Heat dissipation test to estimate groundwater fluxes

- Test case at an unconsolidated coastal aquifer -

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25-29th September 2016 Montpellier, France CORUM CONFERENCE CENTER 43rd IAH congress

1. Motivation

Half of the world's population lives in coastal areas, and 8 of the 10 largest cities in the world are located at the coastline

(Post 2005)

1. Motivation

60% of coastal aquifers are reported as polluted due to seawater intrusion

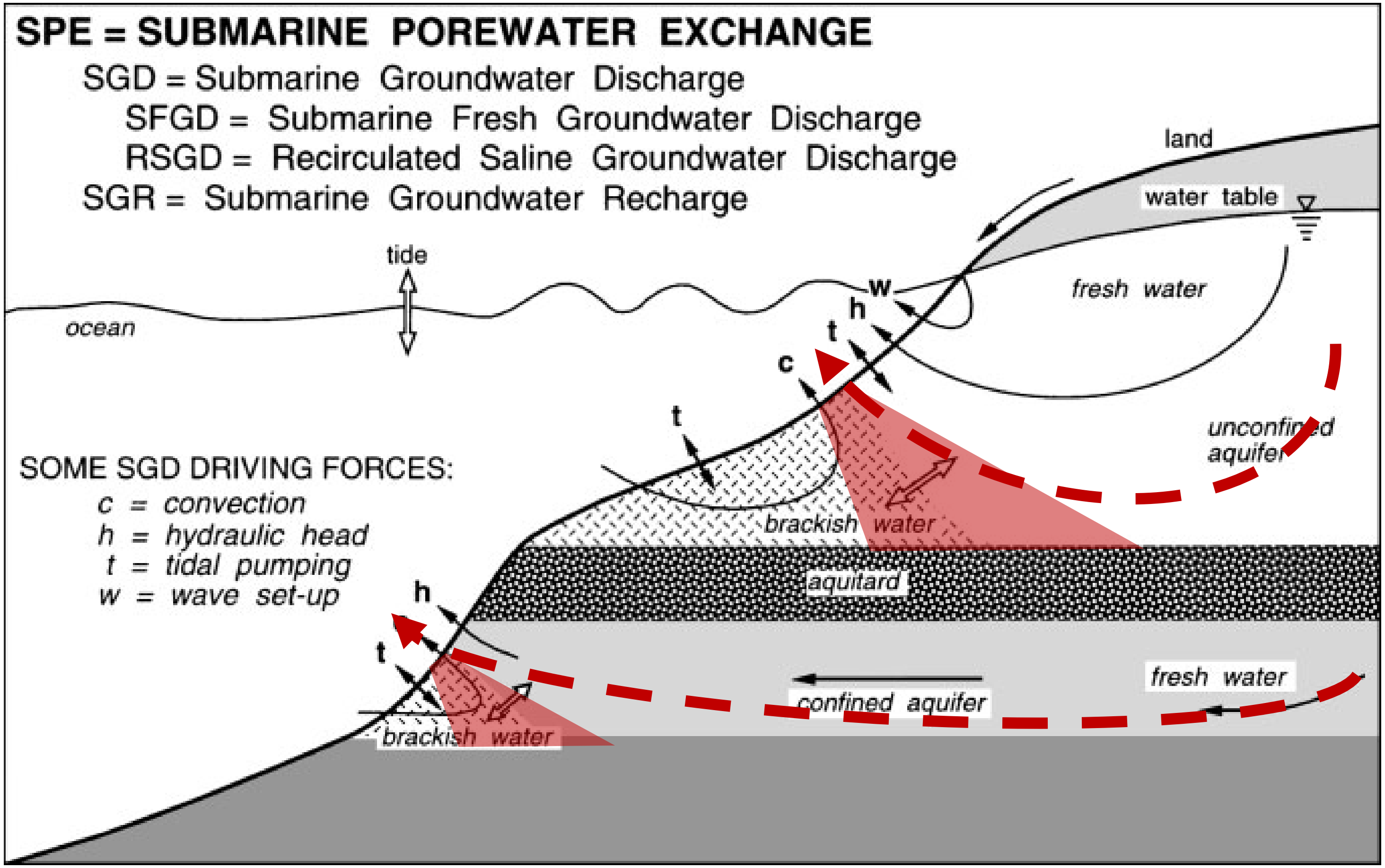
(Benavente, (Instituto del Agua))

