Work Package 5: Monitoring and evaluation of pilot outputs

Deliverable 5.7.1 (former 5.3.1): Monitoring of instrument operation and ground water quality at selected locations

Beneficiary: IHU (former TEICM)

INTERREG V-A COOPERATION PROGRAMME:

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About this document:

The present Deliverable reports on site measurements on selected existing pumps and the geotechnical borehole after the first monitoring period (which is reported in Deliverable 4.7.2 – former 4.3.2).

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1. Scope of Deliverable 5.7.1 (former 5.3.1) – IHU (former TEICM) contribution

The present Deliverable serves as the continuation of Deliverable 4.7.2 - former 4.3.2 (*On site measurements on selected existing pumps and geotechnical borehole*) in terms of reporting the in situ measurements and subsequent interpretation of measurement results in TEICM campus (Technological Educational Institute of Central Macedonia in Serres, Greece). Those measurements concern the following:

- Measurement of pumped water quantities from existing pumps in TEICM campus area.
- Quality measurements of pumped water from the existing campus pumps and the geotechnical borehole.
- Monitoring of the water table level in the geotechnical borehole in TEICM campus area.

Preliminary monitoring data, from the first stage of the project immediately after the initial installation of the monitoring devices, has already been reported in Deliverable 4.7.2 (former 4.3.2). Here, those measurements are enriched with more data of the subsequent period till the end of the project.

As a reminder, water pumped quantity and quality from existing pumps will be taken into account to study a water distribution system for secondary uses and more specifically toilet flushing in the selected building. Water characteristics from existing pumps are also checked through a detailed chemical and microbiological analysis. Additional quality testing took place on the water of the borehole well as described in Deliverable 4.7.2 (former 4.3.2).

2. Measurements on selected existing pumps

2.1 Location of pumps

The location of the monitored pumps at the basement level of Building B and Building C is presented in detail in Deliverable 4.7.2 (former 4.3.2). In the present deliverable we include again Figure 1 and Figure 2 to remind the location of the specific buildings and Figure 3 for Building B (3 pumps) and Figure 4 for Building C (2 pumps) for the exact position of the monitored pumps.

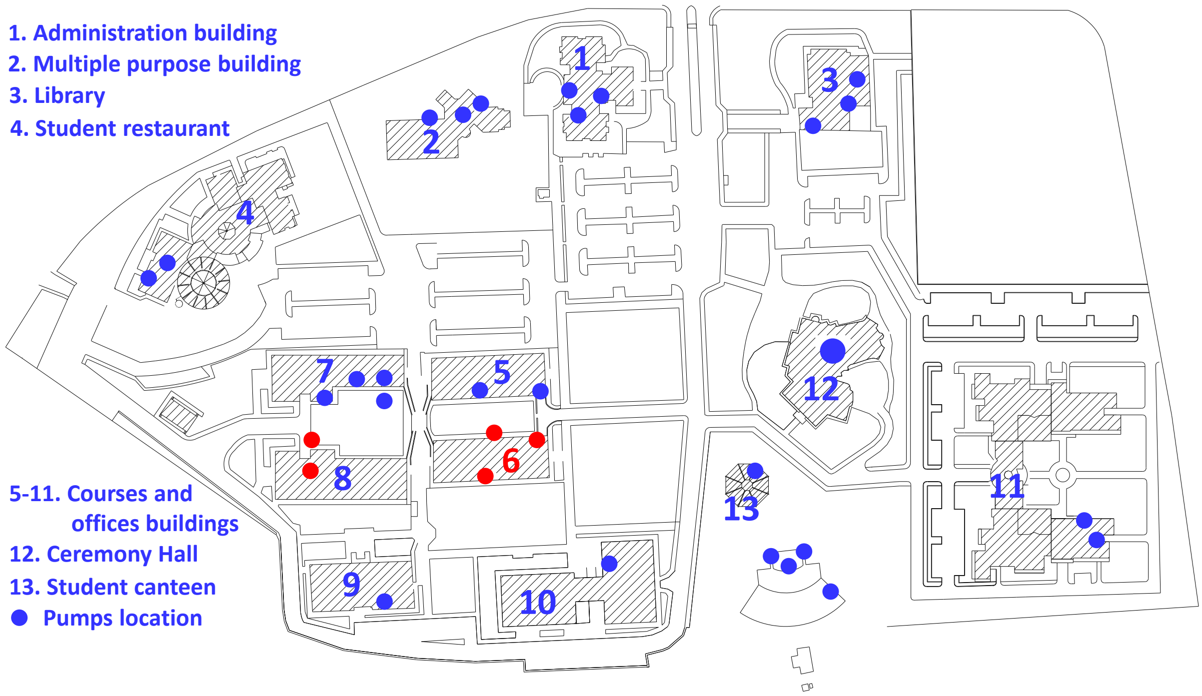

Figure 1. Location of existing water pumps in TEICM campus and selected pumps at the basement of Building B (no. 6) and Building C (no. 8)

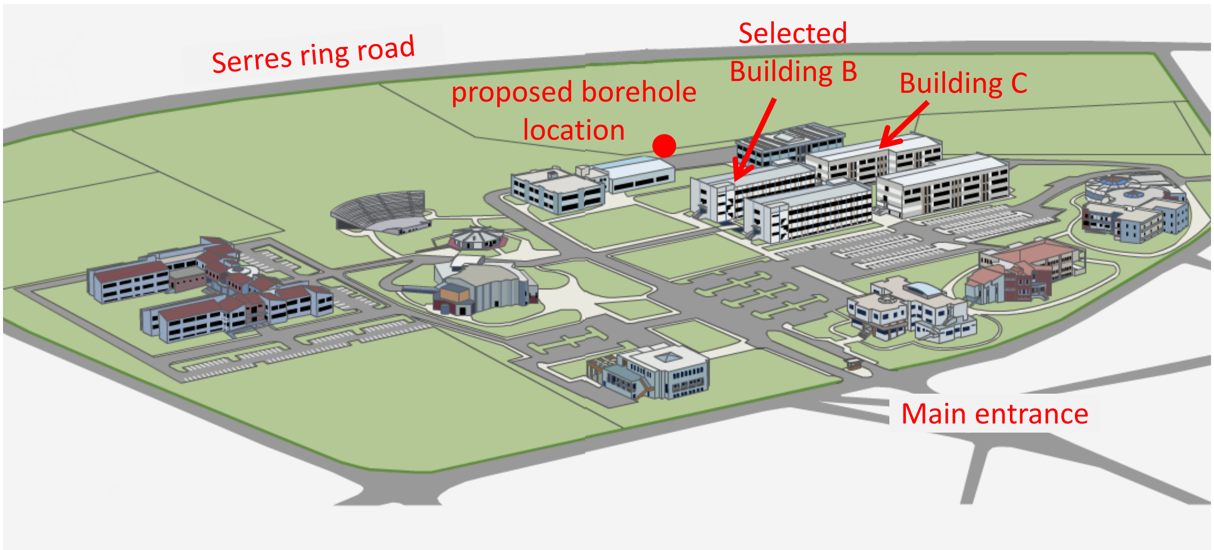

Figure 2. Location of the selected for studies Building B and neighboring Building C

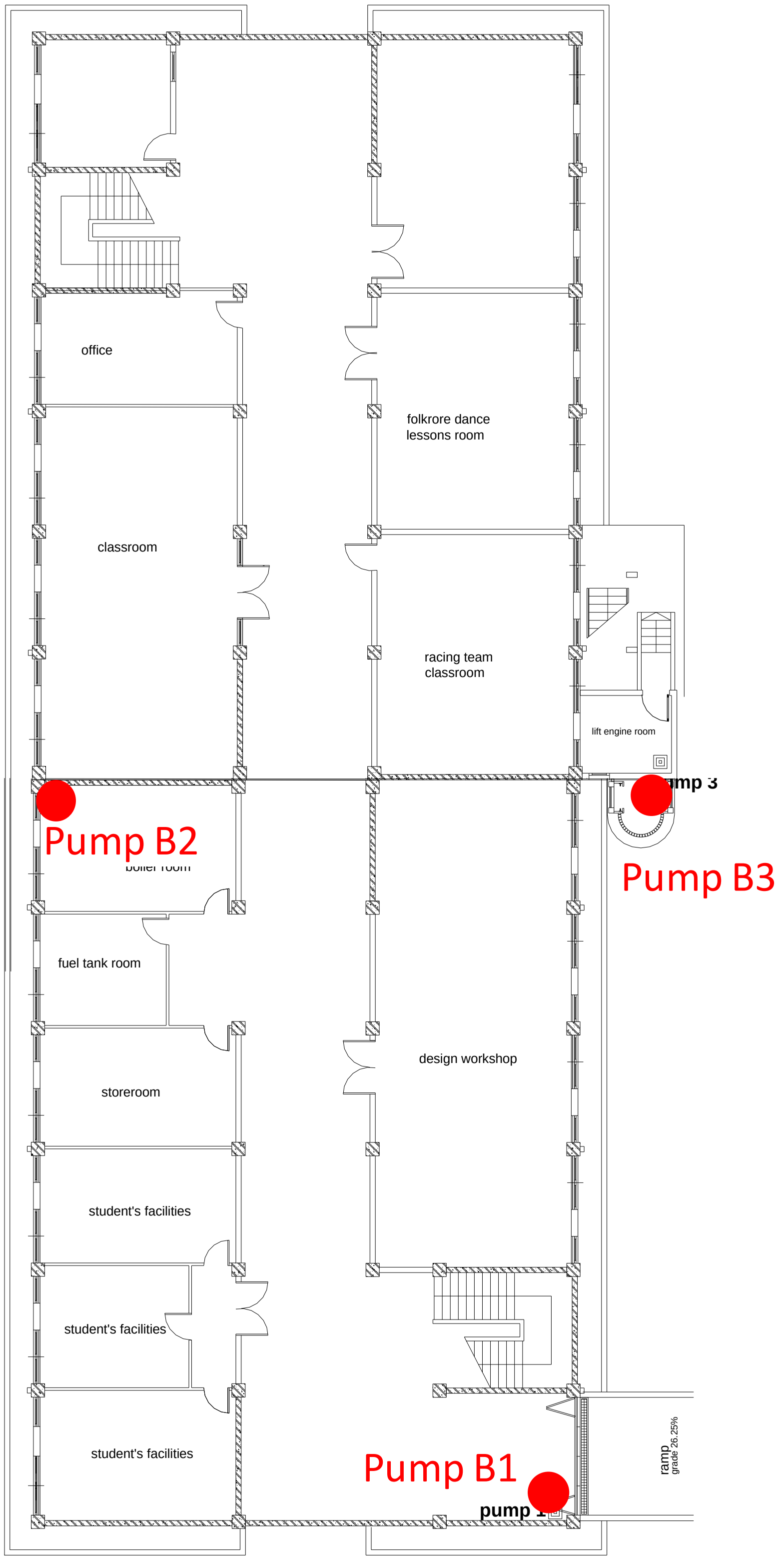

Figure 3. Position of existing pumps at the basement of Building B

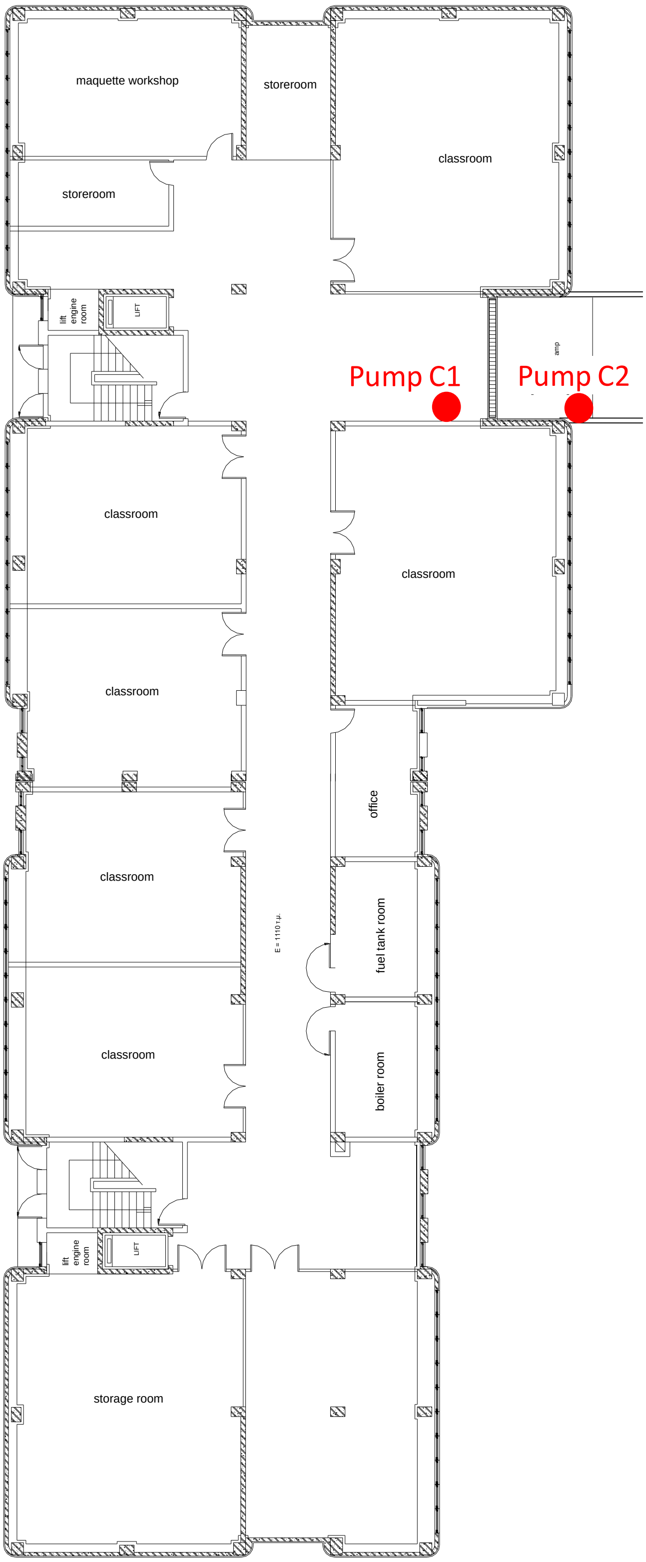

Figure 4. Position of existing pumps at the basement of Building C

2.2 Identification of existing water pumps

Identification and functional characteristics of the monitored water pumps are presented in detail in Deliverable 4.7.2 (former 4.3.2).

