Work Package 4: Elaboration of studies

Deliverable 4.7.2 (former 4.3.2): On site measurements on selected existing pumps and geotechnical borehole

Beneficiary: IHU (former TEICM)

INTERREG V-A COOPERATION PROGRAMME:

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About this document:

The present Deliverable reports the in situ testing procedure and results regarding the required measurements in IHU – former TEICM campus (Technological Educational Institute of Central Macedonia in Serres, Greece). The measurements concern monitoring of selected existing pumps as well as of the borehole well drilled in the framework of the project.

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1. Scope of Deliverable 4.7.2 (former 4.3.2) – IHU (former TEICM) contribution

The present Deliverable 4.7.2 (former 4.3.2) reports the in situ testing procedure and results regarding the required measurements 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.
- Measurement of pumped water quantities of geotechnical borehole in TEICM campus area.
- Quality measurements of pumped water from the existing campus pumps and the geotechnical borehole.

The above measurements were designed to provide the required details for the studies included in GREEN PUMP project. More specifically, 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. The suitability of the water will be verified through a detailed quality check (chemical and microbiological analysis). On the other hand, test pumping from a new borehole in the campus area is expected to provide accurate data concerning the water quantity and temperature for use in a heating system involving a geothermal heat pump. Moreover, complementary use of pumped water from the geotechnical borehole will be also considered for secondary uses during periods when the water quantity from the existing pumps is inadequate.

2. Measurements on selected existing pumps

2.1 Location of pumps

As reported in Deliverable 4.7.1 (former 4.3.1), more than 40 pumps are currently installed in the campus of the TEICM in order to prevent flooding of building basements due to the shallow depth of the water table. In Deliverable 4.7.2 (former 4.3.2), in situ measurements take place on selected pumps in the campus area. More specifically, since Building B was selected for the studies, the examined pumps (in terms of pumped water quantities) are those installed in the basements of Building B and the neighboring Building C, as shown in Figure 1 and Figure 2. The exact position of the monitored pumps are depicted in Figure 3 for Building B (3 pumps) and in Figure 4 for Building C (2 pumps).

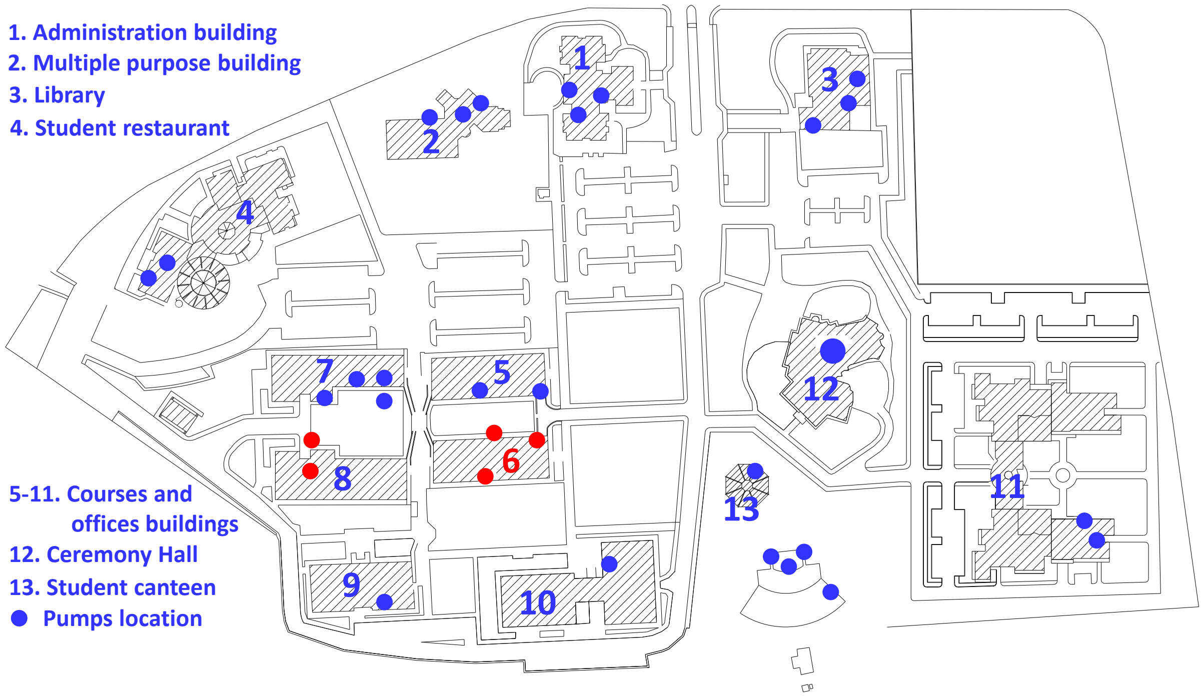

Figure 1. Location of existing water pumps in TEICM campus and selected pumps at the basement of Building B (no. 6) and Building C (no. 8)

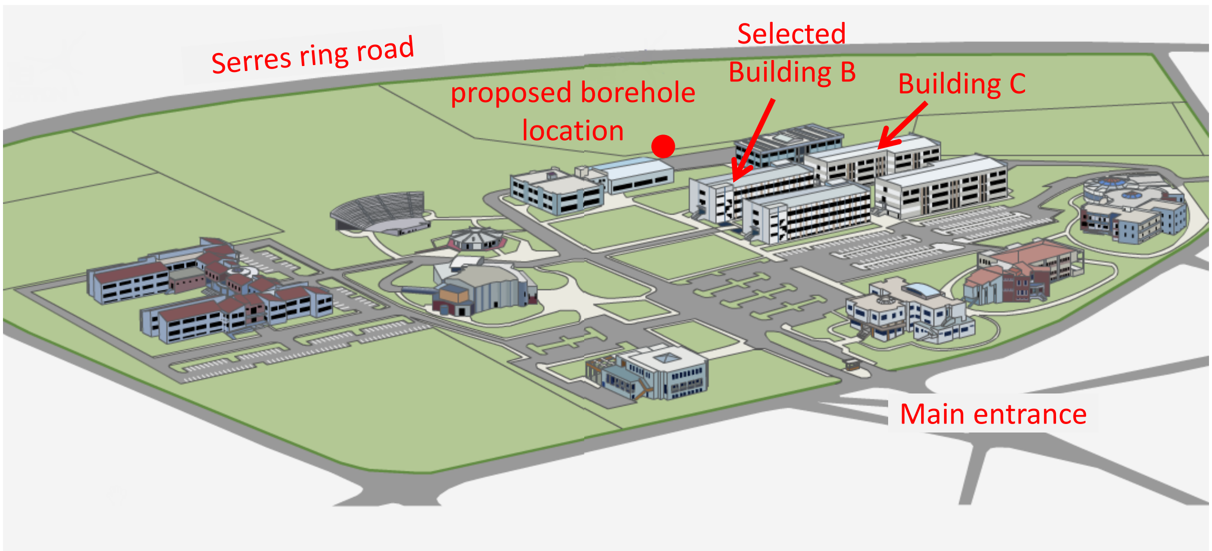

Figure 2. Location of the selected for studies Building B and neighboring Building C

