Title: **Measurement of Groundwater Levels - a Field Guide**			
Document type: Technical guideline ISBN: 978-87-7871-352-0	TG. no.: G03	Version: 1	Created: 15/03/2012
Authors: Lærke Thorling & Carsten Langtofte, GEUS	Valid as from: 01/01/2012		
	Pages: 21		
	Last update: 15/03/2012		
TG references	G01 G02 and TG-groundwater data		

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1 Introduction

Objectives
The objective of this technical guideline is to provide unambiguous instructions for the collection of data on the situation and development of the groundwater table. Furthermore, the guideline serves to document the conditions under which data are collected and recorded.

Principle
Groundwater level measurements are to reflect the groundwater-bearing layers covered by the well's monitoring points. This principle translates into requirements concerning the wells' technical design (See G01-monitoring network). This also means that measurements need to be conducted in accordance with correct and good field practice. Good field practice is based on the instructions provided herein and the professional field worker's insight into groundwater hydrology and into site-specific conditions. These factors, in turn, form the basis of the care and consideration which should characterize the field work performed.

Optimization of field work at the individual monitoring points hinge on a series of technical decisions, which are based on the well's specific technical design and the expected groundwater table variations. The groundwater table may vary due to natural causes as well as water abstraction effects derived from water works and irrigation.

2 Method

A **groundwater level measurement** is a measurement of the groundwater table's spatial localisation at a well monitoring point at a certain point in time. The groundwater level measurement is thus linked to a certain depth interval within an aquifer.

The **measurement** determines the distance from the water table of the well to a fixed measuring point (the reference point) with known coordinates (x, y, z of the well's reference point) situated at the top of the well.

The **reference point** is a fixed measured point. It is situated at a known distance from the levelled physical fix point (permanent reference point of the well. The reference point shall be described in JUPITER (e.g. upper edge of casing). If the reference point is changed, this shall be recorded in JUPITER along with the date such change was made.

For definitions of the fix points and reference points of groundwater wells, see the Localisation Guideline ("Lokaliseringsvejledning", see the reference list herein) and "data-TA-grundvand".

Groundwater level measurements may only be performed on a groundwater table that is unaffected by pumping in the well or in any other well nearby. Wells that are operating (or in which the water table is returning to normal after a pumping operation) are only measured with a view to establishing the effect of the pumping operation on drawdown of the water table in the well. If such data are entered into the JUPITER, data shall always be marked as "Operational" (Danish: "i drift").

Synonyms

In this professional field, a number of synonymous terms are used unsystematically to describe the same concepts. This is also the case for "Lokaliseringsvejledningen" /GEUS, 2008/ and JUPITER as the terms to denominate certain concepts are not always identical, e.g. a reference point in "Lokaliseringsvejledningen" may be a measurement point in JUPITER.

During day-to-day business, the following synonyms are used:

Groundwater table, groundwater level, groundwater potential, water table depth

Potentiometric surface maps and groundwater level maps.

Tape measurement, groundwater level measurement, manual groundwater level measurement.

Reference point, groundwater measurement point and measurement point

Water level meter, manual water level meter, water level measurement device ...

Data logger, water table logger, diver.

2.1 Time, place and period

Groundwater level measurements may be performed all year, as long as it is possible to lower a water level meter into the casing either via a stub or directly into the open casing. In some wells, particularly narrow meters are needed as the dimensions of the tubes impede the use of standard equipment. This is, among others, the case in wells fitted with montejus pumps.

Data are collected electronically at least once a year. Technical conditions may create a need for more frequent data collection to comply with requirements on adequate and timely data reporting.

Collection of data from data loggers should generally not be done at temperatures (far) below zero, as the loggers do not work properly at below-zero temperatures.

2.2 Equipment

Manual groundwater level measurements are made using a hand-held water level meter. A number of different types exist and these often rely on sound or light indicators. If possible, the same hand-held water meter should be used for all measurements at a given well. Every water level meter shall therefore be identifiable, e.g. carry the following information: Company and department, Serial number and date of purchase.

Automatic recording of water table data is done using level loggers. Level loggers are pressure transducers with an integrated logging unit/logging function. If a logger of the "Diver" type is used, it is necessary to adjust for variations in the atmospheric pressure using a separate pressure transducer.

Other types of level loggers contain a capillary pressure transducer and a separate logging unit. These devices automatically compensate for variation in atmospheric pressure so that measurements only record variations in the water table of the well. Nevertheless, these devices call for separate measurements of atmospheric pressure for the data processing of barometer effects on confined aquifers.

2.3 Procedure

2.3.1 Establishment and use of the reference point and permanent reference point of the well

All groundwater table measurements shall be made from the same reference point, see Figure 1. This reduces the risk of error and makes it easier to read level measurements into JUPITER.

In wells with several monitoring points, a reference point shall be established for every monitoring point. More than one monitoring point may share the same physical reference point.

