Flow zone characterization in a fractured aquifer using spring and openwell Temperature and EC monitoring

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Flow zone characterization in a fractured aquifer using spring and open-well Temperature and EC monitoring

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1. Background

The Chalk of which the Kilham Catchment (study area in Fig. 1) forms a part is a very important aquifer in the UK and its aquifer properties derives from a well developed network of solutionally-enhanced fractures and conduits (see Fig. 1B).

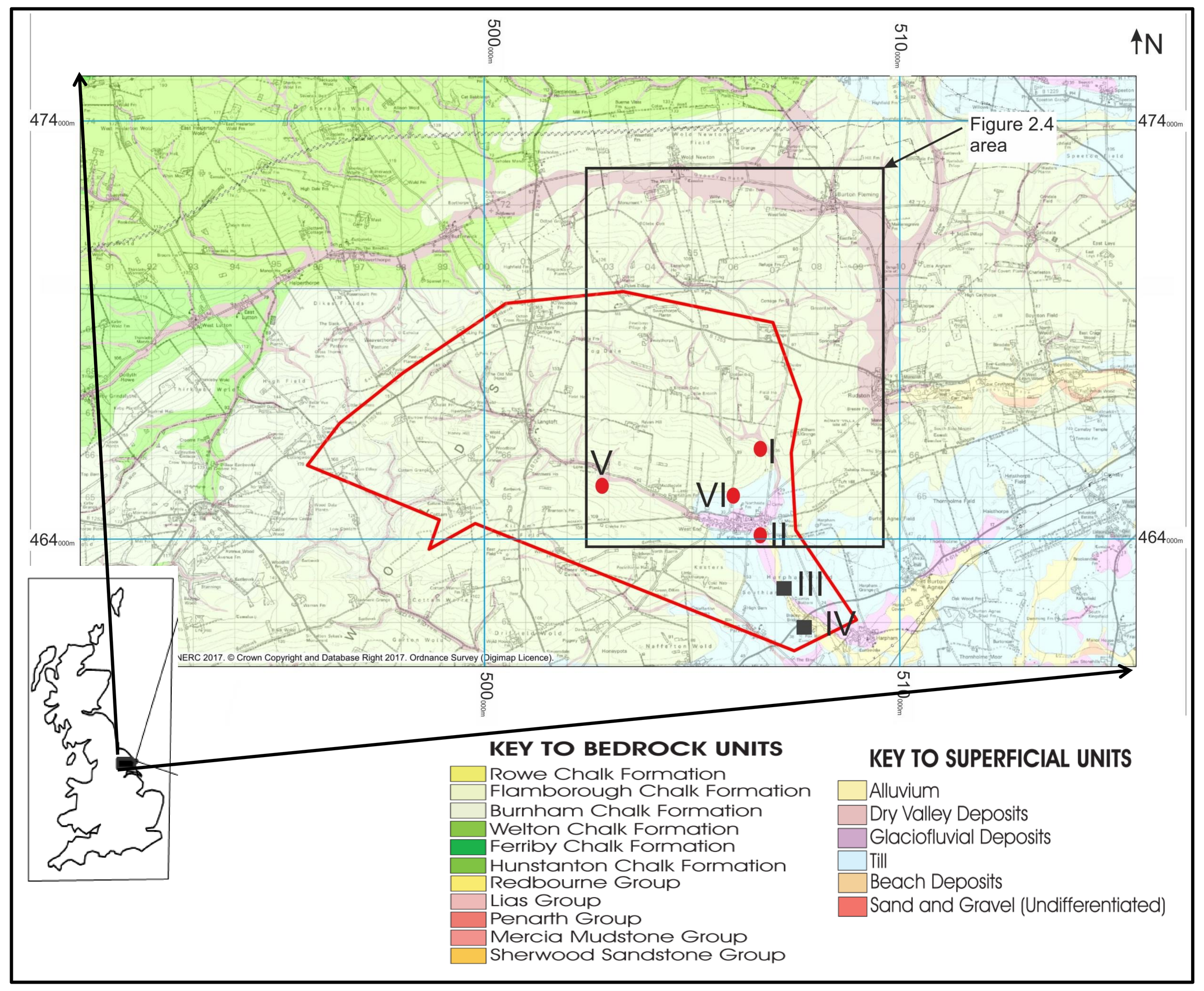


Figure 1A: Geological map of the East Yorkshire Chalk with Kilham catchment (bordered in red by topographic highs.

