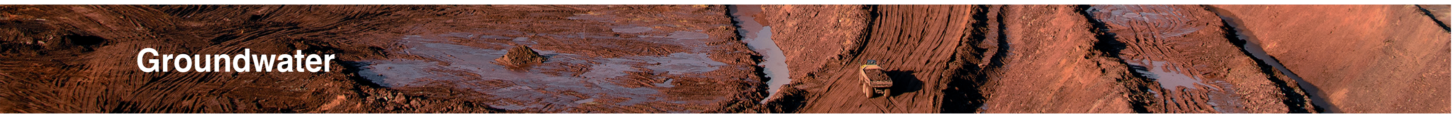
High-performance measurement technology in the water industry

Groundwater

Ensuring good water quality, monitoring and regulating water levels, checking pressure conditions in water pipelines, and measuring the fill levels in tanks – measurement technology plays a major role in the water industry. With its extensive expertise and many years of experience, KELLER AG für Druckmesstechnik is able to offer a wide range of pressure sensors for water-industry applications.

Nothing runs without water! After all, water isn't just one of the great elements; it's also vital for our survival. Water is both a foodstuff and a necessary part of the process for growing food and maintaining livestock. Water also keeps industry moving as a coolant, a means of transport and a component of power generation processes. In other words, without water, our economy would come to a virtual standstill.

Water should therefore be viewed as essential and irreplaceable. Water is not available in unlimited supply, which is why we are all obligated to use it efficiently and carefully – and not just because of economic interests. Reliable and accurate measurement technology is extremely important here, and KELLER AG für Druckmesstechnik has been doing its part by ensuring reliable pressure measurement in the water industry for more than 45 years now. This is accomplished by the use of level sensors, data loggers, remote transmitters and display units that monitor water supply systems, sewage systems, groundwater levels and surface water. This brochure offers an in-depth look at cost-effective solutions for water applications that are based on the extensive H2O expertise at KELLER and the knowledge accumulated by customers over many years.



Groundwater

Challenges in the water industry

Water is the most common chemical compound on Earth, covering more than two-thirds of its surface. This is also why Earth is referred to as the blue planet. At the same time, most of this water cannot simply be used as desired, which is why the creation of a solid and reliable water supply also always requires efficient processing of wastewater, groundwater and surface water.

Despite its abundance, water is a finite resource and we need to be able to work with what we have of it, regardless of how many people there are on the planet. Approximately 2.1 billion people around the world still do not have access to safe drinking water, and more than 800 million don't even have a basic water supply system.[1] In addition, polluted and contaminated water continues to cause repeated outbreaks of epidemics, and the global ecosystem is increasingly coming under attack from water pollution. This means that it is of crucial importance to all of us to not only safeguard water supplies but also ensure the sustainable utilisation of this most valuable resource, regardless of the application in question.

Ensuring a reliable supply of drinking water and implementing effective environmental protection measures are not the only challenges associated with water management, as the illustration above shows. Indeed, if we don't come up with solutions to everyday problems, we'll hardly be able to address the major issues. Yet we must address all challenges large and small if we are to continue to benefit from water in every conceivable way. Efficient and effective water supply and monitoring solutions are needed everywhere around the world – and these solutions must be based on accurate and reliable measurement technology.

1: UNICEF/WHO: «Joint Monitoring Programme Report: Progress on Drinking Water, Sanitation and Hygiene 2017 Update and Sustainable Development Goal Baselines»

Groundwater normally originates from rainwater that seeps into the soil; other sources are rivers and lakes. Water can also be added artificially, however, by means of infiltration using infiltration ponds, special collection trenches or injection wells, for example. As is the case with water above ground, the flow of groundwater is also influenced by gravity and moves in the direction of the steepest gradient, or through the most permeable soil layers. Groundwater movement is usually very much slower than the flow of rivers and streams, however, in some cases amounting to only a few metres per year. Groundwater flows are driven by the pressure forces created by the weight of water itself, whereby the strength of these forces also determine flow rates. Groundwater is part of the water cycle, whereby the time it remains in the ground ranges from less than a year to millions of years. If the groundwater horizon penetrates the land surface, the groundwater will be released in springs and flow into surface water.

