

Design of an Advanced Hydraulics Experiment to Simulate Heat and Solute Transport in Homogeneous and Heterogeneous Saturated Sediment

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Objective

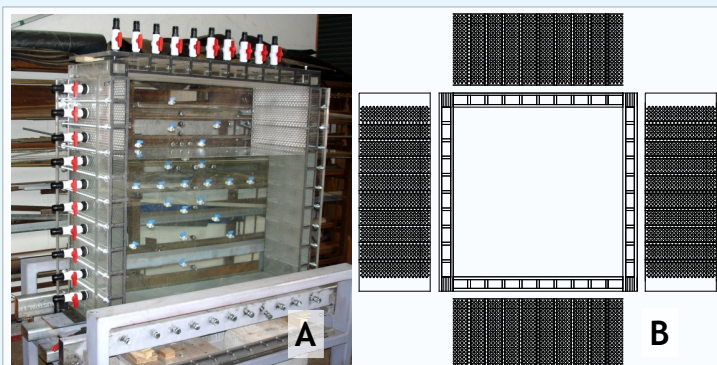
This research focuses on experimental investigations of the difference between solute and heat transport mechanisms in homogeneous and heterogeneous saturated sediments. The aim is to obtain a better fundamental understanding of heat transport and develop tools for the multi-dimensional quantification of surface water groundwater interaction using natural heat as a tracer.

Background

The use of natural heat as a tracer has already provided promising results for the measurement of interactions between surface water and groundwater. However, it is unknown to what extent mathematical heat models correctly describe small scale heat transport, especially in heterogeneous environments. Furthermore, existing analytical models are 1D and their application is limited to field situations where the flow is clearly 1D. This experimental facility was designed to answer fundamental questions for the use of heat as a tracer, and to test new field tools and analytical methodologies.

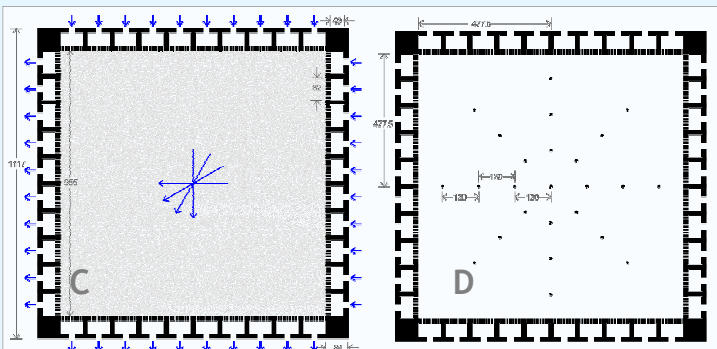
Hydraulic Facility

The hydraulic testing facility (named “Magic Box”) consists of an transparent acrylic box with experiment chamber dimensions of 0.955 x 0.955 x 0.4 m (0.365 m³). The chamber is surrounded by 40 enclosures (10 on each side) where the pressure (induced flow) can be regulated individually (Fig. A and B). Each of these controllable ports is connected to the experiment chamber via equal areas of evenly distributed holes.



A: The hydraulic testing facility (“Magic Box”). B: Schematic exploded view of the individual parts featuring the connection ports.

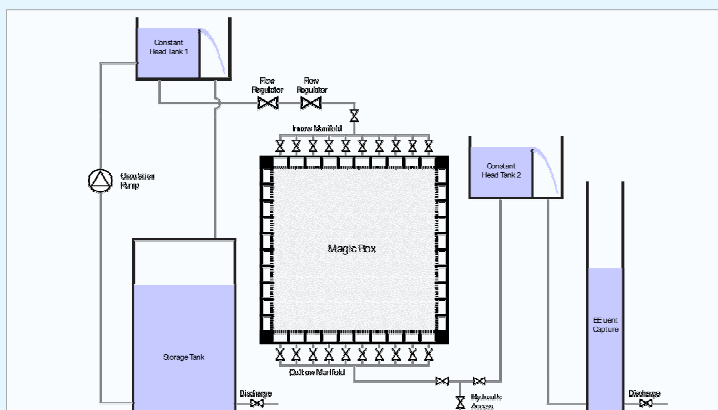
Flow inside the box can be induced by pressurising the individual perimeter enclosures using a hydraulic connection to a manifold. A 2D flow field can be established with variable flow rates, and directions varying between purely vertical and horizontal by 11 intermediate steps (Fig. C). The box represent a vertical slice of a streambed where realistic flow patterns can be simulated under controlled conditions.



C: Side view of the box with arrows indicating flow direction. D: Access points for monitoring the pressure distribution.

Experiment Setup

Flow through the Magic Box is induced by the head difference between two constant head tanks providing stable water levels at different heights (Fig. E). The resulting pressure can be further adjusted using a flow regulator (diaphragm valve). Water is circulated between a storage tank and the upper head tank using a pump to maintain a steady supply. The outflow is captured in a column with known diameter in order to determine flow rates by recording the increase in water level over time. The entire experiment is situated inside a climate control room maintaining ambient temperatures of 20°C.

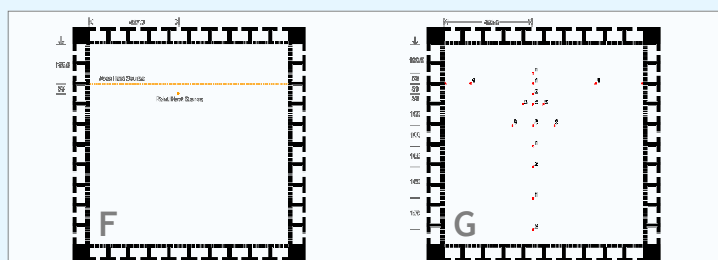


E: Schematics of experimental setup with storage tank, Magic Box, constant head tanks and flow rate metering.

Instrumentation & Measurements

The Magic Box is equipped with custom built micro-probes that are embedded in the sediment (Fig. F and G):

- point heat source using a resistor (2 x 4 mm)
- point solute source using a silicone micro tube (1 mm)
- area heat source using Nichrome resistance wire (0.4 x 0.955 m)
- 30 probes for high resolution temperature measurements (0.6 mK)
- 12 probes for fluid electrical conductivity (EC) measurements
- 6 channel pressure sensing device



F: Location and extend of the point and area heat source. G: Spatial distribution of the sensing probes.

Spatial distribution of the probes in the experiment chamber is optimised for capturing the 3D heat and solute transport mechanism (Fig G). A computer with NIDAQ hardware and specifically designed acquisition software (LabVIEW) is used to operate the heat sources, excite the EC measurement cells and Platinum RTD's, and perform A/D conversion of input and output. All electronic signals are conditioned and amplified using custom designed electronic circuit boards (SMD).

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More Information

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