



Working Report 2011-40

# Slug-Tests in PP- and PVP-Holes at Olkiluoto in 2010

Heikki Hinkkanen

July 2011

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Pöyry Finland Oy

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or pending completion.

## 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-PP36, OL-PP39, OL-PVP4A, OL-PVP4B, OL-PVP6A, OL-PVP6B, OL-PVP7A, OL-PVP8A, OL-PVP8B, OL-PVP9A, OL-PVP9B, OL-PVP9C, OL-PVP10A, OL-PVP10B, OL-PVP11, OL-PVP12, OL-PVP14, OL-PVP17, OL-PVP19, OL-PVP20, OL-PVP30, OL-PVP31A, OL-PVP31B, OL-PVP32, OL-PVP33, OL-PVP34A, OL-PVP34B, OL-HP1, OL-HP2, OL-HP3 and OL-HP4 was measured in summer 2010. The length of PP-holes was between 12 and 14 m, and the test sections (1 m) are located in the bedrock. PVP-tubes have an average length between 3–11 m up to c. 17 m, and the test sections (mostly 2 m) are located in the overburden.

The measurements were carried out using the slug-test technique with renewed equipment. 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 hydraulic conductivity is interpreted from 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  $10^{-4}$  m/s. The observed range is quite similar as in the previous measurements in 2002 and 2004–2009. In general, the results are consistent with the results obtained in earlier measurements. In OL-PVP14, the earlier observed lowering trend of the conductivity seems to have stabilized. Also, the results agree relatively well 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 2010

### TIIVISTELMÄ

Osana ydinjätteen loppusijoitustutkimusta Posiva Oy selvittää Olkiluodon saaren hydrologisia olosuhteita. Matalien reikien vedenjohtavuuksia mitattiin rei'istä OL-PP36, OL-PP39, OL-PVP4A, OL-PVP4B, OL-PVP6A, OL-PVP6B, OL-PVP7A, OL-PVP8A, OL-PVP8B, OL-PVP9A, OL-PVP9B, OL-PVP9C, OL-PVP10A, OL-PVP10B, OL-PVP11, OL-PVP12, OL-PVP14, OL-PVP17, OL-PVP19, OL-PVP20, OL-PVP30, OL-PVP31A, OL-PVP31B, OL-PVP32, OL-PVP33, OL-PVP34A, OL-PVP34B, OL-HP1, OL-HP2, OL-HP3 ja OL-HP4 kesällä 2010. PP-reikien syvyys oli 12–14 m maanpinnasta, ja mittausjaksot (1 m) sijaitsevat kallion yläosassa. PVP-reiät ovat keskimäärin 3–11 m ja pisimmillään noin 17 m syviä. Mittausvälit (useimmiten 2 m) ovat maapeiteosuudella.

Mittaukset suoritettiin käyttäen slug-tekniikkaa. Käytössä oli ensimmäistä kertaa parannettu mittauslaitteisto. Mittauksessa kairareikään 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– $10^{-4}$  m/s. Vaihteluväli on lähes sama kuin vuosien 2002 ja 2004–2009 mittauksissa. Pääosin tulkitut vedenjohtavuudet sopivat hyvin yhteen aiempien tulosten kanssa. Reiän OL-PVP14 tuloksissa edellisinä vuosina havaittu laskeva suuntaus näyttäisi tasaantuneen. Vedenjohtavuustulokset sopivat kohtuullisen 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 carried out by Maarit Yli-Kaila, Katariina Perävainio and Tomas Niemi Posiva Oy, using the technique and equipment developed by PRG-Tec Oy (Hellä & Heikkinen 2004). The interpretation of the results has been done at Pöyry Finland Oy by Heikki Hinkkanen. The report has been compiled at Pöyry Finland Oy by Heikki Hinkkanen. This work is done as part of the contract number 9674-10 by Posiva Oy. Susanna Lindgren has been the contact person at Posiva Oy.

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## 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 tests in 2010 were carried out first time with renewed equipment (Appendix 1). The slug-tests are done in all new shallow holes. 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, 2004–2009 are reported by Hellä & Heikkinen (2004), Tammisto et al. (2005), Tammisto & Lehtinen (2006), Keskitalo & Lindgren (2007), Keskitalo (2008 and 2009) and Isola (2010). The latest slug-test measurements were carried out in 2010, when PP-holes were measured in August 2010 and PVP-tubes in June, July and August 2010. The measurements were done in PP-holes, which represent the upper part of the bedrock, and in PVP- and HP-tubes which are located in the overburden.

This report describes these 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). The measurements were carried out using a renewed equipment and a new version of MSEXcel-macro was used for the interpretation.

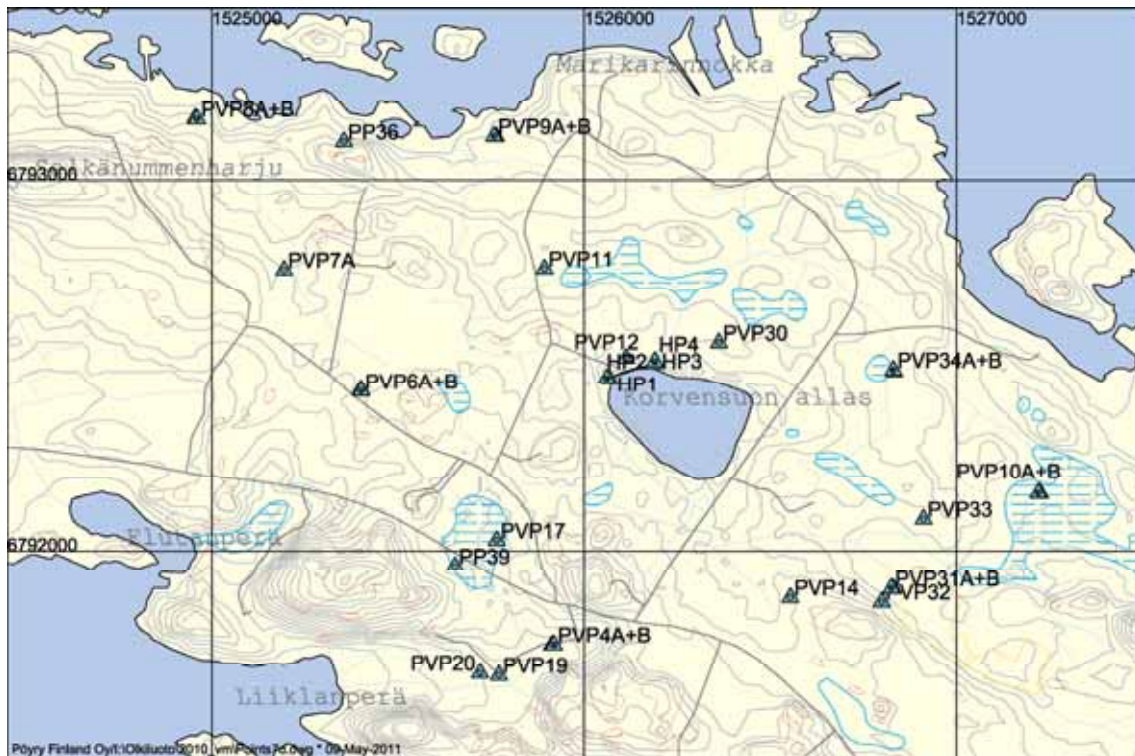




## 2 FIELD MEASUREMENTS

The field measurements were done in June, July and August 2010. 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, Niimimäki & Rautio 2004, Rautio 2004 and Toropainen 2009. Details of the studied holes and tubes are presented in Appendices 3 to 31.

All the shallow drillholes and tubes measured in 2010 have been measured earlier at least once (Table 5-1). OL-PP39 has been measured six times (2004, 2005, 2006, 2007, 2008 and 2009), OL-PP36 four times (2006, 2007, 2008 and 2009), PVP-tubes OL-PVP4A and OL-PVP4B have been measured seven times (2002, 2004, 2005, 2006, 2007, 2008 and 2009), OL-PVP6A and OL-PVP6B five times (2002, 2006, 2007, 2008 and 2009) and OL-PVP14 six times (2004, 2005, 2006, 2007, 2008 and 2009).



**Figure 2-1.** Locations of the shallow holes where slug-tests have been done in summer 2010.

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

| Area      | Hole    | Diam. (mm) | Length (m) | Date start | Time start | Date stop | Time stop | Operator   |
|-----------|---------|------------|------------|------------|------------|-----------|-----------|--|
| Olkiluoto | OL-PP36 | 56         | 12.05      | 27.8.2010  | 8:25       | 27.8.2010 | 12:10     | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy |
| Olkiluoto | OL-PP39 | 56         | 13.71      | 26.8.2010  | 8:10       | 26.8.2010 | 15:03     | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy |

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

| Hole      | Diam. | Length (m)/            | Date      | Time  | Operator   | Pressure sensor movement (m) |
|-----------|-------|------------------------|-----------|-------|--|------------------------------|
|           | (mm)  | perforated section (m) |           |       |  |                              |
| OL-PVP4A  | 56    | 9.55/2                 | 30.6.2010 | 12:55 | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| OL-PVP4B  | 56    | 8.00/2                 | 30.6.2010 | 13:18 | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| OL-PVP6A  | 56    | 7.83/2                 | 1.7.2010  | 13:42 | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| OL-PVP6B  | 56    | 3.83/2                 | 1.7.2010  | 14:08 | Maarit Yli-Kaila, Kataruuna Perävainio/Posiva Oy | 1.5                          |
| OL-PVP7A  | 56    | 5.75/2                 | 19.7.2010 | 12:35 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP8A  | 56    | 9.45/2                 | 30.7.2010 | 11:50 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP8B  | 56    | 5.45/2                 | 30.7.2010 | 12:40 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 0.5                          |
| OL-PVP9A  | 56    | 9.00/2                 | 21.7.2010 | 13:10 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP9B  | 56    | 5.00/2                 | 21.7.2010 |       | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP10A | 56    | 5.50/2                 | 21.7.2010 |       | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP10B | 56    | 3.00/0.2               | 21.7.2010 | 14:59 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP11  | 56    | 5.20/2                 | 2.8.2010  | 14:45 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP12  | 56    | 6.30/2                 | 19.7.2010 | 13:45 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP14  | 56    | 10.40/2                | 30.6.2010 | 14:27 | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| OL-PVP19  | 56    | 17.15/4                | 2.8.2010  | 12:40 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP20  | 56    | 14.10/2                | 2.8.2010  | 12:10 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP30  | 52    | 3.80/1                 | 16.7.2010 | 13:21 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| OL-PVP31A | 52    | 6.50/2                 | 2.7.2010  | 10:25 | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.2                          |
| OL-PVP31B | 52    | 7.00/2                 | 2.7.2010  | 9:28  | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| OL-PVP32  | 52    | 4.60/2                 | 2.7.2010  | 9:54  | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| OL-PVP33  | 52    | 3.90/1                 | 8.7.2010  |       | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.15                         |
| OL-PVP34A | 52    | 7.40/2                 | 8.7.2010  | 13:58 | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| OL-PVP34B | 52    | 7.60/2                 | 8.7.2010  | 14:17 | Maarit Yli-Kaila, Katariina Perävainio/Posiva Oy | 1.5                          |
| HP1       | 50    | 5.00/1                 | 13.7.2010 | 10:10 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.05                         |
| HP2       | 50    | 3.00/1                 | 13.7.2010 | 12:00 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.5                          |
| HP3       | 50    | 5.00/1                 | 13.7.2010 | 12:45 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.0                          |
| HP4       | 50    | 3.00/1                 | 13.7.2010 | 14:49 | Katariina Perävainio, Tomas Niemi/Posiva Oy      | 1.0                          |

## 2.1 Measurements in PP-holes

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

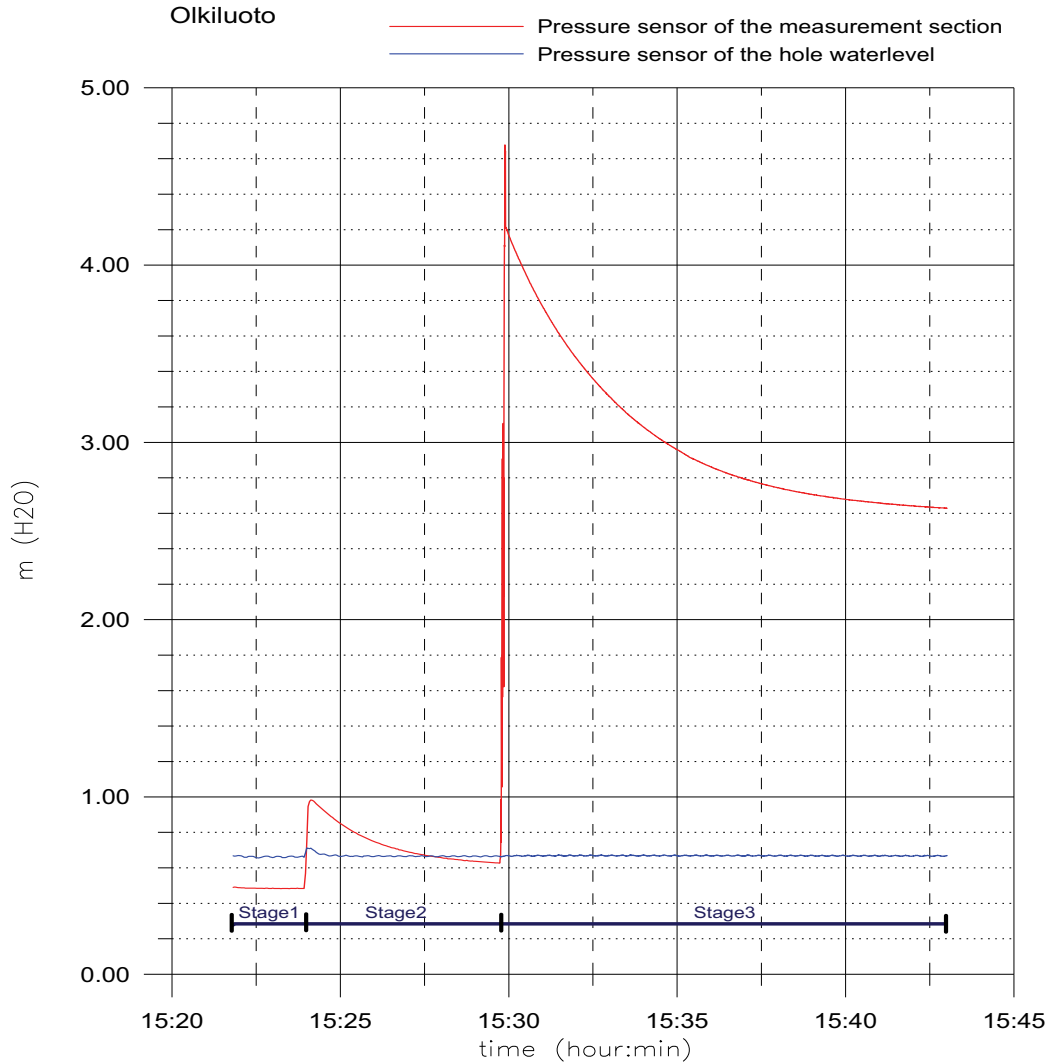
The measurement is divided into three stages:

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 stabilization of the pressure transient is followed up.

Each of the three stages has a specific duration, see Table 2-4. An example of the water levels at different measurement stages is shown in Figure 2-2.

*Table 2-4. Duration of the measurement stages.*

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

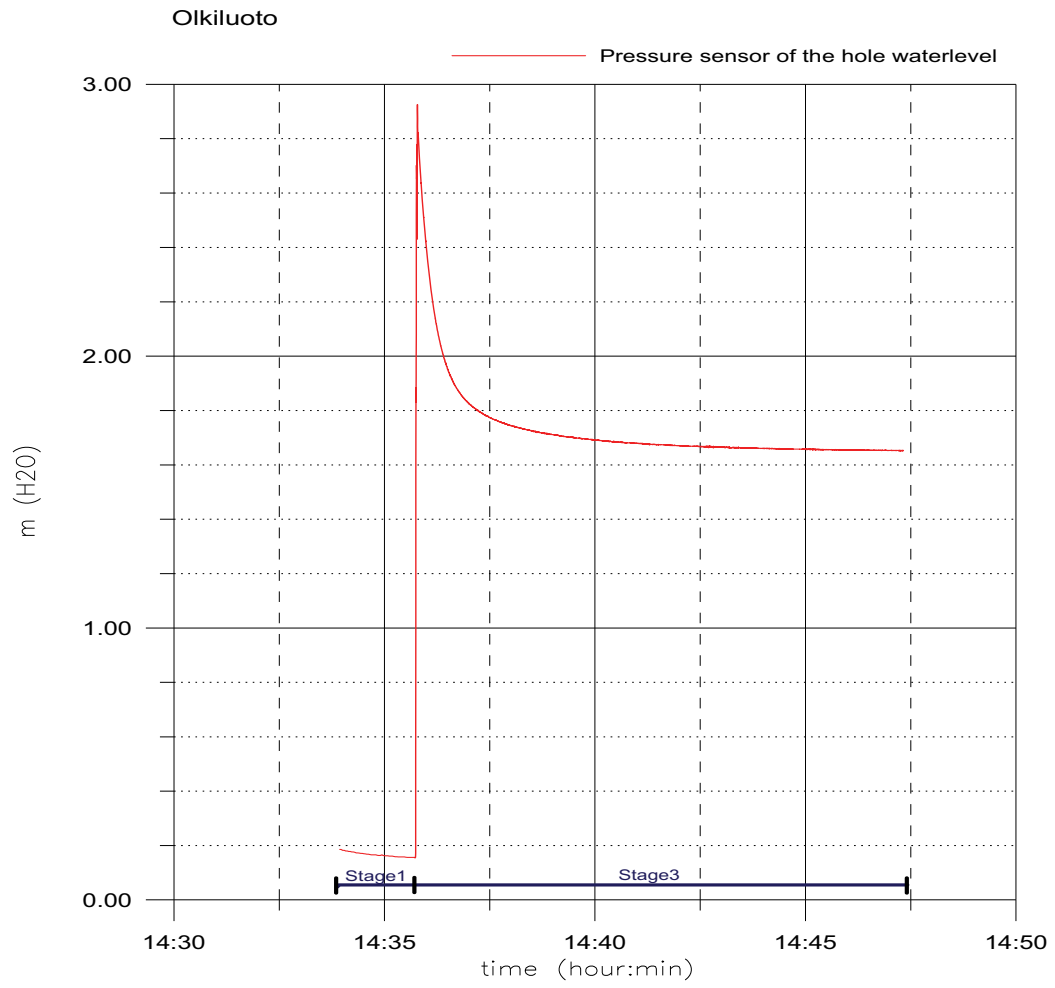


*Figure 2-2. An example of measurement results in a PP-hole.*

## 2.2 Measurements in PVP- and HP-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 2-4. An example of the measurement is presented in Figure 2-3.



*Figure 2-3. An example of measurement results in a PVP- or HP-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:

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

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

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

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

$$T_0 = \pi r^2 / FK. \quad (\text{Equation 3-3.})$$

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

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

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

#### 3.2 Thiem's formula

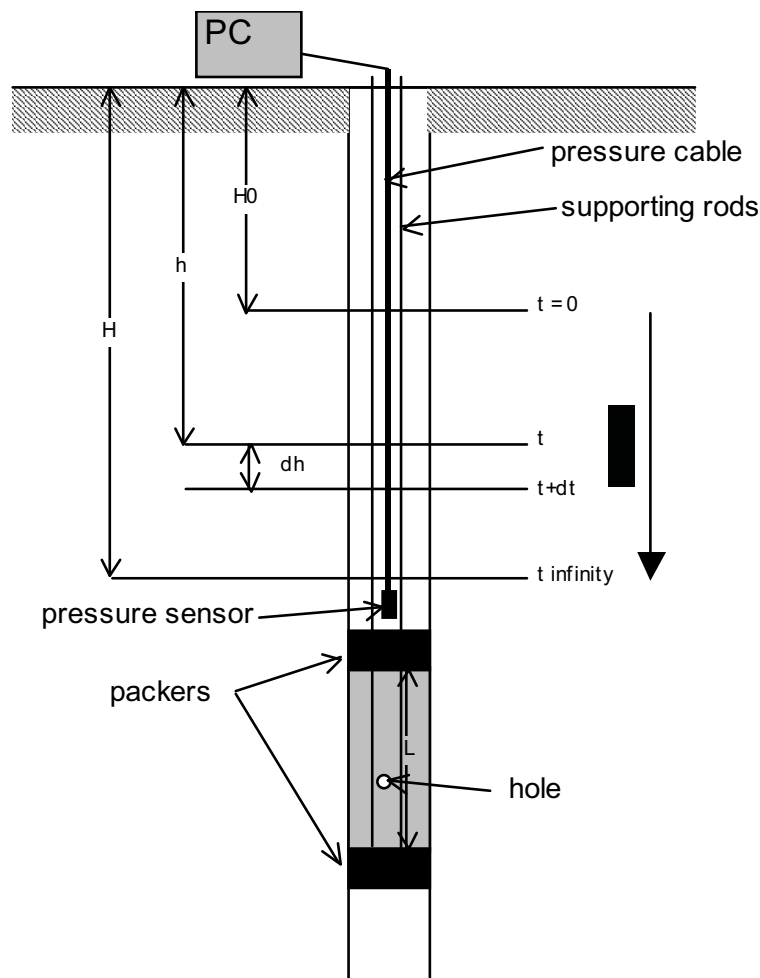
For reference, the hydraulic conductivity  $K$  was also calculated based on Thiem's formula:

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



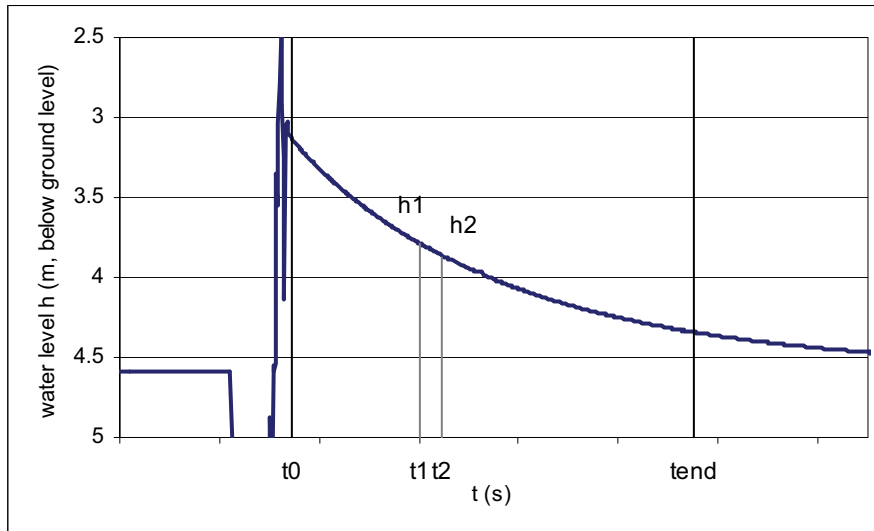
In Equation 3-5,  $Q$  is the flow rate ( $= Adh/dt$ ,  $A$  is the void area between connection rods and the pressure cable, see Figure 3-1,  $dh$  change in head during the time interval  $dt$ ),  $r_0$  is the radius of influence assumed to be 14 m,  $r_w$  is radius of the borehole,  $L$  is the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

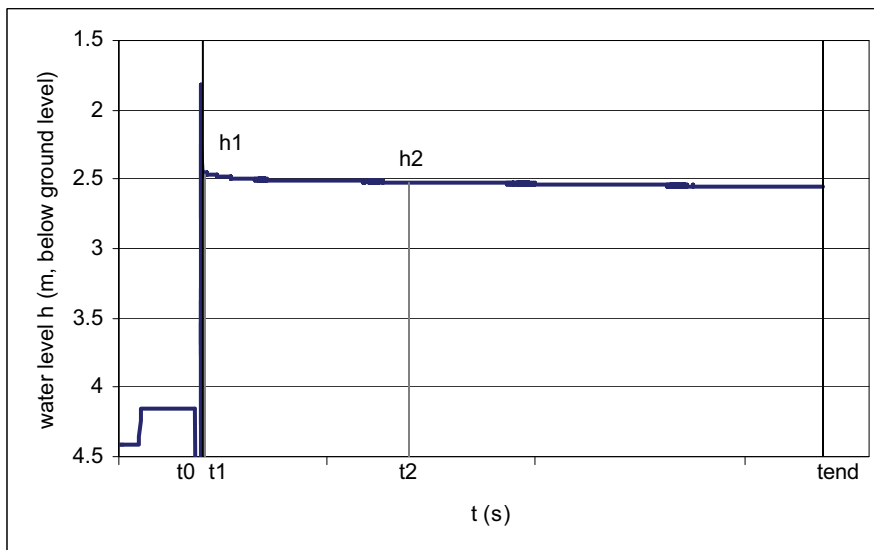


**Figure 3-1.** Principle of the slug-test and interpretation according to Hvorslev's method (modified after Freeze and Cherry 1979).

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.

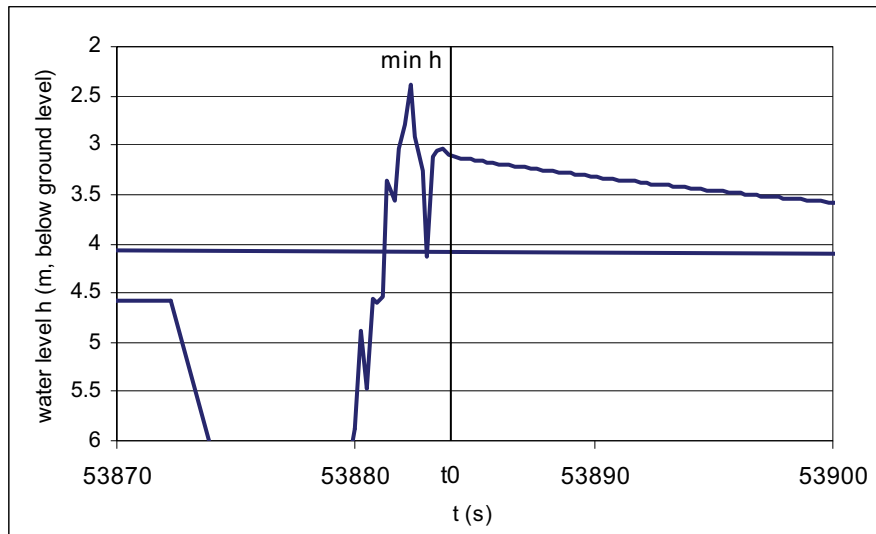


## 4 DATA PROCESSING

For the interpretation of the first measurements in 2002, a set of MSExcel-macros was developed (see Appendix 3 for the details) (Hellä & Heikkinen 2004). The initial macro has been used in the interpretation of the former measurements in 2004–2009. The measurements in 2010 were carried out with the renewed equipment (Appendix 1), and thus the structure of the data was changed slightly. Therefore some minor changes related to starting values had to be done to the macro (version 1.5). The actual analysis of the results uses a template file (xls), which contains the necessary formulas and graph templates (see Appendices 3 to 31). 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 stage one,

Figure 2-2 and Figure 3-1 are referred for the notation. Stage one is used as the water level during it is more stable than during stage 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- and HP-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  $t_{\text{end}}$  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  $K_{\text{Hvorslev}} / K_{\text{Thiem}}$  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

K-values (m/s) in slug-measurements give information about water conductivity in the soil where test sections are located. K-value tells how thick (m) soil layer water will penetrate in one second. Porosity of the sediment/rock, structure of sediment/rock, fractures in rock, grain size in sediment, grain shape, grain sorting and the way K-values are counted, will affect in K-values. There are K-value estimates for different kind of sediment layers and bedrock types. These estimates (see Figure 5-1) have been discovered in numerous field studies and laboratory studies worldwide over the years.

| Sediment type/rock type   | K-Values (m/s)   |
|---|------------------|
| Coarse Gravel   | > 10E-01         |
| Medium Gravel   | 10E-01 - 10E-02  |
| Fine Gravel   | 10E-02 - 10E-03  |
| Sandy Gravel  | 10E-02 - 10E-06  |
| Sand  | 10E-02 - 10E-06  |
| Coarse Sand   | 10E-01 - 10E-04  |
| Medium Sand   | 10E-02 - 10E-05  |
| Fine Sand   | 10E-03 - 10E-06  |
| Silt  | 10E-05 - 10E-09  |
| Coarse Silt   | 10E-04 - 10E-06  |
| Fine Silt   | 10E-05 - 10E-08  |
| Clay  | < 10E-08         |
| Gravelly Till   | 10E-04 - 10E-07  |
| Sandy Till  | 10E-06 - 10E-08  |
| Silty Till  | 10E-07 - 10E-09  |
| Fractured igneous rock and<br>Metamorphic rock                  | 10E-04 - 10E-06  |
| Igneous rock and Metamorphic<br>rock with very little fractures | < 10E-09         |
| Schist  | < 10E-08         |
| Sandstone   | 10E-07 - 10E-010 |

**Figure 5-1.** Known estimates for different kind of soil/rock type. (Niemi et al. 1994; Mälkki 1999)

The interpretation of the hydraulic conductivities in each of the measured holes and sections are presented in Appendices 3 to 31. 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 5-2.

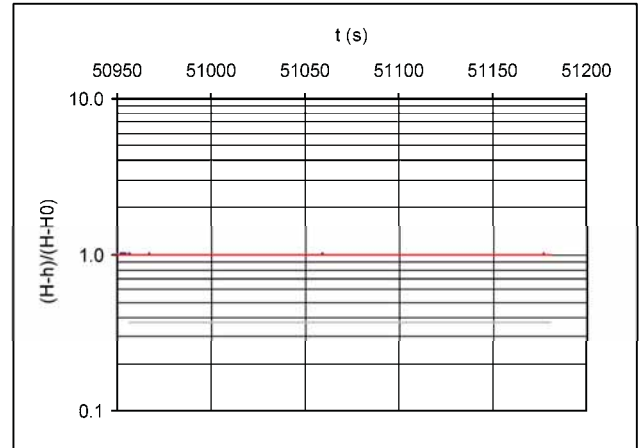
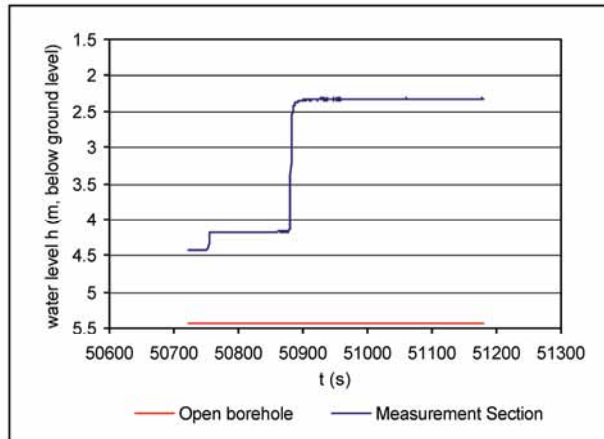
In Figure 5-3, the summary of the results in PP-holes is presented and Figure 5-4 contains the summary of the results in PVP- and HP-tubes. In PP-holes, the test section is one meter along the hole. In PVP- and HP-tubes, the entire hole is measured without packers. The results represent the perforated section, which in tubes measured in 2010 was typically two meters, except tubes OL-PVP10B (0.2 m), OL-PVP19 (two separate 2 m sections), OL-PVP30 (1 m), OL-PVP33 (1 m), OL-HP1 (1 m), OL-HP2 (1 m), OL-HP3 (1 m) and OL-HP4 (1 m).

The cumulative distributions of the measured hydraulic conductivities are presented in Figures 5-5 and 5-6 including also results from 2002, 2004, 2005, 2006, 2007, 2008 and 2009. In PP-holes, the cumulative distribution of the latest measurements agrees quite well with the results from 2006. The conductivities higher than  $10^{-8}$  m/s agree also relatively well with the results from 2002 (Figure 5-5). Also, the results from PVP- and HP-tubes mostly agree well, although the measurements of 2002, 2004, 2005, 2006, 2007, 2008, 2009 and 2010 included partly different tubes (Figure 5-6). In fact there have been only few tubes that have been measured every year (Table 5-1). That explains why results divide quite loosely around average cumulative distribution line. The diagram shows that in 2010 the results agree relatively well with the average cumulative distribution though there is little difference in low conducting values lower than  $3.0 \cdot 10^{-6}$  m/s. In 2004 the conductivities in the overburden were notably higher and in 2002, 2005 and 2006 lower than the average cumulative distribution. The results from 2007 and 2008 seem to follow the average behaviour.

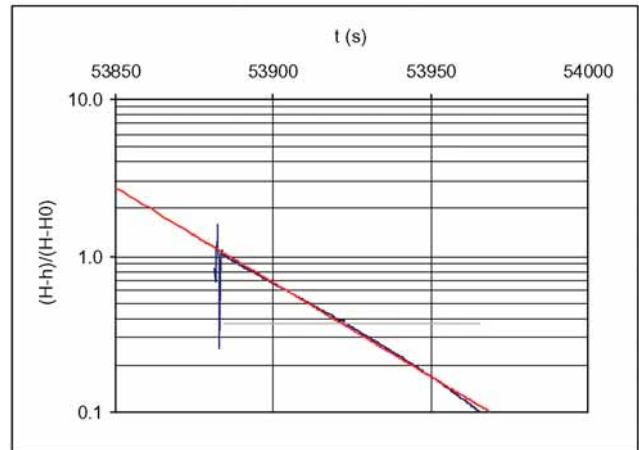
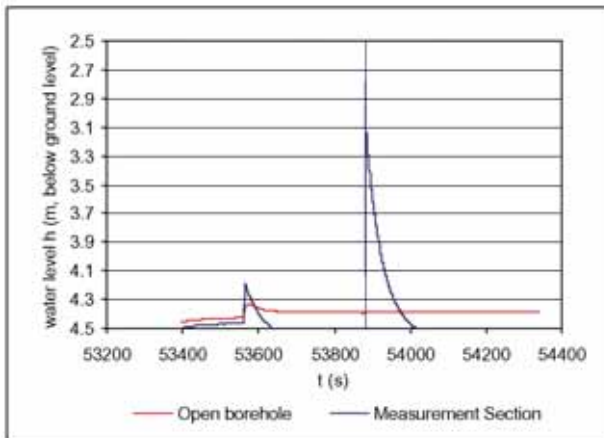
All the PP-holes and PVP- and HP-tubes measured in Olkiluoto Island are presented in Table 5-1. Altogether 12 PP-holes, 42 PVP-tubes and 4 HP-tubes have been measured. In 2002, nine PP-holes and fifteen PVP-tubes were measured. In 2004, the slug-tests included three PP-holes and seven PVP-tubes, in 2005 three PP-holes and nine PVP-tubes, in 2006 included four PP-holes and five PVP-tubes, in 2007 included three PP-holes and 22 PVP-tubes, in 2008 2 PP-holes, 14 PVP-tubes and 3 HP-tubes and in 2009 2 PP-holes, 12 PVP-tubes and 4 HP-tubes. The latest measurements in 2010 included two PP-holes, 25 PVP-tubes and 4 HP-tubes of which two measurements failed (OL-PVP9C and OL-PVP17). As the number of measured holes is rather small, the results of a single hole do affect considerably to the distributions for a single year shown in Figures 5-5 and 5-6.

Any earlier measurements available from the holes measured in 2010 are given in Table 5-1. The results from 2010 are compared with the earlier results in Figures 5-7, 5-8, 5-9 and in Appendix 32.

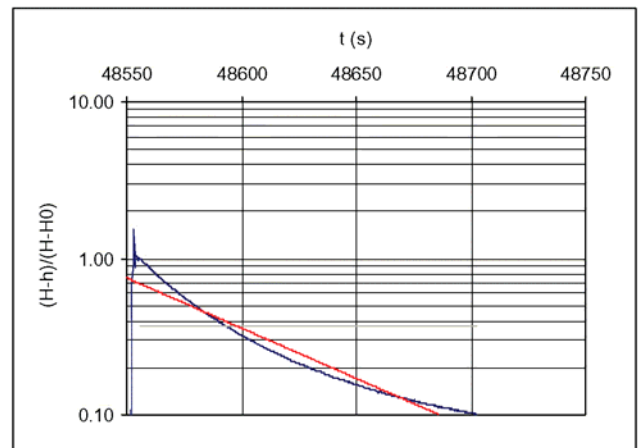
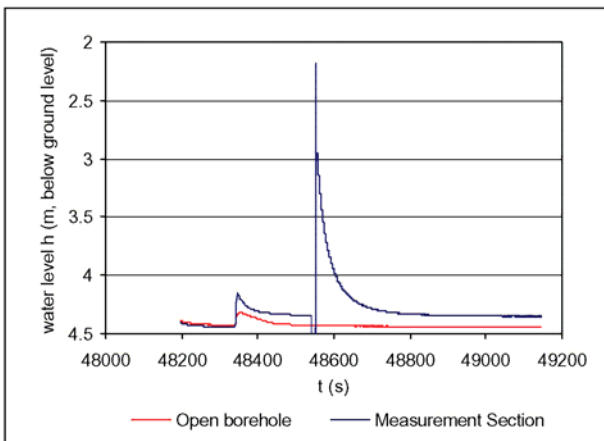
a)



b)

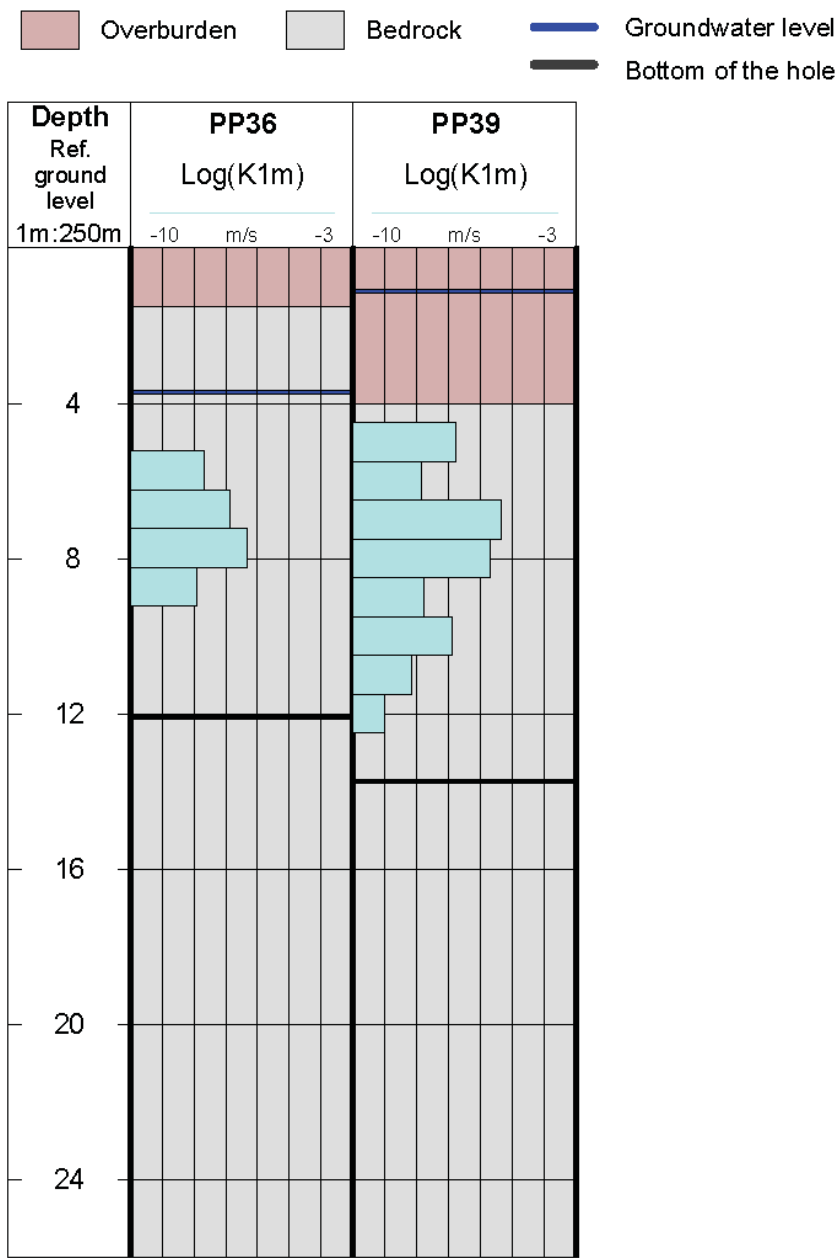


c)



**Figure 5-2.** 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 5-3.** Hydraulic conductivity ( $K_{Hvorslev}$  m/s) in PP-holes.