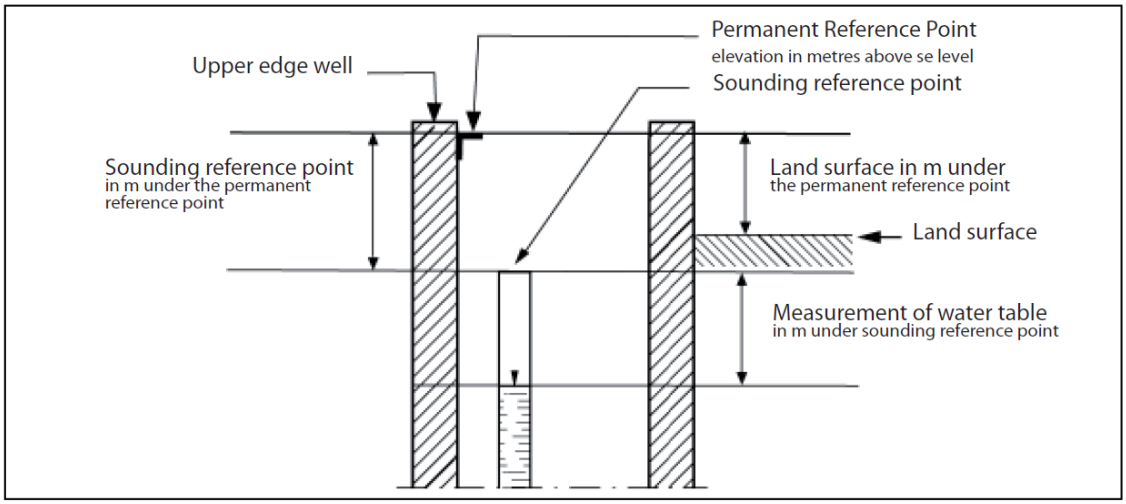

Figure 1. The required measuring of a well in the field as a preparation to monitoring the groundwater table. Figure from "Lokaliseringsvejledningen" /GEUS, 2008/, where a-g are explained.

The reference point (e.g. "Upper edge of casing" or "Upper edge measurement stub") shall be easy to locate and clearly marked on the location with engraving or colour markings (use e.g. a water-resistant speedmarker). The localization of the reference point shall be described on the well sign. The reference point shall be clearly indicated on the latest localization table, and data shall be consistent with those recorded in JUPITER.

The field folder containing the well information and field tables shall also contain photos or sketches allowing a person who has no knowledge of the location to perform a manual groundwater level measurement from the correct reference point. These data shall also be available in JUPITER, see below and “data-TA-grundvand”.

If the reference point is changed, this shall be recorded in JUPITER along with the date such change was made. A reference point should only be changed if reconstruction of the well or other practical conditions makes this necessary.

The permanent reference point of the well shall have been measured using a differential GPS, or its level shall have been determined by reference to a KMS fixpoint. The method used and the accuracy achieved for the level measurement shall be recorded on the localization table. Next, the reference point(s) shall be measured/located by reference to the permanent reference point of the well with a precision of 1 cm. Use a folding ruler or similar. Measurements shall be made according to the ”Lokaliseringsvejledningen” (see the GEUS webpage). Also see Figure 1.

The measurements and photos of the well indicating the reference point(s) are inserted into the localization table which is then reported to the GEUS Well Data Archive, whereby data are made available in JUPITER.

Note: Before the reference point and, if relevant, the permanent reference point of the well are changed in JUPITER, any measurements made with reference to the original reference point shall have been reported to JUPITER.

2.3.2 Manual groundwater level measurements (tape measurements)

Manual groundwater level measurements are performed using a hand-held (manual) groundwater level meter.

The measurement is performed by lowering a water level meter into a well and reading the distance from the water table to the established reference point when the water level meter reaches the water table below. Specifically, when the meter reaches the groundwater table, an electrical current closes a circuit by connecting two poles situated at the meter's tip. The current forms a circuit when the groundwater reaches the upper of the two poles, see Figure 3.

The water level meter is rinsed with water of drinking water quality or demineralized water after use.

In the field tables (see Appendix 6.1-6.2), the following information is entered: DGU no., monitoring point no., date and time, distance from reference point, reference point used and any comments.

Measurements are made with an accuracy of 1 cm. The measurement's accuracy depends on the constant and correct length of the electrical tape vis-a-vis the tape's measurement indications.

Figure 2. Hand-held water level meter and folding ruler at well. Note how the hand-held meter is easily identifiable owing to the yellow "dymo marking".

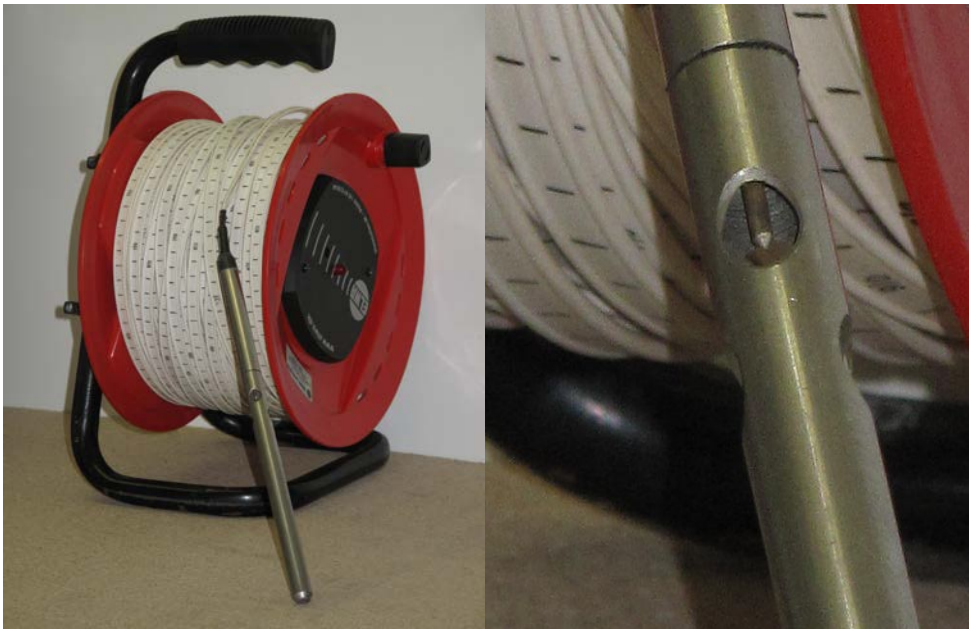

Figure 3. Manual water level meter. This meter emits a signal when an electrical current flows between the two electrodes of the meter. This occurs when water conducts electricity between the electrodes, see the image on the right. Note: Erroneous readings may arise if the water causing electricity to flow is due to condensation from the well casing. Groundwater with a low conductivity will create a weaker circuit which weakens the signal produced.

