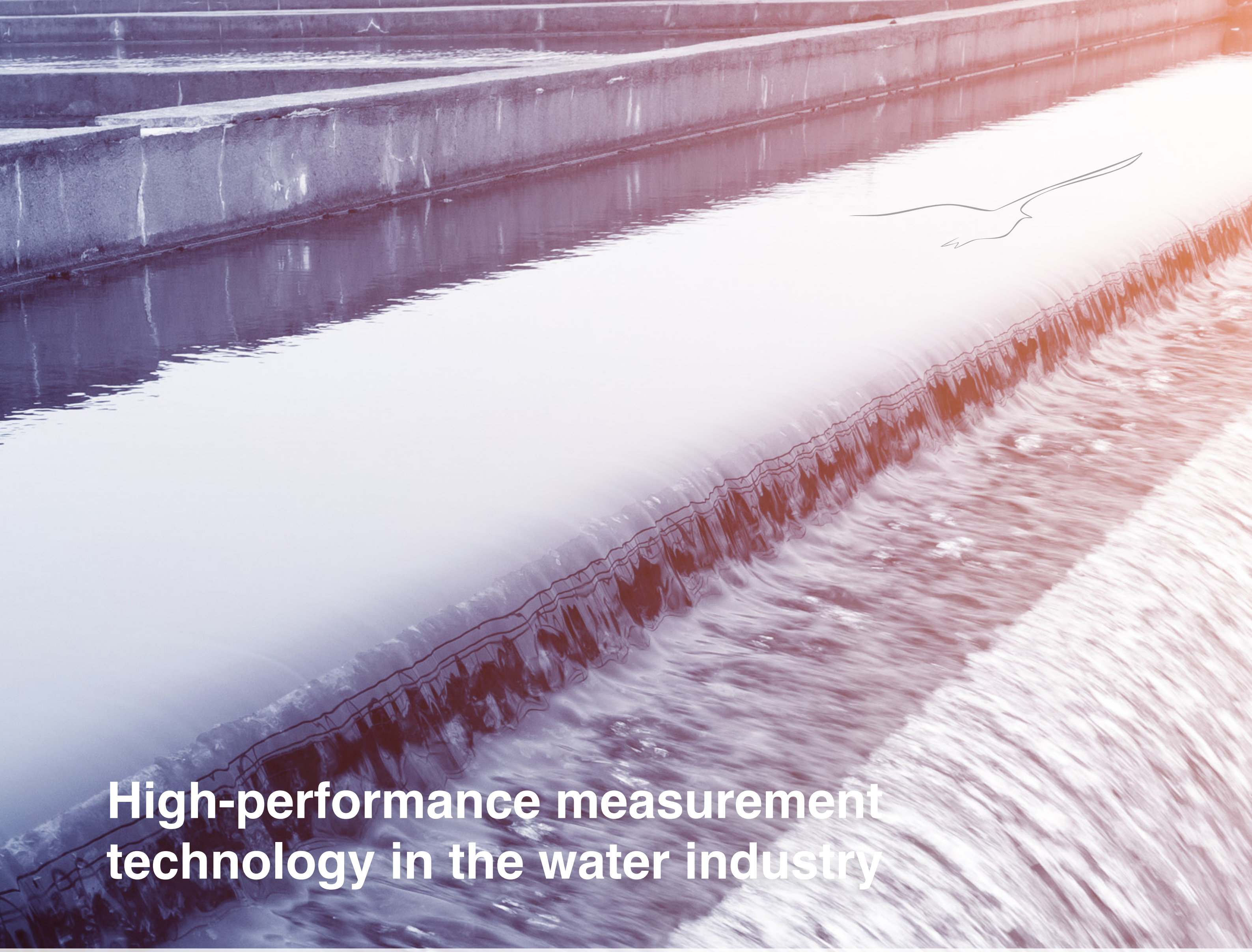
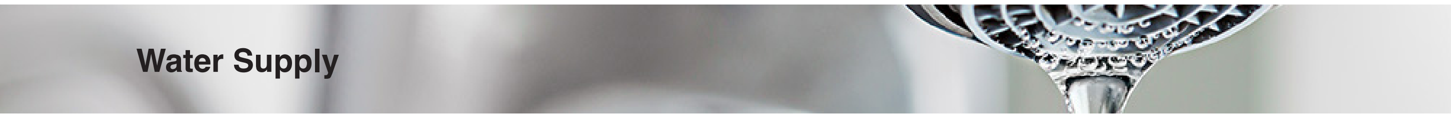


High-performance measurement technology in the water industry

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.

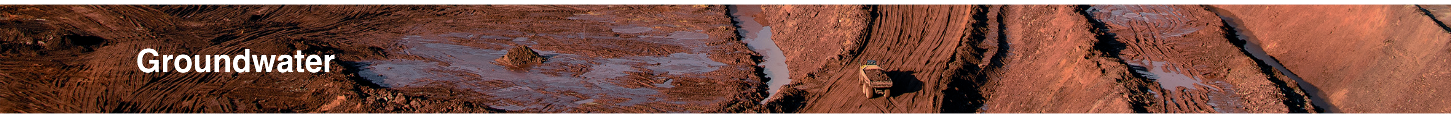
Nothing runs without water! After all, water isn't just one of the great elements; it's also vital for our survival. Water is both a foodstuff and a necessary part of the process for growing food and maintaining livestock. Water also keeps industry moving as a coolant, a means of transport and a component 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.

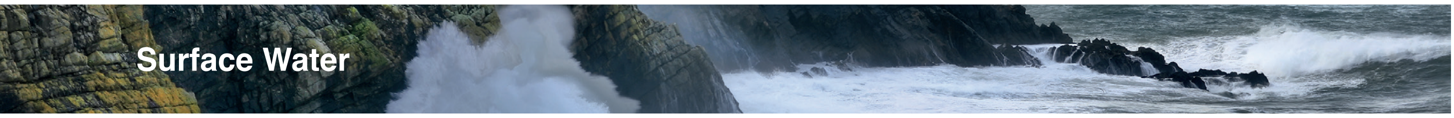


Water Supply

Sewage



Groundwater



Surface Water

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.