2.3 Measurement of pumped water quantities from existing pumps

Measurement approach is described in Deliverable 4.7.2 (former 4.3.2) and includes indirect estimation of pumped water quantity through monitoring of the power consumption of the examined pumps in the following ways:

- Analogue power consumption measurement devices installed in all pumps.
- Digital power consumption measurement devices with Wi-Fi data transfer installed as a pilot application in the two (2) pumps of Building C.

The above measurement approaches are cross-correlated and validated throughout the project.

The measurements of the power consumption of the water pumps during the first months after installation of the devices are included in Deliverable 4.7.2 (former 4.3.2). Additional measurement are taken through the whole project duration (indicative photos in Figure 5, Figure 6 and Figure 7).

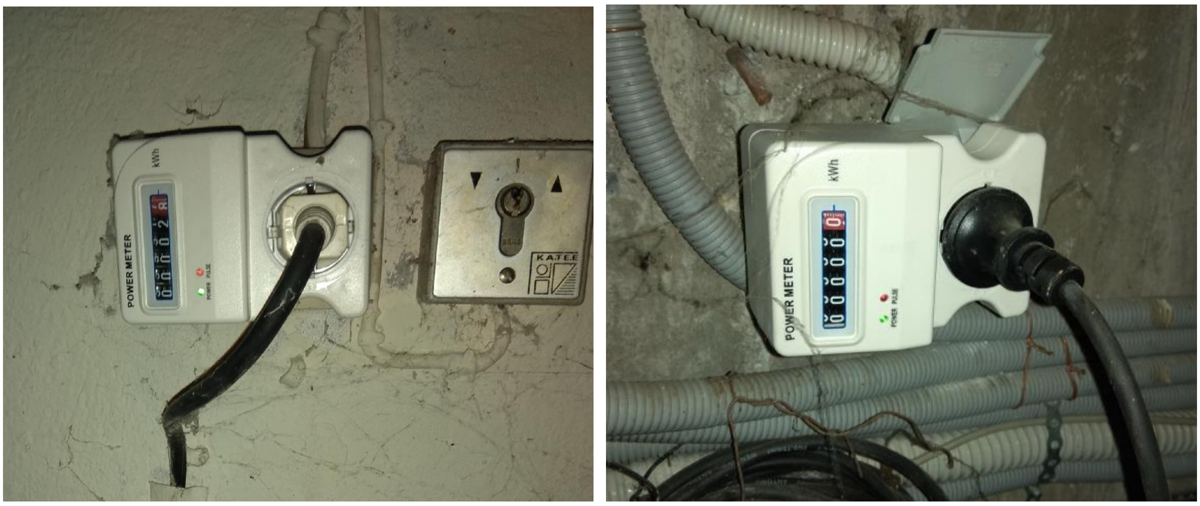

Figure 5. Power consumption measurements of existing water pumps in Building B (Pump B1 on the left and Pump B3 on the right, photo taken on 22/07/2019).

Figure 6. Power consumption measurements of existing water pumps in Building C (Pump C1 on the left and Pump C2 on the right, photo taken on 22/07/2019).

Figure 7. Power consumption measurements of existing water pumps in a) Building C (Pump C1 on the top-left and Pump C2 on the top-right) and (b) Building B (Pump B3 on the bottom-left and Pump B1 on the bottom-right), (photos taken on 11/02/2022).

The digital devices offer several types of monitoring as described in Deliverable 4.7.2 (former 4.3.2):

- Real time recording observation of both instant usage value and time-history of power consumption.
- History usage data in diagram format for each monitoring device.
- Cost calculation due to the pump energy consumption based on pricing details of the local provider (user required information). Since the cost for the occasional pumps' function is not significant, no further data on this feature are included in the present Deliverable (check for indicative diagram in Deliverable 4.7.2 - former 4.3.2 report).

- Approximation of carbon emission (CO_2 in kg) due to the consumed energy of the pump. The CO_2 emissions due to the pumps power consumption is also expected to be negligible and is not reported hereafter (check for indicative diagram in Deliverable 4.7.2 - former 4.3.2 report).
- Reports of power consumption data in convenient format (csv) that allows for further data processing (check for indicative diagram in Deliverable 4.7.2 - former 4.3.2 report).

Power consumption data for water pump C2 (outside pump of Building C) that presents increased functionality are presented in the following Figures till the end of the project. Diagrams should be reviewed carefully since the scale is different between figures.

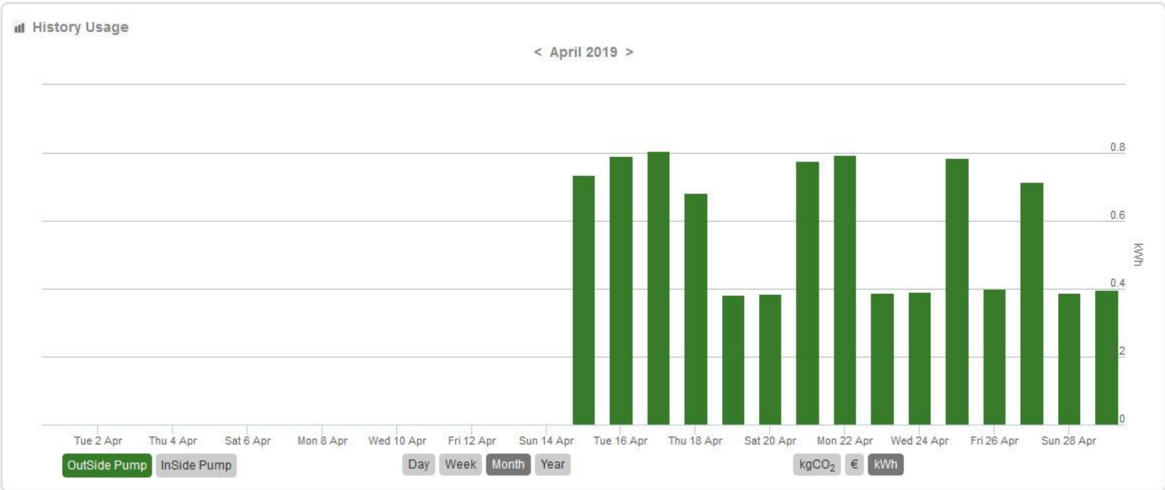

Figure 8. Diagram of history power usage (in kWh) of Pump C2 (April 2019).

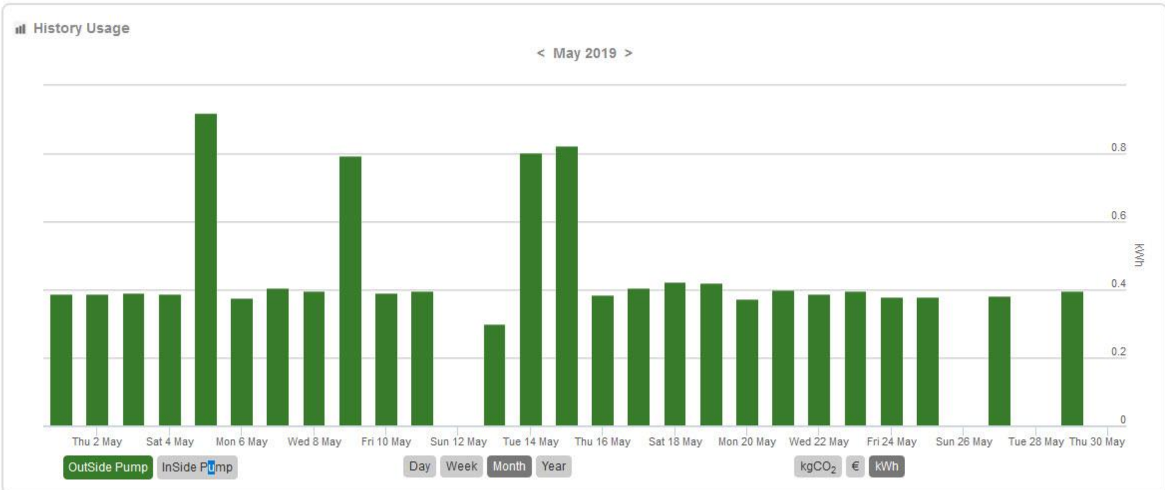

Figure 9. Diagram of history power usage (in kWh) of Pump C2 (May 2019).

Figure 10. Diagram of history power usage (in kWh) of Pump C2 (June 2019).

Figure 11. Diagram of history power usage (in kWh) of Pump C2 (July 2019).

Figure 12. Diagram of history power usage (in kWh) of Pump C2 (August 2019).

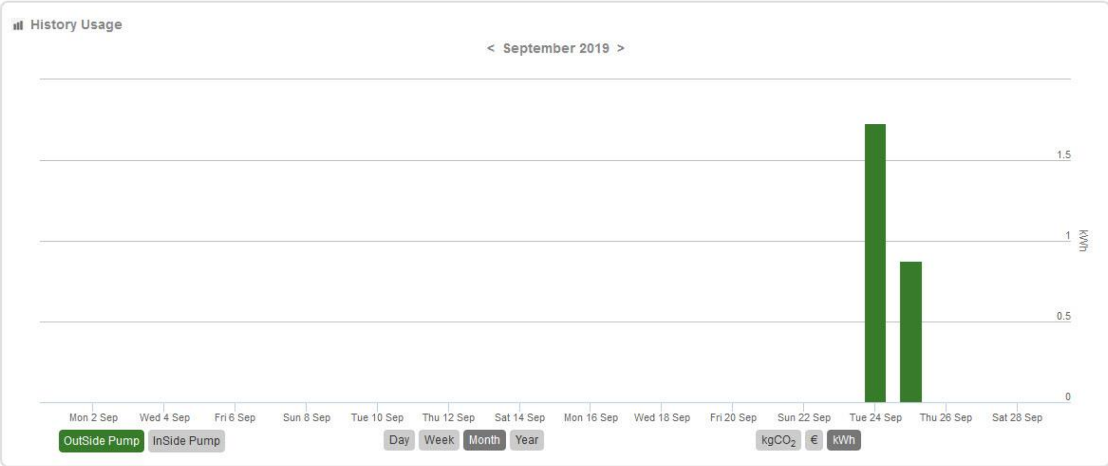

Figure 13. Diagram of history power usage (in kWh) of Pump C2 (September 2019).

Figure 14. Diagram of history power usage (in kWh) of Pump C2 (October 2019).

