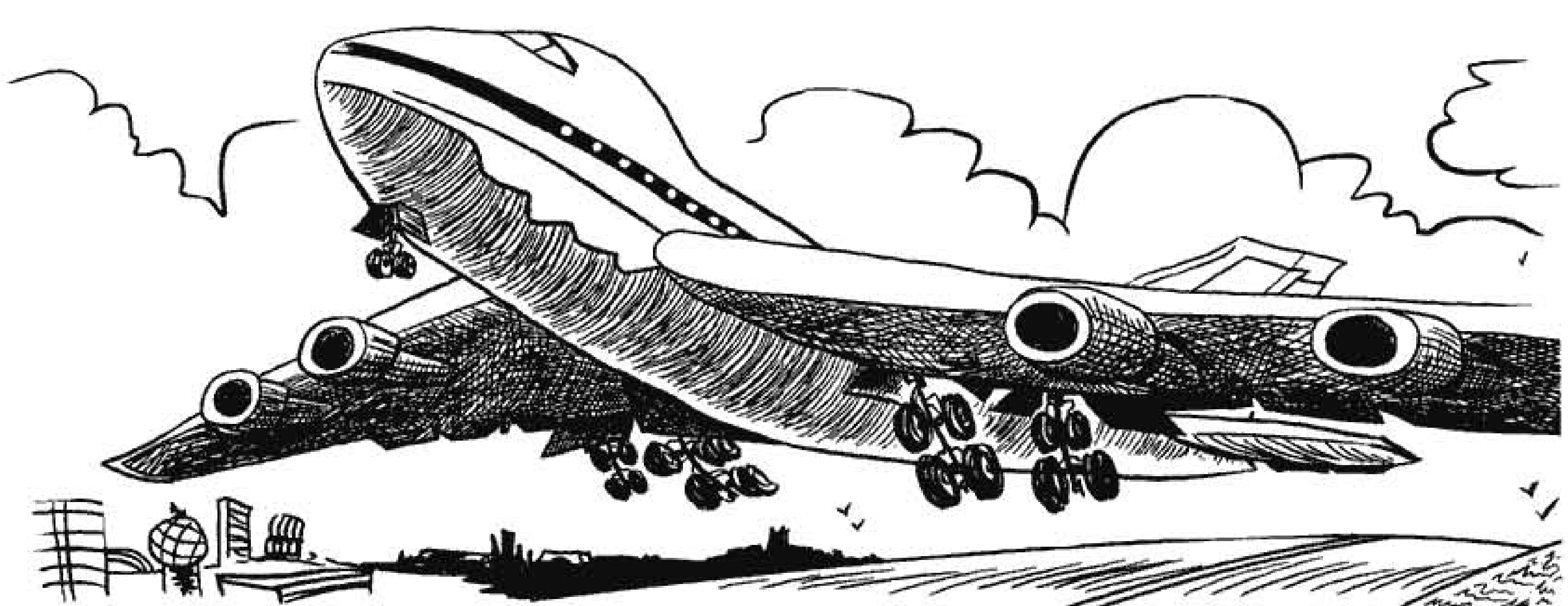
MAP ONE-ORIGINAL BOSTON



2. Charlestown	G- 6	7. Dorchester Heights	K - 15
3. Noddle's Island	L - 6	8. Charles River	A - 11
4. Shawmut Peninsula	G- 10	9. Muddy River	A - 13.5
5. Shawmut Neck	FG - 12 to FG - 13	10. Stony Brook	C - 15
6. Cambridge	B - 8	11. Governor's Island	O - 11

B. To understand Boston's growth, locate the following modern landmarks on your map. If there is too little room to write, simply put down an abbreviation or the number.

12. Fenway Park	B - 12	22. State House	G - 9.5
13. MIT	C - 9.5	23. New Federal Court House	IJ - 10.5
14. Museum of Science	E - 8	24. Old North Church	HI - 8
15. Central Sq., Camb.	A - 8	25. Boston City Hospital	E - 14.5
16. Symphony Hall	CD- 13	26. Museum of Fine Arts	B - 14
17. N. E. Aquarium	I - 9.5	27. Hatch Shell	EF - 10
18. Lechmere Station	E - 7	28. L Street Bath House	K - 15.5
19. Mass General Hospital	H - 7.5	29. Kendall Square	CD - 8.5
20. Commonwealth Pier	JK - 11	30. Bunker Hill Monument	GH - 6
21. Boston Public Library at Copley Square	E - 11.5	31. Southwest boundary of Logan Airport	L - 9.5 to O - 12



As the city grew, it needed more water. The few wells and springs soon proved inadequate, and the concentration of horses and outhouses gradually polluted the groundwater. People channeled roof drains into underground storage tanks called cisterns, but in a city of soot and sea gulls, roof water wasn't always the best quality, either.

In 1795, a group of investors formed the Jamaica Pond Aqueduct Company and constructed a wooden pipeline to bring the relatively untouched waters of Jamaica Pond to the growing town. (Jamaica Pond is just off the southwest corner of our map.) Residents could now fill their cisterns with much cleaner water, and those who began to pipe it into their houses no longer needed to go outside to fetch water.

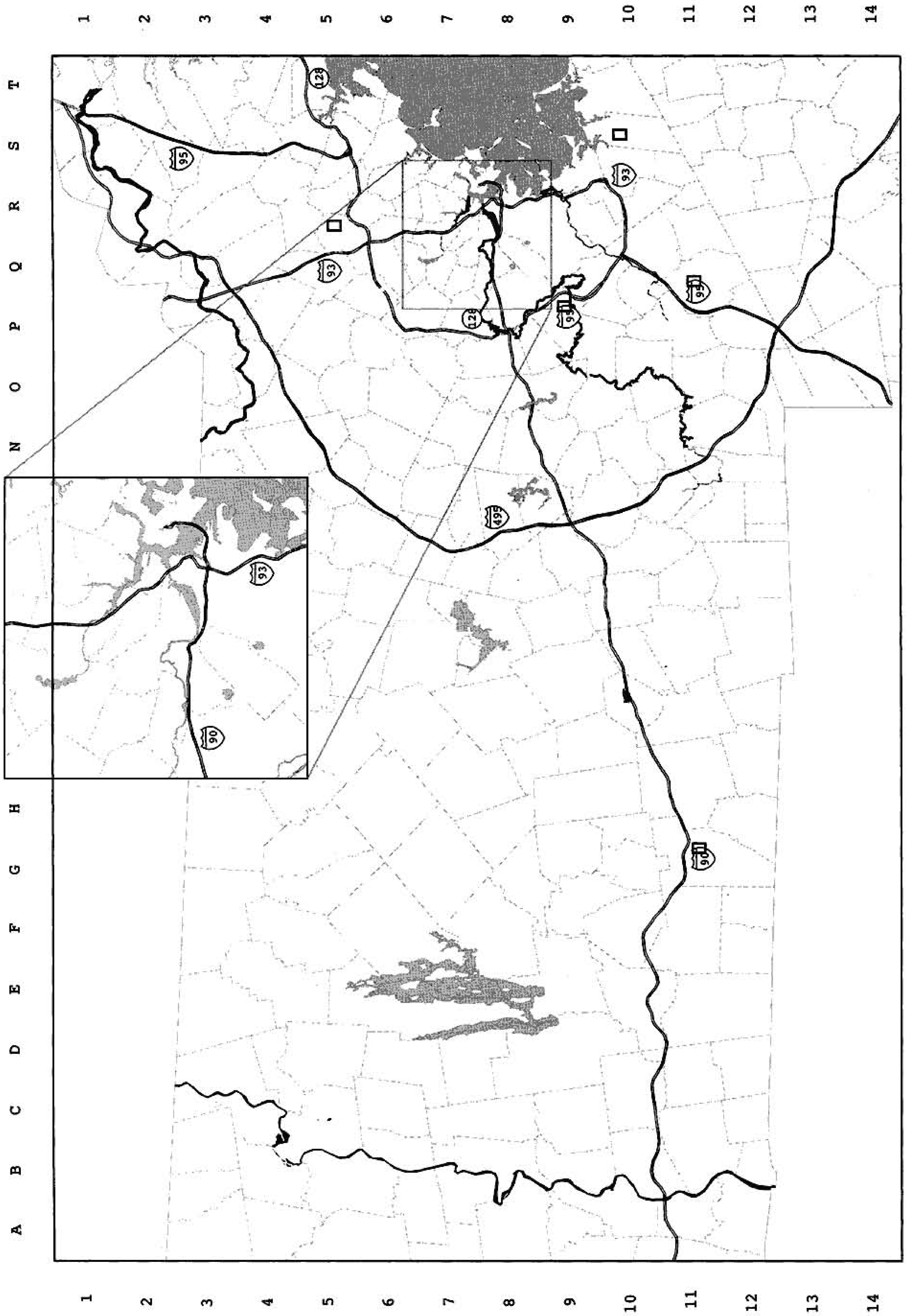
A large fire in 1825 demonstrated the need for a larger water supply, and in 1848 water was brought all the way from Lake Cochituate in Natick. More and more people could now have indoor plumbing. In 1865, the Upper Mystic Lake, northwest of the city, was developed for water supply.

Another fire, the most significant in Boston's history, took place in November, 1872. A series of additional reservoirs were built soon after, concluding with the Sudbury Reservoir in the 1890s. Through these decades, Boston annexed the neighboring towns of Roxbury, Dorchester, Brighton and Charlestown, and the demand for water continued to grow.

In 1895, a new Metropolitan Water District was formed, open to any community within ten miles of the State House, or roughly the area within Route 128 today. Rivers in Central Massachusetts, the Nashua River at the turn of the century and the Swift River in the 1930s, were dammed to form Wachusett and Quabbin Reservoirs, the water sources we depend upon today. Wachusett and Quabbin are the only sources currently in use. All the sources that served Boston earlier in its history, from Jamaica Pond to Sudbury Reservoir, have been retired.

C. **Map Two** covers a portion of Massachusetts, but not Cape Cod or the Berkshire Mountains. It shows some of the major rivers in our area and the water sources that have served Metropolitan Boston over the years. Label those features as listed below. For each body that has served as water supply, include the date when it was developed.

Charles River Basin (inset) KL - 2.5	Merrimack River N - 3 to T - 1
Jamaica Pond (inset) K - 4	Neponset River P - 10.5 to RS - 9
Mystic Lakes (inset) J - 1	Sudbury Reservoir M - 8
Lake Cochituate O - 8	Wachusett Reservoir K - 7.5
Connecticut River C - 3 to B - 12	Quabbin Reservoir E - 7


1 2 3 4 5 6 7 8 9 10 11 12 13 14
A B C D E F G H I J K L M N O P Q R S T
128
95
93
495
90

ACTIVITY 4-2 THE QUABBIN STORY

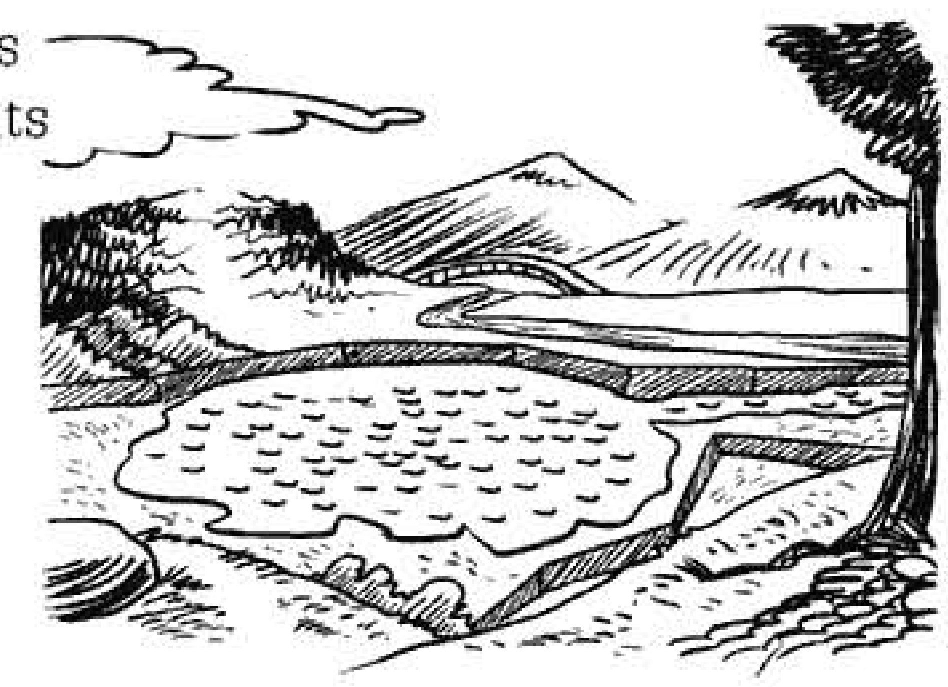
SUMMARY Students learn about the Quabbin Reservoir and its history in the Swift River Valley.

