Curriculum Guide to the Sand Tank Groundwater Model

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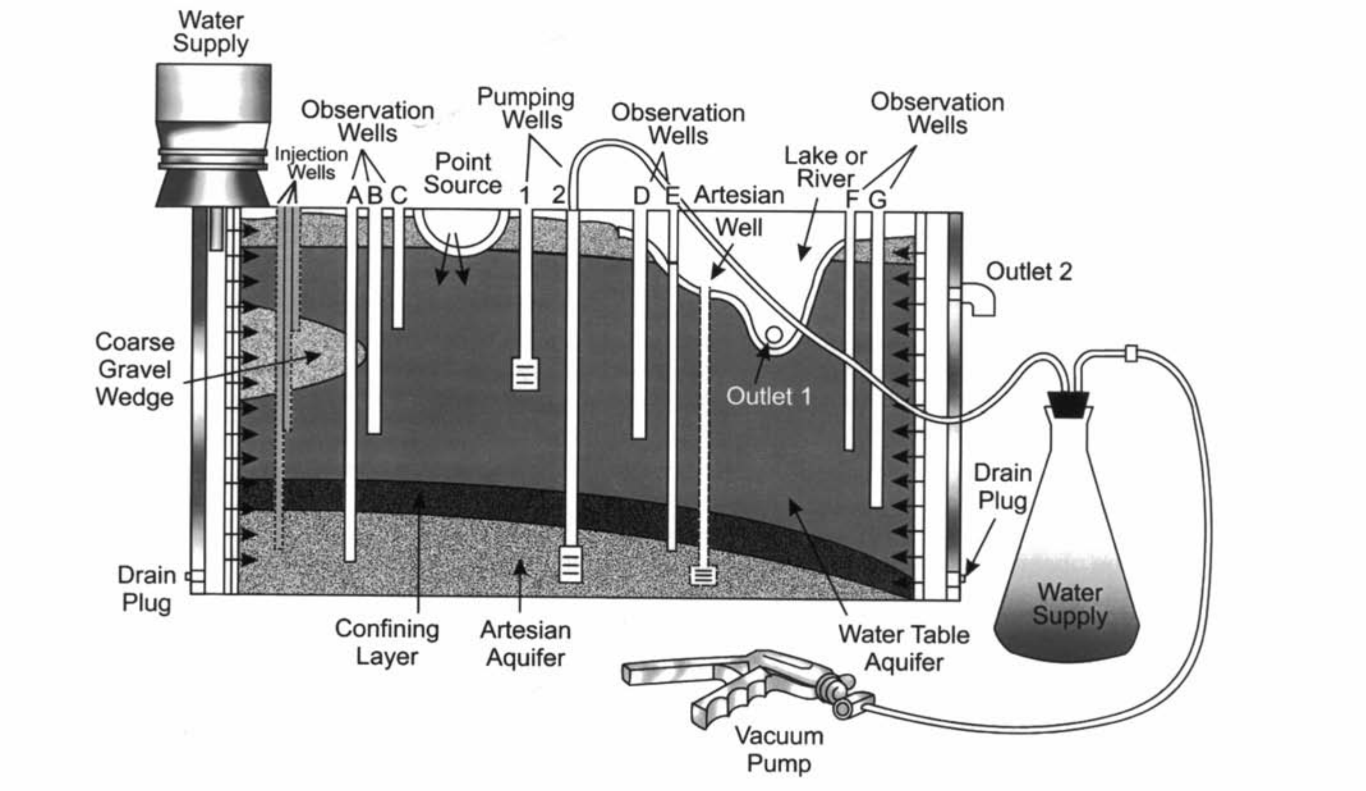
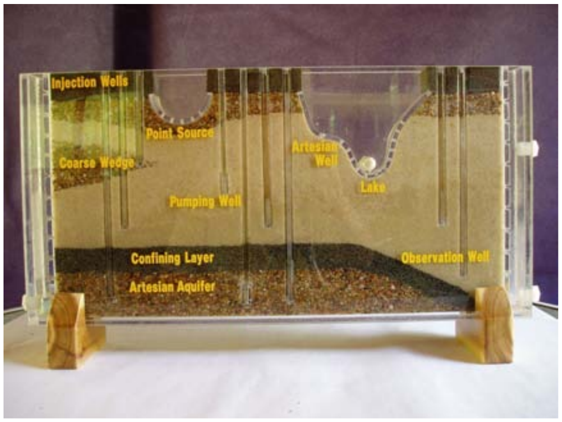


