Temporary Sensor Deployments: a New Method for Assessing Transient Hydraulic Perturbations in Boreholes and Improved Design of Permanent Multilevel Installations

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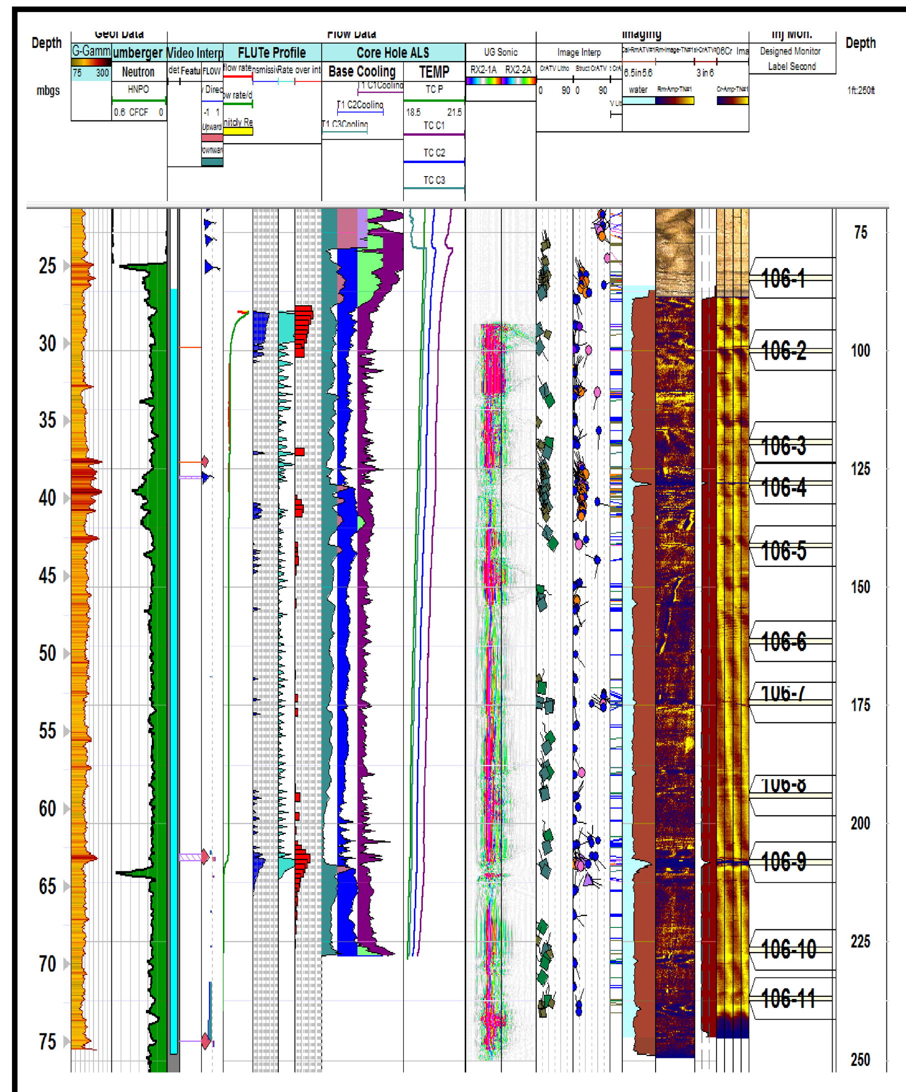
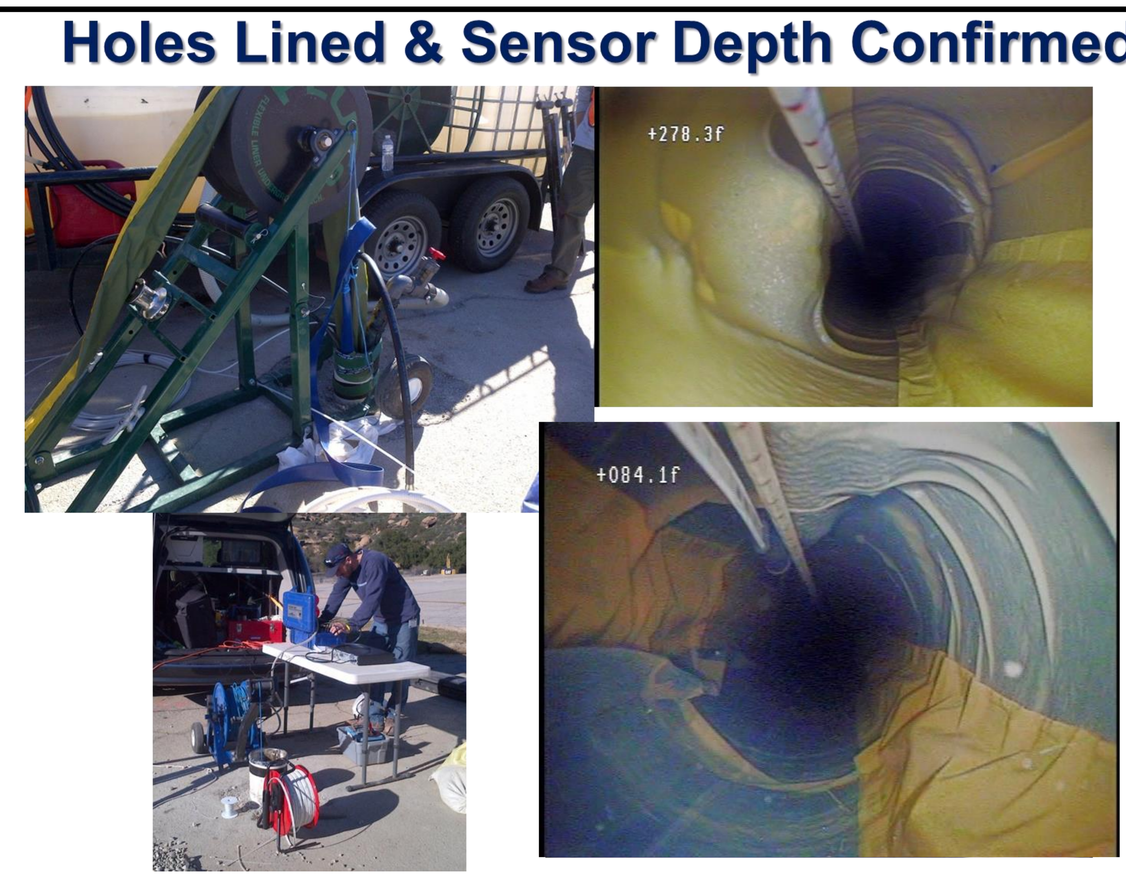
Video Confirmation of Depth and Alignment with respect to Target Fracture Prior to Liner Installation

