

Report

**P-18-11**

August 2018



# Hydrochemical groundwater monitoring

## Results from water sampling in the Forsmark area 2016

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## **Results from water sampling in the Forsmark area 2016**

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*Keywords:* AP SFK-16-012, Measurements, Groundwater.

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## **Abstract**

The present report documents the hydrochemical monitoring of deep groundwaters in the Forsmark area including the Spent Nuclear Fuel Repository Project as well as the SFR Extension Project. The sampling includes 30 out of the 41 borehole sections within the monitoring program.

Sampling was conducted in series of three samples collected at three different occasions during continuous pumping i.e. varying the purged volume prior to sampling. All standpipes connected to the sections were, with a few exceptions, cleaned before sampling.

Generally, the chloride concentrations and also the groundwater composition as a whole is stable in the sampled sections and no significant changes occur.

## Sammanfattning

Denna rapport dokumenterar hydrokemisk monitorering av djupt grundvatten inom Forsmarksområdet där Projekt Kärnbränsleförvaret samt Projekt SFR-Utbyggnad ingår. Provtagningen inkluderar 30 av 41 borrhålssektioner inom monitoreringsprogrammet.

Provtagningen gjordes i serier om 3 prov, tagna vid tre olika tillfällen under tiden som kontinuerlig pumpning pågick det vill säga de omsatta volymerna innan provuttaget varierades. Med några få undantag spolades alla vattenståndsrör, som är kopplade till sektionerna, innan provtagningen.

Generellt är kloridkoncentrationerna såväl som hela grundvattensammansättningarna i de provtagna sektionerna stabil och inga signifikanta förändringar har observerats.

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# 1 Introduction

## 1.1 General

This report includes results from hydrochemical groundwater monitoring in boreholes included in the Spent Nuclear Fuel Repository Project as well as the SFR Extension Project in the Forsmark area during year 2016. The long-term hydrochemical monitoring programme of percussion-drilled and core-drilled boreholes aims at creating long time series of data that will provide a base-line in order to facilitate evaluation of possible future impacts on the groundwater situation from the construction and the operation of the two facilities. The sizes of natural variations are important information in order to identify possible future changes in water composition. Since the two study sites overlap, each project benefit from the increased amount of information about the hydrochemical conditions.

The controlling documents valid for the hydrochemical monitoring activities are listed in Table 1-1. Both activity plan and method descriptions are SKB's internal controlling documents. Original data from the reported activities are stored in the primary database Sicada. Data are traceable in Sicada by the activity plan number (AP SFK 16-012). Only data in the database are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the database may be revised, if needed. However, such revision of the database will not necessarily result in a revision of this report.

**Table 1-1. Controlling documents for performance of the activities.**

<b>Activity plan</b>	<b>Number</b>	<b>Version</b>
Hydrokemisk monitoring i hammar – och kärnbronnhål 2016	AP SFK 16-012	1.0
<b>Method descriptions</b>	<b>Number</b>	<b>Version</b>
Metodbeskrivning för vattenprovtagning och analys i instrumenterade bronnhål.	SKB MD 425.001	1.0
Mätssystembeskrivning (MSB) – Handhavandedel; System för hydrologisk och meteorologisk datainsamling. Vattenprovtagning och utspädningsmätning i observationshål.	SKB MD 368.010	2.0
Provtagning och provhantering*	SKB MD 452.001	10.0

\* Water sampling and measurement procedures are also described in SKB PIR-04-12, "Översikt över provhanterings- och analysrutiner för vatten-prov" (SKB internal documents).

## 1.2 Background

The monitoring program for groundwater has been on-going since 2005 (SKB 2005). It was initiated during the site investigations for a final repository of spent nuclear fuel (SKB 2001) and has continued after the completion of the site investigation in 2007. The current monitoring program is developed from the program in R-07-34 (SKB 2007) and since 2012 boreholes drilled during the site investigations for the SFR extension project (SKB 2008) are incorporated in the monitoring program for the Forsmark area. During the years, the program has been modified concerning sampling techniques and analytical protocol. The full monitoring history for each borehole is presented in Appendix 1.

## 1.3 Boreholes and borehole sections

A total of 41 borehole sections, representing 20 core drilled boreholes and 10 percussion drilled boreholes, are included in the hydrochemical monitoring program for groundwater in the bedrock, Figure 1-1 and Table 1-2. One new section, KFR01:1, was added to the program this year.

