High-Resolution heat tracer test to analysis groundwater flow field and heat transfer characteristic in the coastal aquifer

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Abstract

The increase in global water consumption is mainly owing to urbanization, growing agricultural activities, population growth, economic development, and improving living standards. Groundwater recharged from coastal aquifers to the ocean is a potential alternative water resource have drawn more attention in recent years. Calculating groundwater flux by heat tracer test, According to the results of the heat tracer tests, the high thermal response zones are located at depths of 17-19m, 32-34m, and 42-47m. The low thermal response zones are observed at depths of 3-6m, 6-11m, and 19-26m. At depths of 19-26m, a slow groundwater flux of about 0.05 m/day and poor permeability aligned with the observed heat transfer reactions. However, the results clearly demonstrate the influence of tides on coastal aquifers, indicating a significant tidal effect in the study area. The relationship between tidal variations and the characteristics of coastal aquifers can be further explored.

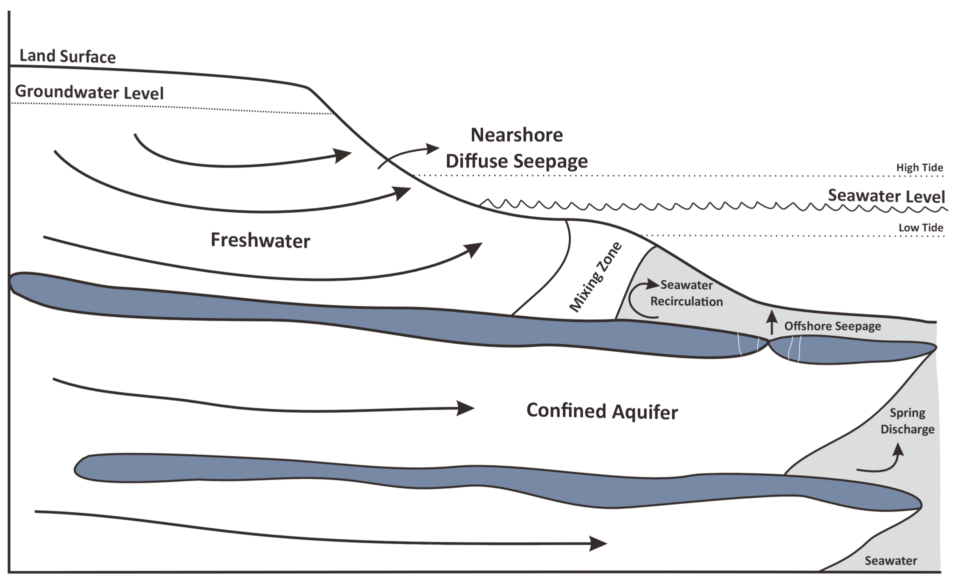

Fig1. Groundwater recharge in coastal aquifer

Methodology

The groundwater flux in the vertical profile of the aquifer was perform to quantified groundwater flux by heat tracer method. This provided spatial and temporal temperature data, which were used to infer the temporal variations in the groundwater flux along the vertical profile.

