ground water

Software Spotlight/ Chunmiao Zheng, Software Editor

IGW/DL: A Digital Library for Teaching and Learning Hydrogeology and Groundwater Modeling

reviewed by Chunmiao Zheng[1] and Rui Ma[2,3]

Introduction

Since the advent of the Internet era and the World Wide Web, teaching and learning has no doubt become easier and resources more accessible. Currently, there is a wealth of useful information freely available online for teaching and learning hydrogeology and groundwater modeling. However, few are as well designed and visually compelling as an educational digital library (DL) called "Interactive Ground Water (IGW) Visualization Library" at the website http://www.egr.msu.edu/igw/DL/. IGW/DL was originally developed for the National Science Foundation's Digital Library Initiative and is continually improved and maintained by Professor Shuguang Li and his associates at Michigan State University. In this column, we review the contents included in the IGW/DL and report our experience in using this innovative online resource.

Contents and Features

The home page of the IGW/DL website http://www.egr.msu.edu/igw/DL/ is organized in two panels as shown in Figure 1. The left panel contains an index of all library content organized in the Windows Help file format, whereas the right panel displays a collection of graphical icons corresponding to the library index headings listed in the left panel. The contents of the IGW/DL are grouped into 24 classes as follows:

- Real-world heterogeneity
- Random field representation
- Effects of spatial heterogeneity
- Effects of interacting heterogeneities
- Effects of temporal variability
- Macrodispersion model
- Effects of multiscale heterogeneity
- Monte-Carlo simulation
- Transport in complex aquifers
- Transport in fractured tills
- The hydrologic cycle
- Aquifer response to pumping
- The law of refraction
- Flow in anisotropic aquifers
- Well head delineation
- Regional vertical circulation
- Seepage under a dam
- Interaction with surfacewater
- Artificial recharge
- Groundwater contamination
- Transport processes
- Groundwater remediation
- Hierarchical modeling
- Algorithmic visualizations

Clicking on any of these class headings, either in the left index panel or in the right graphical display panel, will bring up another window showing all the illustrative examples contained under each class. For instance, clicking on "Interaction with surface water" will bring up a window containing 38 graphical icons, each of which represents a particular field situation such as "Gaining stream," "Losing stream," "Flow-through lake—homogeneous, isotropic aquifer," and so on. Further clicking on any of these icons, a new window will pop up, displaying one of the three types of contents. The first is real-world aquifer heterogeneity images collected from several

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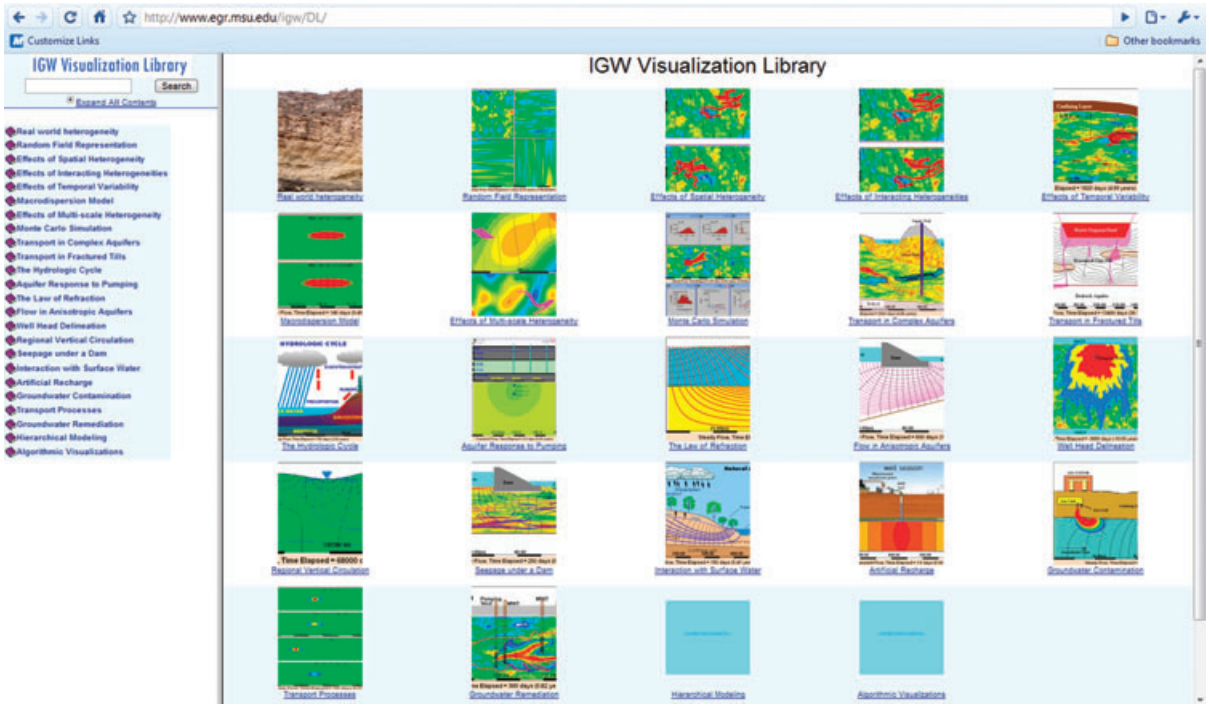

