DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/116

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## Report prepared to E.ON Ruhrgas E&P GmbH

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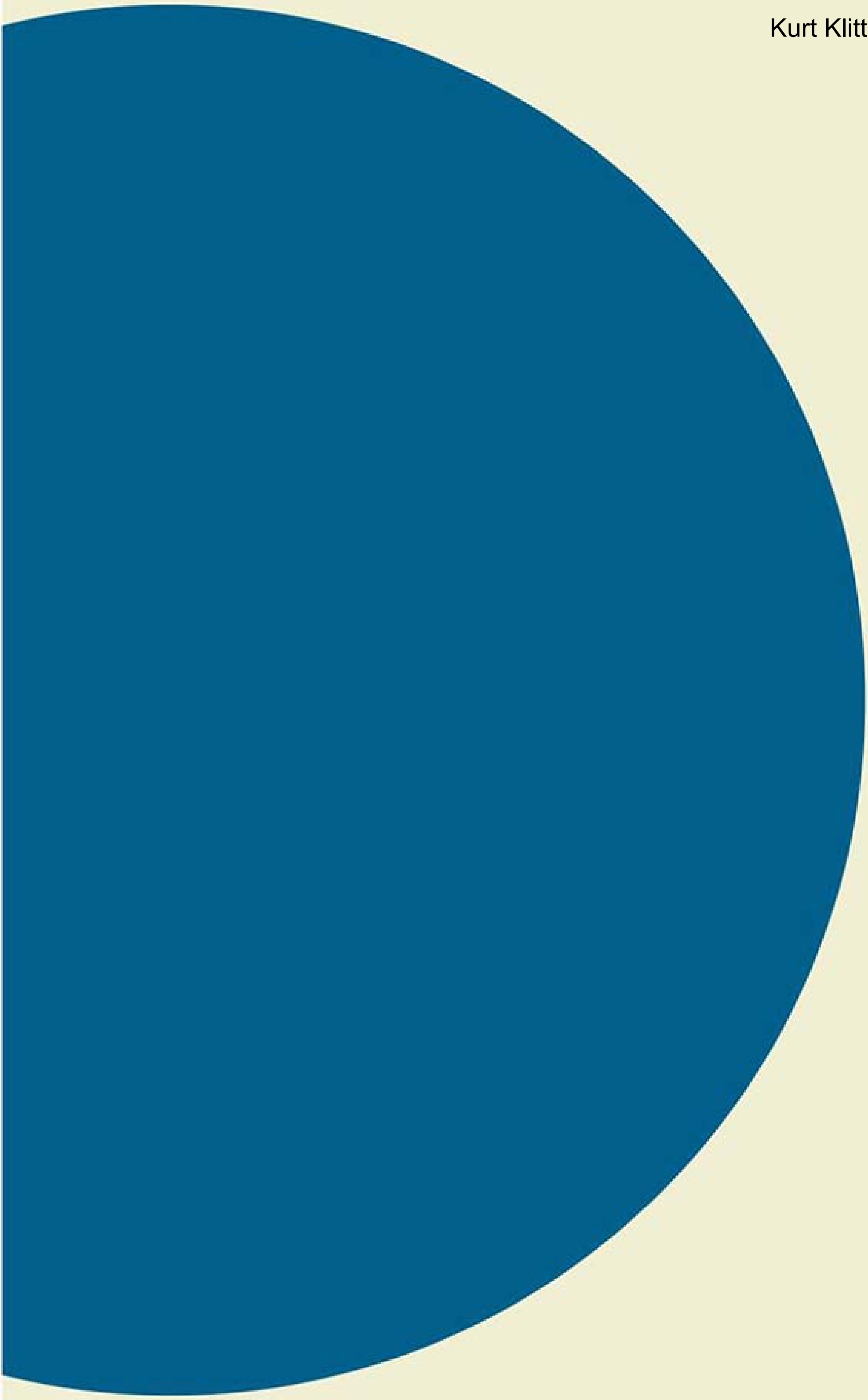

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

G E U S

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GEUS

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# Introduction

As requested by Eon Ruhrgas E&P GmbH, GEUS has conducted accumulated pumping tests of the 128 m deep core drilled research borehole Billegrav 2 (DGU nr. 248.61) located near the stream Ølå and 1.5 km south of Pedersker on the Bornholm island. The tests were carried out from the 1th to the 4th November 2010. The objective was to determine the transmissivity of each of the litho-stratigraphic main units. The planning of the accumulated pumping tests is based on the results from a complete logging programme conducted in the borehole on the 22nd and 23nd September 2010.

## *Geology*

As seen on the composite log-sheet, Fig. 1, the borehole has penetrated 61 m early Silurian Rastrites shale (F1-F5), then 35 m middle to upper Ordovician Jerrestad (E1-E3) and Dicellograptus shale (D1-D3), then 27 m Alun shale (B1-B4), and finally 5 m Rispebjerg sandstone (A). The letters and numbers refer to previously defined litho- and log-stratigraphic sub-units (Pedersen and Klitten, 1989) based on interpretation of gamma-logs in five boreholes in the same area. This sub-division of the litho-stratigraphy is seen verified in this borehole also by the variation of the Formation Conductivity-log as well by the Formation Resistivity-log (Rasmussen et al., 2010).

# Results

## *Accumulated pumping test*

Accumulated pumping tests consists of a number of pumping tests carried out on successively increased depth sections by using hydraulic packer for closing off the section below the packer. The ideal succession is to start with the upper section and stepwise move the packer to deeper position and finally remove the packer and include the whole borehole section in the last pumping. The yield of each test is determined from the result of the flow-log as the inflow of the respective sections in percentage of the total yield applied for the whole borehole. Therefore, the yields are successively increasing with increased depth of the respective sections.

It should be noticed that the borehole is artesian, thus water is flowing out from the top of casing pipe without any pumping. Unfortunately, the pressure head of the water could not be measured.

### Actual programme for the pumping test

The flow-log supported by the pattern of the Fluid Conductivity-log seen on Fig. 1., show inflow zones in the following depths and with inflow percentage in brackets: 20 m (11), 31 m (8), 38 m (6), 48 m (7), 51 m (33), 55 m (9), 61 m (6), 66 m (2), 68 m (3), 77 m (5), 90 m (5), and 97 m (5). The flow-log could not pass the irregularity at 92 m depth seen on the Diameter-log, but the pattern of the Fluid conductivity log below 97 m depth does indicate that there is no water flowing upwards from that section.

By comparing the locations of these zones with the lithology and the belonging estimates of the individual inflow it is seen that there are productive zones in all main lithological units apart from the Rispebjerg sandstone and most of the Alum shale. Surprisingly, the most productive inflow zones are seen in the lower part of the Rastrites shale.

Based on the inflow distribution compared to the lithology it was originally the intention to conduct pumping test on the following sections: above 33 m, above 59 m, above 90 m and the whole borehole, thus in total four pumping tests, see Fig. 2. The depths mentioned reflect the position of the top of the packer. The discharge rate (yield) applied and the time for the individual pumping tests are seen in Table 1 below:

Table 1: Packer sections, discharge rates, pumping and recovery periods

| Depth section | <33m | <48 m | <59 m | <90 m | <128 m |
|---|---|---|---|---|---|
| Percentage inflow (%) | 19 | 25 | 74 | 90 | 100 |
| Discharge rate in average ($m^3/h$) | 0,41 | 0,49 | 1,03 | 1,24 | 1,44 |
| Pumping period (h) | 4 | 4 | 4 | 4 | 4 |
| Recovery period (h) | 4 (5) | 11 (12) | 10 (11) | 4 (5) | 11 (12) |
| Actual order of tests | 2 | 5 | 3 | 4 | 1 |

As seen from the Table 1 and 2 as well as on Fig. 3, the order in which the tests were conducted does not follow the ideal order mentioned above. The reason was the tight time schedule for the whole exercise (3 full days allocated), why the first test done was pumping from the whole borehole without any packer. Afterwards the packer was installed at 33 m, 59 m and 90 m, thus the respective sections investigated from top and downwards. It turns out on such a way that one more test could be achieved late on the third day, and the crew was then instructed to place the packer at 48 m depth and conduct pumping on the section above, see Fig. 2.

All the five tests were run for four hours pumping. It was assumed that full recovery would be established if the recovery period was at least as long as the pumping period. In practise it was much longer during the nights after pumping during evenings. Even after the two pumping tests during day time the recovery period was four hours plus one hour preparation for next pumping.

As seen in Table 2 below, one more working day was allocated in order to make room for redoing the sonic logging in Billegrav 2 as well as in another exploratory borehole, Skelbro 2. The recovery period during daytime in the Billegrav 2 borehole was utilised for sonic logging in the Skelbro 2 borehole.

Table 2: Actual working program in the two exploratory boreholes

| Date | Skelbro 2 | Billegrav 2 | | | | |
|---|---|---|---|---|---|---|
| | Activity | Activity | Location of packer (m) | Discharge ($m^3/h$) | Activity time | Inflow (%) |
| 01.11.10 | | Sonic log (TRSG)<br>Prepare for PT<br>Pumping test<br>Recovery | | 1,44 | 12-16<br>16-17<br>17-21<br>21-08 | 100 |
| 02.11.10 | Sonic log (TRSG) | Prepare for PT | 33 | | 08-09 | |
| | | Pumping test | 33 | 0,41 | 09-13 | 19 |
| | | Recovery | 33 | | 13-17 | |
| | | Prepare for PT | 59 | | 17-18 | |
| | | Pumping test | 59 | 1,03 | 18-22 | 74 |
| | | Recovery | 59 | | 22-08 | |
| 03.11.10 | Sonic log (FWCG) | Prepare for PT | 90 | | 08-09 | |
| | | Pumping test | 90 | 1,24 | 09-13 | 90 |
| | | Recovery | 90 | | 13-17 | |
| | | Prepare for PT | 48 | | 17-18 | |
| | | Pumping test | 48 | 0,49 | 18-22 | 25 |
| | | Recovery | 48 | | 22-09 | |
| 04.11.10 | | Packing equipment<br>Sonic log (FWCG)<br>OPTV-log<br>Transport | | | 09-10<br>10-12<br>12-14<br>14-15 | |

## Practical arrangements for pumping

The borehole diameter is 76-78 mm only, why a MP1 submersible pump (Grundfos) was used for the pumping. At each test the pump setting depth was at 25 m. The water level was measured by a CTD-Diver at a time frequency of 30 seconds. Control measurement of the water level was conducted regularly by hand as seen on the attached Annex 1-5. The depth setting of the Diver was at 29 m at each test.