Figure 1 Components of the Model

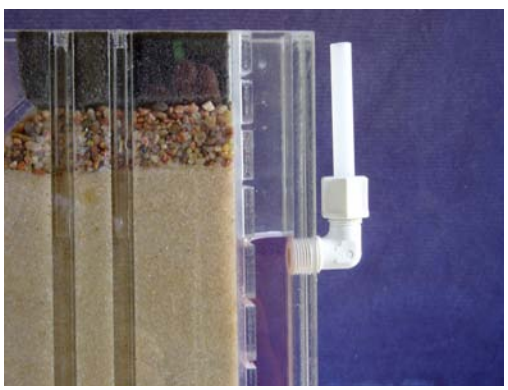
Note: Do not use the injection wells. Liquid placed in the wells takes too long to disperse.

Set Up and Demonstration

1. Place the model on the wooden blocks provided.



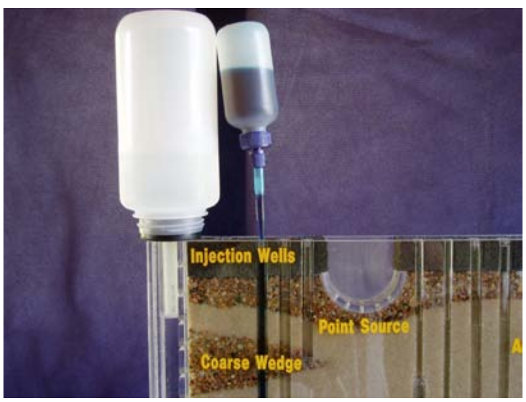
2. Replace the plugs in outlets 1 and 2 with elbows. Turn the elbows upward to prevent water from escaping.



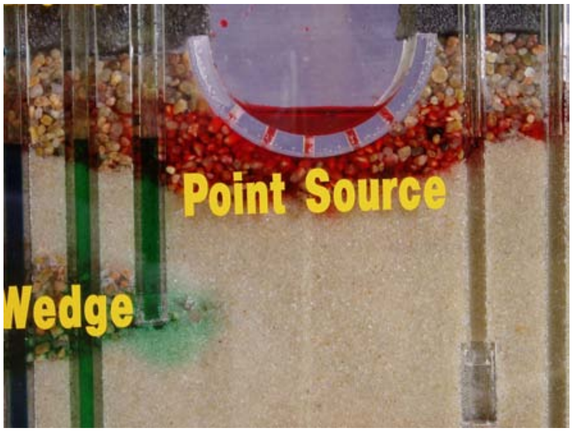
3. Fill the 1000 ml bottle with water. Place the rubber stopper with the short plastic tube tightly into the bottle mouth.

4. Invert the bottle onto the water supply column (left side as you are facing the model).

5. Fill the observation wells or piezometers by attaching a pipette to the green and blue bottles. Fill wells A and E which extend into the artesian aquifer with blue water. Fill wells B, C, and D with green colored water. Fill each well with colored water until it reaches all the way to the bottom and spills out into the adjacent material.

