Groundwater Model Handbook

Understanding Groundwater and Using the Groundwater Model

Purpose and Format

This manual is intended for use with the groundwater model. The groundwater model is an ideal demonstration tool for conveying the basic principles of groundwater movement in the environment. The model is appropriate for use with a wide variety of audiences, including youth, teachers, residents, municipal decision makers, and anyone interested in groundwater and drinking water well protection. In addition, this model demonstrates the interaction of groundwater and surface water, illustrating the need to protect both resources in order for us to maintain water quality.

This manual is divided into three main sections: Groundwater Basics, Using the Groundwater Model, and Pre- and Post Demonstration Activities for youth.

Groundwater Basics covers groundwater as part of the water cycle, the interaction of groundwater and surface water, land use activities that affect groundwater quality, and what individuals can do to protect water quality. You will also find a Glossary, and a For More Information section.
Pages 2-10.

Using The Groundwater Model outlines use and care of the model and contains a 1-hour lesson plan using the model to demonstrate several key points about groundwater movement, recharge, contamination, and protection. Pages 11-19.

Pre- and Post-Demonstration Activities suggest learning activities for youth to supplement use of the model. Pre-activities are intended to introduce students to the water cycle and the many uses of water. Post-activities involve you and your students with water quality protection and conservation.

ACKNOWLEDGEMENTS

Written, compiled and revised by Alyson McCann, Brianne Neptin, and Art Gold, URI Dept. of Natural Resources Science, 2003. We thank Lorraine B. Joubert, Linda T. Green, Elizabeth M. Herron and Holly Burdett for reviewing the manuscript and providing many helpful comments. This work is supported by funding from the US EPA, New England and USDA CSREES. Information for this manual has been taken in part from *Sand – Tank Ground Water Flow Model Manual*, Delynn R. Hay, Department of Biological Systems Engineering, Cooperative Extension, Institute of Agriculture & Natural Resources, University of Nebraska-Lincoln. Graphics modified from *What is Groundwater?* Bulletin Number 1. Lyle S. Rammond Jr. New York Water Resources Institute, Center for Environmental Research, Cornell University.

Groundwater Basics

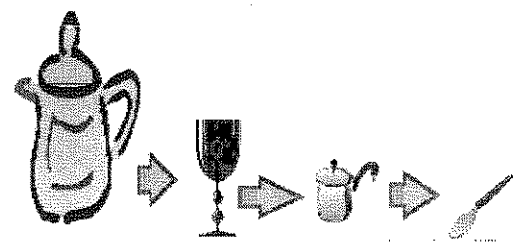


Figure 1. Although three-fourths of the Earth's surface is covered with water, only a fraction of one percent is available for human use. Most water is salty, frozen, or inaccessible in the soil and atmosphere.

Water is all around us. Although 75% of the Earth's surface is covered with water, it is distributed unevenly. Only a small fraction of the Earth's water is available as fresh water (figure 1). In some areas of the nation and the world, serious water supply problems exist. Fresh water is one of our most important natural resources because it is essential to our survival. Unlike energy, which comes in a variety of forms, there are no substitutes for pure, fresh water.

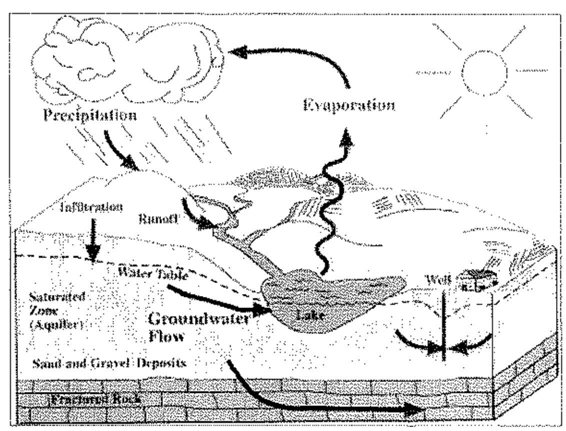
Globally, we are using more and more water, in part because our population is increasing and in part because, on average, each person is using more water each day. All living things require water to survive, but we have come to rely on water for our convenience: we cook and wash with it, and use large quantities for agriculture, manufacturing, mining, and energy production. As our demand for water increases, so does the need to maintain the quality and quantity of this resource.

What is groundwater?

All water on the Earth and in the atmosphere is part of the hydrologic cycle (figure 2). The hydrologic cycle is the continuous circulation of water from the oceans to the atmosphere to the land and back to the oceans. This complex cycle provides us with a renewable supply of water on land.

Water falls from the atmosphere to the land in the form of precipitation (rain, snow, sleet, or hail). Once on land, some of the precipitation may accumulate as *surface water* – in streams and rivers, lakes, ponds, reservoirs, wetlands, and oceans. Some water may seep downward through the soil where it is stored as *groundwater*. Here the spaces between sand and gravel deposits or cracks in the bedrock are filled with water. Groundwater moves very slowly – measured in feet per day – as compared with the speed of surface water, which is measured in feet per second.

Figure 2. The hydrologic cycle. Water cycles from the oceans to the atmosphere to the land and back to the oceans. Once on land, the water may: (1) evaporate from land and re-enter the atmosphere directly, (2) flow into rivers and streams, or (3) seep downward in the soil and become groundwater. Every molecule of water is moving through the hydrologic cycle.



From the Minnesota Pollution Control Agency website

Where does groundwater come from?

Groundwater begins as precipitation and snowmelt that seeps, or *infiltrates* into the ground. The amount of water that infiltrates into the ground varies widely from place to place depending on the type of land surface and soil present. Water readily seeps into *permeable* material, like soil. However, water runs off *impermeable* areas like paved driveways, parking lots, roads, and compacted soil. The rest of the precipitation and snowmelt that does not seep into the ground runs off the land surface into water bodies or returns to the atmosphere by evaporation.

The saturation zone

Some of the water that seeps into the ground may be taken up by plant roots or used by insects, microbes, and other living organisms in the soil. The remainder continues downward under the force of gravity until it reaches a depth where water fills all of the spaces (or pores) between soil or rock. This is called the *saturated zone* (figure 3).

The water table

The top of the saturated zone is called the *water table* (figure 3). The water table rises and falls according to the season and the amount of rain and snowmelt that occurs. During dry summer months the water table is usually lower than during wet spring months when it tends to be higher. In well-drained uplands the minimum depth to the water table is generally 3 feet or more below the earth's surface. In low-lying areas such as wetlands, the water table is at or near the surface during at least part of the year.