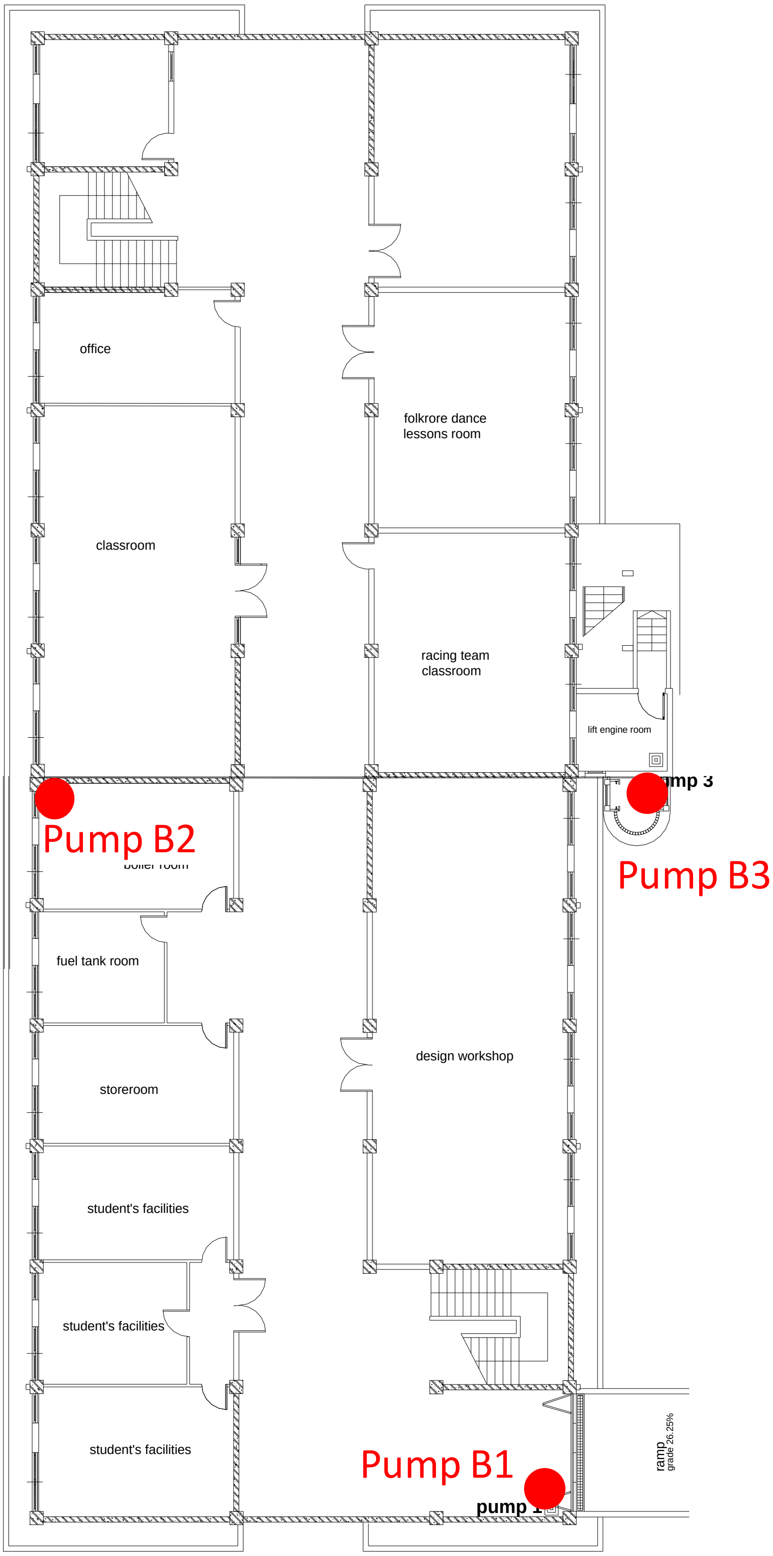

Figure 3. Position of existing pumps at the basement of Building B

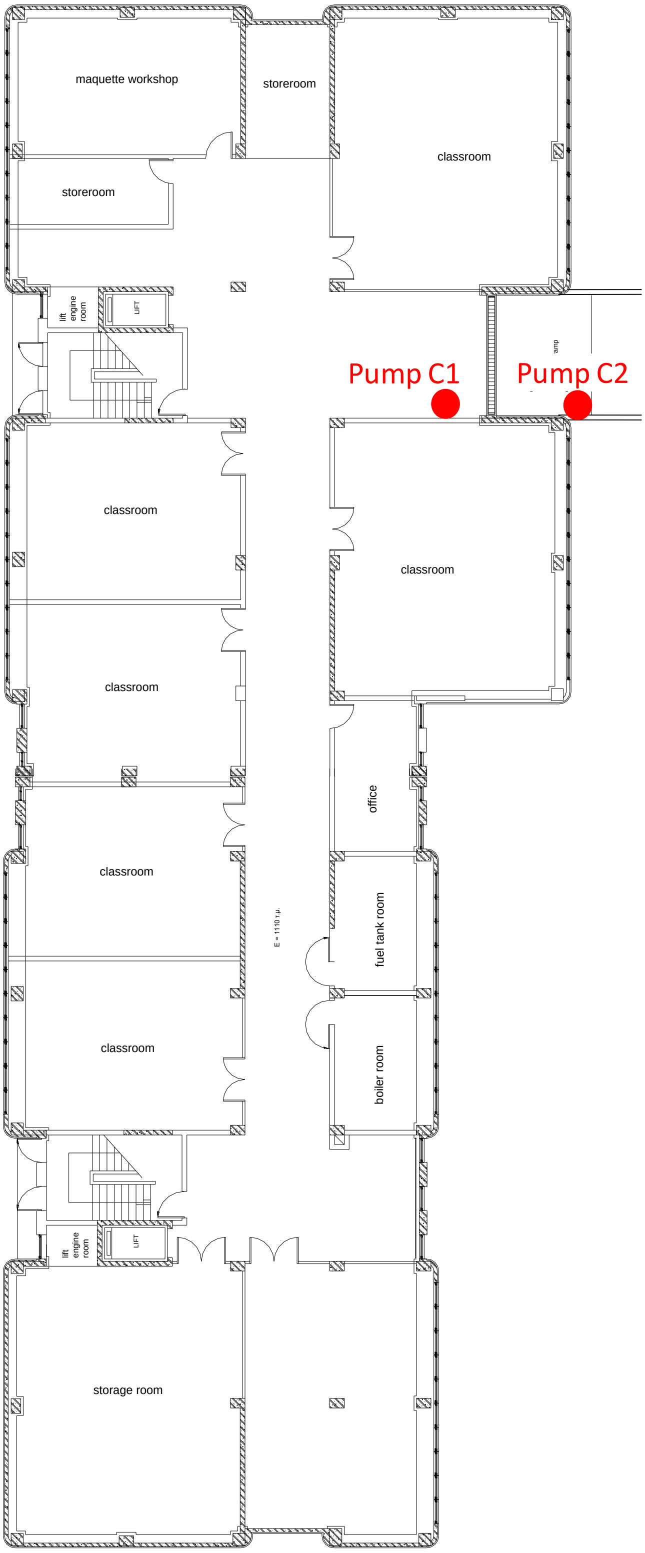

Figure 4. Position of existing pumps at the basement of Building C

There are three (3) existing pumps in Building B, located at the ramp (near the main entrance of the building), in the boiler room as well as below the building's elevator. Building C is served with two (2) water pumps, the one (Pump C2) located in a ramp at basement level next to the building's side entrance and the other (Pump C1) inside the basement at a few meters distance. Indicative photos of installed water pumps are depicted in Figure 5. The basement level of both buildings' basements is at a depth of -2.10m, except the area under the lift (Building B) where the slab is at the depth of -1.00m. In all cases, the pumps are positioned at a shallow depth (approximately 1m) in each constructed pump well (Figure 6 and Figure 7). Pump C2 at the base of Building C ramp is depicted in Figure 8. All water pump installations are placed in concrete casings of dimensions approximately 1x1m, protected by suitable steel grille covers at the top. Details of the monitoring approach, measurements schedule and measured results are included in the next sections.

Figure 5. Water pumps B1 (Building B) and C1 (Building C) with protective grille covers

Figure 6. Water pump B2 installation at shallow depth inside the concrete casing

Figure 7. Water pump C1 installation at shallow depth inside the concrete casing.

Figure 8. Water pump C2 (Building C) at the base of a ramp. The pumped water is currently driven to the rainwater sewer system.

2.2 Identification of existing water pumps

After locating the pumps in Buildings B and C, their type/model is identified so as to determine their functional characteristics. In situ pump's model identification required removing the pump from its installation and trying to distinguish the model number under a thick layer of dirt and mud, as depicted in Figure 9. The condition of a used pump compared to a new pump of the same model is illustrated in Figure 10.

Figure 9. Identification of water pump type/model

Figure 10. Condition of used and new water pumps (C2) during replacement with same model/type

The pumps were visually identified and their functional characteristics were verified from their model/type, as depicted below for both Buildings B and C (Figure 11 to Figure 15). The pump characteristics are summarized in Table 1. In order to provide a more realistic flow value compared to the max flow, a conservative value of 2m head distance is considered (i.e. the water pump is supposed to push water 2m higher than the collection point, to reach the desired sewer level). Specification details concerning the rated flow for different head values can be obtained from water pumps' hydraulic performance curves (Figure 16). It should be mentioned that some models are reported to achieve the maximum flow for the first few meters of head distance, as can be observed in the case of LEPONO XSP18/12/0.75l model in the chart of Figure 17.

It should be mentioned that, in addition to the altitude difference distance, the velocity of the pumped water also requires head distance equal to:

$$h = \frac{v^2}{2g} \qquad \textbf{Eq. 1}$$

where:

v : the velocity of the pumped water in the disposal pipe

g : the gravitational acceleration value ($9.81 m/s^2$)

Assuming an approximate pipe diameter equal to 5cm and a flow of 300lit/min for the aforementioned pump (LEPONO XSP18/12/0.75l), the water velocity is calculated:

$$v = \frac{Q}{A} = \frac{300\frac{lit}{\min}}{\pi D^2/4} = \frac{\frac{300 \cdot 10^{-3}}{60}\frac{m^3}{s}}{\frac{3.14 \cdot 0.05^2}{4}m^2} = 2.55\frac{m}{s} \qquad \textbf{Eq. 2}$$

where:

Q : the water flow

A : the pipe section area

The required additional head distance from Eq. 2 would then equal to 0.33m. This value is not considered significant compared to the assumed head of 2m.

Table 1. Functional characteristics of existing water pumps in Buildings B and C (rated flow values refer to 2m head distance)

Pump ID	Pump model	Power (kW)	Max flow (lit/min)	Rated flow (lit/min)
Pump B1	LEPONO XSP18-12/0.75l	0.75kW	300lit/min	300lit/min
Pump B2	Flotec VIP 130/6	0.32kW	130lit/min	88lit/min
Pump B3	LEPONO XKS 400PW	0.40kW	150lit/min	88lit/min
Pump C1	NOVA WQD 13-9-0.75-2P	0.75kW	267lit/min	220lit/min
Pump C2	LEPONO XSP18-12/0.75l	0.75kW	300lit/min	300lit/min

Company	LEPONO
Model	XSP18-12/0.75l
Power	0.75kW
Discharge	50mm
Max flow	300lit/min
Max head	12m

Figure 11. Water Pump B1 (Building B, ramp area near main basement entrance)

Company	Flotec
Model	VIP 130/6
Power	0.32kW
Discharge	50mm
Max flow	130lit/min
Max head	6m
Voltage	230v
Frequency	50Hz

Figure 12. Water Pump B2 (Building B, boiler room)

Company	LEPONO
Model	XKS 400PW
Power	0,55HP
Max flow	9.000lit/h
Max head	6m
Voltage	220v
Frequency	50Hz

Figure 13. Water Pump B3 (Building B, elevator base)

Company	NOVA
Model	WQD 13-9-0.75-2P
Power	0.75kW
Max flow	16.000lit/h
Max head	9m
Voltage	220v
Frequency	50Hz

Figure 14. Water Pump C1 (Building C, inside, near side entrance)