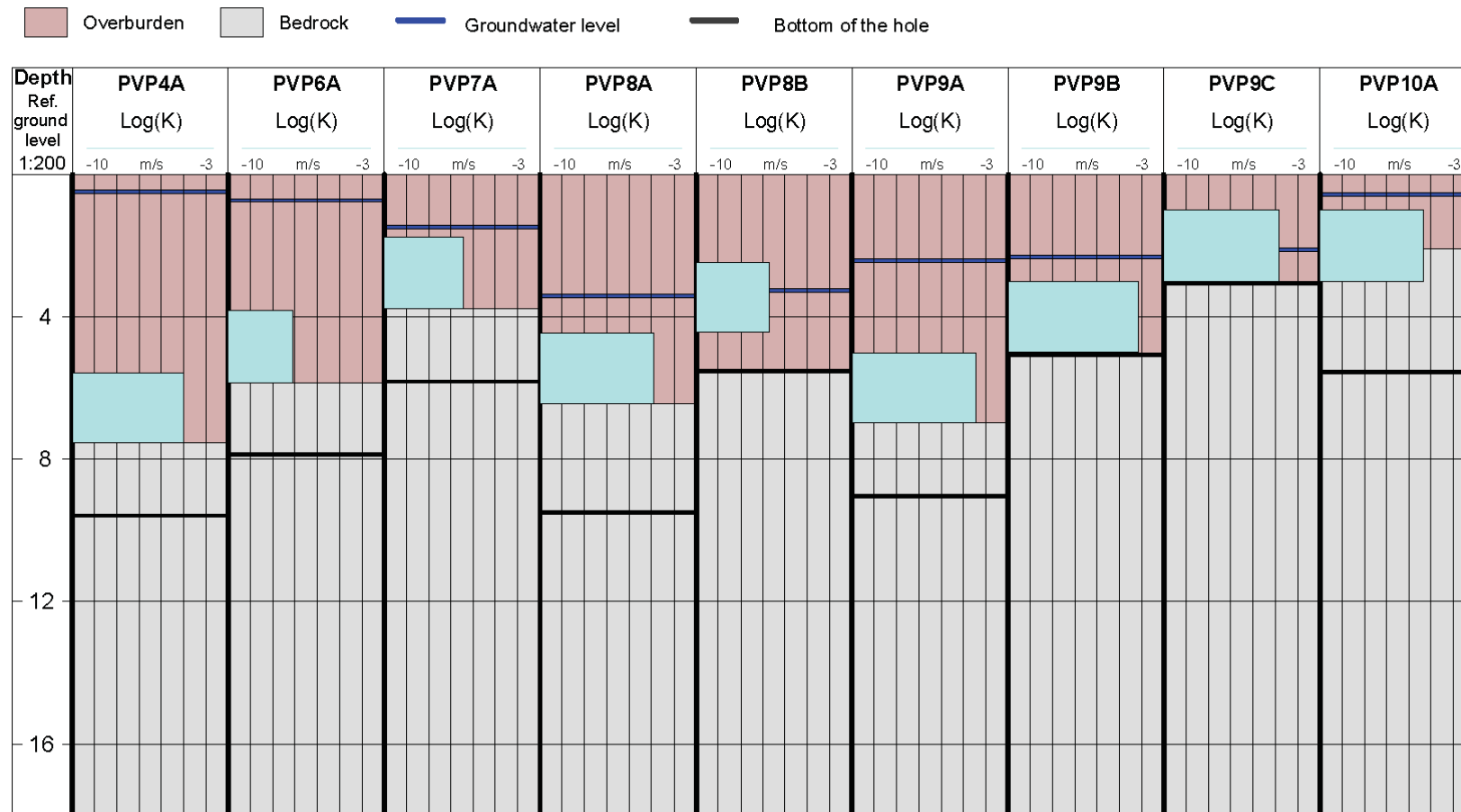
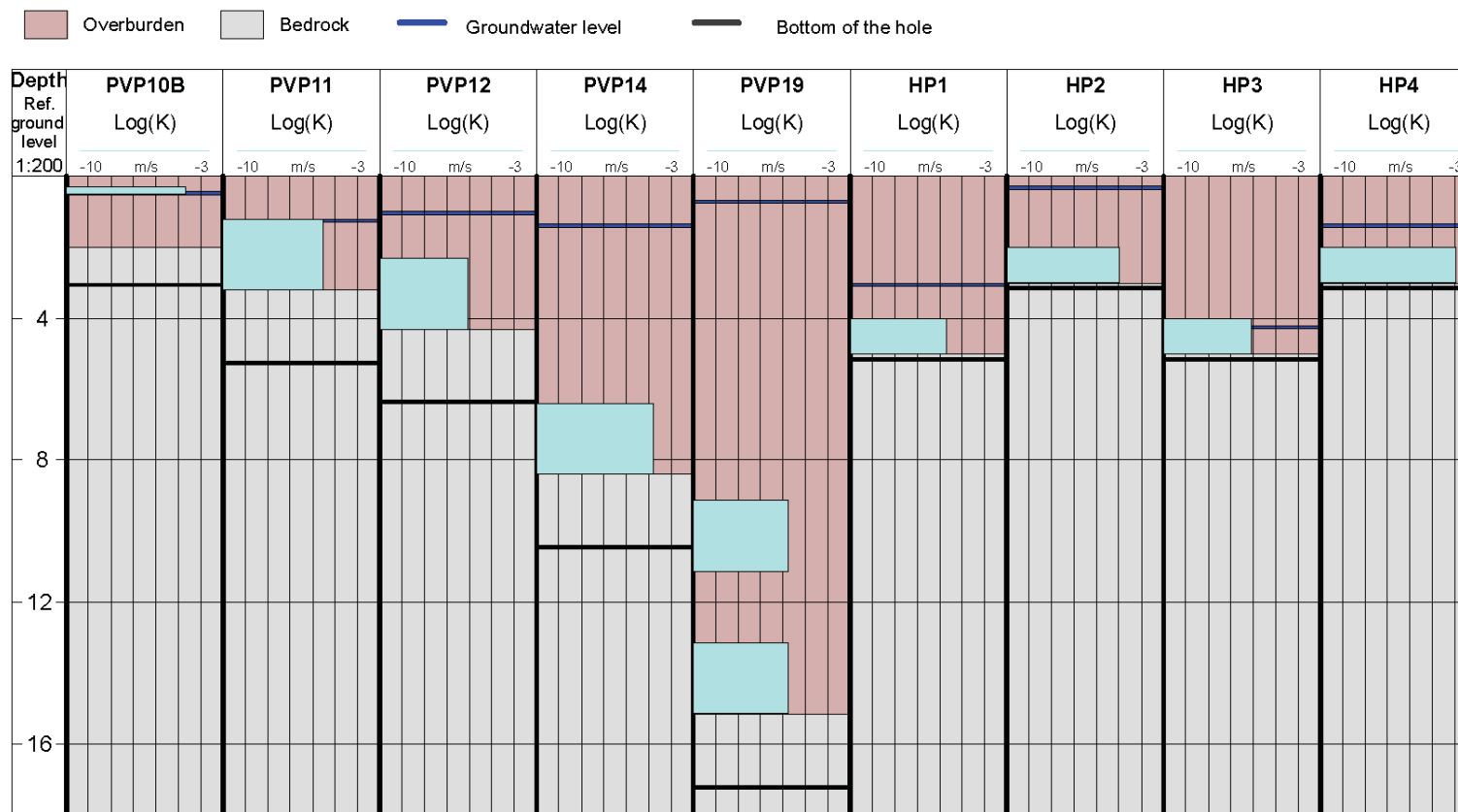
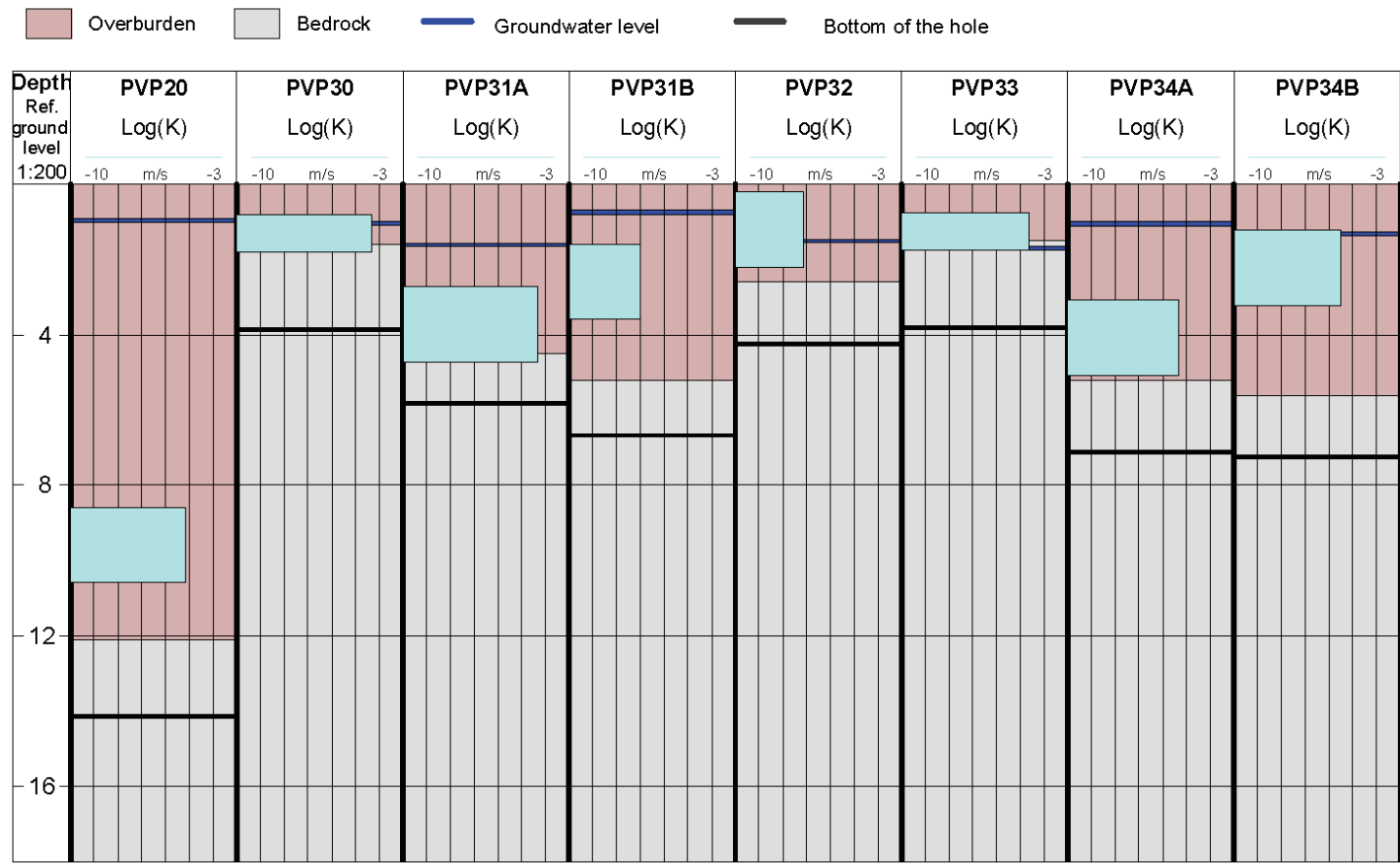


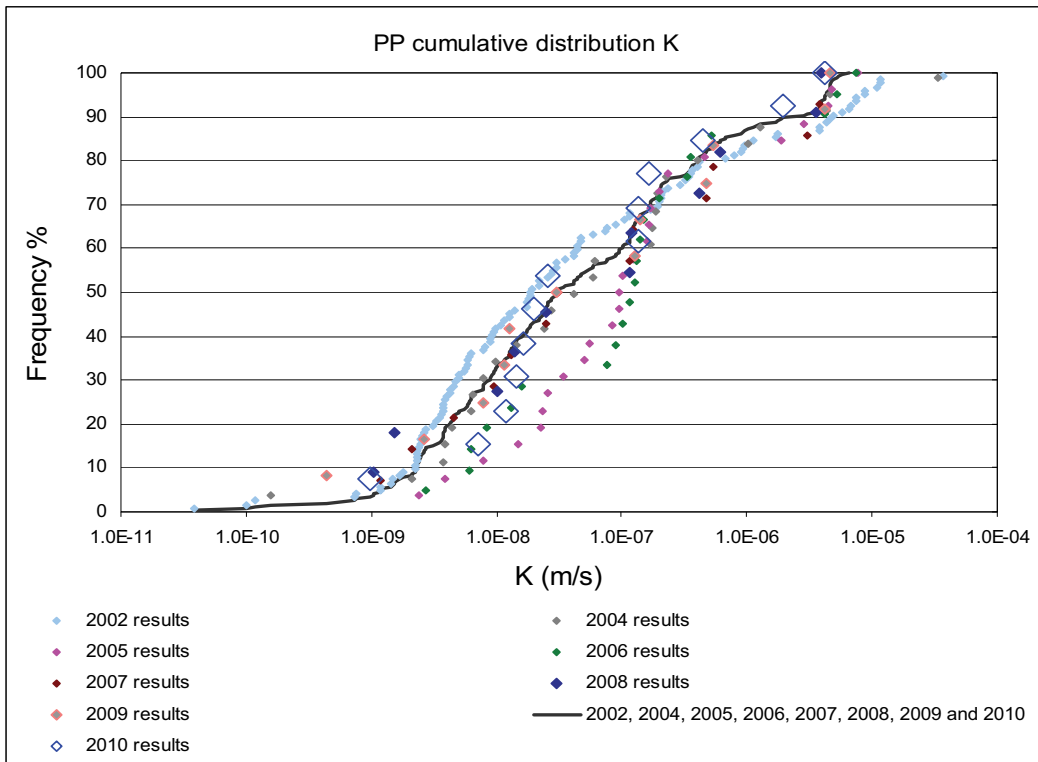
Figure 5-4a. Hydraulic conductivity (m/s) in PVP-tubes. The perforated section is two meters in all tubes.



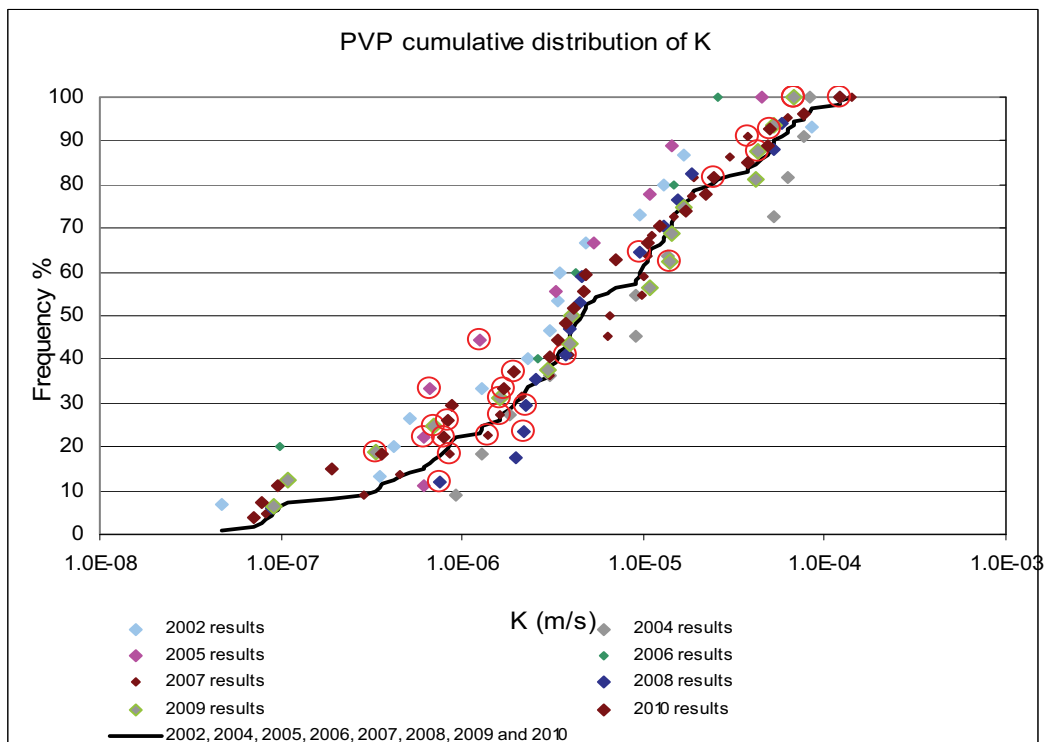
**Figure 5-4b.** Hydraulic conductivity (m/s) in PVP- and HP-tubes. The perforated section is two meters in all PVP-tubes except OL-PVP10B where it is 0.2 m. In HP-tubes the perforated section is 1 m.



**Figure 5-4c.** Hydraulic conductivity (m/s) in PVP-tubes. The perforated section is two meters except PVP-tubes OL-PVP30 and in PVP-33.



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

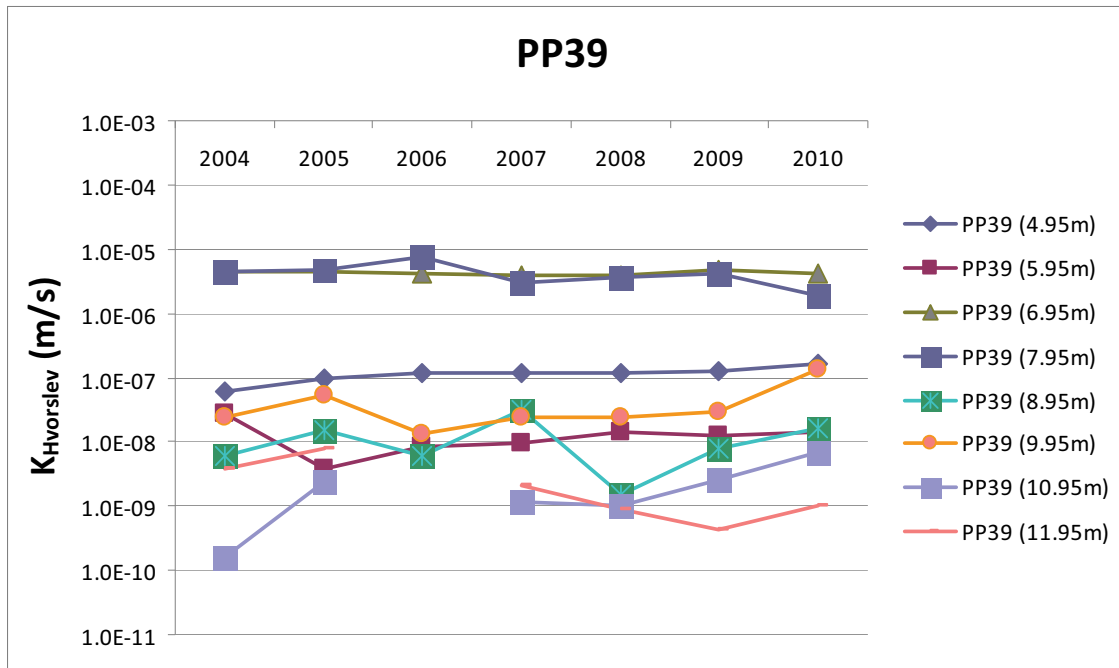


**Figure 5-6.** Cumulative distribution of the hydraulic conductivities (Hvorslev) in PVP- and HP-tubes. The tubes, where perforated section is not two meters, are marked with red circles.

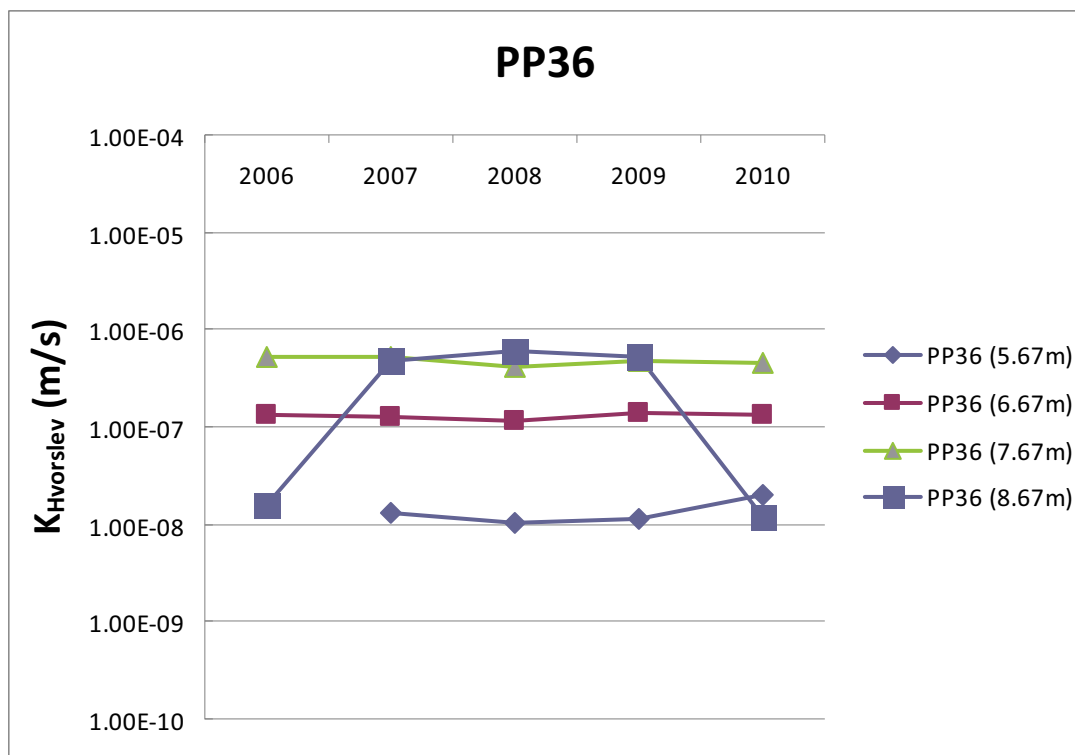
*Table 5-1. The slug-tests done at the Olkiluoto Island at different times. The holes which were originally included in monitoring program are in bold.*

| <b>Hole/Tube</b> | <b>Measured</b>                                | <b>Note</b>          |
|------------------|--|----------------------|
| OL-PP2           | 2002, 2004                                     |                      |
| <b>OL-PP3</b>    | 2002   | collapsed            |
| <b>OL-PP5</b>    | 2002, 2005, 2006                               |                      |
| OL-PP7           | 2002   |                      |
| <b>OL-PP9</b>    | 2002, 2005, 2006, 2007                         |                      |
| OL-PP10          | 2002   |                      |
| OL-PP31          | 2002   |                      |
| OL-PP32          | 2002   |                      |
| OL-PP35          | 2002   |                      |
| OL-PP36          | 2006, 2007, 2008, 2009, 2010                   |                      |
| <b>OL-PP38</b>   | 2004   | destroyed            |
| <b>OL-PP39</b>   | 2004, 2005, 2006, 2007, 2008, 2009, 2010       |                      |
| <b>OL-PVP2</b>   | 2004   | drilled bedrock hole |
| OL-PVP3A         | 2002, 2007                                     |                      |
| OL-PVP3B         | 2002, 2007                                     |                      |
| <b>OL-PVP4A</b>  | 2002, 2004, 2005, 2006, 2007, 2008, 2009, 2010 |                      |
| <b>OL-PVP4B</b>  | 2002, 2004, 2005, 2006, 2007, 2008, 2009, 2010 |                      |
| <b>OL-PVP5A</b>  | 2002   | destroyed            |
| <b>OL-PVP5B</b>  | 2002   |                      |
| <b>OL-PVP6A</b>  | 2002, 2006, 2007, 2008, 2009, 2010             |                      |
| <b>OL-PVP6B</b>  | 2002, 2006, 2007, 2008, 2009, 2010             |                      |
| OL-PVP7A         | 2002, 2007, 2010                               |                      |
| OL-PVP8A         | 2002, 2007, 2010                               |                      |
| OL-PVP8B         | 2002, 2007, 2010                               |                      |
| OL-PVP9A         | 2002, 2007, 2010                               |                      |
| OL-PVP9B         | 2002, 2007, 2010                               |                      |
| <b>OL-PVP9C</b>  | 2002, 2010                                     | failed in 2010       |
| OL-PVP10A        | 2002, 2007, 2010                               |                      |
| OL-PVP10B        | 2002, 2007, 2010                               |                      |
| OL-PVP11         | 2004, 2007, 2010                               |                      |
| OL-PVP12         | 2004, 2007, 2010                               |                      |
| OL-PVP13         | 2004, 2007                                     |                      |
| <b>OL-PVP14</b>  | 2004, 2005, 2006, 2007, 2008, 2009, 2010       |                      |
| OL-PVP17         | 2005, 2007, 2010                               | failed in 2010       |
| OL-PVP18A        | 2005, 2007                                     |                      |
| OL-PVP18B        | 2005, 2007                                     |                      |
| OL-PVP19         | 2005, 2007, 2010                               |                      |
| OL-PVP20         | 2005, 2007, 2010                               |                      |
| OL-PVP21         | 2008   |                      |
| OL-PVP22         | 2008   |                      |

|           |                  |  |
|-----------|------------------|--|
| OL-PVP23  | 2008             |  |
| OL-PVP24  | 2008             |  |
| OL-PVP25  | 2008             |  |
| OL-PVP26  | 2008             |  |
| OL-PVP27  | 2008             |  |
| OL-PVP28  | 2008             |  |
| OL-PVP29  | 2008             |  |
| OL-PVP30  | 2009, 2010       |  |
| OL-PVP31A | 2009, 2010       |  |
| OL-PVP31B | 2009, 2010       |  |
| OL-PVP32  | 2009, 2010       |  |
| OL-PVP33  | 2009, 2010       |  |
| OL-PVP34A | 2009, 2010       |  |
| OL-PVP34B | 2009, 2010       |  |
| HP1       | 2008, 2009, 2010 |  |
| HP2       | 2008, 2009, 2010 |  |
| HP3       | 2009, 2010       |  |
| HP4       | 2008, 2009, 2010 |  |



*Figure 5-7. Results from OL-PP39 measured 2010 versus results from earlier measurements of this hole.*

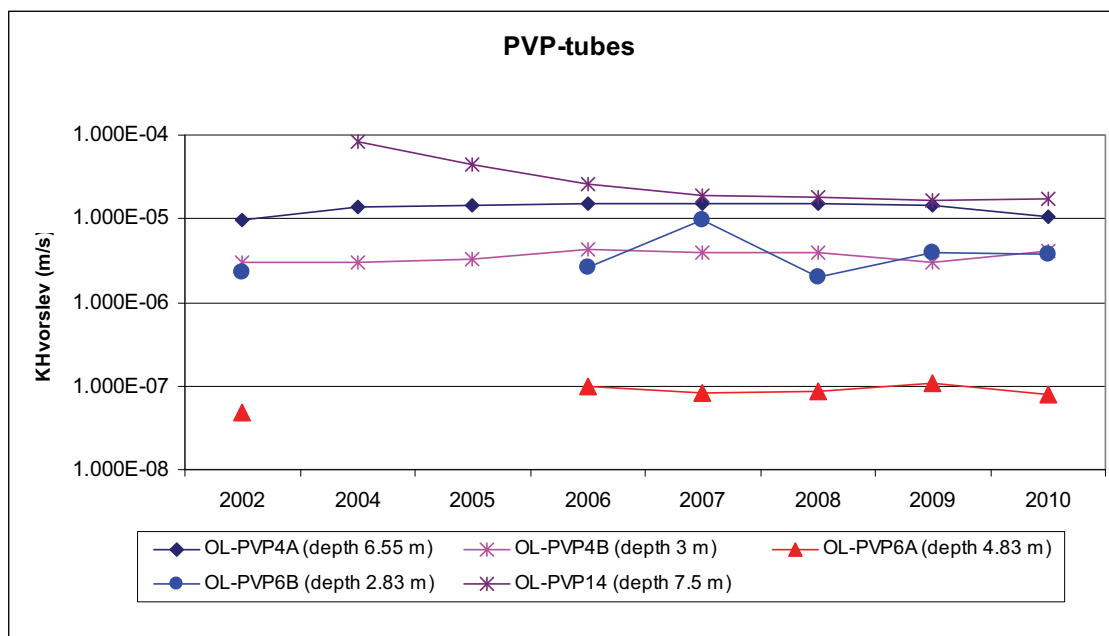


*Figure 5-8. Results from OL-PP36 measured 2010 versus results from earlier measurements of this hole*

Generally the results of 2010 are quite close to the results of the earlier measurements. In OL-PP36, the results from 2010 agree very well with the results from 2009, 2008, 2007 and 2006 (Figure 5-8) except section 8.17–9.17 m, in 2010 8.22–9.22 m, in which K-values from 2006 and 2010 differ from the other years. The section 5.17–6.17 m was not measured in 2006. (Figure 5-8).

In OL-PP36 diverging results in 2006 and 2010 (section 8.17–9.17 m) could be measurement error or caused by disturbance factors in measurement. Also changing circumstances of test section after installation of the PP-tube could cause the diverging result to following year(s). Also macro-related "disturbance" could cause the diverging result.





**Figure 5-9.** Results from part of PVP-tubes measured 2010 and at least once in the earlier measurements in 2002, 2004, 2005, 2006, 2007, 2008 and 2009.

In OL-PP39, all the yearly results from 2004 are quite close to each other (Figure 5-7). In lower section (7.45–8.45 m, 8.45–9.45 m, 9.45–10.45 m and 10.45–11.45 m) K-values are slightly higher in 2010 than in the two previous years. All in all there is more variation in low K-values than in higher ones. There are two main reasons to this: 1) the accuracy of slug-measurement equipment is not good enough for very small values and measurement method errors get bigger in very small conductivities and 2) the macro that calculates K-values may give relatively different values depending on variation of measurement time and error factors on the curve. Minor difference in the water-level-curve may result to very different K-value. Because the water level lowers so slowly in poorly conducting soil, 15 minutes measurement time is not enough to provide reliable result. Also the calculating time should be the same every year. Sections 10.45–11.45 m and 11.45–12.45 m were not measured in 2006. To interpret section 6.45–7.45 m shorter time was used in 2007 and 2008 and in section 7.45–8.45 m shorter time was used in 2007, 2008, 2009 and 2010 because the sections have high conductivity and the recovery is not linear. The time range used is shown in the interpretation plot (Appendix 4).

In PVP-tubes the variations are small (Figure 5-9). In OL-PVP14, the lowering trend of conductivity has settled. The same earlier lowering trend can be seen in the pre-pumping results from 2004, 2005, 2006 and 2007. The pre-pumping results from 2008 and 2010 were slightly higher than the results from 2006 and 2007 (Hirvonen 2005, Lehtinen et al. 2006, Partamies et al. 2007; Partamies et al. 2008; Pitkänen et al. 2009; Penttinen et al. 2011), which may also indicate stabilization. Probably changing circumstances (ground frost, tube movement, porosity of sediment next to test section

tube-holes) after installation of the PVP-tube could have caused the diverging results of the earlier years.

In OL-PVP6B, the results from 2002, 2006, 2008, 2009 and 2010 agree well but the result from 2007 is somewhat higher (Figure 5-9) which is caused by macro. For unknown reason 2007 (OL-PVP6B) macro used only 80 seconds of measurement time though the curve was identical with 2002, 2006, 2008 and 2009 curves. Former macro used +350 seconds measurement time for calculating K-values. Because the curve (OL-PVP6B) that is used for calculating the K-value is exponentially decaying (see figure 6-3), used time-length affects dramatically in K-value. OL-PVP6A and OL-PVP6B were not measured in 2004–2005. In OL-PVP4A results, there has been a slightly lowering trend in 2009 and 2010 compared to the results of 2006, 2007 and 2008.

In OL-PVP10B and OL-PVP33 the water level before the test has been quite low, only few centimetres above the lower part of the perforated measuring section (Figures 5-4b and 5-4c). Thus almost the whole measuring section is unsaturated. Although this seem not to have had any major effect on the results when comparing them with the earlier ones (Appendix 32).

Results in HP-tubes 2010 are close to results from 2008 and 2009. K-values are surprisingly high in OL-HP1 (Appendix 28) and in OL-HP4 (Appendix 31) considering that HP-tubes are located in the embankment of the Korvensuo reservoir. In addition, K-value in OL-HP4 is even showing an increasing trend.



## 6 ON THE ACCURACY OF THE RESULTS

### 6.1 Detection limits

In measurements of 2010, 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  $10^{-4}$  m/s in PVP-tubes. In the following, the detection limits are discussed.

The accuracy of the water level obtained by the pressure sensor is  $\pm 1-2$  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. In the lowest measured K-values ( $10^{-9}-10^{-10}$  m/s) the water level change was barely 5 mm in 15 minutes, so longer time would be needed to have more reliable results. 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<sup>3</sup>/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 to the transmissivity of  $5 \cdot 10^{-9}$  m<sup>2</sup>/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<sup>3</sup>/s. A typical overpressure is 1.5 m leading to the transmissivity of  $2 \cdot 10^{-8}$  m<sup>2</sup>/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<sup>2</sup>/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<sup>2</sup>/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.

In 2010 results the highest observed conductivity in the PP-holes is  $4.2 \cdot 10^{-6}$  m/s in hole OL-PP39 at the depth of 7.00 m (Appendix 4), where the water level in the test section decreased about 1.0 m during 147 seconds. The difference between the water level in the test section and in the open hole was about 20 cm at the most.

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 after more stable conditions are reached so the recovery period should last at least 5 seconds. During the first seconds the water table already decreases noticeably 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 2010 results the highest observed conductivity in PVP- and HP-tubes is  $1.2 \cdot 10^{-4}$  m/s (OL-HP4, see Appendix 31).

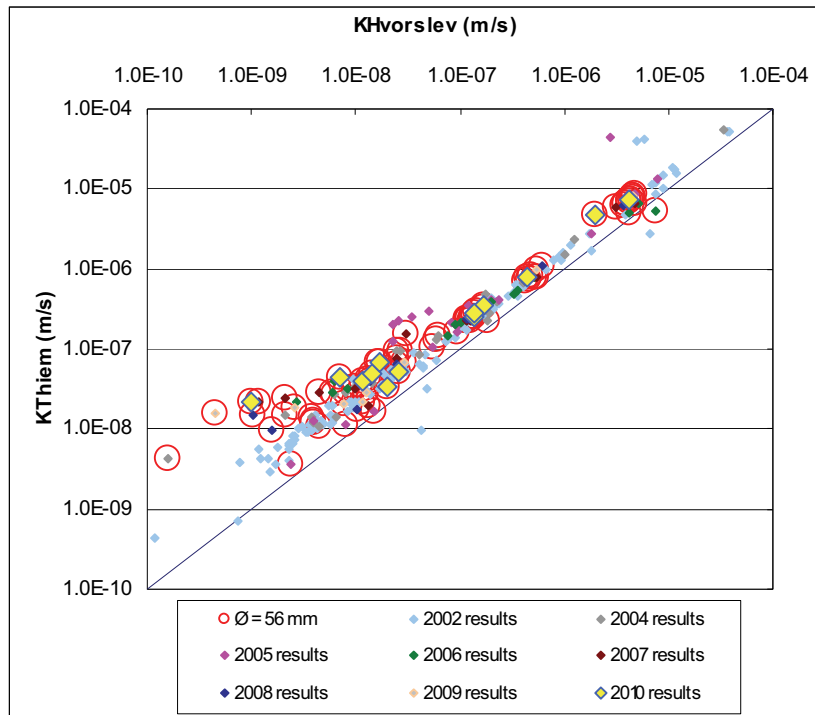
About the same limits are obtained by comparing the hydraulic conductivities resulting from the interpretations using the two methods, Hvorslev and Thiem. In general, the hydraulic conductivities calculated according to Thiem's equation and according to Hvorslev's method seem to be well in accordance, 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,  $K_{\text{Thiem}}$  being approximately two to three times higher than  $K_{\text{Hvorslev}}$ . Exception is in OL-PP39, where  $K_{\text{Thiem}}$  is 22 times higher than  $K_{\text{Hvorslev}}$  in section 11.5–12.5 m and 6 times higher in section 10.5–11.5 m. Water level had minor change within both sections (very low K-value) which may be the reason for the large difference between  $K_{\text{Hvorslev}}$  and  $K_{\text{Thiem}}$ . Same difference was seen in 2007, 2008 and 2009 results.

In the PVP- and HP-tubes, higher conductivities are observed, and the interpreted hydraulic conductivities according to two methods match relatively well. Also in PVP- and HP-tubes higher conductivities correlate better than the lower conductivities. In two tubes, OL-PVP9B and OL-PVP19,  $K_{\text{Thiem}}$  gives a smaller value than  $K_{\text{Hvorslev}}$ .

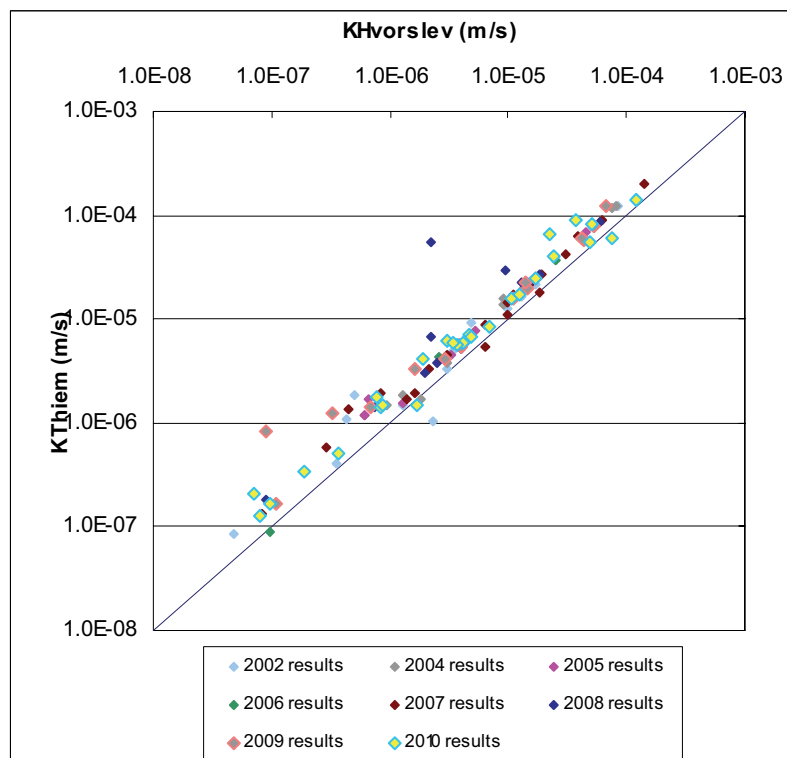
The coefficient of correlation ( $R^2$ ), which measures the linear relationship between  $\ln(H-h) / (H-H_0)$  and time  $t$ , decreases clearly when the hydraulic conductivity in PP-holes is less than  $1 \cdot 10^{-8}$  m/s. In earlier years the correlation slightly decreases in PVP-tubes when the hydraulic conductivity is less than  $1 \cdot 10^{-6}$  m/s. In 2010 results, the correlation is relatively good except in some tubes (OL-PVP9B, OL-PVP10A, OL-PVP32 and OL-PVP 31B) regardless of the value of the hydraulic conductivity (Figure 6-2).