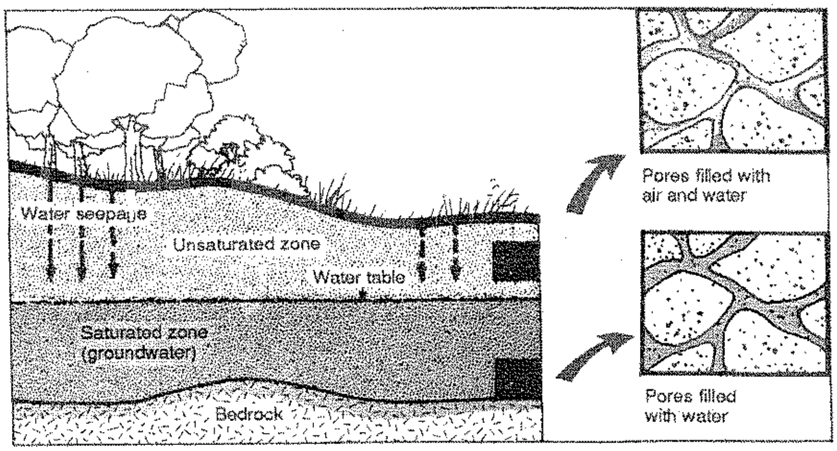


Figure 3. Water seeps through the ground. The water table separates the saturated zone below it from the unsaturated zone above it. The amount of water that seeps into the ground depends on the amount of precipitation, the land surface, and the type of soil present.

The unsaturated zone

The zone between the water table and the land surface is called the *unsaturated zone* (figure 3). Here, the pores in the soil are only partially filled with water – air, plant roots, and soil organisms ranging from insects and earthworms to a multitude of microorganisms such as bacteria and fungi--also fill the pore spaces. Water moves through the unsaturated zone to the water table below. Although plant roots can capture the moisture passing through this zone, the unsaturated zone cannot directly provide water for wells.

How is groundwater stored?

Groundwater is stored in *aquifers*. An aquifer is a soil or rock formation that is capable of yielding usable amounts of water to a water supply well. Rhode Island has two main types of aquifers that are capable of supplying water to a drinking water well. These are stratified drift aquifers and bedrock aquifers. Table 1 summarizes some of the characteristics of these aquifer types.

Table 1: Rhode Island's Aquifers

Stratified drift aquifer	Consists of stratified layers of sands and gravels Most productive aquifers High permeability/Moderate porosity Most susceptible to pollution
Bedrock aquifer	Water is contained within fractures in the bedrock Generally, least productive aquifers Low permeability/low porosity Can yield substantial amounts of water for a private well

Permeability and Porosity

Permeability and *porosity* are important when considering the amount of water an aquifer can hold and supply to a well. *Permeability* is a measure of how readily water flows through connected openings in soil or rock (figure 4). An impermeable material does not allow water to pass through it. Sands and gravels have a high permeability as compared to dense bedrock or a clay material. *Porosity* is the capacity of soil or rock to hold water. Most water movement occurs through the larger soil pores. Although sands and gravels have a lower porosity as compared to clays, they do have larger pores. A measured volume of saturated clay can be as much as 50% water, having a high porosity, clay is not a good source for drinking water wells because the extremely small pore spaces impede water flow to a supply well.

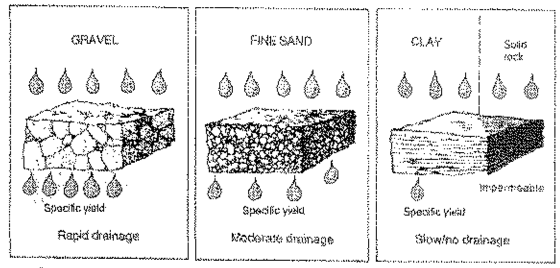


Figure 4. Permeability and porosity are related. An aquifer must be both permeable and porous to supply water to a well.

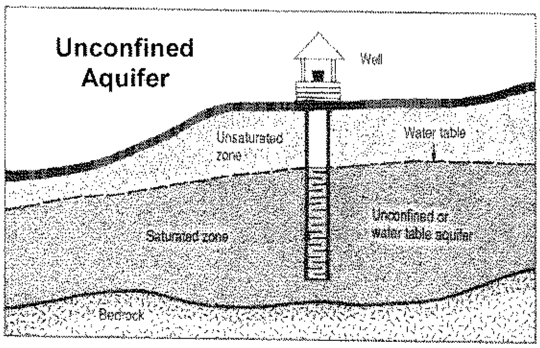
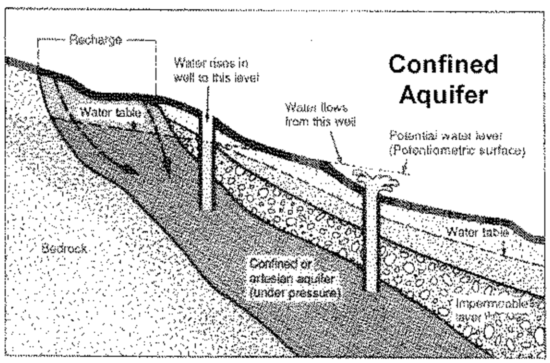


Figure 5. Confined and Unconfined aquifers. Confined aquifers may have very small recharge areas, while the recharge area of an unconfined aquifer can cover many miles.



Groundwater Flow

Groundwater flows from recharge areas to discharge areas. Generally, groundwater flow mimics surface water flow, moving from high to low elevations (figure 6). Where the water table intercepts the ground surface, at a stream for example, groundwater discharges to the stream. Here, groundwater becomes surface water. The stream is receiving *groundwater discharge.* Another example of groundwater discharge is flow from a spring or natural seep (figure 7b). Therefore, groundwater and surface water are interconnected.

Recharge

Groundwater needs to be recharged. Water from precipitation or snowmelt seeping into an aquifer is known as *groundwater recharge.* An aquifer's *recharge area* (figure 5) is the land area that contributes water to an aquifer. Permeable soil or rock formations where recharge occurs may occupy only a very small area or extend over many square miles.

Confined and Unconfined Aquifers

Aquifers may be confined or unconfined (figure 5). *Confined aquifers*, or *artesian aquifers*, are trapped under impermeable soil or rock and are under pressure. The impermeable material is called the *confining layer.* The confining layer slows the movement of water and prevents it from moving down to the confined aquifer below. Water typically hits the confining layer and then moves horizontally along this layer. The confining layer provides some level of protection as contaminants traveling through the soil cannot move down through this layer into the confined aquifer. *Unconfined aquifers*, or *water table aquifers*, do not have restrictive layers separating the aquifer from the ground surface. As a result, they are sensitive to contaminants from overlying surface activities.