Water sampling

Before taking water samples for chemical analysis, manual groundwater level measurements are made at all monitoring point of the well. This is done before turning on any pumps, as pumping in one monitoring point may affect the water table in the others.

Collection of data from data logger
Before data are collected from the data logger, manual measurements need to be performed, as the data series will need to be calibrated with reference to the water table measured within the period covered by the data logger.

Inspection

At inspection of inactive wells, manual groundwater level measurements are performed.

During measurements, the groundwater table shall be unaffected; i.e., it shall not be under the influence of any pumping activity from the well or other wells in the vicinity. The period needed before the groundwater table has returned to normal after pumping activity depends on the volume of water extracted and the hydraulic properties of the aquifer - and for each monitoring point, knowledge hereof shall be based on reverse groundwater level measurements, see below.

In wells with montejus pumps, where the casing forms part of the montejus pump, the groundwater level observed will be equivalent to the highest water table observed since the previous sampling (provided that the non-return valve closes tightly). This information shall be stated in the Comments field of the Localization table of the well and shall furthermore be entered into JUPITER (Field name in Danish: pejlebemærkninger).

In wells with montejus pumps, particularly narrow water level meters may be needed.

Some wells dry out in periods with a low groundwater table. This is noted in the pumping table/groundwater measurement table.

Overflow

Groundwater level measurements which overflow, i.e. where the groundwater table is situated at a level above the upper edge of the casing, are measured by extending the casing by inserting a piece of tube or hose, if this is technically possible.

If additional support points are needed to establish a reference point, these MUST be indicated on a localization table which is reported to JUPITER and kept at hand in the field for all future groundwater level measurements.

The optimal solution is a transparent tube mounted on the measurement stub or casing. The tube is lifted up so that the groundwater table may be measured using afolding ruler or a measuring tape.

If this is not possible, the alternative is to use a non-transparent tube which is lifted upwards until the point at which overflow stops. This height is then recorded as the groundwater table.

Note: Remember to add a - (minus sign) before the measurement when stating the reference of overflowing wells with regard to the reference point. If the water table is located several meters above the terrain, manual measurement of the groundwater level can be impossible to perform. In such case, pressure transducers immersed in a closed system should be used.

Reverse groundwater level measurements

In order to characterize the well's hydraulic properties, the re-establishment of the original water table in the well after drawdown caused by extraction is monitored by so-called reverse groundwater level measurements. Reverse groundwater level measurements shall be performed at least once in all wells. This shall be done after creating a drawdown of the water table equivalent to or greater than the drawdown typically created during standard sampling of the well. Data are stored in the pump table folders and entered to JUPITER in the form of a PDF file describing the well. In the long term, such data will be stored electronically in a specific inspection database.

Reverse groundwater level measurements are used to assess the time needed to re-establish the "unpumped" groundwater table in case it proves necessary to measure the "normal" groundwater table after sampling in a well. Reverse groundwater level measurements provide information on drawdown, but also yield important information about the screen's hydraulic properties and thereby about sampling quality. (Also see Technical guidelines, monitoring network: GO1)

Please note: Wells with overflowing shall also be characterized by the drawdown of the water table making it necessary to perform reverse groundwater measurements.

Sources of error and practical tips

The device used to measure the water table emits sound or light when the water table is reached. If this does not happen, check the battery and also make sure that the cables running along the measuring tape are not damaged, including at the transition from measuring tape to the meter "head". A lacking signal may also simply be caused by the fact that the measuring tape is too short.

If the groundwater has a high salinity, there is a risk of fault current causing the meter to emit a signal above the water table. Remove the water level meter from the well and rinse it with water of drinking water quality or demineralised water.

When the conductivity of the groundwater is very low(< 20 mS/m), it may be difficult to use a manual water level meter because such a meter is based on the water's increased conductivity relative to air. Make sure that the poles of the water level meter are completely clean. Alternatively, it may be necessary to employ other measurement principles, e.g. a meter equipped with a whistle.

When the water level meter is pulled back, it may become entangled in other well equipment, e.g. pumping equipment. The worst case scenario is that the meter cannot be pulled back and ultimately needs to be cut off. There is also a risk of damaging the remaining well equipment.

When narrow water level meters are used in montejus pumps, there is considerable risk of false positive measurements as condensation in the narrow tubes may affect the meter causing it to indicate that the water table is located higher than is actually the case. Therefore, the water table measurement should be repeated several times until it can be reproduced with less than 5 cm of variation. The meter does not have to be drawn back to the surface for this procedure; rather, it can simply be raised marginally to approx. the level at which the water table is expectedly located.

Calibration
The equipment is not calibrated. Inter-calibration of electrical tapes is performed every 5-6 years by using several electrical tapes in the same well on the same day. Electrical tapes deviating more than 5 cm from the median value of at least seven water level meters at approx. 20 meters of depth should not be used. This is the accuracy of the measurement, while measurement precision shall be 1 cm. The supplier states that a 0.2% accuracy may be expected for electrical tapes, corresponding to 4 cm for 20 meter measurements.

