Activity report about field measurements in the pilot area Vienna

Deliverable D.T3.2.2 Updated database of existing and additionally measured data at the pilot areas

Template

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Content

1. Executive summary

Field measurements in the pilot area Vienna focused on hydrogeological properties of the groundwater body Marchfeld, which comprises the entire pilot area and which the city of Vienna already impacts thermally.

Groundwater temperature measurements investigated this so called urban-heat-island effect in the pilot area. Measurements were conducted manually with a well dipper in 19 observation wells and one lake every month. Additionally, LP-GBA manufactured automatic groundwater temperature loggers (called WTF - Wassertemperaturfühler) to enable larger data sets. The WTFs recorded groundwater temperatures daily in multiple depth intervals. During each field trip for manual measurements, the WTFs were checked and maintained. The gathered data shows a temperature increase in areas close to district heating pipes, sewage pipes and open loop systems. The mean groundwater temperature in these areas is 15.0 °C, whereas the mean temperature in uninfluenced areas is 12.4 °C. All temperature data will be incorporated in the elaboration of the numerical model (D.T3.3.3) and in the potential calculations for open loop systems of the pilot area Vienna.

LP-GBA took water samples for chemical analysis at 15 locations and conducted onsite measurements, to identify problematic groundwater zones. These field campaigns focused on the investigation of a possible negative influence of surface water bodies on the groundwater chemistry. Sampling was repeated quarterly at selected locations to take possible seasonal variations into account. Chemical analyses of the water samples do not show any influence of the two investigated lakes Hirschstettner Teich and Asperner See on the groundwater. The chemistry data feeds into the elaboration of the potential layer of problematic groundwater zones.

Thermal properties of sediments from the pilot area Vienna were measured in three outcrops. The measurements were conducted in-situ with the portable device “ISOMET 2104” and a needle probe. Thermal conductivity measurements lie in the expected range of values and are comparable with values from look up tables like those of the German VDI-standards. The analyses will feed into the numerical model (D.T3.3.3) and in the bulk thermal conductivity maps for the pilot area Vienna.

Processed field measurements and associated raw data will be available for download at the GeoPLASMA-CE web portal. All project outputs, which were elaborated based on field measurements, will be published on the web portal as maps including location specific queries (www.geoplasma-ce.eu).

2. Zusammenfassung

Im Rahmen von GeoPLASMA-CE wurden eine Reihe von Feldmessungen im Pilotgebiet Wien durchgeführt. Fokus der Feldmessungen lag auf den hydrogeologischen Eigenschaften des Grundwasserkörpers Marchfeld, der das gesamte Pilotgebiet umfasst und durch das Wiener Stadtgebiet bereits thermisch beeinflusst wird.

Mittels Grundwassertemperaturmessungen wurde dieser Urban-heat-Island Effekt im Pilotgebiet genauer untersucht. Händische Grundwassertemperaturmessungen mittels Kabellichtlot wurden in 19 Grundwassermessstellen und im Asperner See durchgeführt. Zusätzlich wurden in 10 Messstellen neue automatische Temperaturmessketten (WTF – Wassertemperaturfühler) installiert, die eine kontinuierliche Datenaufzeichnung ermöglichten. Die Wassertemperaturfühler zeichneten die Temperaturen in mehreren Tiefenintervallen einmal täglich auf. Während der monatlichen Messrunden wurden sie überprüft und gewartet. Die Temperaturdaten zeigen eine Erhöhung der Grundwassertemperatur im Nahbereich von Fernwärmeleitungen, Kanalleitungen und thermischer Grundwassernutzungen. Die mittlere Grundwassertemperatur liegt hier bei 15.0 °C, während der Mittelwert der unbeeinflussten Messstellen bei 12.4 °C liegt. Die Ergebnisse der Temperaturmessungen fließen in die Erstellung des numerischen Modells des Pilotgebiets Wien (D.T3.3.3) und in die Potentialberechnungen für thermische Nutzungen des Grundwassers ein.

An insgesamt 15 Standorten wurden Wasserproben für chemische Analysen entnommen und vor Ort Messungen durchgeführt, um problematische Grundwassergebiete zu identifizieren. Fokus wurde dabei auf die Untersuchung eines möglichen negativen Einflusses von Oberflächengewässern auf das Grundwasser gelegt. Um einen möglichen saisonalen Einfluss zu berücksichtigen, wurde die Probenahme an ausgewählten Standorten vierteljährlich wiederholt. Dieser konnte jedoch für die beiden untersuchten Seen Hirschstettner Teich und Asperner See nicht nachgewiesen werden. Die chemischen Analysen fließen in die Erstellung der Konfliktkarte für problematische Grundwasserzonen ein.

Thermische Eigenschaften der Sedimente des Wiener Pilotgebiets wurden an drei Aufschlüssen untersucht. Die Messungen wurden mit dem tragbaren Gerät „ISOMET 2104“ und einem Stabsensor insitu durchgeführt. Die Ergebnisse der thermischen Leitfähigkeiten liegen in dem zu erwartenden Bereich und sind vergleichbar mit den Angaben in der Deutschen VDI Richtlinie. Sie werden für die Parametrisierung des numerischen Modells (D.T3.3.3) und die thermischen Leitfähigkeitskarten des Pilotgebiets Wien verwendet.

Die aufbereiteten Feldmessungen, sowie dazugehörige Rohdaten, werden auf dem GeoPLASMA-CE Webportal zum Download bereitgestellt. Alle Projektergebnisse, die mithilfe der Feldmessungen erarbeitet werden, werden ebenfalls auf dem Portal als Karten und in der dazugehörigen Standortabfrage veröffentlicht (www.geoplasma-ce.eu).

3. Introduction

3.1. Aim and scope of this report

This report describes the field measurements in the pilot area Vienna, which have been performed within the frame of Activity A.T3.2. It aims at a full documentation of the assessed field data, which will be published at the GeoPLASMA-CE web portal (www.geoplasma-ce.eu).

This report contains:

- An overview of parameters measured in the pilot areas for creating the aimed project outputs
- A brief description of the methods applied for measurement and data processing
- A documentation of the field measurements performed in the PA area.
- A short description of the results achieved and how these results contribute to the generation of thematic outputs.

3.2. Overview of the chosen strategy for field measurements

A mayor output of the GeoPLASMA-CE in the pilot area Vienna is the analysis of the shallow geothermal potential and possible risks and conflicts of use for open loop systems. Our field measurements provide crucial input data to achieve this goal. Therefore, field work focused on hydrogeological investigations in the groundwater body Marchfeld, a shallow aquifer, which consists mainly of gravel and sand and covers the entire pilot area Vienna.

The Geological Survey of Austria (LP-GBA) conducted both manual and automatic groundwater temperature measurements. Field measurements focused on wells and in areas where a known specific impact on the groundwater temperature regime occurs, such as lakes, district heating pipes, open loop systems and so called reference wells, where an anthropogenic heat impact is presumably absent. A comparison between influenced wells and the reference wells enables a quantitative estimation of the anthropogenic impact on the groundwater temperatures. 19 of the wells and one lake chosen for the temperature measurements have already been monitored monthly by LP-GBA since 2014. The continuation of the measurements allows a better trend analysis of the groundwater temperatures. Well dippers with temperature sensors were used for monthly temperature and water level measurements. Water level measurements provide additional information about the temperatures referring to the depth of the measurement below the water level.

Furthermore, LP-GBA developed a groundwater temperature logger (called WTF). They measured the groundwater temperature daily in 10 wells and stored the data on a SD-card. During the monthly field trips, LP-GBA collected the data from the SD-cards and maintained the loggers, if necessary.

The temperature measurements feed into the numerical model of the pilot area Vienna (D.T3.3.3), which provides groundwater temperature maps. These maps are important input data for the potential calculations for open loop systems, namely the output parameters (OP) “Thermal capacity – peak load” (OP07), “Thermal capacity – base load” (OP08), “Energy content” (OP09), “Thermal productivity” (OP11). The potential maps will be included in the GeoPLASMA-CE web portal.

Chemical analysis of groundwater samples (at the sampling location and in the laboratory) reveal possible risks for open loop and closed loop systems. 10 out of 13 wells chosen for the chemical analysis were also part of the temperature measurement campaign. Main goal of the chemical analysis was to specify the possible impact of surface water bodies on the groundwater chemistry. Therefore, LP-GBA selected groundwater wells for the quarterly measurement campaign, which are located downstream and upstream of two lakes (Asperner See and Hirschstettner Teich), and additionally took samples from the lakes themselves. The output parameter “Problematic groundwater zones” (OP29) will rely on this information and additional existing data from external sources. A map showing the problematic groundwater zones will become part of the location query on the GeoPLASMA-CE web portal.