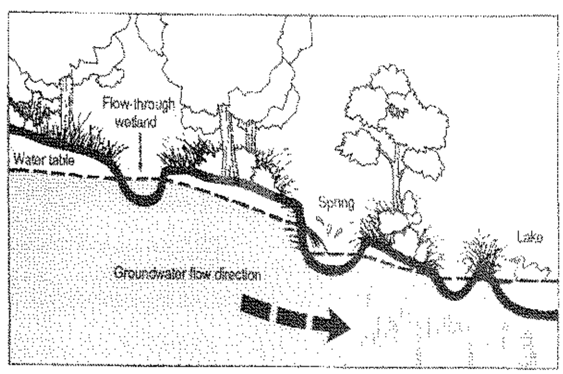
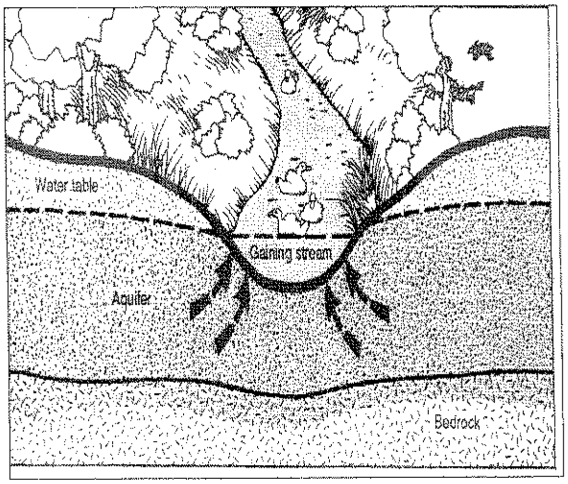


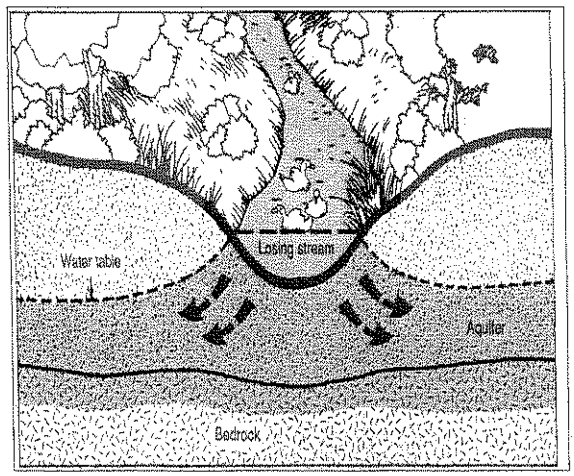
Figure 6. Groundwater flow. Groundwater and surface water are interconnected.

Wells

Wells are installed to withdraw groundwater from an aquifer for our use. An aquifer can supply either a public or private well. In Rhode Island, many communities and private homeowners rely on groundwater for their drinking water supply. Approximately 26% of the state's population gets their drinking water from groundwater.

A public well provides water to a large number of people, schools, nursing homes, or hospitals. The water suppliers monitor the water quality of public wells. Private wells, on the other hand, provide water to a single household and the homeowner is responsible for the quality of the water. Private well owners do not benefit from the public health safeguards provided by a regulated, public water supply system.





Figures 7a &7b. Groundwater becomes surface water where the water table intercepts the ground surface. Surface water can also recharge an aquifer.

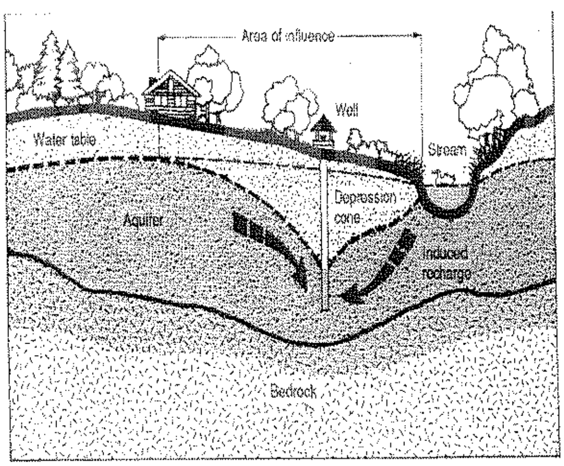


Figure 8. Cone of depression and wellhead area. Groundwater flow is diverted towards a pumping well as it flows into the cone of depression. Wellhead areas vary in size from several square feet to many square miles.

Simply put, a well is circular hole that extends into the earth until it reaches an aquifer. Well depth varies from several feet to several hundred feet. A pumping well lowers the water table around the well in a sloping fashion called the *cone of depression* (figure 8). The land surface overlying the cone of depression is called the *wellhead area.* Land use in this area directly influences groundwater quality and quantity.

A pumping well close to a surface water body can draw the surface water into it. This is called *induced recharge* and is another example of the interconnectedness of surface water and groundwater.

Land Use Activities Affect Groundwater Quality

Point Source and Nonpoint Source Pollution
Water quality is directly related to land use. As water moves over the land surface, it can dissolve or carry contaminants with it to ground or surface waters. Because ground and surface waters are interconnected, the quality of one can affect the quality of the other.

There are two general types of pollution – *point source pollution* and *nonpoint source pollution*. Point source pollution comes from a single point, such as discharge from a sewage treatment plant. Nonpoint source pollution is less obvious. It originates over a widespread area of the landscape rather than from a single point. Common examples of nonpoint source pollution are stormwater runoff, leaking underground storage tanks, fertilizers and pesticides, spilled motor oil, effluent from septic systems, and animal waste from pets and livestock.

In recent years, we have made progress in reducing point sources of pollution by treating industrial discharges and upgrading the treatment capabilities of sewage plants. However, nonpoint source pollution is more difficult to control and is the challenge before us.