Groundwater changes as it flows beneath the earth: If it absorbs carbon dioxide, for example, it reacts with underground limestone minerals and becomes harder. It's also filtered as it flows, leading to the elimination of microorganisms such as bacteria and viruses over time.

Groundwater and groundwater protection

Groundwater is classified as a protected resource in the EU, where it is monitored by authorities at groundwater monitoring stations. Excessive use of fertiliser and pesticides in agriculture and high concentrations of pollutants at contaminated sites pose a danger to groundwater quality. Some 300 million people around the globe cover their water requirements with groundwater.

Since 2002, GRACE satellites have enabled rough measurements to be taken of increases and decreases in groundwater levels. Because it's so important, groundwater needs to be more accurately monitored, however. Since 2007, the Polish Geological Institute has been using KELLER DCX-22 data collectors. The measurements taken with these loggers need to be read on-site, however, which is not easy with this application.

That's why a combination of 36 XW level sensors and GSM-2* remote transmitters have been used in place of the loggers for several years now. It's a perfect solution for fully automated data collection in remote areas. The measuring instruments are usually placed in special well pipes known as piezometers. Thanks to its stainless steel

*Box with mobile communication unit (left) and GSM-2**

Piezometer

* The GSM-2 remote data transmission unit was refined and then replaced by the new ARC-1 unit: www.keller-druck.com/arc-1

housing, the GSM-2 is extremely robust and requires very little energy – attributes that are ideal for customer requirements in this area. There are now 350 groundwater monitoring systems in operation in Poland. These systems store their measurements with the help of GSM-2 modules and forward data on water level and temperatures directly to the main control station and central database located in Warsaw.

The GSM-2 module enables data transfer via GSM/GPRS by using SMS, FTP or e-mail communication. The modules also store the collected data in a buffer with a capacity of 57,000 samples, which increases the security of the collected data. The barometer installed inside the modules enables the use of a capillary free, extremely stable absolute pressure sensor for water level measurement

The PAA-36 XW level sensor is perfect for this. The unit has an error band of only 0.05% FS (0 - 40 °C), which means it can measure the groundwater level precisely. As an additional option, the water temperature can be measured using a Pt1000 sensor with an accuracy of 0.1°C. The low-voltage electronics system requires a voltage supply of only 3.2V, which makes for very low electricity consumption. When the sensor is used with the GSM-2, its internal battery therefore only needs to provide a very small amount of additional power. This means data can be collected and transmitted over a period of several years without having to replace the battery. The lack of a capillary tube eliminates humidity problems, which additionally increases the reliability of the system.

Integrated GSM-2 remote transmitter*

Water tension – a very important parameter

Everyone has walked along a wet beach at some time and noticed how the wet sand wobbles like jello when stepped on several times. This may be fun on a beach, but it's no joke at a construction site or in an earthquake. Houses and streets built on drained swampland or unconsolidated soil or sediment can sink in certain situations, after which they can no longer be used. This phenomenon is known as soil liquefaction, and it can be dealt with by compressing the earth at constructions sites where new structures are to be built.

Structural damage caused by soil liquefaction

Soil liquefaction occurs when water in the earth, in most cases groundwater, cannot drain off quickly enough. This leads to a significant increase in hydrostatic pressure in the ground, which in turn causes the earth to move, and in many cases the structures upon it as well. Even minor vibrations can trigger this effect.

An earthquake that hit Christchurch, New Zealand, in 2011 showed how sandy soil full of water can turn to mush, so to speak. With a magnitude of 6.2, the earthquake itself was rather moderate, but its epicentre was within the city limits and relatively close to the surface. The soil liquefaction that occurred as a result made most of the city uninhabitable. The reason for this is that the centre of Christchurch sits atop sandy ground saturated with water that formed from an alluvial fan – a cone-shaped deposit of sediment – that itself was created by three rivers.

Such liquefaction can also occur in loamy soil or clay soil. This type of high-risk soil can also be found in the Rhine-Rhone valley, for example. Historical records exist that show what happened in Visp (Valais, Switzerland) and the surrounding area in 1855 when an earthquake of the same magnitude as in Christchurch occurred in the region. Fortunately, no one died, but the structural damage was enormous. No one seems to have learned anything from the experience, however, as the areas destroyed back then are once again densely populated today.