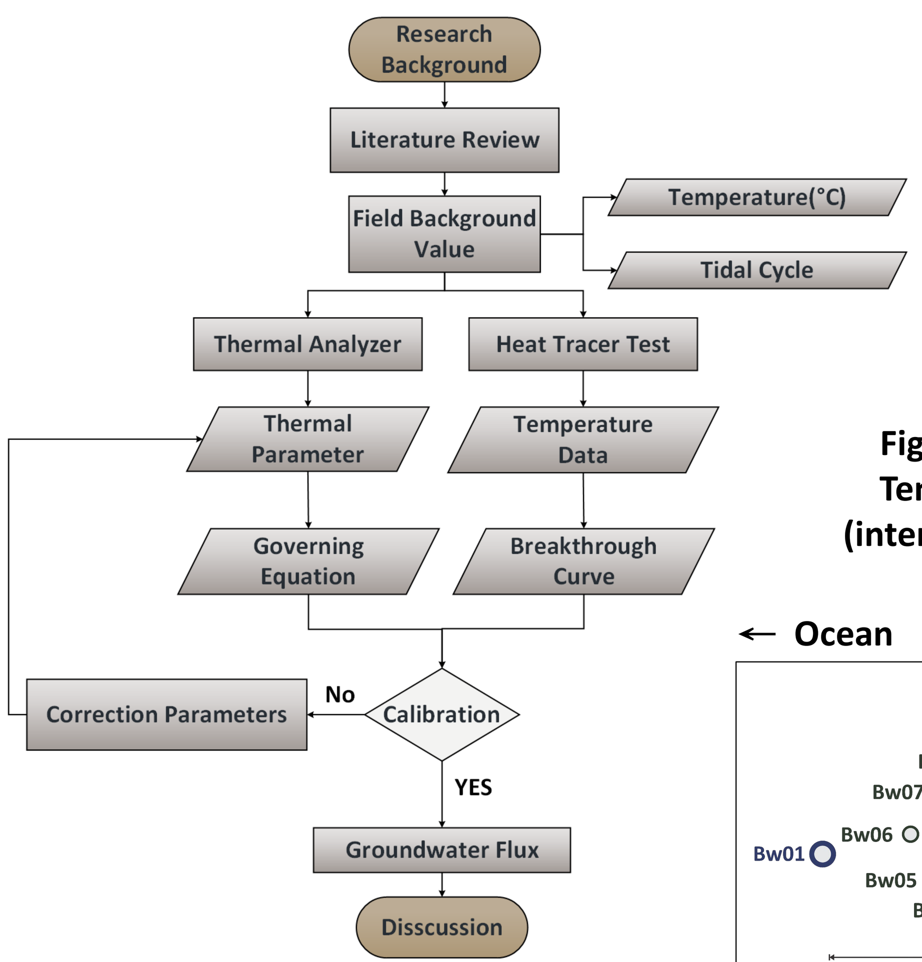

Fig2. Flow chart

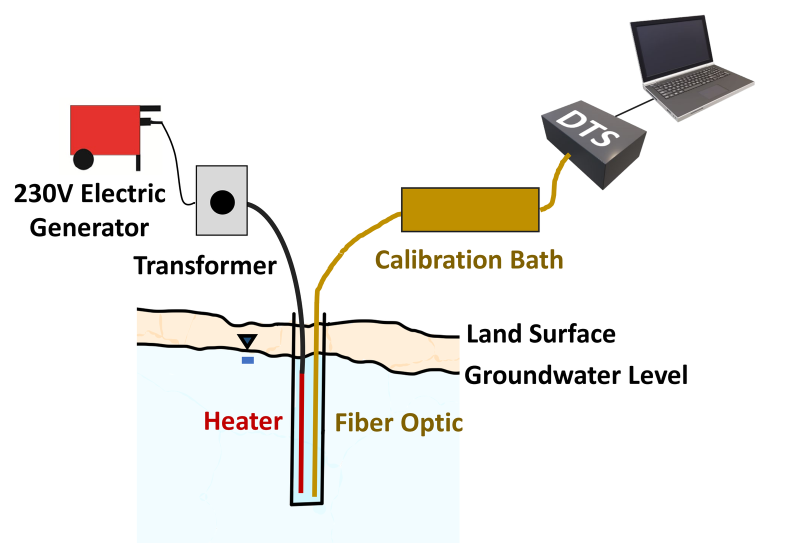

Fig3. Heat tracer experiment setup and Distribution Temperature Sensing(DTS) detected high-resolution (interval = 0.254m) temperature variation of the aquifer.

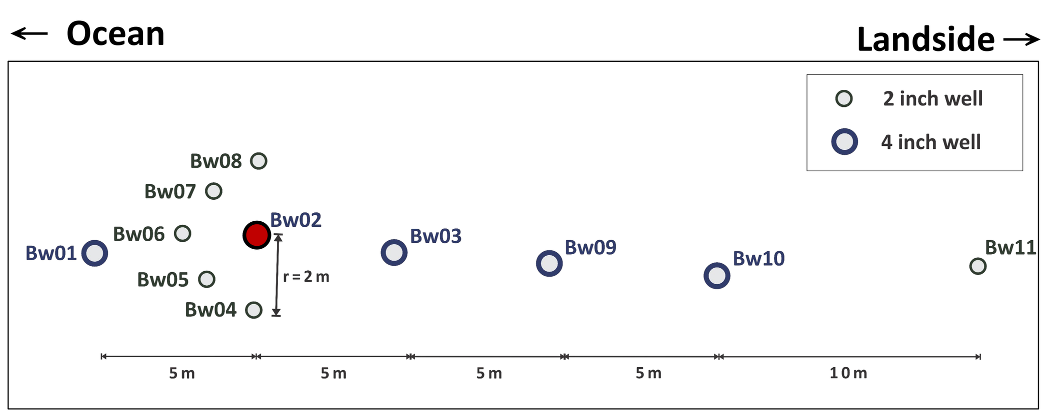

Fig4. Well distribution (heating well - BW02)

