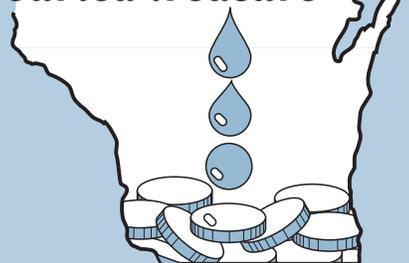


**GROUNDWATER**  
Wisconsin's  
buried treasure



# GROUNDWATER

## STUDY GUIDE

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## Introduction

### To educators

Cool, clear water is a precious and vulnerable resource. In Wisconsin, more than 70 percent of us depend on groundwater for drinking. Agriculture—and thus our food supply—depends on it. Industry depends on it. Yet, until recently, most people rarely thought about this buried treasure. Today we’re becoming more aware of groundwater, mainly because of increasing reports of contamination.

This study guide is designed to help you and your students begin thinking about groundwater — where it comes from, why it’s important, and how it can be conserved and protected. The guide includes a brief overview of groundwater, a glossary, suggested activities, and a list of related Wisconsin Department of Public Instruction (DPI) Wisconsin Model Academic Standards (WMASs) for science, environmental education, health education, social studies and math. The guide is designed to stand alone, yet complements a Wisconsin Department of Natural Resources publication titled *Groundwater: Wisconsin’s Buried Treasure* (PUBL-DG-055 2006) included with the *Groundwater Study Guide* packet.

Talk with your students before beginning your lessons to learn what they already know and think about groundwater. *What is groundwater? Where does it come from? Why is it important? How can it become contaminated? How can we protect it?* By learning your students’ thoughts and opinions about groundwater,

you can help them connect new concepts with what they already know. We encourage you to adapt the activities to meet your students’ needs. You are welcome to reproduce any part of this guide for distribution to students and other educators.

*The groundwater activities in this guide are written for 6th to 9th grade students; however, many of the activities are suitable for older or younger students. You will find a list of relevant DPI Wisconsin Model Academic Standards at the beginning of each activity: Letters identify the appropriate subject or subjects (SC = science, EE = environmental education, SS = social studies, HE=health education, M=Math).*

*As you begin to use the activities in the publication, you should apply all safety guidelines and protocols you typically use in your classroom to each activity. The Department of Natural Resources views science classroom safety as fundamentally important to any laboratory science and feels strongly that the science teacher is the safety expert. The science teacher will provide all needed safety guidelines for each activity.*



## Wisconsin's Buried Treasure

Picture all the water in lakes and streams in the United States. Now, try to imagine 20 times that much water hidden underground, filling cracks and pores in the earth. That's 30–60 quadrillion gallons of water within ½ mile of the earth's surface! However, this vast supply of groundwater isn't evenly distributed. Some areas have ample supplies of usable groundwater, other areas have little.

Wisconsin is water-rich. In fact, our state's name comes from the Chippewa word "Wees-kan-san" which means "gathering of waters." You're probably aware of the large amounts of water in our lakes and rivers, but did you know that 1.2 quadrillion gallons of water—enough to cover the entire state to a depth of over 100 feet—lie hidden underground?

### What is Groundwater?

Groundwater originates as rain or snow. As precipitation falls on the earth's surface, some evaporates, some runs off over land into lakes and streams and some soaks into the ground. A portion of water that enters the soil is taken up and used by plants. (A large, leafy tree can take up a ton of water in a day!) The rest percolates deeper into the earth.

Not all water found in the ground is groundwater. "Groundwater" refers specifically to water that is held in the saturated zone below the water table. Rock and soil material store water in voids or pore spaces, much like a sponge. Imagine two sponges, stacked one on top of the other. The bottom sponge has been soaked in water. It represents the "saturated zone"—all of its pore spaces are filled with water. The top sponge has been wetted, but the water has been squeezed out. This sponge represents the "unsaturated zone"—some of the spaces are filled with water, some are filled with air. The boundary between the two zones represents the "water table." The water in the saturated sponge represents groundwater.

### Where is it Found?

Contrary to popular myths, groundwater doesn't flow in mysterious underground rivers nor is it stored in underground lakes. Most groundwater is found in aquifers—underground layers of porous rock and soil that are saturated with water (like a sponge). Four major aquifers underlie most of our state, but the amount and quality of water they contain is variable.

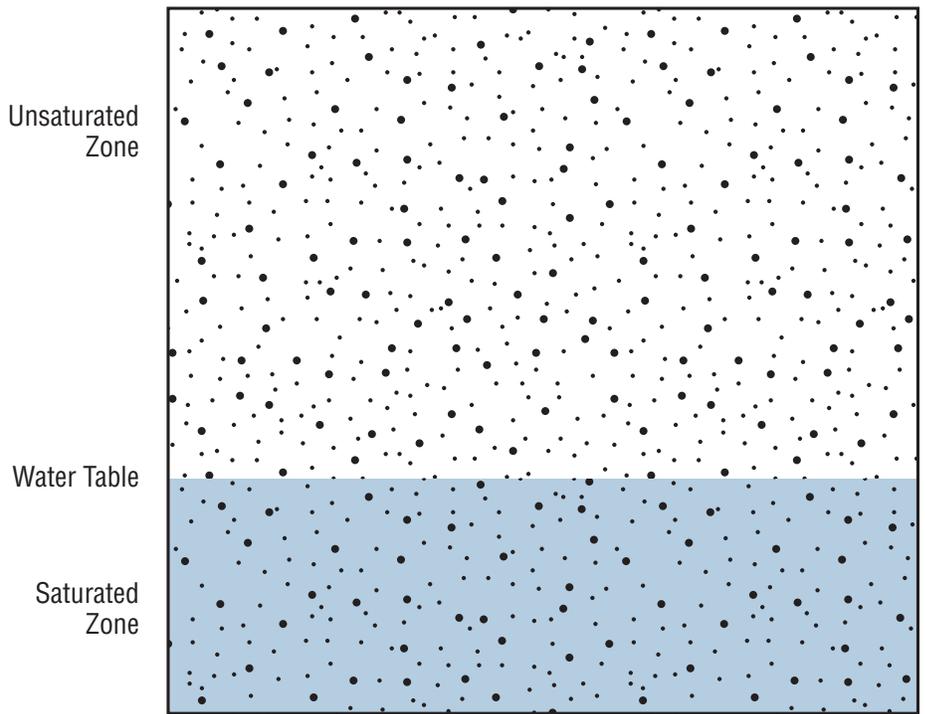
The composition of soil—clay, loam, silt, sand or rock—generally determines the amount of groundwater and the depth at which it is found in a given area. Coarse materials such as sand and gravel, which have large spaces between grains, allow for excellent storage and movement of water. On the other hand, fine-grained materials such as clay or shale restrict water movement.

Like surface water, groundwater flows from higher to lower elevations, moving through connected spaces in soil material. But, unlike water in rivers and streams, groundwater moves slowly—from a few inches to a few feet per day. Variation in rainfall and pumping from wells can affect the rate and direction of groundwater flow.

### Why is it Important?

Water has helped shape Wisconsin's geography, history and industry. More than 70 percent of Wisconsin's homes use groundwater. An average family of four uses 220 gallons of water/day. Over 200 million gallons per day is withdrawn for use in our homes. Nearly 300 million gallons/day is used for irrigation and other agricultural activities. Wisconsin industries like cheese making, beer brewing and paper manufacturing all require lots of water. All together, we use over 800 million gallons of groundwater in Wisconsin each day (*Water Use in Wisconsin, 2000*, U. S. Geological Survey Open File Report 02-356).

Groundwater is also valuable as a source of water for our lakes, rivers, wetlands and springs. It provides the baseflow for most streams and rivers and is the primary source of water for most lakes and wetlands. So it's important to wildlife and to recreation such as fishing, boating and swimming.



## How Does Groundwater Become Contaminated?

Groundwater is never a pure combination of hydrogen and oxygen atoms (H<sub>2</sub>O). As water soaks into the ground, it dissolves minerals and gases from the rock material it encounters. “Natural” groundwater contains many dissolved minerals and gases that may give it a particular taste, odor or color. Typical concentrations of most naturally-occurring contaminants pose no health risk.

Percolating groundwater can also carry human-made pollutants. Contamination can be serious if groundwater contains substances (natural or human-made) that pose a health threat—bacteria, viruses, nitrate, metals such as mercury or lead, pesticides and other synthetic organic compounds. Carelessness and lack of understanding can lead to groundwater contamination from a variety of sources including:

- ❖ leaking underground petroleum pipes and tanks
- ❖ use and storage of road salt
- ❖ improper use, disposal and storage of hazardous materials
- ❖ improper disposal of solid waste
- ❖ practices such as over-application of fertilizers and pesticides
- ❖ improper management of animal wastes

Since groundwater flow is generally slow, pollution may take decades to show up in a well, lake or stream. Removal of contaminants is expensive and difficult (if not impossible), so **prevention** of contamination is the key to maintaining groundwater quality.

## How Can You Help?

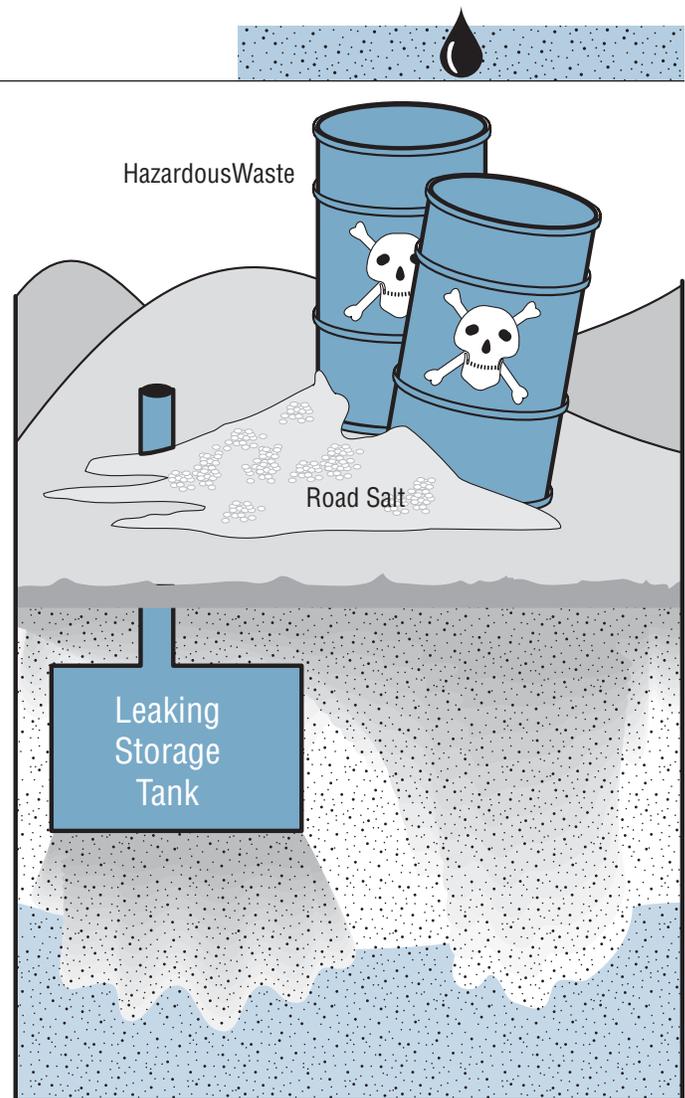
By doing one or more of the exercises in this Study Guide, you and your students will gain a better understanding of groundwater principles and the importance of protecting our “Buried Treasure.” In addition, here are some other ideas for you and your students:

- ❖ Follow local groundwater issues so you’re aware of what the concerns are in your area. Consider with your

students how activities going on locally can affect groundwater quantity or quality.

- ❖ If your school has its own well, consider the recommendations for protecting that well contained in a letter to schools at [dnr.wi.gov/org/water/dwg/gw/whp/whpschools.pdf](http://dnr.wi.gov/org/water/dwg/gw/whp/whpschools.pdf).
- ❖ If your school gets water from a municipal water utility, ask the water utility if it has completed a wellhead protection plan to protect its well or wells from contamination. For more information on wellhead protection, go to [dnr.wi.gov/org/water/dwg/gw/wellhead.htm](http://dnr.wi.gov/org/water/dwg/gw/wellhead.htm).

- ❖ Consider installing a rain garden on school property to promote recharge to groundwater. Check out the following links for more information: [clean-water.uwex.edu/pubs/raingarden](http://clean-water.uwex.edu/pubs/raingarden) and [dnr.wi.gov/org/water/wm/nps/rg/index.htm](http://dnr.wi.gov/org/water/wm/nps/rg/index.htm).
- ❖ Consider becoming a “Green and Healthy School”. Learn about it at [dnr.wi.gov/greenandhealthyschools](http://dnr.wi.gov/greenandhealthyschools).
- ❖ Work with your students to identify ways to reduce the amount of materials going to landfills so that fewer landfills are needed. If your county has a Clean Sweep program, encourage students and their families to take advantage of this opportunity to recycle hazardous chemicals. Visit the Department of Agriculture, Trade and Consumer Protection Clean Sweep website at [datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/clean-sweep/index.jsp](http://datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/clean-sweep/index.jsp) for more information.



- ❖ If your students have private wells, ask them to check to see if there are potential contaminant sources near their well and whether the well is tested annually for bacteria and nitrate levels. For more information, visit [dnr.wi.gov/org/water/dwg/wells.htm](http://dnr.wi.gov/org/water/dwg/wells.htm).
- ❖ Work with your students to identify ways to share information with their parents or the community about the importance of groundwater protection and water conservation at home and in the community. Consider becoming a Groundwater Guardian community. Go to [groundwater.org](http://groundwater.org) for more information.

For additional ideas on protecting groundwater, see *Groundwater: Wisconsin's Buried Treasure* and *Better Homes and Groundwater* included with the *Groundwater Study Guide* packet.

We should all treat water as if our lives depend on it—they do!



## Buried Treasure

- Wisconsin's groundwater would cover the state's 36 million acres to a depth of 105 feet
- More than 70% of us drink groundwater in our homes
- There are more than 800,000 private or municipal wells in Wisconsin
- Wisconsin uses over 800 million gallons of groundwater each day
- 25% of Wisconsin's groundwater is used in our homes for bathing, cooking, etc.
- 20% of Wisconsin's groundwater is used by industry
- Groundwater discharges to lakes, rivers, wetlands and springs

## Glossary

**Aquifer:** A rock or soil layer capable of storing, transmitting and yielding water to wells.

**Artesian:** A condition referring to groundwater that is under enough pressure to rise above the aquifer containing it. Sometimes artesian wells will flow at the surface.

**Baseflow:** That part of stream discharge from groundwater seeping into the stream.

**Dolomite:** Calcium magnesium carbonate, a common rock-forming mineral. Many rocks in Wisconsin generally referred to as limestone are actually dolomite.

**Evaporation:** The process by which water is changed from a liquid or solid into a vapor.

**Groundwater:** Water beneath the surface of the ground in a saturated zone.

**Hazardous waste:** Waste that causes special problems for living organisms or the environment because it is poisonous, explosive, dissolves flesh or metal, ignites easily (with or without a flame) or carries disease.

**Infiltration:** The movement of water into and through soil.

**Leachate:** A liquid formed by water percolating through soluble waste material. Leachate from a landfill has a high content of organic substances and dissolved minerals.

**Limestone:** A sedimentary rock consisting chiefly of the mineral calcite (calcium carbonate).

**Permeability:** The capacity of soil or rock to transmit a fluid, usually water.

**pH:** From the phrase p(otential) of H(ydrogen), pH is a measure of acidity or alkalinity. As a solution becomes more acidic, its pH decreases; as it becomes less acidic its pH increases. A solution with a pH of 7 is considered neutral; a pH less than 7 is acidic and a pH greater than 7 is considered alkaline.

**Porosity:** The amount of open space in a rock or soil sample, normally expressed as the percentage of the total rock or soil volume.

**Sanitary landfill:** A specially engineered site for disposing solid waste on land.

Constructed in a way that reduces hazards to health and safety.

**Spring:** A natural discharge of water at the ground's surface.

**Static water level:** The elevation above sea level of the surface of water in monitoring wells. Used to determine the direction of groundwater flow.

**Transpiration:** The release of water vapor and waste products through the pores (stomata) of plants.

**Water cycle (or hydrologic cycle):** The complete cycle of phases through which water passes from the atmosphere to the earth and back to the atmosphere.

**Water table:** The level below which the soil or rock is saturated with water. The upper surface of the saturated zone.

**Well:** A vertical excavation that taps an underground formation; in Wisconsin, usually to obtain a source of water, to monitor the quality of groundwater or to determine the elevation of the water table.

*Note: Words or phrases italicized in the exercises are defined in the glossary.*



# The Water Cycle

## 'Round and 'Round it Goes!

**Learning Objectives:** Students will: (1) identify where water is found in our environment, (2) explain the steps of the water cycle and how water moves from one location to another, (3) define the components of the water cycle and (4) describe how human activities can affect water quality as it passes through the water cycle.

**Subjects:** Environmental Education, Health Education and Science

**Wisconsin Model Academic Standards (WMASs):** EE: B.8.10, B.8.15, B.8.18

**HE:** A.8.2

**SC:** A.8.6, E.8.1, H.8.3

**Grades:** 6–9

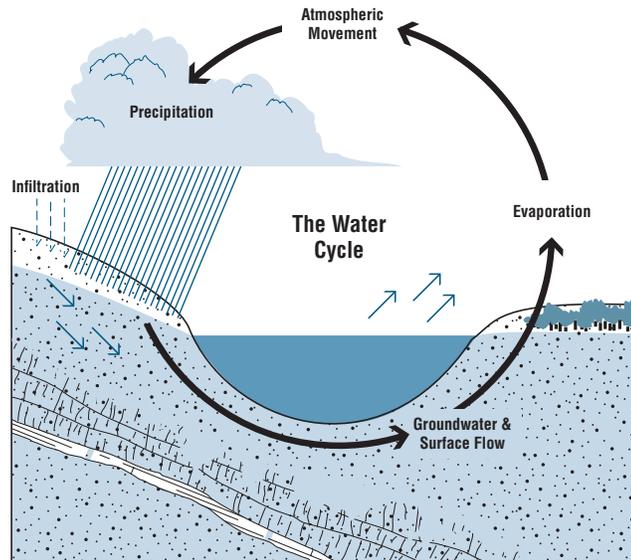
### Materials:

- ❖ Groundwater and Land Use in the Water Cycle poster
- ❖ 'Round and 'Round it Goes! activity sheets
- ❖ Dictionary

**Background:** Water is our most recycled resource. Consider, for example, that the water you bathed in this morning may have contained the same molecules of water that washed over a South Pacific coral reef a million years ago! The amount of water on Earth is basically constant, but the distribution of water changes over time and space due to a dynamic process called the *water cycle* or *hydrologic cycle*. The water cycle is powered by solar energy and gravity.

