**Uncertainty and Risk: Bringing the Geosciences into the Civil Engineering Classroom**

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I suspect that certain concepts in my groundwater course irritate my students. That a rock labeled “sandstone” could have a hydraulic conductivity anywhere from 10-10 to 10-6 m/s, an outrageous range of five orders of magnitude. That that rock is definitely sedimentary, unless of course it is slightly metamorphosed. That a wide array of possible subsurface conditions could all produce the same map of the water table. They want to know what the answer *is*, not what it could *possibly be*. And therein is the teaching opportunity.

Engineering firms increasingly require adroit workers, who are flexible in their approach to problems and who can quickly learn new skills. However, engineering students can become rigid in their thinking; after all, we drill them with years of practice problems that have one right solution. However, learning about the geosciences, with their relatively imprecise earth materials and random hydrologic processes, can help students overcome their reliance on formulaic ways of viewing the world. In my courses, I try to foster alternate modes of thinking through the inclusion of an emphasis on several important geoscience concepts.

Specifically, I think three principles from the geosciences can help all engineers to become better problem solvers and ultimately produce better designs:

* Embracing ambiguity, uncertainty, and risk
* Analyzing a system holistically and recognizing scale-emergent behaviors
* Understanding non-experimental, observational based modes of scientific discovery

Although these principles can be taught in many different contexts, ones that are more familiar to students seem to ease the transition into more sophisticated modes of thinking. For example, in my introductory water resources engineering classes, I reintroduce students to concepts from statistics, now applied to extreme events, like floods and droughts, and even more mundane ones, like the weather for over the past week. We analyze precipitation and streamflow data from our watershed monitoring site on campus (the more recent, the better), and discuss how campus infrastructure has to be designed to accommodate both low flow and high flow events (e.g., sprinkler runoff vs. busted fire hydrants). This course is often the first time that students are exposed to the ideas of probabilistic design; that there is no “factor of safety” for systems that must deal with the natural world. It also teaches them that we sometimes need to make trade-offs in design. Yes, we can construct a culvert to make 99.9% sure that the road will be passable during even the largest of foreseeable floods, but is it really necessary for a gravel driveway on your neighbor’s ranch? Whatever other benefits this approach produces, I consider it a success if, at the end of the semester, every student can correctly define a 100 year flood.

I imagine that teaching sustainability concepts may yield similar cognitive benefits. For instance, life cycle assessment requires a systematic style of thinking about the ultimate consequences of design decisions, while the triple-bottom-line approach forces the simultaneous consideration of multiple design objectives. Moreover, engineers addressing sustainability must tolerate ambiguous, often conflicting societal objectives and the possibility that an “optimal” solution may look different to all parties involved. I look forward to working on integrating sustainability into my courses and hope that this workshop will further my progress.

As for those irritated groundwater students, they eventually calm down…until we talk about karst!