How Do Our Actions Affect Water Quantity

Water is an essential resource for all living things. How we live on our watershed can impact water quantity and quality. It is important to recognize how humans alter watershed dynamics, but students often find it challenging to visualize watershed processes and understand how decisions that they make as individuals and together as a community can affect water resources. Hydrogeology models can provide students with the opportunity to see firsthand how ground cover affects surface runoff and groundwater recharge and how pollution travels through creeks, streams, and aquifers. Although the lab experiment described was written for sixth grade, activities using the model can be adapted to accommodate any grade level.

Hydrogeology models

Hydrogeology models can be used as short demonstrations or as long-term research projects. The creation of the model described here was inspired by similar models that I had seen used for educational outreach demonstrations at community science events (City of Austin Earth Camp; Selah, Bamberger Ranch Preserve; and Hays County Texas Cooperative Extension). I was amazed by how effective the models were at teaching about what happens when it rains and how ground cover affects surface runoff and groundwater recharge. Hydrogeology models can be built (see Figure 1) and used to illustrate how four different ground covers (concrete, soil, nonnative grass, and native plants) influence surface runoff and groundwater recharge and how pollution can contaminate water resources.

The three-day lab experiment described in this article became part of a month-long unit focused on the importance of local water resources and current practices that threaten those resources (Chapa, Gordon, and Parmenter 2004). Prior to conducting the experiment, students should already have an understanding of the water cycle. These hydrogeology models can be used to either introduce or go into a deeper understanding of Earth system processes such as erosion, how water (a solvent) can transport pollution, and how human actions have changed our surrounding environment, as well as to provide opportunities for students to engage in, understand, and experience inquiry as a way scientific knowledge is produced.

In *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning,* the editors outline the essential elements of inquiry along a continuum of the amount of learner self-direction, or inversely, amount of direction from the teacher or curriculum (NRC 2000). The different levels of inquiry include *confirmation experiences*, *structured inquiry*, *guided inquiry*, and *open* or *independent inquiry*. Depending on your students' previous experiences with inquiry, these hydrogeology models can be used along any part of this continuum of inquiry-based science. This lab investigation shifts along the continuum to help students gain insightful understanding of the inquiry process. The end of the article describes potential extension activities that enable students to use the models to engage in open or independent inquiry, where they are formulating their own research questions and experiment designs.

Scientific investigations

Before beginning the experiment, students learned about the watershed that they live in and importance of water resources. As part of a class discussion, students were asked open-ended questions about observations they have made about what happens when it rains, including where the water goes and how rain acts similarly and differently on different surfaces (such as a concrete driveway compared to a grassy field). Next, students worked with a partner to determine how they would design an experiment to test how ground cover affects surface runoff and groundwater recharge. They were asked to briefly write about their experiment or draw their model.

After some students shared their experiment designs with the class, they were presented with the hydrogeology models built to demonstrate how concrete, soil, nonnative grass, and native plants influence surface runoff and groundwater recharge. Students discussed unique features of the four different ground covers that were selected to match local conditions (as an alternative to having preselected the types of ground covers described in this article, students could have a role in suggesting and selecting types of ground covers). Students were asked to hypothesize what would happen if each ground cover received the same amount of rain. They identified the independent and dependent variables, as well as variables that needed to be held constant, such as the amount of water and the rate of "rain." Next, students listed lab equipment that they would use to conduct the experiment. Although the teacher helped students identify the research question of their scientific investigation (How does ground cover affect surface runoff and groundwater recharge?), this lab prepares and inspires students to generate their own research questions for further experimentation.

by Jessica Gordon

Data collection and representation

One of the things students enjoyed the most was "raining" on the models. To begin the experiment, students sprinkled 1,000 mL of "rain" slowly and evenly over each ground cover. (Note: The updated version of the models only requires 250 mL of rain for each ground cover.) Students used graduated cylinders and beakers to measure the volume (mL) of rain they used and the accumulated runoff and recharge. Conducting multiple trials provided an opportunity for everyone to participate as rain simulators, scientists measuring the amount of runoff or recharge for a particular ground cover, data recorders, and materials managers. Clearly identified roles for students helped keep them engaged in the investigation.