I-Tancred Pit Borehole; II-Kilham Sewage Treatment borehole; III- Bellguy spring; IV - Bracey Bridge spring; V- Henpit Hole borehole; VI-Kilham Pumping Station

Characterising flow pathways and catchment boundaries is very important for a fractured aquifer like the Chalk. The information is critical for resource management and determination of source protection zones for supply wells. It also determines the areal extent of contamination and targeted sampling of flow zones.

Currently, a rather simplistic conceptualisation of the unconfined chalk aquifer of East Yorkshire is currently used as a basis for numerical simulations: linearly reducing hydraulic conductivity (K) with depth below the maximum groundwater elevation, reducing to a minimum value below the zone of groundwater table fluctuation.

This study aims to improve the current model by combining different approaches:

i. ambient borehole dilution testing to identify flow zones;
ii. spring and well Specific Electrical Conductance (SEC) and temperature monitoring for flowpath characterisation;
iii. re-analysis of pumping test data to develop a transmissivity distribution map for the catchment.

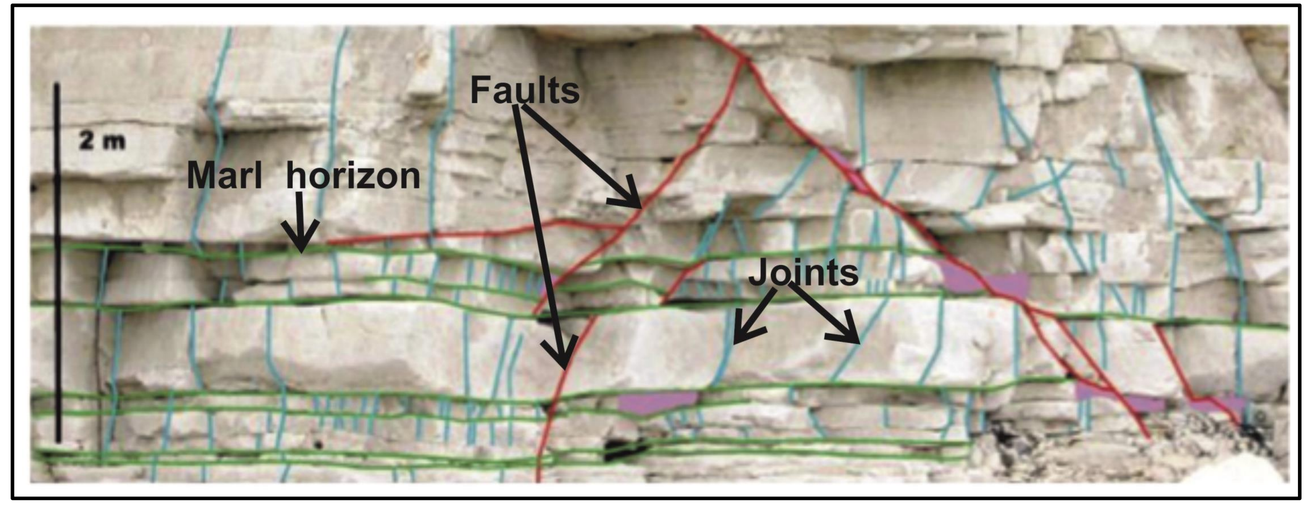


Figure 1B: Photograph of a section of the cliff in the Chalk (Flamborough Formation) (Hartmann et al 2007)

2. Open-well borehole dilution

The open-well borehole dilution method is used to characterise borehole hydraulic property variation with depth in uncased boreholes via the interpretation of specific electrical conductance (SEC) contrasts between aquifer formation fluid and borehole fluid column that has been altered by the introduction of a tracer in the borehole (West & Odling, 2007).

2.1 Tancred Pit borehole (50m depth)

- Rapid dilution of uniformly injected tracer between depth (22-50m bgl) within the first 20 minutes indicative of large inflows at well bottom (Fig. 2.1A).
- Point injected tracer at depth (45mbgl) loses mass and moves upwards at 2m/s. (Fig 2.1B & C).
- Flow conditions in the well captured on borehole CCTV by Southern Science Ltd (Fig 2.1D)
- Flow summary in well showing inflow and possible crossflows at well bottom; upflow; and outflow at casing bottom (Fig 2.1E).