Company	LEPONO
Model	XSP18-12/0.75I
Power	0.75kW
Discharge	50mm
Max flow	300lit/min
Max head	12m

Figure 15. Water Pump C2 (Building C, outside, ramp area at side entrance - identical to Pump B1)

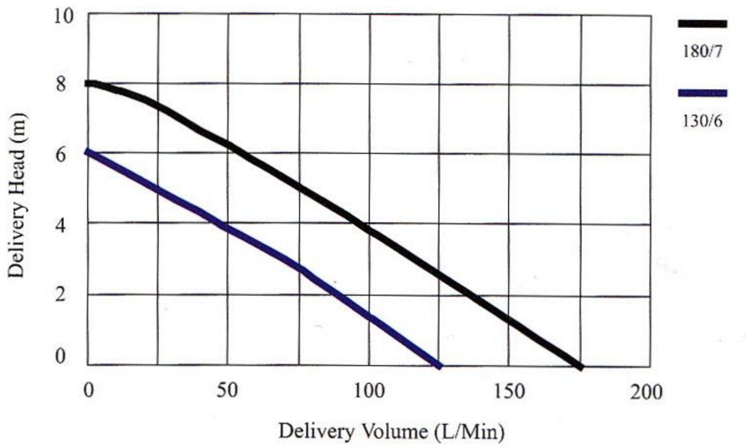

Figure 16. Hydraulic performance curve of Pump B2 (model VIP 130/6)

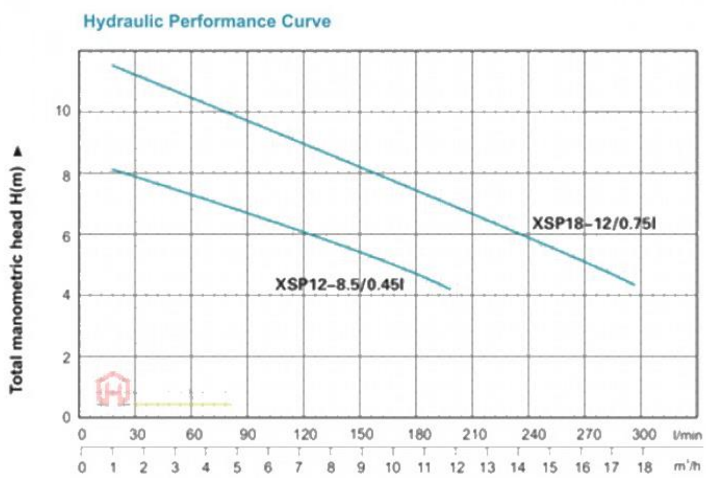

Figure 17. Hydraulic performance curve of Pumps B1 and C2 (model XSP18-12/0.75l)

2.3 Measurement approach for pumped water quantities

In order to measure the pumped water quantities from the existing pumps in the selected Buildings B and C, it was decided to use an indirect approach by measuring the power consumption of the pumps and taking into consideration the pump water flow properties. To this end, two (2) measurement approaches are attempted, using:

- Analogue power consumption measurement devices (Figure 18)

  The main advantages of those devices is the easy installation (the device is installed between the socket and the power plug of the pump) and the continuous recording since there is no danger to loose recorded data due to malfunctions, short-circuit etc.

- Digital power consumption measurement devices with Wi-Fi data transfer (Figure 19)

  The main advantage of those devices is the constant data transfer online and the ability to check the functioning status and recorded measurements remotely. The devices employed in this project measure the power consumption inductively using a proper sensor/transmitter that sends the recorded data wirelessly to a hub connected to the campus network.

Figure 18. Analogue power consumption measurement device

Figure 19. Digital power consumption measurement device with Wi-Fi data transfer (left side: hub connected through LAN to campus network, right side: recording sensor/transmitter)

2.3.1 Installation of power consumption measurement devices

Due to several issues that required special treatment to achieve functionality of the Wi-Fi devices, the analogue devices where installed and started recording almost 2.5 months earlier than the Wi-Fi devices. It should be mentioned that analogue devices were installed in total 4 pumps, 2 in Building B and 2 in Building C. On the other hand, the Wi-Fi devices have been only installed on the 2 pumps of Building C, in parallel with the analogue ones, both for remote access as well as for validation purposes.

2.3.1.1. Installation of analogue devices (01 February 2019)

The installation of analogue devices took place on 01 February 2019 and concerned four (4) pumps in total. The pumps where installation took place were:

- Building B - Pump B1 (Figure 3 and Figure 20).
- Building B - Pump B3 (Figure 3). Initial installation concerned Pump B2, yet, after a 4 month period of zero recorded power consumption it was decided on 23 May 2019 to move the recording device to Pump B3 (right side of Figure 20).
- Building C - Pump C1 (Figure 4).
- Building C - Pump C2 (Figure 4).

Ironically, the day of the installation the basement of Building C was flooded (Figure 21 and Figure 22), due to malfunction of Pump C2 which had to be replaced (Figure 10). Unfortunately, Pump C1 was not able to prevent the flooding, although it should, since it was not properly adjusted to function at the correct water table level limit.

Figure 20. Installation of analogue power consumption measurement devices in the basement of Building B (Pump B1 and Pump B2, photo taken on 17/05/2019)

Figure 21. Flooded basement of Building C (ramp area and hall)

Figure 22. Flooded basement of Building C (teaching and storage rooms and areas)

2.3.1.2. Installation of digital Wi-Fi devices (15 April 2019)

The final installation of the digital Wi-Fi devices took place on 15 April 2019, since a proper setup procedure was required, along with the request of more details regarding the proper installation of the data recording sensor. A current phase of the pump power cable was isolated to apply inductive measurement of the power consumption (Figure 23). The phase cable sensor In order to transfer successfully the recorded power consumption it was required to make a free online registration to a dedicated platform offered be the manufacturer of the device, facilitating the online real-time observation of the measured quantities. Moreover, recorded as well as real time data can be also accessed using a cell phone application (Android or Apple).

The pumps where installation of digital devices took place were:

- Building C - Pump C1 (Figure 4 and Figure 23).
- Building C - Pump C2 (Figure 4).

The purpose of the installation of the digital devices at the same pumps as the analogue devices was twofold. First, it was important to achieve a measurement procedure that would allow for remote control of the pumps functionality and access to the recorded values both during the project and in the future (as a suggested approach for the technical services of the Institution). Second, it was considered important to obtain calibrated measurements both of the analogue and the digital devices, which would be achieved by comparing simultaneous recordings.

Figure 23. Installation of analogue and Wi-Fi digital power consumption measurement device (Pump C1). The isolated current phase of the cable to achieve power consumption measurement inductively is clearly depicted.

2.3.2 Measurement of power consumption data in the first months of the project

The measurements of the power consumption of the water pumps during the first months after installation of the aforementioned devices are included in Deliverable (4.3.2) (indicative photos in Figure 20 and Figure 24).

Figure 24. Indicative power consumption measurements of existing water pumps in Building C (Pump C1 on the left and Pump C2 on the right, photo taken on 17/05/2019).

It should be mentioned that the digital devices (inductive power consumption measurements), apart from the real time data transfer through WiFi offer several more useful features on a dedicated online platform created by the product manufacturer (freeware for product owners):

- Real time recording observation of both instant usage value and time-history of power consumption (Figure 25). Detail of the recorded usage time-history is depicted in Figure 26 (note: the max recorded energy consumption equal to 1kW is larger than the device's nominal value of 0.75kW as reported in Table 1).
- History usage data in diagram format for each monitoring device (Figure 27).
- Cost calculation due to the pump energy consumption based on pricing details of the local provider (user required information). Of course the cost for the occasional pumps' function is not expected to be significant (Figure 28), yet this feature may prove valuable for cost monitoring purposes of other devices/facilities, where efficient

functionality results in reduced cost and reduced energy consumption allowing for an environmental friendly approach.

- Approximation of carbon emission (CO_2 in kg) due to the consumed energy of the pump (Figure 29). The calculation of the CO_2 emissions to be attributed to electricity consumption is based on the country's carbon emission factor (Figure 30).
- Reports of power consumption data in convenient format (csv) that allows for further data processing (Figure 31). The report may even contain data per hour or per minute as depicted in Figure 32. The last data can be easily used, after setting some power consumption trigger value (excluding thus the excel rows 62850 and 62875 of the Figure), to calculate the total working minutes of the pump during a specified period.

Figure 25. Indicative image of real time power usage recording of Pump C2 (instant power usage value in kW on the top left of the figure and consumption time history at the depicted diagram).

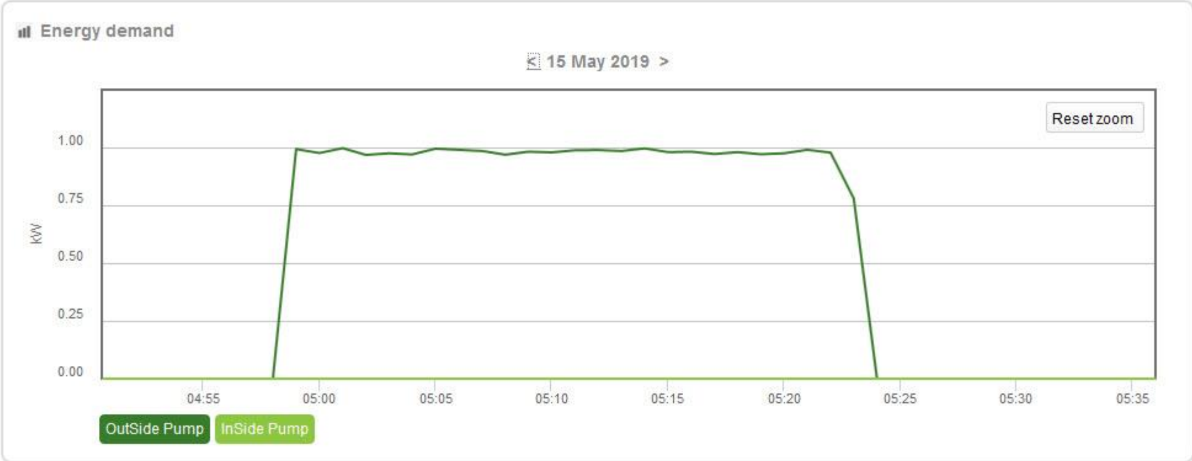

Figure 26. Detail of the recorded usage time history (Pump C2).

