Modeling the Interconnection between Surface and Groundwater

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Three Explorations

1. Model two fundamentally different types of streams.
2. Observe and follow subsurface pollution near a stream.
3. Design an experiment to observe and follow a surface spill in an area away from a stream.

Physical Model

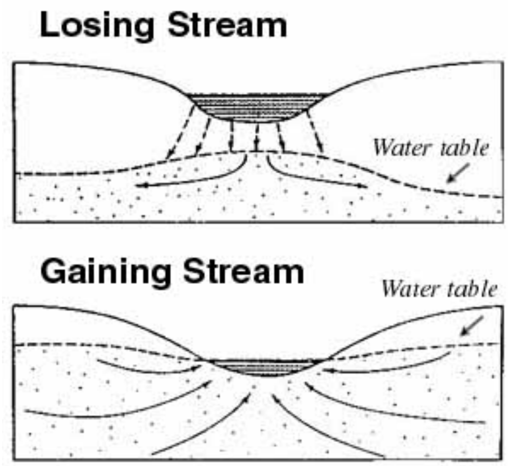
The ground beneath our feet looks different in different parts of the country. In cities, a thin layer of concrete or asphalt covers a layer of soil. Below the soil is bedrock. Soil layers are thicker in flat, moist regions and thinner in arid regions or on steep slopes. Bedrock could consist of igneous, metamorphic, or sedimentary rock. Some common sedimentary rocks such as conglomerate and sandstone can allow water to soak through the large pores. Siltstone, limestone, and igneous and metamorphic rocks have much smaller pore space that limits the rate at which water can flow through. Using sand and silt, we can make a simple model that behaves like our local ground.

Scale

Our model will have the following scale: 1 cm on the model = 2 meters in the real world. Because we are using sand to represent either soil, sandstone, or conglomerate, we have to consider the scale of the pore size in the sand. Since our sand is loose and does not contain a lot of silt, our porosity is probably higher than what might be found in the ground. The effect of the scaling of the pore size is to speed up the rate at which the groundwater moves. This is a good thing for us, because if we used real rock, we would have to wait a long time to see changes. In the real world, groundwater moves very slowly (centimeters/day). After we do some experiments with just sand, you can create more sophisticated models using layers of silt to model impermeable layers such as siltstone, limestone, igneous rocks, and metamorphic rocks.

Exploration #1:

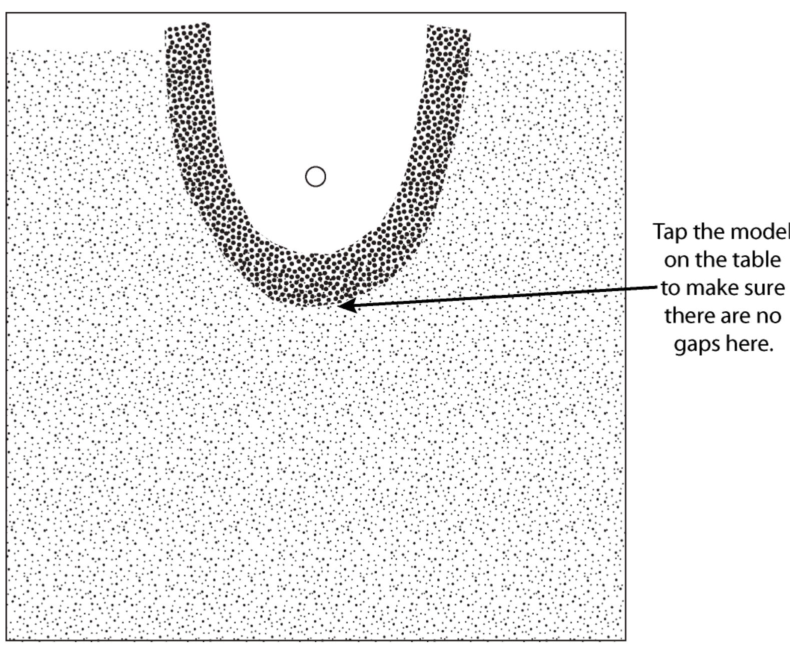
Two Types of Streams



Materials you need:

- Acrylic Groundwater model
- Black foam French fry
- Cup of sieved beach or river sand
- Plastic spoon
- 250 mL squirt bottle filled with tap water
- Pencil
- Catch basin

Step 1: Push the black foam French fry into the model using the eraser end of a pencil. Make it form the shape you see in the figure below. Place the model in the catch basin. Pour the sand into the model on both sides of the black foam, but try not to get any sand in the center loop of foam. Tap the model on the table to get the sand to settle. Add more sand to fill the model until tapping does not produce any new gaps. Slowly add water to the stream channel using the squirt bottle and observe how the water seeps into the ground. This is called an **Losing** (also called 'Influent') stream. Influent streams are common in arid environments where the water table is deep. Rain water that runs across the surface and washes into stream channels will gradually soak into the streambed and help "refill" the aquifer.