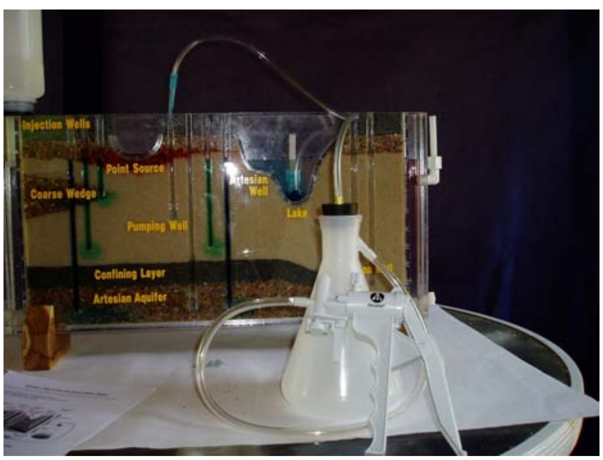


6. When ready add red colored water to the point source or “seepage pond”.



7. Continue to refill the inlet bottle as needed.

Connecting the Vacuum Pump



1. The vacuum pump is connected by plastic tubing to the spout on the neck of the Erlynmeyer flask. The small rubber stopper with the plastic tubing attached is placed tightly into the mouth of the flask. A pipette is placed on the other end of the plastic tubing.

2. Place the pipette tip into a pumping well.

3. Operate the vacuum pump. The pump creates a vacuum in the flask. If the pump becomes difficult to operate, do not attempt to force it. Immediately quit using the pump and report the problem on the feedback form.

4. Empty the flask before it becomes filled.

Vacuum Pump Cautionary Notes

- **Never connect the vacuum pump directly to a pumping well. Always use the flask to create a vacuum and for water collection. Allowing water to enter the pump will destroy it.**
- **Use only light pressure when inserting a pipette into a well. Excessive pressure can cause the Plexiglas to break.**
- **Do not allow water to overflow the flask-water must not be allowed to overflow the pump.**
- **Pump only from pumping wells.**

Cleaning the Model after Use

1. Close outlets 1 and 2.
2. Remove the lower right drain plug.
3. Remove colored water from the observation wells with a syringe.
4. Run 4 bottles of clean water through the model.

Other Cautionary Notes

- **Do not use anything other than water to clean the model. If there is any color left over after flushing, note it on the feedback sheet.**
- **Do not let the model completely dry. This could cause the clay layer to crack as well as keeping sand from shifting into the gravel.**
- **Replace the elbows with the plugs; otherwise the model will not fit back into the case.**
- **If the model is damaged upon receipt from a seam, split do not attempt a repair. Use either packing or duct tape as a quick fix. The model will still be usable.**
- **Remember: the water has to go somewhere. Plan ahead!**
- **Never allow the model to freeze.**
- **The model is fragile. Handle with care.**

Formula for mixing colored water: 1 part food coloring for 75 parts water.

Ground Water Concepts and Model Presentations

GROUND WATER CONCEPTS

These are examples of basic ground water concepts you can demonstrate using the model. You will probably discover many others as you gain experience with the model. As you use the model, keep in mind that the time and distance scales of the model are much different than in an actual aquifer.

1. Concept: Ground water often comes from nearby sources.

Action: Fill the one-quart, wide-mouth bottle with water and invert it on the water supply column.

Discussion: People often erroneously believe that West Virginia's ground water travels hundreds of miles underground. Also, they may believe that the water they drink has been underground for thousands of years. In fact, ground water drawn from shallow wells in West Virginia may have entered the ground within a few miles of the well, and been in the ground only a few years or tens of years. On the other hand, the water in deeper wells may have been in place for a much longer time.

2. Concept: Ground water is contained underground in spaces or pores between sand grains and other soil particles, or in cracks and fractures in rocks. Soil is considered saturated when all pores are filled with water. If some pores contain air, the soil is not saturated.

Action: Allow water to run through the model.

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

3. Concept: Ground water flows from upland areas to low areas or from areas of high hydraulic head to areas of lower hydraulic head.

Action: Allow water to run through the model. Add colored water to the seven observation wells until it moves out of the observation wells into the soil below.

Discussion: Water enters the ground water system in areas called recharge areas. It then flows down gradient until it reaches an area where it can come to the surface of the ground, called a discharge area. When the outlets to the model are closed, there is no flow through it. When either of the outlets are open, water can move through the model, because the elevation of the outlet is lower than the inlet elevation. The colored water that moves into the sand or gravel from the observation wells is carried along by the moving water; thus helping you to see the path and direction of flow.