## Barometric effect on the measured water level data

Since the aquifers are expected to be confined a special Diver for registration of the air pressure was placed at the location above the terrain in order to adjust the measured water level data for eventual barometric effect, and for the Diver Barometric Compensation. The variation of the air pressure is seen on Fig. 4 below. The maximum variation is 12 cm water column. However, within the individual pumping periods of four hours as marked on Fig. 4 the maximum variation is seen to be 3 cm. The barometric effect of a confined aquifer is normally below 70 % and always below 100 %. Accordingly, it will be below or maximum 3 cm, why there is no reason to adjust the water level data for such a small effect.

## *The pumping test results*

The drawdown data of the five pumping tests are shown on Figures 10 to 14 as a semi-logarithmic plot with the time axis in logarithmic scale. Based on the Jacob-equation the transmissivity is calculated from the straight line through the later part of the drawdown graphs resulting in the values shown in the table below:

Table 3: Discharge rate Q, drawdown at 4 hours, specific yield and Jacob-transmissivity

| Pumping test | Q ($m^3/h$) | Drawdown (m) | Spec. Q ($m^3/h/m$) | T ($m^2/min$) x $10^3$ |
|---|---|---|---|---|
| < 128 m | 1,44 | 17,50 | 0,082 | 1,289 |
| < 90 m | 1,24 | 16,27 | 0,076 | 1,557 |
| < 59 m | 1,03 | 13,40 | 0,077 | 2,365 |
| < 48 m | 0,49 | 18,43 | 0,027 | 3,326 |
| < 33 m | 0,41 | 16,28 | 0,025 | 2,923 |

Surprisingly, the transmissivity is increasing towards decreasing depth of borehole section included in the pumping test. This should definitely not be the case, because it should not be possible for smaller depth sections than the total depth to arrive to a higher transmissivity than obtained by pumping from the total borehole depth section.

The most plausible explanation for the too high transmissivities obtained when pumping from each of the four sections above the packer is, that the water pressure of the whole aquifer after each pumping period never has been fully recovered. Even that all the recoveries had arrived to such a stage that the water was overflowing from the top casing when the next pumping period was initialised, that does not necessarily means the total artesian pressure was re-established. Such a situation results in a still ongoing “phantom-recharge” of the aquifer much larger than the applied discharge rate. Accordingly, the inclination of the straight line through the later part of the drawdown-graphs which represent the response of the aquifer on the discharge is not steep enough. Or one could say that the discharge rate applied in the Jacob-equation is too high because some of it is contributed by the “phantom-recharge”.

The reason why the artesian pressure seems not re-established in spite of the recovery periods all being longer than the pumping periods is the overflow. If the borehole casing either has been plugged or extended to several meters above the ground the full recovery might have been reached within the recovery periods applied before the next pumping.

Conclusively, only the very first pumping test of the total borehole section provides a reliable transmissivity representing the multi-aquifer situation which includes all the water bearing lithologic units penetrated by the 128 m deep borehole.

Concerning the five observed specific yields after four hours pumping, see Table 3 above, they vary generally as expected, i.e. they decrease towards decreasing depth of location of packer. The reason for those not being affected heavily by the “phantom-recharge” is that most of the total drawdown after each pumping is not caused by the hydraulic aquifer response but by the hydraulic inflow resistance (pressure well loss) through the fractures nearby the borehole. Accordingly, the largest increase in specific yield is seen when comparing the section <48 m with the section <59 m. The specific yield increases from 0,027 to 0,077 ($m^3/h/m$) by including the high inflow capacity from the lowermost subunit of the Rastrites shale.

## Control of packer tightness

Even that eventual leakage around the packer can not explain the too high transmissivities observed during the pumping test of the individual sections above the packer location, the following discussion of the control of packer tightness is maintained included in the report.

As mentioned previously the control of packer tightness during the individual tests is done by measuring the fluid temperature and fluid conductivity at a depth 4 m below the pump. In case the packer suddenly was not tight against the borehole wall and water from below the packer was passing, it should be seen as an increase of the temperature as well as of the conductivity. Because the two logs on Fig.1 show that both these parameters are increasing towards greater depth.

The two parameters are shown together with the drawdown on Figures 5 to 9, and there is no indication of any such sudden increase neither in temperature nor in conductivity during any of the pumping tests. Therefore leakage of water passing the packer from below can be excluded.

By comparing the temperature and the conductivities of the different pumping tests the differences are not that significant but they increase successively from test to test with increased depth of the packer (Table 4).

Table 4: Fluid conductivity (EC) and fluid temperature (Temp) measured with CTD-Diver

| Packer depth | EC, actual temp (µS/m) | Temp (DegC) | EC, 25 DegC (µS/m) |
|---|---|---|---|
| No packer (128 m) | 780 | 9,41 | 1133 |
| 90 m | 780 | 9,40 | 1134 |
| 59 m | 760 | 9,32 | 1107 |
| 48 m | 740 | 9,25 | 1080 |
| 33 m | 739 | 9,22 | 1080 |

In order to determine the magnitude of the fluid conductivity measured during each test (normalised to 25 $^{o}$C) the fluid conductivity of each inflow is calculated as seen in the table below by using the two logs, flow-log and fluid conductivity log. The sort of mass balance equation starting from below allows to calculate the conductivity of the inflow by reading the conductivity below and above an inflow and by knowing the percentage of water below, coming in, and above. The results are seen in the Table 5. They illustrate that the inflow of the lowermost zone is having the highest conductivity (1152 µS/m at actual temperature), and that the following inflows above are showing much lower conductivity, varying from 970 to 738 µS/m at actual temperature with a general tendency to decrease upwards with the lowest value at the top section.

Table 5: Calculated fluid electrical conductivity (EC) of individual inflow zones

| Depth | Inflow in Depth interval | Inflow below Depth | EC in Depth, actual Temp | EC in interval, actual Temp | Temp | Calc. EC in interval, at 25 DegC |
|---|---|---|---|---|---|---|
| (m) | (%) | (%) | (µS/m) | (µS/m) | (DegC) | (µS/m) |
| 20,3 | | 100 | 738 | | | |
| | 11 | | | 657 | 9,61 | 949 |
| 30,6 | | 89 | 748 | | | |
| | 8 | | | 728 | 9,67 | 1050 |
| 37,4 | | 81 | 750 | | | |
| | 6 | | | 650 | 9,72 | 936 |
| 47,8 | | 75 | 758 | | | |
| | 7 | | | 739 | 9,77 | 1062 |
| 50,6 | | 68 | 760 | | | |
| | 33 | | | 725 | 9,78 | 1042 |
| 55,8 | | 35 | 793 | | | |
| | 9 | | | 732 | 9,91 | 1049 |
| 60,7 | | 26 | 814 | | | |
| | 6 | | | 681 | 9,99 | 973 |
| 66,9 | | 20 | 854 | | | |
| | 2 | | | 755 | 10,13 | 1164 |
| 70,5 | | 18 | 858 | | | |
| | 3 | | | 865 | 10,14 | 1171 |
| 77,5 | | 15 | 865 | | | |
| | 5 | | | 655 | 10,21 | 930 |
| 90,4 | | 10 | 970 | | | |
| | 5 | | | 788 | 10,36 | 1114 |
| 96,6 | | 5 | 1152 | | | |
| | 5 | | | 1152 | 10,44 | 1625 |

## Conclusion on transmissivity of each lithologic depth section

Because of the problematic transmissivities derived from the four packer tests the transmissivity of each of the five lithologic depth sections 0-33 m, 33-48 m, 48-59 m, 59-90 m and 90-128 m is calculated from the reliable transmissivity, $T_t = 1.29 \times 10^{-3}$ ($m^2$ /min) of the total borehole section by using the inflow percentage ($IFP_n$) of each of those sections, i.e. from the equation:

$$T_t*100 = T_t*IFP_1 + T_t*IFP_2 + T_t*IFP_3 + T_t*IFP_4 + T_t*IFP_5$$

Accordingly to the inflow percentages for each packer section, seen in Table 1, the inflow ($IFP_n$) for the five individual lithologic sections are respectively 19, 6, 49, 16 and 10 %.

The transmissivities are then:

$T_{33} = 1.29 \times 10^{-3} \times 0.19 = 0.24 \times 10^{-3}$ ($m^2$ /min) – the upper two subunits of Rastrites shale

$T_{33\text{-}48} = 1.29 \times 10^{-3} \times 0.06 = 0.08 \times 10^{-3}$ ($m^2$ /min) – the middle subunit of Rastrites shale

$T_{48\text{-}59} = 1.29 \times 10^{-3} \times 0.49 = 0.63 \times 10^{-3}$ ($m^2$ /min) – the lowermost subunit of Rastrites shale

$T_{59\text{-}90} = 1.29 \times 10^{-3} \times 0.16 = 0.21 \times 10^{-3}$ ($m^2$ /min) – the Jerrestad and Dicellograptus shale

$T_{90\text{-}128} = 1.29 \times 10^{-3} \times 0.10 = 0.13 \times 10^{-3}$ ($m^2$ /min) – the lowermost Dicellograptus and uppermost Alum shale

Conclusively, most of the Alun shale and the underlying Rispebjerg sandstone do not show any water bearing zones, and therefore have no transmissivity (aquitards).

