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Forsmark site investigation

Groundwater flow measurements in permanently installed boreholes

Test campaign no. 2, 2006

Eva Wass, Geosigma AB

August 2007

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Keywords: Groundwater flow, Dilution test, Tracer test, AP PF 400-06-100.

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Abstract

This report describes the performance and evaluation of groundwater flow measurements in 18 borehole sections in permanently installed boreholes within the Forsmark site investigation area. The objective was to determine the groundwater flow in all, at the time available, borehole sections instrumented for this purpose. This is the second test campaign performed within the monitoring program and it is planned to be repeated once every year.

The groundwater flow in the selected borehole sections was determined through dilution measurements during natural conditions. Measured flow rates ranged from 0.1 to 38 ml/min with calculated Darcy velocities from $4.5 \cdot 10^{-10}$ to $2.3 \cdot 10^{-7}$ m/s. Hydraulic gradients were calculated according to the Darcy concept and varied between 0.0001 and 11.

Sammanfattning

Denna rapport beskriver genomförandet och utvärderingen av grundvattenflödesmätningar i 18 borrhålssektioner i permanent installerade borrhål inom Forsmarks platsundersökningsområde. Syftet var att bestämma grundvattenflödet i samtliga, vid denna tidpunkt och för detta ändamål, instrumenterade sektioner. Detta är den andra mätkampanjen som genomförts i moniteringsprogrammet och mätningarna är planerade att återupprepas en gång per år.

Grundvattenflödet mättes med utspädningsmetoden under naturliga förhållanden i utvalda borrhålssektioner. Uppmätta grundvattenflöden låg i intervallet 0,1–38 ml/min med beräknade Darcy hastigheter mellan $4{,}5 \cdot 10^{-10}$ och $2{,}3 \cdot 10^{-7}$ m/s. Hydrauliska gradienter beräknades enligt Darcy-konceptet och varierade mellan 0,0001 och 11.

Contents

1 Introduction

This document reports the results gained from the groundwater flow measurements in permanently installed boreholes, test campaign no. 2, 2006, which is one of the activities performed within the Forsmark site investigation. The work was carried out in accordance with Activity Plan AP PF 400-06-100 and the field work was conducted during November 2006. In Table 1-1 controlling documents for performing this activity are listed. Both Activity Plan and method descriptions are SKB's internal controlling documents.

A map of the site investigation area at Forsmark including boreholes and drill sites is presented in Figure 1-1.

The original results are stored in the primary data base Sicada and are traceable by the Activity Plan number.

Table 1-1. Controlling documents for performance of the activity.

Activity plan	Number	Version
Monitering av grundvattenflöde i permanent installerade borrhål, kampanj 2, 2006.	AP PF 400-06-100	1.0
Method description	**Number**	**Version**
System för hydrologisk och metrologisk datainsamling. Vattenprovtagning och utspädningsmätning i observationshål.	SKB MD 368.010	1.0

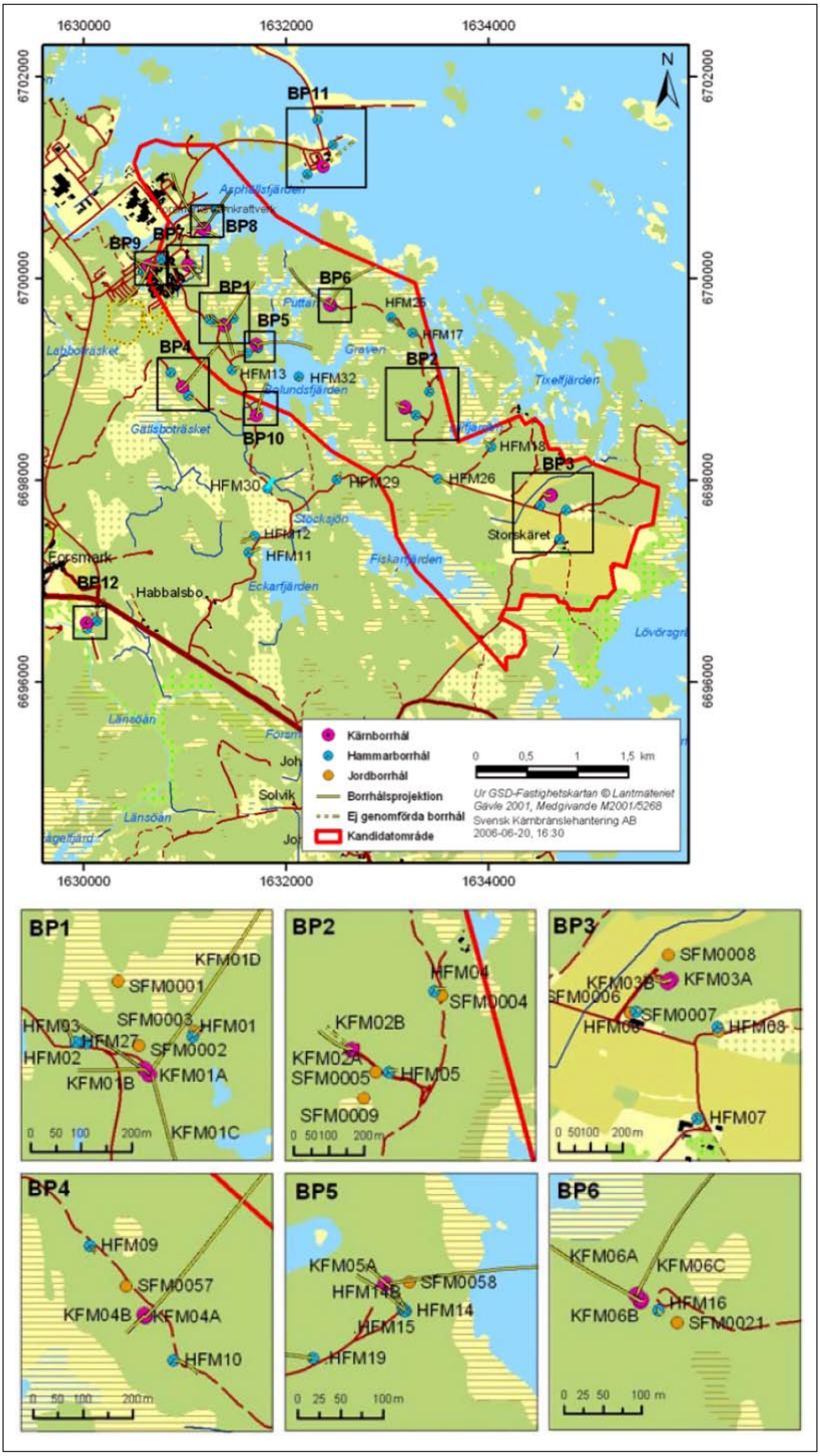

Figure 1-1. *Overview over Forsmark site investigation area, showing borehole locations and drill sites included in this activity in detail.*

2 Objective and scope

The objective of this activity was to determine the groundwater flow in borehole sections in permanently installed boreholes at Forsmark. Eighteen borehole sections instrumented for this purpose (circulation sections) were measured, cf Table 4-1. This was the second test campaign performed within the monitoring program and it is planned to be repeated once every year. The measurements will serve as a basis to study and monitor changes in the hydraulic gradients caused by activities in the area such as underground construction and drilling.

The groundwater flow in the selected borehole sections was determined through dilution measurements during natural conditions.

3 Equipment

3.1 Description of equipment and tracers used

The boreholes involved in the tests are instrumented with 1–9 inflatable packers isolating 2–10 borehole sections each. In Figure 3-1 drawings of the instrumentation in core and percussion boreholes are presented.

All isolated borehole sections are connected to the HMS-system for pressure monitoring. In general, the sections planned to be used for tracer tests are equipped with three polyamide tubes. Two are used for injection, sampling and circulation in the borehole section and one is used for pressure monitoring.

The tracer dilution tests were performed using five identical equipment set-ups, i.e. allowing five sections to be measured simultaneously. A schematic drawing of the tracer test equipment is shown in Figure 3-2. The basic idea is to cause an internal circulation in the borehole section. The circulation makes it possible to obtain a homogeneous tracer concentration in the borehole section and to sample the tracer concentration outside the borehole in order to monitor the dilution of the tracer with time.

Circulation is controlled by a down-hole pump with variable speed and measured by a flow meter. Tracer injections are made with a peristaltic pump and sampling is made by continuously extracting a small volume of water from the system through another peristaltic pump (constant leak) to a fractional sampler. The equipment and test procedure is described in detail in SKB MD 368.010, see Table 1-1.

The tracers used were two fluorescent dye tracers, Uranine (Sodium Fluorescein), from Merck (purum quality) and Amino-G Acid from Aldrich (techn. quality).

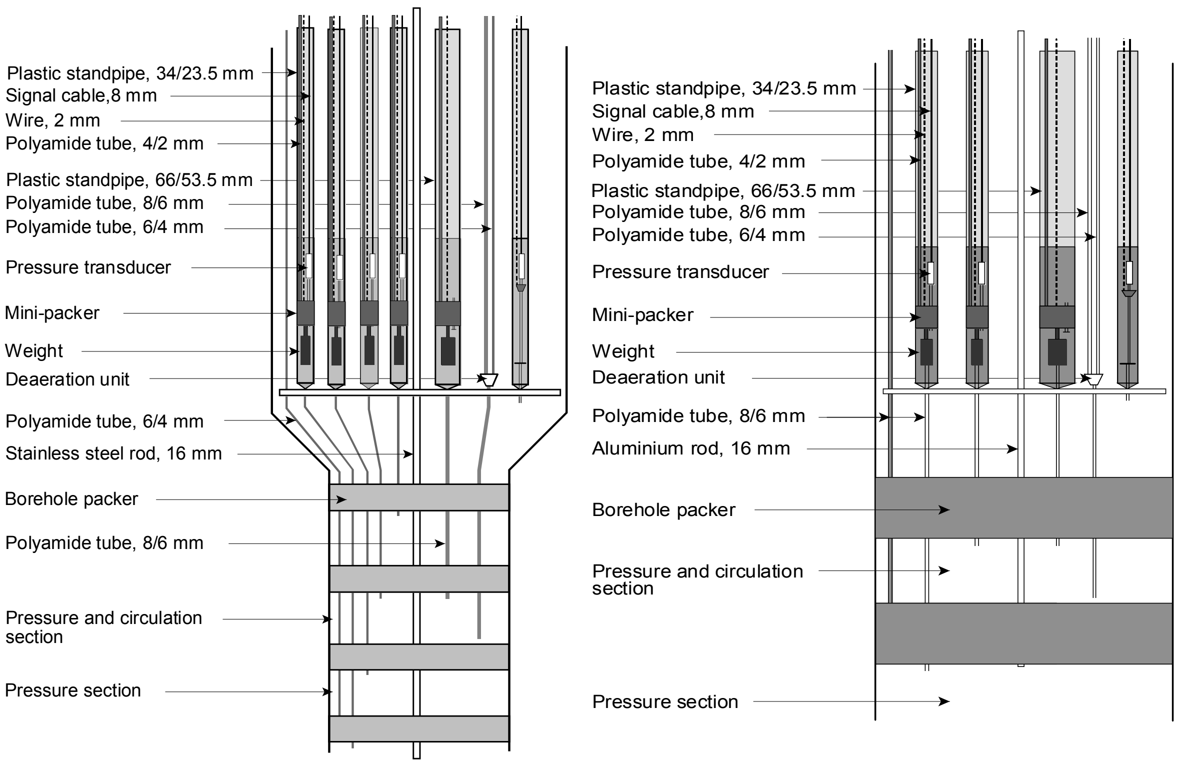

Figure 3-1. *Example of permanent instrumentation in core boreholes (left) and percussion boreholes (right) with circulation sections.*

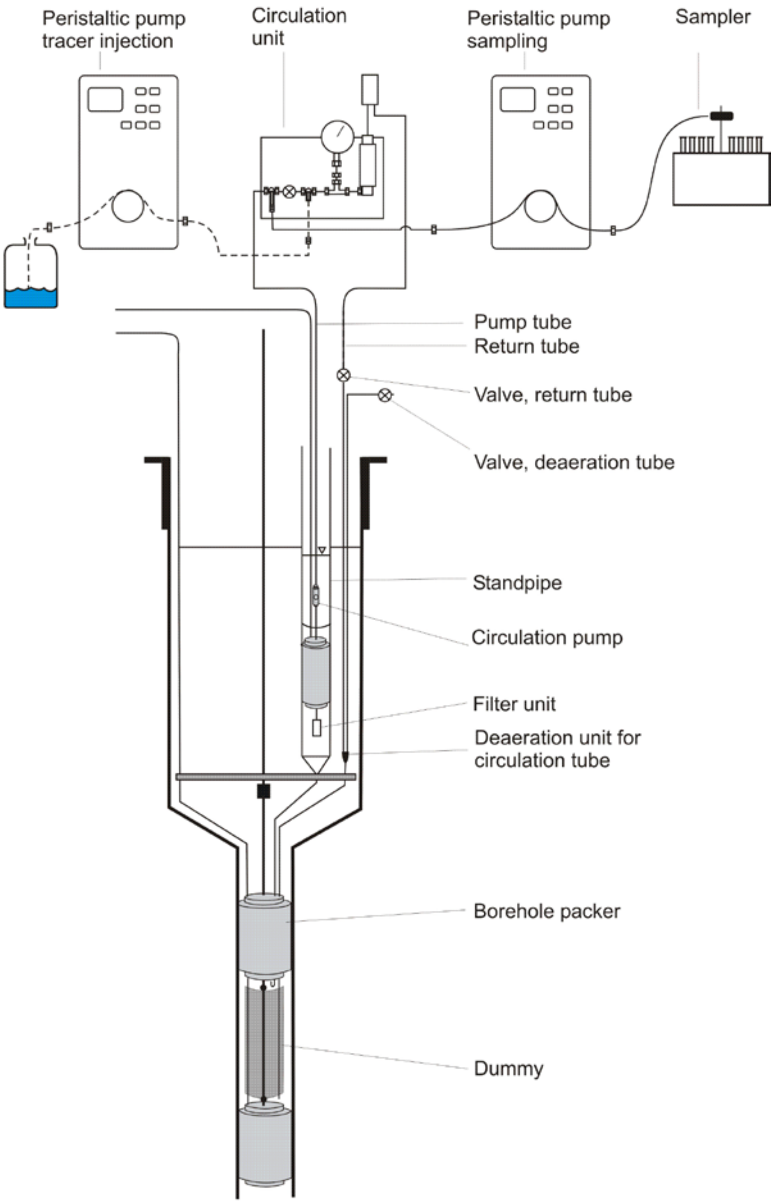

Figure 3-2. *Schematic drawing of the equipment used in tracer dilution measurements.*

4 Execution

4.1 General

In the dilution method a tracer is introduced and homogeneously distributed into a borehole test section. The tracer is subsequently diluted by the ambient groundwater, flowing through the borehole test section. The dilution of the tracer is proportional to the water flow through the borehole section and the groundwater flow is calculated as a function of the decreasing tracer concentration with time, Figure 4-1.

