Working Report 2007-93

Slug-Tests in PP- and PVP-Holes at Olkiluoto in 2006

Katriina Keskitalo
Susanna Lindgren

November 2007

POSIVA OY
FI-27160 OLKILUOTO, FINLAND
Tel +358-2-8372 31
Fax +358-2-8372 3709

Working Report 2007-93

Slug-Tests in PP- and PVP-Holes at Olkiluoto in 2006

Katriina Keskitalo

Pöyry Environment Oy

Susanna Lindgren

Posiva Oy

November 2007

Slug-tests in PP- and PVP-holes at Olkiluoto in 2006

ABSTRACT

As part of the program for the final disposal of the nuclear fuel waste, Posiva Oy investigates the hydrological conditions at the Olkiluoto island. The hydraulic conductivity in the shallow holes OL-PP5, OL-PP9, OL-PP36, OL-PP39, OL-PVP4A, OL-PVP4B, OL-PVP6A, OL-PVP6B and OL-PVP14 was measured in summer 2006. The length of PP-holes varies between 12 and 15 m, and the test sections (1 m) are located in the bedrock. PVP-tubes have a length up to 10 m, and the test sections (2 m) are located in the overburden.

The measurements were done using the slug-test technique. In the slug-test, the hydraulic head in the borehole is abruptly changed either by pouring water into the borehole or by lowering the pressure sensor. The conductivity is interpreted based on the recovery of the water level. This report presents the field measurements and their interpretation. The interpretation has been done using the Hvorslev's method, and for reference, conductivity has also been calculated according to Thiem's equation.

According to the results, hydraulic conductivity in PP-holes ranges from 10^{-9} m/s to 10^{-6} m/s and in PVP-tubes from 10^{-8} m/s to 10^{-5} m/s. The range is similar as observed in measurements of years 2002, 2004 and 2005. In general the results are consistent with the results obtained in earlier measurements. Some exceptions exist in OL-PP9, where the conductivity is lower than in the 2005 measurements, but still at the same level as in the 2002 measurements. Also, the results agree with hydraulic conductivity interpreted from the pre-pumping done in connection with the groundwater sampling.

Keywords: Hydraulic conductivity, slug-test, disposal of spent nuclear fuel, hydrology

Vedenjohtavuusmittaukset PP- ja PVP-rei'issä Olkiluodossa 2006

TIIVISTELMÄ

Osana ydinjätteen loppusijoitustutkimusta Posiva Oy selvittää Olkiluodon saaren hydrologisia olosuhteita. Matalien reikien vedenjohtavuuksia mitattiin rei'istä OL-PP5, OL-PP9, OL-PP36, OL-PP39, OL-PVP4A, OL-PVP4B, OL-PVP6A, OL-PVP6B ja OL-PVP14 kesällä 2006. PP-reikien syvyys vaihtelee välillä 12 - 15 m maanpinnasta, ja mittausjaksot (1 m) sijaitsevat kallion yläosassa. Syvimmät PVP-reiät ovat 10 m, ja mittausvälit (2 m) ovat maapeiteosuudella.

Mittaukset suoritettiin käyttäen slug-tekniikkaa. Mittauksessa kairanreikään saadaan ylipaine joko kaatamalla sinne vettä tai laskemalla paineanturia. Vedenjohtavuus lasketaan vedenpinnan palautumisajan perusteella. Tässä raportissa kuvataan kenttämittaukset ja niiden tulkinta. Mittaukset on tulkittu käyttäen Hvorslevin menetelmää ja tarkistusta varten vedenjohtavuus on laskettu myös Thiemin kaavalla.

Tulosten mukaan vedenjohtavuus PP-rei'issä vaihtelee välillä 10^{-9} m/s - 10^{-6} m/s ja PVP-rei'issä välillä 10^{-8} m/s - 10^{-5} m/s. Vaihteluväli on sama kuin vuosien 2002, 2004 ja 2005 mittauksissa. Pääosin tulkitut vedenjohtavuudet sopivat hyvin yhteen aiempien tulosten kanssa. Reiässä OL-PP9 havaittiin kuitenkin muutamia poikkeuksia, joissa vuoden 2006 vedenjohtavuudet olivat heikompia kuin vuonna 2005, mutta samaa tasoa kuin vuonna 2002. Vedenjohtavuustulokset sopivat hyvin myös pohjavesinäytteenoton yhteydessä saatuihin esipumppauksista tulkittuihin vedenjohtavuuksiin.

Avainsanat: Vedenjohtavuus, slug-testi, käytetyn ydinpolttoaineen loppusijoitus, hydrologia

PREFACE

This report is part of the program for the final disposal of the nuclear fuel waste at the Olkiluoto Island. The main aim of the study is to investigate the hydraulic conductivity close ground surface.

The field measurements were done by Susanna Lindgren and Maarit Yli-Kaila, Posiva Oy, using the technique and equipment developed by PRG-Tec Oy (Hellä & Heikkinen 2004). The interpretation of the results has been done at Posiva by Susanna Lindgren. The report has been compiled at Pöyry Environment Oy by Katriina Keskitalo. This work is done as part of the contract number 9153-07 by Posiva Oy. Susanna Lindgren has been the contact person at Posiva Oy.

Eveliina Tammisto (Pöyry Environment Oy), Pirjo Hellä (Pöyry Environment Oy) and Eero Heikkinen (Pöyry Environment Oy) are thanked for the valuable comments and guidance of the interpretation work and reporting.

TABLE OF CONTENTS

1 INTRODUCTION

As part of the program for the final disposal of the nuclear fuel waste, Posiva Oy investigates the prevailing hydrological conditions at the Olkiluoto island. Since 2002, hydraulic testing has been carried out in the upper parts of the bedrock and in the overburden. The measurement technique applied has been the slug-test technique using the equipment developed by PRG-Tec Oy (Hellä & Heikkinen 2004). The purpose is to test all measurable PP-holes and PVP-tubes. In addition, the slug-tests are repeated yearly in the holes and tubes, which belong to the monitoring program. The results of previous measurement campaigns in 2002, 2004 and 2005 are reported by Hellä & Heikkinen (2004), Tammisto et al. (2005) and Tammisto & Lehtinen (2006). The latest slug-test measurements were done in 2006, when PP-holes were measured in July and August 2006 and PVP-tubes in July 2006. This campaign included one new hole, which had not been measured earlier: OL-PP36, and eight holes and tubes, which belong to the monitoring program. This report describes the new measurements, the method of interpretation, results and detection limits. The results of the measurements from different years are also compared. The descriptions of interpretation, data processing and detection limits are based on the first slug-test report (Hellä & Heikkinen 2004).

2 FIELD MEASUREMENTS

The field measurements were done in July and August 2006. The measured shallow boreholes and groundwater tubes are presented in Figure 2-1 and listed in Table 2-1 and Table 2-2. Drilling of the holes and the installation of the casings are reported by Suomen Malmi Oy 1989, Lehto 2001, Niemi & Roos 2004, Niinimäki & Rautio 2004, Rautio 2004. Details of the studied holes and tubes are presented in Appendices 2 to 10. OL-PVP6A and OL-PVP6B have also been measured in 2002, OL-PP5 and OL-PP9 in 2002 and 2005, OL-PP39 and OL-PVP14 in 2004 and 2005 and OL-PVP4A and OL-PVP4B each year in 2002, 2004 and 2005.

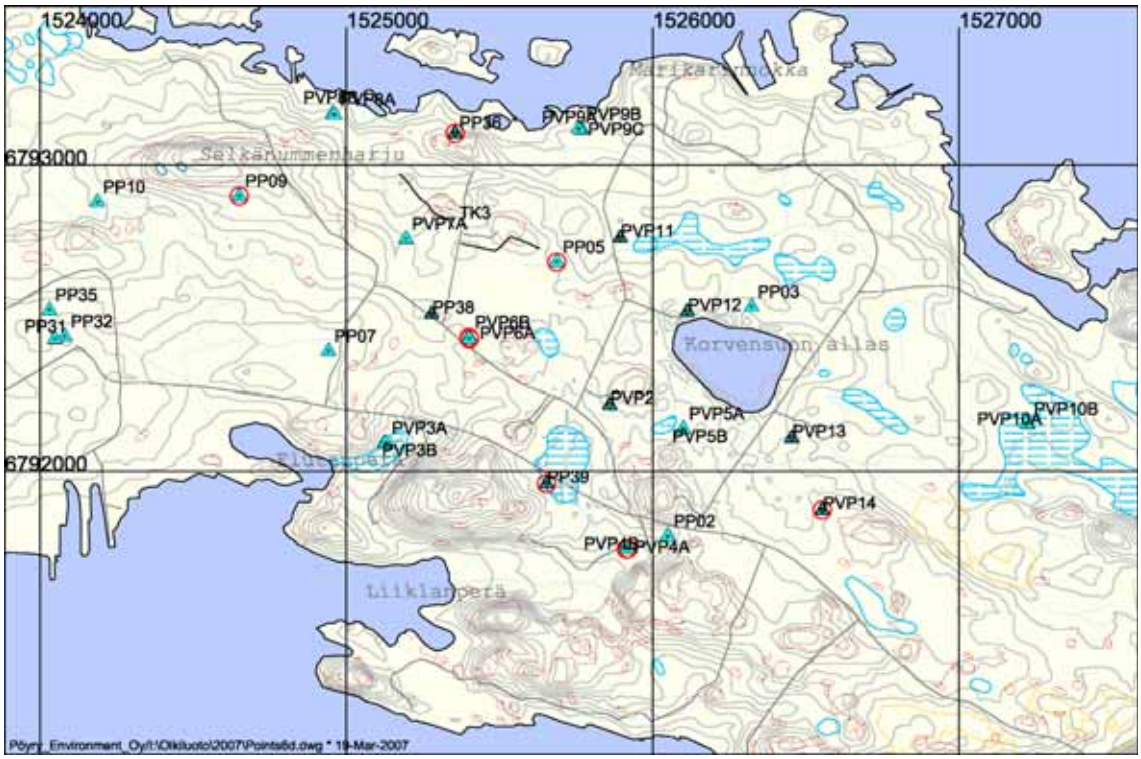


Figure 2-1. *Locations of the shallow holes where slug-tests have been done. The ones measured in summer 2006 and presented in this study are marked with red circles.*

Table 2-1. *Measured PP-holes, measurement times and operators.*

Hole	Diam. (mm)	Length (m)	Date start	Time start	Date stop	Time stop	Operator
OL-PP5	46	12.35	3.8.2006	10:25	3.8.2006	13:57	Susanna Lindgren/ Posiva Oy
OL-PP9	46	14.70	27.7.2006	10:33	27.7.2006	14:00	Susanna Lindgren/ Posiva Oy
OL-PP36	56	12.05	19.7.2006	15:25	19.7.2006	15:53	Susanna Lindgren/ Posiva Oy
OL-PP39	56	13.71	18.7.2006	15:05	19.7.2006	11:00	Susanna Lindgren/ Posiva Oy

Table 2-2. *Measured PVP-tubes, measurement times and main information of the measurements.*

Hole	Diam. (mm)	Length (m)/ perforated section (m)	Date	Time	Operator	Pressure sensor movement/ m
OL-PVP4A	56	9.55/2	6.7.2006	13:24	Susanna Lindgren/Posiva Oy	1.5
OL-PVP4B	56	8.00/2	6.7.2006	13:48	Susanna Lindgren/Posiva Oy	1.5
OL-PVP6A	56	7.83/2	7.7.2006	8:40	Susanna Lindgren/Posiva Oy	1.5
OL-PVP6B	56	3.83/2	7.7.2006	9:00	Susanna Lindgren/Posiva Oy	1.5
OL-PVP14	56	10.40/2	6.7.2006	15:00	Susanna Lindgren/Posiva Oy	1.5

2.1 Measurements in PP holes

The PP-holes have been measured using one-meter test section.

The measurement is divided into three stages:

1. **Stabilization:** the water level is stabilized in the hole after moving the equipment.

2. **Inflation:** the pressure level is stabilized in the hole and in the test section after inflating the packers.

3. **Measurement:** the piston is either pushed or pulled in the test section or water is poured into it. In the measurement, the stabilation of the pressure transient is followed up.

Each of the three stages has a specific duration, see Table 2-3. An example of the water levels at different measurement stages is shown in Figure 2-2.

Table 2-3. *Duration of the measurement stages.*

Stage	Time minimum/min	Time maximum/min
1	1	2
2	2	5
3	5	15

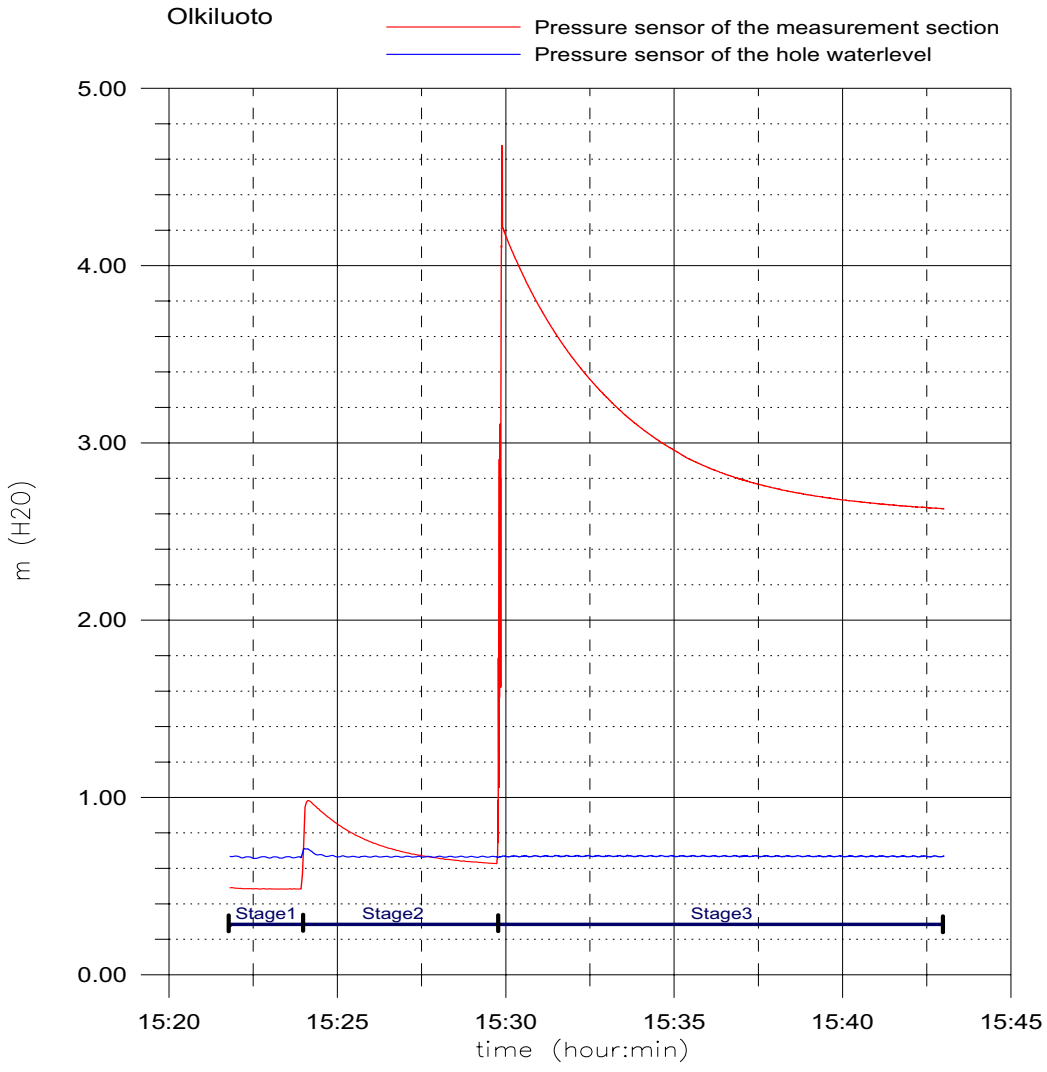


Figure 2-2. *An example of measurement results in a PP-hole.*

2.2 Measurements in PVP-tubes

The groundwater observation tubes are measured without packers, using only the piston (pressure sensor). A PVC-tube is installed around the pressure sensor in order to increase the diameter of the piston and to generate an adequate pressure change after moving the piston. Only one measurement per each hole is made with this method as each hole consists of a plastic tube with a one to four meters perforated section installed in the overburden.

The measurement is divided into two stages, corresponding Stage 1 and Stage 3 of the PP measurements, see Table 2-3. An example of the measurement is presented in Figure 2-3.

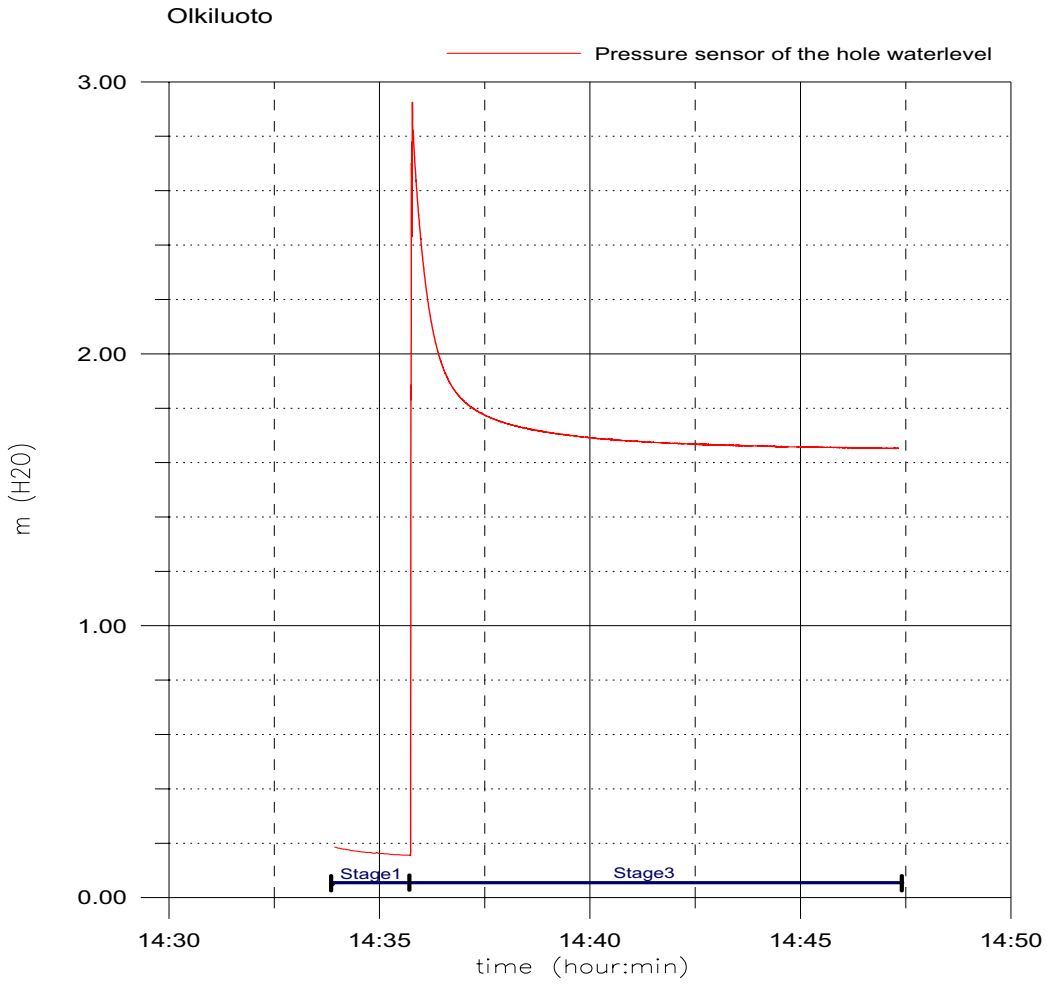


Figure 2-3*. An example of measurement results in a PVP-tube.*

3 METHOD OF INTERPRETATION

3.1 Hvorslev's method

The slug-test results were interpreted using Hvorslev's method (Freeze & Cherry 1979). A homogeneous, isotropic, infinite medium in which both soil and water are incompressible is assumed. This assumption is valid, when a fracture or the network of fractures is homogenous and planar (can be seen in the analysis as a linear behaviour). According to Hvorslev, the flow rate q at time t is related to the hydraulic conductivity K and to the unrecovered head difference H-h (H reference water level, h head at time t) according to following equation:

$$q(t) = \pi r^2 \, dh / dt = FK(H-h), \qquad \textit{(Equation 3-1.)}$$

where r is the radius of the hole and F depends on the shape and dimensions of the piezometer. The flow rate will decrease asymptotically to zero with increasing time. Solution of the differential equation 3-1 is

$$H-h = (H-H_0) \, e^{-t/T_0} \qquad \textit{(Equation 3-2.)}$$

with initial condition $h = H_0$ at $t = 0$ and the basic time lag T_0 defined as

$$T_0 = \pi r^2 / FK \, . \qquad \textit{(Equation 3-3.)}$$

Plotting the normalized head recovery $(H-h) / (H-H_0)$ on a logarithmic scale against time results in a straight line, if a fracture or aquifer under measurement is ideal i.e. homogeneous, planar and cylinder-symmetric. The basic time lag T_0 can be defined from the plot being the time t, when $\ln (H-h)/(H-H_0) = -1$. The shape factor suggested by Hvorslev can be applied if $L/R > 8$ (L length and R radius of the piezometer intake). The resulting equation for the hydraulic conductivity K is

$$K = r^2 \ln(L/R) / 2LT_0 \, . \qquad \textit{(Equation 3-4.)}$$

Figure 3-1 clarifies the notation used in the equations above.

3.2 Thiem's formula

For reference, the hydraulic conductivity K was also calculated based on Thiem's formula:

$$K = Q \ln(r_0/r_w) / (2 \pi \, L \, \Delta h). \qquad \textit{(Equation 3-5.)}$$

In Equation 3-5, Q is the flow rate (= Adh/dt, A is the void area between connection rods and the pressure cable, see Figure 3-1, dh change in head during the time interval dt), r_0 is the radius of influence assumed to be 14 m, r_w is radius of the borehole, L is the length of the test section and Δh is the overpressure i.e. the head difference to the reference water level in the test section.

In interpretation different time interval dt was used for tight intervals with hardly any observed recovery and intervals with clear recovery i.e. in the case of clear observed flow, hydraulic conductivity is interpreted based on head change on a short interval dt in the middle of the recovery period. As the recovery is not linear, the result is sensitive to the selection of the time interval used in interpretation (see Figure 3-2 a). If there is hardly any flow, a longer time interval equal to one third of the recovery period is used (see Figure 3-2 b). Slow recovery is approximately linear and the Thiem's formula gives a reliable estimation of the hydraulic conductivity.

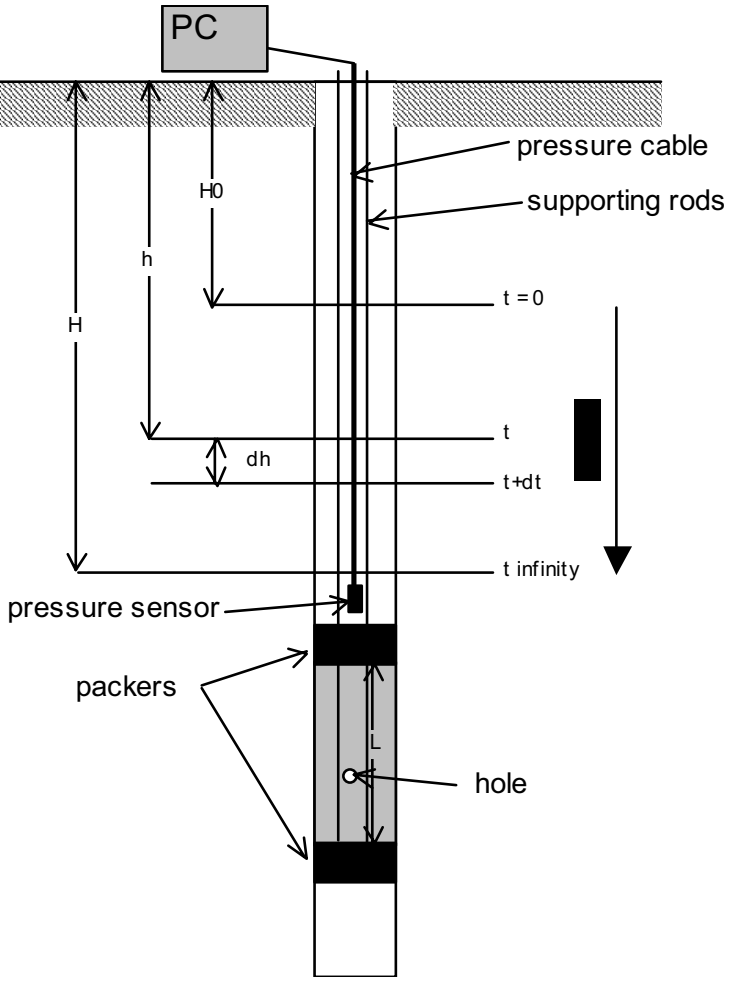
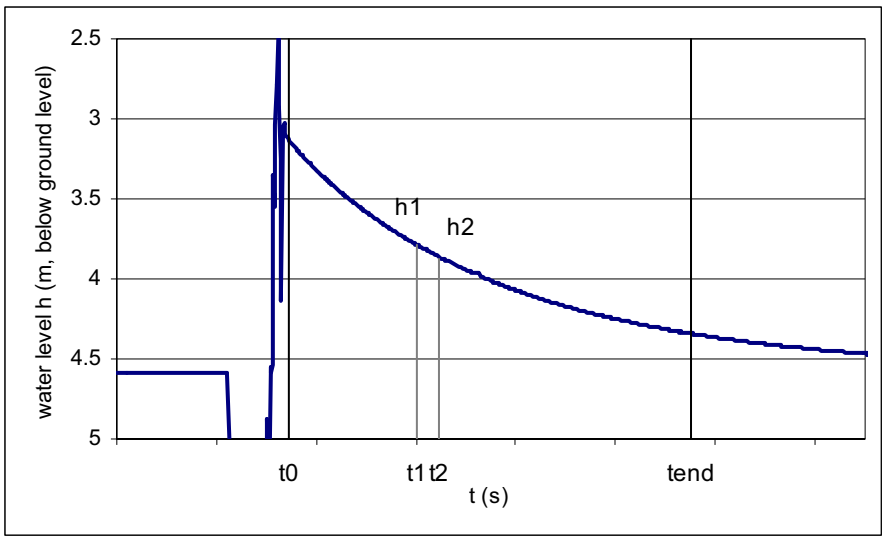


Figure 3-1. *Principle of the slug-test and interpretation according to Hvorslev's method (modified after Freeze and Cherry 1979).*

a)



b)

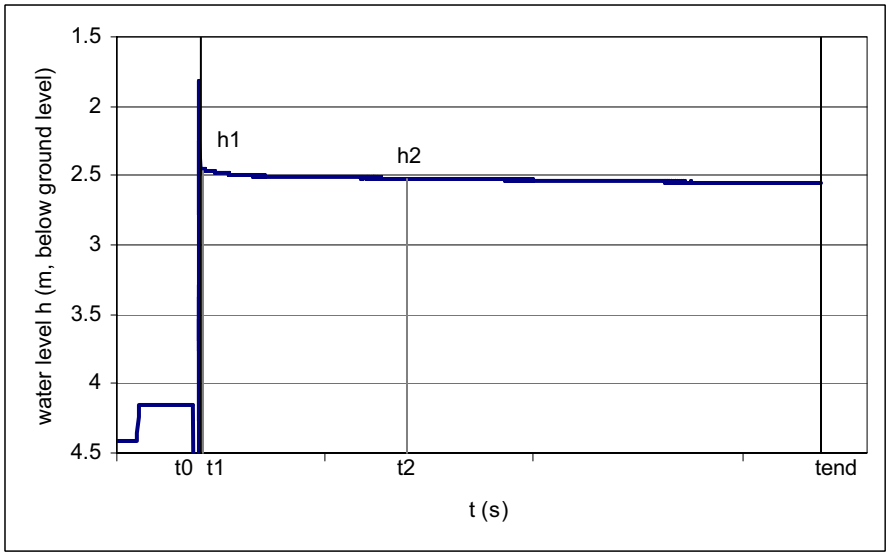


Figure 3-2. *Calculation of the hydraulic conductivity according to Thiem's formula: in case of a) a clear recovery and b) a tight interval with very slow recovery.*

4 DATA PROCESSING

For the interpretation of the first measurements in 2002, a set of MSExcel-macros was developed (see Appendix 1 for the details) (Hellä & Heikkinen 2004). The same macro has been used in the interpretation of the former measurements in 2004, 2005 and 2006. The actual analysis of the results uses a template file (xls), which contains the necessary formulas and graph templates (see Appendices 2 to 10). The figures on the template include a graph of the measured water level both in the borehole and in the test section. Another figure depicts the interpretation i.e. $(H-h)/(H-H_0)$ is plotted in logarithmic scales versus time. In the latter figure also the fitted line through the measured points is plotted. The macro copies the data from the measurement file to the analysis template file. The functions and images in the template file are modified automatically. Further on, the results, the K-values by Hvorslev's method and the two K-values obtained by Thiem's formula, together with some comments are copied to a separate result file.