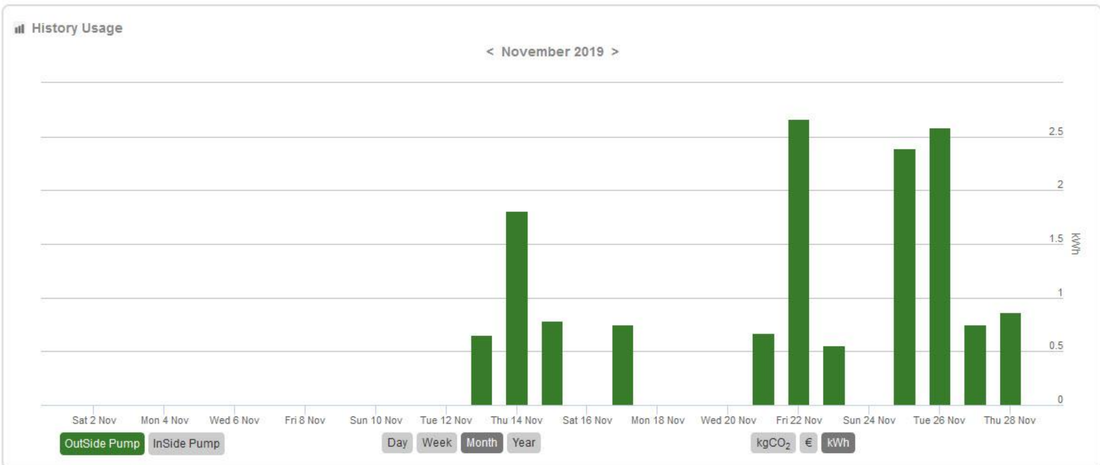

Figure 15. Diagram of history power usage (in kWh) of Pump C2 (November 2019).

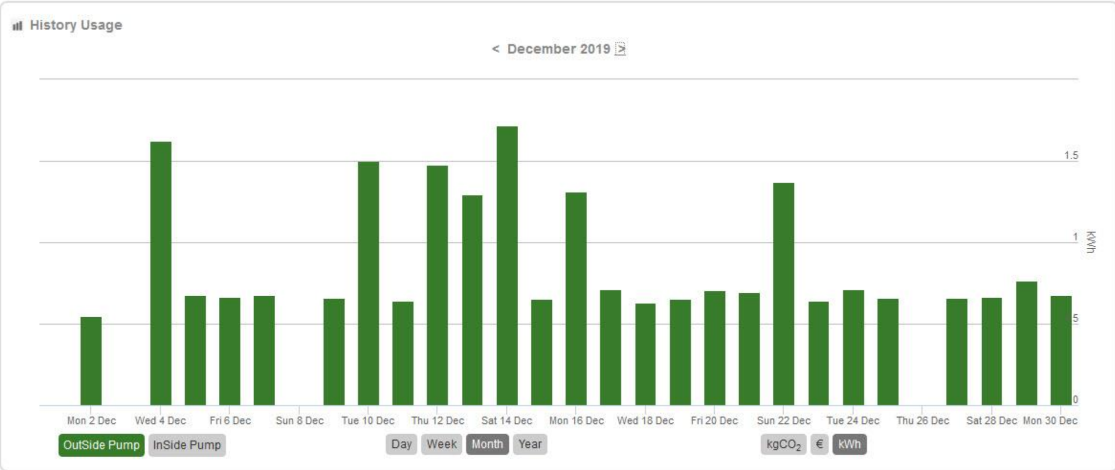

Figure 16. Diagram of history power usage (in kWh) of Pump C2 (December 2019).

Figure 17. Diagram of history power usage (in kWh) of Pump C2 (January 2020).

Figure 18. Diagram of history power usage (in kWh) of Pump C2 (February 2020).

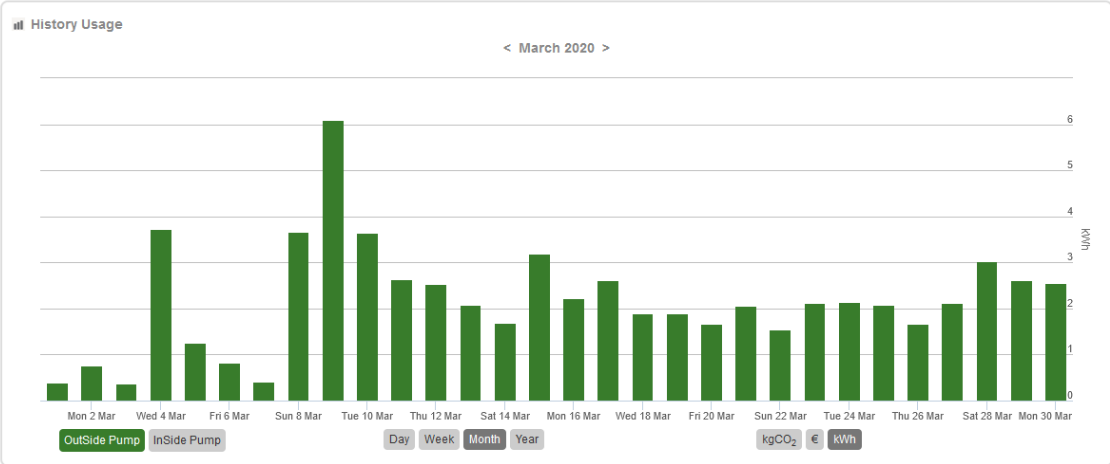

Figure 19. Diagram of history power usage (in kWh) of Pump C2 (March 2020).

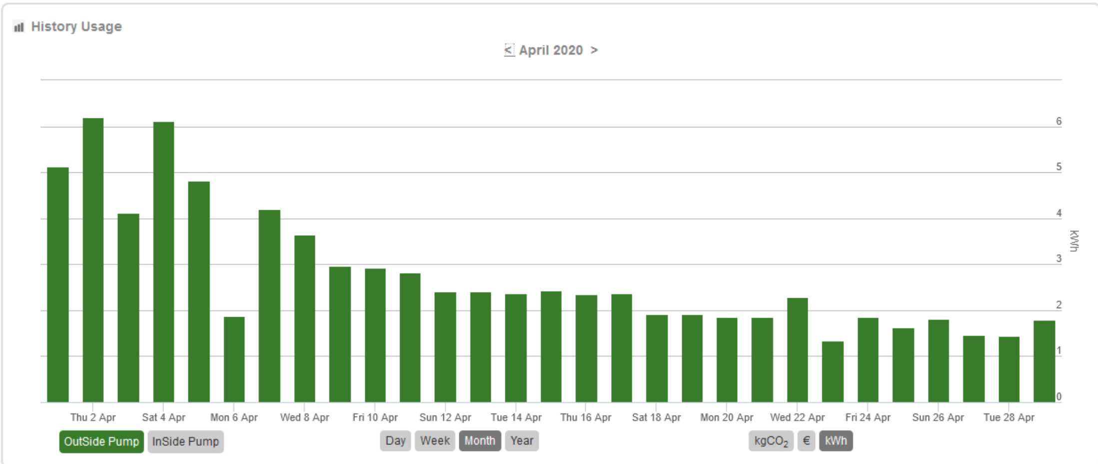

Figure 20. Diagram of history power usage (in kWh) of Pump C2 (April 2020).

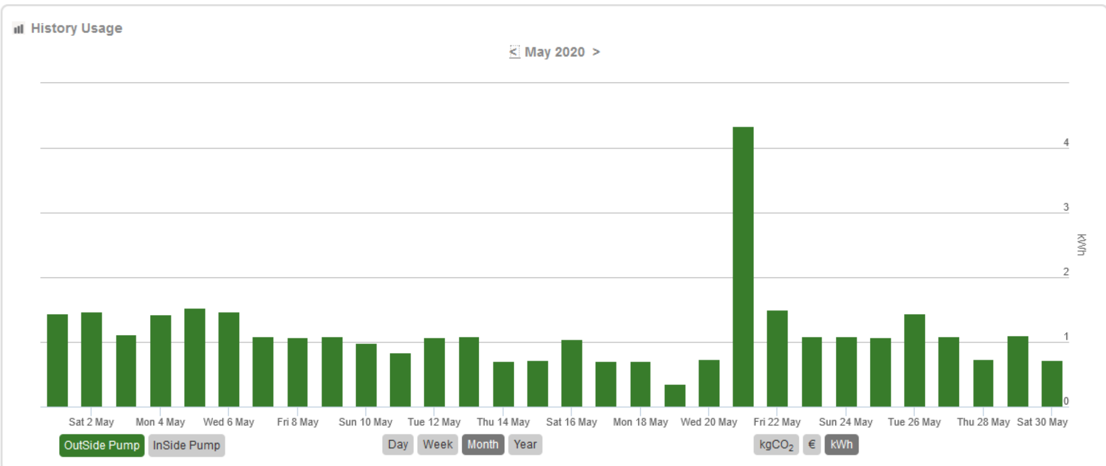

Figure 21. Diagram of history power usage (in kWh) of Pump C2 (May 2020).

Figure 22. Diagram of history power usage (in kWh) of Pump C2 (June 2020).

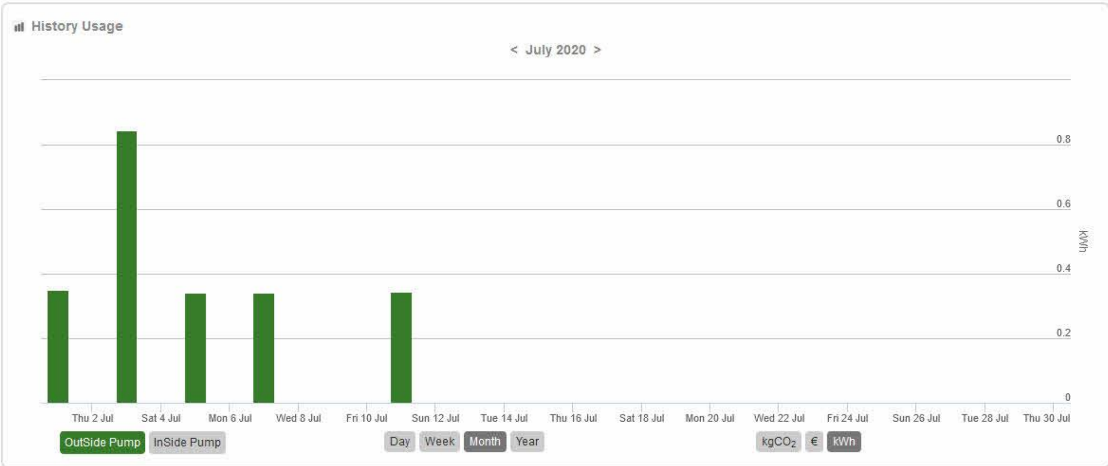

Figure 23. Diagram of history power usage (in kWh) of Pump C2 (July 2020).

Figure 24. Diagram of history power usage (in kWh) of Pump C2 (August 2020).

Figure 25. Diagram of history power usage (in kWh) of Pump C2 (September 2020).

Figure 26. Diagram of history power usage (in kWh) of Pump C2 (October 2020).

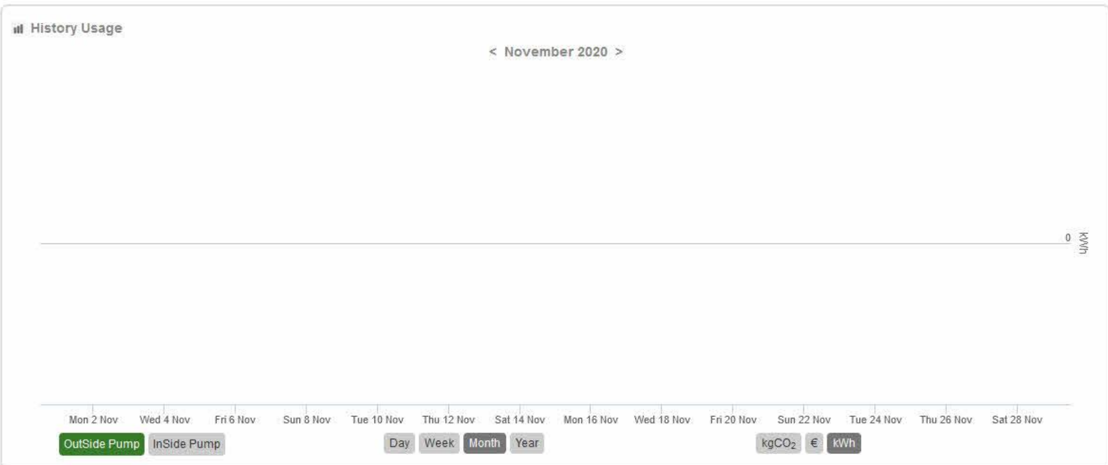

Figure 27. Diagram of history power usage (in kWh) of Pump C2 (November 2020).

