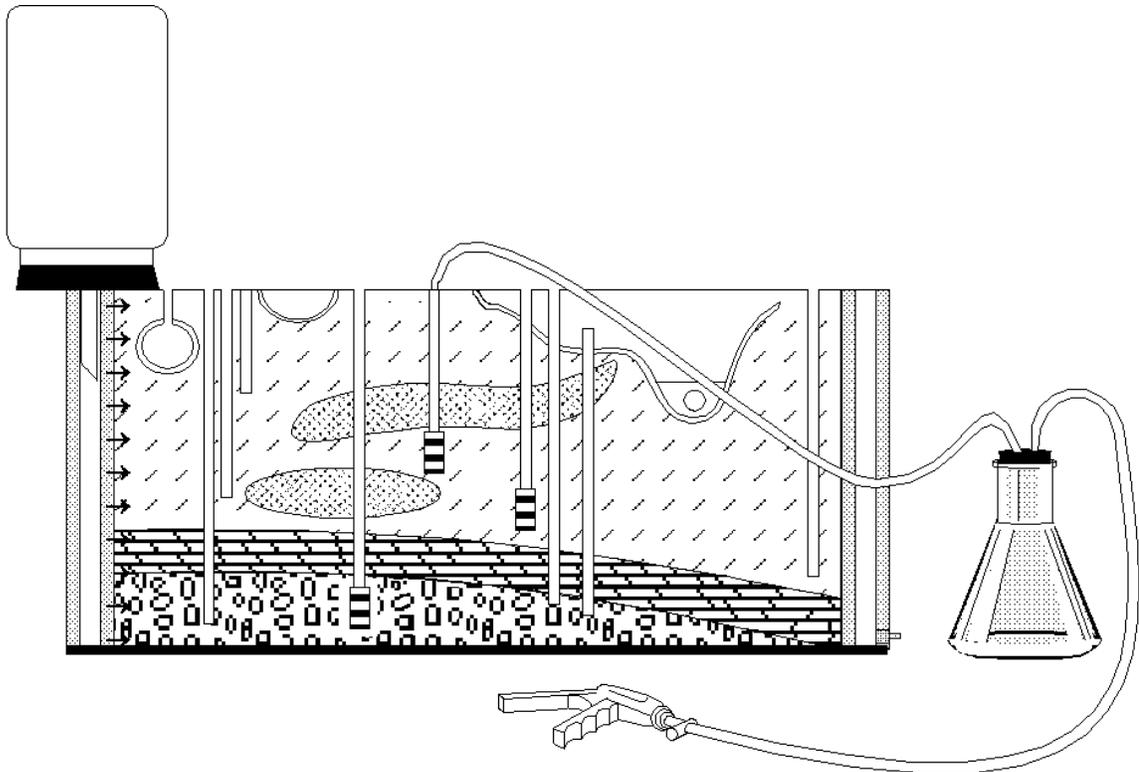


GROUNDWATER FLOW DEMONSTRATION MODEL

ACTIVITIES FOR GRADES 6-12



by

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October 1997

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The following activities are designed to make learning and demonstrating groundwater concepts exciting and fun through the use of a groundwater flow demonstration model! These activities can be used alone or to enhance your own water resources education curricula. The physical model can be obtained through your County Cooperative Extension Service or the Utah Water Resources Education Program and Project Wet (distribution list available from Utah Division of Water Resources).

This material was developed through a grant with the Utah Department of Agriculture Nonpoint Source Pollution Education Program.



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WATER QUALITY

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Activity 1: Groundwater Flow Demonstration Model - Aquifers

Purpose: To teach basic groundwater concepts including aquifer, groundwater flow, and water table.

Background*: This activity is one in a series of four activities designed to work with a groundwater flow demonstration model. The model is a simulated cut-away section of the earth. It shows the make-up of the ground beneath the surface and allows for the demonstration of groundwater principles.

People often erroneously believe that groundwater travels hundreds of miles underground. Usually, it travels slowly, inches per day, depending on the make-up of the aquifer.

Groundwater is stored in the pore spaces of saturated soil, between sand grains, and inside cracks and fractures in rock. An underground unit of soil, sand, gravel, or fractured rock which can yield a significant quantity of groundwater to wells is called an **AQUIFER**.

GROUNDWATER FLOWS through interconnected pore spaces in aquifers. Groundwater may flow at different rates in different types of aquifers. Aquifers are not always uniform either horizontally or vertically because of differences in composition or in properties. You'll notice in the model that some aquifers are fine sand and some are coarse sand or gravel.

Aquifers may be separated by layers which do not transmit much water. These layers are called **confining layers** (aquitards). If a confining layer exists above an aquifer which is fully saturated, this aquifer is then a confined or artesian aquifer. Aquifers without a confining layer above them are called unconfined aquifers or **WATER TABLE** aquifers.

The groundwater model has two aquifers: an unconfined aquifer of white sand with small areas of gravel included, and a confined artesian aquifer of gravel along the bottom. The aquifers are separated by a confining layer containing clay.