The reference for all depth values in the results is the ground level whereas in the data files the reference is the top of the casing (TOC). The subtraction of the TOC is done automatically by the macros. The reference water level H is determined to be the average water level during phase one,

Figure **2-2** and Figure 3-1 are referred for the notation. Phase one is used as the water level during it is more stable than during phase two. H_0, the water level at the test section after the disturbance, either adding water or lowering the pressure sensor in the borehole, is defined to be h at 10 (PP-holes) or 20 (PVP-tubes) time steps after the minimum observed h. The minimum is not used as the data is very noisy soon after lowering the sensor. A disadvantage is that potentially part of the recovery period on highly conductive intervals is lost. An example is given in Figure 4-1. There is a possibility to adjust the time period used for line fitting manually, if necessary. The time range used is shown in the interpretation plot.

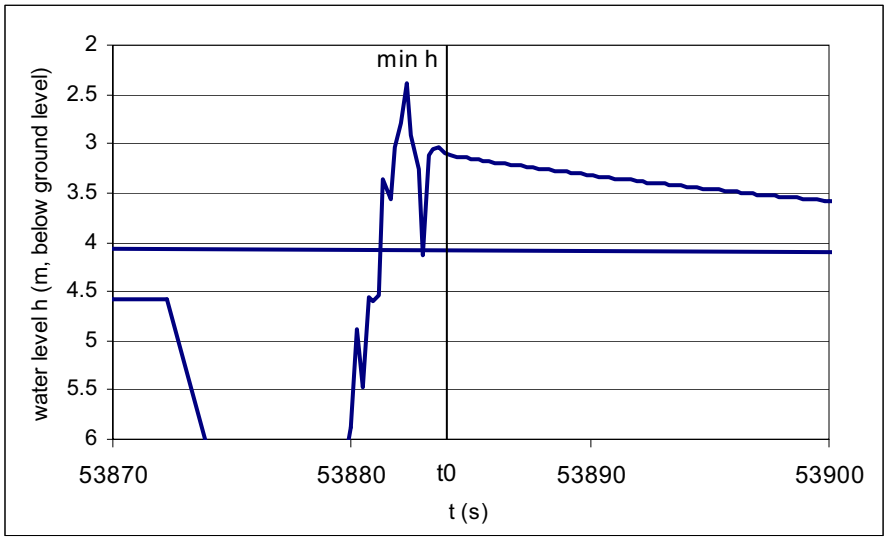


Figure 4-1. *An example of the water level changes in the test section at the time of lowering the pressure sensor.*

A straight line is fitted through $\ln(H-h)/(H-H_0)$ as function of time. The time interval used for the fitting is from t_0, the time corresponding H_0, to t_{end} corresponding either the end time of the test period or the time when $(H-h)/(H-H_0)$ reaches 0.1 or the time when $(H-h)/(H-H_0)$ gets negative. This might happen if the data is noisy at the end of the measurement. The basic time lag T_0 needed for the Hvorslev analysis is then calculated from the resulting line equation. Thereafter the hydraulic conductivity K can be derived from equation 3-4.

The time instants used in the Thiem's formula are determined as described in chapter 3.2 and in Figure 3-2. The water levels h_1 and h_2 corresponding the times t_1 and t_2 are calculated as an average of eleven observed h values around time t. Average is used to compensate the possibly noisy data. Once the corresponding h and t values are defined, an average head difference to borehole can be calculated together with the outflow Q. These are then further used to calculate the hydraulic conductivity K according to equation 3-5.

To check the correctness of the interpretation the quotient of the hydraulic conductivities $K_{Hvorslev}$ / K_{Thiem} is calculated. If the ratio is between 1/3 and three, these two results are considered to be in accordance.

On most of the tight intervals, T_0 is not reached meaning that the value of T_0 has to be extrapolated outside the observed time range and the result is thus more uncertain than in cases when T_0 is reached during the observation period.

5 RESULTS

The interpretation of the hydraulic conductivities in each of the measured holes and sections are presented in Appendices 2 to 10. Three typical recovery curves were observed: a tight section with hardly any recovery, a section with clear recovery resulting in a linear trend on the semi-log plot and a section with rapid recovery, which is not linear on the semi-log plot. An example of each type is given in Figure 5-1.

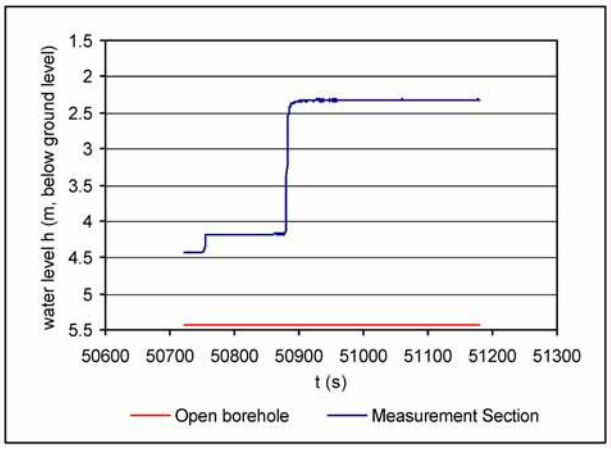
In Figure 5-2, the summary of the results in PP-holes is presented and Figure 5-3 contains the summary of the results in PVP-tubes. In PP-holes, the test section is one meter along the hole. In PVP-tubes, the entire hole is measured without packers, but the results represent the perforated section, which in tubes measured at 2006 was two meters.

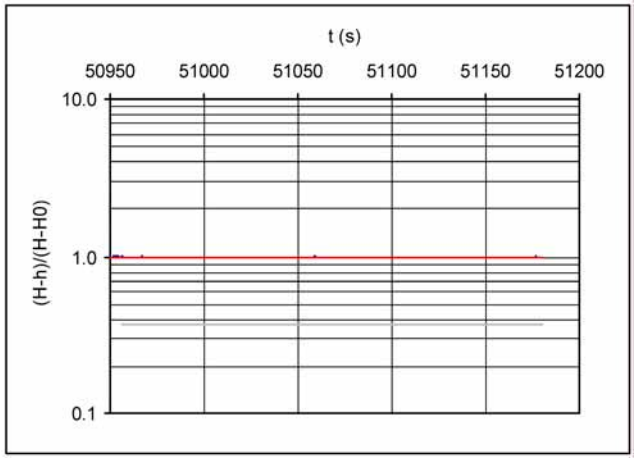
The cumulative distributions of the measured hydraulic conductivities are presented in Figures 5-4 and 5-5 including also results from 2002, 2004 and 2005. In PP-holes, the cumulative distribution of the latest measurements to some extend agrees well with the results from 2005 and in part the results are between the results from 2004 and 2005 (Figure 5-4). Also, the results from PVP-tubes mostly agree well, although the measurements of 2002, 2004, 2005 and 2006 included partly different tubes (Figure 5-5). The diagram shows that in 2002 the conductivities in the overburden were notably lower and in 2004 and 2005 higher than the average cumulative distribution.

All the PP-holes and PVP-tubes measured in Olkiluoto island are presented in Table 5-1. In 2002, nine PP-holes and fifteen PVP-tubes were measured. In 2004, the slug-tests included three PP-holes and seven PVP-tubes, in 2005 three PP-holes and nine PVP-tubes. The latest measurements in 2006 included four PP-holes and five PVP-tubes. As the number of measured holes is rather small, the results of a single hole do affect considerably to the distributions shown in Figures 5-4 and 5-5.

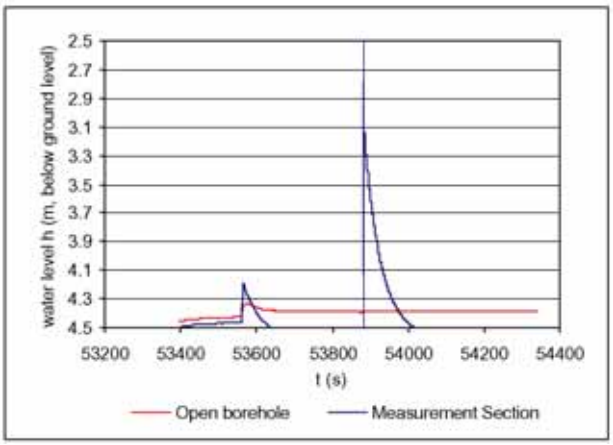
From the holes and tubes measured in 2006 OL-PP5 and OL-PP9 have also been measured in 2002 and 2005, OL-PP39 and OL-PVP13 in 2004 and 2005. PVP-tubes OL-PVP4A and OL-PVP4B have been measured in 2002, 2004 and 2005 and OL-PVP6A and OL-PVP6B in 2002. Only OL-PVP36 has not been measured before. These earlier results are compared in Figures 5-6 and 5-7 and in Appendix 11.

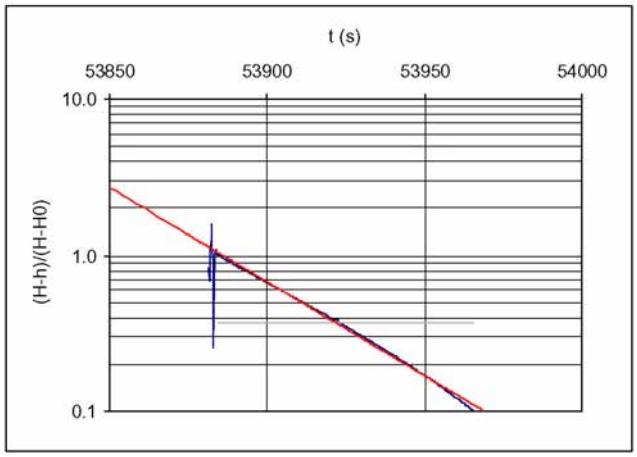
a)



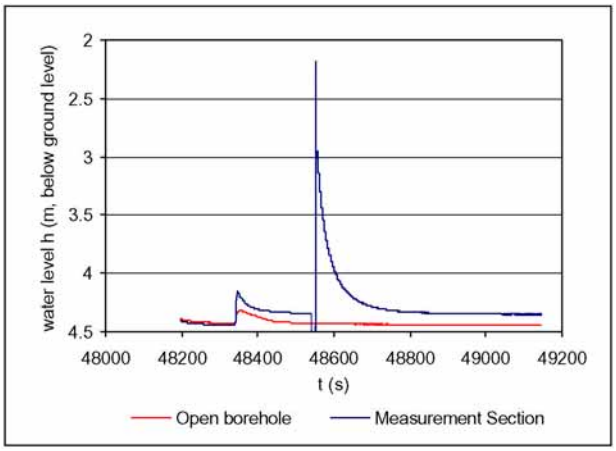


b)





c)



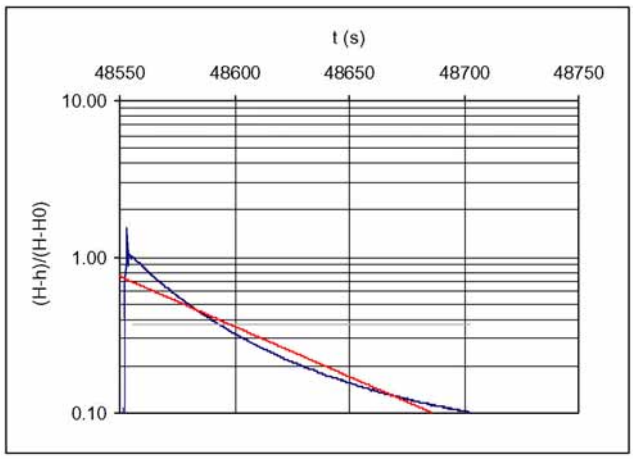


Figure 5-1. *Type of the observed recovery curves, a) a tight section with hardly any recovery, b) a section with clear recovery resulting in a linear trend on the semi-log plot and c) a section with rapid recovery, which is not linear on the semi-log plot.*

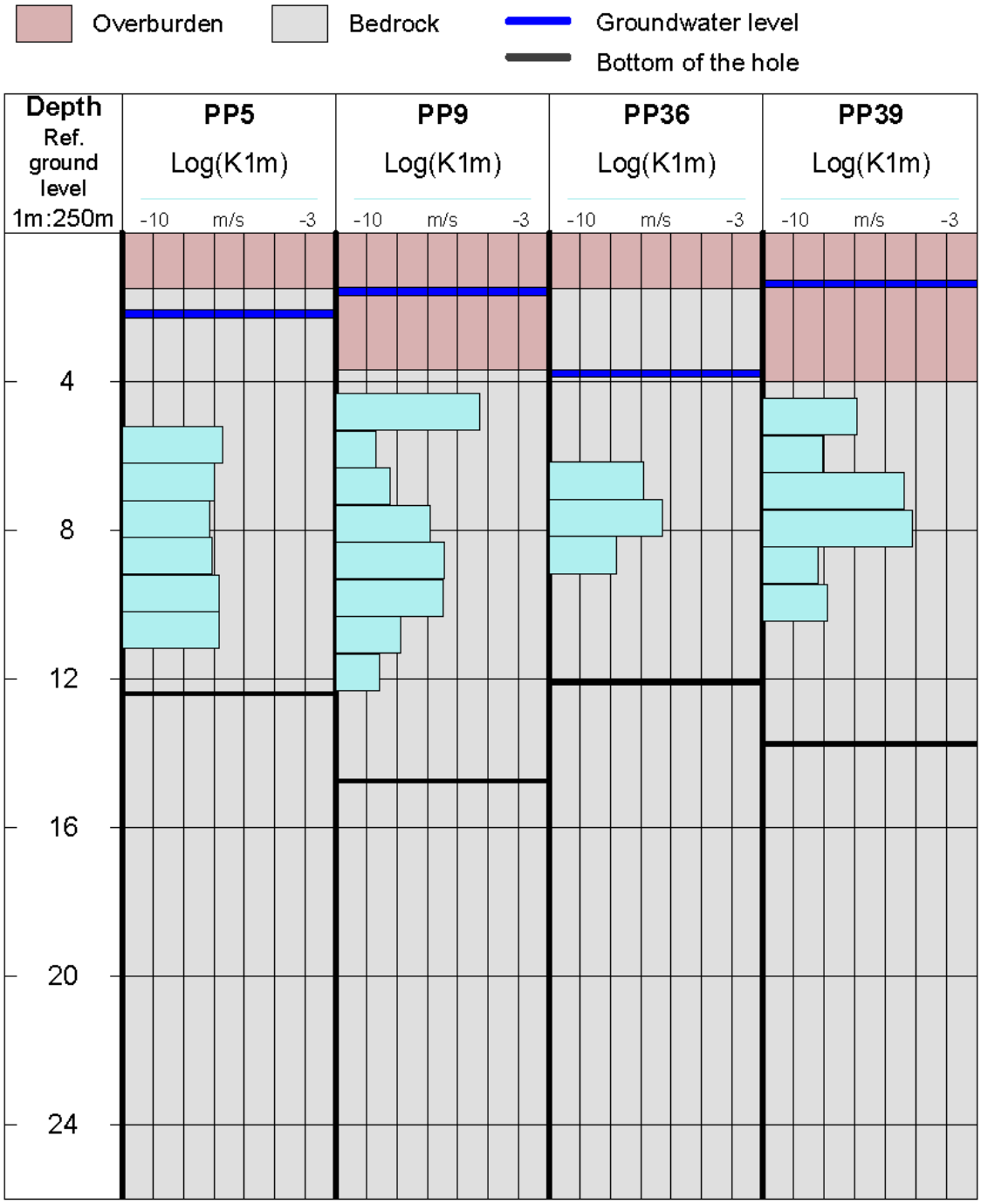


***Figure 5-2**. Hydraulic conductivity ($K_{Hvorslev}$) in PP-holes. In OL- PP9 K_{Thiem} was used in sections 5.33 – 6.33 and 10.33 – 11.33. In OL- PP39 the last measured section 10.45 – 11.45 was tight and no result was obtained and is therefore not shown on the Figure.*

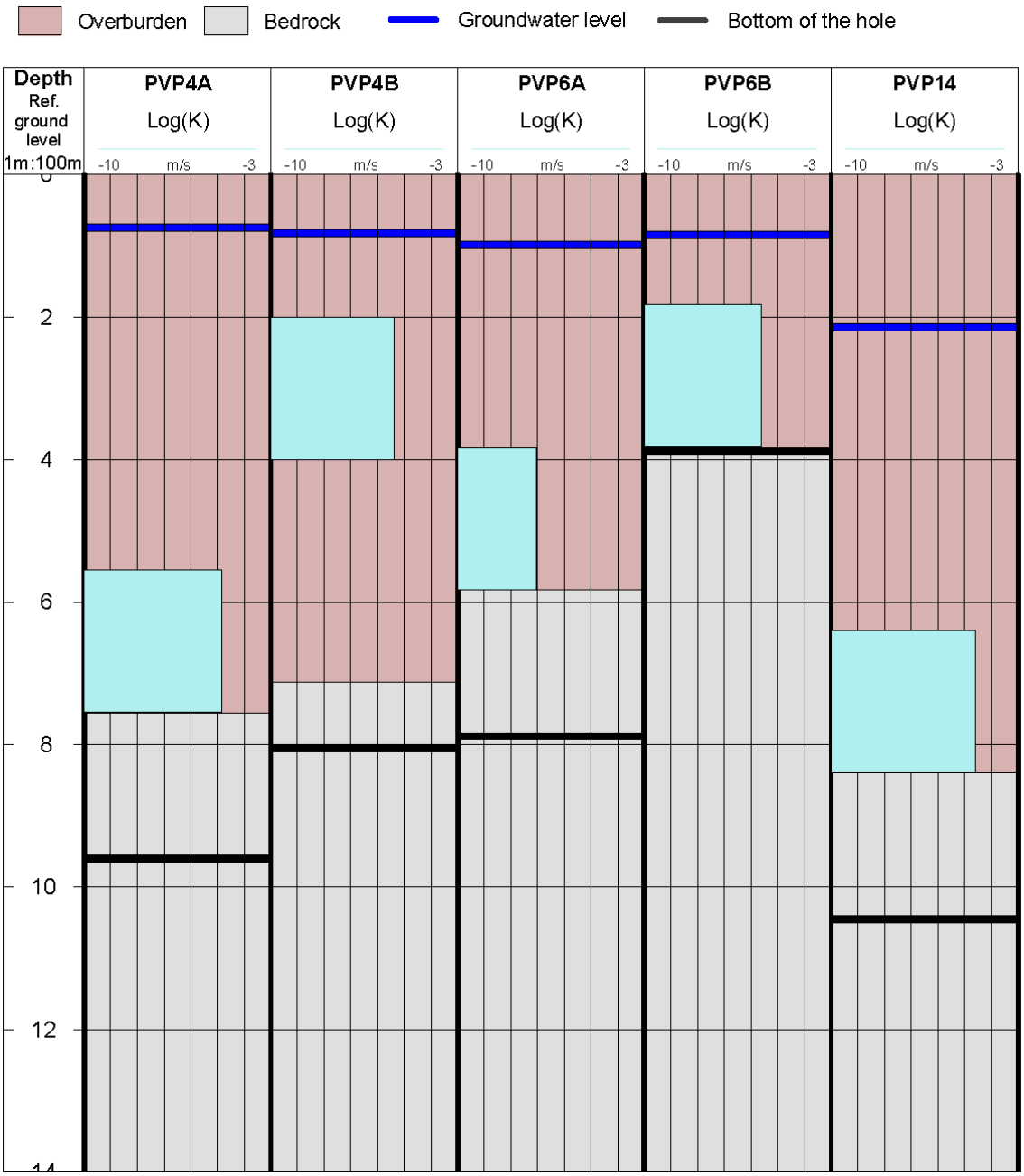


Figure 5-3. *Hydraulic conductivity in PVP-tubes. The perforated section is two meters in each measured PVP-tube.*

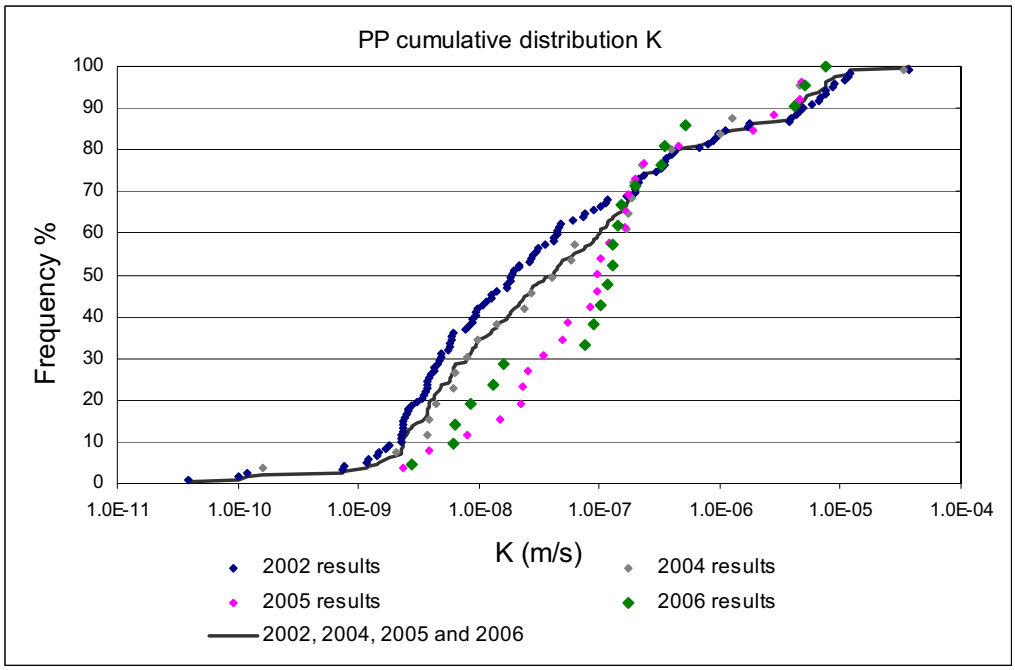


Figure 5-4. *Cumulative distribution of the hydraulic conductivities (Hvorslev) in PP-holes.*

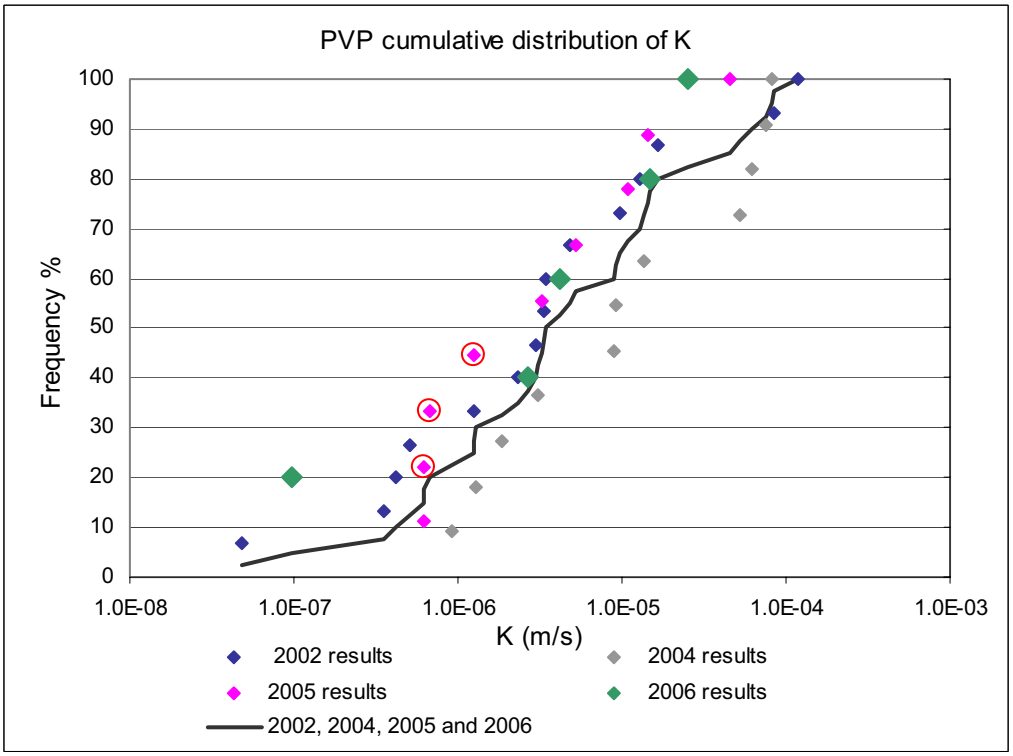


Figure 5-5. *Cumulative distribution of the hydraulic conductivities (Hvorslev) in PVP-tubes. The tubes, where perforated section is not two meters, are marked with red circles.*

Table 5-1. *The slug-tests done at the Olkiluoto Island at different times. The holes which are included in monitoring program are in bold.*

Hole/Tube	Measured	Note
OL-PP2	2002, 2004	
OL-PP3	2002	collapsed
OL-PP5	2002, 2005, 2006	
OL-PP7	2002	
OL-PP9	2002, 2005, 2006	
OL-PP10	2002	
OL-PP31	2002	
OL-PP32	2002	
OL-PP35	2002	
OL-PP36	2006	
OL-PP38	2004	destroyed
OL-PP39	2004, 2005, 2006	
OL-PVP2	2004	drilled bedrock hole
OL-PVP3A	2002	
OL-PVP3B	2002	
OL-PVP4A	2002, 2004, 2005, 2006	
OL-PVP4B	2002, 2004, 2005, 2006	
OL-PVP5A	2002	
OL-PVP5B	2002	
OL-PVP6A	2002, 2006	
OL-PVP6B	2002, 2006	
OL-PVP7A	20002	
OL-PVP8A	2002	
OL-PVP8B	2002	
OL-PVP9A	2002	
OL-PVP9B	2002	
OL-PVP10A	2002	
OL-PVP10B	2002	
OL-PVP11	2004	
OL-PVP12	2004	
OL-PVP13	2004	
OL-PVP14	2004, 2005, 2006	
OL-PVP17	2005	
OL-PVP18A	2005	
OL-PVP18B	2005	
OL-PVP19	2005	
OL-PVP20	2005	

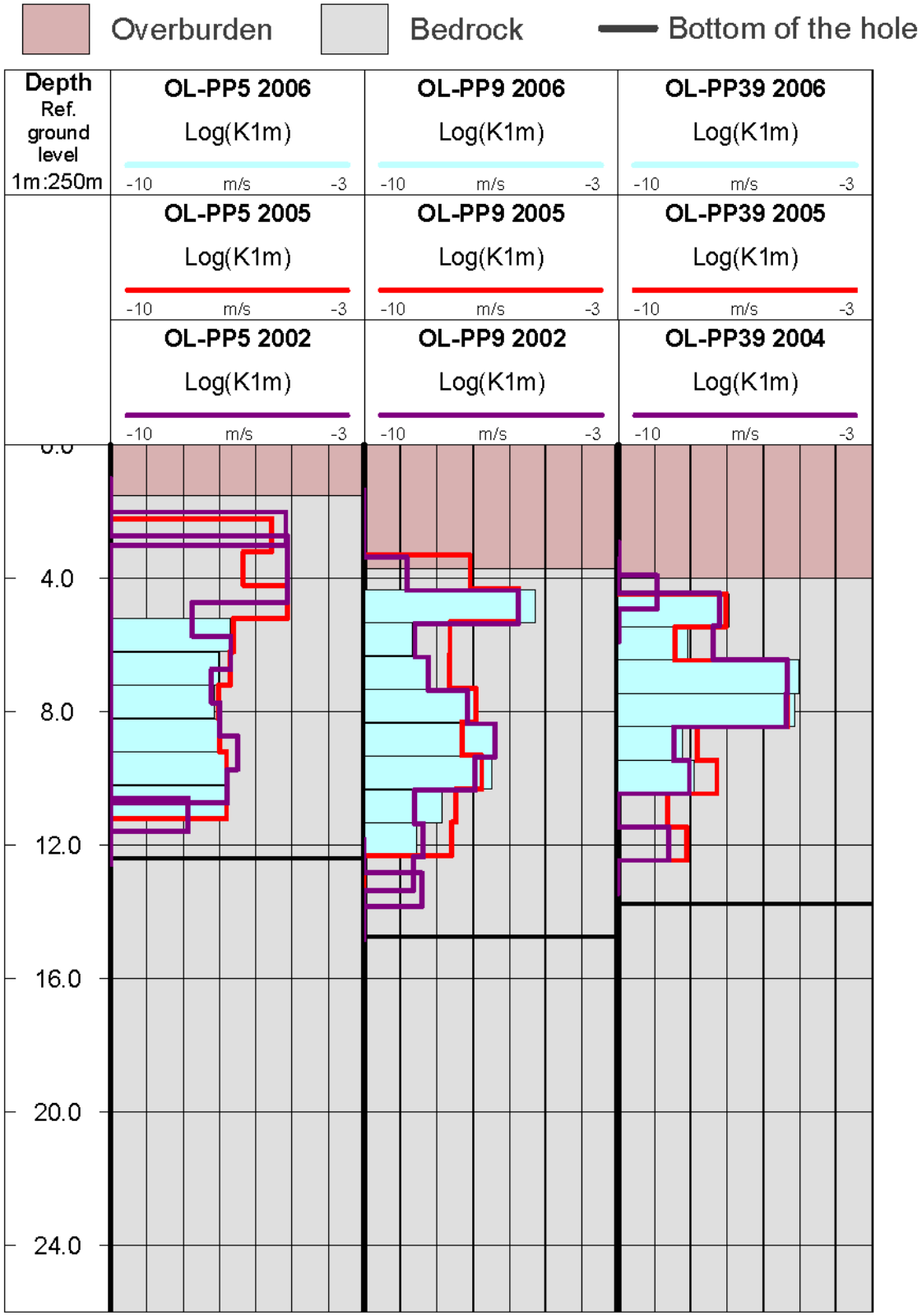


Figure 5-6. *Results from PP-holes measured 2006 versus results from earlier measurements of these holes.*

On average, the results of 2006 are quite close to the results of the earlier measurements. In OL-PP5, the location of test sections from year 2002 differs 0.5 m from sections measured at 2005 and 2006. This explains the small differences in the results, but also makes the comparison more difficult. Comparison between the results from 2005 and 2006 illustrates that the results are very similar to each other. The upper three meters of the hole was not measured in 2006 because the groundwater level was relatively low and also, there were some technical difficulties at field.