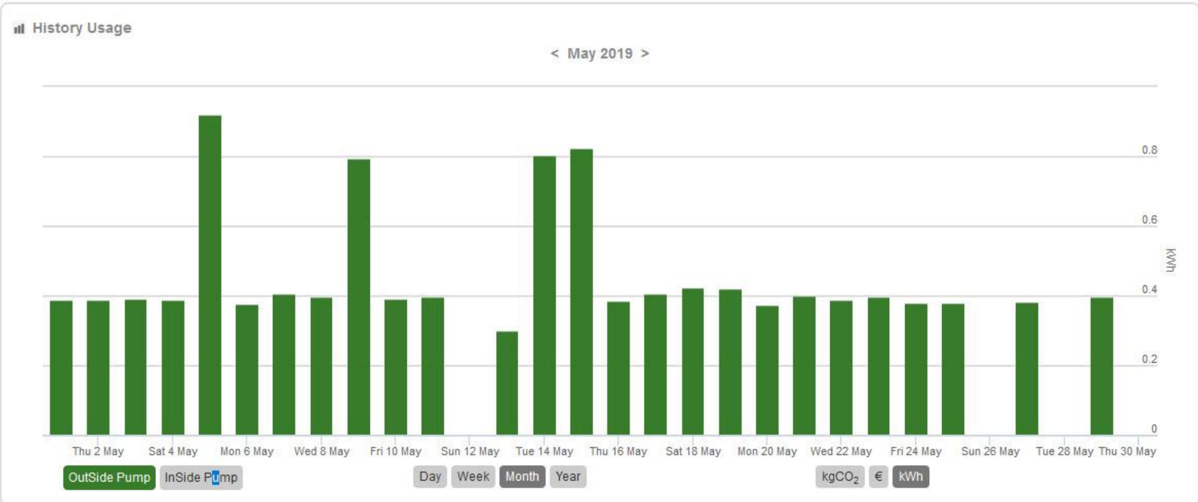

Figure 27. Diagram of history power usage (in kWh) of Pump C2 (May 2019).

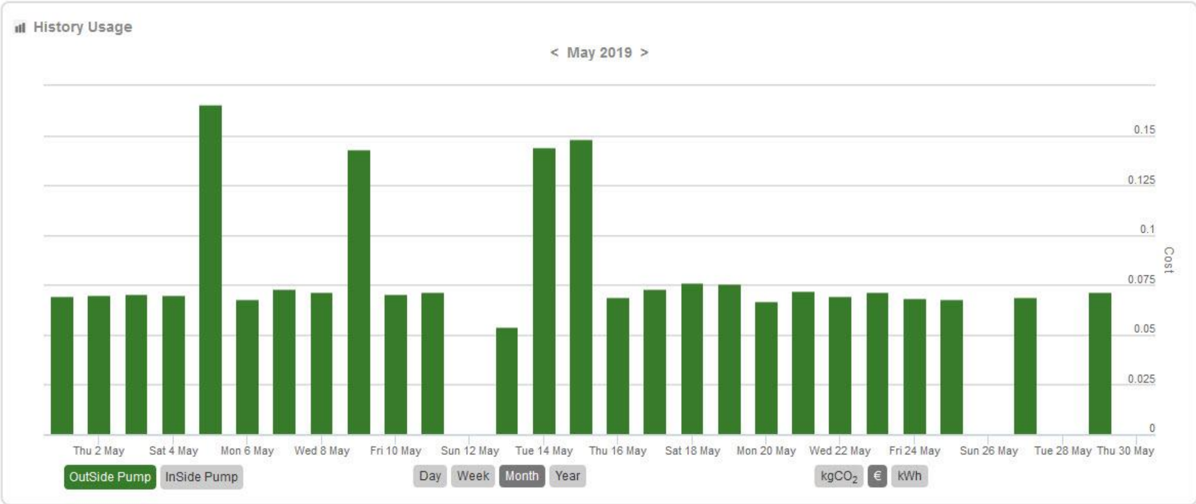

Figure 28. Estimation consumed energy cost (in Euros) of Pump C2 (May 2019).

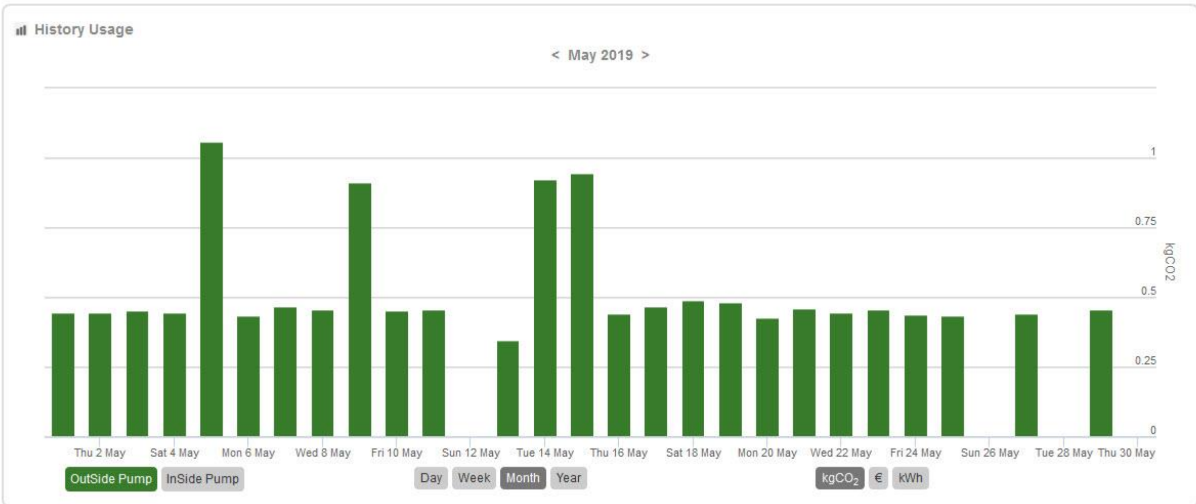

Figure 29. Estimation of the carbon (CO2) emission (in kg) of Pump C2 (May 2019).

National and European emission factors for consumed electricity

Country	Standard emission factor (t CO_2/MWh_e)	LCA emission factor (t CO_2-eq/MWh_e)
Austria	0.209	0.310
Belgium	0.285	0.402
Germany	0.624	0.706
Denmark	0.461	0.760
Spain	0.440	0.639
Finland	0.216	0.418
France	0.056	0.146
United Kingdom	0.543	0.658
Greece	1.149	1.167
Ireland	0.732	0.870
Italy	0.483	0.708
Netherlands	0.435	0.716
Portugal	0.369	0.750
Sweden	0.023	0.079
Bulgaria	0.819	0.906
Cyprus	0.874	1.019
Czech Republic	0.950	0.802
Estonia	0.908	1.593
Hungary	0.566	0.678
Lithuania	0.153	0.174
Latvia	0.109	0.563
Poland	1.191	1.185
Romania	0.701	1.084
Slovenia	0.557	0.602
Slovakia	0.252	0.353
EU-27	**0.460**	**0.578**

Figure 30. National and European carbon emission factors (electricity consumption related) (source: https://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf).

	A	B	C
1	Timestamp	Power (kWh) - sid = 815665 (InSide Pump)	Power (kWh) - sid = 816393 (OutSide Pump)
32	01/05/2019 0:00	0	0.39
33	02/05/2019 0:00	0	0.39
34	03/05/2019 0:00	0	0.39
35	04/05/2019 0:00	0	0.39
36	05/05/2019 0:00	0	0.92
37	06/05/2019 0:00	0	0.38
38	07/05/2019 0:00	0	0.41
39	08/05/2019 0:00	0	0.4
40	09/05/2019 0:00	0	0.79
41	10/05/2019 0:00	0	0.39
42	11/05/2019 0:00	0	0.4
43	12/05/2019 0:00	0	0
44	13/05/2019 0:00	0	0.3
45	14/05/2019 0:00	0	0.8
46	15/05/2019 0:00	0	0.82
47	16/05/2019 0:00	0.01	0.38
48	17/05/2019 0:00	0	0.41
49	18/05/2019 0:00	0	0.42
50	19/05/2019 0:00	0	0.42
51	20/05/2019 0:00	0	0.37
52	21/05/2019 0:00	0	0.4
53	22/05/2019 0:00	0	0.39
54	23/05/2019 0:00	0	0.4
55	24/05/2019 0:00	0	0.38
56	25/05/2019 0:00	0	0.38
57	26/05/2019 0:00	0	0
58	27/05/2019 0:00	0	0.38
59	28/05/2019 0:00	0	0
60	29/05/2019 0:00	0	0.4
61	30/05/2019 0:00	0	0
62	31/05/2019 0:00	0	0.45
63	01/06/2019 0:00	0	0

Figure 31. Report of recorded power consumption data (in kWh) per day (both inside Pump C1 and outside Pump C2 data are depicted).