In addition to groundwater analyses, LP-GBA performed in situ measurements of thermal properties of unconsolidated rocks in the pilot area Vienna. Those analyses will feed into the numerical model (D.T3.3.3) and in the bulk thermal conductivity map (OP02) for the pilot area Vienna.

4. Documentation of field measurements

4.1. Groundwater temperature measurements

4.1.1. Method of groundwater temperature measurements

LP-GBA conducted manual and automatic groundwater temperature measurements in a total of 29 observation wells and one lake in the pilot area Vienna. Two different well dippers (50 m and 150 m length) with temperature sensors were used to measure the groundwater temperatures in 19 wells and one lake manually each month and the remaining wells were equipped with groundwater temperature loggers. Water level measurements provide additional information about the temperatures referring to the depth of the measurement below the water level and were conducted during the manual temperature measurements. Figure 1 shows the equipment for manual groundwater temperature and water level measurements.

Figure 1. Equipment for manual groundwater temperature and water level measurements (well dipper and notepad) next to an observation well.

In order to be able to monitor the groundwater temperature more closely without additional field trips, LP-GBA previously invented an automatic groundwater temperature logger (called WTF – Wassertemperaturfühler). In GeoPLASMA-CE the layout of the WTF was further improved. Centrepiece is a logger, capable of recording data from temperature sensors attached to a cable, at any given time interval (Figure 2).

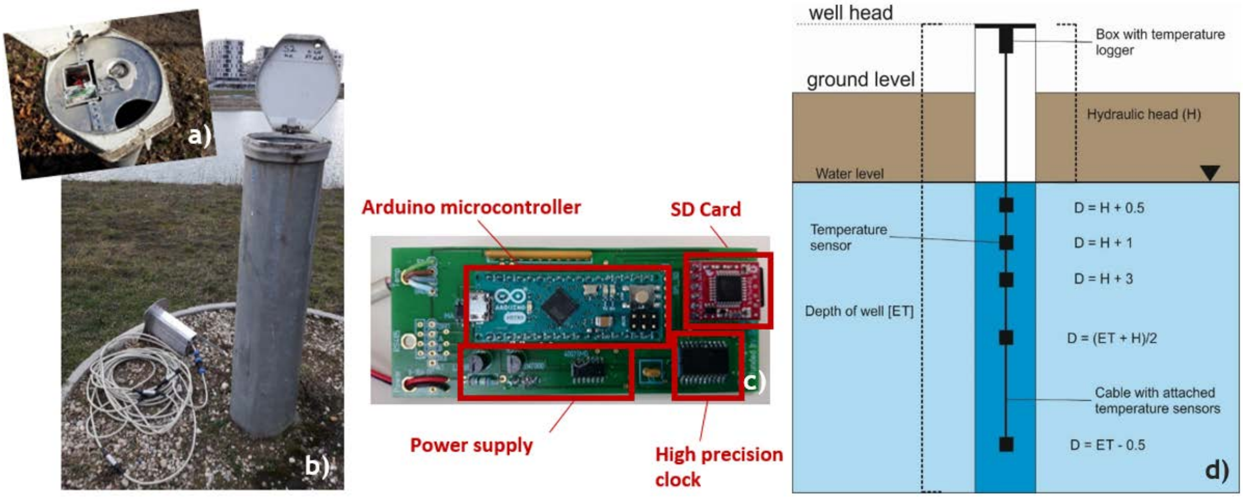


Figure 2. Components and layout of water temperature sensor WTF. a) Well head with temperature logger installed. b) Well S2-See and temperature logger in casing and attached cable with temperature sensors. c) Layout of logger. d) Example for set-up of temperature sensors in the well (WTF).

A number of 4 to 6 pt100 temperature sensors were soldered to a cable in varying depth intervals according to the water level and depth of the well. We placed sensors 50 cm above the bottom of the well, in the middle of the water-saturated zone, 1 m and 50 cm below the water level, based on one representative measurement of the water level. Additional sensors were placed above and/or below sensor in the middle of the saturated zone, depending on the depth of the well. Since the water table of the Marchfeld groundwater body only fluctuates very little - around 50 cm - in the areas of our selected wells, we considered one representative measurement of water level enough to determine the placement of the temperature sensors.

Main components of the logger are an Arduino microcontroller, a SD-card reader and a high precision clock. The program on the Arduino microcontroller sets an alarm for the next time of the next temperature measurement and – to save battery – goes into stand-by mode afterwards. The alarm of the clock turns on the Arduino microcontroller, which records the temperatures of all sensors in a predefined ranking (from the top temperature sensor to the deepest one) and stores the data on the SD-card. As last step the Arduino microcontroller sets again the alarm for the next temperature measurement. In GeoPLASMA-CE we recorded the temperatures every day at 00:00. Batteries provide the power supply of 9 V to 12 V for the logger. Two wells (EW5 and 22-4) had a diameter of only 5 cm and therefore small 9 V monoblock batteries were used in this case. All other WTFs ran on 12 V. The team of LP-GBA has developed the layout and software program of this logger. After assembling the loggers and a successful testing phase of several days in the office, the loggers were approved to be installed in the wells.

The loggers were placed inside metal casings (see Figure 2 a and b), which fit completely inside the well head, and were connected to the cable with a plug. For maintenance and repair purposes it was possible to simply unplug the logger from the cable. Openings in the metal casings were covered with duct tape to protect the loggers.

LP-GBA produced a total of 10 WTFs and installed them in wells, where a known specific impact on the groundwater temperature regime occurs, such as lakes, district heating pipes, open loop systems and so called reference wells, where an anthropogenic heat impact is presumably absent (Table 1). The prototype of the WTFs, developed before GeoPLASMA-CE, was installed in one additional well (S6-IQ).

Table 1. Specifics of groundwater temperature loggers WTF.

Well	22-114	22-4	22-223	22-75	22.21/27	22-246	22-264	22-263	EW3	S2-See
Reason for selection	Close to open loop system for cooling of a data centre	Close to a district heating pipe	Reference well	Downstream of lake Hirschstettner Teich	Upstream of lake Hirschstettner Teich	Reference well	Close to open loop system of Transgourmet for heating and cooling	Close to open loop system of Transgourmet for heating and cooling	Close to open loop system for cooling of a power station	Downstream of lake Asperner See
Depth of temp sensors [m]										
Depth of water level + 0.5 m	4.4	4.2	5.1	7.6	7.2	8.1	7.5	7.7	4.2	6
Depth of water level + 1 m	4.9	4.7	5.6	8.1	7.7	8.6	8	8.2	4.7	6.5
Depth of water level + 3 m				10.1		10.6	10	10.2		8.5
Middle of saturated zone	7	6	6.1	11.7	10.4	12.4	10.9	11	5.4	9.2
Bottom of well - 2 m	8.2			14.3	12	15.1	12.7	12.8		10.9
Bottom of well - 0.5	9.6	7.7	7.1	15.8	13.5	16.6	14.2	14.3	6.5	12.4
Number of temp sensors	5	4	4	6	5	6	6	6	4	6
Diameter of well pipe [cm]	16	5	16	15	16	16	16	16	5	16
Depth of well [m]	10.1	8.15	7.6	16.3	14	17.1	14.65	14.75	7.01	12.9
Depth of water level [m]	3.84	3.67	4.58	7.1	6.65	7.56	6.99	7.15	3.62	5.5

In order to make the measurements of the two different well dippers and the sensors of the automatic loggers comparable, LP-GBA calibrated the equipment with a highly precise temperature sensor. Chapter 5.1 contains information about the calibration procedure.

4.1.2. Documentation of groundwater temperature measurements

An overview of the locations, where LP-GBA performed groundwater temperature measurements in the pilot area Vienna, including the two different methods of manual and automatic measurements is available in Figure 4.