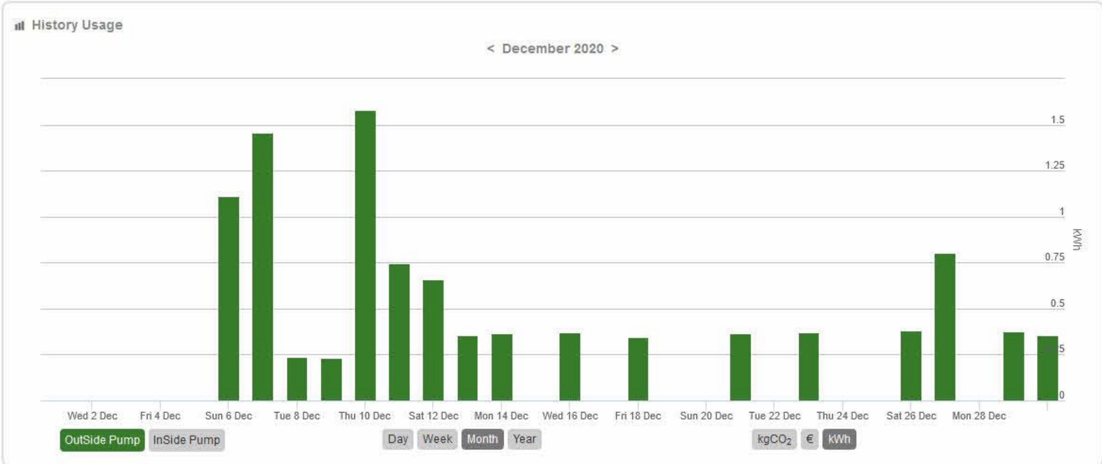

Figure 28. Diagram of history power usage (in kWh) of Pump C2 (December 2020).

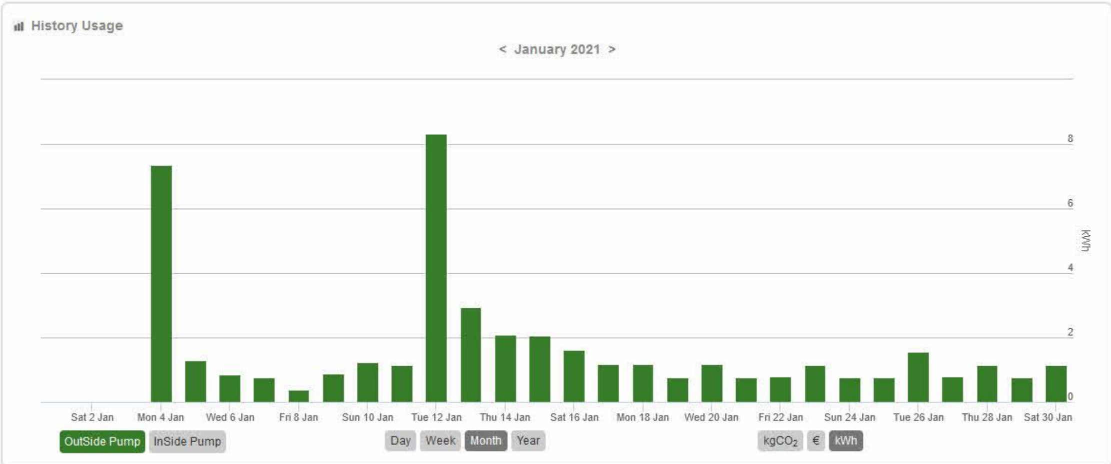

Figure 29. Diagram of history power usage (in kWh) of Pump C2 (January 2021).

Figure 30. Diagram of history power usage (in kWh) of Pump C2 (February 2021).

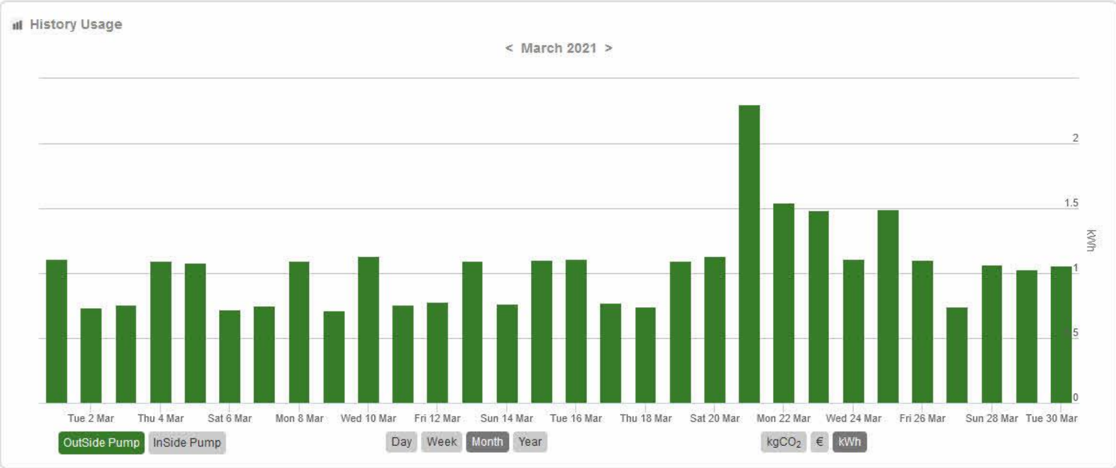

Figure 31. Diagram of history power usage (in kWh) of Pump C2 (March 2021).

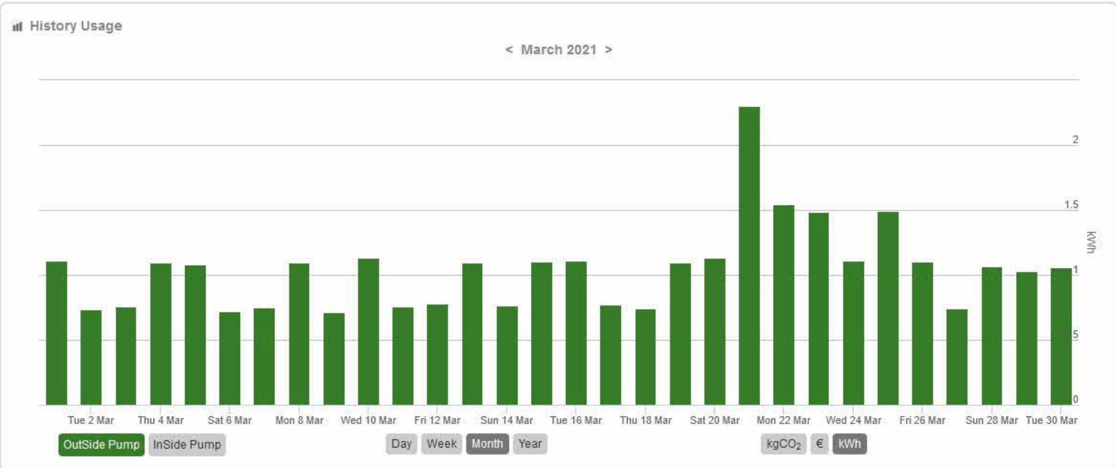

Figure 32. Diagram of history power usage (in kWh) of Pump C2 (April 2021).

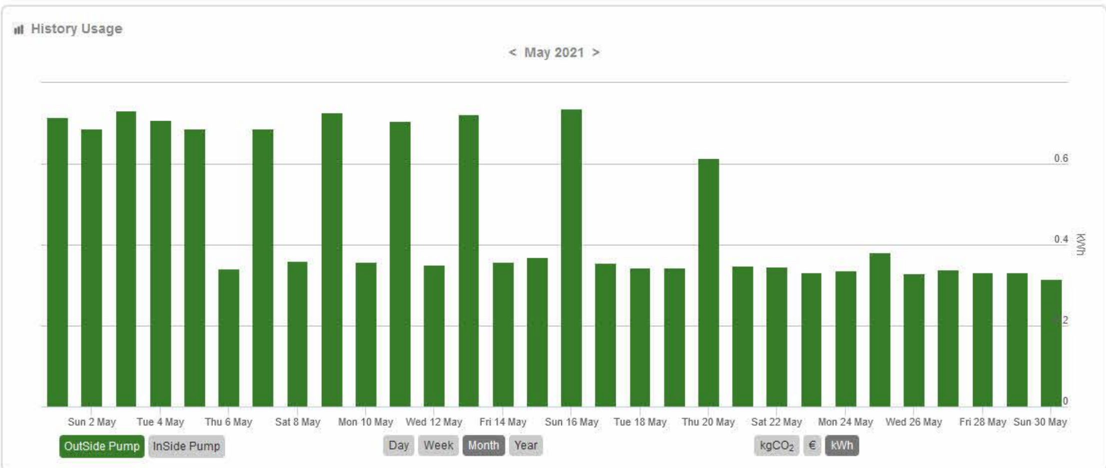

Figure 33. Diagram of history power usage (in kWh) of Pump C2 (May 2021).

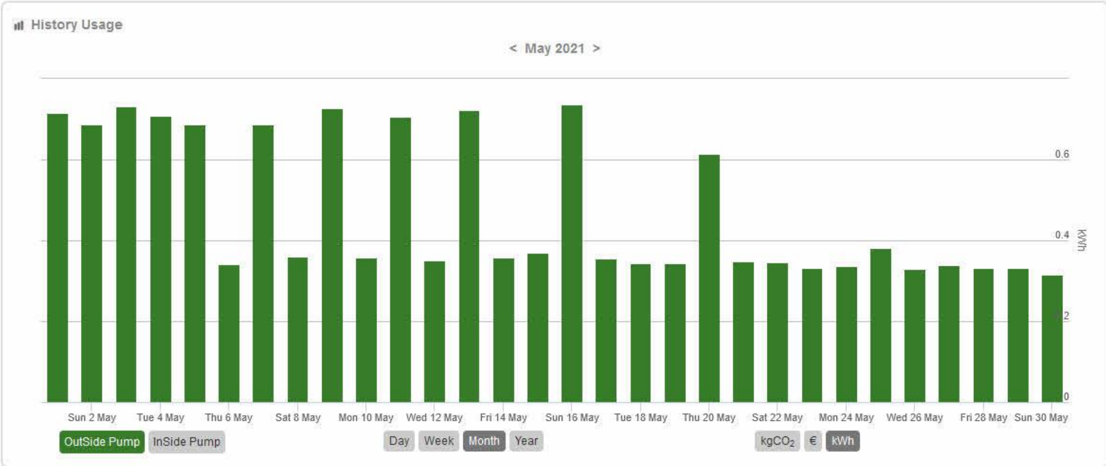

Figure 34. Diagram of history power usage (in kWh) of Pump C2 (June 2021).

Figure 35. Diagram of history power usage (in kWh) of Pump C2 (July 2021).

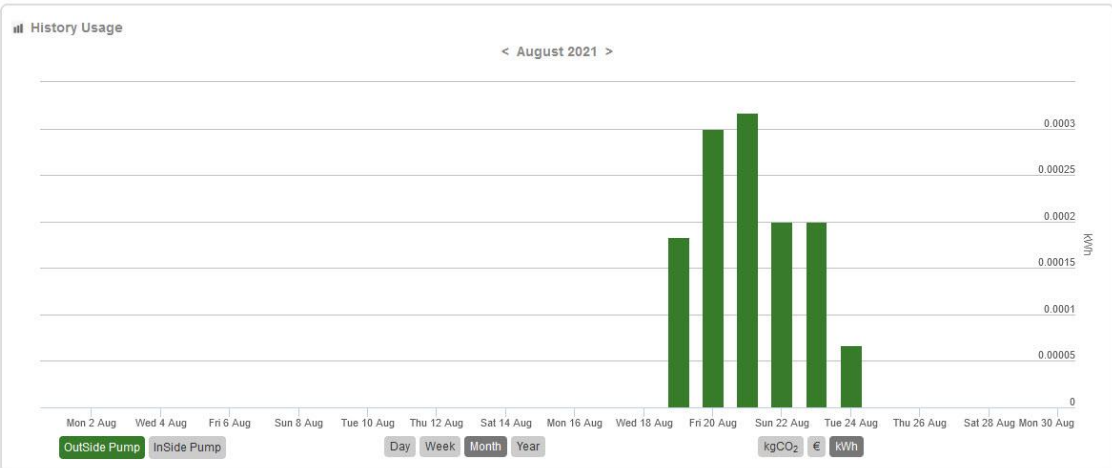

Figure 36. Diagram of history power usage (in kWh) of Pump C2 (August 2021).

Figure 37. Diagram of history power usage (in kWh) of Pump C2 (September 2021).