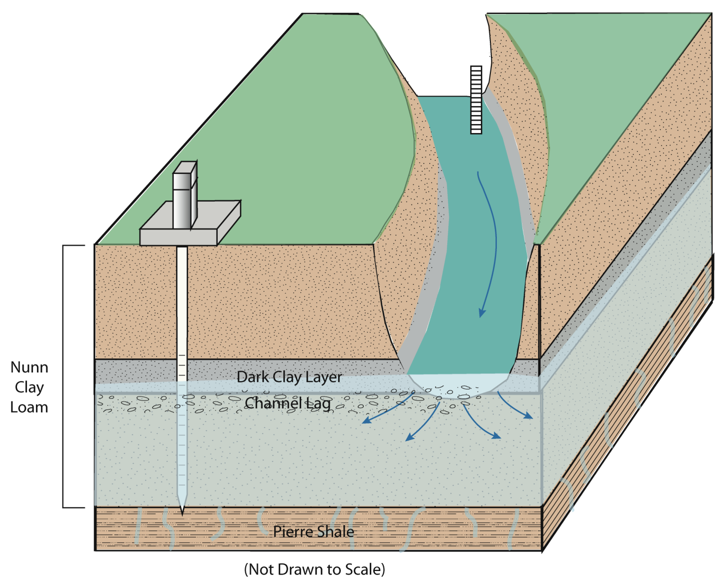


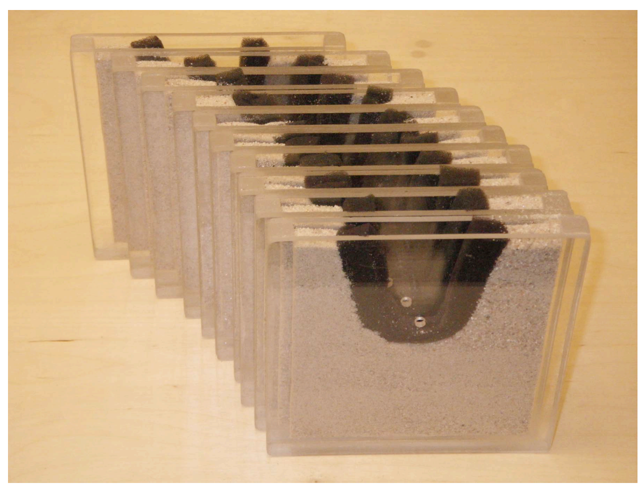
Step 2: Continue to add water until all of the sand in your model is wet. Practice trying to keep the sand wet on either side of the stream channel. Pretend that your squirt bottle is making gentle rain, not a thunder storm. If the sand settles in your model and the sand pulls

away from the black foam, use a spoon to add a little more sand to your model, being careful not to get any sand in the stream channel. Make sure the stream height is at the hole in the model and that water is flowing freely from the hole. (This might take two people.)

This is called an **Gaining** (also called 'Effluent') stream. Effluent streams occur in wetter, temperate environments where the water table is at or above the height of the stream. Is such a situation, the stream will flow even when it is not raining. The source of the water in the channel is rain or snow melt water that was absorbed by the ground over the last several months.

Step 3: Your model is a cross-sectional slice of a stream. If we were to put all of the models in the class together back-to-back as shown in the photo below, we would have a meandering stream. The hole in the model allows the stream to flow downstream.





Exploration #2:

Observing the Motion of Subsurface Pollution near a Stream

For this exercise, we are going to see what happens if we have leaks in underground pipes or tanks near a stream. The pipes and tanks could either contain oil or sewage. The leaks are about 14 meters deep.

To model the groundwater system, it is important to add "rain" to the model to replace the water that flowed out of the stream hole. This will keep the model in ***equilibrium***.

Additional materials you need:

- Pipette
- Concentrated red food coloring to simulate pollution
- Colored pencil
- Vis-a-vis marker

Step 1: Suck up some red food coloring in the pipette.