Salinization of coastal aquifers can affect local economy:

- Salinization of local freshwater supply systems
- Salinization of agriculture lands
- Salinization of groundwater dependent wetlands

López-Geta y de Dios Gómez-Gómez (2007)

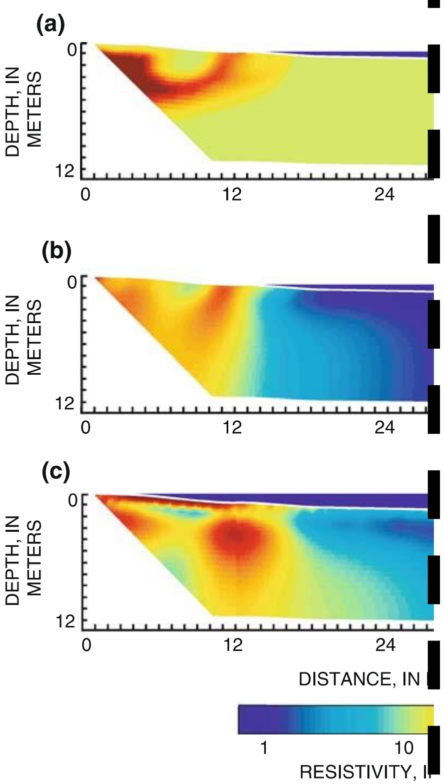
2.Introduction



Taniguchi, M., Burnett, W. C., Cable, J. E., & Turner, J. V. (2002). Investigation of submarine groundwater discharge. Hydrological Processes, 16(11), 2115–2129. http://doi.org/10.1002/hyp.1145

2. Introduction

- Monitoring Fres ... antification interface



Henderson, R. D., et al.(2010).

Monitoring methods

High spatial resolution + Low temporal resolution	Low spatial resolution + High temperal resolution

