

# CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

## TRIP REPORT

**SUBJECT:** Princeton Groundwater Pollution and Hydrology Course  
(AI 06002.01.011.030)

**DATE/PLACE:** February 28–March 4, 2005; San Francisco, California

**AUTHOR:** D. Pickett

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### **PERSONS PRESENT:**

David Pickett, Center for Nuclear Waste Regulatory Analyses (CNWRA)  
A list of other course participants is available upon request.

### **BACKGROUND AND PURPOSE OF TRIP:**

The CNWRA geochemistry staff involved in high-level waste activities often focus on groundwater flux and subsurface radionuclide transport technical issues. A strong grounding in hydrogeological principles is, therefore, desirable. Staff attended the Princeton Groundwater Pollution and Hydrology Course as a professional development activity to obtain more formal instruction in physical and chemical aspects of groundwater flow and contaminant transport.

### **SUMMARY OF PERTINENT POINTS:**

The 5-day course included 3 evening sessions and was attended by 66 professionals representing government agencies, consulting firms, and research centers in the United States, Canada, and Brazil. The four instructors were experienced, knowledgeable, and recognized authorities in their respective areas of expertise. The lectures and supporting materials were of high quality and covered the following topics: (i) fundamental aspects of groundwater hydrology, (ii) groundwater testing and monitoring, (iii) remediation, (iv) contaminant fate and transport, (v) dense non-aqueous phase liquids, (vi) unsaturated zone flow, and (vii) wellhead protection. Organizers provided a complete set of hard copies of the slide presentations, textual materials, and comprehensive reference lists.

### **SUMMARY OF ACTIVITIES:**

B. Cleary (Princeton Groundwater, Inc.) presented most of the lectures, including the Monday introduction to the hydrological literature and fundamental and advanced concepts in contaminant hydrology. Knowledge in the field has increased enormously as, over the past 30 years, society has been faced with the prospect of preventing and correcting contamination of crucial underground water supplies. Cleary's lecture on hydrogeologic concepts included topics such as aquifer materials and types; fundamental parameters such as head, flux, hydraulic conductivity, and specific yield; water flow and behavior of water levels under dynamic conditions; effects of anisotropy and heterogeneity; and laboratory methods, including sandbox

experiments and hydraulic conductivity measurements. The presented information was voluminous, yet effectively delivered and understandable to the non-expert. Two optional lectures on computer modeling of groundwater flow and transport were also offered on Monday. Cleary compared and contrasted analytical and numerical approaches and presented example calculations using variations on the MODFLOW modeling package. On Tuesday morning, Cleary completed his lectures on fundamental and advanced concepts.

D. Nielsen (The Nielsen Environmental Field School) discussed practical aspects of site characterization, drilling and developing water wells, and monitoring and sampling groundwater on Tuesday afternoon and evening. These sessions concerning the materials and methods employed in groundwater wells in the field were highly informative. Topics included well placement, application of conceptual site models, drilling technologies and techniques, screening, and sampling (including multi-level methods). Nielsen emphasized the success of the relatively new accelerated site characterization strategy for more rapid and cost-effective results.

M. Kavanaugh (Malcolm Pirnie, Inc.) introduced groundwater remediation design and implementation on Wednesday morning. Kavanaugh first discussed the regulatory and technical drivers involved in setting remediation goals and strategies. He then described remediation technology options, such as soil vapor extraction, mobilization and extraction, chemical oxidation, biodegradation, containment barriers, and monitored natural attenuation. Under the topic heading Quantitative Hydrogeology, Cleary spent the afternoon and evening discussing (i) the use of slug and pumping tests for hydraulic conductivity, (ii) principles of solute transport, and (iii) the use of these principles in pump and treat remediation approaches.

Cleary returned to the topic of groundwater monitoring techniques on Thursday morning, emphasizing the importance of specific strategies that maximize the potential for detecting and characterizing contaminant plumes.

J. Cherry (University of Waterloo) discussed the unique characteristics of dense non-aqueous phase liquid contamination on Thursday afternoon. These organic fluids—the most significant category of which is chlorinated solvents—occur in three key contaminant forms: (i) in the unsaturated zone as a secondary residual source, (ii) dissolved in groundwater at their solubility limits, and (iii) forming immiscible pools at the base of the aquifer. Cherry described laboratory and field experiments revealing the special behavior of dense non-aqueous phase liquids, field descriptions of plumes in porous and fractured media, and strategies for remediation (with varying levels of success).

Cleary finished the course on Friday morning with two topics. In discussing unsaturated zone hydrology, Cleary touched on the unique approaches needed for describing, modeling, and sampling vadose zone contamination. The final topic was wellhead protection, which is concerned with using field data and models to either prevent contamination of existing groundwater supplies or to define the areas that are safe for groundwater extraction. Both topics were illustrated with case studies.

#### **CONCLUSIONS:**

The course provided a thorough, eclectic, and detailed introduction to practical aspects of detecting, modeling, monitoring, and correcting groundwater contamination. The combined

presentation of scientific principles and real-world examples was effective in making the information potentially more useful for work on radionuclide transport. While the course emphasized organic contaminants at the expense of metals and radionuclides, and porous media over fractured media, most of the concepts and techniques that were covered are universal in application.

**PROBLEMS ENCOUNTERED:**

None.

**PENDING ACTIONS:**

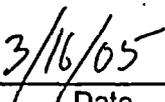
None.

**RECOMMENDATIONS:**

The Princeton groundwater course is highly recommended for non-specialists seeking formal and comprehensive instruction in hydrogeology.

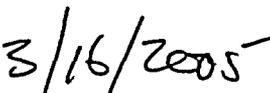
**SIGNATURES:**

  
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David A. Pickett  
Senior Research Scientist

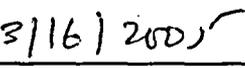
  
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