4. Concept: Ground water is pumped from the ground through wells for use in our homes, farms and industries.

Action: Look at the two pumping wells. Use a syringe or the hand vacuum pump to pump water from the wells.

Discussion: Wells are drilled or driven into water-bearing underground zones (aquifers). Typically a well has a screen 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.) A pump is used to withdraw water from the well. 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 the individual homes.

5. Concept: Ground water is related to surface water and to all other forms of water found on earth through the hydrologic cycle.

Action: Close outlet 1 so that the lake fills with water. Open outlet 2 on the right side of the model.

Discussion: The hydrologic cycle describes the inter-relationship of ground water with surface water, such as lakes and streams, and the water found in the atmosphere, such as clouds, snow and rain. Ground water often feeds lakes and streams. The place where ground water becomes surface water is a discharge area. When ground water 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 ground water and surface water.

6. Concept: The underground units of soil and rock which can 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.

Action: Look at the sand and gravel layers in the model.

Discussion: The fine sand aquifer in the model has a layer of coarse gravel included within it. Below the fine 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 observation wells 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 observation wells.

7. 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. A type of monitoring well called an observation well or piezometer can be used to define the top of the saturated zone.

Action: Allow water to run through the model. Add colored water to the seven observation wells.

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 at either outlet 1 or 2. As water flows from the inlet to the outlet, a slope is created on the water table. Use a water-soluble pen or wax pencil to connect the water levels in each of the observation wells 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 place a small block under the left end of the model. This will increase the difference in height between the inlet and the outlet, 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. The level of the colored water in the observation wells defines the hydraulic head in the aquifer that they penetrate. The observation wells in the sand aquifer nearest the water bottle have higher water levels than observation well D, located near the lake, because they are closer to the recharge area.

8. Concept: The observation wells or piezometers are a type of monitoring well. They differ from drinking water wells in their construction and use.

Action: Look at the observation wells and drinking water wells in the model.
Discussion: Observation wells are usually installed by researchers studying ground water in an area. Since ground water flows from high areas to low areas, knowing the height of water in a number of observation wells (relative to mean sea level) allows you to map the direction of ground water flow. Observation wells are designed to be open only at a single point in the aquifer. Usually water samples can be drawn from them. However, since they are not intended to be permanent sources of water, they are often not as large or as durably constructed as drinking water wells. The construction of drinking water wells is normally regulated by state regulations which specify the methods and materials used in construction. They must be carefully located away from sources of contamination, unlike observation wells, which are often intended to collect contaminated water. Sometimes existing drinking water wells can be used as monitoring wells by researchers if exact details of their construction and depth are known.

9. Concept: Water in artesian aquifers is under pressure. This pressure causes the water level in wells penetrating the artesian aquifer to rise above the top of the aquifer.

Action: At this time, be sure that the small tapered tube is inserted in the artesian well in the lake. Look at the water levels in observation wells A and E. Notice that the water level is above the top of the gravel aquifer which they penetrate, and is also above the water levels in observation wells B, C, and D.

Discussion: The artesian aquifer in the model is under pressure because the confining layer of sandy clay above it significantly retards 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 colored water is injected into the artesian aquifer through the black injection well, this upward flow may be observed as dye streaks upward in the sand above the confining layer after about 20 minutes.

10. Concept: The potentiometric surface is the level to which water will rise in a well penetrating a confined aquifer.

Action: Observe the water levels as defined by colored water levels in the seven observation wells.

Discussion: The fine 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. In the confined artesian gravel aquifer, the potentiometric surface is above the top of the aquifer, and is actually above the water table in the overlying unconfined aquifer.

11. Concept: When the potentiometric surface of an aquifer is above the surface of the ground, a flowing well or spring may result.

Action: 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 colored water to the tube may help you to better see this.) Now remove the tube and close the lake outlet 1. 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 observation well E, since the opening of an outlet for the artesian aquifer reduces the hydraulic pressure caused by the inlet elevation.