Two sections of OL-PP39, 10.5–11.5 m and 11.5–12.5 m, give low  $R^2$  values. That is because the conductivities in those sections are so low that macro can not recognize lowering linear trend on the semi-log plot (Figure 5-1 a). This was also seen in 2006, 2007, 2008 and 2009 results.

a)

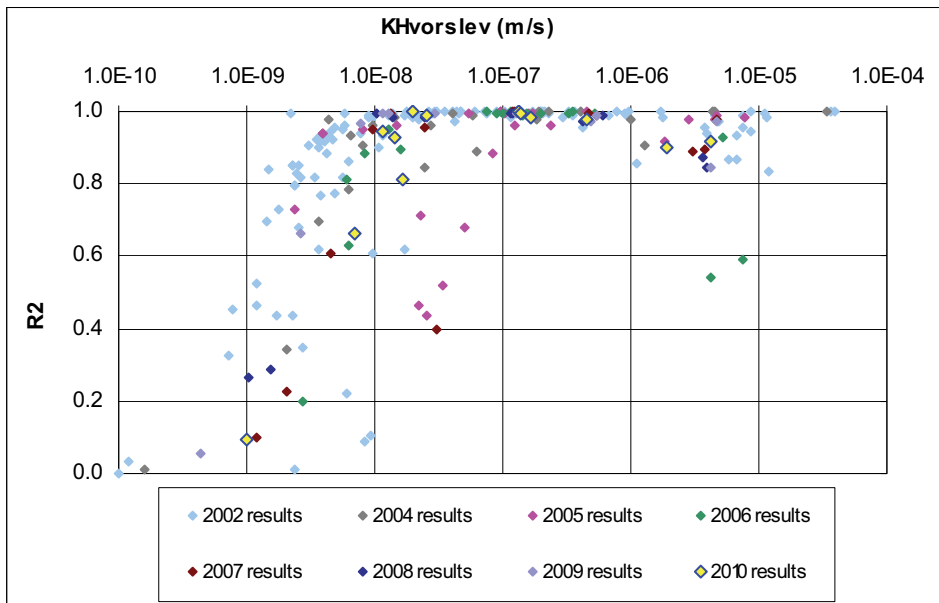


b)

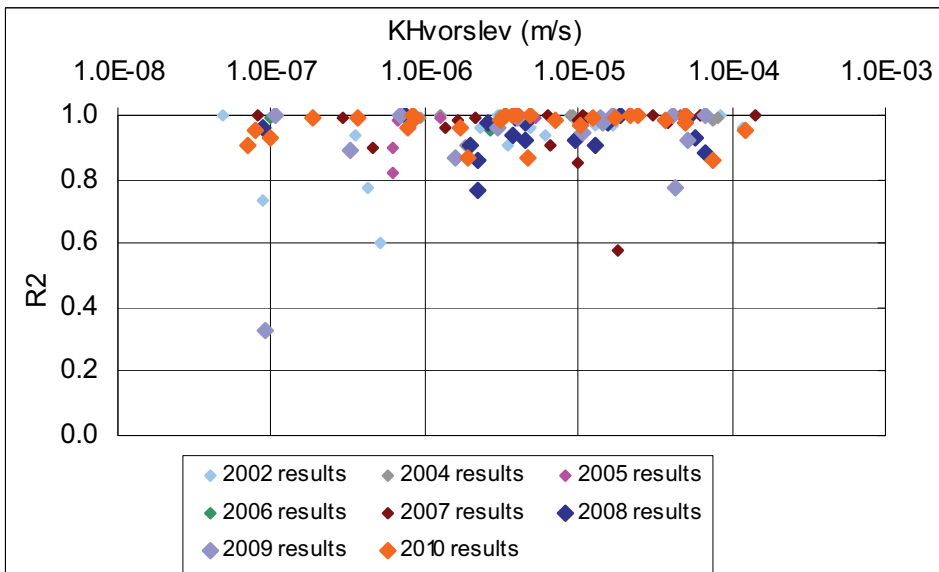


**Figure 6-1.** Comparison of the hydraulic conductivities calculated either by the Hvorslev's method or using Thiem's formula a) in PP-holes, the holes with diameter 56 mm are marked with red circles, and b) in PVP- and HP-tubes.

a)



b)

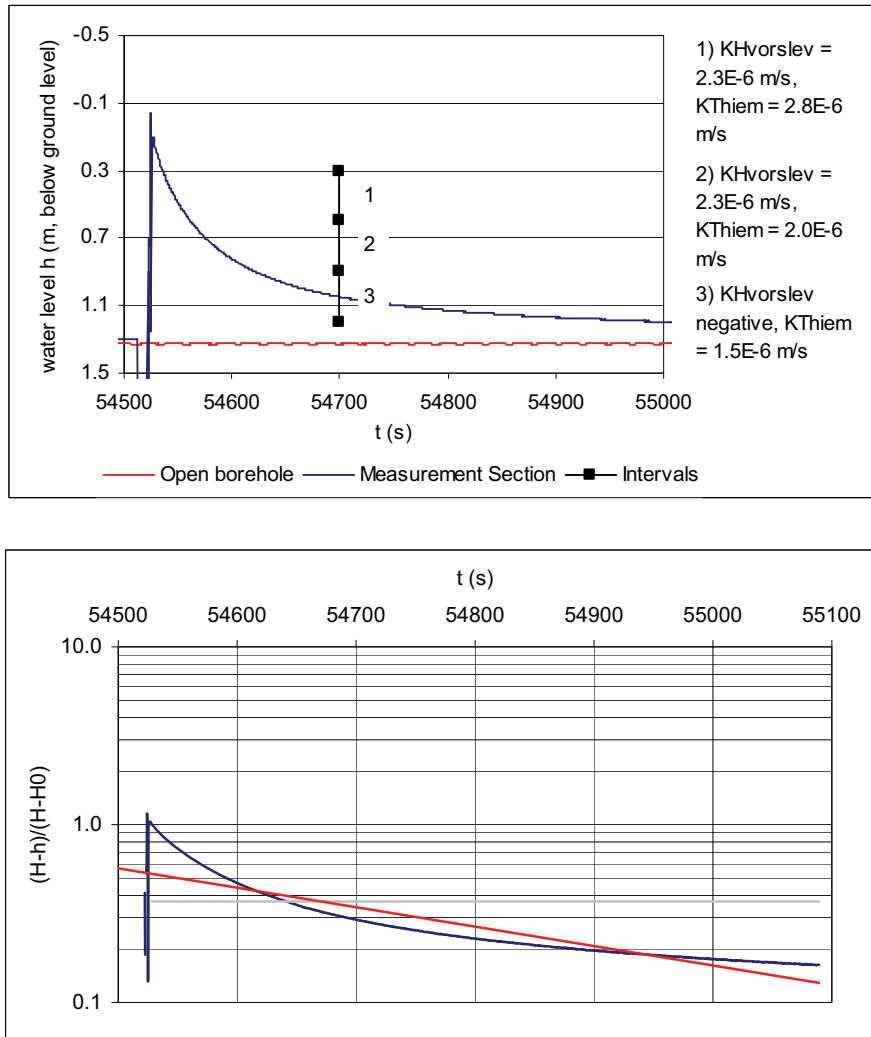


**Figure 6-2.**  $R^2$  as a function of hydraulic conductivity  $K$  in a) PP-holes and b) PVP- and HP-tubes.

## 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. This has proven to be the biggest source of influence that causes variation when comparing earlier year results. If used time interval is different to earlier year, then the  $K$ -value is

also different even when the observed lowering water level curve would be exactly the same. 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 3 to 31), the time range used in the interpretation according to Thiem's formula and in the Hvorslev's method is therefore shown.



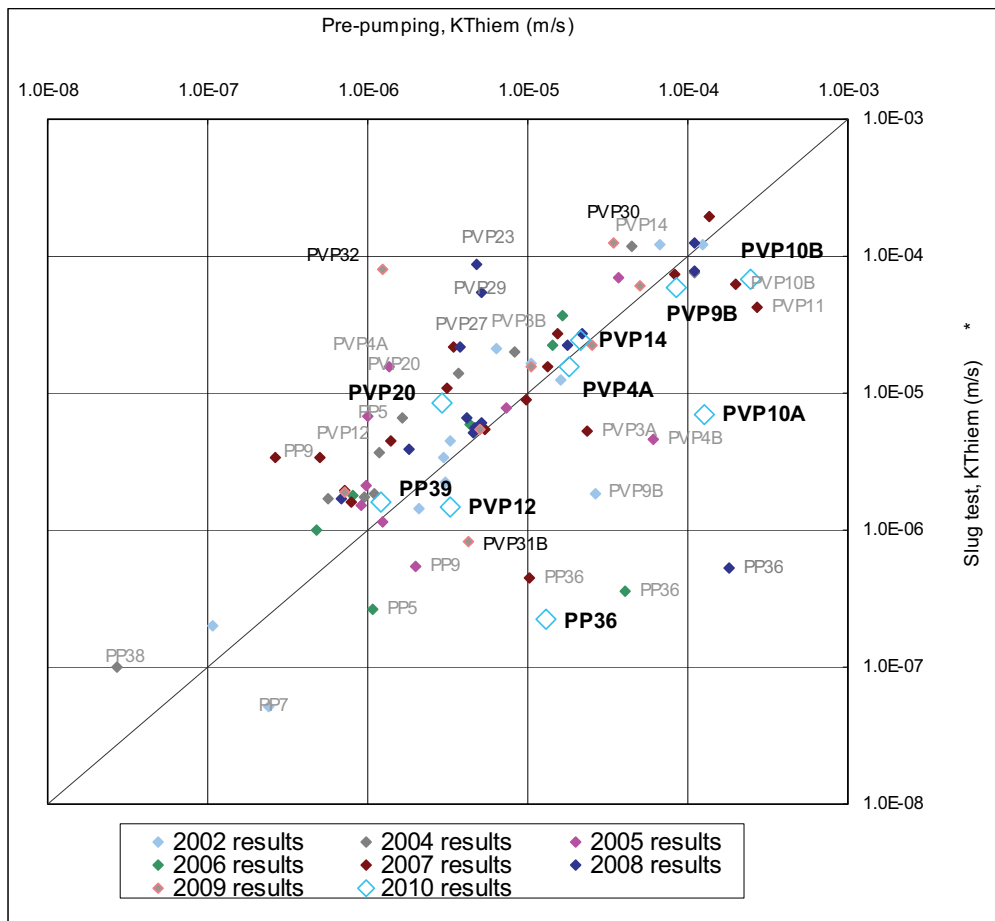
**Figure 6-3.** An example how the time selected for the interpretation affects the resulting hydraulic conductivity. Three time intervals were used each corresponding to approximately one third of the recovery. The example is from OL-PP2 at depth of 19.42 m (Hellä & Heikkinen 2004). The interpreted 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 spring and autumn 2010. Water samples were taken from OL-PP36, OL-PP39, OL-PVP4A, OL-PVP9B, OL-PVP10A, OL-PVP10B, OL-PVP12, OL-PVP14 and OL-PVP20. Before taking the samples, the hole is pre-pumped for a certain period of time, typically for few hours. The yield (l/min) and the change in the water table (m) are measured.

Using the pumping 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 interpreted 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 33.



**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 quite well with those from the slug-tests, though there are exceptions (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; Keskitalo & Lindgren 2007; Partamies et al. 2008; Pitkänen et al. 2009; Penttinen et al. 2011; Keskitalo 2008, 2009, Isola 2010). In general, pre-pumping values are slightly lower. This is natural, because pre-pumping lasts longer than the slug-test and as a result of natural overtime, decrease of flow lower the 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. Another reason could be dirty/clayish water that blocks the small holes in measurement section during slug-test. Longer lasting pre-pumping could clear the holes better.

In the observation tube OL-PVP10A the pre-pumping result differs most from the 2010 slug-test results (Appendix 33). However the pumping result is quite well in accordance with the former slug test results from the years 2002 and 2007.

In 2009 the pre-pumping result in OL-PVP32 was significantly lower than in the slug-test (Isola 2010). The explanation for this a long and deep investigation trench excavated next to OL-PVP32. This caused dramatic water level drop in OL-PVP32. During the slug-test after filling up the trench water level was still very low and it was in the limit that slug-test was even possible to perform. In Isola 2010 it was assumed that when OL-PVP32 is tested again and water level is higher, the K-value should be significantly lower. The observation tube was tested again in 2010 and the slug-test result ( $K_{\text{Thiem}} 2.1 \cdot 10^{-7}$  m/s) was smaller than the previous pre-pumping result  $1.2 \cdot 10^{-6}$  m/s although the groundwater level was still quite low.

In OL-PP36, the pre-pumping result is significantly higher than the slug-test result which is well in accordance with the former slug test results from the years 2006, 2007 and 2008. It is very likely that there is a conductive fracture outside the range measured in the slug-tests.



## 7 CONCLUSIONS

Slug-tests were performed in several shallow PP-holes and PVP/HP-tubes at the Olkiluoto Island during the summer 2010. The measurements were carried out using the same technique developed by PRG-Tec Oy as in the measurements in 2002, 2004, 2005, 2006, 2007, 2008 and 2009 (Hellä & Heikkinen 2004; Tammisto et al. 2005; Tammisto & Lehtinen 2006; Keskitalo & Lindgren 2007; Keskitalo 2008, 2009; Isola 2010). The equipment in use was a renewed version including some modifications.

The measurement results were interpreted by 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 the year 2010, hydraulic conductivities in PP-holes range from  $10^{-9}$  m/s to  $10^{-6}$  m/s and in PVP- and HP-tubes from  $10^{-8}$  m/s to  $10^{-4}$  m/s. The range is quite similar to one in measurements of years 2002 and 2004–2009. With the applied technique in PP-holes hydraulic conductivities in the range  $4 \cdot 10^{-10}$ – $5 \cdot 10^{-5}$  m/s and  $1 \cdot 10^{-8}$ – $7 \cdot 10^{-5}$  m/s in PVP/HP-tubes can be detected. The detection limits of hydraulic conductivity depend on the length of the test sections and the overpressure used.

The results from holes and tubes measured in 2010 and results from earlier measurements were compared. In general, the results are quite close to each other. In OL-PVP14, the earlier observed lowering trend of the conductivity seems to have stabilized. Overall minor difference to earlier years' results can be explained by disturbance factors in measurement, accuracy limit in Slug-testing method and the slightly different way macro analyzes water-level-drop-curves because of the variation of measuring time used.

The interpreted hydraulic conductivities from the slug-tests were also compared to those obtained by the pre-pumping during the water sampling. The comparison showed that results without disturbance factor are in accordance with each other. Only two or three exceptions were noticed in OL-PP36, OL-PVP10A and OL-PVP20.



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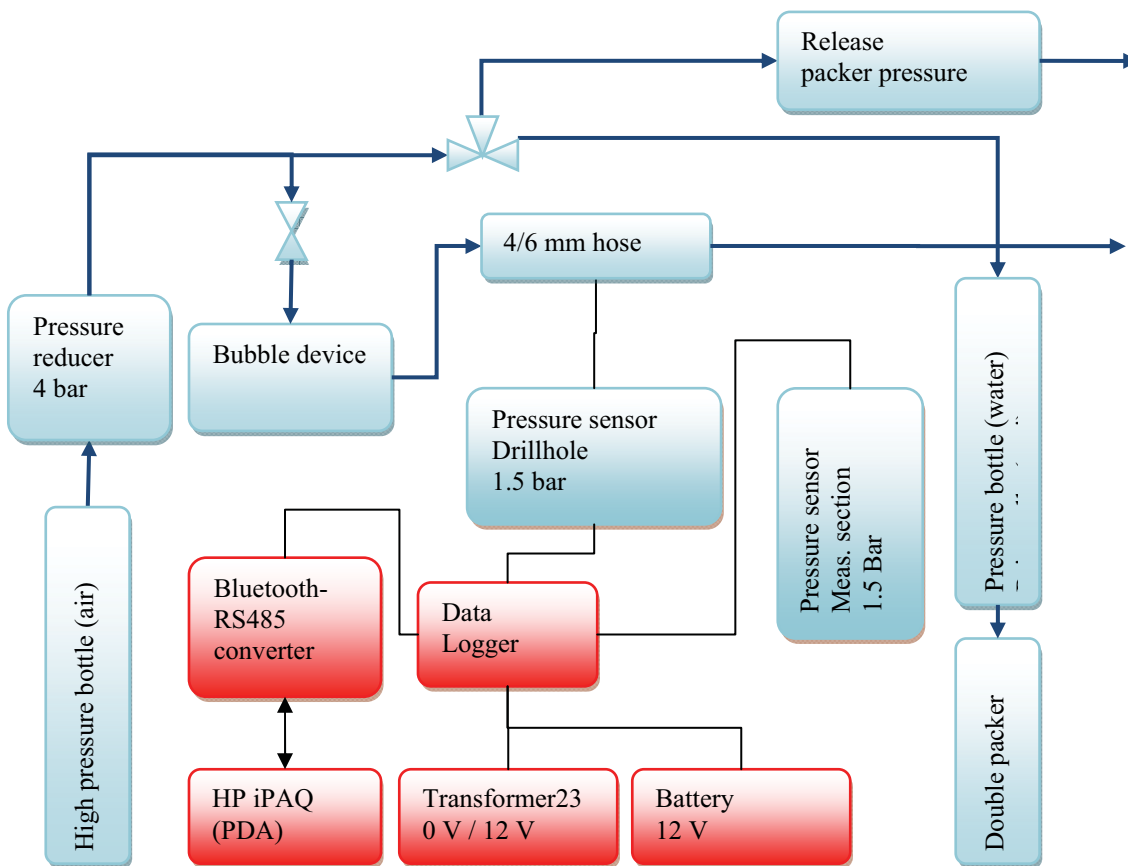
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## APPENDIX 1 MEASUREMENT EQUIPMENT

The principle of the tool was introduced in the first slug-test report (Hellä & Heikkinen 2004). The equipment for measurements was modified in the beginning of the year 2010 but the principle is still the same.

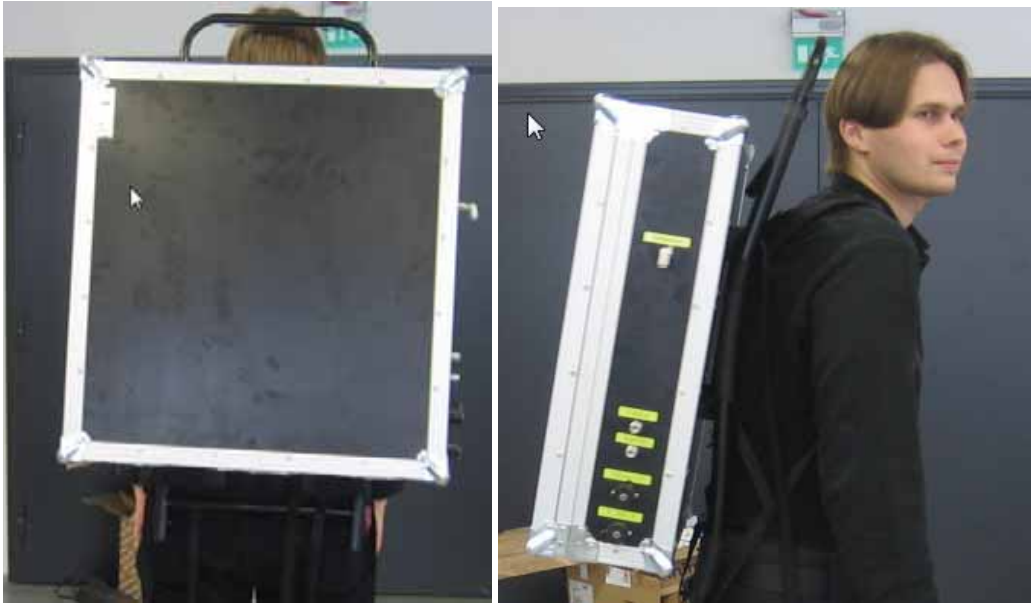
Block diagram in figure 1 shows the main parts of the equipment. Components which are renewed are presented with red shaded. Also a new measuring program was programmed to PDA-unit.



**Figure 1.** Block diagram of the tool.

Other components except those used in a hole were installed into a plywood box which is easy to carry (Figure 2).





**Figure 2.** Transport box was made of plywood and it's easy to carry on one's back.

The equipment is instantly ready for use after opening the box (Figure 3). The tool can be used with 220 V (AC) or 12 V (DC).



**Figure 3.** Transport box opened.

## **APPENDIX 2 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). Use of the renewed measuring equipment in 2010 caused also some modifications to the interpretation macros. More data is given in the makefile instead of the header of a measurement file: Borehole diameter, section length, top of the casing (TOC), depth of pressure sensor/borehole, depth of pressure sensor/measurement section, depth of pressure sensor/measurement section (after movement), depth of the upper part of the perforated section (HP- and PVP-holes). The version number of the macro used in the interpretation is 1.5.

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:

- Drillhole name
- Calibration file name
- Section length (m)
- Runnin number of the test

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  |
| Time (d) (column D)                        | Time, days from the beginning of the year   |
| Phase (column E)                           | 1 = open borehole equipment installed<br>2 = inflation of packers + stabilization of pressure<br>3 = pressure increase + recovery phase |
| WaterLevelBorehole(m) (column G)           | water column above pressure sensor of borehole water  |
| WaterLevelMeasurementSection(m) (column I) | 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
- $H_i$ , 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,  $H_0^* = \min(\text{water level in test section})$ ,  $H_0 = \text{water level in test section 10 observations after } H_0^*$ , 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
- $t_{\text{end}}$  (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  $t_{\text{end}}$
- $T_0$ , 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
  - o  $t_1$  (s) corresponds to the time when h is equal to  $(H + H_0) / 2$ , if such h is not reached  $t_1$  is defined to be the time corresponding to one third of the recovery period.
  - o  $t_2$  (s) is 20 observations later
- no flow
  - o  $t_1$  (s) is 20 observations later than  $t_0$
  - o  $t_2$  (s) is determined to be  $t_0 + (t_{\text{end}} - t_0)/3$ , but if the recovery period is short, less than 40 time steps, then the whole recovery is used i.e.  $t_2$  equal to  $t_{\text{end}}$
- $h_1$  (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,  $\Delta h$  in equation 4-5,  $dh = (h_1 + h_2)/2 - H_0$
- Q (m<sup>3</sup>/s) observed flow in time  $t_1 - t_2$
- $K_{\text{Thiem}}$  (m/s) hydraulic conductivity assuming  $r_0 = 14$  m
- logK
- $K_{\text{Hvorslev}} / K_{\text{Thiem}}$  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.

### APPENDIX 3 MEASUREMENTS AND RESULTS IN OL-PP36

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PP36 \_\_\_\_\_

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 4.30 m

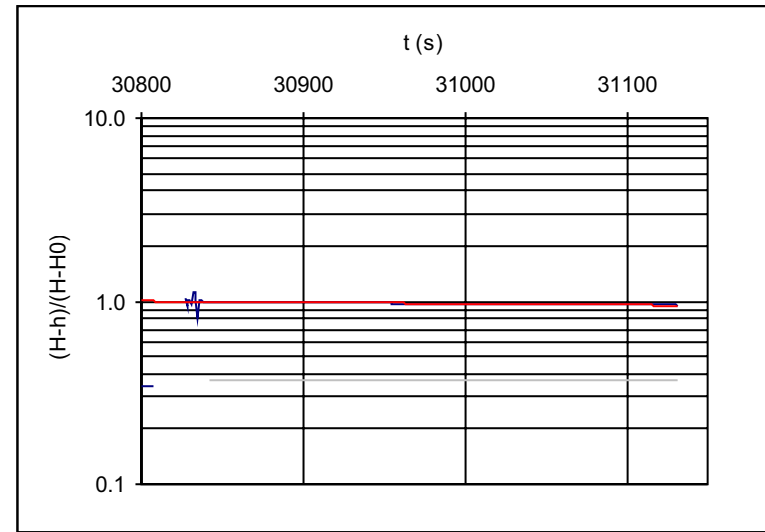
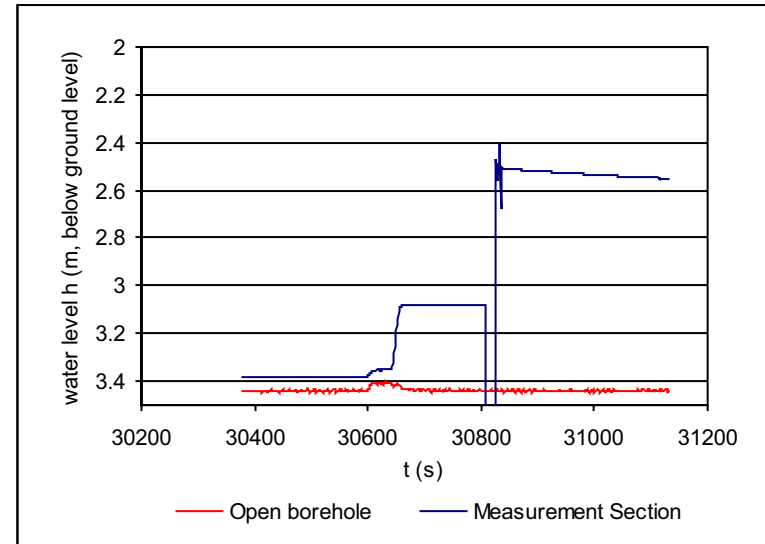
The reference level to depth is top of the casing, the length of the casing is 0.78 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE!                      |
|------|-----------|-------|-------|--|--|-------------------|----------------------------|
| 37   | 27.8.2010 | 8:25  | 6     | 4.45                                       | 4.45                                       | 0.75              | measurement failed         |
| 38   | 27.8.2010 | 8:45  | 6     | 4.45                                       | 4.45                                       | 1.50              | 460 ml water into the tube |
| 39   | 27.8.2010 | 10:10 | 7     | 4.45                                       | 4.45                                       | 1.50              |                            |
| 40   | 27.8.2010 | 10:40 | 8     | 4.45                                       | 4.45                                       | 1.50              |                            |
| 41   | 27.8.2010 | 12:10 | 9     | 4.45                                       | 4.45                                       | 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                       |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|--------------------------------|
| PP36000037.dat        | 5.72   | 2.54E-08             | 0.990 | 4.97E-08               | 5.33E-08                | T0 not reached                 |
| PP36000038.dat        | 5.72   | 2.01E-08             | 0.999 | 3.67E-08               | 3.34E-08                | T0 not reached                 |
| PP36000039.dat        | 6.72   | 1.34E-07             | 0.999 | 2.12E-07               | 2.48E-07                | T0 not reached                 |
| PP36000040.dat        | 7.72   | 4.49E-07             | 0.978 | 7.90E-07               | 8.14E-07                |                                |
| PP36000041.dat        | 8.72   | 1.17E-08             | 0.942 | 2.01E-08               | 4.01E-08                | T0 not reached Thiem different |

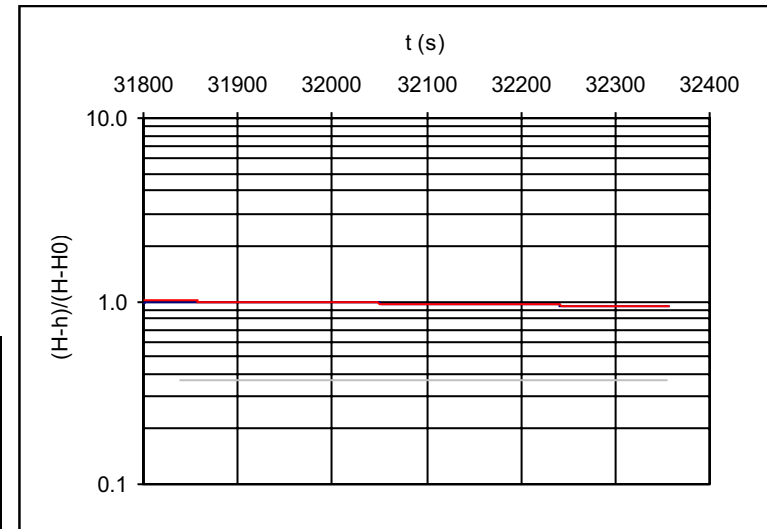
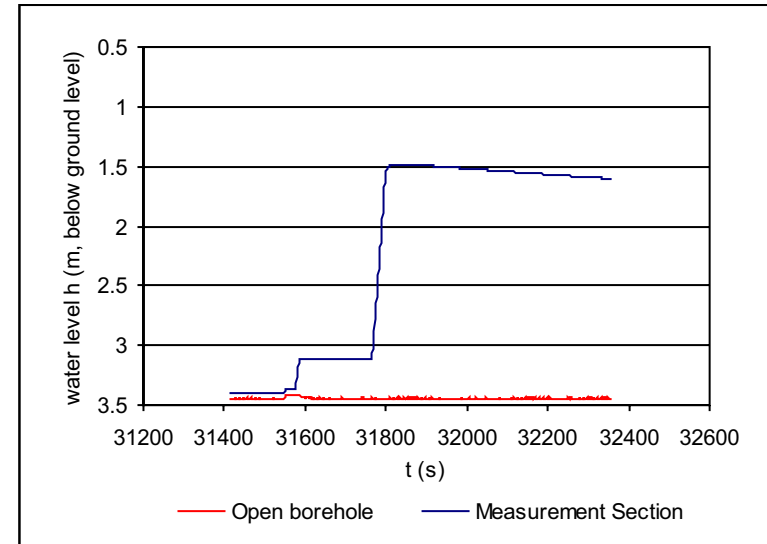
|  |                       |   |                                 |
|--|-----------------------|---|---------------------------------|
| input file                                 | <b>PP36000037.dat</b> | date  |                                 |
| TOC (m)                                    | 0.78                  | ref toc   | min open bore-hole pressure (m) |
| depth of pressure sensor open hole (m)     | 4.45                  | 3.45  | ref ground level                |
| depth of pressure sensor meas. section (m) | 4.45                  | initial, ref toc  |                                 |
| depth of pressure sensor meas. section (m) | 5.2                   | final, ref toc  |                                 |
| depth of meas. section (m)                 | 6                     | ref TOC, top  |                                 |
| depth of meas. section (m)                 | 5.72                  | 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  | 3.38                  | reference water level at the measurement section based on phase 1, ref ground level |                                 |
| H <sub>0</sub>                             | 2.51                  | water level at the measurement section after disturbance, ref ground level          |                                 |
| t <sub>0</sub>                             | 30842.0               | time of disturbance   |                                 |
| t <sub>end</sub> (s)                       | 31131.0               | end of time range used to line fitting  |                                 |
| Time range (s)                             | 289.0                 | Time range used for interpretation  |                                 |
| T <sub>0</sub>                             | 6063.8                | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |                                 |
| 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                 |   |                                 |
| <b>K (m/s)</b>                             | <b>2.54E-08</b>       | <b>T0 not reached</b>   |                                 |
| logK                                       | -7.60                 |   |                                 |

|                                |             |  |                 |        |       |
|--------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                              | b           | <b>flow</b>                                |                 |        |       |
| -0.00016401                    | -0.00547488 | t1   | 30928.0         | h1     | 2.52  |
| 9.93313E-07                    | 0.000165852 | t2   | 30948.0         | h2     | 2.53  |
| <b>0.9895</b>                  | 0.001416085 | Q (m <sup>3</sup> /s)                      | 4.31E-08        | dh (m) | 0.86  |
| 27262.54134                    | 288         | K <sub>Thiem</sub> (m/s)                   | <b>4.97E-08</b> | logK   | -7.30 |
| 0.054669522                    | 0.000577526 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.51            |        |       |
| <b>Stat tests</b>              |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 165.11      | t1   | 30862.0         | h1     | 2.51  |
| test stat, b <> 0              | 33.01       | t2   | 30938.0         | h2     | 2.53  |
| t-critical, 90%                | 1.97        | Q (m <sup>3</sup> /s)                      | 4.66E-08        | dh (m) | 0.87  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>5.33E-08</b> | logK   | -7.27 |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.48            |        |       |



|  |                       |   |                                 |
|--|-----------------------|---|---------------------------------|
| input file                                 | <b>PP36000038.dat</b> | date  |                                 |
| TOC (m)                                    | 0.78                  | ref toc   | min open bore-hole pressure (m) |
| depth of pressure sensor open hole (m)     | 4.45                  | 3.45  | ref ground level                |
| depth of pressure sensor meas. section (m) | 4.45                  | initial, ref toc  |                                 |
| depth of pressure sensor meas. section (m) | 4.45                  | final, ref toc  |                                 |
| depth of meas. section (m)                 | 6                     | ref TOC, top  |                                 |
| depth of meas. section (m)                 | 5.72                  | 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  | 3.40                  | reference water level at the measurement section based on phase 1, ref ground level |                                 |
| H <sub>0</sub>                             | 1.48                  | water level at the measurement section after disturbance, ref ground level          |                                 |
| t <sub>0</sub>                             | 31838.0               | time of disturbance   |                                 |
| t <sub>end</sub> (s)                       | 32356.0               | end of time range used to line fitting  |                                 |
| Time range (s)                             | 518.1                 | Time range used for interpretation  |                                 |
| T <sub>0</sub>                             | 7654.1                | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |                                 |
| 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                 |   |                                 |
| <b>K (m/s)</b>                             | <b>2.01E-08</b>       | <b>T0 not reached</b>   |                                 |
| logK                                       | -7.70                 |   |                                 |

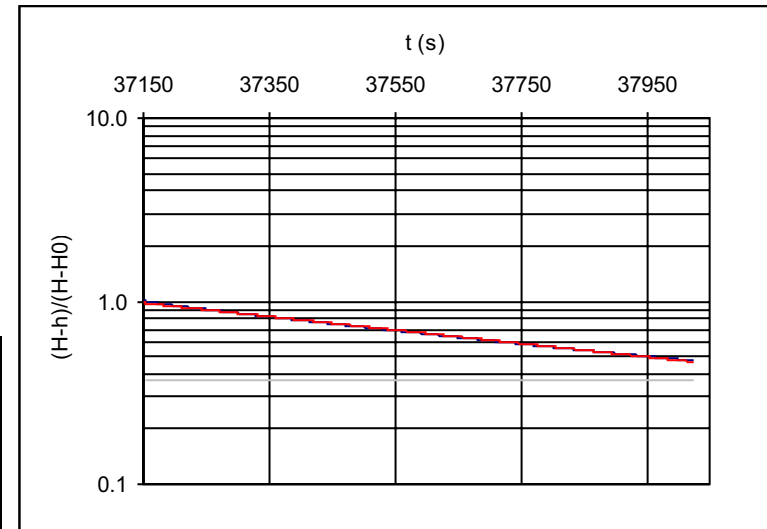
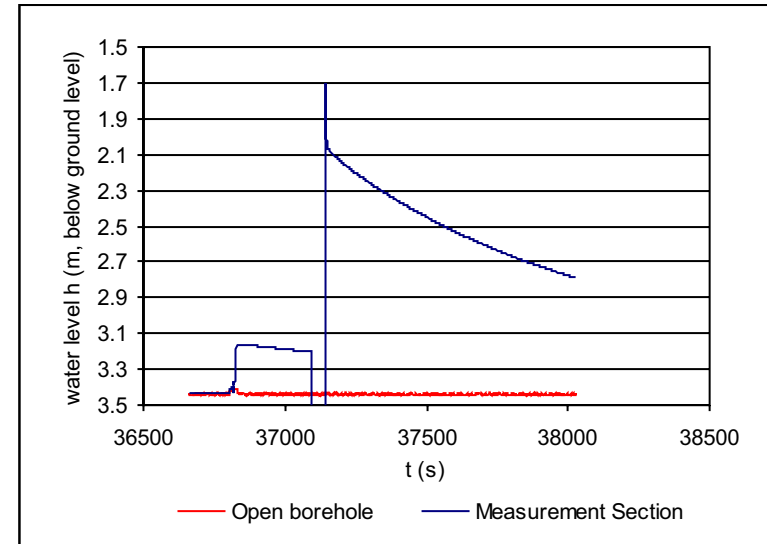
|                                |             |  |                 |        |       |
|--------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                              | b           | <b>flow</b>                                |                 |        |       |
| -0.000130989                   | 0.002603248 | t1   | 32000.0         | h1     | 1.52  |
| 1.54384E-07                    | 4.61982E-05 | t2   | 32020.0         | h2     | 1.52  |
| <b>0.9993</b>                  | 0.00052694  | Q (m <sup>3</sup> /s)                      | 6.99E-08        | dh (m) | 1.88  |
| 719888.6097                    | 517         | K <sub>Thiem</sub> (m/s)                   | <b>3.67E-08</b> | logK   | -7.43 |
| 0.19988831                     | 0.000143553 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.55            |        |       |
| <b>Stat tests</b>              |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 848.46      | t1   | 31858.0         | h1     | 1.48  |
| test stat, b <> 0              | 56.35       | t2   | 32010.0         | h2     | 1.52  |
| t-critical, 90%                | 1.96        | Q (m <sup>3</sup> /s)                      | 6.41E-08        | dh (m) | 1.90  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>3.34E-08</b> | logK   | -7.48 |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.60            |        |       |





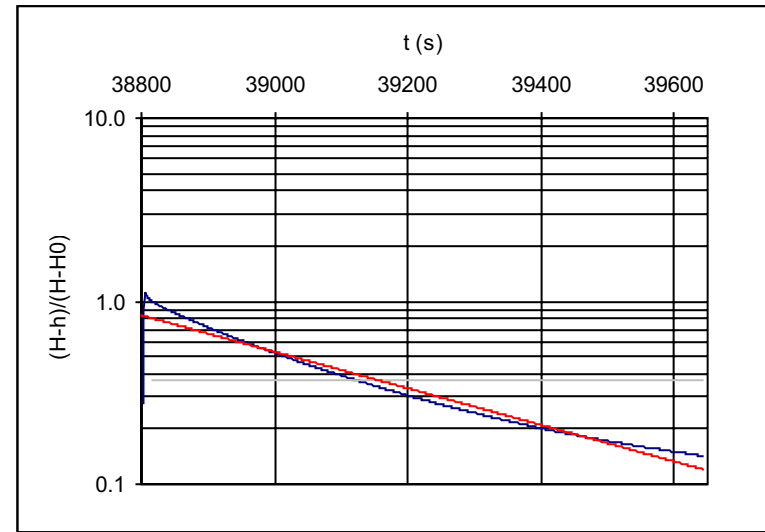
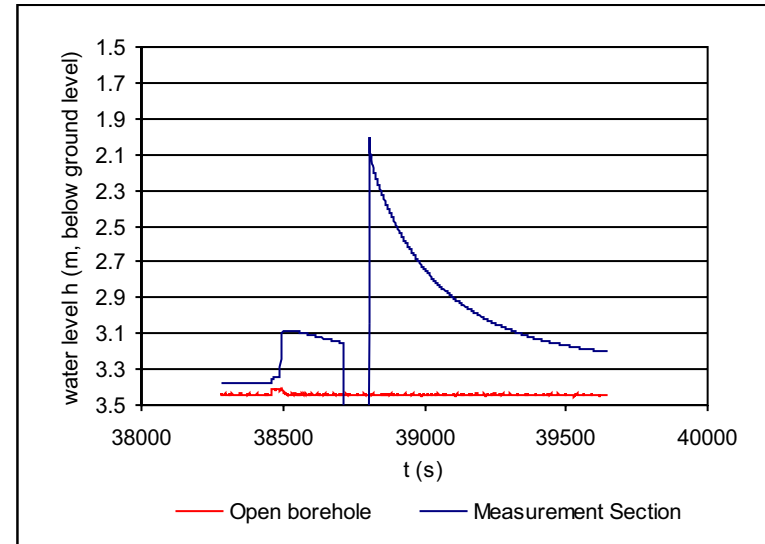
|  |                       |   |                                 |
|--|-----------------------|---|---------------------------------|
| input file                                 | <b>PP36000039.dat</b> | date  |                                 |
| TOC (m)                                    | 0.78                  | ref toc   | min open bore-hole pressure (m) |
| depth of pressure sensor open hole (m)     | 4.45                  | 3.45  | ref ground level                |
| depth of pressure sensor meas. section (m) | 4.45                  | initial, ref toc  |                                 |
| depth of pressure sensor meas. section (m) | 5.95                  | final, ref toc  |                                 |
| depth of meas. section (m)                 | 7                     | ref TOC, top  |                                 |
| depth of meas. section (m)                 | 6.72                  | 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  | 3.43                  | reference water level at the measurement section based on phase 1, ref ground level |                                 |
| H <sub>0</sub>                             | 2.07                  | water level at the measurement section after disturbance, ref ground level          |                                 |
| t <sub>0</sub>                             | 37154.0               | time of disturbance   |                                 |
| t <sub>end</sub> (s)                       | 38025.0               | end of time range used to line fitting  |                                 |
| Time range (s)                             | 871.0                 | Time range used for interpretation  |                                 |
| T <sub>0</sub>                             | 1148.8                | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |                                 |
| 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                 |   |                                 |
| <b>K (m/s)</b>                             | <b>1.34E-07</b>       | <b>T0 not reached</b>   |                                 |
| logK                                       | -6.87                 |   |                                 |

|                                |              |  |                 |        |
|--------------------------------|--------------|--|-----------------|--------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |
| a                              | b            | <b>flow</b>                                |                 |        |
| -0.000847443                   | -0.026478338 | t1   | 37940.0         | h1     |
| 9.65606E-07                    | 0.000485729  | t2   | 37960.0         | h2     |
| <b>0.9989</b>                  | 0.007177676  | Q (m <sup>3</sup> /s)                      | 1.46E-07        | dh (m) |
| 770231.9686                    | 870          | K <sub>Thiem</sub> (m/s)                   | <b>2.12E-07</b> | logK   |
| 39.68160365                    | 0.044821556  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.63            | -6.67  |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |
| test stat, a <> 0              | 877.63       | t1   | 37174.0         | h1     |
| test stat, b <> 0              | 54.51        | t2   | 37444.0         | h2     |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 2.95E-07        | dh (m) |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>2.48E-07</b> | logK   |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.54            | -6.61  |