Sloping ground and ground next to rivers and lakes can also slide on a liquefied soil layer and cause large cracks or fissures to open. This damages not only buildings, bridges and roads but also networks for water, natural gas, wastewater, electricity and telecommunication services – and underwater tanks and manholes can start floating in the earth as well.

10 March 2011: Soil liquefaction in Christchurch after a powerful earthquake (NigelSpiers / Shutterstock.com)

Christchurch 2011: The ground turns to mush (NigelSpiers / Shutterstock.com)

Cone penetration testing

In order to prevent such scenarios as described above, the ground at construction sites needs to be thoroughly analysed before any work is planned. The cone penetration testing method was developed in the Netherlands at the end of 1950 and has been used as an economical method for soil investigation since that time. This method gives a good picture of the soil structure and the various soil layers. It is used globally in all areas where significant changes in soil bearing capacity may occur if drilling and building activities etc. are to be carried out.

Cone penetration testing involves pressing a cone-shaped tip into the ground at a constant speed. A specially equipped truck is used for the test.

The testing results are illustrated in a graph that shows the cone resistance in relation to the cone depth. Along with soil resistance, the cone sensors used in the test measure the inclination of the cone, the friction ratio, soil temperature, conductivity and water tension. The latter parameter is measured using the 21 Y pressure transmitter from KELLER.

Series 21 SY piezoresistive pressure transmitter

Y-line transmitters have a very low temperature error that's achieved by means of an additional circuit with a temperature sensor that subdivides the temperature range into fields of 1.5 Kelvin (K) each. Compensation values are calculated for each temperature field and these values are fed into the analogue signal path during operations, depending on the current temperature in each case. When viewed in this way, one could say that these transmitters always operate at calibration temperature. A high degree of vertical integration, a modular design and programmable electronics enable high-volume customer-specific production. The 21 Y series also stands out through its exceptional resistance against electromagnetic fields. In fact, the units display values that fall below the limits of the CE standard by as much as a factor of ten in the case of conducted and radiated fields. The transmitters are also extremely immune to external voltages between the housing and the electrical connection, which is particularly important when they are used with frequency converters. A high insulation voltage of 300 V also makes this product ideal for use in the roughest environments.

Special trucks used for cone penetration testing

The cone is pressed into the ground

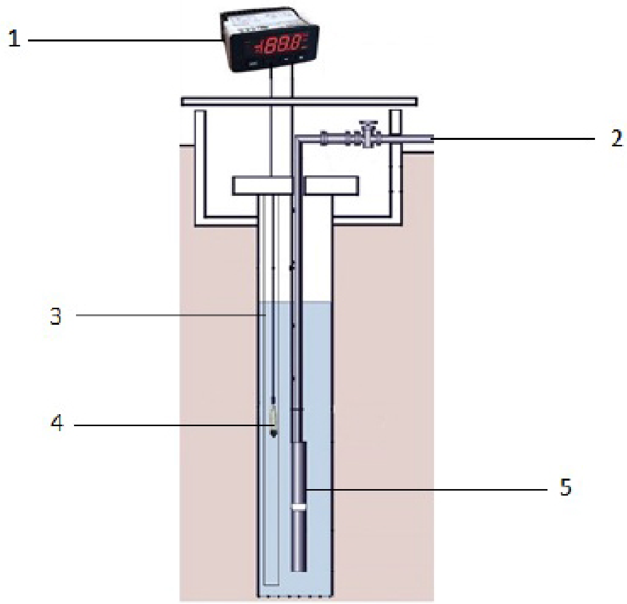
Measuring groundwater at train stations in Russia

According to the Russian “Law on subsoil” (section II, article 11, 12 7; section III, Article 27 PP), a licence for the right to extract groundwater on Russian territory may only be issued if the engineering company in question agrees to monitor the water level in each well.

