CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: The Groundwater Pollution and Hydrology Course (06002.01.011)

DATE/PLACE: February 10–14, 2003
Orlando, Florida

AUTHOR: C. Dinwiddie

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PERSONS PRESENT:

Cynthia L. Dinwiddie, of the Center for Nuclear Waste Regulatory Analyses (CNWRA), attended the Groundwater Pollution and Hydrology Course by Princeton Groundwater, Inc. Instructors included Robert W. Cleary (Princeton Groundwater, Inc.), David M. Nielsen (The Nielsen Environmental Field School), Richard P. Brownell (Malcolm Pirnie, Inc.), and John A. Cherry (Waterloo Centre for Groundwater Research, University of Waterloo). A list of other attendees and sponsors follows:

Name	Company	Location
Beblowski, Peter	NH DES	Concord, NH
Bennett, Nicole A.	Marine Corps Base	Quantico, VA
Cage, Durst	37 CES/CEV Lackland AFB	San Antonio, TX
Christiansen, Gwenette R.	US EPA Region 8	Denver, CO
Cooper, Maurice	37 CES/CEV Lackland AFB	San Antonio, TX
Council, Aaron S.	EnviroSouth	Greenville, SC
Duffy, William	Earth Tech	Fort Walton Beach, FL
Eger, Kelly S.	Miller Legg & Assoc., Inc.	Winter Park, FL
Farnum, Rachel L.	GE Global Research	Niskayuna, NY
Feeney, Leroy P.	GEI Consultants, Inc.	Colchester, CT
Gao, Xiangjing	Unknown	Norcross, GA
Gonzalez, Carlos	Orange County EPD	Orlando, FL
Gordon, Elizabeth	Unknown	Livermore, CA
Hahn, Deirdra	AL Dept. Environ. Mgmt.	Montgomery, AL
Hanna, David M.	Lower Elwha Klallam Tribe	Port Angeles, WA

Name	Company	Location
Hofe, Michael	REI Consultants, Inc.	Beaver, WV
Hoover, Stephen	Westinghouse Savannah River	Aiken, SC
Jernigan, Jeremy	Professional Service Ind.	Pensacola, FL
Johnson, Sharon	ConocoPhillips	Houston, TX
Katz, Mitchell	Orange County EPD	Orlando, FL
Kennedy, Daniel	Ecology & Environ., Inc.	Tallahassee, FL
Lackey, Jessica D.	Bay Assoc. Environ., Inc.	Baltimore, MD
Lang, Peter D.	Navy Public Works Center	Norfolk, VA
Larson, Kevin	Morrow Env. Consultants, Inc.	British Columbia, CANADA
Lokey-Flippo, Laura	US Army CHPPM	Aberdeen, MD
Lueders, Joy	ENVIRON Int'l Corp.	Saint Peters, MO
Martell, Phillip J.	URS Corporation	Cranford, NJ
Martin, Bruce	Avery Dennison	Milford, MA
McCoy, David L.	TVGA Consultants	Jamestown, NY
McMahan, John T.	Westinghouse Savannah River	Aiken, SC
Miles, Leona	Florida DEP	Tallahassee, FL
Moore, William	H2M Associates	Totowa, NJ
Nicholson, Lisa	OASIS Environmental	Anchorage, AK
Paul, Cynthia J.	US EPA	Ada, OK
Peacock, Jeremy	GeoSyntech Consultants, Inc.	Atlanta, GA
Rawlins, Jack D.	Unknown	DeLand, FL
Reese, Nancy Rae	Environ Resourses Mgmt	Dewitt, NY
Revell, Bryan	Navy Public Works Center	Norfolk, VA
Reyes, Wilmer M.	DE Dept of Natural Resources	New Castle, DE
Russell, Kevin	US Army CCHPPM	Aberdeen, MD
Salazar, Stephanie	HCET-FIU	Miami, FL
Scherer, Tilo	ExxonMobile Central Europe	Hamburg, GERMANY
Scroggins, Nicole W.	Seminole Co. Public Safety	Lake Mary, FL