Introduction & Rationale:

Detailed investigations of groundwater flow through fractured rock are consistently progressing towards an increased focus on hydraulic characterization of both large and small aperture fractures, the latter having an important role on matrix diffusion processes influencing plume transport and fate. In sedimentary rock, continuous core and geophysical imaging techniques typically identify abundant fracturing, with complementary rock core chemistry sampling and/or advanced thermal techniques usually indicating numerous potential zones of ambient groundwater flow. With increased frequency, the next stage of investigation is the installation of one of several possible multilevel monitoring systems (MLS). Inevitably the choice of which MLS to use and its design (i.e. details of port and seal intervals) is a compromise between: the number of available ports, borehole condition and potential for blending hydraulic head and groundwater samples across different hydro-stratigraphic units or missing key flow zones. We present a temporary removable and reusable installation to monitor pressure and temperature at numerous (10-20 or more) discrete depth intervals as a pre-screening tool for planning a permanent MLS installation.



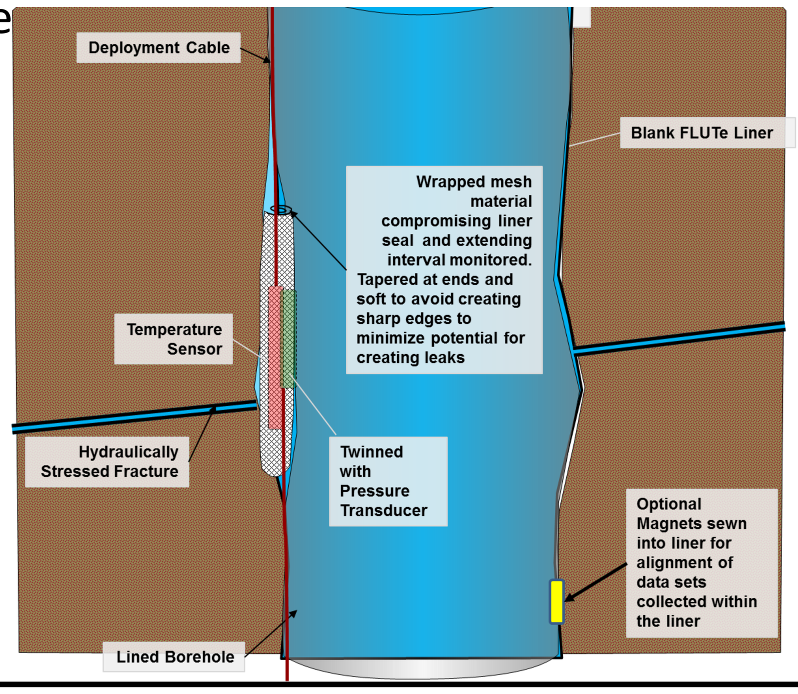
Sensor Array Test Intervals Based DFN Suite of Techniques

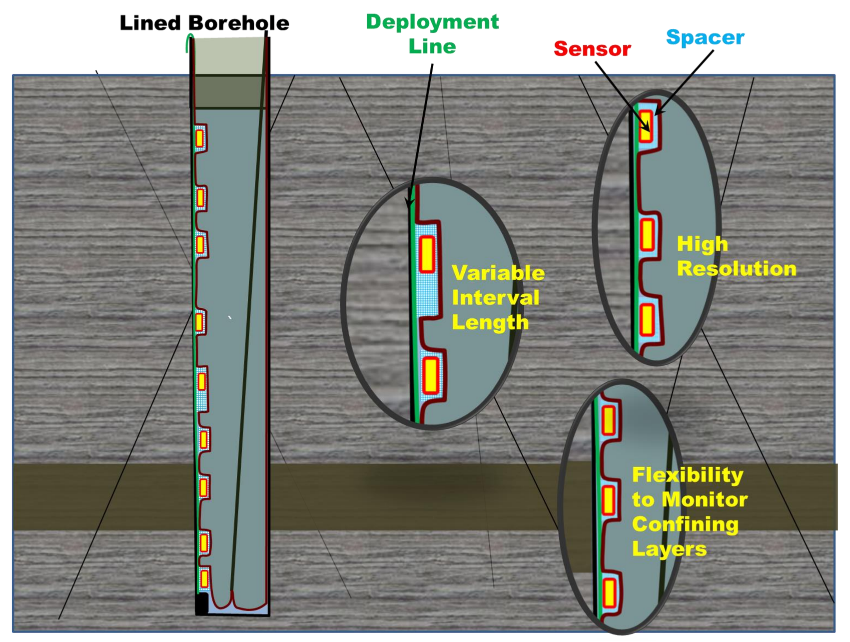


Deployment

The deployment depths are typically designed based on core log data as well as borehole geophysical and hydro-physical testing. The individual sensors are attached to a single deployment line to minimize both stretch and the potential for hydraulic cross-connection between monitoring zones, with a weight attached to the bottom. The location of the transducers relative to the fractures being targeted. The borehole is then lined and the details can be reconfirmed by video. Note: images show the seal created by the liner.