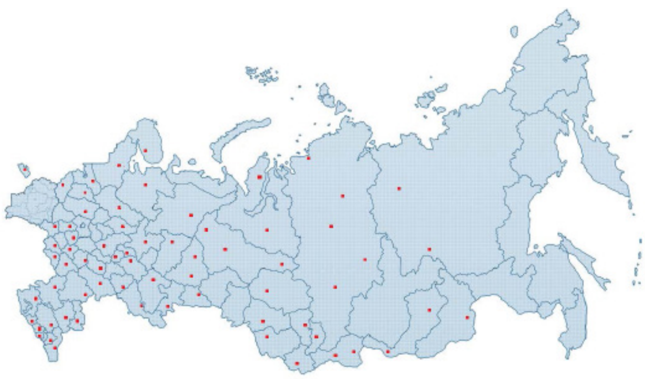
One of Russia’s largest engineering companies chose Series 26 Y level transmitters from KELLER for such monitoring activities. The sensors were installed throughout the Russian Federation, where they are used to monitor and control the consumption of drinking and technical water at key railway stations. Ultimately, the client chose the KELLER level sensors due to their very competitive prices and favourable delivery times.

Series 26 SY: Piezoresistive low-cost level transmitter

Series 26 Y pressure transmitters are used for water level measurements that need to be both affordable and highly accurate. The monocrystalline silicon measuring cell is reliably protected from the measuring medium by a stainless steel membrane. The large membrane diameter of 17 mm makes the unit especially accurate and stable, and the membrane is protected against mechanical stress by a plastic cap.



1 - Evco EVK-512 digital display
2 - Output pipe
3 - Piezometric tube
4 - KELLER 26 Y level transmitter, 4…20 mA
5 - Submersible pump



Location of wells in which KELLER transmitters have been installed

“Novageo” exploration crew

The “Novageo” exploration crew specialises in technological testing, geomechanical and hydrogeological well boring and the monitoring of the level and temperature of underground water. The crew monitors the groundwater in the Chernogorsk open-pit mine, which contains deposits of precious metals such as gold and platinum. The open-pit mining operation has already extended deep into the ground, with the lowest level located far below the groundwater level. The pit would soon be flooded if not for the nearby wells, where water is constantly pumped out.

Groundwater monitoring systems in open-pit mining

Chernogorsk is located in the Norilsk region in the northern part of the Siberian tundra. Average temperatures near the mine in the winter hover at around -31 °C, but can get as low as -45 °C. Within the framework of experimental filtration work and hydrological research, the water wells in the area were equipped with autonomous DCX-22 SG data loggers. The sensors monitor the level and temperature of underground water under perpetually frozen soil at a depth of 400-500 metres.

The sensors themselves are mounted in the lower perforated section of a column made of metal that has a diameter of 33-40 mm, whereby the sensor wires run through the column. The upper parts of the wells are frozen in permafrost. The wellheads are equipped with a protective metal covering and are connected electrically to the data loggers, which transmit their data via a K-114B converter.

The parameters of the groundwater supply are identified on the basis of the results of water level and temperature monitoring under the permafrost. These results also help clarify the filtration parameters and the characteristics of the tectonic fault line, which in turn can provide important information on the remaining deposits of precious metals.

Chernogorsk deposit

Open-pit mining in Chernogorsk

Salar de Altacama is a salt pan situated at the foot of the Cordillera de los Andes in the Atacama Desert. Created by the evaporation of a primeval lake, it is estimated to contain 27% of global lithium reserves, as well as borax and potassium salt, which is why it is one of the world's most important sites for the production of lithium brine. The valuable lithium is extracted by pumping up groundwater containing dissolved salts and guiding it into flat basins. Potassium chloride and potassium sulphate precipitate in the process, while lithium and boron remain in the solution. This brine is then sent through pipelines for further processing. The mining company Rockwood Litio that operates in Salar de Atacama uses a network of KELLER DCX-22 AA CTD data loggers in its wells.

Determining groundwater level and salt composition

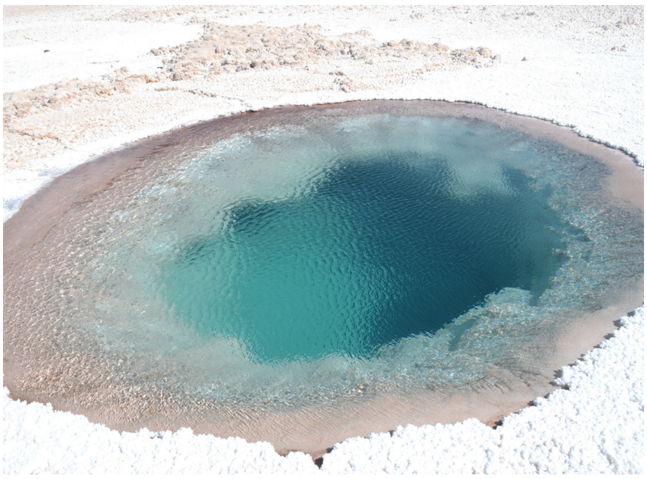
The measuring equipment determines the groundwater level and the composition of the salts it contains. Here, variations in the groundwater level are measured and compared with the volume of water extracted from the wells in order to monitor aquifer recovery following extraction as required by Chilean authorities. This procedure is necessary because Salar de Atacama is a unique and sensitive ecosystem, and excessive groundwater extraction would result in irreparable environmental damage.