CONTENT AREAS history, social studies

GOAL to consider the sacrifices that made Quabbin Reservoir, our main water supply, possible

TIME one session

MATERIALS
- map of Quabbin Watershed and list of landmarks
- two straight edges per student or pair of students



ADVANCE PREPARATION

- Copy maps and student pages.
- Optional : Read "Letting Swift River Go" by Jane Yolen.

BACKGROUND INFORMATION

Many people know that Metropolitan Boston gets much of its drinking water from Quabbin Reservoir. Some remember vaguely that towns were flooded and property taken by eminent domain. Which towns were destroyed? Which of the towns were below the new water line, and which were just too close to the new reservoir? This activity should remind students of the sacrifices others have made for the health and well-being of future generations.

Source protection is one of the most important practices in water supply. Water that doesn't get polluted in the first place needs less treatment and can become better drinking water. Understanding this, planners persuaded the state to buy not only the land that would be flooded, but large areas above the water line, too.

Access to Quabbin is controlled and restricted. Students may have heard that while no one can swim at Quabbin, people can fish from boats in some places and that those boats have gasoline engines. This may seem contradictory to them. However, microorganisms introduced to the water by swimming might persist in the water long enough to enter the aqueduct. Gasoline, on the other hand, floats on water's surface and evaporates readily. The aqueduct intakes are far below the surface, and boats are allowed no closer than half a mile from those intakes.

TEACHER PROCEDURE

1. Hand out maps of the Quabbin watershed and the student instruction pages.
2. Be certain they understand that JK is a coordinate half way between J and K, and that a coordinate 5.5 is about halfway from 5 to 6. Do one or two sample locations with them, then assign the rest as classwork or homework.
3. Discuss the activity when they are done. What reactions did they have? Did it lead them to think differently about our reservoirs and the water they use each day?

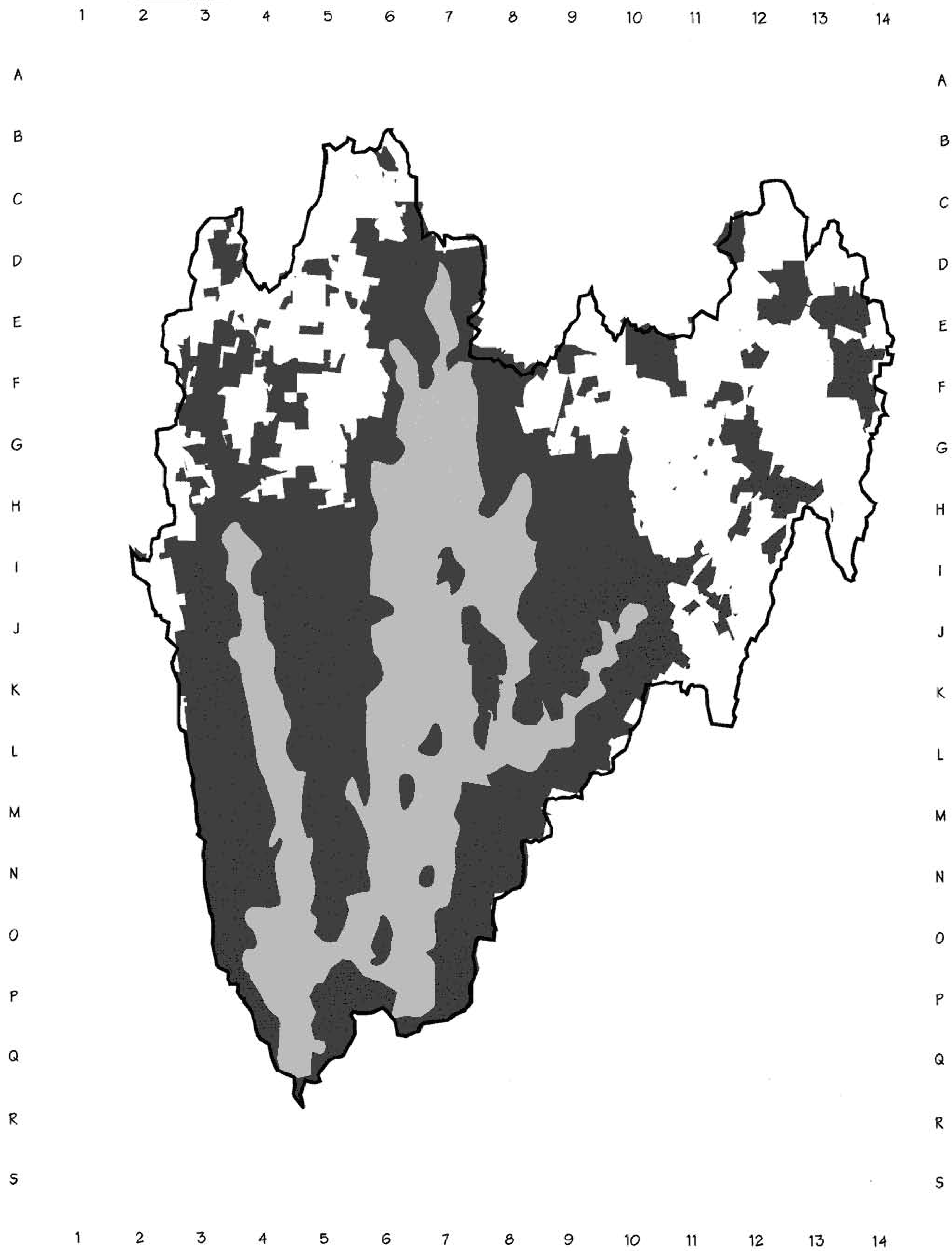
ACTIVITY 4-2 THE QUABBIN STORY

INTRODUCTION

Quabbin Reservoir was built in the 1930s to provide Metropolitan Boston with an ample supply of water. Before the construction, the Swift River Valley was home to several towns and villages, many farms, mills and other businesses, and a railroad that connected Springfield and Athol, Massachusetts. 2,500 people lived in the valley.

Damming the river and flooding the valley meant that everything had to go. All buildings were removed, trees were cut down, and the valley floor was generally cleared of anything that might contaminate the water. The state purchased all the land that would be flooded, plus a good deal of the land around the new reservoir. People had no choice but to sell. A law called "eminent domain" states that owners must sell their property when it stands in the way of a large project, like a highway or reservoir, that will be of benefit to a great many people.

QUABBIN WATERSHED



QUABBIN LANDMARKS

1.	Q - 5	Site of main Quabbin Spillway; elevation 530 feet above sea level
2.	L - 5	Town of Prescott; 1920 population: 236
3.	I - 10	Town of Dana; 1920 population: 599
4.	O - 6	Little Quabbin Hill; site of annual motorcycle hill climb; elevation 740 feet above sea level
5.	MN - 7	Town of Greenwich; 1920 population: 399
6.	N - 6	East Branch of Swift River joins Middle Branch of Swift River
7.	P - 4.5	West Branch of Swift joins Middle Branch
8.	H - 7.5	Village of North Dana (part of the Town of Dana)
9.	N - 6.5	Mount Lizzie
10.	R - 2	Belchertown, Massachusetts; 1990 population: 10,579
11.	S - 10	Ware, Massachusetts; 1990 population: 9,808
12.	QR - 4.5	Site of Winsor Dam, completed 1938
13.	A - 5	Town of Orange, Massachusetts; 1990 population: 7,312
14.	L - 6.5	Quabbin golf course
15.	LM - 7	Lake Quabbin; now the beginning of the aqueduct carrying water to the east
16.	JK - 7.5	Mount Zion
17.	A - 9	Town of Athol, Massachusetts; 1990 population: 11,451
18.	P - 5.5	Great Quabbin Hill; site of observation tower today; elevation: 1020 feet above sea level
19.	O - 5	Town of Enfield, largest town in the valley; 1920 population: 790
20.	I - 7	Mount L.

QUESTIONS AND CONCLUSIONS

1. Suppose you had lived in one of the valley towns. Your parents and grandparents were born there, too, and aunts and uncles had farms and businesses in the valley. How would you have reacted when the state told you that your town would be taken and everyone must move?

2. Quabbin is a beautiful wilderness area. Many have suggested that people be allowed to camp, canoe, or cross-country ski there. Why do you think the rules continue to prohibit such activity?

LESSON 5 WATERSHEDS & WATER QUALITY

LESSON 5 WATERSHEDS & WATER QUALITY

People have divided lands by political boundaries, from property lines to international borders. Water defines nature's boundaries by dividing the earth into watersheds. The watershed concept is increasingly invoked by environmental planners and regulators; roadside signs call attention to these natural boundaries. People will increasingly be called upon to see themselves as citizens not only of a particular town or state, but of a certain watershed.

In the first activity, students create a model landscape and rain on it, observing the movement and accumulation of water. They then locate a community in the watershed and plan their town's water resources. MWRA operates a surface water system, drawing water not from aquifers through wells, but from water bodies on the surface, specifically, reservoirs. Thus it is important that consumers understand the watershed concept as it applies to their drinking water.

In order to assess the safety of water for human consumption, scientists must measure the levels of a variety of contaminants. The second and third activities in this lesson explore the units in which contaminants are measured: parts per million and parts per billion. They are intended to make students more conversant in the terminology that can help them make responsible decisions about their own health and become informed environmental citizens.

Activity 5-1 WATERSHEDS

SUMMARY Students will build a model landscape and use it to investigate the flow of water over land.