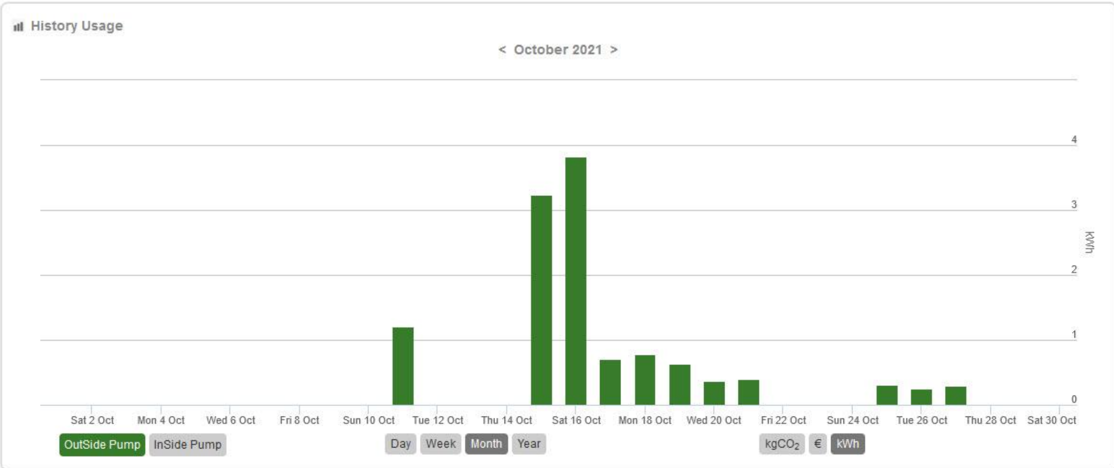

Figure 38. Diagram of history power usage (in kWh) of Pump C2 (October 2021).

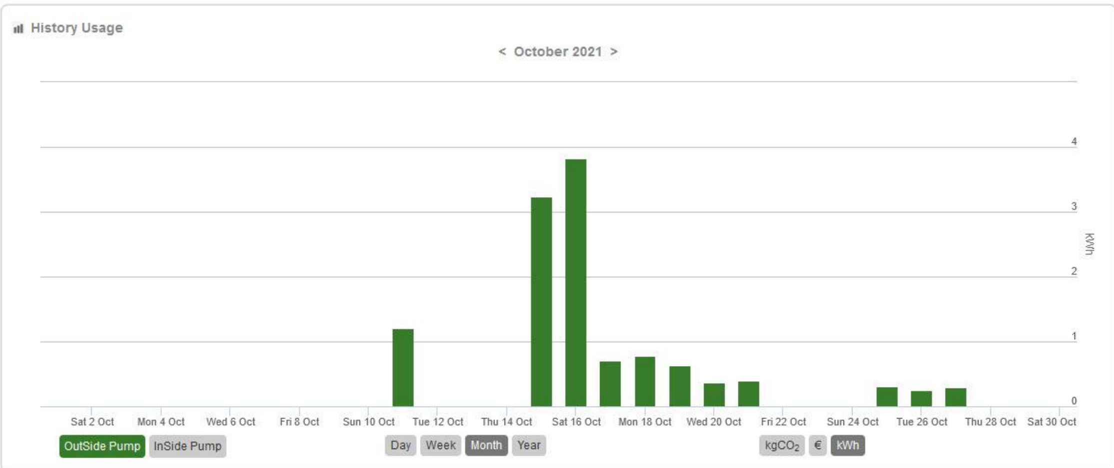

Figure 39. Diagram of history power usage (in kWh) of Pump C2 (November 2021).

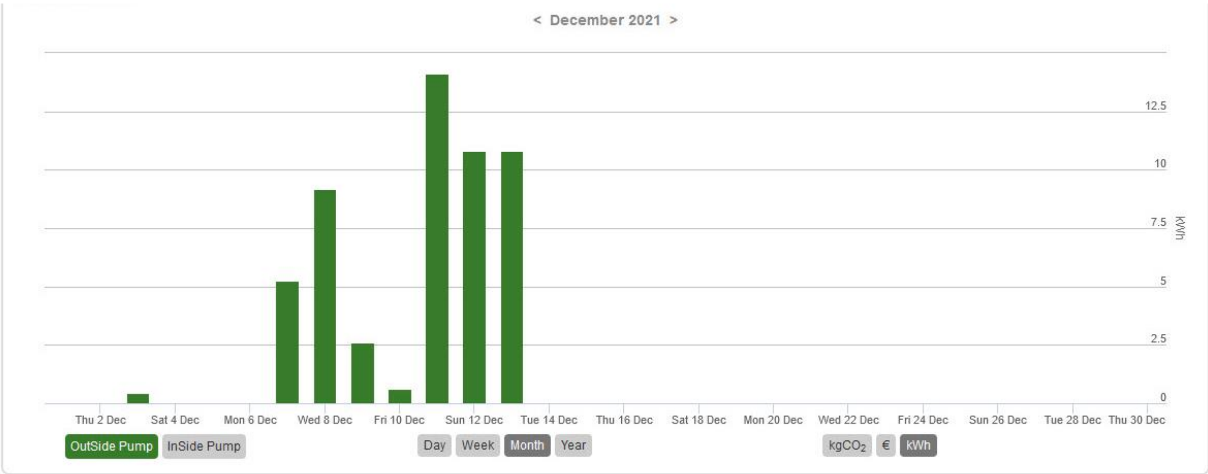

Figure 40. Diagram of history power usage (in kWh) of Pump C2 (December 2021 - malfunction of measurements during the last 15 days of December).

Figure 41. Diagram of history power usage (in kWh) of Pump C2 (January 2022 - malfunction during the first 10 days of January).

As presented from the above Figures, the pump was functioning scarcely during the summer-autumn period, and especially from July to October (be aware of the different scale between figures). At this point it should be mentioned that there were short periods were no recording from the digital devices was achieved:

a) A time period of approximately 1 month (28 days), between 24/07/2019-20/08/2019, due to failure of the internet network at Building C. Nevertheless, the comparison with the analogue measurements during the above period reveals that the pump did not function at all.

b) A time period of approximately 1 month (25 days), between 15/12/2021-10/01/2022, due to battery failure of the power measurement device at the external (outside) pump of Building C.

The observed reduced function of the pump during the summer and the first autumn months is mainly attributed to the lack of significant rain heights for an extended time period after June 2019 and almost till the end of October 2019. The same is observed during the summer-start of autumn period in 2020 and 2021 as well. This lack of significant rain heights caused a lowering of the water table level, as also observed in the respective measurements in the ensuing, which in turn resulted in reduced function requirement of the installed water pumps at the buildings' basements.

On the other hand, when during November 2019 the area experienced some heavy rainy days, the working hours of the external pump C2 where increased significantly, sometimes functioning more than once in the same day. An extreme example is illustrated in Figure 42, revealing the pump C2 was required to function for three (3) discrete time periods in the same day. The correlation between the consumption time-history (upper part of figure) and the recorded total consumption in kWh (lower part of figure) is evident. It should be mentioned though, especially for days with heavy rains, that the water amount that was pumped probably derived not only from the water table but also from surface rainwater, considering the position of the pump at the base of a ramp.

Figure 42. Extreme daily function of Pump C2 on 25/11/2019 (heavy rain event).

The cumulative consumption data of water pumps is presented in Table 1 (in kWh) from the initiation of the monitoring till the end of the project. An indicative validation of the measurement approaches (analogue and digital/WiFi devices) has been presented in Deliverable 4.7.2 (former 4.3.2) and is extended in herein in Table 2.

Table 1. Power consumption measurements of existing water pumps

Pump ID	Date	Power Consumption (analogue) (kWh)	Power Consumption (digital/inductive) (kWh)
Pump B1	01/02/2019	Installation (0.00 kWh)	-
	17/05/2019	2.3 kWh	-
	23/07/2019	2.8 kWh	-
	21/08/2019	2.8 kWh	-

	24/10/2019	3.1 kWh	-
	31/01/2020	4.1 kWh	-
	26/02/2020	4.5 kWh	-
	22/05/2020	9.0 kWh	-
	22/07/2020	9.8 kWh	-
	07/06/2021	13.4 kWh	-
	12/10/2021	13.8 kWh	-
	07/12/2021	14.1 kWh	-
	11/02/2022	16.3 kWh	
Pump B2	01/02/2019	Installation (0.00 kWh)	-
	17/05/2019	0.00 kWh	-
	23/05/2019	Device removed	-
Pump B3	01/02/2019	-	-
	23/05/2019	Installation (0.00 kWh)	-
	23/07/2019	0.00 kWh	-
	21/08/2019	0.00 kWh	-
	31/01/2020	0.00 kWh	-
	26/02/2020	0.00 kWh	-
	22/05/2020	0.00 kWh	-
	22/07/2020	0.00 kWh	-
	07/06/2021	0.00 kWh	-
	12/10/2021	0.00 kWh	-
	07/12/2021	0.00 kWh	-
	11/02/2022	0.00 kWh	
Pump C1	01/02/2019	Installation (0.00 kWh)	-
	25/02/2019	3.4 kWh	-

	08/04/2019	4.0 kWh	-
	15/04/2019	4.0 kWh	Installation (0.00 kWh)
	17/05/2019	4.1 kWh	0.021 kWh
	23/07/2019	4.1 kWh	0.028 kWh
	21/08/2019	4.1 kWh	0.028 kWh
	24/10/2019	4.4 kWh	0.029 kWh
	13/01/2020	4.4 kWh	0.029 kWh
	31/01/2020	4.4 kWh	0.029 kWh
	26/02/2020	4.4 kWh	0.029 kWh
	22/05/2020	4.5 kWh	0.029 kWh
	22/07/2020	4.5 kWh	0.030 kWh
	07/06/2021	4.5 kWh	0.34 kWh
	12/10/2021	12.8 kWh	7.47 kWh
	07/12/2021	24.7 kWh	18.49 kWh
	11/02/2022	46.8 kWh	38.77 kWh
Pump C2	01/02/2019	Installation (0.00 kWh)	-
	21/02/2019	11.7 kWh	-
	25/02/2019	14.2 kWh	-
	08/04/2019	32.9 kWh	-
	15/04/2019	39.4 kWh	Installation (0.00 kWh)
	17/05/2019	55.5 kWh	17.17 kWh
	23/07/2019	65.6 kWh	28.67 kWh
	21/08/2019	65.6 kWh	28.67 kWh
	24/10/2019	67.9 kWh	31.37 kWh
	13/01/2020	110.1 kWh	76.58 kWh
	31/01/2020	118.4 kWh	85.91 kWh
	26/02/2020	131.1 kWh	100.45 kWh
	22/05/2020	290.3 kWh	277.64 kWh

	22/07/2020	313.7 kWh	303.94 kWh
	07/06/2021	459.4 kWh	467.41 kWh
	12/10/2021	465.9 kWh	474.57 kWh
	07/12/2021	480.0 kWh	494.79 kWh
	11/02/2022	585.5 kWh	572.02 kWh

Table 2. Validation of power consumption measurements between analogue – digital*

Pump ID	Date	Power Consumption (analogue) from 15/04/2019 (kWh)	Power Consumption (digital/inductive) (kWh)	Difference (%) (cumulative)
Pump C1	15/04/2019	4.0 kWh	Installation (0.0 kWh)	-
	17/05/2019	0.1 kWh (=4.1-4.0)	0.02 kWh	limited data
	23/07/2019	0.1 kWh (=4.1-4.0)	0.02 kWh	limited data
	21/08/2019	0.1 kWh (=4.1-4.0)	0.02 kWh	limited data
	24/10/2019	0.4 kWh (=4.4-4.0)	0.02 kWh	limited data
	22/05/2020	0.5 kWh (=4.5-4.0)	0.02 kWh	limited data
	22/07/2020	0.5 kWh (=4.5-4.0)	0.03 kWh	limited data
	07/06/2021	0.5 kWh (=4.5-4.0)	0.03 kWh	limited data
	12/10/2021	8.8 kWh (=12.8-4.0)	7.47 kWh	17.8 %
	07/12/2021	20.7 kWh (=24.7-4.0)	18.49 kWh	11.9 %
	11/02/2022	42.8 kWh (=46.8-4.0)	38.77 kWh	10.4 %
Pump C2	15/04/2019	39.4 kWh	Installation (0.0 kWh)	-
	17/05/2019	16.1 kWh (=55.5-39.4)	17.17 kWh	6.2%
	23/07/2019	26.2 kWh (=65.6-39.4)	28.67 kWh	8.6%
	21/08/2019	26.2 kWh (=65.6-39.4)	28.67 kWh	8.6%
	24/10/2019	28.5 kWh (=67.9-39.4)	31.37 kWh	9.1%
	13/01/2020	70.7 kWh (=110.1-39.4)	76.58 kWh	7.7 %
	31/01/2020	79.0 kWh (=118.4-39.4)	85.91 kWh	8.0 %

	26/02/2020	91.7 kWh (=131.1-39.4)	100.45 kWh	8.7 %
	22/05/2020	250.9 kWh (=290.3-39.4)	277.64 kWh	9.6 %
	22/07/2020	274.3 kWh (=313.7-39.4)	303.94 kWh	9.8 %
	07/06/2021	420.0 kWh (=459.4-39.4)	467.18 kWh	10.0 %
	12/10/2021	426.5 kWh (=465.9-39.4)	474.57 kWh	10.1 %
	07/12/2021	440.6 kWh (=480.0-39.4)	494.79 kWh	10.9 %
	11/02/2022	546.1 kWh (=585.5-39.4)	572.02 kWh	4.5 % *

*Data loss due to battery drain for 25 days (between 15/12/2021-10/01/2022) may have resulted in lost measurements of the digital device monitoring pump C2.

