Supplementary information
Mapping Water Content Dynamics in MAR-SAT systems using 3D Electrical Tomography

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SI 1. About the WWTP and SATs

The WWTP was designed for 165,000 equivalent-inhabitants, accommodating the sharp population increase during the summer season when it reaches full capacity. Outside the tourist season, the local population drops to approximately 90,000 inhabitants. The region has a typical Mediterranean climate, with annual precipitation averaging 450 mm, mainly during spring and autumn. Minimum temperatures reach 3 ºC in February and maximums rise to 36 ºC in July-August. The coastline is exposed to strong winds from various directions, occasionally from the sea (typically in January and October), which can increase electrical conductivity due to the inflow of seawater into the sewer collectors A full meteorological station (METER) was installed alongside the SAT systems, recording rainfall, temperature, air water content, solar radiation, and wind velocity and every 15 min (Figure SI. 1).

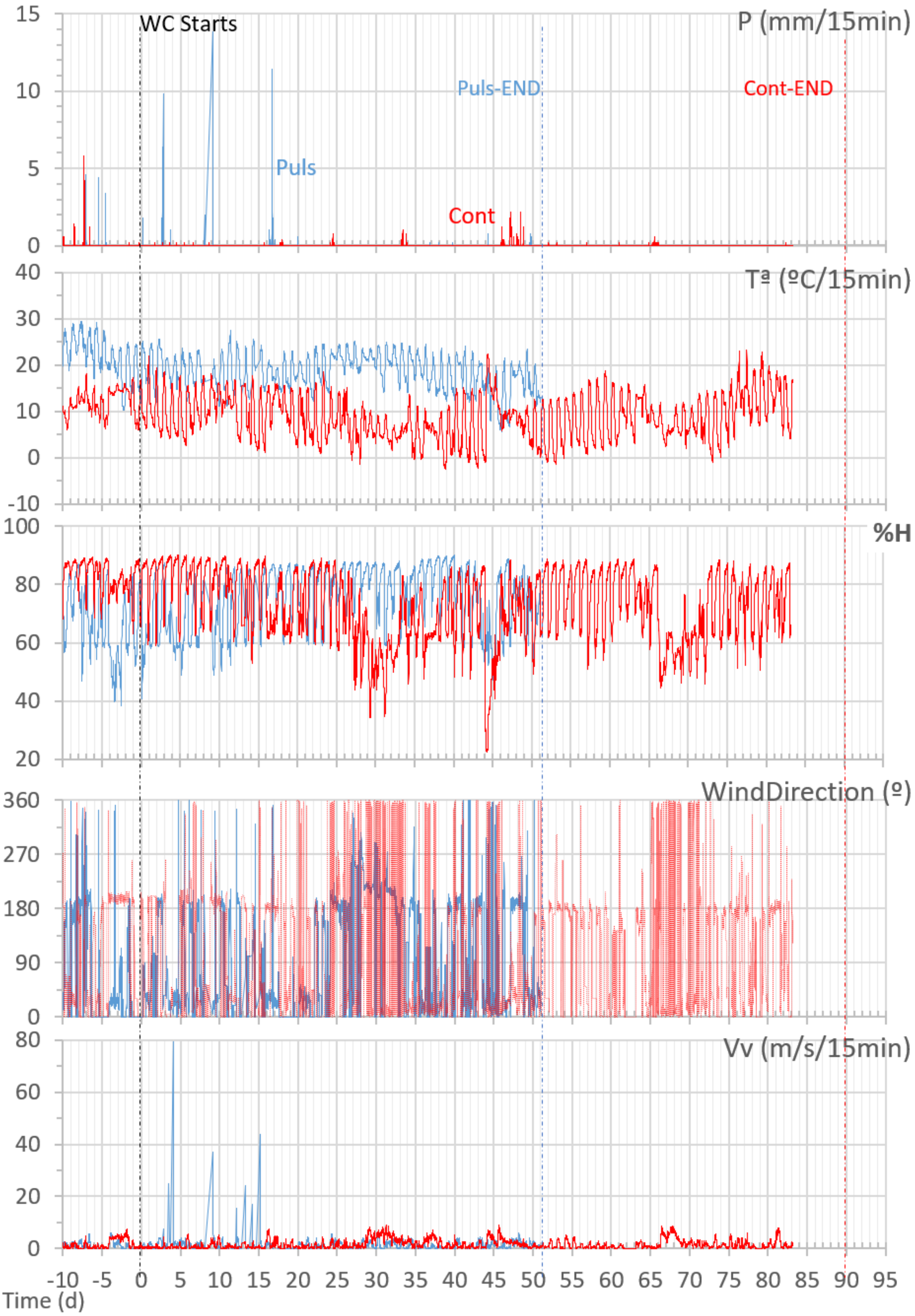
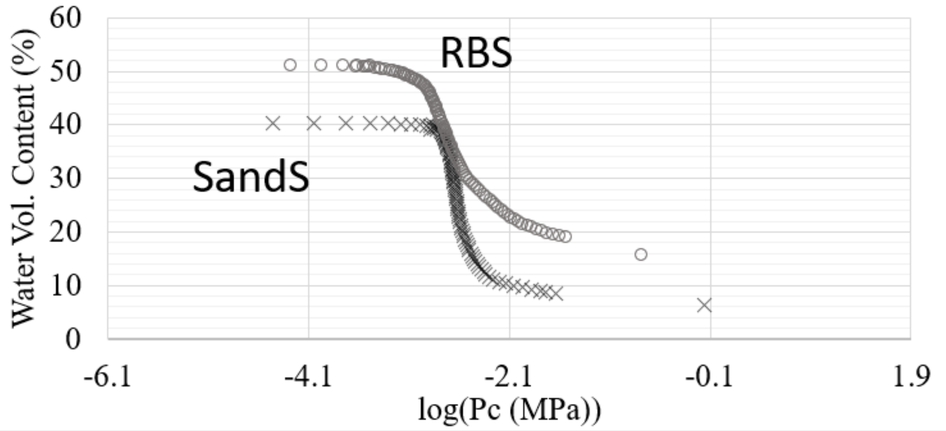