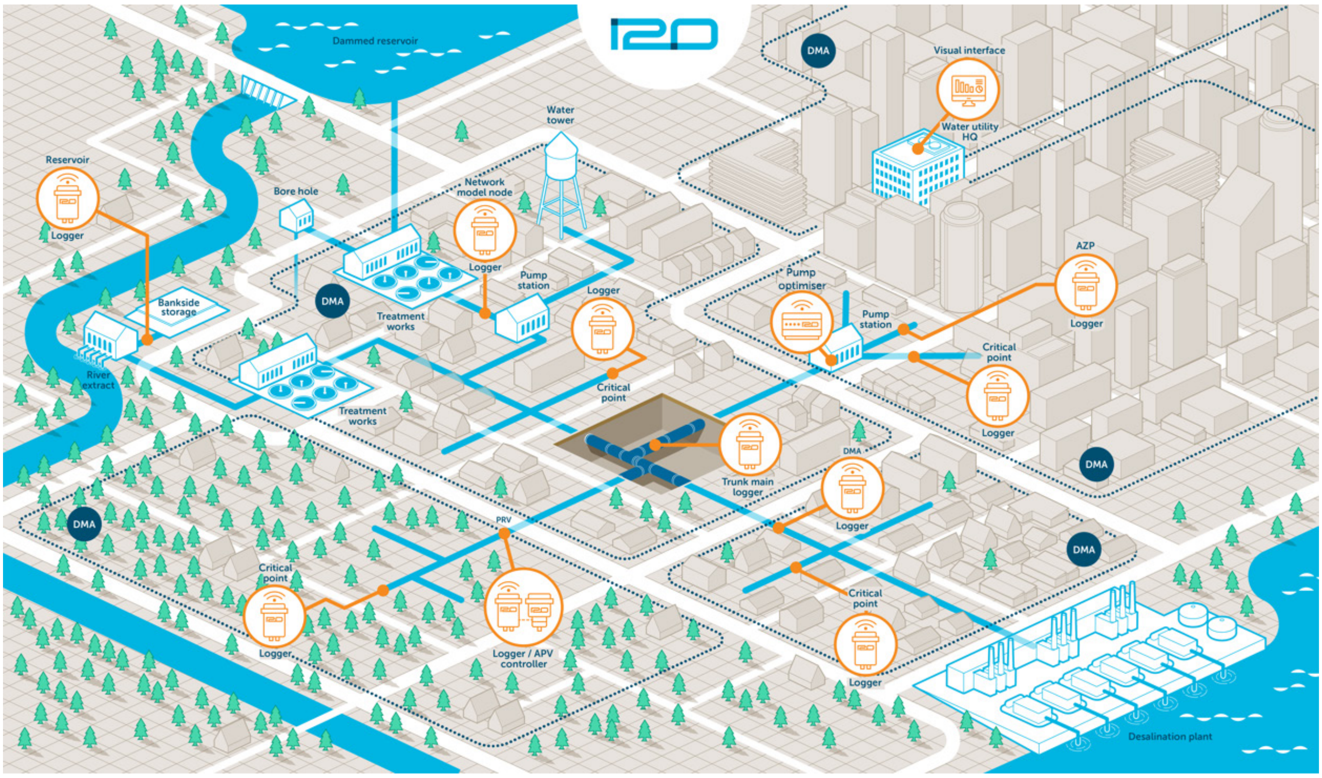
Ensuring a reliable supply of drinking water and implementing effective environmental protection measures are not the only challenges associated with water management, as the illustration above shows. Indeed, if we don't come up with solutions to everyday problems, we'll hardly be able to address the 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»

Accurate data – one of the keys to establishing intelligent water distribution networks

Many countries around the world are suffering from droughts that have lasted for several years. One would think that in such situations especially, people would use water resources wisely, if for no other reason than a sense of self-preservation. The fact is, however, that as much as 60% of the water supply in major cities like Cairo, Nairobi and Mexico City was lost to pipeline leakages in 2010. The situation in Europe is not much better. Spain and Italy suffered water losses of more than 25% in 2010, while the water-loss figure for Germany was just under 10%.[1] It can only be hoped that these numbers have declined in light of recent efforts to improve the situation. Most of the losses are due to outdated water distribution networks. For example, part of Germany's pipeline network dates back to the days of Kaiser Wilhelm, while London neglected to modernise its network for so long that new leaks now form nearly as fast as existing ones can be repaired.

Water losses generally occur when burst pipes go undetected or when cracks form in pipes, although leaky taps are also a frequent cause. This constant dripping in numerous households is hard to identify, and the losses tend to become apparent only after comparisons are made between water supply figures and the water consumption data registered by meters. Local governments often have no other choice but to pay the cost differences or pass them on to consumers. Even in a small water distribution network, a loss reduction of just a few per cent can lead to savings of tens of thousands of euros. Water losses in major cities can quickly reach six or seven figures.[2] It therefore pays to invest in intelligent measurement technology, without which it is virtually impossible to detect water losses at an early stage.



Example of a smart water distribution network

1: sbz-online: Hohe Trinkwasserverluste ("Major drinking water losses" – May 2010)
2: Berliner Zeitung: Berlins Wasserverbrauch steigt ("Berlin's water consumption is on the rise" – 28/4/2017)

One company that offers such measurement technology is i2O, which links together sensor heads from KELLER AG für Druckmesstechnik to create smart network solutions. Here, pressure transmitters provide accurate measurements for relevant points in the pipeline network. The network management system sends the processed data in predefined intervals to various nodes, which then forward the data to a control centre. The control centre analyses the data, identifies anomalies and then looks for the causes. Control parameters can be adjusted remotely if necessary. Teams of technicians only have to be sent out if defective components need to be repaired.

KELLER has been supplying sensor heads for installation in i2O data loggers since 2008. In 2012, the two companies began cooperating extensively on the development of a new range of i2O pressure loggers. The product's success is due to not only the technological advances that have been made but also the close collaboration between two extremely competent enterprises.

The new loggers needed to have a very compact design and be highly accurate and easy to install and remove. A transmitter that met the same requirements was therefore also needed, which is why i2O got in touch with KELLER right from the beginning.

The 20D pressure transmitter was able to meet key requirements here: The digitisation of the measurement values is managed by a microchip integrated directly into the pressure sensor. The logger can read out the pressure values directly from the transmitter via the I^2C-Bus interface. There's no need for an additional electronic circuit, which saves a lot of space.

The pressure connection was equipped with an additional quick release coupling especially for the i2O application, and the housing was also made more compact. Specialised calibration by KELLER was required in order to achieve the high accuracy required by i2O. Here, it was possible was to reduce the total error band as compared to the standard product from 0.5% to 0.2% full scale.

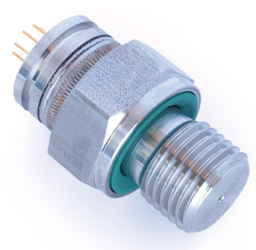
This solid foundation enables i2O to offer accurate, reliable and affordable loggers that provide the relevant data for intelligent water networks in a timely manner. Those who utilise these smart solutions can therefore quickly repair damages in a targeted manner while simultaneously conserving a valuable resource – and saving a substantial amount of money in the process.

dNet

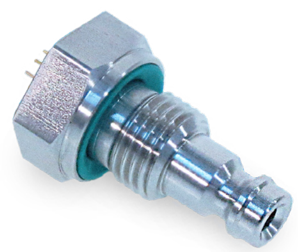
Accurate and reliable data loggers whose data can be displayed and analysed in a centralised network.

oNet

Remote control and automatic pressure optimisation for valves and pumps



Series 20 D pressure transmitter (standard product)



Customer-specific variant in a compact design and with an additional quick release coupling

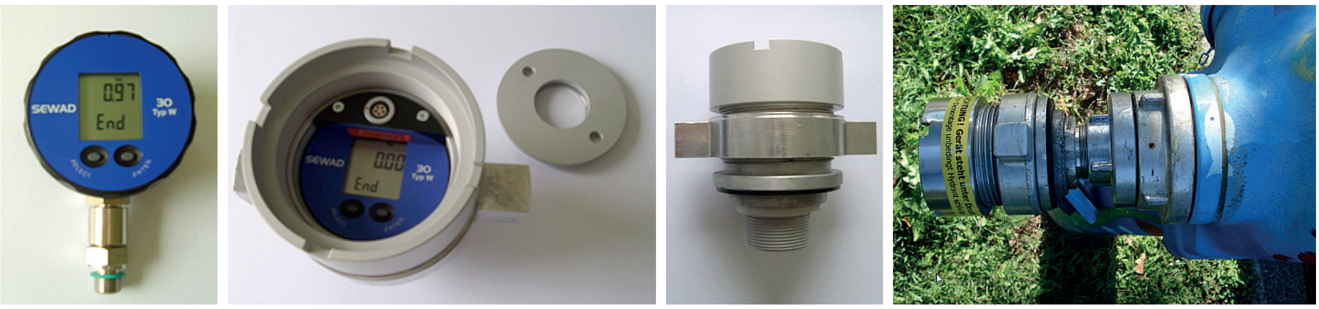
Large urban water supply and distribution networks are like complex organisms. Thousands of people in cities need to be able to get water without delay in their kitchens, bathrooms, washrooms, etc. Pumps can fail or cause pressure surges in pipes. Then there are industrial facilities, which consume large amounts of water in what is sometimes a very irregular manner.