Figure 1. The home page of IGW Visualization Library.

well-known locations; the second is computer-generated representations of aquifer heterogeneity; and the third is animated images illustrating some flow and transport processes based on numerical model simulations (Figure 2). Each animated image is usually followed by a table of the input variables used in the simulation and additional explanations, if any. Some of the explanations are quite elaborate, complete with the problem statement, key observations, and mathematical interpretation.

The content contained in the IGW/DL spans a wide range of subjects in hydrogeology. Some subjects, such as "The hydrologic cycle" and "Aquifer response to pumping," are quite elementary. Other subjects, such as "Effects of multiscale heterogeneity" and "Monte-Carlo simulation," are more advanced. Thus, classes ranging from undergraduate-level introductory hydrogeology to graduate-level advanced groundwater modeling will likely find the IGW/DL a valuable resource for illustrating key concepts and for serving as class exercise materials.

This DL is particularly strong in illuminating the effects of spatial heterogeneity on groundwater flow and transport processes. It includes a collection of real-world examples of heterogeneous aquifer outcrops from around the world, displays the computer simulation results of flow and transport under a whole spectrum of heterogeneity scenarios, demonstrates different realizations of geostatistically simulated hydraulic conductivity distributions, and illustrates the results of Monte-Carlo simulation to quantify the uncertainty stemming from aquifer heterogeneity. Thus, IGW/DL would be especially useful supplemental instructional materials for a contaminant transport modeling class.

All of the flow and transport simulations that were incorporated into much of the illustration and animation contained in the IGW/DL are based on the software "IGW" (Li and Liu 2006a, 2006b). IGW is a graphically oriented groundwater modeling environment for real-time two-dimensional (2D) and three-dimensional (3D) groundwater modeling. The software allows the modeler to visually simulate an aquifer of desired configurations and then immediately investigate and visualize the groundwater flow and transport processes. The combination of IGW/DL and IGW provides an innovative approach to teach and learn groundwater modeling.

User Experience

The reviewers like the overall design of the IGW/DL. The inclusion of real-world heterogeneity images reminds the viewers of the difficulty and uncertainty in modeling and understanding groundwater flow and solute transport processes. The integration of the conceptual model with numerical simulation results on many illustrations and animation images is especially noteworthy, making it much easier to convey the intended messages. An excellent example is Figure 3, which shows many potential sources of groundwater contamination, superimposed by the results of a transport simulation of a hypothetical contaminant spill event.