The method description used was "System för hydrologisk och metrologisk datainsamling. Vattenprovtagning och utspädningsmätning i observationshål." (SKB MD 368.010), cf Table 1-1.

4.2 Preparations

The preparations included mixing of the tracer stock solution, functionality checks of the equipment and calibration of the peristaltic pumps used for sampling and tracer injections.

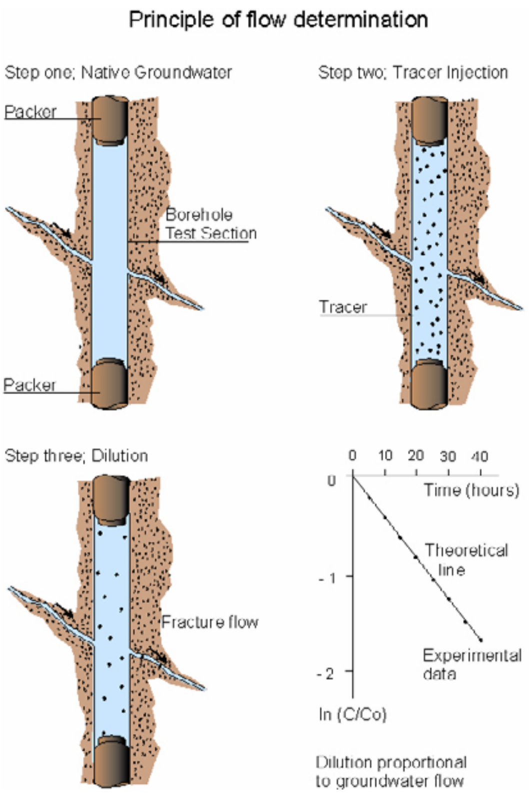

***Figure 4-1.** General principles of dilution and flow determination.*

4.3 Execution of field work

The test campaign involved 18 different borehole sections listed in Table 4-1. The duration of each test varied from 60 to 172 hours.

The tests were made by injecting a slug of tracer (Uranine, 500 mg/l) into the selected borehole sections and allowing the natural groundwater flow to dilute the tracer. In borehole section KFM01A:5 the tracer Amino-G acid was used instead, due to the high background concentration of Uranine. The tracer was injected during a time period equivalent to the time it takes to circulate one section volume. The injection/circulation flow ratio was set to 1/1000, implying that the start concentration in the borehole section would be about 0.5 mg/l. Five sections were injected simultaneously. The tracer solution was continuously circulated and sampled using the equipment described in Section 3.1.

The samples were analysed for dye tracer content at the Geosigma Laboratory using a Jasco FP 777 Spectrofluorometer.

Table 4-1. Borehole sections used for groundwater flow measurements, autumn 2006.

Borehole: section	Depth (m)	Transmissivity (m^2/s)	Geologic character ***	Test period (yymmdd)
KFM01A:5	109–130	1.0 E–7*	Single fracture	061124–061201
KFM02A:3	490–518	2.1 E–6*	Zone ZFMNE00A2	061107–061113
KFM02A:5	411–442	2.5 E–6*	Zone ZFMNE00A2	061114–061120
KFM03A:1	969.5–994.5	5.5 E–7*	5–6 flowing fractures, no deformation zone	Not measured
KFM03A:4	633.5–650	2.4 E–6*	Zone ZFMNE00B1	061114–061121
KFM05A:4	254–272	1.4 E–8*	Single fracture	061117–061124
KFM06A:3	738–748	1.2 E–7*	Single flow anomaly, Zone ZFMNE061	061110–061117
KFM06A:5	341–362	3.5 E–6*	2 flowing fractures, Zone ZFMNE060	061106–061110
KFM06C:3	647–666	5.3 E–8*	Not included in /14/	061106–061113
KFM06C:5	531–540	1.1 E–6*	Not included in /14/	061113–061120
HFM02:2	38–48	5.9 E–4**	Zone ZFMNE00A2	061127–061201
HFM04:2	58–66	7.9 E–5**	Zone ZFMNE0866	061108–061114
HFM13:1	159–173	2.9 E–4**	Zone ZFMNE0401	061114–061120
HFM15:1	85–95	1.0 E–4**	Zone ZFMNE00A2	061121–061127
HFM16:2	54–67	3.5 E–4**	Zone ZFMNE00A2	061107–061113
HFM19:1	168–182	2.7 E–4**	Zone ZFMNE00A2	061120–061127
HFM27:2	46–58	4.0 E–5**	Not included in /14/	061127–061201
HFM32:3	26–31	2.3 E–4**	Not included in /14/	061121–061123

* From PSS measurements, transient evaluation, /1/, /2/, /3/, /4/, /5/ and /6/.

** From HTHB measurements, transient evaluation, /7/, /8/, /9/, /10/, /11/, /12/ and /13/.

*** Deformation zones according to Forsmark 2.1 site descriptive model /14/.

4.4 Analyses and interpretations

Flow rates were calculated from the decay of tracer concentration versus time through dilution with natural unlabelled groundwater, cf /15/. The so-called "dilution curves" were plotted as the natural logarithm of concentration versus time. Theoretically, a straight-line relationship exists between the natural logarithm of the relative tracer concentration (c/c_0) and time, t (s):

$$\ln (c/c_0) = -(Q_{bh}/V) \cdot \Delta t \qquad (4\text{-}1)$$

where Q_{bh} (m^3/s) is the groundwater flow rate through the borehole section and V (m^3) is the volume of the borehole section. By plotting ln (c/c_0) versus t, and by knowing the borehole volume V, Q_{bh} may then be obtained from the straight-line slope. If c_0 is constant, it is sufficient to use ln c in the plot.

The sampling procedure with a constant flow of 4–10 ml/h also creates a dilution of tracer. The sampling flow rate is therefore subtracted from the value obtained from Equation 4-1.

The flow, Q_{bh}, may be translated into a Darcy velocity by taking into account the distortion of the flow caused by the borehole and the angle between the borehole and flow direction. In practice, a 90° angle between the borehole axis and the flow direction is assumed and the relation between the flow in the rock, the Darcy velocity, v (m/s), and the measured flow through the borehole section, Q_{bh}, can be expressed as:

$$Q_{bh} = v \cdot L_{bh} \cdot 2r_{bh} \cdot \alpha \qquad (4\text{-}2)$$

where L_{bh} is the length of the borehole section (m), r_{bh} is the borehole radius (m) and α is the factor accounting for the distortion of flow caused by the borehole.

Hydraulic gradients are roughly estimated from Darcy's law where the gradient, I, is calculated as the function of the Darcy velocity, v, with the hydraulic conductivity, K (m/s):

$$I = \frac{v}{K} = \frac{Q_{bh} \cdot L_{bh}}{\alpha \cdot A \cdot T_{bh}} = \frac{Q_{bh} \cdot L_{bh}}{2 \cdot d_{bh} \cdot L_{bh} \cdot T_{bh}} \qquad (4\text{-}3)$$

where T_{bh} (m^2/s) is the transmissivity of the section, obtained from PSS or HTHB measurements, A the cross section area between the packers and d_{bh}, (m) the borehole diameter.

The factor α is commonly given the value 2 in the calculations, which is the theoretical value for a homogeneous porous medium. Since the rock mostly is heterogeneous and the angles in the sections not always 90°, the calculation of the hydraulic gradient is a rough estimation.

4.5 Nonconformities

Borehole section KFM03A:1 was not possible to circulate and could therefore not be measured. During the previously performed measurement, within the first test campaign in autumn 2005, there was a problem maintaining the circulation rate in the section and a very slow circulation rate (2–3 l/h) had to be used /16/. The reason for this may be the large depth and gasification combined with quite low transmissivity. Also, the section has a large volume (about 90 litres) and long tubing which decreases the circulation capacity of the pump.

5 Results

Original data from the reported activity are stored in the primary database Sicada. Data are traceable in Sicada by the Activity Plan number (AP PF 400-06-100). Only data in databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. However, such revision of the database will not necessarily result in a revision of this report, although the normal procedure is that major data revisions entail a revision of P-reports. Minor data revisions are normally presented as supplements, available at www.skb.se.

A summary of the results obtained is presented in Table 5-1 including measured groundwater flow rates, Darcy velocities and hydraulic gradients together with transmissivities and volumes used. Also, a comparison with flow rates obtained from previously performed measurements during natural gradient is compiled in Table 5-2.

In Figure 5-1 an example of a typical tracer dilution curve is shown. The flow rate is calculated from the slope of the straight-line fit. Tracer dilution graphs for each borehole section are presented in Appendix 1. In Appendix 2 the groundwater level during the entire test period is shown for the selected boreholes, see also Table 4-1 for actual measurement period for each section.

The results show that the groundwater flow during natural conditions varies from 0.1 to 38 ml/min in the measured sections with Darcy velocities ranging from $4.5 \cdot 10^{-10}$ to $2.3 \cdot 10^{-7}$ m/s.

Table 5-1. Results from groundwater flow measurements, test campaign 2, 2006.

Borehole: section	Depth (m)	Transmissivity (m^2/s)	Volume (l)	Measured flow (ml/min)	Darcy velocity (m/s)	Hydraulic gradient (m/m)
KFM01A:5	109–130	1.0 E–7*	33.21	0.1	4.5E–10	0.095
KFM02A:3	490–518	2.1 E–6*	66.33	0.8	3.1E–09	0.041
KFM02A:5	411–442	2.5 E–6*	60.78	0.4	1.3E–09	0.016
KFM03A:4	633.5–650	2.4 E–6*	58.04	0.5	3.4E–09	0.024
KFM05A:4	254–272	1.4 E–8*	40.62	1.4	8.6E–09	11
KFM06A:3	738–748	1.2 E–7*	58.25	0.6	6.1E–09	0.51
KFM06A:5	341–362	3.5 E–6*	46.64	0.6	3.3E–09	0.022
KFM06C:3	647–666	5.3 E–8*	64.00	0.4	2.4E–09	0.86
KFM06C:5	531–540	1.1 E–6*	43.61	0.3	3.8E–09	0.031
HFM02:2	38–48	5.9 E–4**	28.53	8.9	5.4E–08	0.0009
				38	2.3E–07	0.0039
HFM04:2	58–66	7.9 E–5**	27.52	10.4	7.8E–08	0.0079
HFM13:1	159–173	2.9 E–4**	39.28	4.3	1.9E–08	0.0009
HFM15:1	85–95	1.0 E–4**	35.74	5.2	3.1E–08	0.0031
HFM16:2	54–67	3.5 E–4**	43.61	1.6	7.4E–09	0.0003
				6.6	3.0E–08	0.0011
HFM19:1	168–182	2.7 E–4**	44.65	3.4	1.5E–08	0.0008
HFM27:2	46–58	4.0 E–5**	40.29	0.4	2.2E–09	0.0007
HFM32:3	26–31	2.3 E–4**	20.06	0.5	5.7E–09	0.0001

* From PSS measurements, transient evaluation, /1/, /2/, /3/, /4/, /5/ and /6/.
** From HTHB measurements, transient evaluation, /7/, /8/, /9/, /10/, /11/, /12/ and /13/.

Table 5-2. Results from groundwater flow measurements in November 2006 compared with results from earlier performed meaurements (natural gradient).

Borehole: section	Depth (m)	T (m^2/s)	Jun–Jul 2005 /17/ (ml/min)	Nov–Dec 2005 /16/ (ml/min)	Jun–Jul 2006 /18/ (ml/min)	Nov 2006 (ml/min)
KFM01A:5	109–130	1.0 E–7*	0.3	–	–	0.1
KFM02A:3	490–518	2.1 E–6*	–	2.1	1.9	0.8
KFM02A:5	411–442	2.5 E–6*	–	1.0	0.5	0.4
KFM03A:1	969.5–994.5	5.5 E–7*	–	1.7	–	–
KFM03A:4	633.5–650	2.4 E–6*	–	0.5	–	0.5
KFM05A:4	254–272	1.4 E–8*	–	0.5	1.5	1.4
KFM06A:3	738–748	1.2 E–7*	–	0.3	0.8	0.6
KFM06A:5	341–362	3.5 E–6*	–	0.5	0.4	0.6
KFM06C:3	647–666	5.3 E–8*	–	–	–	0.4
KFM06C:5	531–540	1.1 E–6*	–	–	–	0.3
HFM02:2	38–48	5.9 E–4**	80	38	21	8.9–38
HFM04:2	58–66	7.9 E–5**	–	2.2	–	10.4
HFM13:1	159–173	2.9 E–4**	–	24	8.3	4.3
HFM15:1	85–95	1.0 E–4**	1.0	0.8	1.4	5.2
HFM16:2	54–67	3.5 E–4**	–	–	–	1.6–6.6
HFM19:1	168–182	2.7 E–4**	–	9.7	6.2	3.4
HFM27:2	46–58	4.0 E–5**	–	–	–	0.4
HFM32:3	26–31	2.3 E–4**	–	–	3.7	0.5

* From PSS measurements, transient evaluation, /1/, /2/, /3/, /4/, /5/ and /6/.
** From HTHB measurements, transient evaluation, /7/, /8/, /9/, /10/, /11/, /12/ and /13/.