	A	C	I
1	Timestamp	Power (Wm) - sid = 816393 (OutSide Pump)	Outside Pump (min)
62845	14/05/2019 15:23	0	0
62846	14/05/2019 15:24	0	0
62847	14/05/2019 15:25	0	0
62848	14/05/2019 15:26	0	0
62849	14/05/2019 15:27	0	0
62850	14/05/2019 15:28	194	0
62851	14/05/2019 15:29	973	1
62852	14/05/2019 15:30	972	1
62853	14/05/2019 15:31	956	1
62854	14/05/2019 15:32	950	1
62855	14/05/2019 15:33	965	1
62856	14/05/2019 15:34	960	1
62857	14/05/2019 15:35	965	1
62858	14/05/2019 15:36	961	1
62859	14/05/2019 15:37	951	1
62860	14/05/2019 15:38	967	1
62861	14/05/2019 15:39	949	1
62862	14/05/2019 15:40	953	1
62863	14/05/2019 15:41	952	1
62864	14/05/2019 15:42	950	1
62865	14/05/2019 15:43	957	1
62866	14/05/2019 15:44	953	1
62867	14/05/2019 15:45	947	1
62868	14/05/2019 15:46	951	1
62869	14/05/2019 15:47	964	1
62870	14/05/2019 15:48	943	1
62871	14/05/2019 15:49	954	1
62872	14/05/2019 15:50	951	1
62873	14/05/2019 15:51	941	1
62874	14/05/2019 15:52	951	1
62875	14/05/2019 15:53	382	0
62876	14/05/2019 15:54	0	0
62877	14/05/2019 15:55	0	0
62878	14/05/2019 15:56	0	0
62879	14/05/2019 15:57	0	0

Figure 32. Report of recorded power consumption data (in Wm) per minute (only outside Pump C2 data are depicted).

The cumulative consumption data of water pumps are presented in Table 2 (in kWh). Power consumption measurement data will be continuously monitored till the end of the project (Deliverable 5.7.1 – former 5.3.1). From the presented data it is feasible to validate the accuracy of the power consumption measurements by comparing obtained records between the analogue and the digital (inductive) devices. Since the latter started functioning smoothly several weeks after the analogue devices, the comparison concerns the time period from 15/04/2019 to 17/05/2019. Only data from Pump C2 are utilized in the validation, since Pump C1, which is also monitored with both approaches, did not present adequate function in the aforementioned period. The recorded data indicate:

- Analogue measurements: 16.1 kWh (=55.5-39.4)
- Inductive measurements (digital device): 17.17 kWh

The above data reveal a difference of approximately 6%, which is more than satisfactory considering the short validation time period. Similar comparisons to access the accuracy of both systems will be continuously performed till the end of the project.

Table 2. 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	
Pump B2	01/02/2019	Installation (0.00 kWh)	
	17/05/2019	0.00 kWh	
	23/05/2019	Device removed	
Pump B3	23/05/2019	Installation (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	0.02 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

2.4 Estimation of pumped water quantities during the first months of the project

As mentioned earlier, estimation of the pumped water quantities is based on the energy consumption measurements, considering the particular functional characteristics of each pump. More specifically, using the rated flow value Q_r, the pumped water quantity of a pump can be approximated from the following expression:

$$V_w = t \cdot Q_r \quad \textbf{Eq. 3}$$

where:

V_w : the calculated pumped water quantity

t : the functioning time of the pump

Q_r : the rated flow value (Table 1)

In the case of Pump C2, which presented a continuous function, the total power consumption during a period of 3.5months (from 01-02-2019 to 17/05/2019) was measured 55.5kWh. Considering that a pump has a power of 1kW (as recorded in Figure 26), the functioning time of the water pump during this time period can be calculated as:

$$t = \frac{55.5\ kWh}{1.0\ kW} = 55.5\ h$$ **Eq. 4**

Considering a rated flow of Qr=300lit/min, the total pumped water quantity can be calculated from Eq. 5:

$$V_w = t \cdot Q_r = (55.5 \cdot 60)\text{min} \cdot 300\ {}^{lit}\!/\!_{\text{min}} = 999000\ lit = 999\ m^3$$ **Eq. 5**

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 (Figure 26), 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.

The above estimated functioning time of the pump can be also validated through monitoring results as follows. The working pump minutes can be calculated for the time period 15/04/2019 to 17/05/2019:

- From the report of the digital/WiFi devices using the data format of Figure 32, yielding a total of 17.75 hours.
- Alternatively, following the procedure presented in Eq. 4 (power consumption equal to 16.1kWh - 17.1kWh depending on the measurement device), yielding a working time of the pump in the same time period equal to 16.1-17.1 hours.

The comparison between the two approaches verifies that the calculations made previously concerning the functioning hours of the pumps are totally acceptable.

It is quite clear that it is not realistic to associate the calculated pumped water volume of Eq. 5 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 3.5 month period is still quite large. Probably, due to the positioning of the pump at the lower end of a ramp (Figure 8) 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)

Nevertheless, the pumped water quantities could be used for a secondary water network, regardless their initial origin.

3. In-situ measurements in borehole well

3.1 Measurements' objective

Implementation of a geothermal heating system for a building of large dimensions requires detailed information on the water supply quantities and the underground water reserve in the area of interest. More specifically, an open-loop geothermal heating system requires large quantities of constant water flow to exploit the underground water temperature in order to provide heating to the building. Flow testing of the well provides important data for the design of the heat pump system since the groundwater flowrate chosen is based on pumping power.

Moreover, usage of underground water for a secondary water system, concerning especially toilet flushing after short-term storage in properly configured tanks, also requires the absence of particular harmful or unsuitable contents in the water.

To this end, it was deemed necessary to perform a test pumping on a borehole well that will be constructed for the needs of the GREEN PUMP project. The results of the test pumping will determine the suitability and adequacy of the pumped water for the purposes of the project.

3.2 Location of the borehole well

The location of the borehole well in the former TEICM campus is presented in Figure 33 and Figure 34. The well is located in a distance approximately equal to 130m from the Building of interest (Building B). Since the measurement data will be only used for studies in the framework of the project, it was not considered necessary to select a position closer to the aforementioned Building that would disrupt the educational and other activities of the University and/or change the surrounding landscape. On the contrary, it is considered safe to assume that the findings in the selected location would be very close to the water aquifer properties at locations next to the selected Building B for the studies.

Figure 33. Location of the borehole well which was constructed for the needs of the project, along with the location of Building B (source: http://gis.ktimanet.gr)

Figure 34. Photo of the borehole well location

3.3 Technical specifications summary

According to the specifications of the borehole well, a drill depth of 30m is prescribed to make sure that the water flow will be adequate for the purposes of the study. The technical specifications of the well follow those of common water drilling activities. Some indicative specifications employed during the drilling activities are described in the following:

- The borehole well employs high strength UPVC plastic pipes of diameter equal to 4 ½ inches or Ø125 (depending on the final choice of the pipes material). Screen with proper aperture (slot) size is selected to provide a level of filtering to the water entering the well.
- Appropriate circulation slurry or soap is used in the drilling operations. Bentonite use is required during the drilling to achieve vertical configuration of the well before inserting the PVC pipes.
- Soil samples are taken during drilling to facilitate an approximate description of the soil layering properties.
- An artificial filter of gravel of properly selected size distribution (gravel pack), acting at the same time as formation stabilizer, is placed surrounding the pipes to achieve adequate filtering of the water that enters the well.
- Cleaning and development of the well with proper means (air pump generator of "Air–Lift" type) follows the drilling activities, to wash any sediments and fine soil particles as well as any remaining drilling fluids from the water inside the pipes. Preliminary development of the well is continued until the gravel pack ceases to settle.
- A flow testing is contacted after completion of the well development, along with simultaneous measurement of the water table depth, to measure the achieved flow quantity.
- Following the drilling of the well and the test pumping activities, a concrete base is of 1.5x1.5m dimensions is constructed around the well using C16/20 concrete and proper reinforcement bars. Moreover, a 6m galvanized steel pipe is fixed at the concrete base, to facilitate the installation of an automated water level measurement device and the suspension of the required cables.

- The well is finally sealed with proper lid that allows for the installation of the aquifer depth measurement equipment.

3.4 Well drilling and development

Before well drilling initiations, some preparatory works are required to facilitate the drilling activities. More specifically, an excavation of 2x3m dimensions and 2m depth took place next to the drilling position (Figure 35). The purpose of the excavation is to provide water for the drilling activities, serving as a temporary pool, as well as to host the drilling material (drilling slurry and mud, bentonite etc). After completion of the in situ activities, the material placed inside the excavation will be left to settle and dry before restoring it to the previous state.

Figure 35. Excavation to host the drilling material

The drilling rig is afterwards installed at the location of the well, right next to the excavation. In the case of the GREEN PUMP project, a movable drilling rig is employed (Figure 36). The required water for the drilling activities is provided from an outside source through the excavation inside the well. In this case, the excavation serves as a temporary water tank. At the same time, drilling material such as mud, drilling fluids and slurry, bentonite etc, are also deposited inside the same excavation that assumes a two-fold role, as presented in Figure 37.

Figure 36. Installation of the drilling rig next to the excavation

Figure 37. Drilling procedure (the two-fold use of the excavation to provide water and accept the drilling materials can be observed)

Since the soil deposit properties of the area include layers of fine gravel or sandy material, it was not possible to achieve a vertical configuration of the well without the use of bentonite, which is a fine-particle clay material that serves as a temporary formation stabilizer for the walls of the well before inserting the pipes and the surrounding gravel (left side of Figure 38). The bentonite is removed after the successful installation of the PVC pipes, since the gravel that is placed inside the well (surrounding the pipes) is heavier compared to the bentonite material, forcing it to exit the well as can be observed in the right side of Figure 38.