Water supply systems need to be managed professionally if sufficient pressure is to be maintained and damage caused by defective components is to be prevented. Continuous maintenance and the hydraulic analysis of current or potential future problems are effective management instruments in this regard.

Hydraulic network analysis makes use of calibrated models which in turn are based on real measured flow and pressure data. Such an analysis can improve the efficiency and performance of the water supply and distribution system and eliminate energy losses caused by inefficient feed pumps or inadequate water storage technology. Hydraulic network analysis can therefore significantly reduce operating costs for local governments and municipalities.

Network model verification

Water supply network models are like snapshots of a situation that changes as a result of the construction of new residential housing or the establishment of new businesses in a commercial district. This means that every hydraulic water supply model has to be reviewed whenever such changes occur. This is done by subjecting the real network to known operating conditions and comparing calculated and actual flow rates and flow pressure in order to detect significant errors. For example, during a low-load nighttime situation, all measured hydraulic grades should display nearly the same hydrostatic values – i.e. there should be no flow influences to speak of. Discrepancies from the calculated model would indicate errors in elevation data or large unknown leaks. In a high-load situation, the hydraulic resistances of the main network pipes are checked, whereby differences here indicate hydraulic blockages caused by defective fittings or clogs, for example.



Customisation of the LEO Record digital manometer for the use of a waterproof, stainless steel pressure logger housing. The devices are suitable for direct installation on above-ground and underground hydrants.

Field measurements for calibration

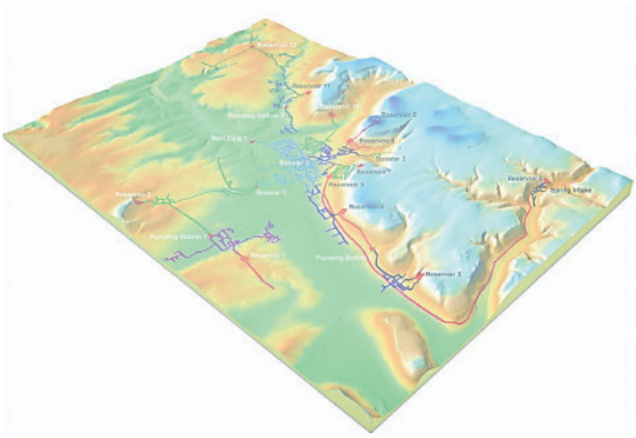
Field measurements are an indispensable component of hydraulic network analyses, as they provide the most important data. A key parameter here is the pipe-roughness coefficient, or Darcy friction factor formula (λ), which must be obtained in order to calculate the pressure drop in a pipe flow. Among other things, this friction value depends on whether the flow is laminar or turbulent, as well as the type of cross-section geometry involved and the design of a pipe's inner walls.

In order to calculate the real friction coefficient, the performance of various system components must be tested and documented. To this end, the pressure, flow and water consumption values must be recorded, whereby this physical data collection is supplemented by operation data collection. Various measurements are relevant here, including continuous 24-hour flow rate recording at selected key locations, such as water catchment sites and the main network pipes. To this is added flow data collected from other key pipes and selected nodes, such as fire hydrants, that are evenly spread over the network. The storage level (hydraulic elevation) also needs to be monitored as well as other factors that influence the measured pressure values, such as inflow and outflow data for pumping stations and booster pumps.

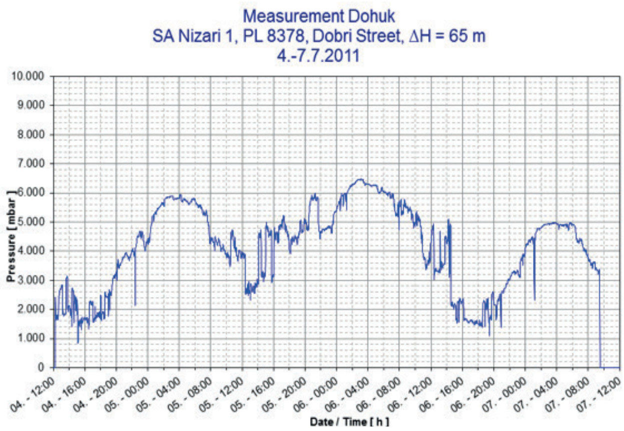
Network model calibration

Pressure measurement sensors and data loggers from KELLER are important components for guaranteeing the intelligent management of water supply systems. The data loggers are evenly spread over the network and record synchronised pressure values in realtime, which are then used to calculate and fine-tune realistic pipe roughness values and identify punctual resistances in the pipe system. This makes it possible to align measured and calculated hydraulic grades for the purposes of roughness calibration.

A verified and calibrated network model helps detect and correct hydraulic problems in existing networks and avoid similar problems when designing future network extensions.



Hydraulic water supply model



Realtime recording of pressure values

Environmental power generation is on everyone's minds today. Hydropower plays a major role here along with wind and solar power. In the Central European Highland and the Alps especially, hydropower has been used to generate energy in countless small plants since the dawn of the industrial age. This tradition is making a comeback within the framework of the current energy transition. A large number of small hydroelectric power plants have been built that enable direct consumers to generate their own green electricity or allow energy companies or local governments to supply green electricity in remote areas. Most of the modern plants are run-of-river facilities located in the middle of rivers, which means fish cannot avoid them. Such a setup disrupts the normal development of populations of certain types of fish, in particular salmon, which are obstructed by the plants as they swim upstream to their spawning grounds. Turbines can also literally suck in fish and chop them up. Solutions such as fish ladders require extensive investments that only really pay off for large hydroelectric power plants.

Breeding and replacing the affected fish species offers an alternative to expensive fish ladders. However, freshwater fish need a constant water exchange to thrive. Breeding trout, grayling and char requires exchanging the entire volume of water they grow in at least three times a day if their healthy development is to be ensured.

The Villitaimen Osuuskunta fish farm in Kemijärvi (Lapland, Finland) has four employees and grows several kinds of white fish from the roe their mother fish provide. The fish live on the farm for two to four years and are then sold to hydroelectric power plants.

The entire water supply for the fish farm comes from a river. A manually operated dam regulates the flow of water to the temporary storage units – screen wells, from which the water then flows to the fish basins solely on the basis of hydrostatic pressure, i.e. without the use of pumps.

The screen wells are each equipped with a water filter and a 36XW level sensor from KELLER that is used to monitor water levels and water temperature. Each screen well also has a GSM-2* remote transmitter that sends the data recorded by the level sensor to employees' mobile phones as an SMS.