CONTENT AREAS earth science, social studies

GOAL to understand the watershed concept

TIME one session

MATERIALS For each group:
- plastic or cardboard box
- white plastic trash bag
- spray bottle
- water with blue coloring
- newspaper
- paper towels
- items to represent buildings in landscape
- red food coloring

Advance Preparation

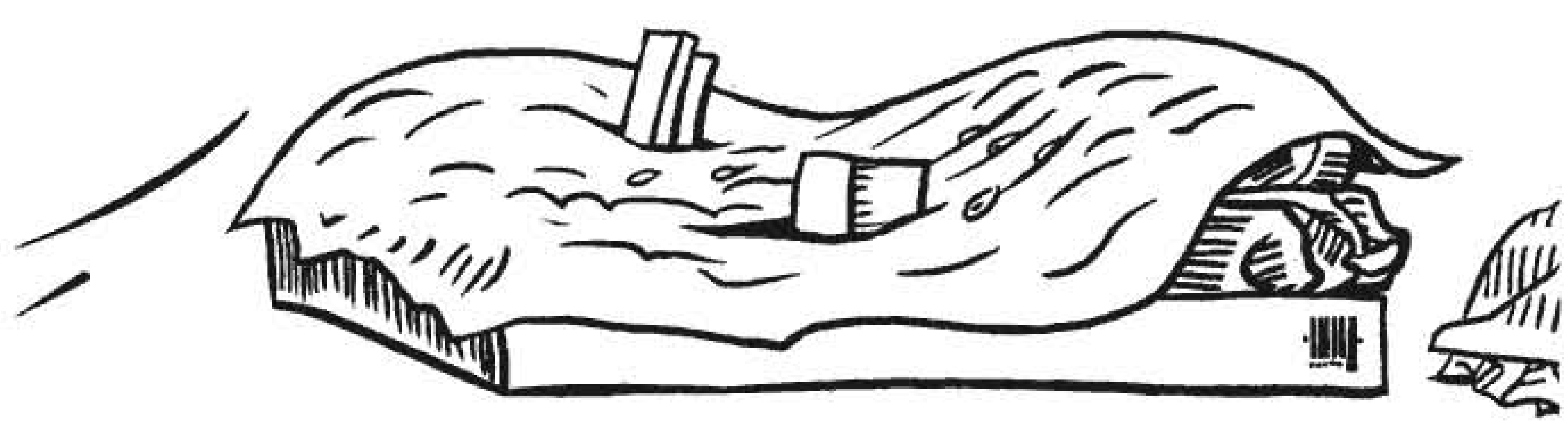
- Copy student pages.
- Create student groups.
- Fill spray bottles with blue water.
- Put student materials on table.
- Create "trash" for landfills by putting 2-3 drops of red food coloring on a small piece of paper towel and folding it into a small ball. It helps to let the first drop of food coloring dry before you add the second, and to allow all coloring to dry before folding the paper.

Background Information

A watershed is the area of land which drains precipitation to a specific body of water. Watersheds vary in size. You might think of the Continental Divide as dividing two huge watersheds: the Atlantic Ocean Watershed and the Pacific Ocean Watershed. You also might think of the road in front of your school as belonging to the "watershed" of the local storm sewer. Ridges or divides are the higher areas of land that separate two watersheds.

Activity 5-1 WATERSHEDS

Reservoir water is collected from watersheds. The precipitation lands on the ground and is "shed" to tributaries that lead to the reservoir. Both meanings of the word "shed" apply to the definition of watershed. Water is "shed" from the land, and a watershed is like a storage area ("shed") for water. Watershed boundaries help water suppliers estimate how much water will drain to the reservoir. The boundaries also help us understand of what type of waste can end up in the reservoir. Pollution that occurs inside the watershed boundary may have an effect on the quality of water. Soil acts as a filter for pollution, but once the contamination reaches a tributary it will travel pretty quickly to the reservoir.



Teacher Procedure

1. Tell students they are going to build a model landscape that will help them understand watersheds.
2. Give each group a set of materials.
3. Each group should create a landscape by putting the crumpled newspaper in the bottom of the box, and then placing the plastic bag over the top of the newspaper. Tell them to make sure that the edges of the plastic bag stay outside the box.

Part A - Getting to know your landscape

4. Ask students to describe the type of land formations they see in their landscapes (hills, mountains, valleys). Ask them to predict what will happen when they spray water over the landscape.
5. The bottle of water represents rain. The students should rain over their landscapes for about one minute. (You may want each student in the group to take ten sprays).
6. While spraying, each group should make four observations about what they see happening in the landscape. They should record these on their **Student Recording Page**.
7. Ask each group to explain one of their observations to the class. Someone may mention that the inclines have water drops clinging to them. Ask the rest of the class if they have the same observation.
8. Students will now try to follow the path of water over their landscape. Tell them to choose one drop of water and predict where that drop will flow when it begins to move. Students should test this prediction by gently spraying water over the drop so that it becomes heavy enough to move. They should do this process several times. The idea is for the students to get to know the landscape. Remind students to predict carefully before they see where the water flows.

9. Ask students to record on their **Student Recording Page** how this landscape is different from the real earth. Have students share some of those answers with the class. Eventually someone will say that the real earth is covered with soil and so water gets absorbed. Give each group two pieces of paper towel* to place over the landscape to act as soil.

10. Students should spray over the landscape again and observe how it acts differently with the "soil" on it. Students should answer question 3 on the **Student Recording Page**.

PART B - Developing a community in your landscape

11. Tell students they are going to plan a community for their landscape. They will need to include a water supply and a landfill.

12. You will give each group something to represent the buildings in the community (small game pieces, building toys, coins). You will also give each group a small piece of paper towel with red food coloring rolled up to represent the landfill. They should place these in the landscape.

13. When they have chosen the locations for those three items (buildings, landfill, reservoir) they should have a rainstorm over their landscape. The "pollution" in the landfill will start to leak out. Some students will find that the landfill contaminated their drinking water supply.

PART C - Discussing the activity

14. Lead a class discussion on the changes students might make to their community design.

15. Some teachers might want to do the activity again after a day or two to see if students can use the information they learned to avoid polluting the water supply.

* Some guidance on paper towels: White is best. Highly absorbant (better quality towel) is better. Push towel gently to conform to shape of hill.

ACTIVITY 5-1 WATERSHEDS

INTRODUCTION

In this activity you will create a model landscape and discover how rain travels over the land.

PROCEDURE

1. Create a landscape using a box, a plastic bag, and newspaper. Once you have completed the model, try not to touch the plastic bag because it will change the shape of your landscape.

2. You will use your spray bottle to "rain" over the landscape at various times during the activity. You will observe and record your observations.

Part A- Getting to know your landscape

3. The bottle of water represents rain. You should rain over your landscape for about one minute.

4. While spraying, make four observations about what you see happening in the landscape. Record these on your **Student Recording Page**.

5. Now you will now try to follow the path of water over the landscape. Choose one drop of water and predict where that drop will flow when it begins to move. Test this prediction by gently spraying water over the drop so that it becomes heavy enough to move. Do this process several times. Remember to predict carefully before spraying any water.

6. Record on your **Student Recording Page** how this landscape is different from the real earth.

Part B- **Developing a community in your landscape**

7. You are going to plan a community for your landscape. You should decide the placement of buildings, the reservoir, and the landfill.

8. When you have chosen the locations for those three items you should have a rainstorm over the landscape. On your **Student Recording Page** describe what happens after you have the rainstorm.

Name ______________________________

Date ______________________________

Student Recording Page

1. Record four observations about spraying water over your landscape.

2. How is this landscape different from the real earth?

3. What happened after you sprayed water over your community?

4. What changes might you make to the design of your community if you did this activity again?

ACTIVITY 5-2 PARTS PER MILLION & PARTS PER BILLION

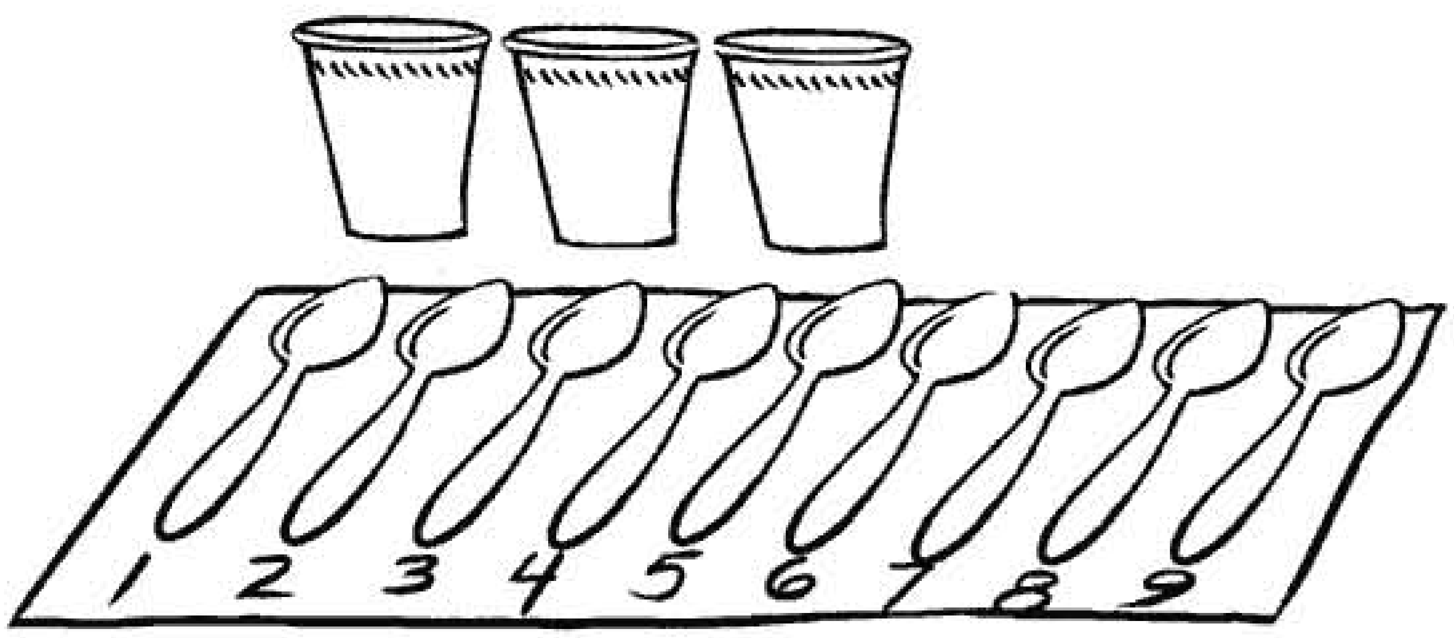
SUMMARY
Students will create several different concentrations of solutions with food coloring.

CONTENT AREAS
physical science, math

GOAL
to demonstrate concentrations that are used to measure water quality

TIME
one session

MATERIALS
For each group:
- toothpicks
- 3-4 droppers
- 9 white plastic spoons
- 4 cups of water for diluting and rinsing
- red food coloring



ADVANCE PREPARATION

- Copy students pages.
- Create student groups.
- Prepare materials.

BACKGROUND INFORMATION

Concentrations of such materials as chemical pollutants and minerals are usually expressed in units of "parts per million" (ppm) or "parts per billion" (ppb.) For example, chemical fertilizers contain nitrates, a chemical which can be dangerous to infants below the age of six months even in quantities as small as 10 ppm. Water suppliers are required to test for and report findings for many substances which might be found in the water.

Following are some more familiar terms to help students understand ppm/ppb:

1. If a CD sells one million copies, than a single CD is one part in a million.
2. Thirty seconds is about one part per million of an entire year.
3. If an average bathtub is twenty-five gallons, two drops of water is one part per million of the water in the tub.

TEACHER PROCEDURE

1. Distribute materials to student groups.

2. Have each group line up the nine spoons side-by-side on the table in front of them with a piece of paper in front of the row. They should number the paper from 1 to 9 in front of the spoons.

3. As students do this activity they should fill out the blank spaces on the **ppm/ppb Data Sheet.**

4. Tell each group to place 10 drops of food coloring into spoon #1. The concentration in the first spoon is one part per ten because there is one part red dye for every 10 parts water. (Food dye comes in a one:ten dilution.) On the board show students how to write one part in ten as a fraction. (1/10)

5. Tell students to place one drop from spoon # 1 into spoon #2, return the rest to spoon #1, and rinse the dropper in clean water.