# References

Pedersen, G.K. and Klitten, K.: “Anvendelse af gamma-logs ved korrelation af marine skifre i vandforsyningsboringer på Bornholm”. Dansk Geologisk Forening, Årsskrift for 1987-89, side 21-35, København, Januar 1990. Abstract in English: Application of gamma-logs for correlation of Lower Palaeozoic marine shale’s on Bornholm.

Rasmussen, P., Klitten, K. and Schovsbo, N.H.: “Geophysical logging investigation of Palaeozoic marine shale’s in exploration borehole Billegrav 2 on Bornholm”. GEUS Report, 2010 (in preparation).

# Figures

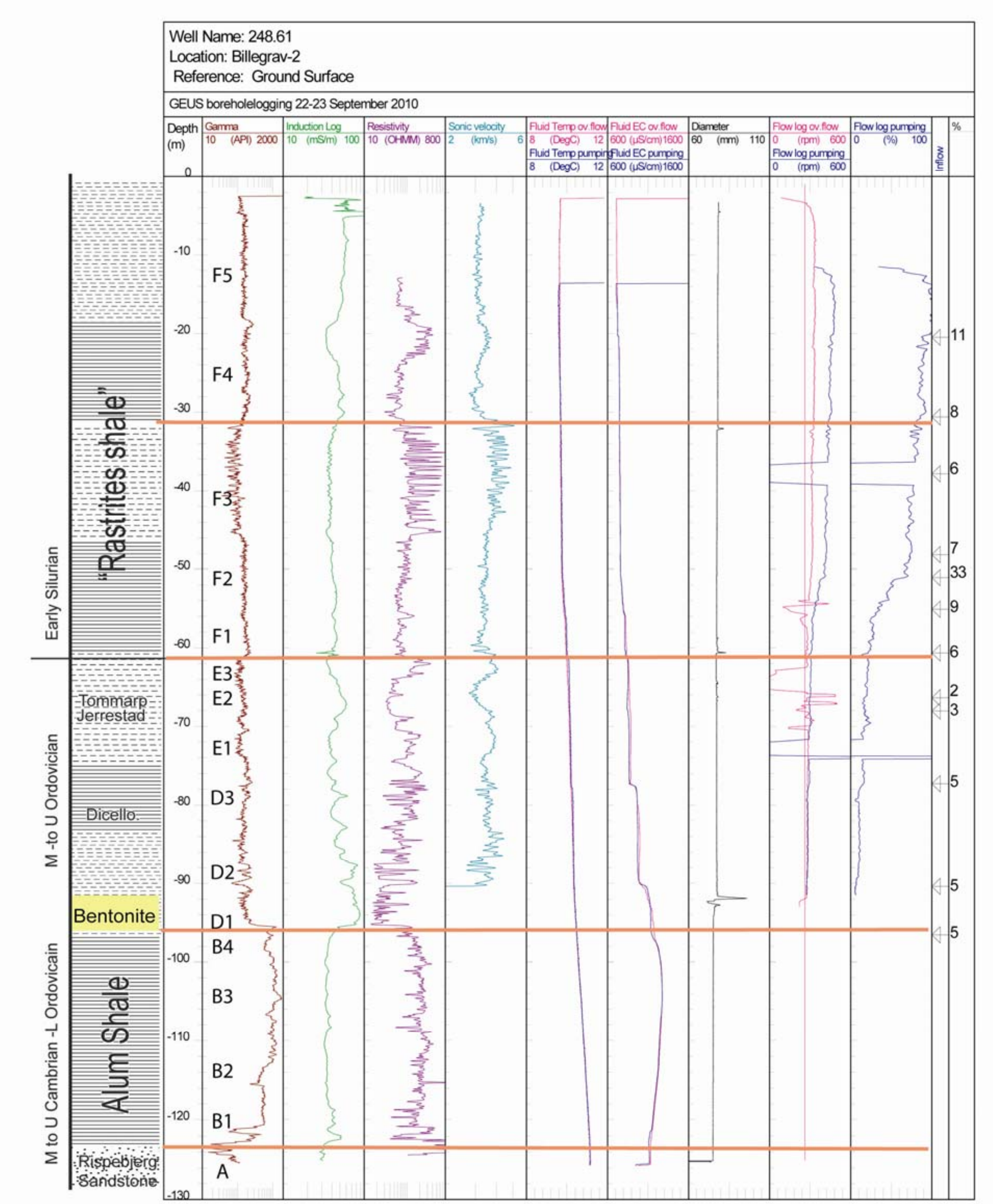

**Fig. 1: Composite geophysical log sheet with following columns: Geology, Depth, Gamma, Formation Conductivity, Formation Resistivity, Velocity, Diameter, Fluid Temperature, Fluid Conductivity, Flow with & without pump. (rpm), Flow pumping (%), Inflow (%). Arrows indicate inflow zones and number inflow percentage. Log units A-F is based on Pedersen & Klitten (1990).**

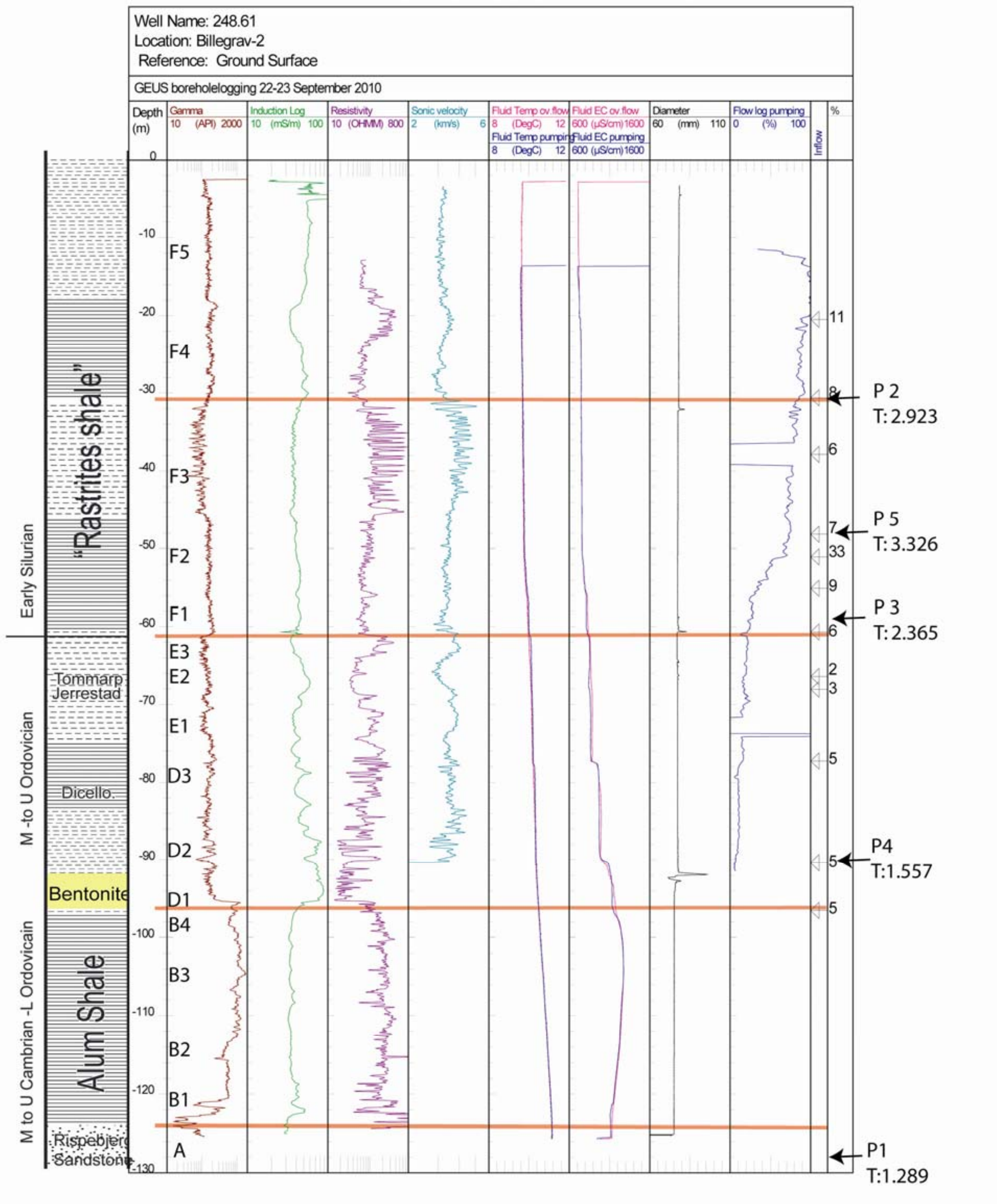

**Fig. 2: Composite geophysical log sheet with packer sections and following columns: Geology, Depth, Gamma, Form. Cond., Form. Resist., Velocity, Diameter, Fl.Temp., Fl.Cond.,. Black arrows indicate pumped sections (P1-P5) and numbers is calculated transmissivities (T in m2/min x $10^3$). Log units A-F is based on Pedersen & Klitten (1990).**