Many people assume that water exists in lakes and rivers beneath the ground. These underground lakes and rivers rarely exist.

* This information was taken from *Manual for Groundwater Flow Model* by the Iowa State University Soil and Water Conservation Society Student Chapter, Ames, IA.

You may think that the water you drink has been underground for thousands of years. In fact, groundwater drawn from shallow wells usually enters the ground within a few miles of the well, and has been in the ground only a few years or tens of years. But the groundwater that we use today may have traveled through the hydrologic cycle hundreds or thousands of times since the earth was formed.

Materials: groundwater flow demonstration model - available through USU Extension Service and Utah Division of Water Resources.

Procedure: 1. Fill the one quart widemouth bottle with water and invert it at the left end.
Concept: Groundwater often comes from nearby sources.

Discussion: People often erroneously believe that groundwater travels hundreds of miles underground. They may also believe that the water they drink has been underground for thousands of years. In fact, groundwater drawn from shallow wells usually enters the ground within a few miles of the well, and has been in the ground only a few years or tens of years.

Procedure: 2. Allow water to run through the model. Concept: Groundwater is contained underground in the spaces between sand grains and other soil particles, or in cracks and fractures in rocks.

Discussion: Underground lakes and rivers rarely exist. Notice that the water entering the model at the left side saturates the sand and gravel and exists at the right, but there are no observable rivers or channels through which it flows.

Procedure: 3. With water running through the model, add dye to the six observation wells (piezometers) until the dye moves out of the piezometers into the soil below. Concept: Groundwater flows from upland areas to low areas, or from areas of high hydraulic head to areas of lower hydraulic head.

Discussion: When the outlet to the model is closed, there is no flow through it. When the outlet is open, water can move through the model, because the elevation of the outlet is lower than the inlet elevation. The water table changes, as shown by the elevation of dye in each well, and as represented by a line that can be drawn with a wax pencil. The dye that moves into the sand or gravel from the piezometers is carried along by the moving water, helping you to see the path and direction of flow. With the outlet open, the dye will move up towards the stream.

Procedure: 4. Look at the sand and gravel layers in the model. Concept: The underground units of soil and rock which yield water to wells are called aquifers. Aquifers are not always uniform either horizontally or vertically. Aquifers may be separated by layers which do not hold or transmit much water. These layers are called confining layers or aquitards.

Discussion: The white sand aquifer in the model has a layer of coarse gravel included within it. Below the white sand layer is a layer of material containing clay. This layer allows very little water to pass through it, so it acts as a confining layer. Below the confining layer, there is a second aquifer of coarse gravel. There is little interconnection between these two aquifers. If you pump the well in the upper aquifer, you will see that the piezometers in that aquifer show a drop in water levels, while those in the lower aquifer show little response. Similarly, pumping the well in the lower aquifer causes little response in the upper wells.

Procedure: 5. Allow water to run through the model. Add dye to the six piezometers. Concept: The soil and rock below the earth's surface normally consist of a saturated and an unsaturated zone. The top of the saturated zone is called the water table. Piezometers can be used to define the top of the saturated zone.

Discussion: Notice that the end of the tube where water drips out of the bottle (the inlet) is higher above the surface of the table than is the plastic elbow where the water flows out of the model (the outlet). As water flows from the inlet to the outlet, a slope is created on the water table.

Use a wax pencil to connect the water levels in each of the piezometers in the upper aquifer. You have now drawn in the water table. Note that it slopes from the inlet downward toward the outlet.

If you wish, you may add a small block under the left end of the model. This will cause the difference in height between the inlet and the outlet to increase, creating a larger and more obvious slope on the water table. Other methods of changing the slope of the water table include raising or lowering the inlet tube in the stopper, or changing the extent to which the outlet elbow is opened.

Procedure: 6. Notice that the water feeding the model enters along the entire vertical channel at either end. Notice that the dye which enters the coarse gravel wedge at the left of the model disperses much faster than the dye in the white sand. The dye movement out of the gravel wedge will radiate out in all directions.

Discussion: Both the coarse gravel wedge and the white sand aquifer are well-sorted, which means that the grains of gravel or sand are all roughly the same size within each unit. Water can move through well-sorted gravel faster than well-sorted sand because larger grain size leads to larger pore size, and larger pore size leads to less surface area in contact with the moving water. The smaller the surface that the water contacts, the less frictional resistance there will be in the moving water. The lower frictional resistance leads to a greater velocity of groundwater flow.

Water flowing through an aquifer will take the path of least resistance. Since the resistance to flow is lower, more of the water entering the model per unit area will enter into the gravel wedge than into the sand layer around it. However, all this water entering into the gravel must have a way to exit. A hydraulic pressure is created which allows the water to exit even in an upward direction into the sand above the gravel wedge. In other words, the unconfined sand aquifer becomes a confining layer for the gravel wedge, creating artesian conditions in the gravel. In this case, down-gradient is actually upward. The dye movement should illustrate this.

This activity was adapted from the Iowa State University Soil and Water Conservation Society Student Chapter's *Manual for Groundwater Flow Model*.