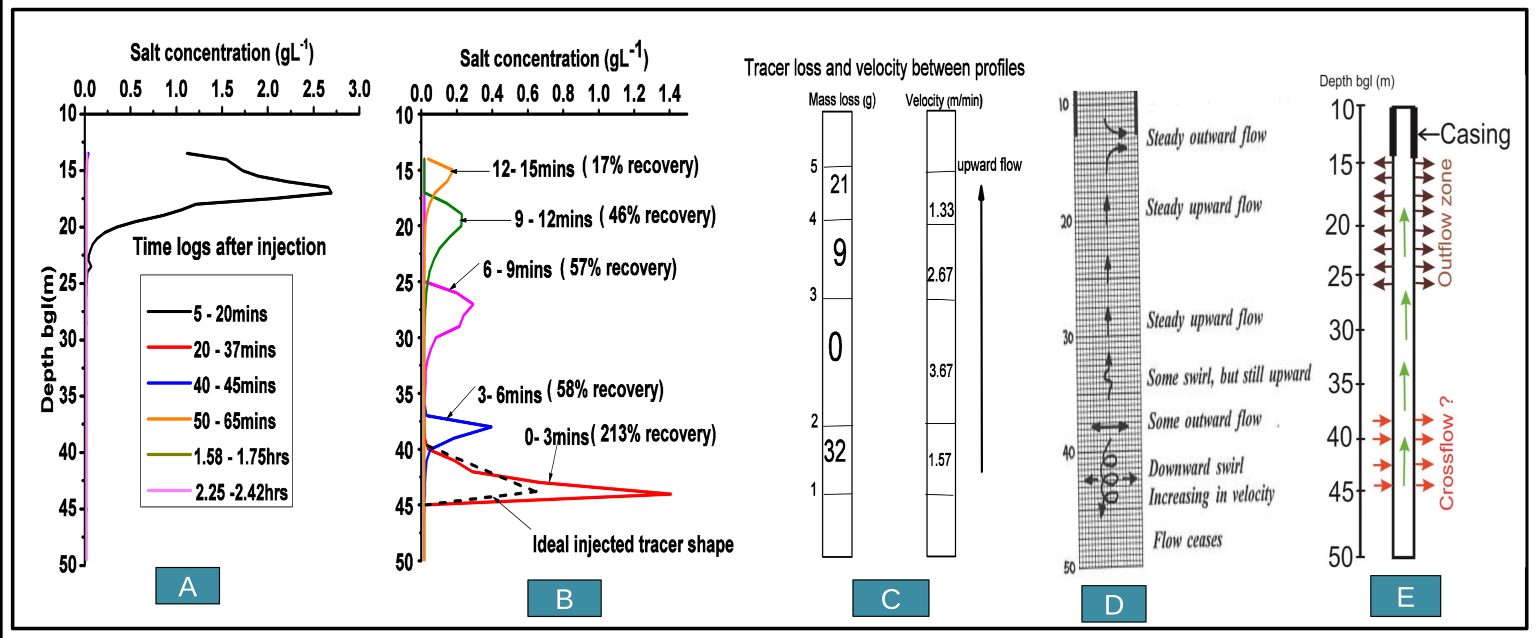