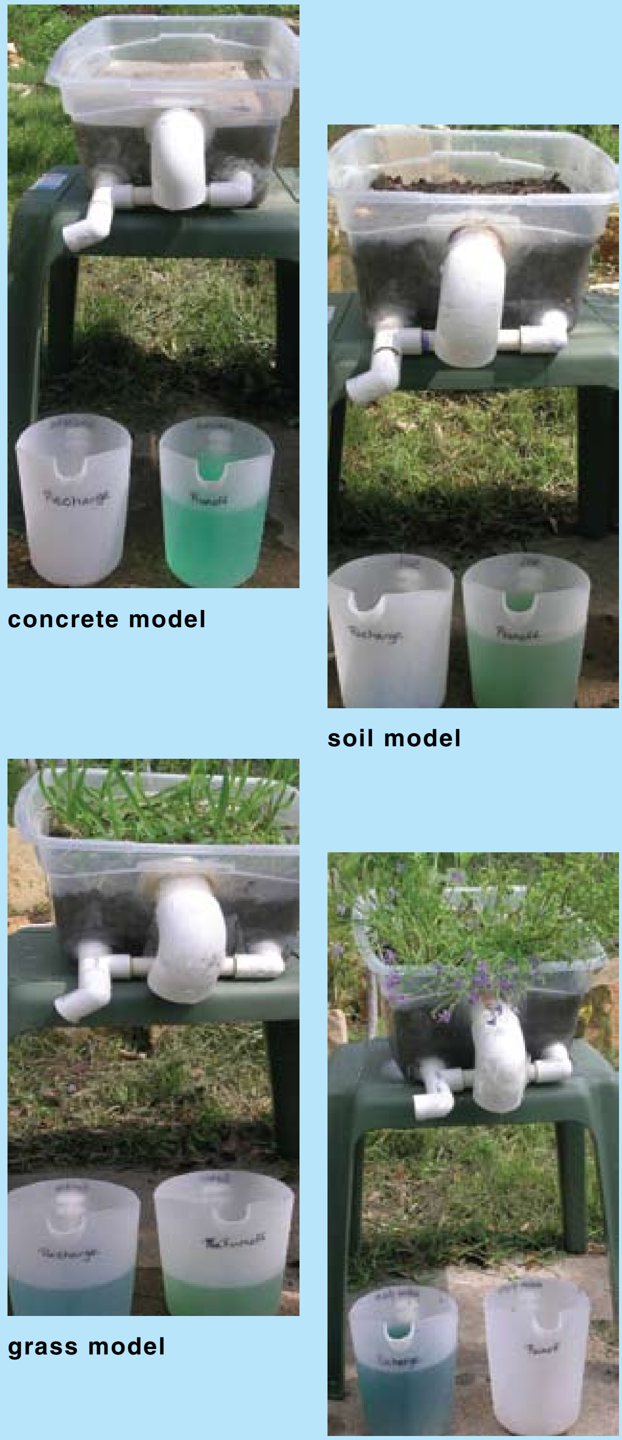
The class collected data as a team of scientists. Results were shared with the class to facilitate completion of individual data-collection charts (Figure 2). We began by running three trials. Each trial had different results, which provided an excellent opportunity to discuss the importance of conducting multiple trials. Students were asked if they thought that conducting three trials was enough. Most students suggested that more trials should be conducted due to inconsistencies in the data and because "more trials leads to more information, which can support a better conclusion." Data are likely to vary throughout the day as the soils become more saturated (although general trends should remain constant). It is interesting to collect a record of data throughout the day so students can analyze more long-term trends than is possible for them to collect in a class period or two.