6. Using a clean dropper, students should add 9 drops of water to spoon #2 and stir the solution with a toothpick. Rinse the dropper. Ask students "what is the concentration of the solution in spoon #2." (One part in 100, or 1/100)

7. Transfer 1 drop of the solution from spoon #2 to spoon #3. Rinse the dropper with water. Add nine drops of clean water to the spoon and stir the solution with a toothpick. Rinse the dropper with clean water. Ask students the concentration of this solution. (One part in 1,000 or 1/1000.)

8. Tell students to transfer 1 drop of the solution in spoon #3 to spoon #4. Rinse the dropper with clean water. Add nine drops of water to spoon #4 and stir.

9. Continue through all nine spoons. You can guide students through the whole activity or have them complete the process with the remaining spoons on their own.

10. Review the **ppm/ppb Data Sheet** and the conclusion questions with the class.

11. Some students may be so focused on getting the right number of drops each time that they miss the point of the activity. You may want to do it a second time so that students can think more about the concentrations.

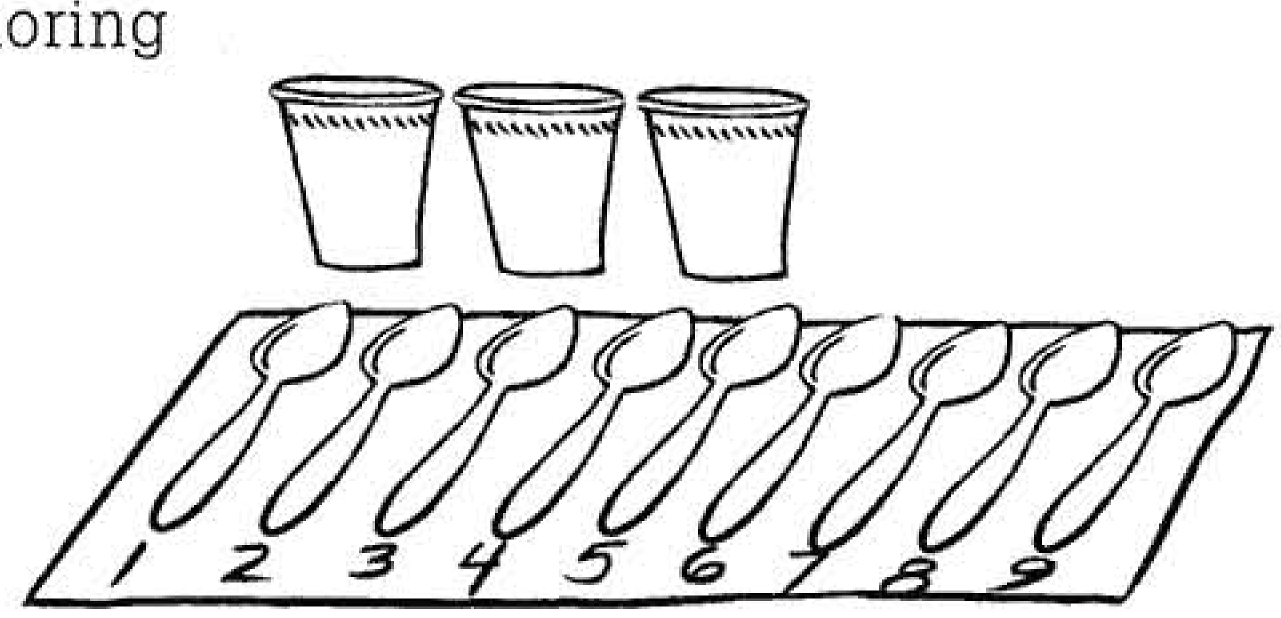
ACTIVITY 5-2 PARTS PER MILLION & PARTS PER BILLION

INTRODUCTION

Concentrations of materials in water are usually expressed in units of "parts per million" (ppm) or "parts per billion" (ppb.) For example, lead in the water can be harmful at levels above 15 ppb. Water suppliers are required to test for and report findings for many substances which might be found in the water.

MATERIAL

- tooth picks
- 3-4 droppers
- 9 white plastic spoons
- 4 cups of water for diluting and rinsing
- red food coloring



PROCEDURE

1. Line up the nine spoons side-by-side. Place a piece of paper in front of the row. Number the paper from 1 to 9.

2. Record your numbers and observations on the **ppm/ppb Data Sheet** as you do this activity.

3. Place 10 drops of food coloring into spoon #1. The concentration in the first spoon is one part per ten because there is one part red dye for every 10 parts water.

4. Place one drop from spoon # 1 into spoon #2.

5. Using a clean dropper, add 9 drops of water to spoon #2 and stir the solution. Rinse the dropper.

6. Transfer 1 drop of the solution from spoon #2 to spoon #3. Rinse the dropper with clean water. Add nine drops of clean water and stir the solution with a toothpick.

7. Transfer 1 drop of the solution in spoon #3 to spoon #4. Rinse the dropper with clean water. Use a clean dropper to add nine drops of water. Stir with a toothpick.

8. Complete the process with the remaining spoons.

9. Compete the **ppb/ppb Data Sheet** and the conclusion questions.

NAME ______________________________

DATE ______________________________

ppm/ppb DATA SHEET

Spoon number	1	2	3	4	5	6	7	8	9
Solution color									

Spoon number	1	2	3	4	5	6	7	8	9
Solution concen-tration									

CONCLUSION

1. What was the concentration of the solution when it first appeared colorless?

2. Do you think there is any food coloring present in the diluted solution even though it is colorless? Explain.

3. What would remain in the spoons if all the water evaporated?

4. What would have happened if you had not used clean water to rinse your dropper?

ACTIVITY 5-3 CONCENTRATIONS

SUMMARY Students will play a dice game about water quality and watersheds.

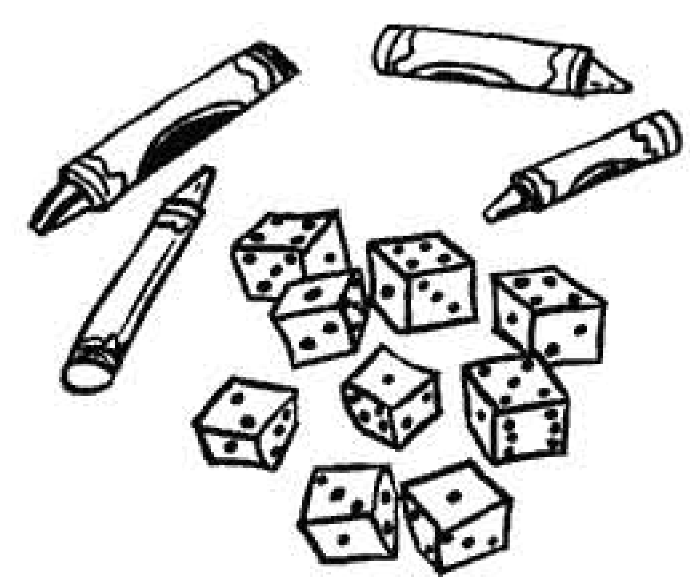
CONTENT AREAS earth science, math

GOAL to understand some of the factors that affect water quality

TIME one session

MATERIALS
For each group:
- pair of dice

For each student:
- copy of thousand dot paper
- four different colored markers, crayons, or pencils



ADVANCE PREPARATION

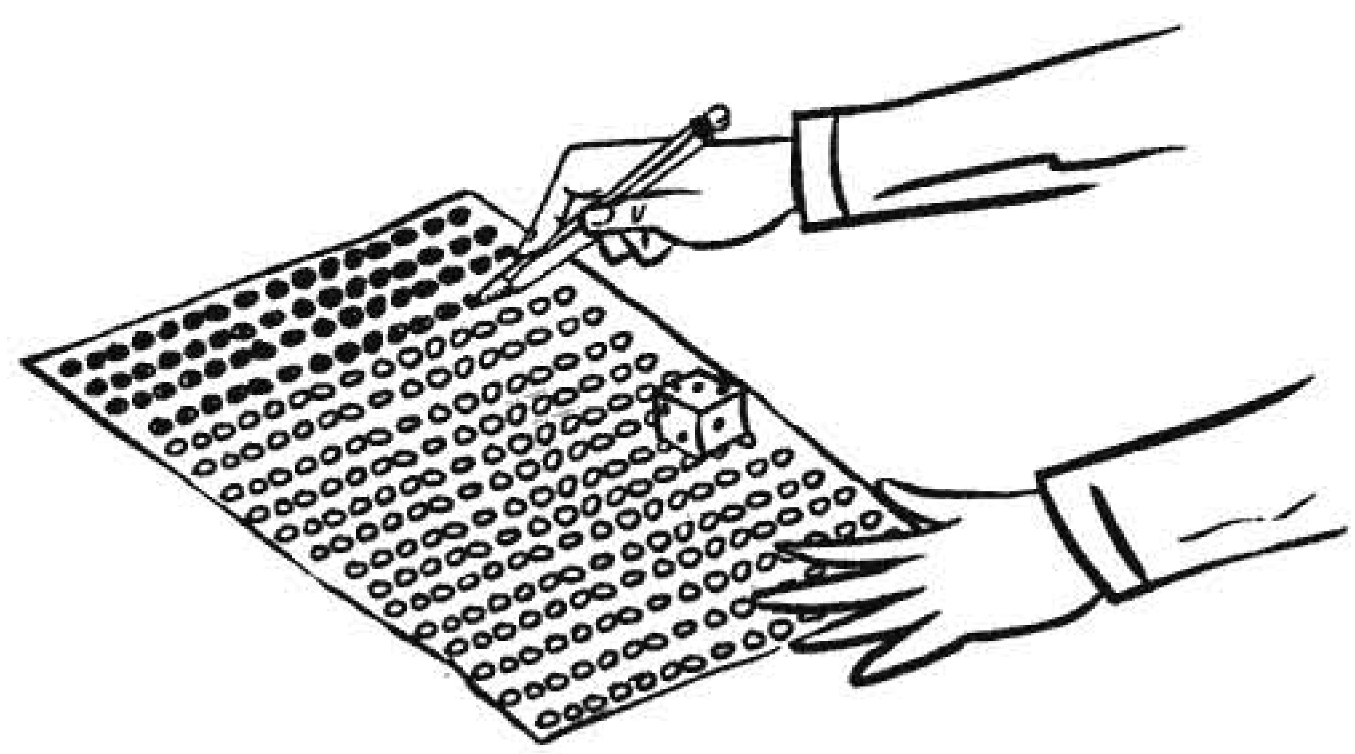
- Copy student pages.
- Create student groups.

BACKGROUND INFORMATION

Contaminants in drinking water are measured by their concentrations; usually in parts per million (ppm) or parts per billion (ppb). You can relate this to percent (which means "per one hundred.") For example, 1 percent means one part per hundred. The maximum contaminant level for lead is 15 ppb. This number means 15 parts of lead for every billion parts of water. Scientists, through research, determined that continued exposure to lead levels higher than 15 ppb could be harmful. Scientists have set standards for all the contaminants listed. Water suppliers must test for the contaminants and report their results. There are many factors that affect water quality. This activity will help students realize some of these factors and also them help them understand how contaminants are measured.