Discussion

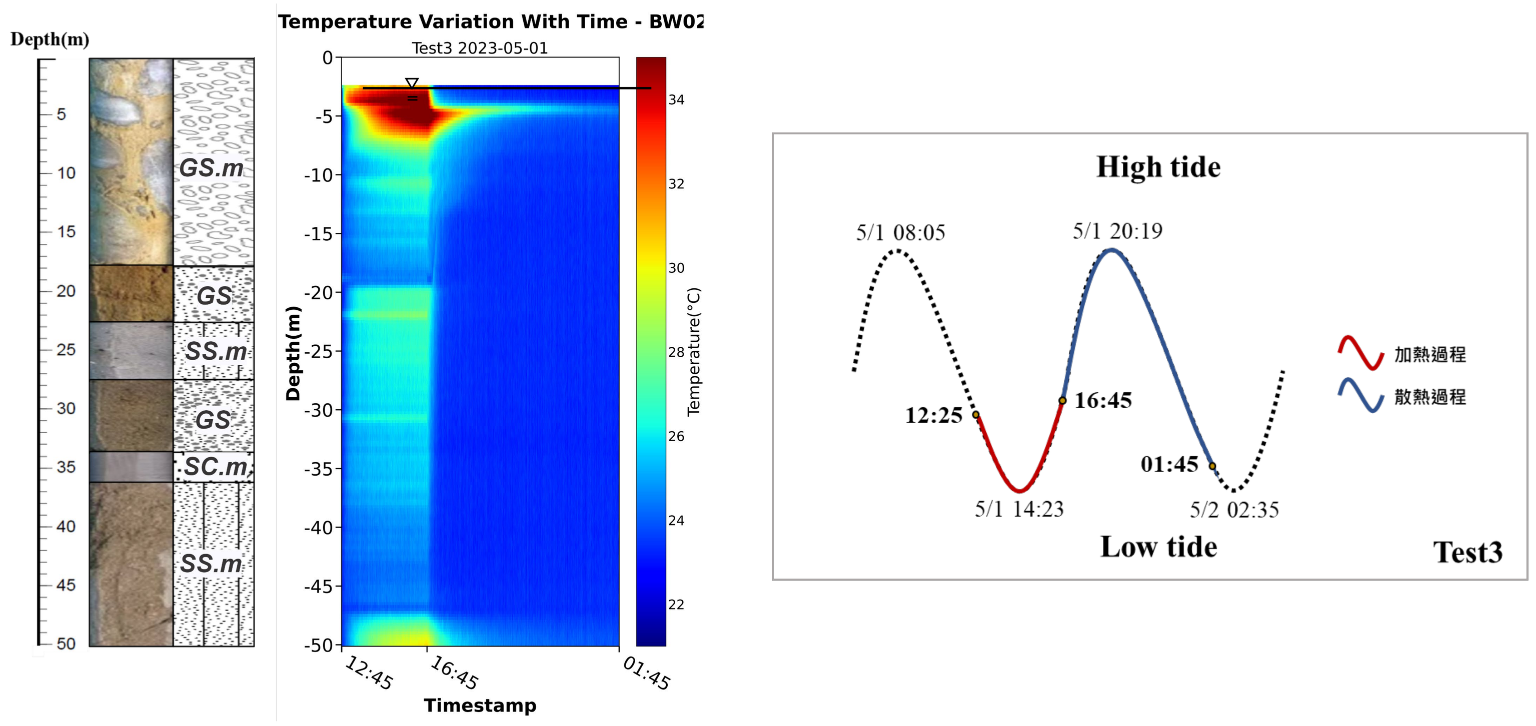

Fig5. The vertical temperature variation in the borehole which indicates the heat transfer is poor or well influence in section by the flow condition and compared with core sample.