Another welcome feature of the IGW/DL is that it provides all the model input variables used to generate the corresponding illustrations and animations. This allows the viewer to see exactly what input parameters are behind the visualization results and, if so desired, to attempt to reproduce the results shown in the IGW/DL,

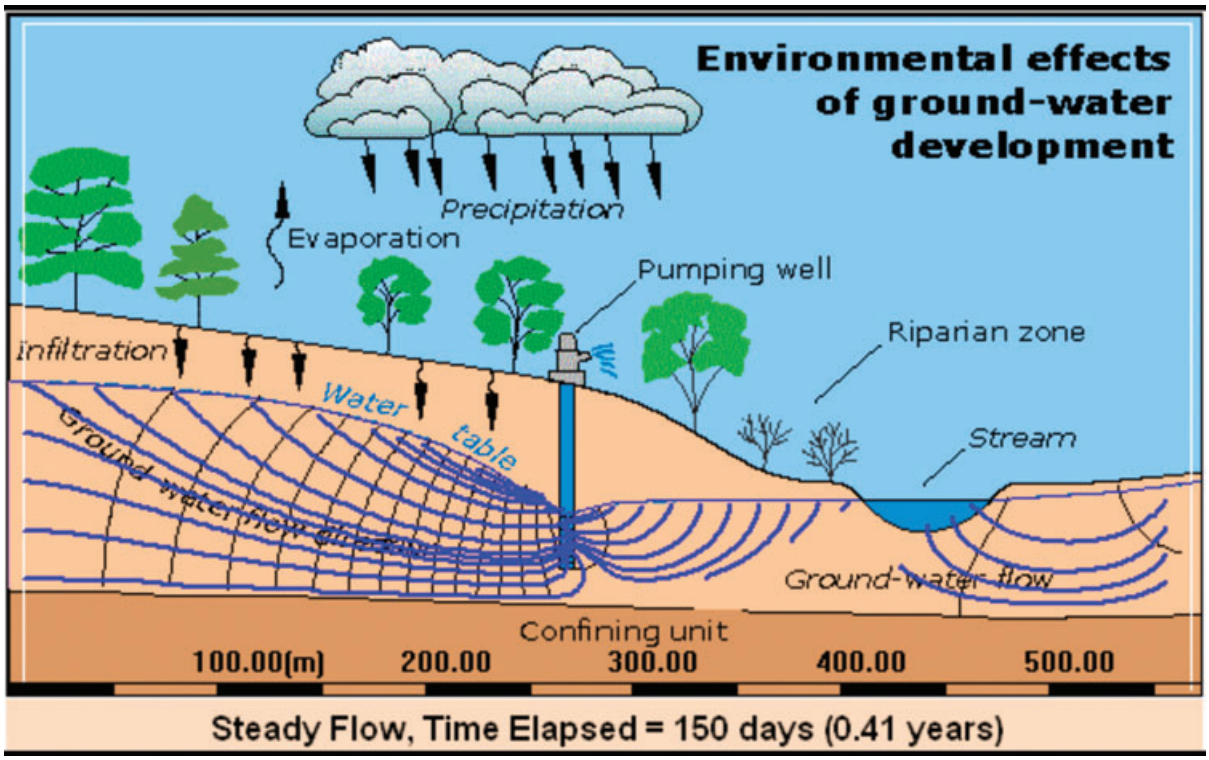

Figure 2. Illustration of the effect of groundwater pumping near a stream.

