

A multi-technique approach to determine temporal and spatial variability of groundwater-stream water exchange

Middle East Lancaster Technical University University

1) OBJECTIVE

Characterizing the spatio-temporal distribution of groundwater-surface water exchange fluxes is of paramount importance in understanding catchment 26.10.2018 Air Temperature (°C The instrument used for EMI survey is **Electromagnetic Conductivity Meter** (CMD) by GF Instruments & used with 6.10.2018 00:00 an effective depth of 1.5 m. P3 Raw Time Series 10.4 10.45 10.5 10.55 1 The DTS unit employed was Silixa XT-DTSTM. DTS measurements were taken at each 0.254 cm over 1 km length fiber-Coordinate System: ED 1950 UTM Zone 36 optic cable in every 23 sec. for 30 min. Geological Formation Alluvial Cone 29.4 - 38.4 26.10.2018 00:0 🛲 Alluvium 38.5 - 5 iButtons: 1-Wire Maxim Integrated Andesite DS1922L having 0.0625 °C resolution & Clavev Limestone 95.8 - 223.2 Evaporites $0.5 \,^{\circ}\text{C}$ accuracy (@ -10°C to 65°C Gravel Gravel - Sandstone - Mudstone Basin and Sub-Bas 400^P. range). Temperature recorded @ 10 min Gypsum Limestone interval. v v v Marble 26.10.18 00:00 31.10.18 00:00 05.11.18 00:00 Melange —— Sensor depth 2 Sensor Precisi Moraine lux (Hatch Amplitude) Old Alluvium 0.0E+00 Olistostrome Pvroclastics -1.0E-06 Jpward flux Sandstone - Mudstone -2.0E-06 rological Station andstone - Mudstone (Shale) - Limesto -3.0E-06 Sandstone - Mudstone - Limestone EC (mS/m) inferred from EM Survey (June, 2018) River Network Schist - Calc Schist -4.0E-06 Study Area Figure 6 EC data inferred from EMI survey (June 2018), Svenite 26.10.18 00:00 31.10.18.00-00 05.11.18 00:00 Basin and Sub-Basi Flux at the depth of 9.5 cm below river bed (m/s Trachyandesite and mean temperature from DTS (26 Oct. 2018 @ evation (meter) Figure 7 Arrangement of iButtons Trachyte Figure 9 Vertical flow estimation @ location P3 2.25 4.5 9 Kilometers Travertine 07:31-08:02 & @ 12:32-13:02) ordinate Svstem: ED 1950 UTM Zone 36N (October 2018) using iButton vertical temperature Volcanic Deposite profile data Downward gradient (+) Figure 1 Study basin (529 km²) Figure 2 Geology of the basin. EC (mS/m) values are shown at sampling points Vertical flow values estimated using vertical temperature Table 1 profiles (see Fig. 5 for locations) 27.06.18 00:00 15.09.18 00:00 05.10.18 00:0 5.10.18 00:00 Upward gradient (-) Time Period S Downward gradient (+) 06.28.2018 27.06.18 00:00 07.02.2018 P3 VHG Result Upward gradient (-09.18.2018 18/09/2018 13:28 - 13:53 DTS Analysis 26/10/2018 07:31 - 08:02 DTS Analysis (b) 10.03.2018 18.09.2018 Air Temperature (°C 26.10.2018 Air Temperature (* Focused area of the study 31 January 2018 10.26.2018 EMI Survey (mS/m) 11.07.2018 Figure 8 Vertical hydraulic gradient values from nested piezometers @ • 0.078 - 5.000 0.125 0.25 0.5 Kilometers mperature (* 5.001 - 10.000 sites P1, P2 and P3 (see Fig. 5 for locations) 10.001 - 15.000 • 15.001 - 20.000 4) **DISCUSSION** • 20.001 - 35.000 The EMI Survey was important for identifying local heterogeneities of streambed structure or pore fluid chemistry. The results obtained from the EMI gure 3 First EMI Survey (31 January, 2018) surveys agreed well with the results of DTS at a location (Fig. 6). However, a marked difference in the temperature of groundwater and streamwater, **B**iButton low discharge rates (proper seasonal conditions), minimizing the effect of solar radiation/shading effect are important factors controlling the value of DTS for identifying influx from groundwater. Vertical hydraulic gradients (Fig. 8) and vertical temperature profiles (Fig. 9 & Table 1) provided us Major Anomaly 25 30 35 40 45 50 55 60 quantitative data to support our results. The results indicate that the downstream sections of the streambed are characterized by downwelling fluxes **Run Number Run Number** regardless of the season, whereas seasonal factors control the direction and magnitude of the exchange fluxes along upstream sections. Mean Temperature Moving avg. of Mean Temperature Mean Temperatur DTS Unit EMI Survev (mS/m Acknowledgement: This research is funded by Scientific & Technological Research Council of Turkey (TUBITAK) (Grant No:115Y041). 5.001 - 10.000 P1 References - 15.000 0.2 Kilometers 5.001 - 20.000 Binley, A., Ullah, S., Heathwaite, L. A., Heppell, C., Byrne, P., ... Zhang, H. (2013). Revealing the spatial variability of water fluxes at the groundwater-surface water interface. *Water Resources Research*, 3978-3992. 20.001 - 43.326 Gordon, R. P., Lautz, L. K., & Daniluk, T. L. (2013). Spatial patterns of hyporheic exchange and biogeochemical cycling around cross-vane restoration structures : Implications for stream restoration design. *Water Resour. Res.*, 49, 2040–2055, DTS Transect. October 2018 doi:10.1002/wrcr.20185 Temperature (°C Temperature (°C