Conductivity is also measured, as it is directly related to the water's salinity, which in turn makes it possible to draw conclusions regarding mineral content (e.g. lithium content) in the water.

Because the properties of the water in Salar can damage even stainless steel over time, KELLER recommended the use of special corrosion-resistant titanium sensors for the project in Salar de Atacama. The AA measurement method (absolute-absolute) was chosen due to the strong temperature fluctuations that occur. With AA measurements, changes in air pressure are measured by a separate barometer and subtracted from the hydrostatic pressure in order to calculate the exact water level. Unlike relative pressure measurements, where air pressure must be channelled up to the measuring cell in the sensor, AA measurements do not require the use of a reference tube, in which condensation would form due to the rapid alternation between high daytime temperatures and nighttime frost. The condensed water could then clog the capillary tubes and lead to incorrect measurement results.

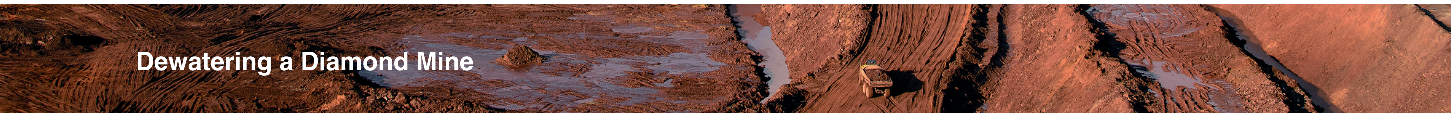
Data loggers with conductivity measurements

The CTD versions of the DCX-22 series are autonomous, battery-operated, low-maintenance data collectors which, along with the water level (pressure) and temperature, also record conductivity values over long periods of time.



Salt lake in Salar de Atacama

27% of global lithium reserves are located in Salar de Altacama



The Russian mining company Severalmaz holds the licence to operate one the of the world's biggest diamond mines – the Lomonosov Diamond Mine in the Arkhangelsk Oblast. The mine's raw diamond reserves are estimated at 220 million carats. Lomonosov became famous on 21 September 2017, when a 28.65-carat pink diamond was found there.

The area where it was discovered is part of the Karelian Craton, a large bedrock mass from the Archean Eon. Russian companies mine for diamonds in the eastern part of this region, Finnish companies in the west. The thing that makes the Lomonosov mine so special is that it contains many coloured diamonds, including pink, violet, green, yellow and brown. It also holds a large amount of high-quality colourless diamonds. This composition is unusual because it is estimated that normally only one out of every 10,000 mined diamonds is coloured.

In any case, the Severalmaz mining company has to bore wells to prevent the open-pit mine from flooding. The groundwater level and temperature are constantly monitored to ensure reliable dewatering. During winter, temperatures can fall as low as -37 °C. This harsh environment presents extreme challenges for the measuring instruments used.

Monitoring 200 meters underground

Severalmaz pumps groundwater out of the open-pit mine through several wells drilled on the perimeter. Between 2013 and 2015, the company installed KELLER DCX-16 data loggers at all 45 dewatering wells.

Data collectors with a small diameter

The DCX-16 is an autonomous, battery-powered data collector in a stainless steel housing with a very small diameter of only 16 mm. The logger can take pressure and temperature readings over long periods of time. The software it comes with makes it possible to set measuring intervals. In addition, the recorded data can be presented in the form of a graph or else converted into water level figures. The client chose this solution because the product can be used in a wet standpipe 200-300 metres underground and also has a very low error band. Thanks to their small diameter, DCX-16 level sensors can also be used at locations where every millimetre of space counts.