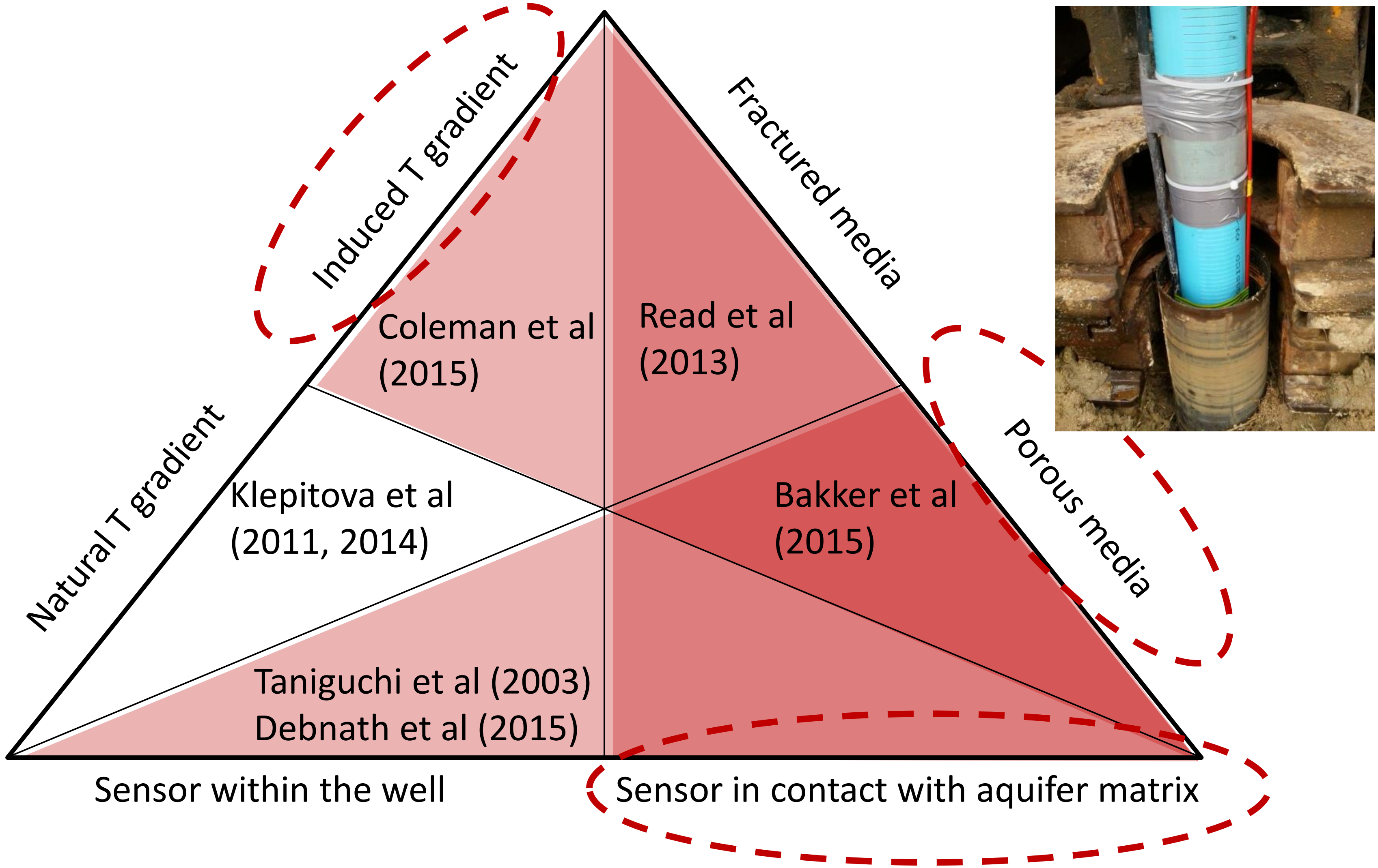
Fibre Optic Distributed Temperature Sensing

High spatial resolution (0.25 m)
+
High temporal resolution (10 sec)
+
No system disturbation like pumping tests