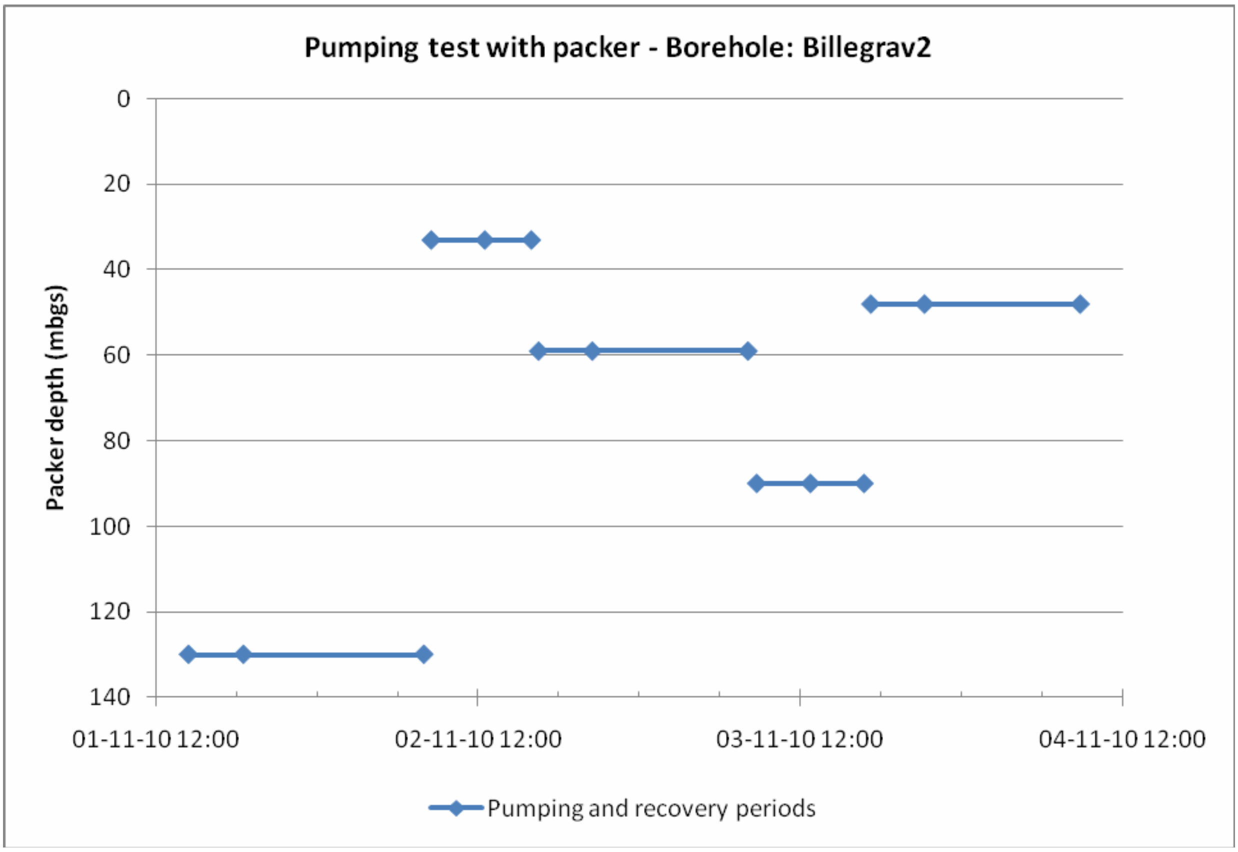

**Fig. 3:** **Diagram showing the order of pumping and recovery periods compared to the bottom depth of the actual section being pumped from.**

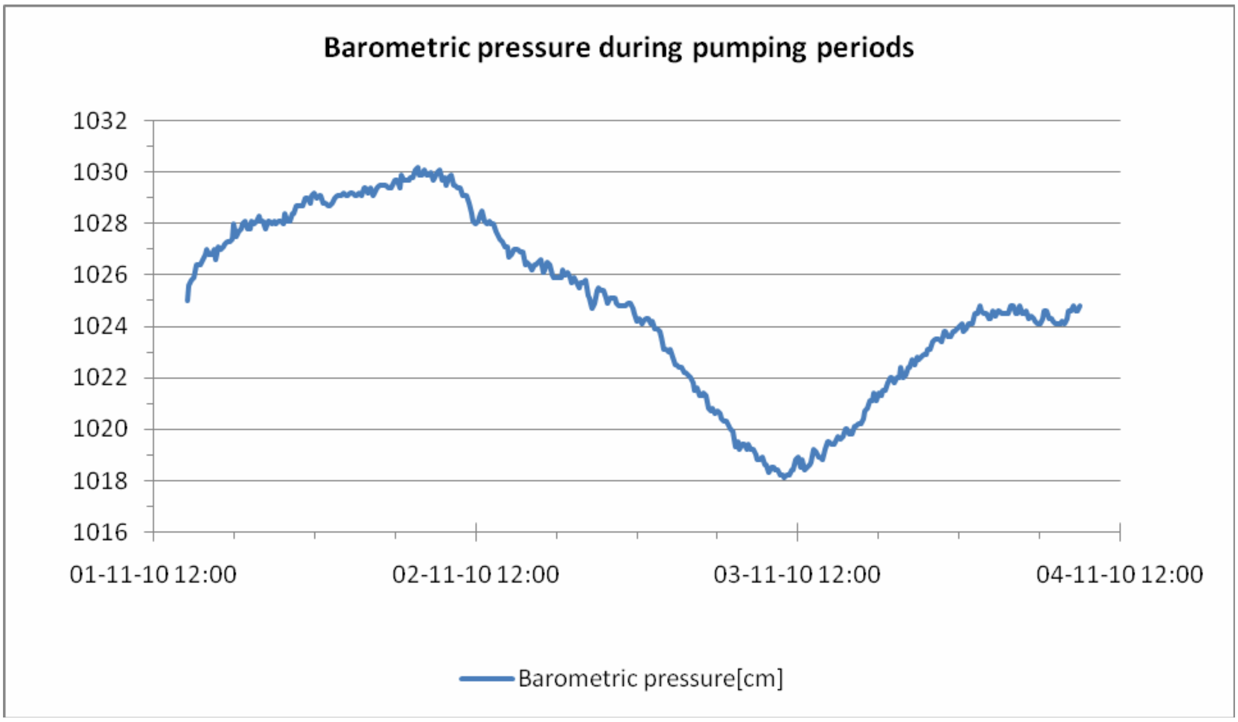

**Fig. 4:** **Diagram showing the variation during time of the barometric pressure (in cm water column) compared to the actual five pumping periods.**

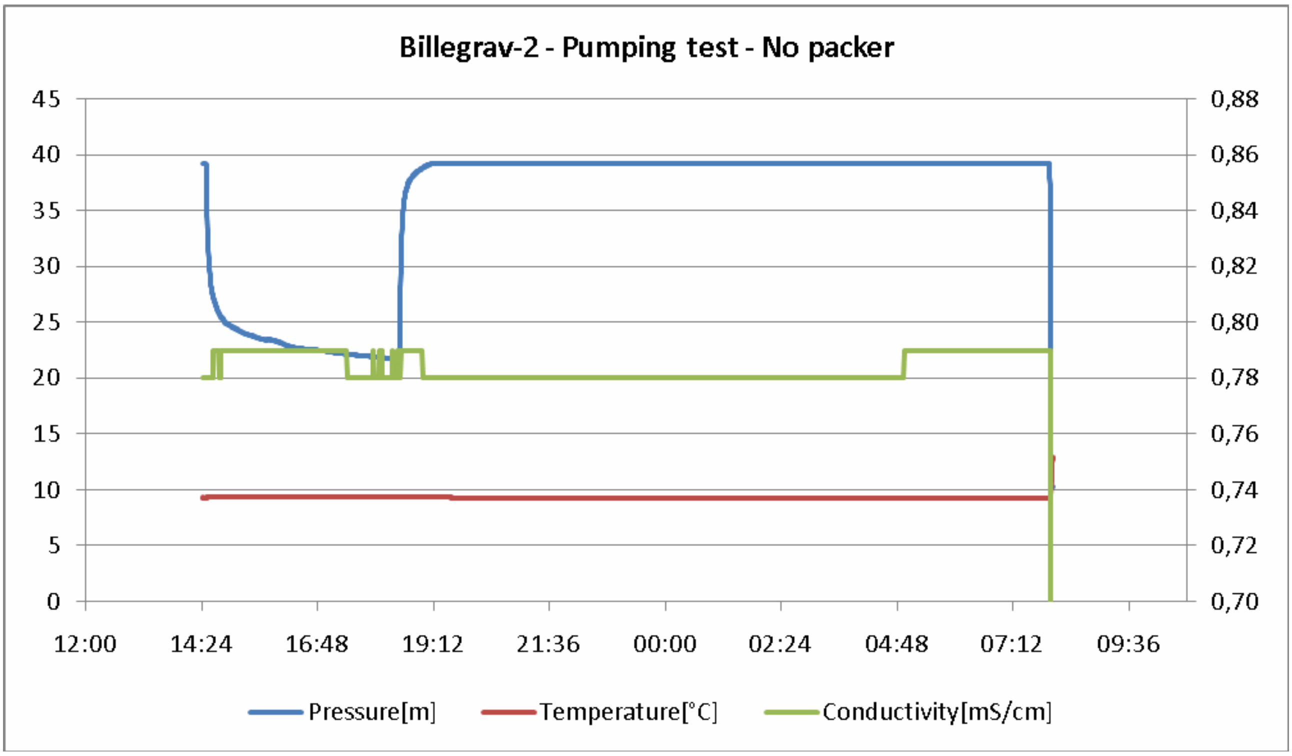

**Fig. 5:** Diagram showing the variation during time of water pressure including the barometric pressure and of temperature and conductivity at 29 m depth, i.e. 4 m below the submersible pump during pumping and recovery of the whole borehole section (without any packer).