Lomonosov diamond mine
(Yakovlev Sergey / Shutterstock.com)

Open-pit diamond mining

One of the largest diamond deposits in the world

The Grib mine, located in Russia's Mezensky District in the Arkhangelsk Oblast, is the second biggest mine in the Russian part of the Karelian Craton, which itself houses one of the world's largest diamond deposits. Low temperatures in the region present major extreme challenges for the products used in the mine – temperatures in the area around Grib can get as low as -25 °C to -37 °C.

The "Arhangelskgeolrazvedka" exploration crew monitors underground water levels and temperature within a radius of five kilometres around the mine. The crew bored a total of 81 wells with depths of 20-270 metres between 2011 and 2014 to monitor the water levels. Each well was equipped with a water level monitoring system from KELLER that consists of hydrostatic level and temperature sensors and 59 GSM remote transmitters (GSM-2 boxes).

Savings potential with the monitoring network

Measuring points located at a close distance to one another were grouped together in order to make it unnecessary to equip each of the 81 water wells with a remote transmitter. Up to three sensors can be connected to a single box module simultaneously, which reduced costs by eliminating the need to install 22 remote transmitters.

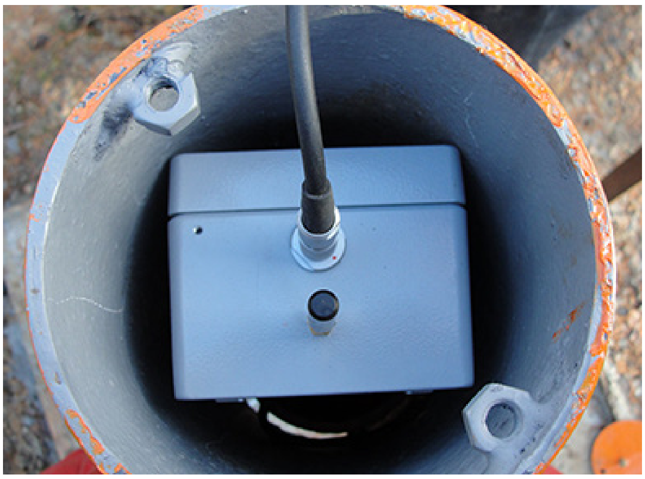
Remote data transmitter and logger in one device

When linked to a pressure transmitter or water level sensor, the GSM-2 box module* can autonomously collect up-to-date measurement values for pressure and temperature (and optionally for conductivity as well) and then transmit this data via SMS, e-mail or FTP using the GSM mobile phone network (GPRS connection).

The GSM-2* is robust, able to withstand short periods of immersion, available in different types of housings, and equipped with several sensor interfaces. The battery in one module can supply power to several level sensors if necessary. The GSM2 box collects and transfers data once a day over a period of several years in sub-freezing temperatures and can even do this with a weak or unstable signal.

As a result of this durability, the "Arhangelskgeolrazvedka" crew never had to replace a single battery during four years of operation and was able to completely forgo manual monitoring at difficult-to-reach locations. The use of an automatic water level monitoring system allowed the "Arhangelskgeolrazvedka" crew to save money that otherwise would have been spent on special purpose vehicles and additional staff.

Installation of level tubes at hard-to-reach locations



GSM-2 box remote transmitter with data logger*

* The GSM-2 remote data transmission unit was refined and then replaced by the new ARC-1 unit: www.keller-druck.com/arc-1

KELLER level sensors are used to measure static and dynamic levels of water in wells in a reliable and precise manner

Why measure well water levels?

Level measurement is of paramount importance, as it provides information on the behaviour of the well and pumping equipment. Suitable measurement and data analysis enable proactive identification of the need for preventive maintenance due to deterioration of the grooved well casing. The greater the incrustation, the less water can enter the well, causing water levels to fall. This reduces the efficiency and effectiveness of the pumps, which in turn increases electricity costs.

Level measurement in conjunction with flow rate measurement also provides information on the status of the pumping equipment and its operational efficiency. Such measurements thus make it possible to diagnose wear and tear on the pumping equipment before it fails completely, and timely maintenance in general helps avoid high repair costs and follow-up expenditure.

