International PhD Course in

HYDROGEOPHYSICS

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International Research School of Water Resources

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Course Aims

To illustrate a number of principles and techniques behind the use of geophysics for hydrological investigations.

We focus on electrical based methods (resistivity, induced polarisation, electromagnetic and radar) because of their widespread use in hydrogeophysics.

We will provide software tools for modelling geophysical data and give some training in the basic use of these tools.

Course Lecturers

Andrew Binley, Lancaster University, UK

Giorgio Cassiani, Università di Milano – Bicocca, Italy

Ingelise Møller Balling, Geological Survey of Denmark and Greenland, Denmark

Esben Auken, University of Aarhus, Denmark,

Majken Looms, University of Copenhagen, Denmark,

Anders Vest Christiansen, University of Aarhus, Denmark

The value of hydrogeophysics

Geophysics has been widely used to support groundwater investigations for many years. However, much of the earlier approaches concentrated on using geophysics to define lithological boundaries and other subsurface structures.

During the 1990s there was a rapid growth in the use of geophysics to provide *quantitative* information about hydrological properties and processes.

Much of this was driven by the need to gain information of direct value to hydrological models, particularly given the developments of ‘data hungry’ stochastic hydrology tools.

The value of hydrogeophysics

Perhaps more significant is that there is a clear demand by government regulators and agencies for tools and technologies to allow characterisation of groundwater systems, for example linked to the EU Water Framework Directive

Advantages

Geophysics offers advantages over conventional sampling to the hydrologist because of:

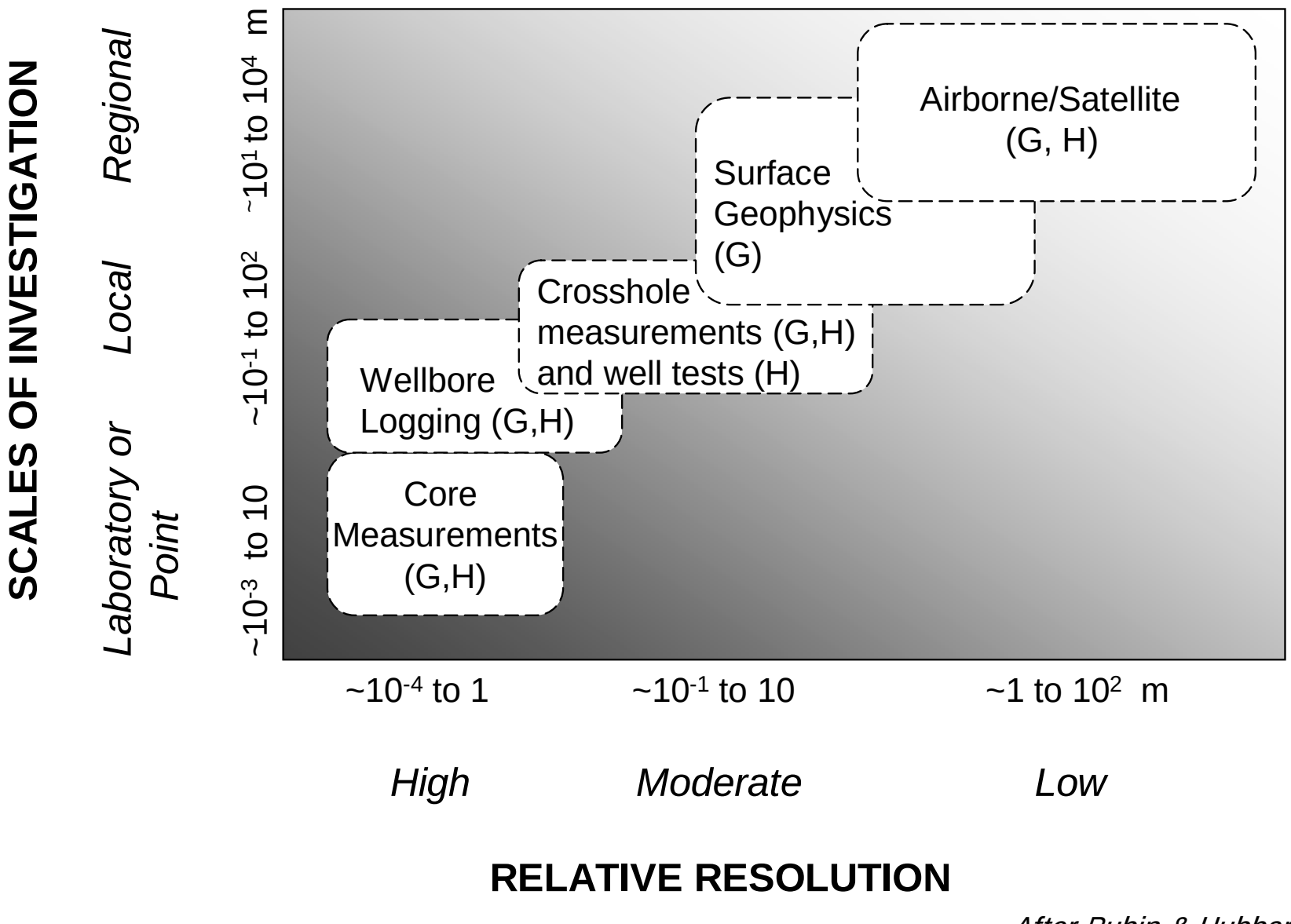
High data sampling density

Relative lower cost of measurements – may avoid use of boreholes and/or allow quicker sampling

Minimally invasive – may allow investigations without affecting the hydrology of the system

Larger measurement volume – more consistent with modelling needs

Advantages



After Rubin & Hubbard (2005)

Hydrogeophysical approach

Geophysical imaging

petrophysical model

structure

(e.g. hydraulic conductivity)

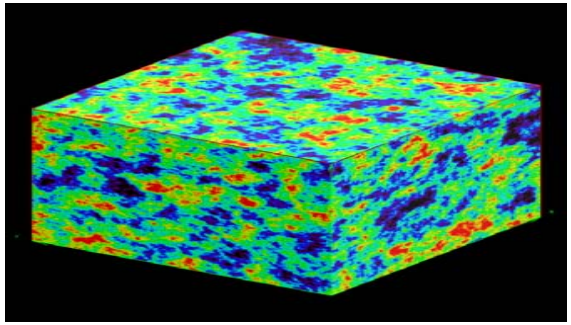
hydrological model

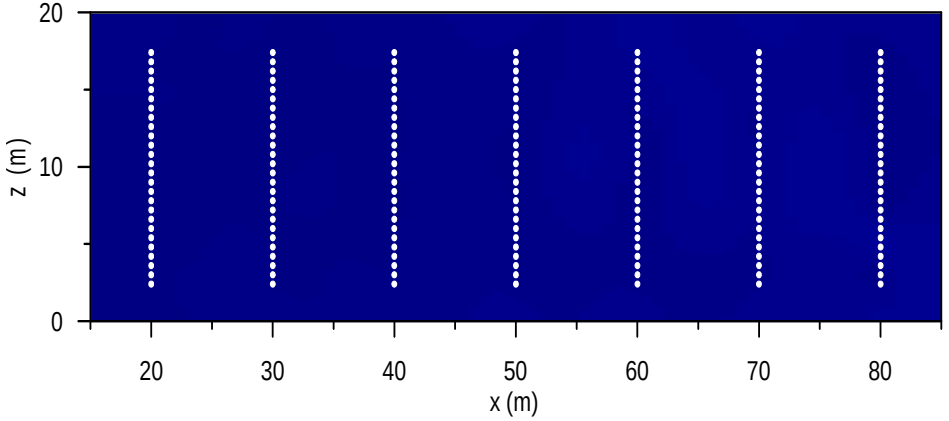
Time-lapse imaging

petrophysical model

process

(e.g. solute transport)