Figure 38. Bentonite material to assist in the drilling process (left side) and removal of bentonite when the gravel pack is placed inside the well surrounding the pipes (right side)

The drilling depth reached 34m whereas the final depth of the borehole piping (Ø125 diameter) reached 32m according to the technical report.

Following the construction of the well and the installation of the piping and gravel pack, the development of the well takes place using air surge (air-lift technique), in order to wash sediments and fine soil particles as well as any remaining drilling fluids from the water inside the pipes (Figure 39). The procedure continuous up to the point that the water exiting the well does not contain any fine soil particles.

Figure 39. Development of the well using the air-lift technique

3.5 Flow testing

After the development of the well, the achieved pumped water quantities are determined through flow testing. To this end, a pump of known specifications is used to pump water from the well, whereas, at the same time, constant measurement of the aquifer depth takes place to determine the sensitivity of the underground water table level to pumping (Figure 40). The pumped water should be disposed in a way that does not interfere with the underground water table level, preferably in a separate sewage system, as presented in Figure 41 for the examined case.

The flow testing procedure was performed in 2 stages, using an 1.5hp power pump. A pre-pumping procedure first took place (6 March), to verify the constant water flow and preparedness of the well for the final test. The actual flow testing phase, with simultaneous measurements of the aquifer depth, was performed a couple of days later (9 March).

Figure 40. Water pumping during flow testing and simultaneous aquifer depth measurement

Figure 41. Disposal of pumped water during flow testing

3.6 Construction of concrete base

In order to secure the well and facilitate the installation of the automated aquifer depth measurement device, a concrete base of 1.5x1.5m dimensions and approximately 20-30cm depth is constructed surrounding the underground piping. The concrete quality is C16/20, whereas proper reinforcement bars are placed to ensure the strength of the base (Figure 42 and Figure 43). During the construction, proper consideration is given to provide access for gravel supplement in the well (cyan pipe attached to the well piping in Figure 42), if such is required in the future due to settlement of the gravel pack. A 6m height galvanized steel pipe is then anchored at the base, to facilitate the installation of the aquifer depth measurement equipment and suspension of the required cables (Figure 44).

Figure 42. Reinforcement bars of the concrete base and placement of access pipe for future gravel supplement (if required)

Figure 43. Concrete type C16/20 is used for the construction of the base

Figure 44. A 6m steel pipe is anchored to the concrete base

3.7 Test flow results and technical report data

The borehole well was found to have adequate underground water, from a near-surface aquifer, to cover the functional requirements of its intended use. The aquifer is related to sand and gravel soil layers of the soil deposit.

The power of the employed pump for the flow test was equal to 1.5hp and achieved an estimated flow rate of $22m^3/h$, yielding an approximate yearly flow of $33000m^3$ (considering pumping 10 hours per day for a total of 150 days). The pump was placed at a depth of 25m (the total depth of the borehole piping is equal to 32m).

During the flow testing, following the Cooper-Jacob method, simultaneous measurements of the aquifer depth were taken to monitor the drop of the water level due to continuous pumping. A piezometric pipe of 25mm diameter was used for the measurements. The underground water table depth was measured equal to 2.58m before the test initiated. After several hours of flow testing, it was found that the depth during pumping dropped at a constant level of 5.01m from the surface. The detailed water table level monitoring data are presented in Table 3.

Table 3. Monitoring data of the water table level during the test flow

Date	Time	Water table depth (m)
09/03/2020	10:00	2.92
09/03/2020	10:30	4.95
09/03/2020	11:00	4.95
09/03/2020	11:30	4.95
09/03/2020	12:00	4.97
09/03/2020	12:30	4.99
09/03/2020	13:00	5.01

Processing of the measurements according to the Cooper-Jacob method yielded a transmissivity equal to $T=1.2m^2/d$ and $K=0.028m/d$. The effective radius of the well is equal to 201m, considering a 10 hour pumping daily (for the whole year).

4. Monitoring of water table level

4.1 Measurements' objective

Although measurements during the borehole drilling revealed a shallow aquifer, it was deemed necessary to monitor the level of the underground water for an extended time period, to verify that there are no significant depth variations especially during the summer months. To this end, an automated monitoring system was installed, comprising of a sensor (water pressure measurements) connected to a data logger (Figure 45) and an external access point to allow for remote connection via WiFi to the campus network. The data logger (type Stylitis-10) is powered using a suspended cable (suspension length of 15m), reinforced with wire rope to withstand oscillations from wind loading (Figure 46).

Figure 45. Data logger (left) installed next to the borehole well and submersible sensor (right)

Figure 46. Installation of water level measurement device

The sampling rate of the installed device was set to 30min, a time period considered adequate since the level of the water table is not expected to present abrupt changes. The measurements logs can be obtained both using a dedicated computer software (Opton4 - Figure 47 and Figure 48), as well as using the online platform CAPTUM of SYMMETRON company (http://www.symmetron.gr/captum, Figure 49 and Figure 50).

It should be mentioned here, that the sensor monitors the depth at which it is submerged inside the water (through water pressure recordings). therefore the obtained results need some processing in order to calculate the depth of the water table level. The installation depth of the sensor was measured equal to 14.75m from the surface (more specifically from the top edge of the concrete base at the well). Therefore, the depth of the aquifer can be calculated as:

$$D_{WT} = 14.75 - Measurement\ depth \qquad \textbf{Eq. 6}$$

where:

D_{WT} : the depth of the water table from the surface (top edge of the concrete base)

The use of the computer software Opton4 allows for the creation of additional columns by the user, to yield the required calculations automatically (check last column of channel Ch51 in Figure 48). The recorded aquifer depth during the first days after the installation (May 2020) was equal to approximately 2.55m.

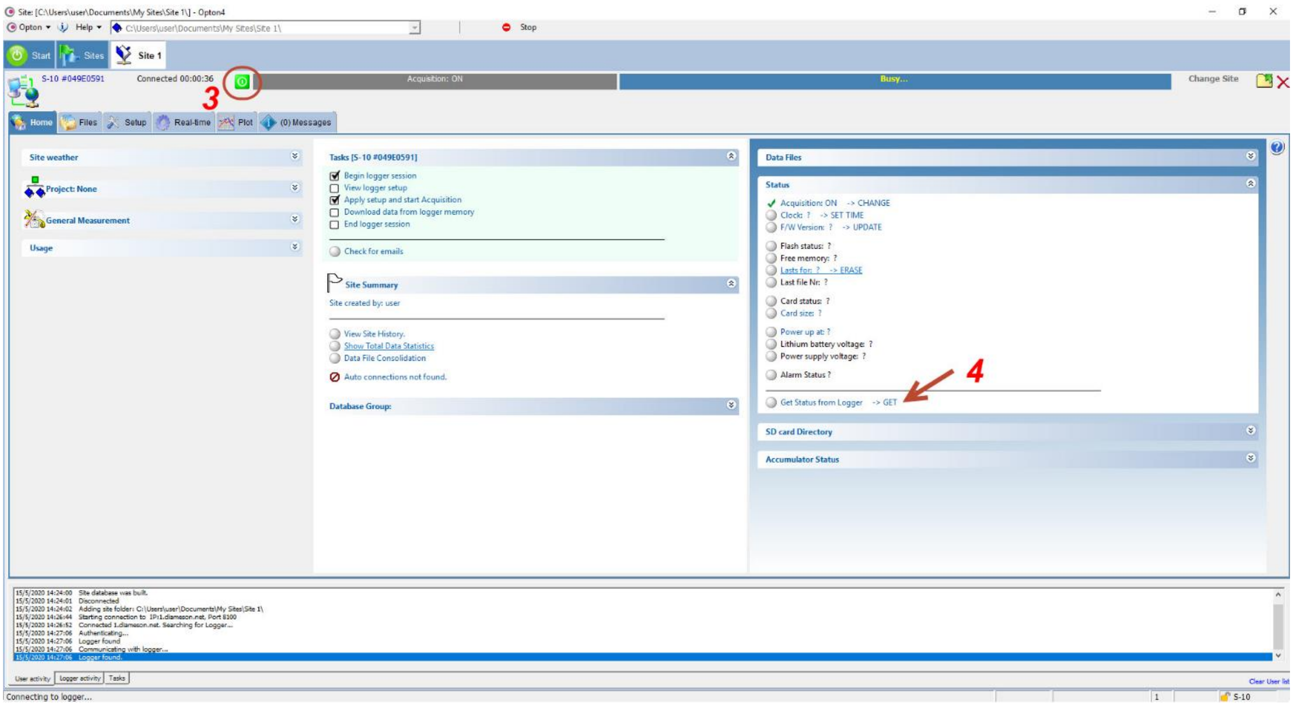

Figure 47. Use of Opton4 software to obtain recorded data files

```
============================================
CALCULATED CHANNEL
------------------------------------------------------------
------------------------------------
Ch51      Ch51=14.75 -Ch2
============================================
============================================
Math Interval = 30:00
Site: GEOTRISI
Description          LEVEL      BATTERY
Date       Time      Ch2:LEVEL   Ch9:BATTERY  Ch51
15/05/2020  14:00:00  12.2166    11.5     2.5334
15/05/2020  14:30:00  12.2174    11.5     2.5326
15/05/2020  15:00:00  12.2181    11.5     2.5319
15/05/2020  15:30:00  12.2166    11.5     2.5334
15/05/2020  16:00:00  12.2135    11.5     2.5365
15/05/2020  16:30:00  12.2128    11.5     2.5372
15/05/2020  17:00:00  12.2113    11.5     2.5387
15/05/2020  17:30:00  12.2052    11.6     2.5448
15/05/2020  18:00:00  12.2036    11.6     2.5464
15/05/2020  18:30:00  12.2021    11.6     2.5479
15/05/2020  19:00:00  12.1975    11.6     2.5525
15/05/2020  19:30:00  12.1968    11.6     2.5532
15/05/2020  20:00:00  12.1937    11.6     2.5563
15/05/2020  20:30:00  12.1907    11.6     2.5593
15/05/2020  21:00:00  12.1891    11.6     2.5609
15/05/2020  21:30:00  12.1891    11.6     2.5609
15/05/2020  22:00:00  12.1861    11.6     2.5639
15/05/2020  22:30:00  12.1868    11.6     2.5632
15/05/2020  23:00:00  12.1830    11.7     2.567
15/05/2020  23:30:00  12.1853    11.7     2.5647
16/05/2020  00:00:00  12.1861    11.7     2.5639
16/05/2020  00:30:00  12.1861    11.5     2.5639
16/05/2020  01:00:00  12.1861    11.6     2.5639
16/05/2020  01:30:00  12.1876    11.7     2.5624
16/05/2020  02:00:00  12.1884    11.7     2.5616
16/05/2020  02:30:00  12.1861    11.7     2.5639
```