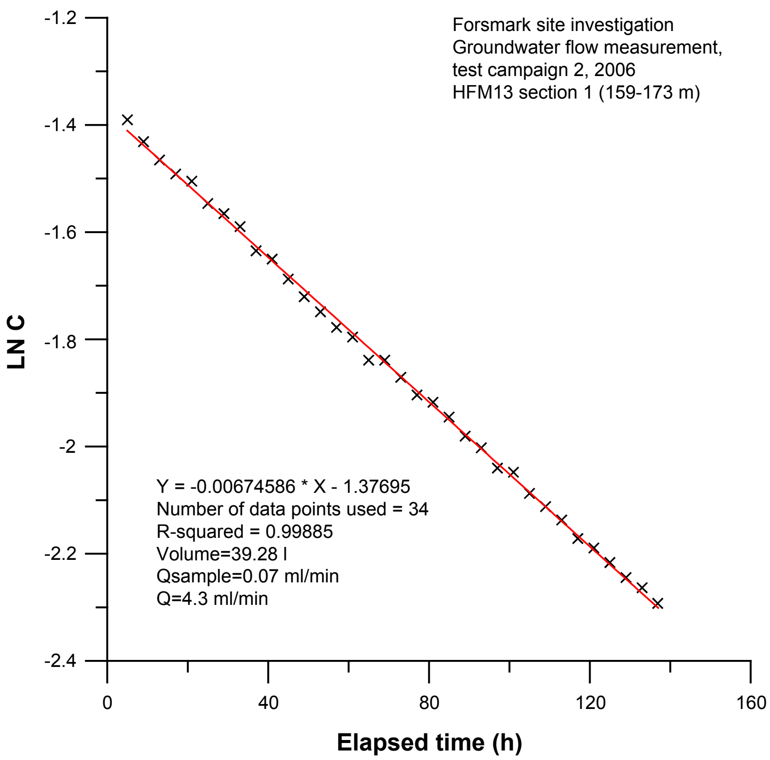

Figure 5-1. *Example of a tracer dilution graph (Logarithm of concentration versus time) for borehole HFM13, section 1, including straight-line fit.*

Hydraulic gradients are calculated according to the Darcy concept and are within the expected range in the majority of the measured sections. It should be noted that the Darcy concept is built on assumptions of a homogeneous porous medium and values for fractures should therefore be treated with great care. In KFM05A:4, KFM06A:3 and KFM06C:3 and the hydraulic gradient is considered to be very large. In KFM05A:4 the groundwater level is decreased 0.5–1 m during the test, as seen in Appendix 2, which may have affected the flow rate and calculated hydraulic gradient. The large gradients may also be due to wrong estimates of the correction factor, α, and/or the hydraulic conductivity of the fracture. Two of the three sections also represent single fractures (cf Table 4-1) where the Darcy concept may be questioned.

In general, the equipment has worked well and no major hydraulic disturbance has occurred during the tests, cf Appendix 2. However, during the dilution measurements in HFM02 and HFM27 in the end of November, a sudden decrease of about 0.1 m in the groundwater level can be seen. This is also reflected in the tracer dilution graph for HFM02:2 where a higher flow rate is indicated from the pressure decrease. The flow rate in HFM27:2, however, is not interpreted to have been affected. As in HFM02, the tracer dilution graph for HFM16:2 gives two different flow rates. In this case the higher flow rate at the end of the measurement corresponds to an increase of about 0.1 m in groundwater level during this period. For both HFM02:2 and HFM16:2, the two different flow rates are presented. However, due to the pressure disturbances at the end of the measurements, the lower flow rates achieved during the first part of the dilution curves are probably the most representative of natural conditions.

HFM04:2 was affected by activities at drill site 2 and the drilling of borehole KFM02B. From the registration of the groundwater level in HFM04 it seems as if some kind of pumping was performed in KFM02B during the dilution measurement in HFM04:2. Hence, the flow rate obtained in HFM04:2 is probably enhanced and not really representative of undisturbed conditions.

The original results are stored in the primary data base Sicada. These data are available for further interpretation and are traceable by the Activity Plan number (AP PF 400-06-100).

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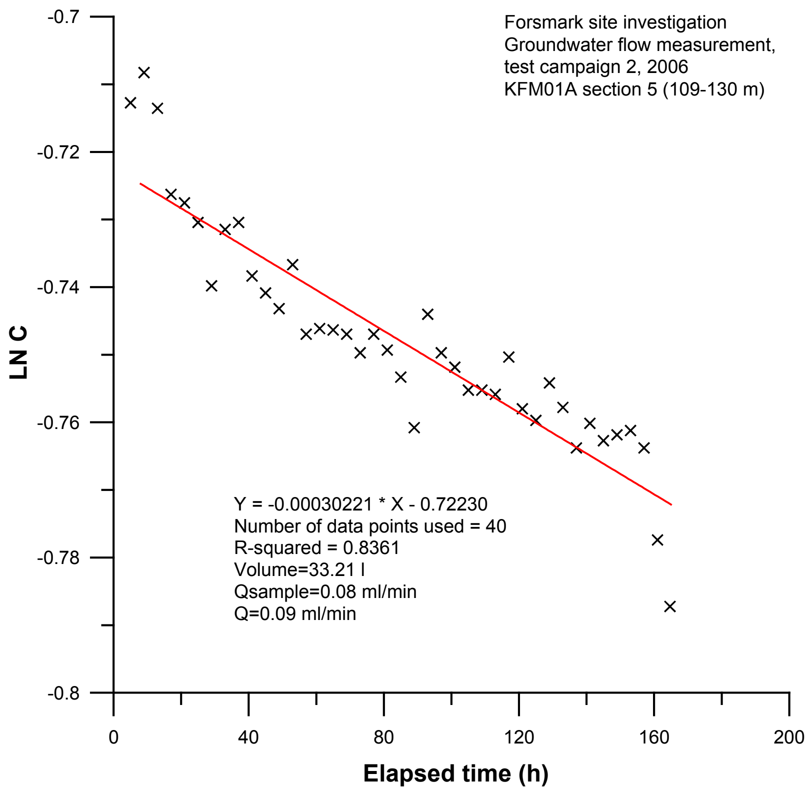
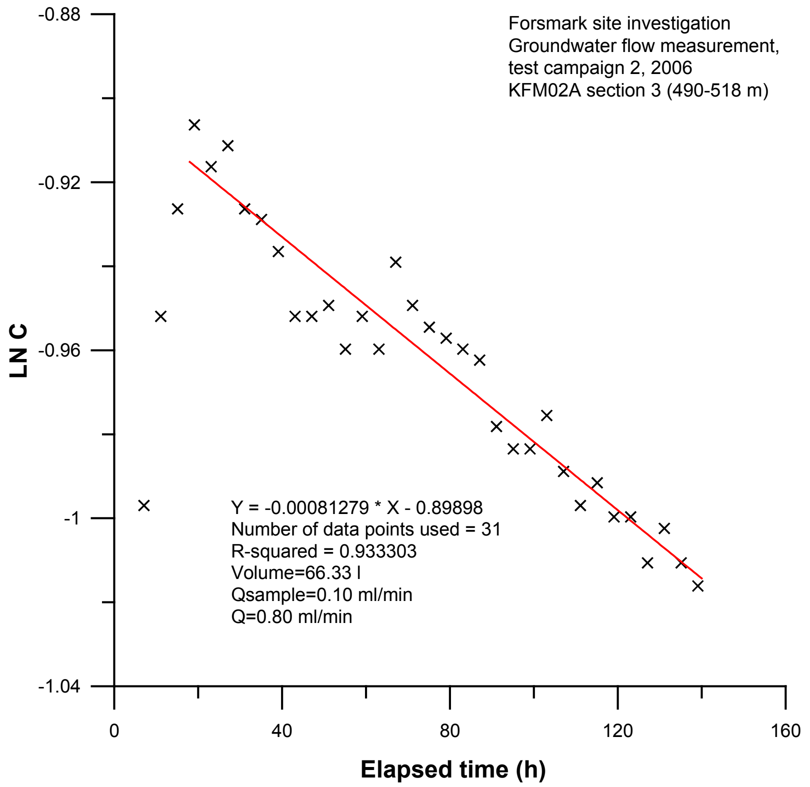
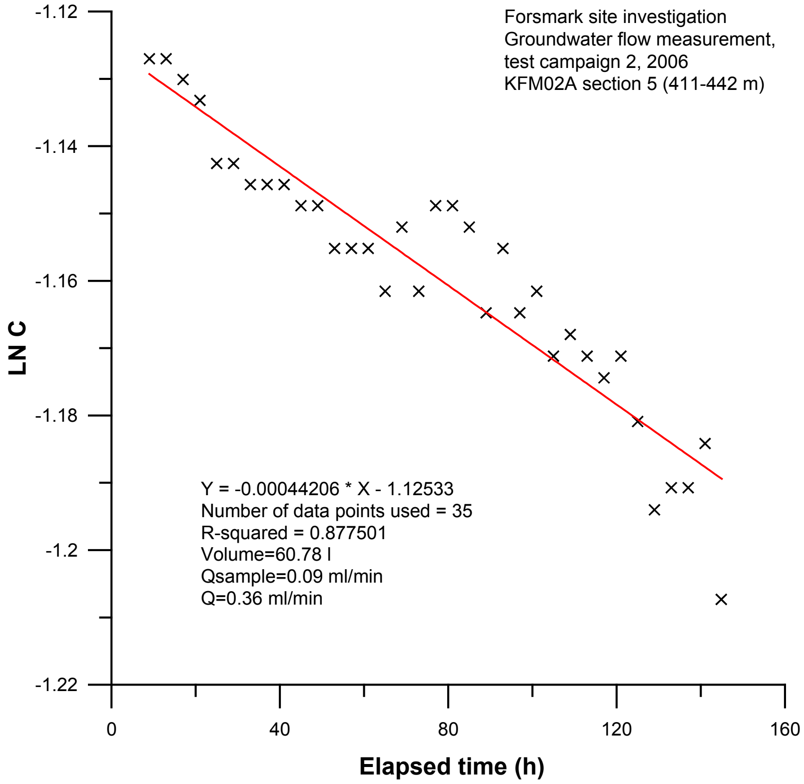
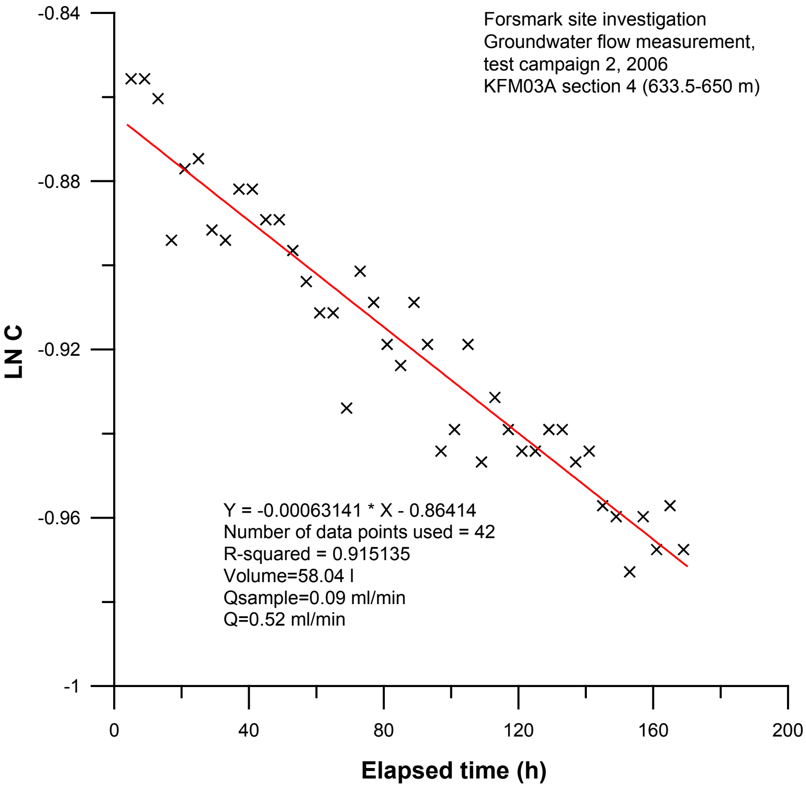
Appendix 1