In order to evaluate the results of groundwater analyses and observed trends in the groundwater chemistry, it is important to have information about previous investigations in each borehole and to understand the implications of these activities on the groundwater chemistry. Investigations likely to affect subsequent water sampling include hydraulic pumping and injection tests, tracer tests, SWIW tests (*Single Well Injection and Withdrawal-tests*) and tracer dilution tests.



**Figure 1-1.** General overview of the Forsmark area and the boreholes included in the hydrochemical monitoring program for groundwater. The (telescopic) cored boreholes and the percussion boreholes within the monitoring program are marked with green and blue filled circles, respectively.

In the boreholes included in the SFR Extension Project, no such activities have been performed before year 2016. Since the last sampling campaign, interference tests (withdrawal-tests) have been performed in KFR105, KFR27 and KFR103 and injection tests have been performed in KFR105 and KFR103. KFR27 and KFR103 are not included in the monitoring program, but the tests in these boreholes could have affected the water in other SFR boreholes included in the monitoring program. The only previous activities in the other boreholes besides drilling and instrumentation are hydrochemical sampling, cleaning of standpipes and pumping (Lindquist and Nilsson 2013).

Some early activities that may have affected, for example, the Uranine or trace metal concentrations are discussed in Nilsson et al. (2010). After 2009, Amino-G most often was used as tracer instead of Uranine for dilution tests. In the boreholes HFM15 and KFM05A, however, Uranine has been used even later, for example during the dilution tests performed in 2013 (Wass 2015). In KFM01D, the borehole equipment has been removed and reinstalled before the sampling 2016. During the open period in 2015, complete chemical characterisation (CCC) was performed in the borehole.

**Table 1-2. Boreholes and borehole sections included in the monitoring programme for percussion- and core-drilled boreholes, corresponding transmissivity values and comments to sections and sampling.**

Borehole [ldcode:section no.]	Section [mbl] <sup>1)</sup>	Elevation secmid [m.b.s.l.] <sup>2)</sup>	Transmissivity [m <sup>2</sup> /s]	Comments
KFM01A:5	109.0–130.0	115.6	1.0 E–7 <sup>3)</sup>	
KFM01D:2	429.0–438.0	343.1	8.0 E–7 <sup>3)</sup>	
KFM01D:4	311.0–321.0	252.5	2.0 E–7 <sup>3)</sup>	
KFM02A:3	490.0–518.0	495.0	2.1 E–6 <sup>3)</sup>	
KFM02A:5	411.0–442.0	417.8	2.5 E–6 <sup>3)</sup>	
KFM02B:2	491.0–506.0	483.8	3.0 E–5 <sup>4)</sup>	
KFM02B:4	410.0–431.0	407.1	2.0 E–5 <sup>4)</sup>	
KFM03A:1	969.5–994.5	969.1	5.5 E–7 <sup>3)</sup>	
KFM03A:4	633.5–650.0	631.1	2.4 E–6 <sup>3)</sup>	Not sampled <sup>6)</sup>
KFM04A:4	230.0–245.0	199.7	2.0 E–5 <sup>3)</sup>	
KFM06A:3	738.0–748.0	622.8	1.2E–7 <sup>3)</sup>	
KFM06A:5	341.0–362.0	298.5	3.5 E–6 <sup>3)</sup>	
KFM06C:3	647.0–666.0	527.1	5.3 E–8 <sup>3)</sup>	
KFM06C:5	531.0–540.0	434.9	1.1 E–6 <sup>3)</sup>	
KFM07A:2	962.0–972.0	795.6	5.0 E–7 <sup>3)</sup>	Not sampled <sup>7)</sup>
KFM08A:2	684.0–694.0	550.6	1.0 E–6 <sup>3)</sup>	Not sampled <sup>7)</sup>
KFM08A:6	265.0–280.0	127.8	1.0 E–6 <sup>3)</sup>	Not sampled <sup>7)</sup>
KFM08D:2	825.0–835.0	622.6	2.4 E–8 <sup>3)</sup>	Not sampled <sup>6) and 7)</sup>
KFM08D:4	660.0–680.0	538.1	2.0 E–7 <sup>3)</sup>	Not sampled <sup>6) and 7)</sup>
KFM10A:2	430.0–440.0	299.8	3.0 E–5 <sup>3)</sup>	Not sampled <sup>6) och 7)</sup>
KFM11A:2	690.0–710.0	593.8	1.0 E–6 <sup>3)</sup>	
KFM11A:4	446.0–456.0	389.6	6.0 E–7 <sup>3)</sup>	Not sampled <sup>6) and 7)</sup>
KFM12A:3	270.0–280.0	226.7	1.0 E–6 <sup>3)</sup>	
HFM01:2	33.5–45.5	37.0	4.0 E–5 <sup>5)</sup>	
HFM02:2	38.0–48.0	39.9	5.9 E–4 <sup>5)</sup>	
HFM04:2	57.9–65.9	57.9	7.9 E–5 <sup>5)</sup>	
HFM13:1	159.0–173.0	138.6	2.9 E–4 <sup>5)</sup>	Not sampled <sup>6) and 7)</sup>
HFM15:1	85.0–95.0	59.1	1.0 E–4 <sup>5)</sup>	
HFM16:2	54.0–67.0	57.2	3.5 E–4 <sup>5)</sup>	
HFM19:1	168.0–182.0	136.2	2.7 E–4 <sup>5)</sup>	
HFM21:3	22.0–32.0	18.8	4.0 E–5 <sup>5)</sup>	Not sampled <sup>6) and 7)</sup>
HFM27:2	46.0–58.0	45.6	4.0 E–5 <sup>5)</sup>	
HFM32:3	26.0–31.0	27.5	2.3 E–4 <sup>5)</sup>	
KFR101:1	279.5–341.8	240.2	5.8E–6 <sup>3)</sup>	No dummy in section
KFR102A:2	423.0–443.0	389.0	1.6E–6 <sup>3)</sup>	
KFR102A:5	214.0–219.0	194.6	3.6E–7 <sup>3)</sup>	
KFR104:1	333.0–454.6	306.5	6.5E–8 <sup>3)</sup>	No dummy in section
KFR105:1	265.0–306.8	153.6	6.1E–8 <sup>3)</sup>	Tunnel borehole. Not sampled <sup>6)</sup>
KFR106:1	260.0–300.1	261.0	1.0E–5 <sup>3)</sup>	No dummy in section
KFR106:2	143.0–259.0	187.2	3.3E–5 <sup>3)</sup>	No dummy in section
KFR01:1	44.65–62.3	94.3	–	