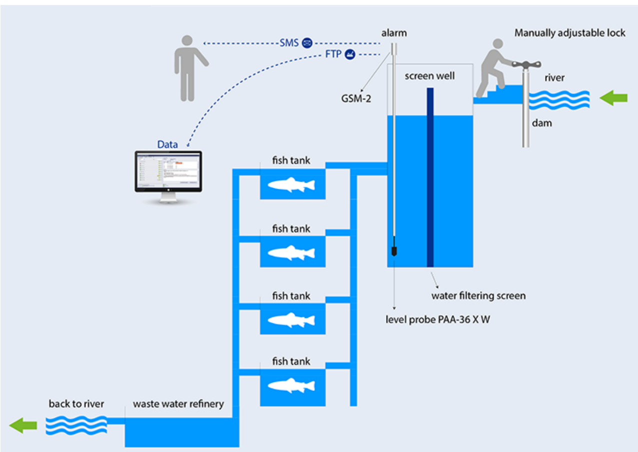


Diagram of water flow management from the river to the farm and vice versa

Fish tanks for grown fish

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

Level sensors guarantee the farm's survival

The engine that powers the entire water supply system is the hydrostatic pressure in the screen wells, which means the system doesn't need any water pumps and is also independent of the power grid. That means there's always enough fresh water for the fish even if there's a power outage. After flowing freely through several fish tanks, the water goes through a biological refinery and then back to the river. The fish farm is only allowed to extract the legally permitted volume of water from the river. The warmer the water in the river, the less oxygen can be dissolved and more water must then be tapped from the river in order to ensure the fish remain healthy.

The well screens are equipped with 36-XW level sensors that operate in combination with a GSM-2* unit. The latter sends out data on filling levels to a computer in the farm's main building once a day. Information on the water flow and the amount of dissolved oxygen is used as the basis for the manual regulation of the dam. In the event that floating objects block the flow to the screen wells and cause the water level to decline, the GSM-2* will send an alert to an employee's mobile phone, after which the problem can immediately be eliminated.

The reliable and highly accurate level transmitters from KELLER thus ensure that the fish remain healthy and the farm remains successful.

Digital output of the transmitter

The level sensor used is based on a stable, oil-filled, piezoresistive transducer and a micro-processor with an integrated 16-bit A/D converter. The non-linearity and temperature dependencies of the sensor are mathematically compensated. The free CCS30 software (Control-CenterSeries30) and the KELLER K-114 converter enable the calculated pressure to be displayed directly on a computer as well. The CCS30 software also allows the recording and graphic display of pressure signals.

36 XW level sensor and GSM-2 unit installed in the screen well*

The complete installation with external antenna. In the background: The farm's main building housing the fry and the mother fish

The first water pipelines were built by ancient civilisations. These pipelines facilitated the irrigation of fields and the supply of water to livestock and humans. A pressurised water pipeline extending for more than 40 kilometres existed in Pergamon as early as the second century BC. However, it wasn't until the second half of the 19th century that reliable drinking water supply systems gradually became widespread. Such systems used water towers with connected pipelines. These days, water is generally supplied via a permanent underground system of pressurised pipes. A total of 99% of the population of Europe has access to such a water supply and people in Europe and elsewhere rely on the certainty that clean drinking water will be available to them every day. In other words, secure water pipeline networks form the backbone of our modern society. The water flow rate in pipelines can be regulated by adjusting the pressure in the system. If the flow rate gets too low, it can have a major negative impact on water quality, as low flow rates can increase germ content in the water and also lead to changes in temperature, colour and taste.

Leaky pipes and pipelines also pose a problem. Not only can leaks lead to the valuable liquid being lost; escaping water can also damage the subsoil, necessitating costly repairs. When new distribution pipelines are to be laid, their leak-tightness is therefore tested and documented before the pipes go into production. These pressure tests require the pipelines to withstand pressure of 16 bar for an hour. The manometer's display screen enables employees to track pressure levels on-site throughout the test. A significant drop in pressure during the test indicates a leaking pipeline, which can be fixed while still in the production stage.

Pressure test preparation phase

Pipes to be tested

Once the measurement process has been completed, a computer is used to read off the measurements recorded by the manometer, which are then graphically displayed. The end customer is thus able to see whether the pipelines are operating smoothly. Here, the LEO Record from KELLER AG für Druckmesstechnik is the tried-and-tested pressure measurement device used for municipal water distribution systems. This battery-operated system equipped with a digital display is autonomous and robust and able to record both pressure and temperature levels over long periods of time.

Because pressure is influenced by temperature, the high-resolution measurement values are also compensated. The basis for this process is a temperature comparison performed at KELLER in special temperature measuring furnaces. The data is used to create mathematical models for each sensor that are then stored internally. The digital measurement values thus attain a very high level of accuracy, while the non-volatile memory ensures a high degree of data security. KELLER supplies free Logger 5 software for configuring and reading the data.

BRINER AG, a leading service and retail company in the construction industry that is headquartered in Winterthur, Switzerland, has been successfully using KELLER's LEO Record autonomous data logger for this purpose for many years and is very satisfied with the results.

"The LEO Record is so easy to operate that even temporary staff can use it unsupervised after a brief introduction", says Fabian Lenz, Head of Supply System Sales at BRINER AG.

Sampling water volume, measuring pressure drop

Pressure test using the pressure drop method

Sewage collects in the sewer system and, in Central Europe, almost invariably ends up in treatment plants. Sewage can contain all different types of pollutants and contaminants, everything from heavy metals and various chemicals to bacteria, fungi, viruses and nitrogen phosphorous compounds that can lead to excessive nutrients in stagnant water in particular. Such a variety of contaminants necessitates the use of a variety of purification and treatment processes. Initially, mechanical devices such as rakes, screens and filters of various sizes are used here. After that, pollutants are broken down into harmless components or components that are easier to remove from water. This is done using both microbiological and abiotic chemical processes. Any bacteria, fungi, viruses or other harmful organic compounds that remain can be destroyed with the help of chlorine, ozone or ultraviolet radiation. After that, the processed water flows into a natural body of water via a pre-flooder or is channelled into groundwater by means of a controlled trickling process.

Water treatment keeps our rivers, lakes, etc. from becoming contaminated. If, however, such a large amount of rain should fall that our sewers become unable to absorb it, the wastewater in the sewers will go its own way, so to speak. In the worst case, the increasing pressure can cause “fountains” of wastewater to shoot out of sewer openings and possibly even contaminate drinking water. That’s why spillover walls are installed in sewer systems. On the other side of these walls are rivers or canals. When necessary, the excess water flows over the wall and into the natural water. This setup is actually only an option for an extreme emergency, however, as it cannot prevent pollutants and contaminants from making their way into the environment. It’s therefore crucial to precisely determine where and in which amounts sewage runs off via this emergency spillover system. KELLER AG supplies the pressure measurement technology needed for this. Here, KELLER “Logger” software calculates the total spillover volume using data from the DCX-22 AA data logger, which measures water levels. Three trigger levels for the data logger can be set in the “Logger” software system in order to regulate the logging speed and the initiation of the flow calculation. The DCX-22 AA is installed in the sewer system with the level sensor placed as low as possible. The battery compartment is installed just below the manhole cover on the pavement or the street.

Wastewater treatment plant

Installation of the DCX-22 AA unit in a sewer system

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

Precise measurement of the spillover volume

Obviously, local governments have buffer systems that mitigate the effects of heavy rainfall. At the same time, heavy rain is expected to occur more often in future due to climate change, and even today municipalities increasingly face situations that conventional sewer systems are unable to cope with. When sewers become overrun, the sewer system is no longer able to take on the excess water and the overflow basins begin to fill up. As soon as the water level reaches the "Trigger ON" value, the DCX-22 AA unit engages and begins taking level measurements once every minute. When the water level exceeds the height of the dividing wall, the flow measurement is initiated and the data recorded until the water recedes. When the water returns to below the "Trigger OFF" value, the DCX-22 AA switches back to normal data logging with one measurement per hour.