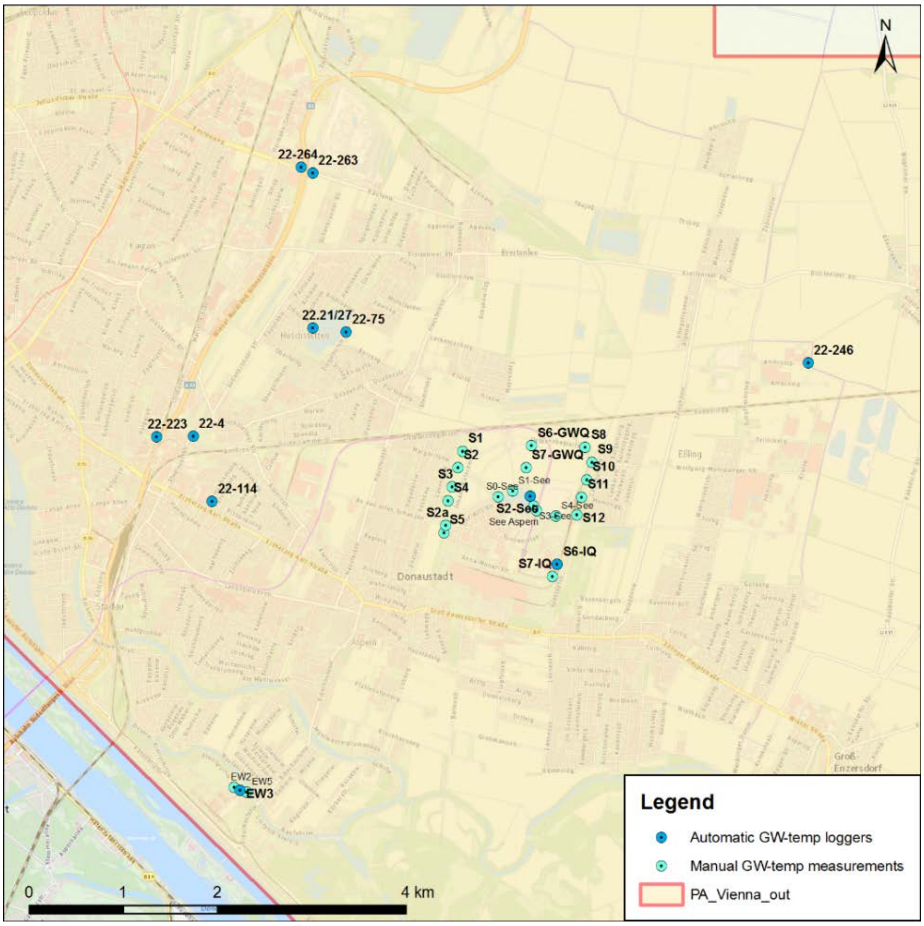


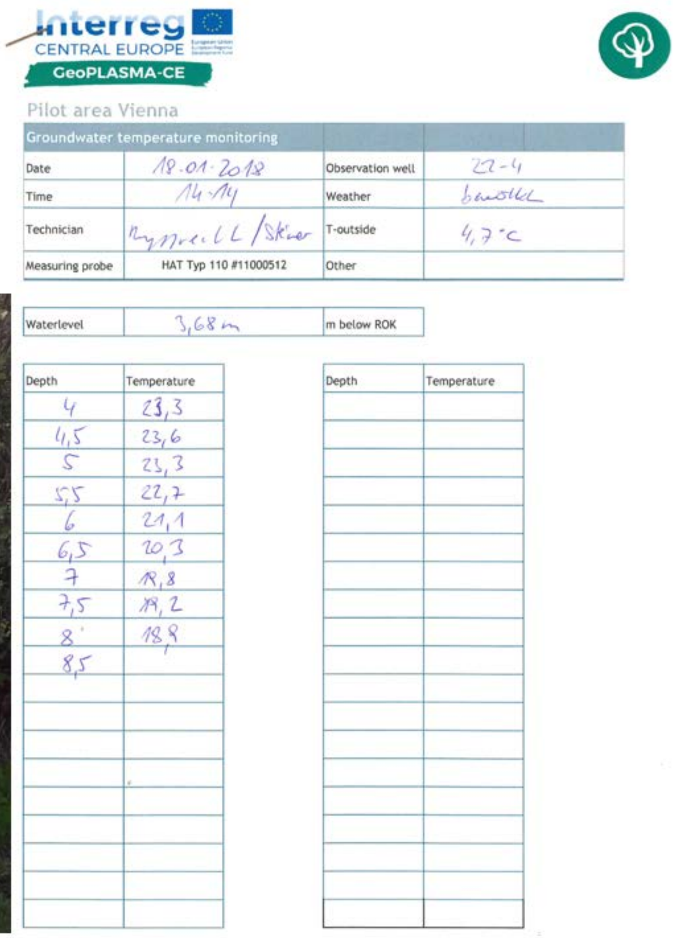
Figure 3. Location of groundwater temperature measurements in the pilot area Vienna.

Manual groundwater temperature measurements for GeoPLASMA-CE started on 11.07.2016. Automatic measurements began later, in December 2017, due to the preliminary work, such as selection of the wells and manufacturing the WTFs. Temperature measurements ended in December 2018. Table 2 shows the time frame of the groundwater temperature measurements and summarizes the numbers of data for each location.

Table 2. All groundwater temperature data points, time frame of the field work, depth intervals of temperature measurements and method for each groundwater well and lake Aspern respectively.

Well/lake	Date of first GW temp measurement	Date of last GW temp measurement	Number of temp measurements	Number of depth intervals	Temp measurement method
22.21/27	30-Dez-17	18-Dez-18	1352	5	Automatic
22-114	30-Dez-17	18-Dez-18	1244	5	Automatic
22-223	30-Dez-17	10-Okt-18	729	4	Automatic
22-263	30-Dez-17	11-Nov-18	1105	6	Automatic
22-264	30-Dez-17	22-Nov-18	1477	6	Automatic
22-246	20-Okt-17	18-Dez-18	1197	6	Automatic
22-4	26-Jän-18	19-Okt-18	1326	4	Automatic
22-75	30-Dez-17	18-Dez-18	1770	6	Automatic
EW3	19-Jän-18	22-Nov-18	840	4	Automatic
S0-See	11-Jul-16	18-Dez-18	609	13	Manual
S1	11-Jul-16	18-Dez-18	1771	19	Manual
S10	11-Okt-17	18-Dez-18	304	23	Manual
S11	11-Jul-16	18-Dez-18	1453	31	Manual
S12	11-Jul-16	18-Dez-18	1179	25	Manual
S1-See	11-Jul-16	18-Dez-18	853	18	Manual
S2	11-Mai-17	18-Dez-18	141	9	Manual
S2a	11-Apr-17	18-Dez-18	231	13	Manual
S2-See	11-Jul-16	18-Dez-18	1121	6	Automatic
S3	11-Mai-17	18-Dez-18	81	7	Manual
S3-See	11-Jul-16	18-Dez-18	669	15	Manual
S4	11-Mai-17	18-Dez-18	241	14	Manual
S4-See	11-Jul-16	18-Dez-18	414	9	Manual
S5	11-Apr-17	18-Dez-18	252	14	Manual
S6	11-Jul-16	18-Dez-18	1183	26	Manual
S6-IQ	11-Jul-16	18-Dez-18	544	10	Manual/Automatic
S7	11-Jul-16	18-Dez-18	832	19	Manual
S7-IQ	11-Jul-16	18-Dez-18	844	18	Manual
S8	11-Jul-16	18-Dez-18	984	21	Manual
S9	11-Jul-16	18-Dez-18	1368	28	Manual
Lake Aspern	11-Jul-16	18-Dez-18	82	4	Manual

A team of two LP-GBA project team members went on monthly field trips for the manual temperature and water level measurements. These manual measurements focused on wells in the urban development area "Seestadt Aspern", to investigate the impact of the artificial lake located in the centre of "Seestadt Aspern" and of sewage pipes on to the groundwater temperature. They measured the depth to the water level and groundwater temperatures in fixed depths of a 50 cm interval with a well dipper. Water level measurements provide additional information about the temperatures referring to the depth of the measurement below water level and were conducted during manual temperature measurements. Data was recorded on paper in the field, and transferred to a digital database in the post processing phase. Figure 6 shows examples of performing the measurements and documenting them in the field. In addition to the temperature and water level, the team also recorded information about weather, well dipper used, date and time of the measurements and the names of the technicians in the field. The information which well dipper was used is crucial for the post processing phase, where the corresponding calibration equation has to be applied.