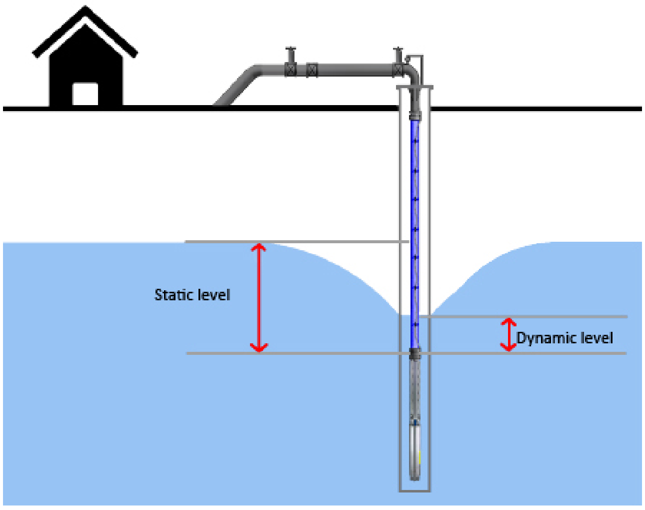
Pumping equipment generally cannot tolerate immersion in water. The measurements taken by a pressure sensor can be used as a basis for programming a frequency converter via a PLC (programmable logic controller). In this manner, the pumping equipment protects itself against level fluctuations by regulating the discharge flow.

Installation of a sheath or hose into which a sensor can be inserted ensures correct operation and cable longevity. In the case of relative pressure sensors, it is also advisable to mount a desiccant drying tube at the end of the reference tube to prevent moisture from entering the inside of the sensor.

Measurement with data loggers and remote transmission

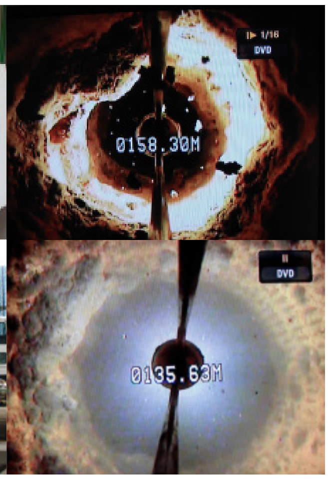
KELLER offers a wide range of level sensors with a data logger function. This setup allows measurement results to be stored in sensors for long periods of time, which makes it possible to analyse the behaviour of the well over time and thus detect problems more quickly.

The ARC-1 is a refinement of the tried-and-tested GSM-2 remote transmitter. The ARC-1 makes it possible to transmit measurement results and alerts in accordance with individual criteria, which reduces the cost and complexity of data collection and monitoring, even while ensuring an immediate response in the event of an emergency. The ARC-1 transmits data via SMS, e-mail, FTP or LoRa.



Static and dynamic level measurement

EV06 digital display



Wells with embedded groove

In the early days of groundwater measurement, a conductivity switch was often lowered into a borehole on a flat steel or plastic cable. This switch emitted an acoustic signal when it hit the water. The depth from the surface to the groundwater could thus be measured in a simple manner. The only problem with this method is that it requires someone to be at the site to manually perform the measurement.

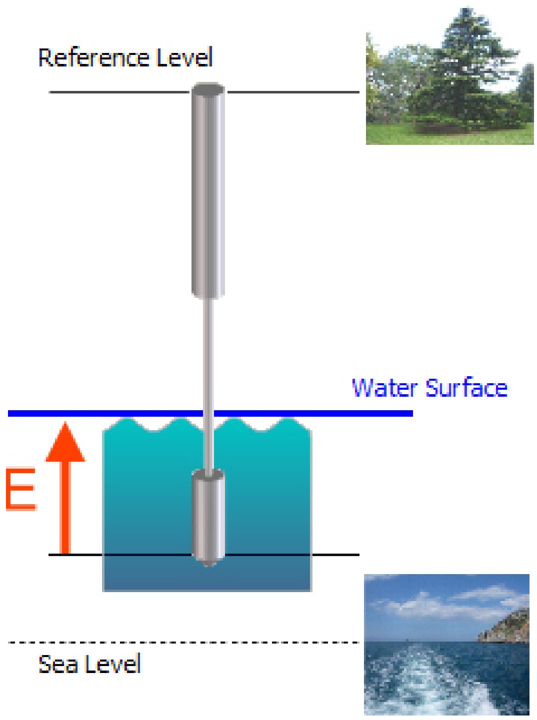
Ground water level measurement with autonomous level data loggers

These days, such measurements can be taken automatically using KELLER data loggers that function as autonomous data collectors consisting of a level sensor, a microprocessor circuit with a storage device, and a battery.