<sup>1)</sup> mbl = metres borehole length

<sup>2)</sup> m.b.s.l. = metres below sea level [RHB 70 = the national levelling system]

<sup>3)</sup> From differential flow logging

<sup>4)</sup> From injection tests

<sup>5)</sup> From flow logging

<sup>6)</sup> Due to other activities in the section

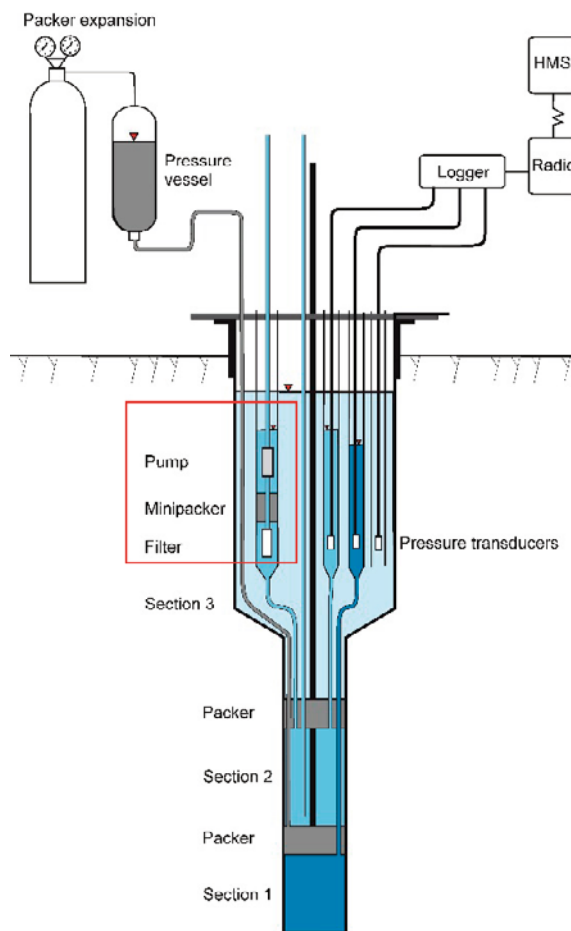
<sup>7)</sup> Due to drilling of KFM24



## 2 Equipment

### 2.1 Installations in a borehole test section with connected standpipe

The monitored boreholes are divided into sections sealed off by inflated rubber packers. The groundwater pressure is measured on-line in standpipes hydraulically connected to each section and transmitted to HMS (*Hydro Monitoring System*), i.e. SKB's hard- and software system for processing and interim storage of hydrological, hydrogeological and meteorological data. Most of the sampled sections are so called circulation sections and are also hydraulically connected to wider standpipes, which allow lowering of a pump. This fixed equipment (packers, tubing, standpipes etc.) remains in the borehole from year to year. An overview of the installation equipment is seen in Figure 2-1.