TEACHER PROCEDURE

1. Give each student one copy of the **Thousand Dots Page** and four different colored pencils, markers, or pens.
2. Give each group a copy of the **Dice Directions**.
3. Students will take turns rolling the dice. After each roll they should find the number on the **Dice Directions** that corresponds to the number they rolled. Then they color in the correct number of dots with the correct color. On the board put the maximum contaminant levels as follows:
   - contaminant blue — 10 parts per thousand
   - contaminant red — 8 parts per thousand
   - contaminant purple — 7 parts per thousand
   - contaminant green — 12 parts per thousand



4. The objective is to end up with as few dots colored in as possible. The game ends once each person has had twelve turns.
5. Follow up the game with a class discussion on factors that affect drinking water quality.

ACTIVITY 5-3 CONCENTRATIONS

INTRODUCTION

Contaminants in drinking water are measured in concentrations. Concentration is the measure of the amount of contaminant in the total volume of water. Some contaminants are so strong that the allowable levels are in parts per millon or parts per billion. For example, the rule for lead in drinking water is fifteen parts per billion (15 ppb). The Safe Drinking Water Act (passed in 1974) requires water suppliers to limit contaminants in water supplies to certain levels.

PROCEDURE

In this game you will imagine you are monitoring a water supply. We will use levels in parts per thousand (because we can't fit a million dots on one page.) Contamination is represented by four different colored dots. The objective of the game is to keep your water supply with the lowest possible levels of contaminants (the fewest dots colored in).

Each player will have a piece of paper with one thousand dots on it and four different colored pencils, markers, or pens. On your paper each dot represents one part per thousand. Each color represents a different contaminant.

The first player should roll the dice and then follow the **Dice Directions** to determine how many dots to color in. For example, if you rolled a 3, you would follow the directions for number 3, and color 2 dots blue. The second player will then take a turn by rolling the dice and following the dice directions. Go around the group twelve times. The objective is to end up with as few dots colored in as possible.
The regulations for the maximum contaminant levels are as follows:

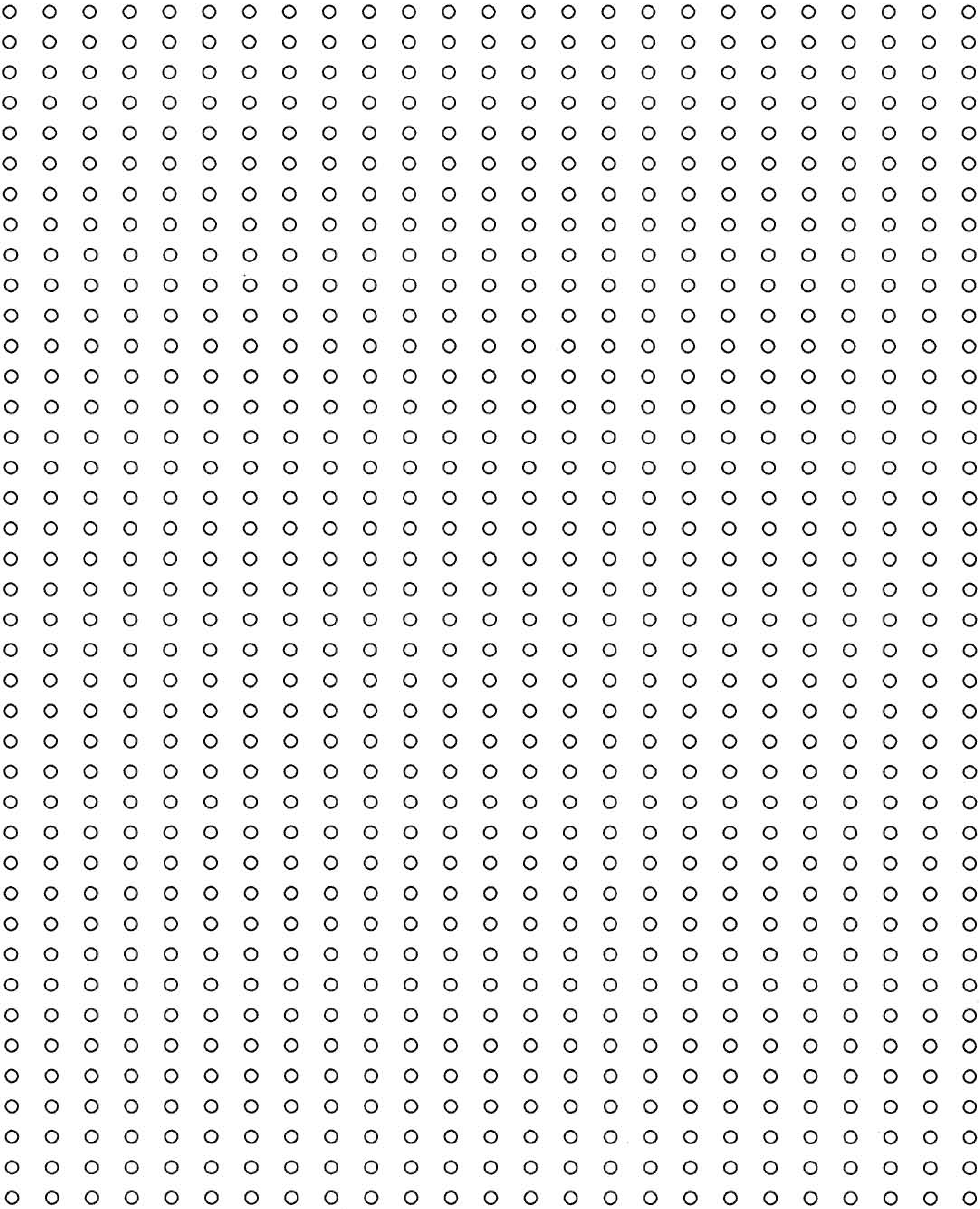
- contaminant blue 10 parts per thousand
- contaminant red 8 parts per thousand
- contaminant purple 7 parts per thousand
- contaminant green 12 parts per thousand

DICE DIRECTIONS

After you roll the dice, follow the directions for the number.

2. Erosion control on the logging roads has been improved. Don't color any dots.
3. A town in your watershed decided to lift restrictions on development. Color 2 dots blue.
4. Your hazardous waste collection day was very successful! Don't color any dots.
5. The local middle school collected several thousand used batteries and brought them to the proper disposal site. Don't color in any dots.
6. Outdated Septic systems found to be leaking during rainy weather. Color 3 dots green.
7. Your town's planning board voted to allow development of a new shopping area near a wetland. Color 2 dots purple.
8. A factory in your watershed did not pretreat its wastewater. Color 2 dots red.
9. New and improved street sweepers that vacuum particles were purchased by your town. Don't color any dots.
10. A plan to reduce the use of road salt was accepted by your town council. Don't color any dots.
11. A farm in your watershed has decided to increase their use of pesticides. Color 3 dots purple.
12. The local sewer line was leaking for several hours. Color 3 dots green.

THOUSAND DOTS PAGE



LESSON 6 DRINKING WATER DECISIONS

LESSON 6 DRINKING WATER DECISIONS

As individuals and communities, we are always making choices about water quality and health. This lesson explores several examples of such decisions.

The first activity introduces the fundamentals of drinking water quality. Students consider the two basic categories of drinking water contamination, biological and chemical, as they make a (hypothetical) personal decision in an emergency situation. The second activity expands the choice from individual to group, as a community weighs a range of health concerns to choose a water supply.

The third activity returns to the watershed concept, expanding on the idea of source protection. We all accept the maxim that it is easier to prevent a problem in the first place than to solve it later. ("A stitch in time saves nine.") Communities need economic activity; how can economic needs be balanced with the need for water resources? People make the decisions, and people must live with the consequences. Students can be assured that similar issues are being debated all around them every day.

ACTIVITY 6-1 CONTAMINANTS IN WATER

SUMMARY

Students confront a perilous short term emergency decision about drinking water. They consider what makes water safe to drink.

CONTENT AREAS

life science, math

GOAL

to distinguish between acute and chronic health effects and their causes in drinking water

TIME

one session

ADVANCE PREPARATION

- Copy student pages.
- Divide students into working groups.
- Optional: Have students read "Water and Germs."

TEACHER PROCEDURE

1. Tell the students they will be solving a problem, a hypothetical emergency situation. They will read and analyze it, and decide on a course of action. Each group will be asked to present its conclusion to the class.
2. Have students read the problem from the student page in their working groups. Allow time for them to discuss the problem and reach consensus on their answers to the questions. If there are conflicting opinions, allow time for students to develop their positions.
3. Once the groups have reached their decisions, have them report to the class. Encourage them to share the reasoning behind their decisions. See background information below to help students draw distinctions between short and long term exposures and heath effects.
4. Emphasize that there is no right answer to this problem; everyone must reach the decision that is right for him or herself. Try to make no value judgments; allow all viewpoints and lines of reasoning to emerge.
5. Optional: After discussion is complete, have students complete a student reflection page. Questions might include:
   - What were the two or three most important issues in your decision?
   - Was there disagreement among group members? What was behind those disagreements?
   - Write a paragraph about this activity, including a topic sentence, a conclusion sentence, and at least two scientific points to back up your opinion.

CONTAMINANTS IN WATER

BACKGROUND INFORMATION

Biological versus chemical

Drinking water contaminants fall into two broad categories: biological and chemical. Generally speaking, biological disease-causing agents ("germs," such as bacteria and viruses, for example) make people sick soon after ingestion, often with only a single exposure; this is an acute health effect. Most chemicals, while they too can have acute effects at extremely high doses, rarely occur in high concentrations in the environment. They are most often experienced in low doses and in multiple exposures over long periods, increasing the risk of chronic health effects, such as cancer, organ damage, or birth defects.

The limit for biological pathogens (disease-causing microorganisms) in drinking water is zero, because single exposures may be sufficient to cause illness. Limits for chemicals, while sometimes very low, are not zero. Toxicologists ("toxin" means "poison," so toxicology is the study of poisons) have determined these limits through research. Even with daily exposure over a lifetime, the risks of negative health effects from these contaminants, at levels below the limits, are very small. (The chemical certainly will not cause acute illness at those levels.)

Disinfection

These two sets of contaminants intersect in an intriguing manner that poses problems for drinking water suppliers. One common method for eliminating bacteria or viruses is to treat drinking water with a disinfectant, such as chlorine. The interaction of chlorine (or other disinfectant) with biological material produces some levels of chemicals called disinfection by-products (DBPs). The level of DBPs depends on two factors: the concentrations of the disinfectant applied and the amount of biological material (precursors) in the water. These precursors might be simple substances such as leaf litter, algae, or other harmless material in the water, or the disinfectant's target: disease-causing microorganisms.

The choices

The assignment presents students with an emergency situation. Lost and severely dehydrated, they face a decision. Should they drink untreated stream water likely to carry disease-causing germs? Or should they treat the stream water with a chemical that will kill the germs but will produce a DBP? The DBP is suspected to cause cancer at some exposure levels.

After students have expressed their opinions, you can help them analyze their decision by asking about the short term and long term consequences of either decision.

First, the stream water.

Short term effects? Likelihood of significant diarrhea. Discomfort, far from medical care, difficult ride or flight out to safety the next day.

Long term effects? Only the unpleasant memories of a bout of diarrhea.

SHORT TERM VS. LONG TERM

Now, the treated water.

Short term effects? None. They won't get an acute health effect from a single exposure to the DBP chemical at that level.

Long term effects? Very small risk. Chronic health effects will occur only after long and repeated exposure. Since tomorrow they will be back home, drinking water that must contain less chemical than the limit, they will have had only a single exposure.

Some students may believe that the increased cancer risk even from that single exposure outweighs the inconvenience and discomfort of having diarrhea in a crowded rescue helicopter. Those students may choose to drink untreated water from the stream. However, when they return home to foods grown under common agricultural practices or breathe air downwind from a gasoline pump, a running automobile or a cigarette smoker, they should recognize that they are also increasing their exposure to carcinogens.