Pilot area Vienna

Groundwater temperature monitoring			
Date	18.01.2018	Observation well	22-4
Time	14:14	Weather	bewölkt
Technician	[illegible] / [illegible]	T-outside	4,7 °C
Measuring probe	HAT Typ 110 #11000512	Other	

Waterlevel	3,68 m	m below ROK

Depth	Temperature	Depth	Temperature
4	23,3		
4,5	23,6		
5	23,3		
5,5	22,7		
6	21,1		
6,5	20,3		
7	19,8		
7,5	19,2		
8	18,8		
8,5			

Figure 4. Procedure of taking manual groundwater temperature measurements in 50 cm depth intervals and documentation sheet.

During these field trips, the team also checked the WTFs, which were programmed to record the temperature daily at 00:00 (see Figure 7). The team stored the temperature data from the SD-card on the field laptop and checked the temperature loggings between the field trips. It was possible to conduct temperature measurements, while the logger was connected to the laptop. This made sure to get at least one temperature measurement for each month. If the WTFs malfunctioned, they were either maintained on-site or taken to the office for reparations. Reasons for occurring malfunctions were:

1. WTF ran out of battery
2. Clock restarted

The first step in fixing malfunctions was to check the battery. Technicians replaced batteries directly in the field and the WTF could start to record temperatures again on the next day. If the battery was still full, the WTF was connected to the laptop to check the settings of the program. This often revealed the second problem, which was a wrong time of the clock. In this case the clock had stopped and restarted with a wrong date and the logger did not record further temperatures from this time on. A reason for this malfunction could not be identified with certainty. It was assumed that a short power failure might cause the clock to restart or that the clock itself got broken, sometimes due to corrosion. The clock was either exchanged, if corrosion was visible, or the clock was set to the actual time and installed again in the well. After the time was set, the logger started to record temperatures again. Where corrosion was identified as problematic, the loggers were coated with lacquer to protect them from short-circuits.

Figure 5. Installation of automatic groundwater temperature logger WTF in low-level observation well.

4.2. Groundwater chemistry

4.2.1. Method of water sampling and analysing groundwater chemistry

LP-GBA sampled 10 observation wells, 3 abstraction wells and 2 lakes in the pilot area Vienna. A team of two project team members conducted the field work. Two different water pumps extracted water from the wells. In the first field campaign, a suction pump was used due to lack of other equipment. Disadvantage of this pump is, that suction causes negative pressure, which changes the concentration of volatile parameters. This is not the case for submersible pumps and therefore LP-GBA borrowed a submersible pump from PP06-SGIDS for the other two sampling campaigns. A sampler for surface water bodies was used for sampling two lakes and tap water was bottled from three extraction wells.

Two technicians from LP-GBA took water samples for analysis in the laboratory and measured on-site parameters in the field. On-site parameters are described in Table 3 and were analysed with a WTW multi-parameter probe 3630 with WTW sensors.

Table 3. On-site parameters of groundwater chemistry analysis.

On-site parameter	Unit	WTW Sensor
Temperature	°C	FDO 925
Electric conductivity	µS/cm	TetraCon 925
pH	-	SenTix 940
Reduction potential	mV	SenTix ORP
Oxygen	mg/l and %	FDO 925

The department Geochemistry of LP-GBA analysed the following parameters in their laboratory in accordance with the routine of the laboratory and the requirements of the workflow for problematic groundwater bodies:

Parameter	Ni [mg/l]
Ca [mg/l]	Co [mg/l]
Mg [mg/l]	Cd [mg/l]
Na [mg/l]	Pb [mg/l]
K [mg/l]	Zn [mg/l]
Sr [mg/l]	Mo [mg/l]
Ba [mg/l]	As [mg/l]
Li [mg/l]	Sb [mg/l]
Rb [mg/L]	Cr [mg/l]
Cs [mg/l]	Hg [mg/l]
NH_4 [mg/l]	U [mg/l]
Total hardness [°dH]	B [mg/l]
Carbonate hardness [°dH]	HCO_3 [mg/l]
Non-carbonate hardness [°dH]	F [mg/l]
Fe [mg/l]	Cl [mg/l]
Mn [mg/l]	NO_3 [mg/l]
Al [mg/l]	PO_4 [mg/l]
V [mg/l]	SO_4 [mg/l]
Cu [mg/l]	NO_2 [mg/l]

4.2.2. Documentation of water sampling and analysing groundwater chemistry

An overview of the locations, where LP-GBA took groundwater samples for chemical analysis, is available in Figure 6. Groundwater samples were taken during three field campaigns, representing different seasons (07.02.2018/08.02.2018, 17.05.2018 and 31.07.2018).

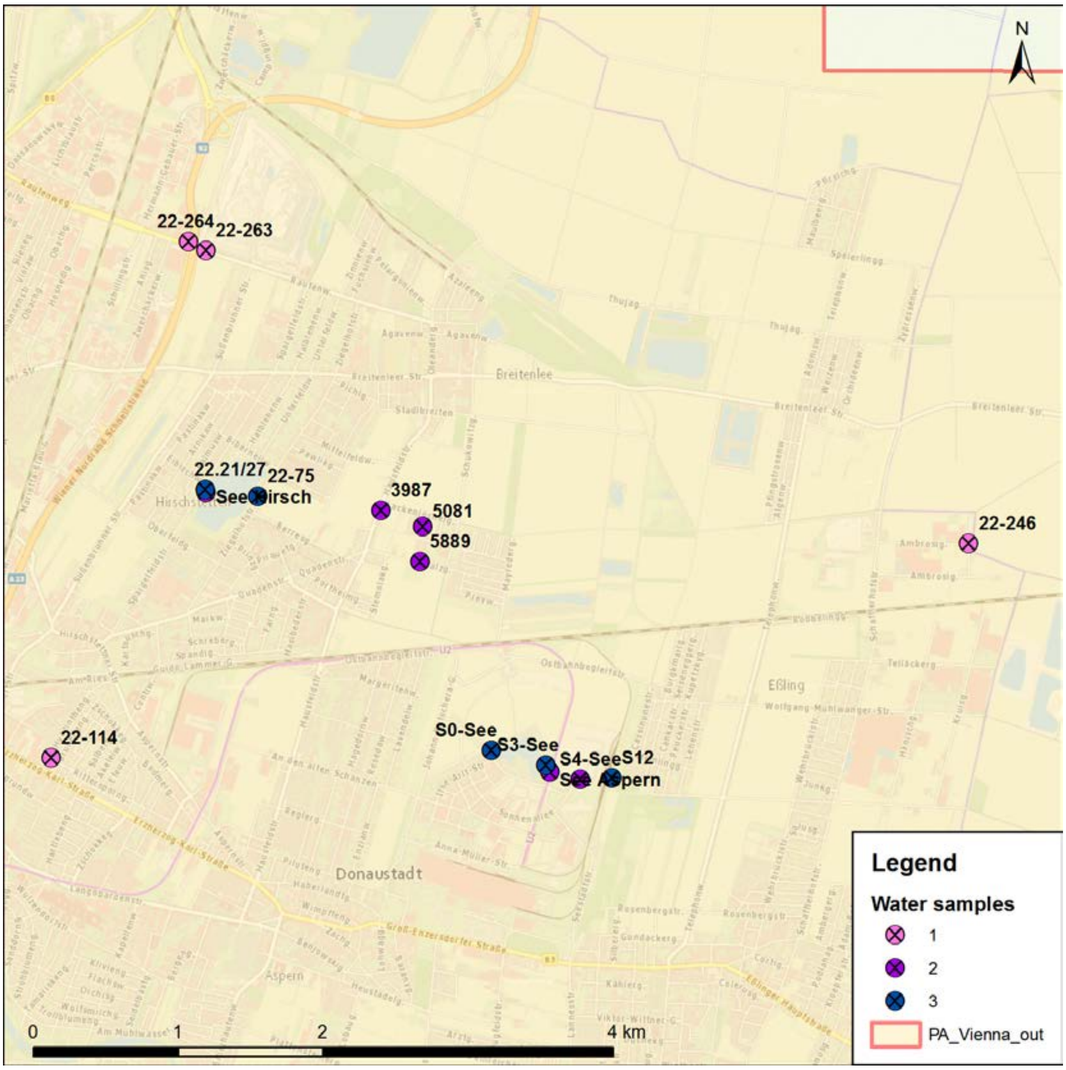


Figure 6 Number of samples taken from 2 lakes, 3 abstraction wells and 10 observation wells in the pilot area Vienna.