**Figure 2-1.** Installations in a borehole test section with connected standpipes and monitoring equipment. The installation is permanent in the borehole, except for the pump and filter (marked with the red frame).

## 2.2 Cleaning equipment for standpipes

The cleaning is conducted using a specially designed nozzle combined with a pressure washer,

Figure 2-2. The nozzle is designed to direct the jet in an upward direction in the standpipe in order to flush any flakes out of the standpipe. To lift the litter out of the standpipe more efficiently, a nitrogen gas tube was mounted just above the nozzle to achieve a gas-lift pumping effect in the standpipe. A more detailed description of the cleaning equipment can be found in (Lindquist et al. 2012).



*Figure 2-2. Cleaning equipment used to clean the standpipes prior to pumping and sampling.*

## 2.3 Sampling equipment

Several identical pumping equipment set-ups (GEOPUMP UV45) were used to retrieve the water samples from the sampled sections, Figure 2-3. The sampling equipment is identical to what was used in previous campaigns and is further described in Lindquist et al. (2012). When using this equipment, a mini-packer is expanded in the standpipe above the inlet to the filter and pump so that only water from the section and lowest part of the standpipe is pumped. In some sections, dissolved gas is released when the pressure decreases. The gas accumulates under the mini-packer and causes pump stops. To avoid such problems, a special evacuation tube is used, allowing the gas to evacuate.

In the borehole sections without connection to wide standpipes for sampling, sampling was performed in the narrow standpipes for pressure measurements. The smaller diameter of these standpipes does not allow pumping with the normal pumping equipment. Therefore these sections were pumped using gas-lift pumping (with nitrogen). The function of this pump is briefly described in Lindquist and Nilsson (2013) and the sampling equipment is also further described by Sandström et al. (2011).



**Figure 2-3.** The pumping equipment (GEOPUMP UV-45) used for pumping in wide standpipes. It consists of a filter and a pump connected to the mini-packer. The small diameter plastic hose is used for expanding the packer and the plastic hose connected to the pump is the pumping hose (enclosed picture right lower corner).

Figure 2-4 shows a photo of the equipment. The sampling conditions caused by gas-lift pumping are different from the conventional pumping generally used in the hydrogeochemical monitoring programme. The more effective (intermittent) pump action might affect the borehole walls (microbe coating, mineral particles etc.), and thus have an impact on the water composition. Especially, constituents such as hydrogen sulphide, TOC, DOC and trace metals may be affected.

In tunnel boreholes, no pumping equipment is needed due to the pressure gradient. When the valve is opened, water flows out from the section.



**Figure 2-4.** The equipment used for gas-lift pumping. On the left, the tubing lowered in the standpipe (the more narrow tube for sample water and the wider for gas) on a bobbin to simplify the lowering. To the upper right the control unit for the pumping/gas supply and lower right the end of the gas-lift pump.



## 3 Performance

### 3.1 General

Monitored boreholes and borehole sections, days between cleaning and pump start, collected samples, as well as SKB class/classes and pumping technique at each sampling location are presented in Table 3-1.

**Table 3-1. Boreholes, borehole sections, collected samples, pumping technique and analyses performed within the monitoring program 2016.**