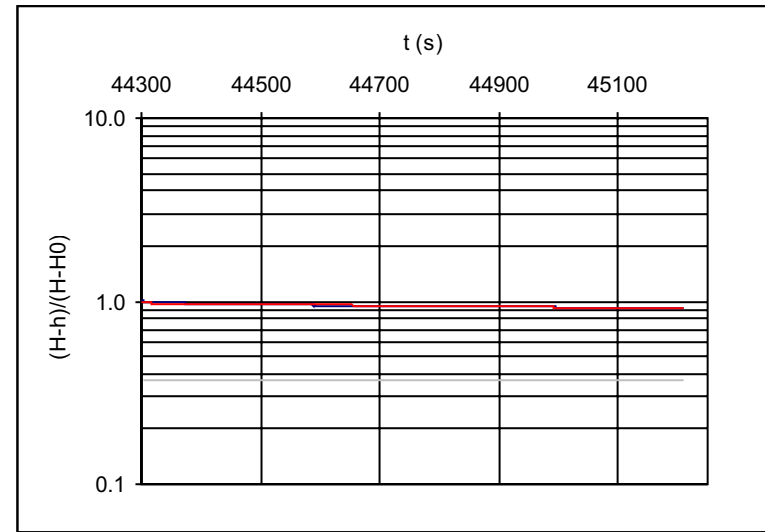
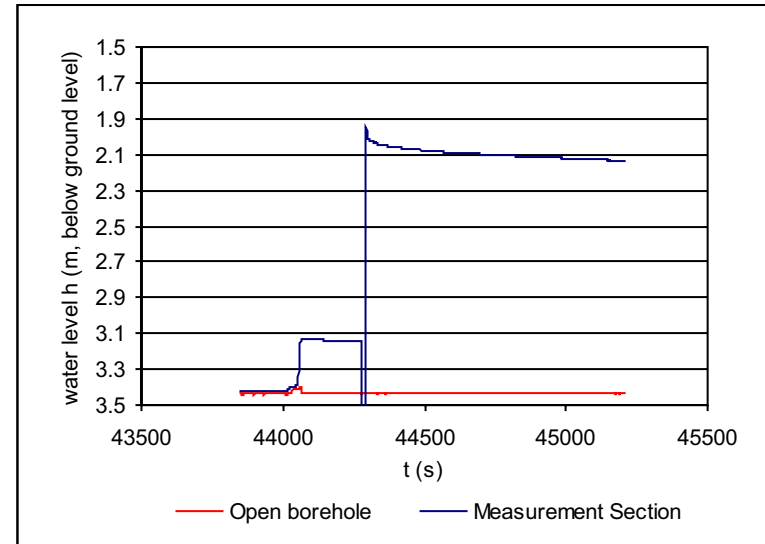
|  |                       |   |                                 |
|--|-----------------------|---|---------------------------------|
| input file                                 | <b>PP36000040.dat</b> | date  |                                 |
| TOC (m)                                    | 0.78                  | ref toc   | min open bore-hole pressure (m) |
| depth of pressure sensor open hole (m)     | 4.45                  | 3.45  | ref ground level                |
| depth of pressure sensor meas. section (m) | 4.45                  | initial, ref toc  |                                 |
| depth of pressure sensor meas. section (m) | 5.95                  | final, ref toc  |                                 |
| depth of meas. section (m)                 | 8                     | ref TOC, top  |                                 |
| depth of meas. section (m)                 | 7.72                  | 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  | 3.38                  | reference water level at the measurement section based on phase 1, ref ground level |                                 |
| H <sub>0</sub>                             | 2.15                  | water level at the measurement section after disturbance, ref ground level          |                                 |
| t <sub>0</sub>                             | 38815.0               | time of disturbance   |                                 |
| t <sub>end</sub> (s)                       | 39643.0               | end of time range used to line fitting  |                                 |
| Time range (s)                             | 828.0                 | Time range used for interpretation  |                                 |
| T <sub>0</sub>                             | 342.8                 | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |                                 |
| 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                 |   |                                 |
| <b>K (m/s)</b>                             | <b>4.49E-07</b>       |   |                                 |
| logK                                       | -6.35                 |   |                                 |

|                                |              |   |                 |        |       |
|--------------------------------|--------------|---|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                            |                 |        |       |
| a                              | b            | <b>flow</b>   |                 |        |       |
| -0.002298054                   | -0.212192766 | t1  | 39004.0         | h1     | 2.75  |
| 1.18802E-05                    | 0.005680748  | t2  | 39024.0         | h2     | 2.78  |
| <b>0.9784</b>                  | 0.081858667  | Q (m <sup>3</sup> /s)                                 | 4.90E-07        | dh (m) | 0.61  |
| 37417.33484                    | 827          | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>7.90E-07</b> | logK   | -6.10 |
| 250.7276224                    | 5.54159575   | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.57            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>  |                 |        |       |
| test stat, a <> 0              | 193.44       | t1  | 38835.0         | h1     | 2.26  |
| test stat, b <> 0              | 37.35        | t2  | 39091.0         | h2     | 2.89  |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                                 | 6.65E-07        | dh (m) | 0.81  |
|                                |              | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>8.14E-07</b> | logK   | -6.09 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.55            |        |       |



|  |                       |   |                                 |
|--|-----------------------|---|---------------------------------|
| input file                                 | <b>PP36000041.dat</b> | date  |                                 |
| TOC (m)                                    | 0.78                  | ref toc   | min open bore-hole pressure (m) |
| depth of pressure sensor open hole (m)     | 4.45                  | 3.44  | ref ground level                |
| depth of pressure sensor meas. section (m) | 4.45                  | initial, ref toc  |                                 |
| depth of pressure sensor meas. section (m) | 5.95                  | final, ref toc  |                                 |
| depth of meas. section (m)                 | 9                     | ref TOC, top  |                                 |
| depth of meas. section (m)                 | 8.72                  | 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  | 3.42                  | reference water level at the measurement section based on phase 1, ref ground level |                                 |
| H <sub>0</sub>                             | 2.02                  | water level at the measurement section after disturbance, ref ground level          |                                 |
| t <sub>0</sub>                             | 44305.0               | time of disturbance   |                                 |
| t <sub>end</sub> (s)                       | 45209.0               | end of time range used to line fitting  |                                 |
| Time range (s)                             | 904.0                 | Time range used for interpretation  |                                 |
| T <sub>0</sub>                             | 13107.4               | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |                                 |
| 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                 |   |                                 |
| <b>K (m/s)</b>                             | <b>1.17E-08</b>       | <b>T0 not reached</b>   |                                 |
| logK                                       | -7.93                 |   |                                 |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -7.44379E-05                   | -0.024314789 | t1   | 44596.0         | h1     | 2.09  |
| 6.14584E-07                    | 0.000320874  | t2   | 44616.0         | h2     | 2.09  |
| <b>0.9420</b>                  | 0.004830174  | Q (m <sup>3</sup> /s)                      | 2.70E-08        | dh (m) | 1.33  |
| 14669.88067                    | 903          | K <sub>Thiem</sub> (m/s)                   | <b>2.01E-08</b> | logK   | -7.70 |
| 0.342256887                    | 0.021067518  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.59            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 121.12       | t1   | 44325.0         | h1     | 2.03  |
| test stat, b <> 0              | 75.78        | t2   | 44606.0         | h2     | 2.09  |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 5.51E-08        | dh (m) | 1.36  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>4.01E-08</b> | logK   | -7.40 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.29            |        |       |



## APPENDIX 4 MEASUREMENTS AND RESULTS IN OL-PP39

Area:  
Olkiluoto

Hole:  
PP39

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio

Water level before starting 1.60 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! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 29   | 26.8.2008 | 8:10  | 5     | 1.75                                       | 1.75                                       | 1.50              |       |
| 30   | 26.8.2008 | 8:37  | 6     | 1.75                                       | 1.75                                       | 1.50              |       |
| 31   | 26.8.2008 | 11:31 | 7     | 1.75                                       | 1.75                                       | 1.50              |       |
| 32   | 26.8.2008 | 12:00 | 8     | 1.75                                       | 1.75                                       | 1.50              |       |
| 33   | 26.8.2008 | 12:25 | 9     | 1.75                                       | 1.75                                       | 1.50              |       |
| 34   | 26.8.2008 | 12:56 | 10    | 1.75                                       | 1.75                                       | 1.50              |       |
| 35   | 26.8.2008 | 14:38 | 11    | 1.75                                       | 1.75                                       | 1.50              |       |
| 36   | 26.8.2008 | 15:03 | 12    | 1.75                                       | 1.75                                       | 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                            |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|-------------------------------------|
| PP39000029_hhi.dat    | 5  | 1.66E-07             | 0.986 | 2.16E-07               | 3.53E-07                | T0 not reached                      |
| PP39000030_hhi.dat    | 6  | 1.43E-08             | 0.927 | 1.95E-08               | 5.00E-08                | T0 not reached Thiem different      |
| PP39000031_hhi.dat    | 7  | 4.24E-06             | 0.916 | 7.45E-06               | 6.40E-06                |                                     |
| PP39000032_hhi.dat    | 8  | 1.94E-06             | 0.900 | 4.72E-06               | 5.59E-06                | Shorter time used in interpretation |
| PP39000033_hhi.dat    | 9  | 1.66E-08             | 0.812 | 4.27E-08               | 6.91E-08                | T0 not reached Thiem different      |
| PP39000034_hhi.dat    | 10   | 1.36E-07             | 0.994 | 2.08E-07               | 2.80E-07                | T0 not reached                      |
| PP39000035_hhi.dat    | 11   | 7.10E-09             | 0.666 | 5.28E-09               | 4.32E-08                | T0 not reached Thiem different      |
| PP39000036_hhi.dat    | 12   | 9.85E-10             | 0.091 | -8.41E-10              | 2.18E-08                | T0 not reached Thiem different      |

input file **PP39000029\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore-hole pressure (m) 1.00 ref ground level

sensor open hole (m)

depth of pressure 1.75 initial, ref toc

sensor meas. section (m)

depth of pressure 3.25 final, ref toc

sensor meas. section (m)

depth of meas. section (m) 5 ref TOC, top

depth of meas. section (m) 5 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 1.14 reference water level at the measurement section based on phase 1, ref ground level

H<sub>0</sub> -0.46 water level at the measurement section after disturbance, ref ground level

t<sub>0</sub> 29929.0 time of disturbance

t<sub>end</sub> (s) 30835.0 end of time range used to line fitting

Time range (s) 906.1 Time range used for interpretation

T<sub>0</sub> 926.4 basic time lag, t corresponding the time when  $\ln((H-h)/(H-H_0)) = -1$

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

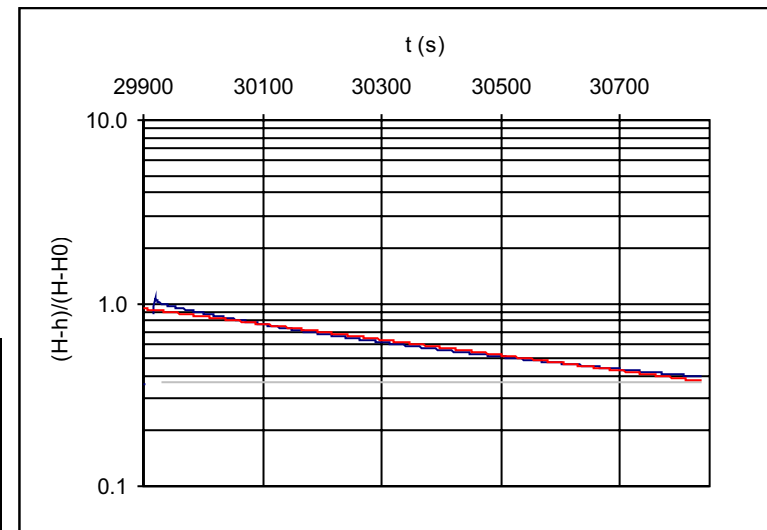
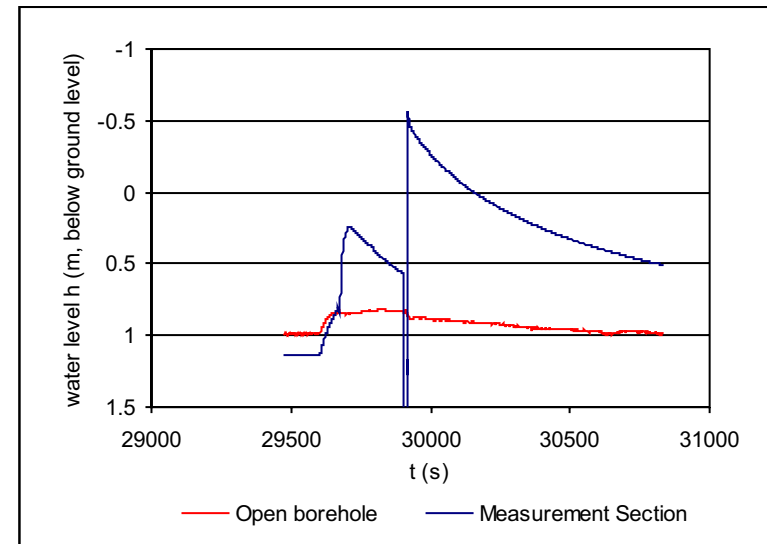
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 1.66E-07 T0 not reached**

logK -6.78

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.000975179                   | -0.096564512 | t1   | 30513.0         | h1     | 0.34  |
| 3.88806E-06                    | 0.00203448   | t2   | 30533.0         | h2     | 0.35  |
| <b>0.9858</b>                  | 0.030658661  | Q (m <sup>3</sup> /s)                      | 1.74E-07        | dh (m) | 0.80  |
| 62907.49278                    | 905          | K <sub>Thiem</sub> (m/s)                   | <b>2.16E-07</b> | logK   | -6.67 |
| 59.13011744                    | 0.850657909  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.77            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 250.81       | t1   | 29949.0         | h1     | -0.39 |
| test stat, b <> 0              | 47.46        | t2   | 30231.0         | h2     | 0.09  |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 4.60E-07        | dh (m) | 1.29  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>3.53E-07</b> | logK   | -6.45 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.47            |        |       |



input file **PP39000030\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore-hole pressure (m) 1.04 ref ground level

sensor open hole (m)

depth of pressure 1.75 initial, ref toc

sensor meas. section (m)

depth of pressure 3.25 final, ref toc

sensor meas. section (m)

depth of meas. section (m) 6 ref TOC, top

depth of meas. section (m) 6 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 1.13 reference water level at the measurement section based on phase 1, ref ground level

H<sub>0</sub> -0.68 water level at the measurement section after disturbance, ref ground level

t<sub>0</sub> 31727.0 time of disturbance

t<sub>end</sub> (s) 32625.0 end of time range used to line fitting

Time range (s) 898.0 Time range used for interpretation

T<sub>0</sub> 10759.6 basic time lag, t corresponding the time when  $\ln((H-h)/(H-H_0)) = -1$

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

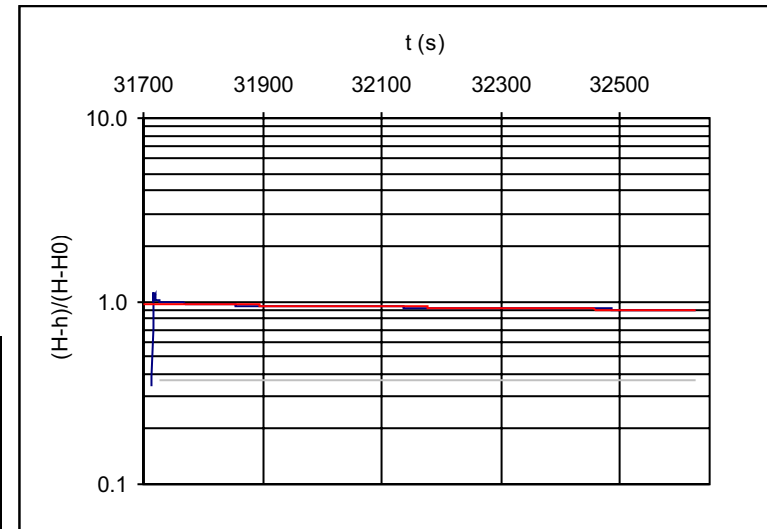
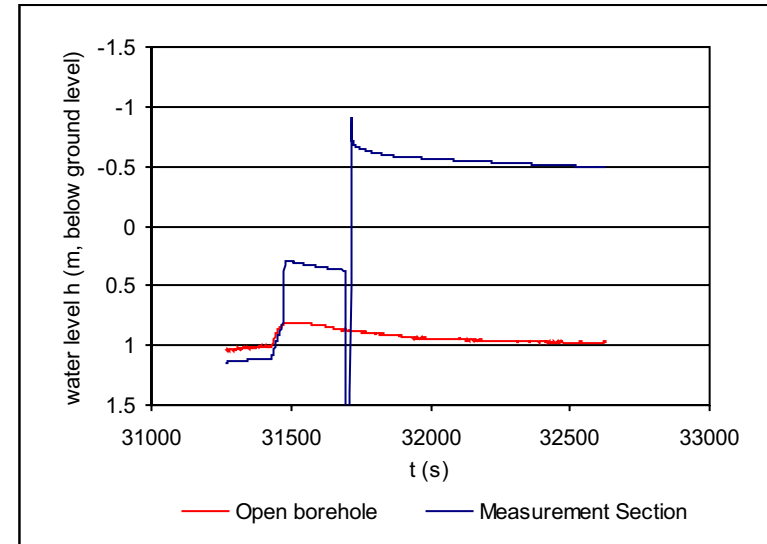
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 1.43E-08 T0 not reached**

logK -7.84

| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -8.96667E-05                   | -0.035223839 | t1   | 32016.0         | h1     | -0.56 |
| 8.38252E-07                    | 0.000434697  | t2   | 32036.0         | h2     | -0.56 |
| <b>0.9273</b>                  | 0.006522637  | Q (m <sup>3</sup> /s)                      | 3.33E-08        | dh (m) | 1.69  |
| 11442.29722                    | 897          | K <sub>Thiem</sub> (m/s)                   | <b>1.95E-08</b> | logK   | -7.71 |
| 0.486810145                    | 0.038162678  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.73            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 106.97       | t1   | 31747.0         | h1     | -0.65 |
| test stat, b <> 0              | 81.03        | t2   | 32026.0         | h2     | -0.56 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 8.77E-08        | dh (m) | 1.73  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>5.00E-08</b> | logK   | -7.30 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.29            |        |       |



input file **PP39000031\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore-hole pressure (m) 1.15 ref ground level

sensor open hole (m)

depth of pressure 1.75 initial, ref toc

sensor meas. section (m)

depth of pressure 3.25 final, ref toc

sensor meas. section (m)

depth of meas. section (m) 7 ref TOC, top

depth of meas. section (m) 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 1.13 reference water level at the measurement section based on phase 1, ref ground level

H<sub>0</sub> 0.47 water level at the measurement section after disturbance, ref ground level

t<sub>0</sub> 42012.0 time of disturbance

t<sub>end</sub> (s) 42159.0 end of time range used to line fitting

Time range (s) 147.0 Time range used for interpretation

T<sub>0</sub> 36.3 basic time lag, t corresponding the time when  $\ln((H-h)/(H-H_0)) = -1$

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

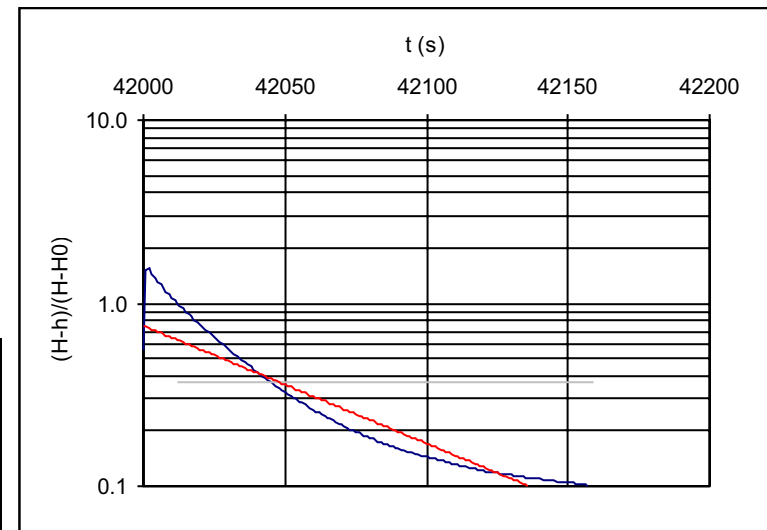
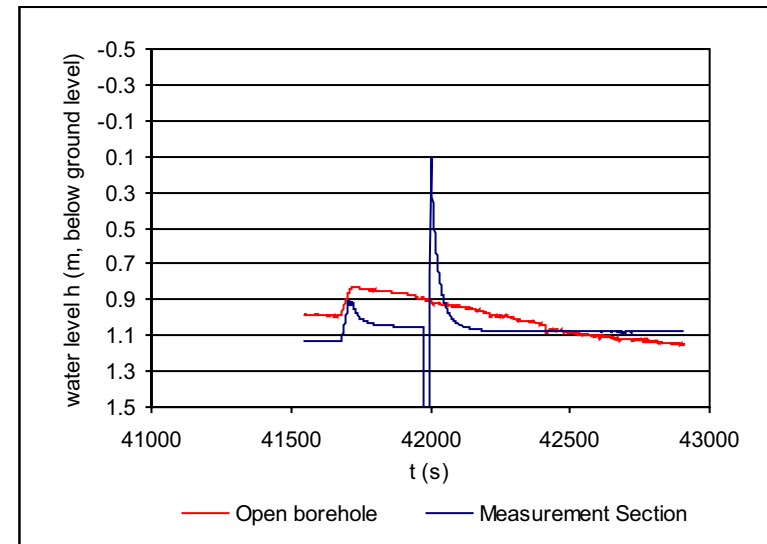
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 4.24E-06**

logK -5.37

| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.014810963                   | -0.461659293 | t1   | 42024.0         | h1     | 0.68  |
| 0.000371481                    | 0.031579969  | t2   | 42044.0         | h2     | 0.88  |
| <b>0.9159</b>                  | 0.193075462  | Q (m <sup>3</sup> /s)                      | 2.66E-06        | dh (m) | 0.35  |
| 1589.620834                    | 146          | K <sub>Thiem</sub> (m/s)                   | <b>7.45E-06</b> | logK   | -5.13 |
| 59.25809837                    | 5.442607554  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.57            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 39.87        | t1   | 42032.0         | h1     | 0.78  |
| test stat, b <> 0              | 14.62        | t2   | 42061.0         | h2     | 0.96  |
| t-critical, 90%                | 1.98         | Q (m <sup>3</sup> /s)                      | 1.71E-06        | dh (m) | 0.26  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>6.40E-06</b> | logK   | -5.19 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.66            |        |       |



input file **PP39000032\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore- 1.17 ref ground  
sensor open hole (m) hole pressure (m) level

depth of pressure 1.75 initial, ref toc

sensor meas. section (m) 3.25 final, ref toc

depth of pressure 8 ref TOC, top

sensor meas. section (m) 8 ref ground level, midpoint of the section

depth of meas. section (m) 18.56 equivalent area to a double tube with outer diam  
tube diameter (mm) 24.9 mm and inner diam 16.6 mm

r (mm) 9.28

H 1.22 reference water level at the measurement section  
based on phase 1, ref ground level

H<sub>0</sub> 0.45 water level at the measurement section after  
disturbance, ref ground level

t<sub>0</sub> 43653.0 time of disturbance

t<sub>end</sub> (s) 43780.0 end of time range used to line fitting

Time range (s) 127.0 Time range used for interpretation

T<sub>0</sub> 79.2 basic time lag, t corresponding the time w hen  
ln((H-h)/(H-H<sub>0</sub>)) = -1

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

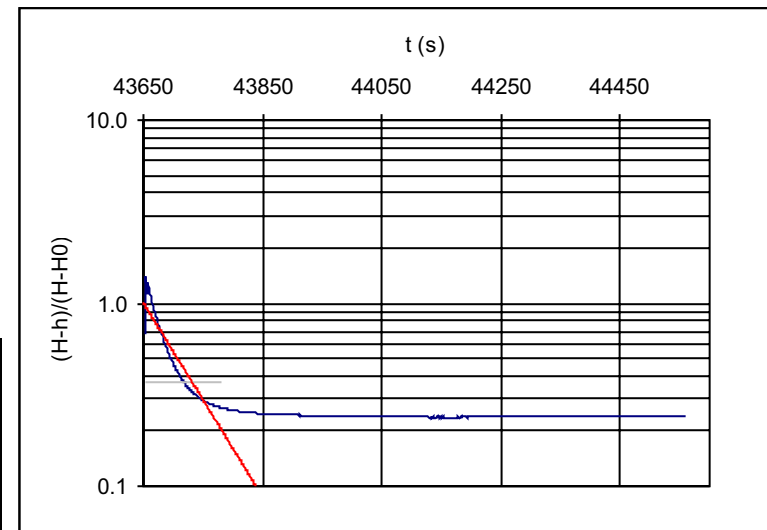
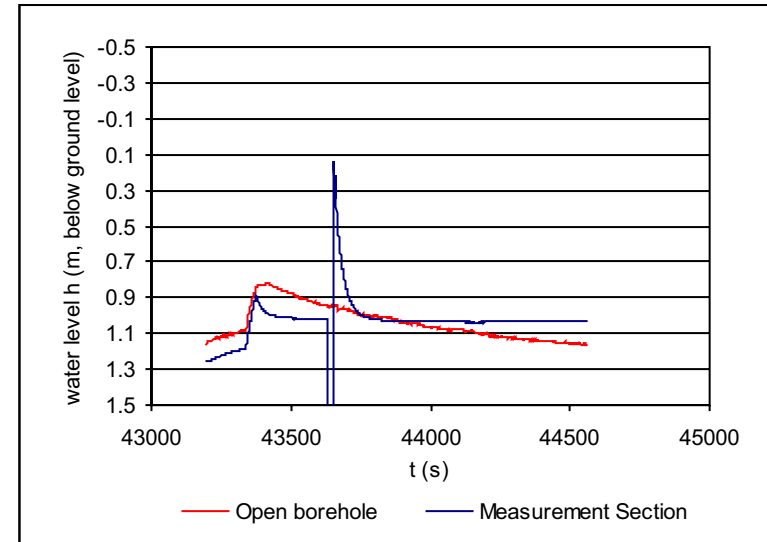
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 1.94E-06**

logK -5.71

|   |              |   |                 |        |       |
|---|--------------|---|-----------------|--------|-------|
| ln((H-h)/(H-H <sub>0</sub> )) = a*t + b |              | Thiem analysis for control                            |                 |        |       |
| a                                       | b            | <b>flow</b>   |                 |        |       |
| -0.012192262                            | -0.033889502 | t1  | 43684.0         | h1     | 0.73  |
| 0.000362884                             | 0.026662058  | t2  | 43704.0         | h2     | 0.88  |
| <b>0.8996</b>                           | 0.1516941    | Q (m <sup>3</sup> /s)                                 | 1.98E-06        | dh (m) | 0.41  |
| 1128.843089                             | 126          | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>4.72E-06</b> | logK   | -5.33 |
| 25.97592117                             | 2.899398596  | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.41            |        |       |
| <b>Stat tests</b>                       |              | <b>tight</b>  |                 |        |       |
| test stat, a <> 0                       | 33.60        | t1  | 43673.0         | h1     | 0.59  |
| test stat, b <> 0                       | 1.27         | t2  | 43695.0         | h2     | 0.83  |
| t-critical, 90%                         | 1.98         | Q (m <sup>3</sup> /s)                                 | 2.89E-06        | dh (m) | 0.51  |
|   |              | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>5.59E-06</b> | logK   | -5.25 |
|   |              | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.35            |        |       |





input file **PP39000033\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore-hole pressure (m) 1.21 ref ground level

sensor open hole (m)

depth of pressure 1.75 initial, ref toc

sensor meas. section (m)

depth of pressure 3.25 final, ref toc

sensor meas. section (m)

depth of meas. section (m) 9 ref TOC, top

depth of meas. section (m) 9 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 1.25 reference water level at the measurement section based on phase 1, ref ground level

H<sub>0</sub> -0.18 water level at the measurement section after disturbance, ref ground level

t<sub>0</sub> 45299.0 time of disturbance

t<sub>end</sub> (s) 46204.0 end of time range used to line fitting

Time range (s) 905.0 Time range used for interpretation

T<sub>0</sub> 9264.2 basic time lag, t corresponding the time when  $\ln((H-h)/(H-H_0)) = -1$

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

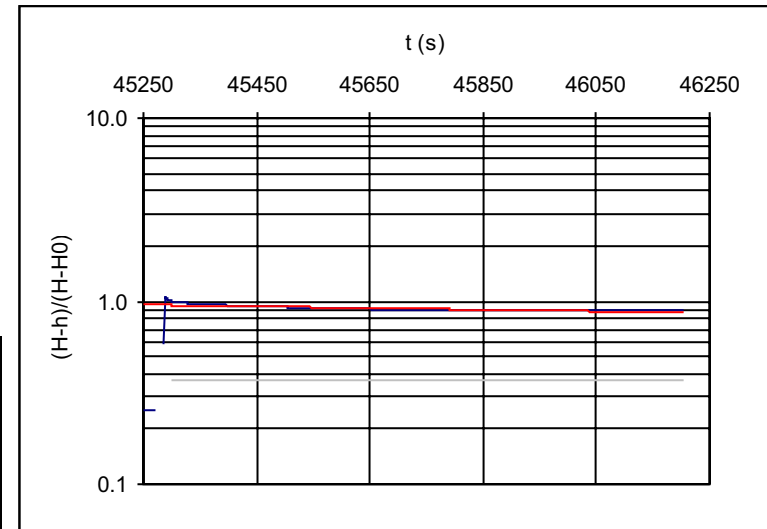
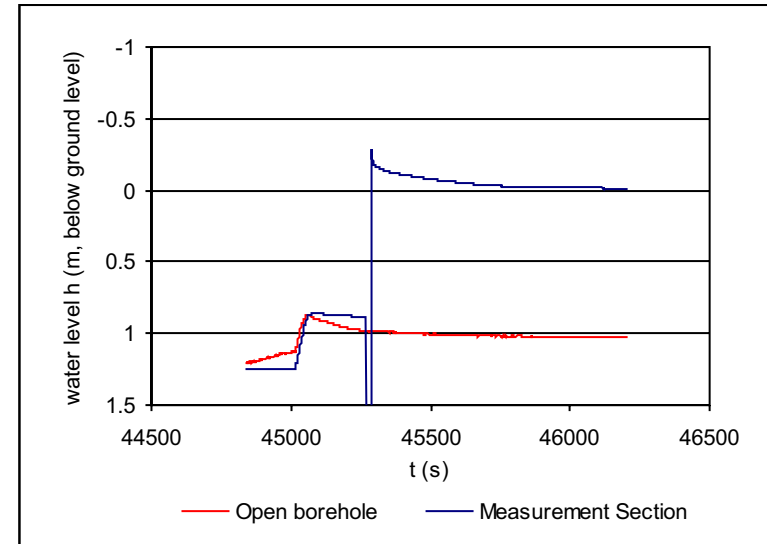
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 1.66E-08 T0 not reached**

logK -7.78

| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.000102525                   | -0.050182938 | t1   | 45590.0         | h1     | -0.06 |
| 1.6399E-06                     | 0.000857081  | t2   | 45610.0         | h2     | -0.05 |
| <b>0.8122</b>                  | 0.012909761  | Q (m <sup>3</sup> /s)                      | 5.64E-08        | dh (m) | 1.31  |
| 3908.650091                    | 904          | K <sub>Thiem</sub> (m/s)                   | <b>4.27E-08</b> | logK   | -7.37 |
| 0.651423191                    | 0.15066239   | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.39            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 62.52        | t1   | 45319.0         | h1     | -0.15 |
| test stat, b <> 0              | 58.55        | t2   | 45600.0         | h2     | -0.06 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 9.46E-08        | dh (m) | 1.35  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>6.91E-08</b> | logK   | -7.16 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.24            |        |       |



input file **PP39000034\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore-hole pressure (m) 1.02 ref ground level

sensor open hole (m)

depth of pressure 1.75 initial, ref toc

sensor meas. section (m)

depth of pressure 3.25 final, ref toc

sensor meas. section (m)

depth of meas. section (m) 10 ref TOC, top

depth of meas. section (m) 10 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 1.10 reference water level at the measurement section based on phase 1, ref ground level

H<sub>0</sub> -0.34 water level at the measurement section after disturbance, ref ground level

t<sub>0</sub> 51363.0 time of disturbance

t<sub>end</sub> (s) 52248.0 end of time range used to line fitting

Time range (s) 885.0 Time range used for interpretation

T<sub>0</sub> 1131.3 basic time lag, t corresponding the time when  $\ln((H-h)/(H-H_0)) = -1$

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

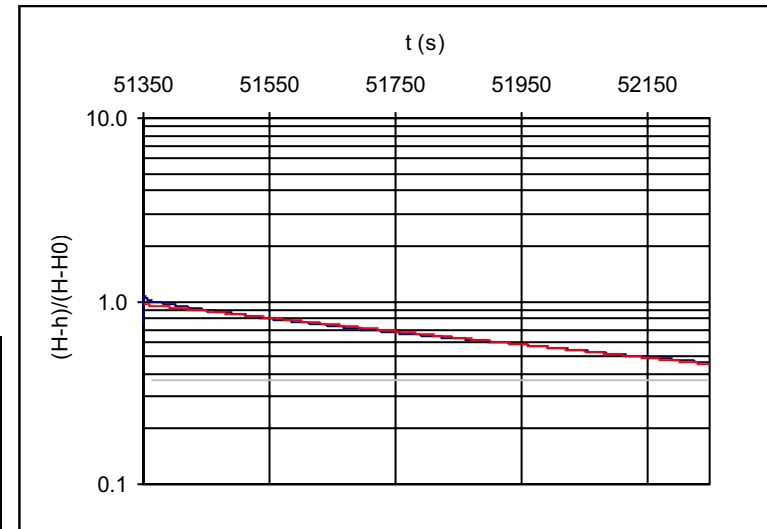
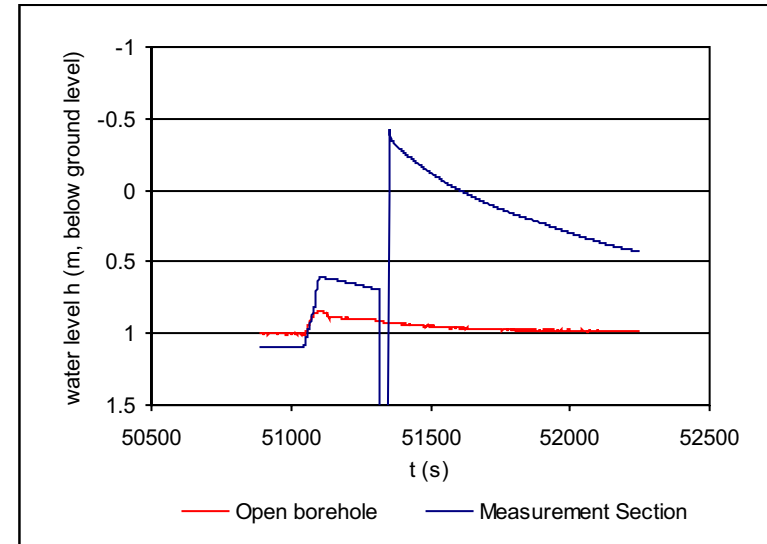
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 1.36E-07 T0 not reached**

logK -6.87

|                                |              |   |                 |        |       |
|--------------------------------|--------------|---|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                            |                 |        |       |
| a                              | b            | <b>flow</b>   |                 |        |       |
| -0.000837722                   | -0.052268554 | t1  | 52124.0         | h1     | 0.37  |
| 2.11478E-06                    | 0.001080893  | t2  | 52144.0         | h2     | 0.38  |
| <b>0.9944</b>                  | 0.016099986  | Q (m <sup>3</sup> /s)                                 | 1.51E-07        | dh (m) | 0.72  |
| 156916.5674                    | 884          | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>2.08E-07</b> | logK   | -6.68 |
| 40.67427228                    | 0.229141239  | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.65            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>  |                 |        |       |
| test stat, a <> 0              | 396.13       | t1  | 51383.0         | h1     | -0.30 |
| test stat, b <> 0              | 48.36        | t2  | 51658.0         | h2     | 0.05  |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                                 | 3.46E-07        | dh (m) | 1.22  |
|                                |              | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>2.80E-07</b> | logK   | -6.55 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.49            |        |       |



input file **PP39000035\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore-hole pressure (m) 1.08 ref ground level

sensor open hole (m)

depth of pressure 1.75 initial, ref toc

sensor meas. section (m)

depth of pressure 3.25 final, ref toc

sensor meas. section (m)

depth of meas. section (m) 11 ref TOC, top

depth of meas. section (m) 11 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 1.16 reference water level at the measurement section based on phase 1, ref ground level

H<sub>0</sub> -0.31 water level at the measurement section after disturbance, ref ground level

t<sub>0</sub> 53168.0 time of disturbance

t<sub>end</sub> (s) 54066.0 end of time range used to line fitting

Time range (s) 898.0 Time range used for interpretation

T<sub>0</sub> 21668.0 basic time lag, t corresponding the time when  $\ln((H-h)/(H-H_0)) = -1$