Figure SI. 1: Rainfall, temperature, air water content, wind direction and velocity every 15 min at the weather station in the WWTP during the testing period. Time 0 represents the WC starts for both Puls (blue) and Cont (red) recharge periods. Vertical slashed lines indicated the start and end for Puls (blue) and Cont (red) wet periods.

Retention curves (Figure SI.2) were measured from undisturbed samples collected from the central part of the USZ for each system (SandS and RBS). The retention curves were obtained using HYPROP 2 (UMS), which also provided density and total porosity data for the tested materials. The results indicate that the RB has a lower density and higher total porosity compared to Sand, attributed to the presence of organic matter in its composition.



	SandS	RBS
Density (gr/cm^3)	1.65	1.08
Porosity (total)	0.38	0.59

Figure SI. 2: Retention curves and density and total porosity values obtained for SandS and RBS.

Figure SI. 3: Plants growth over the recharge surface at the times the ERT acquisitions were made Red square in the upper pictures indicates the surface of the tomography measured.

When the reactive barriers with grass cover were installed to control the growth of vegetation on the basin surfaces, the vegetative cover was left without maintenance. Consequently, plants grew and died depending on the season and recharge evolution, contributing organic carbon to the system upon decomposition. Figure SI. 3 shows photographs illustrating the state of the vegetative cover at the beginning and end of each WC for both Puls and Cont recharge periods. The images for SandS are displayed in the left column, while those for RBS are on the right. At the start of the Puls period, the surface appears dry, following a summer without managed recharge. By the end of the Cont period, a water layer can be observed on the basin surface in the SandS, whereas no such water layer is present on the RBS.

SI 2. Measurements

SI 2.1. Water balance measurements

Figure SI. 4 and Figure SI. 5 present measurements related to the water balance of the USZ. Both figures illustrate the recharge scheme, the water volume content at a depth of 40 cm, and the aquifer's response, represented by dept-to-water measurements at the O piezometer (Figure 1). The Puls period (in blue) consist of 12/12 h cycles with a recharge rate of 0.8 m/d, while the Cont period involves a constant recharge rate of 0.4 m/d. Although the temporal distribution of recharge differed between the two schemes, the total volume of water recharged was identical.

Water is pumped form the WWTP effluent tank (INF) to the basin surface using dosing pumps (PRIUS), with the volume recorded every half hour using an ISOIL MS600 flowmeter. The INF water is distributed over the basin surface via a perforated irrigation pipe. Soil moisture content is measured at six points from the surface at 10 cm depth intervals using an Aquacheck prove. The Aquacheck probe is a capacitance -based moisture sensor that emits an electromagnetic signal to measure the humidity content of the surrounding soil volume.

The head evolution in the aquifer is measured using a CTD Dive sensor, which also allows for the measurement of electrical conductivity (EC) and temperature. The aquifer's response to the SATs, in terms of heads evolution, is illustrated in Figure SI. 4 and Figure SI. 5 (c plots), where it is presented as "Depth to water" in meters. This sensor only functions when saturated; it does not take measurements when dry. Refer to the sensor's position in the c plot.

