Judge's Commentary: The Outstanding Flood Planning Papers

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Introduction

Flood planning for dams is a real-life activity. An analysis of the Saluda Dam at Lake Murray determined that the area below the dam needed to be protected in the event of dam failure, and a second dam is being built. Investigation conclusions can be found on the Web.

Since flood plan analysis is complex, mathematical modeling is appropriate and useful. A sequence of models is typically used to understand a phenomena. For the Saluda Dam, a first model might have a straight river, the dam disappearing instantaneously, and a simple model of water flow. More detailed effects could then be added: the riverbed bends, the riverbed gradient is not uniform, perhaps the dam breaks slowly, perhaps the dam is breached in the center, etc. Starting with a complicated model may make it difficult to determine if the results are reasonable, since there may be little to validate against. A series of models that allows additional effects to be incorporated sequentially is preferable; it may facilitate creation of a sensitivity analysis.

Water flow in open channels has traditionally been modeled by the Saint-Venant equations, which are nonlinear partial differential equations. Many teams started by numerically solving these equations and got immersed in details. (The MCM is not a contest in computation!) Often these teams focused only on the water flow and spent little effort modeling the dam break itself. Although there are many models for dam failure, a dam "vanishing" completely is rather simplistic. (There are a few well-defined dam failure mechanisms. Teams that considered different mechanisms tended to do better than those teams that used simplistic assumptions.)

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Many teams started with static models, but most recognized that these models do not yield reasonable results. The dam-break problem seemed to require a dynamic approach. The approaches varied considerably, but included:

- Continuous technique: use of sophisticated equations, such as Saint-Venant's equation. (Note: Copying an equation derivation achieves little. Pointing out assumptions needed to obtain an equation may be useful.)
- One-dimensional discrete techniques: breaking the Saluda River up into prisms and computing flow from one to the next. Rectangles and trapezoids were popular choices.
- Two-dimensional discrete techniques: cellular automata using USGS data and computing flows from neighboring cells. The cellular approach can be difficult to understand and to implement correctly.

Widely varying techniques obtained approximately the same result. Teams that used more than one approach tended to do better. The usual answers to the specific test questions are: No, the State Capitol doesn't flood, and Rawls Creek backs up about 2.5 miles.

The outstanding papers are remarkable in that each used a fundamentally different technique:

- The University of Washington team pursued an analytic approach. They considered two models, obtained real data, and calibrated their model.
- The Harvey Mudd team numerically solved the Saint-Venant equations.
- The University of Saskatchewan team considered a model, rejected it as being unrealistic, and then numerically solved a dynamic model that they created themselves.

Some overall comments on the submissions:

- Several teams validated their results from evacuation plans and recorded flood events. Many others did not do enough reality checking; a back-of-the-envelope computation frequently would have helped.
- Many teams had perhaps overly complicated models, involving many variables and parameters.
- The reference for a Web page should list the date of access.

About the Author

Daniel Zwillinger attended MIT and Caltech, where he obtained a Ph.D. in applied mathematics. He taught at Rensselaer Polytechnic Institute, worked in industry (Sandia Labs, Jet Propulsion Lab, Exxon, IDA, Mitre, BBN), and has been managing a consulting group for the last dozen years. He has worked in many areas of applied mathematics (signal processing, image processing, communications, and statistics) and is the author of several reference books.