Figure 48. Data files format obtained through Opton4 software (column Ch51 added by user to calculate the water table level depth from the soil surface)

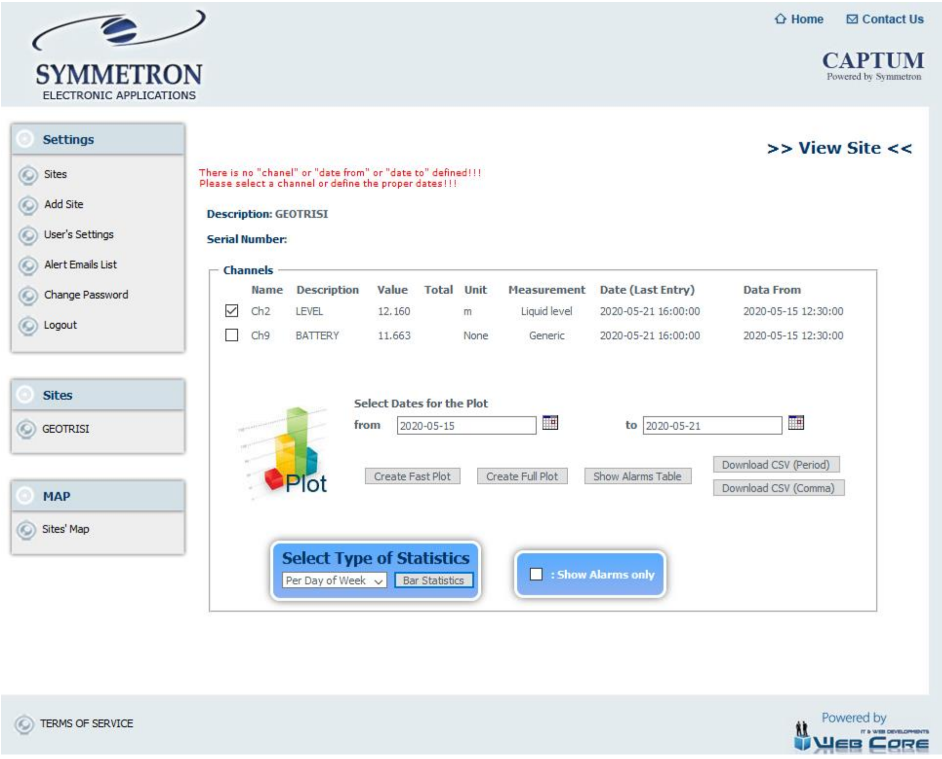

Figure 49. CAPTUM software for online measurements observation (through SYMMETRON)

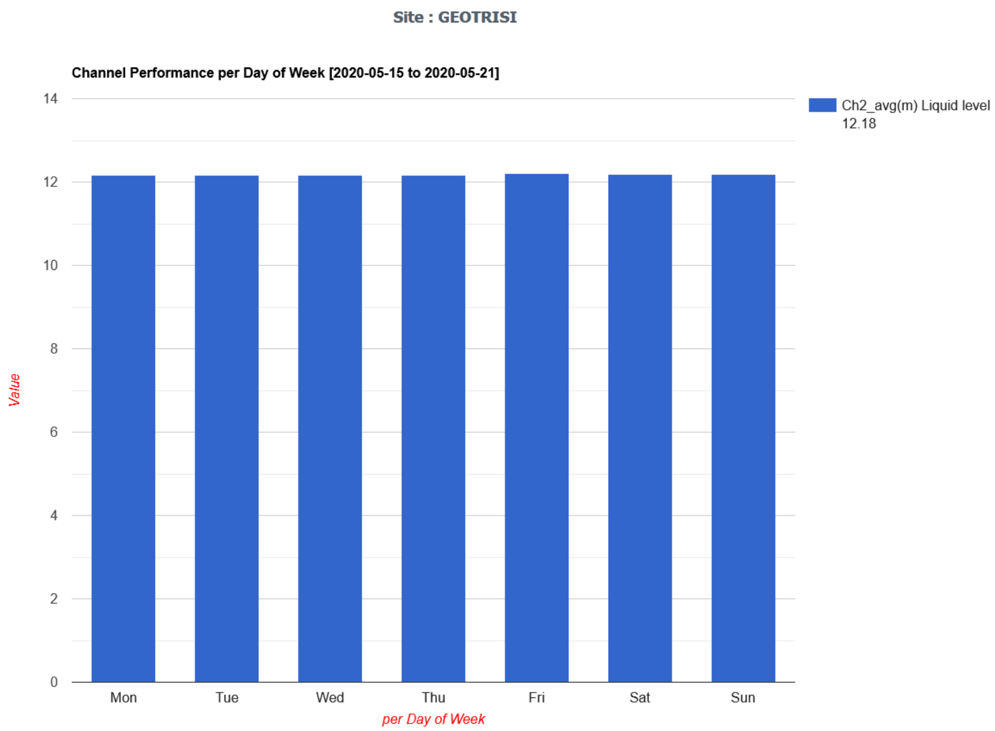

Figure 50. Water pressure measurements available online (CAPTUM)

5. Chemical analysis of the pumped water

5.1 Measurements' objective

In order to determine the suitability of the pumped water, both from the well and from the already existing pumps, a chemical analysis was deemed necessary, to ensure the absence of particular harmful or unsuitable contents. To this end, water samples were collected (Figure 51) and a detailed chemical analysis of the water took place in a specialized laboratory.

Figure 51. Water samples from the borehole well and the existing building pumps

5.2 Chemical/microbiological analysis results of water from the borehole well

In order to achieve a representative sample of the water from the borehole well, it was decided to obtain the sample following a procedure that would prevent collecting stagnant water or water with a large sediment content. More specifically, the sample was retrieved only after the aquifer level was stabilized, after few hours of continuous pumping during the test flow process.

The results of the chemical and microbiological analysis of the water from the well are presented in the following tables. It should be mentioned that the allowed limits refer to potable water. In the microbiological analysis, E.coli and Enterococcuse sp. have not been detected. Moreover, the large Manganese (Mn) value detected during the chemical analysis is not easy to explain taking into consideration the simultaneous absence of other related minerals, and should be monitored accordingly in future analyses.

Table 4. Microbiological analysis of water sample from borehole well (sampling on 09/03/2020)

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	15	cfu/100ml
E. coli	ISO 9308-1:2014	0	cfu/100ml
Enterococcus sp.	ISO 7899-2:2000	0	cfu/100ml
Cl. perfringens	ISO 14189:2013	2	cfu/100ml
P. aeruginosa	ISO 16266:2006	$1.5*10^2$	cfu/100ml

Table 5. Chemical analysis of water sample from borehole well (sampling on 09/03/2020)

Parameter	Units	Result	Reference limit	Uncertainty	Maximum allowed limit	Methodology
Calcium (Ca)	mg/L	139	0.5		-	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Magnesium (Mg)	mg/L	17.8	0.5		-	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Potassium (K)	mg/L	3.3	0.5	8.40%	12	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Sodium (Na)	mg/L	39.5	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.
Zinc (Zn)	μg/L	N.D.	50			O.B.01.040 ICPMS 3125 A,B Mod. St.Met.

Manganese (Mn)	μg/L	1542	10	9.70%	50	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Nitrates (NO_3)	mg/L	13.7	2	9.00%	50	O.B. 01.018 4500 NO3-B Mod St.Met.*
Nitrites (NO_2)	mg/L	0.19	0.03	3.30%	0.5	O.B. 01.011 4500NO2-B Mod St.Met.
Phosphates (P)	mg/L P2O5	N.D.	1.14	8.50%	5	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Ammonium	mg/L	0.69	0.06	4.40%	0.5	O.B.01.009 4500 NH3-F Mod St.Met.
Sulfate (SO4)	mg/L	107	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	30.1	10	2.80%	250	Internal method based on HACH Application DOC 316.52.93091 based on ISO 9297:2000.
pH	units pH 22 oC	7.7	1		≥6.5 και ≤9.5	O.B.01.005 4500-H,B St.Met.
Conductivity	μS/cm σε 20 oC	846	10-11670	2.90%	2500	O.B.01.006 2510 B St.Met.
Total Dissolved Solids (TDS)	mg/L	541	10			2540 St.Met.*
Total hardness	german deg (d)	23.4	0.18		-	O.B. 01.013 2340-B St.Met.
Alkalinity P	mgCaCO3/L	0				O.B.01.019 Volumetric 2320-B mod. St.Met.*
Total alkalinity	mgCaCO3/L	352	20			Internal based on: Application DOC 316.52.93091 based on ISO 9297:2000*
Carbon trioxide (CO3)	mg/L	0				O.B.01.019 volumetric*
Hydrogencarbonate (HCO3)	mg/L	429	25			O.B.01.019 volumetric*
Carbon hardness	German deg (d)	20.4				O.B.01.019 calculated*