The first field trip focused on observation wells with installed WTFs to measure groundwater temperatures. However, the flexible tube of the suction pump did not fit into the two wells 22-4 and EW3 with a small diameter and therefore they were excluded from chemical analysis. After this first field trip, LP-GBA gained information from the Municipal Department for Water Engineering in Vienna (MA45), that surface water bodies might influence the groundwater chemistry downstream. LP-GBA wanted to investigate this hypothesis and therefore focused on wells surrounding both lakes “Hirschstettner Teich” and “Asperner See” for the remaining field trips. Therefore, three extraction wells located downstream of Hirschstettner Teich (5081, 3987 and 5889) were included in the remaining field trips. These wells are used for a groundwater heat pump (5081) and for irrigation (5889 and 3987). Table 3 provides an overview of the water samples taken in the pilot area Vienna.

Table 4. Overview of groundwater water samples taken for chemical analysis in the pilot area Vienna.

	Field trip	07.02.2018/ 08.02.2018	17.05.2018	31.07.2018
Sampling location	**Pump / Name**	**Suction pump**	**Submersible pump**	**Submersible pump**
Observation well	22-114	x		
Observation well	22-246	x		
Observation well	22-263	x		
Observation well	22-264	x		
Observation well	S0-See	x	x	x
Observation well	S3-See	x	x	x
Observation well	S4-See		x	x
Observation well	S12	x	x	x
Lake	Lake Aspern		x	x
Observation well	22.21/27	x	x	x
Observation well	22-75	x	x	x
Lake	See Hirsch		x	x
Extraction well	5081		x	x
Extraction well	3987		x	x
Extraction well	5889		x	x

Before the field trips, the department of Geochemistry of LP-GBA calibrated all WTW sensors. In the field, at first, the pumps removed the standing water column in the wells to get fresh groundwater for sampling. Sampling depth for all observation wells was the middle of the saturated aquifer, derived from water level measurements. Surface water was collected with a surface water sampler. Figure 7 shows sampling equipment used in the pilot area Vienna. Sampling bottles, measuring cups and the surface water sampler were rinsed three times before getting filled with sampling water. Sampling water was injected into the bottles using a syringe and a membrane filter with a porous space of 0.45 µm. At each sampling location one 250 ml and one 50 ml plastic bottles were filled. After filling the small bottle with sampling water, 1 ml of nitric acid was added to preserve the sample. The lids were placed carefully on the brimming bottles to ensure no air bubbles were left inside. A cooling box stored the filled sample bottles during the field trips. Second task in the field was to measure on-site parameters of water samples inside measuring cups. Testing probes for oxygen content and oxygen saturation, electric conductivity, pH and reduction potential were placed inside the measuring cup filled with sampling water. The testing probe for oxygen content and oxygen saturation also measures temperature, which was additionally noted. The technicians entered on-site parameters to the sampling sheets shown in Figure 7a. After field work, all filled sample bottles were stored in a refrigerator until the department Geochemistry at LP-GBA performed the chemical analysis.

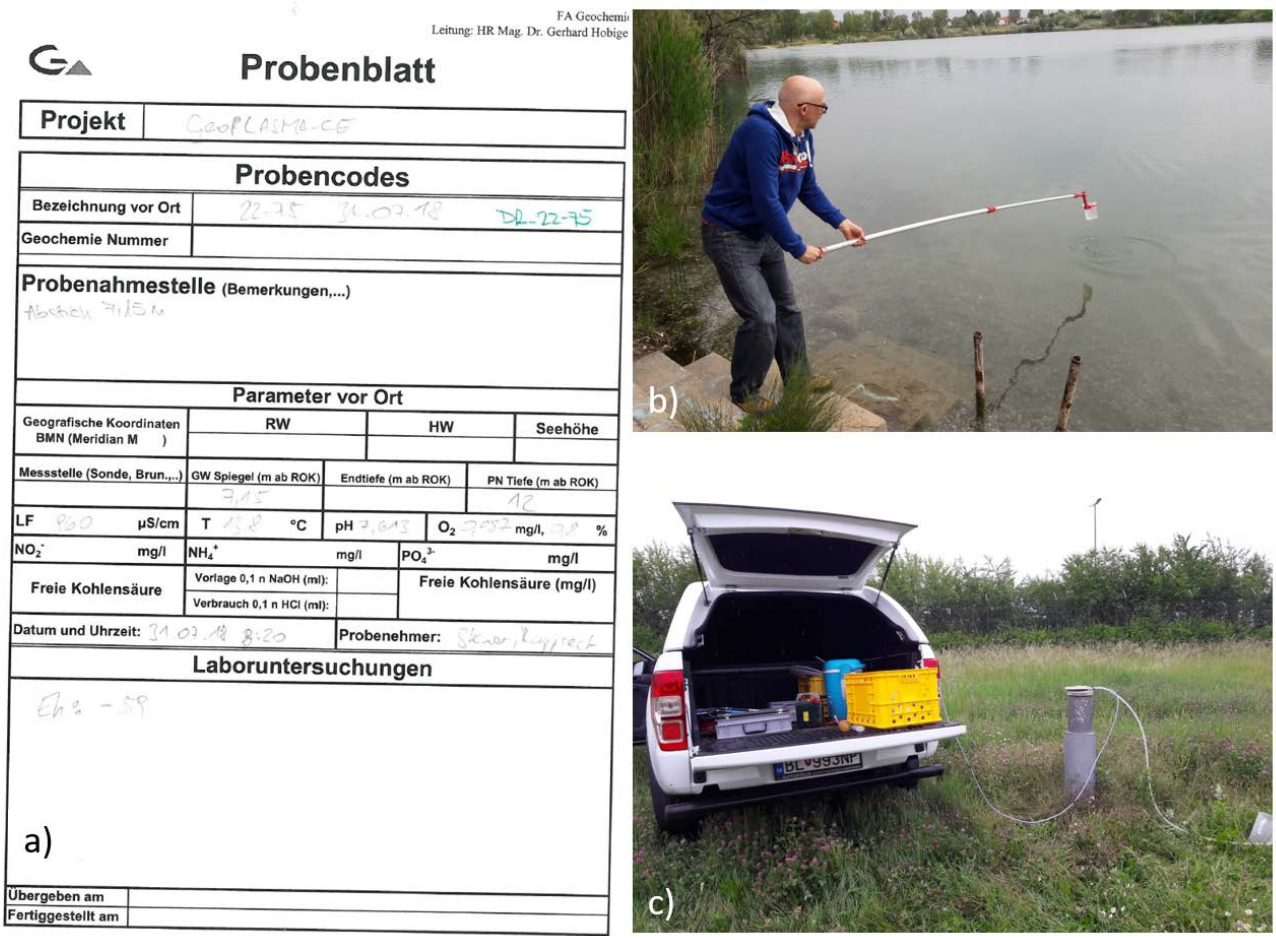


Figure 7. Groundwater sampling. a) Documentation of on-site measurements. b) Sampling equipment – Surface water sampler. c) Sampling equipment – Submersible pump inside well.

4.3. Thermal rock properties

4.3.1. Method of thermal rock property measurements

Thermal rock property measurements compiled data of:

- Thermal conductivity (λ) [W/mK]
- Thermal diffusivity (a) [m²/s]
- Volume heat capacity (cp) [J/m³K]
- Soil moisture [m³/m³]
- Temperature [°C]

Measurement device for the first three parameters was the ISOMET-"Heat transfer Analyser – Model 2104". This is a portable instrument for the direct measurement of thermophysical properties. The instrument measures the temperature response of a material to heat flow impulses. Electrical heating excites a resistor heater, which is in direct contact with the sample. Thermal conductivity and volume heat capacity are evaluated from sampled temperature records as a function of time. The instrument then calculates the thermal diffusivity. Since only sediment outcrops occur in the pilot area Vienna, the needle-probe measurement kit (Figure 8) for soft materials was used for measurements.

Soil moisture and temperature result from measurements with an Em50 data logger in combination with its soil moisture and temperature sensor (5TM) from Decagon Devices' ECH_2O System (Figure 8). The sensor determines the water content by measuring the dielectric constant of the material. Methods behind is the capacitance/frequency domain technology. An on board thermistor measures the temperature.

Executing the measurement, both sensors, the ISOMET needle probe and the 5TM sensor, are carefully pricked into the sediment. All measurements were executed in-situ in the outcrop without application of thermal conductivity pastes. In addition, some samples from selected sediment bed were taken for laboratory investigations at the raw materials department at the GBA. Those additional investigations include screening curves and the mineralogy of the sediments derived with XRD (X-ray diffraction). Whenever possible, both sensors were placed at the same spot. The 5TM sensor is much more fragile compared to the ISOMET needle probe and could not be used in densely bedded sediments. For according test-sites are no temperature data available. Measurement durations are then up to 20 minutes in total. Technicians noted the results in the field and transferred them to the GeoPLASMA-CE database.