2.4 Estimation of pumped water quantities during the project

The following calculations are based on the approach explained in Deliverable 4.7.2 (former 4.3.2). More specifically, using the rated flow value Q_r, the pumped water quantity of a pump can be approximated from the following expression:

$$V_w = t \cdot Q_r \qquad \textbf{Eq. 1}$$

where:

V_w : the calculated pumped water quantity

t : the functioning time of the pump

Q_r : the rated flow value

In the case of Pump C2 which presented a continuous function, the total power consumption between 01-02-2019 to 11/02/2022 was measured equal to 585.5kWh. Considering that a pump has a power of 1kW (as presented in Deliverable 4.7.2 – former 4.3.2), the functioning time of the water pump during this time period can be calculated as:

$$t = \frac{585.5\ kWh}{1.0\ kW} = 585.5\ h \qquad \textbf{Eq. 2}$$

Considering a rated flow of Qr=300lit/min, the total pumped water quantity can be calculated from Eq. 3:

$$V_w = t \cdot Q_r = (585.5 \cdot 60)\min \cdot 300\, {}^{lit}\!/_{\min} = 10539000\ lit = 10539\ m^3 \qquad \textbf{Eq. 3}$$

It should be mentioned that in the above calculations a power value of 1kW for Pump C2 was used, as recorded from the digital measurement device (check Deliverable 4.7.2 – former 4.3.2 for more details), instead of the value of 0.75kW suggested by the pump manufacturer. Since recorded data from the digital (inductive) measurement device were already validated with the analogue energy usage measurements, they were considered more compatible for the above correlations compared to the manufacturer's nominal value.

As explained in Deliverable 4.7.2 (former 4.3.2), it is not realistic to associate the calculated pumped water volume with excessive water deriving from the underground water table alone. Even if half the above value is assumed, taking into consideration other sources of energy loss (increased head requirement to dispose the pumped water etc), the estimated volume for the considered period is still quite large. Probably, due to the positioning of the pump at the lower end of a ramp and the local site topography, there are additional sources of water in the specific pump such as:

- Surface rainwater during rainy days
- Water coming from the irrigation of the surrounding garden (the pump is located 2-3m lower than the soil surface next to the building)
- Possible formation of water well in the location of the specific pump (according to neighborhood testimonies in the past)

3. Monitoring of water table level

3.1 Measurement's objective

The installation of the automatic piezometric device in the drilled borehole allowed for a constant monitoring of the water table level throughout the project. In order to allow for remote monitoring of the measurements, it was required to use a device with the respective connectivity specifications and achieve a WiFi connection to the campus network.

3.2 Campus WiFi range extension

Since the drilled well is located at the south end close to the perimeter of the campus, at a significant distance of the buildings complexion (Figure 43 and Figure 44), the WiFi signal is not strong enough to allow for an undisrupted connectivity of the monitoring device. Therefore, in the framework of the project, it was decided to extend the WiFi range of the existing network, and create a new WiFi network, almost dedicated to the monitoring of the aquifer depth.

To this end, the neighboring Building E of Figure 43 (i.e. Building 9 in Figure 1) was used to install an access point that would create this additional WiFi network. More specifically, access was given to the Soil Mechanics Library at the first floor, where the access point was connected to an existing network outlet and placed outside of the window to achieve maximum range performance (Figure 45). After several tests, a directional WiFi Antenna was selected to achieve coverage in the area of interest (Figure 46).

Figure 43. Borehole well location at significant distance from the campus buildings and out of range of the existing WiFi network

Figure 44. Significant distance of borehole location from the campus buildings (Building E is visible in the background)

Figure 45. Installation of access point in the Soil Mechanics Laboratory (first floor Building E)

Figure 46. Installation of access point with external antenna to create a new WiFi network for the aquifer monitoring device connectivity

After the completion of the installation, the achieved signal strength of the new WiFi network (SSID: Geotrisi) was measured in the exact location of the borehole. The signal is significantly improved compared to other existing wireless networks in the area, as depicted in Figure 47.

Figure 47. WiFi signal strength in the borehole location (SSID: Geotrisi)

3.3 Water table level monitoring

Monitoring of the water table level during the period after the installation was achieved using the installation described in detail in Deliverable 4.7.2 (former 4.3.2). Water pressure measurements from the sensor placed inside the borehole well are transmitted online via WiFi network and then are converted to aquifer depth values.

It is often to observe some artificial peaks during the measurements (Figure 48), probably due to instant loss of electric power, power voltage fluctuations or loss of internet connection. Those peaks can be easily filtered out by employing a simple algorithm to dismiss measurements corresponding to unrealistic abrupt changes of water table depth. The result of this procedure is depicted in Figure 49 where the fluctuation of the water table depth during an extended period of time is evident. More specifically, both during 2020 and 2021, it is observed that the aquifer depth is lowering starting from May-June till October. Then, when rainfall increases during autumn, the water table depth is decreasing reaching its minimum value during spring. This observation corresponds to the almost zero function of the existing water pumps during the summer months as presented in a previous section of the present Deliverable.

As clearly depicted in Figure 49, the depth of the water table fluctuates between 2.5m to 3.5m from the soil surface.

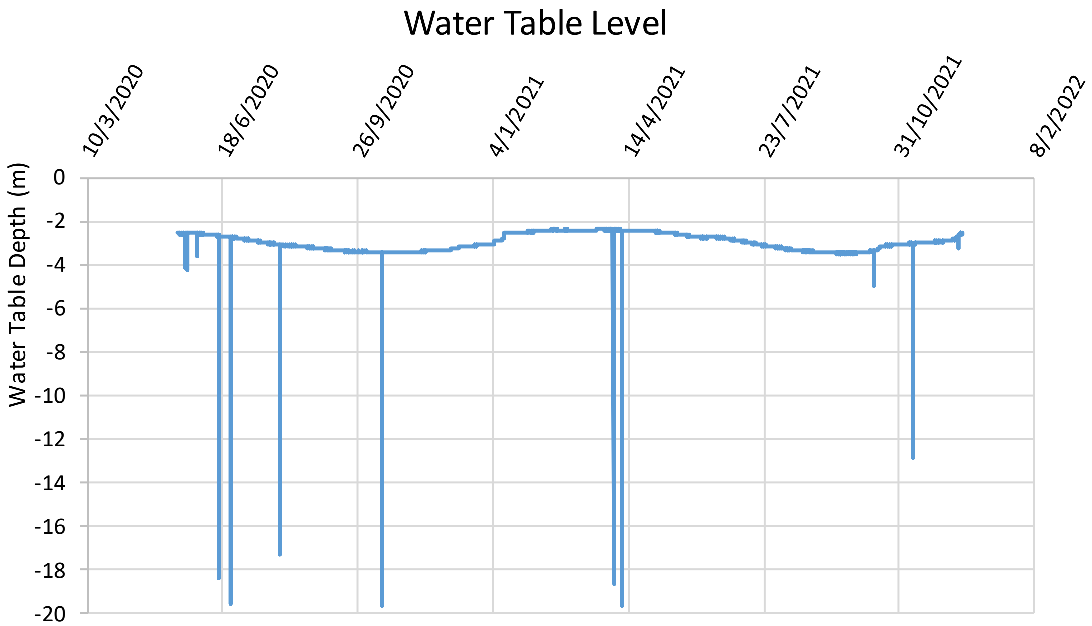

Figure 48. Artificial peaks during the measurement of the water table depth

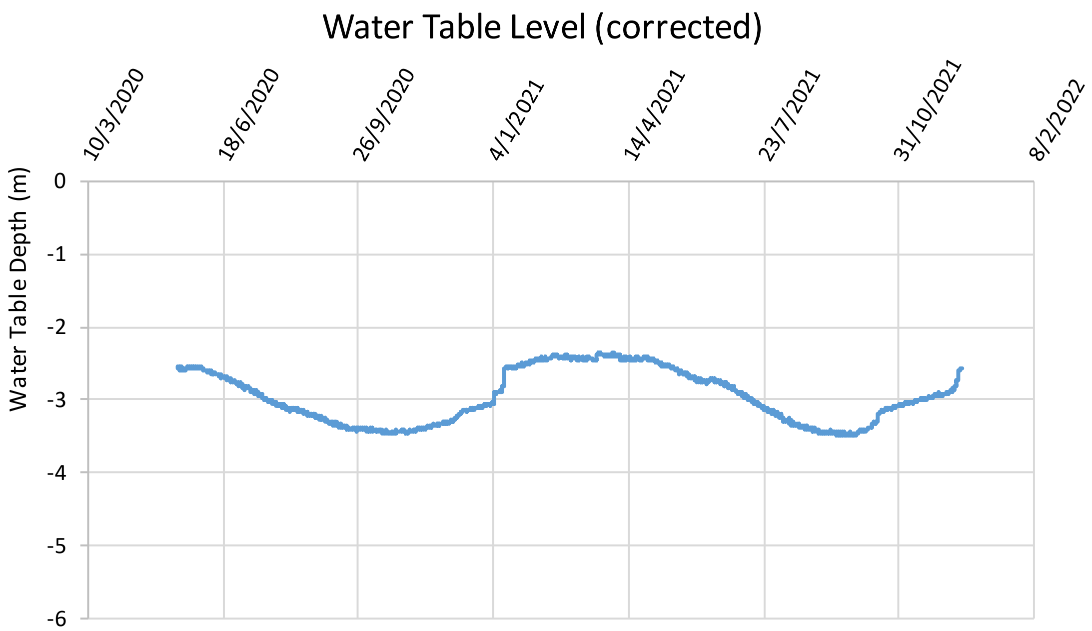

Figure 49. Monitoring of water table depth (corrected) during an extended time period

4. Correlation of water measurements vs rainfall data

4.1 Rainfall data for Serres

An interesting aspect related to the measured pumped water quantity from the existing pumps, namely pump C2 that seems to withstand most of the required pumping, as well as to the monitoring of the water table depth in the campus, is to compare with rainfall data in the same time period to check if a correlation pattern can be identified.

To this end, rainfall data for Serres has been retrieved from https://meteosearch.meteo.gr (Figure 50) for each month since the beginning of the in situ monitoring in the framework of the project. Monthly data can be downloaded in txt format as depicted indicatively for June 2020 in Figure 51. It is clear that rainfall data are provided on a daily basis, whereas the total month rainfall equals to 23.2mm. These data are utilized to provide correlation diagrams with in situ measurements in the following paragraphs.