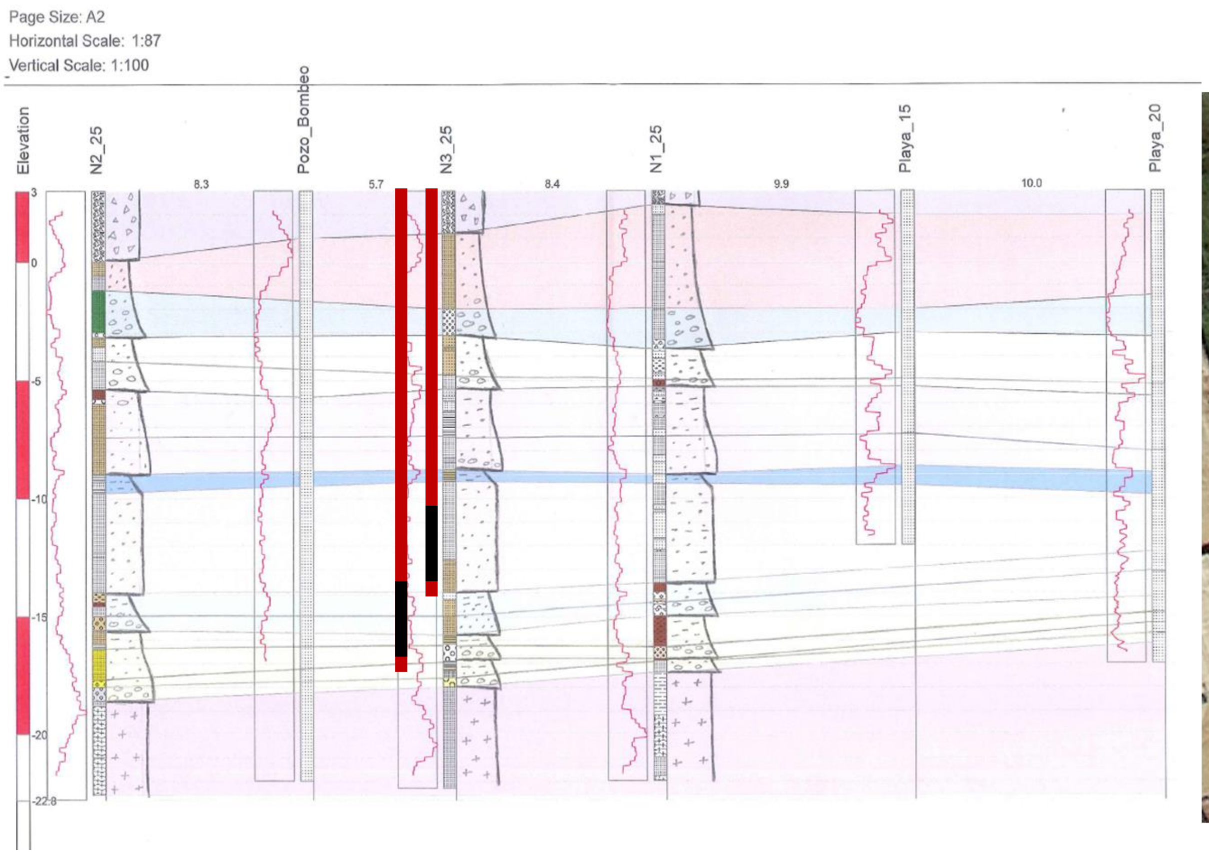
... al. 2006

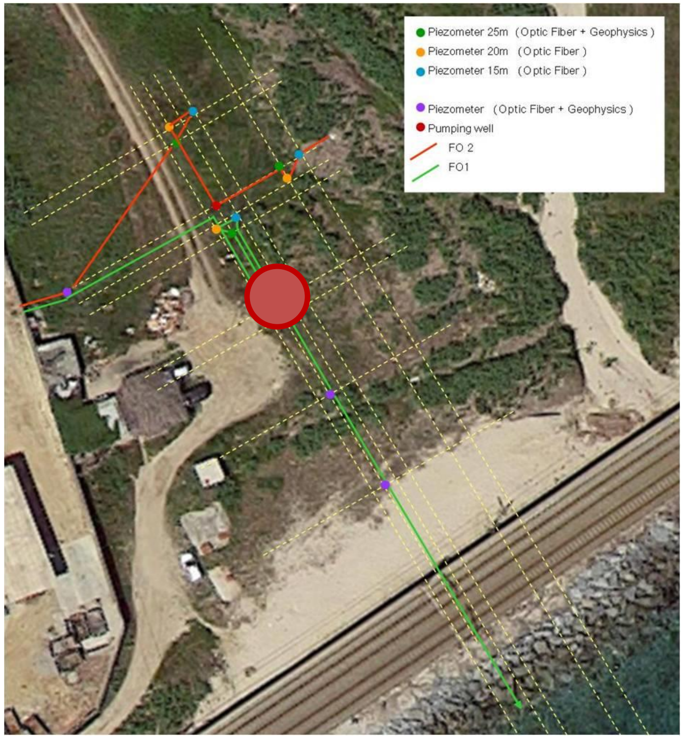
3. State of the art

Principle: Heat dissipation can be used to calculate flow velocity.