Nonpoint Sources of Pollution and Their Effects on Groundwater

Septic systems. Thirty-five percent of Rhode Islanders rely on septic systems to treat wastewater. When sited, operated, and maintained properly, they are of little or no threat to water quality. However, failed septic systems can contribute hazardous contaminants to nearby groundwater supplies, often creating a public health risk.
Contaminants of Concern:
(1) Bacteria and Viruses – can move through ground and surface water; health concerns are gastroenteritis, hepatitis and typhus.
(2) Nitrate-Nitrogen – a form of nitrogen. The drinking water standard for Nitrate-Nitrogen is 10 milligrams per liter (mg/L). Excess nitrate-nitrogen in water supplies causes "blue baby syndrome" in infants, increases nuisance algae in coastal waters, and may also be an indicator of the presence of other dissolved contaminants.
(3) Chemical compounds – discharged into septic systems through the use or disposal of household products.

Urban runoff. Precipitation that falls on impervious surfaces (i.e., roads, parking lots and paved driveways) can dissolve or carry away pollutants as it flows over these areas. If the stormwater runoff is allowed to recharge groundwater then additional pollutants could enter drinking water supplies.
Contaminants of Concern:
(1) Nitrate-Nitrogen – see Septic Systems.
(2) Heavy metals – particularly from the use of vehicles. Many can cause significant health risks.
(3) Bacteria – see Septic Systems.
(4) Road salt – from winter road maintenance. Wells located close to major roads can have elevated sodium levels.
(5) Petroleum products – gasoline, diesel fuel, and motor oil from vehicles.

House and Garage Wastes. Many cleaning products and solvents contain moderately to highly toxic chemicals, which can be a threat to our health and groundwater. Hazardous chemical wastes poured down the drain into septic systems, on the ground, or in sewers may pollute our groundwater supplies. Although they may be disposed of in small amounts, these substances can have significant cumulative effects.
Contaminants of Concern:
(1) Motor oil (2) Battery acid (3) Paint thinner (4) Cleaners and solvents (5) Antifreeze (6) Medicines

Fertilizers. Many fertilizers contain nitrogen, which, if misused, can enter the groundwater. Over-fertilizing and over-watering a lawn or garden can cause nitrogen to leach, or seep, through the soil to the groundwater. Improperly handling these products can also cause a problem for groundwater quality. Spills should be cleaned up and not washed into storm drains.
Contaminants of Concern:
(1) Nitrate-Nitrogen – Fertilizers contain nitrogen, which, once in groundwater supplies, can cause health problems. See Septic Systems.

Pesticides. Pesticides can enter groundwater supplies by leaching through the soil. The likelihood of a pesticide leaching to the groundwater depends on the characteristics of the pesticide and the site. Pesticides can pose significant health problems to humans, pets, livestock, and wildlife if ingested. Certain pesticides may also destroy beneficial insects.
Contaminants of Concern:
Various pesticides

Underground Storage Tanks. Underground storage tanks are used to store home heating fuel, and in some cases, gasoline or other petroleum products. These tanks are located beneath the ground, where, if there is a leak, it can go undetected until the chemical enters a well, nearby surface water, or seeps below the basement of the house. Several Rhode Island communities have already experienced contaminated groundwater from leaking underground storage tanks.
Contaminants of Concern:
(1) Petroleum products.
(2) Toxic compounds such as benzene, toluene, and xylene.
(3) Additives such as organic lead compounds.

Animal Lots. As with human wastes, animal waste contains bacteria and nutrients and can contaminate nearby water supplies. Animal lots that are not properly constructed and maintained, have poor drainage, or are located where the water table is close to the surface can cause groundwater contamination. Allowing animals to graze in or directly next to a water body can also have serious impacts on water quality. Allowing animal access to your drinking water well can result in waste getting into your well.
Contaminant of Concern:
(1) Nitrate-Nitrogen – See Septic Systems
(2) Bacteria and Viruses – See Septic Systems

Abandoned Wells. Unfortunately, wells that are no longer used to supply water are often not sealed properly or are left open. An abandoned well can act as a direct "pipeline" for surface to groundwater contamination.
Contaminants:
Various, depending upon what is disposed.

Protecting Our Groundwater
Private well owners are responsible for the quality of their drinking water. There are many effective, practical steps each of us can take to reduce nonpoint source pollution to nearby groundwater supplies. Some of these steps are outlined below. In addition, the University of Rhode Island's Cooperative Extension Home*A*Syst program offers programs and information to help address your water quality concerns. For information on the Cooperative Extension's programs and publications, see **For More Information**.

Test Your Private Well
Have your well water tested annually by a certified state laboratory. This will help you ensure that your water is safe to drink. Additionally, an annual test will allow you to track any changes that occur with your water quality over time.

Survey Your Property
If you own a well, proper management of the area surrounding it can help protect it from contamination. Keep chemicals and other pollutants away from your well. Map your property and survey the activities

that occur in and around the home. Be sure that your well is properly sealed and the land around the well slopes away so that water cannot pond around the wellhead. Maintain your septic system. Inventorying and inspecting your home for potential nonpoint sources of pollution is a great first step to water quality protection.

Underground Storage Tanks
The best recommendation for an underground storage tank is to have it removed by a professional and replace it with an above ground tank placed within a concrete containment structure and covered from the elements. Routinely check the tank for leaks.

Household Hazardous Products
Use non-hazardous alternatives or the least toxic product whenever possible. Do not pour these products down the drain or toilet, on the ground, or in catch basins or storm drains. It is also important to buy only as much of a hazardous product as you will use.

Recycle Motor Oil
A single quart of motor oil can contaminate thousand of gallons of water. Always recycle your oil at a municipal recycling station.

Landscape Your Yard
Landscape your property so that grass and trees help to retain stormwater and reduce runoff. When deciding on landscape plants, consider sustainable plantings that require minimum fertilizer, pesticide and irrigation inputs. The Cooperative Extension GreenShare Program has a sustainable plant list for Rhode Island. Contact 401-874-2900 for more information.

Fertilizers and Pesticides
Make sure that the fertilizers and pesticides you apply are appropriate for your situation. Always identify your pest problem before selecting a treatment. Read labels carefully and use as little of the product as possible to meet your needs – in the case of pesticides and fertilizers, more is not better. Proper disposal of fertilizers and pesticides is critical for maintaining good water quality. Use non-toxic approaches to pest control whenever possible.

Animal Waste
Keep pets and livestock away from your drinking water well. Pick up after your pet. Properly store livestock waste away from drinking water wells and where stormwater cannot contact it and carry it away in runoff waters.

The state of Rhode Island has developed a groundwater protection strategy. In addition, many communities have developed groundwater protection plans. However, groundwater protection is too important to leave up to government agencies and water companies. Concerned citizens play a vital role in protecting groundwater by wise water use, proper waste disposal and many other routine activities. By demonstrating the groundwater model and following suggested activities, you can teach your audience the value of this resource while promoting its protection.