In general the results of 2006 and 2002 seem to correlate well in OL-PP9. The conductivity in test sections 5.3 – 6.3 m, 6.3 – 7.3 m, 10.3 – 11.3 m and 11.3 – 12.3 m in 2006 was about one order of magnitude lower than in 2005 but also in these sections the results from 2006 and 2002 correlate well. The section 6.3 – 7.3 m has been measured twice in 2005, and the results differ radically from each other. In the figures, the smaller value from year 2005 has been used, as it is closer to the results obtained from the same section in 2002 and 2006. In 2006 the section 3.3 – 4.3 m was not measured.

In OL-PP39 all the results from 2004, 2005 and 2006 are quite close to each other. The section 11.44 – 12.44 m was not measured in 2006.

In PVP-tubes the variations are smaller. Only in OL-PVP6A and OL-PVP14 there are some differences. In OL-PVP14 there seems to be a lowering trend of conductivity. In OL-PVP6A the result from 2006 is two times higher than the one measured in 2002.

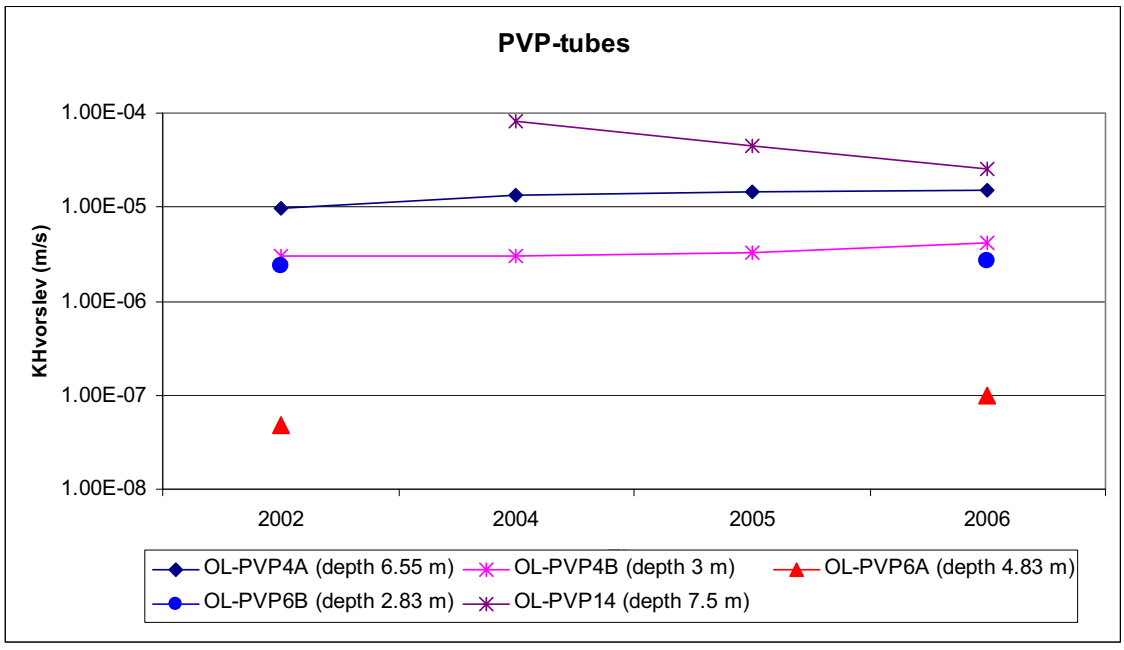


Figure 5-7. *Results from PVP-tubes measured 2006 and at least once in the earlier measurements in 2002, 2004 and 2005.*

6 ON THE ACCURACY OF THE RESULTS

6.1 Detection limits

In measurements of 2006, the interpreted hydraulic conductivities range from 10^{-9} m/s to 10^{-6} m/s in PP-holes and from 10^{-8} m/s to 10^{-5} m/s in PVP-tubes. In the following, the detection limits are estimated.

The accuracy of the water level obtained by the pressure sensor is ±1-2 mm. By analysing the recovery in some of the tight intervals it was noticed that the change in water level has to be at least 5 mm, so that it can be distinguished from the noise. The recovery period varies from 200 s to 1000 s. Taking the geometry of the tool and the hole into account this leads to minimum observable flow of $2 \cdot 10^{-9}$ - $8 \cdot 10^{-9}$ m^3/s (30 ml/h) in PP-holes. The overpressure is typically 1.5 m and test section 1.0 m leading to hydraulic conductivity $1 \cdot 10^{-9}$ - $5 \cdot 10^{-9}$ m/s according to Thiem's formula. Consequently, the lower detection limit in PP-holes is about $5 \cdot 10^{-9}$ m/s, which corresponds the transmissivity of $5 \cdot 10^{-9}$ m^2/s. The diameter of the PVP-tubes and the instrument used are different and the minimum observable flow is $2.5 \cdot 10^{-8}$ m^3/s. A typical overpressure is 1.5 m leading to the transmissivity of $2 \cdot 10^{-8}$ m^2/s. The minimum detection limit is thus $1 \cdot 10^{-8}$ m/s in tubes with 2 m long perforated section.

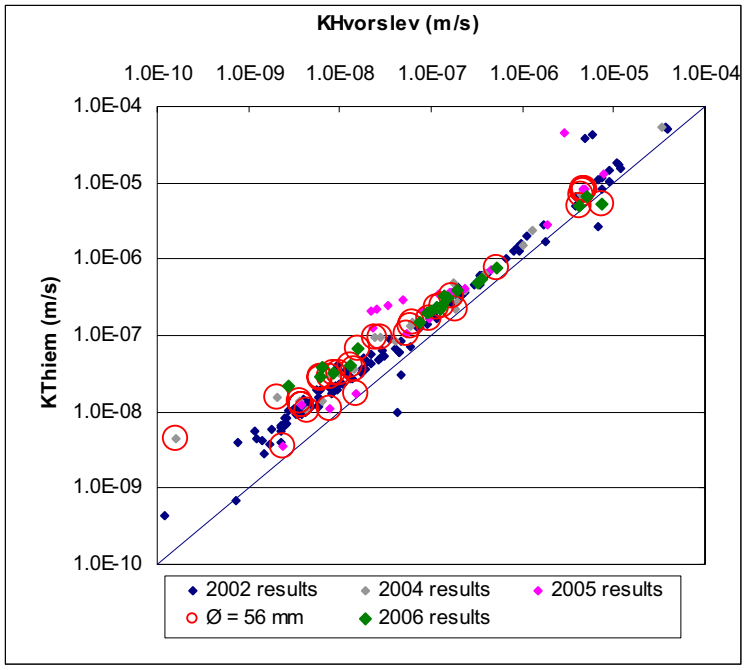
The upper limit of the measurement range is not as clear as the lower limit. In PP-holes, the maximum observable transmissivity is estimated to be in the order of $5 \cdot 10^{-5}$ m^2/s, which leads to hydraulic conductivity of $5 \cdot 10^{-5}$ m/s in 1 m test section. This value is deduced assuming a steel rod with a diameter of 2.5 cm, including the pressure sensor hose inside the rod with a diameter of about half of the steel rod, and further more overpressure of 2 m and a 2 m decrease in water level within 10 seconds. The observed conductivity can be higher as the flow is not necessarily steady-state as assumed in the estimation of the detection limit. In PVP-tubes, the geometry is different and the typical overpressure 1.5 m, resulting in the transmissivity of $1.6 \cdot 10^{-4}$ m^2/s. In PVP-tubes with 2 m long perforated section, the upper limit of hydraulic conductivity is thus $8.0 \cdot 10^{-5}$ m/s. The diameter of PP-holes is 46 mm or 56 mm. The detection limits are calculated to 46 mm holes but are practically the same for 56 mm holes.

The highest observed conductivity in the PP-holes is $7.5 \cdot 10^{-6}$ m/s in hole OL-PP39 at the depth 7.95 m (Appendix 5), where the water level in the test section decreased 0.9 m during 340 seconds. The difference between the water level in the test section and in the open hole was about 15 cm at the most. The same section has been measured in 2004 and 2005 with analogous results. When the sensor is lowered, there is a period of about 2-3 seconds, when the water level is unstable. The interpretation can be started first after more stabile conditions are reached so the recovery period should last at least 5 seconds. During the first seconds the water table already decreases considerably on sections with high conductivity. The overpressure H_0, used in the interpretation, is therefore considerably less than the theoretical value of 2 m, as the example shows. In PVP-tubes, the highest observed conductivity is $2.6 \cdot 10^{-5}$ m/s (OL-PVP14, see Appendix 10). The recovery period is about 35 seconds and the change in water level is about 0.9 m. The same hole has been measured in 2002, 2004 and 2005 with almost the same results. The repeatability seems to be good.

About the same limits are obtained by comparing the hydraulic conductivities resulting from the interpretations using the two methods, Hvorslev and Thiem. In general, the hydraulic conductivities calculated according to Thiem's equation and according to Hvorslev's method seem to be well in accordance, see Figure 6-1. The results from PP-holes agree extremely well, when the conductivity is higher than about $5 \cdot 10^{-8}$ m/s. In these cases T_0 is reached during the observation period. When the hydraulic conductivity is small, i.e. hardly no recovery is observed, the results obtained by the two methods give slightly different results, K_{Thiem} being approximately two to three times higher than $K_{Hvorslev}$. An exception is OL-PP9, where K_{Thiem} is six times higher than $K_{Hvorslev}$ in section 6.3 – 7.3 m and seven times higher in section 11.33 – 12.33 m. Additional exception is in OL-PP39, where K_{Thiem} is more than four times higher than $K_{Hvorslev}$ in section 8.45 – 9.45 m. These three sections were all very tight which maybe the reason for the big difference between $K_{Hvorslev}$ and K_{Thiem}. In the PVP-tubes, higher conductivities are observed, and the interpreted hydraulic conductivities according to two methods match relatively well.

The coefficient of correlation (R^2), which measures the linear relationship between $\ln(H-h) / (H-H_0)$ and time t, decreases clearly when the hydraulic conductivity in PP-holes is less than $5 \cdot 10^{-9}$ m/s and in PVP-tubes less than $5 \cdot 10^{-7}$ m/s, see Figure 6-2. Two sections of OL-PP39, 6.45 – 7.45 m and 7.45 – 8.45 m, differentiate with low R^2 values. That is because the conductivities in those sections are so high they do not follow linear trend on the semi-log plot (Figure 5-1 c).

a)



b)

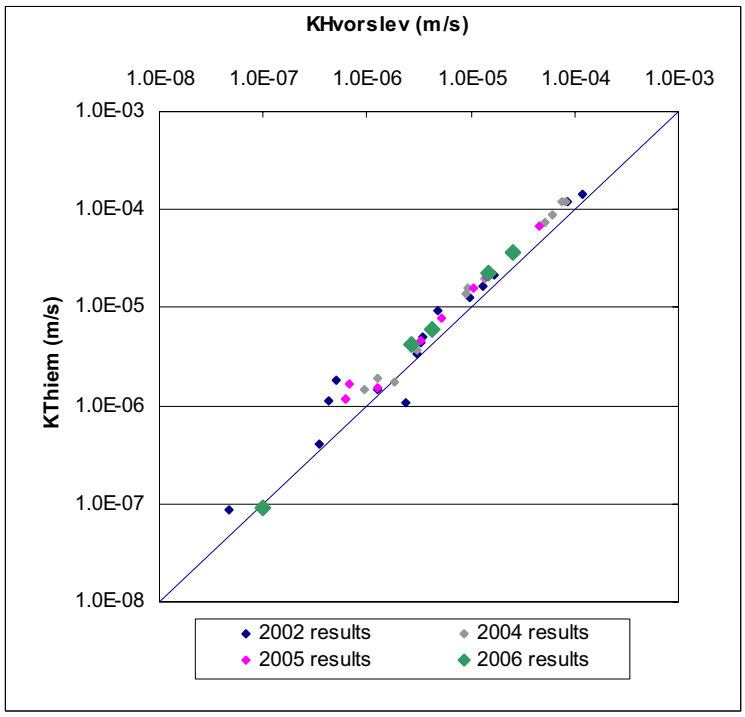
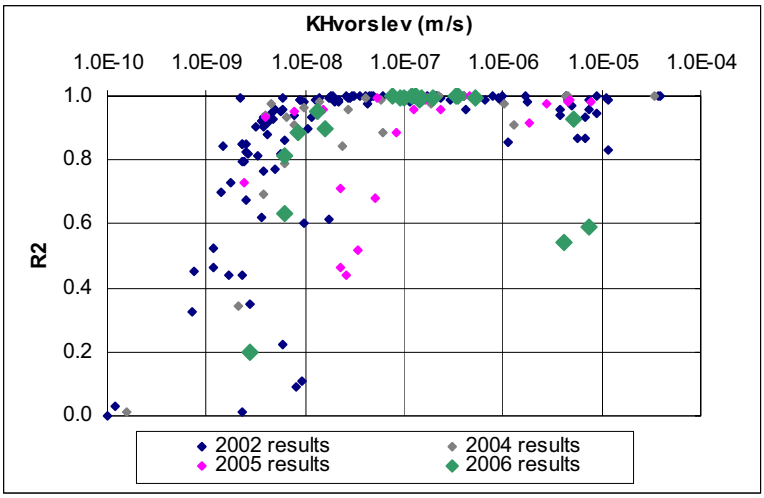


Figure 6-1. *Comparison of the hydraulic conductivities calculated either by the Hvorslev's method or using Thiem's formula a) in PP-holes, the holes with diameter 56 mm are marked with red circles, and b) in PVP-tubes.*

a)



b)

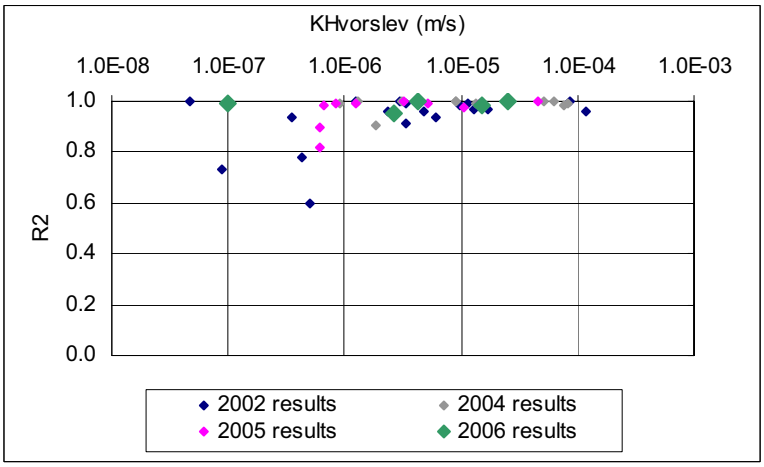


Figure 6-2. *R^2 as a function of hydraulic conductivity K in a) PP-holes and b) PVP-tubes.*

6.2 Effect of the time used in interpretation

As Figure 6-1 shows, the hydraulic conductivity by Hvorslev's method is normally less than the one obtained by Thiem's formula in PP-holes. This is mainly due to the selection of the time range used in the interpretation. Also the time interval chosen for the interpretation can be a significant source of error in cases of rapid recovery. Selection of the starting time affects also the H_0, the reference water level. Figure 6-3 gives an example of the effect of the selected time range. In the result figures (Appendices 2 to 10), the time range used in the interpretation according to Thiem's formula and in the Hvorslev's method is therefore shown.

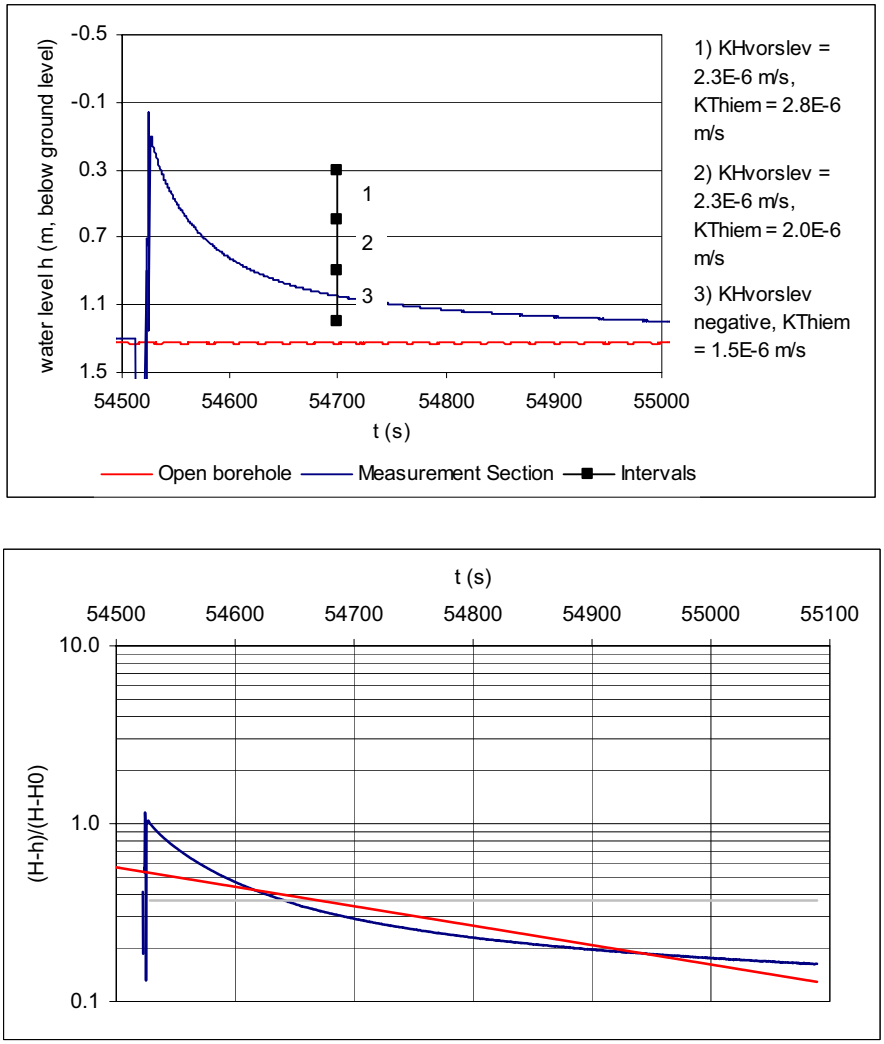


Figure 6-3. *An example how the time selected for the interpretation affects the resulting hydraulic conductivity. Three time intervals were used each corresponding to approximately one third of the recovery. The example is from OL-PP2 at depth of 19.42 m (Hellä & Heikkinen 2004). The interpreted values for this section were* $K_{Hvorslev}$ $1.1 \cdot 10^{-6}$ *m/s and* K_{Thiem} $8.1 \cdot 10^{-7}$ *m/s. For the interval 3 the interpretation according to Hvorslev's method failed as the* T_0 *gets negative.*

6.3 Comparison with the pre-pumping results

Groundwater sampling has been done partly in the same holes as the slug-tests during the summer 2006 (Partamies et. al. 2007). One or more water samples were taken from OL-PP5, OL-PP9, OL-PP36, OL-PP39, OL-PVP4A, OL-PVP4B and OL-PVP14. Before taking the samples, the hole is pre-pumped for a certain period of time, typically few hours. The yield (l/min) and the change in the water table (m) are measured. Using this information and the length of the test section (either part of the hole below the water table or the perforated section in the groundwater observation tubes), hydraulic conductivity can be estimated according to the Thiem's formula (Equation 3-5). These

values were compared to the conductivities resulting from the slug-tests. In case of the PP-holes, where the slug-tests were performed on 1 m test sections, an average conductivity of the entire hole was used in the comparison. The results are shown in Figure 6-4 and listed in Appendix 12.

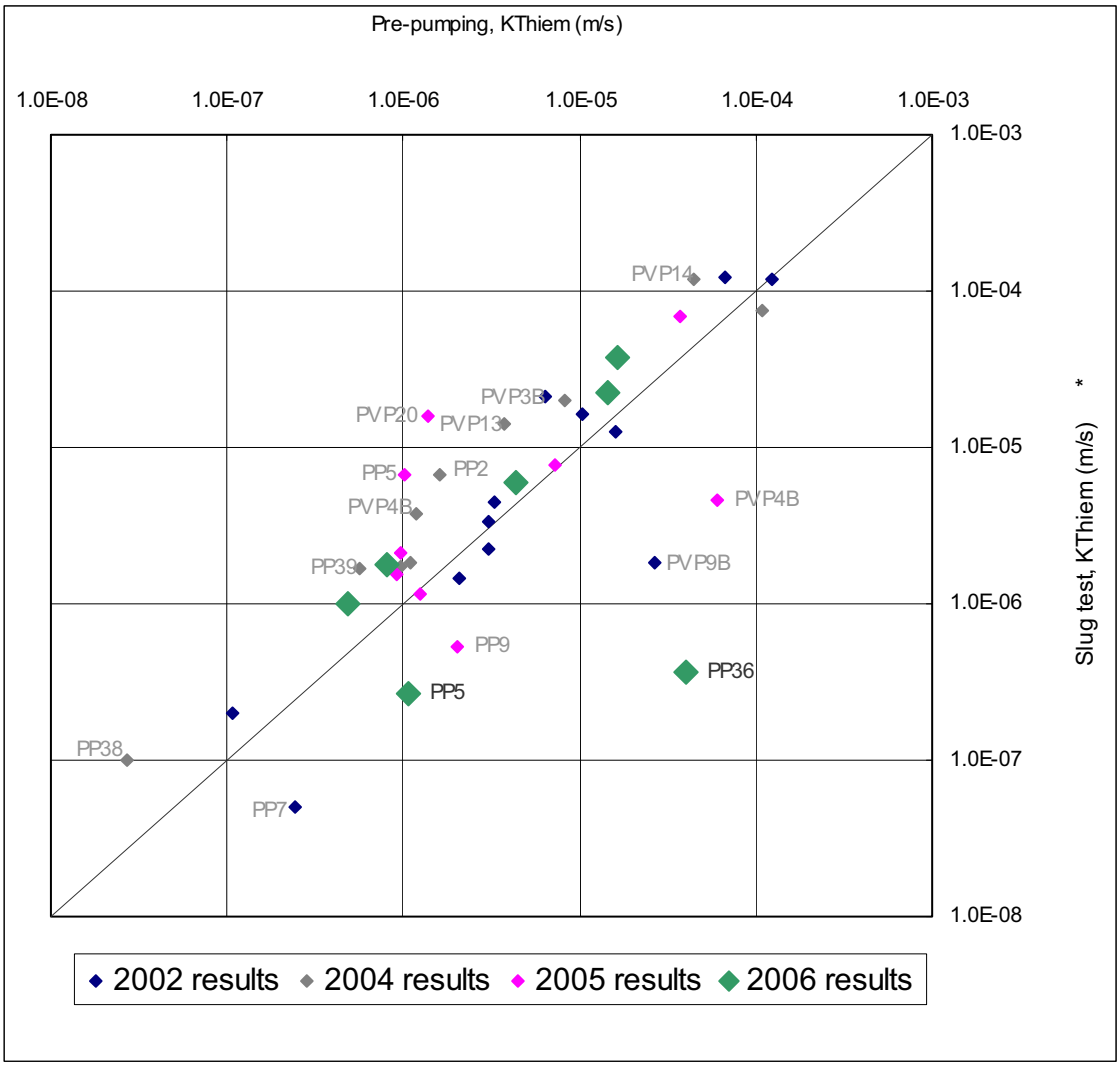


Figure 6-4. *Comparison of the hydraulic conductivities (m/s) obtained by the interpretation of the slug-tests and the pre-pumping in connection with groundwater sampling.*

The results from the pre-pumping match well with those from the slug-tests (Figure 6-4) (Tuominen 1998, Hatanpää 2002, Kröger 2004, Hellä & Heikkinen 2004, Hirvonen 2005, Tammisto et al. 2005, Tammisto & Lehtinen 2006, Lehtinen et al. 2006, Partamies et al. 2007). In general, pre-pumping values are slightly smaller. This is natural, because pre-pumping lasts much longer than the slug-test and as a result of natural overtime, decrease of flow lower hydraulic conductivity based on the pre-pumping results. If the pre-pumping values are higher, it is possible that there is a conductive fracture outside the range measured in slug-tests that affects the pre-pumping that measures the whole open borehole.

The results from PP-holes OL-PP5 and OL-PP36 differ from the other results. In both holes the pre-pumping result is significantly higher. In OL-PP36 it is very likely that there is a conductive fracture outside the range measured in slug-tests. The test sections in slug-test were between 6.17 – 9.17 m, whereas the pre-pumping measures the whole open borehole, which is 12 meters long. In 2006 the groundwater level was relatively low in OL-PP5 and the upper three meters could not be measured. Based on the earlier measurements these upper parts have a high conductivity, which affects the pre-pumping that measures the whole open borehole.

7 CONCLUSIONS

Slug-tests were performed in several shallow PP-holes and PVP-tubes at Olkiluoto island during the summer 2006. The measurements were done using the same technique and equipment developed by PRG-Tec Oy as in the measurements in 2002, 2004 and 2005 (Hellä & Heikkinen 2004, Tammisto et al. 2005, Tammisto & Lehtinen 2006).

The measurement results were interpreted by using Hvorslev's method. For comparison, the conductivity was also calculated using Thiem's formula. The interpretation was done by using MSExcel-macros written for the purpose. The analysis method is easy to use and quick as manual work is hardly needed for the file operations.

In measurements of year 2006, hydraulic conductivities in PP-holes range from 10^{-9} m/s to 10^{-6} m/s and in PVP-tubes from 10^{-8} m/s to 10^{-5} m/s. The range is similar to one in measurements of years 2002, 2004 and 2005. With the applied technique in PP-holes hydraulic conductivities in the range $5 \cdot 10^{-9}$ – $5 \cdot 10^{-5}$ m/s and $1 \cdot 10^{-8}$ – $8 \cdot 10^{-5}$ m/s in PVP-tubes can be detected. The detection limits of hydraulic conductivity depend on the length of the test sections and the overpressure used. The interpreted hydraulic conductivities from the slug-tests were compared to those obtained by the pre-pumping. The comparison showed that both results are in accordance with each other. Only two small exceptions were noticed in OL-PP5 and OL-PP36. Also, the results from holes and tubes measured in 2006 and results from earlier measurements were compared. The results are quite close to each other.

REFERENCES

Freeze, R. A. & Cherry, J.A. 1979. Groundwater. Prentice Hall Inc. Englewood Cliffs, N.J. United States. 604 p.

Hatanpää, E. 2002. Groundwater Sampling from Drilled Holes (PR and PP) and Groundwater Pipes (PVP) at Olkiluoto in 2001. Helsinki, Finland: Posiva Oy. Working Report 2002-20. 90 p. (in Finnish with an English Abstract)

Hellä, P. & Heikkinen, P. 2004. Slug Tests in Shallow Holes at Olkiluoto 2002. Olkiluoto, Finland: Posiva Oy. Working Report 2004-13. 201 p.

Hirvonen, H. 2005. Groundwater Sampling from Shallow Boreholes (PP and PR) and Groundwater Observation Tubes (PVP) at Olkiluoto in 2004. Olkiluoto, Finland: Posiva Oy. Working Report 2005-57. 148 p.

Kröger, T. 2004. Groundwater Sampling from Shallow Boreholes (PP and PR) and Groundwater Observation Tubes (PVP) at Olkiluoto in 2003. Olkiluoto, Finland: Posiva Oy. 117 p. Working Report 2004-44. 117 p.

Lehtinen, A., Hatanpää, H. & Hirvonen H. 2006. Results of Monitoring at Olkiluoto in 2005. Geochemistry. Olkiluoto, Finland: Posiva Oy. Working Report 2006-67. 174 p.

Lehto, K. 2001.Installation of Groundwater Observation Tubes at Olkiluoto in Eurajoki 2001. Helsinki, Finland: Posiva Oy. 58 p. Working Report 2001-39. 58 p.

Niemi, K. & Roos, S. 2004. Havaintoputkien asentaminen, matalien kairareikien kairaaminen, painokairaaminen ja maaperänäytteet Eurajoen Olkiluodon tutkimusalueella vuoden 2003 syksyllä. Eurajoki, Finland: Posiva Oy. 43 p. Working Report 2004-03. 43 p. (in Finnish)

Niinimäki, R. & Rautio, T. 2004. Drillings of Shallow Core Drilling Holes, Percusion Drillings, Video Recordings of Boreholes and Installing Ground Water Monitoring Pipes at Olkiluoto in Eurajoki in Winter and Spring of 2004. Olkiluoto, Finland: Posiva Oy. Working Report 2004-37. 59 p.

Pitkänen, P., Partamies, S., Lahdenperä, A.-M., Lehtinen, A., Ahokas, T., Hirvonen, H. & Hatanpää, E. 2007. Results of monitoring at Olkiluoto in 2006: Hydrogeochemistry. Olkiluoto, Finland: Posiva Oy. Working Report 2007-51. 238 p.

Rautio, T. 2004. Installing Ground Water Monitoring Pipes PVP19 and PVP20 at Olkiluoto in Eurajoki in Summer 2004. Olkiluoto, Finland: Posiva Oy. Working Report 2004-48. 7 p.