Design: The sensor deployment consists of a series of pressure transducers deployed behind a removable poly-urethane coated (FLUTe®) liner as shown schematically in Figure 1. The liner creates a seal, hydraulically isolating successive sampling intervals. In each sampling interval the transducer is surrounded by a plastic weaved covering which is varied in length depending of the sampling interval desired. The weaved covering dictates the length of the monitoring interval and ensures the liner is separated from the borehole wall to provide hydraulic connection with the transducer. In some applications the pressure transducers are paired with a high-sensitivity (0.0001°C) temperature se





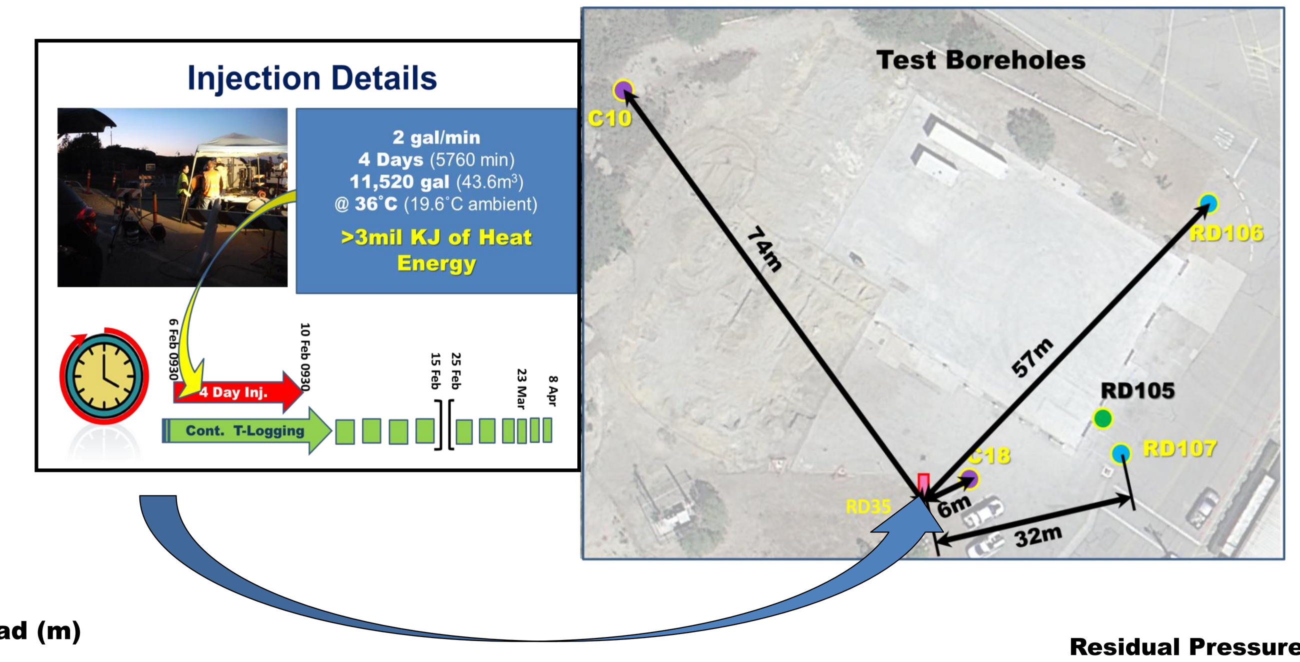
Hot Water Injection Example