Warmth from the sun causes *evaporation* of water from lakes, streams and soils. Solar energy also drives a process called *transpiration*—the release and evaporation of water from tiny pores in the leaves of plants. Evaporated and transpired water vapor is stored in the atmosphere until it condenses and is pulled by gravity back to earth as rain, sleet, snow, hail, dew or frost.

Up to 80 percent of this precipitated water is returned directly to the atmosphere by evaporation. The rest may run

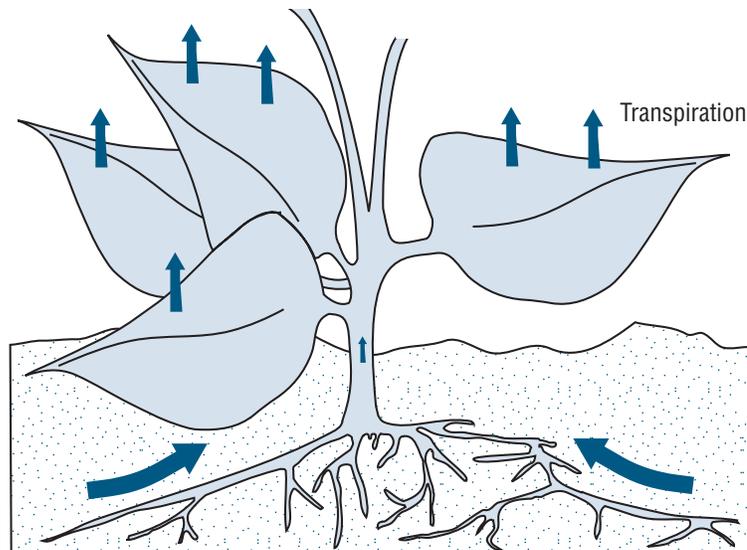


off over land and into lakes and streams or may soak into the ground. Some of the water that soaks into the ground stays in the unsaturated zone. This zone is the rock or soil layer in which some of the spaces between particles are filled with air and some are filled with water. Some of the water in the unsaturated zone is taken up by plant roots and returned to the atmosphere by transpiration.

The rest of the water is pulled deeper into the ground by gravity, filling all the cracks and spaces in the underlying layers of soil, gravel and rock. Water in the saturated zone is called *groundwater*. The top of the saturated zone is the

*water table*. Water continues to move underground from areas of high elevation toward lowland areas. This movement is generally slow, from a few feet per day to a few feet per year. Wherever the water table meets the land surface a *spring* may form or groundwater may seep into to a lake, stream, wetland or ocean. Once above ground, the water can evaporate and return to the atmosphere, and the water cycle begins again.

Human activities may affect the quality of water at any point in the cycle. Air pollution can change the chemical composition of rain and snow. Runoff from rainfall and snow melt can pick up soil,





excess plant nutrients, pesticides, animal wastes, and municipal and industrial pollutants as it flows over land and into lakes and streams.

Contaminated runoff can also soak into the ground and pollute groundwater. Water percolating through soil and rock may pick up natural minerals or other contaminants. Knowledge of the water cycle can help us understand how water becomes polluted and how pollution can be prevented (see *Groundwater: Wisconsin's Groundwater* for more information).

## Procedure:

1. Distribute copies of the poster. Discuss the background information.
2. Working in small groups, complete the activity sheets. Use the "Water Cycle" poster as a reference.

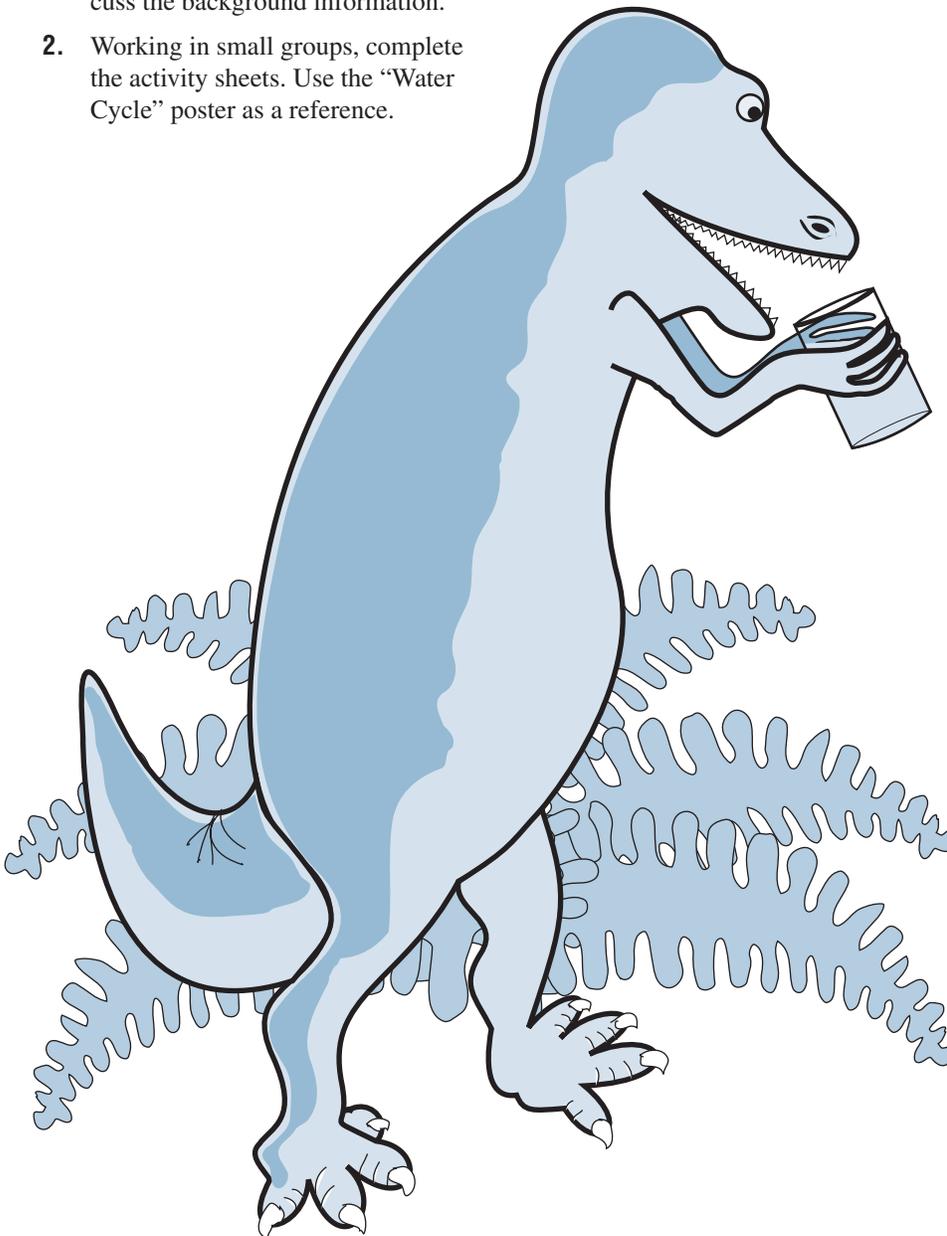
## Going Beyond:

1. Your students can learn about the water cycle online at: [dnr.wi.gov/seek/earth/groundwater/watercycle.htm](http://dnr.wi.gov/seek/earth/groundwater/watercycle.htm) or [ga.water.usgs.gov/edu/watercycle.htm](http://ga.water.usgs.gov/edu/watercycle.htm).
2. Design and construct a graphic or mural of the water cycle for your community. Include the community's water system and local human impacts on the water cycle.
3. Create a mini-water cycle for your classroom. In an aquarium (terrarium) or wide-mouth glass jar, put a one-inch layer of gravel for drainage. Next, add a layer of peat

moss and then a layer of soil. Small houseplants such as violets and ferns can be planted in the terrarium. Water your terrarium lightly and cover it with a piece of glass, leaving approximately ½ inch uncovered for air movement. Keep the terrarium in your classroom and watch what happens over the next week. The plants will take moisture from the soil and release (transpire) it from their leaves. Water molecules will condense on the glass and "rain" back onto the soil.

4. Research how long it might take a drop of water to pass through the entire water cycle.

Adapted from: *Groundwater Study Guide*, 1984, Wisconsin Department of Natural Resources, Bureau of Information and Education (out of print).



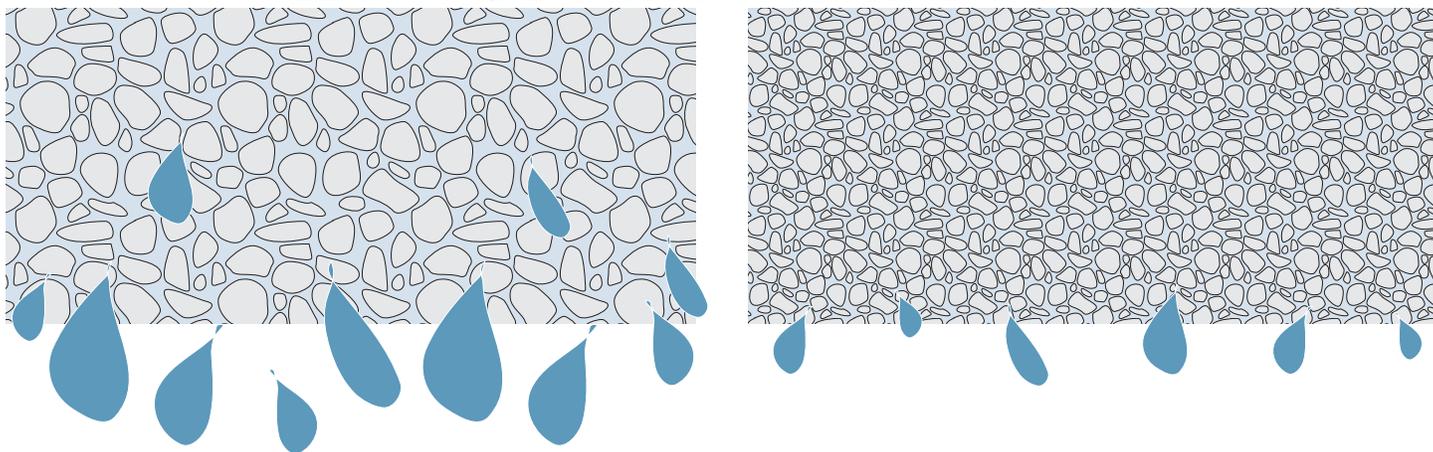
## Recycled

*The glass of water you're about to drink  
Deserves a second thought, I think  
For Avogadro, oceans and those you follow  
Are all involved in every swallow.  
The molecules of water in a single glass  
In number, at least five times, outclass  
The glasses of water in stream and sea,  
Or wherever else that water can be.  
The water in you is between and betwixt,  
And having traversed is thoroughly mixed,  
So someone quenching a future thirst  
Could easily drink what you drank first!  
The water you are about to taste  
No doubt represents a bit of waste  
From prehistoric beast and bird—  
A notion you may find absurd.  
The fountain spraying in the park  
Could well spout bits of Joan of Arc,  
or Adam, Eve, and all their kin;  
You'd be surprised where your drink has  
been!  
Just think! The water you cannot retain  
Will some day hence return as rain,  
Or be held as the purest dew.  
Though long ago it passed through you!*

Verne N. Rockcastle



# How Groundwater Moves



## Porosity and Permeability

**Learning Objectives:** Students will: (1) predict which soil materials are more porous and permeable, (2) measure and compare the porosity and permeability of different soil materials to test their hypothesis, (3) calculate porosity of gravel, sand, and clay, (4) create bar graphs of the experimental results and (5) interpret and discuss the results.

**Subjects:** Science and Math

**Wisconsin Model Academic Standards (WMASs):** SC: A.8.6, C.8.4, C.8.6, E.8.1

**M:** D.8.3, E.8.2, E.8.4, E.8.5

**Grades:** 6–9

**Materials:**

- ❖ Porosity and Permeability activity sheet
- ❖ gravel\*
- ❖ sand\*
- ❖ clay\*
- ❖ potting soil\*
- ❖ containers for used clay, soil, sand and gravel

For each group of 2–3 students:

- ❖ 4 test tubes
- ❖ test tube rack
- ❖ 100 milliliter (ml) glass beaker
- ❖ small funnel
- ❖ 100 ml graduated cylinder

- ❖ 4 sheets of round filter paper
- ❖ glass marking crayon

\* These materials must be very dry. Spread soil materials on a cookie sheet and dry in oven at 250–275° F. Break up clay and potting soil after drying so that no clumps remain.

**Background:** Just how solid is “solid ground?” The material beneath our feet is rarely solid. Soil is made up of particles of rock and the spaces between these particles. The amount of space between soil particles is called *porosity*. You can estimate the porosity of a soil by measuring the amount of water it can hold.

Underground, water percolates down through soil and flows from higher elevations (such as a hill) to lower elevations. The ease with which water moves through a soil or rock type is called *permeability*. You can estimate the permeability of soil by timing how quickly water can flow through it.

Physical characteristics of soil particles, such as size and shape, influence the porosity and permeability of soils and rocks. Coarse materials, like gravel and sand, tend to be both porous (they have large pore spaces that can fill with water) and permeable (water passes easily between the large particles). Some fine materials, such as clay, may hold a lot of water yet transmit very little because water cannot move easily through the tiny pore spaces.

An *aquifer* is a rock or soil formation that can both store and transmit a significant amount of water. A *well* drilled in a sand aquifer is likely to yield a lot of water; a well drilled in clay will probably yield little.

## Procedure:

**A)** Predicting porosity and permeability.

**1.** Examine the gravel, sand, soil and clay. Predict which materials can hold the most water and which ones water will flow through fastest. Record your predictions on the chalkboard. Then, in small groups, either investigate each material or assign groups to one soil material and compile class results on the chalkboard.

**B)** Measuring porosity.

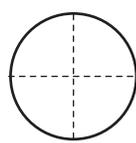
**1.** With a marking crayon, place a line about ½ way up the side of a small beaker. Fill the beaker with water to the line. Pour this water into a 100 ml graduated cylinder. Record this volume on your data sheet under “total volume.” Dry the beaker.



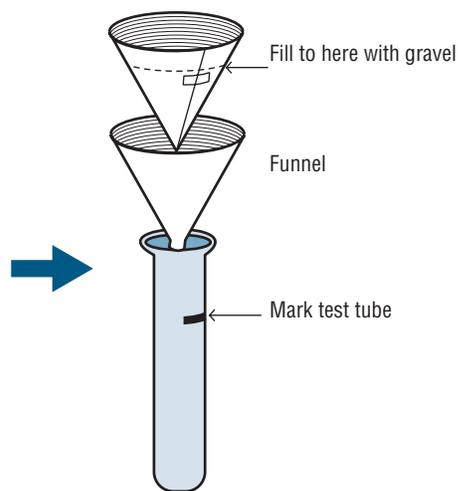
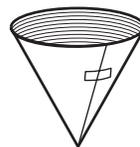
2. Fill the beaker with gravel to the line and fill the graduated cylinder to the 100 ml mark with water. Pour water from the graduated cylinder into the beaker until it reaches the line. Record the volume of water needed to saturate (fill the pores of) the gravel on your data sheet under “pore space.” Divide this volume by the “total volume” and multiply by 100 to get percent pore space in your sample of gravel. Record this value under “porosity” (% pore space). Repeat the investigation with samples of sand, soil and clay. (*Note: For potting soil and clay, make sure that the water has time to soak in completely.*) Record your results.

**C) Measuring permeability.**

With a marking crayon, place a line about 1/2 way up a test tube. Put the test tube in the rack and put the stem of a small funnel inside the test tube. Fold a circular filter paper into quarters, open it into a cone, and insert it into the funnel. Fill the cone with gravel to about 1/2 inch from the top. Pour water from a beaker into the filter. Using a clock, a watch or by counting, time how long it takes to fill the test tube to the line. Record the results on your data sheet under “permeability.” Return the sample of gravel to the used gravel container and discard the filter paper. Repeat the experiment with sand, soil and clay.



Fold



Make bar graphs of your results and complete questions on the “Porosity and Permeability” activity sheet. Discuss your results and answers:

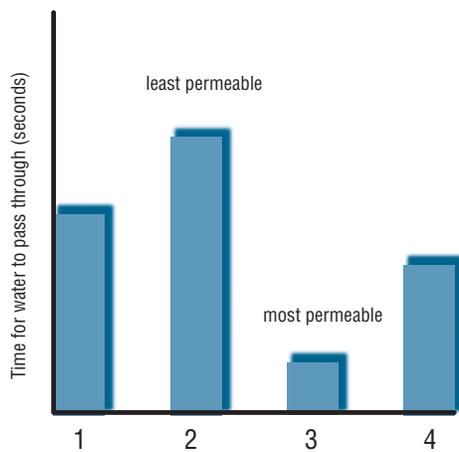
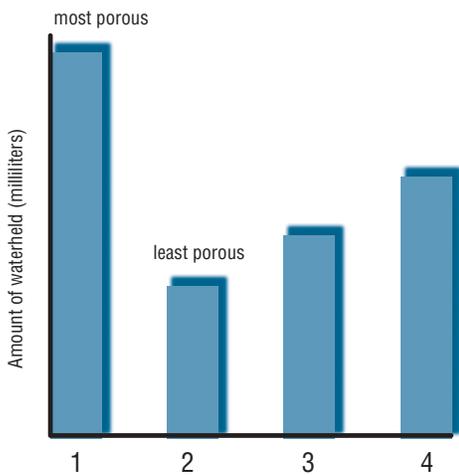
- ❖ Did your results match your predictions?
- ❖ Which material is the most permeable? Why?
- ❖ Which is the least permeable? Why?
- ❖ Which soil is the most porous? Why?
- ❖ Which is the least porous? Why?
- ❖ If you drilled a well in these materials, which one do you think would yield the most water?