Discussion: There are 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, or artesian, 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 in springs 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.

12. Concept: The texture of the materials in an aquifer affects the rate of flow through the aquifer.

Action: Notice that the water feeding the model enters along the entire vertical channel at either end. Inject colored water into the three injection wells at the left end of the model. Notice that the colored water injected into the coarse gravel wedge at the left of the model disperses much faster than the colored water injected into the fine sand. The colored water movement out of the coarse gravel wedge will radiate out in all directions.

Discussion: Both the coarse gravel wedge and the fine 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 area the water contacts, the less frictional resistance there will be in the moving water. The lower frictional resistance leads to a greater velocity of ground water flow. The gravel can then be said to have a higher **intrinsic permeability**, and as a result, a higher hydraulic conductivity. 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 coarse gravel wedge than into the sand layer around it. However, all this water entering into the wedge must have a way to exit. Hydraulic pressure is created which allows the water to exit even in an upward direction into the sand above the wedge. In other words, the unconfined sand aquifer becomes a confining layer for the wedge, creating artesian conditions in the gravel. In this case, down gradient is actually upward. The colored water movement should illustrate this. You will also notice that the color spot injected into the injection well in the sand aquifer moves more slowly than the color spots that come from observation wells B and C, indicating that less water per unit area moves through this area of the model because of preferential movement through the wedge.

13. Concept: Water flows into rivers from many directions.

Action: Use a second bottle and stopper unit to add water at the right end of the model. Turn the elbow upward at outlet 2 and the elbow of outlet 1 downward. Be sure the observation wells are still filled with colored water.

Discussion: Rivers are natural discharge areas for ground water. In the model, you will observe color traces moving from all directions toward the river and then entering into the river when outlet 1 is open.

14. Concept: Pumping wells draw water toward them 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.

Action: Use a syringe or the vacuum pump to withdraw water from pumping well 2. Observe that the colored water level in observation well D, and to a lesser extent the colored water levels in observation well B and C, become lower as you pump well 2. Notice that colored water traces from above, below, to the right and to the left all move toward the bottom of the pumping well.

Discussion: Pumping the well causes a zone around it to become unsaturated. This unsaturated zone is called a cone of depression. 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 many directions, even the direction that we would normally consider to be "downstream". If you vary the pumping rate on the vacuum pump, you can observe changes in the size and shape of the cone of depression by observing the changes in the water level in surrounding observation wells and the change in the rate at which dye traces are drawn toward the well. The source of water drawn from pumping well 2 is basically gravity drainage of water stored in the aquifer. However, the source of water drawn from pumping well 1 in the artesian aquifer is quite different. The artesian aquifer yields water mainly because reduction in pressure in the aquifer as water is withdrawn leads to expansion of the water in the aquifer and compaction and settling of the aquifer materials. Cones of depression in confined aquifers are usually not as deep, but spread out over a larger area than those in unconfined aquifers.

15. Concept: Drawing water from a well can interfere with the ability of neighboring wells to produce adequate water.

Action: Pump well 2 with the vacuum pump at a very rapid rate.

Discussion: If well 2 is pumped rapidly enough, the water level in the aquifer will drop below the level of observation wells C and D, so that these observation wells 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.

16. Concept: Human activities at or near the land surface can contaminate ground water.

Action: Pour colored water into the "point source" to a level above the holes drilled in the sides of the lagoon (point source). If the lagoon does not leak, help it by inserting the needle of the syringe through the holes in the lagoon into the gravel below.

Discussion: The point source can represent various sources of ground water contamination, such as landfills, septic systems, manure storage areas, or leaking waste lagoons. Colored water should quickly move out of the lagoon through the surface unsaturated zone to the water table. Observe that this "contamination" moves downward in the saturated zone and discharges either outlet 1 or outlet 2.

17. Concept: Wells can be contaminated by human activities at or near the land surface.

Action: Pump water from well 2 with the vacuum pump after filling the point source with colored water. Notice that well 2 draws water toward it from all directions. It draws the colored water traces from the point source as well as those from the observation wells on either side. If you have added red colored water to the lagoon, observe that the water being pumped from well 2 is also red.