Suomen Malmi Oy. 1989. Bedrock Surface Drillings in Olkiluoto, Eurajoki. Helsinki, Finland: Teollisuuden Voima Oy. 6 p. Working Report 89-70. 6 p.

Tammisto, E., Hellä, P. & Lahdenperä, J. 2005. Slug-Tests in PP- and PVP-Holes at Olkiluoto in 2004. Olkiluoto, Finland: Posiva Oy. Working Report 2005-76. 87 p.

Tammisto, E. & Lehtinen, A. 2006. Slug-tests in PP- and PVP-holes at Olkiluoto in 2005. Olkiluoto, Finnland: Posiva Oy. 93 p. Working Report 2006-100.

Tuominen, M. 1998. Hydrogeochemical Studies at Olkiluoto During 1997: Drilled Holes PR3 and PR4 and Ground Water Pipes PVP1 and PVP2. Helsinki, Finland: Posiva Oy. 39 p. Working Report 98-07. 39 p.

Öhberg, A. & Rouhiainen, P. 2000. Posiva Groundwater Flow Measuring Techniques. Helsinki, Finland: Posiva Oy. POSIVA 2000-12. 81 p.

APPENDIX 1 DESCRIPTION OF THE DATA PROCESSING MACROS

In the interpretation of the measurement data the same macros developed for interpretation of the slug-tests in 2002 (Hellä & Heikkinen 2004) were used. Some modifications were done, when slug-tests of 2004 were interpreted (Tammisto et al. 2005):

- The separate macros for interpreting the results from PP-holes and PVP-tubes were combined.
- An input box was added in the start of program which enables the user to select whether he is processing data from PP-holes or PVP-tubes.
- In the input box it is also possible to select if the time range used in the interpretation is automatically selected or if the user wants to define the time range manually.
- The borehole diameter and section length information can now be given in the makefile, the values replace the erroneous or missing values in the data files.
- The time instants used in Thiem's equation were adjusted. They are now based on the change in head not on the length of the recovery period.
- Handling of errors was enhanced and the user is given information of the reason why the processing stops.

For the interpretation a MSExcel-file containing the necessary functions and graphs was used as a template. The macro copies the necessary data from the measurement file to the analysis template. The functions and graphs in the template file are modified automatically. Further on the results, K-values by Hvorslev's method and the two K-values obtained by Thiem's equation, together with some comments are copied to a separate result file. Also, the sheet with the interpretations is printed both as a paper copy and to a pdf-file.

Input Data

Data from the header of the measurement files used for interpretation:

- Top of the casing (m), reference level of all the depth values in the measurement file
- Depth of the pressure sensor, borehole (m)
- Initial depth of the pressure sensor of the test section (m)
- Depth of the pressure sensor of the test section after movement (m)
- Length of the test section (m)
- Hole diameter (mm)

And from the data columns:

Cable Depth (column A)	depth of the top of the test section (ref TOC), only first value used
Date (column B)	date, only first value used
Time (s) (column C)	Time
Phase (columnD)	1 = open borehole equipment installed 2 = inflation of packers + stabilization of pressure 3 = pressure increase + recovery phase
WaterLevelBorehole(m) (column G)	water column above pressure sensor of borehole water
WaterLevelMeasurementSection(m) (column K)	water column above pressure sensor of test section

The template workbook

The template workbook analysis_template.xls contains three sheets

parameters for input parameters, results and figure of the water level at the borehole and in the test section during the measurement and a figure with the measurement results and the fitted line. The data copied from the input file is marked with italic. The contents with some comments is described below:

- input file, name of the input file containing the hole id and the file number
- date, date of the measurement
- TOC (m), length of the casing above ground level
- depth of pressure sensor open hole (m), measured from the top of the casing
- depth of pressure sensor meas. section (m), measured from the top of the casing
- depth of meas. section (m), top of the section measured from the top of the casing
- depth of meas. section (m), midpoint of the section measured from ground level
- tube diameter (mm), diameter of the tube having an equal area to a double tube with given inner and outer diameter (16.6/24.9 mm in PP-holes and 40/56 mm in PVP-tubes)
- r (mm), radius of the tube with the above diameter
- H, initial water level (m, below ground level) average of the observed values during phase 1
- H_0, water level (m, below ground level) after the disturbance, H_0* = min(water level in test section), H_0 = water level in test section 10 observations after H_0*, the shift is done because the water level changes rapidly just after the moving of the pressure sensor.
- t_0, time corresponding H_0, start time of the line fitting or the time instant given by the user
- t_{end} (s), end time of the line fitting, is either the end time of the measuring period, or the time when $(H-h)/(H-H_0)$ reaches 0.1 or the time when $(H-h)/(H-H_0)$ gets negative, this might happen if the data is noisy at the end of the measurement, the user can also define the t_{end}
- T_0, time when $(H-h)/(H-H_0) = 0.37$, calculated from the estimated line equation
- L (m), length of the test section
- screen diam. (mm), hole diameter
- screen radius R (mm), hole radius

- L/R
- K (m/s), hydraulic conductivity calculated according to equation 4-4.
- logK

For the calculation of hydraulic conductivity according to Thiem's equation following data is used:

Two time instants are used in calculating the flow for the Thiem analysis and two cases are considered:

- flow
    - t_1 (s) corresponds to the time when h is equal to (H + H0) / 2, if such h is not reached t1 is defined to be the time corresponding to one third of the recovery period.
    - t_2 (s) is 20 observations later
- no flow
    - t_1 (s) is 20 observations later than t_0
    - t_2 (s) is determined to be $t_0 + (t_{end} - t_0)/3$, but if the recovery period is short, less than 40 time steps, then the whole recovery is used i.e. t_2 equal to t_{end}
- h_1 (m) is the average of 11 observed h values at time t_1, average is used to compensate the possibly noisy data, otherwise erroneous results are obtained especially in case of no flow
- h_2 (m) is the average of 11 observed h values at time t_2
- dh (m) is the average change in water level, Δh in equation 4-5, $dh = (h_1+h_2)/2 - H_0$
- Q (m^3/s) observed flow in time $t_1 - t_2$
- K_{Thiem} (m/s) hydraulic conductivity assuming $r_0 = 14$ m
- logK
- $K_{Hvorslev}$ / K_{Thiem} quotient of the hydraulic conductivities according to the two methods

The sheet contains also two figures, the first one presents the measured water levels in the open borehole and in the test section. The measured values are corrected so that the reference is always ground level. The other figure shows the results of the Hvorslev's method, the measured $(H-h)/(H-H_0)$ values are plotted on a logarithmic scale as a function of time, also the fitted line is shown as well as the line $(H-h)/(H-H_0) = 0.37$.

data initial measurement data together with the processed one. The columns are the following:

- Time(s), copy of the time column of the input file
- Phase, copy of the phase column of the input file
- WaterLevelBorehole(m), copy of the water level/borehole column of the input file
- WaterLevelMeasurementSection(m), copy of the water level/measurement section column of the input file
- Open borehole, corrected water level in the open borehole below ground level (m) taking into account the depth of the pressure sensor and the casing (=ps_depth – toc - wl)

- Measurement Section, h, corrected water level in the test section below ground level (m) taking into account the depth of the pressure sensor and the casing (=ps_depth – toc - wl). Here, the possible change in the pressure sensor depth is taken into account.
- t, time from t_0 i.e. start of the line fitting
- H-h, change in the water level at the test section
- $H-H_0$, the total over pressure (m)
- $(H-h)/(H-H_0)$
- $\ln((H-h)/(H-H_0))$
- fitted, the fitted values at the given time
- $(H-h)/(H-H_0)<0.1$, used to define the end of the time interval used in the line fitting

support data needed to draw a line $(H-h)/(H-H_0) = 0.37$ in the lower figure on sheet parameters.

Subprograms

The interpretation macro consists of following subprograms:

prepare_file_for_analysis
opens a file containing measurement data and copies the necessary data to the analysis template deleting the header rows of the input data file

preliminary_analysis
modifies the functions and images in the analysis template workbook to correspond the current data file.

Write_results
writes the results of the analysis to the results workbook (filename, depth of test section, hydraulic conductivity K according to Hvorslev's method and the two Thiem approximations, R^2-value of the line fitting and comments:

T0 not reached means that during the recovery period $(H-h)/(H-H_0)$ does not reach value 0.37 corresponding the time needed for the recovery assuming steady state flow. This means that the value of T_0 has to be extrapolated outside the observed time range and the result is thus more uncertain than in the case when T_0 is reached during the observation period.

Thiem different means that the hydraulic conductivity by Hvorslev's method is at least three times greater or smaller than the one obtained by Thiem's method.

q increasing with time means that the fitted line has a positive slope and thus no recovery is observed, indicates an error.

Negative K means hydraulic conductivity obtained by Hvorslev's method is negative indicating an error.

Print_results
prints the paper copy and a pdf-file from the parameters-sheet.

Area: Olkiluoto

Hole: PP5

Measurer: Susanna Lindgren

Water level before starting 2.82 m
The reference level to depth is top of the casing, the length of the casing is 0.75 m

File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
271	3.8.2006	10:25	5.95	2.92	2.92	1.50	
272	3.8.2006	10:40	6.95	2.92	2.92	1.50	
273	3.8.2006	12:57	7.95	2.92	2.92	1.50	
274	3.8.2006	13:15	8.95	2.92	2.92	1.50	
275	3.8.2006	13:28	9.95	2.92	2.92	1.50	
276	3.8.2006	13:57	10.95	2.92	2.92	1.50	

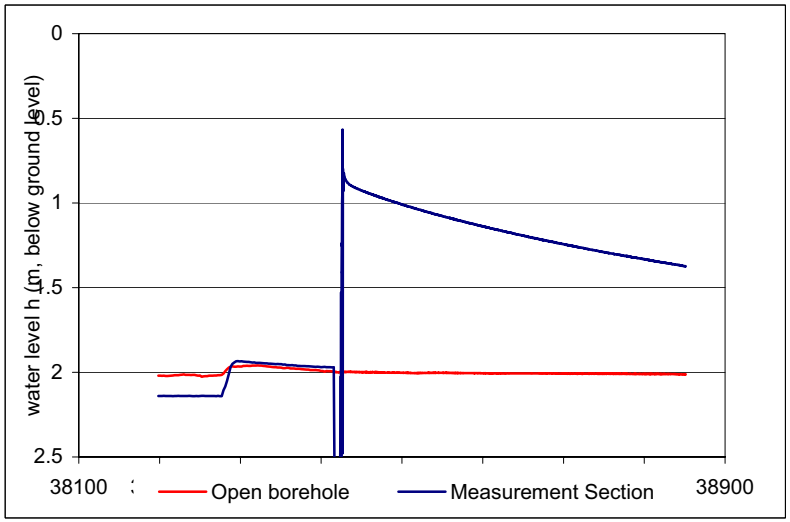
measurement/ hole&run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s)tight	comments
OLPPP5000271.DAT	5.7	1.97E-07	9.97E-01	3.03E-07	3.86E-07	T0 not reached
OLPPP5000272.DAT	6.7	1.01E-07	9.94E-01	1.55E-07	2.14E-07	T0 not reached
OLPPP5000273.DAT	7.7	7.56E-08	9.98E-01	1.11E-07	1.46E-07	T0 not reached
OLPPP5000274.DAT	8.7	9.10E-08	9.92E-01	1.58E-07	1.99E-07	T0 not reached
OLPPP5000275.DAT	9.7	1.51E-07	9.95E-01	2.74E-07	3.15E-07	T0 not reached
OLPPP5000276.DAT	10.7	1.42E-07	9.87E-01	2.35E-07	3.29E-07	T0 not reached

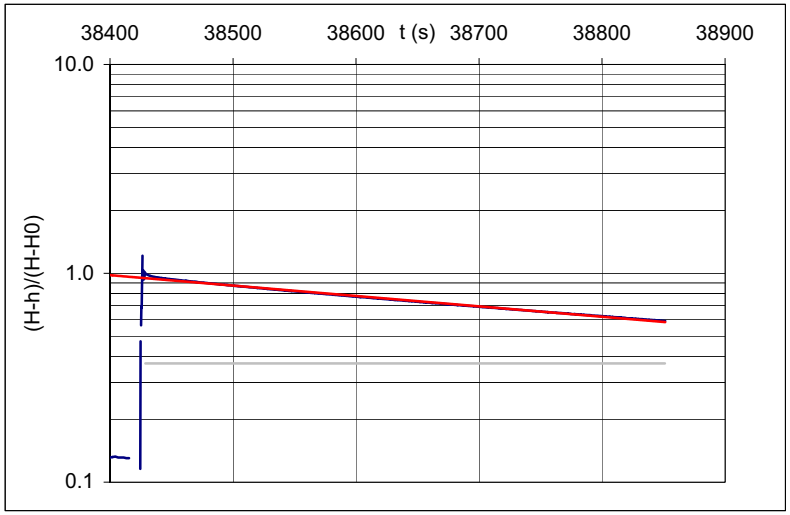
input file	**OLPPP5000271.DAT**	date	*3.8.2006*		
TOC (m)	*0.75*				
depth of pressure sensor open hole (m)	*2.92*	ref toc	min open bore-hole pressure (m)	2.03	ref ground level
depth of pressure sensor meas. section (m)	*2.92*	initial, ref toc			
depth of pressure sensor meas. section (m)	*4.42*	final, ref toc			
depth of meas. section (m)	*5.95*	ref TOC, top			
depth of meas. section (m)	5.7	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	2.14	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.84	water level at the measurement section after disturbance, ref ground level			
t_0	38428.8	time of disturbance			
t_{end} (s)	38851.1	end of time range used to line fitting			
Time range (s)	422.3	Time range used for interpretation			
T_0	826.0	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**1.97E-07**	**T0 not reached**			
logK	-6.71				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.001145899	-0.053438577
1.55242E-06	0.000378516
0.9967	0.00803284
544844.7905	1798
35.15694009	0.116018689

Stat tests	
test stat, a <> 0	738.14
test stat, b <> 0	141.18
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	38567.1	h1	1.10
t2	38571.8	h2	1.10
Q (m^3/s)	3.09E-07	dh (m)	1.04
K_{Thiem} (m/s)	**3.03E-07**	logK	-6.52
$K_{Hvorslev}$ / K_{Thiem}	0.65		
tight			
t1	38433.5	h1	0.88
t2	38569.4	h2	1.10
Q (m^3/s)	4.34E-07	dh (m)	1.15
K_{Thiem} (m/s)	**3.86E-07**	logK	-6.41
$K_{Hvorslev}$ / K_{Thiem}	0.51		



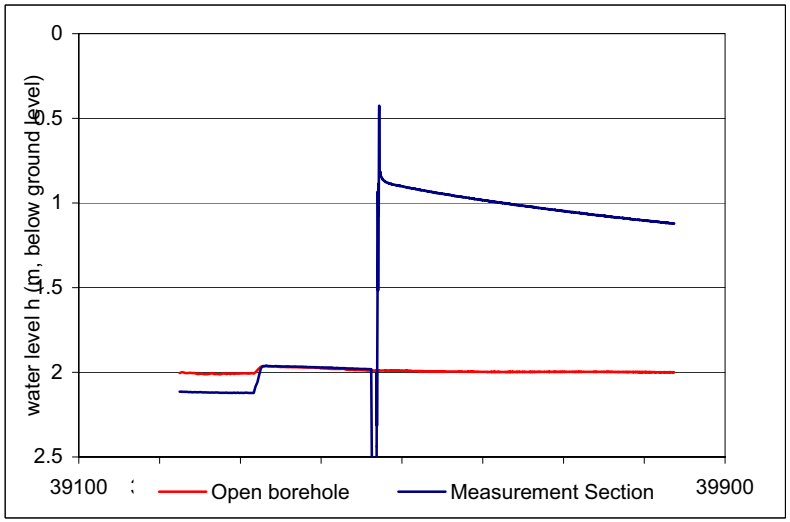


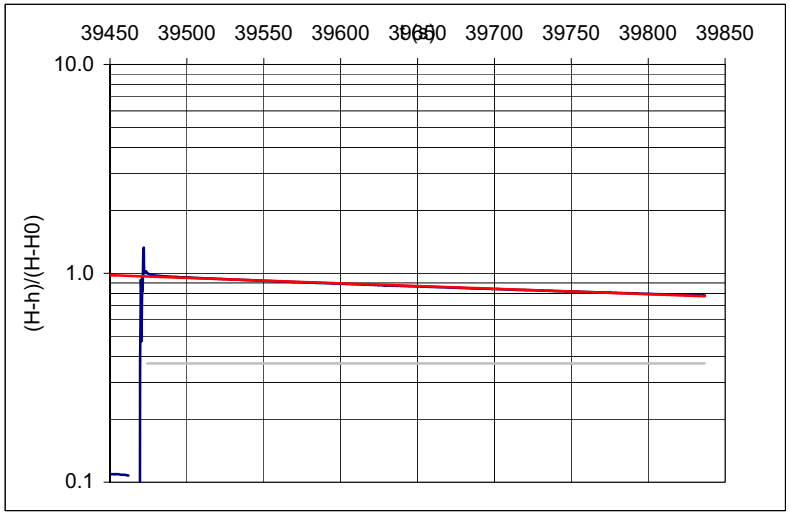
input file	**OLPPP5000272.DAT**	date	*3.8.2006*		
TOC (m)	*0.75*				
depth of pressure sensor open hole (m)	*2.92*	ref toc	min open bore-hole pressure (m)	2.01	ref ground level
depth of pressure sensor meas. section (m)	*2.92*	initial, ref toc			
depth of pressure sensor meas. section (m)	*4.42*	final, ref toc			
depth of meas. section (m)	*6.95*	ref TOC, top			
depth of meas. section (m)	6.7	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	2.12	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.85	water level at the measurement section after disturbance, ref ground level			
t_0	39474.3	time of disturbance			
t_{end} (s)	39836.7	end of time range used to line fitting			
Time range (s)	362.4	Time range used for interpretation			
T_0	1609.8	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**1.01E-07**	**T0 not reached**			
logK	-7.00				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000599391	-0.035119525
1.19793E-06	0.000250689
0.9939	0.00492912
250353.9139	1543
6.082655897	0.037489081

Stat tests	
test stat, a <> 0	500.35
test stat, b <> 0	140.09
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	39592.6	h1	0.98
t2	39597.3	h2	0.98
Q (m^3/s)	1.73E-07	dh (m)	1.14
K_{Thiem} (m/s)	**1.55E-07**	logK	-6.81
$K_{Hvorslev}$ / K_{Thiem}	0.65		
tight			
t1	39479.0	h1	0.87
t2	39594.9	h2	0.98
Q (m^3/s)	2.50E-07	dh (m)	1.19
K_{Thiem} (m/s)	**2.14E-07**	logK	-6.67
$K_{Hvorslev}$ / K_{Thiem}	0.47		



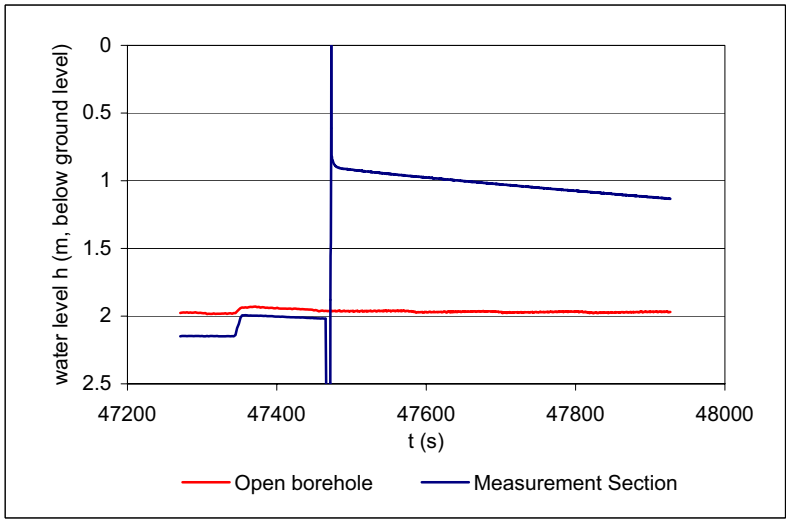


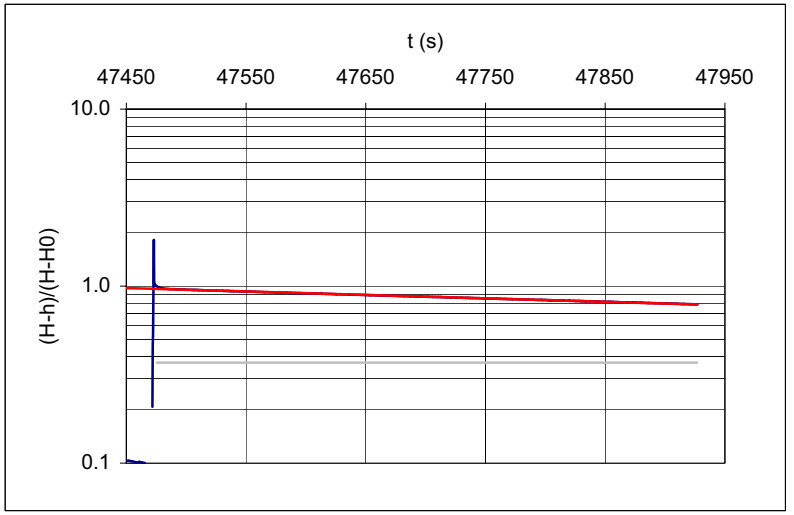
input file	**OLPPP5000273.DAT**	date	*3.8.2006*		
TOC (m)	*0.75*				
depth of pressure sensor open hole (m)	*2.92*	ref toc	min open bore-hole pressure (m)	1.99	ref ground level
depth of pressure sensor meas. section (m)	*2.92*	initial, ref toc			
depth of pressure sensor meas. section (m)	*4.42*	final, ref toc			
depth of meas. section (m)	*7.95*	ref TOC, top			
depth of meas. section (m)	7.7	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	2.15	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.86	water level at the measurement section after disturbance, ref ground level			
t_0	47475.4	time of disturbance			
t_{end} (s)	47926.8	end of time range used to line fitting			
Time range (s)	451.4	Time range used for interpretation			
T_0	2149.4	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**7.56E-08**	**T0 not reached**			
logK	-7.12				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000448409	-0.036193092
4.63083E-07	0.0001207
0.9980	0.002648233
937630.1725	1922
6.575730674	0.013479253

Stat tests	
test stat, a <> 0	968.31
test stat, b <> 0	299.86
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	47623.5	h1	0.99
t2	47628.2	h2	0.99
Q (m^3/s)	1.26E-07	dh (m)	1.16
K_{Thiem} (m/s)	**1.11E-07**	logK	-6.96
$K_{Hvorslev}$ / K_{Thiem}	0.68		
tight			
t1	47480.0	h1	0.90
t2	47625.8	h2	0.99
Q (m^3/s)	1.72E-07	dh (m)	1.20
K_{Thiem} (m/s)	**1.46E-07**	logK	-6.84
$K_{Hvorslev}$ / K_{Thiem}	0.52		



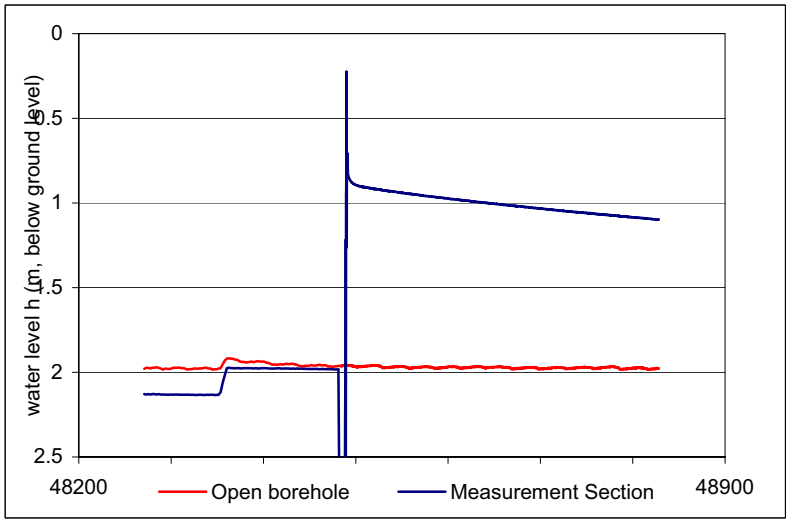


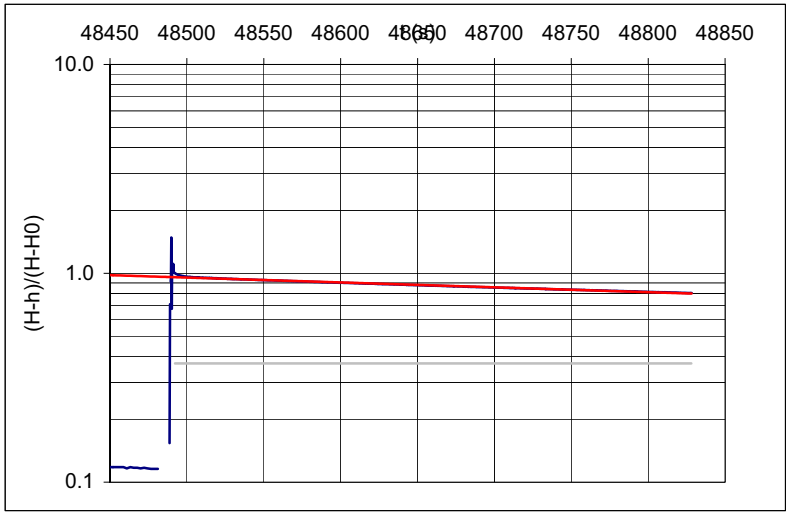
input file	**OLPPP5000274.DAT**	date	*3.8.2006*		
TOC (m)	*0.75*				
depth of pressure sensor open hole (m)	*2.92*	ref toc	min open bore-hole pressure (m)	1.98	ref ground level
depth of pressure sensor meas. section (m)	*2.92*	initial, ref toc			
depth of pressure sensor meas. section (m)	*4.42*	final, ref toc			
depth of meas. section (m)	*8.95*	ref TOC, top			
depth of meas. section (m)	8.7	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	2.13	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.85	water level at the measurement section after disturbance, ref ground level			
t_0	48492.3	time of disturbance			
t_{end} (s)	48828.0	end of time range used to line fitting			
Time range (s)	335.8	Time range used for interpretation			
T_0	1784.4	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**9.10E-08**	**T0 not reached**			
logK	-7.04				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000536403	-0.042847728
1.26989E-06	0.000246207
0.9921	0.004659185
178422.9176	1429
3.873205927	0.031020742

Stat tests	
test stat, a <> 0	422.40
test stat, b <> 0	174.03
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	48601.7	h1	0.98
t2	48606.4	h2	0.98
Q (m^3/s)	1.78E-07	dh (m)	1.15
K_{Thiem} (m/s)	**1.58E-07**	logK	-6.80
$K_{Hvorslev}$ / K_{Thiem}	0.58		
tight			
t1	48497.0	h1	0.88
t2	48604.0	h2	0.98
Q (m^3/s)	2.34E-07	dh (m)	1.20
K_{Thiem} (m/s)	**1.99E-07**	logK	-6.70
$K_{Hvorslev}$ / K_{Thiem}	0.46		



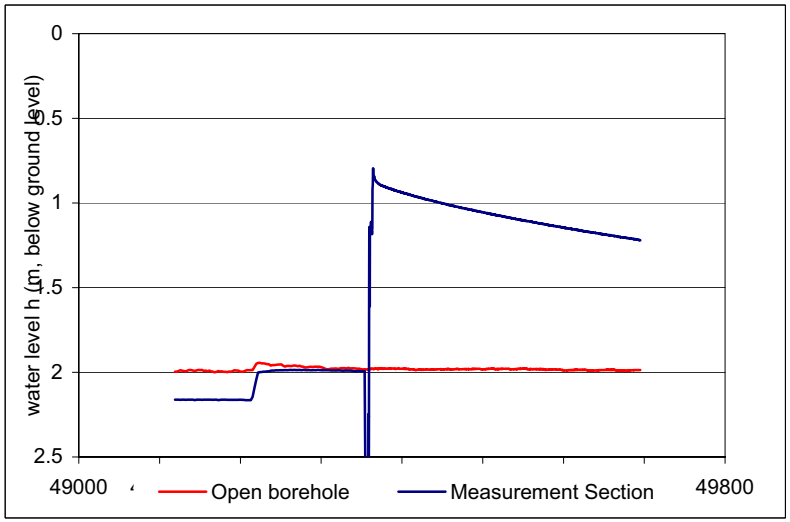


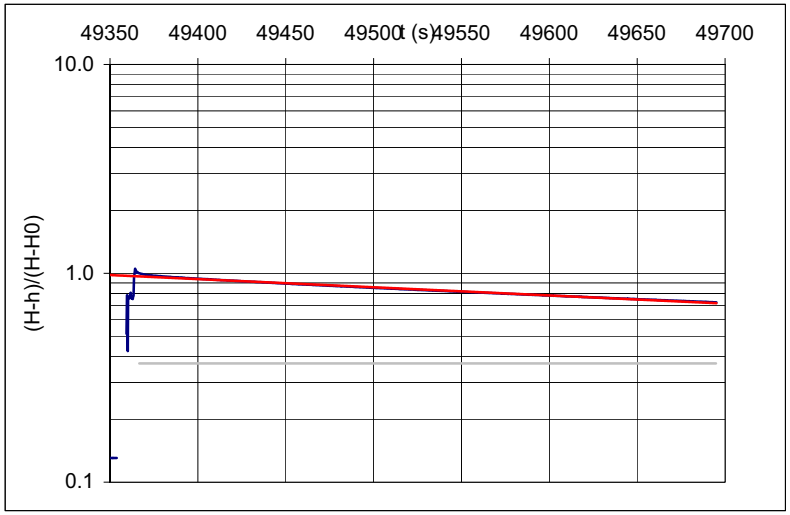
input file	**OLPPP5000275.DAT**	date	*3.8.2006*		
TOC (m)	*0.75*				
depth of pressure sensor open hole (m)	*2.92*	ref toc	min open bore-hole pressure (m)	2.00	ref ground level
depth of pressure sensor meas. section (m)	*2.92*	initial, ref toc			
depth of pressure sensor meas. section (m)	*4.42*	final, ref toc			
depth of meas. section (m)	*9.95*	ref TOC, top			
depth of meas. section (m)	9.7	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	2.16	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.86	water level at the measurement section after disturbance, ref ground level			
t_0	49366.7	time of disturbance			
t_{end} (s)	49694.8	end of time range used to line fitting			
Time range (s)	328.2	Time range used for interpretation			
T_0	1073.6	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**1.51E-07**	**T0 not reached**			
logK	-6.82				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000899959	-0.033773975
1.76629E-06	0.0003347
0.9946	0.00626273
259610.3929	1397
10.18238381	0.054792838