10/97



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WATER QUALITY

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Activity 2: Groundwater Flow Demonstration Model - Flow Concepts

Purpose: To teach basic groundwater concepts including the relationship between groundwater and surface water, saturated and unsaturated zones, piezometer, and recharge area.

Background*: This activity is one in a series of four activities designed to work with a groundwater flow demonstration model. The model is a simulated cut-away section of the earth. It shows the make-up of the ground beneath the surface and allows for the demonstration of groundwater principles.

Groundwater is not new water; it is "recycled" water that is related to all the other water on earth by a process called the hydrologic cycle. The hydrologic cycle describes the **INTER-RELATIONSHIP OF GROUNDWATER WITH SURFACE WATER**, such as lakes and streams, and the water found in the atmosphere, such as clouds, snow, and rain. When rain falls on the surface of the ground, some of it runs off the land into lakes and streams. This is considered run-off. When it soaks into the ground, it is referred to as infiltration. The water soaking into the ground may first go throughout an unsaturated zone, where some may be taken up by plants and "lost" to evapotranspiration.

The **UNSATURATED ZONE** contains spaces between the soil particles, some of which are filled with air and the rest with the water that soaks in. Soils in the unsaturated zone are able to hold water in small pores against the force of gravity because of surface tension or cohesion, which is the attraction that water molecules have for one another. Water in larger pores is more subject to the force of gravity and is the source of water that moves downward to become groundwater.

Below the unsaturated zone, the water reaches a zone in the sand and gravel where all the cracks and spaces in the soil or rock are filled with water. This is the **SATURATED ZONE**. Water in the saturated zone is groundwater. The top of the saturated zone is called the water table. In the model, the dye in the observation wells (piezometers) sits at the same elevation as the water table.

* This information was taken from *Manual for Groundwater Flow Model* by the Iowa State University Soil and Water Conservation Society Student Chapter, Ames, IA.

Water enters the groundwater system in areas called **RECHARGE AREAS**. The amount of groundwater recharge that occurs is related to a number of factors, including the porosity and permeability of the soil, the topography of the land surface, and the amount and timing of the precipitation that occurs.

Timing of rainfall is important. If rain falls at a time when crops are actively growing and using water, very little may make its way to the saturated zone. In fact, in many areas, the major recharge periods occur in spring and fall, when precipitation is greater and crops are not actively intercepting and using as much water.

Topography influences the rate of groundwater recharge as well. Groundwater recharge areas are usually located in upland areas. Water may then flow down-gradient until it reaches an area where it can come to the surface of the ground, called a discharge area. Groundwater discharge areas are normally low areas such as lakes, rivers, and wetlands.

Groundwater often feeds lakes and streams. The place where groundwater becomes surface water is a discharge area. When groundwater simply bubbles up at the surface of the ground, that discharge area is called a spring. The stream in the model is an example of the inter-relationship of groundwater and surface water, where the groundwater enters the stream in the form of a spring.

Materials: groundwater flow demonstration model - available through USU Extension Service and Utah Division of Water Resources

Procedure: 1. Close the lake outlet so that the lake fills with water. Open the outlet.
Concept: Groundwater is related to surface water and to all other forms of water found on earth through the hydrologic cycle.

Discussion: The hydrologic cycle describes the inter-relationship of groundwater with surface water, such as lakes and streams, and the water found in the atmosphere, such as clouds, snow, and rain. Groundwater often feeds lakes and streams. The place where groundwater becomes surface water is a discharge area. When groundwater simply bubbles up at the surface of the ground, that discharge area is called a spring. The lake in the model is an example of the inter-relationship of groundwater and surface water.

Groundwater often feeds lakes and streams. You can demonstrate this by closing the stream outlet and observing that the stream slowly fills with water flowing throughout the ground.

Procedure: 2. Allow water to run through the model. Add dye to the six observation wells (piezometers). Concept: The soil and rock below the earth's surface normally consists of both a saturated and an unsaturated zone. The top of the saturated zone is called the water table. Piezometers can be used to define the top of the saturated zone.

Discussion: Notice that the end of the tube where water drips out of the bottle (the inlet) is higher above the surface of the table than is the plastic elbow where the water flows out of the model (the outlet). As water flows from the inlet to the outlet, a slope is created on the water table. Use a wax pencil to connect the water levels in each of the piezometers in the upper aquifer. You have now drawn in the water table. Note that it slopes from the inlet downward toward the outlet.

If you wish, you may add a small block under the left end of the model. This will cause the difference in height between the inlet and the outlet to increase, creating a larger and more obvious slope on the water table.

Procedure: 3. Notice the dye traces moving in all directions toward the river. Concept: Water flows into rivers from many directions.

Discussion: Rivers are natural discharge areas for groundwater. In the model, you will observe dye traces moving from all directions toward the river, then entering into the river when the river outlet is open.

Procedure: 4. Notice that the water collecting in the lake is not clear. It has been affected by the dye that has been injected at various points. Concept: There is an inter-relationship between groundwater and surface water.