2. Compare the porosity of a variety of rocks. Record the weights of small pieces of *limestone*, sandstone, shale, granite, obsidian, lava, etc. Soak the rocks in water for several days. Remove them from the water and pat them dry. Weigh the rock pieces again and record your results. Compare the mass of each rock before and after soaking. Discuss your results in terms of the rock’s ability to hold water. *Note: water may move through cracks in rock as well as through the pore spaces. The amount of cracking in a rock determines its “secondary porosity.”*

3. Investigate the effect of organic material on a soil’s permeability and its ability to filter contaminants. Prepare four “contaminated” water samples containing 1) vegetable oil, 2) vinegar, 3) detergent and 4) green food coloring. Pour small amounts of each sample through 1) sand, 2) equal amounts of sand + potting soil, 3) clay, 4) equal amounts of clay + potting soil. Compare filtering times of the different soils. Compare appearance of contaminant samples before and after filtering (use pH paper for vinegar). Filter plain tap water as a control.

**Going Beyond:**

1. Invite a certified soil tester or county on-site waste disposal (septic system) specialist to discuss how porosity and permeability of soil and rock are measured in the laboratory and in the field.



Adapted from: *Groundwater: A Vital Resource*, Cedar Creek Learning Center and the Tennessee Valley Authority, Knoxville, TN 37902.



## Well, Well, Well...

**Learning Objectives:** Students will: (1) describe how a well works, (2) explain the relationship between groundwater and precipitation and (3) visualize the movement of contaminants with groundwater.

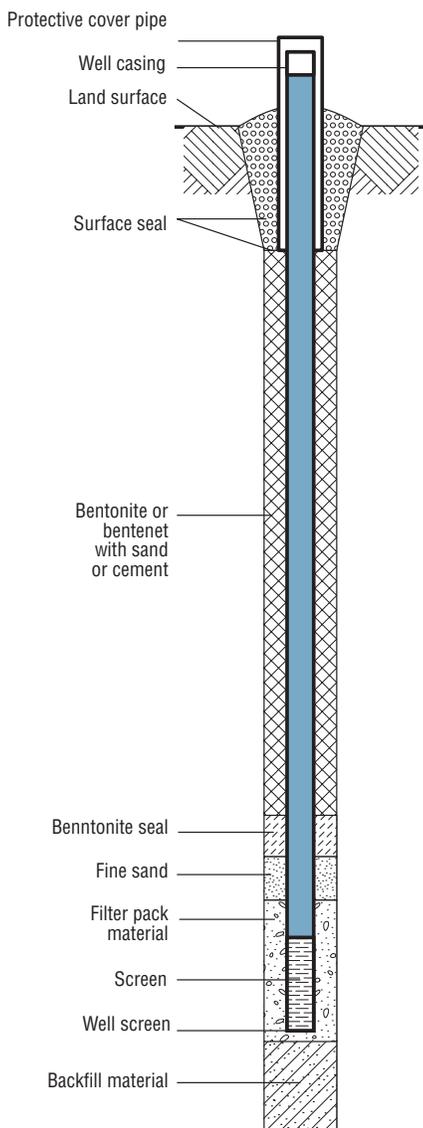
**Subjects:** Science, Health Education and Environmental Education

**WMASs: SC:** A.8.6, C.8.4, C.8.5, C.8.6, E.8.1, H.8.3

**HE:** A.8.2, C.8.3

**EE:** A.8.4, A.8.5, B.8.10, B.8.15, B.8.16, B.8.18, B.8.21

**Grades:** 6–9



**Monitoring Well**

### Materials:

- ❖ Well, Well, Well... activity sheet
- ❖ one 10 gallon aquarium (may be adapted for 5 gallon aquarium)
- ❖ one 5 gallon bucket filled with coarse, clean sand
- ❖ one quart of aquarium gravel
- ❖ one piece 1" (inch) wide diameter plastic tubing
- ❖ three pieces 1/8" outside diameter glass tubing:
  - ✓ one piece, 20" long
  - ✓ two pieces, 4" long
- ❖ two pieces 1/8" outside diameter rubber tubing:
  - one piece 3' (feet) long
  - one piece 2' long
- ❖ two glass rods 12" long (or similar diameter wooden dowels)
- ❖ two #7 rubber stoppers:
  - ✓ one 1-holed
  - ✓ one 2-holed
- ❖ one 500 milliliter Erlenmeyer glass flask
- ❖ one hand pump/siphon\*
- ❖ small nail
- ❖ watering can or spray bottle
- ❖ 3" X 3" piece of cheesecloth
- ❖ small rubber band
- ❖ aquarium glue
- ❖ green food coloring
- ❖ 5 gallons of water

\* available at sporting goods stores, pet shops and hardware stores

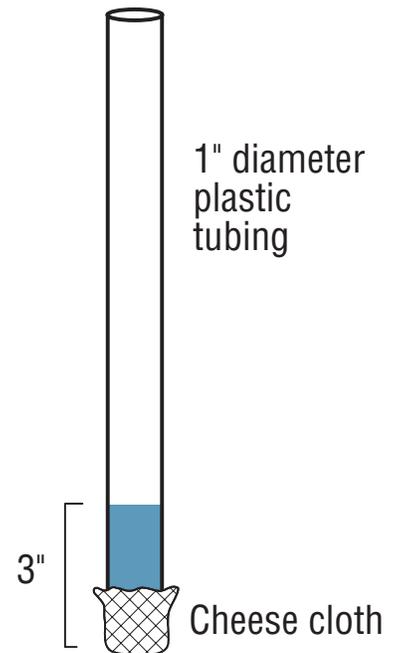
**Background:** Wells are constructed to bring groundwater to the land surface so we can use it (or monitor its quality). Holes are drilled and pipes put in the ground to a depth below the water table. Pumps are connected to the well pipe so that water in and around the well is drawn up the pipe and into a house or wherever the water is used.

Following are instructions for constructing a well model. You can use the model to demonstrate how surface water soaks into the ground to become groundwater and how a pump recovers water. By adding food coloring to represent a contaminant, you can also use the model to demonstrate how groundwater can become polluted.

### Procedure:

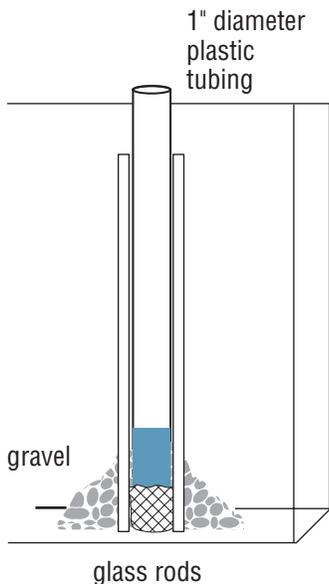
#### A) Preparation.

1. Using a small nail, make approximately 30 1/16" (inch) diameter holes beginning at one end of the 1" diameter plastic tubing and extending three inches from that end. Cover the bottom of the tube with cheesecloth and secure with a small rubber band. This will prevent sand from entering the bottom of the tube later.



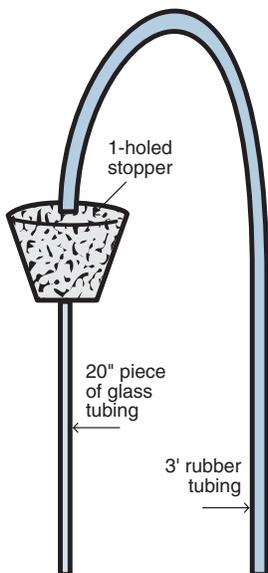


2. Using aquarium glue, attach the two glass rods (or dowels) and the 1" diameter plastic tube to the long side of the aquarium perpendicular to the bottom. Allow glue to dry.



3. Place gravel so that all holes at the bottom of the 1" diameter plastic tubing are covered. The gravel will help keep sand from entering the well during pumping.

4. Insert the 20" piece of glass tubing into the one-holed stopper so that the tube extends one to two inches above the top of the stopper.

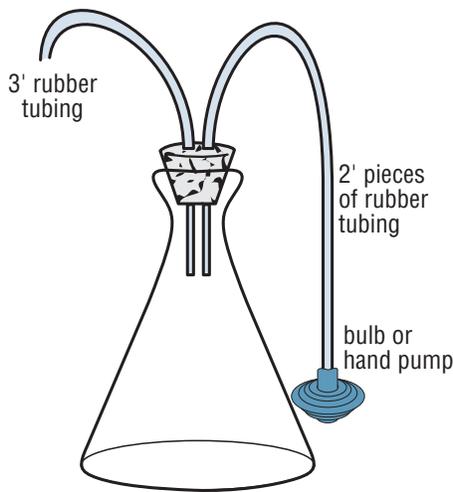


5. Attach one end of the 3' (foot) rubber tubing to glass tube extending out of the stopper.

6. Insert this assembly into the 1" plastic tube in aquarium.

7. Insert two 4" pieces of glass tubing into holes of 2-holed stopper so that 1" of tubing extends above the stopper. Attach the loose end of 3' rubber tubing to one of the glass tubes extending from 2-holed stopper.

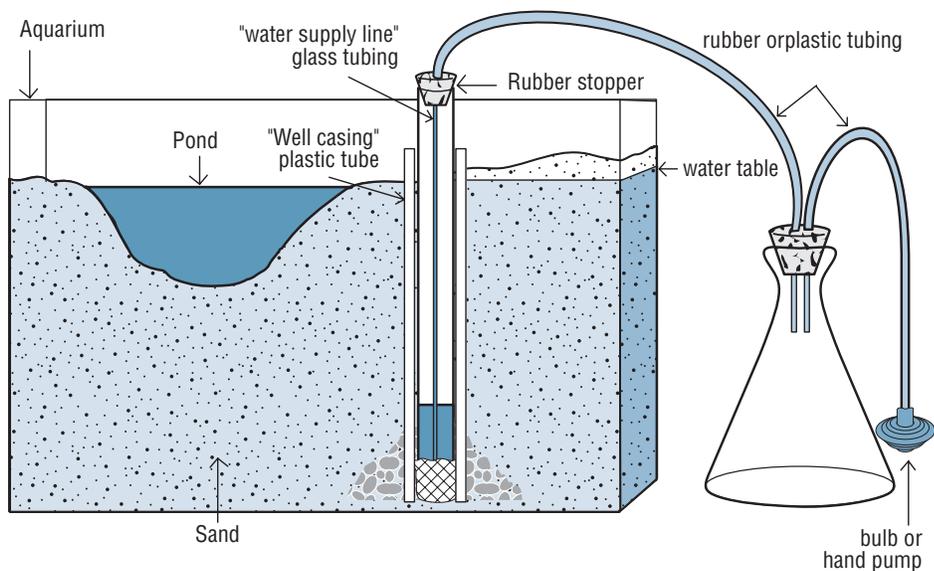
8. Attach one end of 2' piece of rubber tubing to the other glass tube extending from the stopper.



9. Insert stopper into the flask.

10. Attach the hand pump/siphon to the other end of the 2' tubing. Check that all connections are airtight.

11. The model works best when the flask is positioned lower than the aquarium to create a continuous siphon thus eliminating the need to continuously pump.



12. Fill the aquarium 1/2 to 3/4 full with sand. Create a depression in sand opposite to the well. This simulates a pond or lake.

13. Add water to the aquarium so that it's about 1/2 full. The completed model should look like the illustration below.

## B) Demonstration.

1. Discuss the model. Identify the groundwater and the water table. Mark the water table on the side of the aquarium with a wet erase or other nonpermanent marker. Begin to slowly pump water from the well. Note the level of the water table and pond surface. As the surface level of the pond is lowered, a rain storm may be simulated by pouring water from a watering can over the land and water.

2. Experiment with more rainfall ("recharge") than pumping to simulate a wet year, and with more pumping ("withdrawal") than rainfall to simulate a drought. Groundwater "overdraft" occurs when the rate of withdrawal of water is greater than recharge, resulting in a lowering of the water table. Observe the runoff and infiltration. When you are finished with the experiments, continue pumping until the flask is full.



3. Empty the flask and “pollute” the pond or the land surface with green food coloring. Pump the well and see what happens to the polluted water (food coloring represents a water-soluble pollutant). Point out that, unlike food coloring, many contaminants don’t change the color, odor or taste of water. These contaminants are difficult to detect. Many other pollutants may be filtered out by soil or broken down by chemical or physical processes before they reach groundwater. Notice also that the dyes in the food coloring move at different rates through the soil.

*Note: If using model for consecutive classes, leave time to flush dye pollutant from model (by adding water and pumping) or work dye contaminant into next demonstration, e.g. have students determine the source of contamination, find how much water/how much pumping is required to remove contaminant, etc.*

**C) Discussion.**

1. Complete the activity sheet. Discuss your answers.

## Going Beyond:

1. Contact a licensed well driller (check the yellow pages of your phone book). Arrange a field trip to a drilling site. Ask the driller to show and discuss the drilling record. Using a flashlight, look down the new well (attach flashlight to a string to make sure it isn’t lost down the well).

Attach a cork to a fishing line and lower down well to measure depth of the water table. When the cork floats, mark the spot on the fishing line that is even with the top of the well casing. Pull the line up and measure the length of line from the mark to the cork and subtract the distance that the casing extends above the ground. The resulting distance is the depth of the water table from the ground surface. Compare your measurement to the well driller’s measurement.

## More ways to use your groundwater model

### 1. Fertilizer/Pesticide Model

Build the groundwater model as directed. Sprinkle powdered grape drink mix on the surface to represent fertilizer or pesticide put on a field. Sprinkle water over the surface to simulate rain. Observe and discuss.

### 2. Landfill/Abandoned Waste Site Model

Roll a paper towel into a ball and saturate it with food coloring. Bury it just beneath the surface to represent an improperly designed or abandoned waste disposal site. Pour water on the surface. Observe and discuss.

### 3. Leaking Underground Storage Tank Model

Fill a film canister with colored water and puncture it in several places with a pin. Bury it just beneath the surface (not along the side of the box). Pour water on the surface. Observe and discuss.

### 4. Abandoned Well Model

Puncture a drinking straw in several places with a pin and plug the bottom with clay. Bury the straw, plugged end down, in the sand to represent an abandoned well. Pour colored water into the abandoned well. Pump from the working well. Observe and discuss.

### 5. Leaky Lagoon Model

Cut the bottom off a small paper cup and puncture the bottom in several places with a pin. Partially bury the cup bottom in the sand to simulate a settling lagoon. Fill the lagoon with colored water. Pump from your well. Observe and discuss.

From: *GREAT: Groundwater Resources and Educational Activities for Teaching*, 1989, Iowa Department of Natural Resources, Wallace Building, Des Moines, IA 50319.

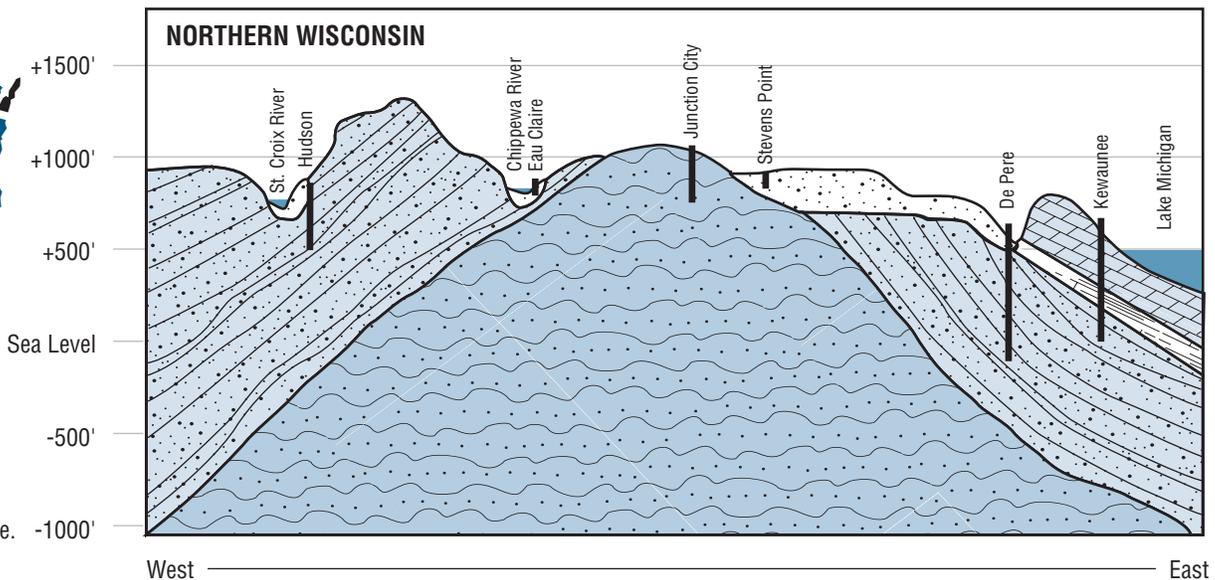
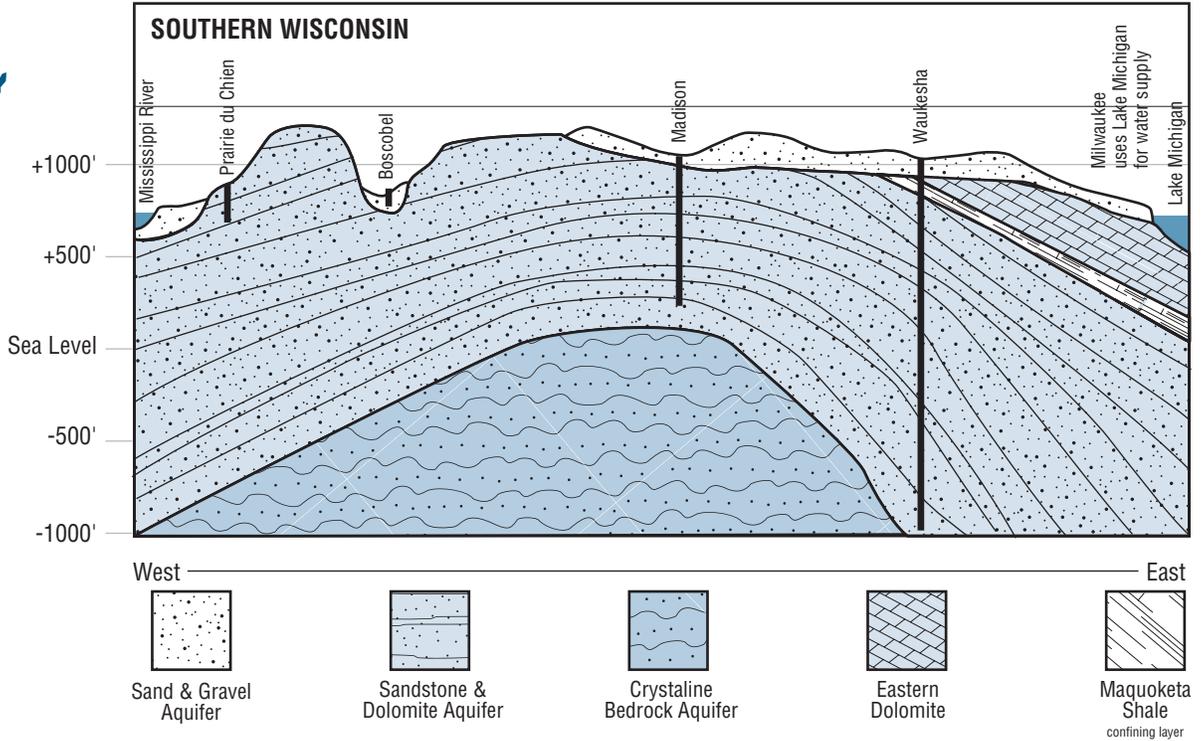
A 2-dimensional groundwater sand tank model can be purchased from the Center for Watershed Science and Education at the University of Wisconsin–Stevens Point. For more information, go to [uwsp.edu/stuorg/awra/h2omodel.html](http://uwsp.edu/stuorg/awra/h2omodel.html) or call (715) 346-4613. For a list of locations from which a groundwater model can be borrowed, go to [dnr.wi.gov/org/water/dwg/gw/education/models.pdf](http://dnr.wi.gov/org/water/dwg/gw/education/models.pdf).