Non-carbonate hardness	German deg (d)	3				O.B.01.019 calculated*
Fluoride (F)	mg/L	0.26	0.2	11.50%	1.5	O.B.01.030 4500 F-D SPADNS Method Mod. St.Met.
Odor		Acceptable				O.B.01.033 Mod. based on 2160C St.Met.
Taste		Not acceptable				O.B.01.033 Mod. based on 2160C St.Met.
Total Organic Carbon (TOC)	mgC/L	N.D.	3			O.B.01.038 HACH LCK 385
Oxidizability	mgO2/L	N.D.	1.5	3.60%	5	O.B.01.037 mod. based on EN ISO 8467
COD	mg/l	N.D.	33	3.9%	-	APHA 5220D, modified closed refluxed method
BOD	mg/l	N.D.	6	15%	-	Manometric method based on APHA 5210D

5.3 Chemical/microbiological analysis results of water from existing pumps (phase A)

Unlike the case of the borehole well, obtaining "representative" water samples from the existing pumps is not a straightforward task. Since only one of the monitored pumps is working frequently (Pump C2 of Figure 4, as presented in Table 2), the water from the other pumps (B1, B2, B3 and C1) would unavoidably have developed some characteristics similar to stagnant water. On the other hand, due to often heavy rains during the sampling period of phase A and considering the position at the base of a ramp construction, the water from Pump C2 would resemble rain water and not underground water coming from the aquifer. Therefore, Pump C2 was excluded from the sampling process at this stage.

Taking into account the above, and in order to obtain the best possible sample, it was decided during the first chemical analysis stage to use water from Pump B1 (Figure 3) which was found to function more often than the remaining pumps B2, B3 and C1. At the same time, a partial interconnection of the pump with the sewer network, which is activated if some rain limits are exceeded, may have prevented stagnation of the pump water. On the other hand, the function of Pump B1 remains at very low levels (few hours or minutes per month or even inactive during some prolonged time periods). Therefore, interpretation of obtained analysis results should bear in mind those factors.

The results of the chemical and microbiological analysis of the water from Pump B1 are presented in the following tables. As probably expected, due to the water conditions that were explained in the previous paragraph, the microbiological analysis identified amounts of E.coli and Enterococcuse sp. On the other hand, chemical analysis yields satisfactory results, whereas Manganese (Mn) is not detected in the water of the existing pumps compared to the borehole well. Once again, all referred allowed limits of the tables concern potable water.

Table 6. Microbiological analysis of water sample from pump B1 (sampling on 09/03/2020)

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	$1.5*10^4$	cfu/100ml
E. coli	ISO 9308-1:2014	Presence $<10^3$	cfu/100ml
Enterococcus sp.	ISO 7899-2:2000	56	cfu/100ml
Cl. perfringens	ISO 14189:2013	25	cfu/100ml
P. aeruginosa	ISO 16266:2006	$<10^2$	cfu/100ml

Table 7. Chemical analysis of water sample from pump B1 (sampling on 09/03/2020)

Parameter	Units	Result	Reference limit	Uncertainty	Maximum allowed limit	Methodology
Calcium (Ca)	mg/L	24.5	0.5		-	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Magnesium (Mg)	mg/L	3.3	0.5		-	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Potassium (K)	mg/L	4.8	0.5	8.40%	12	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Sodium (Na)	mg/L	10.3	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.

Zinc (Zn)	μg/L	N.D.	50			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	8.1	2	9.00%	50	O.B. 01.018 4500 NO3-B Mod St.Met.*
Nitrites (NO_2)	mg/L	0.38	0.03	3.30%	0.5	O.B. 01.011 4500NO2-B Mod St.Met.
Phosphates (P)	mg/L P2O5	1.21	1.14	8.50%	5	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Ammonium	mg/L	0.18	0.06	4.40%	0.5	O.B.01.009 4500 NH3-F Mod St.Met.
Sulfate (SO4)	mg/L	N.D.	20	6.80%	250	O.B. 01.008 4500 SO4-E Mod. St.Met
Boron (B)	mg/L	N.D.	0.05	14.90%	1	O.B.01.040 ICPMS 3125 A,B Mod. St.Met.
Chlorides (Cl)	mg/L	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	1		≥6.5 και ≤9.5	O.B.01.005 4500-H,B St.Met.
Conductivity	μS/cm σε 20 oC	192	10-11670	2.90%	2500	O.B.01.006 2510 B St.Met.
Total Dissolved Solids (TDS)	mg/L	123	10			2540 St.Met.*
Total hardness	german deg (d)	4.2	0.18		-	O.B. 01.013 2340-B St.Met.
Alkalinity P	mgCaCO3/L	0				O.B.01.019 Volumetric 2320-B mod. St.Met.*
Total alkalinity	mgCaCO3/L	100	20			Internal based on: Application DOC 316.52.93091 based on ISO 9297:2000*
Carbon trioxide (CO3)	mg/L	0				O.B.01.019 volumetric*
Hydrogencarbonate (HCO3)	mg/L	121	25			O.B.01.019 volumetric*

Carbon hardness	German deg (d)	4.2				O.B.01.019 calculated*
Non-carbonate hardness	German deg (d)	<0.2				O.B.01.019 calculated*
Fluoride (F)	mg/L	N.D.	0.2	11.50%	1.5	O.B.01.030 4500 F-D SPADNS Method Mod. St.Met.
Odor		Acceptable				O.B.01.033 Mod. based on 2160C St.Met.
Taste		Not acceptable				O.B.01.033 Mod. based on 2160C St.Met.
Total Organic Carbon (TOC)	mgC/L	N.D.	3			O.B.01.038 HACH LCK 385
Oxidizability	mgO2/L	2.83	1.5	3.60%	5	O.B.01.037 mod. based on EN ISO 8467
COD	mg/l	N.D.	33	3.9%	-	APHA 5220D, modified closed refluxed method
BOD	mg/l	N.D.	6	15%	-	Manometric method based on APHA 5210D

6. Simplified detection of other water properties

6.1 Measurement device

Since a detailed chemical/microbiological analysis can only performed once or twice within the framework of the project, and requires an external service of a specialized laboratory, it was deemed necessary to also employ measurements using a mobile device. To this end, the device HI-991300 from HANNA Instruments (Figure 52) was used to perform some minor testing and determination of water characteristics and mode specifically of pH, conductivity, temperature and TDS content (total dissolved solids). The technical specifications of this device can be summarized to the following:

- pH Range 0.00 to 14.00 pH
- pH Resolution 0.01 pH
- pH Accuracy 0.01 pH

- pH Calibration — automatic, at one or two points with two sets of standard buffers (pH 4.01 / 7.01 / 10.01 or pH 4.01 / 6.86 / 9.18)
- Conductivity Range — 0 to 3999 S/cm
- Conductivity Resolution — 1 S/cm
- Conductivity Accuracy — 2% F.S.
- TDS Range — 0 to 2000 ppm (mg/L)
- TDS Resolution — 1 ppm (mg/L)
- TDS Accuracy — 2% F.S.
- Temperature Range — 0.0 to 60.0C / 32.0 to 140.0F
- Temperature Resolution — 0.1C / 0.1F
- Temperature Accuracy — 0.5C /1F
- Temperature Compensation — pH: automatic; EC/TDS: automatic with β adjustable from 0.0 to 2.4% / °C
- EC/TDS Calibration — automatic, one-point at: 1382 ppm (CONV=0.5), 1500 ppm(CONV=0.7), 1413 S/cm
- TDS Conversion Factor — 0.45 to 1.00
- Electrode/Probe — HI1288 PVC body, pre-amplified multiparameter probe with internal temperature sensor, DIN connector and 1m cable
- Environment — 0 to 50C (32 to 122F); RH max 100%

Before using the device for measurements a calibration procedure was required as indicatively presented in Figure 53.

Figure 52. HI-991300 measurement device

Figure 53. Calibration of HI-991300 measurement device

6.2 Measurement results of water from the borehole well

Due to a delay in the delivery of calibration liquid for the HI-991300 device, the measurements concerning the pumped water from borehole well took place a few months after the sampling date. Indicative device display is presented in Figure 54. The measurements' results (Table 8) are quite close to the detailed chemical analysis that took place for the same water sample on 03/2020 and were presented previously (Table 5).

Figure 54. HI-991300 measurements display of borehole water

Table 8. Measurements of borehole water using the HI-991300 device

Parameter	Value (sample 03/2020)
pH	7.42
Electrical Conductivity (EC)	781 µS/cm
Total Dissolved Solids (TDS)	393 ppm
Temperature	24.2 °C *[1]

*[1] This value is not taken during sampling and represents the water temperature exposed in the environment

6.3 Measurement results of water 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 (Table 9) present a substantial difference between the two sampling dates (09/03/2020 and 22/07/2020), especially when comparing the electrical conductivity value (the TDS calculation depends strongly on the EC value). In general, the 07/2020 water samples from all the examined pumps (B1, C1 and C2) yield a much larger conductivity value compared to 03/2020 sample of B1. On the other hand, the latter are quite close with the detailed chemical analysis of the same water sample that was presented in Table 7.

Table 9. Measurements of water in pump B1 using the HI-991300 device

Parameter	Value (sample 03/2020)*[1]	Value (sample 07/2020)
pH	7.28	8.26
Electrical Conductivity (EC)	160 μS/cm	851 μS/cm
Total Dissolved Solids (TDS)	80 ppm	429 ppm
Temperature	23.6 °C *[2]	25.7 °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 10. Measurements of water in pump C1 using the HI-991300 device

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

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

Table 11. Measurements of water in pump C2 using the HI-991300 device

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

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

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