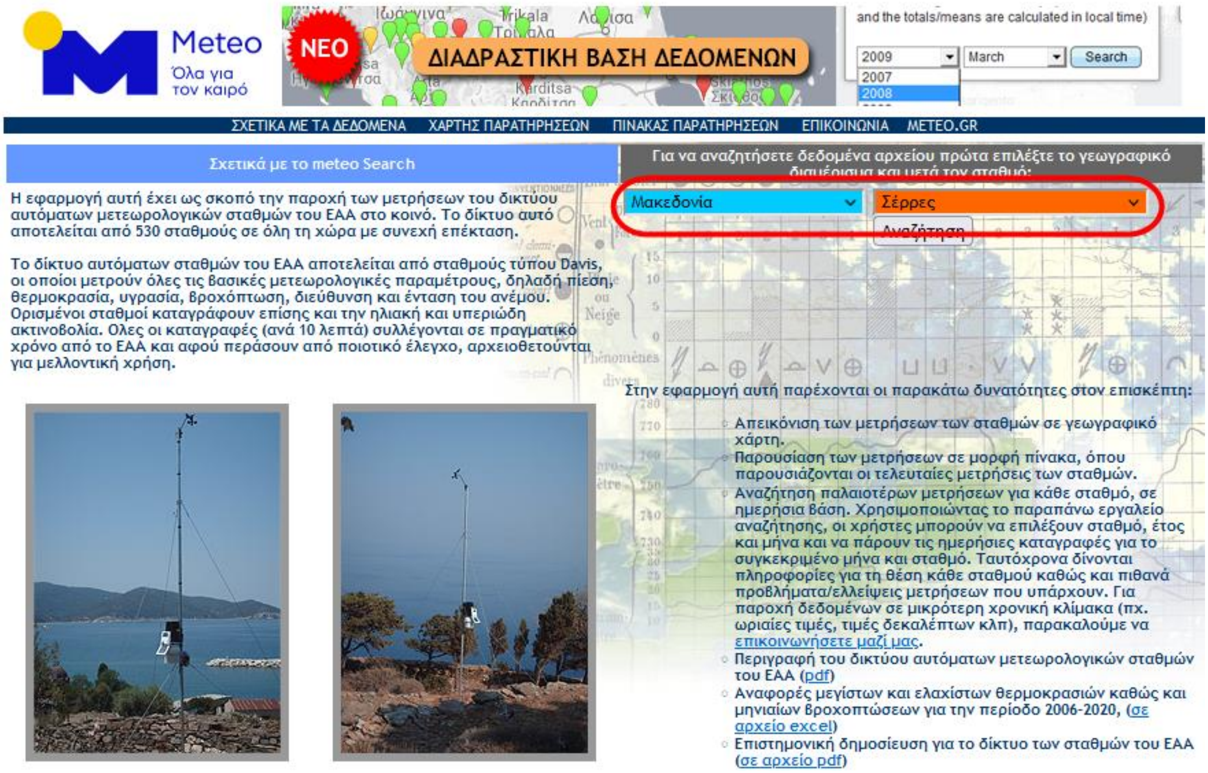

Figure 50. Rainfall data for Serres (https://meteosearch.meteo.gr)

MONTHLY CLIMATOLOGICAL SUMMARY for JUN. 2020

NAME: Serres ELEV: 32 m LAT: 41deg 06min LONG: 23deg 30min

TEMPERATURE (`C), RAIN (mm), WIND SPEED (km/hr)

DAY	MEAN TEMP	HIGH	TIME	LOW	TIME	MAX RH	MIN RH	RAIN	AVG WIND SPEED	HIGH	TIME	DOM DIR
01	18.0	24.2	16:10	13.7	06:30	95	43	0.4	4.7	29.0	13:30	SE
02	18.3	25.4	16:50	9.8	06:10	92	38	0.4	7.3	33.8	11:10	ENE
03	19.1	25.6	17:50	12.3	06:30	89	29	0.0	5.8	30.6	16:10	ENE
04	20.2	29.5	15:30	10.9	05:40	92	31	0.0	5.6	32.2	19:40	E
05	21.3	28.2	14:20	14.1	06:10	88	44	0.0	7.9	35.4	15:40	SE
06	20.7	26.9	13:00	16.9	02:20	91	36	1.2	7.5	38.6	13:00	SE
07	21.7	29.6	16:50	13.9	05:10	97	44	0.0	4.8	25.7	19:30	SW
08	22.9	30.6	16:10	15.3	05:20	91	47	0.0	3.9	27.4	20:40	E
09	22.8	29.2	16:10	16.3	05:40	93	50	0.0	3.6	17.7	18:00	ENE
10	23.3	31.6	14:50	14.7	06:40	93	33	0.0	4.4	43.5	23:00	ENE
11	21.1	27.8	14:10	15.4	06:00	95	45	4.4	8.8	38.6	17:50	NW
12	21.5	27.1	15:50	13.8	06:20	89	39	0.0	13.3	41.8	15:00	NW
13	24.4	30.4	16:30	17.6	05:50	74	42	0.0	12.0	38.6	10:10	NW
14	25.3	32.8	18:50	19.7	02:20	82	37	0.8	6.5	25.7	13:50	W
15	25.1	32.0	16:50	17.3	06:40	91	29	1.6	5.7	35.4	15:50	ENE
16	23.3	29.1	14:00	16.2	05:10	88	51	0.0	2.9	22.5	17:10	SE
17	21.2	27.3	13:50	16.8	06:30	94	57	11.8	3.7	33.8	15:00	W
18	24.0	31.2	16:50	17.4	05:00	91	39	0.0	7.5	38.6	13:30	WNW
19	25.3	31.9	16:20	17.1	06:10	91	33	0.0	9.7	37.0	10:30	W
20	24.8	32.4	17:20	15.3	06:30	86	31	0.0	4.5	22.5	20:30	SW
21	21.7	27.9	15:00	17.1	23:40	88	51	0.0	5.0	38.6	16:10	ENE
22	21.2	29.6	14:10	13.3	05:20	92	40	0.0	4.2	27.4	17:10	ENE
23	22.1	28.8	13:40	15.7	06:20	91	47	0.2	5.2	25.7	14:00	SE
24	24.3	30.7	16:40	18.2	05:20	94	45	0.0	4.3	24.1	18:30	ENE
25	24.8	32.0	16:30	18.8	05:10	88	38	0.0	2.5	24.1	17:10	ENE
26	25.1	33.6	15:50	18.0	06:10	92	39	2.4	4.2	27.4	20:20	SE
27	25.7	32.8	17:00	19.1	05:00	93	39	0.0	3.7	20.9	18:40	SE
28	27.0	34.7	17:10	18.8	06:00	82	29	0.0	4.0	19.3	20:50	SE
29	26.9	34.6	17:20	18.1	06:20	82	32	0.0	4.1	27.4	19:40	W
30	27.8	36.3	16:30	18.2	06:00	90	29	0.0	4.9	24.1	13:40	ENE
	23.0	36.3	30	9.8	2	89.8	39.6	23.2	5.7	43.5	10	ENE

Figure 51. Rainfall data indicative txt file for June 2020 (https://meteosearch.meteo.gr)

4.2 Correlation of existing pumps function vs rainfall data

The diagram of Figure 52 presents the correlation of the C2 pump function (pump placed outside Building C), measured in kWh, versus rainfall data for Serres area in the same time period. The diagram presents the time period from April 2019 when monitoring of the existing pumps function initiated in Building C using the digital power consumption measurement devices.

It is quite evident from the diagram that there is a clear link between the rainy periods and increase of C2 pump function hours. On the other hand, when rainfall is reduced mainly during summer months, the function hours of C2 pump are also reduced.

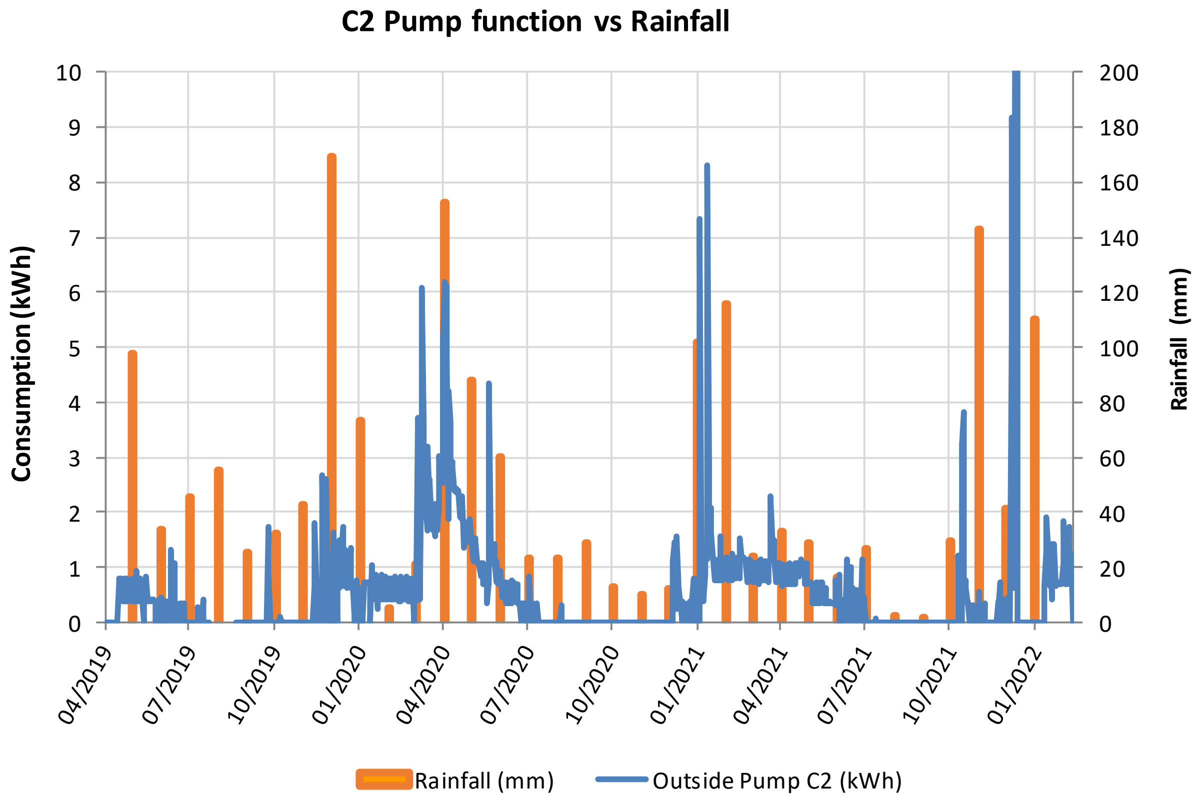

Figure 52. Correlation of C2 pump function with Rainfall data for Serres area

4.3 Correlation of water table level vs rainfall data

The second correlation between the monitored water table depth at the borehole well in the campus versus rainfall data for Serres area is presented in Figure 53. The diagram presents the time period from May 2020 when monitoring of the water table depth initiated.

As observed from the diagram, increased heights of rainfall (mm) result in elevation of the water table depth. Indeed, between 12/2020 and 02/2021 it is clear that rainfall was increased providing heights equal to 100-120mm on a monthly basis (orange columns in the diagram). During the same period, the aquifer depth depicted with the blue line is clearly elevating from -3.5m to -2.4m from the surface. It is therefore quite clear that increased rainfall resulted in water table level elevation. The same phenomenon is observed during the time period between 09/2021 and 12/2021.

On the contrary, when the rainfall is reduced the aquifer level drops as can be seen for the time periods 06/2020-10/2020 and 06/2021-09/2021.

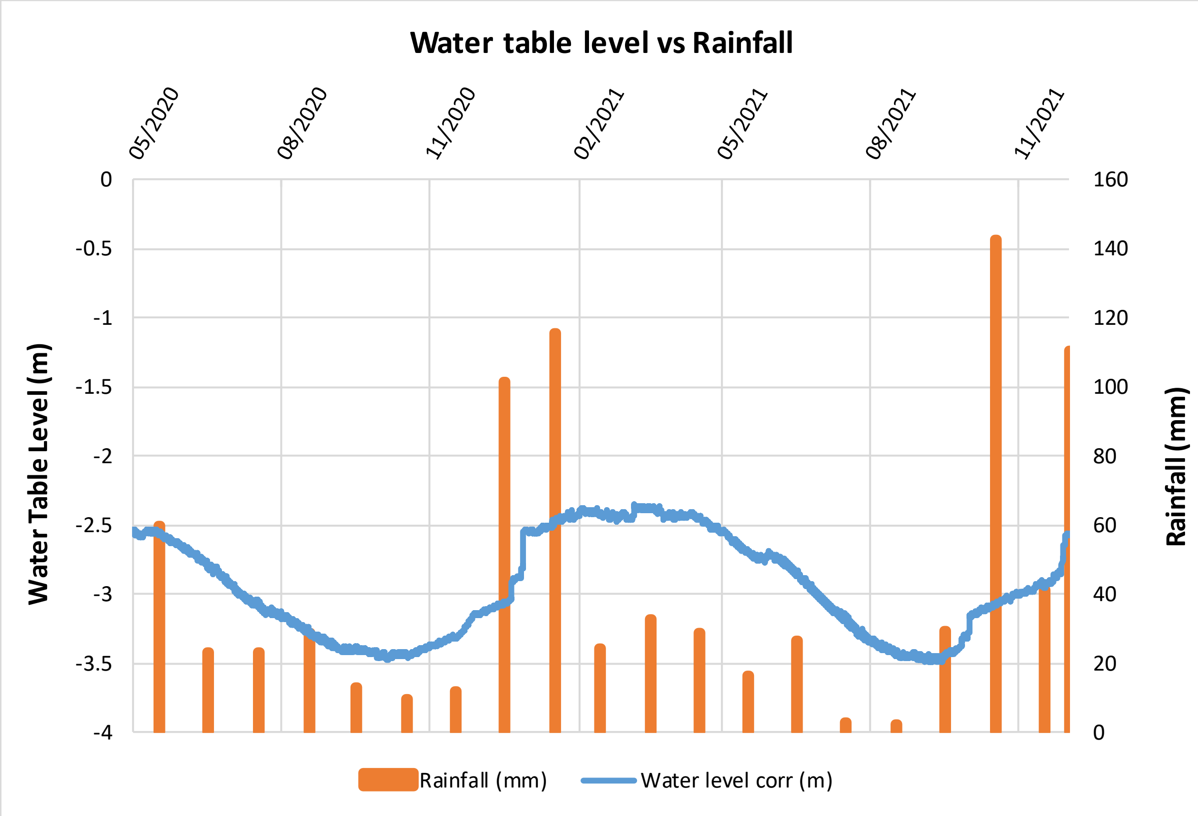

Figure 53. Correlation of Water table level with Rainfall data for Serres area

5. Chemical/microbiological analysis of water from existing pumps

5.1 Sampling procedure (phase B)

A second phase of analyses includes water sampling from the existing pumps at a different year period. Since the first sample was retrieved at the end of winter, it was deemed appropriate to perform the second sampling phase after the end of summer. The sampling procedure was carefully performed whereas both simple bottles and sterile containers have been used for the chemical and the microbiological analysis respectively. Indicative photos are presented in

The second phase included sampling from two different pumps, one located at the basement of Building B (pump B1 of Figure 3) and one located at the basement level of Building C, right outside the building (pump C2 of Figure 4). It is reminded that the 1st analysis phase also included a sample from pump B1, thus a straightforward comparison of the water properties at different year periods is feasible.