Students calculated the average amount of surface runoff and groundwater recharge for each groundcover. They were asked to think about what kind of graph(s) would most effectively convey information about the runoff and recharge for different types of ground covers. Most students drew bar graphs to visually represent the data that they had collected (Figure 3). While analyzing their graphs, students noticed an inverse relationship between runoff and recharge. In their lab reports, they described patterns in their graphs such as "when recharge declines runoff increases," or said another way, "as runoff increases, recharge decreases."

Assessment

Students were formatively assessed throughout the activity. Their ability to use evidence for supporting conclusions provided summative assessment opportunities. Most students concluded that "native plants had the highest amount of recharge…[and] concrete had the most runoff." Some students successfully used data to support this conclusion: "The cement had 85% of runoff and 15% of recharge. That is not very good for the environment…the native plants has 4% runoff and 45% recharge…at first I did not understand anything. But then I started to understand." Although many students predicted that concrete would have the most runoff and native plants would have the most recharge, they did not expect the water to run off as quickly as it did, nor did they expect the different ground covers would cause such a striking difference in runoff and recharge.

FIGURE 1 How to build the hydrogeology models



concrete model

soil model

grass model

native plant model

These hydrogeology models can be made with four 7–15 quart rectangular plastic containers. In the pictures at left, blue food coloring was placed in the containers that catch the recharge and green food coloring was placed in the containers that catch the runoff so the water levels could easily be seen from afar.

Materials

The following description of materials provides instructions for building a set of four hydromodels (you may choose to build one set for the class or multiple sets). A 7-quart hinged-lid storage box (13½” L × 7 7/8” W × 6½” H) works well for the models ($2–$3 each). Other containers that size or larger could work as long as containers are sturdy and have a flat edge (where the runoff and recharge spouts will be attached). Kid’s metal watering cans can be purchased (for about $6–$7 each at garden stores). As a less expensive alternative, plastic watering cans can be purchased (at garden stores, Target, or Wal-Mart) or made out of plastic containers (such as 266 mL plastic cups with holes poked in the bottom). It is recommended that they have many holes evenly distributed to simulate rain. Eight clear containers (large enough to hold at least 250 mL of water) are needed to catch the surface runoff and groundwater recharge (measuring cups, large graduated cylinders, pitchers, or plastic cups could be used). Plants, soil, and gravel can be obtained from your own yard, the schoolyard, or a local garden store. Avoid using potting soil, for it does not accurately model real-world conditions. It is better to use local soils or a landscaping, garden, or compost mix. A ratcheting PVC cutter, a drill, 1” drill bit, ¾” PVC tubing, four ¾” 45° elbows, two ¾” couplers, 7/8” drill bit, ½” PVC tubing, four ½” Ts, four ½” couplers, four ½” 90° elbows, four ½” 45° elbows, teflon tape (optional), four ¾” washers (optional), eight international washers for garden/utility hose (optional), and a bag of Quikrete can be purchased at a hardware store.