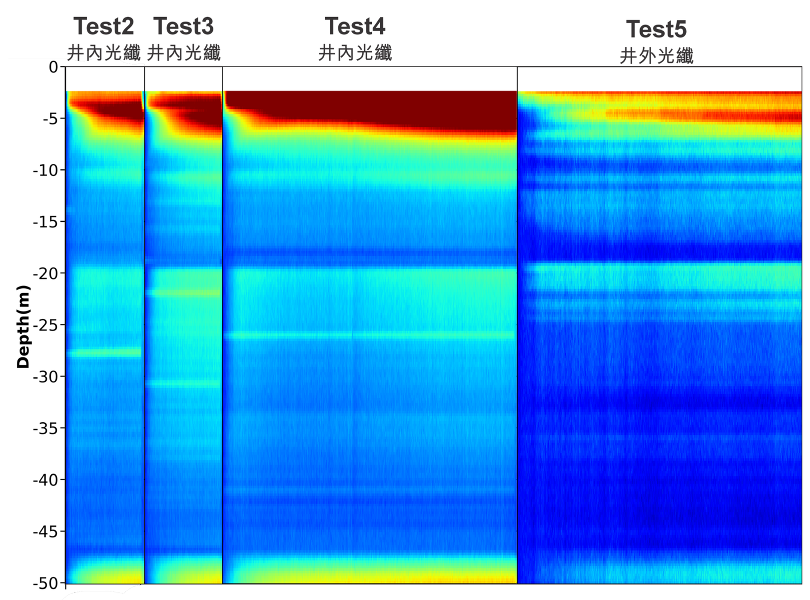

Fig6. Connect the optical fiber between the inside and outside of the well and compare the heat transfer responses of each test.

Using the heat tracer method to detect the groundwater temperature variation, combined with the thermal conductivity and volumetric heat capacity the drilled core samples, the groundwater flux can be determined. This information can be compared with the geological materials obtained from on-site drilling to assist in assessing the geological stratification and the characteristics of permeable zones.

$$A = \frac{r^2}{4D_x},\ B = D_x\frac{\rho c}{q\rho_w c_w},\ r = \sqrt{x^2 + \frac{D_x}{D_y}y^2}$$

$$T(t) = \begin{cases} \dfrac{T(t_\infty)}{2k_0\left(\frac{r}{B}\right)} W\left(\dfrac{A}{t}, \dfrac{r}{B}\right) & , 0 < t \le t_0 \\ \dfrac{T(t_\infty)}{2k_0\left(\frac{r}{B}\right)} \left[W\left(\dfrac{A}{t}, \dfrac{r}{B}\right) - W\left(\dfrac{A}{t - t_0}, \dfrac{r}{B}\right)\right] & , t > t_0 \end{cases}$$

$$q = \frac{1}{\rho_w c_w}\left[\left(\frac{r/B}{\sqrt{A}}\right)^2 \frac{\beta_x \rho c}{2} + \frac{r/B}{\sqrt{A}}\sqrt{k\rho c + \left(\frac{1}{2}\frac{r/B}{\sqrt{A}}\beta_x \rho c\right)}\right]$$