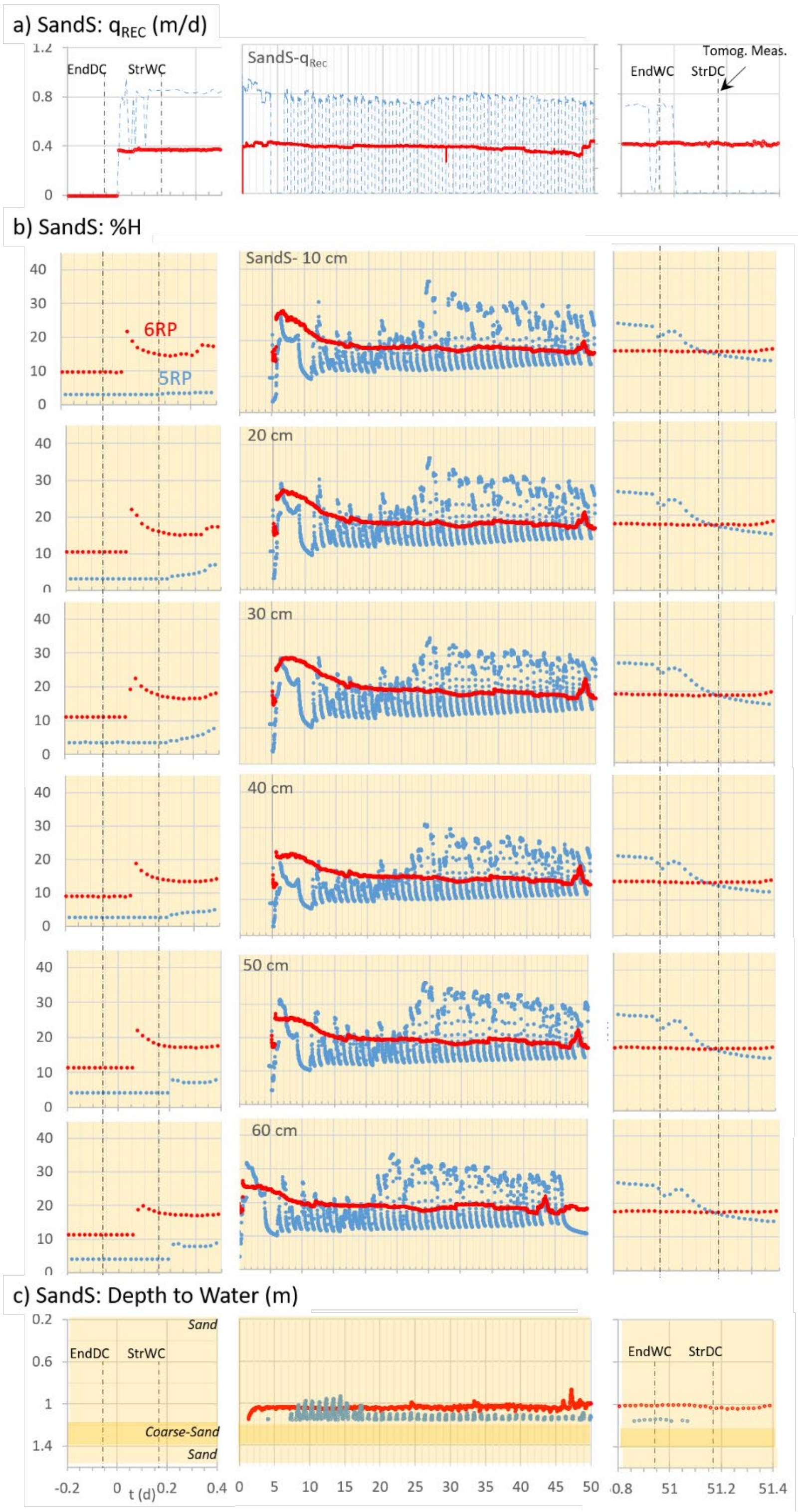


Figure SI. 4: Measurements in the SandS. These plots are distributed in three columns to zoom the initial and final times to see better the moment in which the tomography data were registered. We show the start data of the Puls. and Cont. at 0 time, but only the stop of the Puls. (at 51 d), to facilitate the data visualization, it is because that that only the Puls. data (blue dots) respond to the recharging stop. The time in which the tomography data were registered are indicated with a dotted vertical line, labelled as EndDC: End Dry Cycle, StrWC: Start Wet Cycle, EndWC: End Wet Cycle and StrDC: Start Dry Cycle. In a) figure is show the recharge flow rate during the Puls (in blue) and Cont (in red) operational schemes. Notice double q_{rec} during Puls to recharge the same daily volume than Cont. This recharge distribution behaviour, in b), has an effect on the %H distribution with depth in the USZ. C) figure draw the piezometric head in the aquifer, Depth to Water, as a pressure over the sensor initially dry (1.2 m). This graphics draws the position of the different materials that composed the USZ just to the aquifer, where the gravitational water arrives to the saturated zone (aquifer).

