Imperial College London

Characterising the role of heterogeneity on surface water-groundwater interaction in the Permo-Triassic Sandstone aquifers of the Eden Valley, NW England

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Introduction

The Permo-Triassic Sandstone aquifers of the Eden Valley are an important water source for public water supply and local agriculture.

The aquifers typically have large storage capacities and moderate transmissivities. However, these characteristics vary greatly on a range of scales, for example:

- Granulation seams (deformation bands) that are millimetres thick, extend for hundreds of metres on analogous sandstones
- Silicified layers that are several metres thick extend 10s to 100s of metres laterally
- Lithological variation and faulting that juxtapose hydrogeological units with different hydraulic properties

The heterogeneities are likely to impose local controls on groundwater flow and are compounded by highly variable overlying superficial deposits that may increase the indirect recharge component.

This research demonstrates a possible methodology for characterising surface water – groundwater interaction spatially and temporally in an ungauged upland sub-catchment using low-cost ultrasonic sensors.

Challenges

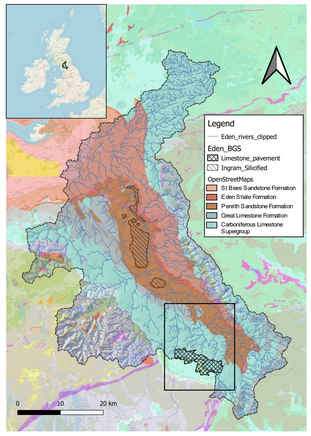
- Uncertain spatial and temporal distribution of recharge to the Permo-Triassic Sandstone aquifers of the Eden Valley
- Uncertain connectivity between Permo-Triassic Sandstone aquifer and underlying strata (Carboniferous Limestone & Millstone Grit)
- Uncertain 3-dimensional spatial distribution of superficial deposits and sources of heterogeneity

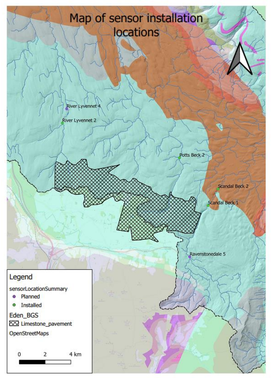
Approach

1. Design and build a low-cost river stage sensor that does not disturb channel flow
2. Install sensors at key locations to investigate the hydrological impact of heterogeneity
3. Conduct flow gauging while sensors are installed to generate rating curves to convert stage to flow
4. Use this data to improve conceptual understanding of surface water – groundwater interaction

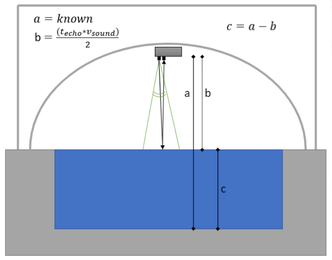
1. Ultrasonic sensor design

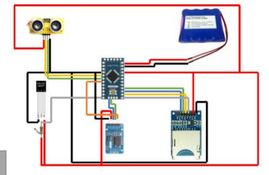
- Battery life: estimated 168 days (5.5 months)
- Range: 2 - 400cm
- Accuracy: +- 3mm
- Data storage and transfer: SD memory card
- Low cost ~£50 (€58) per unit





Geological maps of the Eden Valley 1:250,000 scale (DigMapGB-250)





Above. Circuit design for ultrasonic sensor 2.0 using the Arduino Mini Pro microcontroller, US-026 ultrasonic distance sensor, digital thermometer, SD card read/writer, clock and 10,400 mAh Li-ion battery

Left. Ultrasonic sensor operation schematic, measuring the distance from mounting point to water surface.

2. Sites & installation

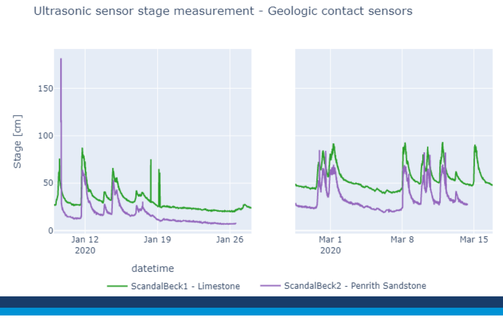
Desktop investigation conducted to identify suitable sites for sensor installation. Key criteria: 1) located close to region with heterogeneity feature; 2) straight river/stream channel; 3) existing infrastructure for mounting sensor.

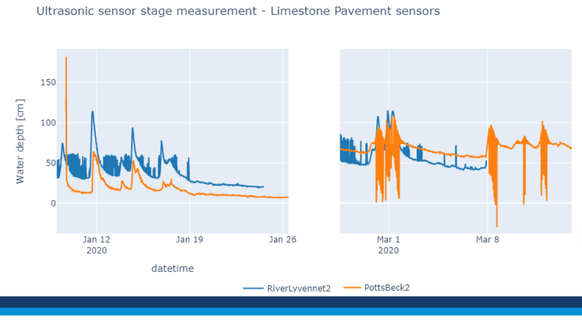
4 sites selected to investigate the impact of:

- Limestone pavement in the upper Eden catchment (River Lyvennet and Potts Beck)
- Geological contact between the underlying Carboniferous Knipe Scar Limestone Formation onto the Permian Penrith Sandstone Formation (Scandal Beck 1 & 2)

Photos of installation sites A) Scandal Beck 1 B) Scandal Beck 2 C) River Lyvennet D) Potts Beck

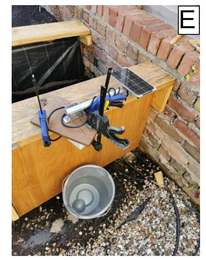
2. Initial data

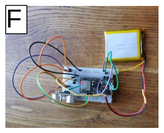




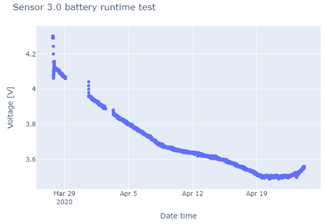
Sensor Improvements

- Inclusion of 6V 3W solar panel to extend battery life, theoretically forever
- Reduction in battery size to 3000mAh, offsetting the cost of the solar panel
- Move to integrated microcontroller and micro-SD card to further reduce the power losses due to manual solder connections





Photos of testing sensor 3.0
E) Sensor 3.0 with solar panel measuring distance to bucket of water
F) Sensor 3.0 prototype on breadboard
G) 3W solar panel and charge controller



Plot of battery voltage while sensor 3.0 is operating at 1-minute interval.

Further work

- Replace existing sensors with version 3.0
- Install new sensors at additional sites to investigate:
  - The Pennine fault system
  - Silicified layers of the Penrith Sandstone
- Conduct spot flow gauging to generate a rating curve at sensor locations
- Investigate the temporal and spatial connectivity between the surface water and groundwater along short stretches of rivers in the Eden Valley, Cumbria
  - Identifying the direction of flow, through comparison of river level with regional groundwater level
  - Quantifying flux, using horizontal Darcian flow estimation
- Utilize the flow data collected in future groundwater modelling

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https://youtu.be/5Pq2vFsP8q4

Citations
DiGMapGB-250 [ESRI Shapefile geospatial data], Scale 1:100,000, Updated: December 2018, Version, British Geological Survey (BGS), UK, Using: EDINA Geology Digimap Service, <http://digimap.edina.ac.uk/>, Downloaded: December 2018