Glossary

Aquifer – any soil or rock formation that is capable of supplying groundwater for human use.

Artesian aquifer – an aquifer that is under a confined layer. The groundwater in an artesian aquifer is under pressure.

Cone of depression – a roughly circular area around a well where the groundwater level is lowered by pumping.

Confined aquifer – see artesian aquifer.

Confining layer – impermeable soil or rock layers that restrict water movement.

Groundwater – water in a subsurface, water-saturated layer of soil or rock.

Groundwater discharge – groundwater that flows to the ground surface. Where the water table intercepts the ground surface, i.e., at a stream or wetland.

Groundwater recharge – the replenishment of groundwater by infiltration or seepage of precipitation or surface runoff.

Induced recharge – infiltration of surface water from a water body into an adjacent aquifer caused when the cone of depression created by a pumping well captures surface water from a lake, pond or stream.

Infiltrate – to permeate something by penetrating its pores; to seep into a substance.

Nonpoint source pollution –pollution that originates over a widespread area of the landscape.

Permeable – penetrable; having pores or openings that permit water to pass through.

Permeability – the capacity of water movement through soil or rock.

Point source pollution – pollution that comes from a single point, such as a discharge pipe

Porosity – the capacity of soil or rock to hold water.

Recharge area – the overlying land that contributes water to an aquifer.

Saturated zone – a subsurface zone in which all pores in a soil or rock formation are filled with water.

Surface water – water from precipitation or snowmelt that accumulates above ground in streams and rivers, lakes, ponds, reservoirs, wetlands, and oceans.

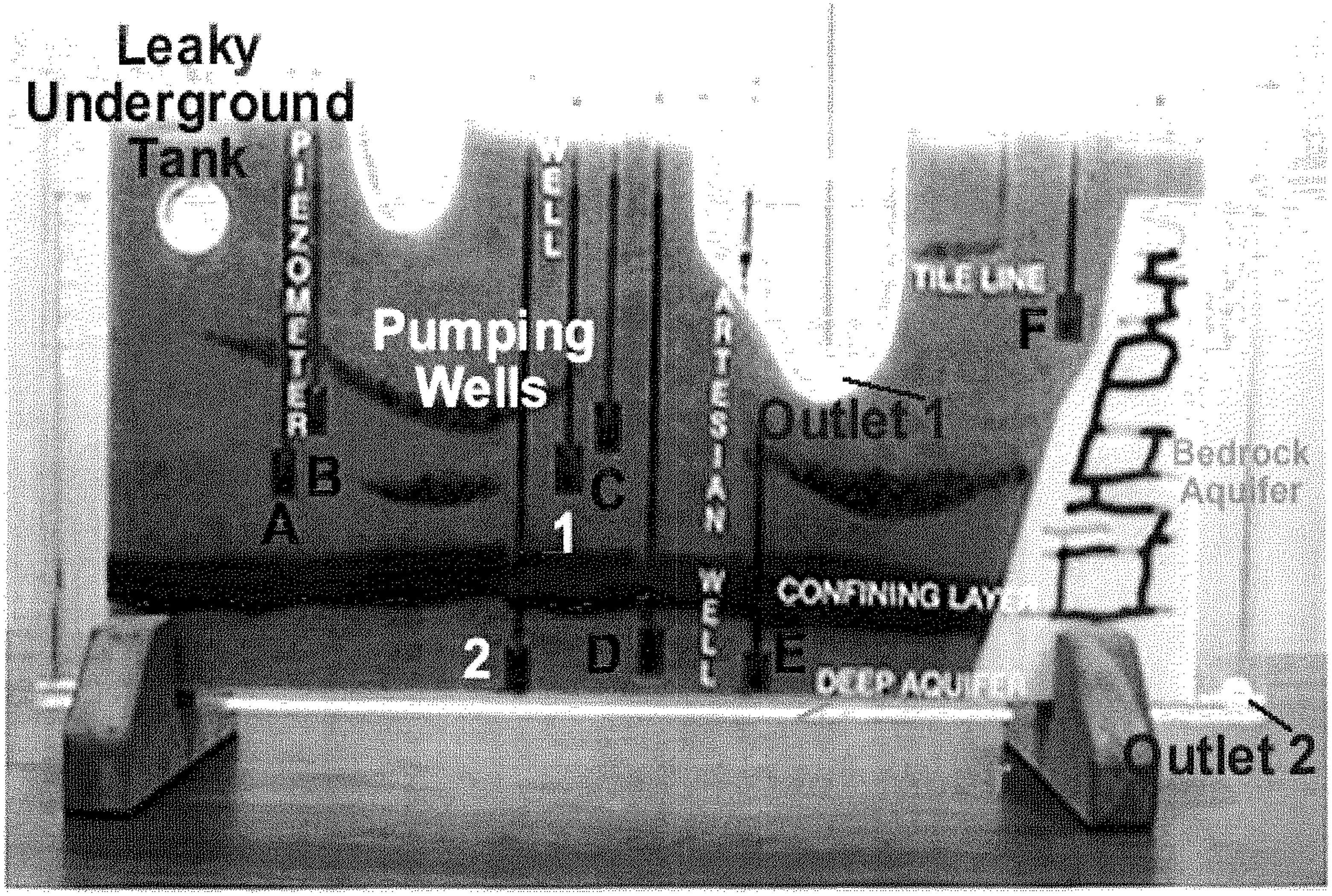
Unconfined aquifer – an aquifer in which the water table forms the upper boundary. Susceptible to contamination from activities occurring at the land's surface.

Unsaturated zone – a soil or rock zone above the water table and extending to the land's surface in which the pore spaces are only partially filled with water.

Water table – the top of the saturated zone.

Water table aquifer – see unconfined aquifer.

Using the Groundwater Model



D & E: Piezometers, also known as observation wells, artesian aquifer
A, B, C, and F: Piezometers, also known as observation wells, unconfined aquifer
1: Pumping well, unconfined aquifer
2: Pumping well, artesian aquifer
Instructions refer to pumping wells 1 & 2, however, you can pump any of the wells in the model.

USING THE GROUNDWATER MODEL

This section will help you set up, use, and maintain the groundwater model. A diagram of the model is included on page 11 for your reference.

<u>Set up</u>

ALLOW YOURSELF TIME TO PRACTICE AND BECOME FAMILIAR WITH THE MODEL BEFORE DEMONSTRATING IT. All the equipment needed to operate the model is included in the accessory kit.