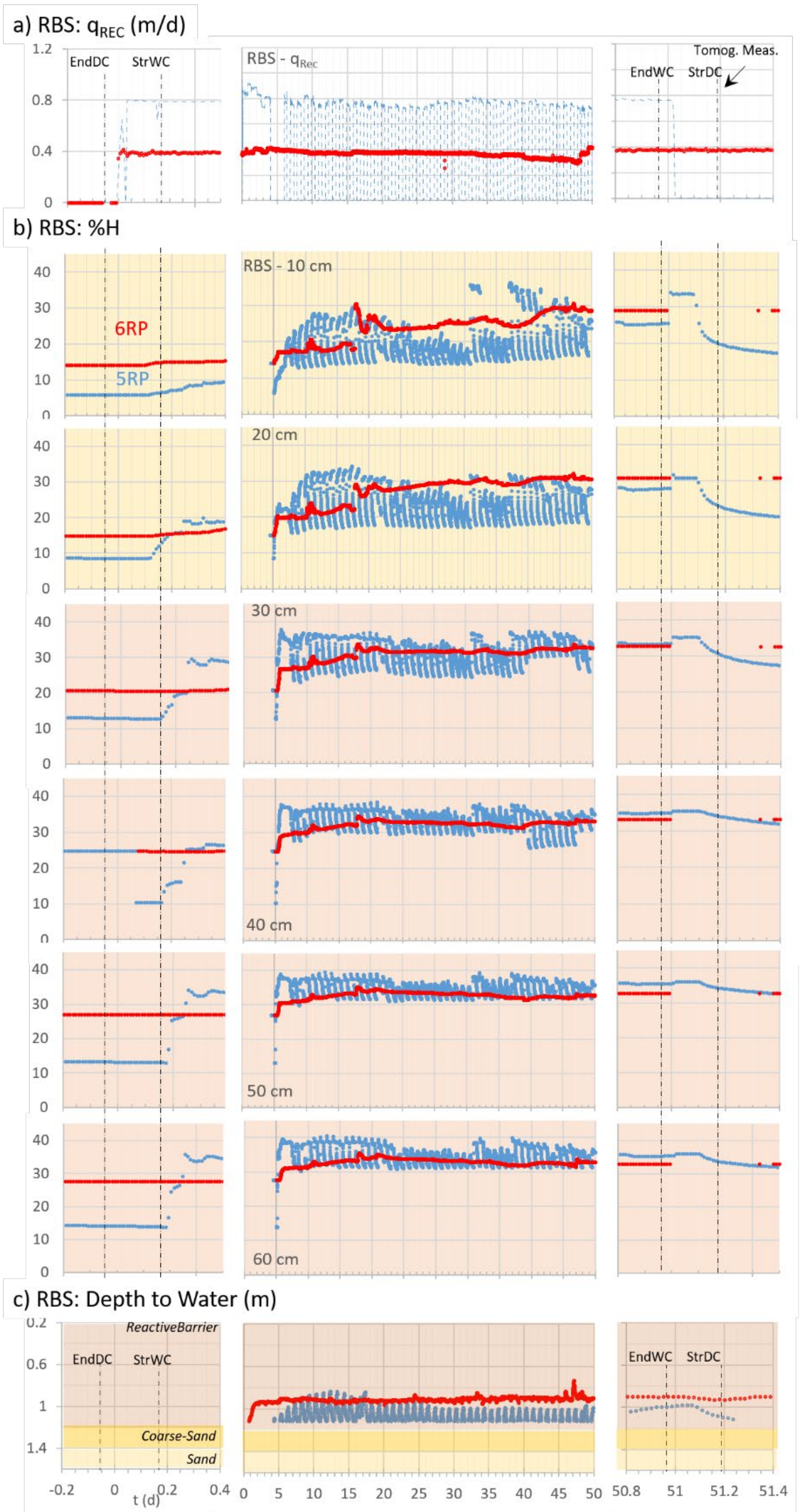


Figure SI. 5: Measurements in the SandS. These plots are distributed in three columns to zoom the initial and final times to see better the moment in which the tomography data were registered. We show the start data of the Puls. and Cont. at 0 time, but only the stop of the Puls. (at 51 d), to facilitate the data visualization, it is because that that only the Puls. data (blue dots) respond to the recharging stop. The time in which the tomography data were registered are indicated with a dotted vertical line, labelled as EndDC: End Dry Cycle, StrWC: Start Wet Cycle, EndWC: End Wet Cycle and StrDC: Start Dry Cycle. In a) figure is show the recharge flow rate during the Puls (in blue) and Cont (in red) operational schemes. Notice double q_{rec} during Puls to recharge the same daily volume than Cont. This recharge distribution behavior, in b), has an effect on the %H distribution with depth in the USZ. C) figure draw the piezometric head in the aquifer, Depth to Water, as a pressure over the sensor initially dry (1.2 m). This graphics draws the position of the different materials that composed the USZ just to the aquifer, where the gravitational water arrives to the saturated zone (aquifer).

SI 2.2. Electrical Conductivity

Electrical Conductivity is recorded every 30 min using a CTD-Diver. Figure SI. 6 illustrates EC variations during Puls (blue) and Cont (red) recharge periods in the INF (solid line) and O piezometers (in dots), for SandS (a) and RBS (b). The baseline EC measurement in the INF is around 2 mS/cm with localized peaks caused by rainfall (dilution) and seawater entrance into the sewerage system due to winds, which increase EC values.