The software reads the DCX-22 data storage device to calculate the flow. The GSM-2* transfers the data wirelessly to a computer – i.e. a technician does not need to be on-site to retrieve the data. A special conversion module calculates the flow and volume of the sewage water as follows: First the system subtracts the height of the dividing wall for each measurement of the water column. The remainder is then the water level on top of the sewer barrier. The system then calculates the average of all measured water levels and converts this into a flow rate (volume/time). The module now multiplies the average flow by the total time period of the overflow, which yields the total volume of overflow wastewater. Once this process has been completed, the KELLER software automatically generates an official report for each overflow location. The report lists the number of overflows and the amount of overflow wastewater in each case. Government agencies, such as "Waterschap" in Holland, can use this information to develop and implement additional measures. The reports also provide an overview of locations negatively affected by bottlenecks and insufficient capacity. Should overflows become more frequent, the Dutch government can instruct local governments to build additional wastewater buffers, for example.

Wastewater buffer tank

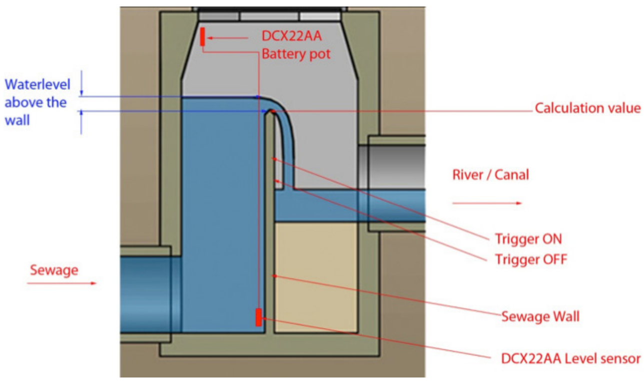


Diagram showing Trigger ON / Trigger OFF levels

The notorious Genoa low, also known as “the V(5)-track cyclone”, repeatedly brings catastrophic rainfall in its wake. The low pressure system extends across the Mediterranean region near the Gulf of Genoa. As it moves above the Mediterranean, it fills up with humid air and then strengthens as it heads in a northwesterly direction around the Eastern Alps. Depending on the path it takes, the front can cause extensive and long-lasting steady rain in eastern and southeastern Germany, Poland and the Czech Republic.

Nearly all of the major flooding disasters in recent years on the Oder, Elbe and Danube rivers can be attributed to the Genoa low. In 2010, for example, the Oder catchment area experienced the second-worst flooding disaster since the end of the 1940s. Between 15 May and 20 May 2017, a huge amount of rain fell in the Oder catchment area, with rainfall accumulation as high as 180mm/m². The second-highest rate of rainfall since weather services began recording such data – 2,100 cubic metres per second – was registered at the Czech-Polish border.[1] Poland, which has been among the hardest-hit countries in terms of flooding, has invested a substantial amount of money in flood protection measures over the last few years. Unfortunately, Poland still faces major challenges, as instances of heavy rainfall continue to increase due to climate change. The expansion and monitoring of sewer systems is crucial here – and since 2007, more than 5,000 KELLER Series 46 X transmitters have been installed for sewage applications in Poland. The transmitters are mostly used in newly built or upgraded lift stations, which pump wastewater in so-called backflow loops to a level higher than the downstream manholes in the sewer system. In heavy rainfall, a situation is thus prevented in which wastewater is pushed back into buildings and ends up flooding basements.

The pressure transmitters for level measuring serve as the main sensors for wastewater level monitoring, whereas the floating switches are used as a secondary control element. The main advantage of the 46 X is a chemically resistant AL2O3 membrane with a gold layer, which is also more resistant to mechanical damage than a steel membrane. Modern digital electronic systems enable free scaling of the 4-20-mA output, as well as the incorporation of the unit into a MODBUS communication network. In addition, the 46 X displays outstanding reliability in this extremely tough application.

Underground lift station at a sewage plant

Above ground lift station at a sewage plant

1: Ministerium für Umwelt, Gesundheit und Verbraucherschutz des Landes Brandenburg; Fachbeiträge des LUGV, Heft 129: Das Sommerhochwasser der Oder 2010 (“Summer Flooding on the Oder in 2010”)

Inefficient wastewater level measurement system

In a wastewater level measurement system that was originally set up with float switches, the first switch initiates the filling of the tank when the level drops to a minimum. A second switch stops filling the tank when it reaches the maximum level, while switch number three acts as an alarm that also prevents the tank from being refilled.

There is a simpler method, however, which involves using KELLER 26 Y level transmitters instead of several floats. This electronic measurement technology offers clear advantages in sewage applications. For one thing, the piezoresistive level sensors do not detect foam as a level of liquid (as is the case with ultrasonic sensors), which ensures accurate level values. Because the system does not have mechanical components that can get jammed or blocked, it's also less likely to break down. In addition, measurements are taken continuously and current level values can be read off a display at any time. All in all, it's a highly reliable and simple solution.

Piezoresistive level transmitters

Series 26 Y pressure transmitters are used in level measurement applications that are price-sensitive but also require a high degree of accuracy.

These transmitters have a very low temperature error due to digital compensation of what is a purely analogue signal path. Here, amplification and the zero point can be influenced by digital-analogue converters.

The accuracy of the end product depends in large part on the sensitivity and linearity of the measuring cell and the compensation of disruptive influences. The silicon measuring cell in the 26 Y series is reliably protected from the measured medium by a stainless steel membrane. The latter, in turn, is protected against mechanical stress by a plastic cap, while its large diameter of 17 mm makes it especially accurate and stable.

Sewage pumping stations equipped with a continuous measuring system to control the level of wastewater capacity

A non-fouling solution to avoid pump failures resulting from grease accumulation

In wastewater measurement, accurate readings are essential to ensure proper pump operation. If such a measurement system fails, unhygienic wastewater can overflow and pollute the environment. The pump systems themselves can also suffer damage if operated incorrectly on the basis of erroneous measurement values. Among other things, wastewater contains organic compounds such as proteins, carbohydrates and fats (grease). The latter in particular have the unpleasant habit of clumping together and forming sediments that are difficult to dislodge.

False measurements due to the formation of sediments

Newport News, Virginia in the USA offers a good example of what can happen in such a situation. Newport News was founded in 1621. It is situated along the James River and its nearly 180,000 residents make it the fifth largest city in Virginia. Here, several restaurants were built in an area serviced by the same municipal wastewater lift station. The high grease content in the wastewater then polluted the existing level measurement equipment, ultimately leading it to break down completely.

Antiquated solutions

Prior to the development of the commercial district, the Newport News Waterworks and the Hampton Roads Sanitation District relied on a combination of mechanical floats and conventional submersible transmitters. Both measurement systems stopped working after the restaurants opened: Both the primary and redundant level measurement equipment failed to properly transmit level data to the pump controller.

The heightened grease content in the wastewater caused by the restaurants led clumps to form on the level transmitter membranes, which ultimately blocked the flow of water to the measuring membrane. On the redundant float switch, whose purpose was to trigger the pump in the event of a failed level transmitter, the accumulation of grease blocked the mechanical operation of the float ball. The failure of the level transmitter and the backup system led to the failure of the entire lift station because the pumps either operated constantly or not at all. If technicians hadn't acted quickly, the entire sewage system could have come to a complete standstill.