Procedure

1. Drill a hole near the top center of the box using a 1” drill bit. Slide a 2” long tube cut from ¾” PVC through the hole. Then, attach a surface-runoff spout made of ¾” 45° elbow onto the tube on the outside of the box. On the inside of the box, slide a ¾” rubber washer (optional) and ¾” coupler onto the tube, and push together for a tight fit. (Note: All couplers should be cut in half lengthwise before use.)
2. Next, drill two holes at the bottom outside corners of the box under the surface-runoff spout using a 7/8” drill bit. (Note: The side that will allow water to pass out of the box should be cut slightly lower than the other to allow for more efficient drainage.) Run ½” PVC tubing (1½” in length) through the lower hole and attach a ½” T on the outside and an international garden/utility-hose rubber washer (optional) and ½” coupler on the inside of the box, and push together for a tight fit. (Note: All couplers have been cut in half.) For the hole on the other side, run tubing through the hole and attach a ½” 90° elbow on the outside and an international garden/utility-hose rubber washer (optional) and coupler on the inside. Then, cut a piece of tubing to fit between the T and the elbow on the outside of the box. Add a ½” 45° elbow to the drainage hole to help direct the water into the catching containers. Teflon tape (optional) can be used to fix potential leaks.
3. Each box will have a different ecosystem: concrete, compact soil, nonnative grass, and native plants. Line the bottom of the containers with about ½” of gravel. Fill one of the boxes with soil to the surface-runoff spout (slightly above the bottom of the spout, but below the top of the spout). Use the same soil to plant grass and native plants in boxes so that the surface level of the plants is slightly above the bottom of the surface-runoff spout (but below the top of the spout). For the container with concrete, fill in soil to 2” below the bottom of the surface-runoff spout. Quikrete should be prepared outdoors (or in a well-ventilated area) as the instructions on the bag indicate (add water to the powder in a mixing bucket with a mixing stick). Then add a 2” layer of Quikrete on top of the soil up to the surface-runoff spout (slightly above the bottom of the spout, but make sure not to clog the spout with concrete). Allow 24 hours to dry.
4. Place the boxes on a table (or box or crate) with the back ends slightly elevated (small blocks of wood can be used to create the desired slope). Next, place containers under the spouts to catch the surface runoff and groundwater recharge.
5. Additional tips: If there are problems with the water splashing out of the runoff spout, you can add extensions using ¾” PVC tubing. Have towels handy to clean up any spilled water. If soil clogs the runoff spout (especially for the model with only soil), then use a pencil or poking stick to unclog the spout.

Fostering engagement and participation

This lab experiment fostered participation of students who are not usually actively engaged in learning science. One sixth-grade teacher described how one student "usually just slouches in the back of the room and resists participating in science labs, but he was right up front interacting with the hydrogeology models and eagerly worked through the math to find the percentage of runoff and recharge for every ground cover."

This activity was also beneficial for the English Language Learners (ELL). The teacher was excited to see them participating and understanding the science concepts. She stated that they "were able to see the lab and participate. This gives them confidence in their ability to participate in science class, rather than just observe; they were able to take on an active role in their learning."

Although this lab was performed as a whole class with one set of models, students could potentially rotate through lab stations to collect data on different ground covers and change roles with each rotation, or a set of models could be provided to each lab group.

Additional benefits

According to the teacher, the models enabled students to "truly understand what runoff and recharge are. Before we only read about it and looked at pictures, but when they actually saw the water running off and coming down the pipes, they got it! Previously, students had nothing to relate the words *runoff* and *recharge* to, but now I can refer to this lab and they will all have an experience to relate to and understand what I am talking about." She also described how this lab experiment links to important local issues that directly affect their community. Water rationing, flash floods, the closing of a spring-fed pool due to pollution, and rapid development that is resulting in the transformation of vegetated areas to impervious cover provide real-world context for discussions. This activity changed the way students think about surface runoff, groundwater recharge, and how decisions they make can influence water quantity and quality.

Pollution, sources, and solutions

As an extension activity to examining how ground cover influences surface-water runoff and groundwater recharge, students can discover in greater detail how their actions affect water quality. As a class, students brainstormed potential sources of pollution for each ground cover. Ideally, this would be done in small groups of about three to four students. Some of the sources identified by students included cars with oil leaks, people using too many chemical fertilizers, pesticides, litter, and paint. Students added one to four drops of red food coloring to each ground cover to represent pollution before "raining" on the model. The amount of pollution can either be held constant to test if the four ground covers filter the pollution differently, or the amount can vary depending on how much pollution is expected on each type of ground cover.