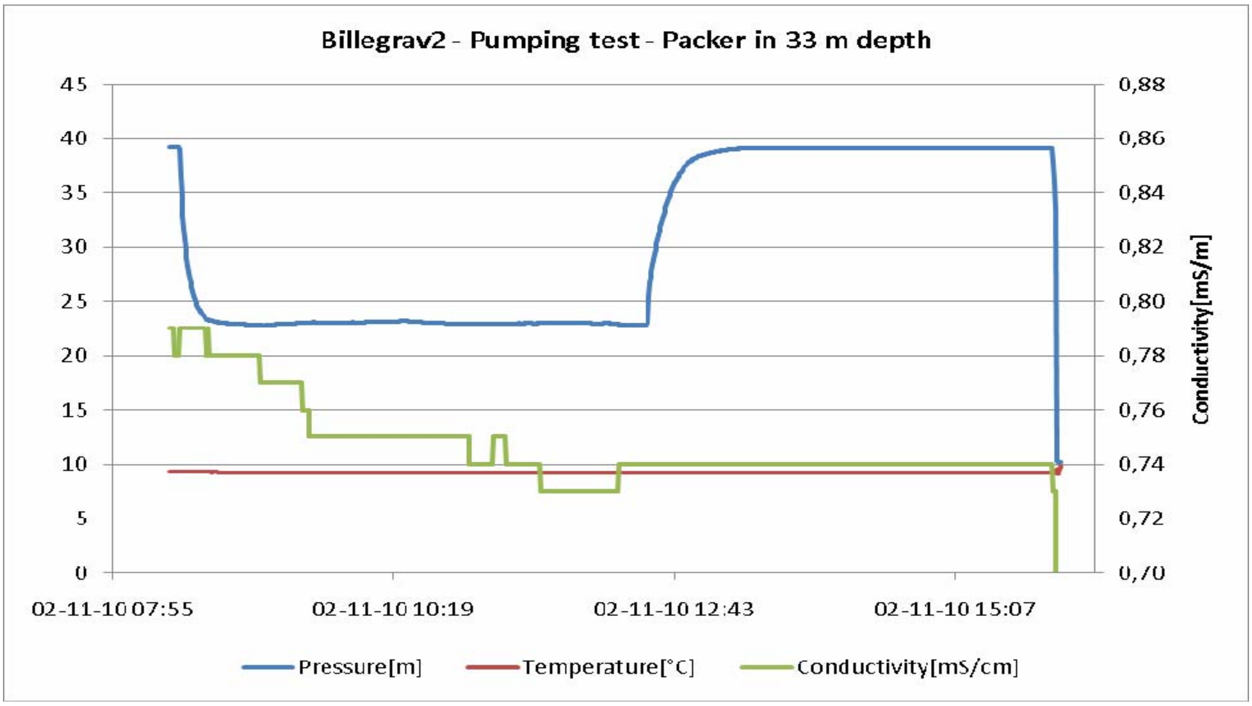

**Fig. 6:** Diagram showing the variation during time of water pressure including the barometric pressure and of temperature and conductivity at 29 m depth, i.e. 4 m below the submersible pump during pumping and recovery of the 33 m uppermost section of the borehole (with packer at 33 m depth).

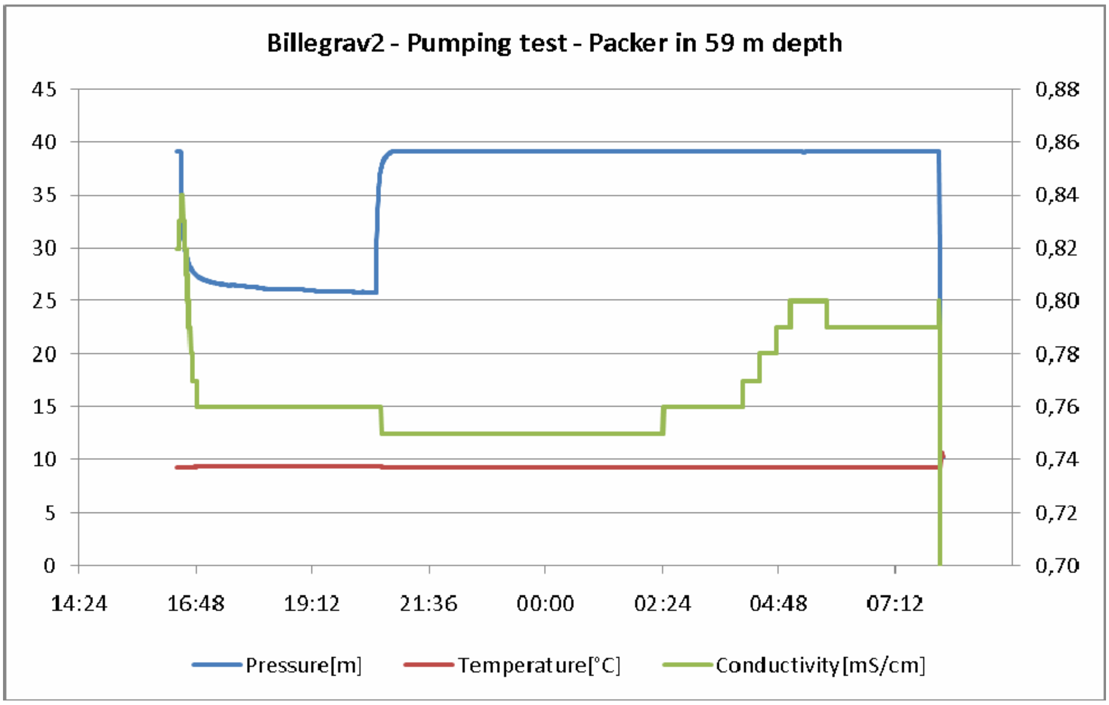

**Fig. 7:** **Diagram showing the variation during time of water pressure including the barometric pressure and of temperature and conductivity at 29 m depth, i.e. 4 m below the submersible pump during pumping and recovery of the 59 m uppermost section of the borehole (with packer at 59 m depth).**

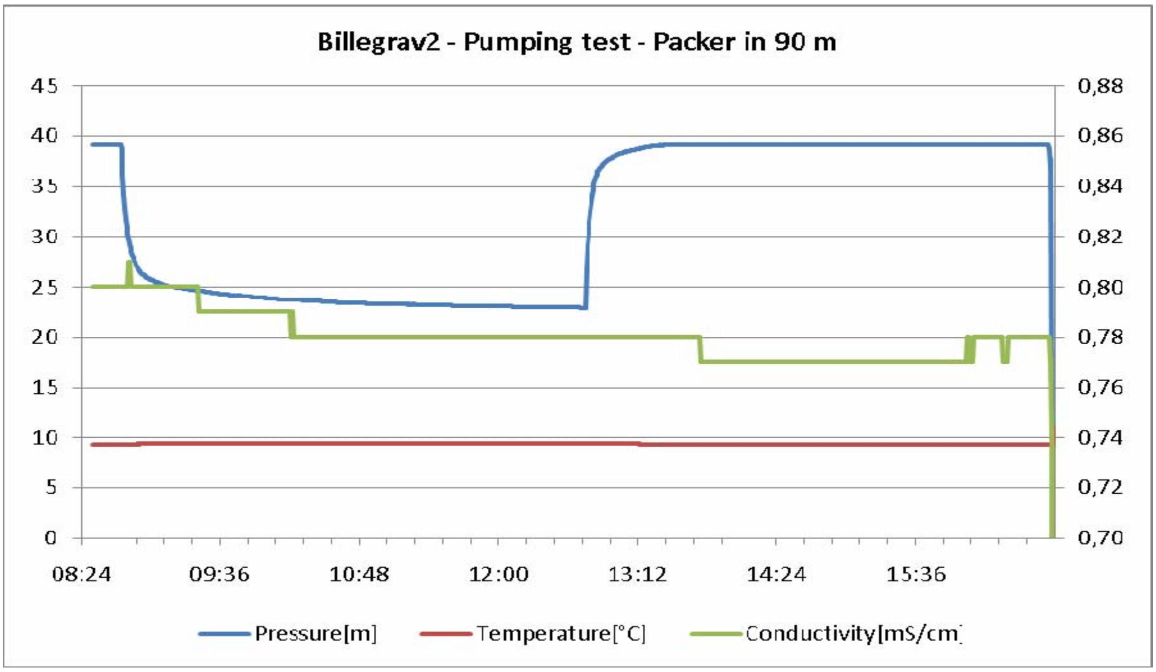

**Fig. 8:** **Diagram showing the variation during time of water pressure including the barometric pressure and of temperature and conductivity at 29 m depth, i.e. 4 m below the submersible pump during pumping and recovery of the 90 m uppermost section of the borehole (with packer at 90 m depth).**

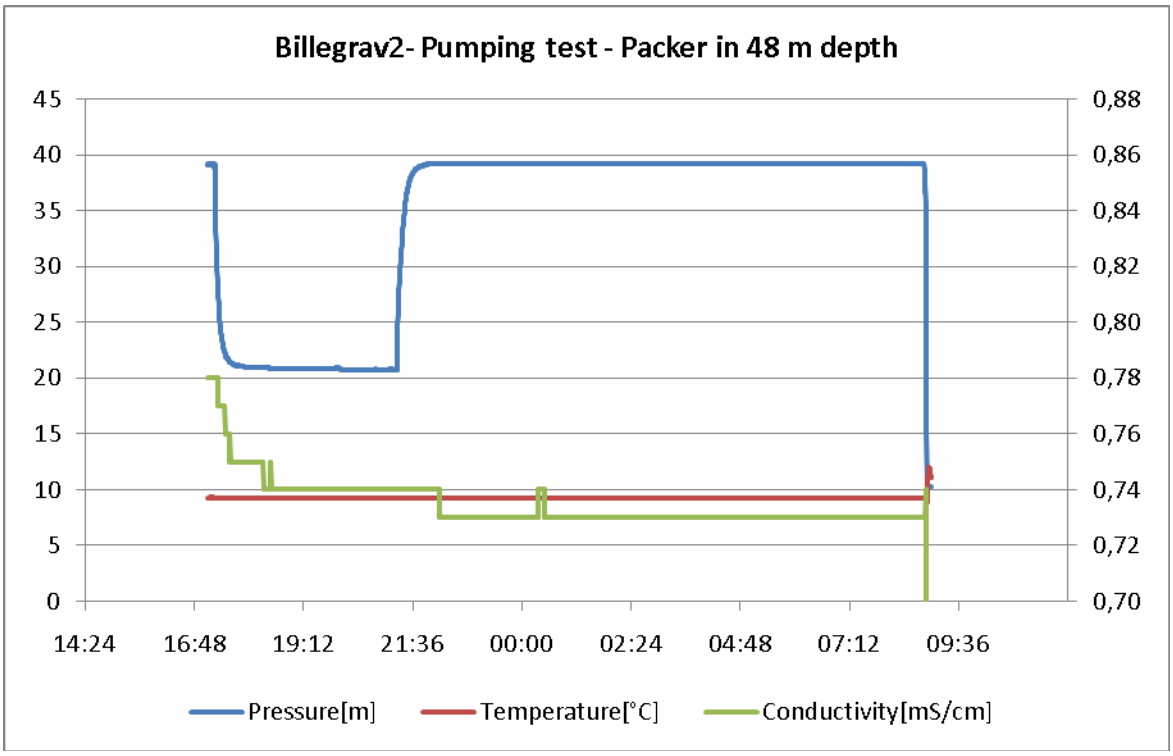

**Fig. 9:** **Diagram showing the variation during time of water pressure including the barometric pressure and of temperature and conductivity at 29 m depth, i.e. 4 m below the submersible pump during pumping and recovery of the 48 m uppermost section of the borehole (with packer at 48 m depth).**