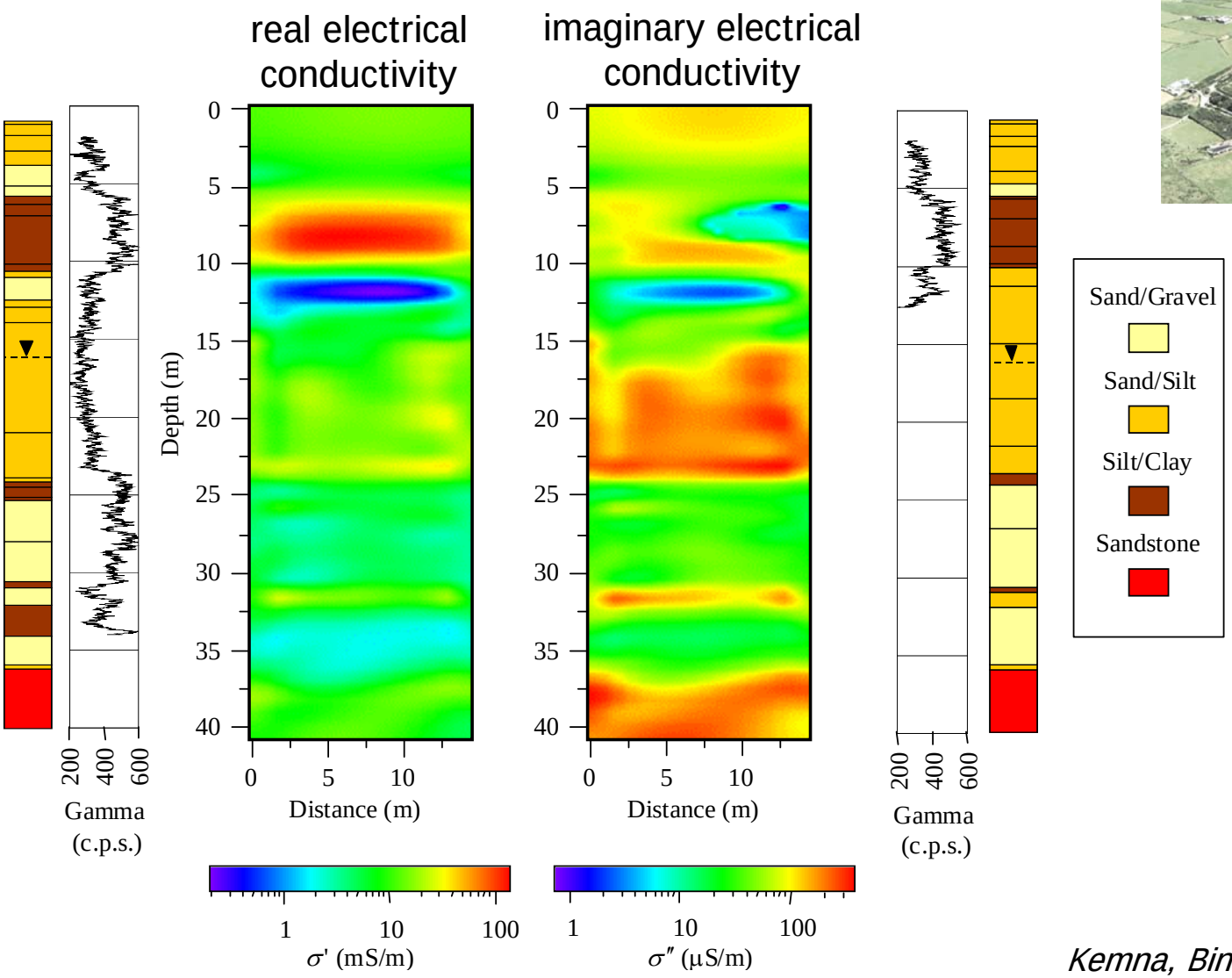




After Kemna (2003)

Structural characterisation example

Complex resistivity at the Drigg nuclear site, UK

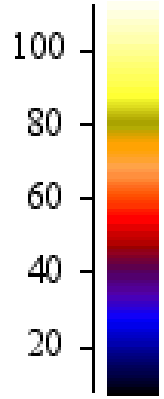


Kemna, Binley and Slater (2003)

Process characterisation example

Tracer experiment at the Krauthausen test site

day 1



electrical conductivity changes (%)

Kemna, Vanderborght, Kulessa and Vereecken (2002)

Expectations

The hydrologist **may expect** the following:

1. Coverage over a large area at high resolution

2. Significant depth penetration

3. To make use of existing infrastructure

4. That the geophysicist will use the most appropriate method available

5. An (error free) image of the hydraulic property that they are interested in

Expectations versus reality

The hydrologist **may get**:

1. Coverage of a small plot of the site of interest

2. Limited depth penetration due to surface cover and conditions

3. Gaps in coverage or anomalies due to steel cased boreholes, for example

4. The geophysicist used the method that he/she is most familiar with

5. An image of a geophysical property (with unquantified uncertainty) that is somehow related to a hydraulic property

Expectations – essential communication

It is important, therefore, to communicate in order to establish:

1. What exactly does the hydrologist want ?

2. Does geophysics offer any solution ? There may be a better solution.

3. What exactly is realistic given the site conditions (geology, access, cover, etc.)

4. How will the geophysical property be related to what the hydrologist wants ? Can this be quantified ?

5. Is it possible to determine some level of uncertainty in the results that are communicated ?

Course outline

Day 1

09:00 – 10:00	***Registration, course introduction.*** (Binley)
10:00 – 11:00	***Hydrological – geophysical relationships.*** (Binley)
11:00 – 12:00	***Surface georadar methods.*** (Cassiani)
12:00 – 13:00	***Lunch***
13:00 – 14:00	***Borehole georadar methods.*** (Cassiani)
14:00 – 15:00	***Computer Practical: Processing surface georadar data.*** (Møller Balling/Cassiani)
15:00 – 16:00	***Field demo: surface georadar***. (Møller Balling/Cassiani)
16:00 – 17:00	***Computer Practical: Processing borehole georadar data.*** (Møller Balling/Cassiani)
17:00 – 17:30	***Day summary and presentation of findings.*** (Students)

Course outline

Day 2

09:00 – 10:00	***Resistivity and IP methods.*** (Binley)
10:00 – 11:00	***Inversion of resistivity and IP data.*** (Binley)
11:00 – 12:00	***Computer Practical: Analysis of surface resistivity data.*** (Binley/Cassiani)
12:00 – 13:00	***Lunch***
13:00 – 14:00	***Computer Practical: Generalised resistivity imaging.*** (Binley/Cassiani/Looms)
14:00 – 15:00	***Field demo: Surface resistivity.*** (Looms/ Binley/ Cassiani)
15:00 – 16:00	***Computer Practical: Analysis of surface resistivity field data.*** (Binley/ Looms/ Cassiani)
16:00 – 17:00	***Day summary and presentation of findings.*** (Students)

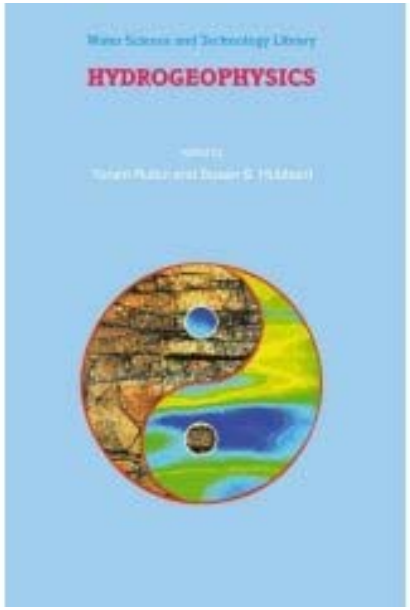
Course outline

Day 3

09:00 – 10:00	***Joint resistivity/radar case study***. (Looms)
10:00 – 11:00	***Data fusion.*** (Binley)
11:00 – 12:00	***Introduction to the transient electromagnetic (TEM) method.*** (Auken)
12:00 – 13:00	***Lunch***
13:00 – 14:00	***Mapping strategy for large scale structural aquifer characterization.*** (Auken)
14:00 – 15:00	***Estimating aquifer vulnerability using an inverse approach.*** (Christiansen)
15:00 – 15:30	***Limitations, challenges and emerging techniques.*** (Binley)
15:30 – 16:00	***Course summary***. (All)

Course Materials

The book
Hydrogeophysics
by Rubin and
Hubbard (Eds.),
2005, accompanies
the course

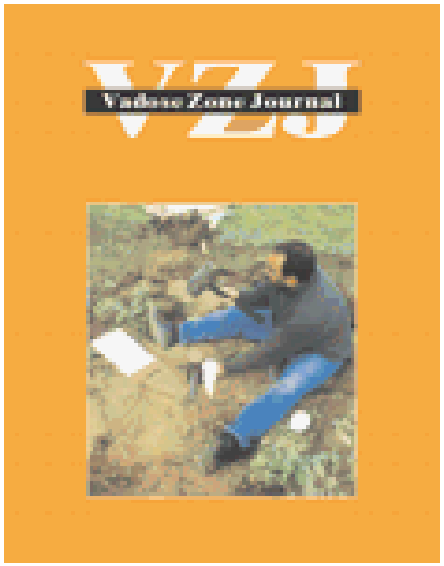


Additional materials are available in the course notes

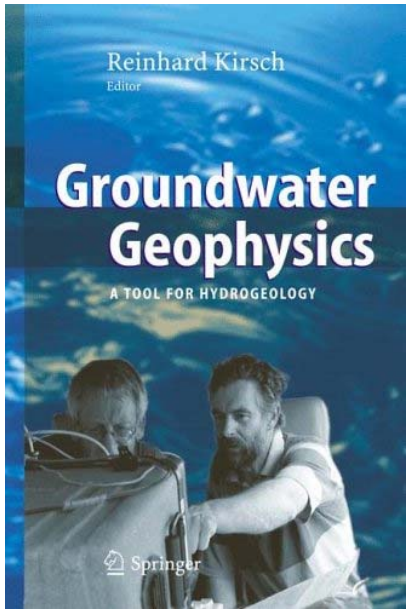
A CD containing software and additional materials will be available at the end of the course