Name	Company	Location
Shields, Jr., Richard H.	Dir of Environ and Safety Instal	Fort Riley, KS
Smith, Clyde	Westinghouse Savannah River	Aiken, SC
Steffan, George D.	Navy Public Works Center	Norfolk, VA
Stein, Kristine M.	Marine Corps Base	Quantico, VA
Stern, Eric J.	Earth Tech	Roswell, GA
Sumner, Elizabeth	Coastal Environ. Svcs., Inc.	Ahoskie, NC
Sylvester, Arthur	Naval Station Newport	Newport, RI
Warner, Lynn	Transport Canada	Ontario, CANADA
Wilson, Michelle	US Army Corps of Engineers	Tulsa, OK
Wolcott, Dennis	Parker Hannifin Corp.	Cleveland, OH
Wolf, Shawn E.	Blasland, Bouck & Lee, Inc.	Pittsburgh, PA

BACKGROUND AND PURPOSE OF TRIP:

This was a professional development course for which 3.8 continuing education units were awarded. The course began as a Princeton University mini-course taught by Robert W. Cleary, through which a semester of hydrology studies were taught within a single week. No longer affiliated with Princeton University, this course is now a product of Princeton Groundwater, Inc.

The course began with a review of several hundred important references within the hydrology literature. This was followed by an introduction to relevant U.S. environmental legislation, as well as water issues in European countries. Fundamental and advanced groundwater hydrology, well-head protection, monitoring techniques, and fate and transport concepts were presented by Robert W. Cleary. David M. Nielsen lectured on field methods for site characterization, as well as the natural attenuation of petroleum hydrocarbons and MTBE. Richard P. Brownell discussed strategies, technology, and the design of engineered remediation systems, and John A. Cherry gave an overview of issues related to dense non-aqueous phase liquids.

SUMMARY OF PERTINENT POINTS:

The vertical distribution of horizontal hydraulic conductivity leads to velocity stratification within an aquifer, and contaminant stratification within a plume. Average values of horizontal hydraulic conductivity (e.g., from a pumping test) are well-suited for volumetric water-supply calculations. But, in the discipline of contaminant fate and transport, there is a need for reliable predictors of contaminant origin, present location, future migration patterns, and travel times. Until the development of borehole flowmeters, slug tests performed in a nested well system (i.e., multiple wells screened at different depths, but in essentially the same lateral location) were the only way to approximate the vertical distribution of horizontal hydraulic conductivity. After a rocky start, which included the development of impeller borehole flowmeters and thermal pulse borehole flowmeters (each with undesirable characteristics), the electromagnetic borehole flowmeter was developed by the Tennessee Valley Authority, and is here to stay. All borehole flowmeters yield vertical discharge as a function of position along a screened well bore. Differencing the flow data between positions where measurements are made yields incremental discharge from horizontal aquifer layers; from this, one can determine the vertical distribution of horizontal hydraulic conductivity. Application of such a tool at multiple existing wells across a site allows three-dimensional models of aquifer heterogeneity to be readily ascertained—an important boon to a discipline where an understanding of field-scale heterogeneity is often likened to a sought-after grail.

Multilevel sampling for groundwater constituents and concentrations should be a standard procedure at every radionuclide-contaminated site, and the results should be included in every environmental report about such a site. Without multilevel sampling, it is impossible to know the three-dimensional extent of a plume, or the three-dimensional concentration distribution within the plume. In a conventional monitoring well with a screen of non-negligible length, contaminated water entering the screen will mix with less- or non-contaminated water entering the screen, thus causing significant dilution to occur. Such dilution will lead to concentration results that are dependent upon the position and length of the well screen, because the samples are averaged over the length of the well screen; additionally, the average will be a weighted average that is biased toward the contamination existing within geologic units of high hydraulic conductivity. In the end, conventional monitoring well sampling leads to maximum contaminant concentrations that are often underestimated by an order of magnitude or more. Yet, this is not the extent of the damage incurred through conventional monitoring well sampling, because dispersivities calculated from diluted tracer concentrations will be overestimated, which is why old literature values (pre-multilevel sampling) are typically excessively high. Regulators should be wary of accepting unrealistically high dispersivity values in models, as this will have the net effect of increasing the size of the modeled plume, while simultaneously decreasing the maximum concentrations therein, and unrealistically decreasing the apparent risk to the public.