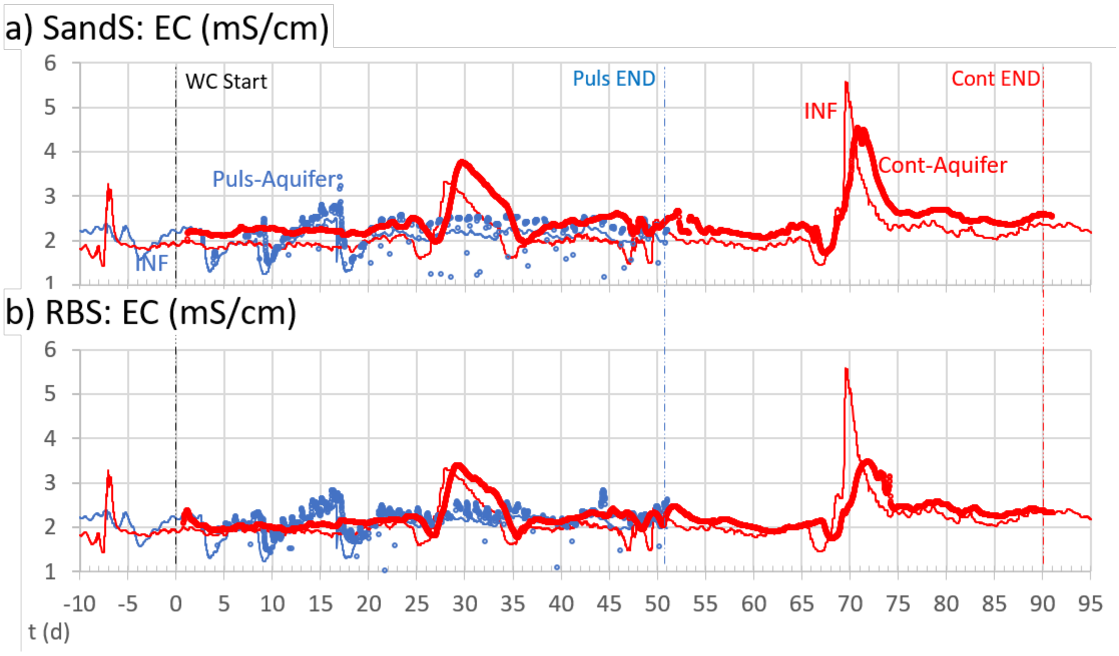


Figure SI. 6: Electrical Conductivity values measured in water by means CTD Diver. In continuous line values from WWTP Effluent (INF), and in dotted line from the aquifer in O piezometer. In blue measurement during Puls recharge and during Cont recharge in red. a) plot draws data for the SandS and b) for the RBS.

SI 2.3. Temperature

The Aquachek probe measures water content and temperature at the same points, from 10 cm to 60 cm depth every 10 cm. Figure SI. 7 shows measurements at 40 cm depth for SandS (a) and RBS (b), for comparison which those used in the main text of this paper.

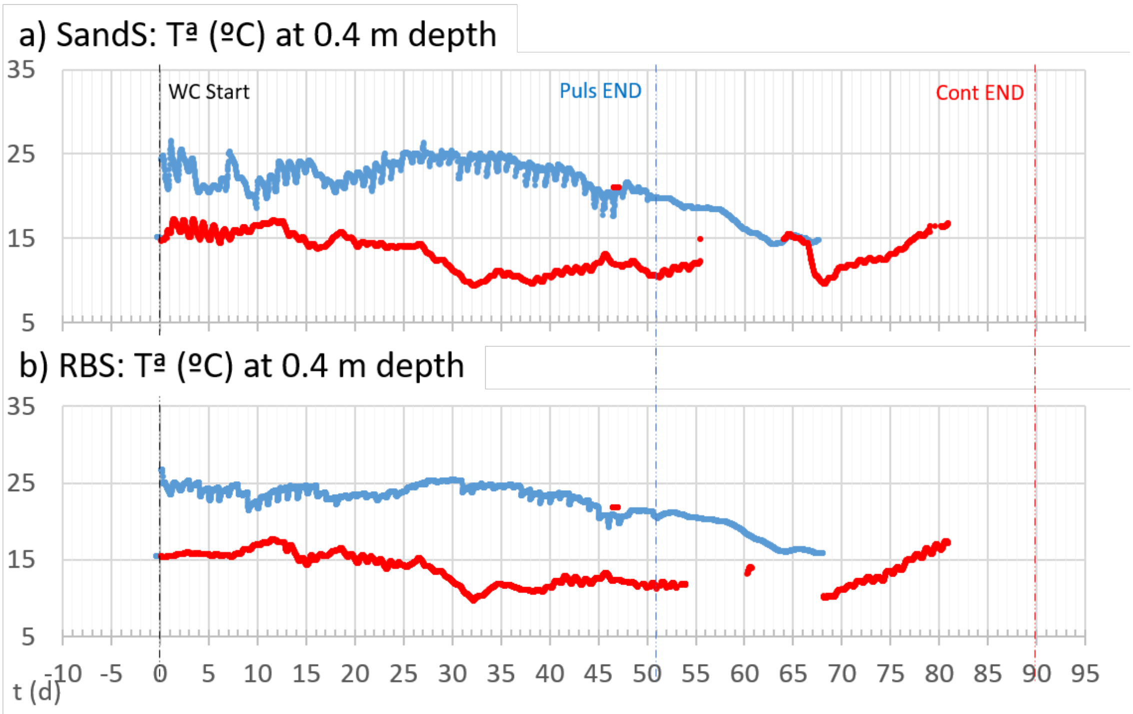


Figure SI. 7: Temperature measured every 30 min at 0.4 m depth in SandS and RBS during the recharge in Cont (red) and in Puls (blue). Recharge in Cont occurred between December to March (winter) and those of Puls between May to July (summer).

SI 2.4. Dissolved Oxygen Measurements

Oxygen dipping probes measure the partial pressure of both gaseous and dissolved oxygen. Consist of a polymer optical fiber (POF) with a polished distal tip which is coated with a planar oxygen sensitive foil. The end of this POF is covered with a high-grade steel tube to protect the sensor. The detection limit is 15 ppb, 0 – 100% oxygen (Oxygen Dipping Probe PSt3, PreSens Precision Sensing). Figure SI. 8 and Figure SI. 9 present measurements from sensors located at depths of 35 and 90 cm in SandS and RBS respectively. The values recorded during the Puls (blue) and Cont (red). Dotted line indicates the end of each WC.

