INTERNATIONAL SCHOOL FOR GEOSCIENCE RESOURCES (IS-Geo)
KOREA INSTITUTE OF GEOSCIENCE AND MINERAL RESOURCES (KIGAM)

REGULAR TRAINING COURSE ON
Groundwater Theory and Practices

The **International School for Geoscience Resources** of KIGAM presents an intensive training course on **"Groundwater Theory and Practices"**. The course will take place at the International School for Geoscience Resources of KIGAM in Daejeon (Korea) from **June 19 - 30, 2017** and includes the following **2 modules**.

Modules	Date	Lecturers
Module 1. Fundamentals of Groundwater Topic 1. Introduction and Theory of Groundwater Flow Topic 2. Theory of Groundwater Flow Topic 3. Field Investigations, Aquifer Tests Topic 4. Response of Aquifers to Pumping: Aquifer Tests Topic 5. Case Studies: World Water Issues	June 19~23	Prof. Schwartz/Lee (Ohio State Univ.)
☆**Field Excursion**	June 24	Dr. Yongcheol Kim (KIGAM)
Module 2. Contaminant Groundwater Hydrogeology, Field Exercises Topic 1. Natural Constituents and Contaminants in Water Topic 2. Contaminants in Water, NAPLs, Theory of Contaminant Transport Topic 3. Water Contamination and Remediation: Case Study Topic 4: Field Exercises: Groundwater sampling, measuring field parameters, aquifer test	June 26~29	Prof. Schwartz/Lee (Ohio State Univ.)
☆**Country Report Workshop**	June 30	IS-Geo

COURSE INFORMATION

- **Agenda & Summary of Course Content and Learning Objectives**

Groundwater is an important, readily available source of freshwater for countries around the world. Not surprisingly, the rate of groundwater utilization has increased in the face of growing populations and the decrease in available surface-water sources. Now, groundwater is mined from aquifers at rates far in excess of their natural replenishment.

Among the available sources of freshwater, groundwater is the most important. The quantities of water stored in major aquifers can be large and relatively uncontaminated. Although locally important, surface water can fluctuate dramatically in its availability according to monsoon or snowmelt cycles, and is readily contaminated from agricultural and urban runoff. Thus, given the importance of groundwater now and in the future, it is essential that decision makers recognize the potential vulnerabilities associated with the over-exploitation of groundwater.

The goal of this intensive training course then is to provide participants with a broad understanding of water as a resource, focusing on groundwater but also including surface water with measures to provide for their sustainability. To achieve this goal, the course combines lectures, hands-on practical exercises and field work. It links both theory and practice in a way designed to highlight the importance of each. Specific learning objectives of the program are (i) to develop fundamental knowledge on the water budget and sustainability, concepts and theories of groundwater flow and aquifer tests, field investigation, and water quality; (ii) to use illustrative problems and field exercises to foster a deep understanding of these basic concepts; (iii) to apply theory and concepts to problems of groundwater over-utilization, contamination assessments, health, and water security; and (iv) to develop practical know-how in basic field investigations through exercises.

The study of groundwater is complicated by the fact that to a large extent the resource is hidden below the ground surface. Moreover, the flow of groundwater is dependant in a critical way on the patterns of recharge, the architecture and hydraulic characteristics of aquifers and confining beds and pumping from wells. The first part of the course provides a clear understanding of these basic concepts from both a theoretical and practical perspective. Particular emphasis is provided on the fundamentals of flow through porous media, field methods used to describe groundwater flow, and ideas of regional groundwater flow.

By its very nature, groundwater is a field-oriented science. Thus, the next major segment of the course explores field hydrogeology including drilling and sampling, well-design and installation and both surface and borehole geophysics. These techniques are designed to provide a foundation for students to develop an understanding of the architecture of aquifers and confining beds, and their important role in groundwater flow. Carefully designed exercises illustrate how these ideas are used in practice. Another essential focus for field investigations is aquifer testing including both the design of field tests and the interpretation of test results. By combining classroom work elucidating fundamental theories of well hydraulics with a field exercise on the KIGAM site, course participants will come away with a thorough understanding of this essential component of groundwater-resource assessments.