Repeat your field trip when the well, pump and piping are complete and ask driller to explain how well and pressure tank work to bring water to the surface. Ask well driller to explain a “pitless adapter.” Inspect the adapter with a flashlight. Collect a water sample for bacterial and nitrate analysis.

Adapted from: *Groundwater Study Guide*, 1984, Wisconsin Department of Natural Resources, Bureau of Information and Education (out of print).



# Wisconsin's Major Aquifers



Maps are not to scale.

**Learning Objectives:** Students will: (1) identify the state's four major aquifers, (2) describe the geologic arrangement of the aquifers, (3) explain the significance of confining layers, (4) estimate the depths of several wells and (5) interpret the information to make conclusions about groundwater quality in the aquifers.

**Subjects:** Science, Health Education and Math

**WMASs: SC:** A.8.1, A.8.6

**HE:** D.8.2

**M:** D.8.4

**Grades:** 6–9

**Materials:**

- ❖ Wisconsin's Aquifers—activity sheet\*
- ❖ colored pencils

\* Two cross-sections of the state are provided. You may choose a northern or southern cross-section for this activity.

**Background:** An *aquifer* is an underground formation that can store and transmit water. Most of Wisconsin is underlain by thick, permeable deposits. These layers of rock and soil make up our state's four major aquifers: 1) the sand and gravel aquifer, 2) the eastern dolomite aquifer, 3) the sandstone and

dolomite aquifer and 4) the crystalline bedrock aquifer. A few areas in northern Wisconsin are made up of clay soils overlying granite or other non-porous materials. Since these materials can't store or transmit much water, substantial well water supplies aren't available there (see *Groundwater: Wisconsin's Buried Treasure* for more information).

1) The sand and gravel aquifer covers most of Wisconsin, except for the unglaciated areas in the southwestern part of the state. This aquifer layer was deposited by glacial ice and river floodplains between 10,000 and 1 million years ago. Many of the irrigated farmlands in southern and northwestern Wisconsin tap this aquifer. Because the top of the sand and gravel aquifer is also the land surface, the groundwater it contains may easily become contaminated.

2) The eastern dolomite aquifer lies beneath the sand and gravel aquifer in eastern Wisconsin, and extends from Door County to the Wisconsin-Illinois border. It is made up of the Niagara dolomite formation underlain by the Maquoketa shale formation. These layers were deposited about 400 million years ago.

Dolomite is like limestone and contains groundwater in interconnected cracks. The yield of water from wells in this aquifer is variable and depends on the number of fractures through which a well passes. Where this fractured formation is close to the land surface, groundwater may easily be contaminated.

The underlying Maquoketa shale layer doesn't transmit water readily. This formation isn't important as an aquifer but as a confining layer or barrier between the eastern dolomite aquifer and the sandstone and dolomite aquifer.

3) The sandstone and dolomite aquifer is made up of layers of sandstone and dolomite bedrock. Water is found in fractures in the dolomite layers. In the sandstone, water also occurs in pore spaces between the loosely cemented sand grains. This aquifer covers the entire state, except for the

north central region. Materials in the sandstone and dolomite aquifer were deposited between 425 and 600 million years ago. This is the principal bedrock aquifer for southern and western portions of the state. Most cities and industries in eastern Wisconsin also tap this deep aquifer.

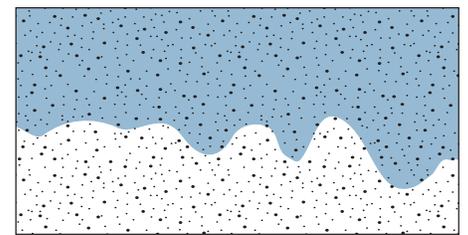
4) The crystalline bedrock aquifer is made up of a variety of rock types formed between 600 and 4,000 million years ago. This granite-like rock formation underlies the entire state. In the north central region this aquifer lies directly beneath the sand and gravel aquifer. Water is stored in cracks that may be many feet apart. To draw water from this aquifer a well must pass through some of these cracks. Good quality water can be obtained from shallow wells in this formation, but wells that penetrate deep into the aquifer have been found to yield salty water because the water becomes concentrated with naturally occurring salts and minerals as it passes through many rock layers.

### Procedure:

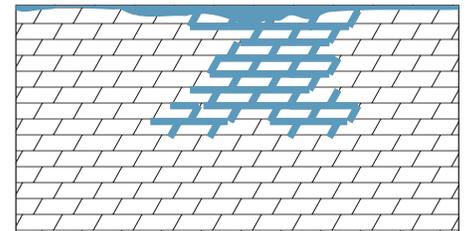
1. Discuss the background information.
2. Complete the activity sheet for either the northern or southern cross-section.
3. Discuss your answers.

### Going Beyond:

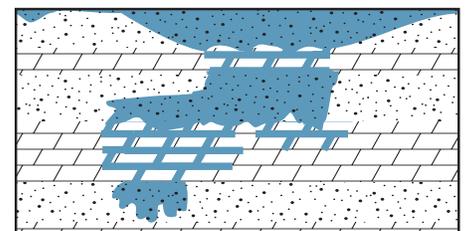
1. Investigate what aquifer your town well taps, its depth, and how much water is pumped per minute, per day and per year. Investigate the water quality and treatment methods used. Visit or contact your local water department for this information. You can also obtain information by visiting the DNR's Bureau of Drinking Water and Groundwater website at [dnr.wi.gov/org/water/dwg/index.htm](http://dnr.wi.gov/org/water/dwg/index.htm). Click on "Public Water Systems" or "Well construction" and type in the name of your community. Also see the "Where Does it Come From? ... Where Does it Go?" exercise.



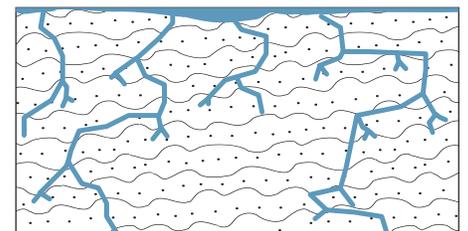
Sand & gravel aquifer



Dolomite



Sandstone & dolomite



Crystalline bedrock

2. Construct a geological model of your area using topographic, geologic, and groundwater susceptibility maps. Maps are available from the Wisconsin Geologic and Natural History Survey (visit [uwex.edu/wgnhs](http://uwex.edu/wgnhs)). Using modeling clay, markers, and labels, show local soil and rock types, topography, depth to bedrock, depth to groundwater, and groundwater susceptibility. (This activity could be used as an art class project.)

From: *GREAT: Groundwater Resources and Educational Activities for Teaching*, 1989, Iowa Department of Natural Resources, Wallace Building, Des Moines, IA 50319.



## A Plume of Contamination

**Learning Objectives:** Students will: (1) determine the extent of contamination by taking samples and testing them for pH, (2) interpret data to draw a plume of contamination, (3) evaluate whether more information is needed and (4) make conclusions about the movement of contaminants in groundwater.

**Subjects:** Science, Health Education and Environmental Education

**WMASs: SC:** A.8.6, C.8.6, H.8.3

**HE:** A.8.2, C.8.3

**EE:** A.8.4, C.8.2

**Grades:** 6–9

### Materials:

- ❖ A Plume of Contamination activity sheet
- ❖ clear plastic containers—one for demonstration and one for each group of 3–4 students
- ❖ sand
- ❖ powdered grape drink mix (do not add water)
- ❖ powdered lemonade mix (do not add water)
- ❖ for each group of 3–4 students
  - ❖ watering cans or spray bottles
  - ❖ plastic straw, cut in half
  - ❖ pH paper
  - ❖ tape
  - ❖ plastic container lids or pencil erasers for props

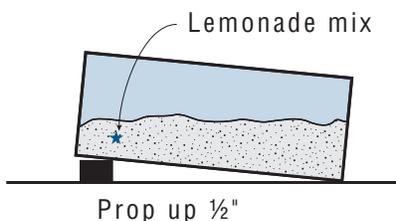
**Background:** Contaminants on the surface of the ground can move slowly through soils and reach groundwater. Contaminants spread outward from the point of origin, forming a plume which “points” to the source of contamination. A small amount of some contaminants can ruin a large quantity of groundwater.

Some chemical contaminants are easily detected by changes in color, odor, or taste of groundwater. However, most contaminants are “invisible” and require chemical testing for detection. Testing of many wells in an area may be required to determine the source of contamination.

### Procedure:

#### A) Preparation.

1. Before class, fill one clear plastic container for each group of 3–4 students with 1 inch of sand. Wet the sand with water and smooth off the surface. Station containers around classroom.

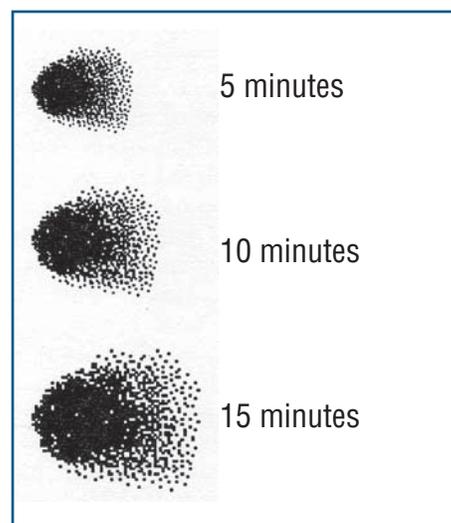


2. Prop up one end of each container about 1/2 inch.
3. Make a small depression in the sand and add 1/2 teaspoon of dry lemonade mix at the elevated end. Cover the lemonade with sand. Vary the location of the lemonade contaminant in each container and keep a record of the contaminant location. After the demonstration, students will use pH paper to find the source of contamination.

#### B) Demonstration.

1. Prepare a plastic container as above, but don't add lemonade.
2. Make a small depression on the elevated side of the container. Place about 1/4 teaspoon of powdered grape drink mix in the depression. This represents a chemical contaminant.
3. “Rain” water on the contaminant, using the spray bottle or watering can. The “rain” should be light so the food coloring is diluted and seeps into the sand rather than running off the surface. If sand erodes badly, try again, using lighter “rain” or spread a layer of pea gravel on top to hold the sand in place.
4. Every 2–3 minutes check the bottom of the container for evidence of color. After about five minutes, a plume of color should begin to appear. Draw the shape of this plume, to scale, on the chalkboard.

5. Check the size and shape of the plume after 1/2 hour and draw the new plume, to scale, on the chalkboard. Discuss the results. The plume should be broad and fanlike, pointing to the source of contamination. Notice that the red and blue dye components of the grape drink mix separate. Why do you think this happens?



#### C) Investigation.

1. Tell students they will now have to use a chemical test to find the source of an invisible contaminant. Point out the containers in which you've placed the lemonade mix. Explain that a lemonade “contaminant” has been put in a different location in each container and they will be using pH paper to find the plume of contamination. Lemonade is acidic and will lower the pH of water it encounters. It may be helpful to review the meaning of pH and the use of pH paper. Remind students that as acidity increases, pH decreases.
2. Work in small groups at the lemonade contaminant stations.
3. Lay a 6-inch strip of pH paper on a dry desk or counter. You may need to secure the paper to the desk or counter by placing a piece of tape at each end. Put a small drop of water on one end of the pH paper, note the



color and record the pH of the water on your activity sheet.

4. With a watering can, “rain” lightly on the upper end of each container so there’s no runoff. Keep watering lightly for about 5 minutes. Wait 15 to 20 minutes.

5. Using a piece of plastic straw, remove a plug of sand (and water) from one of the locations indicated on the activity sheet diagram. Drop the wet sand on the pH paper. Note the color of the pH paper and determine the pH of the sample. If the sample is more acidic (has a lower pH) than tap water, place a “+” on that location on your activity sheet. If the acidity is the same or lower (pH same or higher), place a “-” at that location on your activity sheet. Rinse the straw.

6. Take a total of 12 “test well” samples from the locations shown on the diagram, rinsing the straw after each sample. Determine the pH of each sample and record a “+” or “-” on your activity sheet at each location.

7. Complete the activity sheet and discuss your results.

- ❖ What makes a contaminant move from where it is buried?
- ❖ What is a “plume of contamination?”
- ❖ What are some real contaminants that could be seen, smelled or tasted if they got into groundwater?
- ❖ What are some real contaminants that could not be seen if they got into groundwater?
- ❖ In the real world, what factors underground might influence the movement of contaminants?

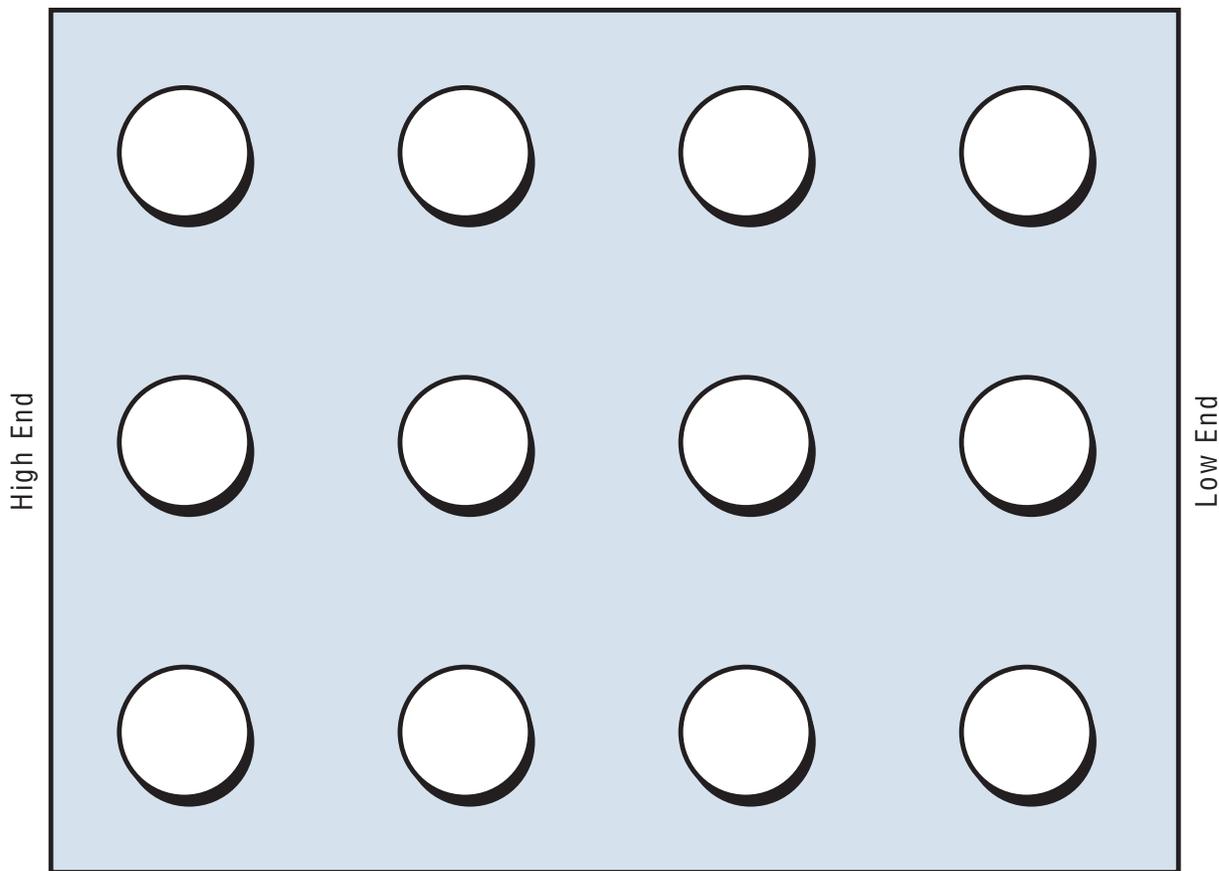
if your water utility has conducted an inventory of potential contaminant sources around its’ wells. Check out the *Wisconsin Groundwater Directory* included with the Groundwater Study Guide packet for databases containing information on potential contaminant sources.

2. Research and report on the effects contaminated groundwater may have on human health. Have a physician or public health official visit and discuss the topic.
3. Investigate bottled drinking water. Where does it come from? How much does it cost? What does the company do to ensure that it is safe for human consumption? What regulations govern the quality of bottled water?