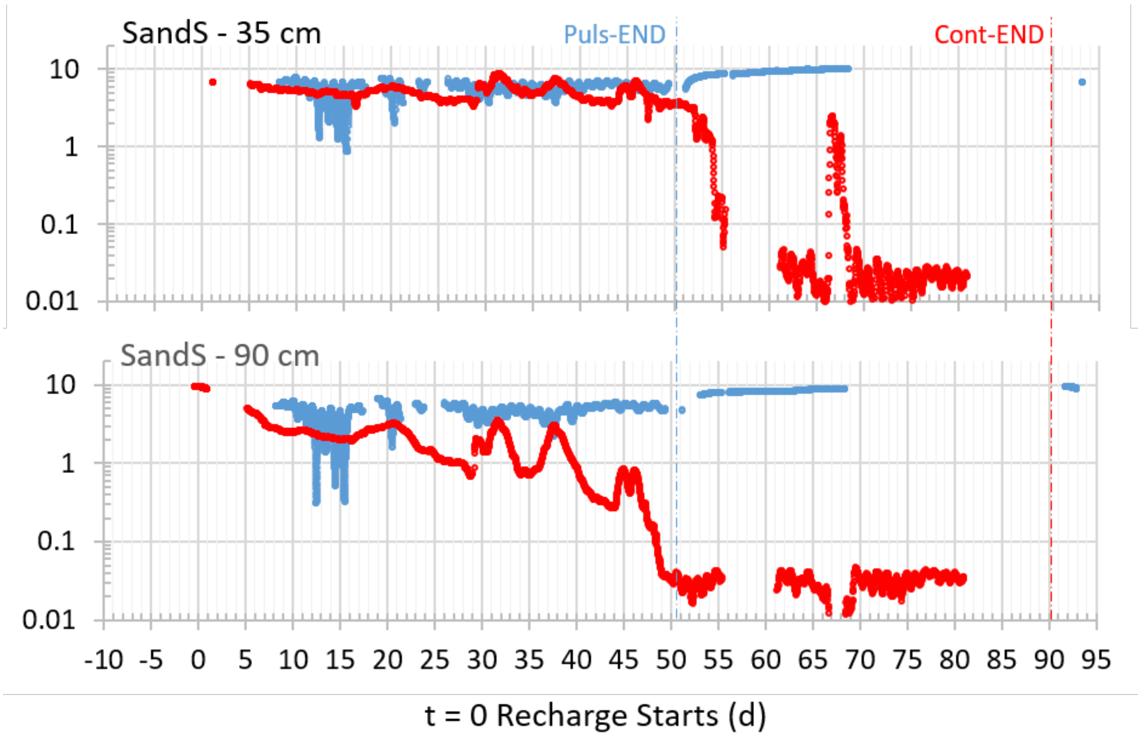


Figure SI. 8: Recorded Dissolved Oxygen in USZ at two depths during the Cont (red) and Puls (blue) RP for SandS. Vertical dotted lines indicate the end of the WC for each RP.

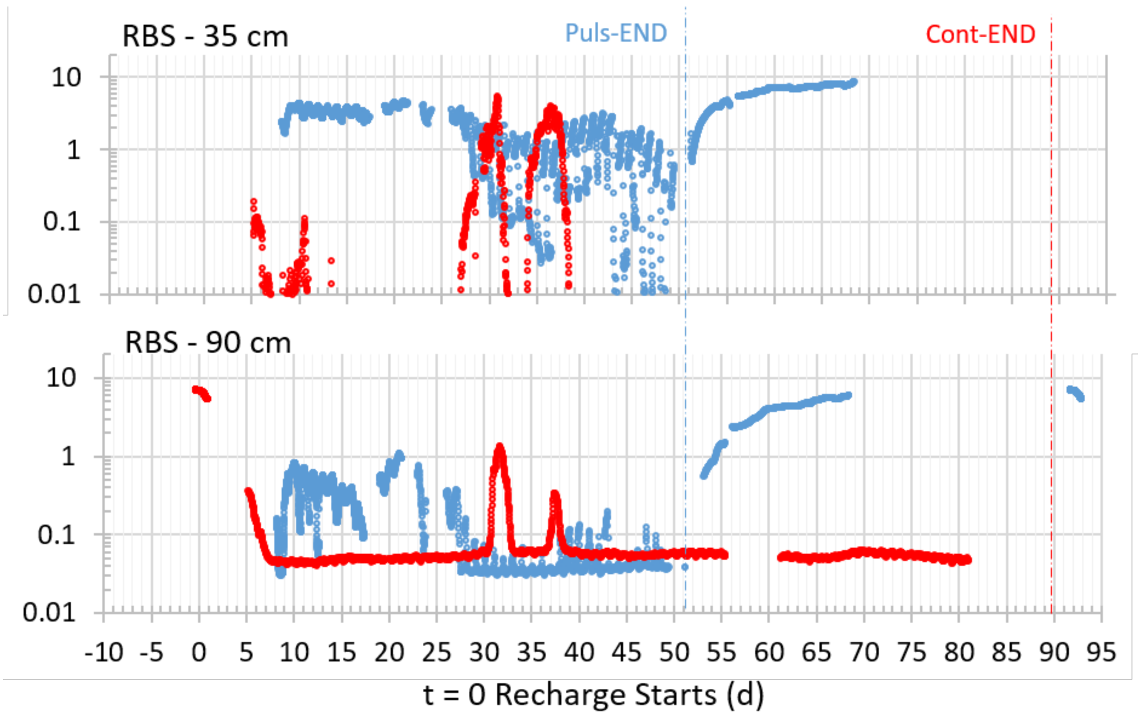


Figure SI. 9: Recorded Dissolved Oxygen in USZ at two depths during the Cont (red) and Puls (blue) RP for RBS. Vertical dotted lines indicate the end of the WC for each RP