Step 2: Slowly and carefully insert the pipette into the sand close to the front edge of the box on one side of the stream. When the tip of the pipette is about 2 cm from the bottom of the model, squeeze the bulb to inject the "pollution" into the wet sand. Keep the bulb squeezed as you pull it out of the sand, or else you will slurp up all of the pollution again. Do the same for the other side of the stream. Depending on where the tip of your pipette ended up, the pollution might be easier to see on the back of the model.

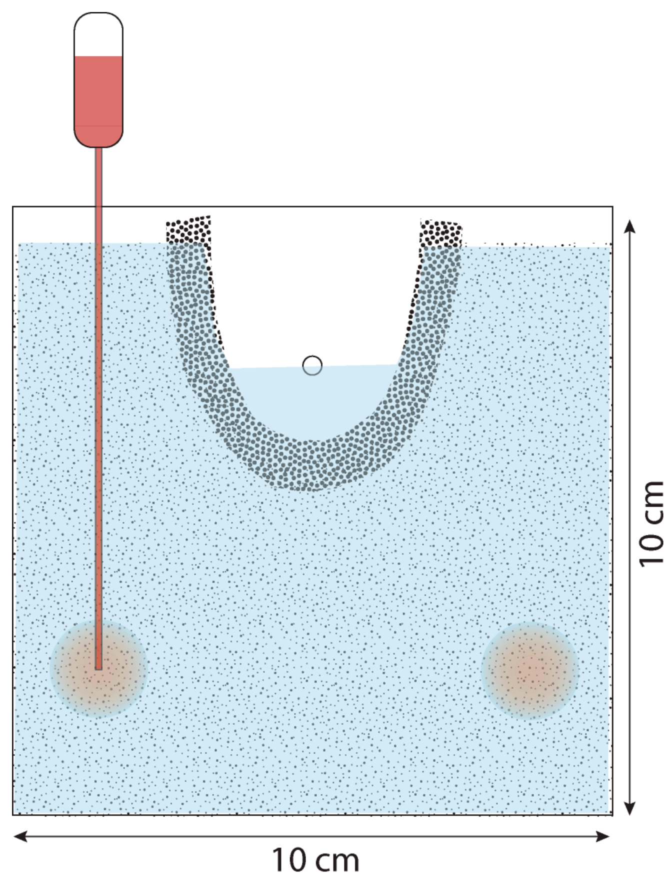
Step 3: Use the Vis-a-Vis pen to circle the plume of pollution on the model.

Step 4: On the diagram to the right, draw a prediction as to what you think will happen to the pollution if it begins to rain.

Step 5: Use the squirt bottle to keep slowly dribbling "rain" onto the sand on either side of the stream channel. Have another person make sure the water continues to flow out of the hole in the stream.

Step 6: Observe what is happening.

Step 7: On the same diagram, use a different colored pencil to show what happened to the pollution.



Step 8: Describe what you see happening. Was your prediction correct?

Step 9: Look at what is happening to the models of other groups.

Step 10: When everyone gets to this step, we will have a group discussion on what could be causing the behavior you observed.

Step 11: Dump the sand into the wet sand collection bucket, rinse, and shake dry.

Exploration #3:

Modeling Surface Pollution near a Drinking Water Well

Antifreeze is a brightly colored liquid that helps to keep a car's engine cool. A car has about 8 to 16 liters of antifreeze in its radiator. Antifreeze has a sweet smell and animals like to lick it, but it is a deadly poison.

Your final task is to design and conduct an experiment that answers the following question: "Can spilled automobile antifreeze contaminate a 14 meter deep drinking water well near a farm house on flat land?" Hint: start with water saturated sand.

Materials you need:

- Acrylic Groundwater Model
- Clean beach or river sand
- Catch basin
- A small piece of black tape to cover the hole in the model.
- 250 mL squirt bottle filled with tap water
- Foam cutout of a car and a house
- Food coloring to simulate antifreeze
- Pipette
- Metric ruler
- Plastic cup
- Colored pencils

Step 1: Describe what you think happens to antifreeze that is spilled on the ground:

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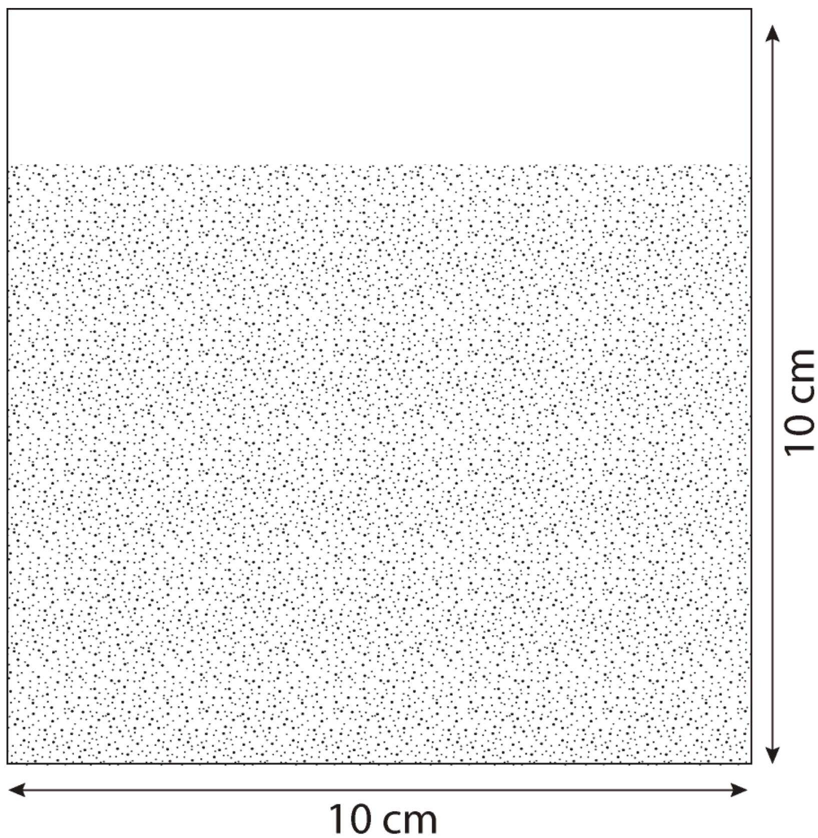
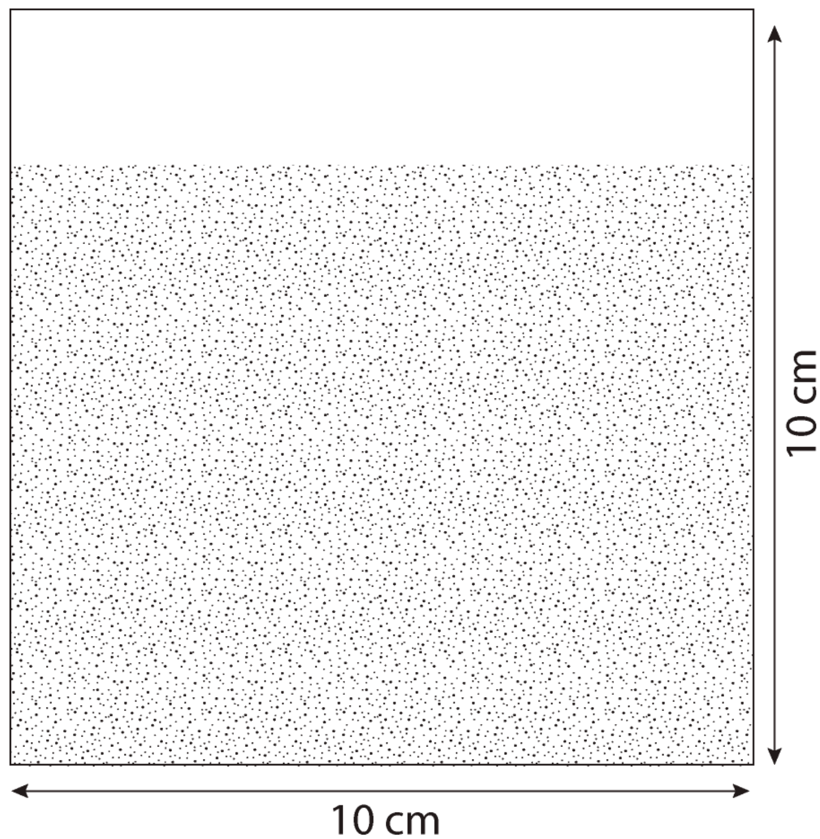
Step 2: Next, draw a picture in the box below of how you plan to set up your model and make a prediction of what you think will happen to the pollution.



Step 3: Next, outline what steps you will need to take to perform your experiment:

Step 4: Conduct your experiment following the outline you made above.

Step 5: Finally, draw what you observed:



Step 6: What conclusions can you draw from your experiment? How has your experiment changed or confirmed what you thought would happen in real life?