Large amounts of grease from restaurant chains put a strain on sewage systems (Barry Blackburn / Shutterstock.com)

Wastewater treatment plant in Newport News

Kynar® membrane offers better resistance

If a lift station is to function properly, grease must not be allowed to block the measuring devices. Various manufacturers offer non-fouling products that often present difficulties in other areas, however. The instruments usually employ a Teflon-coated elastomer membrane, which, while non-fouling, is also relatively weak and prone to puncture. The membrane is therefore equipped with a rather bulky protective shield that is mounted on bolts. Grease tends to accumulate in the gaps that result from this setup, however, which means the problem just moves to another location, as clumps of fibres, grease and sludge form the wastewater continue to impair correct measurements.

In the case of Newport News, city officials contacted KELLER AG für Druckmesstechnik, whose 36 XKY level transmitter, which is known in the USA as the LevelRat, enables a unique approach to wastewater level measurement.

The Kynar® membrane used in the 36 XKY is harder and offers superior abrasion and puncture resistance relative to other non-fouling solutions. Bulky shields are therefore no longer needed, which also enables a more compact design for the sensor. The 36 XKY can fully exploit the advantages offered by a non-fouling membrane without anyone having to worry about floating particles and small objects. Put simply, the level transmitter is perfect for this application. No incorrect measurements due to grease deposits have been recorded at Newport News Waterworks since the new transmitters went into operation: The LevelRat solved the problem.

36 XKY level transmitter with Kynar® membrane

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, ground-

*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

water 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 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

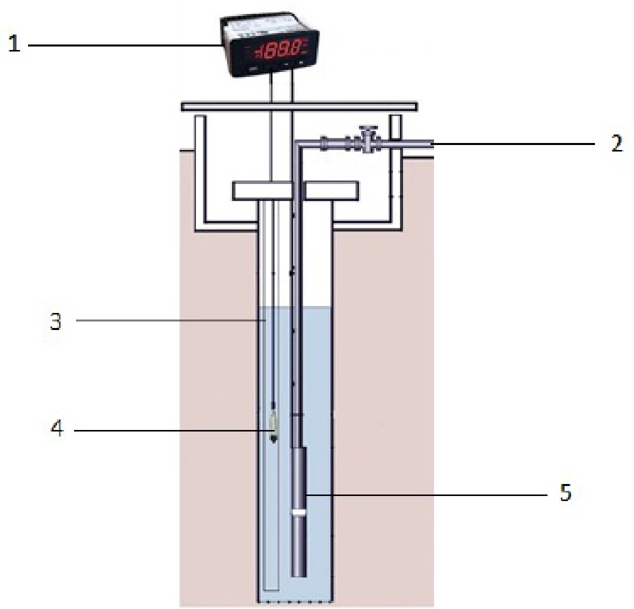
Measuring groundwater at train stations in Russia

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.

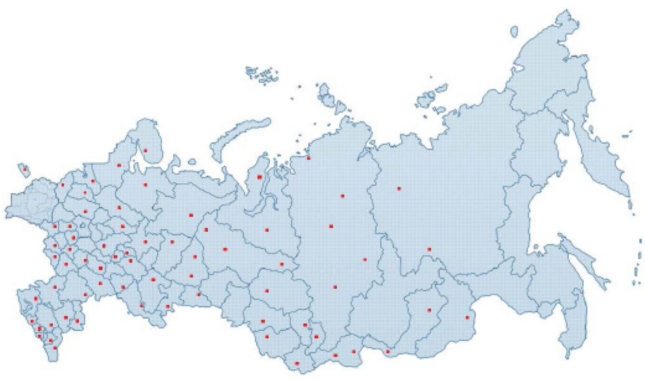
One of Russia’s largest engineering companies chose Series 26 Y level transmitters from KELLER for such monitoring activities. The sensors were installed throughout the Russian Federation, where they are used to monitor and control the consumption of drinking and technical water at key railway stations.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

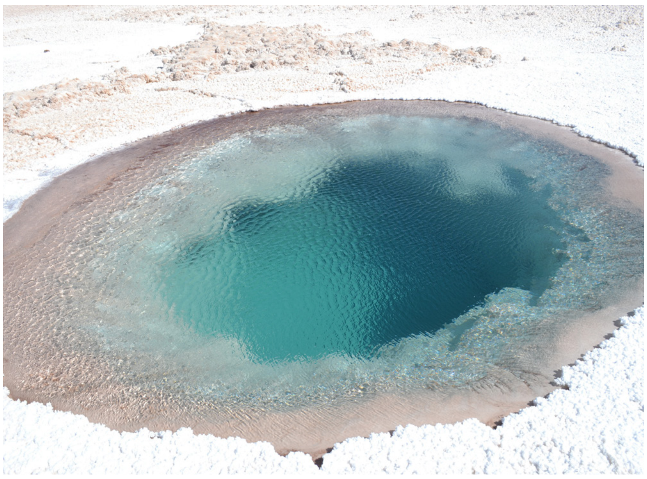
The measuring equipment determines the groundwater level and the composition of the salts it contains. Here, variations in the groundwater level are measured and compared with the volume of water extracted from the wells in order to monitor aquifer recovery following extraction as required by Chilean 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.

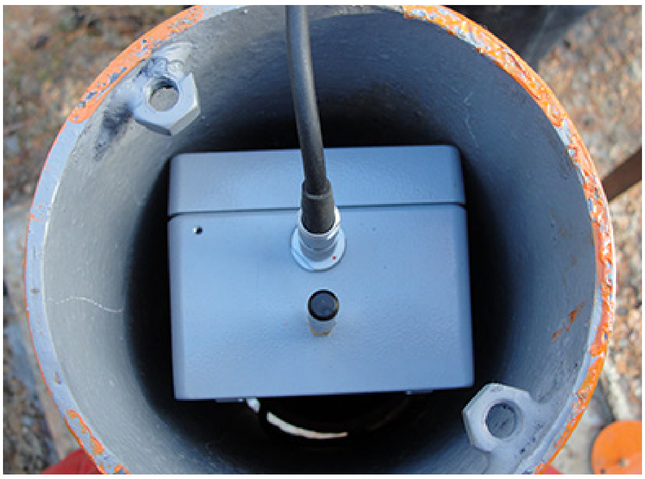
Remote data transmitter and logger in one device

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.

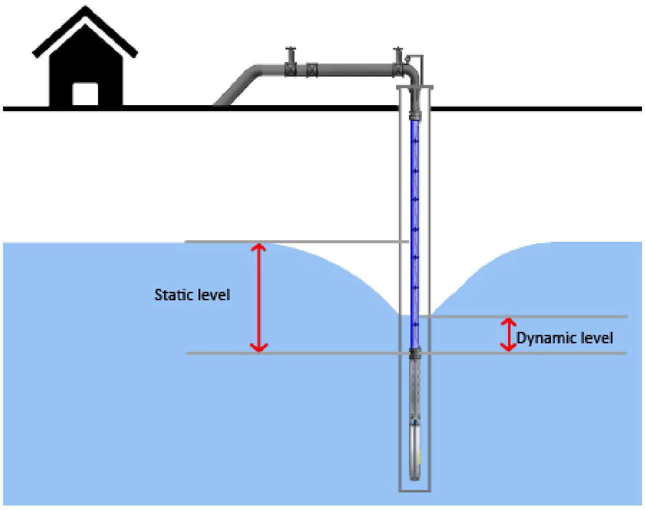
Pumping equipment generally cannot tolerate immersion in water. The measurements taken by a pressure sensor can be used as a basis for programming a frequency converter via a PLC (programmable logic controller). In this manner, the pumping equipment protects itself against level fluctuations by regulating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

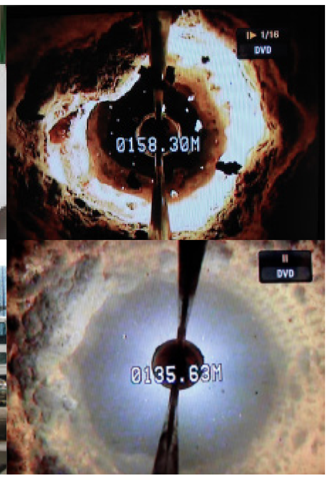
KELLER offers a wide range of level sensors with a data logger function. This setup allows measurement results to be stored in sensors for long periods of time, which makes it possible to analyse the behaviour of the well over time and thus detect problems more quickly.