Figure 54. Sampling procedure for chemical and microbiological analysis (pump C2)

Figure 55. Water samples from existing pump C2

5.2 Chemical/microbiological analysis results (phase B)

The microbiological and chemical analysis results of the pump B1 water samples are presented in Table 3 and Table 4 respectively. Results are given in comparison with the 1st analysis stage that took place on March 2020, to facilitate the identification of any distinct differences. It should be mentioned that the 2nd phase of chemical analysis was not identical to the first with respect to the measured elements in the water.

From the microbiological analysis results it seems that the total coliforms, E.coli an enterococcus sp. presence is rather increased in the second sample, which is expected since the 2nd phase of the analysis took place in the first days of November, after a prolonged "dry" period (Figure 52) when rainfall was scarce and water in the borehole of the existing pump was not renewed for the whole summer period.

Chemical analysis yields results close to the 1st analysis phase. Some elements that were identified in concentrations exceeding the reference limits (those limits refer to potable water), should be monitored more often in the future if implementation of the studies takes place.

Table 3. Microbiological analysis of water sample from pump B1 (sampling on 03/11/2021)

Parameter	Methodology	Result (09/03/2020)	Result (03/11/2021)	Units
OMX @22°C	ISO 6222: 1999	>300	>300	cfu/ml
OMX @37°C	ISO 6222: 1999	>300	>300	cfu/ml
Total coliforms	ISO 9308-1:2014	$1.5*10^4$	$4.0*10^3$	cfu/100ml
E. coli	ISO 9308-1:2014	Presence $<10^3$	Presence $<10^2$	cfu/100ml
Enterococcus sp.	ISO 7899-2:2000	56	$3.2*10^2$	cfu/100ml
Cl. perfringens	ISO 14189:2013	25	estimated 5	cfu/100ml
P. aeruginosa	ISO 16266:2006	$<10^2$	48	cfu/100ml

Table 4. Chemical analysis of water sample from pump B1 (sampling on 03/11/2021)

Parameter	Units	Result (09/03/20)	Result (03/11/21)	Reference limit	Uncertainty	Maximum allowed limit	Methodology
Sodium (Na)	mg/L	10.3	15.3	0.5	3.80%	200	O.B.01.040 ICPMS 3125 A,B Mod.

							St.Met.
Copper (Cu)	mg/L	N.D.	N.D.	0.01	10.00%	2	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Iron (Fe)	μg/L	N.D.	N.D.	10	13.70%	200	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Manganese (Mn)	μg/L	N.D.	N.D.	10	9.70%	50	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Nitrates (NO_3)	mg/L	8.1	13.2	2	9.00%	50	O.B. 01.018 4500 NO3-B Mod St.Met.*
Nitrites (NO_2)	mg/L	0.38	0.10	0.03	3.30%	0.5	O.B. 01.011 4500NO2-B Mod St.Met.
Ammonium (NH4)	mg/L	0.18	N.D.	0.06	4.40%	0.5	O.B.01.009 4500 NH3-F Mod St.Met.
Sulfate (SO4)	mg/L	N.D.	30.6	20	6.80%	250	O.B. 01.008 4500 SO4-E Mod. St.Met
Boron (B)	mg/L	N.D.	0.07	0.05	14.90%	1	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Chlorides (Cl)	mg/L	N.D.	N.D.	10	2.80%	250	Internal method based on HACH Application DOC 316.52.93091 based on ISO 9297:2000.
pH	units pH 22 oC	7.5	7.8	1		≥6.5 και ≤9.5	O.B.01.005 4500-H,B St.Met.
Conductivity	μS/cm at 20°C	192	384	10-11670	2.90%	2500	O.B.01.006 2510 B St.Met.
Fluoride (F)	mg/L	N.D.	N.D.	0.2	11.50%	1.5	O.B.01.030 4500 F-D SPADNS Method Mod. St.Met.

Antimony (Sb)	μg/L	-	1.4	1.0	14.3%	5.0	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Selenium (Se)	μg/L	-	N.D.	1.0	19.6%	10	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Lead (Pb)	μg/L	-	N.D.	1.0	11.5%	10	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Cadmium (Cd)	μg/L	-	N.D.	1.0	10.5%	5	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Nickel (Ni)	μg/L	-	N.D.	1.0	9.3%	20	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Chromium (Cr)	μg/L	-	2.1	1.0	17.1%	50	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Arsenic (As)	μg/L	-	4.9	1.0	13.6%	10	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Mercury (Hg)	μg/L	-	N.D.	0.10	23.3%	1.0	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Aluminum (Al)	μg/L	-	N.D.	100	9.9%	200	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Color	Units Pt-Co	-	26	10			O.B.01.029 2012C Mod.St.Met
Turbidity	NTU	-	0.61	0.50			O.B.01.028 2130B St.Met
Cyanides (CN)	μg/L	-	N.D.	10	7.1%	50	O.B.01.027 HACH LCK 315
Bromate (BrO3)	μg/L	-	N.D.	5.0	18.7%	10	O.B.01.039 Mod based on St Met 4110A,D

The microbiological and chemical analysis results of the pump C2 water samples are presented in Table 5 and Table 6 respectively.

The microbiological analysis are comparable to those of pump B1, presenting only slight differences. Chemical analysis results are also not far from the sample of pump B1. In both cases, the prolonged "dry" period before sampling should be considered when reviewing the analysis results. In case of implementation a series of analyses should be carefully designed to monitored variation of water properties throughout the year.

Table 5. Microbiological analysis of water sample from pump C2 (sampling on 03/11/2021)

Parameter	Methodology	Result	Units
OMX @22°C	ISO 6222: 1999	>300	cfu/ml
OMX @37°C	ISO 6222: 1999	>300	cfu/ml
Total coliforms	ISO 9308-1:2014	$1.1*10^3$	cfu/100ml
E. coli	ISO 9308-1:2014	$1.0*10^2$	cfu/100ml
Enterococcus sp.	ISO 7899-2:2000	$4.0*10^2$	cfu/100ml
Cl. perfringens	ISO 14189:2013	15	cfu/100ml
P. aeruginosa	ISO 16266:2006	$1.5*10^2$	cfu/100ml

Table 6. Chemical analysis of water sample from pump C2 (sampling on 03/11/2021)

Parameter	Units	Result	Reference limit	Uncertainty	Maximum allowed limit	Methodology
Sodium (Na)	mg/L	20.2	0.5	3.80%	200	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Copper (Cu)	mg/L	N.D.	0.01	10.00%	2	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Iron (Fe)	μg/L	N.D.	10	13.70%	200	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Manganese (Mn)	μg/L	N.D.	10	9.70%	50	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.

Nitrates (NO_3)	mg/L	22.9	2	9.00%	50	O.B. 01.018 4500 NO3-B Mod St.Met.*
Nitrites (NO_2)	mg/L	0.04	0.03	3.30%	0.5	O.B. 01.011 4500NO2-B Mod St.Met.
Ammonium (NH4)	mg/L	N.D.	0.06	4.40%	0.5	O.B.01.009 4500 NH3-F Mod St.Met.
Sulfate (SO4)	mg/L	30.8	20	6.80%	250	O.B. 01.008 4500 SO4-E Mod. St.Met
Boron (B)	mg/L	0.06	0.05	14.90%	1	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Chlorides (Cl)	mg/L	15.7	10	2.80%	250	Internal method based on HACH Application DOC 316.52.93091 based on ISO 9297:2000.
pH	units pH 22 oC	7.5	1		≥6.5 και ≤9.5	O.B.01.005 4500-H,B St.Met.
Conductivity	μS/cm at 20°C	553	10-11670	2.90%	2500	O.B.01.006 2510 B St.Met.
Fluoride (F)	mg/L	N.D.	0.2	11.50%	1.5	O.B.01.030 4500 F-D SPADNS Method Mod. St.Met.
Antimony (Sb)	μg/L	1.1	1.0	14.3%	5.0	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Selenium (Se)	μg/L	N.D.	1.0	19.6%	10	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Lead (Pb)	μg/L	N.D.	1.0	11.5%	10	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Cadmium (Cd)	μg/L	N.D.	1.0	10.5%	5	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Nickel (Ni)	μg/L	N.D.	1.0	9.3%	20	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Chromium (Cr)	μg/L	1.5	1.0	17.1%	50	O.B.01.040 ICPMS

						3125 A,B Mod.St.Met
Arsenic (As)	μg/L	4.2	1.0	13.6%	10	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Mercury (Hg)	μg/L	N.D.	0.10	23.3%	1.0	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Aluminum (Al)	μg/L	N.D.	100	9.9%	200	O.B.01.040 ICPMS 3125 A,B Mod.St.Met
Color	Units Pt-Co	N.D.	10			O.B.01.029 2012CMod.St.Met
Turbidity	NTU	N.D.	0.50			O.B.01.028 2130B St.Met
Cyanides (CN)	μg/L	N.D.	10	7.1%	50	O.B.01.027 HACH LCK 315
Bromate (BrO3)	μg/L	N.D.	5.0	18.7%	10	O.B.01.039 Mod based on St Met 4110A,D

5.3 Simplified detection of water properties from the existing pumps

Measurements of water properties from the existing pumps have taken place several times during the project. Results from each pump are presented in the following tables. It should be mentioned that the displayed temperature value does not correspond to the actual underground water temperature, since the pumps were not functioning during sampling. Therefore, the presented values represent the water temperature exposed in the environment. Moreover, since most of the pumps were not working for a while before sampling, the examined water may have been standing and contaminated by the near-surface environment.

The measurements' results of pump B1 present a substantial difference between different sampling dates, especially when comparing the electrical conductivity value (the TDS calculation depends strongly on the EC value). In general, the 07/2020 and 11/2021 water samples from all the examined pumps (B1, C1 and C2) yield a much larger conductivity value compared to 03/2020 sample of B1.

Table 7. Measurements of water in pump B1 using the HI-991300 device

Parameter	Value (sample 03/2020)*[1]	Value (sample 07/2020)	Value (sample 11/2021)
pH	7.28	8.26	8.11
Electrical Conductivity (EC)	160 μS/cm	851 μS/cm	630 μS/cm
Total Dissolved Solids (TDS)	80 ppm	429 ppm	310 ppm
Temperature	23.6 °C *[2]	25.7 °C *[2]	23.1 °C *[2]

*[1] This sample was stored and measured at a later date a few months after sampling
*[2] Temperature values correspond to water exposed in the environment

Table 8. Measurements of water in pump C1 using the HI-991300 device

Parameter	Value (sample 07/2020)	Value (sample 11/2021)
pH	8.14	7.72
Electrical Conductivity (EC)	712 μS/cm	685 μS/cm
Total Dissolved Solids (TDS)	355 ppm	340 ppm
Temperature	24.9 °C *[1]	22.9 °C *[1]

*[1] Temperature values correspond to water exposed in the environment

Table 9. Measurements of water in pump C2 using the HI-991300 device

Parameter	Value (sample 07/2020)	Value (sample 11/2021)
pH	7.43	7.55
Electrical Conductivity (EC)	610 μS/cm	590 μS/cm
Total Dissolved Solids (TDS)	300 ppm	288 ppm
Temperature	25.3 °C *[1]	22.8 °C *[1]

*[1] Temperature values correspond to water exposed in the environment

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