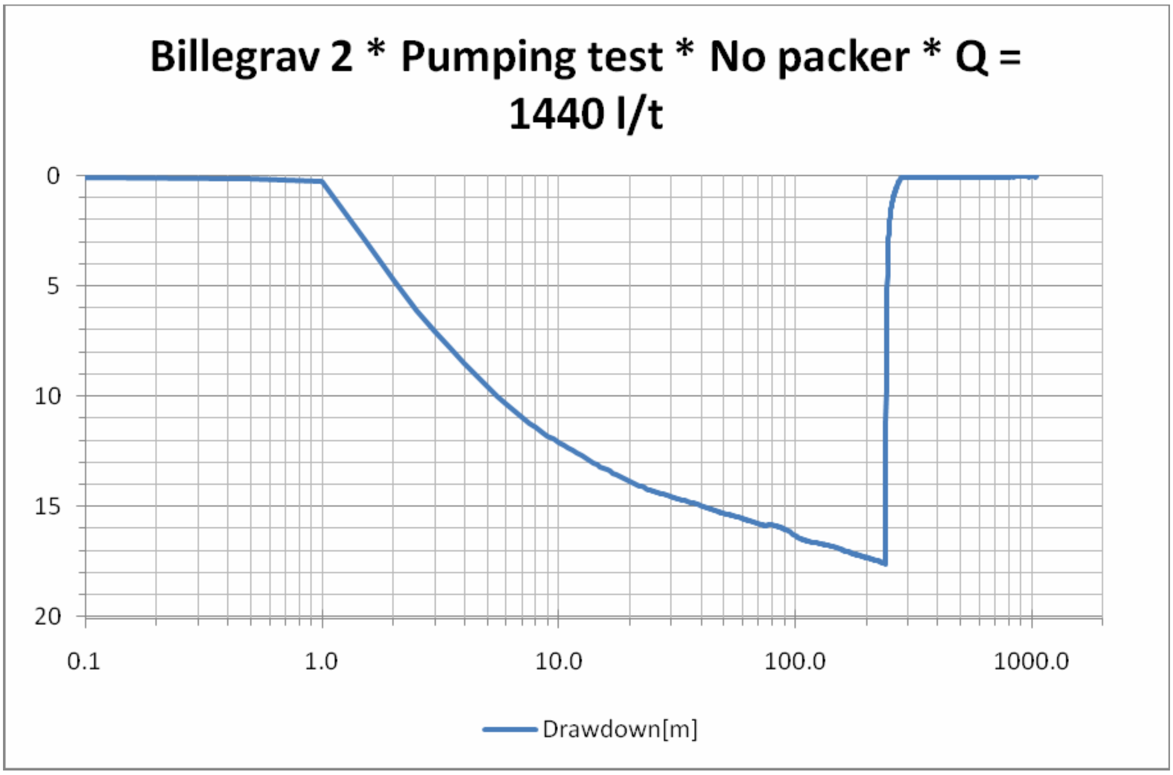

**Fig. 10:** **The drawdown data plotted against time in logarithmic scale during four hours pumping of the whole borehole section (without any packer).**

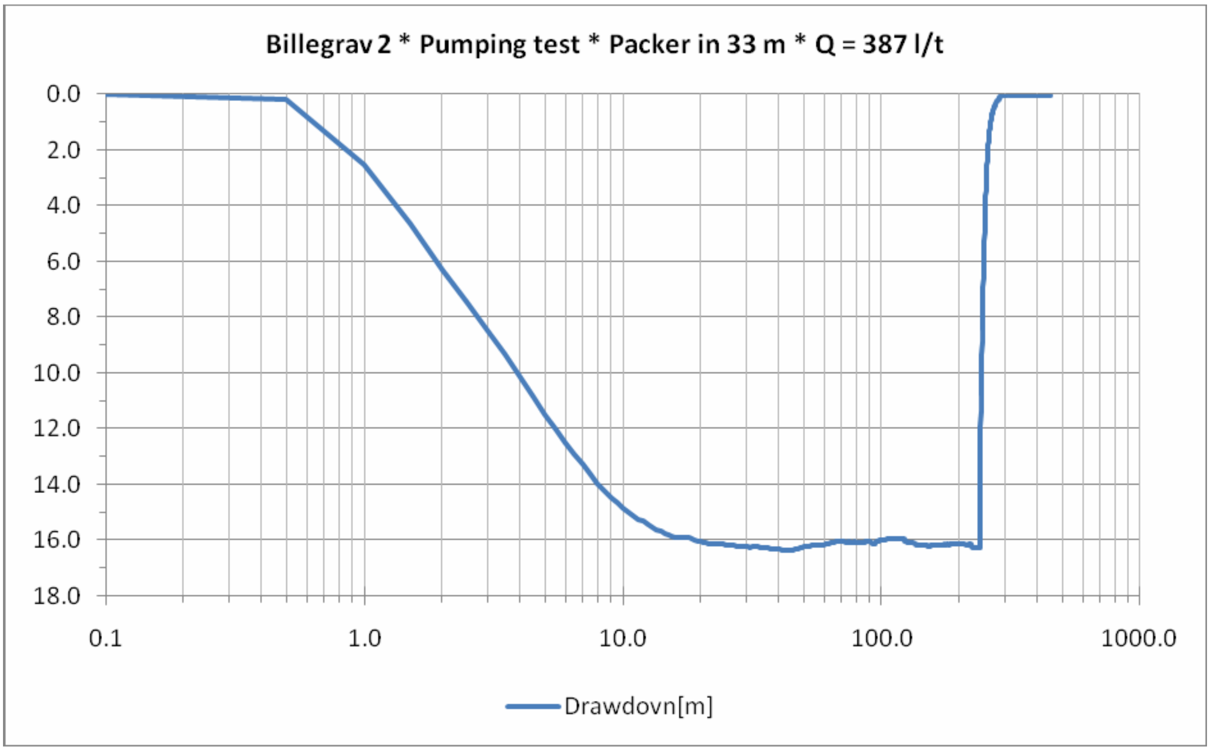

**Fig. 11:** **The drawdown data plotted against time in logarithmic scale during pumping of the 33 m uppermost section of the borehole (with packer at 33 m depth).**

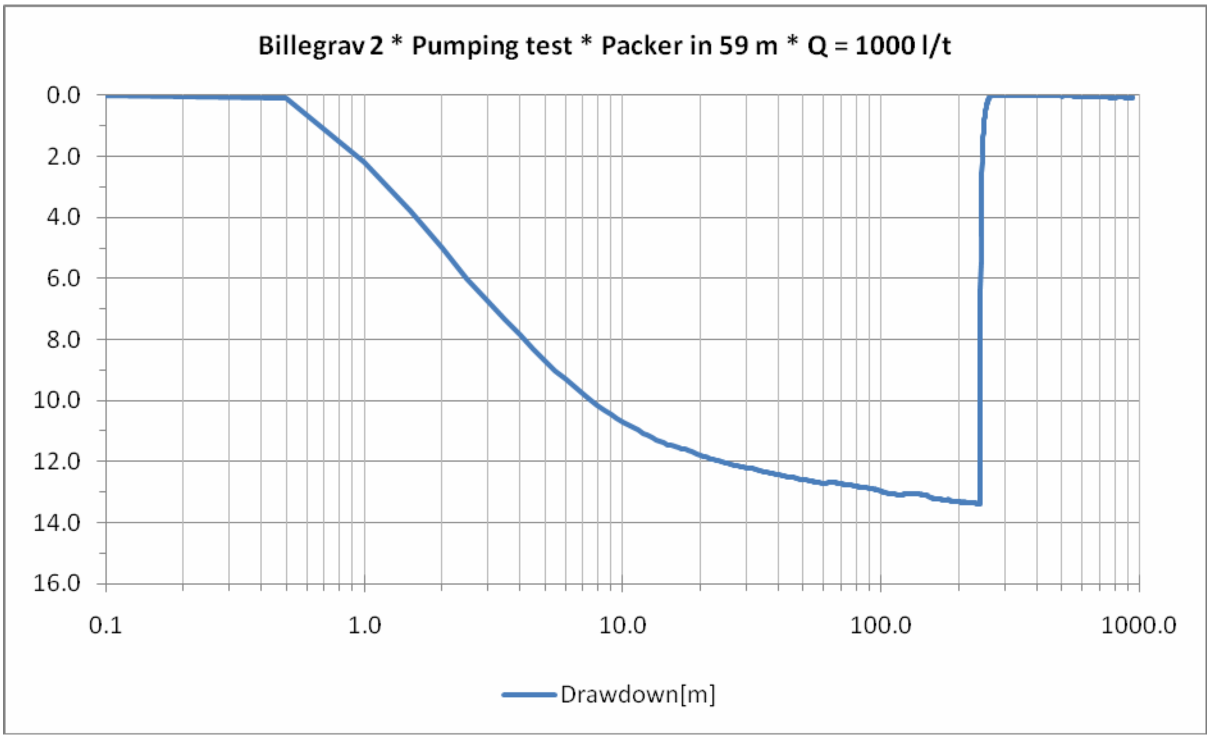

**Fig. 12:** **The drawdown data plotted against time in logarithmic scale during pumping of the 59 m uppermost section of the borehole (with packer at 59 m depth).**