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."

18. Concept: Pollutants travel with the ground water, but they may travel at different rates.

Action: Observe that the plumes of green colored water which you have injected at various points in the model have separated into blue and yellow areas.

Discussion: Ground water can carry pollutants that it has picked up as it flows through the system. However, some chemicals move faster than others in ground water. 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.

19. Concept: Contaminated ground water may pollute surface water.

Action: Notice that the water collecting in the lake is not clear. It has been affected by the colored water that has been injected at various points.

Discussion: Surface water bodies such as lakes and rivers have two major sources of water: surface runoff from rainfall and snowmelt, and ground water flow, called baseflow. Baseflow is the reason that streams flow even during dry spells. In addition, since the temperature of ground water is about 55degrees F year-round, baseflow allows streams to flow in winter even when the ground is frozen. Any contaminants in ground water can then be discharged into surface water. In many ways, surface water is able to treat contaminants better than ground water can. Natural processes such as sunlight, aeration, and turbulence break down some pollutants. However, other pollutants from ground water, such as nutrients, can cause algae blooms, weed problems, and turbidity in surface waters.

20. Concept: Contaminated surface water can pollute ground water.

Action: Pump well 2 steadily with the vacuum pump until you see colored water being drawn toward it from the river.

Discussion: If the cone of depression created by pumping well 2 extends all the way to the river, the river can actually recharge the ground water. 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 enter the aquifer in this way.

21. Concept: Ground water is recharged by precipitation and snowmelt.

Action: Use a sprinkling device to add water along the surface of the model.

Discussion: Recharge of the aquifer from above creates additional head that pushes colored water plumes near the surface deeper into the aquifer. Recharging the model in this way represents natural conditions. Ground water contaminants normally enter the system from the surface, not at discrete points deep within the aquifer as the injection through observation wells might suggest.

22. Concept: Capillary action can cause upward movement of water and contaminants above the surface of the water table.

Action: Observe that most of the colored water 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.

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 gravelly 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.

23. Concept: Water quality can vary within an aquifer.

Action: Observe that colored water spots, when they first enter the aquifer, occur only in a narrow zone. As the colored water plumes move down gradient, they become wider.

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 that small volume of water. Often the contaminant is concentrated near the top of the water table. However, as ground water continues to move, the zone of contamination widens out. Contaminant transport, or the movement of contaminants in the ground water system, is composed of a number of factors:

- **Diffusion** begins when a pollutant comes in contact with the ground water.
- **Advection** is the process by which contaminants are transported by the motion of flowing ground water.
- **Dispersion** is the process by which contaminants follow a variety of distinct flow paths through the porous medium (the aquifer) and become more mixed.
- **Degradation** 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.
- **Retardation** shows that pollutants have the tendency to disassociate in ground water into positively charged cations and negatively charged anions. It is possible for the soil's charge to attract, or adsorb, the oppositely charged pollutant ion.
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It is also useful to note that if recharge were induced by sprinkling water over the top of the entire model, the colored water traces would angle downward and widen as they moved across the model. This method of recharge would more closely simulate natural conditions.

24. Concept: Confining layers that separate aquifers usually leak.

Action: Pump water from well 1 using the vacuum pump. Notice that the water levels in observation wells A and E, which extend into the artesian layer, drop rapidly. The water levels in observation wells B, C, and D are relatively stable, since a confining layer separates the two aquifers. However, also notice that colored water begins to move downward in the sand aquifer toward the confining layer.

Discussion: Most of the recharge in the gravel artesian aquifer occurs on the left side. 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 colored water 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.

25. Concept: Wells can cause ground water pollution.

Action: Inject colored water into the seven observation wells or into the two pumping wells using a syringe. Fill them until the solution reaches all the way to the bottom and begins to spill out below.

Discussion: Wells with defects such as cracked or rusted casings or wells not properly sealed at the surface can serve as conduits for contaminated surface water to enter the ground water. 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 government has regulations addressing the proper construction, maintenance and abandonment of wells.