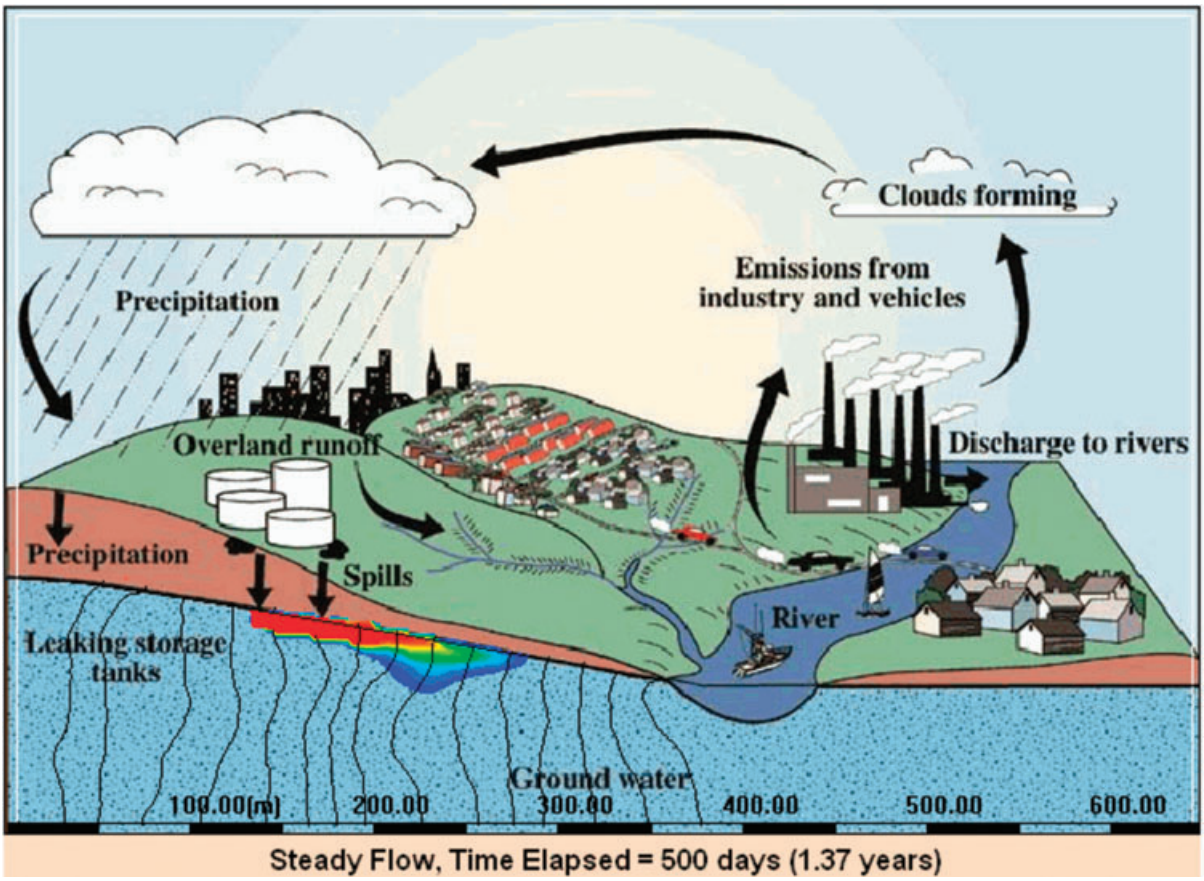

Figure 3. Illustration of the conceptual model and numerical simulation of groundwater contamination due to leakage from storage tanks.

which can be a very useful exercise in teaching and learning groundwater modeling. The summary of key observations and mathematical interpretation is another source of valuable information on the example flow and transport problems being illustrated and examined.

A minor problem encountered during the review is that some text labels or headings for the illustrations or animations are distorted and illegible. Some adjustment to the default window size normally fixes the problem. Also, the animated images seem to appear as blank in printouts. Finally, the two categories listed in the library index, "Hierarchical modeling" and "Algorithmic visualizations" are not yet supported.

Online Resources

The IGW Visualization Library is maintained by Professor Shuguang Li and his associates at Michigan State University and can be freely accessed at the website http://www.egr.msu.edu/igw/DL/. Complete information and download instructions for the related groundwater modeling software "IGW" can be found at the website http://www.egr.msu.edu/igw/.

Summary

The reviewers are very impressed with the innovative interface design and rich scientific contents of the "IGW Visualization Library." The DL beautifully illustrates some of the most fundamental concepts in hydrogeology. It is particularly useful for anyone interested in groundwater modeling as most of the illustrations and animations in the IGW/DL are based on model simulations with complete model input information and some mathematical interpretation provided for the viewers. The reviewers enthusiastically recommend the IGW/DL as an excellent resource for teaching and learning hydrogeology and groundwater modeling. We are confident that both novice and experienced modelers will take something useful away from experimenting with the IGW/DL.

Our Mission

The goal of *Software Spotlight* is to help readers identify well-written, intuitive, and useful software. Independent reviewers from government, industry, and academia try out full working versions of software packages and provide readers with a concise summary of their experiences and opinions regarding the capability, stability, and ease-of-use of these packages.

References

Li, S.G., and Q. Liu. 2006a. A real-time, computational steering environment for integrated groundwater modeling. *Ground Water* 44, no. 5: 758–763.

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