### Going beyond:

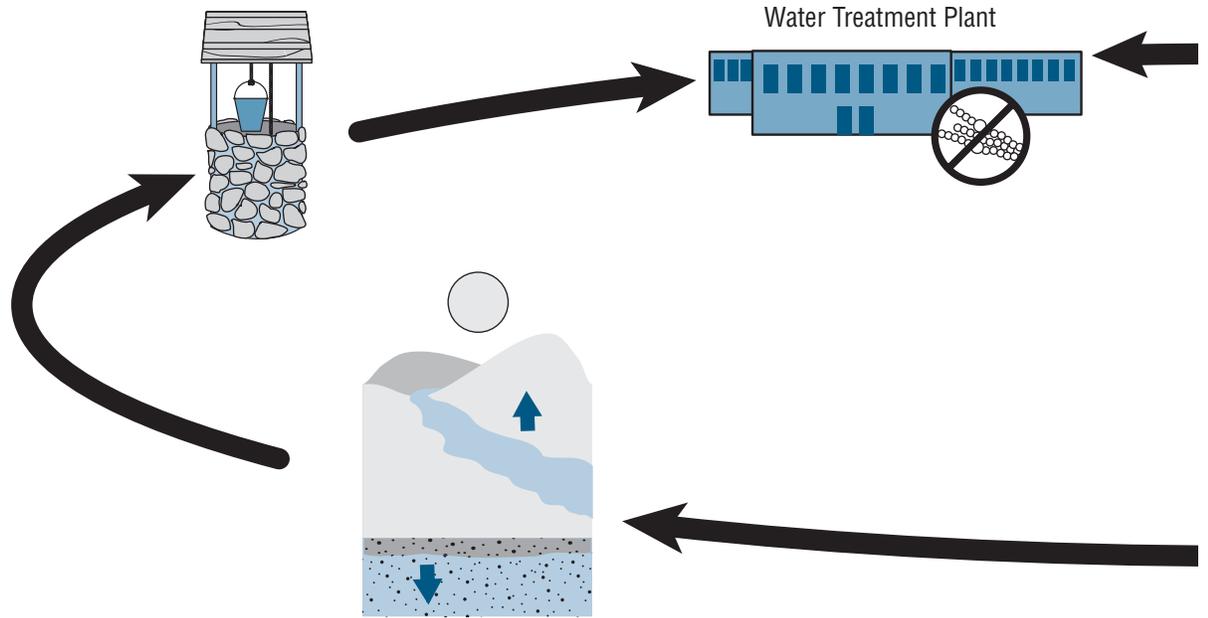
1. Research and report on the types and effects of groundwater contamination from various sources in your area (e.g. private homes, schools, farms, landfills, gasoline stations, mine sites, septic tanks, industries, businesses, salt stockpiles, etc.) See

Adapted from: *Groundwater Quality Protection in Oakland County: A Sourcebook for Teachers*, 1984, The East Michigan Environmental Action Council, 21220 West 14 Mile Road, Birmingham, MI 48010.





# Household Water



## Where Does it Come From?...Where Does it Go?

**Learning Objectives:** Students will: (1) summarize and illustrate how a water treatment plant and wastewater treatment plant work, (2) describe the source of water for their community and the adequacy of groundwater to meet the community's needs and (3) explain where the wastewater goes after it has been treated.

**Subjects:** Environmental Education, Science, Health Education and Social Studies

**WMASs: EE:** A.8.1, B.8.22

**SC:** C.8.1, G.8.1

**HE:** D.8.2

**SS:** D.8.4, E.8.5

**Grades:** 6–9

**Materials:**

- ❖ pencils and paper

**Background:** Have you ever wondered where the water comes from when you turn on your tap or where it goes after it drains from your bathtub? Water for most urban and suburban areas in Wisconsin comes from city or town wells that tap an underlying aquifer. *Groundwater* from these wells passes through a water treatment facility on the way to our homes and through a wastewater treatment facil-

ity after draining from our sinks, bathtubs and toilets.

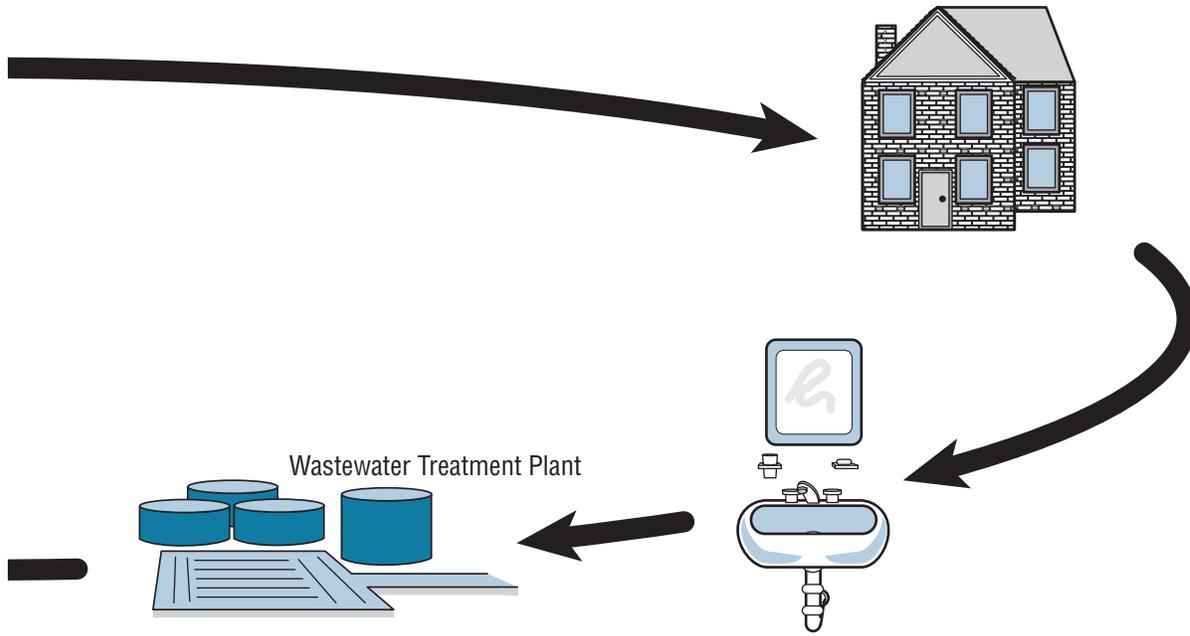
The following field trips (or guest speakers) can help students understand the workings of these facilities and encourage them to think about where their water comes from, how it is changed as it passes through their homes and how it must be treated before it is allowed to return to the groundwater supply.

### Procedure:

**A)** Investigate a water treatment facility.

1. Contact your municipal water treatment facility and obtain permission to visit it. Arrange with the manager or other resource person to guide your trip and be available to answer questions. If a field trip is not possible, arrange for a water treatment specialist to speak to your class.
2. Before visiting the water treatment plant or having a guest speaker, develop a list of questions you would like answered. Send the list to the guide or guest speaker in advance so he/she can prepare responses. Questions to consider include:

- ❖ From what aquifer(s) does your school or municipality get its water?
- ❖ What is the extent (area), boundaries and depth of the aquifer?
- ❖ What geological materials make up the aquifer?
- ❖ How many wells does your school or community use? Where are they? How deep are they? How much water can they pump per minute/hour/day? When were they installed?
- ❖ What is a “cone of depression?” What is the extent of the cone of depression surrounding the well(s)? How does the cone of depression affect groundwater movement in the area?
- ❖ What time of the day, year, does the system pump the most water? Why?
- ❖ What is the natural chemical composition of the water before it is treated? How does the natural chemical composition compare with other wells around the state?



- ❖ How is water transported from the treatment plant to homes and businesses?
- ❖ Does the municipality have an adequate water supply for future needs?
- ❖ Are there any present or potential sources of contamination to the well(s)?
- ❖ What does the treatment plant do to ensure that the water is safe to drink? What treatment methods are used?
- ❖ Is your community planning to drill new wells in the near future? If so, how much will it cost? Who will pay?
- ❖ How are local households charged for the water they use? (Do all local homes have water meters?)
- ❖ Does the price per gallon of water increase, decrease or stay the same as the amount used goes up? Does this pricing system encourage conservation?
- ❖ Does your community encourage water conservation in any other way?

**3.** Ask students to draw a diagram of a water treatment plan (including wells and aquifers) and describe how the facility works.

**B)** Investigate a wastewater treatment facility.

**1.** Arrange a field trip or guest speaker as outlined in part A.

**2.** Prepare and send a list of questions you would like answered to the field trip guide or guest speaker so he/she can prepare responses. Questions to consider include:

- ❖ What household water passes through a wastewater treatment plant?
- ❖ Are all the homes in the community connected to a wastewater treatment facility?
- ❖ How does a wastewater treatment facility work?
- ❖ What is “graywater?”
- ❖ What is “sludge?” Is it solid or hazardous waste? Why?
- ❖ What is done with sludge from the treatment plant?
- ❖ How much wastewater is processed each day?

- ❖ What training does the operator have?
- ❖ What happened to wastewater before the treatment plant was built?
- ❖ How might wastewater affect groundwater?
- ❖ What household materials should not be washed down the drain? Why?
- ❖ Can household chemicals affect bacteria at the wastewater treatment facility?
- ❖ How might sludge affect groundwater?
- ❖ What is the difference between a septic system and a wastewater treatment plant?
- ❖ How might a septic system affect groundwater?
- 3.** Ask students to draw a diagram of a wastewater treatment plant and describe how the facility works.

Adapted from: *Groundwater Study Guide*, 1984, Wisconsin Department of Natural Resources, Bureau of Information and Education (out of print).



# How Septic Systems Work

**Learning Objectives:** Students will: (1) construct a model of a septic system, (2) examine and describe how the components of a septic system work and (3) discuss the location of a septic system as a potential threat to groundwater and surface water with someone who has a septic system.

**Subjects:** Environmental Education, Science, Health Education and Social Studies

**WMASs: EE:** A.8.3, A.8.5

**SC:** A.8.6

**HE:** A.8.2

**SS:** A.8.10, D.8.11

**Grades:** 6–9

**Materials:**

- ❖ How Septic Systems Work activity sheet
- ❖ 6 Steps to a Successful Septic Tank System overhead\*
- ❖ The Septic Tank at Work overheads\*
- ❖ for each group of 2–4 students:
  - ❖ one small (6–8 oz. (ounce)) glass jar or beaker
  - ❖ one large (12 oz.) glass jar or beaker
  - ❖ sand
  - ❖ paper towel
  - ❖ potting soil
  - ❖ green food coloring

- ❖ flexible straws
- ❖ small pieces of white paper (e.g. holes from paper punch)

\* masters provided

**Background:** Many rural homes use septic tank systems for disposal of wastewater from sinks, bathtubs and toilets. Septic systems are a type of onsite wastewater treatment device used to treat domestic wastes where there is no public wastewater treatment system available. The Wisconsin Department of Commerce uses the term “private onsite wastewater treatment system” (or POWTS) to identify these systems. The Department of Commerce allows a number of different designs for new or replacement installation. This exercise focuses on septic systems since the vast majority of onsite wastewater treatment systems in use today are septic systems.

There are two parts to a septic system: a settling/storage container (septic tank) and a filtering area (soil absorption or leaching field). Both parts of this system are essential for proper wastewater disposal.

The main purpose of the settling tank is to protect the soil absorption field. Inside the settling tank, solids settle and form a sludge layer on the bottom and floating materials accumulate in a scum layer at the water surface. Clarified wastewater leaves the settling tank through a submerged outlet. The scum and sludge are left behind. This is important because scum and sludge can clog soil pores and cause the leach field to fail.

Bacteria in the septic tank helps to break down the scum and sludge that remains. Decomposition of these layers is slow, so scum and sludge gradually build up and must be removed periodically. Using kitchen garbage disposals increases the amount of solids in wastewater and speeds up sludge accumulation. (Composting vegetable matter instead of putting it down the garbage disposal keeps extra solids out of septic systems and also provides good fertilizer for flowerbeds and gardens.)

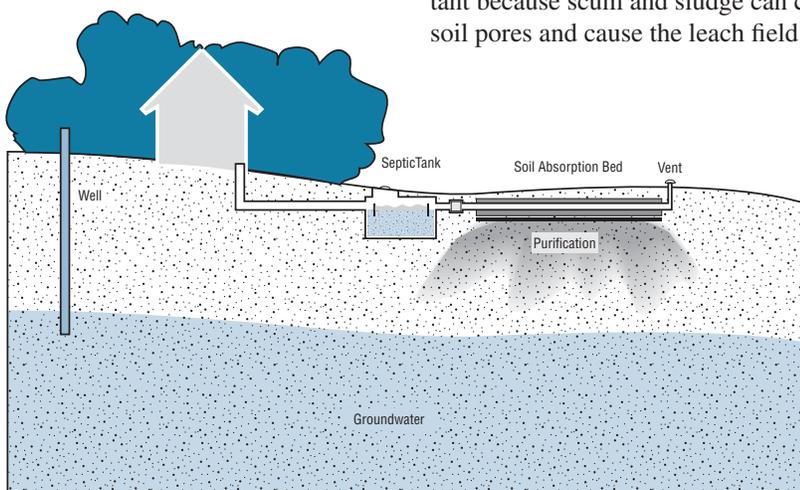
The soil absorption or leaching field does two things. It slowly disposes of wastewater below the surface of the ground, and it filters out harmful bacteria and many chemical contaminants before they reach groundwater.

Watertight pipes transport wastewater from the septic tank to the absorption field. In the absorption field, the water is divided among several trenches. Perforated, rigid plastic pipe or agricultural drain tile distributes the water throughout the trenches. A gravel bed below the distribution pipes temporarily stores the wastewater until it is absorbed by soil surrounding the trench.

Septic systems can pollute groundwater if the capacity of the surrounding soil to filter the wastewater is exceeded or if the underlying soils are very permeable, allowing contaminants to move rapidly to the water table before filtering is complete. Groundwater may also become contaminated if chemicals that are not decomposed by soil bacteria are dumped down sinks or toilets.

Adequate spacing of homes and proper planning, design, construction and maintenance of septic systems is the best insurance against groundwater contamination by household wastewater. Planners must consider the location of buildings, water supplies and soil characteristics. They must also decide how large a septic tank and absorption field is needed.

Proper maintenance of the system includes periodic pumping of sludge from the septic tank. Depending on the size of the tank and the number of persons in





the household, cleaning may be needed as often as every two years or as seldom as every 10 years, but tanks should be checked yearly.

## Procedure:

### A) Explanation.

1. Using the overheads, briefly discuss where wastewater goes in rural areas. Explain how a septic system works.

### B) Investigation.

1. Work in small groups. Prepare a “wastewater” sample—water, sand, bits of paper and 2–3 drops of green food coloring.

2. Construct a model septic tank system:

a) Label small jar or beaker “septic tank.”

b) Pour a well-stirred sample of wastewater into the septic tank until it is about  $\frac{3}{4}$  full.

c) Allow the sample to settle. Make observations.

d) Prepare a “leach field” as follows: Add alternating layers of sand and potting soil, separated by paper towels to the large jar or beaker. Wet the leach field.

e) Set the septic tank on a book or other riser. Place the leach field directly below the septic tank. Bend the flexible straw and fill it with water. Place fingers over both ends to keep the water in. After the wastewater has settled, connect the septic tank with the leach field as shown. Keep fingers over the ends of the straw until it is placed in the wastewater. This should create a siphon, allowing wastewater to flow onto the leach field. (It may be helpful to demonstrate this step for your students.) Observe the action of wastewater on the leach field.

### 3. Discuss your results.

❖ What settled to the bottom of the septic tank? What stayed on the surface?

❖ What was filtered out of the wastewater as it passed through the leach field? What was not? As in your septic system model, some components of wastewater (such as bacteria) are usually filtered out by soil. Other components (such as chloride, nitrates and volatile organic chemicals) are not effectively filtered and may be carried into groundwater.

❖ How did the green dye change as it passed through the leach field soil layers? Why?

4. Using part B of the worksheet, interview a friend or relative who has a septic tank system (instead of being connected to a municipal wastewater treatment plant). Find answers to the following questions:

❖ Where does their water come from?

❖ If their water is from a private well, how far is the septic tank from their well?

❖ How far is the absorption field from their well?

❖ How far is their house from the septic tank?

❖ How far is their house from the leach field?

❖ Refer to the table on the worksheet. Is there anything closer to the septic tank or absorption field than the recommended minimum separation distance? If so, circle the unit and record next to the table how close it is.

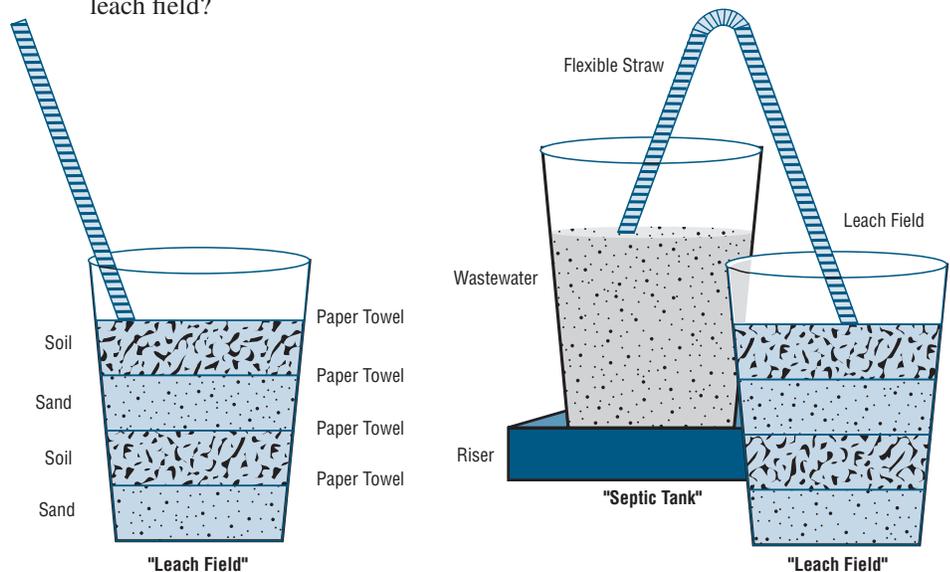
❖ What is one other factor (besides separation distance) to consider when planning a septic system?

Students may find that many people don’t know the answers to these questions. Should they? Why is this important? Discuss.

## Going Beyond:

Investigate and compare different types of onsite wastewater treatment systems. Visit [wra.org/pdf/government/landuse/onsite\\_system\\_descriptions.pdf](http://wra.org/pdf/government/landuse/onsite_system_descriptions.pdf) for a copy of General Descriptions of Common Types of Onsite Sewage Systems. Invite the county onsite waste disposal specialist to speak to your class. Ask him/her to bring diagrams of conventional and mound septic systems. Under what circumstances should a mound system be built? Are there other onsite wastewater treatment system designs? When are they used?

Adapted from: *GREAT: Groundwater Resources and Educational Activities for Teaching*, 1989, Iowa Department of Natural Resources, Wallace Building, Des Moines, IA 50319.





## Caution: This Product May be Hazardous to Your Health!

**Learning Objectives:** Students will: (1) locate and interpret information on use, storage, disposal, and hazards of household products, (2) explain how disposal and storage of chemicals can cause potential groundwater contamination and (3) compare and contrast less harmful alternatives that can be used in place of many household hazardous products.

**Subjects:** Environmental Education, Health Education and Science

**WMASs: EE:** B.8.5, B.8.18, B.8.21

**HE:** A.8.2, B.8.4, D.8.2, G.8.3

**SC:** C.8.2, H.8.3

**Grades:** 6–9

This activity is divided into two parts: Part 1 is designed to teach students to read instructions and information on household chemical labels. In Part 2, students are asked to complete a home inventory of hazardous materials with the help of their parents.