4. Experimental site

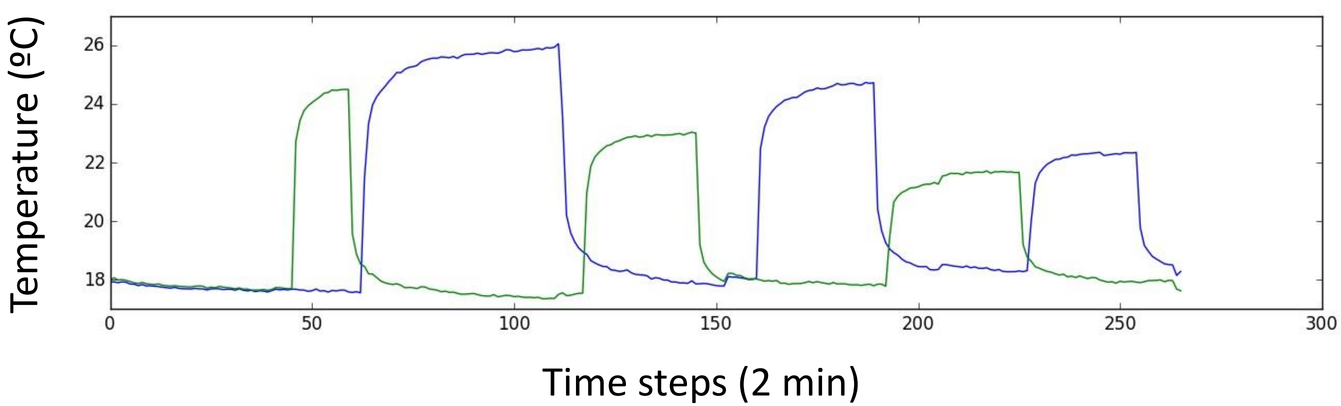




Poster nº 2213

5. Methodology

Pumping well N3-20	Heated well N3-25	Heated well N3-20
Pumping rate: 0,55 l/s (11/09/2015)	10 W/m 8 W/m 5 W/m	10 W/m 8 W/m 5 W/m
Pumping rate: 0,06l/s		10 W/m (9/9/2015) 5 W/m (10/9/2015)



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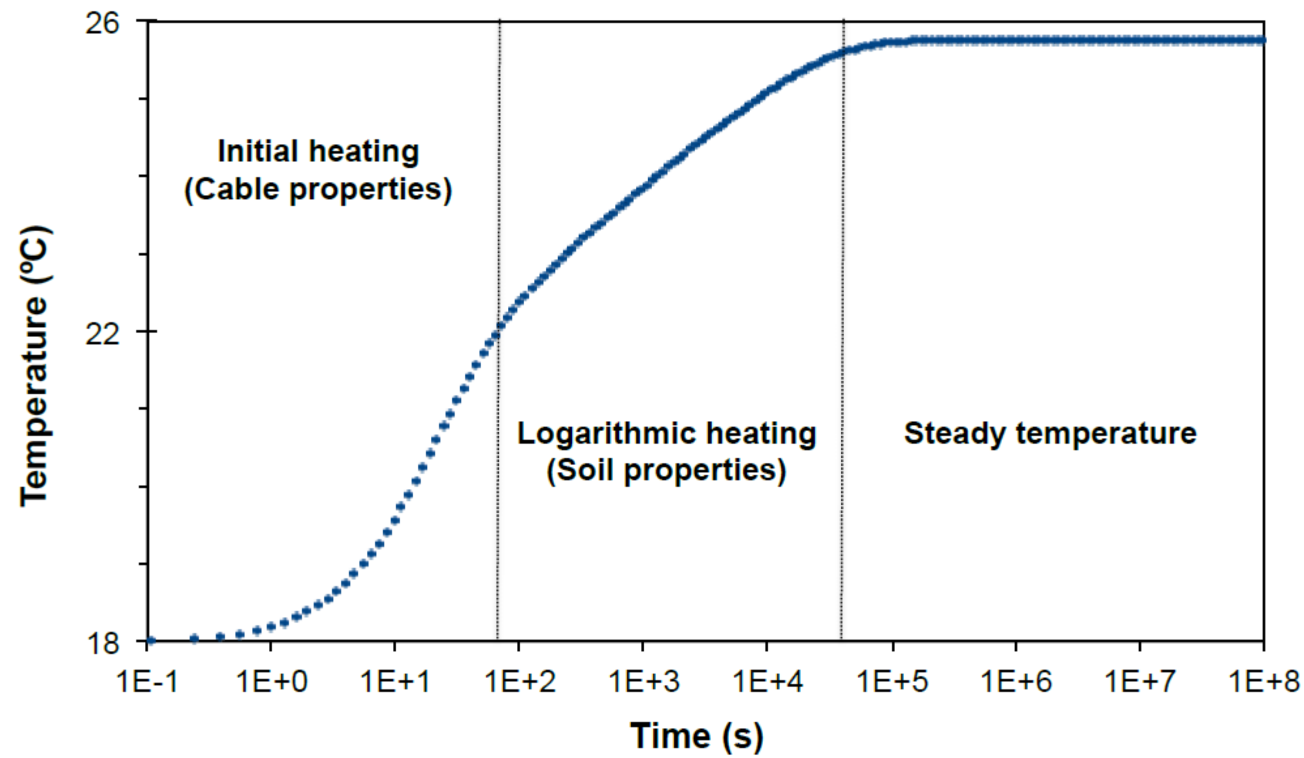
6. Heat transport – analytical method