Discovering groundwater is only a first step in determining its potential as a water supply for drinking water or irrigation. To a significant extent, the chemical quality of groundwater dictates its potential usability. Groundwater can be impaired due to either natural salinity or contaminants from a variety of human activities. Careful sampling and chemical analysis thus is required as part of an overall assessment. The course touches on the chemical constituents found in natural groundwater and the most common contaminants. A framework for evaluating water quality is provided by water quality standards and maximum contaminant limits (MCLs). This introduction leads naturally to a detailed treatment of contaminant hydrogeology including the key types of contamination problems, families of contaminants and their health implications, and mechanisms important for understanding the spread of dissolved and non-aqueous phase contaminants. A series of exercises focuses on conceptualizing problems of contamination and techniques needed for investigating and treating contaminated water resources such as contaminant plumes, urban and agricultural runoff, and acid mine drainages. Finally, knowledge obtained from this course will be utilized to understand water security issues around the world.

This course is structured to appeal to those with a diverse background. Participants will enjoy a student-focused learning environment that moves at a pace dictated by your abilities and understanding. You will come away with a foundational understanding of surface and groundwater resources appropriate for supporting national water agendas.

Module 1. Fundamentals of Groundwater
- Dr. Schwartz/ Dr. Lee/ Dr. Kim

The first part of this module addresses the concept of a water cycle, water budgets from a hydrologic and groundwater perspective, the development of ideas of sustainability and basic concepts of flow through porous media and the controlling parameters. Another focus of this module is regional groundwater flow, the historical development of ideas and basic concepts. Students will explore dynamics of groundwater flow and the construction of hydrogeologic cross-sections. The objectives of this part of the module are to provide students with a clear understanding of fundamental concepts and theories of the occurrence of water and the quantitative description of its flow, and the historical development of foundational ideas.
This module will also cover key aspects related to the field practice of hydrogeology including, drilling and sampling, and the design and installation of piezometers and monitoring wells. It will provide an introduction of the theory of flow to wells and the application of this theory in aquifer testing, and regional water resource assessments. Examination of case studies and exercise questions will provide instruction in correlation of lithologic data, and the interpretation of aquifer test results. In addition, this module will address water issues around the world, focusing on understanding causes and consequences of water scarcity, conflicts, privatization, and pollution, and potential solutions to those critical issues through discussion of real-world cases and analyses of historic events and available data.

Content of topics

- **Day 1. Introduction and Theory of Groundwater Flow (June 19) - Schwartz, Lee**
  - Introduction and Overview (Schwartz)
  - Water occurrence and cycle (Lee)
  - Water budget
    - Estimating water budget (Schwartz)
    - Estimating runoff ratios (Lee)
  - Darcy's Law
    - Theory (Schwartz)

- **Day 2. Theory of Groundwater Flow (June 20) -Schwartz, Lee**
  - Darcy's Law
    - Hydraulic head estimation and applications (Lee)
  - Flownets
    - Theory (Lee)

        - Applications (Schwartz)

    - Regional groundwater flow (Schwartz)

    - Aquifers
        - Occurrence, transmissivity, and storativity (Lee)
        - Types of aquifers (Schwartz)

- **Day 3. Field Investigations, Aquifer Tests (June 21) -Schwartz, Lee**
    - Field investigations
        - Common drilling and sampling methods (Schwartz)
        - Preparation of hydrogeologic cross-section (Lee)
        - Piezometer design, installation, head measurements (Schwartz)
        - Geoprobe – Theory, data analyses (Lee)

    - Aquifer Tests: Theis solution for transient flow
        - Theory, forward and inverse methods (Schwartz)
        - Type-curve methods (Lee)

- **Day 4. Response of Aquifers to Pumping: Aquifer Tests (June 22) -Schwartz, Lee**
    - Theis solution for transient flow - Continued
        - Cooper-Jacob straight line methods (Schwartz)
    - Multiple wells, bounded aquifers
        - Principles of superposition, image wells (Schwartz, Lee)
    - Hantusch and Jacob method
    - Slug test