2.3.3 Collection of groundwater level measurements using data loggers

Automatic collection of logged water table data is performed using level loggers, Figures 4 and 5.

Principle
Level loggers measure the pressure at the depth at which the pressure sensitive membrane is placed within the well. The measured pressure above the logger membrane is the sum total of the pressure from the water column above the membrane and the atmospheric pressure exercised on the groundwater table in the well's monitoring points.

As the atmospheric pressure varies over time according to weather changes, the measurement shall be adjusted for variations in atmospheric pressure before the final data set may be established. This is made possible through simultaneous logging of the atmospheric pressure, typically using a barodiver. Some types of level loggers make such correction automatically.

Set up

A level logger with an integrated collection unit/logging function (e.g. a Diver, see Figures 4 and 5) is mounted in the well with a non-elastic line made from kevlar or steel wire. The line's length shall be minimally sensitive to changes in temperature. The length of the string/wire from the reference point to the top of the level logger is noted in the groundwater measurement table.

It is crucial that the logger is placed at the same depth every time it has been retrieved for inspection and data collection. The kevlar line/steel wire must therefore be free of knots and other impediments which would cause a change in its length.

Figure 4. Two different types of pressure transducers before mounting in a well. A larger older version and the smaller, newer version.

Level loggers shall be placed sufficiently low as to ensure that they are permanently covered by water. A logger with a dynamic interval (of 5, 10, 20, ... m) should be used to ensure that the expected water table variations are covered. The annual variations as well as longer term variations resulting from several years with dry or humid periods should be taken into consideration.

Both level and baro loggers should be mounted to ensure contact to the atmosphere. If the logger's line/wire is attached to the well's lid, a hole should be made herein to ensure that pressure equalization may occur between the well and the atmosphere. To minimize the influence from wind-borne contamination and precipitation, the hole should be as small as possible and be placed keeping the contamination risk in mind.

If technically possible, the DGU no. and monitoring point no. are entered into the logger's data file before data collection is initiated. Please refer to the relevant logger's user manual.

Figure 5. Barodiver suspended at the top of a well above the water table with a view to measuring air pressure. It should be suspended a minimum of 3 meters below the surface to ensure frost-free conditions. If the logger is mounted as described, it is important to remember to make a hole in the well lid to enable pressure equalisation between the well and the atmosphere. To minimize the influence from wind-borne contamination and precipitation, the hole should be as small as possible and be placed keeping the contamination risk in mind.

Before the level logger is mounted, a manual control measurement should be made. Immediately after mounting the level logger, another manual control measurement is made. Furthermore, a control measurement should be made just before collecting data from the level logger. Additionally, a man-

ual control measurement should be made annually and half way through the measuring period, see the section on data quality below.

Unless special conditions apply, level and baro loggers shall be programmed to perform four daily measurements. Wells affected by the tide should be programmed to measure 12 times daily.

Data quality

When setting up a new level logger, note that in some cases it takes as much as a week to reach equilibrium. In this period, readings will be consistently erroneous. The time needed to reach equilibrium was established for loggers of the Diver type, but time may possibly also be required for other types.

When operating normally, a measuring accuracy in the range of 0.05-0.15% of the measurement area may be expected.

The manual groundwater level measurement performed half way through the measurement period without disengaging the logger is the measurement best suited for subsequent calibration and conversion of the logger's pressure measurements to tape measurement data. In contrast, the manual groundwater level measurements made after collection (and therefore deletion of logger data) will have been made outside of the period covered by the collected data series.

The application (Diver Office) used for conversion of pressure measurements can only perform interpolations between two known data values and points in time. It cannot base calculations on groundwater level measurements made outside of the time-period during which data were collected.

Figure 6 presents a data series of pressure measurements shown as black markings, a tape measurement meter shown in green as it was performed within the measurement period and a measurement performed after data collection in red. The final measurement (red) cannot be directly used for calibration and conversion of the series. The time needs to be reverse dated so that it falls within the measurement period. This presupposes that the water level and the barometer pressure are identical at the measurement time and at the adjusted time.