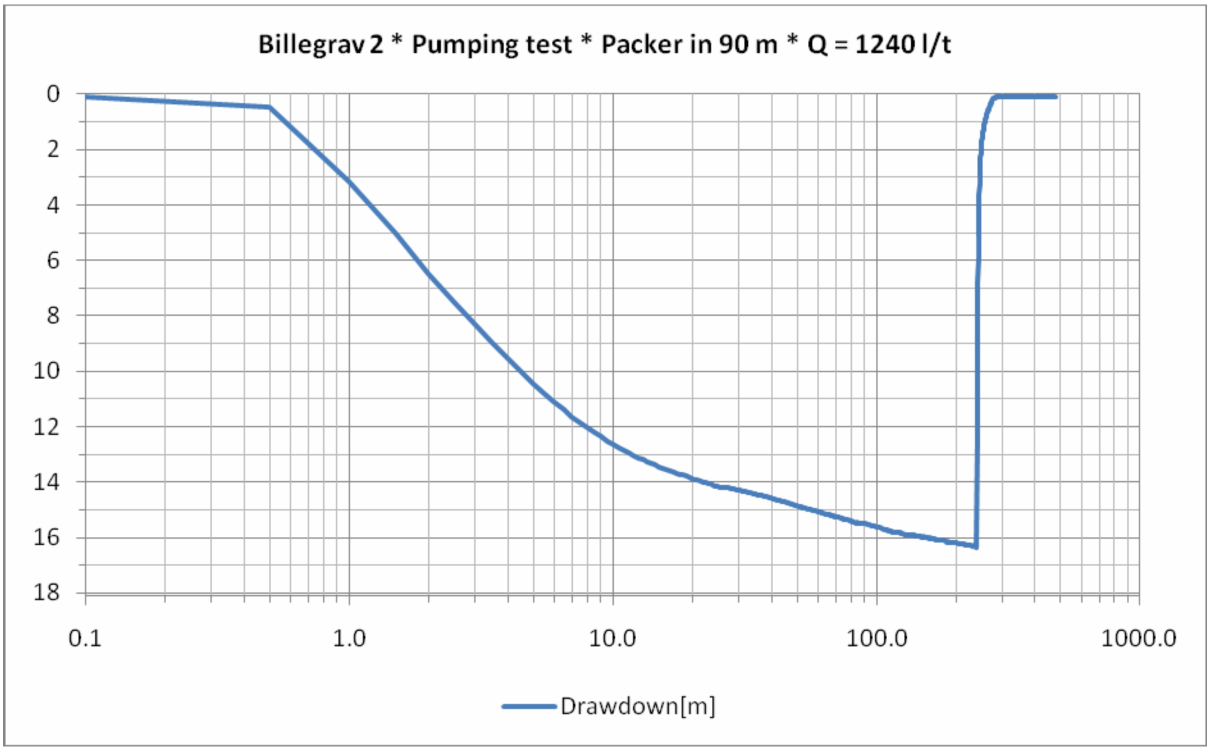

**Fig. 13:** The drawdown data plotted against time in logarithmic scale during pumping of the 90 m uppermost section of the borehole (with packer at 90 m depth).

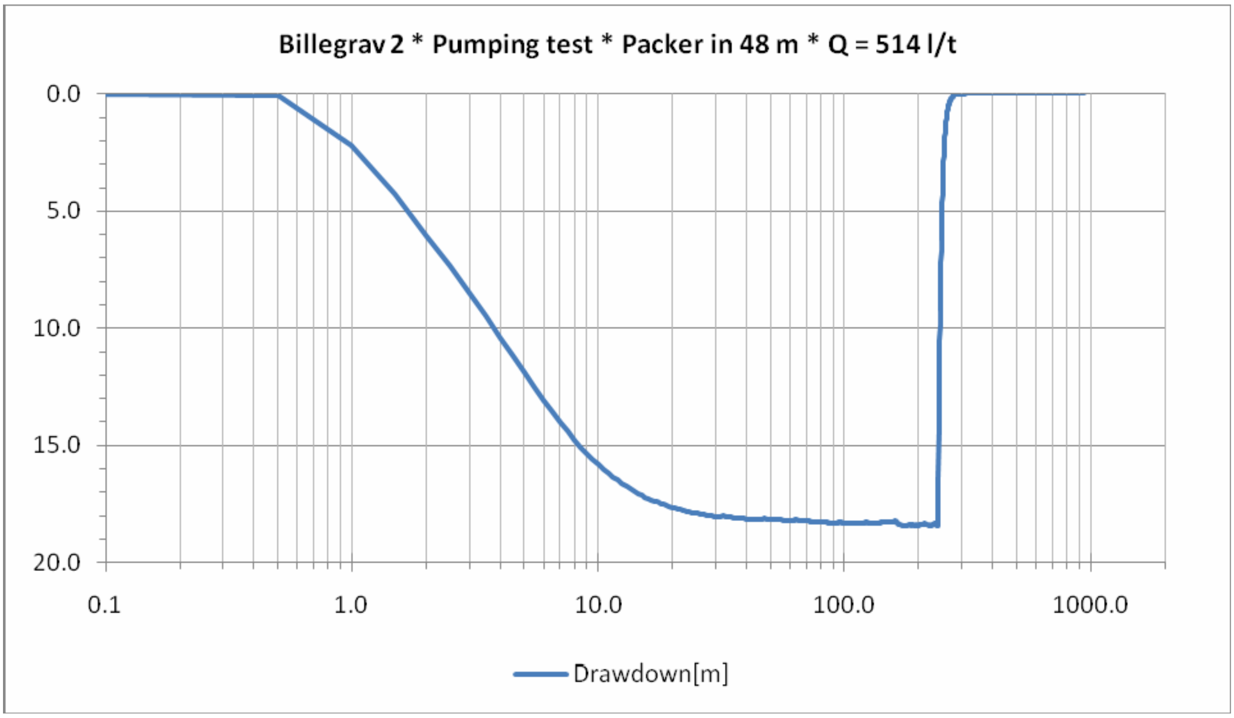

**Fig. 14:** The drawdown data plotted against time in logarithmic scale during pumping of the 48 m uppermost section of the borehole (with packer at 48 m depth).

# Appendix: Field measurements of water level and pumping rates from the five pumping tests; with no packer, packer at 33, 59, 90, and 48 m depth

| Field measurements | Time | Minute | Pumping | Minute | Water level (mbgl.) | Minute | Pumping rate (sec/10 l) | Pumping rate (l/h) | Minute | Packer pressure (bar) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 14:25 | | | -1 | | | | | | |
| Date: 1-11-10 | 14:30 | 0 | Start | | | | | | | |
| Int: Pej | 14:31 | 1 | | 1 | | | | | | |
| Projekt: GASH | 14:32 | 2 | | 2.5 | 7.20 | 2 | 20 | 1800 | | 0 |
| Location: Billegrav 2 | 14:35 | 5 | | 5 | 10.27 | | | | | |
| DGUnr.: 248.61 | 14:36 | | | | | 6 | 23 | 1565 | | |
| | 14:40 | 10 | | 10 | 12.27 | | | | | |
| Remarks: | 14:41 | | | | | 11 | 25 | 1440 | | |
| **No packer** | 14:45 | 15 | | 15 | 13.25 | | | | | |
| | 14:46 | | | | | 16 | 25 | 1440 | | |
| MP1 pump 25 mbgs. | 15:00 | 30 | | 30 | 14.53 | | | | | |
| | 15:01 | | | | | 31 | 24 | 1500 | | |
| Diver 29 mbgs. | 15:15 | 45 | | 45 | 15.11 | | | | | |
| | 15:16 | | | | | 46 | 25 | 1440 | | |
| | 15:30 | 60 | | 60 | 15.49 | | | | | |
| | 15:31 | | | | | 61 | 25 | 1440 | | |
| | 16:00 | 90 | | 90 | 15.98 | | | | | |
| | 16:01 | | | | | 91 | 25 | 1440 | | |
| | 16:30 | 120 | | 120 | 16.58 | | | | | |
| | 16:31 | | | | | 121 | 26 | 1385 | | |
| | 17:00 | 150 | | 150 | 16.81 | | | | | |
| | 17:01 | | | | | 151 | 24 | 1500 | | |
| | 17:30 | 180 | | 180 | 17.12 | | | | | |
| | 17:31 | | | | | 181 | 25 | 1440 | | |
| | 18:00 | 210 | | 210 | 17.34 | | | | | |
| | 18:01 | | | | | 211 | 25 | 1440 | | |
| | 18:30 | 240 | Stop | 240 | 17.54 | | | | | |