<u>IMPORTANT:</u> Use the two wooden blocks provided to serve as feet for the model.

Fill the one-quart, wide-mouth bottle with water. Place the rubber stopper (with the short rigid plastic tube) assembly tightly in the bottle opening. Invert the bottle at the left end of the model so that the water runs into the open channel on the left side. When the model is full to within 1-2 inches from the top of the gravel surface at the top of the model, remove the wide mouth bottle. Photo 1 shows the wide-mouth bottle filling the model.

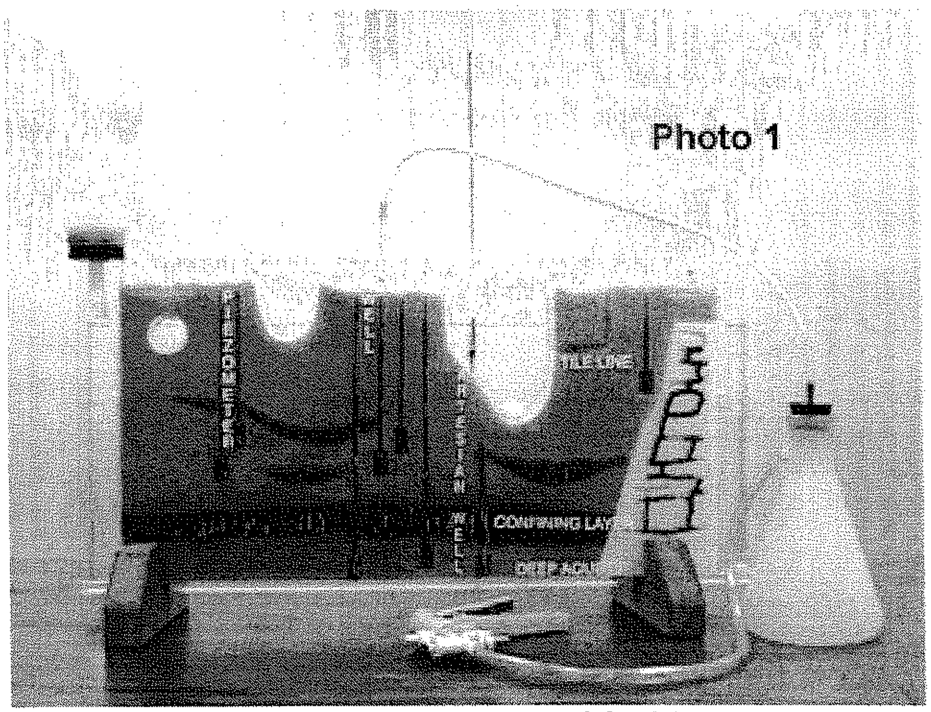


Photo 1

There are two outlets on the model. One outlet is on the back of the model and allows water to flow from the lake/river (outlet 1). The other outlet is on the right-hand side of the model (outlet 2).

You will need to use a colored water solution to track the water movement in the model. **DO NOT USE STRAIGHT FOOD COLORING IN THE MODEL – ALWAYS USE A FOOD COLORING-WATER MIXTURE!** Make up red and green solutions. Fill observation well D, which extends into the artesian aquifer, with green colored water. (See the diagram for help.) Fill observation wells A, B, C, and F with red colored water. Add colored water until it reaches all the way to the bottom of the observation well and spills out slightly into the sand below. Inject red colored water into pumping well 1 and green colored water into pumping well 2. Inject green colored water into the bedrock aquifer wells.

Place a rubber-tipped plastic tube provided with the model into the artesian well outlet in the lake, observation well E. Add green colored water to this tube for easier observation of the water level.

USE ONLY ERASABLE MARKER WHEN DRAWING ON THE MODEL. PERMANENT INK WILL NOT COME OFF THE PLEXIGLAS.

Operating the Pumping Wells

There are two pumping wells in the model – one is the unconfined aquifer, pumping well 1, and the other is in the confined (artesian) aquifer, pumping well 2. Both of the pumping wells are labeled as such on the diagram on page 11. The model comes with a hand-operated vacuum pump for pumping wells. Photo 1 shows the proper way to use the vacuum pump to "pump" the wells. The vacuum pump is connected by plastic tubing to the Erlenmeyer flask (tapered sides) using the spout on the neck of the flask. The small rubber stopper is placed in the top of the flask. Plastic tubing is connected to the metal tube in the stopper. The other end of the tubing has a pipette tip inserted. The pipette tip is placed into the pumping well. Use only light pressure by using a slight twisting motion and holding the pipette tip in place while pumping, you should be able to maintain the seal at the pipette tip and well. Remove the wide mouth bottle from the model before pumping the wells and reposition it after pumping.

After you have assembled the vacuum pump and flask as indicated above, you are ready to pump the well. Operate the hand vacuum pump. This creates a vacuum in the flask. The vacuum then causes water to flow from the model's well to the flask. The pumped water collects in the flask.

Empty the flask before the flask is filled completely. **DO NOT ALLOW WATER TO OVERFLOW THE FLASK – WATER MUST NOT BE ALLOWED TO ENTER THE VACUUM PUMP.** Liquids will damage the internal mechanisms of the pump. The pump cannot be disassembled for repairs. It is permanently sealed at the factory.

To prevent breakage, do not force the pump handle. If operation become difficult, let Cooperative Extension staff know.

NEVER CONNECT THE VACUUM PUMP DIRECTLY TO A PUMPING WELL. Always use the flask to create the vacuum and for the water collection. Connecting the vacuum pump directly to a well and allowing water to enter the pump will destroy the pump.

Cleanup of Model After Use

When you finish your demonstration, the colored water should be flushed out of the model within 24 hours. Run 3-4 bottles of clean water through the model. Once the model is full, pump water from the recharge outlet on the right side. Continue to add clean water to the left side recharge outlet until all color is flushed from the model. Remove all of the color traces. Remaining color might interfere with the visualization of the next demonstration.

NEVER ALLOW THE MODEL TO FREEZE.
HANDLE THE MODEL CAREFULLY; IT IS FAGILE. DO NOT ALLOW IT TO DROP.

When transporting the model you can help to prevent shifting of sand into the gravel wedge by having the materials in the model wet.

The exterior plastic surfaces can be cleaned using commercial plastic cleaners. **DO NOT USE GLASS CLEANERS THAT CONTAIN AMMONIA, VINEGAR, OR OTHER ACIDIC MATERIALS**. Glass cleaners will cloud the clear plastic.