Discussion: Surface water bodies such as lakes and rivers have two major sources of water: surface runoff from rainfall and snowmelt, and groundwater flow, called baseflow. Baseflow is the reason that streams flow even during dry spells. In addition, since the temperature of groundwater is about 50°F year-round, baseflow allows streams to flow in winter even when the ground is frozen.

Procedure: 5. Use a sprayer to add water along the surface of the model. Concept: Groundwater is recharged by precipitation and snowmelt.

Discussion: Recharge of the aquifer from above creates additional head that pushes dye plumes near the surface deeper into the aquifer. It is also useful to note that if recharge were induced by sprinkling water over the top of the entire model, the dye traces would angle downward and widen as they moved across the model. This method of recharge would also more closely simulate natural conditions.

This activity was adapted from the Iowa State University Soil and Water Conservation Society Student Chapter's *Manual for Groundwater Flow Model*. 10/97



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WATER QUALITY

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Activity 3: Groundwater Flow Demonstration Model - Wells

Purpose: To teach basic groundwater concepts of piezometers, wells, artesian wells, and springs.

Background*: This activity is one in a series of four activities designed to work with a groundwater flow demonstration model. The model is a simulated cut-away section of the earth. It shows the make-up of the ground beneath the surface and allows for the demonstration of groundwater principles.

In the model, the dye in the observation wells (piezometers) sits at the same elevation as the water table. **PIEZOMETERS** are wells installed to monitor water level and water quality.

Groundwater is withdrawn from the ground through **WELLS** for use in our homes, farms, and industries. Wells are drilled or driven into water-bearing underground zones called aquifers. A screen is placed at the bottom of the well to keep soil from being pumped out along with the water. In the case of bedrock wells, there is not always a screen used. A pump is used to withdraw water from the well.

When a well is drilled to penetrate any aquifer, water will enter the well casing. In an unconfined aquifer, the water level will stabilize in the well at the top of the saturated zone, which is called the water table. In a confined aquifer, when water in the well rises above the top of the aquifer, potentially resulting in the flow of water above the surface of the ground, a flowing well or **ARTESIAN WELL** may result. In the model, you can see the artesian well protruding above the stream. There is a confining layer of 5-10% bentonite clay above the bottom aquifer of gravel which supplies water to the artesian well. The artesian well flows as water tries to move down-gradient.

Groundwater often feeds lakes and streams. The place where groundwater becomes surface water is a discharge area. When groundwater simply bubbles up at the surface of the ground, that discharge area is called a **SPRING**. The stream in the model is an example of the inter-relationship of groundwater and surface water, where the groundwater enters the stream in the form of a spring.

* This information was taken from *Manual for Groundwater Flow Model* by the Iowa State University Soil and Water Conservation Student Chapter, Ames, IA.

Materials: groundwater flow demonstration model - available through USU Extension Service and Utah Division of Water Resources

Procedure: 1. Look at the piezometers and water wells in the model. Concept: Piezometers are a type of monitoring well. They differ from drinking water wells in their construction and use.

Discussion: Piezometers are usually installed by researchers studying groundwater. Since groundwater flows from high areas to low areas, knowing the height of water in a number of piezometers (relative to mean sea level) can allow you to map the direction of groundwater flow. Piezometers are designed to be open only at a single point in the aquifer. They usually can have water samples drawn from them, but they are smaller and less durably constructed than drinking water wells since their main purpose is for observation.

The construction of drinking water wells is normally regulated by state codes which specify the depth required and the materials used in construction. They must be carefully located away from sources of contamination, unlike piezometers, which are often intended to collect contaminated water. Existing drinking water wells can sometimes be used as monitoring wells by researchers if exact details of their construction and depth are known.

Procedure: 2. Look at the two pumping wells. Use the hand pump to pump water from the wells. Concept: Groundwater is withdrawn from the ground through wells for use in our homes, farms, and industries.

Discussion: Wells are drilled or driven into water-bearing underground zones called aquifers. A screen is placed at the bottom of the well to keep soil from being pumped out along with the water (bedrock wells do not always have screens). Municipal water systems usually have one or more wells, a water tower or ground level reservoir for storage, and a distribution system of underground pipes which carries water to individual homes.

Procedure: 3. Observe the water levels as defined by the dye levels in the six piezometers. Concept: The potentiometric surface is the level to which water will rise in a well penetrating a confined aquifer.

Discussion: The white sand aquifer is an unconfined aquifer because it has no confining layer above it. The level to which water rises in a well in an unconfined aquifer is the water table.

Procedure: 4. Look at the two pumping wells. Use the hand pump to pump water from the wells. Concept: Pumping wells draw water toward themselves from all directions. The water table gradually becomes lower around a well in an unconfined aquifer as water is withdrawn from the ground. The unsaturated zone (the zone which has been dewatered) around the well is called the cone of depression or drawdown cone.