- **Day 5. Case Studies: World Water Issues (June 23) -Schwartz, Lee**
    - When Rivers Run Dry (Schwartz)
    - Water Privatization (Lee)
    - Groundwater Over-pumping (Schwartz)
    - Water Security and Sustainability (Lee)
    - Managed Aquifer Recharge (Kim, 1 hour) (optional)

- **Day 6. Field Excursion (June 24) -Kim**
    - Multi-purposes Dam (Daecheong Dam)
    - Natural Mineral Water Plant (HITEJINRO Co., LTD)
    - Water-curtain Insulated Green House

Module 2. Contaminant Groundwater Hydrogeology and Field Exercises- Dr. Schwartz/ Dr. Lee/ Dr. Kim

This module provides an in depth overview of basic concepts of contaminant hydrogeology and remediation techniques. It begins with an introduction of the variety of dissolved mass found in natural water, measures of concentration and types of water analyses. It includes a discussion of water standards and how they are used and how water evolves chemically in the subsurface. This module presents discussions of real-world examples in water pollutions and options for remediation, on the issues of groundwater and surface water contamination in the United States and around the world. The objectives of the first part of this module are to provide students the basic tools to interpret chemical data in the context of groundwater and water pollution investigations.

Contaminant hydrogeology brings together knowledge from other parts of the course and adds new ideas of physical and chemical transport. This module explains how contaminants originate in groundwater and how they are organized for study. It discusses the difference between problems of inorganic contaminants and those involving LNAPLs and DNAPLs. This section also explains the key processes involved in contaminant migration and develop conceptual models. Examination of case studies will help focus learning on the most important lessons. The objective is to provide an introduction to the subject that will provide a good understanding of the topic and integrate theory and practice. Field demonstrations and exercises will provide students with a basic understanding of field hydrorgeological methods and their relationship to theoretical concepts.

Content of topic

- **Day 1. Natural Constituents and Contaminants in Water (June 26) -Schwartz, Lee**
  - Ions, measures of concentrations, epm balance (Schwartz)
  - Water analyses, drinking water standards (Schwartz)
  - Plotting chemical data (Schwartz)
  - Contaminants and types of contamination
    - Families of contaminants (Schwartz)

- **Day 2-1. Contaminants in Water, NAPLs, Theory of Contaminant Transport (June 27) -Schwartz, Lee**
  - NAPLs – properties, occurrence, petroleum hydrocarbons (Lee)
  - NAPLs dynamics in soil and groundwater (Schwartz)
  - Advection: Otis Air Base (Lee)

- **Day 2-2. Theory of Contaminant Transport (June 27) -Schwartz, Lee**
  - Diffusion, Dispersion and Key Reactions
    - Diffusion, dispersion (Schwartz)
    - Dispersion, quantitative methods (Lee)
    - Sorption and retardation (Lee)

  - Groundwater Contamination and Remediation
    - Savage Well Superfund site, USA (Schwartz, Lee)
      - Pump-and-treat (Schwartz)

- **Day 3. Water Contamination and Remediation: Case Study (June 28) -Schwartz, Lee**
  - Groundwater Contamination and Remediation
      - In situ chemical oxidation (Lee)

  - Surface Water Contamination and Remediation
    - Hypoxia (Schwartz)
    - Acid Mine Drainage (Lee)
    - Arsenic Contamination - Asia (Schwartz)
    - Human Health Problems (Lee)
      - Case studies – E. Coli, Typhoid, Cholera (Schwartz, Lee)

- **Day 4. Case Study, Field Exercises (June 29) -Kim, Schwartz, Lee**
  - Human Health Problems (Schwartz, Lee)

  - Field Exercise: Aquifer tests (Kim, Schwartz, Lee)
    - Head Measurement
      - Measure water table depth from top of casing using electrical tape
      - Convert water table depth to elevation head
    - Hydraulic test
      - Data logger installation
      - Performing slug test(injection/withdrawal)
      - Performing pumping test
    - Groundwater sample collection (non-pumping well)
      - Bailer
      - Peristaltic pump