### Part 1: Reading Product Labels.

#### Materials:

- ❖ Reading Product Labels activity sheet
- ❖ Letter to Parents handout (for Home Search activity)
- ❖ A Home Chemical Search activity sheet (for Home Search activity)

**Background:** Many materials commonly found in our homes can be hazardous for children, adults and pets. The U.S. Environmental Protection Agency estimates that each home throws out an average of six pounds of hazardous waste every year. While six pounds may not seem like very much, it all adds up. A town of 10,000 homes can generate 60,000 pounds of hazardous waste in just one year! Take a quick inventory of materials you use and store in your kitchen, basement and garage. Many of the products you might find, including aerosol sprays, cleaners,



insect repellents and poisons, motor vehicle products, paints, paint thinners, furniture strippers and fabric stain removers are considered hazardous. They should be used, stored and disposed of with care.

Chances are the only advice you receive for using and storing these products is from the label on the container. Unfortunately, many product labels contain little or no information for disposal of leftover material or empty containers. If these products are poured or buried in the backyard or dumped into the drain or toilet they can soak through soils and reach groundwater (they can also run off into surface waters). Many products can also interfere with your wastewater treatment plant by killing bacteria essential for treating sewage.

It is important to read and follow product labels carefully to avoid possible illness, death and environmental damage that can result from misuse of or improper disposal of hazardous materials.

#### Procedure:

1. Using the following information, discuss what “hazardous” means. Explain toxic, corrosive, reactive, and ignitable.

Hazardous materials and wastes are chemical substances that can harm, contaminate or kill living organisms. Hazardous materials have one or more of the following characteristics:

- ❖ **Toxic:** Poisonous, potentially harmful to human health, can cause cancer and/or birth defects, and can contaminate, harm or kill fish and wildlife.
- ❖ **Corrosive:** A substance that can corrode storage containers or damage human tissue if touched.
- ❖ **Reactive:** An unstable substance that can react if exposed to heat, shock, air or water. Reactions include explosions.
- ❖ **Ignitable:** A substance that can explode, catch fire or emit toxic gases or fumes into the environment.

2. Generate a list of hazardous materials from each category that might be found in the home. How do people know how to use, store and dispose of these materials?
3. Complete the “Reading Labels” activity sheet.
4. Discuss your answers.
  - ❖ How might this product find its way into groundwater?
  - ❖ What effects might contamination have on people drinking the water?
  - ❖ Can you think of any alternatives to using the product?
5. Distribute the “Household Chemical Search” activity sheet and the “Letter to Parents.” Ask students to fill out only the first two columns on the activity sheet (i.e. mark with an X if the product is found and estimate the amount of chemical present). Go through the list of substances and possible locations in the home. Ask students if they have questions about any of the substances.

This activity can be an excellent opportunity for students and their parents to learn about hazardous chemicals together. **Remind students to ask their parents for help filling out the worksheet, to avoid touching any of the substances, to read container labels carefully and to wash**



**their hands when through.** Students should have 1–2 days to complete the inventory.

You might also investigate hazardous materials in your school by conducting a hazardous chemical search of your science room or cleaning supply closet!

Adapted from: *Groundwater Quality Protection in Oakland County: A Sourcebook for Teachers*, 1984, The East Michigan Environmental Action Council, 21220 West 14 Mile Road, Birmingham, MI 48010.

## Part 2: A Home Chemical Search

### Materials:

- ❖ Can Some of Your Household Products Harm You? Handout
- ❖ Household Hazardous Waste Wheel patterns and directions
- ❖ Completed Home Chemical Search activity sheet
- ❖ glue
- ❖ manila folders (2 per student)
- ❖ brads
- ❖ scissors

### Procedure:

1. Distribute “Household Hazardous Waste Wheel” patterns, directions and materials. Construct Household Hazardous Waste Wheels (follow directions printed on activity sheet 8-6). When the wheels are complete, demonstrate how to use them. It would be helpful to have some examples of hazardous household products in the room.
2. Work in small groups. Using the “Can Some of Your Household Products Harm You?” handout, rate the toxicity of the products found in your homes. Ratings are 1–6, with 1 representing the least toxic materials and 6 the most toxic. Record your ratings on the “Home Chemical Search” activity sheet.
3. Calculate the total quantity of substances listed in each category (1–6) for your group. Using the Household Hazardous Waste Wheels, list directions for disposing of all products which are at least “very toxic” (a toxicity rating of 4 or greater). For all products which are at least “very toxic,” also list at least one viable alternative to using the product.

4. Discuss the completed activity sheets.
  - ❖ What kinds of products were found in each toxicity category?
  - ❖ What was the total quantity of hazardous material in each category for your class?
  - ❖ What makes these products hazardous (e.g. toxic, corrosive, reactive, flammable)?
  - ❖ What alternatives were suggested?
  - ❖ How viable are these alternatives? Discuss advantages and disadvantages of using the alternatives and of using the products with a toxicity rating of 4 or greater.
  - ❖ Which products represent “needs” and which represent “wants?”
  - ❖ Using your homes as the average, estimate how much hazardous waste would be found in your community, in the state and in the nation.
  - ❖ How might these products enter groundwater?
  - ❖ How should these materials be disposed?
  - ❖ What kinds of warnings did you find on the containers? How can you tell if a product is considered hazardous?

### Going beyond:

1. Research the disposal of household hazardous materials in your area. Does your county, city or town offer a Clean Sweep program? If so, when is it? What products should be taken there for disposal? How much hazardous waste is collected at the Clean Sweep each year? Does your community have a waste oil disposal facility? How much waste oil is collected there each year? What is done with the waste oil? Do people in your community know that these services exist? Do most people use them? If not, what do they do with their household hazardous waste? Your city/county Health Department should be able to provide information on household hazardous waste disposal programs or see box below.
2. For more information on alternatives to household hazardous wastes and options for disposal, see *Better Homes and Groundwater* included with the Groundwater Study Guide packet.

Adapted from: *Groundwater Quality Protection in Oakland County: A Sourcebook for Teachers*, 1984, The East Michigan Environmental Action Council, 21220 West 14 Mile Road, Birmingham, MI 48010.

Many counties, cities and towns offer a “Clean Sweep” collection program. This is an opportunity for home owners to bring household hazardous materials to a central location for safe disposal. To find out about Clean Sweep programs in your area, contact your city or county health department or visit the Department of Agriculture, Trade and Consumer Protection Clean Sweep website at [datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/clean-sweep/index.jsp](http://datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/clean-sweep/index.jsp).

# Resource Protection, Value and Conflict

## It'll Go With the Flow...

**Learning Objectives:** Students will: (1) construct a water table elevation contour map, (2) predict groundwater flow patterns using the water table elevation contour map and (3) evaluate a hypothetical landfill site based on the direction of groundwater flow.

**Subjects:** Environmental Education, Science, Social Studies, Health Education and Math

**WMASs: EE:** A.8.2, A.8.4, B.8.17, B.8.18, D.8.1

**SC:** A.8.1, C.8.6, D.8.6, E.8.1, H.8.3

**SS:** A.8.1, C.8.7

**HE:** A.8.2, B.8.4, C.8.3

**M:** E.8.4

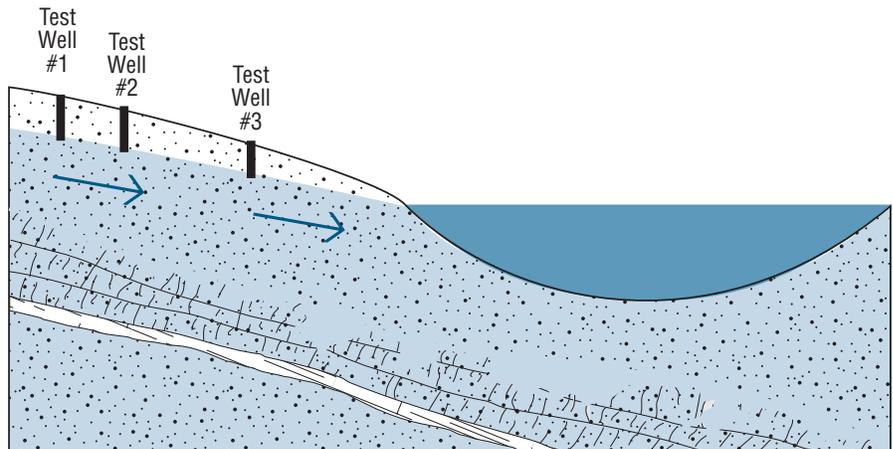
**Grades:** 7–9

### Materials:

- ❖ It'll Go With the Flow activity sheet
- ❖ It'll Go With the Flow teachers key
- ❖ rulers
- ❖ pencils
- ❖ book and a marble for demonstration (optional)

**Background:** Groundwater usually flows in the same direction as the land slopes, often toward a nearby lake or stream. Many factors, such as rate of percolation from the surface and pumping from wells, can influence the direction and rate of groundwater flow, but it is possible to get an idea of how groundwater is moving in a given area by determining the slope or “plane” of the water table. To do this, at least three monitoring wells must be installed (three points determine a plane). By measuring the “static water level” (SWL), or elevation of the water table above sea level, we can estimate how groundwater will flow at a certain location.

Groundwater flows from areas of high static water levels to areas of low static water levels. This can be illustrated using a book and a marble. The marble will roll off



the book in the direction of the slope and the speed of the marble will be determined by the steepness of the slope. Groundwater moves in much the same way.

It is important to consider the direction and rate of groundwater flow when planning land development to avoid potential contamination problems. Using static water level data, students will be asked to determine the general direction and relative rate of groundwater flow on a given map, and evaluate a proposed landfill site on the basis of this information.

### Procedure:

- A)** Determine the slope of the water table and the direction of groundwater flow. The activity sheet gives land elevation/depth to water table. Ask students to subtract depth to water table from land elevation to get static water levels (SWL's). Mark SWL's on activity sheet next to each well. Remind students that SWL's are height above sea level not depth from the land surface. Point out that the water table generally follows the contour of the land surface.

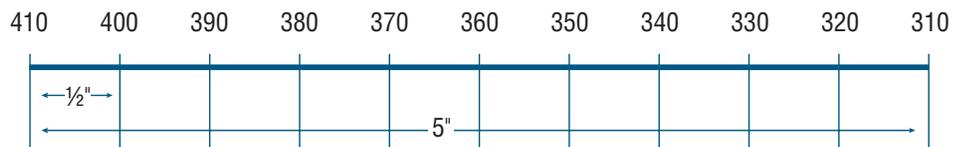
Construct contour lines by doing the following for each adjacent pair of wells:

1. Draw a line between the two wells. Measure the length of the line.
2. Subtract the smaller of the two SWL's from the larger. This is the difference in water table elevation (in feet) between these two wells.
3. Divide the line between the two wells into units representing 10 ft. (foot) intervals.
  - a) Calculate the number of subdivisions needed by dividing the difference in water table elevations by 10.
  - b) Calculate the distance between subdivisions by dividing the distance between the wells by the number of subdivisions needed (see example).
4. Label each subdivision mark with the appropriate SWL as in example.

Example:

Distance between wells = 5 inches  
 SWL A = 410 ft. SWL B = 310 ft.  
 SWL difference:  $410 - 310 = 100$  ft.  
 Number of subdivisions:  $100 \text{ ft.} / 10 \text{ ft. intervals} = 10$

Distance between subdivisions:  $5 \text{ inches} / 10 \text{ subdivisions} = \frac{1}{2} \text{ inch per subdivision}$





5. Repeat steps 1–4 for each pair of adjacent wells.

6. Connect equivalent SWL's with light dashed pencil lines. These lines represent the contour of the water table elevation. (The lines are analogous to contour lines on a topographic map which connect equivalent land elevations.)

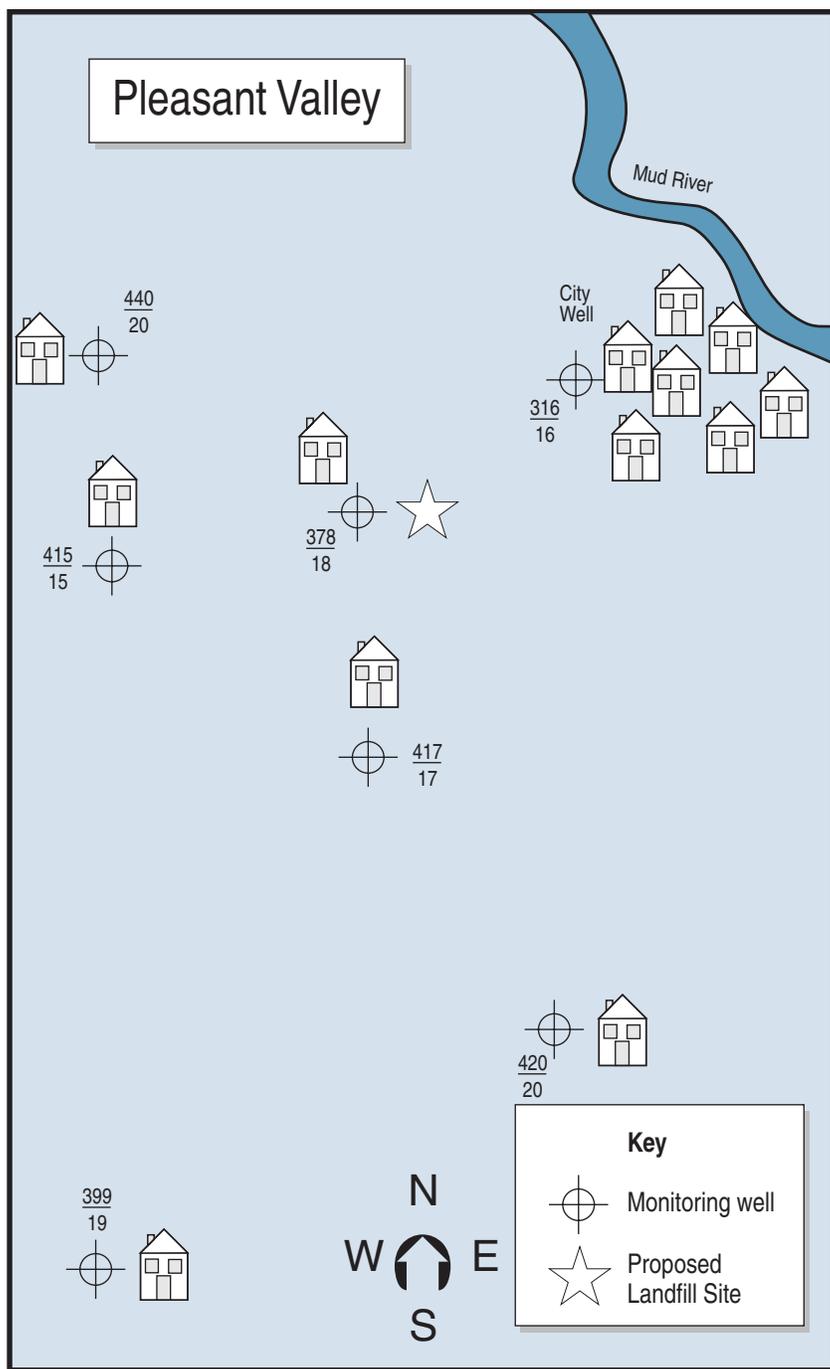
7. After all contour lines have been drawn, round sharp “corners” and draw solid lines over the original dashed lines. The groundwater flow at any point on your maps is perpendicular to the contour lines at that location. (See Teacher’s Key)

**B)** Evaluate the proposed landfill site, marked “☆,” using groundwater flow information from your contour maps.

1. Write a paragraph evaluating the proposed landfill site based on groundwater flow at “☆.” (Note locations of the private wells.) If you think that locating the landfill at “☆” is not advisable, suggest two locations that might be better suited for a landfill. Support your choices by comparing rate and direction of groundwater movement at your proposed sites with that at “☆.”

**C)** Discuss your findings.

- ❖ What is “static water level?” How is it different from water table depth?
- ❖ How are SWL's used to determine the slope or plane of the water table? How does the plane of the water table affect groundwater flow (direction and rate)? What other factors might influence groundwater flow?
- ❖ What do the contour lines on your map show?
- ❖ In what general direction does groundwater flow in Pleasant Valley?
- ❖ Can we make assumptions about the speed of groundwater movement at certain locations?
- ❖ Would the contour lines change if you had SWL information from more wells? Fewer wells?
- ❖ What is the level of Mud River as it passes by town?
- ❖ Is “X” a good location for the landfill? Why?
- ❖ Can you suggest better locations for the landfill, based on groundwater flow? If so, why do you think these sites are better than “X”?



### Going Beyond:

Conduct a hearing to decide where to locate a landfill in your community. Take on roles of people involved in making the decision: local landowners, politicians, industry representatives, geologists, environmentalists, waste managers and others. The *Groundwater Contamination Susceptibility in Wisconsin* map (in your packet) and topographic maps of your area may be helpful.

Adapted from: *Groundwater: Michigan's Hidden Resource Workbook*, 1989, Michigan Department of Natural Resources, Environmental Response Division, P O Box 30028, Lansing, MI 48909.



## What if Water Cost as Much as Gasoline?

**Learning Objectives:** Students will: (1) explain how the availability of a resource has an effect on how much people are willing to pay for a resource, (2) describe how cost influences the willingness of people to conserve natural resources and (3) discuss ways to encourage people to conserve natural resources.

**Subjects:** Environmental Education, Science and Social Studies

**WMASs: EE:** B.8.16, C.8.3

**SC:** E.8.6

**SS:** A.8.11, D.8.2, D.8.11

**Grades:** 6–9

### Materials:

- ❖ What if Water Cost as Much as Gasoline? activity sheet
- ❖ play money
- ❖ legal size envelope for each student

**Background:** At one time energy—gasoline and fuel oil—was so inexpensive that people did little to conserve it. People drove as much as they wanted, energy-efficient cars were less of a concern and homes were built with very little insulation. Today water is relatively inexpensive. Few people try to conserve water just as few people conserved gasoline or fuel oil when they were less expensive. This activity is designed to help students begin thinking about the value of water.

### Procedure:

1. Interview a grandparent or older neighbor. Ask about the present and past price of gasoline, fuel oil and water. Ask also about conservation of these resources. Questions should include:
  - ❖ What is the lowest price you remember paying for gasoline? Did you conserve gasoline then?
  - ❖ What price do you pay for gasoline today? Do you try to conserve it now? If so, how?
  - ❖ When you began driving, what would your response have been if someone had told you that the

price of gas would reach more than \$3.00/gallon?