During your use of the model, if you have any problems or if something becomes damaged, please let Cooperative Extension staff know so that the model can be repaired and materials replaced as necessary.

LESSON: DEMONSTRATING GROUNDWATER CONCEPTS

This section will help you demonstrate the groundwater model. This lesson takes about 1 hour. There are 11 concepts listed below to demonstrate. Each concept is followed by an action step and a discussion. The action details how to illustrate the concept and the discussion provides abbreviated background information. The page numbers listed after the discussion are those pages in the background section, which discuss the concept at hand.

1. **Concept:** Groundwater is part of the hydrologic cycle.
   Action: First, fill up the model and place the dye in the wells as indicated on page 11. Using the squirt bottle, spray some water over the entire top of the model. Watch the movement of the water through the gravel material.
   Discussion: The hydrologic cycle describes the relationship between groundwater, the water in the atmosphere, such as rain and snow, and surface water such as lakes and streams. Water being sprayed over the top of the model acts like precipitation. The water seeping downward through the soil becomes groundwater. Precipitation that does not enter the soil runs off the land into surface water bodies or evaporates back to the atmosphere.

   As water moves through the soil, it first enters the unsaturated zone where pore spaces between soil particles or cracks in the bedrock contain air, water, plant roots, and soil organisms. As the water continues to move through the soil, it enters the saturated zone where pore spaces are completely filled with water. (Page 2)

2. **Concept:** The water table is the boundary between the saturated and unsaturated zone.
   Action: With an erasable marker, draw a line across the water level, connecting the top of the water level in the red and green wells and the top of the water level in the lake.
   Discussion: The top of the saturated zone is the water table. Observation wells that are placed into an unconfined aquifer can help determine the height of the water table as the level of water in those wells corresponds to the water table. (Page 3)
   Photo 2 illustrates this.

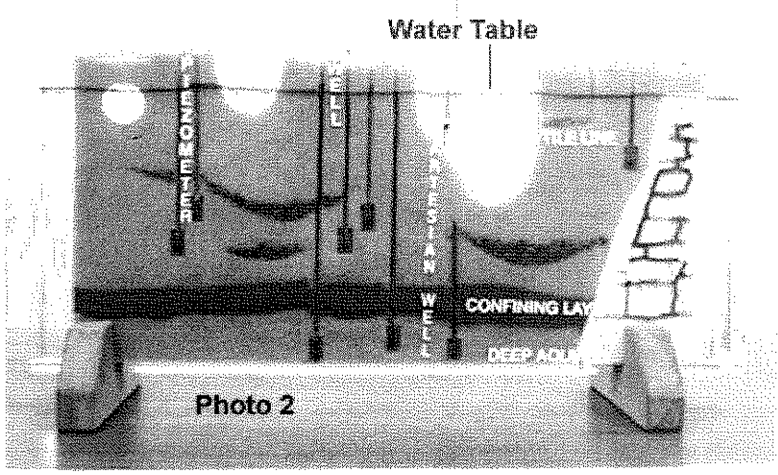
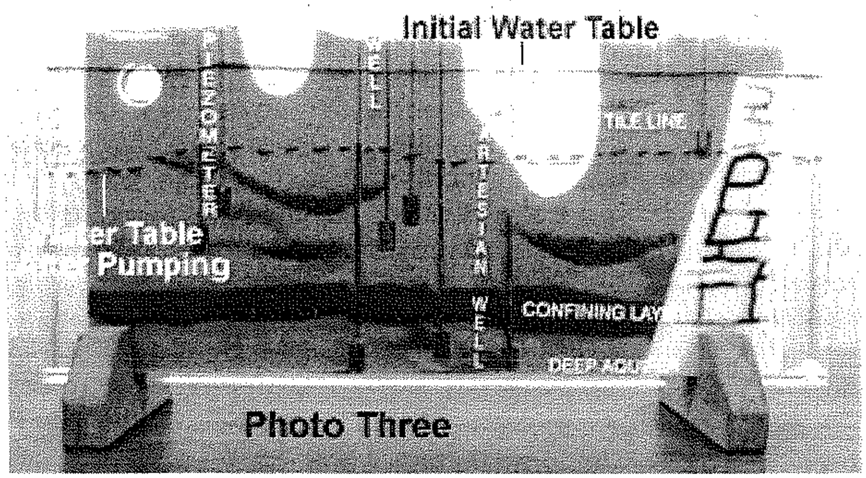


Photo 2

3. **Concept:** Wells supply groundwater for our use.
   Action: Pump the unconfined, red pumping well 1 for several seconds, and then remove the

pump. (By noting the flow of the dye through the model, you will see how the groundwater flows through the soil.)
Discussion: The pumping of this well causes the water level in the other unconfined wells to be lowered. Also, notice how the groundwater from the other red wells is being drawn toward the pumping well (indicated by the red plumes). The green colored water in the confined wells does not move toward the well being pumped. (Page 5)

4. **Concept:** The water table rises and falls.
Action: Completing #3, redraw a line illustrating the new water table.
Discussion: The water table rises and falls according to the amount of rain and snowmelt that occurs. A pumping well will also lower the water table. (Page 3) Photo 3 illustrates this.



5. **Concept:** Groundwater needs to be recharged.
Action: Refill the one quart bottle and invert it into the left side recharge outlet (as you face the front) of the model. Refill the unconfined wells with red colored water.
Discussion: Groundwater is recharged by precipitation or snowmelt seeping into an aquifer. The water in the inverted bottle simulates precipitation. It recharges the groundwater. As the groundwater is recharged, the water table rises. (Page 5)

6. **Concept:** Water table aquifers, or unconfined aquifers, do not have restrictive layers separating them from the land's surface.
Action: Notice that no confining layer exists above the unconfined aquifer. The water level in wells placed in unconfined aquifers corresponds to the height of the water table.
Discussion: The absence of a confining layer means that unconfined aquifers are more susceptible to contamination from land use activities. (Pages 4-5)

7. **Concept:** Artesian, or confined wells, are trapped under impermeable soil or rock. The confining layer separates the deeper, artesian wells from the unconfined wells. The water in artesian aquifers is under pressure. This

pressure causes the water level in the wells penetrating the artesian aquifer to rise above the top of the confining aquifer.
Action: Note that the water level in observation wells D and E and pumping well 2 is above the top of confined aquifer. Pump the green artesian well.
Discussion: Notice that the green colored water from the unconfined wells does not move toward the artesian pumping well. The water level in the artesian wells, however, is lowered as the well is pumped. (Pages 4-5)

8. **Concept:** Bedrock aquifers are capable of storing and supplying water to a drinking water well.
Action: Pump the bedrock aquifer wells and notice how the water flows through the bedrock fractures.
Discussion: Drilled wells are placed into bedrock aquifers where they intercept fractures in the bedrock. The well draws the water from these fractures to supply water.