Discussion: Pumping the well causes a zone around it to become unsaturated. The slope of the water table from the water level in the pumping well to surrounding areas is much greater than the normal slope of the water table, so water can move toward the well much faster than it normally would. The cone of depression is three-dimensional, so water can be drawn toward the well from any direction, even the direction that we would normally consider to be "downstream". If you vary the pumping rate, you can observe changes in the size and shape of the cone of depression by observing the changes in the water level in surrounding piezometers and the change on the rate at which dye traces are drawn toward the well.

Procedure: 5. Pump a well with the hand pump at a very rapid rate. Concept: Drawing water from a well can interfere with the ability of neighboring wells to produce adequate water.

Discussion: If the well is pumped rapidly, the water level in the aquifer may drop below the level of the piezometers so that these piezometers no longer contain any water. A high-capacity well may be able to lower the water table enough so that shallow wells nearby will fall within the cone of depression and will produce little or no water while the high-capacity well is being pumped. This is called well interference.

Procedure: 6. Observe the flow of water out of the artesian well. Concept: Water in the artesian aquifer is under pressure. This pressure causes the water level in wells penetrating the artesian aquifer to rise above the top of the aquifer.

Discussion: The artesian aquifer in the model is under pressure because the confining layer of sandy clay above it significantly retards the water movement upward. Also, this aquifer has a recharge area on the left, but no obvious discharge area. If the confining layer was totally impermeable, there would be no flow in the artesian aquifer at this time. However, in the model and in nature, confining layers usually leak. The pressure in the aquifer allows water to move upward through the confining layer. If dye is injected into the artesian aquifer through one of the deep wells, this upward flow may be observed as dye streaks upward in the sand above the confining layer after about 20 minutes.

Procedure: 7. Close the lake outlet so that the lake fills with water. Open the outlet. Concept: Groundwater is related to surface water and to all other forms of water found on earth through the hydrologic cycle.

Discussion: The hydrologic cycle describes the inter-relationship of groundwater with surface water, such as lakes and streams, and the water found in the atmosphere, such as clouds, snow, and rain. Groundwater often feeds lakes and streams. The place where groundwater becomes surface water is a discharge area. When groundwater simply bubbles up at the surface of the ground, that discharge area is called a spring. The lake in the model is an example of the inter-relationship of groundwater and surface water.

Procedure: 8. Look at the small tapered tube in the artesian outlet in the lake. Notice that the water level in the tube is above the lake level (adding dye to the tube may help you to see this better). Now remove the tube and close the lake outlet. Notice that water flows from this opening, and the lake level begins to rise. Also, observe that there is a slight lowering of the water level in the piezometers since the opening of an outlet for the artesian aquifer reduces the hydraulic pressure caused by the inlet elevation. Concept: When the potentiometric surface of an aquifer is above the surface of the ground, a flowing well or spring may result.

Discussion: There several types of springs that occur in nature, but the most common type of spring is a spot where the water table of an unconfined aquifer intersects the land surface. Such springs often occur in the bottoms and sides of lakes and rivers. Sometimes they appear at the surface of dry land and become the headwaters of a stream. The spring in the model is the result of penetration into and discharge from the artesian aquifer. It is more correctly thought of as a flowing well.

People sometimes believe that springs have mysterious health-giving properties, and that any water coming from a spring must be pure. However, since the water coming from a spring is simply water that is moving through the hydrologic cycle, it can be affected by any ground-water pollution source that contaminates the aquifer supplying the spring.

This activity was adapted from the Iowa State University Soil and Water Conservation Society Student Chapter's *Manual for Groundwater Flow Model*. 10/97





WATER QUALITY

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Activity 4: Groundwater Flow Demonstration Model - Groundwater Contamination

Purpose: To teach basic groundwater concepts including potential contamination sources and groundwater contamination.

Background*: This activity is one in a series of four activities designed to work with a groundwater flow demonstration model. The model is a simulated cut-away section of the earth. It shows the make-up of the ground beneath the surface and allows for the demonstration of groundwater principles.

Water is a vital resource for all living things. It is believed that life originated in water. The bodies of living organisms are mainly composed of water. All living things need water to survive. The many unique properties of water also cause it to have a tremendous impact on our physical environment.

What properties of water make it unique? Water can dissolve more substances in greater quantities than any other liquid; however, this natural ability to dissolve and carry materials allows it to be easily contaminated by human activities as well.

Groundwater contaminants normally enter the system from the surface, not at points deep within the aquifer as the injection of dye through a piezometer might suggest.

Human activities at or near the land surface can contaminate groundwater by moving through the unsaturated zone to the water table. Contamination can continue to move within the saturated zone, and discharge at the stream outlet. Human activities which may contaminate groundwater include over-fertilization, misuse of pesticides, oil spills, leaky landfills, leaky septic systems, and leaky underground storage tanks.

Soil types also play a role in groundwater contamination. Different chemicals react differently with different soils. The cation exchange capacity (CEC) of a soil plays an important part. Sands have low CEC values and pass most contaminants through. Clay has a high CEC and therefore, holds onto many cations. One must know the characteristics of soils and chemicals to manage human activities and reduce the potential for groundwater contamination.