Borehole [ldcode]	Days between cleaning and pump start	Sample No in serie	Analyses <sup>1)</sup>	Comments	Used pumping technique <sup>4)</sup>
KFM01A:5	62	30843–30845	Class 4		A
KFM01D:2	54	30828–30830	Class 4		A
KFM01D:4	58	30840–30842	Class 4		A
KFM02A:3	44	30800–30802	Class 4 <sup>2)</sup>		A
KFM02A:5	42	30797, 30794, 30790	Class 4		A
KFM02B:2	49	30806–30808	Class 4		A
KFM02B:4	48	30803–30805	Class 4		A
KFM03A:1	–	30825–30827	Class 4	Gas evacuation	A
KFM04A:4	38	30779–30781	Class 4		A
KFM06A:3	43	30789, 30798, 30799	Class 4	Gas evacuation	A
KFM06A:5	42	30785–30787	Class 4	Gas evacuation	A
KFM06C:3	39	30791–30793	Class 4 <sup>3)</sup>	Gas evacuation	A
KFM06C:5	42	30782–30784	Class 4	Gas evacuation	A
KFM11A:2	–	30874–30876	Class 4	Gas evacuation	A
KFM12A:3	37	30776–30778	Class 4		A
HFM01:2	–	30846–30848	Class 4		A
HFM02:2	68	30877–30879	Class 4		A
HFM04:2	49	30809–30811	Class 4		A
HFM15:1	56	30837–30839	Class 4		A
HFM16:2	43	30788, 30795, 30796	Class 4		A
HFM19:1	54	30831–30833	Class 4		A
HFM27:2	62	30849–30851	Class 4		A
HFM32:3	–	30834–30836	Class 4		A
KFR101:1	–	30883–30885	Class 4 <sup>3)</sup>		B
KFR102A:2	67	30880–30882	Class 4		A
KFR102A:5	63	30855–30857	Class 4		A
KFR104:1	–	30852–30854	Class 4 <sup>3)</sup>		B
KFR106:1	–	30819–30821	Class 4 <sup>2)3)</sup>		B
KFR106:2	–	30822–30824	Class 4 <sup>2)3)</sup>		B
KFR01:1	–	30886–30888	Class 4		C

<sup>1)</sup> If no other comment, third sample in series were class 4+ (or class 3+).

<sup>2)</sup> Third sample in series was class 5.

<sup>3)</sup> No HS<sup>-</sup> or Fe<sup>2+</sup> analyses due to pumping technique.

<sup>4)</sup> A = UV45 pump, B = nitrogen lifting pump (in standpipe for pressure measurements), C = valve opening (no pump) and D = docking unit.

### 3.2 Cleaning of standpipes

A special cleaning procedure was performed in most of the standpipes connected to the borehole sections prior to the sampling campaign. Some sections were not cleaned for different reasons; KFR03A:1 and KFM11A:2 due to risk of disturbing ongoing measurements in other sections in the boreholes, HFM32:3 and HFM01:2 because the locations of the boreholes make it difficult to transport the cleaning equipment and KFR101:1, KFR104:1, KFR106:1 and KFR106:2 due to staff shortages. The tunnel boreholes KFR105 and KFR01 are not connected to standpipes, so no cleaning is needed.

After cleaning, the water in the standpipes was evacuated with gas (mammoth pumping) so that the standpipe filled up from underneath with section water. This was done to remove cleaning water from the standpipe and avoid cleaning water in the samples. The mammoth pumping was done twice in each standpipe. The groundwater in the standpipes and the borehole sections was then allowed to settle for a period of at least 3 weeks before the pumping and sample collection started. The time between cleaning of the standpipes and start of pumping for collection samples in each section is given in Table 3-1.

### 3.3 Water sampling in series and field measurements

Sampling in series was performed in all sampled borehole sections. Each series consisted of three samples distributed with respect to pumped “plug-flow volumes” (including also the volume of the tube connecting to the section). The term “plug-flow volume” refers to the theoretical volume that has to be withdrawn in order to remove the exchangeable water present in the borehole section and get samples with close to 100 % formation water (water originating directly from water bearing fractures in the surrounding rock). As the theoretical plug-flow volume may be underestimated due to laminar flow effects, 100 % formation water is assumed at minimum 1.5 times the calculated plug-flow volume. The plug-flow volume varies from section to section depending on the distribution of water-yielding fractures along the section and their hydraulic transmissivities. This concept is further described in Nilsson et al. (2010) and Lindquist et al. (2012). With some exceptions 1.5, 3 and 5 plug-flow volumes were planned to be removed before sampling. The exceptions are KFM06A:3, KFM06C:3 and KFM11A:2 where larger volumes were planned to be removed before sampling due to the high pH values that was observed during monitoring previous years (see Appendix 2, Table A2-2).

Due to time constraints, the adequate water volumes according to the plug flow calculations were not always removed. In KFR101:1, KFR102A:2, KFR104:1 and KFR106:2 the plug flow volumes were based on less than 100 % formation water. The volumes and percent formation water for each of these borehole sections are presented in Appendix 2 (Table A2-3).