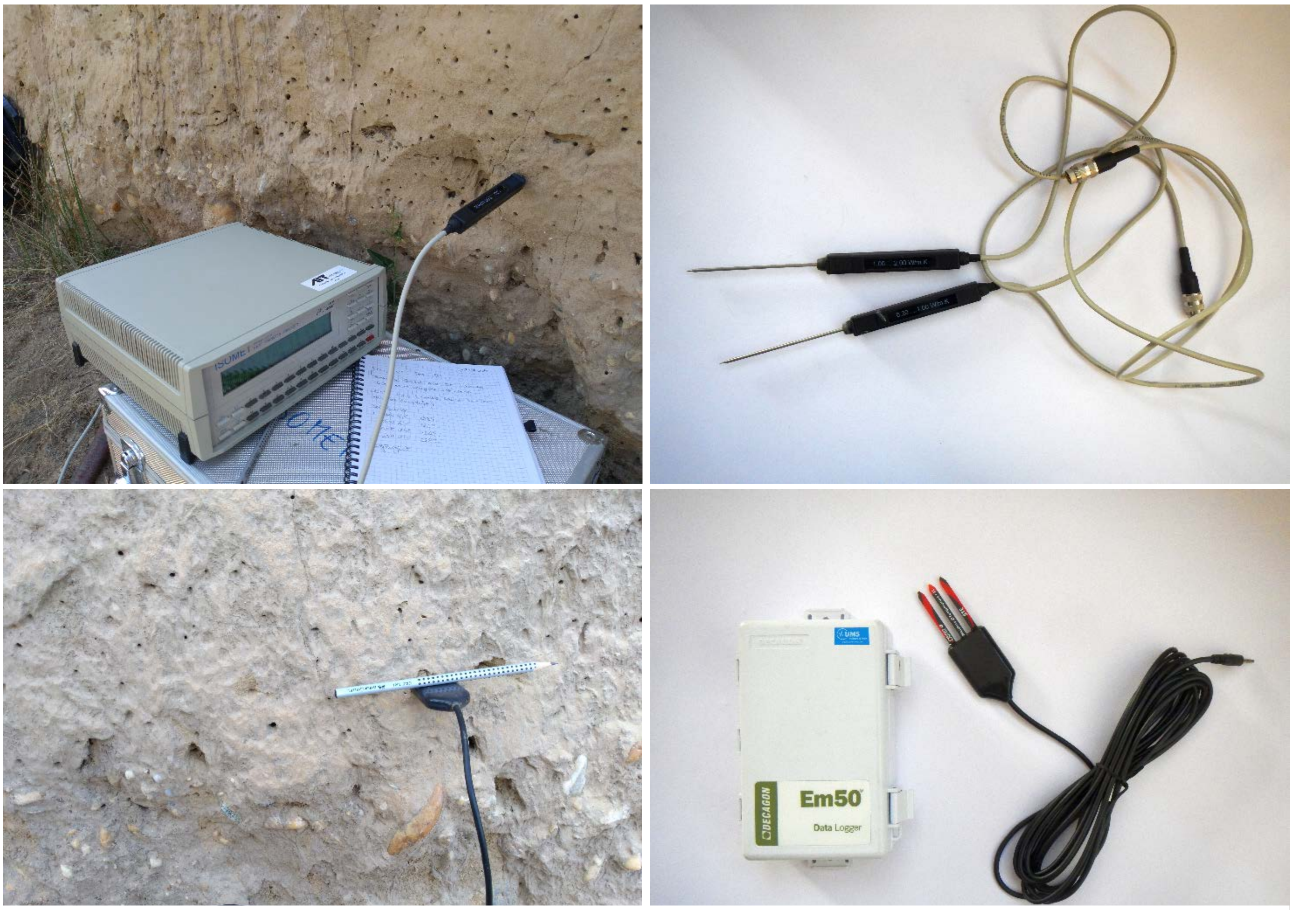


Figure 8 Measurement devices for the determination of thermophysical properties in the pilot area Vienna. Top left: The Isomet 2104 during measurement. Top right: Needle probes used for the investigation of unconsolidated rocks. Bottom left: EM50 data logger during measurement. Bottom right: EM50 data logger with soil moisture and temperature sensor.

4.3.2. Documentation of thermal rock property measurements

Figure 9 and Figure 10 show the outcrops, where LP-GBA performed thermal rock property measurements in the pilot area Vienna. Table 4 summarizes the number of thermal conductivity and soil moisture measurements.

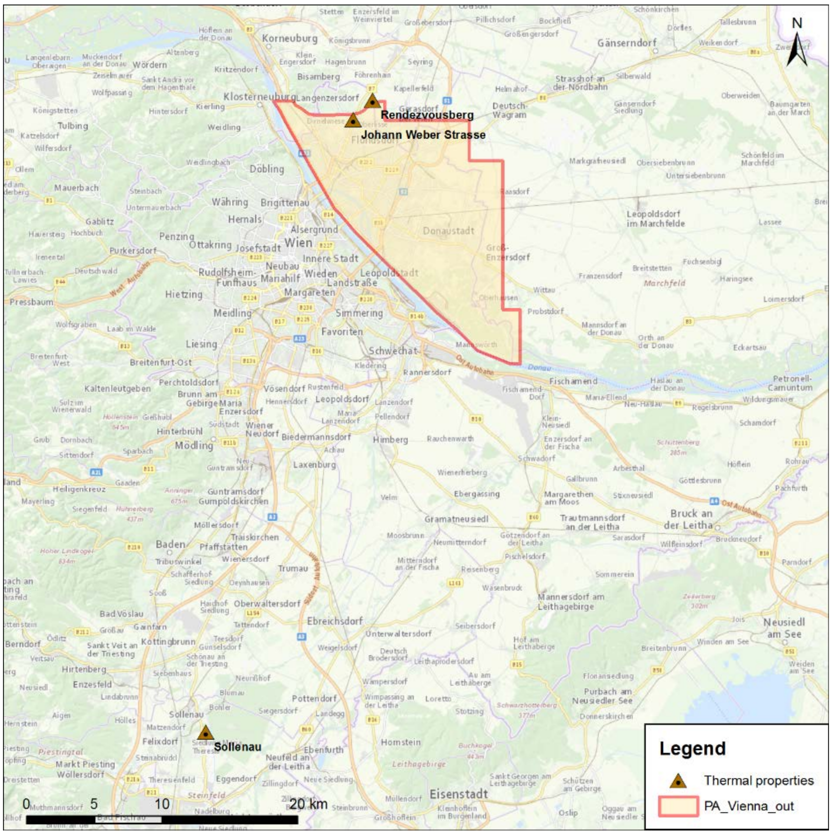


Figure 9 Location of thermal rock property measurements in outcrops in the pilot area Vienna.

Table 5. Overview of the measurements of thermophysical properties in the PA Vienna

Outcrop PA Vienna	Date	Measurements		
		Thermal conductivity	Soil moisture	Additional investigations
Sand pit “Rendevouzberg”	09.07.2018	3	3	Screening curve and mineralogy for 1 sampling point
Construction site “Johann-Weber Straße”	13.07.2018	2	1	Screening curve and mineralogy for 1 sampling point
Sand pit “Sollenau”	20.07.2018	4	4	Screening curve and mineralogy for 1 sampling point

For the performance of thermophysical property measurements LP-GBA investigated three outcrops. The selection of outcrops was depending on their availability, since the pilot area Vienna lacks in appropriate sites due to the high building density of the city. Two available outcrops, a sandpit in the north of Vienna (*Rendezvousberg*) and a construction site in the 21th district (*Johann-Weber Straße*) are directly in the pilot area Vienna. The third outcrop in *Sollenau* is outside the PA Vienna but has sediments of the same depositional environment and stratigraphy. Table 4 summarizes date and measurements performed for the pilot area Vienna. Figure 10 presents an overview of the sites. All measurements were performed as described in chapter 4.3.1. The two different needle probes had a thermal conductivity range of 0.20 – 1.00 W/mK and 1.00 – 2.00 W/mK. The first measurement was always executed with needle probe 1.00 - 2.00 W/mK. In case the values were lower than 1.00 W/mK, the measurement was repeated with the needle probe 0.20 - 1.00 W/mK. All sampling points had at least two measurements. The department Raw Materials of GBA additionally investigated the mineralogy and provided screening curves for selected samples. All data are available via the database of the pilot area Vienna (Deliverable D.T3.2.1, for more information about the transfer to the joint GeoPLASMA-CE database see chapter 5.2).