Stat tests	
test stat, a <> 0	509.52
test stat, b <> 0	100.91
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	49473.7	h1	1.03
t2	49478.4	h2	1.03
Q (m^3/s)	3.03E-07	dh (m)	1.13
K_{Thiem} (m/s)	**2.74E-07**	logK	-6.56
$K_{Hvorslev}$ / K_{Thiem}	0.55		
tight			
t1	49371.4	h1	0.89
t2	49476.1	h2	1.03
Q (m^3/s)	3.72E-07	dh (m)	1.20
K_{Thiem} (m/s)	**3.15E-07**	logK	-6.50
$K_{Hvorslev}$ / K_{Thiem}	0.48		



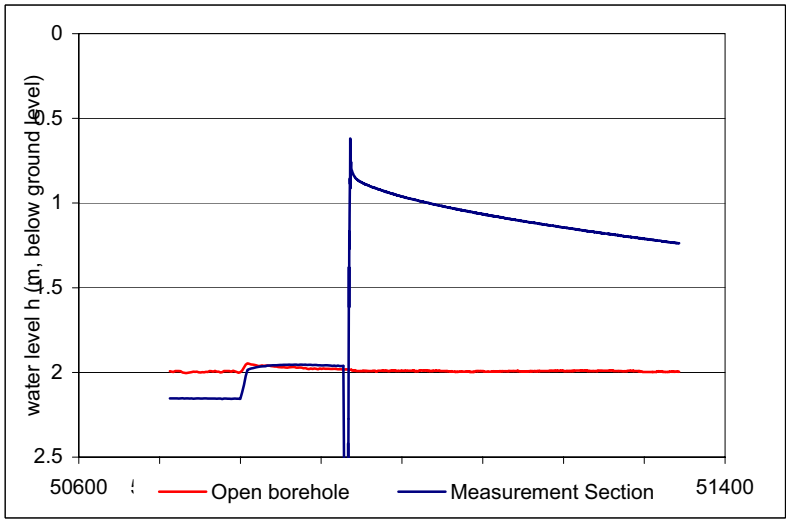


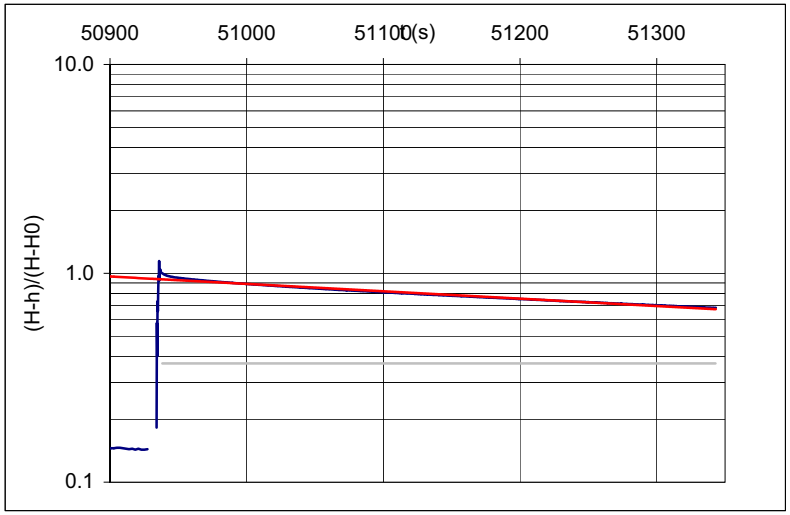
input file	**OLPPP5000276.DAT**	date	*3.8.2006*		
TOC (m)	*0.75*				
depth of pressure sensor open hole (m)	*2.92*	ref toc	min open bore-hole pressure (m)	2.00	ref ground level
depth of pressure sensor meas. section (m)	*2.92*	initial, ref toc			
depth of pressure sensor meas. section (m)	*4.42*	final, ref toc			
depth of meas. section (m)	*10.95*	ref TOC, top			
depth of meas. section (m)	10.7	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	2.15	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.81	water level at the measurement section after disturbance, ref ground level			
t_0	50938.3	time of disturbance			
t_{end} (s)	51343.0	end of time range used to line fitting			
Time range (s)	404.7	Time range used for interpretation			
T_0	1147.5	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**1.42E-07**	**T0 not reached**			
logK	-6.85				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000813556	-0.066407214
2.26431E-06	0.000529092
0.9868	0.010991861
129093.445	1723
15.59720005	0.208174596

Stat tests	
test stat, a <> 0	359.30
test stat, b <> 0	125.51
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	51070.7	h1	1.04
t2	51075.4	h2	1.04
Q (m^3/s)	2.56E-07	dh (m)	1.11
K_{Thiem} (m/s)	**2.35E-07**	logK	-6.63
$K_{Hvorslev}$ / K_{Thiem}	0.60		
tight			
t1	50943.0	h1	0.85
t2	51073.1	h2	1.04
Q (m^3/s)	3.88E-07	dh (m)	1.21
K_{Thiem} (m/s)	**3.29E-07**	logK	-6.48
$K_{Hvorslev}$ / K_{Thiem}	0.43		





Area: Olkiluoto **Hole:** PP9 **Measurer:** Susanna Lindgren

Water level before starting 2.09 m
The reference level to depth is top of the casing, the length of the casing is 0.62 m

File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
263	27.7.2006	10:33	4.95	2.19	2.19	1.50	
264	27.7.2006	10:57	5.95	2.19	2.19	1.50	
265	27.7.2006	12:35	6.95	2.19	2.19	1.50	
266	27.7.2006	12:50	7.95	2.19	2.19	1.50	
267	27.7.2006	13:15	8.95	2.19	2.19	1.50	
268	27.7.2006	13:26	9.95	2.19	2.19	1.50	
269	27.7.2006	13:44	10.95	2.19	2.19	1.50	
270	27.7.2006	14:00	11.95	2.19	2.19	1.50	

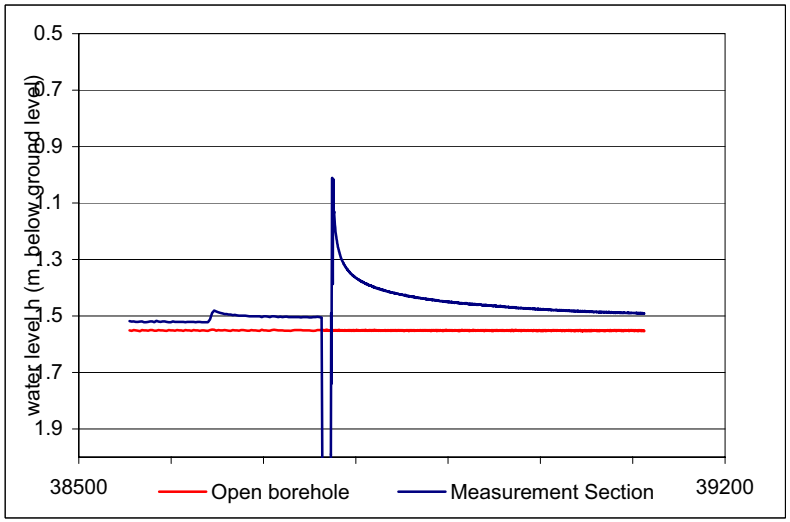
measurement/ hole&run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s) tight	comments
OLPPP9000263.DAT	4.83	5.17E-06	9.30E-01	6.74E-06	3.34E-06	recovery not linear
OLPPP9000264.DAT	5.83	-9.62E-10	8.04E-02	-1.79E-08	2.13E-09	negative K
OLPPP9000265.DAT	6.83	6.30E-09	6.32E-01	2.20E-08	3.88E-08	T0 not reached
OLPPP9000266.DAT	7.83	1.29E-07	9.99E-01	1.97E-07	2.21E-07	T0 not reached
OLPPP9000267.DAT	8.83	3.51E-07	9.98E-01	5.67E-07	5.36E-07	T0 not reached
OLPPP9000268.DAT	9.83	3.30E-07	9.97E-01	5.37E-07	4.94E-07	T0 not reached
OLPPP9000269.DAT	10.83	-6.011E-10	2.71E-02	0	1.35E-08	negative K
OLPPP9000270.DAT	11.83	2.7342E-09	1.97E-01	-2.30E-08	2.13E-08	T0 not reached

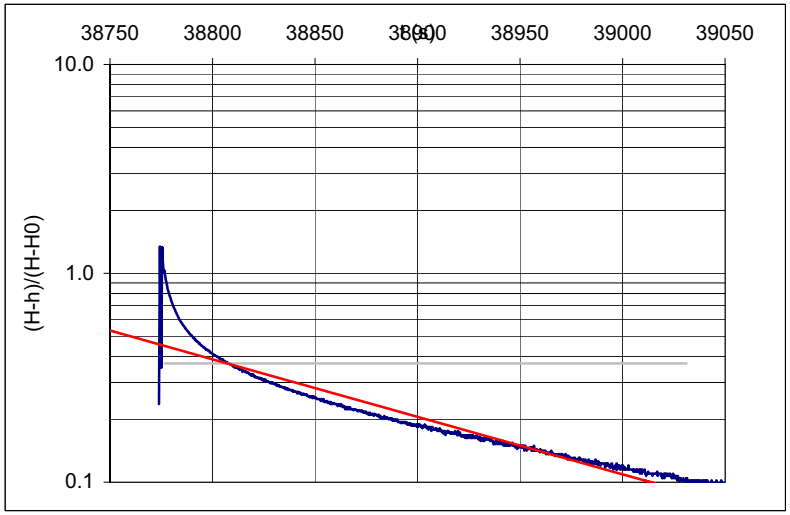
input file	**OLPPP9000263.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*4.95*	ref TOC, top			
depth of meas. section (m)	4.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.52	reference water level at the measurement section based on phase 1, ref ground level			
H_0	1.14	water level at the measurement section after disturbance, ref ground level			
t_0	38776.7	time of disturbance			
t_{end} (s)	39031.2	end of time range used to line fitting			
Time range (s)	254.5	Time range used for interpretation			
T_0	31.4	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**5.17E-06**				
logK	-5.29				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.006339756	-0.800731046
5.28266E-05	0.007763709
0.9301	0.127944794
14402.55661	1083
235.7679843	17.72856958

Stat tests	
test stat, a <> 0	120.01
test stat, b <> 0	103.14
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	38787.8	h1	1.32
t2	38792.5	h2	1.34
Q (m^3/s)	1.25E-06	dh (m)	0.19
K_{Thiem} (m/s)	**6.74E-06**	logK	-5.17
$K_{Hvorslev}$ / K_{Thiem}	0.77		
tight			
t1	38781.4	h1	1.26
t2	38861.5	h2	1.43
Q (m^3/s)	5.65E-07	dh (m)	0.17
K_{Thiem} (m/s)	**3.34E-06**	logK	-5.48
$K_{Hvorslev}$ / K_{Thiem}	1.55		



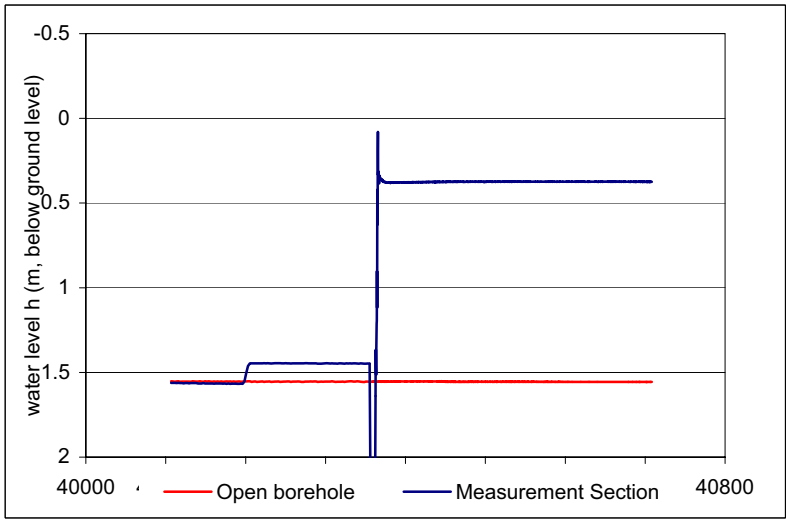


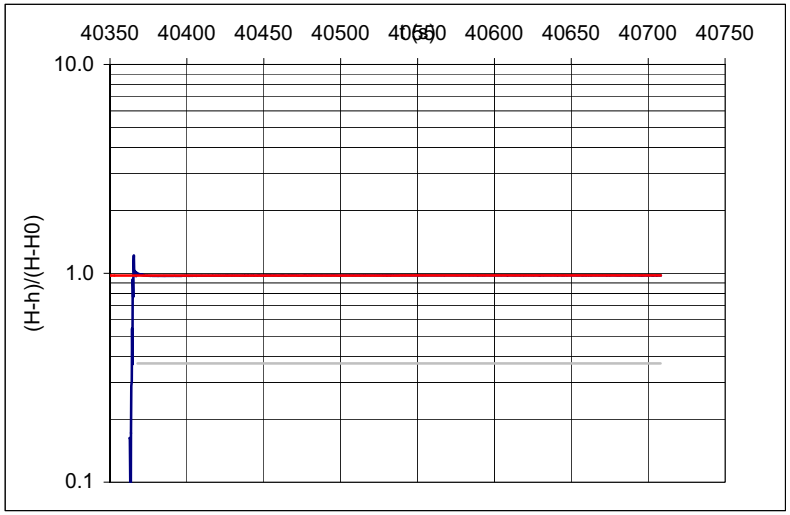
input file	**OLPPP9000264.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*5.95*	ref TOC, top			
depth of meas. section (m)	5.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.56	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.35	water level at the measurement section after disturbance, ref ground level			
t_0	40367.9	time of disturbance			
t_{end} (s)	40708.1	end of time range used to line fitting			
Time range (s)	340.2	Time range used for interpretation			
T_0	-168911.7	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**-9.62E-10**				
logK	#NUM!				

ln((H-h)/(H-H0)) = a*t + b	
a	b
5.77341E-06	-0.024803411
5.13018E-07	0.000100784
0.0804	0.001919804
126.6484302	1448
0.000466781	0.005336816

Stat tests	
test stat, a <> 0	11.25
test stat, b <> 0	246.11
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	40478.9	h1	0.37
t2	40483.6	h2	0.37
Q (m^3/s)	-2.09E-08	dh (m)	1.19
K_{Thiem} (m/s)	**-1.79E-08**	logK	#NUM!
$K_{Hvorslev}$ / K_{Thiem}	0.05		
tight			
t1	40372.6	h1	0.37
t2	40481.3	h2	0.37
Q (m^3/s)	2.49E-09	dh (m)	1.19
K_{Thiem} (m/s)	**2.13E-09**	logK	-8.67
$K_{Hvorslev}$ / K_{Thiem}	-0.45		



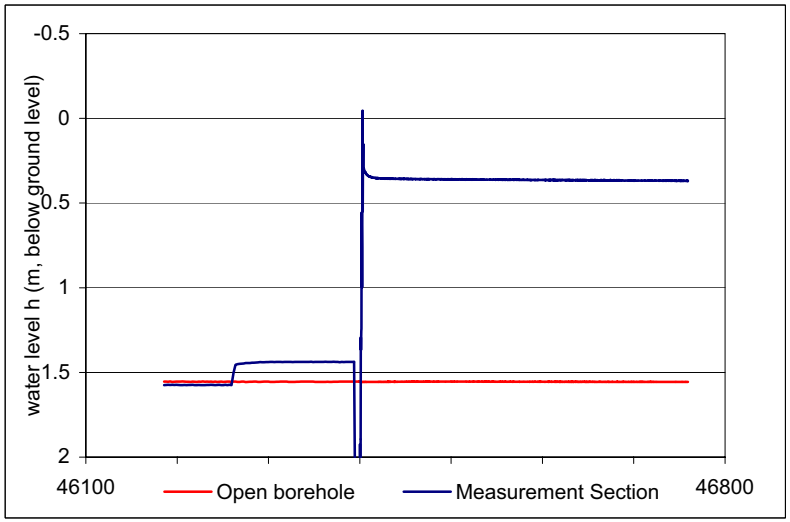


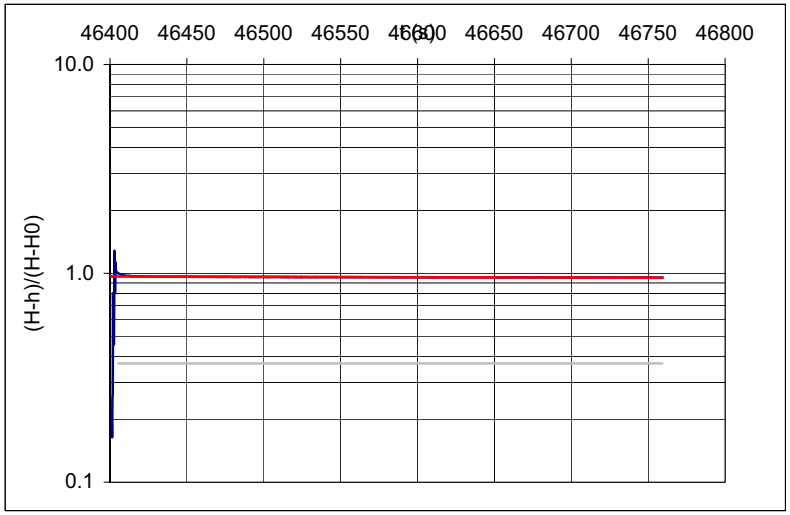
input file	**OLPPP9000265.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*6.95*	ref TOC, top			
depth of meas. section (m)	6.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.57	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.31	water level at the measurement section after disturbance, ref ground level			
t_0	46405.3	time of disturbance			
t_{end} (s)	46759.2	end of time range used to line fitting			
Time range (s)	353.9	Time range used for interpretation			
T_0	25790.1	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**6.30E-09**	**T0 not reached**			
logK	-8.20				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-3.73961E-05	-0.035549485
7.35145E-07	0.000150216
0.6321	0.002918117
2587.657646	1506
0.022034957	0.012824202

Stat tests	
test stat, a <> 0	50.87
test stat, b <> 0	236.66
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	46520.8	h1	0.36
t2	46525.5	h2	0.36
Q (m^3/s)	2.62E-08	dh (m)	1.21
K_{Thiem} (m/s)	**2.20E-08**	logK	-7.66
$K_{Hvorslev}$ / K_{Thiem}	0.29		
tight			
t1	46410.0	h1	0.34
t2	46523.2	h2	0.36
Q (m^3/s)	4.65E-08	dh (m)	1.22
K_{Thiem} (m/s)	**3.88E-08**	logK	-7.41
$K_{Hvorslev}$ / K_{Thiem}	0.16		



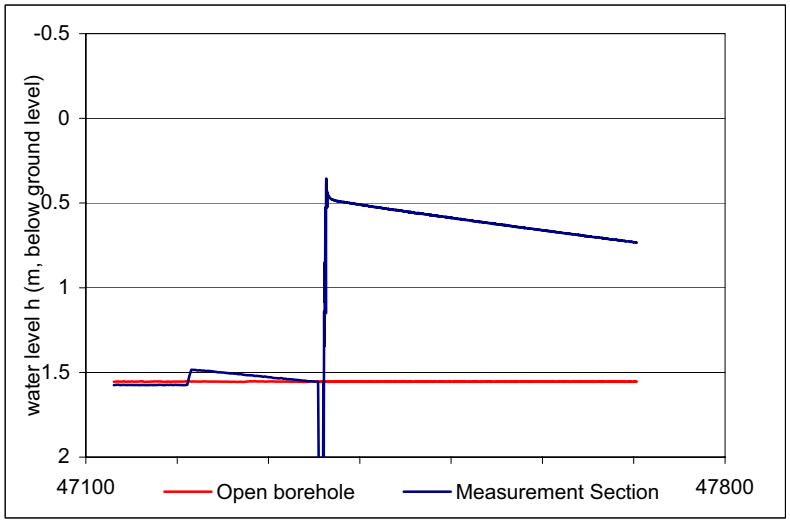


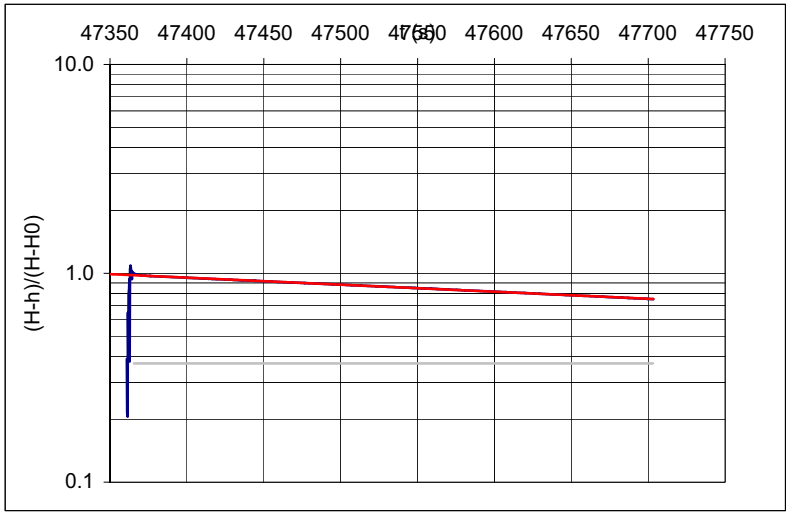
input file	**OLPPP9000266.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*7.95*	ref TOC, top			
depth of meas. section (m)	7.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.57	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.46	water level at the measurement section after disturbance, ref ground level			
t_0	47365.6	time of disturbance			
t_{end} (s)	47703.1	end of time range used to line fitting			
Time range (s)	337.5	Time range used for interpretation			
T_0	1262.1	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**1.29E-07**	**T0 not reached**			
logK	-6.89				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000775648	-0.0210868
4.66408E-07	9.08896E-05
0.9995	0.00172418
2765657.556	1436
8.221737429	0.004268936

Stat tests	
test stat, a <> 0	1663.03
test stat, b <> 0	232.00
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	47475.8	h1	0.57
t2	47480.5	h2	0.57
Q (m^3/s)	1.94E-07	dh (m)	1.00
K_{Thiem} (m/s)	**1.97E-07**	logK	-6.71
$K_{Hvorslev}$ / K_{Thiem}	0.65		
tight			
t1	47370.3	h1	0.48
t2	47478.1	h2	0.57
Q (m^3/s)	2.27E-07	dh (m)	1.05
K_{Thiem} (m/s)	**2.21E-07**	logK	-6.66
$K_{Hvorslev}$ / K_{Thiem}	0.58		



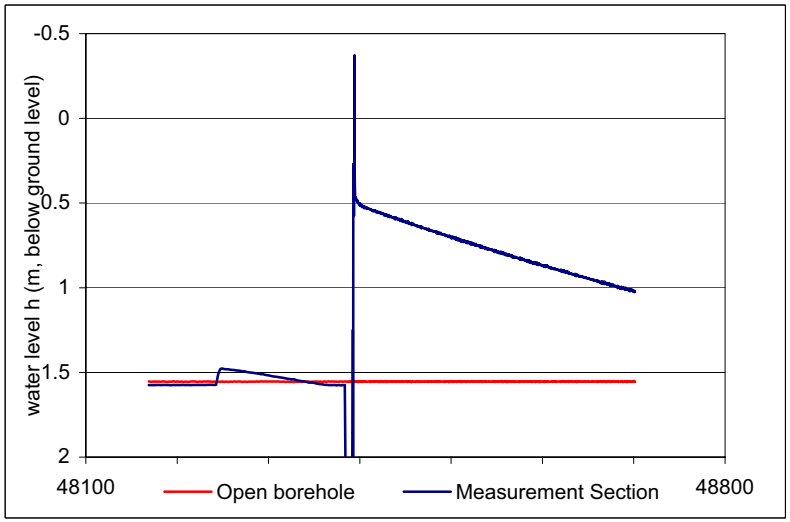


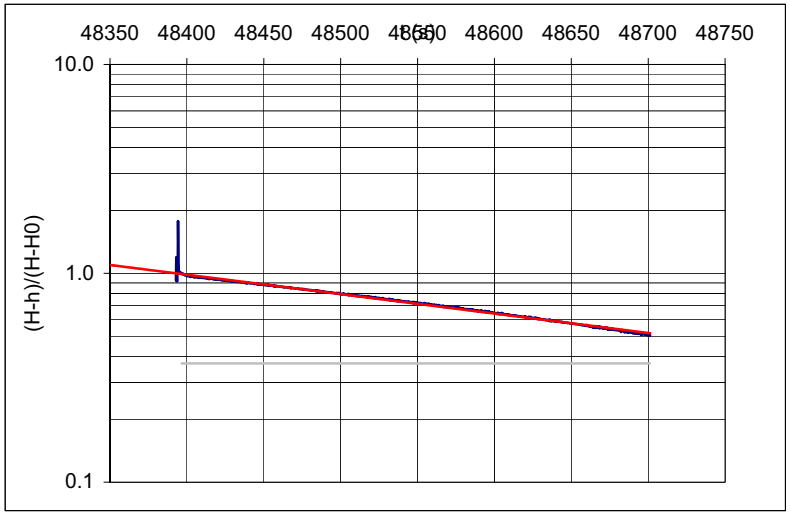
input file	**OLPPP9000267.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*8.95*	ref TOC, top			
depth of meas. section (m)	8.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.57	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.48	water level at the measurement section after disturbance, ref ground level			
t_0	48396.6	time of disturbance			
t_{end} (s)	48701.1	end of time range used to line fitting			
Time range (s)	304.4	Time range used for interpretation			
T_0	463.0	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**3.51E-07**	**T0 not reached**			
logK	-6.45				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.002142252	-0.008042843
2.8957E-06	0.00050907
0.9976	0.009172593
547310.4896	1295
46.04877271	0.108956729

Stat tests	
test stat, a <> 0	739.80
test stat, b <> 0	15.80
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	48495.8	h1	0.69
t2	48500.5	h2	0.70
Q (m^3/s)	4.87E-07	dh (m)	0.88
K_{Thiem} (m/s)	**5.67E-07**	logK	-6.25
$K_{Hvorslev}$ / K_{Thiem}	0.62		
tight			
t1	48401.3	h1	0.51
t2	48498.1	h2	0.70
Q (m^3/s)	5.09E-07	dh (m)	0.97
K_{Thiem} (m/s)	**5.36E-07**	logK	-6.27
$K_{Hvorslev}$ / K_{Thiem}	0.65		



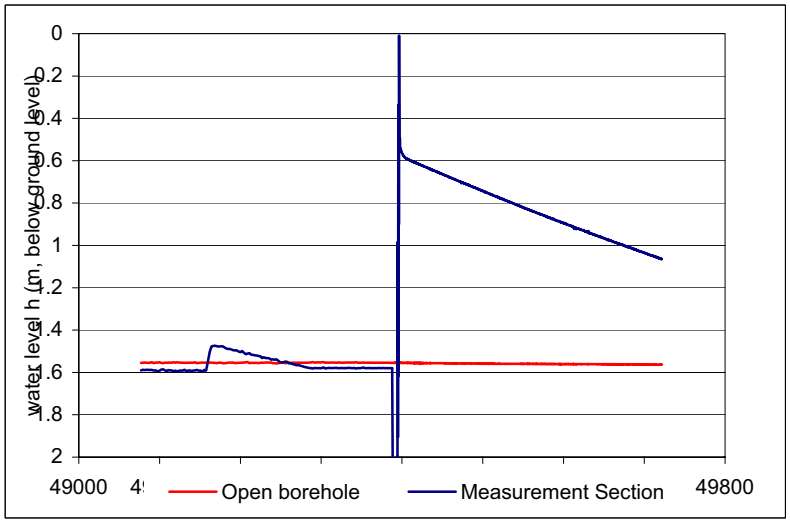


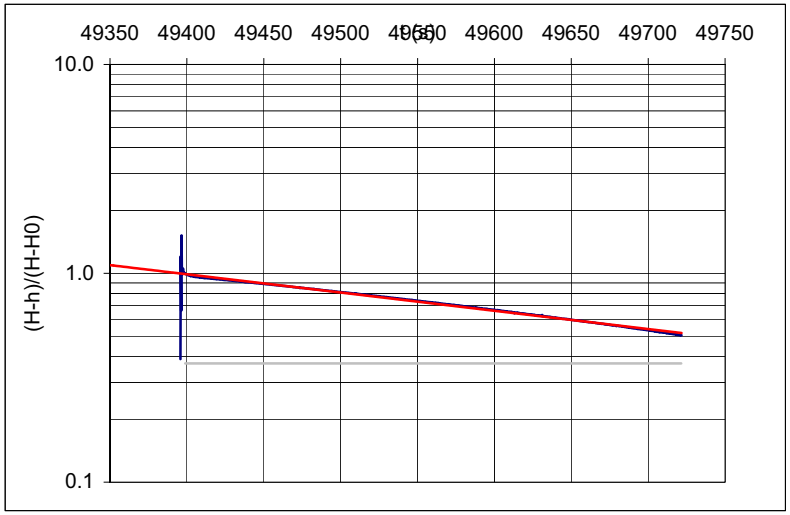
input file	**OLPPP9000268.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*9.95*	ref TOC, top			
depth of meas. section (m)	9.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.59	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.55	water level at the measurement section after disturbance, ref ground level			
t_0	49398.9	time of disturbance			
t_{end} (s)	49721.5	end of time range used to line fitting			
Time range (s)	322.6	Time range used for interpretation			
T_0	492.6	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**3.30E-07**	**T0 not reached**			
logK	-6.48				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.002013755	-0.008120618
2.87494E-06	0.000535522
0.9972	0.009934065
490633.1795	1373
48.41844951	0.135495384