- ❖ Do you remember when it was less expensive to heat your home? Did you conserve energy then? How?
- ❖ How much does it cost to heat your home in the winter today? Do you try to conserve energy now? How?
- ❖ How much water do you use in your home in a year? Do you try to conserve water? Why? How?
- ❖ Do you work harder to conserve energy or water? Why?

2. Discuss your findings.

3. Ask students to imagine they are taking a trip into the future over a specified weekend. Water costs the same as the current price of gasoline (record current price on activity sheet master before photocopying or write a whole dollar amount on sheet to make calculations easier). They will have to purchase all the water they use in a weekend by placing “money” in an envelope. (Make a master sheet of play money and make copies to distribute to the students.)

Since some people have more money than others do, some students should be given more money than others. Randomly give students \$30, \$40, \$50. Students should also be given the “Sale on Water” activity sheet to record the water they use. Remind them to estimate the amount of water used on their behalf when a parent does laundry or prepares a meal (e.g. wash 4 loads of laundry, 4 people in family, assume that the water for one load was used on the behalf on the student).

Each time water is used, calculate the cost and deposit money in the envelope.

4. Discuss your results.

- ❖ Who used the least water? Who used the most? What accounted for the difference?

- ❖ Was it easy to live within your water budget?
- ❖ Did you have to conserve water? Why? How did you try to conserve water?
- ❖ Should people try to conserve water? Why or why not?
- ❖ Should water cost so much that some people are forced to conserve it more than others?
- ❖ Making a natural resource expensive is one way to encourage people to conserve. What are other ways to encourage people to conserve natural resources?



### Examples:

Education programs—try to teach people to conserve the resource

Rationing programs—set strict limits on water use

Tax credits and deductions—Provide economic incentives to conserve the resource

- ❖ Which methods to encourage conservation do you think would be most effective? Which are the most fair?
- ❖ Should people conserve water even if it's inexpensive? If so, why?

### Going Beyond:

As a class, investigate how a public works department in a dry western/southwestern city (e.g. Tucson, Santa Fe, Denver, Los Angeles or Las Vegas) charges residents for water. Do they encourage conservation? If so, how?

Adapted from: *Local Watershed Problem Studies*, 1981, Cooperative Educational Service Agency 16, Waukesha, and the Water Resources Institute, 1975 Willow Drive, University of Wisconsin, Madison (out of print).



## Rights or Fights

**Learning Objectives:** Students will: (1) explain the four doctrines of groundwater use law, (2) compare and contrast doctrines of groundwater use law and (3) decide a groundwater case based on the groundwater use law.

**Subjects:** Environmental Education, Science and Social Studies

**WMASs: EE:** B.8.16, B.8.22, B.8.23, D.8.4

**SC:** F.8.10

**SS:** E.8.11

**Grades:** 9 (and up)

**Materials:**

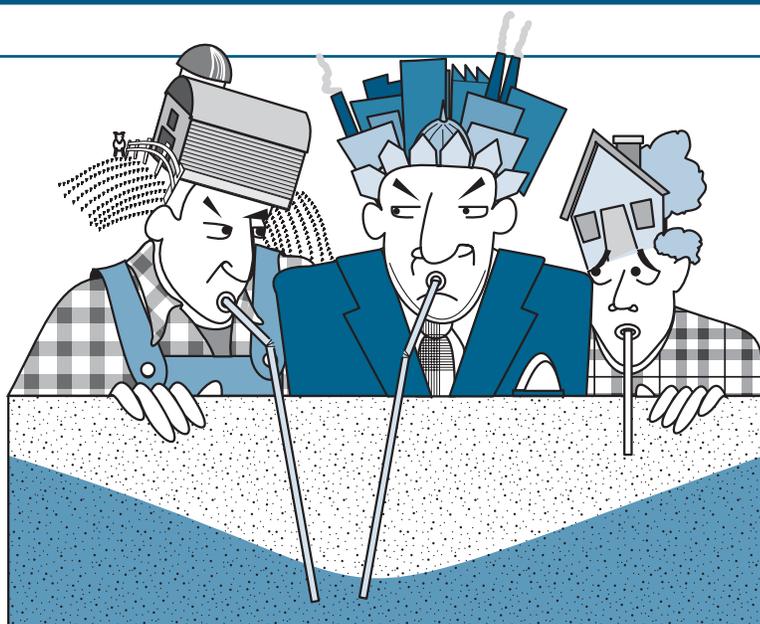
- ❖ Groundwater Law activity sheets

**Background:** Who owns groundwater? Who has the right to use it? How much can they use? Should they be allowed to change its quality? Can water rights be sold? As with any limited resource, we must have rules and laws to regulate groundwater use and protect its quality. Making groundwater laws is not easy. Courts and lawmakers must consider competing uses, water availability and water quality. Laws must evolve as uses, availability and quality change.

Groundwater rights involve two separate issues, **WATER USE** (quantity) and **WATER QUALITY**. In Wisconsin, groundwater quality is generally covered by legislative law. Legislative law is created by the State's legislative or administrative processes. Legislative laws include constitutions, treaties, statutes, administrative rules and regulations, and ordinances.

Groundwater quantity laws, on the other hand, are generally based on "common law." Common law is law which is developed through court case decisions. A judge establishes societal values as law by issuing decisions in cases that he/she hears. Common law may change as societal values change. This activity focuses on the evolution of Wisconsin's groundwater common law.

Over time, four doctrines of groundwater use law have evolved in the United States. Each state treats groundwater conflicts differently, relying on one or more of the following doctrines as the basis for its groundwater use law.



### 1. English Rule:

Groundwater use is a property right. Under this doctrine, a landowner has the right to use the water under his or her land at any time and for any purpose. The landowner may also sell or allow others to use his or her water. This rule grew out of the belief that groundwater movement could not be understood and that landowners couldn't anticipate the consequences of pumping groundwater.

### 2. Reasonable Use Rule:

Groundwater use is a property right. But water may only be used for "reasonable" purposes. A property owner may use the water on the land from which it came or elsewhere, as long as his or her use is reasonable in comparison to the water needs and uses of his neighbors.

### 3. Correlative Rights Rule:

All landowners in an area have a right to use groundwater. The amount of water each landowner can use depends on the amount of land he or she owns. The landowner cannot pump more than his or her share of water, even for use on his or her own land if other water users don't have enough water to meet their needs.

### 4. Appropriation Rule:

Sometimes called the rule of "first in time, first in right." Groundwater rights under this doctrine are not connected to land ownership. A person has a right to use groundwater if he or she has obtained

it and put it to a beneficial use such as irrigation, mining, manufacturing, power generation, raising fish, watering farm animals, household or recreational uses. (Water uses may be assigned priority.) Water may be used on the land from which it came or from elsewhere. Appropriation rights may be sold or given to others.

Under the Appropriation Doctrine, in times of water shortage, those who have used the water longest (i.e. those who have the earliest "appropriation date") may use all the water they have used in the past and newcomers may be left with little or no water. If a person stops using his share of water for a beneficial purpose, he or she may lose the right to use the water at all.

With a better understanding of groundwater movement and the water cycle, there has been a general trend from viewing groundwater as **private property** to recognizing it as a valuable **public resource**. The two Wisconsin landmark cases used for this activity, *Huber v. Merkel* and *State v. Michels Pipeline*, illustrate this trend. Another recent trend in groundwater use law is increased legislation rather than a dependence on case law.



Until 1974, Wisconsin's groundwater law was based on the English Rule. In 1903, a Wisconsin Supreme Court decision (in *Huber v. Merkel*) established that a landowner has an absolute property right to use groundwater under his/her land. The judge determined that a landowner may use his or her water for any purpose, including malicious waste.

As you can probably imagine, the 1903 decision was heavily criticized, but the English Rule stood until 1974, when the State took *Michels Pipeline Construction, Inc.* to court for harming local wells and building foundations when they dewatered soil for construction of a sewage pipeline. The Court in *State of Wisconsin v. Michels Pipeline* determined that such injury could be considered a "public nuisance." The 1903 decision was overruled as the judge found in favor of the State on the basis of a Modified Reasonable Use Rule. This doctrine is the basis of Wisconsin's groundwater use common law today. (*Huber v. Merkel* and *State v. Michels Pipeline* are outlined in greater detail on Rights or Fights activity sheet.)

Groundwater use is still considered a property right under Wisconsin's Modified Reasonable Use Rule, but a landowner may withdraw and use groundwater only for beneficial purposes and only if pumping does not cause unreasonable harm to his/her neighbors. "Unreasonable" harm includes lowering the water table, reducing *artesian* pressure and direct effects on water levels of streams and lakes.

## Procedure:

1. Explain the four doctrines of groundwater rights law.
2. Read aloud *Huber v. Merkel* from activity sheet. (It may be helpful to explain flowing artesian wells.)
3. Discuss *Huber v. Merkel*.
  - ❖ Why did Mr. Huber take Mr. Merkel to court?
  - ❖ What is a flowing artesian well?
  - ❖ How did Mr. Merkel's actions affect neighboring wells?
  - ❖ What did the State Supreme Court decide in this case?

- ❖ On what groundwater doctrine was the Court's decision based?
4. Read aloud *State of Wisconsin v. Michels Pipeline Construction, Inc.* from activity sheet.
  5. Discuss *State v. Michels Pipeline*.
    - ❖ Why did the State take *Michels Pipeline Construction Co.* to court?
    - ❖ What did dewatering the soil do to local wells and properties?
    - ❖ What did the State ask that the company do to correct this problem?
    - ❖ What did the Court decide in this case?
    - ❖ On the basis of what groundwater doctrine was this case decided?
    - ❖ What is the difference between this doctrine and the one used to decide *Huber v. Merkel*? What are the similarities?
    - ❖ How would this case have been decided on the basis of the old English Rule Doctrine?
    - ❖ How did the *State v. Michels Pipeline* case change the course of groundwater use law in Wisconsin?
  6. Ask students to imagine that they're on the 1903 Wisconsin Supreme Court. Work in small groups and assign a scenario (a–c on the activity sheet) to each group. Tell students that they are responsible for deciding *Huber v. Merkel*. Complete the appropriate section of your activity sheets.
  7. As a class, complete scenario *d*.
  8. Discuss your answers.
    - ❖ How would the case have been decided using Wisconsin's Modified Reasonable Use Doctrine? The Correlative Rights Doctrine? The Appropriation Doctrine?
    - ❖ Which doctrine do you think is the most fair for deciding scenario *d*? Why?

- ❖ Do you think water availability influences the groundwater doctrine followed by individual states? If so, how?
- ❖ In some states groundwater and surface water laws are based on different doctrines. What problems might result if a state used the Appropriation Doctrine for its surface water and the English Rule for its groundwater? (Hint: think about the water cycle!)

## Going Beyond:

1. Invite an attorney or other Wisconsin water law expert to discuss laws pertaining to groundwater quality in Wisconsin. Discuss *State of Wisconsin v. Michels Pipeline*. What laws would the Court need to consider if the State's complaint was groundwater contamination by the construction company?
2. Wisconsin follows the modified Reasonable Use Doctrine. Research and report on a state that follows the English Rule, Appropriation or the Correlative Rights Doctrine. How is this state different from Wisconsin? What historical and/or environmental factors do you think influenced groundwater use laws in that state?
3. Collect newspaper and magazine articles on groundwater-related issues in Wisconsin. Using a map of the state, make a display of issues by location. Discuss related groundwater laws, personal costs, responsibility, solutions, etc.
4. Watch the Wisconsin Public Television video *Water Rich Water Poor* and discuss and compare groundwater quality and quantity issues in different parts of the state. See the back of the Groundwater Study Guide packet cover letter for information on the video. See if your school library or public library has a copy.
5. Collect newspaper and magazine articles about groundwater-related issues in a western state (e.g. California or Colorado). Using a map of the state, make a display of issues by location. How are the problems similar to those in Wisconsin? How



are they different? Compare personal costs, responsibility, solutions, etc.

6. Research and report on which governmental agencies (municipal, county, state, and federal) regulate and protect groundwater. How do these groups work together? Discuss roles that other groups play (for more information, see *Groundwater: Wisconsin's Buried Treasure*).

7. Research and report on how water resources have influenced the history of your community. How has water helped your community develop? Has groundwater played a special role? Many areas of Wisconsin are known for having “healthful” spring water. Is part of your community’s history related to spring water? How does your community feel about protecting groundwater?

8. Groundwater is important in the production and processing of many Wisconsin products such as cheese, beer and paper. Investigate some of these products. How much water do they use? How clean should the water be? Are there laws or regulations that govern the quality of the water they use?

## Trouble in Paradise

**Learning Objectives:** Students will: (1) determine the source of groundwater contamination in the mythical town of Paradise using knowledge gained from previous activities, (2) discuss the implications of groundwater contamination in Paradise and (3) recommend possible solutions to the groundwater contamination problem in Paradise.

**Subjects:** Environmental Education, Science, Health Education and Social Studies

**WMASs: EE:** A.8.4, A.8.5, B.8.10, B.8.15, B.8.17, B.8.21, B.8.23, C.8.2, D.8.1

**SC:** A.8.6, B.8.6, C.8.6, E.8.1

**HE:** A.8.2, G.8.3

**SS:** A.8.1, A.8.11, D.8.11

**Grades:** 7–9 (and up)

**Materials:**

- ❖ Trouble in Paradise handouts
- ❖ colored pencils—red, blue and green

**Background:** In this activity, wells in the mythical town of Paradise have been contaminated with volatile organic compounds (VOCs). VOCs are a group of commonly used chemicals that evaporate, or “volatilize” when exposed to air. Since they dissolve many other substances, VOCs are widely used as cleaning and liquifying agents in fuels, degreasers, solvents, cosmetics, polishes, drugs and dry cleaning solutions. VOCs are found at airports and service stations; machine, print and paint shops; electronics and chemical plants; dry cleaning establishments; and in household products. Two common VOCs—1,2-dichloroethylene and trichloroethylene—are referred to in this activity.

When VOCs are spilled or dumped, some will evaporate and some will soak into the ground. Once in the soil, VOCs can be carried deeper into the ground by percolating rainwater. If they reach the water table, VOCs can persist for years because the cool, dark, low-bacteria environment does not promote decomposition. If VOCs in groundwater migrate to nearby wells, they can end up in someone’s drinking water.

At least one VOC has been detected in about 2,500 drinking water wells in Wisconsin. Over 80 different VOCs have been found in Wisconsin’s groundwater, with trichloroethylene being the VOC most commonly found. Some 770 private or public water supply wells have had concentrations of at least one VOC above a Wisconsin groundwater standard.

Some VOCs can harm the central nervous system, liver and kidney. For these types of health effects, researchers can determine a “no-observable-effect level”—a maximum VOC dose that does not produce any effect in exposed experimental animals. This “no-observable-effect level” is further reduced by a safety factor, which ranges from one tenth to one ten thousandth (depending on the strength of scientific evidence). From this number state groundwater standards are established.

Some VOCs (such as trichloroethylene) are known or suspected carcinogens (cancer-causers). State groundwater standards for carcinogens in drinking water are conservatively set so that lifetime consumption of the water will cause no more than 1 to 10 additional cancers for every million persons exposed. Additional information on how Wisconsin ground-

water quality standards are developed can be found in Wisconsin’s groundwater law, chapter 160, Wis. Stats., at: [legis.state.wi.us/statutes/1993/93stat0160.pdf](http://legis.state.wi.us/statutes/1993/93stat0160.pdf). Chapter NR 140, Wis. Administrative Code, contains the groundwater quality standards that have been adopted in Wisconsin. NR 140 can be found online at: [legis.state.wi.us/rsb/code/nr/nr140.pdf](http://legis.state.wi.us/rsb/code/nr/nr140.pdf).

Federal drinking water standards (Maximum Contaminant Levels) are set in a similar manner by the U. S. Environmental Protection Agency. Check out [epa.gov/safewater/standards.html](http://epa.gov/safewater/standards.html) for information on how federal drinking water standards are developed.

Several factors influence a well’s vulnerability to VOC contamination. One factor is the distance between the well and the source or sources of contamination. Another factor is time. Groundwater usually moves very slowly and it can sometimes take years for a spilled contaminant to reach nearby wells. The time and distance contaminants must travel are extremely important because many wells which presently show no contamination may eventually become contaminated by spills that have already occurred. In other words, we may not know the full effects of contamination we already have caused for many years to come (For more information, see *Groundwater: Wisconsin's Buried Treasure*).

There are two options for dealing with VOC contamination. The well owner can either construct a new well or treat water from the contaminated one. Treatment of the well water has the benefit of removing contaminated water from the ground. Both options are expensive. Drilling a new municipal well can cost as much



as \$1 million or more; building a water treatment facility for a contaminated municipal well generally costs between \$500,000 and \$1 million.

### Activity setting:

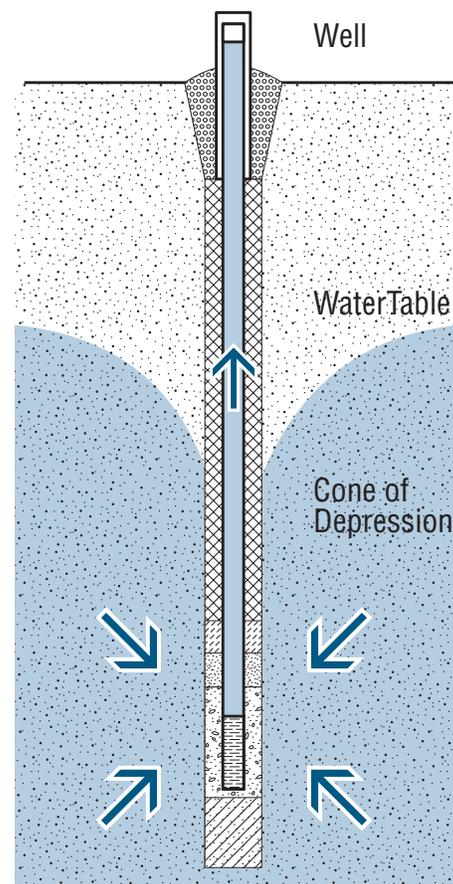
VOC contamination has occurred in “Paradise” and your students will be asked to determine where the VOCs came from and what should be done about the problem. The contamination was first noticed after the installation of a high capacity community well. Wells that draw a large volume of water can affect the direction and rate of groundwater flow by creating a “cone of depression.” As groundwater is depleted under the well site, it is replaced by groundwater from soils surrounding the well. So even water that initially flowed away from the well can be drawn toward it as groundwater immediately under the well is removed.