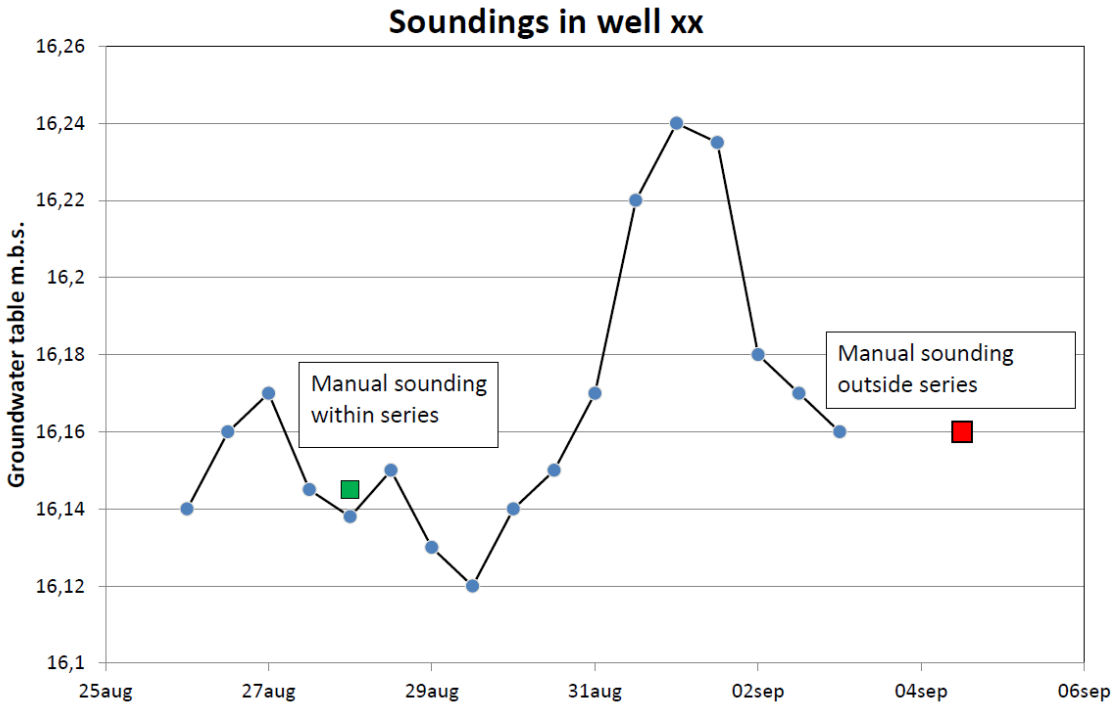

Figure 6. Use of manual groundwater level measurements for quality assurance of level logger data.
Tekst på figure rettes til :Manual measurement within the data series - Manual measurement outside the data series

Measurement of atmospheric pressure variations
Simultaneous measurements of atmospheric pressure are used for correction of the logged pressure measurements in several types of level loggers. Baro loggers are typically used for this purpose.

The measurement frequency for Baro loggers should be the same as that used in the level loggers, which will draw on the measured atmospheric pressure for calculation of corrections. The baro logger shall be programmed so that the measurement series starts simultaneously with the data logger. The baro logger shall be mounted in a representative distance from the loggers which are to be corrected, and as recommended by the supplier (normally no more than approx. 40 km away from the data loggers). For details on calculations and data processing, please see Technical guidelines: Groundwater data.

In the field, baro loggers shall be placed above the water table in a well that was previously equipped with the level logger which requires correction. The baro logger shall be placed in a frost-free depth, which is only possible if the water table is located a minimum of three meters below terrain at all times of the year. At times it is expedient to place one of the baro loggers at the office (where frost is not a problem) to be able to perform pressure correction. This is only possible if the office is within the representative distance.

Collecting data from the logger (groundwater level measurements and barometric readings)
All well information (DGU no. and monitoring point no.), date and time, monitoring points and control measurements (manual measurements) are noted in the groundwater measurement tables, see appendices. Any imperfections/anomalies are noted (e.g. if the line had a knot causing the data logger not to be suspended at the correct depth).

Data from level and baro loggers shall be collected as described in the user's manual covering these devices. To ensure sufficient data storage space for the next logging period, data loggers should usually be reset after every data collection.

The new starting time of the data logger shall be approx. 1 hour after resetting the device. If logging is initiated immediately, the data recorded before the final mounting of the device shall subsequently be deleted at the office during data processing.

When collecting data from the logger, data/curves should be revised to assess if they seem probable. Typical signs of errors or defects are e.g. many linear (horizontal) lines in a data series and in some cases inexplicable "jumps" between these, see Figures 7-10. This may also be caused by too large or small an amount of water above the logger.

Maintenance
If a data logger seems to be defective, see Section 4, an additional logger should be placed alongside it to check for any errors during the next measurement period. If the logger proves to be defective, it is discarded.

If data cannot be collected from a logger, it is sent to the supplier. In some cases, the supplier will be able to retrieve the data. Furthermore, a new logger should be mounted to replace the one removed.

2.3.4 Online groundwater table measurement stations

Wireless systems exist which use two-way communication between the level logger and a PC. These systems allow for programming, adjustment and collection of data from the logger from the office, provided the system was initially set up correctly. Data may be transmitted via the GSM net. See Technical guidelines: Groundwater data.

Online groundwater level measurement stations are checked manually before set up and subsequently at least annually. Collection of data can then be done from the office.

All field observations are noted on the groundwater measurement table as always.

2.3.5 Temperature measurements

If the level logger can measure temperature, it is noted at which depth the logger is placed relative to the reference point. This measurement has an accuracy of 1 cm. The level logger shall be placed at the same depth for all measurements.

The measuring frequency for temperature is the same as that used for groundwater level measurements. Temperature data are collected from the level logger when the groundwater table data are collected.

The level logger's temperature is calibrated with reference to a thermometer which has been benchmarked at the laboratory for the 5-15 °C interval. Temperature is measured at an accuracy of 0.2 °C and a precision of 0.1 °C (deviation from true value and uncertainty).

2.4.Checklist

Packing list:
Overview map showing all relevant wells, photos of the surroundings, the well and any reference points, if relevant.
Groundwater measurement table
Field folder with well information and field tables
Prints of the description of the reference point from the latest localization table, which shall have been updated in JUPITER
Print of time series (e.g. for assessment of the dynamic interval to be covered by the level logger, and for initial quality assurance of the collected data)
PC or similar with the relevant software installed for collection of data from loggers
External storage unit (USB flash memory) for backup of data while in the field
Key and tools for use at the well
Manual water table meter (preferably 2 and a spare 9 V battery).
Lines for mounting of data loggers + equipment to anchor the lines.
Folding ruler or measuring tape
Toolbox
Extra line/cable with snap hooks.
Small ladder (in case measurements are to be performed in a well).
Extra logger.
Spare batteries.