SI 2.5. Superficial water layer

During the recharge period, a thin water layer may accumulate on the basin surface mainly due to the deposition of fine organic material carried by WWTP effluent (INF). With a proper management of the system, this layer may remain only a few centimetres thick or not form at all. However, when a sudden increase on thickness is observed, it indicates the need to initiate the dry cycle (DC) to allow these fine particles to degrade. A normal wet cycle (WC) can starts after a few days.

Figure SI. 10 (SandS) and Figure SI. 11 (RBS) illustrate the evolution of the parameters measured in this layer over the course of the recharge period. In the SandS, under a continuous recharge scheme, the layer began to form after 70 days, reaching a thickness of 5 cm and remaining stable for 5 days. After this period, the water layer continued to accumulate, eventually reaching a thickness of 25 cm. At that point, the recharge process was stopped.

The RBS recharged normally without any Surface water accumulation.

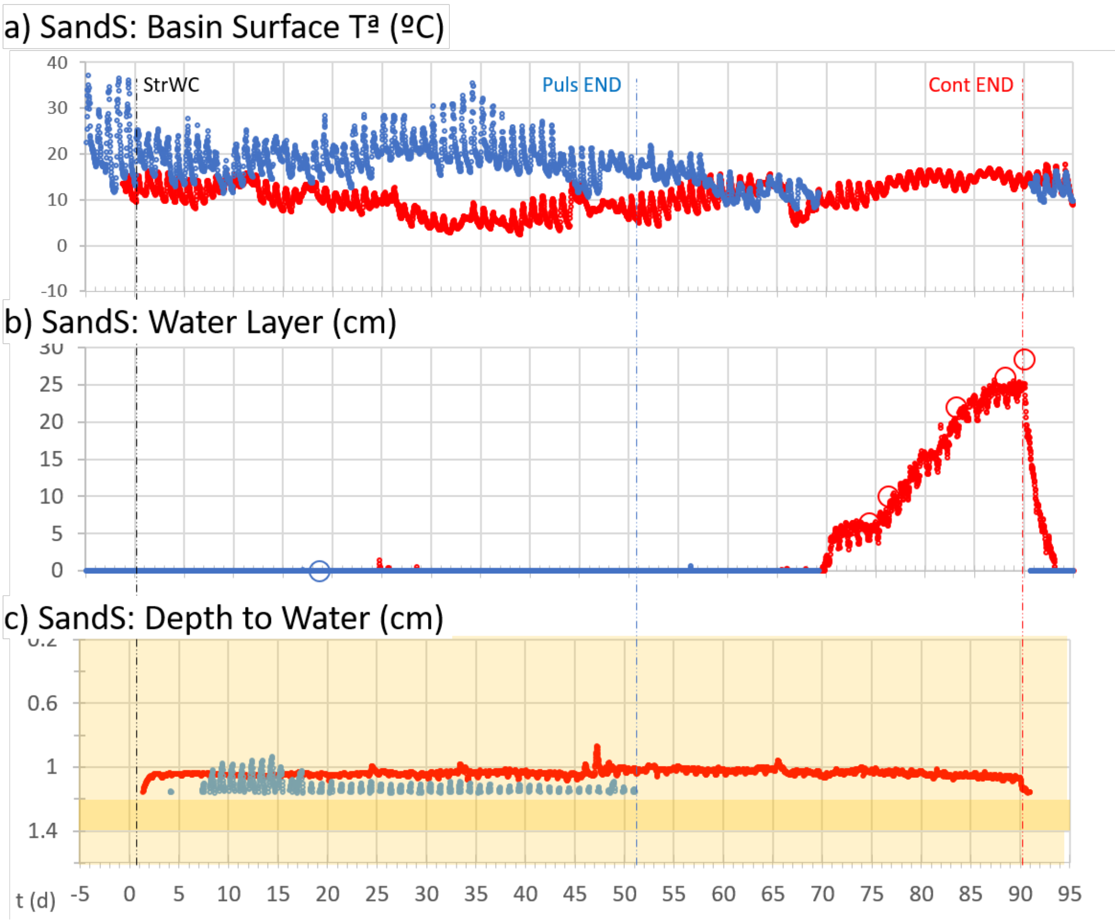


Figure SI. 10: a) Evolution of Tª (ºC), b) water layer accumulation (big circles represent the manual measurements), and c) depth to water in the aquifer on the SandS surface during the Puls (blue) and Cont (red) RPs.