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.

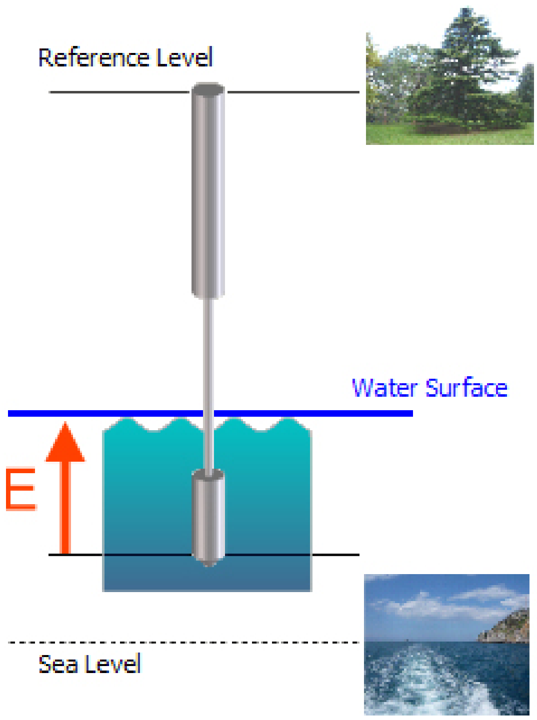
Ground water level measurement with autonomous level data loggers

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.

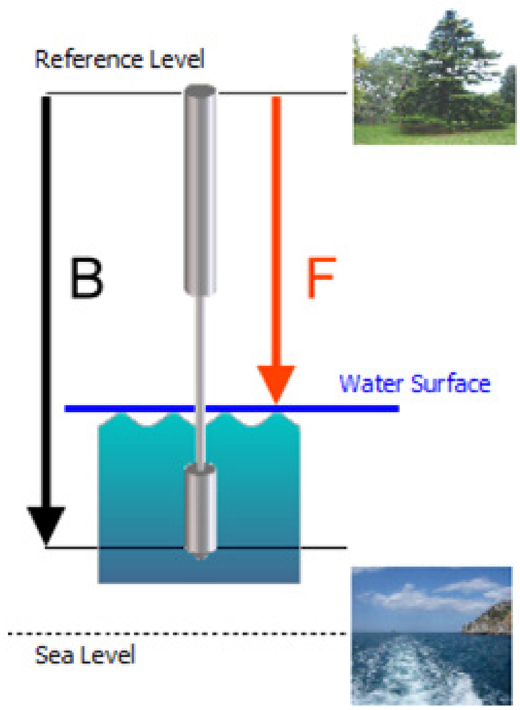
The user can set the intervals at which measurements are to be performed. After the measurement result has been saved to the internal storage device, the logger is ready to go back into action. This sleep mode enables a battery lifetime of up to ten years. Data is configured and read via a USB converter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



Water column calculation using a membrane



Water column: "Depth-to-water-surface" level will be incorrect, since a pressure difference of even one mbar corresponds to one centimetre of water level. In 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

Flash floods are sudden and unpredictable. Within minutes, floods can rise over the banks of streams and onto roads, where they then sweep away cars, devastate houses and endanger people.

Although weather services usually issue warnings before severe weather occurs, the towns affected are generally poorly prepared for flash flooding. This is hard to believe, since most regions in Germany have detailed special maps that deliberately highlight the danger zones so that places at risk can prepare accordingly. However, these maps are rarely to be found in town halls, fire stations or at emergency services centres, which is why people usually fail to take proactive measures. What's more, the special maps are relatively roughly drawn; obstructive buildings and roads acting as channels are not always shown. In addition, because of climate change, extreme weather events are occurring more and more frequently and are also becoming harder to predict. As a result of such developments, the maps are not able to solve every problem, which is why an IoT solution is required that can identify dangers early on in the farthest-flung corners and reliably raise the alarm for any imminent floods around the clock. This makes it possible to notify the necessary agencies (e.g. emergency services) automatically in a matter of seconds, thereby enabling appropriate measures to be taken promptly. KELLER's GSM-2* remote transmitter forms part of such a warning system. The GSM-2* combines an autonomous data logger and a remote transmitter in one device. When used with a pressure transmitter or a level sensor, it reliably transmits water levels and pressure data via the GSM mobile phone network by SMS, e-mail or FTP to those responsible in order to issue flood warnings in good time.

The US National WeatherService (NWS), for example, uses a GSM-2* solution with accurate level sensors, a remote transmitter and a special type of software adapted to its needs. KELLER also provides technical support for setting up, installing and programming the system, which sends the responsible municipal workers an SMS notification when water levels rise. After the system has been implemented, the infrastructure can be converted from manually positioned mobile barriers to permanently installed swing gates that close when flash flooding occurs.

11 June 2013: Elbe river flood in Germany
(science photo / Shutterstock.com)

3 June 2016: Flooding in the streets of Gera in Germany
(science photo / Shutterstock.com)

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

Water level monitoring at dams is a basic measurement. The main requirements for such a measurement are reliability and very high accuracy. Series 36 X W level sensors from KELLER can fulfil these requirements while also providing an added benefit in the form of communication via a bus system.

Hundreds of PAA-36 X W level sensors have been installed at numerous dams in Poland, which experiences major flooding on a regular basis. Here, capillary solutions with relative pressure sensors are often not acceptable due to humidity problems. Thanks to RS485 MODBUS communications, all the absolute pressure sensors in the PAA-36 X W series can easily communicate with barometric sensors that also use MODBUS. Their very strong additional lightning protection also makes the level sensors virtually indestructible. None of the sensors has failed since 2009, whereas prior to that time the electronic systems were often damaged by lightning. Apart from the elimination of humidity problems, the use of the absolute pressure sensors provides for extraordinary long term stability and a total accuracy of 0.05% to 0.1% in real conditions.

Dam in Niedzica, Poland

Dam near the Lomnica river in Karpacz, Poland

M.O.S.E helping keep Venice afloat

The idea that Venice might sink into the sea has been circulating in the media for many years now. Around one hundred years ago, the city was 25 centimetres higher out of the water than it is today. When its industries moved to the mainland in the 1960s and began to grow and expand rapidly, there was a great need for fresh water, and Venice therefore decided to pump groundwater out from under the Venetian Lagoon. That's when the city began to sink. The problem was actually identified in the 1960s, and Venice then began restricting the volume of water that was pumped out – but this could not stop the process entirely. The situation was exacerbated when the channels in the lagoon were expanded to accommodate ships travelling to Mestre. Tourism also increased and the water connection from the city to the Adriatic Sea was widened. The huge amount of water thus introduced carries sediment away and out of the lagoon, and this phenomenon is being reinforced by the effects of global warming.