Stat tests	
test stat, a <> 0	700.45
test stat, b <> 0	15.16
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	49504.1	h1	0.75
t2	49508.8	h2	0.76
Q (m^3/s)	4.40E-07	dh (m)	0.84
K_{Thiem} (m/s)	**5.37E-07**	logK	-6.27
$K_{Hvorslev}$ / K_{Thiem}	0.61		
tight			
t1	49403.6	h1	0.58
t2	49506.4	h2	0.75
Q (m^3/s)	4.46E-07	dh (m)	0.92
K_{Thiem} (m/s)	**4.94E-07**	logK	-6.31
$K_{Hvorslev}$ / K_{Thiem}	0.67		

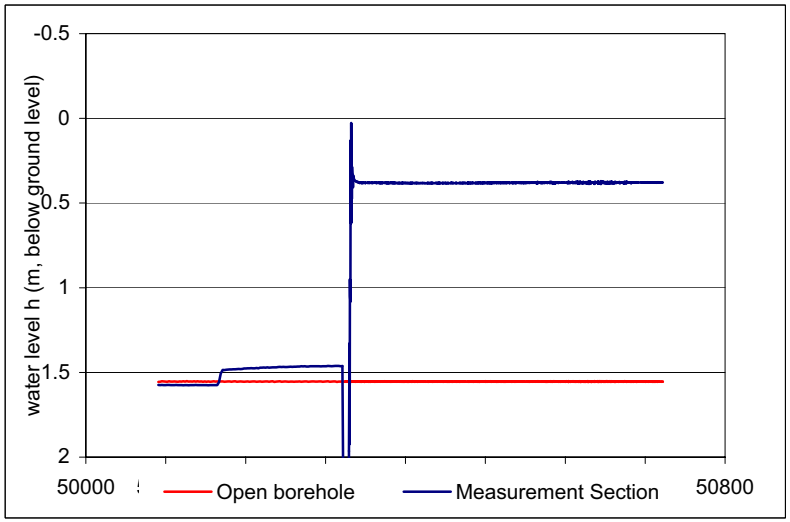


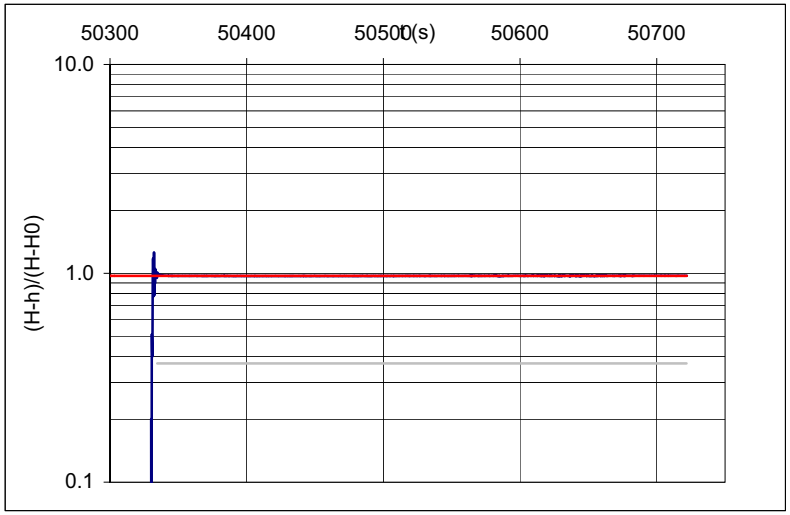


input file	**OLPPP9000269.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*10.95*	ref TOC, top			
depth of meas. section (m)	10.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.57	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.35	water level at the measurement section after disturbance, ref ground level			
t_0	50334.5	time of disturbance			
t_{end} (s)	50721.8	end of time range used to line fitting			
Time range (s)	387.3	Time range used for interpretation			
T_0	-270215.8	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**-6.01E-10**				
logK	#NUM!				

ln((H-h)/(H-H0)) = a*t + b	
a	b
3.59371E-06	-0.028924136
5.30024E-07	0.000118526
0.0271	0.002408476
45.97206825	1648
0.000266673	0.009559644
Stat tests	
test stat, a <> 0	6.78
test stat, b <> 0	244.03
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	50461.1	h1	0.38
t2	50465.8	h2	0.38
Q (m^3/s)	0.00E+00	dh (m)	1.19
K_{Thiem} (m/s)	**0.00E+00**	logK	#NUM!
$K_{Hvorslev}$ / K_{Thiem}	#DIV/0!		
tight			
t1	50339.2	h1	0.37
t2	50463.5	h2	0.38
Q (m^3/s)	1.58E-08	dh (m)	1.20
K_{Thiem} (m/s)	**1.35E-08**	logK	-7.87
$K_{Hvorslev}$ / K_{Thiem}	-0.04		



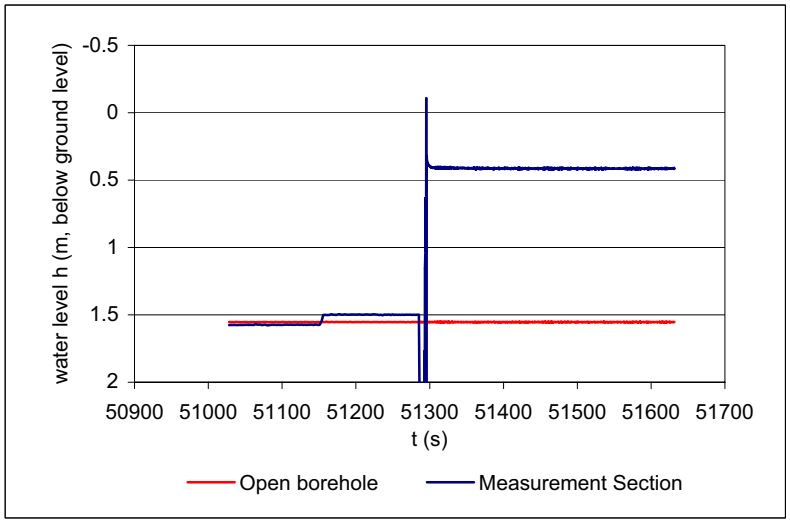


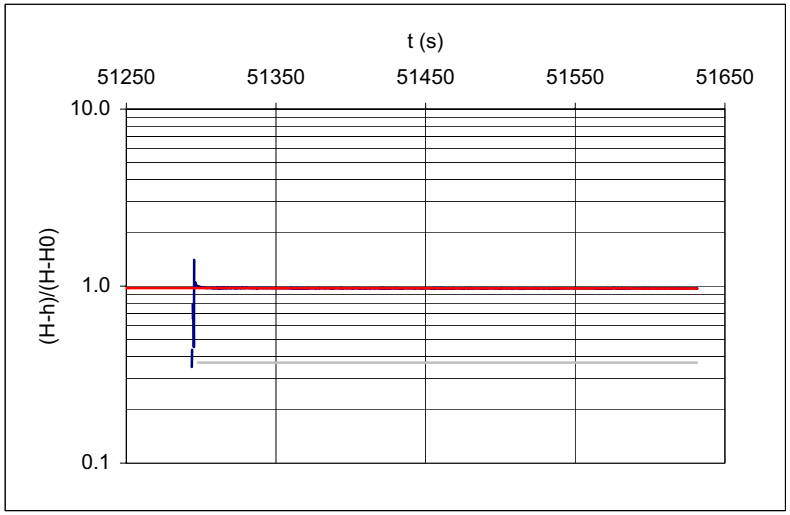
input file	**OLPPP9000270.DAT**	date	*27.7.2006*		
TOC (m)	*0.62*				
depth of pressure sensor open hole (m)	*2.19*	ref toc	min open bore-hole pressure (m)	1.56	ref ground level
depth of pressure sensor meas. section (m)	*2.19*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.69*	final, ref toc			
depth of meas. section (m)	*11.95*	ref TOC, top			
depth of meas. section (m)	11.83	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.57	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.38	water level at the measurement section after disturbance, ref ground level			
t_0	51297.7	time of disturbance			
t_{end} (s)	51631.3	end of time range used to line fitting			
Time range (s)	333.6	Time range used for interpretation			
T_0	59403.6	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*46*	equal to borehole diameter			
screen radius R (mm)	23	equal to borehole radius			
L/R	43.48				
K (m/s)	**2.73E-09**	**T0 not reached**			
logK	-8.56				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-1.6406E-05	-0.025422487
8.7859E-07	0.000169242
0.1973	0.003191655
348.6864844	1419
0.003551952	0.014454877

Stat tests	
test stat, a <> 0	18.67
test stat, b <> 0	150.21
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	51406.5	h1	0.41
t2	51411.2	h2	0.41
Q (m^3/s)	-2.62E-08	dh (m)	1.16
K_{Thiem} (m/s)	**-2.30E-08**	logK	#NUM!
$K_{Hvorslev}$ / K_{Thiem}	-0.12		
tight			
t1	51302.4	h1	0.40
t2	51408.8	h2	0.41
Q (m^3/s)	2.43E-08	dh (m)	1.17
K_{Thiem} (m/s)	**2.13E-08**	logK	-7.67
$K_{Hvorslev}$ / K_{Thiem}	0.13		





Area:	Hole:	Measurer:
Olkiluoto	PP36	Susanna Lindgren

Water level before starting 4.46 m
The reference level to depth is top of the casing, the length of the casing is 0.78 m

File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
260	19.7.2006	15:25	6.95	4.56	4.56	1.50	casing measured on field
261	19.7.2006	15:36	7.95	4.56	4.56	1.50	
262	19.7.2006	15.53	8.95	4.56	4.56	1.50	

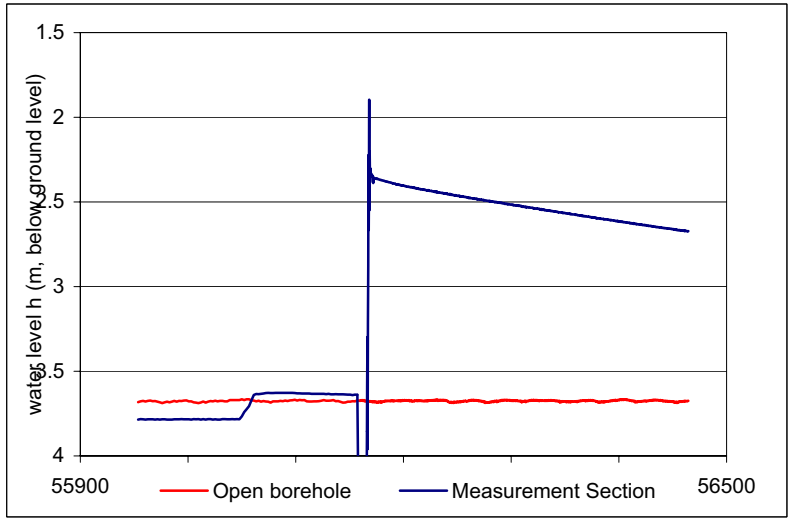
measurement/hole &run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s)tight	comments
OLPP36000260.DAT	6.67	1.30E-07	9.99E-01	2.43E-07	2.53E-07	T0 not reached
OLPP36000261.DAT	7.67	5.25E-07	9.96E-01	7.70E-07	1.02E-06	
OLPP36000262.DAT	8.67	1.60E-08	8.95E-01	5.23E-08	6.67E-08	T0 not reached

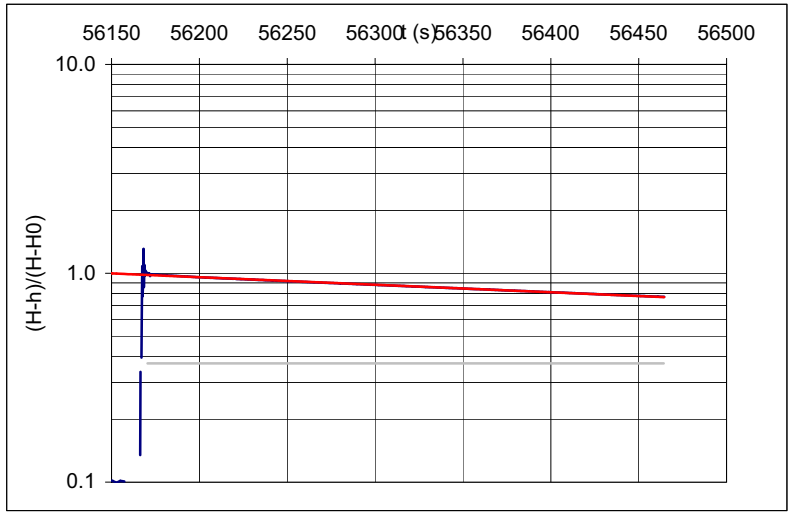
input file	**OLPP36000260.DAT**	date	*19.7.2006*		
TOC (m)	*0.78*				
depth of pressure sensor open hole (m)	*4.56*	ref toc	min open bore-hole pressure (m)	3.69	ref ground level
depth of pressure sensor meas. section (m)	*4.56*	initial, ref toc			
depth of pressure sensor meas. section (m)	*6.06*	final, ref toc			
depth of meas. section (m)	*6.95*	ref TOC, top			
depth of meas. section (m)	6.67	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	3.78	reference water level at the measurement section based on phase 1, ref ground level			
H_0	2.34	water level at the measurement section after disturbance, ref ground level			
t_0	56170.5	time of disturbance			
t_{end} (s)	56464.2	end of time range used to line fitting			
Time range (s)	293.7	Time range used for interpretation			
T_0	1182.5	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**1.30E-07**	**T0 not reached**			
logK	-6.89				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000829675	-0.018878489
8.0872E-07	0.000137157
0.9988	0.002427993
1052492.035	1250
6.204597886	0.007368937

Stat tests	
test stat, a <> 0	1025.91
test stat, b <> 0	137.64
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	56266.1	h1	2.48
t2	56270.8	h2	2.49
Q (m^3/s)	3.20E-07	dh (m)	1.30
K_{Thiem} (m/s)	**2.43E-07**	logK	-6.61
$K_{Hvorslev}$ / K_{Thiem}	0.54		
tight			
t1	56175.2	h1	2.36
t2	56268.4	h2	2.48
Q (m^3/s)	3.48E-07	dh (m)	1.36
K_{Thiem} (m/s)	**2.53E-07**	logK	-6.60
$K_{Hvorslev}$ / K_{Thiem}	0.52		



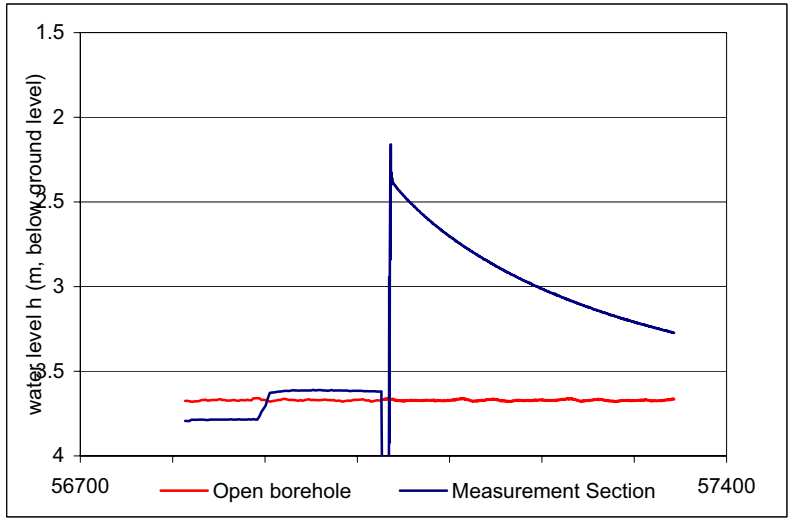


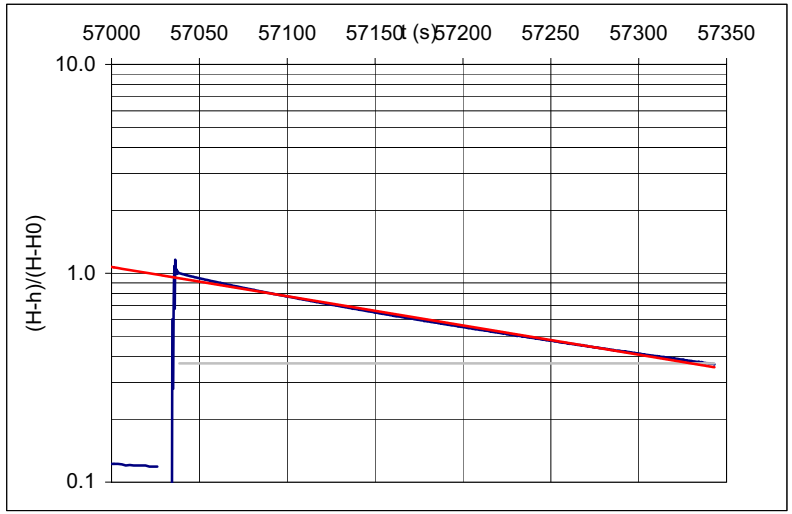
input file	**OLPP36000261.DAT**	date	*19.7.2006*		
TOC (m)	*0.78*				
depth of pressure sensor open hole (m)	*4.56*	ref toc	min open bore-hole pressure (m)	3.68	ref ground level
depth of pressure sensor meas. section (m)	*4.56*	initial, ref toc			
depth of pressure sensor meas. section (m)	*6.06*	final, ref toc			
depth of meas. section (m)	*7.95*	ref TOC, top			
depth of meas. section (m)	7.67	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	3.79	reference water level at the measurement section based on phase 1, ref ground level			
H_0	2.39	water level at the measurement section after disturbance, ref ground level			
t_0	57038.6	time of disturbance			
t_{end} (s)	57342.9	end of time range used to line fitting			
Time range (s)	304.3	Time range used for interpretation			
T_0	293.3	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**5.25E-07**				
logK	-6.28				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.003221279	-0.055253869
5.75984E-06	0.001012004
0.9959	0.018233836
312778.0861	1295
103.9901979	0.430552242

Stat tests	
test stat, a <> 0	559.27
test stat, b <> 0	54.60
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	57230.7	h1	3.08
t2	57235.4	h2	3.09
Q (m^3/s)	5.44E-07	dh (m)	0.70
K_{Thiem} (m/s)	**7.70E-07**	logK	-6.11
$K_{Hvorslev}$ / K_{Thiem}	0.68		
tight			
t1	57043.3	h1	2.42
t2	57140.0	h2	2.85
Q (m^3/s)	1.19E-06	dh (m)	1.15
K_{Thiem} (m/s)	**1.02E-06**	logK	-5.99
$K_{Hvorslev}$ / K_{Thiem}	0.51		



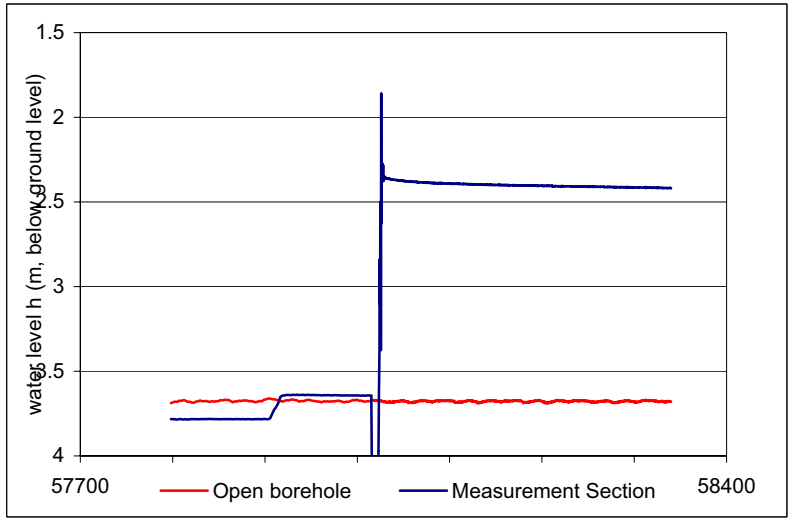


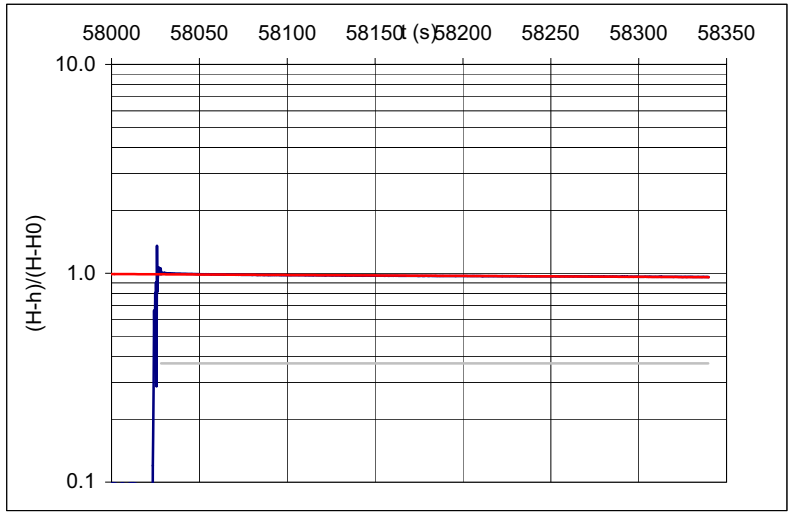
input file	**OLPP36000262.DAT**	date	*19.7.2006*		
TOC (m)	*0.78*				
depth of pressure sensor open hole (m)	*4.56*	ref toc	min open bore-hole pressure (m)	3.69	ref ground level
depth of pressure sensor meas. section (m)	*4.56*	initial, ref toc			
depth of pressure sensor meas. section (m)	*6.06*	final, ref toc			
depth of meas. section (m)	*8.95*	ref TOC, top			
depth of meas. section (m)	8.67	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	3.78	reference water level at the measurement section based on phase 1, ref ground level			
H_0	2.36	water level at the measurement section after disturbance, ref ground level			
t_0	58028.2	time of disturbance			
t_{end} (s)	58339.5	end of time range used to line fitting			
Time range (s)	311.3	Time range used for interpretation			
T_0	9615.6	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**1.60E-08**	**T0 not reached**			
logK	-7.80				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000102831	-0.011222054
9.69395E-07	0.000174278
0.8947	0.003176243
11252.33995	1325
0.113519485	0.013367292

Stat tests	
test stat, a <> 0	106.08
test stat, b <> 0	64.39
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	58129.6	h1	2.40
t2	58134.3	h2	2.40
Q (m^3/s)	7.33E-08	dh (m)	1.39
K_{Thiem} (m/s)	**5.23E-08**	logK	-7.28
$K_{Hvorslev}$ / K_{Thiem}	0.31		
tight			
t1	58032.9	h1	2.36
t2	58132.0	h2	2.40
Q (m^3/s)	9.46E-08	dh (m)	1.40
K_{Thiem} (m/s)	**6.67E-08**	logK	-7.18
$K_{Hvorslev}$ / K_{Thiem}	0.24		





Area:	Hole:	Measurer:
Olkiluoto	PP39	Susanna Lindgren

Water level before starting 1.78 m
The reference level to depth is top of the casing, the length of the casing is 0.50 m

File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
250	18.7.2006	15:05	4.95	1.88	1.88	1.50	
251	18.7.2006	15:25	5.95	1.88	1.88	1.50	
252	18.7.2006	15:50	6.95	1.88	1.88	1.50	
253	19.7.2006	10:05	7.95	1.88	1.88	1.50	
254	19.7.2006	10:20	8.95	1.88	1.88	1.50	
255	19.7.2006	10:43	9.95	1.88	1.88	1.50	
256	19.7.2006	11:00	10.95	1.88	1.88	1.50	

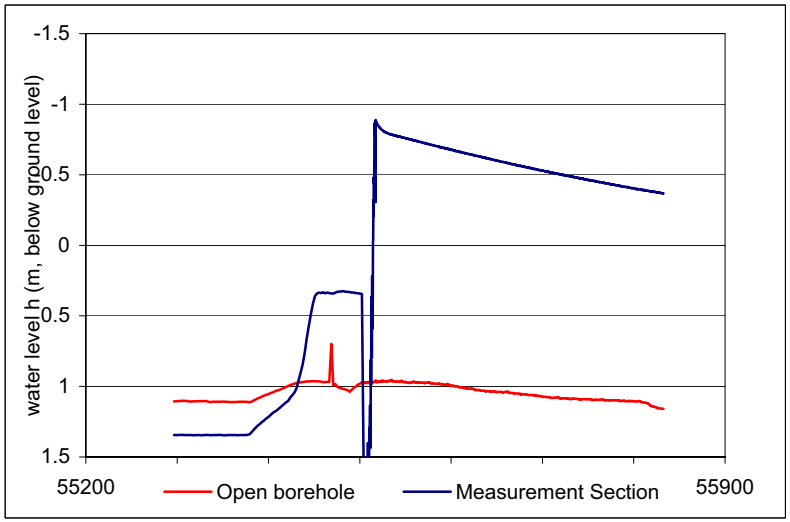
measurement/hole &run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s)tight	comments
OLPP39000250.DAT	4.95	1.17E-07	9.98E-01	2.14E-07	2.29E-07	T0 not reached
OLPP39000251.DAT	5.95	8.45E-09	8.86E-01	2.60E-08	3.19E-08	T0 not reached
OLPP39000252.DAT	6.95	4.20E-06	5.40E-01	5.09E-06	2.63E-06	recovery not linear
OLPP39000253.DAT	7.95	7.54E-06	5.89E-01	5.32E-06	2.89E-06	recovery not linear
OLPP39000254.DAT	8.95	6.08E-09	8.14E-01	2.82E-08	-1.03E-08	T0 not reached
OLPP39000255.DAT	9.95	1.30E-08	9.51E-01	1.04E-08	4.08E-08	T0 not reached
OLPP39000256.DAT	10.95	-1.46E-09	6.90E-01	-1.99E-21	-2.95E-09	negative K

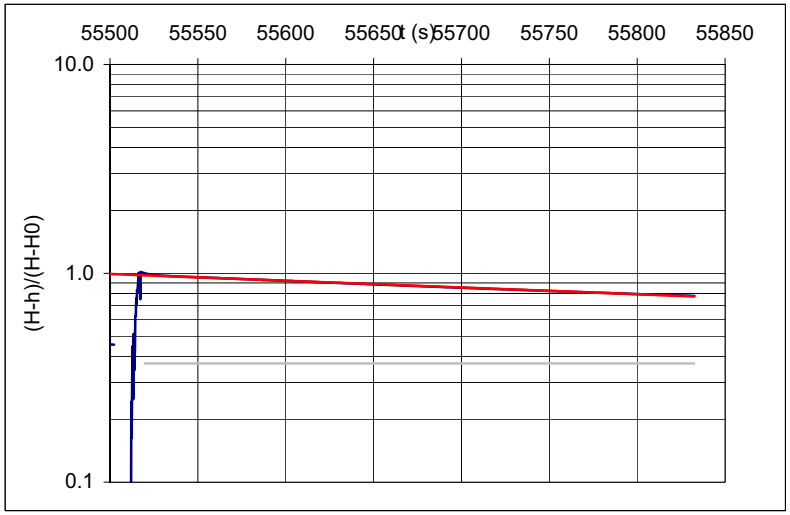
input file	**OLPP39000250.DAT**	date	*18.7.2006*		
TOC (m)	*0.5*				
depth of pressure sensor open hole (m)	*1.88*	ref toc	min open bore-hole pressure (m)	1.16	ref ground level
depth of pressure sensor meas. section (m)	*1.88*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.38*	final, ref toc			
depth of meas. section (m)	*4.95*	ref TOC, top			
depth of meas. section (m)	4.95	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.35	reference water level at the measurement section based on phase 1, ref ground level			
H_0	-0.85	water level at the measurement section after disturbance, ref ground level			
t_0	55519.8	time of disturbance			
t_{end} (s)	55832.3	end of time range used to line fitting			
Time range (s)	312.5	Time range used for interpretation			
T_0	1312.8	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**1.17E-07**	**T0 not reached**			
logK	-6.93				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000744912	-0.022058939
9.1974E-07	0.000165958
0.9980	0.003029958
655964.5075	1330
6.022176522	0.012210256