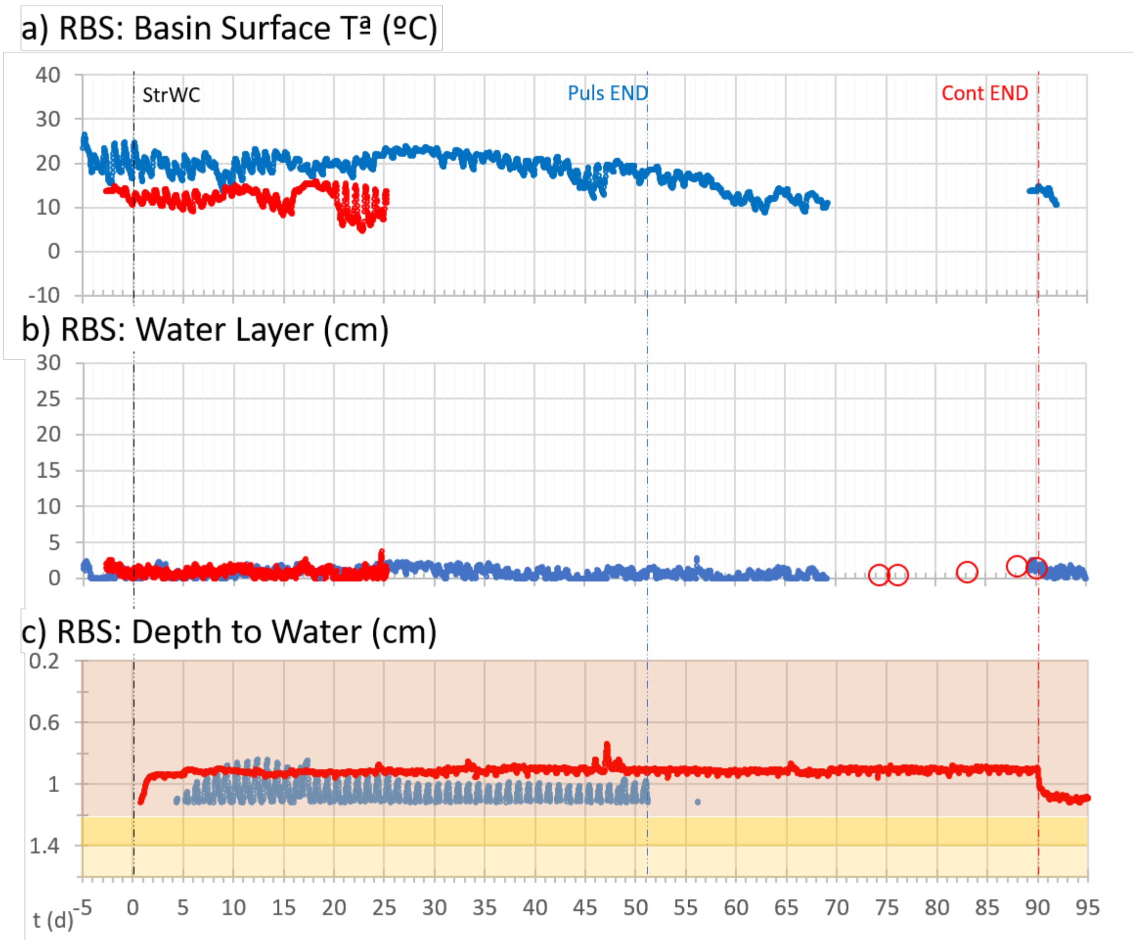


Figure SI. 11: a) Evolution of Tª (ºC), b) water layer accumulation (big circles represent the manual measurements), and c) depth to water in the aquifer on the SandS surface during the Puls (blue) and Cont (red) RPs.

SI 2.6. Extracellular polymeric substances (EPS) soil content.

Samples for EPS quantification were collected at three depths (28, 41, and 54 cm) in each system during the wet cycles. EPS are considered a key indicator of biofilm development. Table SI. 1 presents the total EPS concentrations measured at these depths in both SandS and RBS during the Puls and Cont wet cycles.

Table SI. 1: Total EPS concentration (µg/g) measured on each sampling day (t = 0 d: recharge starts) at depths of 28, 41, and 51 cm. An asterisk (*) indicates that no sample was recovered due to dry material conditions.

Recharge strategy	**Puls WC**					
System	**SandS**			**RBS**		
Days/Depth (cm)	**28**	**41**	**54**	**28**	**41**	**54**
1	126.94	*	*	779.64	340.43	417.69
2	*	*	*	532.40	555.63	579.50
5	118.91	60.64	31.25	293.86	350.20	434.20
12	41.79	44.49	39.50	315.21	430.46	258.88
20	57.42	56.98	46.29	272.70	293.83	349.81
26	101.11	100.13	74.02	301.95	226.78	287.34
34	98.93	88.35	100.51	397.01	363.67	413.31
Recharge strategy	**Cont WC**					
System	**SandS**			**RBS**		
Days/Depth (cm)	**28**	**41**	**54**	**28**	**41**	**54**
1	52.66	50.74	53.70	110.86	144.51	195.99
2	*	*	*	*	*	*
5	31.08	45.07	41.83	201.99	222.16	183.02
12	55.37	37.96	28.46	176.92	137.08	198.31
20	39.05	22.44	25.69	169.52	164.36	148.10
26	213.19	52.00	85.87	295.68	208.08	275.58
34	92.47	70.21	103.51	319.31	300.20	165.41
39	41.28	111.07	53.86	221.04	236.16	510.82
53	95.78	107.03	78.71	338.89	219.48	220.06
74	101.31	99.80	73.60	296.61	179.29	223.98

* Sample not collected due to insufficient water content in the sediment to obtain a core.