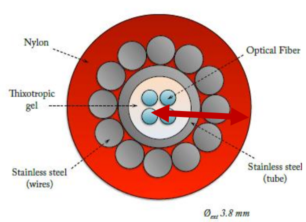


Skin Effect

Soil properties effect

Flow effect:

- Unit discharge
- Cable properties
- Bulk properties



6. Heat transport – analytical method

- Two dimensional heat transport equation

$$C_b \frac{\partial T}{\partial t} = (\lambda + Cw \cdot Dp_L)\left(\frac{\partial^2 T}{\partial x^2}\right) + (\lambda + Cw \cdot Dp_T)\left(\frac{\partial^2 T}{\partial y^2}\right) - qC_w \frac{\partial T}{\partial x} + \Psi$$

- Final Temperature → Advection

$$T(x_D, y_D, t_D) = \frac{T_c}{4\pi\sqrt{AB}} e^{x_D/2A} W_H\left(\frac{Bx_D^2 + Ay_D^2}{16ABt_D}, \sqrt{\frac{Bx_D^2 + Ay_D^2}{4A^2B}}\right)$$

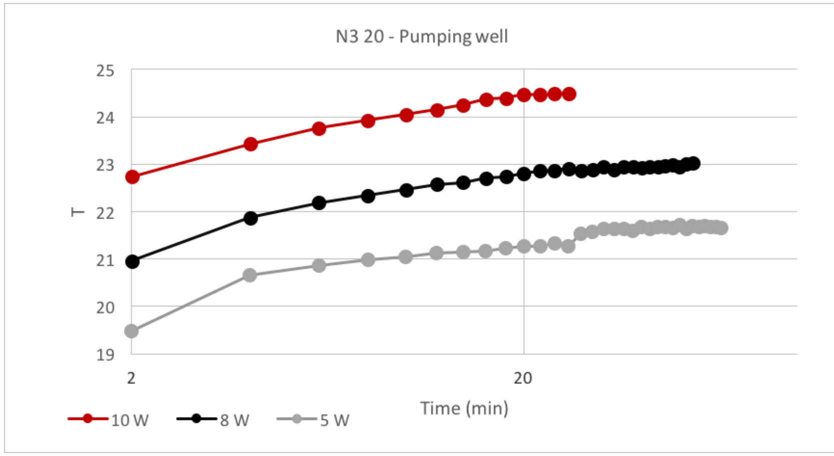
$$W_H(u,\beta) = \int_u^{+\infty} \frac{1}{\xi} \exp\left(-\xi - \frac{\beta^2}{4\xi}\right) d\xi$$

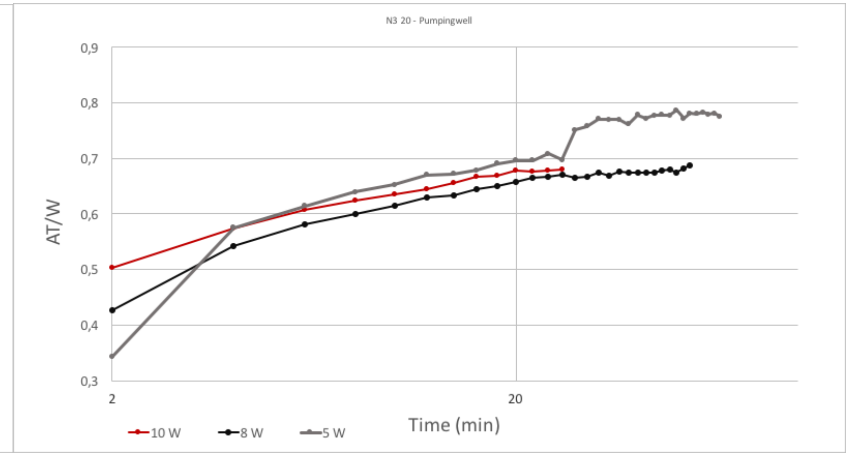
- Rate of growth → Skin effect and aquifer matrix properties