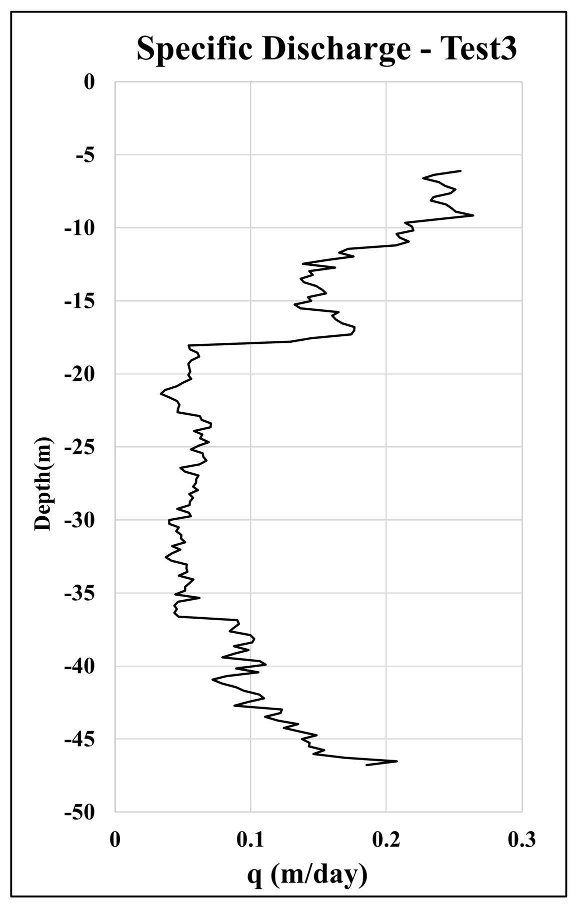

Fig7. Specific discharge vertical variation

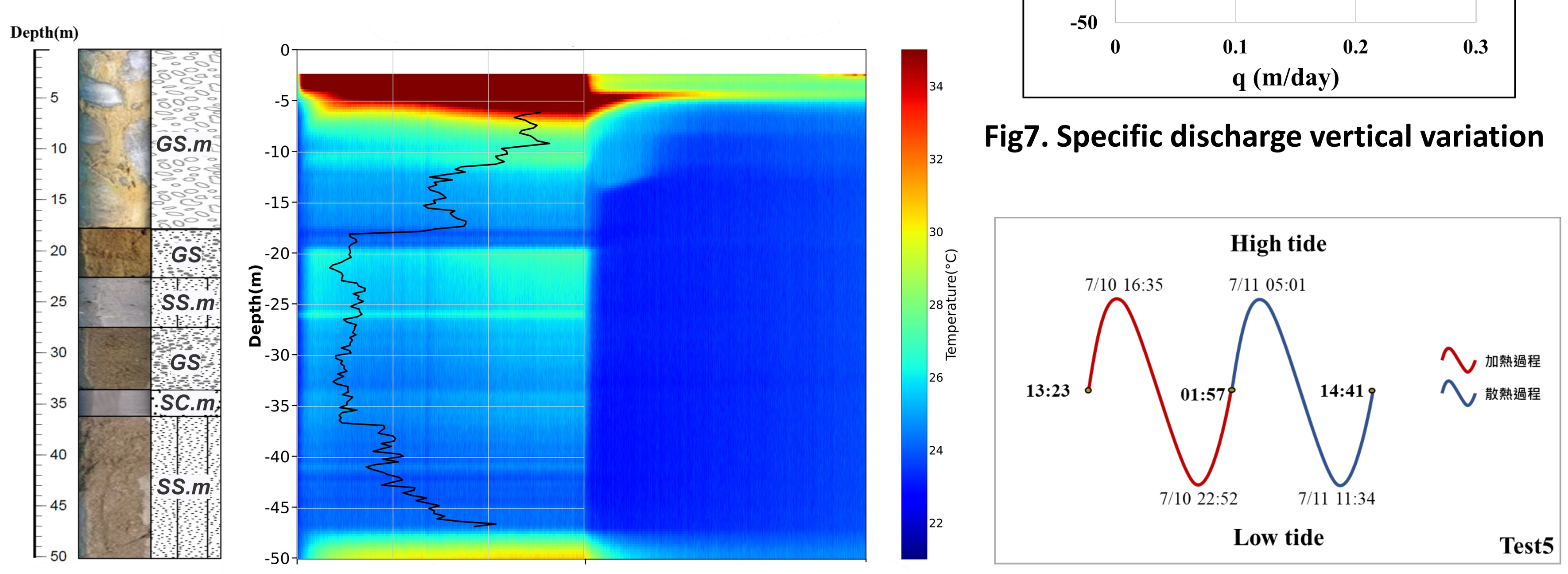

Fig8. Comparison of Heat Transfer Reaction Results from Heating Tests with Groundwater Flux.

Conclusion

Coastal aquifers exhibit interactions between saltwater and freshwater as well as tidal fluctuations. Heating during high tide causes well water levels to rise, leading to temperature decrease. On the other hand, heating during low tide gradually raises temperatures as water levels decline. However, the short tidal cycle and eventual return to high tide can disrupt the well's temperature stabilization during heating tests. This study examines how different heating tests and tidal cycles influence temperature data. Testing during low tide is advised to minimize temperature fluctuations caused by saltwater-freshwater interactions during high tide.