Calculating risk

How do toxicologists calculate risk? The Environmental Protection Agency (EPA) sets limits on contaminants at exposure levels that are expected to cause at most one case of cancer in one million exposed people.

In our case, the level of DBP in the treated water is twice the EPA limit. Suppose it were even higher, say 10 times the limit. Let us assume that this increases risk by a factor of 10, from one in a million ($1/10^6$, or 10^{-6}) to one in a hundred thousand (10^{-5}), based on life-time exposure at that level.

But in our example we don't have lifetime exposure. We only have one day's exposure if the campers drink 2 liters of this water. What part of a 70 year lifetime is one day? 70 years X 365 days/year = 25,550 days. Using only the order of magnitude, another conservative step, call that 10^4 days. Your risk is now $(10^{-5}) \times (10^{-4})$ or 10^{-9}, or 1 in a billion! That's 1000 times less risk than you might be exposed to under normal conditions in a public water system. With this in mind, that case of helicopter diarrhea would look pretty avoidable to a toxicologist. The point of this activity is to help students make their own decisions based more on analysis than on fear.

ACTIVITY 6-1 CONTAMINANTS IN WATER

PROCEDURE

1. Read the following problem with your group and answer the questions at the end. There are not necessarily right answers to all these questions.

2. Share your conclusions in class discussion. Did other groups analyze the problem in the same terms that yours did?

A Water Emergency

You and four friends were climbing a mountain on a day trip. The summit was beautiful, and you spent too long admiring the view. On the way down it began to get dark, and then you lost the trail.

You spent an uncomfortable night in the woods. You started with only day trip provisions, so your food and water are gone, and you have awakened the next morning hungry and very thirsty. At last you find a trail, which leads to a shelter. Desperate for rescue, and extremely thirsty, you enter.

There is a portable phone there, and you call for help. The ranger who responds is relieved to hear from you, but says they are busy with a more urgent rescue, and they won't be able to reach you until tomorrow. Just stay right there, she tells you. You have shelter, and there are a few old mattresses and blankets. They will tell your families you are safe, and help will arrive sometime tomorrow.

As hungry as you are, you know you won't starve before being rescued. But thirst is another matter. You are dehydrated already, and you know that people can't live more than two or three days without water.

There is a stream behind the shelter that looks quite inviting, but you have been told never to drink untreated water in nature. In fact, there is a notice in the shelter warning hikers that the stream is likely to contain Giardia, a microorganism that causes severe diarrhea, among other symptoms. The disease, called giardiasis, can lead to extreme dehydration requiring medical treatment.

In a cabinet, you find some tablets which will kill microorganisms, including Giardia, in drinking water. A note of caution on the package states, however, that the tablets will react with any organic matter in the water, from tiny bits of leaves or pine needles to microorganisms, to produce chemical by-products, and that these by-products (DBPs, for "disinfection by-products") are suspected human carcinogens (substances that increase the risk of cancer over long exposure). In fact, a note in the shelter states that using the tablets in this particular stream water will create a concentration of the DBPs twice as high as the EPA drinking water standard for lifetime exposure. The EPA limit for DBPs is 80 ppb (parts per billion). If you treat the water with that tablets, DBPs will be at least 150 ppb.

Some group members say they have had family members with cancer, and they aren't about to swallow any amount of cancer-causing material. Another knows a person who once had to go to the hospital because of giardiasis; it was indeed more serious than a typical case of diarrhea. She is very concerned about being that sick so far from medical care, and about the embarrassment of riding in a rescue helicopter during a severe episode of diarrhea.

You know you must drink some water to survive until you are rescued. You must decide whether to drink water from the stream untreated, and risk getting giardiasis, or to treat the water with the tablets and expose yourself to the chemical by-products.

1. Which would you choose: to drink the untreated stream water or to use the treatment tablets? Why? What were the factors in your decision?

2. Suppose the shelter had a small stove, and you could boil the water. Would this change your decision? Why?

3. What further information would you like to have had to help with your decision?

ACTIVITY 6-2 TOWN WATER SUPPLY

SUMMARY Students consider a long term decision about water sources. They participate in a community planning process.

CONTENT AREAS life science, physical science, social studies

GOAL to learn to distinguish between acute and chronic health effects and their causes in drinking water

TIME one or two class sessions

ADVANCE PREPARATION

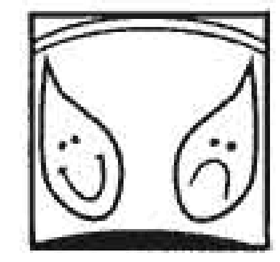
- Create student working groups.
- Copy student pages.
- Read teacher background.

TEACHER PROCEDURE

1. Tell the students they will be making a water supply decision for a community. They will need to read and discuss the problem statement and a technical report, then answer questions, the last of which is their recommendation for action.
2. Assign students to their working groups, perhaps five or so students each. Instruct them to read the problem and the **Engineering Report**.
3. They will probably have questions for you as they try to understand the report. You can answer these group by group, or you may want to convene the whole class so they all hear the same discussion. They should answer the questions in their working groups.
4. Once groups have reached their decisions, have them report to the class. Emphasize that there is no right answer to this problem. Each group must find the recommendation that is right for them. Encourage them to share the reasoning behind their recommendations. If they have done the previous activity, 6.1, some of that background, on short and long term exposures and health effects, will be helpful.
5. Optional: After discussion is complete, have students complete a student reflection page. Questions might include:

- What were the two or three most important issues in your decision?
- Was there disagreement among group members? What was behind those disagreements?
- Write a paragraph about this activity, including a topic sentence, a conclusion sentence, and at least two scientific points to back up your opinion.

ACTIVITY 6-2 TOWN WATER SUPPLY



BACKGROUND INFORMATION

This activity asks students to act as town planners and citizens, deciding between two water sources for the future of their community. It is intended to broaden their understanding of drinking water issues and to suggest questions a consumer might ask about drinking water quality.

The technical report uses two acronyms, EPA and SDWA, which bear explanation. The Safe Drinking Water Act (SDWA) is a federal law, first passed in 1974 by the US Congress and signed by the President. The legislation directs the EPA (United States Environmental Protection Agency) to establish rules for drinking water quality and to assure that they are enforced across the nation. EPA accomplishes this by working with a single agency in each state (in Massachusetts, it is the Department of Environmental Protection, or DEP) to administer SDWA. States can make individual portions of their own laws more strict (but never less strict) than SDWA.

THE CASE STUDY

The prospective sources in the activity represent the two basic alternatives in water supply: water drawn from aquifers beneath the surface (groundwater), or water in natural (or constructed) water bodies on the earth's surface (surface water). An **Engineering Report** summarizes the issues with these alternatives.

A. Groundwater

The overriding issue in the groundwater proposal is the concentration of cadmium. Because the levels are far too low to cause acute health effects (illness soon after one or two exposures), the issue is the possibility of chronic health effects. Cadmium is our example, therefore, of any of about 70 substances regulated by SDWA to reduce chronic health effects from drinking water.

Chronic health effects are more difficult to explain than acute health effects. Acute effects, such as digestive tract illness from bacteria, are pretty certain to result from a single exposure within a few days. Chronic health effects take much longer exposure (years) to develop, don't occur in most of the people exposed, tend to be more serious (such as cancer or organ damage), and can result from quite low levels of contamination (depending on the contaminant).

Regarding cadmium specifically, The Environmental Protection Agency (EPA) states, "Some people who drink water containing cadmium in excess of the Maximum Contaminant Limit (MCL) over many years could experience kidney damage." Note four points in that statement (emphasis added):

1. *Some* people,
2. *in excess* of the MCL (elevated exposure),
3. over *many years* (long term exposure),
4. *could* experience the health effect.

Perhaps exposure to tobacco smoke can best illustrate chronic health effects to your students. 1. Some people smoke much of their lives with no apparent ill effect. 2. While smoking increases the chance of certain illnesses, smoking heavily increases the chances more. 3. Health effects usually occur after long term exposure (years of smoking). 4. No one can say with certainty that a smoker will develop cancer or that a non-smoker won't. (This reinforces point 1.) But most people now accept that you can improve your chance of staying healthy by not smoking.

Could water be treated to remove cadium? Cadmium is dissolved in water as ions; that is, molecular sized particles. Cadmium could be removed by installing an ion exchange treatment system. The system would be fairly costly to build and would have ongoing operating costs. (Note: Boiling does not remove minerals such as cadmium or lead from drinking water. In fact, it may increase its concentration.)

B. Surface water

All bodies of surface water contain some level of bacteria and other microorganisms. The sources of these "germs" are primarily animals living around the lake. The microorganisms that cause disease are best suited to life in the digestive tract of an animal, where they can thrive and are likely to cause infections. The wastes of an infected animal carry the germs into the environment, where they begin to die off. But if some are ingested by a new host before they die, they can multiply rapidly, causing a new illness and producing millions of replicas to go forth into the environment. (This process is explained in more detail in "Water and Germs.")

Surface waters are much less likely that groundwater to contain significant levels of metals, such as cadmium, or organic chemicals such as industrial wastes. The water lacks the long contact time with natural minerals, such as cadmium, that it would have in an aquifer. Many organic chemicals are volatile; that is, they evaporate quite readily when exposed to the air, as they would be in our lake.

WHAT IS GIARDIA?

Giardia is an intestinal microorganism (actually a protozoan) that can cause severe diarrhea in people. It is of concern because it is so hardy in the environment. While bacteria such as E. coli die off quickly outside the warm, dark confines of an intestinal tract, Giardia oocysts, or eggs, can live for weeks in an aquatic environment, maturing to the parent organism when signaled by the body temperature of a new host. Giardia is also fairly resistant to chlorine, a common water industry disinfectant that is quite effective against bacteria. Ozone is a more effective disinfectant against Giardia.

ACTIVITY 6-2 TOWN WATER SUPPLY

DISINFECTION BY-PRODUCTS

DBPs were introduced in the previous activity. They occur when chemical disinfectants, such as chlorine, come in contact with organic matter in the water. The organic precursors might be the microorganisms targeted by the treatment, or just benign bits of plant matter or algae in the water.

Filtering the water before disinfection could eliminate most precursors and thus reduce DBPs, but it would greatly increase the cost of the lake water option. The DBP levels are low enough, in the engineers' opinion, that the benefit of filtration would be minimal.

DBPs complicate the issue of surface water treatment somewhat. While chlorine can eliminate most microorganisms and thus eliminate risk of acute illness, it can produce DBPs and thus introduce the question of chronic health effects. Even the highest DBP readings in our case study are well within SDWA standards, but the language is still sobering. When the risk is a chronic health effect, such as kidney damage or cancer, consumers' emotions become a factor in an otherwise analytical decision process.

SOURCE PROTECTION

Water suppliers, whether they use groundwater or surface water, recognize that pollution prevention, or "source protection," is their first and best step in assuring safe water supply. The lake receives precipitation runoff from its tributaries and the watershed lands, not just from the immediate shoreline. The most sensitive areas are the shorelines, however, and not just of the lake but of its tributary streams. Recent laws protecting river corridors and wetlands acknowledge the increasing awareness of their importance in protecting our surface waters.

Because the land around the lake is relatively undeveloped, and the town plans to protect the watershed by purchasing a good bit of it, the lake's freedom from pesticides and other chemicals is likely to continue. The risk might arise should development pressure in this beautiful area lead town officials to permit homes or other human activities near the water.