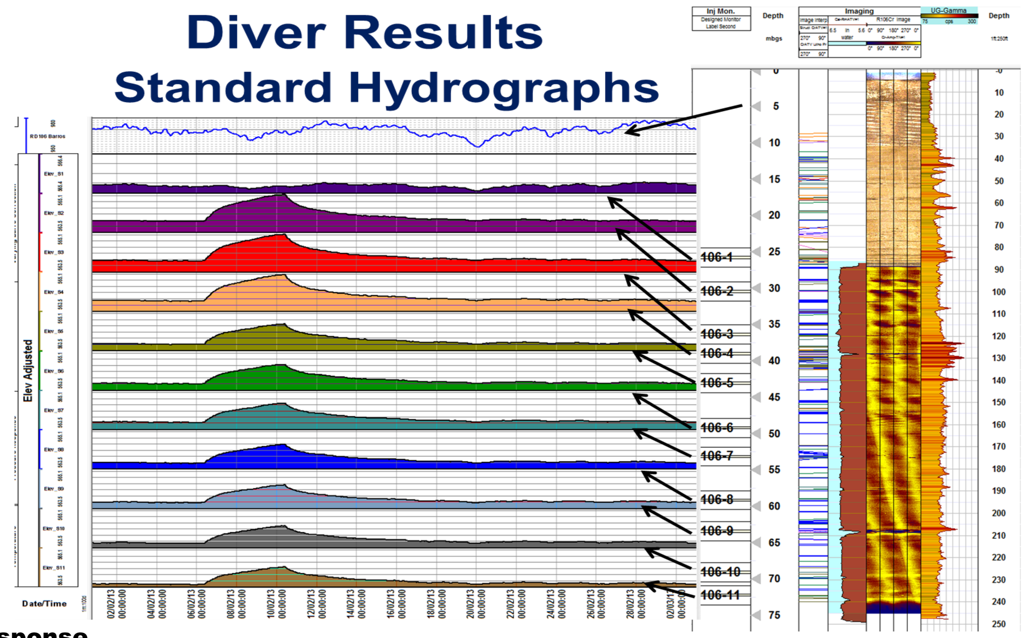
As a precursor to a permanganate injection test (in RD35) at the Santa Suzanna Field Laboratory it was critical that the multi-level systems used to monitor the process were optimally designed to detect the chemical. Four new holes (C18, RD105, RD106 & RD107) and one existing well (C10) were characterized using the DFN approach and 11-12 temporary sensors (pressure and temperature) sensors were deployed in each hole (except RD105 which had a Waterloo ML system). Hot water was injected into RD35 for 4 days. The process was monitored pre, during and post (38 days) injection.

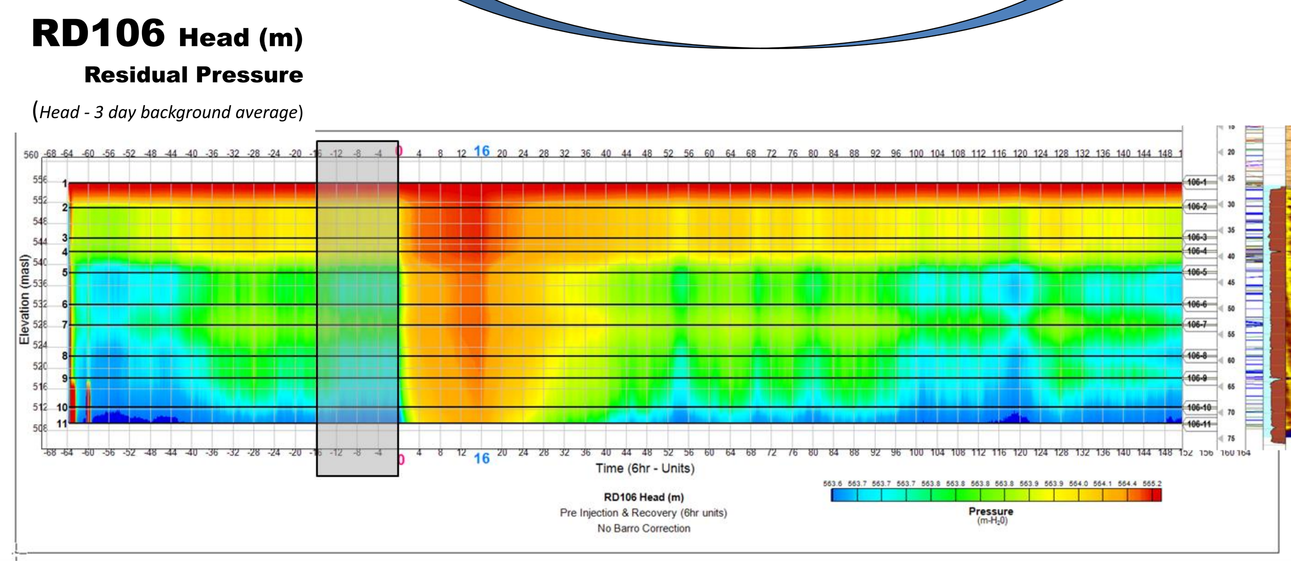
The data density both in space and more so in time creates challenges for presentation and assessment.