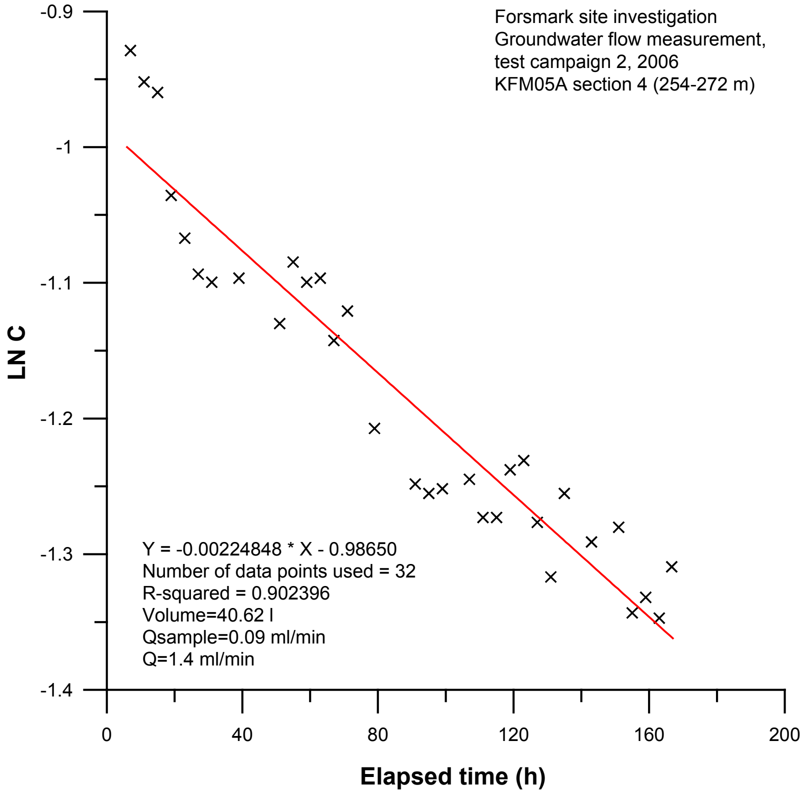
Tracer dilution graphs

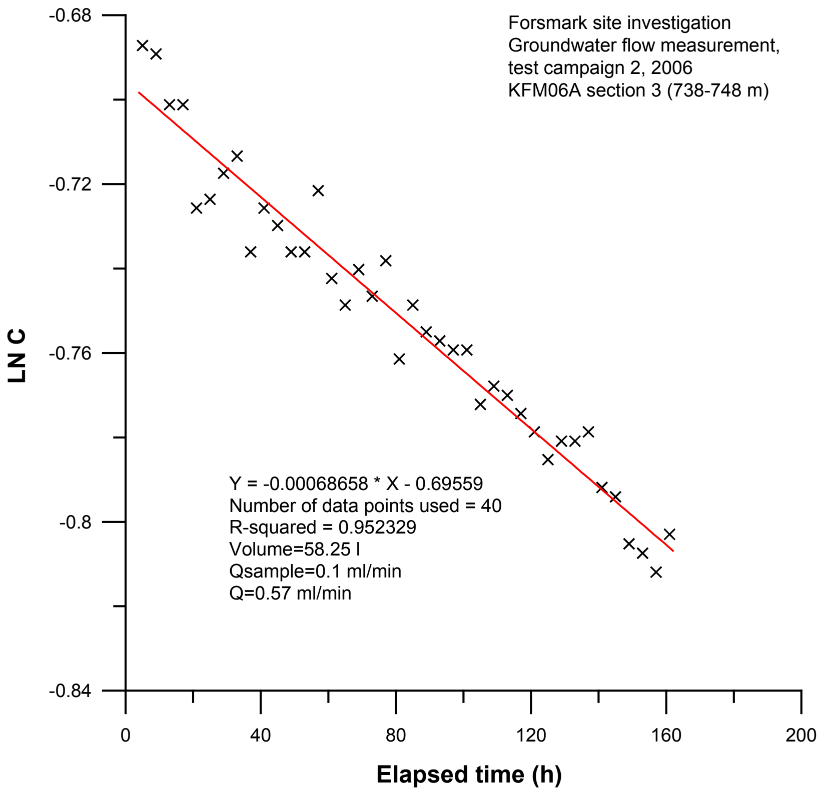


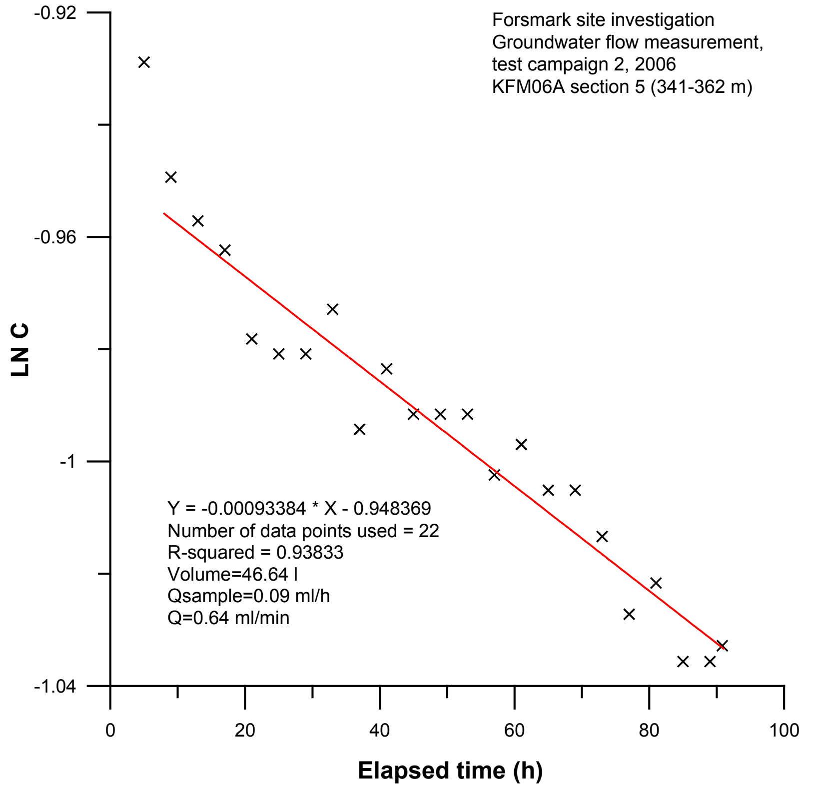


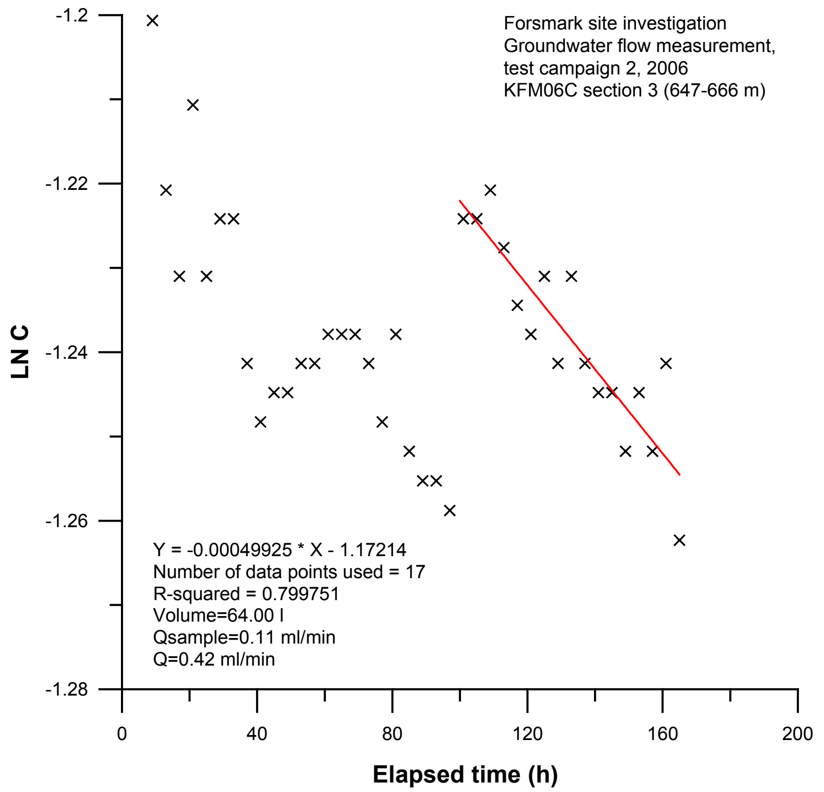

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
KFM02A section 5 (411-442 m)
Y = -0.00044206 * X - 1.12533
Number of data points used = 35
R-squared = 0.877501
Volume=60.78 l
Qsample=0.09 ml/min
Q=0.36 ml/min
LN C
Elapsed time (h)

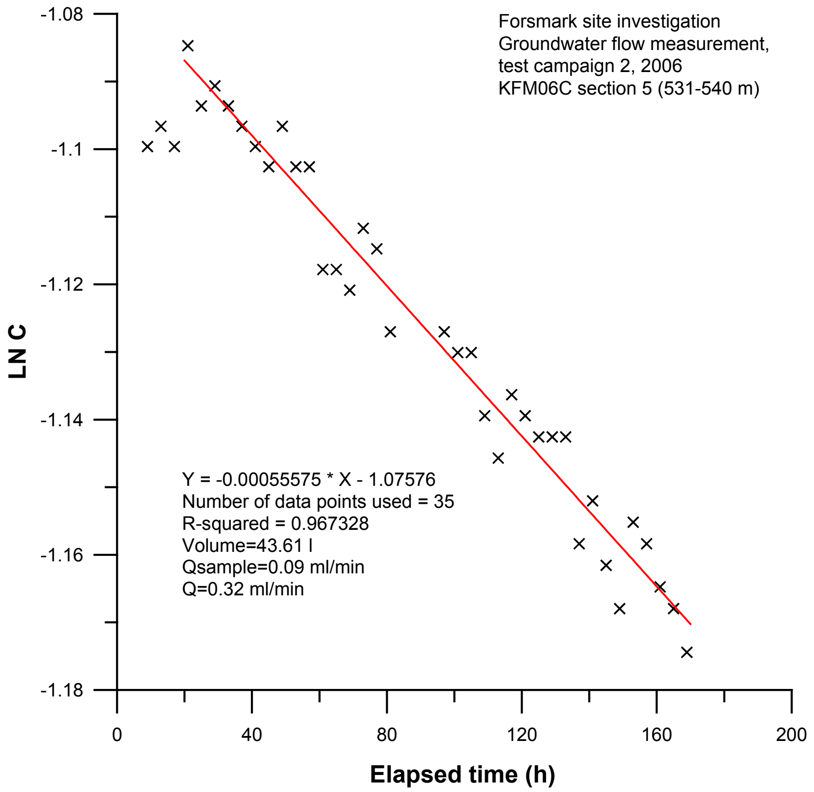

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
KFM03A section 4 (633.5-650 m)
Y = -0.00063141 * X - 0.86414
Number of data points used = 42
R-squared = 0.915135
Volume=58.04 l
Qsample=0.09 ml/min
Q=0.52 ml/min
LN C
Elapsed time (h)

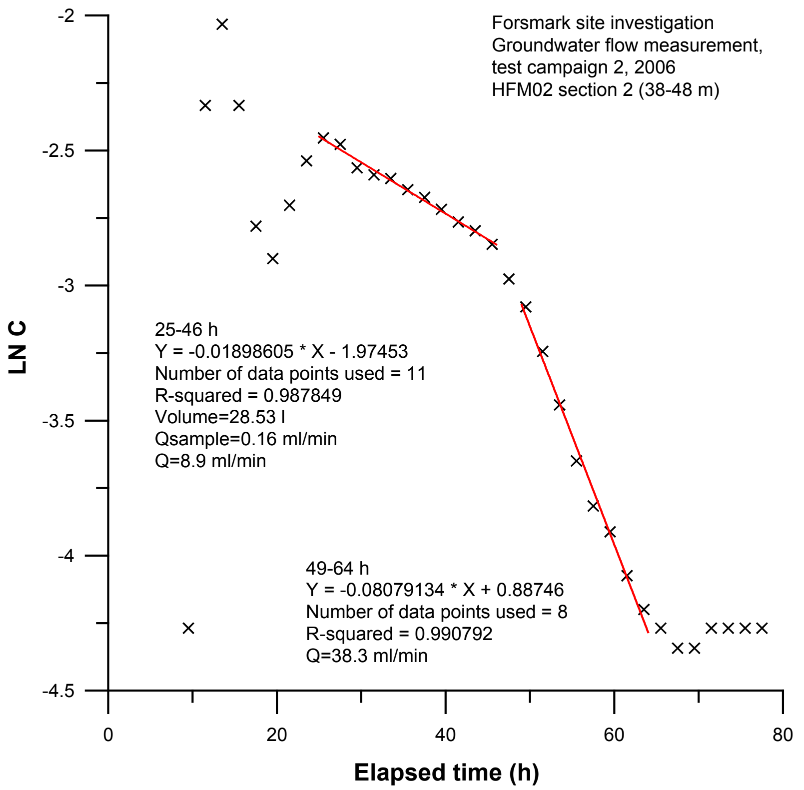

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
KFM05A section 4 (254-272 m)
Y = -0.00224848 * X - 0.98650
Number of data points used = 32
R-squared = 0.902396
Volume=40.62 l
Qsample=0.09 ml/min
Q=1.4 ml/min
LN C
Elapsed time (h)
-0.9
-1
-1.1
-1.2
-1.3
-1.4
0
40
80
120
160
200