Stat tests	
test stat, a <> 0	809.92
test stat, b <> 0	132.92
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	55621.5	h1	-0.64
t2	55626.2	h2	-0.64
Q (m^3/s)	4.29E-07	dh (m)	1.99
K_{Thiem} (m/s)	**2.14E-07**	logK	-6.67
$K_{Hvorslev}$ / K_{Thiem}	0.55		
tight			
t1	55524.5	h1	-0.82
t2	55623.9	h2	-0.64
Q (m^3/s)	4.81E-07	dh (m)	2.07
K_{Thiem} (m/s)	**2.29E-07**	logK	-6.64
$K_{Hvorslev}$ / K_{Thiem}	0.51		



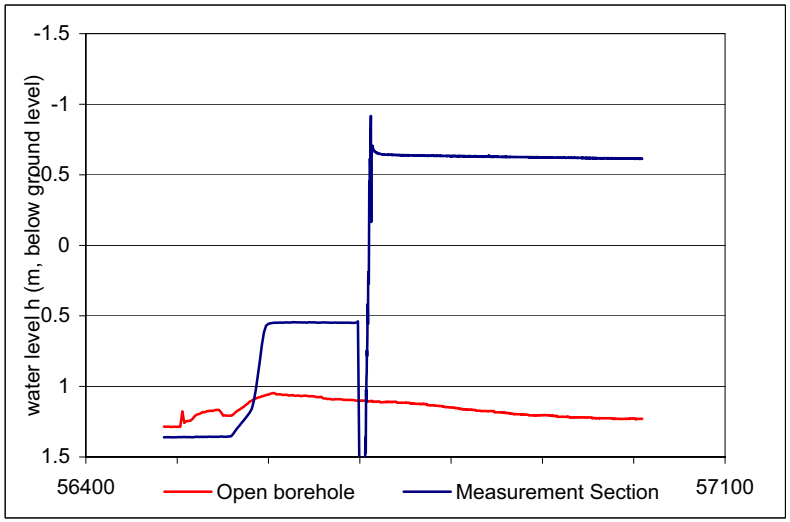


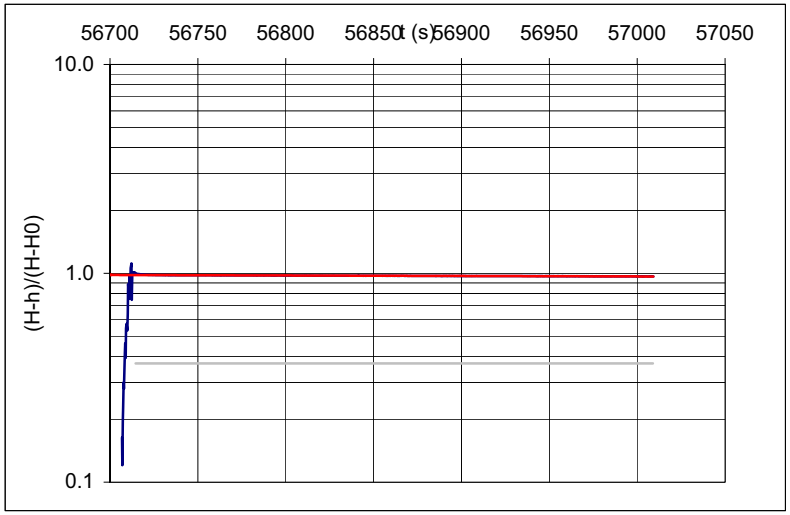
input file	**OLPP39000251.DAT**	date	*18.7.2006*		
TOC (m)	*0.5*				
depth of pressure sensor open hole (m)	*1.88*	ref toc	min open bore-hole pressure (m)	1.29	ref ground level
depth of pressure sensor meas. section (m)	*1.88*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.38*	final, ref toc			
depth of meas. section (m)	*5.95*	ref TOC, top			
depth of meas. section (m)	5.95	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.36	reference water level at the measurement section based on phase 1, ref ground level			
H_0	-0.68	water level at the measurement section after disturbance, ref ground level			
t_0	56714.6	time of disturbance			
t_{end} (s)	57008.9	end of time range used to line fitting			
Time range (s)	294.4	Time range used for interpretation			
T_0	18211.7	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**8.45E-09**	**T0 not reached**			
logK	-8.07				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-5.38649E-05	-0.019027318
5.45503E-07	9.27298E-05
0.8861	0.001643555
9750.293628	1253
0.02633819	0.003384693

Stat tests	
test stat, a <> 0	98.74
test stat, b <> 0	205.19
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	56810.3	h1	-0.63
t2	56815.0	h2	-0.63
Q (m^3/s)	5.23E-08	dh (m)	1.99
K_{Thiem} (m/s)	**2.60E-08**	logK	-7.58
$K_{Hvorslev}$ / K_{Thiem}	0.33		
tight			
t1	56719.2	h1	-0.65
t2	56812.7	h2	-0.63
Q (m^3/s)	6.45E-08	dh (m)	2.00
K_{Thiem} (m/s)	**3.19E-08**	logK	-7.50
$K_{Hvorslev}$ / K_{Thiem}	0.27		



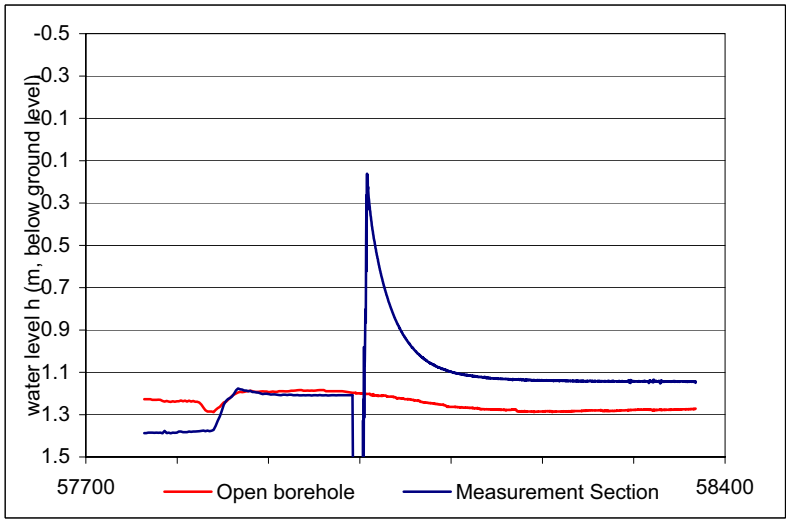


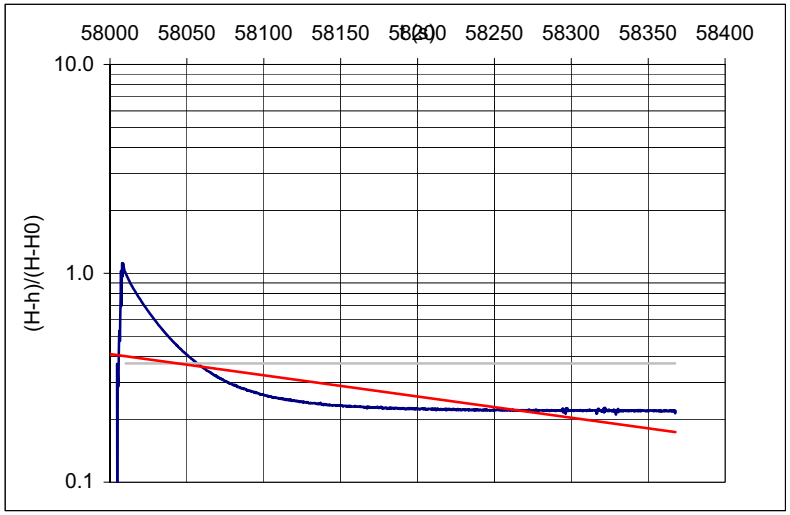
input file	**OLPP39000252.DAT**	date	*18.7.2006*		
TOC (m)	*0.5*				
depth of pressure sensor open hole (m)	*1.88*	ref toc	min open bore-hole pressure (m)	1.29	ref ground level
depth of pressure sensor meas. section (m)	*1.88*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.38*	final, ref toc			
depth of meas. section (m)	*6.95*	ref TOC, top			
depth of meas. section (m)	6.95	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.38	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.29	water level at the measurement section after disturbance, ref ground level			
t_0	58010.2	time of disturbance			
t_{end} (s)	58367.5	end of time range used to line fitting			
Time range (s)	357.3	Time range used for interpretation			
T_0	36.7	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**4.20E-06**				
logK	-5.38				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.002339604	-0.914183322
5.53385E-05	0.011417738
0.5403	0.222887492
1787.435165	1521
88.79769531	75.56150689

Stat tests	
test stat, a <> 0	42.28
test stat, b <> 0	80.07
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	58035.3	h1	0.81
t2	58040.0	h2	0.86
Q (m^3/s)	2.82E-06	dh (m)	0.55
K_{Thiem} (m/s)	**5.09E-06**	logK	-5.29
$K_{Hvorslev}$ / K_{Thiem}	0.82		
tight			
t1	58014.9	h1	0.45
t2	58129.2	h2	1.12
Q (m^3/s)	1.58E-06	dh (m)	0.60
K_{Thiem} (m/s)	**2.63E-06**	logK	-5.58
$K_{Hvorslev}$ / K_{Thiem}	1.60		



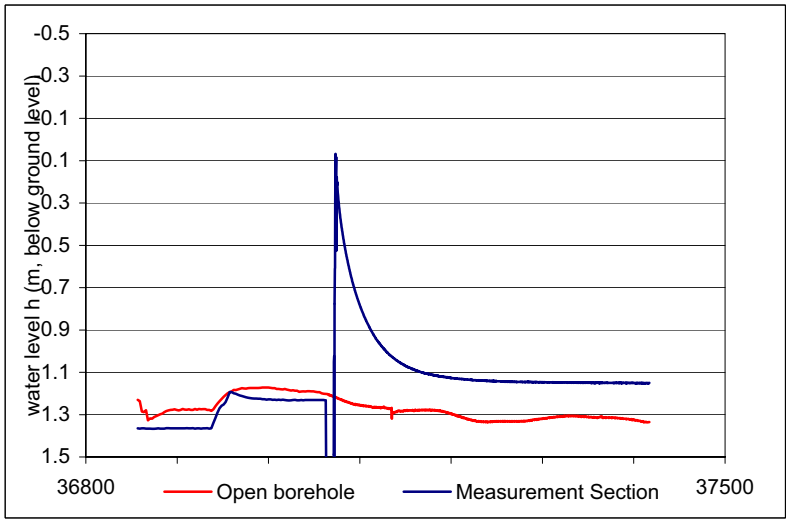


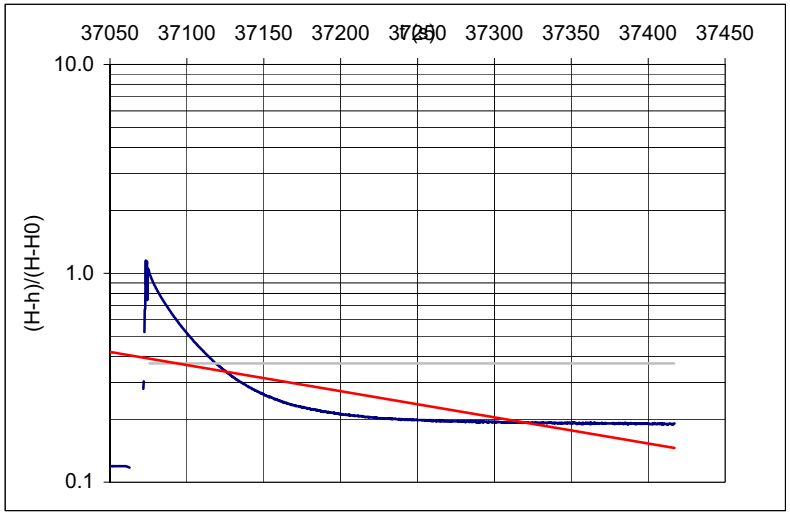
input file	**OLPP39000253.DAT**	date	*19.7.2006*		
TOC (m)	*0.5*				
depth of pressure sensor open hole (m)	*1.88*	ref toc	min open bore-hole pressure (m)	1.34	ref ground level
depth of pressure sensor meas. section (m)	*1.88*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.38*	final, ref toc			
depth of meas. section (m)	*7.95*	ref TOC, top			
depth of meas. section (m)	7.95	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.37	reference water level at the measurement section based on phase 1, ref ground level			
H_0	0.24	water level at the measurement section after disturbance, ref ground level			
t_0	37075.7	time of disturbance			
t_{end} (s)	37416.8	end of time range used to line fitting			
Time range (s)	341.1	Time range used for interpretation			
T_0	20.4	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**7.54E-06**				
logK	-5.12				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.002883621	-0.941116611
6.31977E-05	0.012449996
0.5891	0.237468563
2081.969486	1452
117.4050037	81.88019399

Stat tests	
test stat, a <> 0	45.63
test stat, b <> 0	75.59
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	37099.4	h1	0.78
t2	37104.1	h2	0.83
Q (m^3/s)	3.03E-06	dh (m)	0.56
K_{Thiem} (m/s)	**5.32E-06**	logK	-5.27
$K_{Hvorslev}$ / K_{Thiem}	1.42		
tight			
t1	37080.4	h1	0.42
t2	37189.4	h2	1.12
Q (m^3/s)	1.73E-06	dh (m)	0.59
K_{Thiem} (m/s)	**2.89E-06**	logK	-5.54
$K_{Hvorslev}$ / K_{Thiem}	2.61		



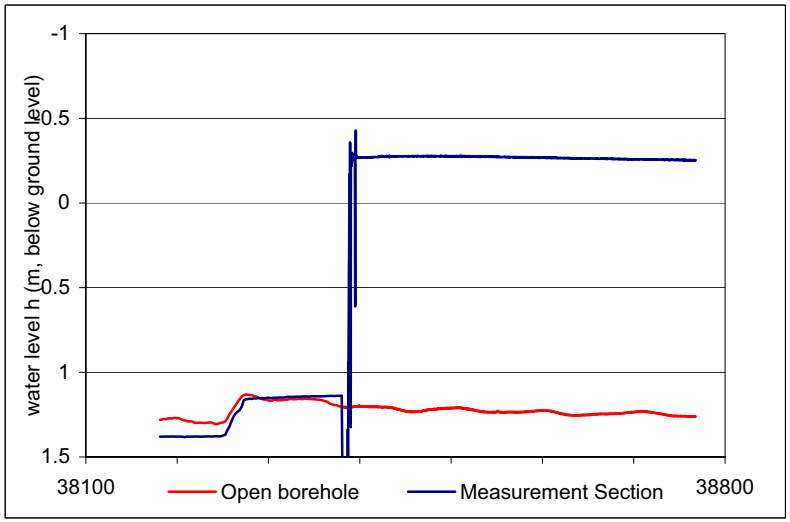


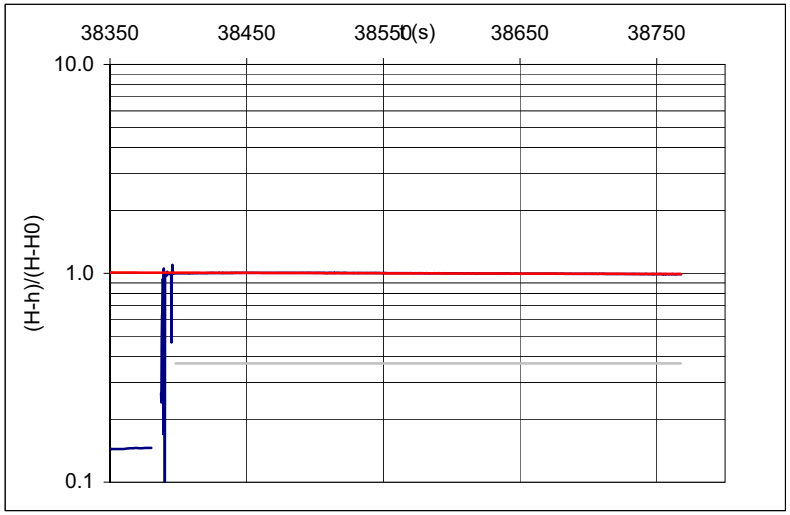
input file	**OLPP39000254.DAT**	date	*19.7.2006*			
TOC (m)	*0.5*					
depth of pressure sensor open hole (m)	*1.88*	ref toc	min open bore-hole pressure (m)	1.31	ref ground level	
depth of pressure sensor meas. section (m)	*1.88*	initial, ref toc				
depth of pressure sensor meas. section (m)	*3.38*	final, ref toc				
depth of meas. section (m)	*8.95*	ref TOC, top				
depth of meas. section (m)	8.95	ref ground level, midpoint of the section				
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm				
r (mm)	9.28					
H	1.38	reference water level at the measurement section based on phase 1, ref ground level				
H_0	-0.27	water level at the measurement section after disturbance, ref ground level				
t_0	38398.0	time of disturbance				
t_{end} (s)	38767.5	end of time range used to line fitting				
Time range (s)	369.5	Time range used for interpretation				
T_0	25322.3	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1				
L (m)	*1*	length of measurement section				
screen diam. (mm)	*56*	equal to borehole diameter				
screen radius R (mm)	28	equal to borehole radius				
L/R	35.71					
K (m/s)	**6.08E-09**	**T0 not reached**				
logK	-8.22					

ln((H-h)/(H-H0)) = a*t + b	
a	b
-3.97624E-05	0.00687603
4.78814E-07	0.000102178
0.8143	0.0020284
6896.216143	1573
0.028373824	0.006471959

Stat tests	
test stat, a <> 0	83.04
test stat, b <> 0	67.29
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	38518.7	h1	-0.28
t2	38523.4	h2	-0.27
Q (m^3/s)	4.71E-08	dh (m)	1.65
K_{Thiem} (m/s)	**2.82E-08**	logK	-7.55
$K_{Hvorslev}$ / K_{Thiem}	0.22		
tight			
t1	38402.7	h1	-0.27
t2	38521.0	h2	-0.28
Q (m^3/s)	-1.72E-08	dh (m)	1.65
K_{Thiem} (m/s)	**-1.03E-08**	logK	#NUM!
$K_{Hvorslev}$ / K_{Thiem}	-0.59		



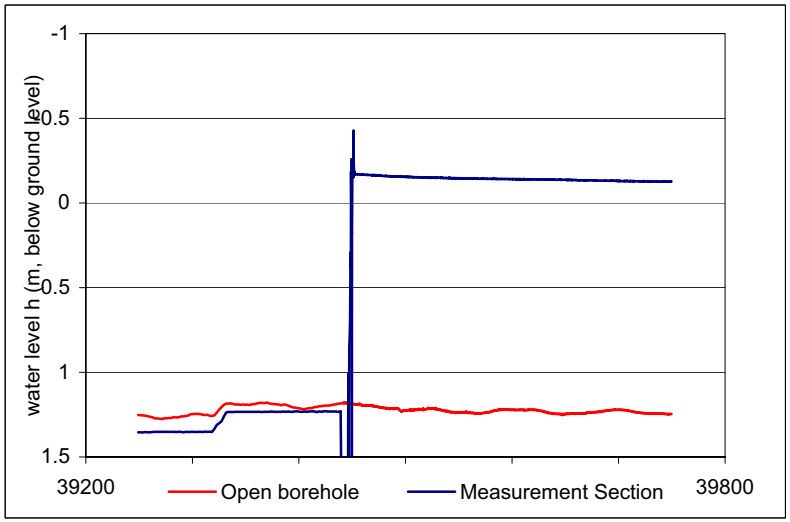


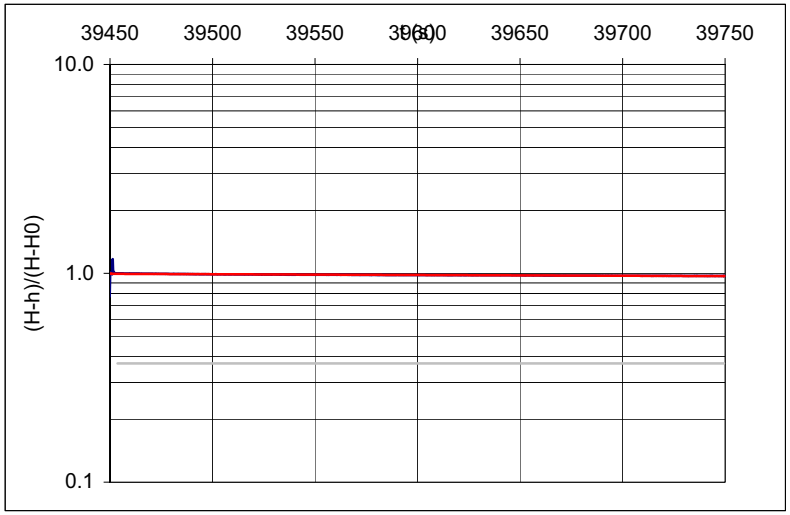
input file	**OLPP39000255.DAT**	date	*19.7.2006*		
TOC (m)	*0.5*				
depth of pressure sensor open hole (m)	*1.88*	ref toc	min open bore-hole pressure (m)	1.28	ref ground level
depth of pressure sensor meas. section (m)	*1.88*	initial, ref toc			
depth of pressure sensor meas. section (m)	*3.38*	final, ref toc			
depth of meas. section (m)	*9.95*	ref TOC, top			
depth of meas. section (m)	9.95	ref ground level, midpoint of the section			
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm			
r (mm)	9.28				
H	1.35	reference water level at the measurement section based on phase 1, ref ground level			
H_0	-0.17	water level at the measurement section after disturbance, ref ground level			
t_0	39453.6	time of disturbance			
t_{end} (s)	39749.5	end of time range used to line fitting			
Time range (s)	295.8	Time range used for interpretation			
T_0	11807.7	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1			
L (m)	*1*	length of measurement section			
screen diam. (mm)	*56*	equal to borehole diameter			
screen radius R (mm)	28	equal to borehole radius			
L/R	35.71				
K (m/s)	**1.30E-08**	**T0 not reached**			
logK	-7.88				

ln((H-h)/(H-H0)) = a*t + b	
a	b
-8.41915E-05	-0.005890577
5.38749E-07	9.20329E-05
0.9510	0.001635028
24420.95203	1259
0.065284954	0.003365706

Stat tests	
test stat, a <> 0	156.27
test stat, b <> 0	64.01
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	39549.9	h1	-0.15
t2	39554.6	h2	-0.15
Q (m^3/s)	1.57E-08	dh (m)	1.50
K_{Thiem} (m/s)	**1.04E-08**	logK	-7.98
$K_{Hvorslev}$ / K_{Thiem}	1.26		
tight			
t1	39458.3	h1	-0.17
t2	39552.3	h2	-0.15
Q (m^3/s)	6.23E-08	dh (m)	1.51
K_{Thiem} (m/s)	**4.08E-08**	logK	-7.39
$K_{Hvorslev}$ / K_{Thiem}	0.32		



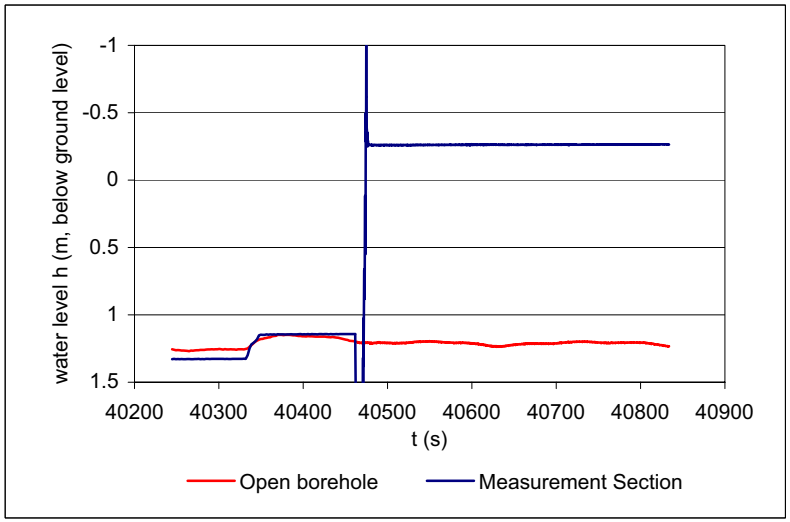


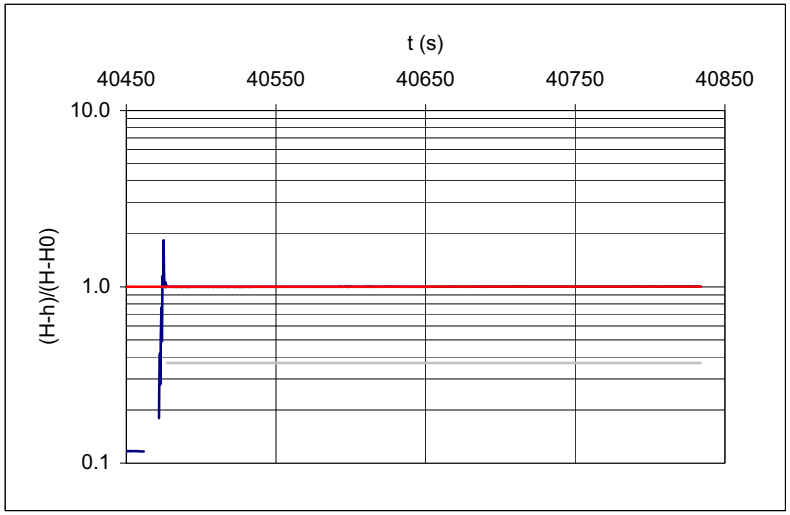
input file	**OLPP39000256.DAT**	date	*19.7.2006*			
TOC (m)	*0.5*					
depth of pressure sensor open hole (m)	*1.88*	ref toc	min open bore-hole pressure (m)	1.27	ref ground level	
depth of pressure sensor meas. section (m)	*1.88*	initial, ref toc				
depth of pressure sensor meas. section (m)	*3.38*	final, ref toc				
depth of meas. section (m)	*10.95*	ref TOC, top				
depth of meas. section (m)	10.95	ref ground level, midpoint of the section				
tube diameter (mm)	18.56	equivalent area to a double tube with outer diam 24.9 mm and inner diam 16.6 mm				
r (mm)	9.28					
H	1.33	reference water level at the measurement section based on phase 1, ref ground level				
H_0	-0.26	water level at the measurement section after disturbance, ref ground level				
t_0	40477.2	time of disturbance				
t_{end} (s)	40833.6	end of time range used to line fitting				
Time range (s)	356.4	Time range used for interpretation				
T_0	-105746.4	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1				
L (m)	*1*	length of measurement section				
screen diam. (mm)	*56*	equal to borehole diameter				
screen radius R (mm)	28	equal to borehole radius				
L/R	35.71					
K (m/s)	**-1.46E-09**					
logK	#NUM!					

ln((H-h)/(H-H0)) = a*t + b	
a	b
9.46078E-06	0.00044314
1.62662E-07	3.34719E-05
0.6904	0.000652617
3382.828916	1517
0.001440778	0.000646104

Stat tests	
test stat, a <> 0	58.16
test stat, b <> 0	13.24
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	40593.7	h1	-0.26
t2	40598.4	h2	-0.26
Q (m^3/s)	-3.20E-21	dh (m)	1.59
K_{Thiem} (m/s)	**-1.99E-21**	logK	#NUM!
$K_{Hvorslev}$ / K_{Thiem}	732228836223.84		
tight			
t1	40481.9	h1	-0.26
t2	40596.0	h2	-0.26
Q (m^3/s)	-4.74E-09	dh (m)	1.59
K_{Thiem} (m/s)	**-2.95E-09**	logK	#NUM!
$K_{Hvorslev}$ / K_{Thiem}	0.49		





Area: Olkiluoto

Hole: PVP4A

Measurer: Susanna Lindgren

Water level before starting 1.40 m
The reference level to depth is top of the casing, the length of the casing is 0.7 m

File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
245	6.7.06	13:24	1.5	not in use	1.5	1.5	

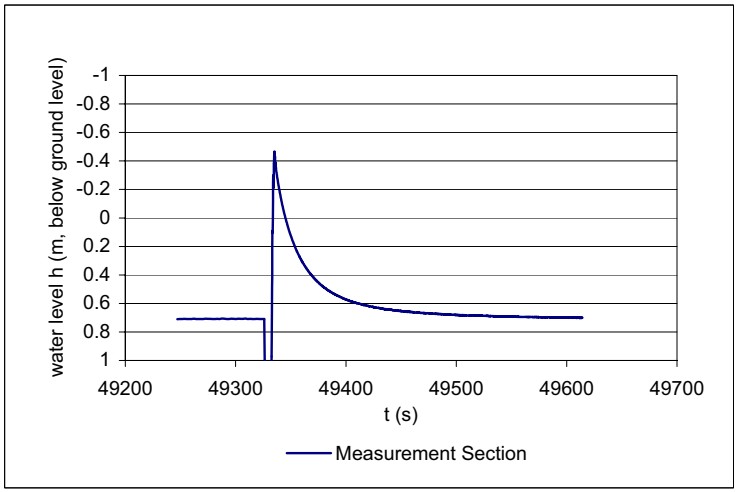
measurement/hole &run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s)tight	comments
OLPV4A000245.DAT	6.55	1.48E-05	9.87E-01	2.22E-05	2.14E-05	