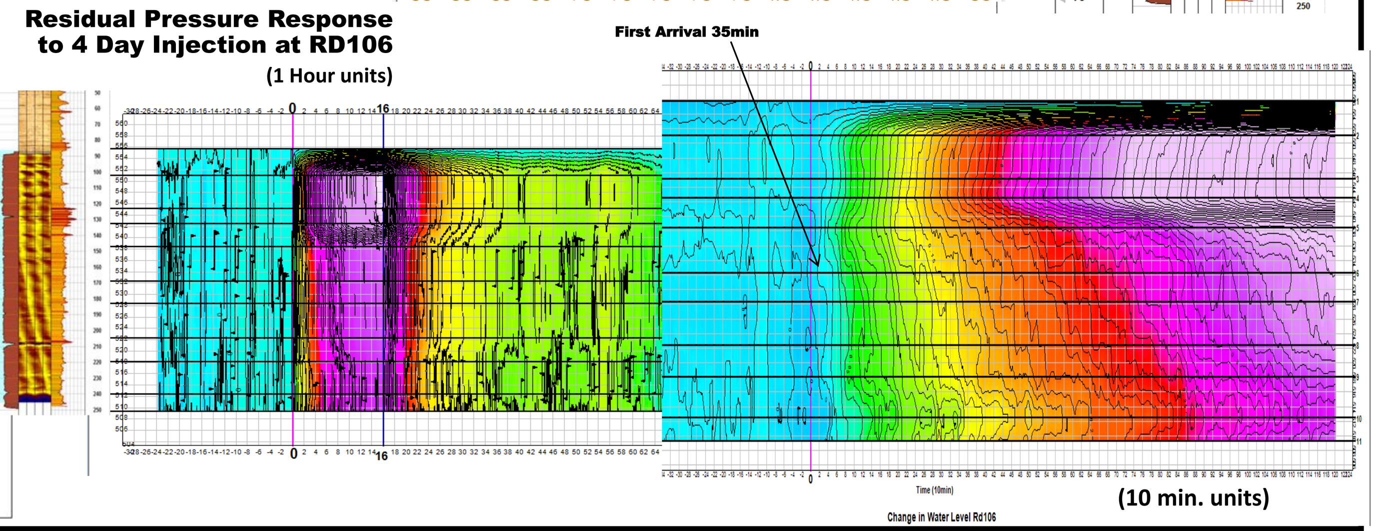
Conventional data presentation is as hydrographs (line plots head vs time)

Using Time-Elevation-Head (TEH)(1) plots of head (or residual pressure) plotted as a colour on a X=time, Y=elevation plot allows for improved visualization and assessment of pressure (or temperature). Full scale plots (6hr or 1 hr units) allow the entire injection to be assed or expanded scale (10min) facilitate detailed examination and comparison of pressure breakthrough.









Summary:

The temporary sensor deployments are simple to deploy and have flexibility in their configuration, limited only by the number of transducers available and the space within a borehole to deploy them while achieving adequate seal between the monitored zones. The length of the individual monitoring intervals can be as short as the length of the transducer itself or several metres by adjusting the length of the surrounding mesh spacer. Although the cost of the configured array and liner can be 5-10 thousand dollars or more, the entire system is retrievable. It can be modified and reused at another borehole of suitable length and diameter (for the liner). The only exception occurs when the borehole is highly contaminated with organic sorbing chemicals and although the transducers can be decontaminated, the liners are generally not reusable in this case. The technique has a broad range of applications including planning MLS, assessment of hydrogeologic variations / processes, cross-hole testing as well as assessment of other technologies / techniques.

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References:

1) Pehme P.E. and B.L. Parker, 2013. Time-Elevation Head Sections: Improved Visualization of Data from Multi-Levels, Ground Water Monitoring & Remediation V33, No 2.

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