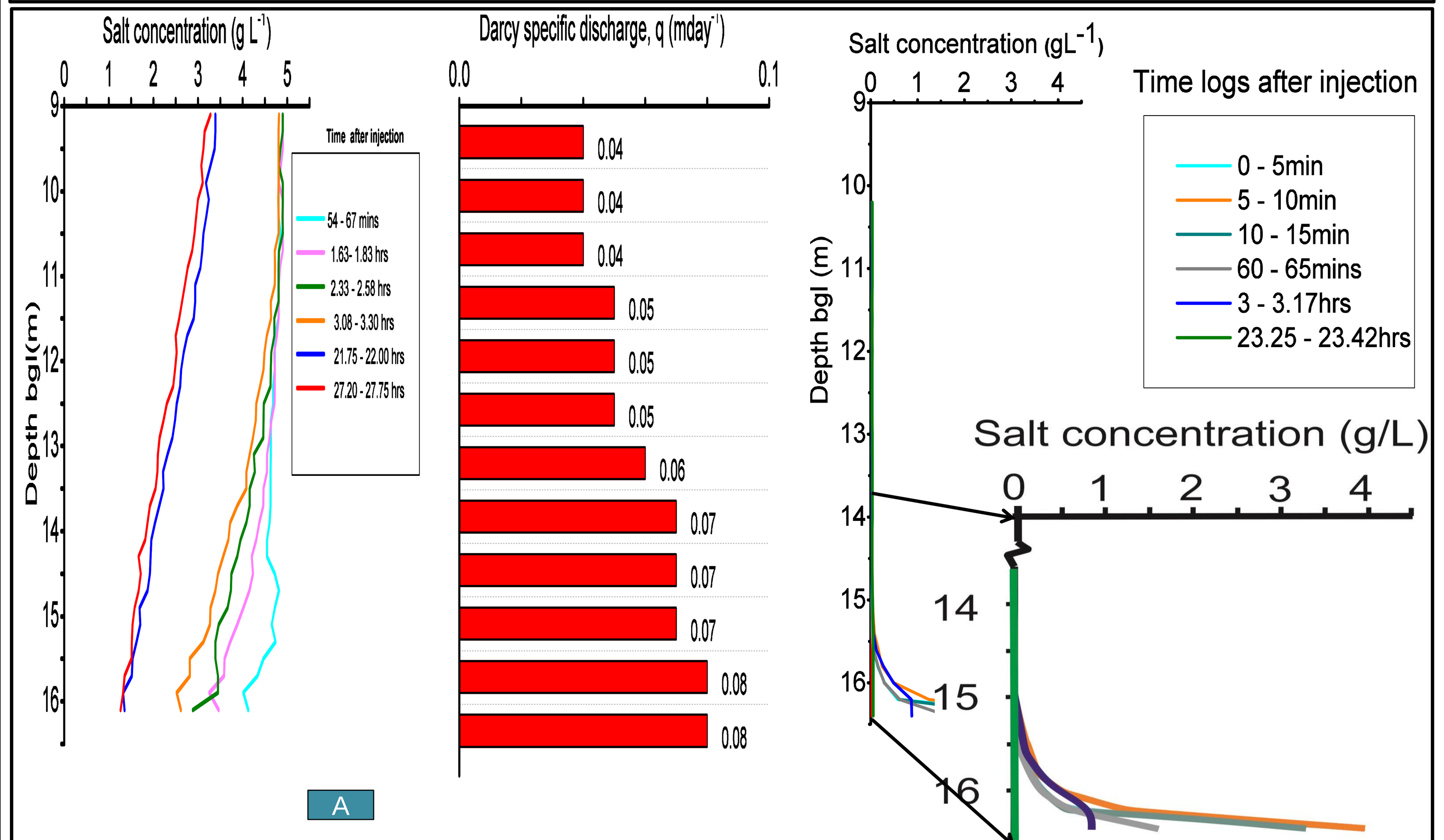