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

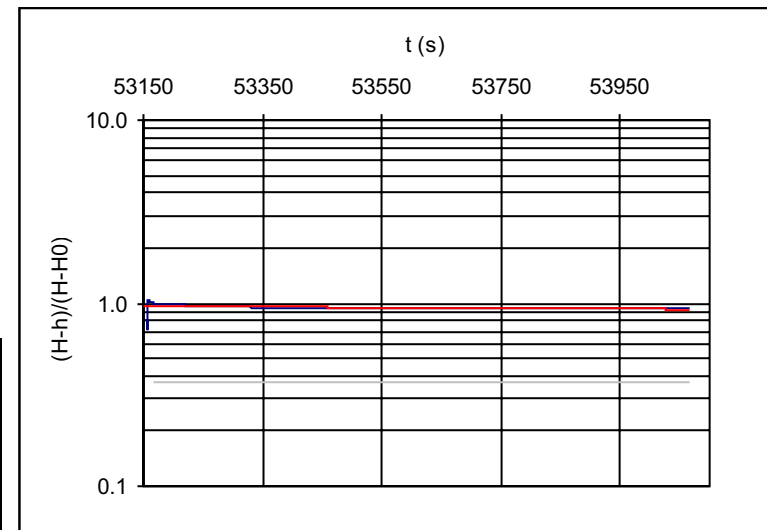
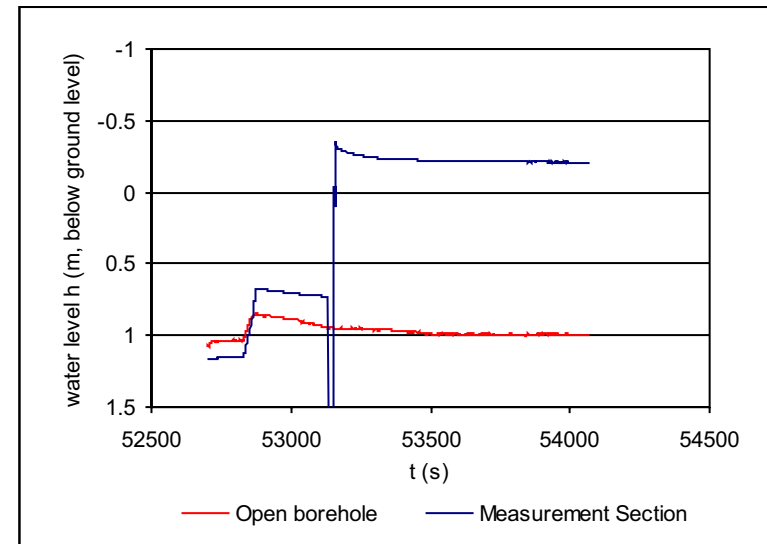
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 7.10E-09 T0 not reached**

logK -8.15

|                                |              |   |                 |        |       |
|--------------------------------|--------------|---|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                            |                 |        |       |
| a                              | b            | <b>flow</b>   |                 |        |       |
| -4.44243E-05                   | -0.037413042 | t1  | 53457.0         | h1     | -0.22 |
| 1.05143E-06                    | 0.00054531   | t2  | 53477.0         | h2     | -0.22 |
| <b>0.6656</b>                  | 0.008181438  | Q (m <sup>3</sup> /s)                                 | 7.36E-09        | dh (m) | 1.38  |
| 1785.172061                    | 897          | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>5.28E-09</b> | logK   | -8.28 |
| 0.119492149                    | 0.060041528  | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 1.35            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>  |                 |        |       |
| test stat, a <> 0              | 42.25        | t1  | 53188.0         | h1     | -0.29 |
| test stat, b <> 0              | 68.61        | t2  | 53467.0         | h2     | -0.22 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                                 | 6.17E-08        | dh (m) | 1.41  |
|                                |              | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>4.32E-08</b> | logK   | -7.36 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.16            |        |       |



input file **PP39000036\_hhi.dat** date

TOC (m) 0.5

depth of pressure 1.75 ref toc min open bore- 1.13 ref ground  
 sensor open hole (m) hole pressure (m) level

depth of pressure 1.75 initial, ref toc

sensor meas. section (m)

depth of pressure 3.25 final, ref toc

sensor meas. section (m)

depth of meas. section (m) 12 ref TOC, top

depth of meas. section (m) 12 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 1.18 reference water level at the measurement section  
 based on phase 1, ref ground level

H<sub>0</sub> -0.32 water level at the measurement section after  
 disturbance, ref ground level

t<sub>0</sub> 54736.0 time of disturbance

t<sub>end</sub> (s) 55633.0 end of time range used to line fitting

Time range (s) 896.9 Time range used for interpretation

T<sub>0</sub> 156342.1 basic time lag, t corresponding the time w hen  
 $\ln((H-h)/(H-H_0)) = -1$

L (m) 1 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

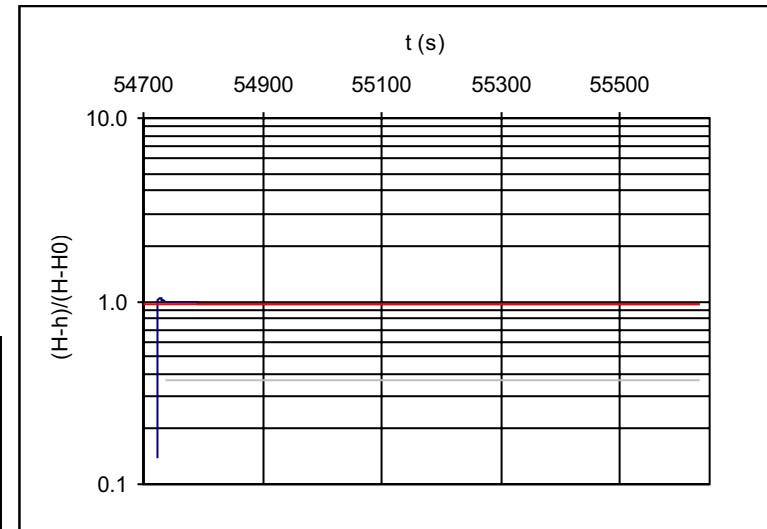
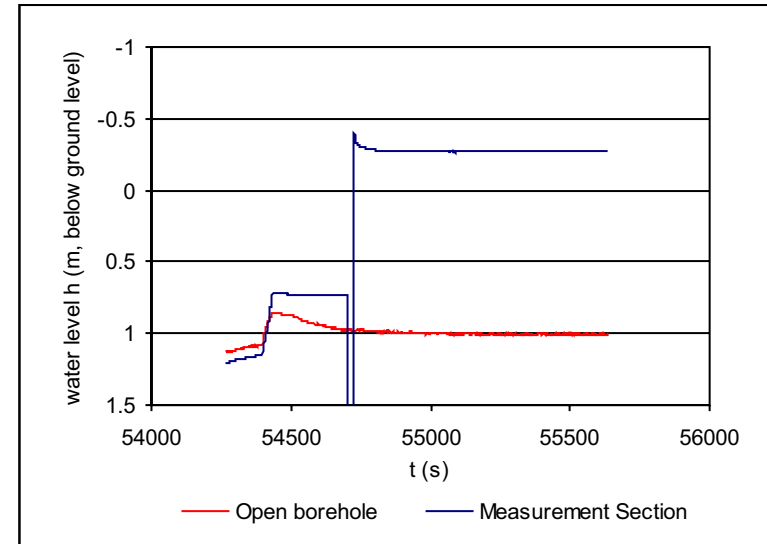
screen radius R (mm) 28 equal to borehole radius

L/R 35.71

**K (m/s) 9.85E-10 T0 not reached**

logK -9.01

|                                |              |   |                  |        |       |
|--------------------------------|--------------|---|------------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                            |                  |        |       |
| a                              | b            | <b>flow</b>   |                  |        |       |
| -6.19504E-06                   | -0.031454998 | t1  | 55025.0          | h1     | -0.27 |
| 6.52794E-07                    | 0.00033814   | t2  | 55045.0          | h2     | -0.27 |
| <b>0.0913</b>                  | 0.005071073  | Q (m <sup>3</sup> /s)                                 | -1.23E-09        | dh (m) | 1.44  |
| 90.06065006                    | 896          | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>-8.41E-10</b> | logK   | #NUM! |
| 0.00231598                     | 0.023041342  | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | -1.17            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>  |                  |        |       |
| test stat, a <> 0              | 9.49         | t1  | 54756.0          | h1     | -0.30 |
| test stat, b <> 0              | 93.02        | t2  | 55035.0          | h2     | -0.27 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                                 | 3.22E-08         | dh (m) | 1.46  |
|                                |              | K <sub>T<sub>hiem</sub></sub> (m/s)                   | <b>2.18E-08</b>  | logK   | -7.66 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>T<sub>hiem</sub></sub> | 0.05             |        |       |





## APPENDIX 5 MEASUREMENTS AND RESULTS IN OL-PVP4A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP4A \_\_\_\_\_

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 1.19 m

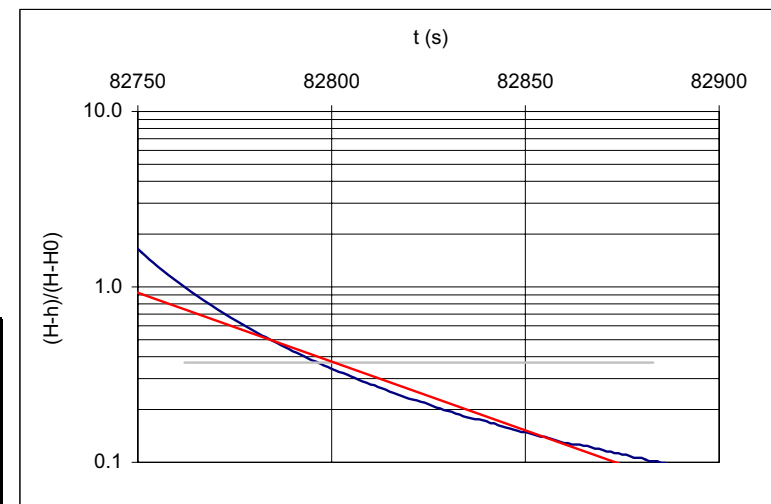
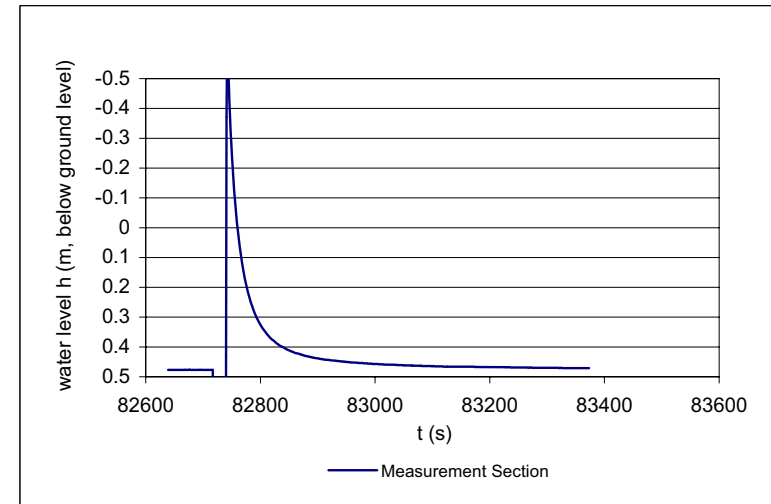
The reference level to depth is top of the casing, the length of the casing is 0.70 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE!                   |
|------|-----------|-------|-------|--|--|-------------------|-------------------------|
| 1    | 30.6.2011 | 12:55 | 1.34  | not in use                                 | 1.34                                       | 1.50              | 0.1 l water out of tube |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP4A000001.dat       | 6.55   | 1.05E-05             | 0.971 | 1.56E-05               | 1.42E-05                |          |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP4A000001.dat</b> | date  |
| TOC (m)                                    | 0.7                    |   |
|  | 0                      |   |
| depth of pressure sensor meas. section (m) | 1.34                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 2.84                   | 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  | 0.48                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.0340                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 82762.04               | time of disturbance   |
| t <sub>end</sub> (s)                       | 82883                  | end of time range used to line fitting  |
| Time range (s)                             | 120.96                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 39.04                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>1.04963E-05</b>     |   |
| logK                                       | -4.98                  |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.018056529                   | -0.295041108 | t1   | 82773.96        | h1     | 0.179 |
| 0.000285081                    | 0.019945881  | t2   | 82794           | h2     | 0.303 |
| <b>0.970956411</b>             | 0.110892098  | Q (m <sup>3</sup> /s)                      | 7.46E-06        | dh (m) | 0.24  |
| 4011.720718                    | 120          | K <sub>Thiem</sub> (m/s)                   | <b>1.56E-05</b> | logK   | -4.81 |
| 49.33236008                    | 1.475646892  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.67            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 63.34        | t1   | 82781.99        | h1     | 0.241 |
| test stat, b <> 0              | 14.79        | t2   | 82801.95        | h2     | 0.331 |
| t-critical, 90%                | 1.98         | Q (m <sup>3</sup> /s)                      | 5.47E-06        | dh (m) | 0.19  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>1.42E-05</b> | logK   | -4.85 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.74            |        |       |



## APPENDIX 6 MEASUREMENTS AND RESULTS IN OL-PVP4B

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP4B

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 1.49 m

The reference level to depth is top of the casing, the length of the casing is 0.86 m

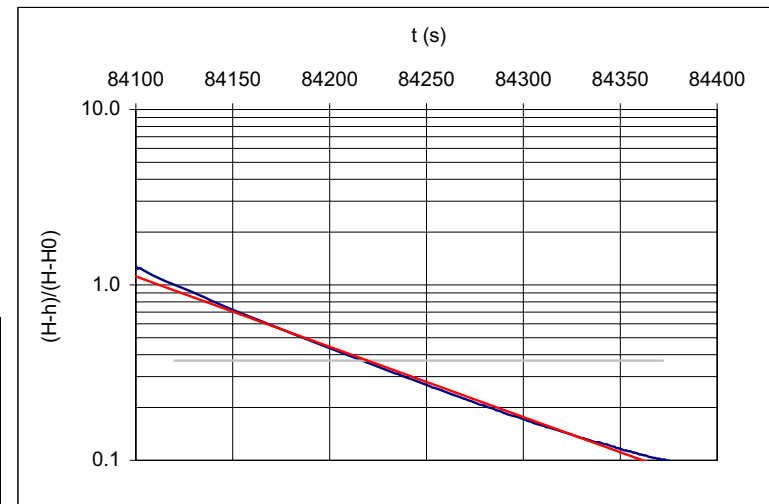
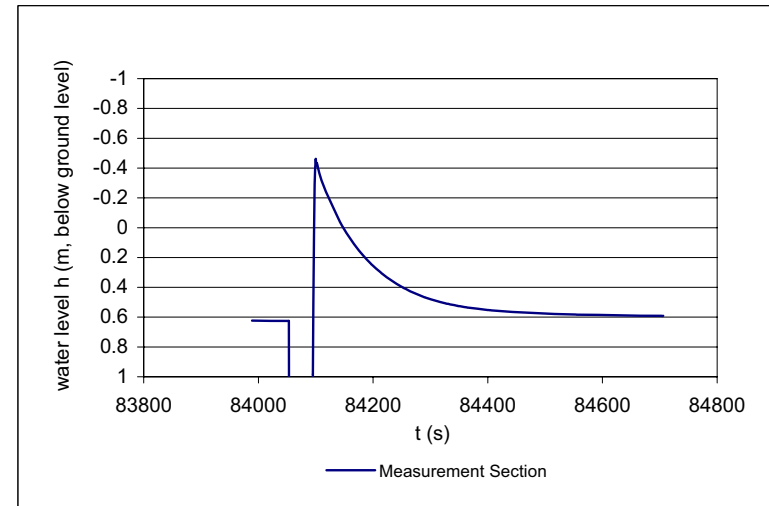
| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 2    | 30.6.2011 | 13:18 | 1.64  | not in use                                 | 1.64                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP4B000002.dat       | 3  | 4.08E-06             | 0.997 | 5.93E-06               | 5.87E-06                |          |



|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP4B000002.dat</b> | date  |
| TOC (m)                                    | 0.86                   |   |
|  | 0                      |   |
| depth of pressure sensor meas. section (m) | 1.64                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.14                   | 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  | 0.62                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | -0.2220                | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 84119.99               | time of disturbance   |
| t <sub>end</sub> (s)                       | 84372.01               | end of time range used to line fitting  |
| Time range (s)                             | 252.02                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 100.33                 | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>4.08431E-06</b>     |   |
| logK                                       | -5.39                  |   |

|                                |              |  |                 |        |        |
|--------------------------------|--------------|--|-----------------|--------|--------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |        |
| a                              | b            | <b>flow</b>                                |                 |        |        |
| -0.00923524                    | -0.073391724 | t1   | 84175.97        | h1     | 0.156  |
| 3.28724E-05                    | 0.004787579  | t2   | 84196.02        | h2     | 0.241  |
| <b>0.996829989</b>             | 0.038187223  | Q (m <sup>3</sup> /s)                      | 5.11E-06        | dh (m) | 0.43   |
| 78928.53997                    | 251          | K <sub>Thiem</sub> (m/s)                   | <b>5.93E-06</b> | logK   | -5.23  |
| 115.098648                     | 0.366024263  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.69            |        |        |
| Stat tests                     |              | <b>tight</b>                               |                 |        |        |
| test stat, a <> 0              | 280.94       | t1   | 84140.03        | h1     | -0.057 |
| test stat, b <> 0              | 15.33        | t2   | 84203.97        | h2     | 0.269  |
| t-critical, 90%                | 1.97         | Q (m <sup>3</sup> /s)                      | 6.16E-06        | dh (m) | 0.52   |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>5.87E-06</b> | logK   | -5.23  |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.70            |        |        |



## APPENDIX 7 MEASUREMENTS AND RESULTS IN OL-PVP6A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP6A \_\_\_\_\_

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 1.42 m

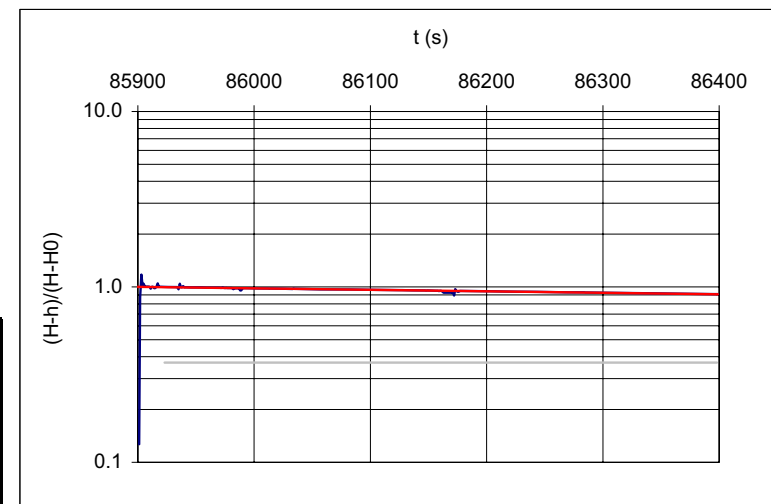
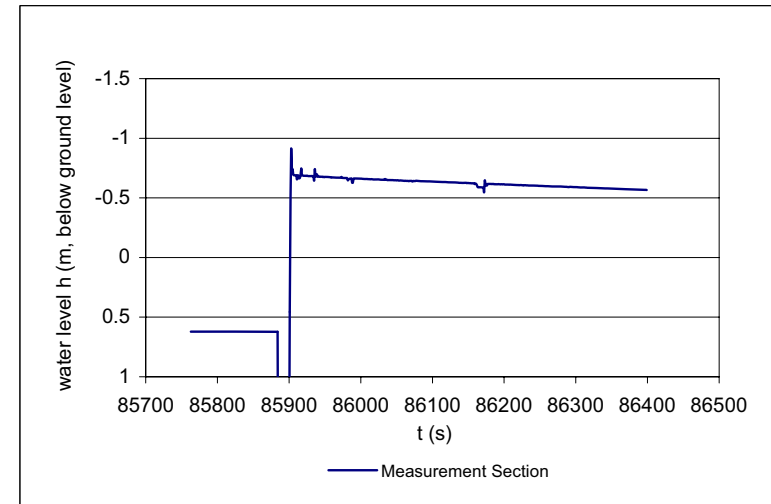
The reference level to depth is top of the casing, the length of the casing is 0.70 m

| File | Date     | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE!                   |
|------|----------|-------|-------|--|--|-------------------|-------------------------|
| 4    | 1.7.2010 | 13:42 | 1.57  | not in use                                 | 1.57                                       | 1.50              | 0.5 l water out of tube |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments       |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------------|
| PVP6A000004.dat       | 4.83   | 7.93E-08             | 0.953 | 4.50E-08               | 1.29E-07                | T0 not reached |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP6A000004.dat</b> | date  |
| TOC (m)                                    | 0.7<br>0               |   |
| depth of pressure sensor meas. section (m) | 1.57                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.07                   | 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  | 0.62                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | -0.6850                | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 85922.98               | time of disturbance   |
| t <sub>end</sub> (s)                       | 86398.01               | end of time range used to line fitting  |
| Time range (s)                             | 475.03                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 5169.88                | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>7.92658E-08</b>     | <b>T0 not reached</b>   |
| logK                                       | -7.10                  |   |

|                                |              |  |                 |        |        |
|--------------------------------|--------------|--|-----------------|--------|--------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |        |
| a                              | b            | <b>flow</b>                                |                 |        |        |
| -0.000192593                   | -0.004314093 | t1   | 86070.98        | h1     | -0.641 |
| 1.9656E-06                     | 0.00053936   | t2   | 86091.03        | h2     | -0.639 |
| <b>0.952950388</b>             | 0.005892706  | Q (m <sup>3</sup> /s)                      | 1.15E-07        | dh (m) | 1.26   |
| 9600.472076                    | 474          | K <sub>Thiem</sub> (m/s)                   | <b>4.50E-08</b> | logK   | -7.35  |
| 0.333366618                    | 0.016459167  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 1.76            |        |        |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |        |
| test stat, a <> 0              | 97.98        | t1   | 85943.03        | h1     | -0.680 |
| test stat, b <> 0              | 8.00         | t2   | 86081.01        | h2     | -0.641 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 3.35E-07        | dh (m) | 1.28   |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>1.29E-07</b> | logK   | -6.89  |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.61            |        |        |



## APPENDIX 8 MEASUREMENTS AND RESULTS IN OL-PVP6B

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP6B

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 1.52 m

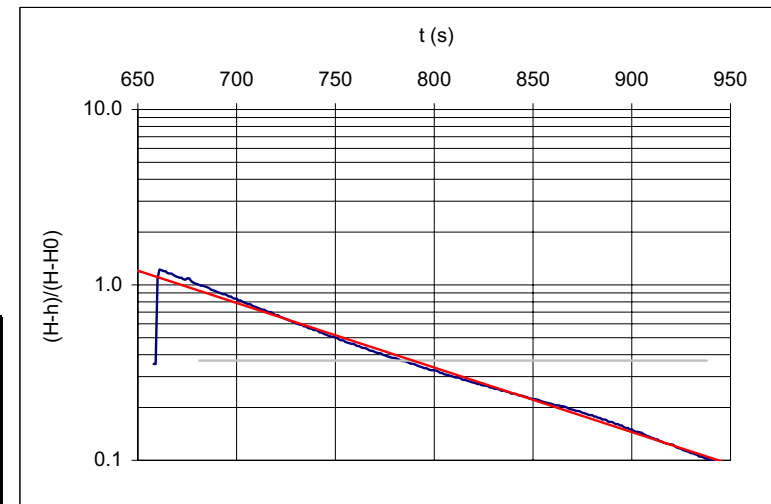
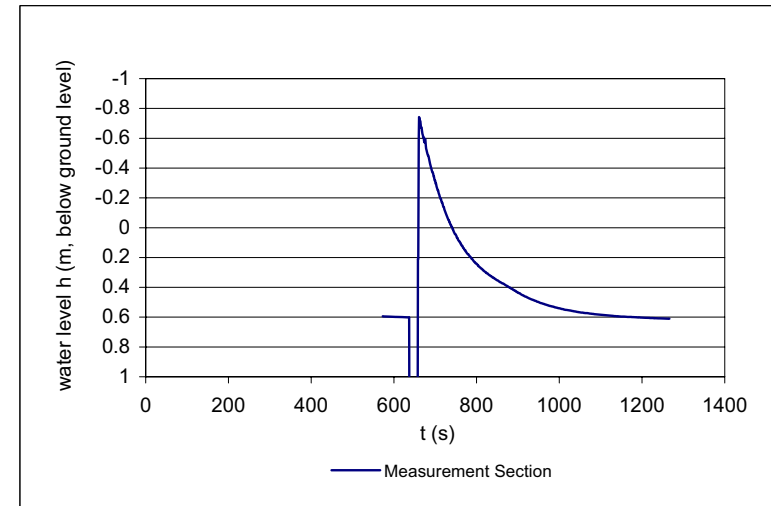
The reference level to depth is top of the casing, the length of the casing is 0.90 m

| File | Date     | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|-------|-------|--|--|-------------------|-------|
| 5    | 1.7.2010 | 14:08 | 1.67  | not in use                                 | 1.67                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP6B000005.dat       | 2.83   | 3.76E-06             | 0.997 | 5.70E-06               | 5.71E-06                |          |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP6B000005.dat</b> | date  |
| TOC (m)                                    | 0.9<br>0               |   |
| depth of pressure sensor meas. section (m) | 1.67                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.17                   | 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  | 0.60                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | -0.4970                | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 681                    | time of disturbance   |
| t <sub>end</sub> (s)                       | 937.95                 | end of time range used to line fitting  |
| Time range (s)                             | 256.95                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 108.99                 | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>3.75997E-06</b>     |   |
| logK                                       | -5.42                  |   |

|                                |              |  |                 |        |        |
|--------------------------------|--------------|--|-----------------|--------|--------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |        |
| a                              | b            | <b>flow</b>                                |                 |        |        |
| -0.008471452                   | -0.076706512 | t1   | 740.01          | h1     | -0.004 |
| 3.05503E-05                    | 0.004537308  | t2   | 759.97          | h2     | 0.101  |
| <b>0.996681732</b>             | 0.036546649  | Q (m <sup>3</sup> /s)                      | 6.34E-06        | dh (m) | 0.55   |
| 76892.68349                    | 256          | K <sub>Thiem</sub> (m/s)                   | <b>5.70E-06</b> | logK   | -5.24  |
| 102.7022915                    | 0.341928327  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.66            |        |        |
| Stat tests                     |              | <b>tight</b>                               |                 |        |        |
| test stat, a <> 0              | 277.30       | t1   | 700.96          | h1     | -0.299 |
| test stat, b <> 0              | 16.91        | t2   | 766.02          | h2     | 0.127  |
| t-critical, 90%                | 1.97         | Q (m <sup>3</sup> /s)                      | 7.90E-06        | dh (m) | 0.68   |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>5.71E-06</b> | logK   | -5.24  |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.66            |        |        |



## APPENDIX 9 MEASUREMENTS AND RESULTS IN OL-PVP7A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP7A \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 2.07 m

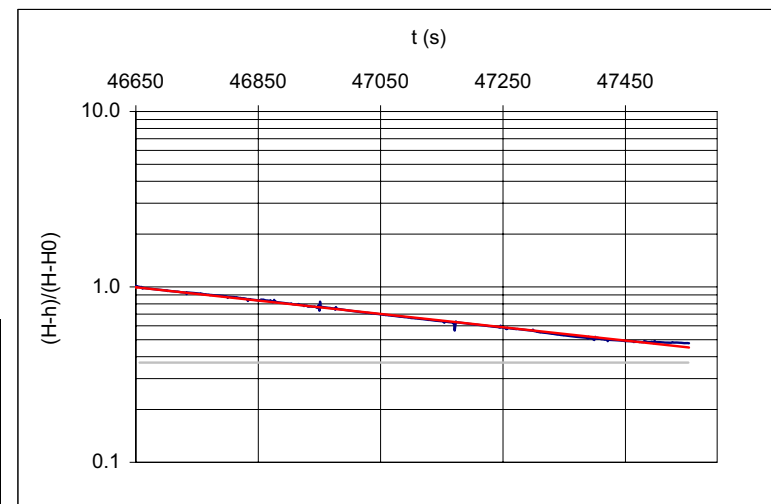
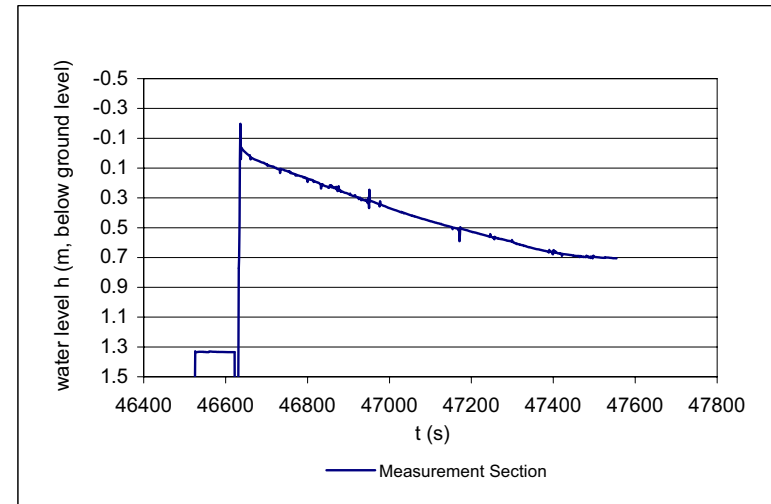
The reference level to depth is top of the casing, the length of the casing is 0.60 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 18   | 19.7.2010 | 12:35 | 2.22  | not in use                                 | 2.22                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments       |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------------|
| PVP7A000018.dat       | 2.75   | 3.62E-07             | 0.996 | 3.85E-07               | 5.04E-07                | T0 not reached |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP7A000018.dat</b> | date  |
| TOC (m)                                    | 0.6<br>0               |   |
| depth of pressure sensor meas. section (m) | 2.22                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.72                   | final, ref toc  |
| depth of meas. section (m)                 | 1.75                   | ref ground level, top   |
| depth of meas. section (m)                 | 2.75                   | 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  | 1.34                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.0130                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 46655.99               | time of disturbance   |
| t <sub>end</sub> (s)                       | 47553                  | end of time range used to line fitting  |
| Time range (s)                             | 897.01                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 1131.07                | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>3.62307E-07</b>     | <b>T0 not reached</b>   |
| logK                                       | -6.44                  |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.000875715                   | -0.009504909 | t1   | 47387.98        | h1     | 0.659 |
| 1.89218E-06                    | 0.000980209  | t2   | 47408.02        | h2     | 0.668 |
| <b>0.99583425</b>              | 0.014698912  | Q (m <sup>3</sup> /s)                      | 5.25E-07        | dh (m) | 0.68  |
| 214191.2986                    | 896          | K <sub>Thiem</sub> (m/s)                   | <b>3.85E-07</b> | logK   | -6.41 |
| 46.27774772                    | 0.193587985  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.94            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 462.81       | t1   | 46675.95        | h1     | 0.047 |
| test stat, b <> 0              | 9.70         | t2   | 46955.03        | h2     | 0.320 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 1.18E-06        | dh (m) | 1.16  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>5.04E-07</b> | logK   | -6.30 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.72            |        |       |



## APPENDIX 10 MEASUREMENTS AND RESULTS IN OL-PVP8A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP8A \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 4.31 m

The reference level to depth is top of the casing, the length of the casing is 0.90 m

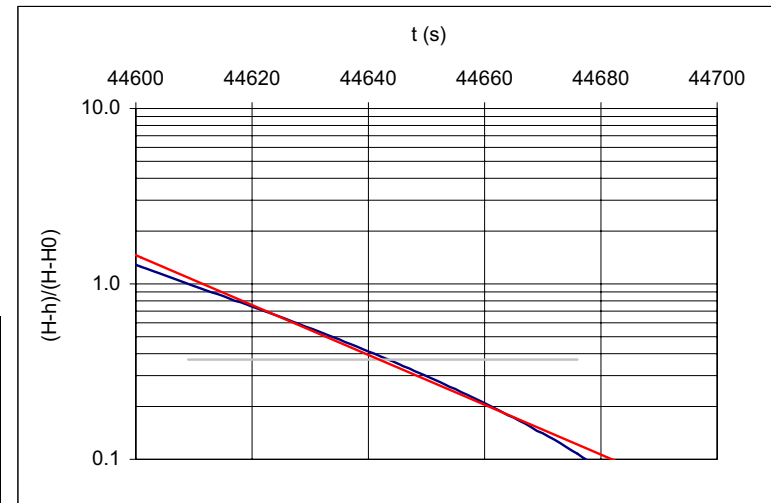
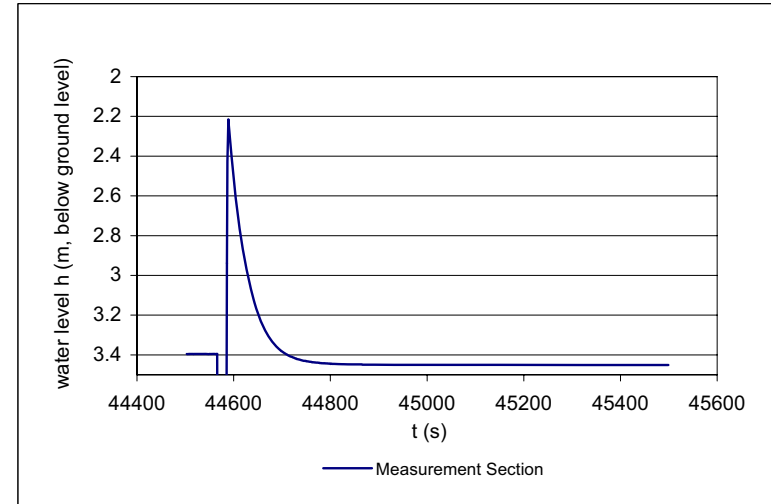
| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 24   | 30.7.2010 | 11:50 | 4.46  | not in use                                 | 4.46                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP8A000024.dat       | 5.45   | 1.24E-05             | 0.995 | 1.74E-05               | 1.68E-05                |          |



|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP8A000024.dat</b> | date  |
| TOC (m)                                    | 0.9<br>0               |   |
| depth of pressure sensor meas. section (m) | 4.46                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 5.96                   | final, ref toc  |
| depth of meas. section (m)                 | 4.45                   | ref ground level, top   |
| depth of meas. section (m)                 | 5.45                   | 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  | 3.40                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 2.7060                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 44609.01               | time of disturbance   |
| t <sub>end</sub> (s)                       | 44675.97               | end of time range used to line fitting  |
| Time range (s)                             | 66.96                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 33.07                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>1.23936E-05</b>     |   |
| logK                                       | -4.91                  |   |

|                                |             |  |                 |        |       |
|--------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                              | b           | <b>flow</b>                                |                 |        |       |
| -0.032699281                   | 0.081202949 | t1   | 44623.95        | h1     | 2.936 |
| 0.000291323                    | 0.011307309 | t2   | 44644           | h2     | 3.144 |
| <b>0.994788686</b>             | 0.047151203 | Q (m <sup>3</sup> /s)                      | 1.25E-05        | dh (m) | 0.36  |
| 12598.75213                    | 66          | K <sub>Thiem</sub> (m/s)                   | <b>1.74E-05</b> | logK   | -4.76 |
| 28.00999915                    | 0.146733575 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.71            |        |       |
| Stat tests                     |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 112.24      | t1   | 44628.96        | h1     | 2.997 |
| test stat, b <> 0              | 7.18        | t2   | 44631.04        | h2     | 3.020 |
| t-critical, 90%                | 2.00        | Q (m <sup>3</sup> /s)                      | 1.31E-05        | dh (m) | 0.39  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>1.68E-05</b> | logK   | -4.77 |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.74            |        |       |



## APPENDIX 11 MEASUREMENTS AND RESULTS IN OL-PVP8B

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP8B

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 3.75 m

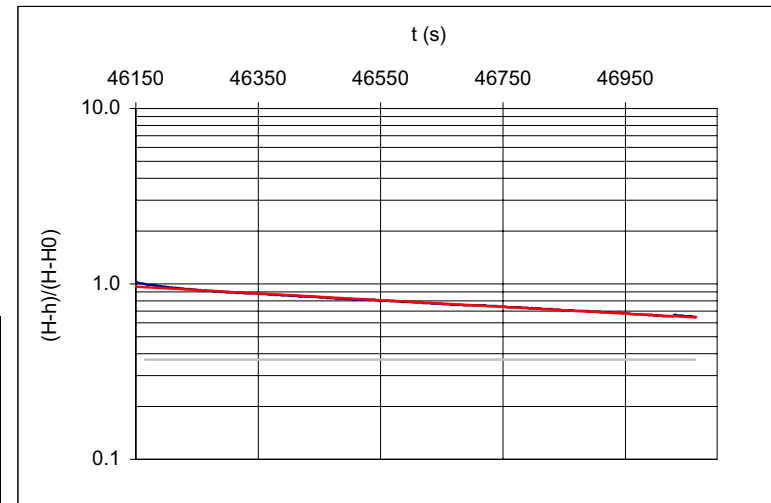
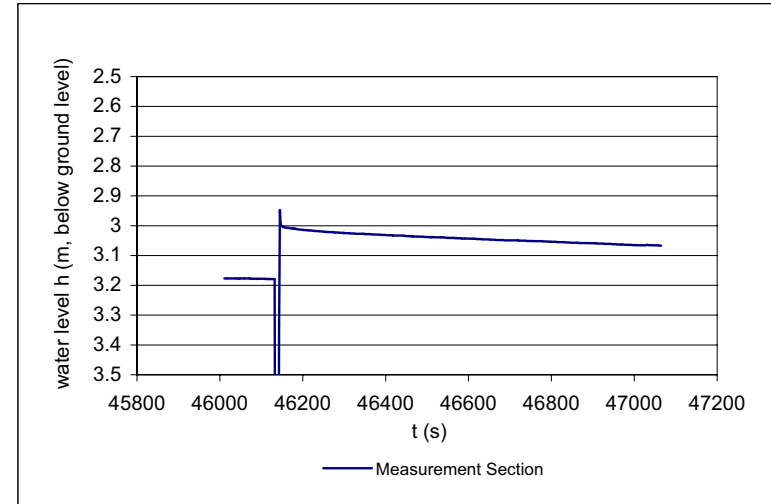
The reference level to depth is top of the casing, the length of the casing is 0.50 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 25   | 30.7.2010 | 12:40 | 3.90  | not in use                                 | 3.90                                       | 0.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments       |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------------|
| PVP8B000025.dat       | 3.45   | 1.89E-07             | 0.995 | 3.05E-07               | 3.38E-07                | T0 not reached |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP8B000025.dat</b> | date  |
| TOC (m)                                    | 0.5                    |   |
|  | 0                      |   |
| depth of pressure sensor meas. section (m) | 3.90                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 4.40                   | final, ref toc  |
| depth of meas. section (m)                 | 2.45                   | ref ground level, top   |
| depth of meas. section (m)                 | 3.45                   | 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  | 3.18                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 3.0070                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 46164.98               | time of disturbance   |
| t <sub>end</sub> (s)                       | 47063.98               | end of time range used to line fitting  |
| Time range (s)                             | 899                    | Time range used for interpretation  |
| T <sub>0</sub>                             | 2163.82                | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>1.89385E-07</b>     | <b>T0 not reached</b>   |
| logK                                       | -6.72                  |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.000442344                   | -0.042848885 | t1   | 46453.99        | h1     | 3.035 |
| 1.09011E-06                    | 0.000565982  | t2   | 46474.04        | h2     | 3.036 |
| <b>0.994575785</b>             | 0.008496579  | Q (m <sup>3</sup> /s)                      | 8.75E-08        | dh (m) | 0.14  |
| 164655.9169                    | 898          | K <sub>Thiem</sub> (m/s)                   | <b>3.05E-07</b> | logK   | -6.52 |
| 11.88681559                    | 0.064828283  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.62            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 405.78       | t1   | 46185.03        | h1     | 3.011 |
| test stat, b <> 0              | 75.71        | t2   | 46464.01        | h2     | 3.036 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 1.05E-07        | dh (m) | 0.15  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>3.38E-07</b> | logK   | -6.47 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.56            |        |       |



## APPENDIX 12 MEASUREMENTS AND RESULTS IN OL-PVP9A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP9A \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 3.03 m