ANSWERS TO STUDENT QUESTIONS

Question 2. A power failure would shut down the pumping and monitoring of the groundwater system. Because the water needs minimal treatment, water quality would not be affected. Because the lake is in the hills above town, it will arrive by gravity, so there would be water in faucets and hydrants in a power outage. However, the treatment plant might be out of service, so people would need to take emergency measures such as boiling their drinking and cooking water.

ACTIVITY 6-2 TOWN WATER SUPPLY

PROCEDURE

Read and discuss the following problem with your working group. Then answer the questions at the end, stating your group's recommended course of action and the reason for your decision.

Your teacher will be available to help clarify definitions and other issues, but you should try to develop your own opinions.

You live in a small community where residents, until now, have depended on their own private wells for drinking water. The town has grown, a couple of small businesses have moved in and the local economy is looking bright. The businesses need ample water supply, and as houses have been built closer together, it has become clear that you need to establish a community water system. You must decide whether to develop

a) a groundwater system, with a town well, or
b) a surface water system from a nearby lake in the hills above town.

Several important issues emerge in the **Engineering Report**. Both sources, a well or the lake, could provide sufficient water not only for the town today but even if the town should grow in years ahead. Costs of either system are comparable; in either case, installing distribution pipes in the streets is a big part of the expense. The question comes down to water quality.

Read the **Engineering Report** on the following page. Then answer the four questions, the last of which is your recommendation concerning which water supply to develop.

ENGINEERING REPORT

We have evaluated two possible water sources for the town: a groundwater system with wells, and a surface water system from the lake. Here are our results.

Groundwater Option

Testing has shown that concentrations of cadmium in the water at the proposed well site are about half the EPA limit for that contaminant. (The Safe Drinking Water Act (SDWA) standard is 10 parts per billion; test results range from 3 to 6 ppb.)

<u>What is cadmium?</u> Cadmium is a naturally occurring element, Cd on the periodic table. It is a member of the heavy metal group of elements; other natural metals are iron, lead, manganese, mercury and gold. Some of these metals, like lead, mercury, and cadmium, are considered toxic; that is, they cause health effects over long periods of even low levels of exposure; others, such as iron and manganese, are essential for human health and are not regulated under SDWA primary standards.

<u>How did the cadmium get there?</u> The cadmium is not a result of carelessness or pollution. Minerals like cadmium and the others are found in various rock formations, and where the rocks are rich enough to be considered ore, mining operations are developed to extract the metal for human use. Your area is not rich enough in cadmium to make mining profitable, but there is enough to impart background levels of cadmium to the ground water.

<u>What are the health effect of cadmium?</u> Short term, or acute health effects, are only possible at extremely high levels, thousands of times greater than in your well water. That is clearly not the concern here. In fact, people in the area have probably been drinking small amounts of cadmium every day in their private wells, and no one has gotten sick. However, EPA states, "Some people who drink water containing cadmium in excess of the Maximum Contaminant Limit (MCL) over many years could experience kidney damage."

<u>Can the cadmium be removed from the water?</u> Yes, but only by building a treatment system that would double the cost of the entire project and would require careful (and expensive) operation and maintenance.

ABBETT & SIEGEL ENGINEERING COMPANY

Surface Water Option

Like all surface waters (but unlike groundwater), the lake is exposed to plants and animals and their waste products. Testing of the lake water has confirmed the presence of the expected array of bacteria and viruses, only some of which cause illness. Some samples have also contained a microorganism called Giardia lamblia, which causes severe diarrhea.

Can the lake water be treated to protect consumers from Giardia and other microorganisms? Yes, the water can be disinfected with common disinfectant chemicals, such as chlorine and ozone, to kill the germs.

Will disinfection form harmful by-products? Because the lake has very low levels of organic matter, DBPs will average between 20 and 40 ppb; the current SDWA standard, or MCL, is 80 ppb. EPA states, "Some people who drink water containing trihalomethanes [a typical form of DBPs] in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer."

Are there other contaminants in the lake water? What about cadmium? The lake water has very low levels of minerals, and no detectable cadmium. It was tested for about one hundred regulated pesticides and industrial chemicals; only tiny amounts of one or two were found, at trace levels far below SDWA limits.

Will the lake always stay this clean? What if the area around it becomes more developed? There are only a few summer cottages on the lake now. The cost of developing the lake for water supply includes purchasing the entire lake shore, including these cottages, and land along several brooks leading to the lake. A popular swimming beach on the lake would certainly be closed, and people would no longer be able to walk or run their dogs in the area.

ABBETT & SIEGEL ENGINEERING UNLIMITED

NAME ______________________________

DATE ______________________________

QUESTIONS & CONCLUSIONS

1. Discuss the two alternatives with your group. What are the most important factors in your discussion?

2. Some citizens are concerned that pumping stations or treatment plants, especially small ones like yours would be, break down sometimes, or lose electric power during storms. Would a power failure present different risks depending on the water source, groundwater or lake, you chose? If so, what would those different risks be?

3. What further information would you like to have to help with your decision?

4. Based on the information available, do you think the town should develop the groundwater or the lake for its water supply?

ACTIVITY 6-3 WATERSHED CHOICES

SUMMARY Students will choose five development projects to include within the watershed boundary of a reservoir. They will establish rules for those developments.

CONTENT AREAS social studies, earth science

GOAL to understand that regulations and source protection are important to maintaining drinking water quality

TIME one or two sessions

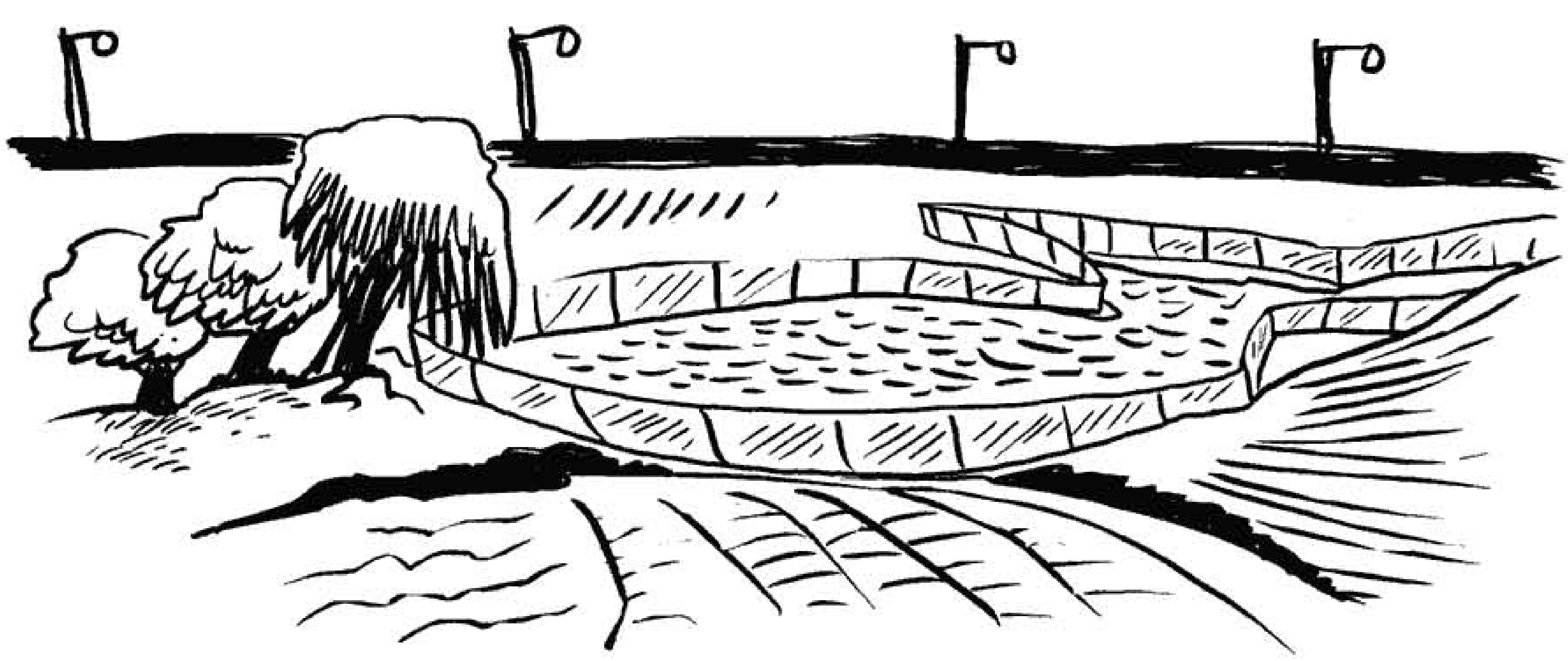
ADVANCE PREPARATION

- Create student groups
- Copy materials for each group.

BACKGROUND INFORMATION

Watershed protection is an important aspect of providing high quality drinking water. Protecting the watershed includes regulating development, monitoring activities, and creating public awareness. Rules and regulations help accomplish these goals. In this activity students will investigate and contemplate how development might affect water quality. They will then create regulations so that the effects of development will be minimized. There are no right or wrong answers; students should work together to weigh the issues and come to a conclusion.

Pollution is a complicated issue, but students might understand it best if you divide pollution into two categories: chemical and biological. Chemical contamination sources include pesticides, oil, or gasoline. Chemical contamination is most harmful through long-term exposure. Continued exposure through the water over several years may increase the risk for developing certain chronic diseases, including cancer. It is difficult to treat water for chemical contamination, so preventing it from entering the reservoir is usually a more successful tactic.



Biological contamination comes from living sources: human waste from septic systems, livestock waste from farms, and wild animal waste. These biological sources contribute microorganisms which may cause illness soon after ingestion. Small amounts of bacteria in the source water (the reservoir) are inevitable. That is why the water is treated to kill pathogens (disease-causing microorganisms).

Complicating the pollution issue is the fact that we use chemicals to kill the bacteria. When chlorine combines with organic matter in the water disinfection by-products (DBPs) are created. DBPs are regulated and monitored just as other contaminants in the water. The less contamination in the water, the less chemical you have to use to kill bacteria, and the fewer DBPs will result.

Regulations and water testing are an important component of maintaining water quality. Drinking water quality is regulated at the federal level by the Safe Drinking Water Act (SDWA) passed by Congress in 1974. Regulators study the scientific literature on a wide range of chemical and biological contaminants, setting maximum contaminant levels (MCLs) and required treatment technologies, based on that research. Most people agree, however, that keeping source water as clean as possible is the first step toward safer drinking water. Preventing a pollution problem is usually easier and more cost effective than solving the problem after it happens. This activity helps students understand the role of planning in the prevention of problems.

TEACHER PROCEDURE

1. Review the term watershed with students. (Activity 5.1 is good preparation.) Explain to them that a watershed is an area of land that drains into a body of water. Remind them that along with the water, contamination can also enter the reservoir.
2. Describe the activity to students. Each group is a planning board for towns in the reservoir's watershed. Students should review the ten proposals for land use and decide which five to accept. They should then determine where the projects can be located and specify any regulations for the accepted proposals. Emphasize that they are responsible for maintaining as a high a level of water quality as possible.
3. Give each student a copy of the student pages.
4. When students have completed their proposal selections, have them report to the rest of the class.

ACTIVITY 6-3 WATERSHED CHOICES

INTRODUCTION

Your group is the planning board for towns located within the watershed of a local drinking water supply. You have decided to allow the development of five projects who want to site facilities in the watershed. The board has received applications from ten organizations who want to use the land. You must decide which proposals to accept and what regulations those groups must follow. Remember, these are proposals. You can specify any restrictions you want on the accepted proposals. 10,000 people use this water every day and expect it to be safe to drink. They are relying on the board to make thoughtful decisions about development.