In those cases where the well is the property of someone else, the keys have not always been handed over. Information about the station in question and any specifics concerning keys shall be described in the folder holding the well information.

2.5 Maintenance of instruments

The electrical tape of manual water level meters shall regularly be checked for wear. Water level meters with excessive wear are replaced. Level loggers are rinsed with water of drinking water quality or demineralised water at every well.

The batteries of the manual water table meters shall always be kept sufficiently charged to remain operational in the field.

2.6 Special precautions - pitfalls

If nearby wells are being pumped, this will affect the groundwater level measurements in the current well. If the measurement is affected by drawdown in the immediate surrounding of the well, the collected data should be discarded.

If capillary pressure transducers are used, make sure that there are no water drops on the capillary tube and that is has no leaks, as the pressure transducer readings will otherwise be incorrect.

Before the reference point and, if relevant, the permanent reference point of the well are changed in JUPITER, any measurements made with reference to the original reference point shall have been reported to JUPITER.

3 Data processing

A comprehensive description of data processing and handling is available in the Technical guidelines: Groundwater data. Data-technical instructions are included herein when these are relevant to the field work.

3.1. Calculations

The pressure transducer measures pressure using units such as atm, mm Hg or hPa. The measured pressure needs to be convertible into metres of water column which, in turn can be converted into a specific depth. Conversion is typically performed using measurement logger software - e.g. DIVER Office.

Conversion from mm_{H2O} / m_{H2O} to hPa (hectopascal)

As from 2011 it has been possible to enter 'LufttrykHPa' (English: AirpressureHPa) into JUPITER

Conversion factors: 1 m H_2O = 98.066499 hPa

For example: 10.332 m_{H2O} * 98.066499hPa/mm_{H2O} = 1013.2 hPa = 1 atm

Please note: If the groundwater has a high salinity, its density may change making it necessary to employ a different conversion factor. This is only relevant if measurements are performed in wells affected by salty water (seawater). The conversion factor may be determined by multiplying the relative density relative to normal groundwater.

3.2 Data and codes

In the field the primary metadata shall be attached to all observations. The field table is used for this purpose and, when possible, also the data files.

For all groundwater measurements the following is stated:
DGU. no.
Monitoring point number
Time of groundwater level measurement (day-month-year hour:minutes)
Water level, tape measurement in metres below reference point
Reference point
Method (only use categories from the JUPITER code list e.g. "N" for tape measurement and "T" for transducer/measurement logger)
Quality of the groundwater measurement (code list: G: good, M: average and D: poor)
Measurement situation (code list: "no pumping" or "pumping")
Information about extreme situation, if relevant (T: dry and O: overflow)
Sampler initials
Notes

Optional information Measurement campaign ID (only used during groundwater measurement campaigns)

For water level meter and baro loggers, the following shall also be prepared:
Water level meter logger data file
Baro logger data file
Manual measurement (see above) before removing the data logger.
The level logger's depth below the reference point (if temperatures are measured or if such depth is necessary to convert logger data into water table depth)

4 Quality assurance

4.1 Quality assurance of method used

At manual measurements, the current measurement is checked by comparing results to a previous time series brought along to the measurement site, e.g. in the form of previous groundwater measurement tables. In case of substantial discrepancy which cannot be explained, data should be discarded, and groundwater measurement tables should be kept for assessment of future data. If possible, repeat the manual measurement until a reproducible measurement result is achieved. These assessments shall subsequently be stored in JUPITER along with the data, as described in the data-technical guideline. The electrical tape may have been read off incorrectly or data may have been recorded incorrectly (slip of the pen). The original data shall be stored in the field notes, which should not be discarded. If the inexplicable data subsequently prove to be reproducible and consistent, they should be added to JUPITER as active
data, following a professional assessment. This procedure ensures that relevant data are not discarded.

Data-logging measurements are revised as raw data when collecting data from the logger. Check if the measurement series is smooth and free of inexplicable fluctuations or numerous identical measurements, see Figures 7-10. Log all relevant field observations in the field table.

Before transferring data to JUPITER, the collected time series should undergo data preparation and quality assurance at the office, cf. Technical guidelines: Groundwater data.

4.2 Quality assurance of data and data submission

Initially, any clearly erroneous data should be removed from groundwater measurement and temperature time series. Figures 7-10 provides a series of examples illustrating how this may be done.

This process is called data processing. A constant challenge in data processing is that of finding a suitable balance between removing gross/clear errors and respecting inexplicable outliers, which represent real groundwater conditions.