behavior. The objective of this study is to quantify the spatio-temporal distribution of these exchange fluxes along the Cakit Stream (Nigde, Turkey) characterized by complex topography (Fig. 1) and geology (Fig. 2). We start with Electromagnetic Induction (EMI) survey at longer stream reaches to determine potential exchange zones. These zones were then investigated in detail using multiple techniques including fiber-optic Distributed Temperature Sensing (DTS), temperature-based vertical flux estimation, nested piezometers and water quality parameters in a hierarchical manner. 2) METHODOLOGY EMI surveys were performed over long reaches of Cakit Stream to pinpoint potential groundwater upwelling sections along the streambed (Fig. 3). Electrical Conductivity (EC) of the streambed sediments is estimated from the EMI surveys by considering the EC variation and depth of the water column. EC anomalies guided our focus to a 600 meter-long reach of the stream (Fig. 4). Along this selected reach, fiber-optic DTS system was utilized to investigate streambed-temperature variations at fine spatial and temporal scales (Fig. 5 & Fig. 6). Furthermore, nested piezometers and iButton temperature loggers (Fig. 7) were installed at three potential locations to investigate vertical hydraulic gradient (Fig. 8) and exchange fluxes (Fig. 9 & Table 1).



(iButtons) and DTS transect along with EMI Survey conducted on 27 June, 2018

Figure 5 DTS results of two measurement periods (a) inconclusive results on 18/09/2018 13:28-13:53, (b) successful results on 26/10/2018 07:31-08:02

Kasımcan Koruk ^{(1)*}, Koray K.Yılmaz ⁽¹⁾, Zuhal Akyürek⁽²⁾, and Andrew Binley⁽³⁾

⁽¹⁾Department of Geological Engineering, Middle East Technical University, Turkey; ⁽²⁾Department of Civil Engineering, Middle East Technical University ⁽³⁾Lancaster Environment Centre, Lancaster University, UK *Email: kasimcan.koruk@metu.edu.tr



ite	Vertical Flow Estimates		Flow
	Depth below top of streambed (cm)	Velocity (m/s)	Direction
P1	9.5	2.2x10-6 - 2.5x10-6	Downward
P2	9.5	5x10-7 - 2x10-6	Upward
P3	5.5	1x10-6 – 1x10-5	Upward
P2	9.5	6x10-7-1x10-6	Downward
P3	9.5	2x10-6-3x10-6	Upward
В	9.5	4x10-6-6x10-6	Upward

Hatch, C. E., Fisher, A. T., Revenaugh, J. S., Constantz, J., & Ruehl, C. (2006). Quantifying surface water-groundwater interactions using time series analysis of streambed thermal records: method development. Water Resour. Res., 42, W10410 doi:10.1029/2005WR004787

Matheswaran, K., Blemmer, M., Rosbjerg, D., & Boegh, E. (2014). Seasonal variations in groundwater upwelling zones in a Danish lowland stream analyzed using Distributed Temperature Sensing (DTS). HYDROLOGICAL PROCESSES, 1422-1435. Varli, D., & Yilmaz, K. K. (2018). A Multi-Scale Approach for Improved Characterization of Surface Water-Groundwater Interactions: Integrating Thermal Remote Sensing and in-Stream Measurements. Water, 10, 854.