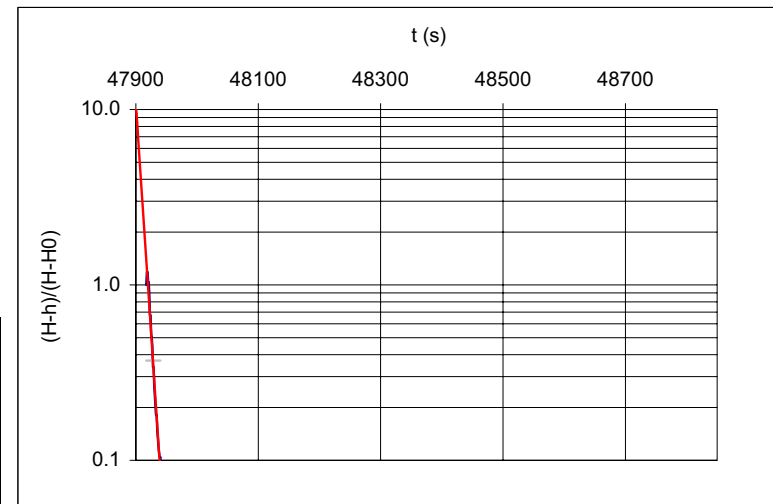
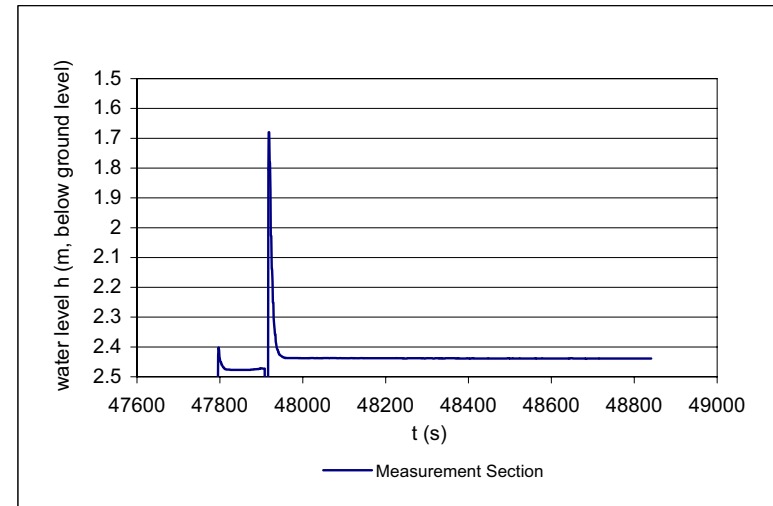
The reference level to depth is top of the casing, the length of the casing is 0.60 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 20   | 21.7.2010 | 13:10 | 3.18  | not in use                                 | 3.18                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments                            |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|-------------------------------------|
| PVP9A000020.dat       | 6  | 3.73E-05             | 0.982 | 9.04E-05               | -7.18E-05               | Shorter time used in interpretation |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP9A000020.dat</b> | date  |
| TOC (m)                                    | 0.6<br>0               |   |
| depth of pressure sensor meas. section (m) | 3.18                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 4.68                   | final, ref toc  |
| depth of meas. section (m)                 | 5                      | ref ground level, top   |
| depth of meas. section (m)                 | 6                      | 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  | 2.48                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 1.8050                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 47917                  | time of disturbance   |
| t <sub>end</sub> (s)                       | 47939.99               | end of time range used to line fitting  |
| Time range (s)                             | 22.99                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 11.00                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>3.72666E-05</b>     |   |
| logK                                       | -4.43                  |   |

| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                  |        |       |
|--------------------------------|-------------|--|------------------|--------|-------|
| a                              | b           | <b>flow</b>                                |                  |        |       |
| -0.120509055                   | 0.325153526 | t1   | 47913.98         | h1     | 3.080 |
| 0.0035102                      | 0.047113109 | t2   | 47934.02         | h2     | 2.357 |
| <b>0.98167621</b>              | 0.119079925 | Q (m <sup>3</sup> /s)                      | -4.36E-05        | dh (m) | -0.24 |
| 1178.624975                    | 22          | K <sub>Thiem</sub> (m/s)                   | <b>9.04E-05</b>  | logK   | -4.04 |
| 16.71293578                    | 0.311960628 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.41             |        |       |
| Stat tests                     |             | <b>tight</b>                               |                  |        |       |
| test stat, a <> 0              | 34.33       | t1   | 47917            | h1     | 2.492 |
| test stat, b <> 0              | 6.90        | t2   | 47939.99         | h2     | 2.410 |
| t-critical, 90%                | 2.07        | Q (m <sup>3</sup> /s)                      | -4.28E-06        | dh (m) | 0.03  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>-7.18E-05</b> | logK   | #NUM! |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | -0.52            |        |       |



## APPENDIX 13 MEASUREMENTS AND RESULTS IN OL-PVP9B

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP9B

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 2.91 m

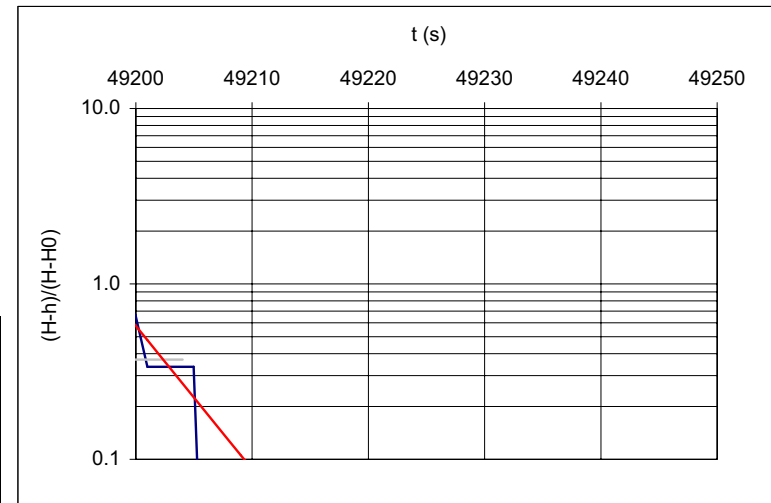
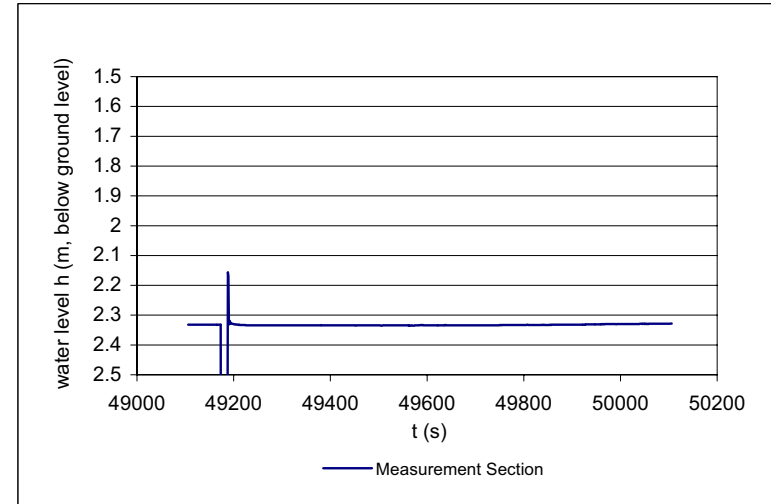
The reference level to depth is top of the casing, the length of the casing is 0.60 m

| File | Date      | Time | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|------|-------|--|--|-------------------|-------|
| 21   | 21.7.2010 |      | 3.16  | not in use                                 | 3.16                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP9B000021.dat       | 4  | 7.64E-05             | 0.858 | 5.95E-05               | 1.11E-04                |          |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP9B000021.dat</b> | date  |
| TOC (m)                                    | 0.6<br>0               |   |
| depth of pressure sensor meas. section (m) | 3.16                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 4.66                   | final, ref toc  |
| depth of meas. section (m)                 | 3                      | ref ground level, top   |
| depth of meas. section (m)                 | 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  | 2.33                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 2.3290                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 49197.02               | time of disturbance   |
| t <sub>end</sub> (s)                       | 49204.02               | end of time range used to line fitting  |
| Time range (s)                             | 7                      | Time range used for interpretation  |
| T <sub>0</sub>                             | 5.36                   | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>7.64029E-05</b>     |   |
| logK                                       | -4.12                  |   |

|                                      |             |  |                 |        |       |
|--------------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a \cdot t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                                    | b           | <b>flow</b>                                |                 |        |       |
| -0.188107915                         | 0.008936275 | t1   | 49188.98        | h1     | 2.722 |
| 0.03119517                           | 0.129979832 | t2   | 49209.03        | h2     | 2.332 |
| <b>0.858361298</b>                   | 0.202515884 | Q (m <sup>3</sup> /s)                      | -2.35E-05       | dh (m) | -0.20 |
| 36.36130318                          | 6           | K <sub>Thiem</sub> (m/s)                   | <b>5.95E-05</b> | logK   | -4.23 |
| 1.491274608                          | 0.246076099 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 1.28            |        |       |
| <b>Stat tests</b>                    |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0                    | 6.03        | t1   | 49197.02        | h1     | 2.328 |
| test stat, b <> 0                    | 0.07        | t2   | 49204.02        | h2     | 2.331 |
| t-critical, 90%                      | 2.45        | Q (m <sup>3</sup> /s)                      | 5.33E-07        | dh (m) | 0.00  |
|                                      |             | K <sub>Thiem</sub> (m/s)                   | <b>1.11E-04</b> | logK   | -3.96 |
|                                      |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.69            |        |       |



## APPENDIX 14 MEASUREMENTS AND RESULTS IN OL-PVP10A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP10A \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.28 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! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 22   | 21.7.2010 | 14:32 | 1.43  | not in use                                 | 1.43                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments   |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|--|
| PVP10A000022_hhi.da   | 2.00   | 4.73E-06             | 0.871 | 6.93E-06               | 6.45E-06                | H changed for interpetation<br>Shorter time used in interpretation |



input file **PVP10A000022\_hhi.dat** date

TOC (m) 0.7  
0

depth of pressure sensor meas. section (m) 1.43 initial, ref toc

depth of pressure sensor meas. section (m) 2.93 final, ref toc

depth of meas. section (m) 1 ref ground level, top

depth of meas. section (m) 2 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 0.68 reference water level at the measurement section based on phase 1, ref ground level

H<sub>0</sub> 0.6680 water level at the measurement section after disturbance, ref ground level

t<sub>0</sub> 52787.03 time of disturbance

t<sub>end</sub> (s) 52954.04 end of time range used to line fitting

Time range (s) 167.01 Time range used for interpretation

T<sub>0</sub> 86.72 basic time lag, t corresponding the time when  $\ln((H-h)/(H-H_0)) = -1$

L (m) 2 length of measurement section

screen diam. (mm) 56 equal to borehole diameter

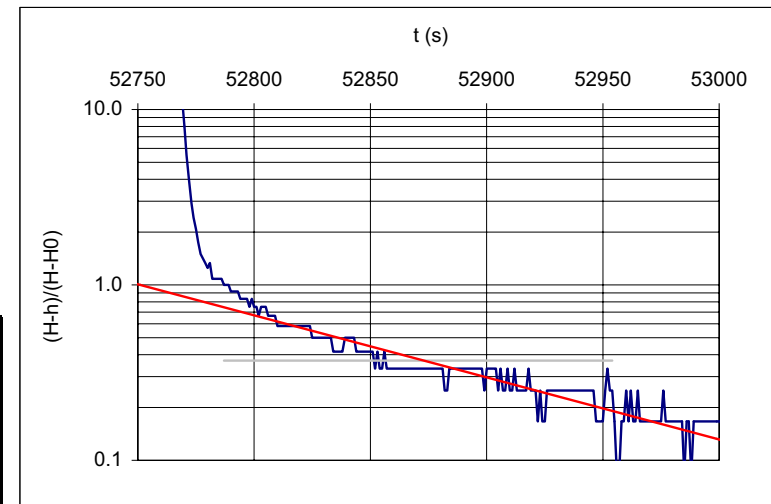
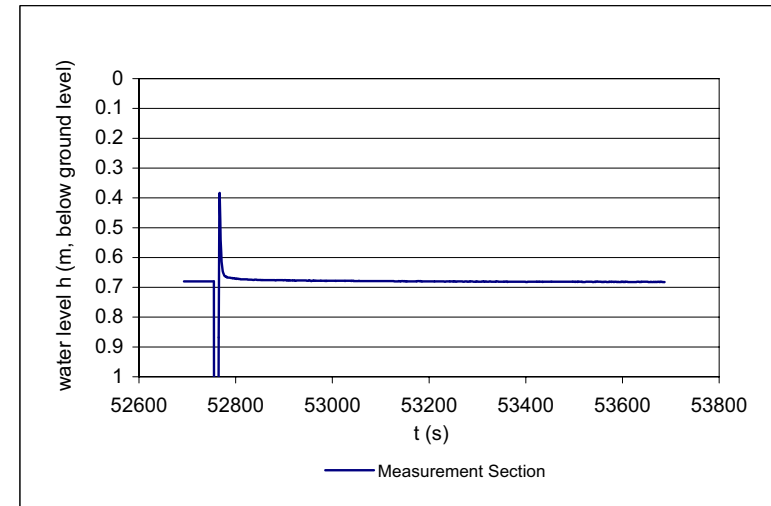
screen radius R (mm) 28 equal to borehole radius

L/R 71.43

**K (m/s) 4.72532E-06**

logK -5.33

| $\ln((H-h)/(H-H_0)) = a \cdot t + b$ |              | Thiem analysis for control                 |                 |        |       |
|--------------------------------------|--------------|--|-----------------|--------|-------|
| a                                    | b            | <b>flow</b>                                |                 |        |       |
| -0.008149033                         | -0.293289744 | t1   | 52815.02        | h1     | 0.673 |
| 0.000243605                          | 0.023515814  | t2   | 52834.98        | h2     | 0.674 |
| <b>0.870819235</b>                   | 0.153126973  | Q (m <sup>3</sup> /s)                      | 8.79E-08        | dh (m) | 0.01  |
| 1119.021034                          | 166          | K <sub>Thiem</sub> (m/s)                   | <b>6.93E-06</b> | logK   | -5.16 |
| 26.23865968                          | 3.892346411  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.68            |        |       |
| Stat tests                           |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0                    | 33.45        | t1   | 52806.98        | h1     | 0.672 |
| test stat, b <> 0                    | 12.47        | t2   | 52841.98        | h2     | 0.675 |
| t-critical, 90%                      | 1.97         | Q (m <sup>3</sup> /s)                      | 8.77E-08        | dh (m) | 0.01  |
|                                      |              | K <sub>Thiem</sub> (m/s)                   | <b>6.45E-06</b> | logK   | -5.19 |
|                                      |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.73            |        |       |



## APPENDIX 15 MEASUREMENTS AND RESULTS IN OL-PVP10B

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP10B

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.47 m

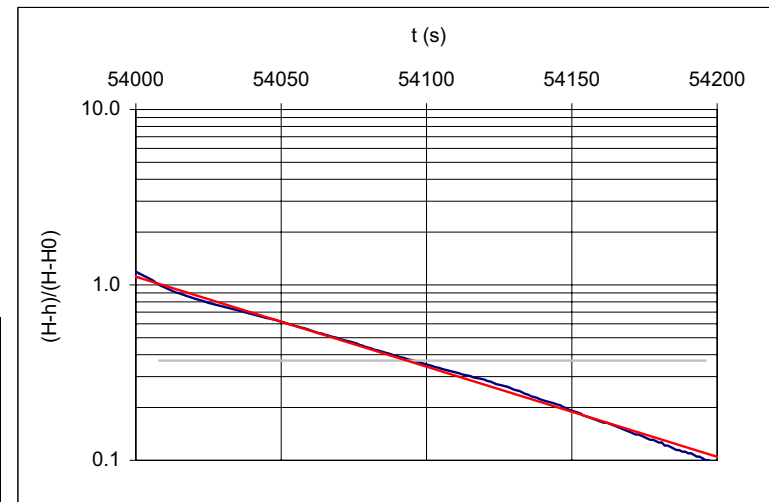
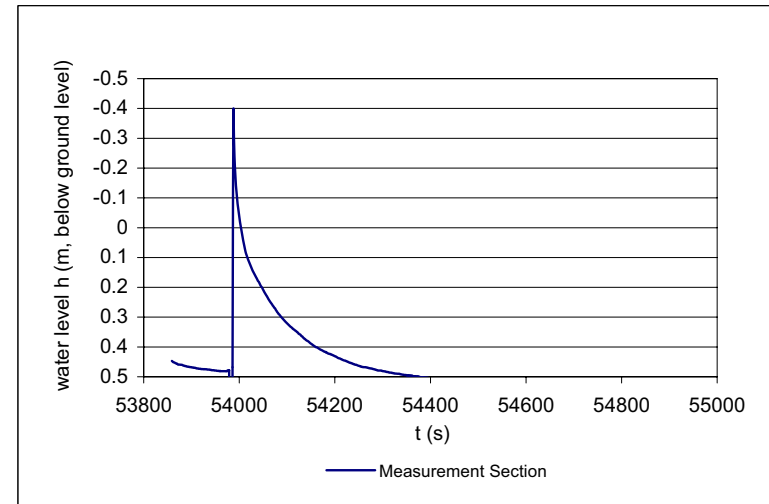
The reference level to depth is top of the casing, the length of the casing is 1.00 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 23   | 21.7.2010 | 14:59 | 1.62  | not in use                                 | 1.62                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments        |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|-----------------|
| PVP10B000023.dat      | 0.40   | 2.20E-05             | 0.997 | 6.70E-05               | 6.18E-05                | Thiem different |

|  |                         |   |
|--|-------------------------|---|
| input file                                 | <b>PVP10B000023.dat</b> | date  |
| TOC (m)                                    | 1<br>0                  |   |
| depth of pressure sensor meas. section (m) | 1.62                    | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.12                    | final, ref toc  |
| depth of meas. section (m)                 | 0.3                     | ref ground level, top   |
| depth of meas. section (m)                 | 0.4                     | 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  | 0.47                    | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.0450                  | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 54008.03                | time of disturbance   |
| t <sub>end</sub> (s)                       | 54196.04                | end of time range used to line fitting  |
| Time range (s)                             | 188.01                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 85.71                   | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 0.2                     | length of measurement section   |
| screen diam. (mm)                          | 56                      | equal to borehole diameter  |
| screen radius R (mm)                       | 28                      | equal to borehole radius  |
| L/R  | 7.14                    |   |
| <b>K (m/s)</b>                             | <b>2.20206E-05</b>      |   |
| logK                                       | -4.66                   |   |

|                                |             |  |                 |        |       |
|--------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                              | b           | <b>flow</b>                                |                 |        |       |
| -0.011817275                   | 0.012904952 | t1   | 54059.01        | h1     | 0.233 |
| 5.03927E-05                    | 0.005475512 | t2   | 54078.96        | h2     | 0.281 |
| <b>0.996611022</b>             | 0.037797699 | Q (m <sup>3</sup> /s)                      | 2.89E-06        | dh (m) | 0.21  |
| 54991.88457                    | 187         | K <sub>Thiem</sub> (m/s)                   | <b>6.70E-05</b> | logK   | -4.17 |
| 78.56503867                    | 0.267160552 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.33            |        |       |
| Stat tests                     |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 234.50      | t1   | 54027.99        | h1     | 0.144 |
| test stat, b <> 0              | 2.36        | t2   | 54069.98        | h2     | 0.260 |
| t-critical, 90%                | 1.97        | Q (m <sup>3</sup> /s)                      | 3.36E-06        | dh (m) | 0.27  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>6.18E-05</b> | logK   | -4.21 |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.36            |        |       |



## APPENDIX 16 MEASUREMENTS AND RESULTS IN OL-PVP11

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP11 \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.84 m

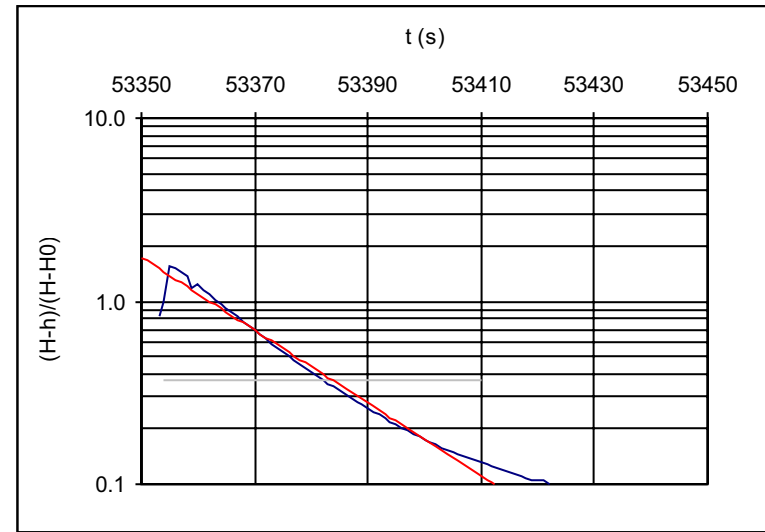
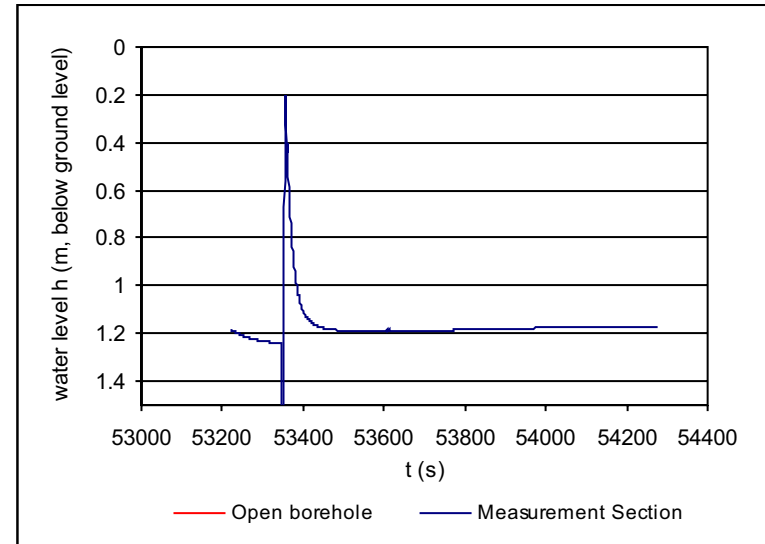
The reference level to depth is top of the casing, the length of the casing is 0.60 m

| File | Date     | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|-------|-------|--|--|-------------------|-------|
| 28   | 2.8.2010 | 14:45 | 1.99  | not in use                                 | 1.99                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments                            |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|-------------------------------------|
| PVP11000028.dat       | 2.20   | 3.07E-06             | 0.987 | 6.22E-06               | 6.92E-06                | Shorter time used in interpretation |

|  |                        |   |                                 |
|--|------------------------|---|---------------------------------|
| input file                                 | <b>PVP11000028.dat</b> | date  |                                 |
| TOC (m)                                    | 0.6                    | ref toc   | min open bore-hole pressure (m) |
| depth of pressure sensor open hole (m)     |                        |   | -0.62 ref ground level          |
| depth of pressure sensor meas. section (m) | 1.99                   | initial, ref toc  |                                 |
| depth of pressure sensor meas. section (m) | 3.45                   | final, ref toc  |                                 |
| depth of meas. section (m)                 | 1.2                    | ref TOC, top  |                                 |
| depth of meas. section (m)                 | 1.6                    | 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  | 1.22                   | reference water level at the measurement section based on phase 1, ref ground level |                                 |
| H <sub>0</sub>                             | 0.56                   | water level at the measurement section after disturbance, ref ground level          |                                 |
| t <sub>0</sub>                             | 53354.0                | time of disturbance   |                                 |
| t <sub>end</sub> (s)                       | 53410.0                | end of time range used to line fitting  |                                 |
| Time range (s)                             | 56.0                   | Time range used for interpretation  |                                 |
| T <sub>0</sub>                             | 29.9                   | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |                                 |
| 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                  |   |                                 |
| <b>K (m/s)</b>                             | <b>3.07E-06</b>        |   |                                 |
| logK                                       | -5.51                  |   |                                 |

|                                |             |  |                 |        |       |
|--------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                              | b           | <b>flow</b>                                |                 |        |       |
| -0.045691456                   | 0.365994875 | t1   | 53368.0         | h1     | 0.70  |
| 0.000719956                    | 0.023391138 | t2   | 53388.0         | h2     | 1.03  |
| <b>0.9865</b>                  | 0.089433377 | Q (m <sup>3</sup> /s)                      | 4.45E-06        | dh (m) | 0.35  |
| 4027.713033                    | 55          | K <sub>Thiem</sub> (m/s)                   | <b>6.22E-06</b> | logK   | -5.21 |
| 32.21497331                    | 0.439908086 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.49            |        |       |
| <b>Stat tests</b>              |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 63.46       | t1   | 53374.0         | h1     | 0.85  |
| test stat, b <> 0              | 15.65       | t2   | 53372.0         | h2     | 0.81  |
| t-critical, 90%                | 2.00        | Q (m <sup>3</sup> /s)                      | 5.52E-06        | dh (m) | 0.39  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>6.92E-06</b> | logK   | -5.16 |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.44            |        |       |



## APPENDIX 17 MEASUREMENTS AND RESULTS IN OL-PVP12

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP12 \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.52 m

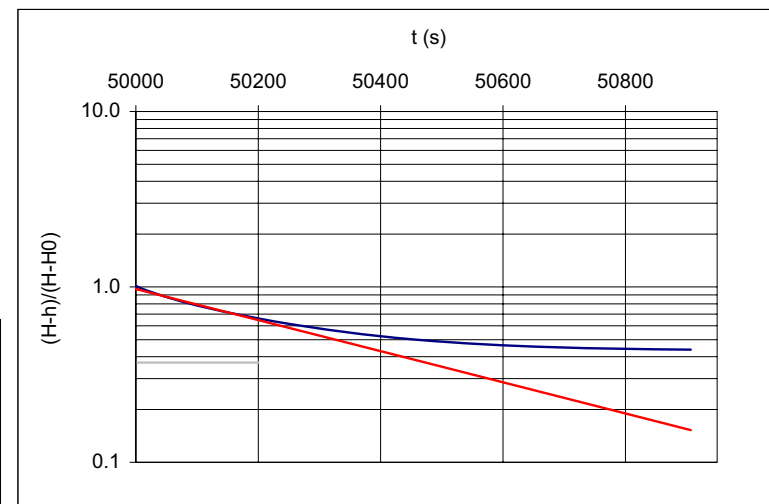
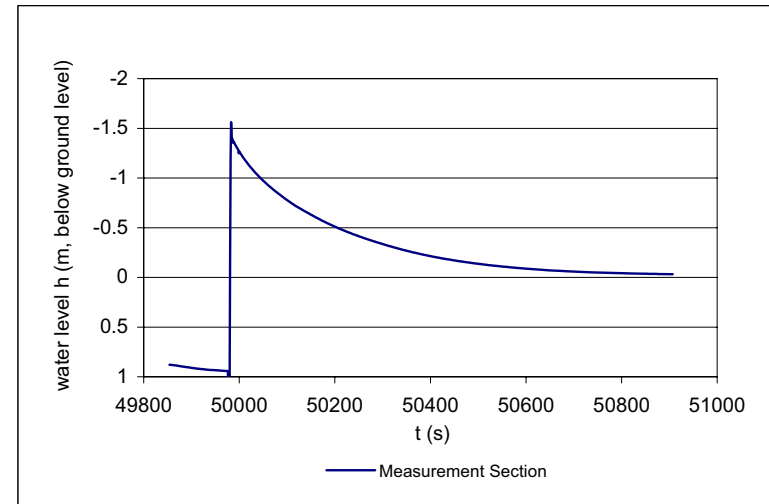
The reference level to depth is top of the casing, the length of the casing is 0.50 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 19   | 19.7.2010 | 13:45 | 1.67  | not in use                                 | 1.67                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments   |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|--|
| PVP12000019.dat       | 3.30   | 8.65E-07             | 0.990 | 1.31E-06               | 1.49E-06                | T0 not reached Shorter time used in interpretation |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP12000019.dat</b> | date  |
| TOC (m)                                    | 0.5                    |   |
| depth of pressure sensor meas. section (m) | 1.67                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 2.17                   | final, ref toc  |
| depth of meas. section (m)                 | 2.3                    | ref ground level, top   |
| depth of meas. section (m)                 | 3.3                    | 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  | 0.92                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | -1.2440                | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 50002.96               | time of disturbance   |
| t <sub>end</sub> (s)                       | 50200.04               | end of time range used to line fitting  |
| Time range (s)                             | 197.08                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 473.55                 | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>8.6536E-07</b>      | <b>T0 not reached</b>   |
| logK                                       | -6.06                  |   |

|                                |              |  |                 |        |        |
|--------------------------------|--------------|--|-----------------|--------|--------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |        |
| a                              | b            | <b>flow</b>                                |                 |        |        |
| -0.002042923                   | -0.032564342 | t1   | 50057.99        | h1     | -0.938 |
| 1.42943E-05                    | 0.001628312  | t2   | 50077.95        | h2     | -0.858 |
| <b>0.990495483</b>             | 0.01149655   | Q (m <sup>3</sup> /s)                      | 4.80E-06        | dh (m) | 1.81   |
| 20425.77353                    | 196          | K <sub>Thiem</sub> (m/s)                   | <b>1.31E-06</b> | logK   | -5.88  |
| 2.6996878                      | 0.025905448  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.66            |        |        |
| Stat tests                     |              | <b>tight</b>                               |                 |        |        |
| test stat, a <> 0              | 142.92       | t1   | 50023           | h1     | -1.113 |
| test stat, b <> 0              | 20.00        | t2   | 50068.02        | h2     | -0.897 |
| t-critical, 90%                | 1.97         | Q (m <sup>3</sup> /s)                      | 5.79E-06        | dh (m) | 1.92   |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>1.49E-06</b> | logK   | -5.83  |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.58            |        |        |



## APPENDIX 18 MEASUREMENTS AND RESULTS IN OL-PVP14

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP14 \_\_\_\_\_

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 2.09m

The reference level to depth is top of the casing, the length of the casing is 0.70 m

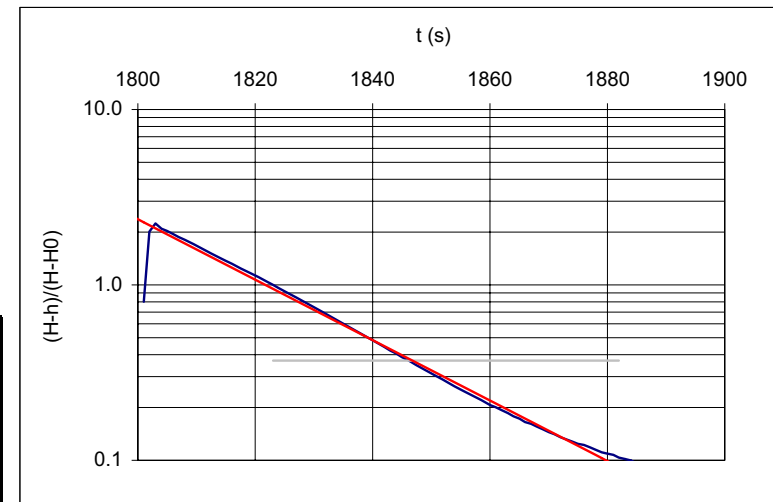
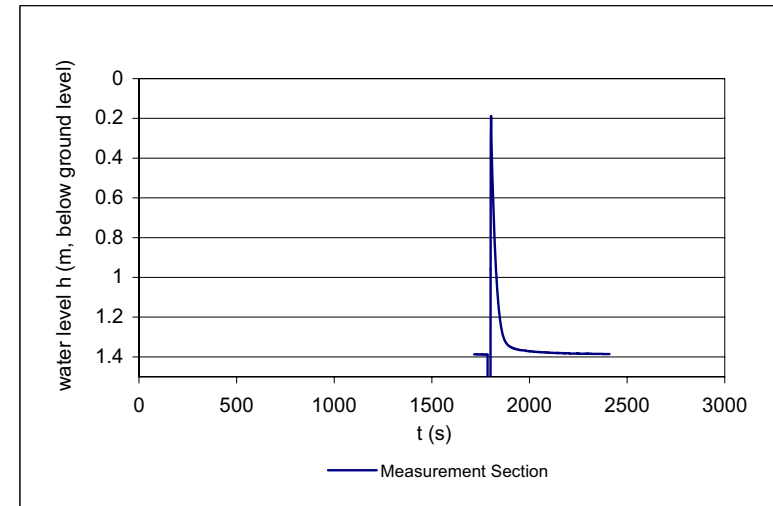
| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 3    | 30.6.2010 | 14:27 | 2.24  | not in use                                 | 2.24                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP14000003.dat       | 7.4  | 1.71E-05             | 0.996 | 2.44E-05               | 2.52E-05                |          |



|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP14000003.dat</b> | date  |
| TOC (m)                                    | 0.7                    |   |
| depth of pressure sensor meas. section (m) | 2.24                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.74                   | 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  | 1.39                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.8520                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 1823.03                | time of disturbance   |
| t <sub>end</sub> (s)                       | 1881.96                | end of time range used to line fitting  |
| Time range (s)                             | 58.93                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 23.91                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>1.71397E-05</b>     |   |
| logK                                       | -4.77                  |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.039666156                   | -0.051616677 | t1   | 1829            | h1     | 0.967 |
| 0.000343741                    | 0.011748474  | t2   | 1848.95         | h2     | 1.211 |
| <b>0.995663273</b>             | 0.046110858  | Q (m <sup>3</sup> /s)                      | 1.47E-05        | dh (m) | 0.30  |
| 13316.14206                    | 58           | K <sub>Thiem</sub> (m/s)                   | <b>2.44E-05</b> | logK   | -4.61 |
| 28.31293051                    | 0.12332025   | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.70            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 115.40       | t1   | 1842.99         | h1     | 1.158 |
| test stat, b <> 0              | 4.39         | t2   | 1841.96         | h2     | 1.148 |
| t-critical, 90%                | 2.00         | Q (m <sup>3</sup> /s)                      | 1.19E-05        | dh (m) | 0.23  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>2.52E-05</b> | logK   | -4.60 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.68            |        |       |



## APPENDIX 19 MEASUREMENTS AND RESULTS IN OL-PVP19

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP19 \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.36 m

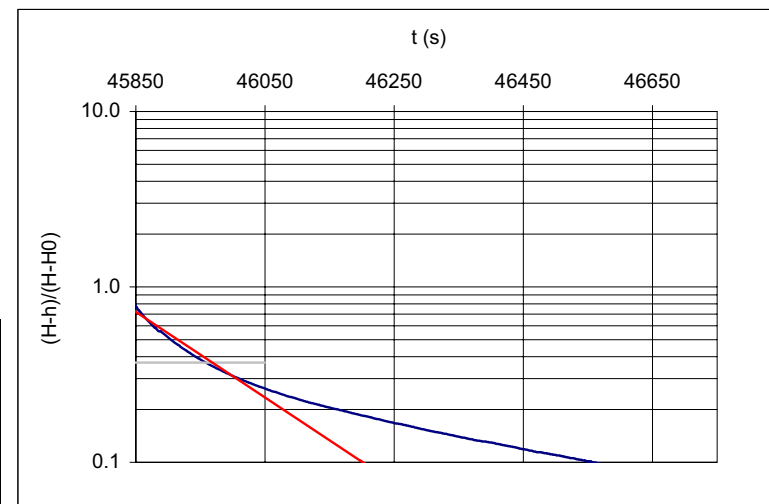
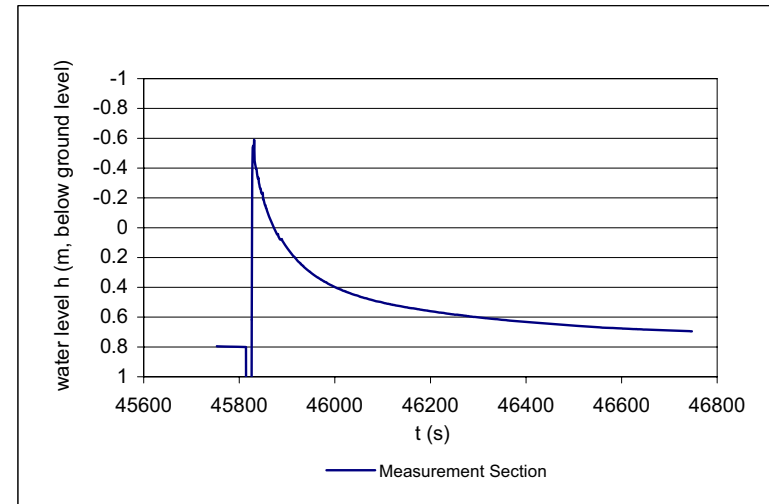
The reference level to depth is top of the casing, the length of the casing is 0.64 m

| File | Date     | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE!                   |
|------|----------|-------|-------|--|--|-------------------|-------------------------|
| 27   | 2.8.2010 | 12:40 | 1.51  | not in use                                 | 1.51                                       | 1.50              | 0.1 l water out of tube |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments                            |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|-------------------------------------|
| PVP19000027.dat       | 11.15  | 1.71E-06             | 0.964 | 1.46E-06               | 2.38E-06                | Shorter time used in interpretation |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP19000027.dat</b> | date  |
| TOC (m)                                    | 0.64                   |   |
| depth of pressure sensor meas. section (m) | 1.51                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.01                   | final, ref toc  |
| depth of meas. section (m)                 | 9.15                   | ref ground level, top   |
| depth of meas. section (m)                 | 11.15                  | 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  | 0.80                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | -0.4890                | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 45830.01               | time of disturbance   |
| t <sub>end</sub> (s)                       | 46049.99               | end of time range used to line fitting  |
| Time range (s)                             | 219.98                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 139.52                 | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 4                      | length of measurement section   |
| screen diam. (mm)                          | 56                     | equal to borehole diameter  |
| screen radius R (mm)                       | 28                     | equal to borehole radius  |
| L/R  | 142.86                 |   |
| <b>K (m/s)</b>                             | <b>1.70707E-06</b>     |   |
| logK                                       | -5.77                  |   |

|                                |             |  |                 |        |        |
|--------------------------------|-------------|--|-----------------|--------|--------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |        |
| a                              | b           | <b>flow</b>                                |                 |        |        |
| -0.005619261                   | -0.21600479 | t1   | 45941.03        | h1     | 0.279  |
| 7.38594E-05                    | 0.00939116  | t2   | 45960.99        | h2     | 0.327  |
| <b>0.963544049</b>             | 0.07004876  | Q (m <sup>3</sup> /s)                      | 2.92E-06        | dh (m) | 0.49   |
| 5788.249757                    | 219         | K <sub>Thiem</sub> (m/s)                   | <b>1.46E-06</b> | logK   | -5.84  |
| 28.40195021                    | 1.074595492 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 1.17            |        |        |
| Stat tests                     |             | <b>tight</b>                               |                 |        |        |
| test stat, a <> 0              | 76.08       | t1   | 45849.97        | h1     | -0.201 |
| test stat, b <> 0              | 23.00       | t2   | 45903.02        | h2     | 0.149  |
| t-critical, 90%                | 1.97        | Q (m <sup>3</sup> /s)                      | 7.94E-06        | dh (m) | 0.82   |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>2.38E-06</b> | logK   | -5.62  |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.72            |        |        |



## APPENDIX 20 MEASUREMENTS AND RESULTS IN OL-PVP20

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP20 \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.56 m