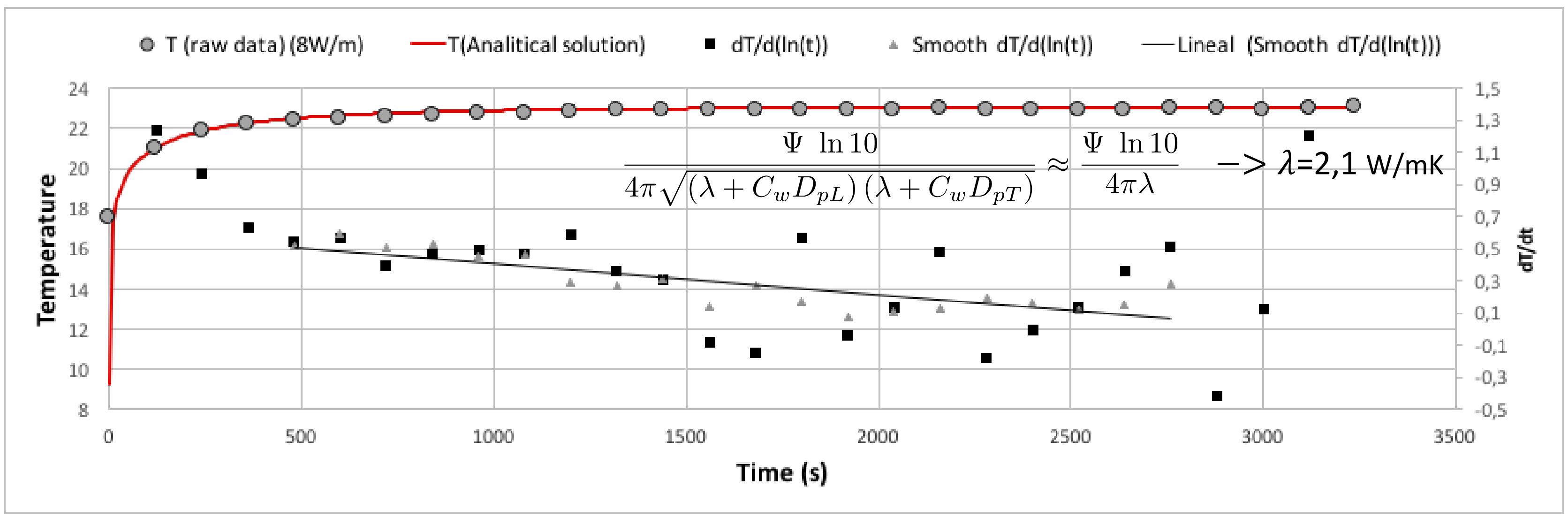
$$\frac{dT}{d(\ln t)} \approx \begin{cases} \dfrac{T_c}{4\pi\sqrt{AB}} \\ \dfrac{T_c}{4\pi\sqrt{AB}}\left(1 - \dfrac{t}{4At_c}\right) \end{cases}$$

7. Preliminary results

Logarithmic heating
depending on Soil properties







8. Conclusions

- Fibre Optics can be installed successfully in the outer casing of a well to characterise aquifer properties in a cost effective way

- Heat dissipation tests can be used to measure groundwater flow, however
  - Range of application to be tested
  - Skin effects need to be corrected
  - Longer test need to be performed to the stationary
  - Method validation needs to be improved


Thank you!