After observing the models, students described what happened to the pollution and how pollutants applied to the different ground covers can contaminate water resources. Students described what they can do as individuals to help maintain water quality. Their suggestions

FIGURE 2 Data-collection chart

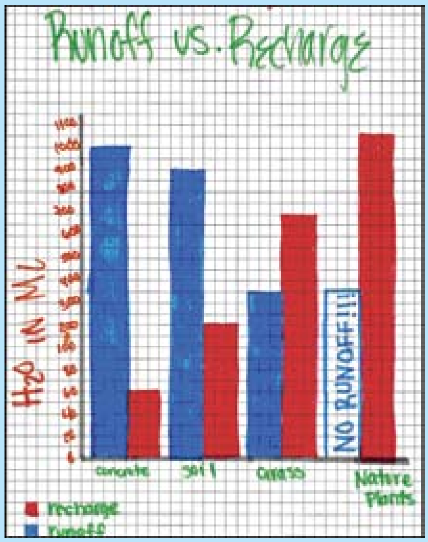
Shows the amount of surface runoff and groundwater recharge for concrete, soil, nonnative grass, and native plants.

unit of measure mL

	Concrete		Soil		Grass		Native Plants	
	Runoff	Recharge	Runoff	Recharge	Runoff	Recharge	Runoff	Recharge
Trial 1	1000	0	550	150	118	800	10	900
Trial 2	910	62	700	215	150	850	0	950
Trial 3	950	40	750	155	400	650	22	950
Average	953	34	666	173	222	766	16	933

FIGURE 3 Runoff and recharge graphs

Shows the amount of surface runoff and groundwater recharge for concrete, soil, nonnative grass, and native plants.



included living lightly on their watershed, using native-plant landscaping, organic gardening, supporting smart land-use decisions, and pollution control. Students can compare what they came up with to the Environmental Protection Agency's (EPA) list of 15 things you can do to make a difference in your watershed (*www.epa.gov/adopt/earthday*) and do's and don'ts around the home (*www.epa.gov/owow/nps/dosdont.html*). As extension activities, they could conduct online searches to find more recommendations and possibly even design experiments to test those recommendations. For example, the EPA suggests that people spread mulch on bare ground to help prevent erosion and runoff. Students could use the hydrogeology models to test this theory by having one model represent bare ground and adding mulch to the second model (otherwise the same as the first model). Students could compare the amount of runoff and erosion for bare ground compared to bare ground with mulch.

Students could also become involved in community action. One of the students who participated in this lab reported to the teacher that it inspired her to organize a creek cleanup in her neighborhood. Students could also write letters to the school groundskeeper, town parks manager, local golf courses, or other representatives to encourage future legislation and actions that protect and conserve water resources, especially in view of the severe drought conditions much of the country is suffering.

Additional extensions

Hydrogeology models that show how different kinds of ground cover affect surface runoff and groundwater recharge can be used in a large variety of ways. Here is a list of a few additional potential extension activities:

- Conduct more trials of the experiment and compare the results to when you conducted three trials.
- Have students do an experiment of their choice keeping the type of ground cover constant, but changing the slope or amount or rate of rain.
- Experiment with additional ground covers, including gravel, sand, mulch, and different types of soils or plants. Measure porosity and permeability of the different substrates.
- Experiment with various designs to prevent or reduce soil erosion (see link to lesson at the end of this article).
- Test the acidity of the water before and after it travels through limestone.
- Have students map types of ground cover in the schoolyard and describe how they influence surface runoff and groundwater recharge.
- Print an aerial photograph of your school or town and have students identify the amount of different types of ground cover, potential sources of pollution, and how each type of ground cover affects the water cycle.
- Obtain two images of your school or town to compare changes in ground cover over time.
- Have students plan future development of their town based on evidence collected in their experiments with the models.

Conclusion

Providing students with opportunities to interact with models can help them gain a deeper understanding of scientific processes while engaging them in the activities of a scientist. I hope that this article inspires teachers to build similar models for their students. Groups of teachers from the same school can collaborate on how they could all use the models via a rotation system to optimize the number of students that are given the opportunity to interact with the models. The lab activities described in this article can be found at *www.jsg.utexas.edu/outreach.* ■

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