The new municipal well in “Paradise” has created a cone of depression and is drawing water and the plume of VOC contamination toward itself. The source of contamination is the closed landfill at the Johnson farmsite which, while it operated, may have accepted wastes containing VOCs from local industries and households. This landfill was designed as a “natural attenuation” site, meaning that the landfill depended only on the characteristics of surrounding soils to contain and filter leachate from the waste deposited there. Today landfills must be lined with a layer of impermeable clay which helps to contain leachate. Modern waste disposal regulations also limit the type of wastes that can be deposited in a municipal landfill.

*Note: The groundwater standard listed for 1,2-dichloroethylene (1,2-DCE) on the activity sheets is actually the groundwater standard for 1,2-dichloroethylene (cis), which is an isomer of 1,2-DCE. On the activity sheets, 1,2-DCE is considered to be one substance to simplify the exercise.*

### Procedure:

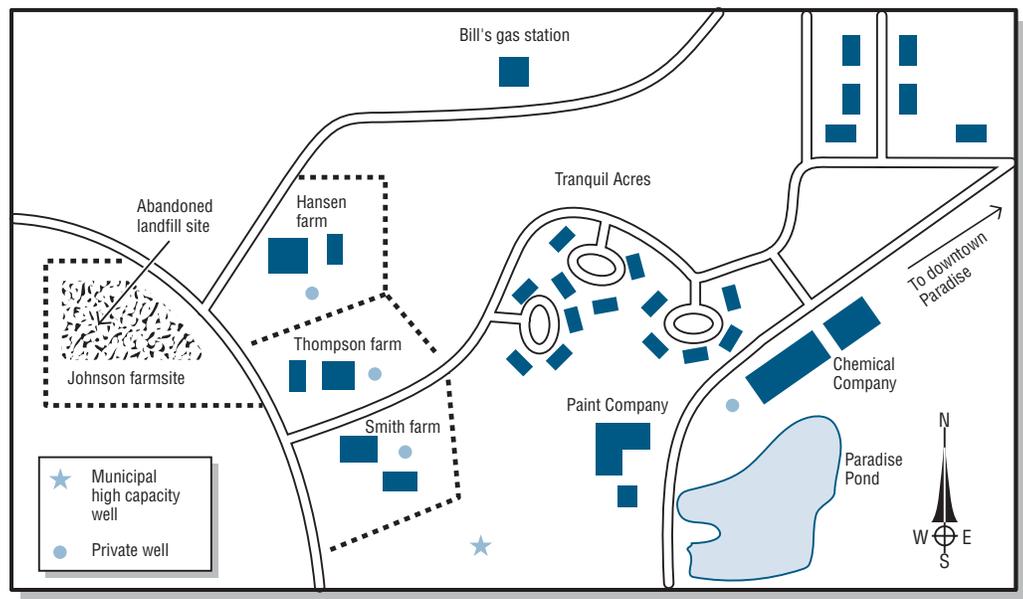
1. Using How Much is a Part per Billion? handout, discuss the idea of parts per trillion (ppt), parts per billion (ppb) and parts per million. Explain that drinking water standards and laboratory results are often stated in micrograms per liter ( $\mu\text{g/L}$ ) which is equivalent to ppb. Because it's easier to understand the concept of ppb than  $\mu\text{g/L}$ , the Trouble in Paradise Activity Sheets use parts per billion.
2. Tell students that the mythical town they will be investigating is based on several Wisconsin communities that actually experienced groundwater contamination. Explain what VOCs are and their many sources. Briefly discuss how groundwater standards are set in Wisconsin.
3. Distribute “Trouble in Paradise” handouts. Have students read the case study.
4. Ask individual students to read aloud the problems on the activity sheet. Clarify any uncertainties about the problems.
5. Working in small groups, complete the activity sheet. Remind students that they will need to use the information given in the case study AND what they have learned in previous activities to answer the questions. It may be helpful to review the reading of topographic maps.
6. Using the completed worksheets, construct a master time line on the chalkboard. Discuss the time line and answers to activity sheet questions.
  - ❖ In what general direction does groundwater flow in Paradise?
  - ❖ What is the source of contamination? How do you know?
  - ❖ Where would you place test wells to confirm the source of contamination?
  - ❖ What is a plume of contamination?
  - ❖ How did the shape of the plume of VOC contamination change? What caused it to change?



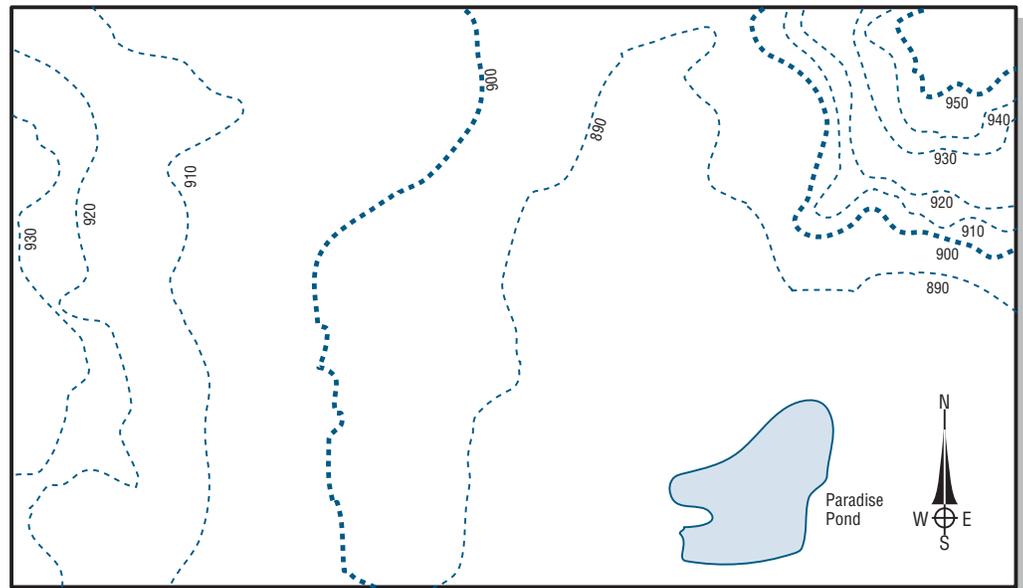
- ❖ Why did it take so long for the VOCs to move from their source into surrounding wells?
- ❖ Why did the contamination appear in the Hansens' well then seem to disappear?
- ❖ Why was there such a delay between the time that VOCs were first discovered in the Hansens' well and when city officials decided to take action?
7. Discuss the implications of groundwater contamination in Paradise.
  - ❖ What are VOCs used for?
  - ❖ Who might have put materials containing VOCs in the landfill?
  - ❖ When is groundwater “contaminated”? Is water that contains 200 ppb 1,2-dichloroethylene considered contaminated? Is 200 ppb 1,2-dichloroethylene considered unhealthy?
  - ❖ Does contaminated necessarily mean unhealthy?



- ❖ Why do you think the groundwater standard for 1,2-DCE is so much higher than the MCL for trichloroethylene (TCE)?
- ❖ Who's to blame for the contamination?
- ❖ Who should pay to solve the problem?
- ❖ How did the citizens react to the contamination? Were their demands reasonable? What else could citizens do?
- ❖ How did the contamination affect private well owners?
- ❖ Should the Smiths' and Thompsons' well water be restored (either by construction of a new well or by treating water from existing wells)? If so, who should pay?
- ❖ Could the contamination affect the new community well?
- ❖ How long can Paradise's problem continue?
- ❖ If hazardous materials are removed from the landfill in Paradise, they may have to be moved to a hazardous waste landfill in another state. Is that fair? Who should pay to maintain and operate the disposal site?
- ❖ Could the contamination have been avoided? If so, how?
- ❖ What can Paradise do about the contamination now?
- ❖ Could your community have problems like this?
- ❖ How can your community help prevent groundwater contamination problems?



Map A



Map B

2. Use the websites listed in this exercise as a starting point to learn how Wisconsin groundwater standards and federal Maximum Contaminant Levels are established. Look at the similarities and differences in how health standards are set and in which substances have standards at the state and federal level.
3. Have your students do calculations to understand the concepts of 1 part per million, 1 part per billion and 1 part per trillion. For example, how long is 1 million seconds? How long is 1 billion feet?

## Going Beyond:

### Going Beyond:

1. Using selected discussion questions as an outline, research and report on a groundwater contamination issue in your area.

Adapted from: *Discovering Groundwater: A Supplementary Activities Guide for Upper Elementary Social Studies and Science Classes*, 1984, Wisconsin Department of Natural Resources, Western District (out of print).



# More Groundwater Activity Ideas!

- ❖ Make a collection of rocks and soils important in Wisconsin's aquifers. Make a display for your school or local library.
- ❖ Schools must have their water tested regularly. Find out how often your school's water is tested. Who collects the water? What tests are run? Obtain a copy of the most recent test results and discuss.
- ❖ Send a sample of your school's water to a certified water testing lab for nitrate and bacteria testing. Labs that test for bacteria in water are certified by the Wisconsin Department of Agriculture, Trade and Consumer Protection and can be found online at [dnr.wi.gov/org/water/dwg/SDWAbaclist.pdf](http://dnr.wi.gov/org/water/dwg/SDWAbaclist.pdf). The Wisconsin DNR certifies labs that test for contaminants such as nitrate, pesticides, metals, and VOCs; that list is available online at [dnr.wi.gov/org/es/science/lc/info/lablists.htm](http://dnr.wi.gov/org/es/science/lc/info/lablists.htm). You can also look in your yellow pages for certified water testing labs in your area.
- ❖ Visit the State Laboratory of Hygiene (2601 Agriculture Drive) in Madison or a certified water testing laboratory. What water tests are done at the laboratory? How much do the tests cost? How often are public wells tested? What tests are run on public water supplies? How often should private wells be tested? What tests are normally run on private water supplies? When is water considered "contaminated?" When is water considered "unhealthy?"
- ❖ If you and your students are interested in water conservation in your school, consider becoming a "Green and Healthy School." Learn about it at [dnr.wi.gov/greenandhealthyschools](http://dnr.wi.gov/greenandhealthyschools).
- ❖ Research and report on methemoglobinemia (blue baby syndrome) caused by high levels of nitrate in drinking water.
- ❖ Interview someone who has had a contaminated well. How did she/he determine that the well was contaminated? With what was the well contaminated? What was the source of contamination? Was the problem solved? If so, how?
- ❖ Visit a beverage or food-processing industry. What is produced at the site? Is water used in the production? How? Where does the water come from? How does the company ensure that the water used is of good quality? Is wastewater produced? If so, what does it contain? How is it disposed of?
- ❖ Investigate your home or school's use of lawn chemicals. What chemicals are used? What do they do for the lawn? How are they stored? How are excess chemicals disposed of? Where do chemicals placed on lawns go when it rains? What effects might the chemicals have if they get into groundwater? Are there any alternatives to using lawn chemicals?
- ❖ Invite the county Extension agricultural agent to speak to your class about the advantages and disadvantages of insecticide and herbicide use. How should pesticides be used? What can be done to decrease the amount of chemical applied to a field or garden? Are there any pesticide contamination problems in your county? If so, what is being done about them? Can farmers eliminate the use of pesticides? Check into Wisconsin's School Integrated Pest Management program at [ipcm.wisc.edu/programs/school/default.htm](http://ipcm.wisc.edu/programs/school/default.htm).
- ❖ Interview someone who farmed before the time of widespread use of nitrogen fertilizers. Find out about yields, prices, profits, conservation practices and groundwater concerns.
- ❖ Invite an organic gardener or farmer to speak to your class. What is organic farming? What alternatives to pesticides are used? How are natural pest controls, such as insect predators and companion planting used? How does not using pesticides affect crop yield? Crop appearance? Crop sales?
- ❖ Research and report on water needs of various agricultural crops grown in Wisconsin. How are these water needs met? What are some ways to irrigate farmland? Which methods cause the greatest and the least water loss (though runoff and evaporation)? What is the relationship between pesticide use and irrigation practices on groundwater?
- ❖ Interview a person involved in the production or distribution of pesticides or fertilizer. Ask about use, disposal, health, pollution, etc.
- ❖ Using newspapers and magazines, research groundwater contamination by landfills and dumps. Where did the contamination happen? Who was affected? What were the health consequences? Were there economic consequences? How was the source of contamination determined? Who was responsible for clean-up? How much will clean-up cost?
- ❖ Demonstrate that groundwater provides the baseflow for rivers and streams. Visit a stream in early fall or late spring. What is the temperature of the stream? Why is the stream cold? Has it rained or snowed recently? Do you see water running off the land? If not, where do you think the water for the stream comes from?
- ❖ Research and report on the potential environmental and health effects of placing disposable diapers in municipal landfills. Compare the cost of using cloth diapers and a diaper service to that of using disposable diapers.
- ❖ Find out what materials are used to make paper, plastic and glass. What happens to these materials in a landfill? What effects might these materials, if leached from a landfill, have on groundwater?
- ❖ Make a magazine photo display of environmentally safe products sold in non-polluting packaging.
- ❖ Organize or participate in a recycling project. Report on how the recycled materials are used.



- ❖ Invent and demonstrate new uses for product packaging that you would normally just throw away.
- ❖ Write a list of rules and guidelines for your home for handling, storing and disposing of household hazardous materials.
- ❖ Interview a person who operates a gas station or other business that uses underground storage tanks. What is kept in the tanks? Could this material be harmful if it got into groundwater? How often are the tanks checked for leaks? How does the owner know if the tanks develop a leak? What is done if the tanks leak?
- ❖ Make a poster showing how your family or school can conserve water.
- ❖ Make a display of newspaper clippings involving groundwater issues for your school or local library.

Adapted from: *Groundwater Study Guide and Groundwater Resources and Educational Activities for Teaching*.

### Additional Field Trip Ideas:

When planning a field trip, be sure to secure permission and discuss your activity with people at the site before your visit.

- ❖ municipal or county landfill site—possibly monitoring wells
- ❖ municipal water treatment plant, well and water tower
- ❖ agricultural operation—irrigation with wells, integrated pest management
- ❖ water resource sites—springs, rivers, lakes, wetlands
- ❖ rock exposures showing groundwater effects

### Resource People:

Representatives from the following groups can explain their interest in groundwater and can often give insight into groundwater problems or issues of local interest. Contact with the community not only helps reinforce what is learned in the classroom, but also helps develop concern and sustains the enthusiasm of students.

Before you involve a resource person in your class, discuss with him or her your objectives and what you expect from his/her visit.

- ❖ water chemists
- ❖ licensed well driller (check the yellow pages of your phone book)

- ❖ pump dealers
- ❖ Department of Natural Resources environmental specialists (addresses of DNR regional offices are found on the back of the Groundwater Study Guide packet cover letter).
- ❖ municipal/county health or environmental specialists or county planners
- ❖ county University of Wisconsin–Extension resource or agricultural agents
- ❖ water treatment plant operators
- ❖ hydrologists, hydrogeologists, and engineers – private industry and governmental agencies

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## Publications

In addition to this booklet and activity sheets, the Groundwater Study Guide packet contains additional materials which are excellent sources of additional information.

- ❖ The *Wisconsin Groundwater Directory* contains contact information and resources available on a variety of groundwater topics, including groundwater protection and land use, groundwater contamination and clean-up and groundwater education. The Directory is included with the Groundwater Study Guide packet and is also available online by going to [uwsp.edu/cnr/gndwater/info/index.htm](http://uwsp.edu/cnr/gndwater/info/index.htm).
- ❖ *Groundwater: Wisconsin's Buried Treasure* includes introductory information on groundwater, discusses the threats to groundwater, describes what Wisconsin agencies do to protect groundwater and lists steps individuals can take to protect this valuable resource. It is available online by going to [dnr.wi.gov/org/water/dwg/gw/educate.htm](http://dnr.wi.gov/org/water/dwg/gw/educate.htm).

- ❖ *Better Homes and Groundwater* describes actions that individuals can implement and practice to protect, conserve, and replenish groundwater. Topics include yard care, raingardens, household cleansers, wise water use, water conserving fixtures, water supply protection, and safe disposal practices. It can be downloaded online at [dnr.wi.gov/org/water/dwg/gw/pubs/bhgw.pdf](http://dnr.wi.gov/org/water/dwg/gw/pubs/bhgw.pdf).
- ❖ *Groundwater Models Available* provides a listing of locations from which it might be possible to borrow a groundwater model for use in the classroom. The list is also available at [dnr.wi.gov/org/water/dwg/gw/education/models.pdf](http://dnr.wi.gov/org/water/dwg/gw/education/models.pdf).
- ❖ Water Resources Websites is a listing of websites for additional information on water resources, especially groundwater.

# Selected Department Of Public Instruction (DPI) Wisconsin Model Academic Standards For Environmental Education, Health Education, Science, Social Studies And Math Relevant To The Activities In This Booklet

## Environmental Education Standards

- A. Questioning and Analysis
- B. Knowledge of Environmental Process and Systems
- C. Environmental Issue Investigation Skills
- D. Decision and Action Skills

## Health Education Standards

- A. Health Promotion and Disease Prevention
- B. Healthy Behaviors
- C. Goal Setting and Decision Making
- D. Information and Services
- G. Advocacy

## Science Standards

- A. Science Connections
- B. Nature of Science
- C. Science Inquiry
- D. Physical Science
- E. Earth and Space Science
- F. Life and Environmental Science
- G. Science Applications
- H. Science in Social and Personal Perspectives

## Social Studies Standards

- A. Geography: People, Places, and Environment
- C. Political Science and Citizenship: Power, Authority, Governance and Responsibility
- D. Economics: Production, Distribution, Exchange, and Consumption
- E. The Behavioral Sciences: Individuals, Institutions, and Society

## Math Standards

- D. Measurement
- E. Statistics and Probability

Activities in this guide may also relate to other subject areas such as: English/Language Arts and Family and Consumer Education. For detailed descriptions of all the Wisconsin Model Academic Standards including those listed in this guide please visit [dpi.wi.gov/standards/index.html](http://dpi.wi.gov/standards/index.html).

*The purpose of the Department of Natural Resources study guides is to help increase Wisconsin citizens' knowledge about and understanding of our state's environment. We hope to provide information about important environmental issues, encourage respect for the environment and help citizens become active stewards of our natural resources.*

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Please address comments and questions about this study guide to:

Wisconsin Department of Natural Resources  
Bureau of Drinking Water and Groundwater  
Groundwater Section  
PO Box 7921  
Madison, Wisconsin 53707-7921  
(608) 266-0821