There are direct routes of groundwater pollution. Abandoned wells can be contaminated by human activities at or near the land surface. Remember that pumping water from wells draws water toward it from all directions. Since

wells create a cone of depression around them as they draw water, they can also draw contaminants toward them from any direction: above, below, or even the area that would normally be considered "downstream".

Materials: groundwater flow demonstration model - available through USU Extension Service and Utah Division of Water Resources

Procedure: 1. Pour dye into the "point source." Concept: Human activities at or near the land surface can contaminate groundwater.

Discussion: 1. The "point source" can represent various sources of groundwater contamination, such as landfills, septic systems, manure storage areas, or leaking waste lagoons. Dye should quickly move out of the point source area through the unsaturated zone to the water table. Observe that the "contamination" moves downward in the saturated zone and discharges either at the lake outlet or the outlet on the right side.

Procedure: 2. Pump water from the well next to the lagoon after filling the leaky lagoon with dye. Notice that the well draws water toward it from all directions. It draws the dye from the leaky lagoon as well as those from the piezometers on either side. If you have added red dye to the lagoon, observe that the water being pumped from the well is also red. Concept: Wells can be contaminated by human activities at or near the land surface.

Discussion: Since wells create a cone of depression around them as they draw water, they can also draw contaminants toward them from any direction: above, below, or even the area that would normally be considered "downstream."

Procedure: 3. Observe that the plumes of green dye which you have injected at various points in the model have separated into blue and yellow areas. Concept: Pollutants travel with the groundwater, but they may travel at different rates.

Discussion: Groundwater can carry pollutants that it has picked up as it flows through the system. However, some chemicals move faster than others in groundwater. The soil particles that make up an aquifer may weakly adsorb some chemicals, slowing their flow rate. Others are more soluble and move through more rapidly. These soluble chemicals are good indicator chemicals to test for in drinking water. They can tell us that a pathway exists between a source of contamination and a drinking water well. Other chemicals associated with that source may also move down that pathway, although perhaps not as quickly or in as great a concentration.

Procedure: 4. Notice that the water collecting in the lake is not clear. It has been affected by the dye that has been injected at various points. Concept: Contaminated groundwater may pollute surface water.

Discussion: Surface water bodies such as lakes and rivers have two major sources of water: surface runoff from rainfall and snowmelt, and groundwater flow, called baseflow. Baseflow is the reason that streams flow even during dry spells. In addition, since the temperature of groundwater is about 50°F year-round, baseflow allows streams to flow in winter even when the ground is frozen. Any contaminants in groundwater can then be discharged into surface water. In many ways, surface water is better able to treat contaminants than groundwater. Natural processes such as sunlight, aeration, and turbulence break down some pollutants. However, other pollutants from groundwater, such as nutrients, can cause algae blooms, weed problems, and turbidity in surface waters.

Procedure: 5. Pump the well next to the stream steadily until you see dye being drawn toward it from the stream. Concept: Contaminated surface water can pollute groundwater.

Discussion: If the cone of depression created by pumping the well extends all the way to the stream, the stream can actually recharge the groundwater. This occurs in some municipal wells and irrigation wells located in sandy aquifers near river systems. The filtering action of the sand removes most microorganisms, but chemical contamination can still enter the aquifer.

Procedure: 6. Observe that most of the dye you have added to the leaky lagoon has moved downward and to the right. However, some has moved upward into the gravel layer, above the potentiometric surface. Concept: Capillary action can cause upward movement of water and contaminants above the surface of the water table.

Discussion: Capillarity is a phenomenon that explains the upward movement of water above the surface of the water table. Water is attracted to and adheres to surfaces of solid materials. In addition, cohesive forces (also called hydrogen bonding) bind water molecules to each other. This allows water to move upward in small pores above a saturated layer. The pore spaces in the sandy and gravel materials are small enough to act as capillary tubes. The smaller the size of the pores, the higher the water will rise in them. Because soil pores are not straight uniform openings, capillary rise in natural soils is less than in similar sized glass tubes.

Procedure: 7. Observe that dye spots, when they first enter the aquifer, occur only in a narrow zone. As the dye plumes move down-gradient, they become wider.
Concept: Water quality can vary within an aquifer.

Discussion: Contaminants entering an aquifer often do so only at a point or in a narrow zone. The concentration of the contaminant may be quite high in the small volume of water. Often the contaminant is concentrated near the top of the water table. However, as groundwater continues to move, the zone of contamination widens. Contaminant transport, or the movement of contaminants in the groundwater system, is composed of a number of factors: 1) Advection is the process by which contaminants are transported by the motion of flowing groundwater; 2) Dispersion is the process by which contaminants follow a variety of distinct flow paths through the porous medium (the aquifer) and become more mixed; and 3) Reactions may occur which weakly adsorb contaminants, causing them to move at a slower rate than the water in the aquifer.

The net effect of these processes is dilution--as the plume moves along and widens, a greater volume of water is mixed with the same quantity of contaminants.