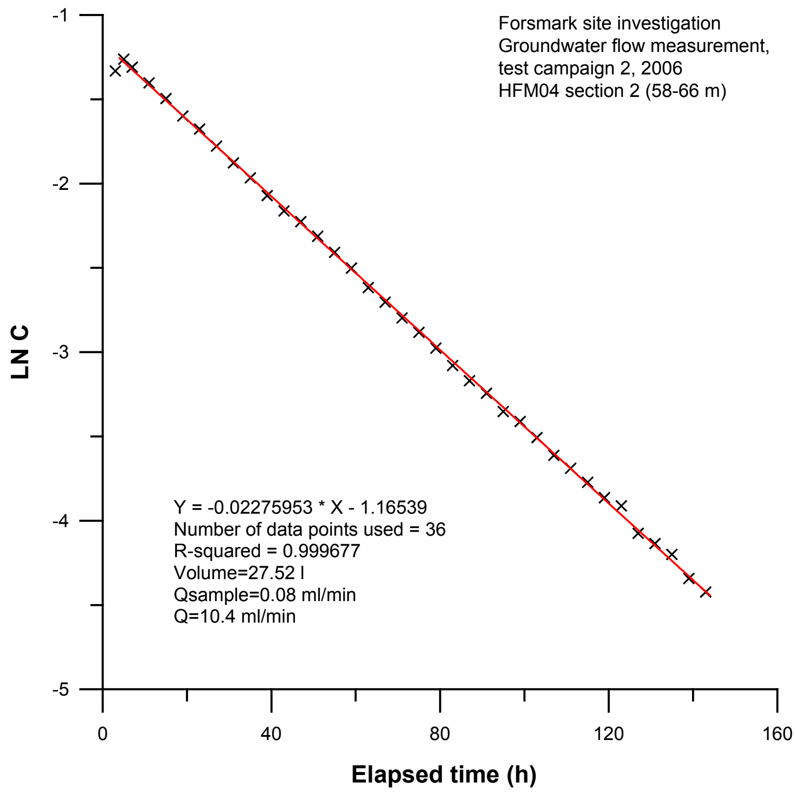

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
KFM06A section 3 (738-748 m)
Y = -0.00068658 * X - 0.69559
Number of data points used = 40
R-squared = 0.952329
Volume=58.25 l
Qsample=0.1 ml/min
Q=0.57 ml/min
LN C
Elapsed time (h)
-0.68
-0.72
-0.76
-0.8
-0.84
0
40
80
120
160
200

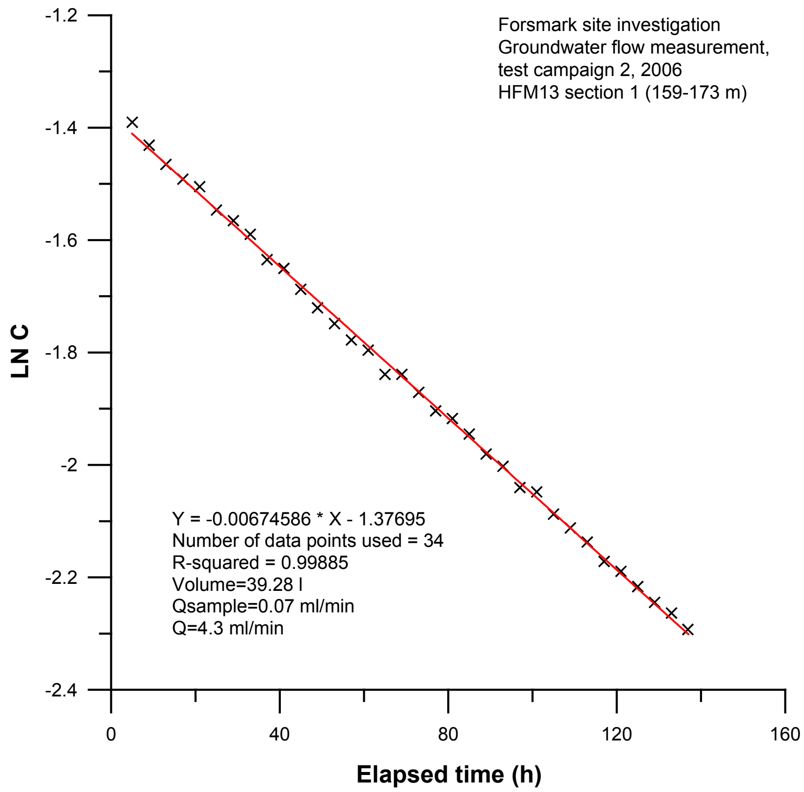

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
KFM06A section 5 (341-362 m)
Y = -0.00093384 * X - 0.948369
Number of data points used = 22
R-squared = 0.93833
Volume=46.64 l
Qsample=0.09 ml/h
Q=0.64 ml/min
LN C
Elapsed time (h)
-0.92
-0.96
-1
-1.04
0
20
40
60
80
100

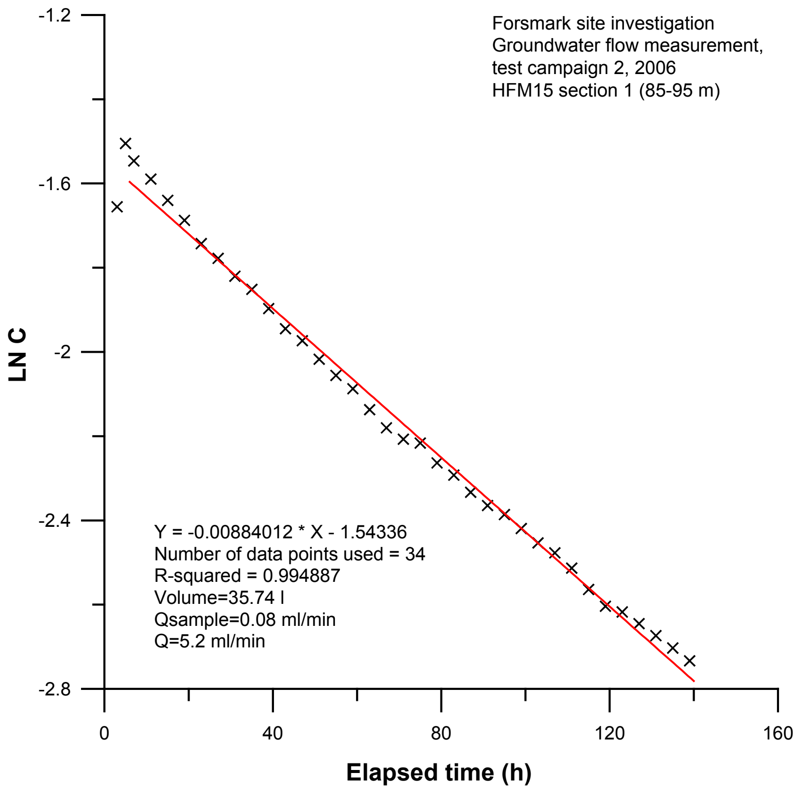

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
KFM06C section 3 (647-666 m)
Y = -0.00049925 * X - 1.17214
Number of data points used = 17
R-squared = 0.799751
Volume=64.00 l
Qsample=0.11 ml/min
Q=0.42 ml/min
LN C
Elapsed time (h)
-1.2
-1.22
-1.24
-1.26
-1.28
0
40
80
120
160
200

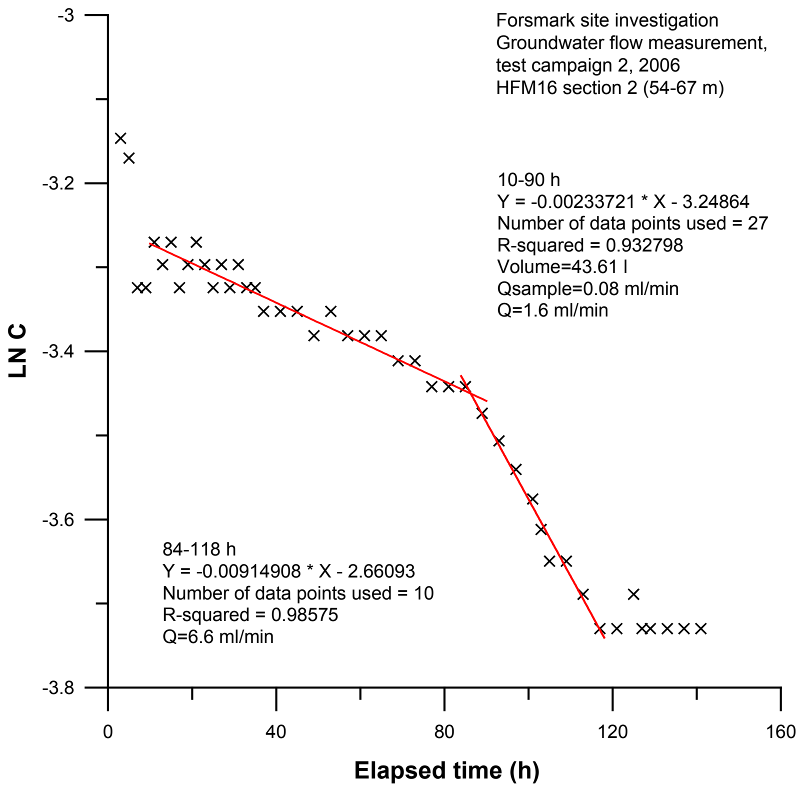

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
KFM06C section 5 (531-540 m)
Y = -0.00055575 * X - 1.07576
Number of data points used = 35
R-squared = 0.967328
Volume=43.61 l
Qsample=0.09 ml/min
Q=0.32 ml/min
LN C
Elapsed time (h)
-1.08
-1.1
-1.12
-1.14
-1.16
-1.18
0
40
80
120
160
200

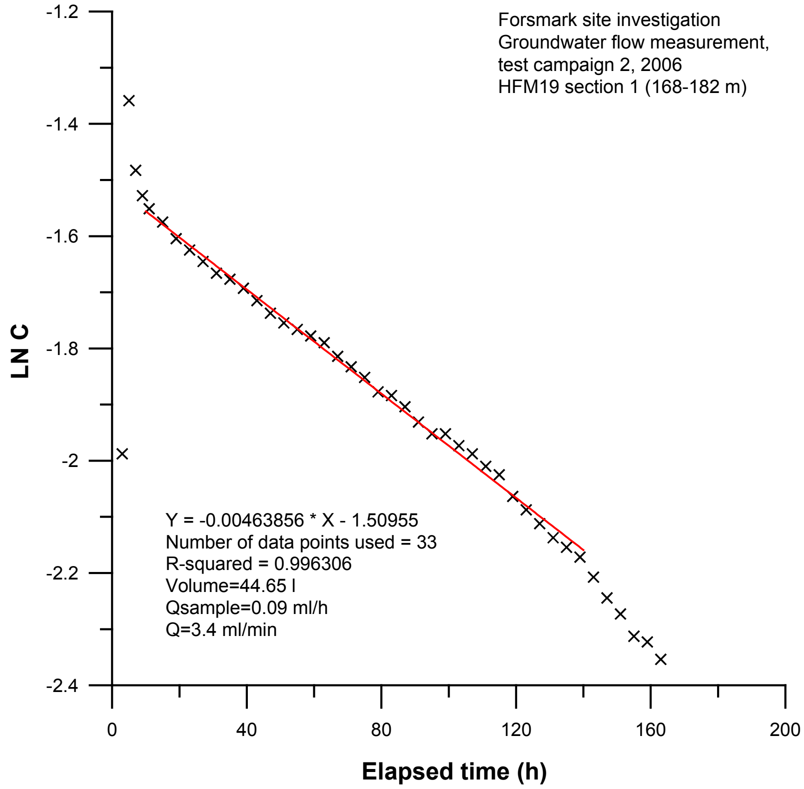

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM02 section 2 (38-48 m)
25-46 h
Y = -0.01898605 * X - 1.97453
Number of data points used = 11
R-squared = 0.987849
Volume=28.53 l
Qsample=0.16 ml/min
Q=8.9 ml/min
49-64 h
Y = -0.08079134 * X + 0.88746
Number of data points used = 8
R-squared = 0.990792
Q=38.3 ml/min
LN C
Elapsed time (h)
-2
-2.5
-3
-3.5
-4
-4.5
0
20
40
60
80

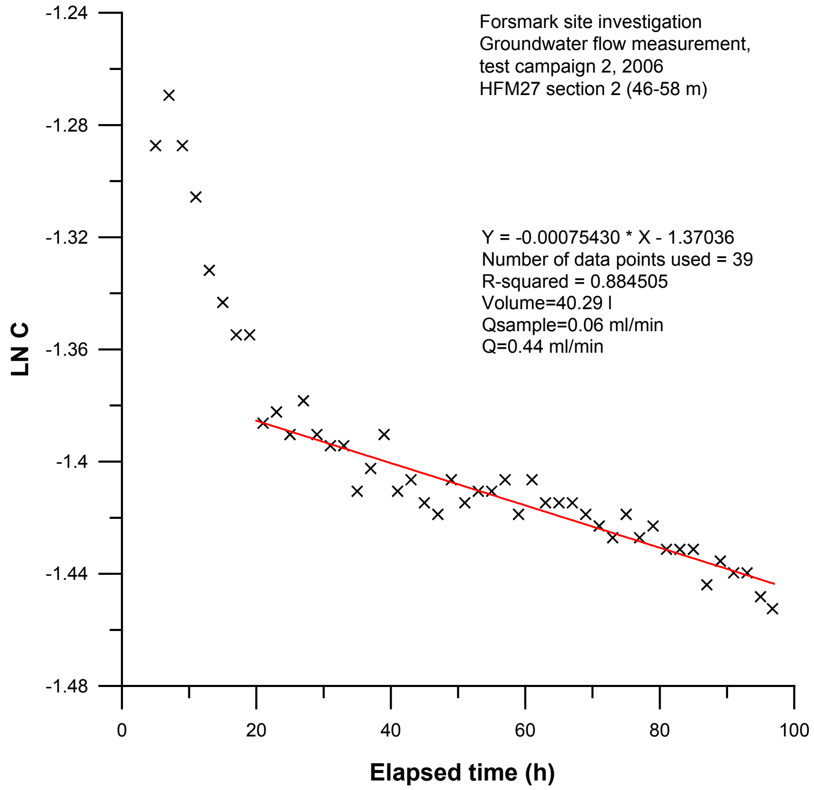

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM04 section 2 (58-66 m)
Y = -0.02275953 * X - 1.16539
Number of data points used = 36
R-squared = 0.999677
Volume=27.52 l
Qsample=0.08 ml/min
Q=10.4 ml/min
LN C
-1
-2
-3
-4
-5
0
40
80
120
160
Elapsed time (h)