Other sources of information

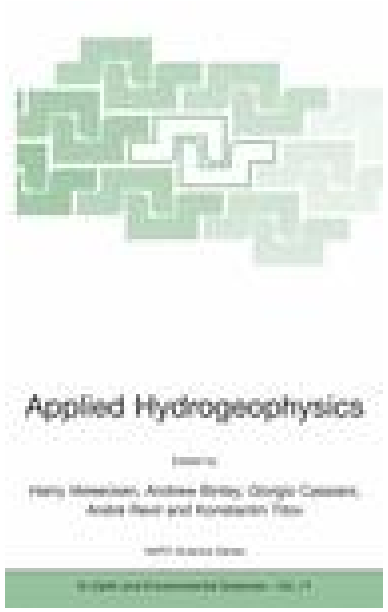
Vadose Zone Journal
Special Section on *Hydrogeophysics*
2004, Volume 3(4)



***Groundwater Geophysics*, Reinhard Kirsch (Ed.), 493 pages, Springer-Verlag, 2006.**

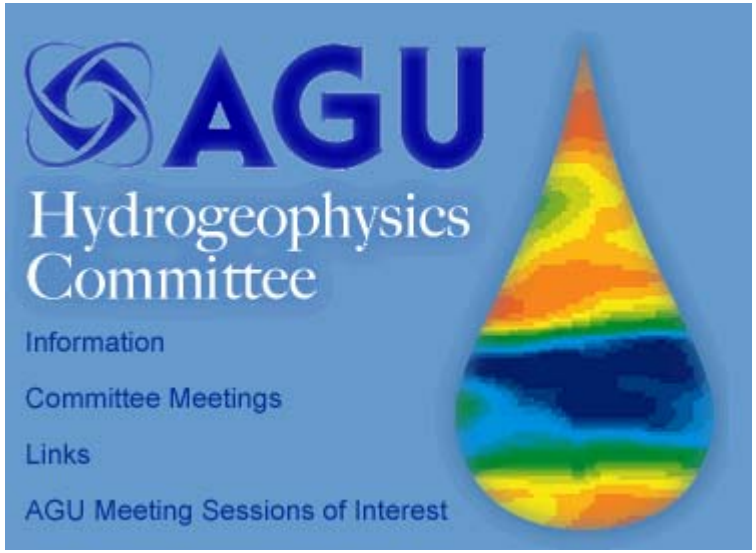


***Applied Hydrogeophysics*, H Vereecken, A Binley, G Cassiani, A Revil and K Titov (Eds.), 395 pages, Springer-Verlag, 2006.**



Other sources of information

AGU *Hydrogeophysics* Committee of the Hydrology Section



http://esd.lbl.gov/people/shubbard/agu/hydro_info.html

Other sources of information

http://www.eegs.org/sageep/

Special Session on Watershed Geophysics

Other sources of information

CMWR XVI
Computational Methods in Water Resources

XVI International Conference,
Copenhagen, Denmark, June 19-22 2006

http://www.cmwr-xvi.org

Special Session on Hydrogeophysics data fusion

Future hydrogeophysics events

AGU Fall 2006 *Hydrogeophysics* Sessions

11–15 December 2006, Monday–Friday
Moscone Center West, 800 Howard Street
San Francisco, CA, USA

http://www.agu.org/meetings/fm06/

Future hydrogeophysics events

Society of Exploration Geophysicists

Summer Research Workshop 2006
in Vancouver, Canada

HYDROGEOPHYSICS

31 July - 3 August 2006

This workshop will focus on the use of geophysical methods for the characterization of groundwater aquifers, and the long-term management of the resource. We wish to explore geophysical approaches from the petroleum industry that can be adapted and transferred to applications in water resources.

Sessions:

Characterization of Aquifers and Reservoirs at the Site Scale
Characterization Aquifers and Reservoirs at the Regional Scale
Imaging of Subsurface Flow and Transport Processes
Emerging Hydrogeophysical Methods

Organizers: Rosemary Knight (Stanford University),
Klaus Holliger (ETH Zurich), David Hyndman (Michigan State University)