It has become standard practice in the State of California for environmental regulators to demand rose diagrams of the local hydraulic gradient from their permitees. Regulators elsewhere should be aware that maps of equipotential or hydraulic head at a site may become outdated, and that industry does not always openly acknowledge the use of old maps. That is, a map determined through hydraulic head measurements two years ago is not necessarily indicative of the equipotential distribution today, and as a result, the hydraulic head gradient can shift in both magnitude and direction with time. The reasons for this should become clear as one considers seasonal changes in precipitation and anthropogenic effects, such as well start-ups, shut-downs, and lagoon or pond installations. Shifting gradients cause plumes to shift and become irregular. The take-home message is that regulators should begin asking licensees for rose-diagrams of head gradient (magnitude and direction) at their respective sites. When one conducts a performance assessment of a site, one should be able to elucidate the average head gradient (magnitude and direction) over the recorded history at that site, as well as the worst case and best case, in order to assess inherent uncertainties. Given the effect of short term transients on the hydraulic head gradient, one should consider the ramifications of climate change to the magnitude and direction of the gradient when longer time periods (1,000–10,000 years) are involved.

Regulators should also be aware that there is danger when a licensee places a background well too close to a lagoon or pond. The licensee may anticipate that because the background well is located upgradient laterally from the lagoon or pond that no wastes will enter this monitoring well. The licensee may indicate that background contaminant levels are "high" for an inexplicable reason, but in reality, the pond or lagoon is causing a local groundwater mound and thus a vertical hydraulic gradient that is forcing lagoon contaminants into the "background" well.

Permeable Reactive Barriers (PRBs) are applicable to radionuclide contamination. A reactive barrier composed of calcium acetate limestone has been found to sorb radionuclides. Various approaches to reactive barriers include high permeability walls, funnel and gate systems, and trench and gates systems. It is technically and economically feasible today to install permeable reactive barriers to a depth of 33 m (100 ft).

Many site investigation and remediation programs have failed in the past. To avoid these failures in the future, an old concept has been recently repackaged: it is known as "Expedited Site Characterization." The first step is to establish site assessment objectives. Second, one reviews existing site information. Third, the initial conceptual model of site conditions is developed. Fourth, the data collection and analysis program is developed. Fifth, one attempts to implement an iterative onsite process using rapid sampling techniques, the scientific method, and analytical field work with quality assurance and quality control, all within one single field mobilization. The initial data are collected, analyzed, interpreted and evaluated; the conceptual model is refined based on the data analysis; a decision is made as to whether the assessment is complete or not. If not, an evaluation is made as to whether or not appropriate methods are being used to collect and analyze the necessary data. If not, the data collection and analysis program is modified and a new iteration of the above procedure is initiated. When the assessment is found to be complete, the sixth step is to consider interim remedial actions, and the final step is to report all of the findings. Whereas the conventional site assessment is focused on a two-dimensional plan view of the site, has a predetermined rigid work plan, and multiple field mobilization phases, an expedited site assessment is based on a conceptual three-dimensional model of the subsurface, has a flexible and dynamic work plan that is updated as new data become available, and has a single field mobilization phase.

Natural attenuation can appear to be taking place if one is not savvy in looking for the right indicators. Cleverly placed wells (on the edge of a plume and then outside of the plume) may fool a regulator. What one must look for is not just the loss of contaminants (spatially and temporally), but also the loss of electron acceptors (spatially and temporally), and the accumulation of metabolic by-products (spatially and temporally). When each of these three factors appears to be behaving as expected in downgradient wells, along with changes in alkalinity and redox potential, then a regulator can be confident that natural attenuation has truly been demonstrated.

CONCLUSIONS:

This course has the basics for those who are new to the field of hydrology, as well as bits of wisdom, practical guidance, and discussions of new technology that are useful to those intimately familiar with the discipline.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

For those who have attended this course in the past, it could be of value to attend again, as the course materials are continuously updated to keep abreast of current happenings in the field of hydrology.

SIGNATURES:

Cynthia L. Dinwiddie
Cynthia L. Dinwiddie
Research Engineer

Date 02/24/03

CONCURRENCE:

[signature] for ECP
English C. Pearcy
Manager, Geohydrology and Geochemistry

Date 02/25/2003

[signature]
Henry F. Garcia
Director of Administration

Date 2/24/03