PROCEDURE

1. Review the ten proposals for land use.
2. Discuss them with the members of your group. You may want to make a list of positive and negative things about each proposal.
3. Decide which five proposals you want to accept.
4. Decide where on the map each proposal should be located.
5. Make a short list of regulations that those organizations must follow in order to use the land.
6. Present your recommendations to the class.

PROPOSALS FOR LAND USE

1. Clark's Pig Products Company

We want to establish a fifty acre pig farm. We propose to raise 5,000 pigs each year for sale to slaughter houses. Modern odor control will be implemented. Our proposal will creating new farming jobs and will add tax money to the towns.

2. Camping Haven

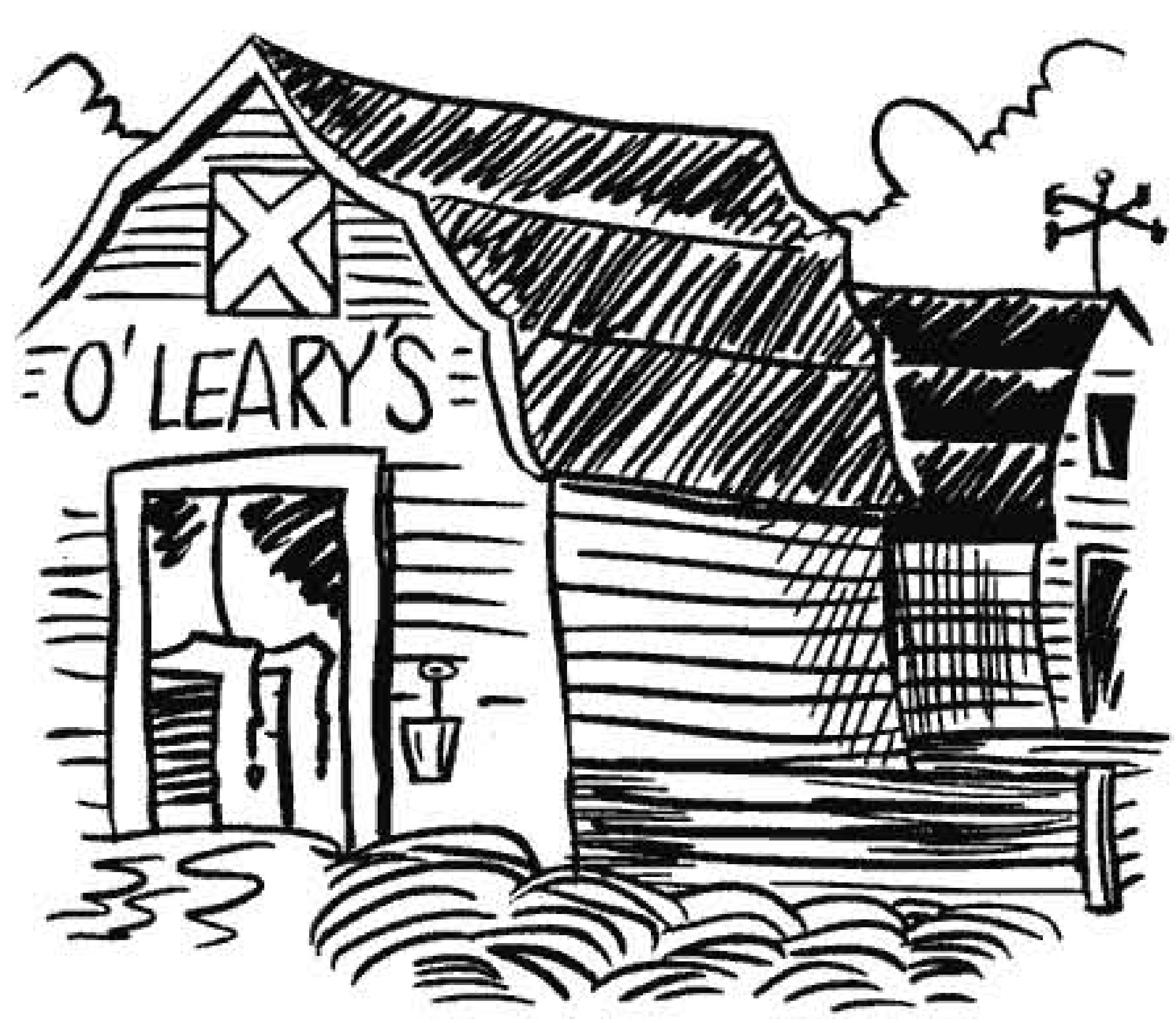
We want to create a 25 acre campground. We would like to have 50 sites for tent camping only. We would need three bath houses with toilets and showers. We would like to be near a river where campers can swim. We will only allow pets on leashes.

3. McClure's Marvelous Gas and Go

We want to create a gas station and mini-mart. We need a half acre of land. We would have eight filling areas for regular gas and two for diesel fuel for trucks. Our market would sell automotive products such as oil and wiper fluid, as well as groceries. We would be open 24 hours a day, seven days a week. We will meet all state required precautions against gasoline spillage.

4. Pat's Potato Chip factory

Pat's Potato Chips are the most popular in this region. We want to open a new production facility. We need a ten acre site. We pretreat all of our oil and potato peel waste before it leaves the factory. We will have five delivery trucks that will leave our site each morning and return that afternoon.



PROPOSALS FOR LAND USE

5. Dandy Dairy Farm

We propose a 100 acre dairy farm. We will have 50 milk cows in our barn. We will feed them with hay we grow on our land which will be fertilized with the cow manure from our herd. Our products are organic and we do not treat our cows with hormones. We pride ourselves on the proper treatment of our animals and land. Our farm will have jobs for the farmers in the area.

6. Housing Development

We propose a 100 unit condominium complex on 15 acres of land. We want to include a playground, paved walking paths, three swimming pools, and a parking area for 200 cars. We want to dig a well for the water supply and create septic systems for waste disposal. These units will be more affordable than equivalent houses in the area.

7. Nature Preserve

We want to create a place where the public can enjoy the land around the reservoir. We propose a five acre nature preserve that will include one of the three wetlands in the watershed. Each wetland has rare species of plants that are not found anywhere else in the state. We would have a small visitors center and a bathroom with a septic system. Picnicking would be allowed near the visitor's center only. A ranger would be on site during all hours of operation.

PROPOSALS FOR LAND USE

8. Highway Department

We want to expand the highway between the two towns on opposite ends of the reservoir from two lanes to four lanes. This expansion would bring in greater truck traffic, especially those providing home heating oil to the communities in the area. Many of the people in the area work for our department and this would benefit them in terms of salaries and work hours. (Right now these trucks travel out of the watershed to use the state highway to get to these communities.)

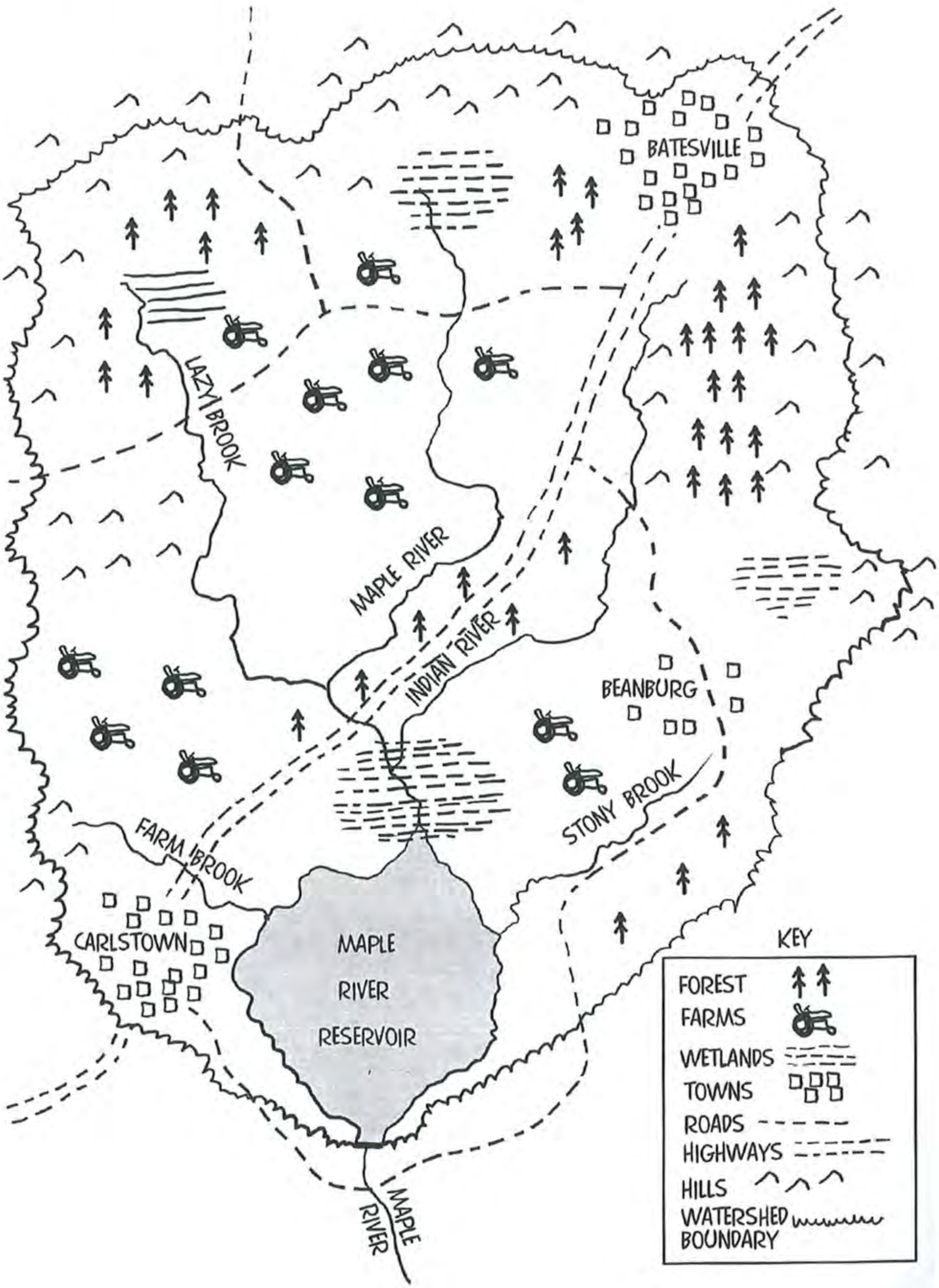
9. Pressure Treated Lumber Products

We produce high quality pressure treated lumber products for purchase by the general public and contractors. Lumber will be delivered here daily by trucks. We will chemically treat the lumber and store it on a one acre paved lot where our customers can view it. We will have products for building swing sets, porches, and play equipment. We would like to be located near a river for waste disposal. Our company will create many new jobs for this region.

10. Strawberry Fields

Due to our advanced techniques in pesticide applications we grow the biggest and best strawberries in the nation. We propose ten acres of strawberry fields. We would install a computerized irrigation systems for maximum crop production. During the summer, citizens can pick their own strawberries. We host a lovely strawberry festival in June with music, clowns, pony rides, and strawberry shortcake.

WATERSHED CHOICES



Massachusetts Water Resources Authority
School Education Program
100 First Avenue
Charlestown Navy Yard
Boston, MA 02129
www.mwra.com