Figure 10. Pictures of the investigated outcrops in Vienna. Top left: Rendezvousberg; Bottom left: Sollenau; Right: Johann-Weber Straße

5. Data processing

5.1. Groundwater temperature measurements

The groundwater temperatures were transferred into two MS Excel databases, one for manual measurements and one for automatic measurements.

For quality management, LP-GBA calibrates new equipment using a highly precise temperature sensor Testo “Hochpräziser Tauch-/Einstechfühler” and the handheld instrument Testo 735-2. All well dippers had been calibrated previously to GeoPLASMA-CE, and the new WTFs were calibrated with the same highly precise temperature sensor. The procedure was a 4-point-calibration with temperature steps 5 °C, 10 °C, 15 °C and 20 °C in a water bath. Based on temperature measurements of the calibration device Testo and the sensors of the WTF, we determined a calibration equation for each temperature sensor in MS Excel. Figure 11 shows an example of the calibration results for WTF 22-223 temperature sensor 1. The calibration equations for each sensor were applied to the temperatures measured in the field and only the calibrated temperatures were entered in the joint database as described in the following chapter.

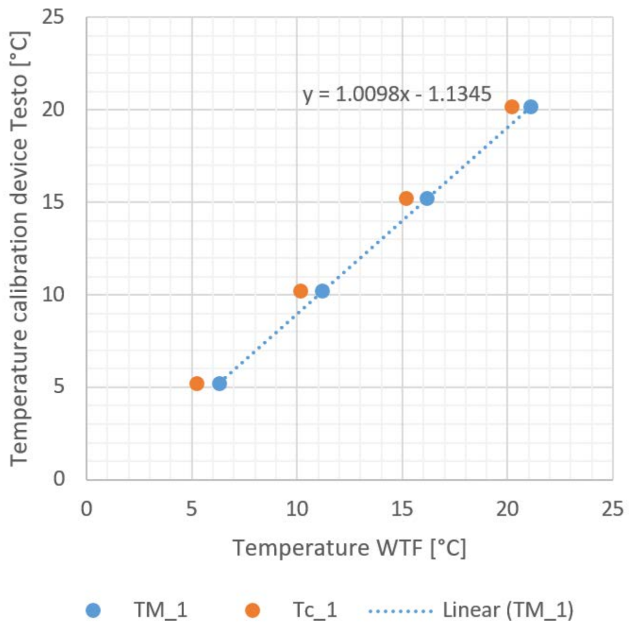


Figure 11 Temperature measurements of sensor 1 from WTF 22-223 compared to measurements of calibration device Testo before (blue dots) and after (orange dots) calibration and calibration line (dotted line) with calibration equation.

5.2. Groundwater chemistry analysis

The department of Geochemistry of LP-GBA analysed all water samples and delivered the results as Excel-Sheets. Project team members of GeoPLASMA-CE afterwards compiled the data in one MS Excel database for further data analysis. Before the assessment of the data regarding to possible risks for shallow geothermal energy applications, the cation anion balance was checked. The ion balance was below 1.9 % for all measurements and therefore stayed in the threshold stated in the workflow of ±2 % for 3.0 – 10.0 meq/L.

5.3. Transfer of field data to the joint databases

In a last step, the processed field data were summarized, documented and transferred to the following databases:

- Metadata database of relevant input data (D.T3.1.2) for a full documentation of the achieved datasets.
- Key value database for publishing the achieved results (D.T3.2.1).

The metadata description of the produced datasets follows the joint concept of geodata management, which is described in Deliverable D.T2.3.1.

The summarized datasets, shown in the key value database, are characterized by:

- Number of individual measurements (≥1)
- Presentation of either alpha-numeric (e.g. <0,01 mg/l) or numeric values
- The dataset is characterized by a single or mean-, minimum- and maximum value (in case of at least 2 single datum points).
- All presented values are allocated to a measurements period, a surface location and a depth interval of the measurements.

The key value database of field measurements also contains links to corresponding documents of raw data.

6. Results

6.1. Groundwater temperature measurements

Analysis of Groundwater temperatures in the pilot area Vienna, show a – partly – large anthropogenic impact on the groundwater temperature regime. All investigated impacts (sewage system, district heating system and open loop systems) increase groundwater temperatures, see Figure 12. At Locations, where air temperature was the only influence of groundwater temperatures that could be identified, the mean temperature is 12.4 °C and the amplitude is below 2.6 °C. Groundwater wells located downstream of a lake (Hirschstettner Teich or Asperner See) have a mean temperature comparable to the "natural" locations, but higher amplitudes. Anthropogenically influenced locations show an antithetic pattern, with high mean temperatures (15.0°C average) and low amplitudes.

Understanding these correlations between mean temperature and amplitude can further be used to evaluate possible influences on the groundwater temperature in unknown locations. This will be applied to the already existing temperature data from other sources in the pilot area Vienna.

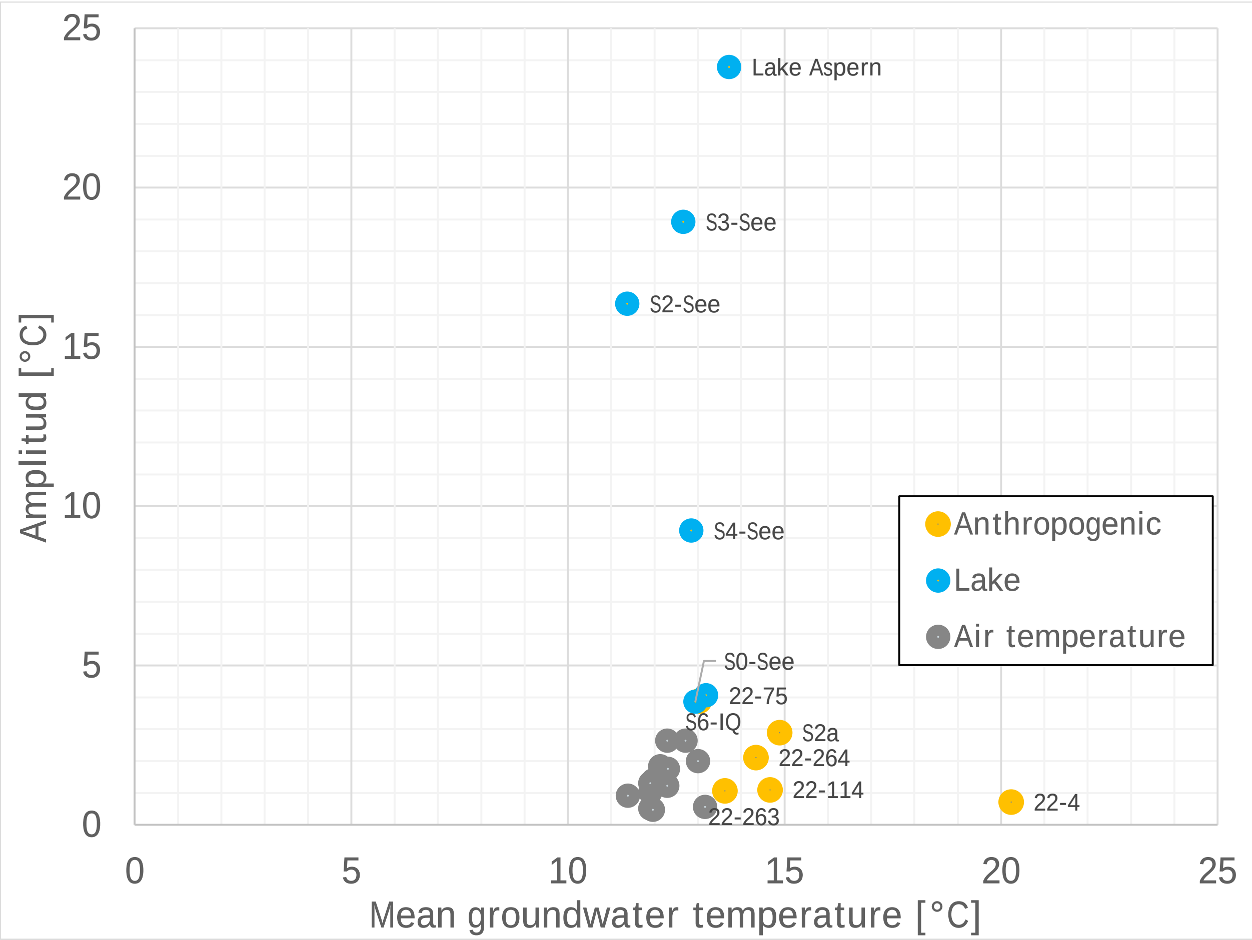


Figure 12. Mean temperatures and amplitude of entire measurement campaign for observation wells and lakes measured by LP-GBA. Classification shows main influences on the temperatures.