Over the years, various proposals were presented to deal with the problem, but there were also corruption scandals and protests by the local population. Finally, the parties involved agreed to launch a project known as M.O.S.E. (Modulo Sperimentale Elettromeccanico – "Electromechanical Experimental Module").

This flood prevention project uses moveable flood gates installed at the four entrances to the Venetian Lagoon. The idea is to protect the historical centre of Venice from floods that are becoming ever more frequent. The concept is not completely new, as similar flood barriers have also been built in London (Thames Barrier) and Rotterdam (Maeslant Barrier).

When a flood alert is issued, the four entrances to the lagoon are closed off using floating barriers. The flood protection system consists of a total of 78 movable elements. The technology used here is tried and tested, as it's been employed for quite some time at the gates of large ship docks. MO.S.E. is a lot bigger, however, and its gates are also networked with one another and equipped with intelligent control and monitoring systems. Data from throughout the system is sent to a control centre. Information on weather conditions and sea currents is also analysed and used as a basis for decisions on when to close the flood gates.

The Grand Canal and the Rialto Bridge

Concrete element with maintenance walkways and supply conduits

KELLER transmitters in the foundation

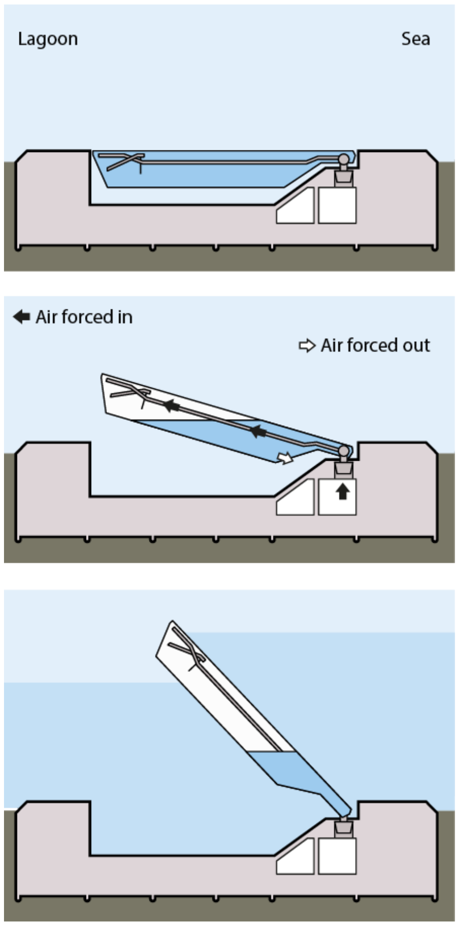
Secured by giant hinges set in concrete, the steel gates are 20 metres wide, five metres thick and up to 30 metres high. When there is a danger of flooding, air is pumped into the gates, which causes them to rise up to form a protective barrier against the Adriatic Sea and block off the lagoon like a floodwall. When the water is at a normal level, the gates lie retracted beneath it. (see illustration below right.)

Extremely precise data is needed to control and monitor the gates. In order to monitor the structure of the caissons, geotechnical specialists at Agisco s.r.l. therefore installed digital (bus) profilometers in the concrete elements. The profilometers work with highly accurate KELLER X series transmitters with IP-68 protection. This solution guarantees impressively high precision – down to one-tenth of a millimetre over a length of several kilometres.

Caissons made of reinforced concrete form the foundation of the flood protection system

High-precision pressure transmitters The X series

The pressure transmitter's extremely high accuracy of 0.01%FS is available as an option; the standard precision of the X series (33X, 35X and 36X) is 0.05%FS. This high degree of measurement precision is achieved by combining a stable, floating, built-in piezoresistive transducer with an XEMICS microprocessor with an integrated 16-bit A/D converter. The latter uses mathematical compensation to eliminate the temperature dependencies and non-linearity of the sensor. The transducer registers even the tiniest pressure fluctuations. In order to ensure that this high sensitivity is effectively exploited, the measuring element must be well shielded from disruptive external influences. For example, the floating installation setup completely decouples the transducer from mechanical tension in the outer housing.



M.O.S.E gate system

The Russian Federal Service for Hydrometeorology and Environmental Monitoring (“Roshydromet”) is increasingly making use of systems for monitoring water levels and temperature in rivers and lakes. Some time ago, six divisions at the Federal Service began to switch over to a fully automated hydrological system manufactured by KELLER AG für Druckmesstechnik. The monitoring system must provide measurements that are highly accurate and transparent, as Russian state-owned institutions need to be able to control the security and confidentiality of their own data.

Monitoring icy surface water

The water level monitoring system consists of a 36 XW level sensor, which measures pressure and temperature, and a GSM-2* autonomous remote transmitter, which is used for automatic data collection and transmission. The GSM-2* modules are also equipped with a barometer.

The GSM box* needs to transmit correct readings and work consistently and independently over several years and in extreme weather, as Roshydromet’s northern divisions also use KELLER systems in remote areas in the Gulf of Finland and the Barents Sea. The former is an elongated bay in the Baltic Sea, south of Finland, while the latter is situated north of Finland and flows into the Arctic Ocean, where temperatures can fall to -30 °C.

The data logger is used to help monitor the condition of the ice. All GSM-2*-based monitoring systems are equipped with autonomous still and video cameras for security purposes to protect against theft and vandalism. The GSM boxes* are installed in walk-in containers in close proximity to the measuring points.

A measurement station operated by Roshydromet’s Northern division

Siberian division equipment protected against theft and vandalism

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

Regular long-term measurements

The hydrostatic systems have been gathering precise measurements every hour for several years now. This data is transmitted to Roshydromet every 12 hours via GSM/GPRS. Measurements are only deleted every five to seven years, as this is when the lithium batteries also need to be replaced. No other maintenance work is required throughout this entire period. The battery charge status is also transmitted along with other data, which makes it easy to plan battery replacements in good time.

Comprehensive installations

Roshydromet's Northern division installed 22 hydrostatic systems fitted with security recorders in the Arkhangelsk region in 2016.

In October 2017, the Siberian division began operating 12 GSM-2 modules* with level transmitters. The Siberian part of Russia is also a place where icy temperatures pose the greatest challenge, as the air temperature there can drop to as low as -38 °C. In addition to the security cameras, the containers are surrounded by metal fencing to prevent any kind of vandalism. The video recorder is linked up to the GSM-2 module*, to which it sends a signal if anyone gets inside the metal fencing. The module then sends a notification of this to Roshydromet's Siberian division.

In November 2017, four hydrostatic systems were installed in the Chernozem Region in central Russia, where the air temperature generally drops to "only" a maximum of -25 °C. High masts made from steel tubing are used to build these hydrological measuring stations. This type of installation requires the use of GSM modules* with dimensions that allow them to be installed inside the masts. More specifically, a diameter of 57 mm (two inches) is standard in the industry here. When set up this way, the measuring station remains hidden and protected from flooding. It monitors the ice levels on rivers and is also fitted with an autonomous camera for security purposes.

There are two systems at Roshydromet's testing site in the Novgorod region, where the measuring stations are also connected to a rain catcher.

Roshydromet operations in the Chernozem (Black Earth) Region

GSM-2 box (below) with rain catcher at a testing site in the Novgorod Oblast*