ESTIMATING HYDRAULIC CONDUCTIVITY FROM INDUCED FLOW LOGGING

SUMMARY

Low resolution, non-continuous hydraulic conductivity measurements from packer testing alone can severely impact on hydrological model reliability. Measured hydraulic conductivity from induced flowmeter logging can facilitate better packer siting, fill in the data gaps or replace packer testing all together – all leading to more reliable and higher certainty models. Data can be augmented with water quality and temperature as well as fracture imaging using televiewers to provide a more complete understanding of the hydrogeological controls.

PROBLEM

For the hydrologist, locating not just the currently active aquifers but all zones within the borehole that have flow potential is of prime importance when it comes to building reliable hydrological models.

For the most part the hydraulic conductivity information has been attained by discrete point measurements like packer testing. Due to cost, time and the physical size of the equipment, the number and location of packer tests can be limited in any given borehole. The positioning of packers is usually derived from core logs and thin, single-fracture flow points can easily be overlooked.

The likelihood of missing potential flow points is therefore elevated and downstream hydrological model reliability will be negatively affected by the non-continuous and low-resolution nature of the packer test results.

SOLUTION

Impeller flow meters have been around in the logging industry for many years but are generally run under steady state conditions in the borehole. The acquired data, although useful, is temporal in nature and results can vary from day to day or season to season. The indicated flow points will also be limited to actual flow at the time of logging. Potential flow points where no measurable flow was detected at the time of logging will not be missed.

By keeping the well under a constant positive pressure, while the impeller flowmeter logging is conducted, overcomes the shortfalls of the non-induced steady state measurements. The locality of wider flow zones and thin flow points can now be accurately mapped in the borehole wall and corresponding egress flow volumes measured. This will include both the active and inactive (non-induced states) flow points / zones due to the greater pressure differential.

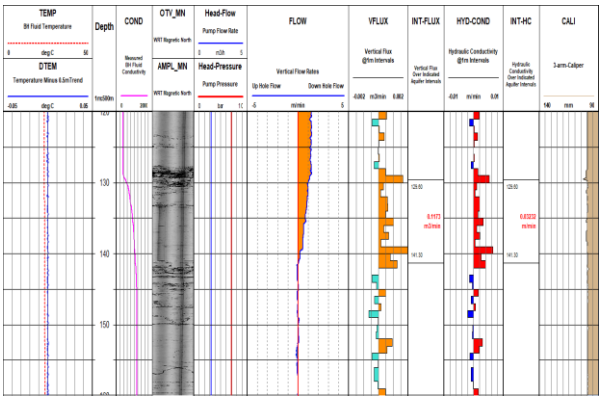
Acquired data sets using this induced flow methodology also include the wellhead flow and pressure monitoring along with the downhole impeller flow profile, all with a 1cm continuous vertical sampling.

Correction of the impeller profile for pumping induced artefacts is possible using the wellhead pressure and flow information acquired. The corrected impeller flow profile is usually block-averaged to 1m intervals and a modified version of Darcy's law applied to calculate an estimate of *vertical flux* (m3/min) and *hydraulic conductivity* (m/min) for each interval, over the entire log length.

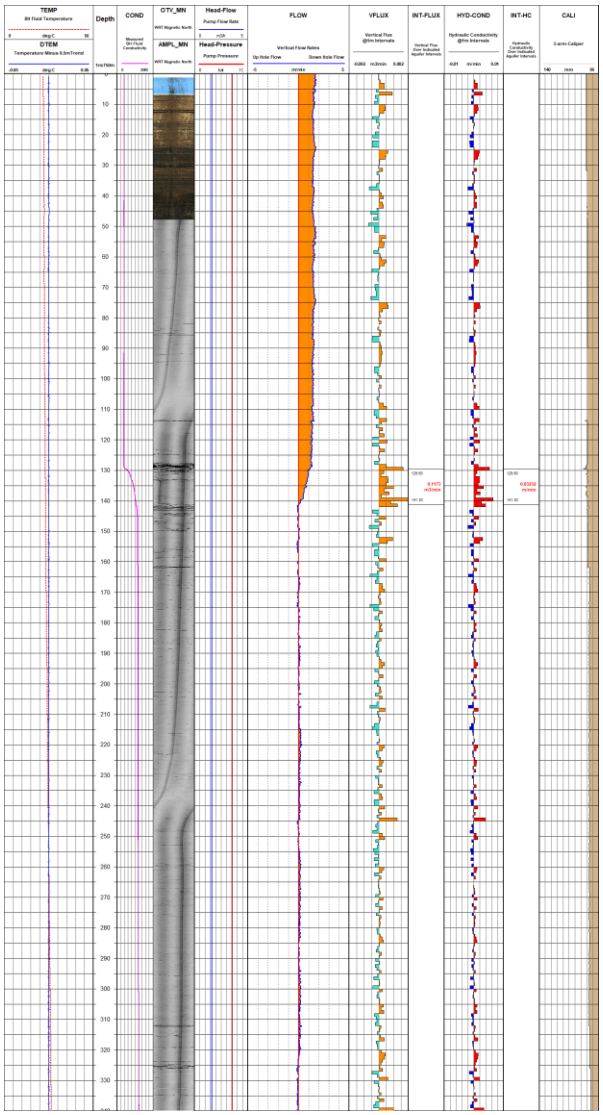
The 1m blocked intervals have a good sensitivity to both wider flow zones and very thin flow points.

It is possible to calculate block averages over broader zones in the borehole where required.

Incorporating fluid property measurements, like temperature and conductivity, along with borehole wall imaging, like acoustic or optical televiewer logs, facilitates a greater insight into the locality, magnitude and appearance of any aquifer or potential aquifer intersected down the length of the well.



Detail across aquifer between 120m to 160m



Hydraulic conductivity plot incorporating borehole fluid temperature and conductivity profiles and televiewer imaging of the borehole wall.

IMPACT

Clear and detailed mapping of flow zones both broad or thin is now possible with a regular sample spacing over the entire length of the borehole. Estimating the hydraulic conductivity in this way will both facilitate better siting of packer placement, and can act as a separate correlation parameter increasing data certainty in downstream hydrological models.

In cases where steady state flow logs produce too few results due to low natural flow rates and where packer testing is either unavailable or impractical, this methodology can be successfully implemented to gather hydraulic conductivity values that would otherwise not have been attainable.

ALTERNATIVES

	Packer Testing	Core	Logging	BMR*
In-situ	✓	✗	✓	✓
Accuracy	✓ ✓ ✓	✓ ✓	✓	✓ ✓ ✓ ✓
Porosity	✗	✓	✓	✓
Free-water Porosity	✗	✓	✗	✓
Clay-bound Porosity	✗	✗	✗	✓
Capillary-bound Porosity	✗	✓	✗	✓
Permeability	✓	✓	✓	✓
Real-time Data	✗	✗	✓	✓
Continuous Profile	✗	✗	✓	✓
Rig-less Operation	✗	✗	✓	✓
Crane-free Operation	✗	✓	✗	✓
Test Speed	✓ ✓	✓	✓ ✓ ✓	✓ ✓ ✓ ✓
Test Efficiency	✓ ✓	✓	✓ ✓ ✓	✓ ✓ ✓ ✓
Test Cost	$$$$	$$$	$$	$
Cost Benefit	4	3	2	1

**Borehole Magnetic Resonance*