In order to rule out factors in the sampling procedure that could affect for example the sulphide concentrations, the discharge flow rate from each borehole section was set to the same flow rate as was used in previous years. In sections with low hydraulic transmissivity, where a low flow rate has to be used, all three samples in the series could not be collected during the working hours of a day. The collected samples and the removed water volumes prior to each sample are presented in Appendix 2. The discrepancy between actually removed volumes and those prescribed is partly due to practical reasons (sampling could not be performed in the middle of the night). If the sampling was performed earlier or later than scheduled, subsequent sampling was adjusted to maintain, as far as possible, the desired difference in removed volume between the samples in each series. The total removed volumes were calculated from the readings in the field protocols (where date, time and flow rates for the discharge periods and sampling occasions were noted).

To avoid problems with the gas-lift pumping, the same pump settings as previous years were used instead of trying to adjust the pump flows. In KFR104:1 and KFR106:2, extra-long tubings were used when pumping. The higher pump flow was expected but since the plug-flow volumes for these sections represents less than 100 % formation water to decrease the time for pumping, the extra pumped volumes were only advantageous and no adjusting of the sampling schedule was done.

Generally, sampling was carried out successfully with the exception of one pump stop. In the section where the pump stop occurred, the pumped volume prior to the next sample was measured from the new pump start, but the documented total pumped volume include both pumping periods.

Sample portions intended for analysis of major constituents and trace metals (by ICP technique), DOC, iron (by spectrometry) and nutrient salts were filtered on-line in the field. Disposable 0.4 µm filters were fitted directly to the 8/6 mm polyamide-tube leading the pumped water from the borehole section. During the entire sampling, laboratory gloves were used to minimize the risk of contaminating the samples.

In addition to sampling of groundwater, field measurements of temperature, electrical conductivity (EC) and pH were conducted. The water from the borehole was led through a measurement cell on the ground surface with probes and electrodes as well as a temperature sensor for measurements of field pH (pH\_F), field electrical conductivity (EC\_F) and groundwater temperature. The results are given in Appendix 3.

The pumped water was, where needed, collected in tanks to prevent saline water from affecting the surroundings of the boreholes. The water was then discharged to the Baltic Sea.

The pressure in the borehole sections is continuously monitored by HMS, also during sampling. Pressure diagrams for each borehole and sampling occasion are given in Appendix 4. Possible short-circuiting, indicated by pressure responses in one or more sections other than the sampled ones, can be observed in several boreholes, see Appendix 4. However, observation of pressure propagation does not necessary mean that water is transported between the sections. Information on flow rates, removed volumes and pressure responses are reported in Appendix 2. In the boreholes sampled from the small diameter stand-pipes where gas-lift pumping was used, the pressure transducers had to be lifted and the pressure in the pumped section could not be monitored during pumping.

### 3.4 Water sample treatment and analyses

The constituents included in the different SKB chemistry classes are listed in Table 3-2. Sample treatment (filtration conservation, storage etc.) of samples for internal analyses as well for analyses by consulted laboratories generally follows standard procedures. An overview of sample treatment and analysis routines/methods for major constituents, minor anions, organic carbon, trace metals and isotopes is given in Appendix 5. The routines are applicable independently of sampling method or sampling object.

**Table 3-2. Constituents determined in the different SKB chemistry classes. Constituents in white cells are included in the classes 3 to 5. Constituents in blue cells are determined in the last sample in the sample series from each section (3+, 4+ and 5). Green cells and orange cells contain additional constituents determined in SKB class 4 and 4+ and in classes 4+ and 5, respectively. White, blue, green, orange and grey cells together contain the determinations included in SKB class 5.**