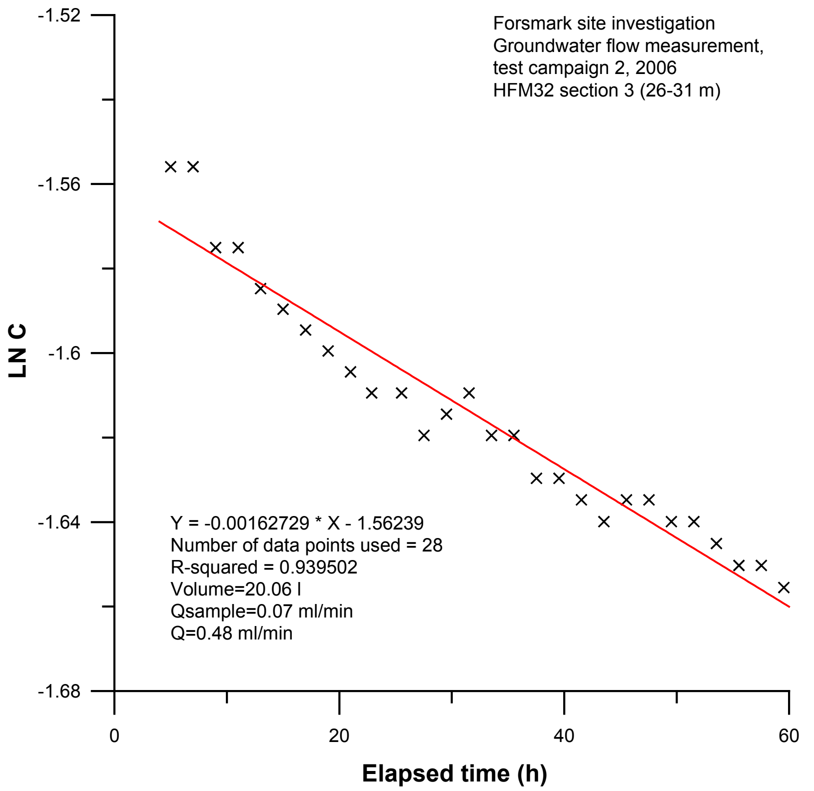

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM13 section 1 (159-173 m)
Y = -0.00674586 * X - 1.37695
Number of data points used = 34
R-squared = 0.99885
Volume=39.28 l
Qsample=0.07 ml/min
Q=4.3 ml/min
LN C
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
0
40
80
120
160
Elapsed time (h)


Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM15 section 1 (85-95 m)
Y = -0.00884012 * X - 1.54336
Number of data points used = 34
R-squared = 0.994887
Volume=35.74 l
Qsample=0.08 ml/min
Q=5.2 ml/min
LN C
Elapsed time (h)
-1.2
-1.6
-2
-2.4
-2.8
0
40
80
120
160


Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM16 section 2 (54-67 m)
10-90 h
Y = -0.00233721 * X - 3.24864
Number of data points used = 27
R-squared = 0.932798
Volume=43.61 l
Qsample=0.08 ml/min
Q=1.6 ml/min
84-118 h
Y = -0.00914908 * X - 2.66093
Number of data points used = 10
R-squared = 0.98575
Q=6.6 ml/min
LN C
Elapsed time (h)
-3
-3.2
-3.4
-3.6
-3.8
0
40
80
120
160


Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM19 section 1 (168-182 m)
Y = -0.00463856 * X - 1.50955
Number of data points used = 33
R-squared = 0.996306
Volume=44.65 l
Qsample=0.09 ml/h
Q=3.4 ml/min
LN C
Elapsed time (h)

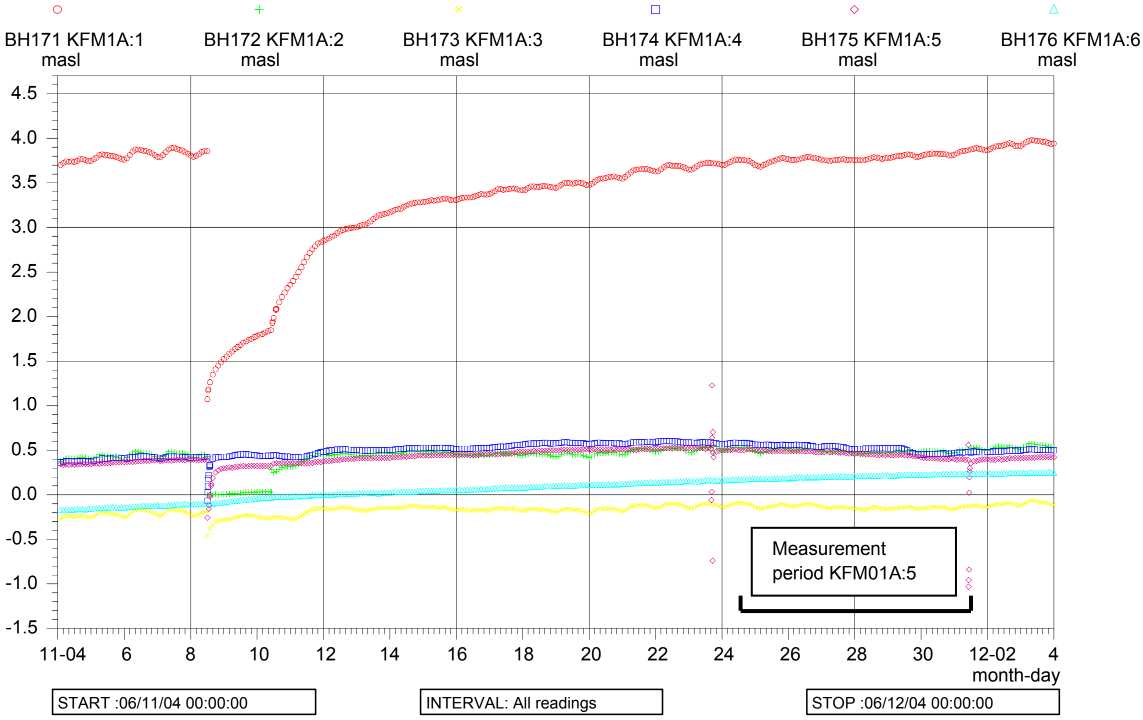

Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM27 section 2 (46-58 m)
Y = -0.00075430 * X - 1.37036
Number of data points used = 39
R-squared = 0.884505
Volume=40.29 l
Qsample=0.06 ml/min
Q=0.44 ml/min
LN C
Elapsed time (h)


Forsmark site investigation
Groundwater flow measurement,
test campaign 2, 2006
HFM32 section 3 (26-31 m)
Y = -0.00162729 * X - 1.56239
Number of data points used = 28
R-squared = 0.939502
Volume=20.06 l
Qsample=0.07 ml/min
Q=0.48 ml/min
-1.52
-1.56
-1.6
-1.64
-1.68
LN C
0
20
40
60
Elapsed time (h)

Groundwater levels (metres above sea level)

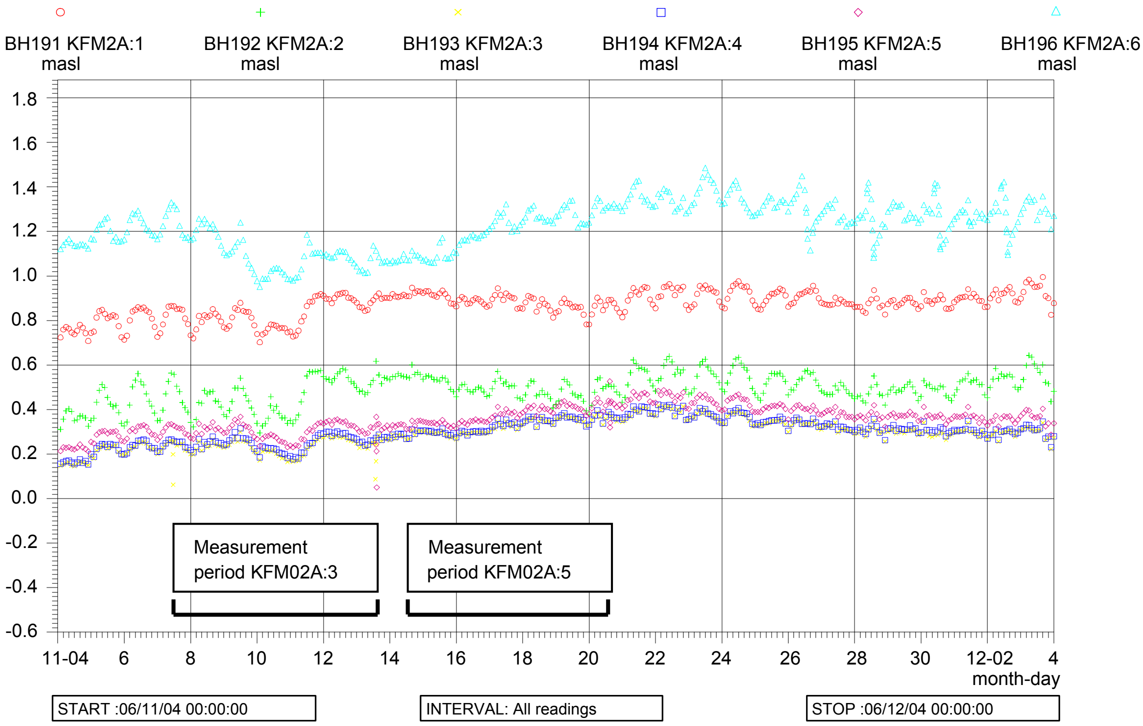
2006-11-04–2006-12-04

KFM01A



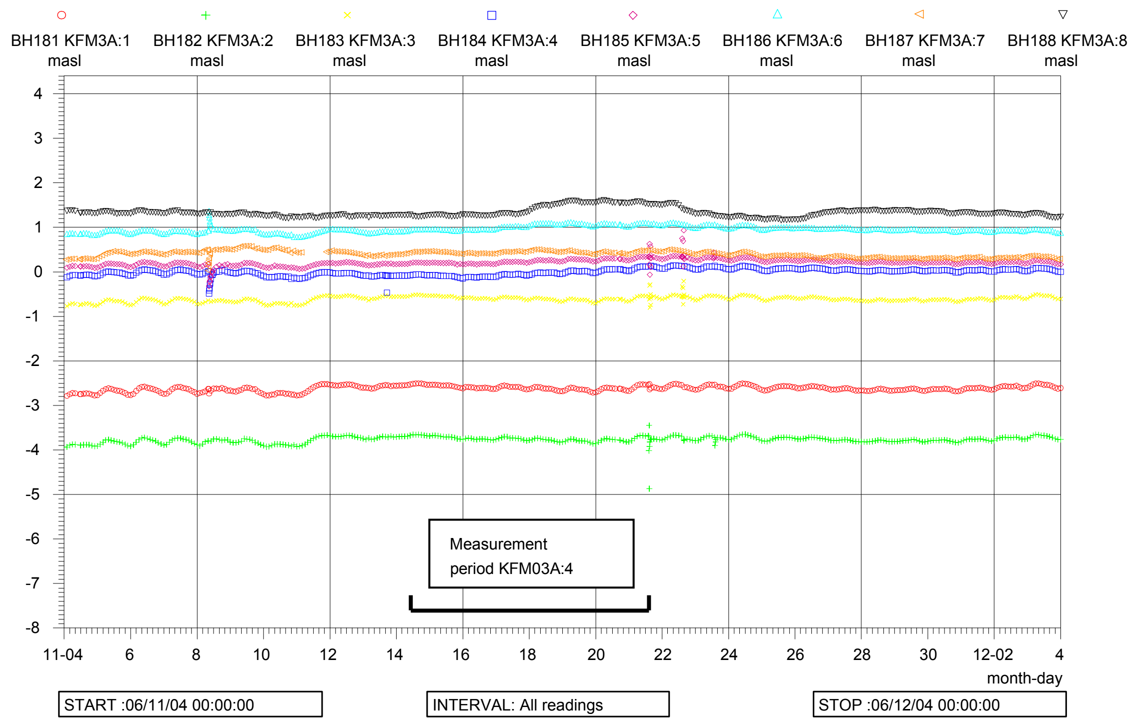
Measured section: KFM01A:5 (mauve)

KFM02A



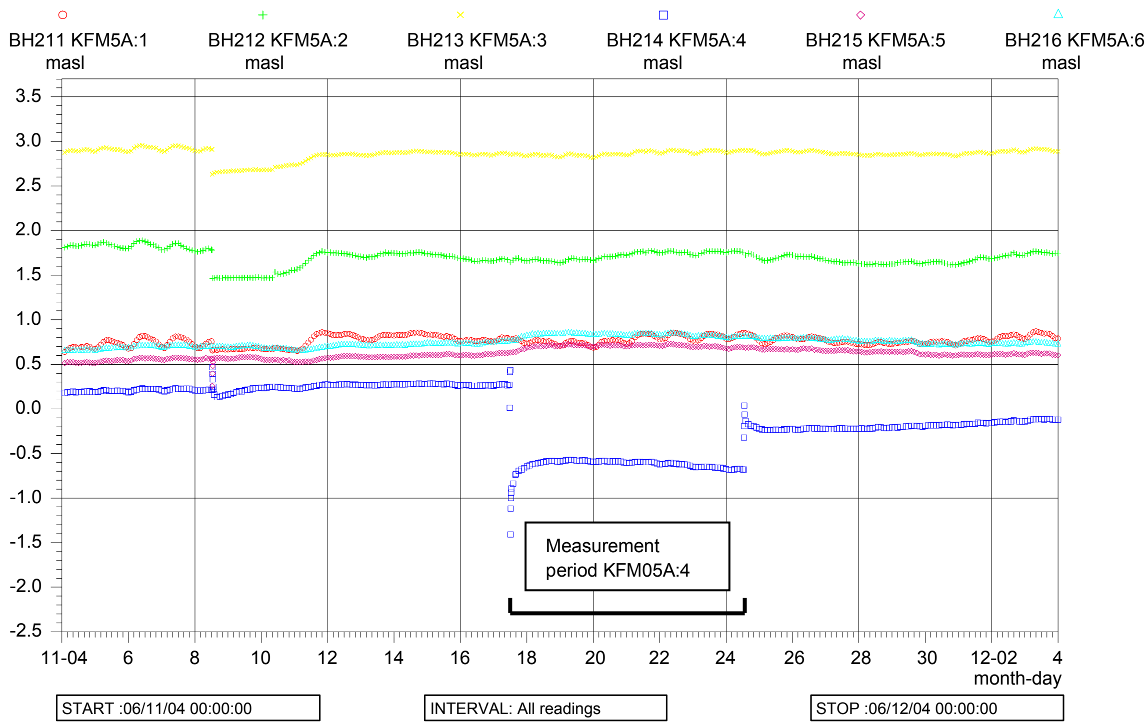
Measured sections: KFM02A:3 (yellow) and KFM02A:5 (mauve)