- Filtering and water chemistry measurements (Bypass from pumping well
  - Demonstrate filtering process with filtering equipment
  - Water chemistry measurement such as EC, pH, Temp., DO, ORP using flow-through cell and peristaltic pump
  - Compare water chemistry result between samples collected by bailer and peristaltic pump

- **Day 5. Country Report Workshop (June 29)**

About the presenter –*Professor Frank W. Schwartz*

Frank W. Schwartz received B. Sc. M. Sc., and Ph.D. degrees in hydrology from University of Western Ontario, University of Manitoba, and University of Illinois, respectively. Professor Schwartz joined School of Earth Sciences of The Ohio State University in Columbus, OH in 1988 as the Ohio Eminent Scholar in Hydrogeology. Dr. Schwartz is the author of more than 190 publications and is known internationally for his work on field and theoretical aspects of contaminant hydrogeology and remediation, mass transport, ground-water geochemistry, and watershed hydrology. He has co-authored two textbooks, *Physical and Chemical Hydrogeology* (John Wiley & Sons, Inc., New York, Domenico, P.A. and F.W. Schwartz, 1998), and *Fundamentals of Ground Water* (John Wiley & Sons, Inc., New York, F.W. Schwartz, and H. Zhang, 2003), which are widely used for teaching hydrogeology around the world. Professor Schwartz has received major awards recognizing his status as a scientific leader. He is a recipient of the O.E. Meinzer Award, the Excellence in Science and Engineering Award, the King Hubbert Science Award, and was elected as a Fellow of the American Geophysical Union and Geological Society of America. He served as the Editor-in-Chief for the Journal of Contaminant Hydrology (1991-2003), and the Editor-in-Chief for the Groundwater (2009-2013). In addition, he has served on a variety of expert panels of the U.S. National Research Council, the U.S. Department of Energy, U.S. Geological Survey, the Lawrence Berkeley National Laboratory, and the US EPA. Dr. Schwartz has taught five educational programs that included 5-day courses in contaminant hydrogeology and remedial technologies (in Valencia, Spain, San Deigo, CA, Lima, OH, and Columbus, OH).

About the presenter- *Professor Eung Seok Lee*

Eung Seok Lee received B. Sc. and M. Sc. in geology from Yonsei University, South Korea and Ph.D. in hydrogeology from Indiana University, USA. Professor Lee teaches hydrogeology at Department of Geological Sciences of Ohio University in Athens, OH as an Associate Professor. An author of more than 30 international journal publications, Professor Lee has performed sponsored research in the areas of karst hydrogeology, contaminant hydrogeology and remediation (US DOE, DOD), isotope hydrology (NSERC, Canada), acid mine drainage (American Electric Power), urban runoff management (Global Research Laboratory, MEST, Korea), and conducted various research with Environmental Protection Agency on groundwater flow and contaminant transport modelling, landfill leachate treatment using constructed wetlands, metal treatment in acid mine drainage, surface water-groundwater interaction, and vapor intrusion due to DNAPL contamination. Professor Lee has received John Patton Award, Shell Scholarship, and served as an associate editor of journal *Groundwater*. He teaches Water and Pollution, Natural Disaster, Water Resources and Sustainability, Principles of Hydrogeology, and Advanced Hydrogeology courses at Ohio University.

About the presenter- *Dr. Yongcheol Kim*

Yongcheol Kim received PhD (2004) in hydrogeology from Seoul National University, South Korea. In 2003-2005, he researched at CESEP (Center for Experimental Study of Subsurface Environmental Processes) in Colorado School of Mines, Colorado, USA. as a visiting scholar and post-doctoral researcher. Since 2005, he has been a researcher at department of groundwater, Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, Korea. His research interests include managed aquifer recharge, coastal aquifer management, flow and transport in saturated/unsaturated porous/fractured media, DNAPL problems, tracer tests and hydraulic tests for site characterization.