| **Field measurements** | **Time** | **Minute** | **Pumping** | **Minute** | **Water level (mbgl.)** | **Minute** | **Pumping rate (sec/10 l)** | **Pumping rate (l/h)** | **Minute** | **Packer pressure (bar)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | 08:25 | | | -1 | | | | | | |
| Date: 02-11-10 | 08:30 | 0 | Start | | | | 32 | 1125 | | 10 bar |
| Int: Pej | 08:31 | | | 1 | 4.30 | | 44 | 818 | | |
| Projekt: GASH | 08:32 | | | | | 2 | | | | |
| Location: Billegrav 2 | 08:35 | | | 5 | 12.05 | | | | | |
| DGUnr.: 248.61 | 08:36 | | | | | 6 | 62 | 581 | | |
| | 08:40 | | | 10 | 15.06 | | | | | |
| Remarks | 08:41 | | | | | 11 | 85 | 424 | | |
| **Packer 33 mbgs.** | 08:45 | | | 15 | 15.90 | | | | | |
| | 08:46 | | | | | 16 | 83 | 434 | | |
| MP1 pump 25 mbgs. | 09:00 | | | 30 | 16.27 | | | | | |
| | 09:01 | | | | | 31 | 90 | 400 | | |
| Diver 29 mbgs. | 09:15 | | | 45 | 16.36 | | | | | |
| | 09:16 | | | | | 46 | 90 | 400 | | |
| | 09:30 | | | 60 | 16.18 | | | | | |
| | 09:31 | | | | | 61 | 95 | 379 | | |
| | 10:00 | | | 90 | 16.06 | | | | | |
| | 10:01 | | | | | 91 | 93 | 387 | | |
| | 10:30 | | | 120 | | | | | | |
| | 10:31 | | | 122 | 16.07 | 122 | 93 | 387 | | |
| | 11:00 | | | 150 | 16.19 | | | | | |
| | 11:01 | | | | | 151 | 90 | 400 | | |
| | 11:30 | | | 180 | 16.15 | | | | | |
| | 11:31 | | | | | 181 | 85 | 424 | | |
| | 12:00 | | | 210 | 16.12 | | | | | |
| | 12:01 | | | | | 211 | 87 | 414 | | |
| | 12:30 | 240 | Stop | 240 | 16.27 | | | | | 10 bar |

| Field measurements | Time | Minute | Pumping | Minute | Water level (mbgl.) | Minute | Pumping rate (sec/10 l) | Pumping rate (l/h) | Minute | Packer pressure (bar) |
|---|---|---|---|---|---|---|---|---|---|---|
|  | 16:25 |  |  | -1 |  |  |  |  |  |  |
| Date: 02-11-10 | 16:30 | 0 | Start |  |  |  |  |  |  | 13 bar |
| Int: Pej | 16:31 | 1 |  | 1 | 4.21 |  |  |  |  |  |
| Projekt: GASH |  |  |  |  |  | 1 | 26 | 1385 |  |  |
| Location: Billegrav 2 | 16:35 | 5 |  | 5 | 9.03 |  |  |  |  |  |
| DGUnr.: 248.61 | 16:36 |  |  |  |  | 6 | 32 | 1125 |  |  |
|  |  | 10 |  | 10 |  |  |  |  |  |  |
| Remarks: | 16:44 |  |  |  | 11.40 | 15 | 34 | 1059 |  |  |
| **Packer 59 mbgs.** | 16:45 | 15 |  | 15 |  |  |  |  |  |  |
|  |  |  |  |  |  | 16 |  |  |  |  |
| MP1 pump 25 mbgs. | 17:00 | 30 |  | 30 | 12.22 |  |  |  |  |  |
|  | 17:01 |  |  |  |  | 31 | 37 | 973 |  |  |
| Diver 29 mbgs. | 17:18 | 48 |  | 48 | 12.58 |  |  |  |  |  |
|  | 17:19 |  |  |  |  | 49 | 36 | 1000 |  |  |
|  | 17:30 | 60 |  | 60 | 12.73 |  |  |  |  |  |
|  | 17:31 |  |  |  |  | 61 | 38 | 947 |  |  |
|  | 18:00 | 90 |  | 90 | 12.88 |  |  |  |  |  |
|  | 18:01 |  |  |  |  | 91 | 37 | 973 |  |  |
|  | 18:30 | 120 |  | 120 | 13.11 |  |  |  |  |  |
|  | 18:31 |  |  |  |  | 121 | 35 | 1029 |  |  |
|  | 19:00 | 150 |  | 150 | 13.10 |  |  |  |  |  |
|  | 19:01 |  |  |  |  | 151 | 35 | 1029 |  |  |
|  | 19:30 | 180 |  | 180 | 13.26 |  |  |  |  |  |
|  | 19:31 |  |  |  |  | 181 | 35 | 1029 |  |  |
|  | 20:00 | 210 |  | 210 | 13.33 |  |  |  |  |  |
|  | 20:01 |  |  |  |  | 211 | 35 | 1029 |  |  |
|  | 20:30 | 240 | Stop | 240 | 13.39 |  |  |  |  | 13 bar |

| **Field measurements** | **Time** | **Minute** | **Pumping** | **Minute** | **Water level (mbgl.)** | **Minute** | **Pumping rate (sec/10 l)** | **Pumping rate (l/h)** | **Minute** | **Packer pressure (bar)** |
|---|---|---|---|---|---|---|---|---|---|---|
|  | 08:30 |  |  | -1 |  |  |  |  |  |  |
| Date: 03-11-10 | 08:45 | 0 | Start |  |  |  |  |  |  | 16 bar |
| Int: Pej | 08:46 |  |  | 1 | 4.70 |  |  |  |  |  |
| Projekt: GASH | 08:47 |  |  |  |  | 2 | 22 | 1636 |  |  |
| Location:Billegrav 2 | 08:50 |  |  | 5 | 10.68 |  |  |  |  |  |
| DGUnr.: 248.61 | 08:51 |  |  |  |  | 6 | 25 | 1440 |  |  |
|  | 08:55 |  |  | 10 | 12.66 |  |  |  |  |  |
| Remarks: | 08:56 |  |  |  |  | 11 | 27 | 1333 |  |  |
| **Packer 90 mbgs.** | 09:00 |  |  | 15 | 13.38 |  |  |  |  |  |
|  | 09:01 |  |  |  |  | 16 | 28 | 1286 |  |  |
| MP1 pump 25 mbgs. | 09:15 |  |  | 30 | 14.20 |  |  |  |  |  |
|  | 09:16 |  |  |  |  | 31 | 28 | 1286 |  |  |
| Diver 29 mbgs. | 09:30 |  |  | 45 | 14.64 |  |  |  |  |  |
|  | 09:31 |  |  |  |  | 45 | 29 | 1241 |  |  |
|  | 09:45 |  |  | 60 | 14.98 |  |  |  |  |  |
|  | 09:46 |  |  |  |  | 61 | 29 | 1241 |  |  |
|  | 10:15 |  |  | 90 | 15.40 |  |  |  |  |  |
|  | 10:16 |  |  |  |  | 91 | 28 | 1286 |  |  |
|  | 10:45 |  |  | 120 | 15.71 |  |  |  |  |  |
|  | 10:46 |  |  |  |  | 121 | 28 | 1286 |  |  |
|  | 11:15 |  |  | 150 | 15.87 |  |  |  |  |  |
|  | 11:16 |  |  |  |  | 151 | 28 | 1286 |  |  |
|  | 11:45 |  |  | 180 | 16.00 |  |  |  |  |  |
|  | 11:46 |  |  |  |  | 181 | 29 | 1241 |  |  |
|  | 12:15 |  |  | 235 | 16.12 |  |  |  |  |  |
|  | 12:16 |  |  |  |  | 236 | 29 | 1241 |  |  |
|  | 12:45 | 240 | Stop |  | 16.20 |  |  |  |  | 16 bar |

| **Field measurements** | **Time** | **Minute** | **Pumping** | **Minute** | **Water level (mbgl.)** | **Minute** | **Pumping rate (sec/10 l)** | **Pumping rate (l/h)** | **Minute** | **Packer pressure (bar)** |
|---|---|---|---|---|---|---|---|---|---|---|
|  | 17:00 |  |  | -1 |  |  |  |  |  |  |
| Date: 03-11-10 | 17:15 | 0 | Start |  |  |  |  |  |  | 12,5 bar |
| Int: Pej | 17:16 |  |  | 1 | 4.30 |  |  |  |  |  |
| Projekt: GASH | 17:17 |  |  |  |  | 2 | 37 | 973 |  |  |
| Location: Billegrav 2 | 17:20 |  |  | 5 | 12.60 |  |  |  |  |  |
| DGUnr.: 248.61 | 17:21 |  |  |  |  | 6 | 48 | 750 |  |  |
|  | 17:25 |  |  | 10 | 16.07 |  |  |  |  |  |
| Remarks | 17:26 |  |  |  |  | 11 | 58 | 621 |  |  |
| **Packer 48 mbgs.** | 17:30 |  |  | 15 | 17.25 |  |  |  |  |  |
|  | 17:31 |  |  |  |  | 16 | 62 | 581 |  |  |
| MP1 pump 25 mbgs. | 17:45 |  |  | 30 | 18.07 |  |  |  |  |  |
|  | 17:46 |  |  |  |  | 31 | 69 | 522 |  |  |
| Diver 29 mbgs. | 18:00 |  |  | 45 | 18.20 |  |  |  |  |  |
|  | 18:01 |  |  |  |  | 45 | 68 | 529 |  |  |
|  | 18:15 |  |  | 60 | 18.25 |  |  |  |  |  |
|  | 18:16 |  |  |  |  | 61 | 70 | 514 |  |  |
|  | 18:48 |  |  | 93 | 18.33 |  |  |  |  |  |
|  | 18:49 |  |  |  |  | 94 | 67 | 537 |  |  |
|  | 19:15 |  |  | 120 | 18.38 |  |  |  |  |  |
|  | 19:16 |  |  |  |  | 121 | 71 | 507 |  |  |
|  | 19:52 |  |  | 157 | 18.30 |  |  |  |  |  |
|  | 19:53 |  |  |  |  | 158 | 72 | 500 |  |  |
|  | 20:15 |  |  | 180 | 18.46 |  |  |  |  |  |
|  | 20:16 |  |  |  |  | 181 | 73 | 493 |  |  |
|  | 20:45 |  |  | 210 | 18.44 |  |  |  |  |  |
|  | 20:46 |  |  |  |  | 211 | 74 | 486 |  |  |
|  | 21:15 | 240 | Stop | 240 | 18.45 |  |  |  |  | 12,5 bar |

# On CD only: Raw measurements in excel files