KFM03A



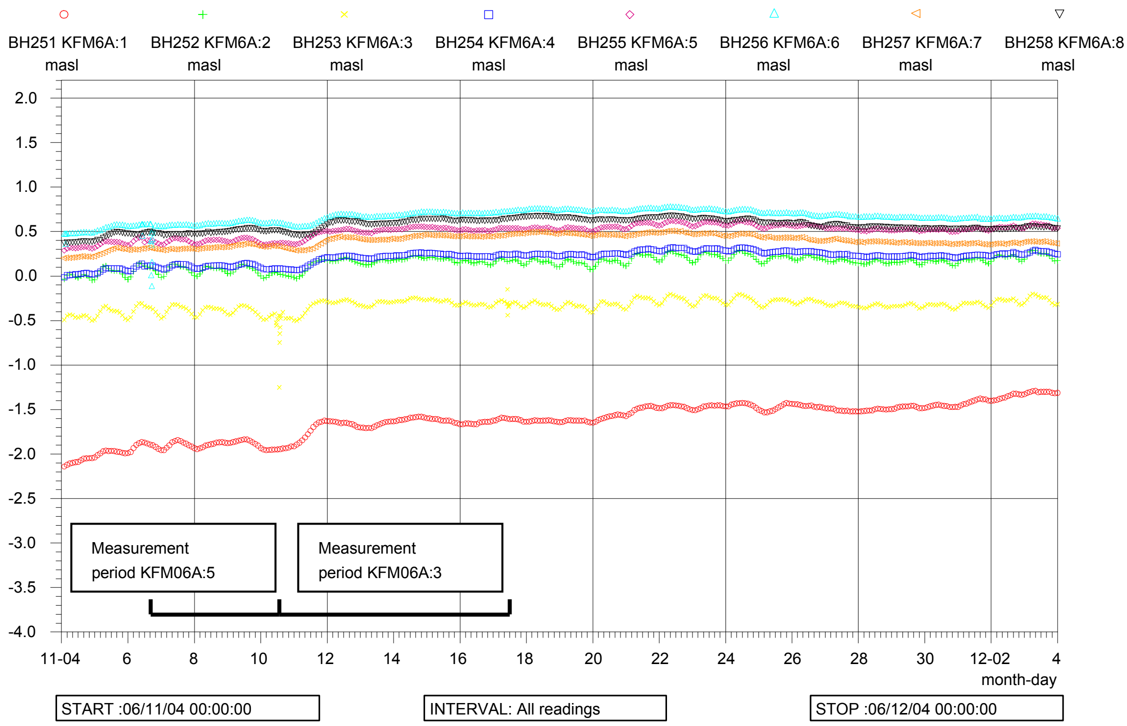
Measured section: KFM03A:4 (dark blue)

KFM05A



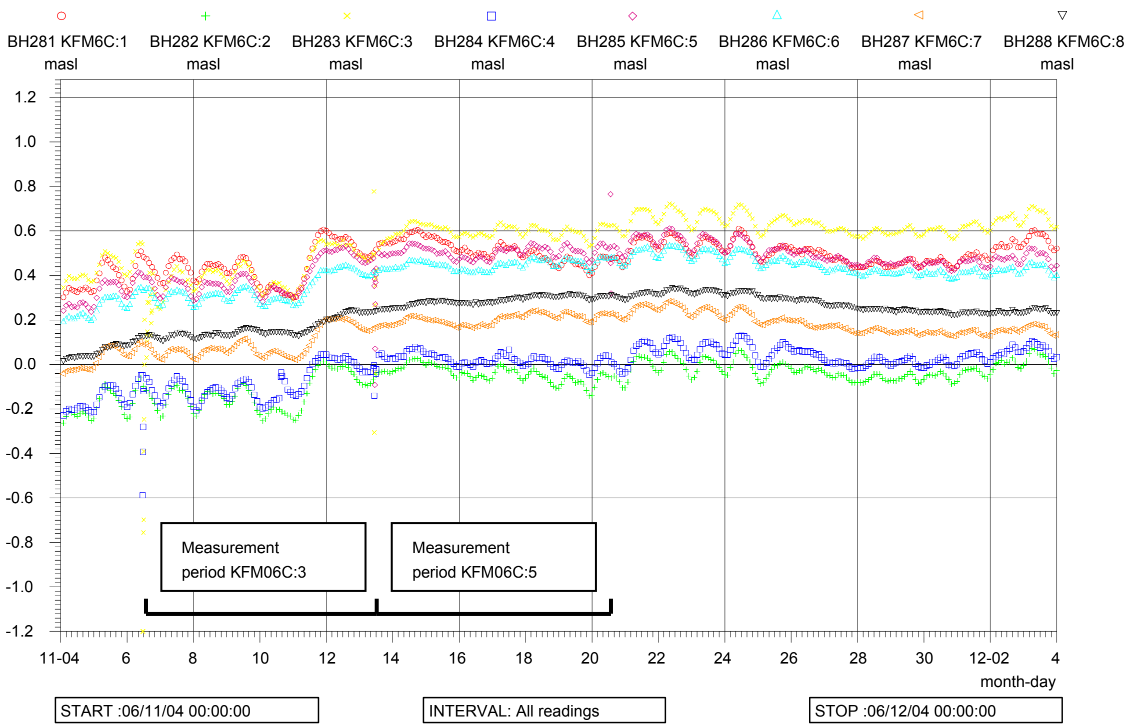
Measured section: KFM05A:4 (dark blue)

KFM06A



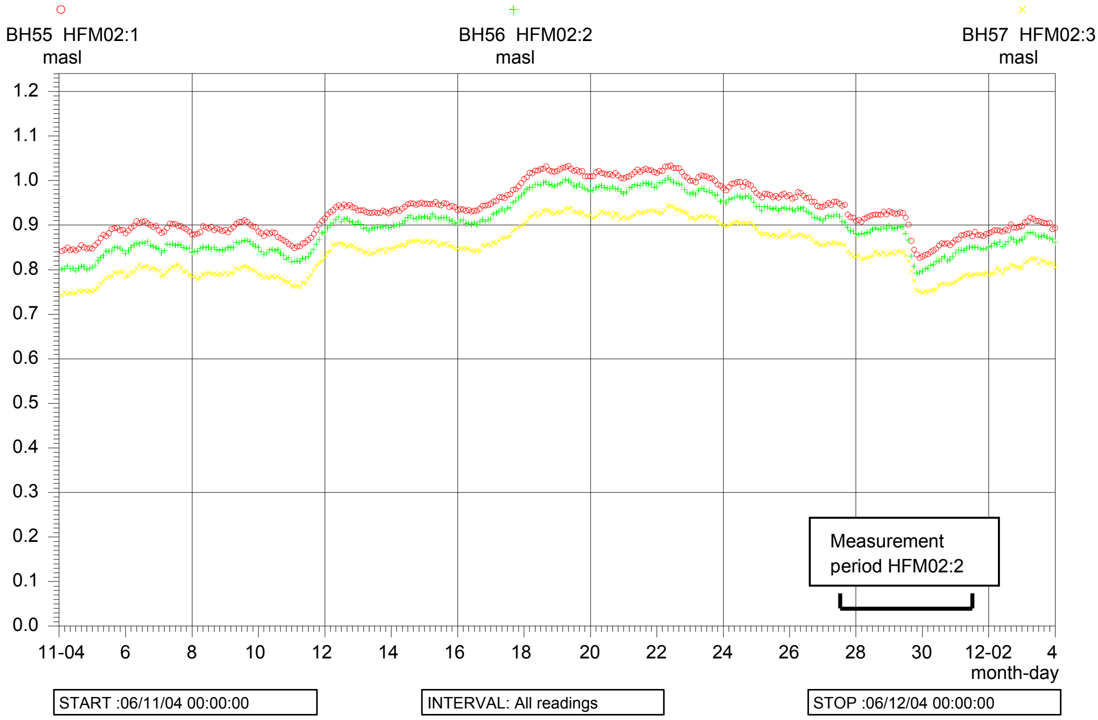
Measured sections: KFM06A:3 (yellow) and KFM06A:5 (mauve)

KFM06C



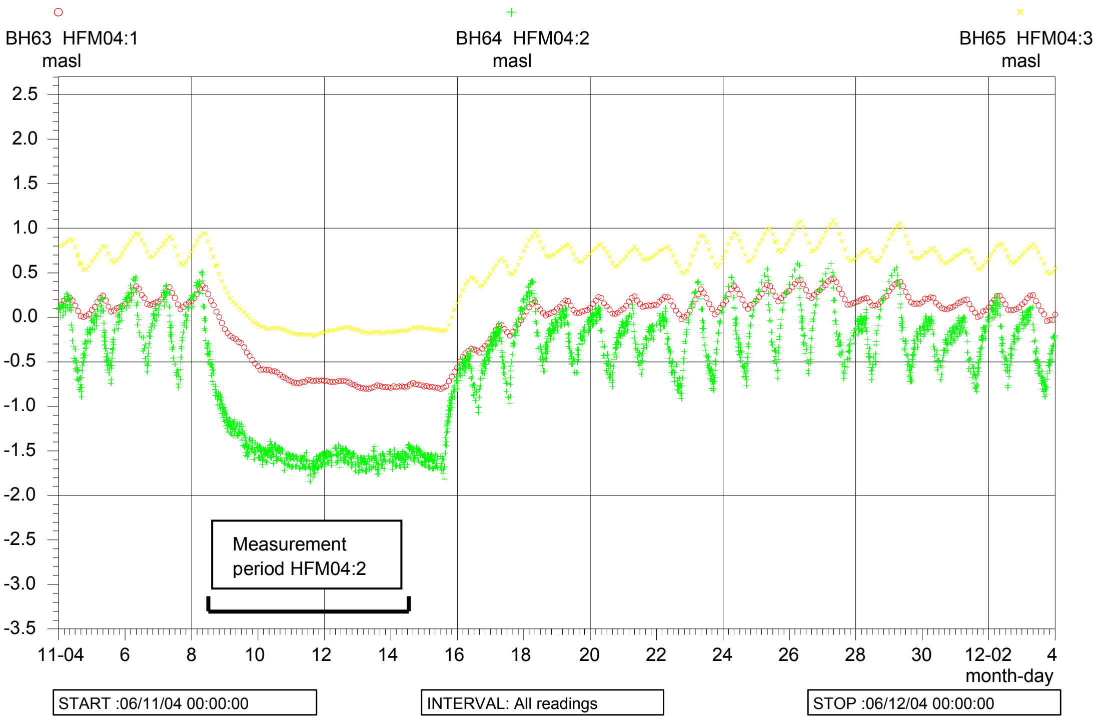
Measured sections: KFM06C:3 (yellow) and KFM06C:5 (mauve)

HFM02



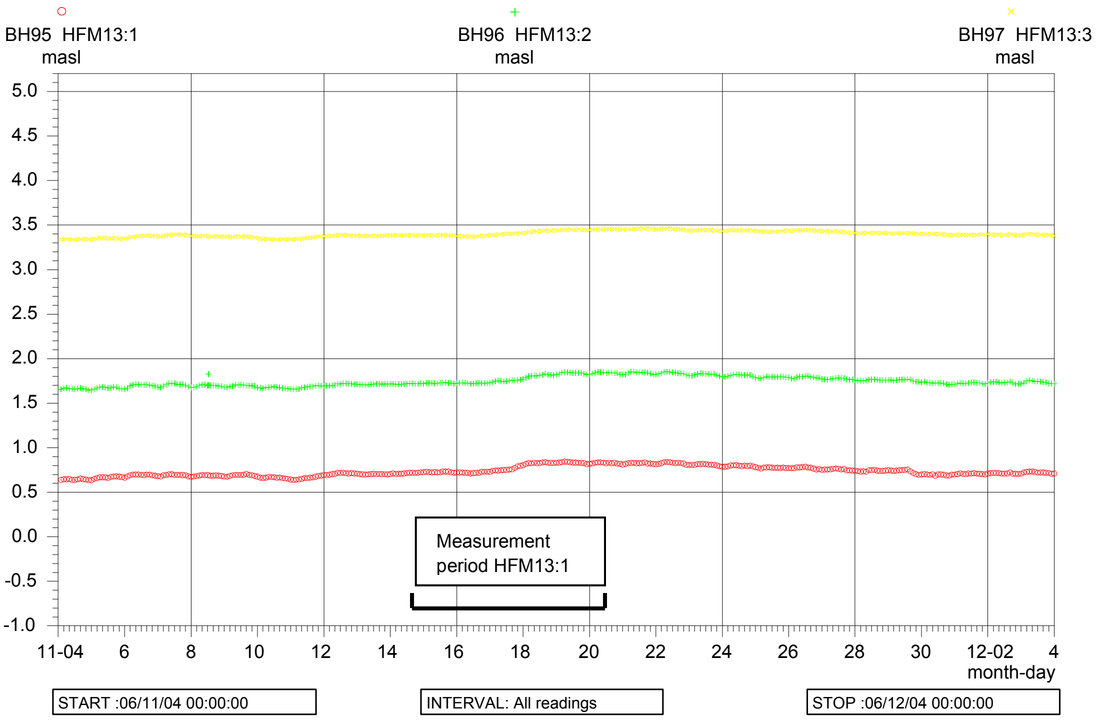
Measured section: HFM02:2 (green)