Figure 2.1: Tancred Pit borehole test results and summary.

2.2 Kilham Sewage Works borehole (15m depth)



Faster dilution of uniformly placed tracer at the bottom of the well (12-16mbgl) indicative of larger inflows at well bottom.

The dilution but stagnation of point placed tracer at well bottom shows no vertical flow in the well from the bottom of the well..

Figure 2.2: Kilham Sewage Works borehole test results and summary.

Tancred Pit shows upflow; Kilham Sewage shows crossflow. Difference in flow characteristics probably reflects the depth difference of the two wells (Tancred Pit is deeper).

SEC and temperature monitoring

- Constant temperature (as compared to air temperature) in springs show they are not affected by runoff.
- Well waters show a constant temperature and SEC.
- Springs show slight fluctuations in SEC, which is probably indicative of atmospheric contact.
- SEC difference between shallow and deeper flows is probably from confinement differences, i.e. extent of open- versus closed-system (see cross-section in 2.3C).

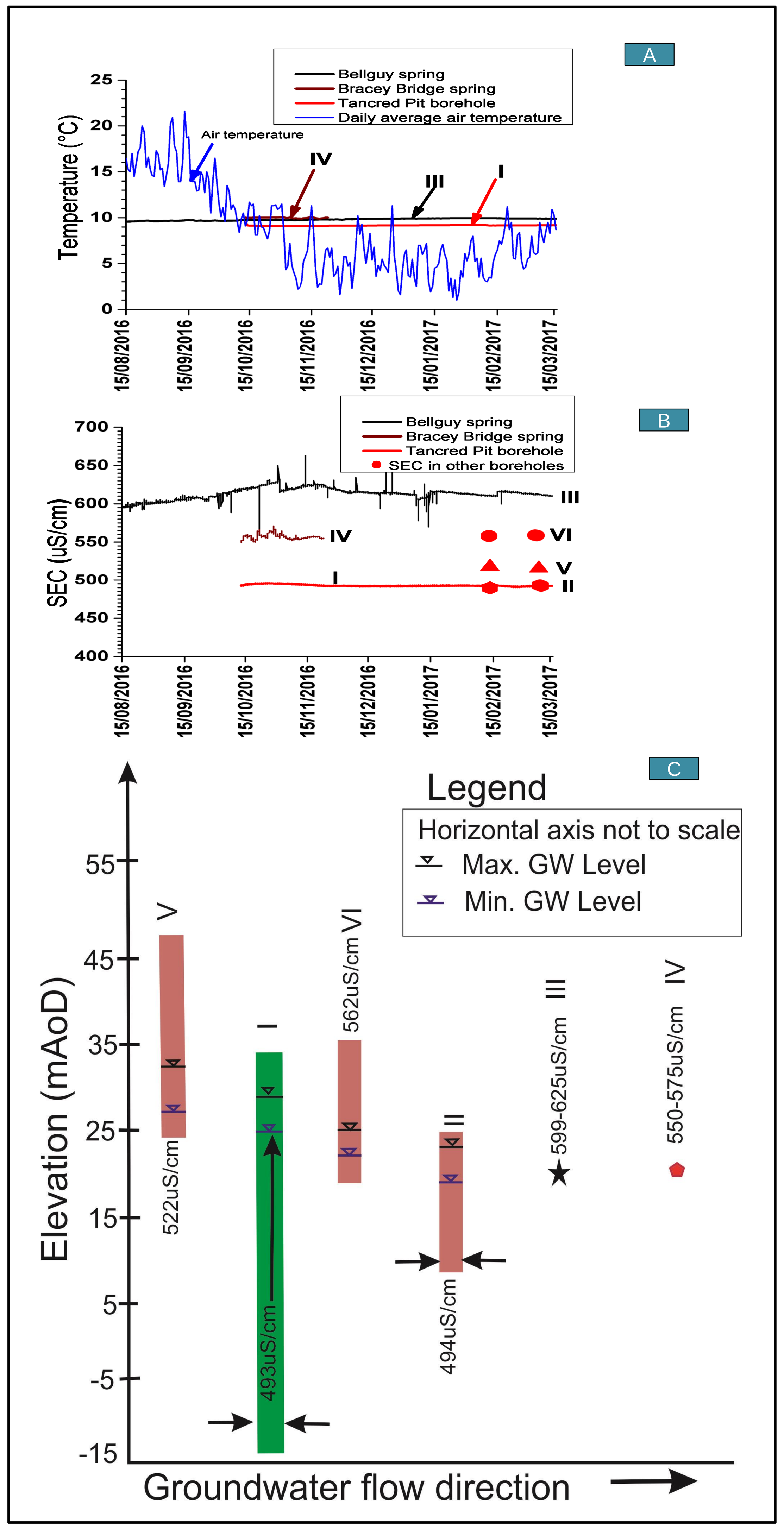


Figure 2.3: Spring and borehole Temperature (A); SEC logging and monitoring (B); well elevations and relative positions (C)

Transmissivity

- The transmissivity and fault map (Fig 2.4) based on pumping tests shows wide spatial variation of T for the catchment.
- Higher values of Transmissivity in red are that for recovery phase, whilst the others are for the drawdown phase.
- The spatial distribution of Transmissivity is indicative of catchment heterogeneity.
- Transmissivity values do not show any relationship with fault location.