9. **Concept:** Groundwater can become surface water.
Action: Open the lake outlet and drain the lake. Place a cup under the spout to catch the water. Watch the lake refill as the water table discharges into the surface water (lake bed). Note: depending on how much water was pumped in Concept 7, you may need to refill the model with water before demonstrating this activity.
Discussion: Where is the lake water coming from? The lake is being refilled or recharged with groundwater as the water table is intercepting the ground surface at this location. (Page 5)

10. **Concept:** Surface water can become groundwater.
Action: Allow the lake to refill. Draw a line indicating the water level in the lake. Refill the unconfined wells with red colored water. Pump the unconfined pumping well 1 until you notice the water level in the lake drop. Stop pumping and draw a new line across the water level of the lake.
Discussion: The surface water from the lake is recharging the unconfined aquifer. When the well is pumped, water from the lake is drawn toward the well. (Pages 5-6)

11. **Concept:** Springs are groundwater discharges to surface water. Some springs may originate from unconfined aquifers, while others can originate from confined aquifers.
Action: Refill artesian wells with green colored water. Drain the lake outlet. Refill the model with water. Allow the lake to fill up. Notice that the lake turns green. To illustrate this concept more clearly, take a small pipette and stick it into the hidden spring hole, located on the left sloping side of the lake. Notice that the pipette fills with green water.
Discussion: The lake turns green because there is a spring originating in the artesian aquifer, and it is discharging into the lake. The green water in the pipette is the water flowing from the artesian aquifer (groundwater that is

under pressure) to the spring. This is another source of groundwater discharge. (Page 5)

12. **Concept:** Groundwater contamination has many sources. (Pages 6-8)

(a) **Abandoned wells**

Action: Consider observation well C to be an abandoned well. Inject green colored water into the well. Notice how the color moves into the groundwater. Pump the unconfined pumping well 1 until you see the colored water enter the unconfined well.

Discussion: Abandoned wells are a source of groundwater contamination. Wells that are no longer used to supply water are often not properly sealed. Since wells are installed directly into the groundwater supply, contamination from wastes entering an abandoned well can quickly and adversely affect the quality of water in nearby wells.

(b) **Underground Tanks**

Action: Consider the underground tank to be a leaking underground storage tank (commonly used to store home heating oil) or a failing septic system. After refilling the model, add some green colored water to the tank. Pump the red unconfined pumping well 1 until the water table is about ½" below the tank. Notice the contamination (the colored water) from the tank moving toward the well. Refill the tank with colored water and refill the model with clean water. Notice the movement of the contamination.

Discussion: The contamination now moves downward through the soil until it hits the water table (which was lowered from pumping the blue well). The contamination then moves with the groundwater (which fluctuates depending on the amount of recharge and water pumped). Many toxic and unwanted contaminants can enter our drinking water supplies form faulty underground tanks. Photo 4 illustrates this.

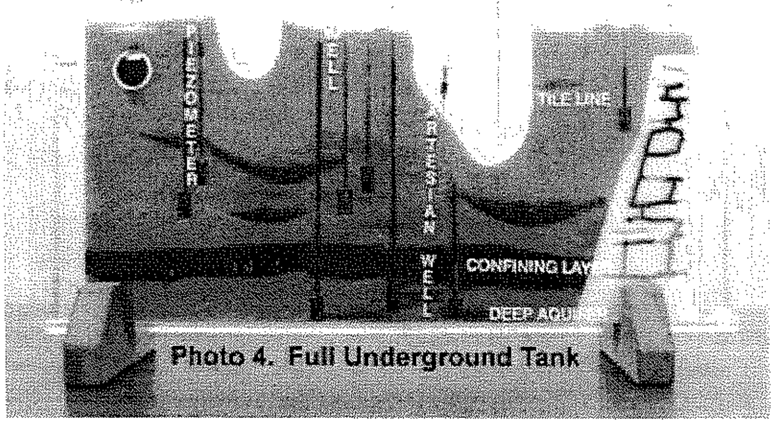


Photo 4. Full Underground Tank

(c) **Dumping hazardous chemicals on the ground**

Action: Squirt some green colored water directly over the top of the model. Pour clear water over the model also by pouring it directly over the top of the model. Notice the movement of the green colored water.

Discussion: The green colored water acts like a pollutant, motor oil for example, that has been dumped on the ground. The water from the bottle simulates rain or snow. The contaminant seeps into the ground with the precipitation. Eventually, the oil will continue to move downward to the groundwater supply.

(d) **Contaminated surface water**
Action: Refill the model with water. Add a few more drops of colored water to the lake and pump the unconfined well. Notice the colored water moving toward the well.
Discussion: Groundwater and surface water are interconnected. The contaminated lake is contaminating the groundwater supply as it loses water to (recharges) the aquifer.

13. **Concept:** Once groundwater becomes contaminated, it is very difficult and very costly to clean up.
Action: After completing Concepts 1-9 in the demonstration, let the model sit untouched. Go back to the model in an hour, 3 hours, a day. Notice that the contamination, the colored water, which entered the groundwater and/or wells, is still there. Refill the model and pump the water out from the right side. Add more water to the model. Pump the water out again. Notice how long it takes for the model to become completely clean.
Discussion: Because groundwater contamination can persist over long periods of time, it becomes important to guard our groundwater supplies. Water quality is directly related to land use. Nonpoint sources of pollution, like leaky underground storage tanks, failing septic systems, and abandoned wells can contribute contamination to our groundwater supplies. However, there are many things we can do to reduce the amount of pollution entering our groundwater, including using non-hazardous cleaning products, recycling motor oil, and maintaining septic systems to name a few. Remember, the best way to protect our groundwater supplies from contamination is to prevent pollution from entering groundwater in the first place! (Page 9)

University of Rhode Island, United States Department of Agriculture and local governments cooperating. Cooperative Extension in Rhode Island provides equal opportunities in programs and employment without regard to race, color, national origin, sex or preference, creed or disability. This publication is supported by URI Cooperative Extension. It is contribution number 3948 of the College of Environmental and Life Sciences, University of Rhode Island with support from the Rhode Island Agricultural Experiment Station. Funding provided by USDA Forest Service.