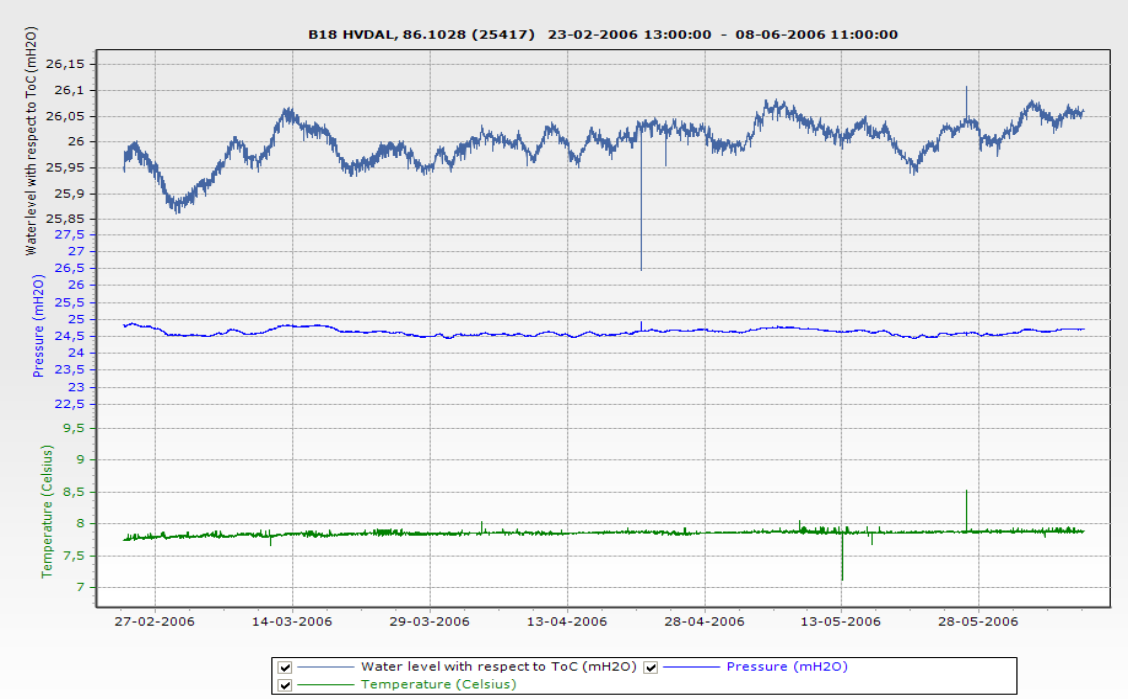

Figure 7. Data processing. In the upper time series, the three diverging data points are removed as are the two diverging data points of the temperature series.

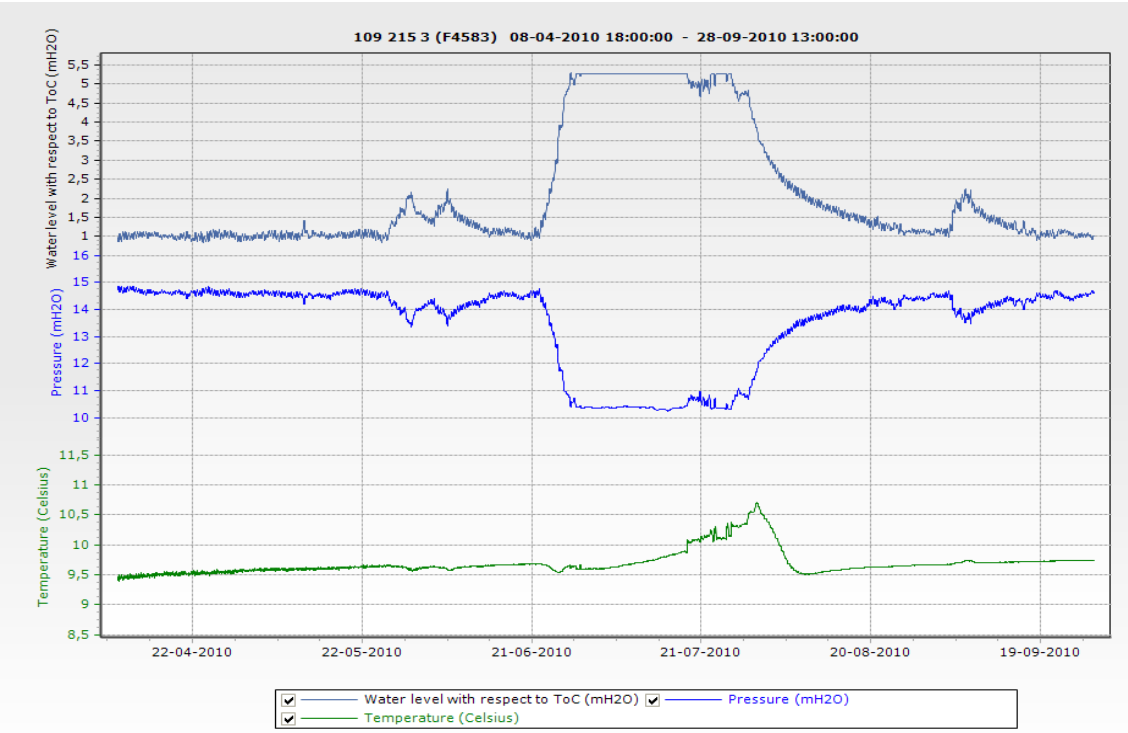

Figure 8. Data processing. In this groundwater measurement time series (data from tape measurement is the uppermost series), the two "horizontal peaks" are removed as the logger was then suspended in the air rather than under water.