Constituent	Bottle <sup>1)</sup> /Volume	Preparation	Comment
pH_F, EC_F, temperature	–	–	On-line measurement in field.
pH_L, EC_L, alkalinity	500 mL	–	Analysis within 24h.
Uranine	60 mL		Dark bottle.
Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> , Br <sup>-</sup> , F <sup>-</sup>	250 mL	Filtered with 0.4 µm filter	–
Na, K, Ca, Mg, SO <sub>4</sub> -S, Si, Fe, Mn, Li, Sr, Th and U	Acid washed, 125 mL	Filtered with 0.4 µm filter Conserved with 1 mL HNO <sub>3</sub> .	Suprapure acid is used for conservation. U is only included for the last sample in sections KFM02A:3, KFR106:1 and KFR106:2.
Archive	2 × 250 mL	Filtered with 0.4µm filter.	–
Archive	2 × 100 mL	Filtered with 0.4 µm filter Conserved with 1 mL HNO <sub>3</sub> .	Suprapure acid is used for conservation.
Archive	1000 mL	–	
δ <sup>2</sup> H, δ <sup>18</sup> O	100 mL	–	
<sup>3</sup> H	500 mL	Bottle volume exchanged 3 times.	
HS <sup>-</sup>	2 × 120 mL glass Winkler bottles	Conserved with 0.5 mL 1 M ZnAc and 0.5 mL 1 M NaOH in field. Bottle volume exchanged 2 times	Not included in sections where nitrogen lifting is used as pump method i.e. in sections KFR101:1, KFR104:1, KFR106:1 and KFR106:2.
TOC	100 mL		Stored in freezer
DOC	100 mL	Filtered with 0.4 µm filter.	Stored in freezer
Fe (+II), Fe-tot	250 mL plastic Winkler bottles	Filtered with 0.4 µm filter. Conserved with 2.5 mL HCl	Analysis within 20 h. Suprapure acid is used for conservation. Not included in sections where nitrogen lifting is used as pump method i.e. in sections KFR101:1, KFR104:1, KFR106:1 and KFR106:2.
NH <sub>4</sub> -N, NO <sub>2</sub> -N-N+NO <sub>3</sub> and PO <sub>4</sub> -P	250 mL	Filtered with 0.4µm filter	Do not store sample together with bottles containing HNO <sub>3</sub> .
<sup>238</sup> U, <sup>234</sup> U	1000 mL	–	Only included in sections KFM02A:3, KFR106:1 and KFR106:2.

<sup>1)</sup> Plastic bottles are used if nothing else is mentioned.

### 3.5 Nonconformities

The hydrochemical monitoring of deep groundwater has been conducted according to the SKB internal controlling document AP SFK 16-012 with the following nonconformities.

#### Pumping procedures

- Pump stop occurred in one section, KFM02A:3.
- For some sections (e.g. KFM01D:4 and HFM04:2) the pumped volume before the first sample was lower than planned (see Appendix 2) because the pump started with a lower flow than planned (the first flow measurement after pump start took place when the first sample was collected but the flow was probably lower already from start).
- Pump flow in HFM16 was lower than planned during a part of the pumping period. Therefore, pumped volumes are smaller than planned.
- Flow rates are difficult to adjust when gas-lift pumping is used. Therefore, pumped volumes are higher or lower than planned for some of the sections pumped with this kind of pump.

#### Sampling

- KFR105:1 was not available for sampling due to hydraulic injection tests that were performed during the same period as chemistry sampling was performed.

#### Pressure measurements

- No pressure data is available for KFM04A:4 during the pumping period in KFM04A:4 due to corrosion problems.
- Pressure data for KFM06C:4 are not available during the pumping period in KFM06C:3 and KFM06C:5 due to problems with the pressure transducer.

#### Analyses

- No analysis of  $\text{HS}^-$  in first sample from HFM32:3 due to broken sample bottles.
- No analysis of  $\text{PO}_4\text{-P}$  after hydrolysis in sample from HFM04:2 due to mistake at the laboratory.

## 4 Results

### 4.1 Water analysis and measurements

The results from analyses and field measurements are presented in Appendix 3. Table A3-1 includes the major constituents Na, K, Ca, Mg,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{SO}_4\text{-S}$ ,  $\text{Br}^-$ ,  $\text{F}^-$ , Si, Fe, Mn, Li and Sr as well as minor constituents like  $\text{HS}^-$ ,  $\text{NO}_2^- + \text{NO}_3^-$ ,  $\text{NH}_4^+$ ,  $\text{PO}_4^{3-}$ , TOC and DOC from all sampled boreholes. Furthermore, this table contains laboratory data and field measurement data on pH, electrical conductivity (EC) and the water temperature recorded in the field.