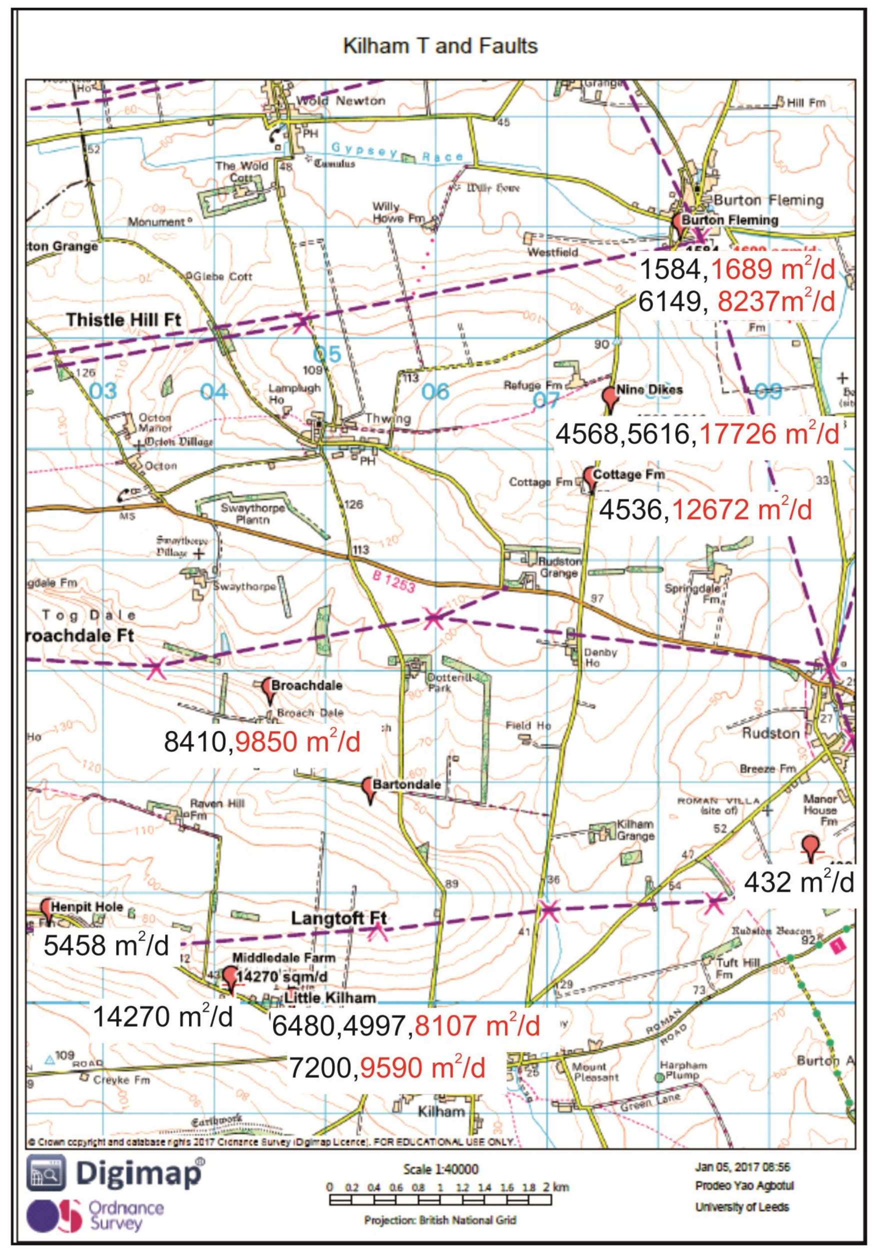


Figure 2.4: Catchment Transmissivity and fault map.

3. Conclusions

- Open well dilution method identifies permeable zones and vertical head gradient. Inflow zones identified at the bottom of Tancred Pit, with an upward flow of 2m/s. Shallower well at Kilham Sewage Work shows crossflow.
- Springs and the well show similar constant temperature characteristics, so springs sourced from groundwater. Differences in SEC may reflect degree of confinement and travel path differences (refer to Fig. 2.3C).
- Wide variation in Transmissivity reflects solutionally-enhanced fracture development, and no detectable effect of faults.

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