

## Know the Flow: Exploring Ground Water Flow with Computer Modeling

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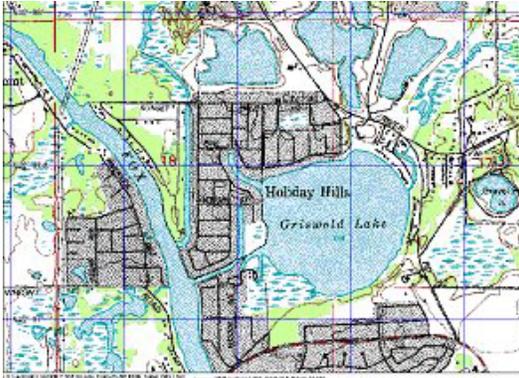
When someone asks a question of a geologist, they're likely to get an answer sketched on a napkin or the back of an envelope. Most of us talk with our students with pencils or chalk in our hands, drawing as we talk, illustrating our discussions with cross sections or crystal structures or geomorphologic time-lapse sequences. We "read" the figures before we read the article; we're visual learners; we think in pictures. It only stands to reason that we would look to visualization as an effective way to help students learn.

I'm a hydrogeologist, so I'll describe how I use visualization to help students understand ground water flow. I use two pre-packaged ground water flow models in my upper-level introductory hydrogeology course. The first, called FLOWNET, is packaged with the textbook. It animates water movement in 2-D layers of different hydraulic properties, and allows the user to change properties, layer characteristics, and hydrogeologic configuration.

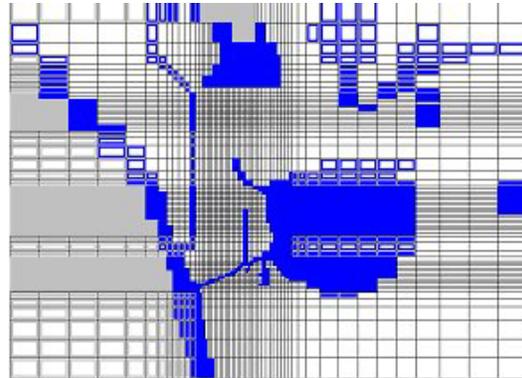
Once students figure out how to use FLOWNET (it is DOS-based and the learning curve is short, but steep for the Windows-dependent), they are fully engaged. I have seen them sit at a computer screen, transfixed, watching the animated "flow" of ground water for minutes at a time, as if it were an aquarium full of tropical fish.

FLOWNET is visually and graphically almost primitive, when compared to the look of even a simple web page. And yet it is effective. Why? I suspect it's because the program is thoroughly interactive, and because the results of any changes to the variables are immediately visible. It gives the student control of the flow system, so they can experiment, testing out hypotheses about how altering aquifer properties will affect the flow. A successful visualization tool should incorporate hands-on inquiry possibilities.

The second visualization tool I use extensively in my hydro class is Graphic Groundwater (GGW), shareware easily downloadable from the internet at the academic website of the author, Steve Esling at Southern Illinois University/Carbondale. (<http://bear.geo.siu.edu/GraphicGroundwaterPage.htm>). GGW is a graphical user interface for the USGS ground water modeling code MODFLOW. It allows the user to start with a topographic map, build a model grid directly on the map, enter hydraulic properties into grid cells as one would into a spreadsheet, click on the grid to enter the positions of water wells, and (among other things) track imaginary "particles" that would flow into the well from the surrounding area.



Students begin with borehole data and a topographic map like this.



They construct a model grid directly on the map, set well locations, and enter hydraulic properties in each grid cell (e.g. blue indicates a cell where surface water is connected to the aquifer).



The completed model allows students to track imaginary particles (the black “spiders” on this map) flowing to the three wells from the surrounding area within a five-year period. Community planners now know what area to designate a “wellhead protection area”.

My students use GGW to delineate the area from which a well will draw recharge during a five-year period. It’s a practical problem and one that allows them to put together geologic skills (reading maps, drawing cross sections) with hydrogeologic concepts (recharge area, ground water flow, hydraulic properties of earth materials) to produce something that would be meaningful to a community—say, a zoning or planning board.

If I’m successful, by the end of the project, the students have an intuitive grasp of the principles of ground water flow, and can describe how altering some of the variables—e.g. increasing pumping rates, decreasing recharge due to drought, or manipulating river levels by using locks and dams—will affect the size of the wellhead protection area. This visualization is successful because the students control the whole look and shape of it and can alter variables at will to experiment with how each change affects ground water flow.

Students in some scientific fields can combine two chemicals in a test tube and watch what happens. Geologists can’t always work that way, because often what we study is underground and hidden from view. Useful visualization tools allow our students to perform hands-on experimentation, creating a virtual laboratory for testing hypotheses that heretofore could not be easily explored in the geology classroom or lab.