Procedure: 8. Pump water from the well in the deep aquifer. Notice that the water levels drop rapidly in the piezometers which extend into the artesian layer. The water levels in the piezometers in the shallow aquifer are relatively stable, since a confining layer separates the two aquifers. However, also notice that dye begins to move downward in the sand aquifer toward the confining layer.
Concept: Confining layers that separate aquifers may leak.

Discussion: The gravel aquifer is able to yield large volumes of water and recharge itself quite rapidly. However, when water is withdrawn from the artesian aquifer, a zone of lower pressure is created which induces water movement downward through the confining layer. Water moves through the confining layer very slowly, carrying dye with it and showing that the confining layer is not the totally impermeable barrier to flow that it might appear to be. In addition, most naturally occurring confining layers vary in thickness, and may be fractured or discontinuous. The presence of a confining layer below is not always sufficient to protect a valuable aquifer below from contamination if a large waste source is placed above it.

- Procedure:** 9. Inject dye into the six piezometers or into the three pumping wells. Fill them until the solution reaches all the way to the bottom and begins to spill out below. Concept: Wells can cause groundwater pollution.
- Discussion:** Wells with defects such as cracked or rusted casings or wells not properly sealed at the surface can serve as conduits for contamination. Wells should be protected from damage while they are being used, and should be properly sealed when they are to be permanently abandoned. Wells should never be used to dispose of unwanted materials. State and county governments have codes regulating the proper construction, maintenance, and abandonment of wells.
- Procedure:** 10. Observe that in operating the model, you need to add dye solutions to the piezometers periodically if you want a continuous dye trace. A single addition of dye at the beginning of the demonstration results in only a single spot of dye to follow. Concept: Sources of groundwater contamination may be continuous or intermittent.
- Discussion:** Some sources of contamination may occur as a single slug, such as a spill. These will eventually move through and be flushed out of the groundwater system. The contamination sources may input contaminants continuously, such as a wastewater treatment lagoon, septic system, or landfill. As these are flushed out of the groundwater system, additional contaminants from the source will move in to replace them.
- Procedure:** 11. Observe that the dye is eventually flushed out of the model. Concept: Once groundwater becomes contaminated, the contamination may persist for long periods of time and over long distances.
- Discussion:** Unlike our model, the environment is not easily able to eliminate pollutants. Contaminants in groundwater may move only a few feet each year, meaning that they will remain in groundwater for many years. Eventually, the contaminants that are not chemically or biologically modified will reach a discharge zone. The contaminated groundwater that discharges into rivers, if not removed by natural treatment processes, eventually makes its way to the ocean.

This activity was adapted from the Iowa State University Soil and Water Conservation Society Student Chapter's *Manual for Groundwater Flow Model*.

10/97



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GLOSSARY

Aeration - The process of bubbling air water or wastewater to remove impurities.

Aquifer - Areas underground where groundwater exists in sufficient quantities to supply wells or springs.

Coagulation - A clumping of particles in water or wastewater to settle out impurities; it is often induced by chemicals such as lime, alum, and iron salts.

Condensation - The process by which a vapor becomes a liquid.

Contamination (Water) - Damage to the quality of water sources by sewage, industrial waste, or other matter.

Disinfection - A process whereby most microorganisms in or on a substance are killed; there is a high probability that pathogenic (disease causing) bacteria are killed in the process but depending on the process, destruction of viruses is not as certain.

Distillation - The separation of different substances in a solution by boiling off those of low boiling point first. For example, water can be distilled and the steam condensed back into a liquid that is almost pure water. The impurities (minerals) remain in the concentrated residue.

Diatomaceous Earth - An earthy deposit formed mainly of diatoms (one-celled marine life forms) that are pulverized and resemble sandy flour.

Erosion - The wearing away of the land surface by wind, water, ice, or other geologic agents. Erosion occurs naturally from weather or runoff but is often intensified by human land use practices.

Evaporation - The process by which water becomes a vapor at a temperature below the boiling point.

Filtration - A mechanical process which involves moving water through a material, usually sand, designed to catch and remove particles.

Groundwater - Water found under the ground, in aquifers and between soil particles.

Groundwater Recharge - Water that moves below the root zone as "deep percolation" and eventually joins the groundwater.

Hard Water - Water containing excessive amounts of calcium and magnesium ions which prevents soap from lathering and produces scale and incrustation.

Hydrologic Cycle (Water Cycle) - The cycle of water movement from the atmosphere to the earth and back to the atmosphere through precipitation, runoff, infiltration, percolation, storage, evaporation, transpiration, and condensation.

Infiltration - The gradual downward flow of water from the surface into the soil.

Irrigation - The controlled application of water for agricultural purposes through human-made systems to supply water requirements not satisfied by rainfall.

Leaching - The process by which soluble materials in the soil, such as nutrients, pesticide chemicals, or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

Nonpoint Source (NPS) Pollution - Forms of pollution caused by sediment, organic and inorganic chemicals, and biological, radiological, and other toxic substances originating from land use activities, which are carried to lakes and streams by surface runoff. Nonpoint source pollution occurs when the rate of materials entering these waterbodies exceeds natural levels.

Percolation - The movement of water through the subsurface soil layers, usually continuing downward to groundwater.