HFM04



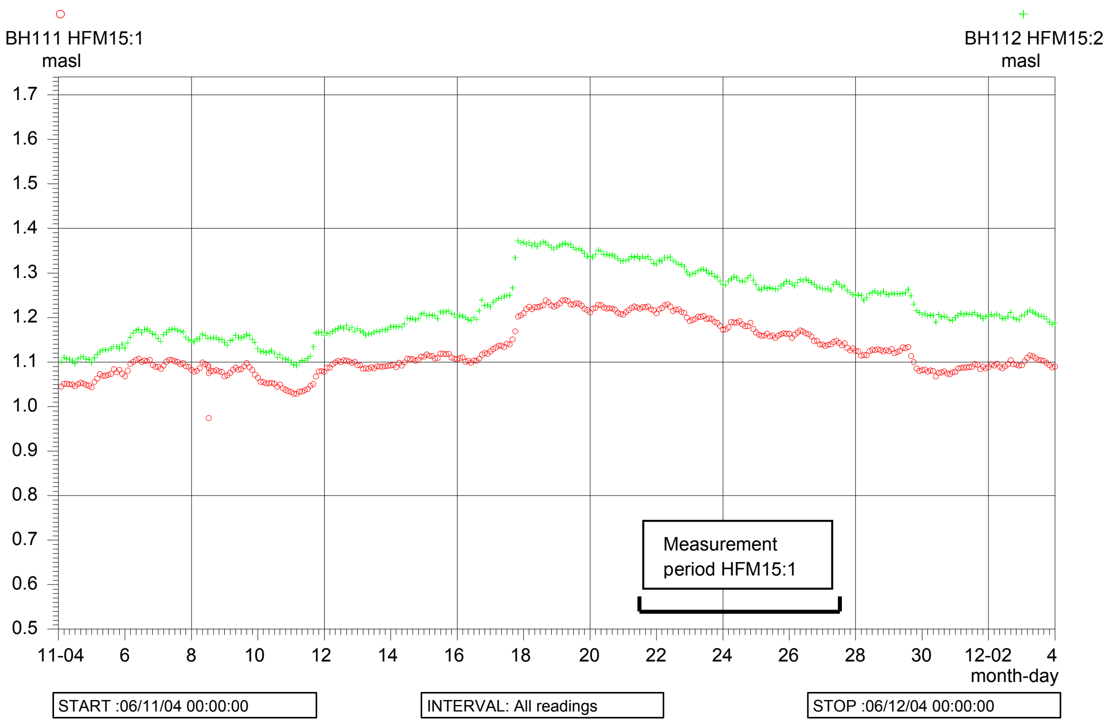
Measured section: HFM04:2 (green)

HFM13



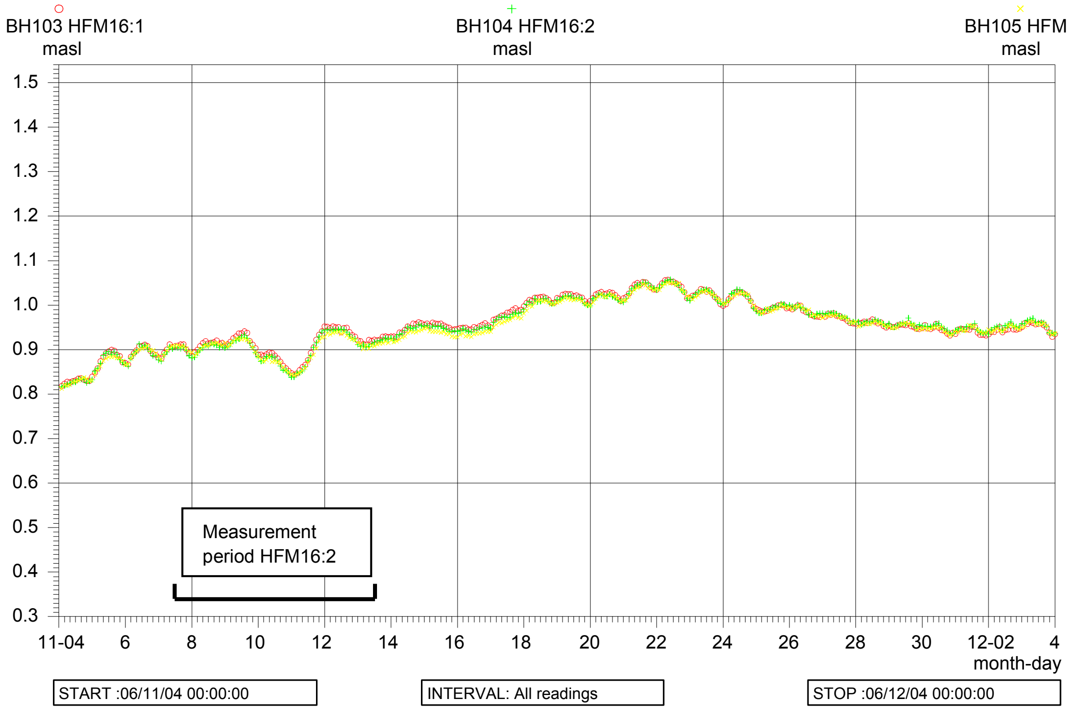
Measured section: HFM13:1 (red)

HFM15



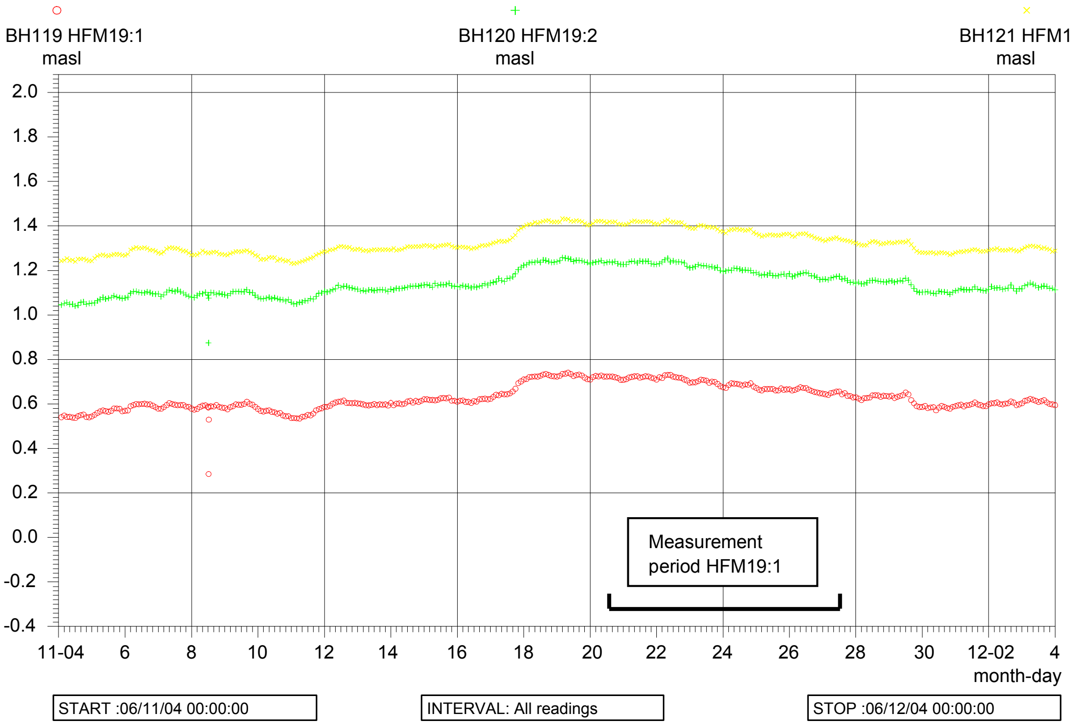
Measured section: HFM15:1 (red)

HFM16



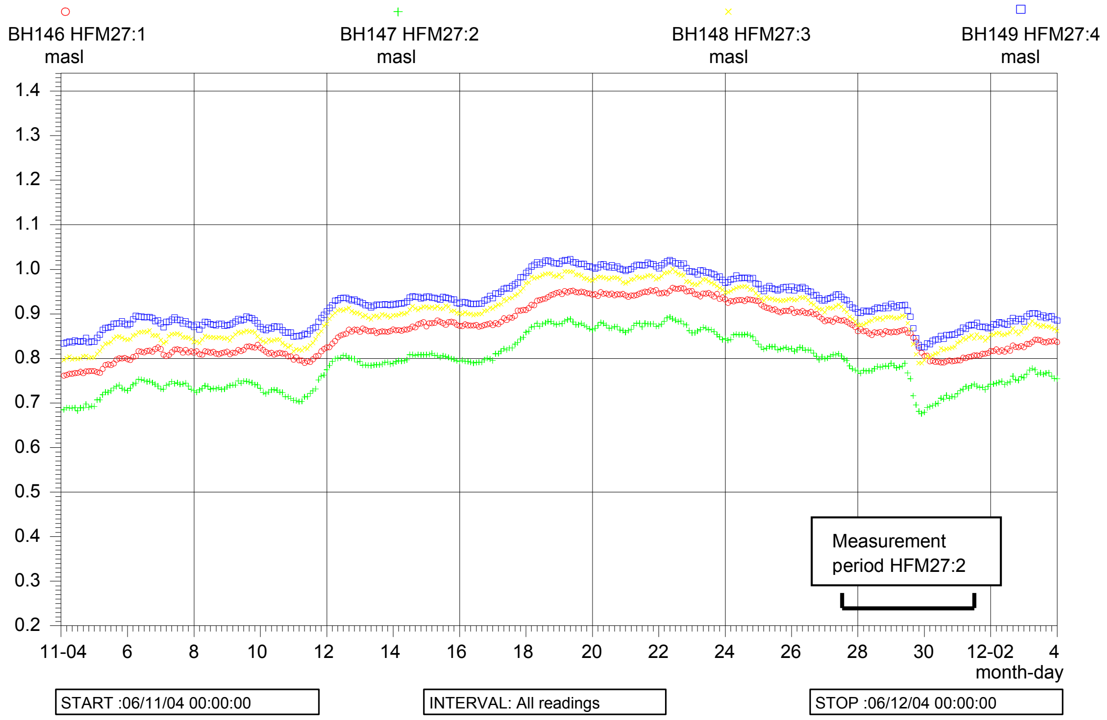
Measured section: HFM16:2 (green)

HFM19



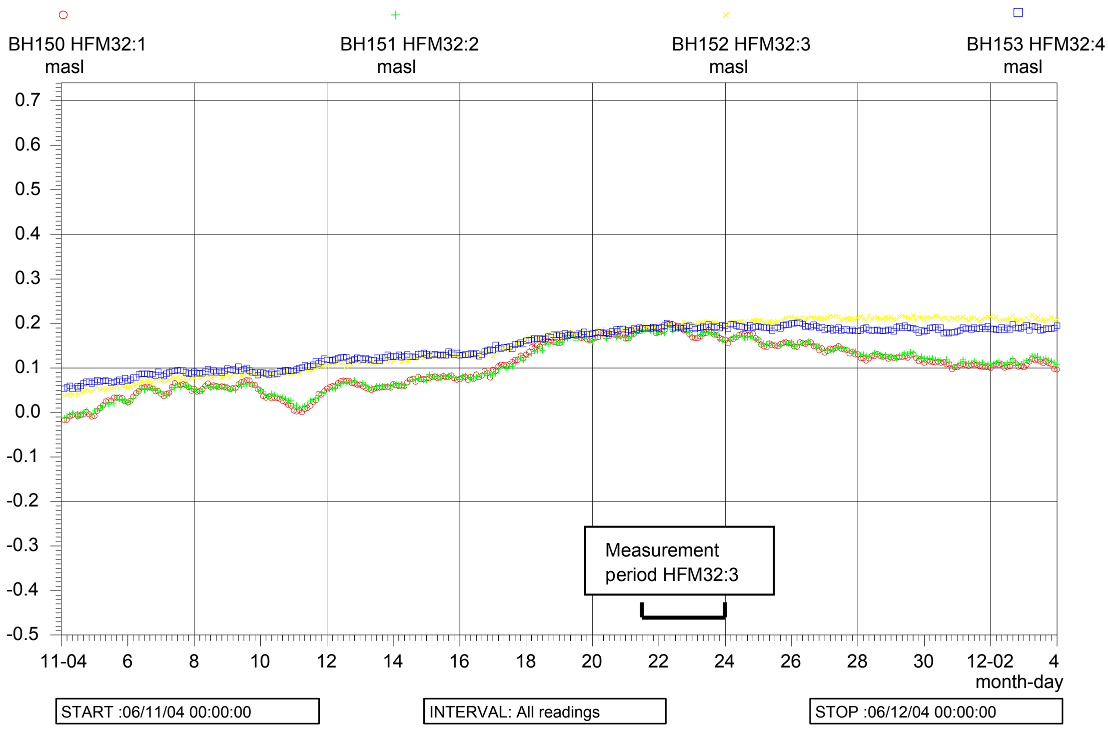
Measured section: HFM19:1 (red)

HFM27



Measured section: HFM27:2 (green)

HFM32



Measured section: HFM32:3 (yellow)