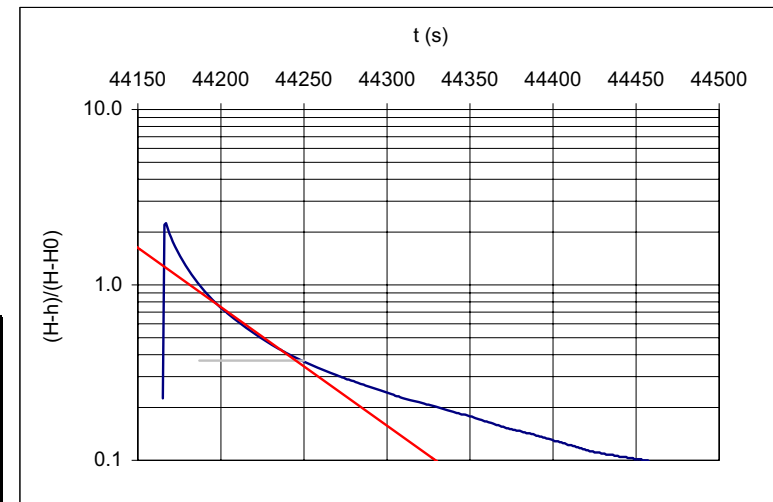
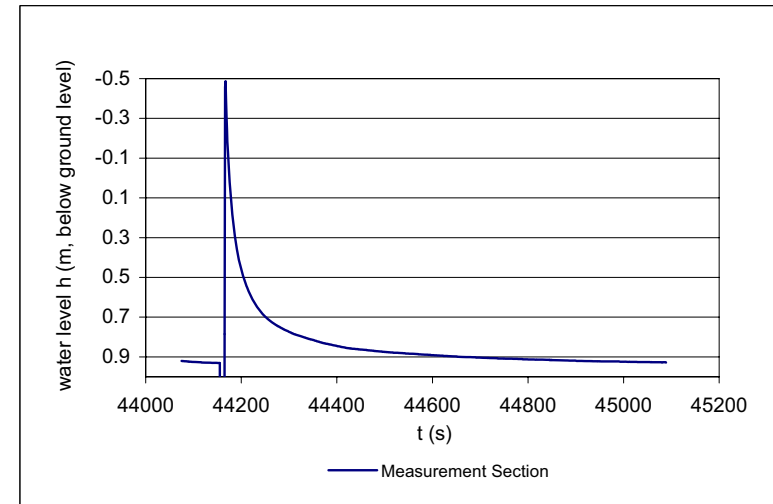
The reference level to depth is top of the casing, the length of the casing is 0.59 m

| File | Date     | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|-------|-------|--|--|-------------------|-------|
| 26   | 2.8.2010 | 12:10 | 1.71  | not in use                                 | 1.71                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments                            |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|-------------------------------------|
| PVP20000026.dat       | 9.60   | 7.01E-06             | 0.987 | 8.43E-06               | 1.01E-05                | Shorter time used in interpretation |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP20000026.dat</b> | date  |
| TOC (m)                                    | 0.59                   |   |
| depth of pressure sensor meas. section (m) | 1.71                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.21                   | final, ref toc  |
| depth of meas. section (m)                 | 8.6                    | ref ground level, top   |
| depth of meas. section (m)                 | 9.6                    | 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  | 0.93                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.2980                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 44187.03               | time of disturbance   |
| t <sub>end</sub> (s)                       | 44250.01               | end of time range used to line fitting  |
| Time range (s)                             | 62.98                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 58.49                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| 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                  |   |
| <b>K (m/s)</b>                             | <b>7.00588E-06</b>     |   |
| logK                                       | -5.15                  |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.015569166                   | -0.089313107 | t1   | 44213.99        | h1     | 0.561 |
| 0.000228667                    | 0.008343333  | t2   | 44234.03        | h2     | 0.652 |
| <b>0.986802321</b>             | 0.033789997  | Q (m <sup>3</sup> /s)                      | 5.46E-06        | dh (m) | 0.32  |
| 4635.795753                    | 62           | K <sub>Thiem</sub> (m/s)                   | <b>8.43E-06</b> | logK   | -5.07 |
| 5.292984338                    | 0.070789363  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.83            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 68.09        | t1   | 44206.99        | h1     | 0.515 |
| test stat, b <> 0              | 10.70        | t2   | 44208.02        | h2     | 0.522 |
| t-critical, 90%                | 2.00         | Q (m <sup>3</sup> /s)                      | 8.31E-06        | dh (m) | 0.41  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>1.01E-05</b> | logK   | -5.00 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.70            |        |       |



## APPENDIX 21 MEASUREMENTS AND RESULTS IN OL-PVP30

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP30 \_\_\_\_\_

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 2.25 m

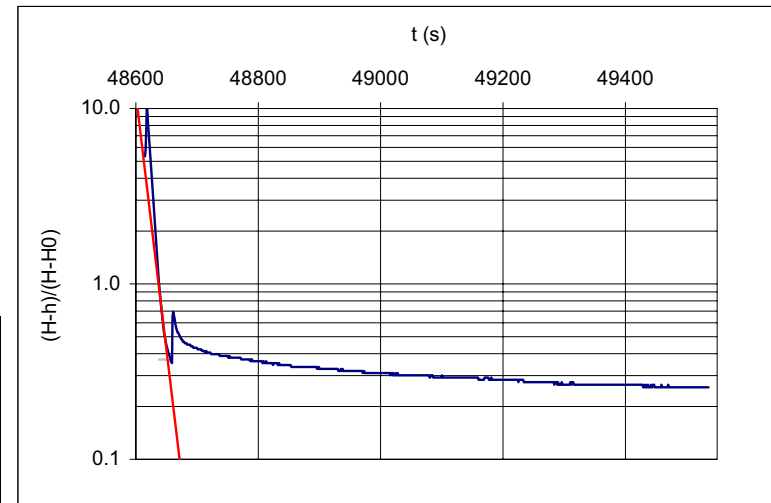
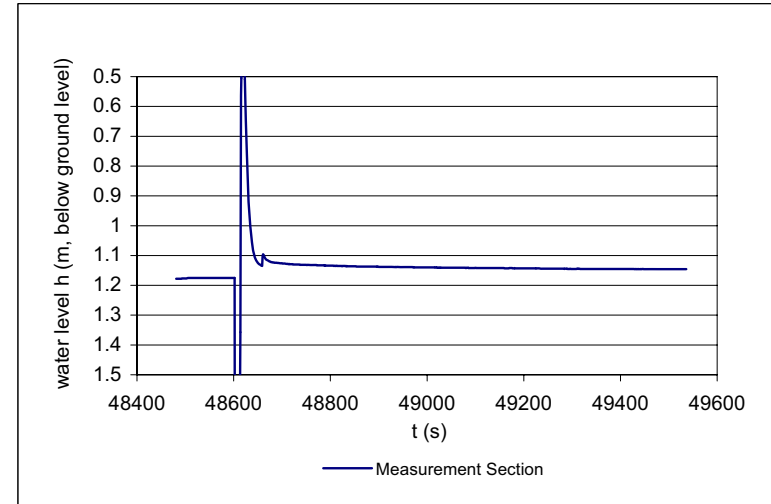
The reference level to depth is top of the casing, the length of the casing is 1.20 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 17   | 16.7.2010 | 13:21 | 2.40  | not in use                                 | 2.40                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments   |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|--|
| PVP30000017.dat       | 1.30   | 5.03E-05             | 0.980 | 8.04E-05               | 8.15E-05                | T0 not reached Shorter time used in interpretation |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP30000017.dat</b> | date  |
| TOC (m)                                    | 1.2                    |   |
| depth of pressure sensor meas. section (m) | 2.40                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.90                   | final, ref toc  |
| depth of meas. section (m)                 | 0.8                    | ref ground level, top   |
| depth of meas. section (m)                 | 1.3                    | 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  | 1.18                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 1.0610                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 48638.01               | time of disturbance   |
| t <sub>end</sub> (s)                       | 48650.02               | end of time range used to line fitting  |
| Time range (s)                             | 12.01                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 13.94                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 1                      | length of measurement section   |
| screen diam. (mm)                          | 52                     | equal to borehole diameter  |
| screen radius R (mm)                       | 26                     | equal to borehole radius  |
| L/R  | 38.46                  |   |
| <b>K (m/s)</b>                             | <b>5.02724E-05</b>     | <b>T0 not reached</b>   |
| logK                                       | -4.30                  |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.06717078                    | -0.063722955 | t1   | 48631.96        | h1     | 0.931 |
| 0.002914714                    | 0.020585539  | t2   | 48652.01        | h2     | 1.127 |
| <b>0.9797082</b>               | 0.039348357  | Q (m <sup>3</sup> /s)                      | 1.18E-05        | dh (m) | 0.15  |
| 531.0908957                    | 11           | K <sub>Thiem</sub> (m/s)                   | <b>8.04E-05</b> | logK   | -4.09 |
| 0.822284403                    | 0.017031225  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.63            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 23.05        | t1   | 48638.01        | h1     | 1.052 |
| test stat, b <> 0              | 3.10         | t2   | 48650.02        | h2     | 1.123 |
| t-critical, 90%                | 2.20         | Q (m <sup>3</sup> /s)                      | 7.18E-06        | dh (m) | 0.09  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>8.15E-05</b> | logK   | -4.09 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.62            |        |       |



## APPENDIX 22 MEASUREMENTS AND RESULTS IN OL-PVP31A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP31A

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 2.24 m

The reference level to depth is top of the casing, the length of the casing is 0.62 m

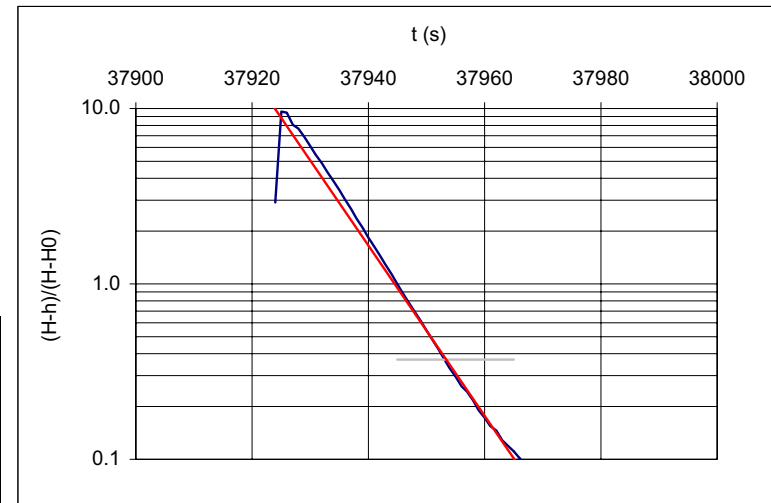
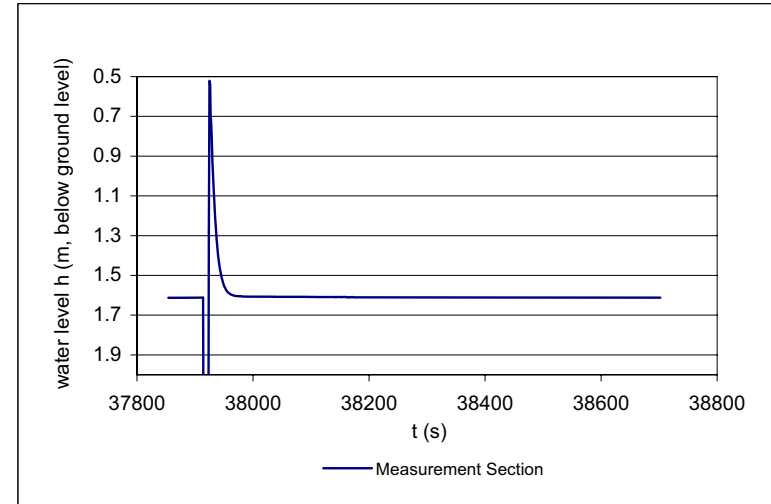
| File | Date     | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|-------|-------|--|--|-------------------|-------|
| 9    | 2.7.2010 | 10:25 | 2.39  | not in use                                 | 2.39                                       | 1.2               |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP31A000009.dat      | 3.72   | 4.91E-05             | 0.997 | 5.52E-05               | 4.84E-05                |          |



|  |                         |   |
|--|-------------------------|---|
| input file                                 | <b>PVP31A000009.dat</b> | date  |
| TOC (m)                                    | 0.62                    |   |
| depth of pressure sensor meas. section (m) | 2.39                    | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.59                    | final, ref toc  |
| depth of meas. section (m)                 | 2.72                    | ref ground level, top   |
| depth of meas. section (m)                 | 3.72                    | 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  | 1.61                    | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 1.4990                  | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 37944.97                | time of disturbance   |
| t <sub>end</sub> (s)                       | 37965.02                | end of time range used to line fitting  |
| Time range (s)                             | 20.05                   | Time range used for interpretation  |
| T <sub>0</sub>                             | 8.49                    | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 2                       | length of measurement section   |
| screen diam. (mm)                          | 52                      | equal to borehole diameter  |
| screen radius R (mm)                       | 26                      | equal to borehole radius  |
| L/R  | 76.92                   |   |
| <b>K (m/s)</b>                             | <b>4.91282E-05</b>      |   |
| logK                                       | -4.31                   |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.111751246                   | -0.051661712 | t1   | 37944.97        | h1     | 1.490 |
| 0.001458984                    | 0.017091472  | t2   | 37960.96        | h2     | 1.594 |
| <b>0.996771907</b>             | 0.040508102  | Q (m <sup>3</sup> /s)                      | 7.78E-06        | dh (m) | 0.07  |
| 5866.828619                    | 19           | K <sub>Thiem</sub> (m/s)                   | <b>5.52E-05</b> | logK   | -4.26 |
| 9.626916149                    | 0.03117722   | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.89            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 76.60        | t1   | 37944.97        | h1     | 1.490 |
| test stat, b <> 0              | 3.02         | t2   | 37965.02        | h2     | 1.599 |
| t-critical, 90%                | 2.09         | Q (m <sup>3</sup> /s)                      | 6.55E-06        | dh (m) | 0.07  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>4.84E-05</b> | logK   | -4.32 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 1.02            |        |       |



## APPENDIX 23 MEASUREMENTS AND RESULTS IN OL-PVP31B

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP31B

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 1.73 m

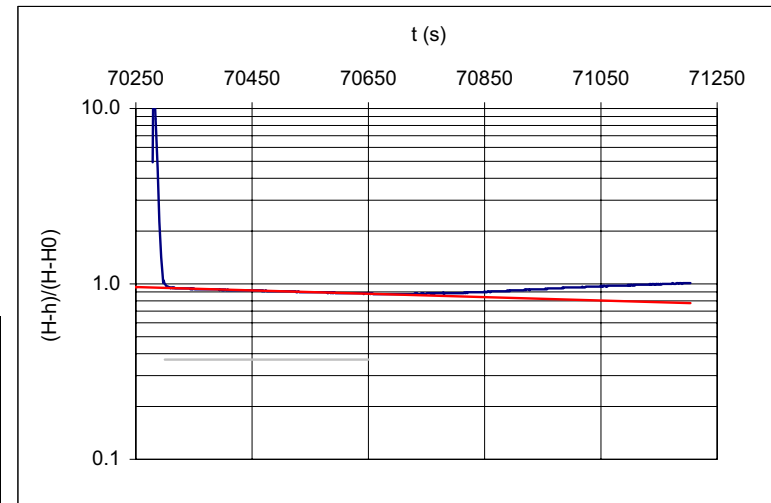
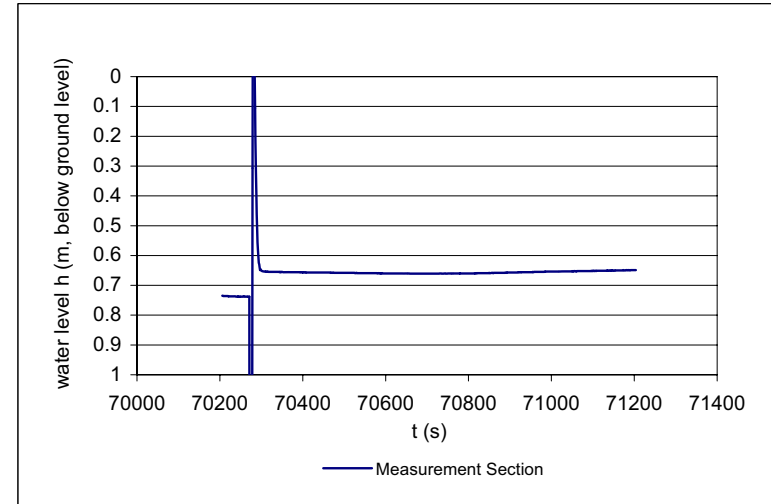
The reference level to depth is top of the casing, the length of the casing is 0.99 m

| File | Date     | Time | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|------|-------|--|--|-------------------|-------|
| 7    | 2.7.2010 | 9:28 | 1.88  | not in use                                 | 1.88                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments   |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|--|
| PVP31B000007.dat      | 2.59   | 9.69E-08             | 0.931 | 1.02E-07               | 1.69E-07                | T0 not reached Shorter time used in interpretation |

|  |                         |   |
|--|-------------------------|---|
| input file                                 | <b>PVP31B000007.dat</b> | date  |
| TOC (m)                                    | 0.99                    |   |
| 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)                 | 1.59                    | ref ground level, top   |
| depth of meas. section (m)                 | 2.59                    | 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  | 0.74                    | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.6500                  | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 70299.96                | time of disturbance   |
| t <sub>end</sub> (s)                       | 70649.97                | end of time range used to line fitting  |
| Time range (s)                             | 350.01                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 4301.01                 | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 2                       | length of measurement section   |
| screen diam. (mm)                          | 52                      | equal to borehole diameter  |
| screen radius R (mm)                       | 26                      | equal to borehole radius  |
| L/R  | 76.92                   |   |
| <b>K (m/s)</b>                             | <b>9.69328E-08</b>      | <b>T0 not reached</b>   |
| logK                                       | -7.01                   |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.000220337                   | -0.052326975 | t1   | 70405.97        | h1     | 0.657 |
| 3.21057E-06                    | 0.00064933   | t2   | 70426.02        | h2     | 0.657 |
| <b>0.931012717</b>             | 0.006094672  | Q (m <sup>3</sup> /s)                      | 1.64E-08        | dh (m) | 0.08  |
| 4709.903414                    | 349          | K <sub>Thiem</sub> (m/s)                   | <b>1.02E-07</b> | logK   | -6.99 |
| 0.174949471                    | 0.012963613  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.95            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 68.63        | t1   | 70320           | h1     | 0.655 |
| test stat, b <> 0              | 80.59        | t2   | 70415.99        | h2     | 0.657 |
| t-critical, 90%                | 1.97         | Q (m <sup>3</sup> /s)                      | 2.74E-08        | dh (m) | 0.08  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>1.69E-07</b> | logK   | -6.77 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.57            |        |       |



## APPENDIX 24 MEASUREMENTS AND RESULTS IN OL-PVP32

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP32 \_\_\_\_\_

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 2.30 m

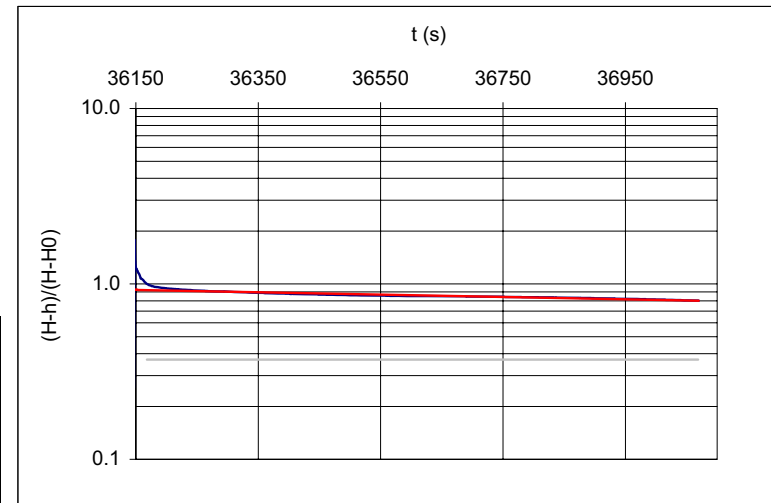
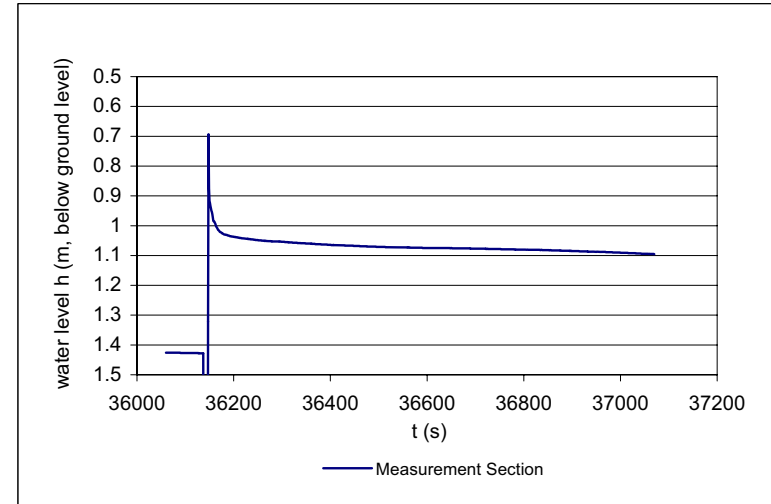
The reference level to depth is top of the casing, the length of the casing is 0.80 m

| File | Date     | Time | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|------|-------|--|--|-------------------|-------|
| 8    | 2.7.2010 | 9:54 | 2.45  | not in use                                 | 2.45                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments       |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------------|
| PVP3200008.dat        | 1.20   | 7.06E-08             | 0.907 | 1.23E-07               | 2.09E-07                | T0 not reached |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP32000008.dat</b> | date  |
| TOC (m)                                    | 0.8                    |   |
| depth of pressure sensor meas. section (m) | 2.45                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.95                   | final, ref toc  |
| depth of meas. section (m)                 | 0.2                    | ref ground level, top   |
| depth of meas. section (m)                 | 1.2                    | 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  | 1.43                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 1.0140                 | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 36167.99               | time of disturbance   |
| t <sub>end</sub> (s)                       | 37068.96               | end of time range used to line fitting  |
| Time range (s)                             | 900.97                 | Time range used for interpretation  |
| T <sub>0</sub>                             | 5906.93                | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 2                      | length of measurement section   |
| screen diam. (mm)                          | 52                     | equal to borehole diameter  |
| screen radius R (mm)                       | 26                     | equal to borehole radius  |
| L/R  | 76.92                  |   |
| <b>K (m/s)</b>                             | <b>7.05797E-08</b>     | <b>T0 not reached</b>   |
| logK                                       | -7.15                  |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.000155581                   | -0.080995789 | t1   | 36458.03        | h1     | 1.068 |
| 1.66422E-06                    | 0.000865964  | t2   | 36477.99        | h2     | 1.070 |
| <b>0.906634718</b>             | 0.013014564  | Q (m <sup>3</sup> /s)                      | 8.79E-08        | dh (m) | 0.36  |
| 8739.557505                    | 900          | K <sub>Thiem</sub> (m/s)                   | <b>1.23E-07</b> | logK   | -6.91 |
| 1.480296502                    | 0.152440996  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.57            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 93.49        | t1   | 36188.03        | h1     | 1.033 |
| test stat, b <> 0              | 93.53        | t2   | 36467.97        | h2     | 1.069 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 1.57E-07        | dh (m) | 0.38  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>2.09E-07</b> | logK   | -6.68 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.34            |        |       |



## APPENDIX 25 MEASUREMENTS AND RESULTS IN OL-PVP33

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP33 \_\_\_\_\_

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 2.93 m

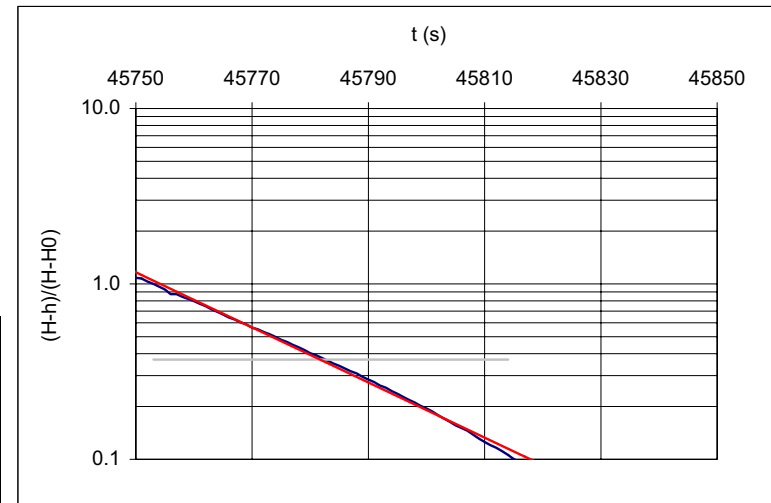
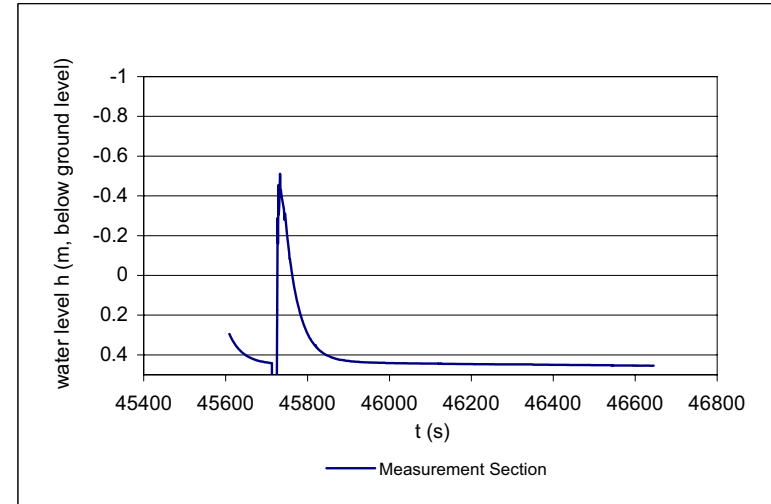
The reference level to depth is top of the casing, the length of the casing is 1.24 m

| File | Date     | Time | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|------|-------|--|--|-------------------|-------|
| 10   | 8.7.2010 |      | 3.08  | not in use                                 | 3.08                                       | 1.15              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP3300010.dat        | 1.26   | 2.43E-05             | 0.997 | 3.94E-05               |                         |          |

|  |                        |   |
|--|------------------------|---|
| input file                                 | <b>PVP33000010.dat</b> | date  |
| TOC (m)                                    | 1.24                   |   |
| depth of pressure sensor meas. section (m) | 3.08                   | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 4.23                   | final, ref toc  |
| depth of meas. section (m)                 | 0.76                   | ref ground level, top   |
| depth of meas. section (m)                 | 1.26                   | 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  | 0.40                   | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | -0.1520                | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 45753.03               | time of disturbance   |
| t <sub>end</sub> (s)                       | 45814.03               | end of time range used to line fitting  |
| Time range (s)                             | 61                     | Time range used for interpretation  |
| T <sub>0</sub>                             | 28.84                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 1                      | length of measurement section   |
| screen diam. (mm)                          | 52                     | equal to borehole diameter  |
| screen radius R (mm)                       | 26                     | equal to borehole radius  |
| L/R  | 38.46                  |   |
| <b>K (m/s)</b>                             | <b>2.43002E-05</b>     |   |
| logK                                       | -4.61                  |   |

|                                |             |  |                 |        |         |
|--------------------------------|-------------|--|-----------------|--------|---------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |         |
| a                              | b           | <b>flow</b>                                |                 |        |         |
| -0.036162297                   | 0.042796231 | t1   | 45764           | h1     | 0.015   |
| 0.000242851                    | 0.008580451 | t2   | 45783.96        | h2     | 0.205   |
| <b>0.997301352</b>             | 0.034216547 | Q (m <sup>3</sup> /s)                      | 1.15E-05        | dh (m) | 0.29    |
| 22173.35818                    | 60          | K <sub>Thiem</sub> (m/s)                   | <b>3.94E-05</b> | logK   | -4.40   |
| 25.95994918                    | 0.070246326 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.62            |        |         |
| <b>Stat tests</b>              |             | <b>tight</b>                               |                 |        |         |
| test stat, a <> 0              | 148.91      | t1   | 45772.99        | h1     | 0.115   |
| test stat, b <> 0              | 4.99        | t2   | 45772.99        | h2     | 0.115   |
| t-critical, 90%                | 2.00        | Q (m <sup>3</sup> /s)                      | #DIV/0!         | dh (m) | 0.29    |
|                                |             | K <sub>Thiem</sub> (m/s)                   | #DIV/0!         | logK   | #DIV/0! |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | #DIV/0!         |        |         |



## APPENDIX 26 MEASUREMENTS AND RESULTS IN OL-PVP34A

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP34A

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 1.98 m

The reference level to depth is top of the casing, the length of the casing is 0.92 m

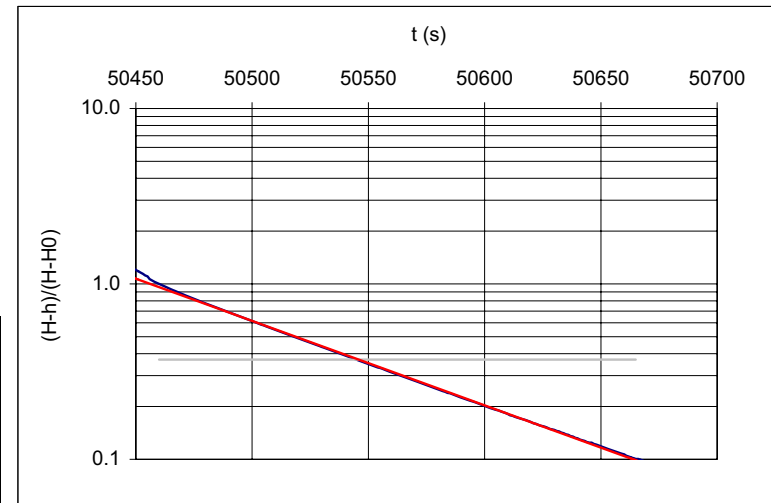
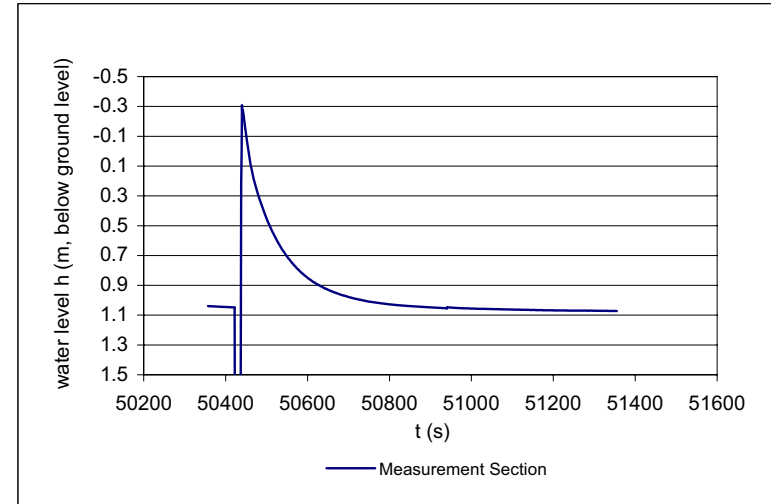
| File | Date     | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|----------|-------|-------|--|--|-------------------|-------|
| 11   | 8.7.2010 | 13:58 | 2.13  | not in use                                 | 2.13                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP34A000011.dat      | 4.08   | 4.83E-06             | 1.000 | 6.79E-06               | 6.73E-06                |          |



|  |                         |   |
|--|-------------------------|---|
| input file                                 | <b>PVP34A000011.dat</b> | date  |
| TOC (m)                                    | 0.92                    |   |
| depth of pressure sensor meas. section (m) | 2.13                    | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.63                    | final, ref toc  |
| depth of meas. section (m)                 | 3.08                    | ref ground level, top   |
| depth of meas. section (m)                 | 4.08                    | 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  | 1.04                    | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.0790                  | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 50460.01                | time of disturbance   |
| t <sub>end</sub> (s)                       | 50664.95                | end of time range used to line fitting  |
| Time range (s)                             | 204.94                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 86.39                   | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 2                       | length of measurement section   |
| screen diam. (mm)                          | 52                      | equal to borehole diameter  |
| screen radius R (mm)                       | 26                      | equal to borehole radius  |
| L/R  | 76.92                   |   |
| <b>K (m/s)</b>                             | <b>4.82617E-06</b>      |   |
| logK                                       | -5.32                   |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.011084362                   | -0.042476775 | t1   | 50507.97        | h1     | 0.503 |
| 1.40123E-05                    | 0.001660296  | t2   | 50528.01        | h2     | 0.613 |
| <b>0.999674099</b>             | 0.01195939   | Q (m <sup>3</sup> /s)                      | 6.59E-06        | dh (m) | 0.49  |
| 625752.6961                    | 204          | K <sub>Thiem</sub> (m/s)                   | <b>6.79E-06</b> | logK   | -5.17 |
| 89.49953998                    | 0.029177511  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.71            |        |       |
| <b>Stat tests</b>              |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 791.05       | t1   | 50479.97        | h1     | 0.297 |
| test stat, b <> 0              | 25.58        | t2   | 50528.01        | h2     | 0.613 |
| t-critical, 90%                | 1.97         | Q (m <sup>3</sup> /s)                      | 7.93E-06        | dh (m) | 0.59  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>6.73E-06</b> | logK   | -5.17 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.72            |        |       |



## APPENDIX 27 MEASUREMENTS AND RESULTS IN OL-PVP34B

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
PVP34B

Measurer:  
Maarit Yli-Kaila, Katariina Perävainio \_\_\_\_\_

Water level before starting 2.09 m

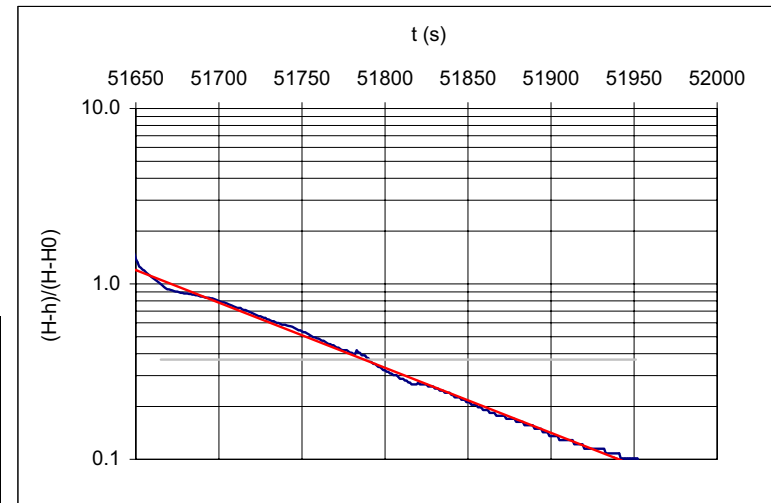
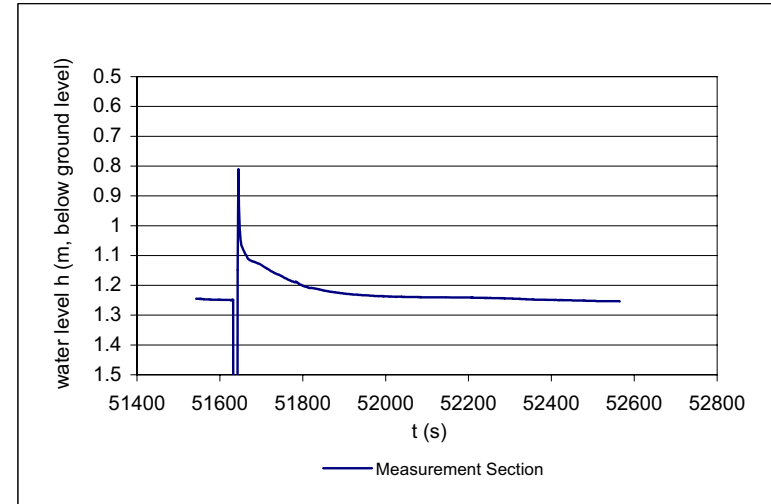
The reference level to depth is top of the casing, the length of the casing is 0.79 m

| File | Date      | Time | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|------|-------|--|--|-------------------|-------|
| 12   | 28.5.2008 | 9:50 | 1.43  | not in use                                 | 1.43                                       | 1.50              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| PVP34B000012.dat      | 2.21   | 3.39E-06             | 0.997 | 5.90E-06               | 4.54E-06                |          |

|  |                         |   |
|--|-------------------------|---|
| input file                                 | <b>PVP34B000012.dat</b> | date  |
| TOC (m)                                    | 0.79                    |   |
| depth of pressure sensor meas. section (m) | 2.24                    | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.74                    | final, ref toc  |
| depth of meas. section (m)                 | 1.21                    | ref ground level, top   |
| depth of meas. section (m)                 | 2.21                    | 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  | 1.25                    | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 1.1030                  | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 51665.03                | time of disturbance   |
| t <sub>end</sub> (s)                       | 51951.02                | end of time range used to line fitting  |
| Time range (s)                             | 285.99                  | Time range used for interpretation  |
| T <sub>0</sub>                             | 123.15                  | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 2                       | length of measurement section   |
| screen diam. (mm)                          | 52                      | equal to borehole diameter  |
| screen radius R (mm)                       | 26                      | equal to borehole radius  |
| L/R  | 76.92                   |   |
| <b>K (m/s)</b>                             | <b>3.38544E-06</b>      |   |
| logK                                       | -5.47                   |   |

|                                |             |  |                 |        |       |
|--------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                              | b           | <b>flow</b>                                |                 |        |       |
| -0.008544929                   | 0.052287569 | t1   | 51745.99        | h1     | 1.167 |
| 2.8316E-05                     | 0.00467885  | t2   | 51766.04        | h2     | 1.181 |
| <b>0.99688015</b>              | 0.039743111 | Q (m <sup>3</sup> /s)                      | 8.64E-07        | dh (m) | 0.07  |
| 91065.55139                    | 285         | K <sub>Thiem</sub> (m/s)                   | <b>5.90E-06</b> | logK   | -5.23 |
| 143.839392                     | 0.450161736 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.57            |        |       |
| Stat tests                     |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 301.77      | t1   | 51684.99        | h1     | 1.122 |
| test stat, b <> 0              | 11.18       | t2   | 51759.99        | h2     | 1.177 |
| t-critical, 90%                | 1.97        | Q (m <sup>3</sup> /s)                      | 8.86E-07        | dh (m) | 0.10  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>4.54E-06</b> | logK   | -5.34 |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.75            |        |       |



## APPENDIX 28 MEASUREMENTS AND RESULTS IN OL-HP1

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
HP1 Korvensuo

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 4.09 m

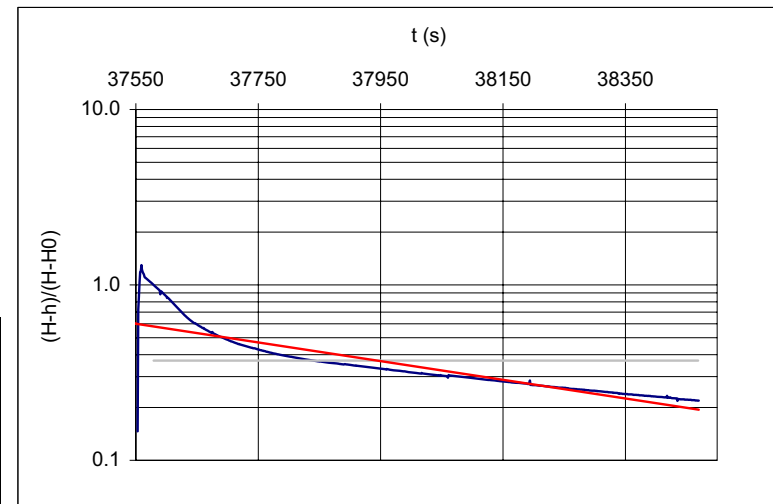
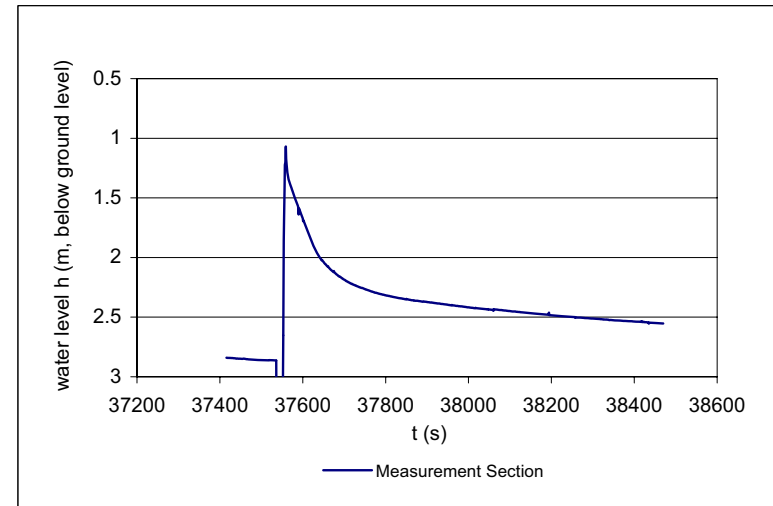
The reference level to depth is top of the casing, the length of the casing is 1.03 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 13   | 13.7.2010 | 10:10 | 4.24  | not in use                                 | 4.24                                       | 1.05              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| HP1000013.dat         | 4.5  | 1.91E-06             | 0.866 | 4.21E-06               | 3.66E-06                |          |

|  |                      |   |
|--|----------------------|---|
| input file                                 | <b>HP1000013.dat</b> | date  |
| TOC (m)                                    | 1.03                 |   |
|  | 0                    |   |
| depth of pressure sensor meas. section (m) | 4.24                 | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 5.29                 | final, ref toc  |
| depth of meas. section (m)                 | 4                    | ref ground level, top   |
| depth of meas. section (m)                 | 4.5                  | 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  | 2.85                 | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 1.4790               | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 37578.98             | time of disturbance   |
| t <sub>end</sub> (s)                       | 38468.99             | end of time range used to line fitting  |
| Time range (s)                             | 890.01               | Time range used for interpretation  |
| T <sub>0</sub>                             | 370.60               | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 1                    | length of measurement section   |
| screen diam. (mm)                          | 50                   | equal to borehole diameter  |
| screen radius R (mm)                       | 25                   | equal to borehole radius  |
| L/R  | 40.00                |   |
| <b>K (m/s)</b>                             | <b>1.91112E-06</b>   |   |
| logK                                       | -5.72                |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.001226128                   | -0.545593489 | t1   | 37681.97        | h1     | 2.142 |
| 1.62004E-05                    | 0.008326978  | t2   | 37702.02        | h2     | 2.190 |
| <b>0.865654267</b>             | 0.124379891  | Q (m <sup>3</sup> /s)                      | 2.88E-06        | dh (m) | 0.69  |
| 5728.255176                    | 889          | K <sub>Thiem</sub> (m/s)                   | <b>4.21E-06</b> | logK   | -5.38 |
| 88.61815361                    | 13.75314754  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.45            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 75.69        | t1   | 37599.03        | h1     | 1.664 |
| test stat, b <> 0              | 65.52        | t2   | 37874.99        | h2     | 2.363 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 3.06E-06        | dh (m) | 0.84  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>3.66E-06</b> | logK   | -5.44 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.52            |        |       |