Pollutant - Anything which alters the physical, chemical, or biological properties of water making it harmful or undesirable for use.

Precipitation - Water received on Earth directly from clouds as rain, hail, sleet, or snow.

Runoff - The portion of rainfall, melted snow, or irrigation water that flows across the land surfaces and eventually runs into surface waters such as streams, rivers, and lakes.

Sediment - Transported and deposited particles derived from rocks, soil, or biological material.

Sedimentation - The removal, transport, and deposition of detached soil particles by flowing water or wind. Also, the process of solid particles settling out of water and wastewater treatment processes.

Soft Water - Any water that is not "hard," i.e., does not contain a significant amount of dissolved minerals such as salts containing calcium or magnesium.

Soil Profile - A vertical section of the earth's highly weathered upper surface often showing several distinct layers or horizons.

Stream - A general term for a body of flowing water. In hydrology, the term is generally applied to the water flowing in a natural channel as distinct from a canal. More generally, it is applied to the water flowing in any channel, natural or artificial.

Transpiration - The process by which water vapor escapes from the living plant, principally the leaves, and enters the atmosphere.

Wastewater Treatment Plant - A facility that receives wastewaters (and sometimes runoff) from domestic and/or industrial sources, and by a combination of physical, chemical, and biological processes reduces (treats) the wastewaters to less harmful byproducts; also known by the acronyms WWTP, STP (sewage treatment plant), and POTW (publicly owned treatment works).

Water Table - The upper surface of the zone of saturation; the upper surface of the groundwater.

Watershed - The geographic area in which water sediments and dissolved materials drain to a common outlet such as a larger stream, lake, underlying aquifer, estuary, or ocean.

CORRELATION TO THE UTAH CORE CURRICULUM FOR SCIENCE--1994

To assist educators and students in meeting the requirements of the new Science core Curriculum, the following *Groundwater Flow Demonstration Model Activities* have been correlated to the science standards and objectives for levels K-8.

LEVEL 3 - THIRD GRADE

STANDARD 3030-0 3	Students will recognize various geological features and investigate geological processes.
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OBJECTIVE

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3000-03 02 Identify processes that form geological features.

GROUNDWATER FLOW DEMO. MODEL

Activity 1: Aquifers
Activity 2: Flow Concepts
Activity 3: Wells

LEVEL 4 - FOURTH GRADE

STANDARD 3040-0 3	Students will explain the water cycle.
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OBJECTIVE

3040-03 01 Explain the processes of melting, precipitation, evaporation, condensation, percolation, and erosion.

GROUNDWATER FLOW DEMO. MODEL

Activity 1: Aquifers
Activity 2: Flow Concepts
Activity 3: Wells
Activity 4: Groundwater Contamination

3040-03 02 Construct a chart or drawing of the water cycle.

Activity 1: Aquifers
Activity 2: Flow Concepts
Activity 3: Wells
Activity 4: Groundwater Contamination

LEVEL 5 - FIFTH GRADE

STANDARD 3050-0 1	Students will compare and contrast changes in physical features of Earth over time.
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OBJECTIVE

3050-01 02 Cite and categorize examples of Earth's natural resources.

GROUNDWATER FLOW DEMO. MODEL

Activity 1: Aquifers
Activity 2: Flow Concepts
Activity 3: Wells

STANDARD 3050-0 2	Students will evaluate conservation practices in relation to natural resources.
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OBJECTIVE

GROUNDWATER FLOW DEMO. MODEL

3050-02 <u>01</u>	Identify available natural resources.	Activity 1: Aquifers Activity 2: Flow Concepts Activity 3: Wells Activity 4: Groundwater Contamination
3050-02 <u>02</u>	Analyze conservation practices and pollution problems.	Activity 1: Aquifers Activity 2: Flow Concepts Activity 3: Wells Activity 4: Groundwater Contamination
3050-02 <u>04</u>	Accept the responsibility to become aware of ecological and social issues related to natural resources.	Activity 1: Aquifers Activity 2: Flow Concepts Activity 3: Wells Activity 4: Groundwater Contamination

STANDARD 3050-0 3	Students will understand the characteristics and management of water.
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OBJECTIVE

GROUNDWATER FLOW DEMO. MODEL

3050-03 <u>01</u>	Understand the properties of water.	Activity 1: Aquifers Activity 2: Flow Concepts Activity 3: Wells Activity 4: Groundwater Contamination
3050-03 <u>02</u>	Cite examples of personal, recreational, industrial, and biological uses of water..	Activity 1: Aquifers Activity 2: Flow Concepts Activity 3: Wells
3050-03 <u>03</u>	Estimate amounts of water used daily by individuals, families, and communities.	Activity 1: Aquifers Activity 2: Flow Concepts Activity 3: Wells Activity 4: Groundwater Contamination
3050-03 <u>04</u>	Based on gathered information, form an opinion and defend it regarding management of water resources.	Activity 1: Aquifers Activity 2: Flow Concepts Activity 3: Wells Activity 4: Groundwater Contamination