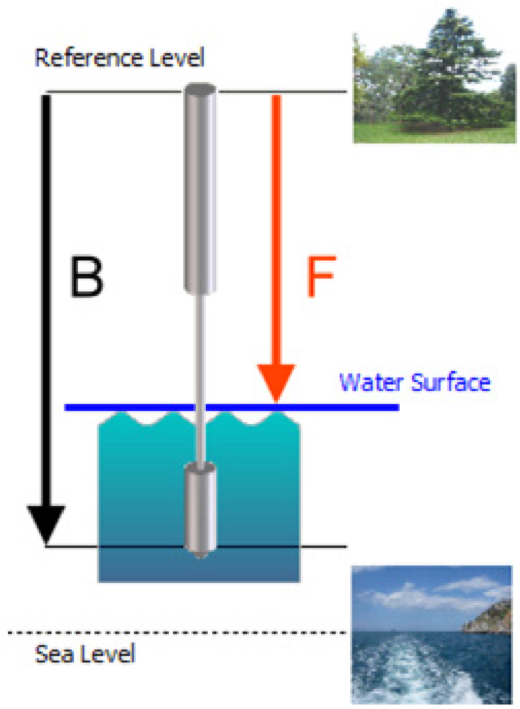
The user can set the intervals at which measurements are to be performed. After the measurement result has been saved to the internal storage device, the logger is ready to go back into action. This sleep mode enables a battery lifetime of up to ten years. Data is configured and read via a USB converter and Logger 5 software from KELLER.

The data loggers measure the water column (E) via the membrane in the submersible transmitter, as shown in the illustration below (left). However, most geohydrologists are more interested in the distance from the top of the borehole to the actual water surface level in the borehole (F), as shown in the illustration on the right. The water column is used as a basis to calculate the depth to the water surface level: The total installation depth (B) can be programmed as a passive parameter in the data logger. When the measured water column is subtracted from the installation depth, the depth-to-water surface value remains (F= B - E).

Barometric compensation is also needed in order to achieve highly precise measurements. Along with the fluid column, level sensors placed in a fluid also always measure the air column, which rests on the water. If the barometric pressure is not corrected, the measured water level will be incorrect, since a pressure difference of even one mbar corresponds to one centimetre of water level. In



Water column calculation using a membrane



Water column: "Depth-to-water-surface" other words, in such a situation the sensor would deliver an excessively high measurement value. The barometric pressure must therefore be subtracted from the hydrostatic pressure, and this can be done in several different ways. The most common method employed with conventional level sensors is to use a capillary, which is a tube in the level sensor's cable via which the air pressure can push back on the reverse side of the membrane (as is the case with the DCX-22VG, for example). This mechanical compensation of the air pressure is not suitable for every environment, however. In the event of sharp temperature fluctuations, for example, moisture can condense in the tube and impair the measurement.

In order to prevent such a problem from occurring, a second pressure sensor can be used to measure the air pressure. In this case, the current air pressure only needs to be subtracted from the level sensor's measured value to obtain the hydrostatic pressure in the water column. If such a measurement with a logger without air pressure compensation (e.g. with a DCX-22 or DCX-22SG) is to be performed, the air pressure needs to be measured separately, as combining the data later on would be a complex process that's also prone to error.

The KELLER DCX-22 AA brings together all benefits in one device. It's equipped with a second sensor at its upper end that measures air pressure. Besides taking barometric and hydrostatic readings, the logger can also perform calculations and directly store barometrically compensated water levels and depth-to-water-surface values.

The modular Logger 5 software from KELLER can be used with all KELLER data loggers. The software offers a variety of configuration possibilities and graphic depiction modes, as well as other interesting options. For example, the air pressure sensor in the DCX-22 AA can also be used for compensation in several other types of loggers that are not equipped with their own barometer.

Autonomous groundwater level measurement

Sensor in a DCX-22 AA data logger