## APPENDIX 29 MEASUREMENTS AND RESULTS IN OL-HP2

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
HP2 Korvensuo

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.11 m

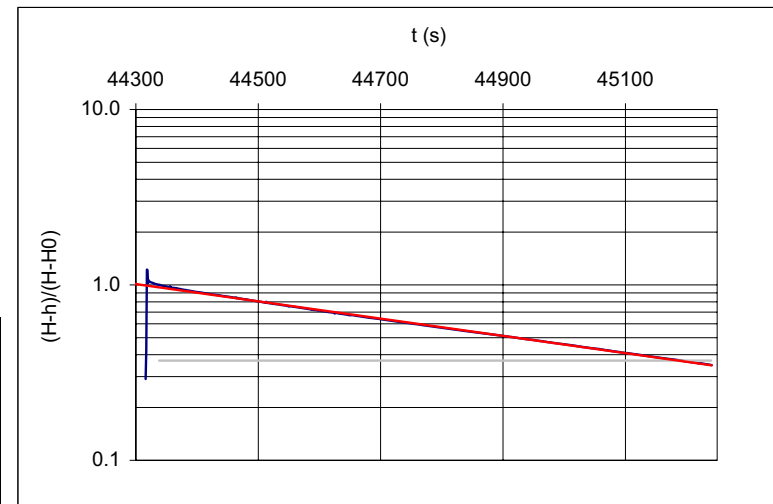
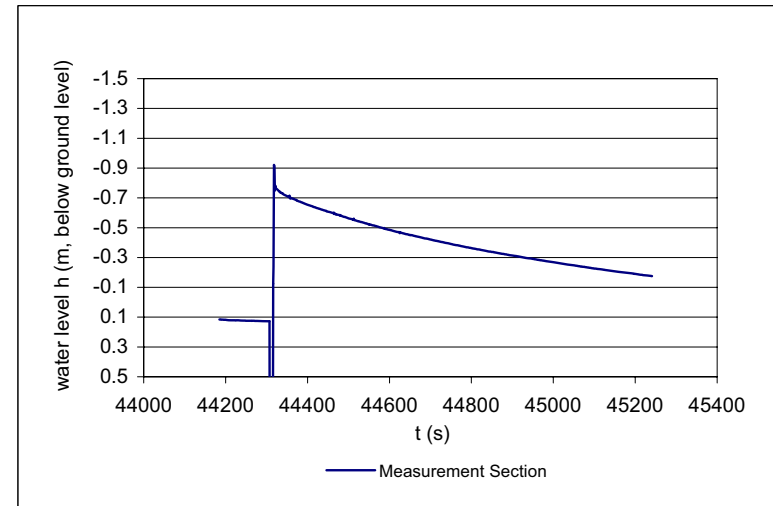
The reference level to depth is top of the casing, the length of the casing is 0.80 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE!                    |
|------|-----------|-------|-------|--|--|-------------------|--------------------------|
| 14   | 13.7.2010 | 12:00 | 1.26  | not in use                                 | 1.26                                       | 1.50              | c. 1 l water out of tube |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| HP2000014.dat         | 2.5  | 8.30E-07             | 0.999 | 1.42E-06               | 1.50E-06                |          |

|  |                      |   |
|--|----------------------|---|
| input file                                 | <b>HP2000014.dat</b> | date  |
| TOC (m)                                    | 0.8<br>0             |   |
| depth of pressure sensor meas. section (m) | 1.26                 | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 2.76                 | final, ref toc  |
| depth of meas. section (m)                 | 2                    | ref ground level, top   |
| depth of meas. section (m)                 | 2.5                  | 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  | 0.12                 | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | -0.7300              | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 44337.97             | time of disturbance   |
| t <sub>end</sub> (s)                       | 45239.99             | end of time range used to line fitting  |
| Time range (s)                             | 902.02               | Time range used for interpretation  |
| T <sub>0</sub>                             | 853.73               | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 1                    | length of measurement section   |
| screen diam. (mm)                          | 50                   | equal to borehole diameter  |
| screen radius R (mm)                       | 25                   | equal to borehole radius  |
| L/R  | 40.00                |   |
| <b>K (m/s)</b>                             | <b>8.29615E-07</b>   |   |
| logK                                       | -6.08                |   |

|                                |              |  |                 |        |        |
|--------------------------------|--------------|--|-----------------|--------|--------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |        |
| a                              | b            | <b>flow</b>                                |                 |        |        |
| -0.00113418                    | -0.031720167 | t1   | 44628.01        | h1     | -0.466 |
| 9.7473E-07                     | 0.000507773  | t2   | 44647.97        | h2     | -0.452 |
| <b>0.999334971</b>             | 0.007635286  | Q (m <sup>3</sup> /s)                      | 8.19E-07        | dh (m) | 0.58   |
| 1353926.98                     | 901          | K <sub>Thiem</sub> (m/s)                   | <b>1.42E-06</b> | logK   | -5.85  |
| 78.9306863                     | 0.052526133  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.59            |        |        |
| Stat tests                     |              | <b>tight</b>                               |                 |        |        |
| test stat, a <> 0              | 1163.58      | t1   | 44358.01        | h1     | -0.702 |
| test stat, b <> 0              | 62.47        | t2   | 44638.04        | h2     | -0.459 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 1.05E-06        | dh (m) | 0.70   |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>1.50E-06</b> | logK   | -5.82  |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.55            |        |        |



## APPENDIX 30 MEASUREMENTS AND RESULTS IN OL-HP3

Area: Olkiluoto

Hole: HP3 Korvensuo

Measurer: Katariina Perävainio, Tomas Niemi

Water level before starting 5.36 m

The reference level to depth is top of the casing, the length of the casing is 1.12 m

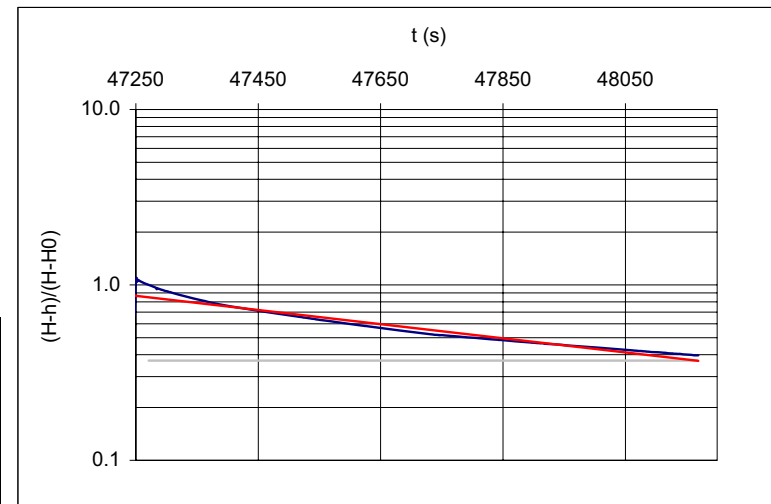
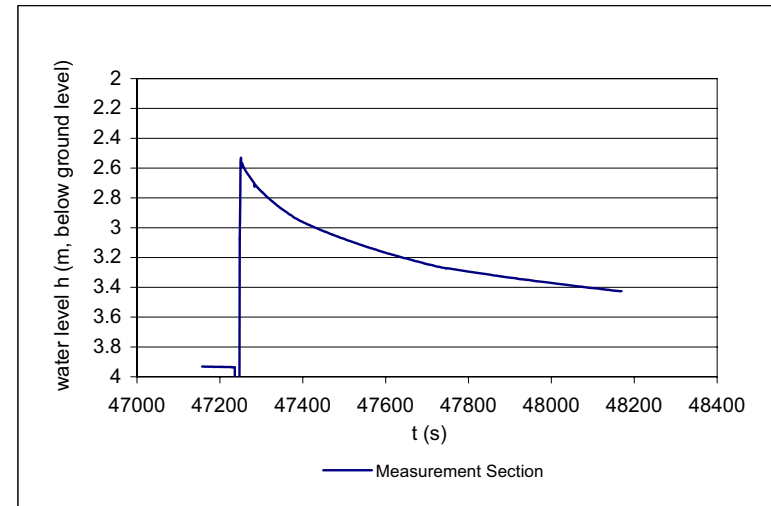
| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 15   | 13.7.2011 | 12:45 | 5.51  | not in use                                 | 5.51                                       | 1.00              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments       |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------------|
| HP3000015.dat         | 4.5  | 7.86E-07             | 0.963 | 7.51E-07               | 1.79E-06                | T0 not reached |



|  |                      |   |
|--|----------------------|---|
| input file                                 | <b>HP3000015.dat</b> | date  |
| TOC (m)                                    | 1.12                 |   |
|  | 0                    |   |
| depth of pressure sensor meas. section (m) | 5.51                 | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 6.51                 | final, ref toc  |
| depth of meas. section (m)                 | 4                    | ref ground level, top   |
| depth of meas. section (m)                 | 4.5                  | 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  | 3.93                 | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 2.6550               | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 47270.99             | time of disturbance   |
| t <sub>end</sub> (s)                       | 48168                | end of time range used to line fitting  |
| Time range (s)                             | 897.01               | Time range used for interpretation  |
| T <sub>0</sub>                             | 900.99               | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 1                    | length of measurement section   |
| screen diam. (mm)                          | 50                   | equal to borehole diameter  |
| screen radius R (mm)                       | 25                   | equal to borehole radius  |
| L/R  | 40.00                |   |
| <b>K (m/s)</b>                             | <b>7.86097E-07</b>   | <b>T0 not reached</b>   |
| logK                                       | -6.10                |   |

|                                |              |  |                 |        |       |
|--------------------------------|--------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |              | Thiem analysis for control                 |                 |        |       |
| a                              | b            | <b>flow</b>                                |                 |        |       |
| -0.000928793                   | -0.163167494 | t1   | 47791.98        | h1     | 3.291 |
| 6.05105E-06                    | 0.003134642  | t2   | 47812.03        | h2     | 3.299 |
| <b>0.963362828</b>             | 0.047006108  | Q (m <sup>3</sup> /s)                      | 4.76E-07        | dh (m) | 0.64  |
| 23560.0359                     | 896          | K <sub>Thiem</sub> (m/s)                   | <b>7.51E-07</b> | logK   | -6.12 |
| 52.05764694                    | 1.979778463  | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 1.05            |        |       |
| Stat tests                     |              | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 153.49       | t1   | 47291.03        | h1     | 2.730 |
| test stat, b <> 0              | 52.05        | t2   | 47570.02        | h2     | 3.141 |
| t-critical, 90%                | 1.96         | Q (m <sup>3</sup> /s)                      | 1.78E-06        | dh (m) | 1.00  |
|                                |              | K <sub>Thiem</sub> (m/s)                   | <b>1.79E-06</b> | logK   | -5.75 |
|                                |              | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.44            |        |       |



## APPENDIX 31 MEASUREMENTS AND RESULTS IN OL-HP4

Area:  
Olkiluoto \_\_\_\_\_

Hole:  
HP4 Korvensuo

Measurer:  
Katariina Perävainio, Tomas Niemi \_\_\_\_\_

Water level before starting 1.83 m

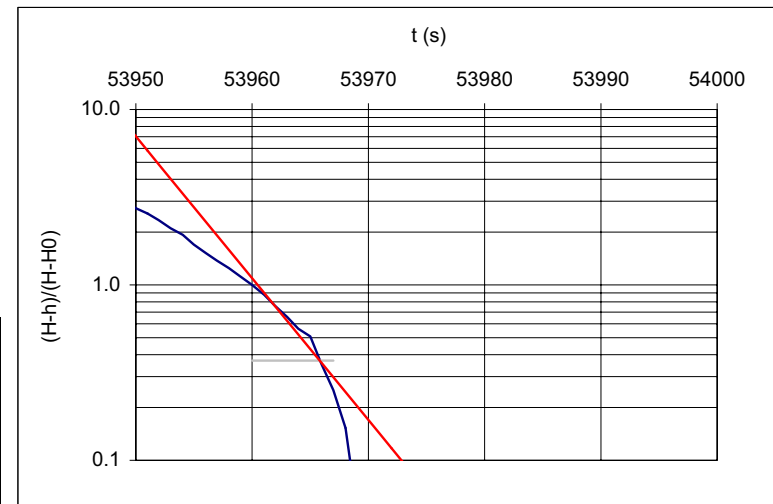
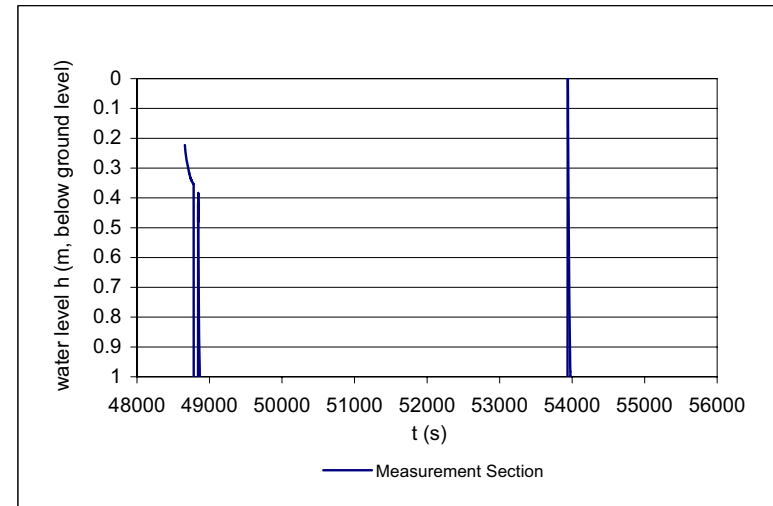
The reference level to depth is top of the casing, the length of the casing is 0.44 m

| File | Date      | Time  | Depth | Depth of pressure sensor open borehole (m) | Depth of pressure sensor meas. section (m) | Moving piston (m) | NOTE! |
|------|-----------|-------|-------|--|--|-------------------|-------|
| 16   | 13.7.2011 | 14.49 | 2.01  | not in use                                 | 2.01                                       | 1.00              |       |

| measurement/hole &run | measurement depth (m) below ground level midpoint of the section | $K_{Hvorstev}$ (m/s) | R2    | $K_{Thiem}$ (m/s) flow | $K_{Thiem}$ (m/s) tight | comments |
|-----------------------|--|----------------------|-------|------------------------|-------------------------|----------|
| HP4000016.dat         | 2.5  | 1.21E-04             | 0.952 | 1.42E-04               | 2.03E-04                |          |

|  |                      |   |
|--|----------------------|---|
| input file                                 | <b>HP4000016.dat</b> | date  |
| TOC (m)                                    | 0.44                 |   |
|  | 0                    |   |
| depth of pressure sensor meas. section (m) | 2.01                 | initial, ref toc  |
| depth of pressure sensor meas. section (m) | 3.51                 | final, ref toc  |
| depth of meas. section (m)                 | 2                    | ref ground level, top   |
| depth of meas. section (m)                 | 2.5                  | 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  | 0.89                 | reference water level at the measurement section based on phase 1, ref ground level |
| H <sub>0</sub>                             | 0.7060               | water level at the measurement section after disturbance, ref ground level          |
| t <sub>0</sub>                             | 53959.99             | time of disturbance   |
| t <sub>end</sub> (s)                       | 53966.99             | end of time range used to line fitting  |
| Time range (s)                             | 7                    | Time range used for interpretation  |
| T <sub>0</sub>                             | 5.85                 | basic time lag, t corresponding the time when $\ln((H-h)/(H-H_0)) = -1$             |
| L (m)                                      | 1                    | length of measurement section   |
| screen diam. (mm)                          | 50                   | equal to borehole diameter  |
| screen radius R (mm)                       | 25                   | equal to borehole radius  |
| L/R  | 40.00                |   |
| <b>K (m/s)</b>                             | <b>1.21E-04</b>      |   |
| logK                                       | -3.92                |   |

|                                |             |  |                 |        |       |
|--------------------------------|-------------|--|-----------------|--------|-------|
| $\ln((H-h)/(H-H_0)) = a*t + b$ |             | Thiem analysis for control                 |                 |        |       |
| a                              | b           | <b>flow</b>                                |                 |        |       |
| -0.186182617                   | 0.089990209 | t1   | 53951.96        | h1     | 0.461 |
| 0.017131003                    | 0.071583383 | t2   | 53972           | h2     | 0.923 |
| <b>0.951658545</b>             | 0.110511153 | Q (m <sup>3</sup> /s)                      | 2.78E-05        | dh (m) | 0.20  |
| 118.1170744                    | 6           | K <sub>Thiem</sub> (m/s)                   | <b>1.42E-04</b> | logK   | -3.85 |
| 1.442530154                    | 0.073276289 | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.85            |        |       |
| Stat tests                     |             | <b>tight</b>                               |                 |        |       |
| test stat, a <> 0              | 10.87       | t1   | 53959.99        | h1     | 0.701 |
| test stat, b <> 0              | 1.26        | t2   | 53966.99        | h2     | 0.840 |
| t-critical, 90%                | 2.45        | Q (m <sup>3</sup> /s)                      | 2.40E-05        | dh (m) | 0.12  |
|                                |             | K <sub>Thiem</sub> (m/s)                   | <b>2.03E-04</b> | logK   | -3.69 |
|                                |             | K <sub>Hvorslev</sub> / K <sub>Thiem</sub> | 0.59            |        |       |



# APPENDIX 32 SUMMARY OF THE RESULTS

| Hole    | 2010  |                            |                          | 2009  |                            |                          | 2008  |                            |                          | 2007  |                            |                          | 2006  |                            |                          | 2005  |                            |                          | 2004  |                            |                          | Comments   |
|---------|---|----------------------------|--------------------------|---|----------------------------|--------------------------|---|----------------------------|--------------------------|---|----------------------------|--------------------------|---|----------------------------|--------------------------|---|----------------------------|--------------------------|---|----------------------------|--------------------------|--|
|         | Test section, ref ground level, midpoint of the section (m) | K <sub>Horslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | Test section, ref ground level, midpoint of the section (m) | K <sub>Horslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | Test section, ref ground level, midpoint of the section (m) | K <sub>Horslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | Test section, ref ground level, midpoint of the section (m) | K <sub>Horslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | Test section, ref ground level, midpoint of the section (m) | K <sub>Horslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | Test section, ref ground level, midpoint of the section (m) | K <sub>Horslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | Test section, ref ground level, midpoint of the section (m) | K <sub>Horslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) |  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 2.69  | 2.8E-06                    | 4.5E-05                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 19 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 2.69  | 1.6E-05                    | 3.8E-05                  |   |                            |                          | the measurement has not succeeded  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 3.69  | 4.6E-07                    | 7.3E-07                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 4.69  | 7.7E-06                    | 1.3E-05                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 5.7   | 2.0E-07                    | 3.9E-07                  | 5.69  | 2.4E-07                    | 4.1E-07                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 6.7   | 1.0E-07                    | 2.1E-07                  | 6.69  | 2.0E-07                    | 4.1E-07                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 7.7   | 7.6E-08                    | 1.5E-07                  | 7.69  | 9.6E-08                    | 1.9E-07                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 8.7   | 9.1E-08                    | 2.0E-07                  | 8.69  | 1.0E-07                    | 2.1E-07                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 9.7   | 1.5E-07                    | 3.2E-07                  | 9.69  | 1.6E-07                    | 3.3E-07                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 10.7  | 1.4E-07                    | 3.3E-07                  | 10.69   | 1.6E-07                    | 3.6E-07                  |   |                            |                          | depths of test sections in 2002 and 2005 differ 46 cm  |
| OL-PP5  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 3.8   | 8.3E-08                    | 2.1E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          | 4.83  | 4.7E-06                    | 6.7E-06                  | 4.83  | 5.2E-06                    | 6.7E-06                  | 4.8   | 1.9E-06                    | 2.8E-06                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          | 5.83  | 4.5E-09                    | 1.3E-08                  | 5.83  | -9.6E-10                   | 2.1E-09                  | 5.8   | 2.3E-08                    | 1.3E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 6.8   | 5.3E-06                    | 1.0E-05                  |   |                            |                          | K-value differs radically from two other measurements from the same section in 2002 and 2005 |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 6.83  | 6.3E-09                    | 3.9E-08                  | 6.8   | 2.2E-08                    | 2.1E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 7.83  | 1.3E-07                    | 2.2E-07                  | 7.8   | 1.2E-07                    | 3.5E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 8.83  | 3.5E-07                    | 5.4E-07                  | 8.8   | 5.0E-08                    | 3.0E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 9.83  | 3.3E-07                    | 4.9E-07                  | 9.8   | 1.7E-07                    | 3.6E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 10.83   | -6.0E-10                   | 1.4E-08                  | 10.8  | 3.4E-08                    | 2.5E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          | 11.83   | 2.7E-09                    | 2.1E-08                  | 11.8  | 2.6E-08                    | 2.3E-07                  |   |                            |                          |  |
| OL-PP9  |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |  |
| OL-PP36 | 5.72  | 2.0E-08                    | 3.3E-08                  | 5.67  | 1.2E-08                    | 2.1E-08                  | 5.67  | 1.0E-08                    | 1.8E-08                  | 5.67  | 1.3E-08                    | 2.3E-08                  |   |                            |                          |   |                            |                          |   |                            |                          | T0 not reached   |
| OL-PP36 | 6.72  | 1.3E-07                    | 2.5E-07                  | 6.67  | 1.4E-07                    | 3.0E-07                  | 6.67  | 1.2E-07                    | 2.4E-07                  | 6.67  | 1.3E-07                    | 2.2E-07                  | 6.67  | 1.3E-07                    | 2.4E-07                  |   |                            |                          |   |                            |                          | T0 not reached   |
| OL-PP36 |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |   |                            |                          |  |
| OL-PP36 | 7.72  | 4.5E-07                    | 7.9E-07                  | 7.67  | 4.8E-07                    | 8.3E-07                  | 7.67  | 4.2E-07                    | 7.3E-07                  | 7.67  | 5.3E-07                    | 7.8E-07                  | 7.67  | 5.2E-07                    | 7.7E-07                  |   |                            |                          |   |                            |                          |  |
| OL-PP36 | 8.72  | 1.2E-08                    | 4.0E-08                  | 8.67  | 5.4E-07                    | 9.6E-07                  | 8.67  | 6.0E-07                    | 1.1E-06                  | 8.67  | 4.7E-07                    | 7.5E-07                  | 8.67  | 1.6E-08                    | 5.2E-08                  |   |                            |                          |   |                            |                          |  |
| OL-PP39 | 5.00  | 1.7E-07                    | 3.5E-07                  | 4.95  | 1.3E-07                    | 2.5E-07                  | 4.95  | 1.2E-07                    | 2.4E-07                  | 4.95  | 1.2E-07                    | 1.8E-07                  | 4.95  | 1.2E-07                    | 2.3E-07                  | 4.94  | 9.6E-08                    | 1.7E-07                  | 4.92  | 6.2E-08                    | 1.5E-07                  | T0 not reached   |
| OL-PP39 | 6.00  | 1.4E-08                    | 5.0E-08                  | 5.95  | 1.3E-08                    | 2.9E-08                  | 5.95  | 1.4E-08                    | 3.9E-08                  | 5.95  | 9.7E-09                    | 6.0E-09                  | 5.95  | 8.5E-09                    | 3.2E-08                  | 5.94  | 3.9E-09                    | 1.3E-08                  | 5.92  | 2.7E-08                    | 9.5E-08                  | T0 not reached   |
| OL-PP39 | 7.00  | 4.2E-06                    | 7.4E-06                  | 6.95  | 4.6E-06                    | 8.0E-06                  | 6.95  | 3.9E-06                    | 6.6E-06                  | 6.95  | 3.8E-06                    | 6.7E-06                  | 6.95  | 4.2E-06                    | 5.1E-06                  | 6.94  | 4.5E-06                    | 8.1E-06                  | 6.94  | 4.6E-06                    | 7.6E-06                  |  |
| OL-PP39 | 8.00  | 1.9E-06                    | 4.7E-06                  | 7.95  | 4.2E-06                    | 6.8E-06                  | 7.95  | 3.6E-06                    | 6.4E-06                  | 7.95  | 3.1E-06                    | 5.9E-06                  | 7.95  | 7.5E-06                    | 5.3E-06                  | 7.94  | 4.8E-06                    | 8.4E-06                  | 7.94  | 4.3E-06                    | 7.2E-06                  | shorter time used in interpretation  |
| OL-PP39 | 9.00  | 1.7E-08                    | 6.9E-08                  | 8.95  | 7.8E-09                    | 2.0E-08                  | 8.95  | 1.5E-09                    | 9.7E-09                  | 8.95  | 3.1E-08                    | 4.4E-08                  | 8.95  | 6.1E-09                    | 2.8E-08                  | 8.94  | 1.5E-08                    | 1.7E-08                  | 8.94  | 6.2E-09                    | 2.7E-08                  | T0 not reached   |
| OL-PP39 | 10.00   | 1.4E-07                    | 2.8E-07                  | 9.95  | 3.0E-08                    | 6.8E-08                  | 9.95  | 2.5E-08                    | 6.6E-08                  | 9.95  | 2.5E-08                    | 4.8E-08                  | 9.95  | 1.3E-08                    | 4.1E-08                  | 9.94  | 5.5E-08                    | 1.0E-07                  | 9.94  | 2.4E-08                    | 9.7E-08                  | T0 not reached   |
| OL-PP39 | 11.00   | 7.1E-09                    | 4.3E-08                  | 10.95   | 2.6E-09                    | 1.8E-08                  | 10.95   | 1.0E-09                    | 1.5E-08                  | 10.95   | 1.2E-09                    | -3.5E-09                 | 10.95   | -1.5E-09                   | -2.0E-21                 | 10.94   | 2.4E-09                    | 3.6E-09                  | 10.94   | 1.6E-10                    | 4.3E-09                  | T0 not reached Thiem different   |
| OL-PP39 | 12.00   | 9.8E-10                    | 2.2E-08                  | 11.95   | 4.4E-10                    | 1.6E-08                  | 11.95   | -9.1E-10                   | 1.7E-08                  | 11.95   | 2.1E-09                    | 6.6E-09                  |   |                            |                          | 11.94   | 7.9E-09                    | 1.1E-08                  | 11.94   | 3.7E-09                    | 1.4E-08                  | T0 not reached Thiem different   |

| Tube      | Perforated section from ground surface (m-m) | 2010                        |                          | 2009                        |                          | 2008                        |                          | 2007                        |                          | 2006                        |                          | 2005                        |                          | 2004                        |                          | 2002                        |                          | Comments                         |
|-----------|--|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|----------------------------------|
|           |  | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) | K <sub>Hvorslev</sub> (m/s) | K <sub>Thiem</sub> (m/s) |                                  |
| OL-PVP3A  | 3.80-5.80                                    |                             |                          |                             |                          |                             |                          | 6.5E-06                     | 5.3E-06                  |                             |                          |                             |                          |                             |                          | 1.3E-05                     | 1.6E-05                  |                                  |
| OL-PVP3B  | 1.80-3.80                                    |                             |                          |                             |                          |                             |                          | 1.1E-05                     | 1.7E-05                  |                             |                          |                             |                          |                             |                          | 1.7E-05                     | 2.1E-05                  |                                  |
| OL-PVP4A  | 5.55-7.55                                    | 1.0E-05                     | 1.6E-05                  | 1.4E-05                     | 2.0E-05                  | 1.5E-05                     | 2.2E-05                  | 1.5E-05                     | 2.2E-05                  | 1.5E-05                     | 2.2E-05                  | 1.4E-05                     | 2.1E-05                  | 1.4E-05                     | 2.0E-05                  | 9.7E-06                     | 1.3E-05                  |                                  |
| OL-PVP4B  | 2.00-4.00                                    | 4.1E-06                     | 5.9E-06                  | 2.9E-06                     | 4.2E-06                  | 4.0E-06                     | 5.2E-06                  | 3.9E-06                     | 5.5E-06                  | 4.2E-06                     | 6.0E-06                  | 3.3E-06                     | 4.6E-06                  | 3.1E-06                     | 3.7E-06                  | 3.0E-06                     | 3.4E-06                  |                                  |
| OL-PVP5A  |  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          | 3.3E-06                     | 4.4E-06                  |                                  |
| OL-PVP5B  |  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          | 1.3E-06                     | 1.5E-06                  |                                  |
| OL-PVP6A  | 3.83-5.83                                    | 7.9E-08                     | 1.3E-07                  | 1.1E-07                     | 1.6E-07                  | 8.8E-08                     | 1.8E-07                  | 8.3E-08                     | 1.4E-07                  | 9.8E-08                     | 8.9E-08                  |                             |                          |                             |                          | 4.8E-08                     | 8.6E-08                  | T0 not reached                   |
| OL-PVP6B  | 1.83-3.83                                    | 3.8E-06                     | 5.7E-06                  | 3.9E-06                     | 5.5E-06                  | 2.0E-06                     | 3.0E-06                  | 9.8E-06                     | 1.4E-05                  | 2.6E-06                     | 4.3E-06                  |                             |                          |                             |                          | 2.3E-06                     | 1.1E-06                  |                                  |
| OL-PVP7A  | 1.75-3.75                                    | 3.6E-07                     | 5.0E-07                  |                             |                          |                             |                          | 2.9E-07                     | 4.1E-07                  |                             |                          |                             |                          |                             |                          | 3.5E-07                     | 4.1E-07                  |                                  |
| OL-PVP8A  | 4.45-6.45                                    | 1.2E-05                     | 1.7E-05                  |                             |                          |                             |                          | 1.1E-05                     | 1.6E-05                  |                             |                          |                             |                          |                             |                          | 3.4E-06                     | 5.0E-06                  |                                  |
| OL-PVP8B  | 2.45-4.45                                    | 1.9E-07                     | 3.4E-07                  |                             |                          |                             |                          | 4.5E-07                     | 6.3E-07                  |                             |                          |                             |                          |                             |                          | 4.2E-07                     | 1.1E-06                  |                                  |
| OL-PVP9A  | 5.00-7.00                                    | 3.7E-05                     | 9.0E-05                  |                             |                          |                             |                          | 6.2E-05                     | 8.9E-05                  |                             |                          |                             |                          |                             |                          | 8.5E-05                     | 1.2E-04                  |                                  |
| OL-PVP9B  | 3.00-5.00                                    | 7.6E-05                     | 5.9E-05                  |                             |                          |                             |                          | 1.8E-05                     | 7.3E-05                  |                             |                          |                             |                          |                             |                          | 5.1E-07                     | 6.0E-06                  |                                  |
| OL-PVP10A | 1.00-3.00                                    | 4.7E-06                     | 6.9E-06                  |                             |                          |                             |                          | 1.4E-04                     | 2.0E-04                  |                             |                          |                             |                          |                             |                          | 1.2E-04                     | 1.5E-04                  |                                  |
| OL-PVP10B | 0.30-0.50                                    | 2.2E-05                     | 6.7E-05                  |                             |                          |                             |                          | 3.8E-05                     | 6.3E-05                  |                             |                          |                             |                          |                             |                          | 4.8E-06                     | 9.3E-06                  |                                  |
| OL-PVP11  | 1.20-3.20                                    | 3.07E-06                    | 6.2E-06                  |                             |                          |                             |                          | 3.0E-05                     | 4.2E-05                  |                             |                          |                             |                          | 5.2E-05                     | 7.5E-05                  |                             |                          |                                  |
| OL-PVP12  | 2.30-4.30                                    | 8.7E-07                     | 1.5E-06                  |                             |                          |                             |                          | 2.1E-06                     | 3.4E-06                  |                             |                          |                             |                          | 1.8E-06                     | 1.7E-06                  |                             |                          |                                  |
| OL-PVP13  | 3.10-5.10                                    |                             |                          |                             |                          |                             |                          | 6.4E-06                     | 8.8E-06                  |                             |                          | 5.3E-06                     | 7.7E-06                  | 9.2E-06                     | 1.6E-05                  |                             |                          |                                  |
| OL-PVP14  | 6.40-8.40                                    | 1.7E-05                     | 2.4E-05                  | 1.7E-05                     | 2.4E-05                  | 1.9E-05                     | 2.7E-05                  | 1.9E-05                     | 2.7E-05                  | 2.6E-05                     | 3.7E-05                  | 4.5E-05                     | 6.9E-05                  | 8.2E-05                     | 1.2E-04                  |                             |                          |                                  |
| OL-PVP17  | 2.30-4.30                                    |                             |                          |                             |                          |                             |                          | 3.1E-06                     | 4.5E-06                  |                             |                          | 6.2E-07                     | 1.2E-06                  |                             |                          |                             |                          |                                  |
| OL-PVP18A | 3.00-6.00                                    |                             |                          |                             |                          |                             |                          | 1.6E-06                     | 2.0E-06                  |                             |                          | 1.3E-06                     | 1.5E-06                  |                             |                          |                             |                          |                                  |
| OL-PVP18B | 2.00-3.00                                    |                             |                          |                             |                          |                             |                          | 8.5E-07                     | 1.2E-06                  |                             |                          | 8.4E-07                     | 2.0E-06                  |                             |                          |                             |                          |                                  |
| OL-PVP18B | 2.00-3.00                                    |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          | 6.7E-07                     | 1.7E-06                  |                             |                          |                             |                          |                                  |
| OL-PVP19  | 9.15-11.15<br>13.15-15.15                    | 1.7E-06                     | 1.5E-06                  |                             |                          |                             |                          | 1.4E-06                     | 1.7E-06                  |                             |                          | 6.2E-07                     | 1.3E-06                  |                             |                          |                             |                          | two separate perforated sections |
| OL-PVP20  | 8.60-10.60                                   | 7.0E-06                     | 8.4259E-06               |                             |                          |                             |                          | 1.0E-05                     | 1.1E-05                  |                             |                          | 1.1E-05                     | 1.6E-05                  |                             |                          |                             |                          |                                  |
| OL-PVP21  | 6.75-8.75                                    |                             |                          |                             |                          | 4.5E-06                     | 6.1E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP22  | 5.22-7.22                                    |                             |                          |                             |                          | 2.5E-06                     | 3.9E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP23  | 2.43-4.43                                    |                             |                          |                             |                          | 5.9E-05                     | 8.6E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP24  | 1.91-3.91                                    |                             |                          |                             |                          | 4.5E-06                     | 6.5E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP25  | 1.91-2.91                                    |                             |                          |                             |                          | 6.8E-05                     | 1.2E-04                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP26  | 0.81-2.81                                    |                             |                          |                             |                          | 5.2E-05                     | 7.7E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP27  | 0.59-2.59                                    |                             |                          |                             |                          | 1.3E-05                     | 2.2E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP28  | 1.32-2.82                                    |                             |                          |                             |                          | 3.7E-06                     | 5.6E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP29  | 1.59-3.09                                    |                             |                          |                             |                          | 2.2E-06                     | 5.5E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP30  | 0.80-1.80                                    | 5.0E-05                     | 8.2E-05                  | 6.7E-05                     | 1.2E-04                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP31A | 1.59-3.59                                    | 4.9E-05                     | 5.5E-05                  | 4.2E-05                     | 6.0E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP31B | 2.72-4.72                                    | 9.7E-08                     | 1.7E-07                  | 9.1E-08                     | 8.3E-07                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          | T0 not reached Thiem different   |
| OL-PVP32  | 0.20-2.20                                    | 7.1E-08                     | 2.1E-07                  | 5.2E-05                     | 7.9E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP33  | 0.76-1.76                                    | 2.4E-05                     | 3.9E-05                  | 1.4E-05                     | 2.3E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP34A | 3.08-5.08                                    | 4.8E-06                     | 6.8E-06                  | 4.0E-06                     | 5.4E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-PVP34B | 1.21-3.21                                    | 3.4E-06                     | 5.9E-06                  | 1.1E-05                     | 1.6E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-HP1    | 4.00-5.00                                    | 1.9E-06                     | 4.2E-06                  | 1.6E-06                     | 3.3E-06                  | 2.2E-06                     | 6.8E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |
| OL-HP2    | 2.00-3.00                                    | 8.3E-07                     | 1.4E-06                  | 7.0E-07                     | 1.4E-06                  | 7.4E-07                     | 1.4E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          | T0 not reached                   |
| OL-HP3    | 4.00-5.00                                    | 7.9E-07                     | 1.8E-06                  | 3.3E-07                     | 1.2E-06                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          | Thiem different, T0 not reached  |
| OL-HP4    | 2.00-3.00                                    | 1.2E-04                     | 1.4E-04                  | 4.3E-05                     | 5.9E-05                  | 9.6E-06                     | 2.9E-05                  |                             |                          |                             |                          |                             |                          |                             |                          |                             |                          |                                  |

## APPENDIX 33 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-PP36      | 071010        | 2.2         | 3.67E-05   | 4.24                     | 4.14                       | -0.1 | 7.81                    |     | 1.3E-05    | 1.0E-04 | 2.2E-07          | 4   | 58.35                  |
| OL-PP39      | 240510        | 0.9         | 1.50E-05   | 1.05                     | 2.06                       | 1.01 | 12.66                   |     | 1.2E-06    | 1.5E-05 | 1.6E-06          | 8   | 0.757                  |
| OL-PVP4A     | 280410        | 3.20        | 5.33E-05   | 0.83                     | 2.33                       | 1.5  |                         | 2   | 1.8E-05    | 3.6E-05 | 1.6E-05          | 2   | 1.161                  |
| OL-PVP9B     | 111010        | 4.80        | 8.00E-05   | 2.75                     | 3.23                       | 0.48 |                         | 2   | 8.5E-05    | 1.7E-04 | 5.9E-05          | 2   | 1.429                  |
| OL-PVP10A    | 270410        | 4.35        | 7.25E-05   | 0.81                     | 1.1                        | 0.29 |                         | 2   | 1.3E-04    | 2.5E-04 | 6.9E-06          | 2   | 18.403                 |
| OL-PVP10B    | 040510        | 1.65        | 2.75E-05   | 1.06                     | 1.63                       | 0.57 |                         | 0.2 | 2.5E-04    | 4.8E-05 | 6.7E-05          | 2   | 3.674                  |
| OL-PVP12     | 111010        | 0.26        | 4.33E-06   | 1.51                     | 2.18                       | 0.67 |                         | 2   | 3.3E-06    | 6.5E-06 | 1.5E-06          | 2   | 2.215                  |
| OL-PVP14     | 280910        | 2.30        | 3.83E-05   | 2.04                     | 2.96                       | 0.92 |                         | 2   | 2.1E-05    | 4.2E-05 | 2.4E-05          | 2   | 0.871                  |
| OL-PVP20     | 071010        | 1.3         | 2.17E-05   | 0.91                     | 4.72                       | 3.81 |                         | 2   | 2.9E-06    | 5.7E-06 | 8.4E-06          | 2   | 0.344                  |