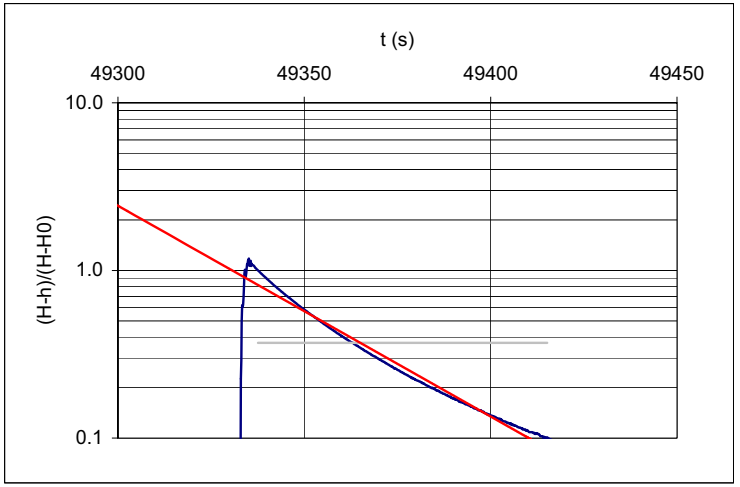
input file	**OLPV4A000245.DAT**	date	*6.7.2006*
TOC (m)	*0.7*		
	0		
depth of pressure sensor meas. section (m)	*1.5*	initial, ref toc	
depth of pressure sensor meas. section (m)	*3*	final, ref toc	
depth of meas. section (m)	*5.55*	ref ground level, top	
depth of meas. section (m)	6.55	ref ground level, midpoint of the section	
tube diameter (mm)	39.19	equivalent area to a double tube with outer diam 56 mm and inner diam 40 mm	
r (mm)	19.60		
H	0.71	reference water level at the measurement section based on phase 1, ref ground level	
H_0	-0.2900	water level at the measurement section after disturbance, ref ground level	
t_0	49337.57	time of disturbance	
t_{end} (s)	49415.16	end of time range used to line fitting	
Time range (s)	77.59	Time range used for interpretation	
T_0	27.65	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1	
L (m)	*2*	length of measurement section	
screen diam. (mm)	*56*	equal to borehole diameter	
screen radius R (mm)	28	equal to borehole radius	
L/R	71.43		
K (m/s)	**1.4823E-05**		
logK	-4.83		

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.028945286	-0.199782149
0.000131166	0.00587941
0.987248486	0.073944508
48698.47538	629
266.2730495	3.439240075

Stat tests	
test stat, a <> 0	220.68
test stat, b <> 0	33.98
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	49352.96	h1	0.186
t2	49355.44	h2	0.232
Q (m^3/s)	2.24E-05	dh (m)	0.50
K_{Thiem} (m/s)	**2.22E-05**	logK	-4.65
$K_{Hvorslev}$ / K_{Thiem}	0.67		
tight			
t1	49340.03	h1	-0.179
t2	49363.46	h2	0.345
Q (m^3/s)	2.70E-05	dh (m)	0.63
K_{Thiem} (m/s)	**2.14E-05**	logK	-4.67
$K_{Hvorslev}$ / K_{Thiem}	0.69		





Area: Olkiluoto **Hole:** PVP4B **Measurer:** Susanna Lindgren

Water level before starting 1.64 m
The reference level to depth is top of the casing, the length of the casing is 0.86 m

File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
246	6.7.2006	13:48	1.74	not in use	1.74	1.5	

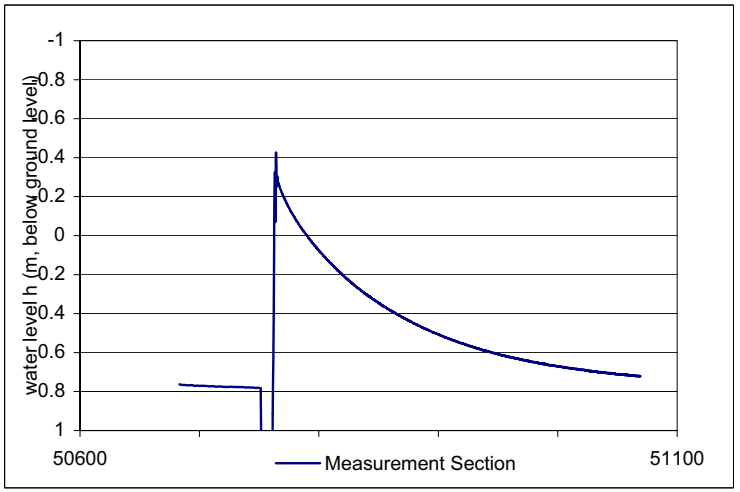
measurement/hole &run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s)tight	comments
OLPV4B000246.DAT	3.0	4.24E-06	1.00E+00	5.98E-06	5.92E-06	

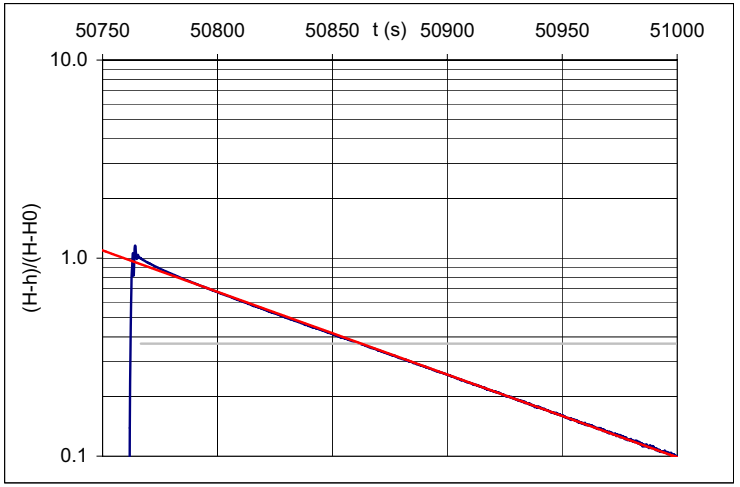
input file	**OLPV4B000246.DAT**	date	*6.7.2006*
TOC (m)	*0.86*		
	0		
depth of pressure sensor meas. section (m)	*1.74*	initial, ref toc	
depth of pressure sensor meas. section (m)	*3.25*	final, ref toc	
depth of meas. section (m)	*2*	ref ground level, top	
depth of meas. section (m)	3	ref ground level, midpoint of the section	
tube diameter (mm)	39.19	equivalent area to a double tube with outer diam 56 mm and inner diam 40 mm	
r (mm)	19.60		
H	0.77	reference water level at the measurement section based on phase 1, ref ground level	
H_0	-0.2630	water level at the measurement section after disturbance, ref ground level	
t_0	50766.61	time of disturbance	
t_{end} (s)	50999.4	end of time range used to line fitting	
Time range (s)	232.79	Time range used for interpretation	
T_0	96.59	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1	
L (m)	*2*	length of measurement section	
screen diam. (mm)	*56*	equal to borehole diameter	
screen radius R (mm)	28	equal to borehole radius	
L/R	71.43		
K (m/s)	**4.24262E-06**		
logK	-5.37		

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.009620391	-0.070765235
4.14716E-06	0.000557474
0.999641291	0.012258752
5381262.2	1931
808.680005	0.29018491

Stat tests	
test stat, a <> 0	2319.75
test stat, b <> 0	126.94
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	50828.8	h1	0.250
t2	50831.2	h2	0.262
Q (m^3/s)	6.26E-06	dh (m)	0.52
K_{Thiem} (m/s)	**5.98E-06**	logK	-5.22
$K_{Hvorslev}$ / K_{Thiem}	0.71		
tight			
t1	50769.01	h1	-0.220
t2	50844.21	h2	0.321
Q (m^3/s)	8.67E-06	dh (m)	0.72
K_{Thiem} (m/s)	**5.92E-06**	logK	-5.23
$K_{Hvorslev}$ / K_{Thiem}	0.72		





Area: Olkiluoto **Hole:** PVP6A **Measurer:** Susanna Lindgren

Water level before starting 1.64 m
The reference level to depth is top of the casing, the length of the casing is 0.7 m

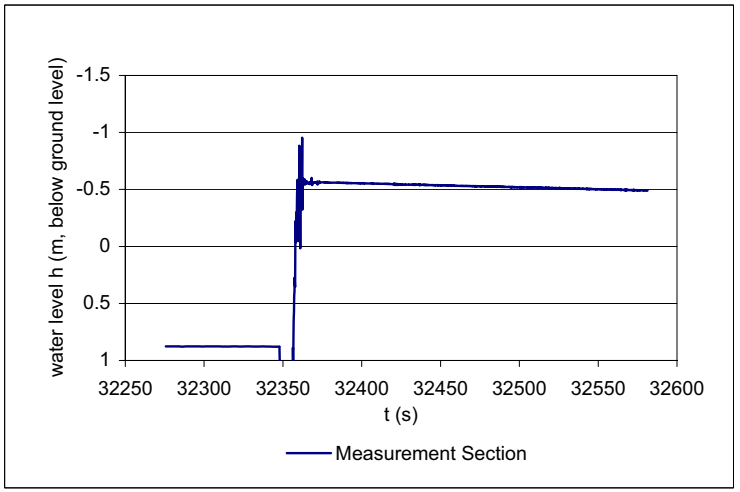
File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
248	7.7.2006	8:40	1.74	not in use	1.74	1.5	

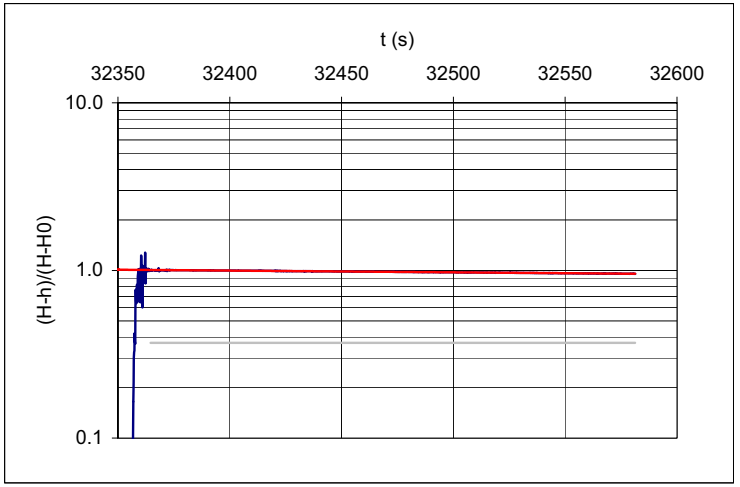
measurement/hole &run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s)tight	comments
OLPV6A000248.DAT	4.83	9.77E-08	9.89E-01	2.70E-07	8.94E-08	T0 not reached

input file	**OLPV6A000248.DAT**	date	*7.7.2006*
TOC (m)	*0.7*		
	0		
depth of pressure sensor meas. section (m)	*1.74*	initial, ref toc	
depth of pressure sensor meas. section (m)	*3.24*	final, ref toc	
depth of meas. section (m)	*3.83*	ref ground level, top	
depth of meas. section (m)	4.83	ref ground level, midpoint of the section	
tube diameter (mm)	39.19	equivalent area to a double tube with outer diam 56 mm and inner diam 40 mm	
r (mm)	19.60		
H	0.88	reference water level at the measurement section based on phase 1, ref ground level	
H_0	-0.5560	water level at the measurement section after disturbance, ref ground level	
t_0	32364.58	time of disturbance	
t_{end} (s)	32581.23	end of time range used to line fitting	
Time range (s)	216.65	Time range used for interpretation	
T_0	4194.98	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1	
L (m)	*2*	length of measurement section	
screen diam. (mm)	*56*	equal to borehole diameter	
screen radius R (mm)	28	equal to borehole radius	
L/R	71.43		
K (m/s)	**9.7687E-08**	**T0 not reached**	
logK	-7.01		

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.000239901	0.006379149
5.88542E-07	7.36254E-05
0.989300404	0.001561942
166153.2642	1797
0.405358027	0.004384075
Stat tests	
test stat, a <> 0	407.62
test stat, b <> 0	86.64
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	32435.55	h1	-0.542
t2	32437.96	h2	-0.540
Q (m^3/s)	7.74E-07	dh (m)	1.42
K_{Thiem} (m/s)	**2.70E-07**	logK	-6.57
$K_{Hvorslev}$ / K_{Thiem}	0.36		
tight			
t1	32366.99	h1	-0.556
t2	32436.75	h2	-0.541
Q (m^3/s)	2.58E-07	dh (m)	1.43
K_{Thiem} (m/s)	**8.94E-08**	logK	-7.05
$K_{Hvorslev}$ / K_{Thiem}	1.09		





Area: Olkiluoto **Hole:** PVP6B **Measurer:** Susanna Lindgren

Water level before starting 1.70 m
The reference level to depth is top of the casing, the length of the casing is 0.90 m

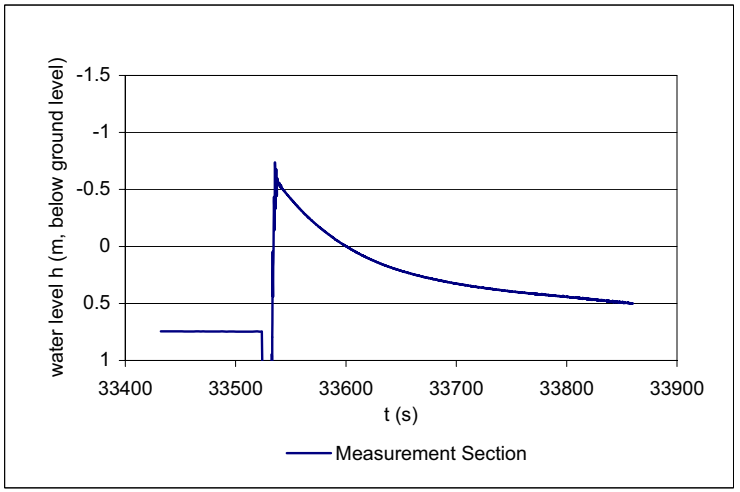
File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
249	7.7.2006	9:00	1.80	not in use	1.80	1.5	

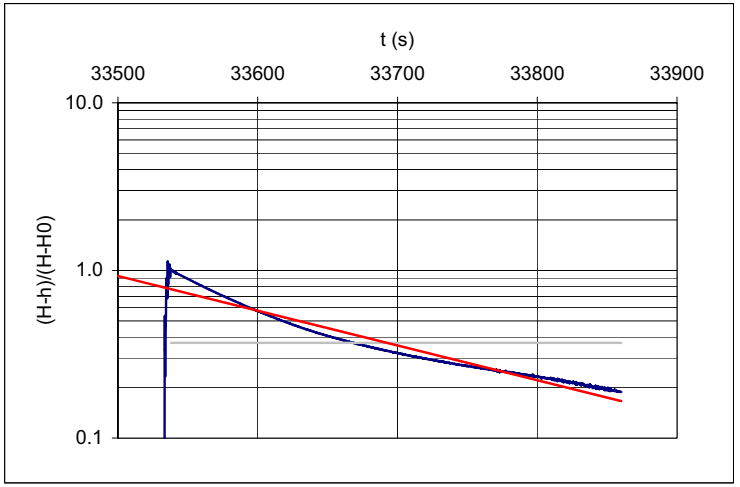
measurement/hole &run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s)tight	comments
OLPV6B000249.DAT	2.83	2.64E-06	9.55E-01	4.25E-06	4.57E-06	

input file	**OLPV6B000249.DAT**	date	*7.7.2006*
TOC (m)	*0.9*		
	0		
depth of pressure sensor meas. section (m)	*1.8*	initial, ref toc	
depth of pressure sensor meas. section (m)	*3.3*	final, ref toc	
depth of meas. section (m)	*1.83*	ref ground level, top	
depth of meas. section (m)	2.83	ref ground level, midpoint of the section	
tube diameter (mm)	39.19	equivalent area to a double tube with outer diam 56 mm and inner diam 40 mm	
r (mm)	19.60		
H	0.75	reference water level at the measurement section based on phase 1, ref ground level	
H_0	-0.5610	water level at the measurement section after disturbance, ref ground level	
t_0	33538.05	time of disturbance	
t_{end} (s)	33860.02	end of time range used to line fitting	
Time range (s)	321.97	Time range used for interpretation	
T_0	155.50	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1	
L (m)	*2*	length of measurement section	
screen diam. (mm)	*56*	equal to borehole diameter	
screen radius R (mm)	28	equal to borehole radius	
L/R	71.43		
K (m/s)	**2.63527E-06**		
logK	-5.58		

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.004772292	-0.257889506
2.01053E-05	0.003735188
0.955175953	0.096164402
56342.19489	2644
521.0296415	24.45063375
Stat tests	
test stat, a <> 0	237.37
test stat, b <> 0	69.04
t-critical, 90%	1.96

Thiem analysis for control			
flow			
t1	33616.56	h1	0.087
t2	33618.96	h2	0.098
Q (m^3/s)	5.62E-06	dh (m)	0.65
K_{Thiem} (m/s)	**4.25E-06**	logK	-5.37
$K_{Hvorslev}$ / K_{Thiem}	0.62		
tight			
t1	33540.45	h1	-0.533
t2	33645.25	h2	0.199
Q (m^3/s)	8.43E-06	dh (m)	0.91
K_{Thiem} (m/s)	**4.57E-06**	logK	-5.34
$K_{Hvorslev}$ / K_{Thiem}	0.58		





Area: Olkiluoto **Hole:** PVP14 **Measurer:** Susanna Lindgren

Water level before starting 2.79 m
The reference level to depth is top of the casing, the length of the casing is 0.70 m

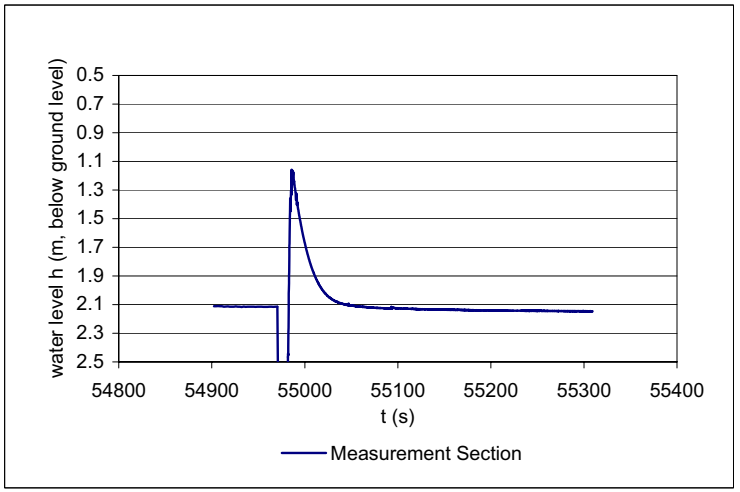
File	Date	Time	Depth	Depth of pressure sensor open borehole (m)	Depth of pressure sensor meas. section (m)	Moving piston (m)	NOTE!
247	6.7.2006	15:00	2.89	not in use	2.89	1.5	

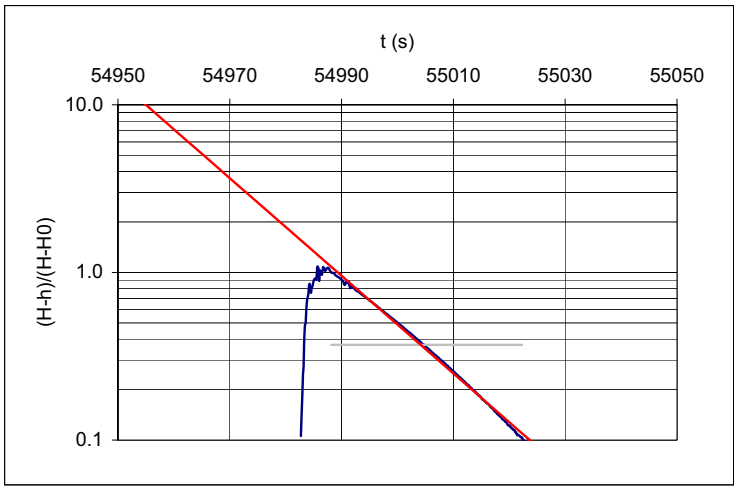
measurement/hole &run	measurement depth (m) below ground level midpoint of the section	$K_{Hvorslev}$ (m/s)	R2	K_{Thiem} (m/s) flow	K_{Thiem} (m/s) tight	comments
OLPV14000247.DAT	7.4	2.55E-05	9.97E-01	3.73E-05	3.43E-05	

input file	**OLPV14000247.DAT**	date	*6.7.2006*
TOC (m)	*0.7*		
	0		
depth of pressure sensor meas. section (m)	*2.89*	initial, ref toc	
depth of pressure sensor meas. section (m)	*4.39*	final, ref toc	
depth of meas. section (m)	*6.4*	ref ground level, top	
depth of meas. section (m)	7.4	ref ground level, midpoint of the section	
tube diameter (mm)	39.19	equivalent area to a double tube with outer diam 56 mm and inner diam 40 mm	
r (mm)	19.60		
H	2.11	reference water level at the measurement section based on phase 1, ref ground level	
H_0	1.2330	water level at the measurement section after disturbance, ref ground level	
t_0	54988.16	time of disturbance	
t_{end} (s)	55022.28	end of time range used to line fitting	
Time range (s)	34.12	Time range used for interpretation	
T_0	16.07	basic time lag, t corresponding the time when ln((H-h)/(H-H0)) = -1	
L (m)	*2*	length of measurement section	
screen diam. (mm)	*56*	equal to borehole diameter	
screen radius R (mm)	28	equal to borehole radius	
L/R	71.43		
K (m/s)	**2.55048E-05**		
logK	-4.59		

ln((H-h)/(H-H0)) = a*t + b	
a	b
-0.067061419	0.077498987
0.000207601	0.004093504
0.997304794	0.034580033
104348.2181	282
124.7773732	0.337209584
Stat tests	
test stat, a <> 0	323.03
test stat, b <> 0	18.93
t-critical, 90%	1.97

Thiem analysis for control			
flow			
t1	54998.89	h1	1.640
t2	55001.31	h2	1.707
Q (m^3/s)	3.33E-05	dh (m)	0.44
K_{Thiem} (m/s)	**3.73E-05**	logK	-4.43
$K_{Hvorslev}$ / K_{Thiem}	0.68		
tight			
t1	54990.57	h1	1.343
t2	54999.49	h2	1.658
Q (m^3/s)	4.25E-05	dh (m)	0.61
K_{Thiem} (m/s)	**3.43E-05**	logK	-4.46
$K_{Hvorslev}$ / K_{Thiem}	0.74		





	2006			2005			2004			2002			
Hole	Test section, ref ground level, midpoint of the section (m)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	Test section, ref ground level, midpoint of the section (m)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	Test section, ref ground level, midpoint of the section (m)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	Test section, ref ground level, midpoint of the section (m)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	Comments
OL-PP5				2.69	2.81E-06	4.49E-05				2.5	6.82E-06	1.11E-05	depths of test sections in 2002 and 2005 differ 19 cm
OL-PP5				2.69	1.64E-05	3.80E-05							the measurement has not succeeded
OL-PP5				3.69	4.59E-07	7.32E-07				3.23	7.49E-06	8.46E-06	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5				4.69	7.68E-06	1.32E-05				4.23	7.57E-06	1.19E-05	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5	5.7	1.97E-07	3.86E-07	5.69	2.37E-07	4.14E-07				5.23	1.84E-08	3.54E-08	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5	6.7	1.01E-07	2.14E-07	6.69	1.98E-07	4.11E-07				6.23	2.09E-07	3.27E-07	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5	7.7	7.56E-08	1.46E-07	7.69	9.57E-08	1.89E-07				7.23	5.98E-08	7.19E-08	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5	8.7	9.10E-08	1.99E-07	8.69	1.03E-07	2.15E-07				8.23	1.04E-07	1.90E-07	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5	9.7	1.51E-07	3.15E-07	9.69	1.62E-07	3.34E-07				9.23	3.23E-07	5.04E-07	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5	10.7	1.42E-07	3.29E-07	10.69	1.62E-07	3.65E-07				10.23	1.70E-07	2.65E-07	depths of test sections in 2002 and 2005 differ 46 cm
OL-PP5										11.07	1.38E-08	2.70E-08	
OL-PP9													
OL-PP9										2.84	3.82E-11	2.42E-22	
OL-PP9				3.8	8.28E-08	2.14E-07				3.84	1.50E-09	2.89E-09	
OL-PP9	4.83	5.17E-06	6.74E-06	4.8	1.86E-06	2.80E-06				4.84	1.79E-06	1.71E-06	
OL-PP9	5.83	-9.62E-10	2.13E-09	5.8	2.31E-08	1.25E-07				5.84	2.51E-09	6.60E-09	
OL-PP9				6.8	5.34E-06	1.02E-05							K-value differs radically from two other measurements from the same section in 2002 and 2005
OL-PP9	6.83	6.30E-09	3.88E-08	6.8	2.23E-08	2.07E-07				6.84	5.92E-09	1.20E-08	
OL-PP9	7.83	1.29E-07	2.21E-07	7.8	1.23E-07	3.54E-07				7.84	7.31E-08	1.25E-07	
OL-PP9	8.83	3.51E-07	5.36E-07	8.8	5.01E-08	2.97E-07				8.84	4.21E-07	6.36E-07	
OL-PP9	9.83	3.30E-07	4.94E-07	9.8	1.72E-07	3.58E-07				9.84	1.15E-07	1.70E-07	
OL-PP9	10.83	-6.01E-10	1.35E-08	10.8	3.40E-08	2.48E-07				10.84	2.35E-09	6.76E-09	
OL-PP9	11.83	2.73E-09	2.13E-08	11.8	2.58E-08	2.25E-07				11.84	4.29E-09	1.00E-08	
OL-PP9										12.84	2.31E-09	2.58E-08	
OL-PP9										13.32	3.78E-09	1.10E-08	
OL-PP39	4.95	1.17E-07	2.29E-07	4.94	9.58E-08	1.65E-07	4.92	6.17E-08	1.47E-07				
OL-PP39	5.95	8.45E-09	3.19E-08	5.94	3.91E-09	1.25E-08	5.92	2.74E-08	9.47E-08				
OL-PP39	6.95	4.20E-06	5.09E-06	6.94	4.54E-06	8.09E-06	6.94	4.58E-06	7.62E-06				
OL-PP39	7.95	7.54E-06	5.32E-06	7.94	4.78E-06	8.44E-06	7.94	4.34E-06	7.18E-06				
OL-PP39	8.95	6.08E-09	2.82E-08	8.94	1.50E-08	1.69E-08	8.94	6.23E-09	2.69E-08				
OL-PP39	9.95	1.30E-08	4.08E-08	9.94	5.45E-08	1.05E-07	9.94	2.42E-08	9.65E-08				
OL-PP39	10.95	-1.46E-09	-1.99E-21	10.94	2.38E-09	3.61E-09	10.94	1.59E-10	4.34E-09				
OL-PP39				11.94	7.92E-09	1.11E-08	11.94	3.71E-09	1.39E-08				

	2006			2005		2004		2002		
Tube	Perforated section from ground surface (m-m)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	$K_{Hvorslev}$ (m/s)	K_{Thiem} (m/s)	Comments
OL-PVP4A	5.55-7.55	1.48E-05	2.22E-05	1.43E-05	2.05E-05	1.36E-05	1.99E-05	9.65E-06	1.25E-05	
OL-PVP4B	2.00-4.00	4.24E-06	5.98E-06	3.29E-06	4.55E-06	3.06E-06	3.72E-06	3.02E-06	3.38E-06	
OL-PVP6A	3,83-5,83	9.77E-08	8.94E-08					4.77E-08	8.64E-08	
OL-PVP6B	1,83-3,83	2.64E-06	4.25E-06					2.33E-06	1.06E-06	
OL-PVP13	3.10-5.10			5.27E-06	7.72E-06	9.17E-06	1.55E-05			
OL-PVP14	6.40-8.40	2.55E-05	3.73E-05	4.55E-05	6.90E-05	8.25E-05	1.22E-04			
OL-PVP17	2.30-4.30			6.17E-07	1.16E-06					very noisy data
OL-PVP18A	3.00-6.00			1.27E-06	1.52E-06					
OL-PVP18B	2.00-3.00			8.43E-07	2.02E-06					noisy data
OL-PVP18B	2.00-3.00			6.67E-07	1.67E-06					
OL-PVP19	9.15-11.15 13.15-15.15			6.19E-07	1.27E-06					two separate perforated sections
OL-PVP20	8.60-10.60			1.07E-05	1.57E-05					

APPENDIX 12

COMPARISON OF THE K-VALUES WITH THE PRE-PUMPING RESULTS

Pumping hole	Sampling date	Yield l/min	Yield m3/s	water table at start (m)	water table at the end (m)	dh m	length outside casing m	L m	KThiem m/s	T m2/s	**Slug test** Kthiem	L m	**Comparison** Kpump/Kslug
OL-PP5	060406	0.75	1.25E-05	2.3	3.48	1.18	10.05		1.08E-06	1.06E-05	2.64639E-07	6	4.06
OL-PP9	091006	0.19	3.17E-06	0.78	1.26	0.48	13.92		4.84E-07	6.60E-06	1.00882E-06	8	0.48
OL-PP36	250406	4.70	7.83E-05	3.47	3.7	0.23	8.58		4.05E-05	3.41E-04	3.63126E-07	3	111.54
OL-PP39	240406	0.64	1.07E-05	1.08	2.14	1.06	12.63		8.13E-07	1.01E-05	1.79012E-06	7	0.45
OL-PVP4A	270406	3.90	6.50E-05	0.85	3.16	2.31		2	1.44E-05	2.81E-05	2.21802E-05	2	0.65
OL-PVP4B	031006	1.00	1.67E-05	1.53	3.47	1.94		2	4.38E-06	8.59E-06	5.97597E-06	2	0.73
OL-PVP6A													
OL-PVP6B													
OL-PVP14	260406	4.86	8.10E-05	0.85	3.36	2.51		2	1.65E-05	3.23E-05	3.73484E-05	2	0.44