6.2. Groundwater chemistry analysis

The groundwater chemistry data was implemented into one MS Excel database. First results show no significant difference between parameters relevant for GeoPLASMA-CE derived from samples taken with the suction pump and with the submersible pump. Therefore, analysis of the groundwater chemistry also includes data from samples taken with the suction pump.

The presentation of the results in Figure 13 and Figure 14 only focuses on the main outcomes, important for the workflow to determine problematic groundwater bodies for shallow geothermal energy systems in GeoPLASMA-CE. Both figures show box plots (including minimum, maximum, 25th and 75th percentile and median) of sampling locations with comparable results. The chemistry of surface water bodies also influences the groundwater in their vicinity downstream, similar to groundwater temperatures, which are also affected by lakes. Despite their general similarities, such as pH-value and oxygen content, the two lakes in the pilot area Vienna also have some differences. Iron and manganese contents e.g. are higher downstream of Hirschstettner Teich than in the vicinity of Lake Aspern, see Figure 14. The differences may result from the different age of the lakes and/or a treatment facility of a contaminated site upstream of Hirschstettner Teich (location 22-75).

The working thesis, that lakes impact the groundwater negatively regarding the suitability for shallow geothermal energy applications could not be verified with these field measurements.

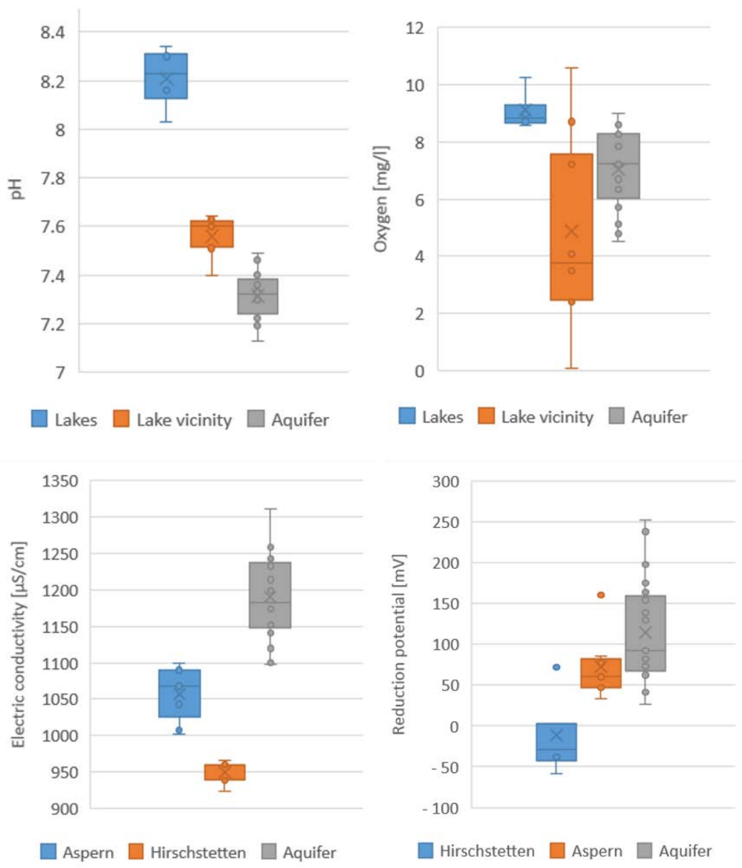


Figure 13. Chemical analysis of selected on-site parameters. Box plots group sampling locations with comparable results.

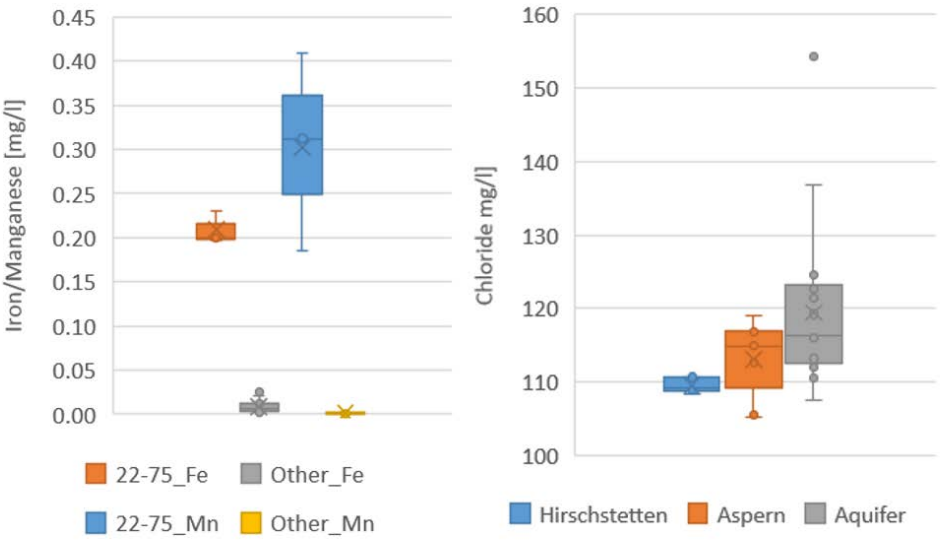


Figure 14. Iron (Fe), manganese (Mn) and chloride content. Box plots group sampling locations with comparable results.

6.3. Thermal rock property measurements

Thermal conductivity measurements lie in the expected range of values and are comparable with values from look up tables like those of the German VDI-standards. Compared with look-up tables the GeoPLASMA-CE investigations allow a more precise calculation with the measured thermophysical rock properties. Further investigations at different seasons would improve the data quality and would enable a correlation with soil moisture results.

7. Summary and conclusions

During the GeoPLASMA-CE project, field measurements in the pilot area Vienna focused on groundwater temperature, chemical groundwater properties and thermal rock properties of sediments. The key value database includes a total of 236 measurements and links to raw data. Figure 7 provides a short summary of field measurements included in the database.

Number of measurements	Input parameter
9	Thermal diffusivity
9	Thermal conductivity of saturated rock sample
9	Heat Capacity
31	Groundwater: pH value
31	Groundwater: Electrical conductivity of water sample
31	Groundwater: Eh
31	Groundwater: Content of O2
38	Groundwater temperature (single measurement, time series)
47	Groundwater level
236	**Total**

Figure 15 Number of field measurements entered in the GeoPLASMA-CE key value database for the pilot area Vienna.

The field measurements not only led to a better understanding of the groundwater and thermal properties of the sediments, but also revealed a few small shortcomings in the used methods. Lesson learned for the automatic groundwater temperatures was, that it would be good to have an additional pressure sensor to measure the water level. Measurements would then include information about the depth of the temperature measurements below the water level for each data point. Since the groundwater body Marchfeld in the pilot area Vienna has little fluctuation of the water level - around 50 cm in each of the last three years - this can be neglected. The incorporation of the pressure sensor to the WTF would have also needed further adjustments of the program and layout of the logger. However, it would be favourable to assign a depth below water level to each temperature measurement and thus allow a more detailed analysis of the temperature data. To consider this method for future projects in other aquifers, with higher fluctuations of the water level, it would be important to improve the set-up of the WTFs and include pressure sensors.

Thermal conductivity measurements with the used hand-held measuring device are favourable for unconsolidated rocks. Advantage of this method is the in-situ measurement, where the original storage density of the sediments remains original. Comparable values result from a consistent measuring arrangement. For the pilot area Vienna all sites had the same measuring arrangement to provide this consistency. Nevertheless, the quality of some measurements is suboptimal since the placing of the needle probe can create air inclusions between the sample and the probe. For future measurements, it would be favourable to improve measurements with the use of a thermal conductivity paste. Before application, a validation of the use of a thermal conductivity paste is important.