26. Concept: Sources of ground water contamination may be continuous or intermittent.

Action: Observe that in operating the model, you need to add colored water solutions to the observation wells periodically if you want a continuous color trace. A single addition of colored water at the beginning of the demonstration results in only a single spot of color to follow.

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 ground water system. The time period required may be days to years. Other contamination sources may input contaminants continuously, such as a wastewater treatment lagoon, septic system, or landfill. As these are flushed out of the ground water system, additional contaminants from the source will move in to replace them.

27. Concept: Once ground water becomes contaminated, the contamination may persist for long periods of time and over long distances.

Action: Observe that the colored water is eventually flushed out of the model.

Discussion: Unlike our model, the environment is not able to eliminate pollutants easily. Contaminants in ground water may move only a few feet each year, meaning that they will remain in ground water for many years. Eventually, the contaminants that are not chemically or biologically modified will reach a discharge zone. The contaminated ground water that discharges into rivers, if not removed by natural treatment processes, eventually makes its way to the ocean.

28. Concept: Ground water flow lines have curved paths.

Action: Observe colored water traces that extend from the recharge area to the discharge area. Notice that they travel in a nearly straight line across the model and then curve upward at the discharge area.

Discussion: Recall that the force potential, or the driving energy behind ground water flow, is made up of two energy components: the pressure head and the elevation head. Recall also that ground water moves from areas of high total head to areas of lower total head. At the recharge area of the model, the sum of the energy forces causes water and color to move in a downward direction. At the discharge area, the pressure head and the total head become lower, since water is being removed from the system at that point. Although water is moving "uphill," it is actually moving from an area of higher total head to an area of lower total head.

Suggested Ground Water Model Presentations

These are suggestions for how concepts can be combined to make a unified presentation using the model. At first, you may find it difficult to organize your presentation, so these suggestions will help you get started. Later, with practice and familiarity with using the model, you will discover your own “favorite presentation,” specially tailored to the audience you are presenting the information to.

1. **General information about ground water.**
C1. Ground water often comes from nearby sources.
C2. Ground water is contained in pore spaces and cracks.
C3. Ground water flows from high head to low head.
C4. Ground water can be withdrawn from wells.
C5. Ground water is part of the hydrologic cycle.
C21. Ground water is recharged by precipitation.
C16. Human activities can contaminate ground water.
C17. Wells can be contaminated by human activities.

2. **Water quality.**
C23. Water quality can vary within an aquifer.
C26. Contamination may be continuous or intermittent.
C18. Pollutants travel with the ground water.
C25. Wells can cause ground water pollution.
C19. Contaminated ground water can pollute surface water.
C20. Contaminated surface water can pollute ground water.

3. **Properties of aquifers.**
C6. Definition of aquifers.
C7. Definition of water table.
C10. Definition of potentiometric surface.
C9. Definition of artesian aquifers.
C11. Springs may originate in artesian aquifers.
C24. Confining layers usually leak.
C12. Texture of the aquifer materials affects flow rate.
C22. Capillary action may cause upward movement of water.

4. **Characteristics of water wells.**
C4. Ground water can be withdrawn from wells.
C8. Observation wells and drinking water wells may differ.
C10. Definition of potentiometric surface.
C11. Flowing wells may result from artesian aquifers.
C14. Definition of cone of depression.
C15. Wells may interfere with each other.
C17. Wells can be contaminated by human activities.
C25. Wells can cause ground water pollution.

5. **Interrelationship of ground water and surface water.**
C5. Ground water is part of the hydrologic cycle.
C13. Water flows into rivers from many directions.
C19. Contaminated ground water can pollute surface water.
C20. Contaminated surface water can pollute ground water.
C11. Springs may result from artesian aquifers.

Material for this manual was adapted from: "Sand-Tank Ground Water Flow Model Manual"; University of Nebraska-Lincoln; Department of Biological Systems Engineering, Cooperative Extension; http://groundwater.unl.edu/.

Appendix
A Tour of a Typical Demonstration