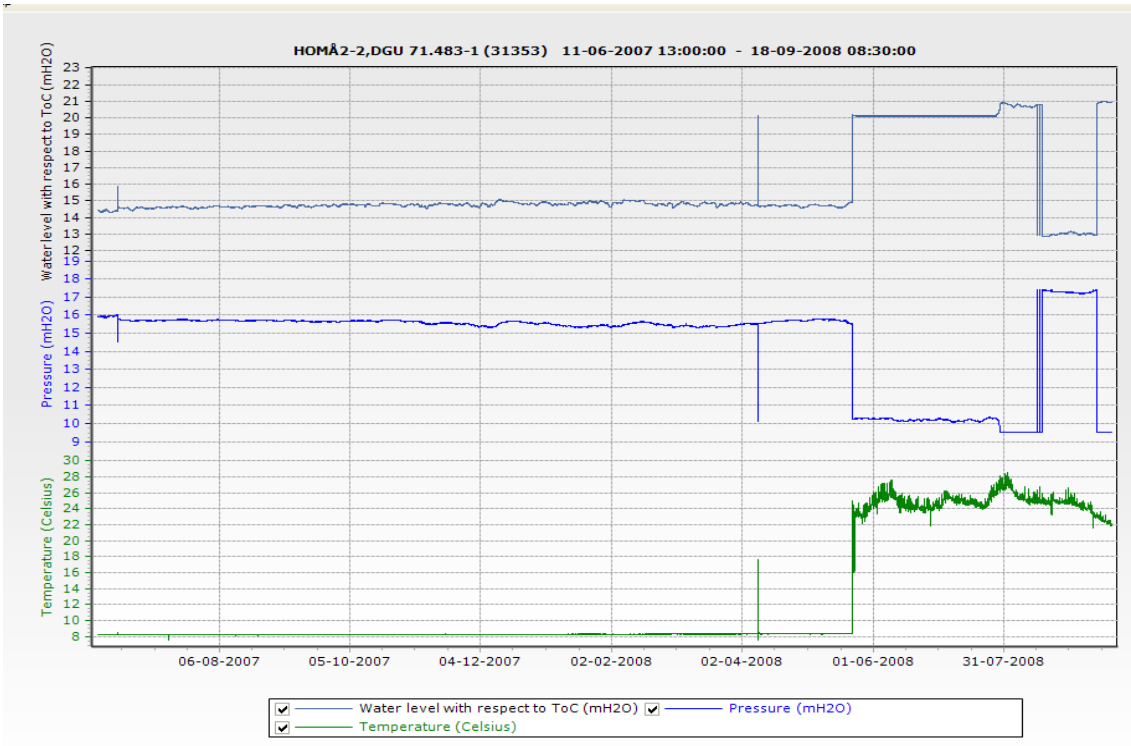

Figure 9. Data processing. The cause of the steep increase at the beginning of the curve is investigated and compensated, provided there is a reasonable cause to do so. In any case, the final part of the time series, from the end of May 2008 is discarded.

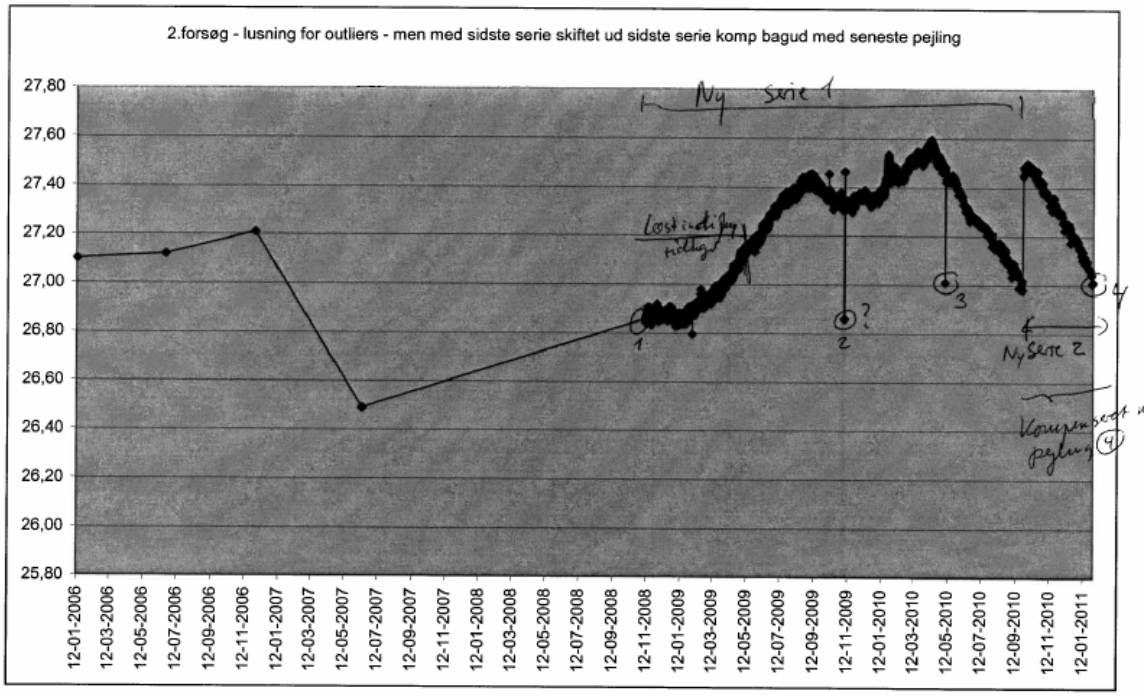

Figure 10. Data processing. This time series is discarded as the Diver apparently drifts several metres and the time series data cannot be adjusted to fit the manual measurements.

5 References

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Personal communication with Ib Kjeldsen, Rotek, 30 January 2012 on the accuracy of tape measures on manual water level meters.

5.1 Relevant links

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Pressure conversion factors: http://www.sensorsone.co.uk/pressure-units-conversion.html/

6 Appendices

6.1 Field table for groundwater level measurements

Data loggers

Aim of soundings

DGU-no, Station number	Date/time	Brand/ logger no/ scale of measurement	Location m.b.mp	Sample-rate	measurement point (mp) Description	Eqipment ID	sounding m.b.mp.	mp kote	VSP kote	Comments	Added to JUPITER

kote is meter above sealevel.

This table can be found as a pdf file on the Groundwater monitoring homepage: www.grundvandsovervaagning.dk