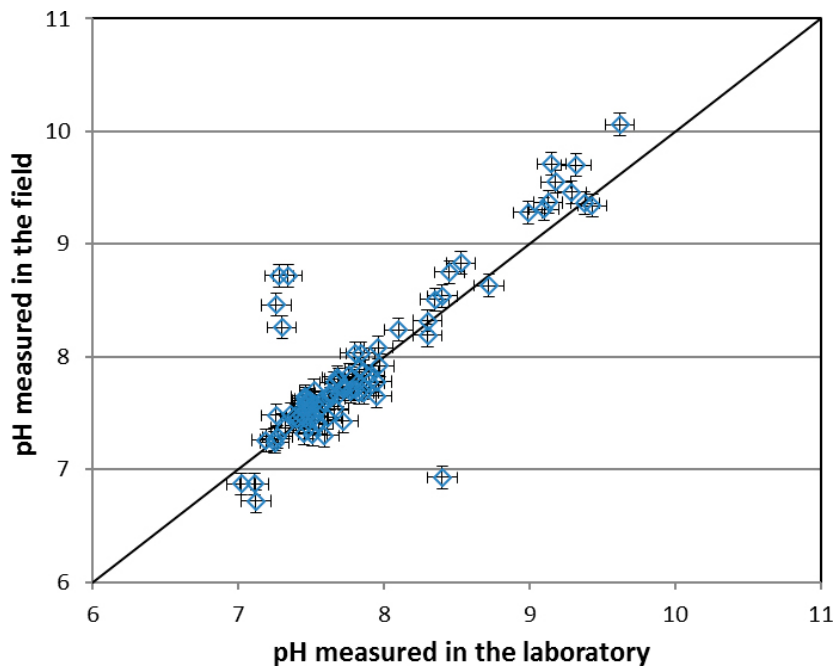
The relative charge imbalance (RCB) provides an indication of the quality and uncertainty of the analyses of major constituents and, the charge balance errors were calculated for all samples. Relative errors within  $\pm 5\%$  are considered acceptable.

$$\text{rel. error}(\%) = 100 \times \frac{\sum \text{cation}(\text{equivalents}) - \sum \text{anion}(\text{equivalents})}{\sum \text{cation}(\text{equivalents}) + \sum \text{anion}(\text{equivalents})}$$

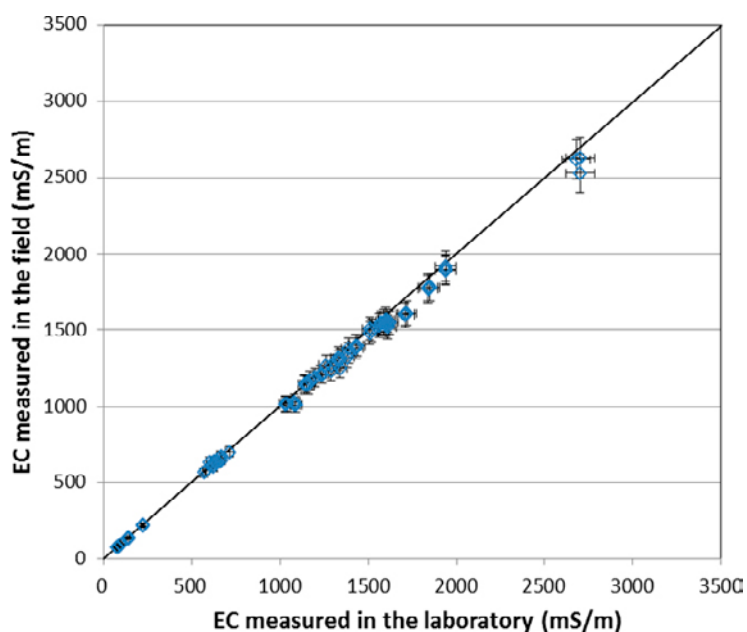
The charge imbalances were all within the acceptable limit of  $\pm 5\%$ .

Trace elements and the isotopes  $\delta^2\text{H}$ ,  $\delta^{18}\text{O}$  and  $^3\text{H}$  (TU) were determined in the last sample in each series (Table A3-4). Furthermore, the uranium and thorium element concentrations and isotopes ( $^{238}\text{U}$ ,  $^{235}\text{U}$ ,  $^{234}\text{U}$ ,  $^{232}\text{Th}$  and  $^{230}\text{Th}$ ) were determined in the last sample from sections KFM02A:3, KFR106:1 and KFR106:2 (Table A3-3 and A3-5).

The laboratory measurements and field measurements of pH and EC from 2016 are compared in Figure 4-1 and Figure 4-2, respectively. The compared pH values deviate more than the measurement uncertainty in several of the samples, which may be due to temperature and pressure differences and/or time delay. The large discrepancy between laboratory and field measurement in the first sample from KFM03A:1 (the data point with low field value and high laboratory value) is probably caused by mistakes during field measurement. The agreement between the different EC values is very good.



**Figure 4-1.** Comparison between laboratory measurements and field measurements of pH. The laboratory measurements are performed at 25 °C and the field measurements are performed at the actual water temperature.



**Figure 4-2.** Comparison between laboratory measurements and field measurements of EC. All values are corrected to the conductivity at 25 °C.

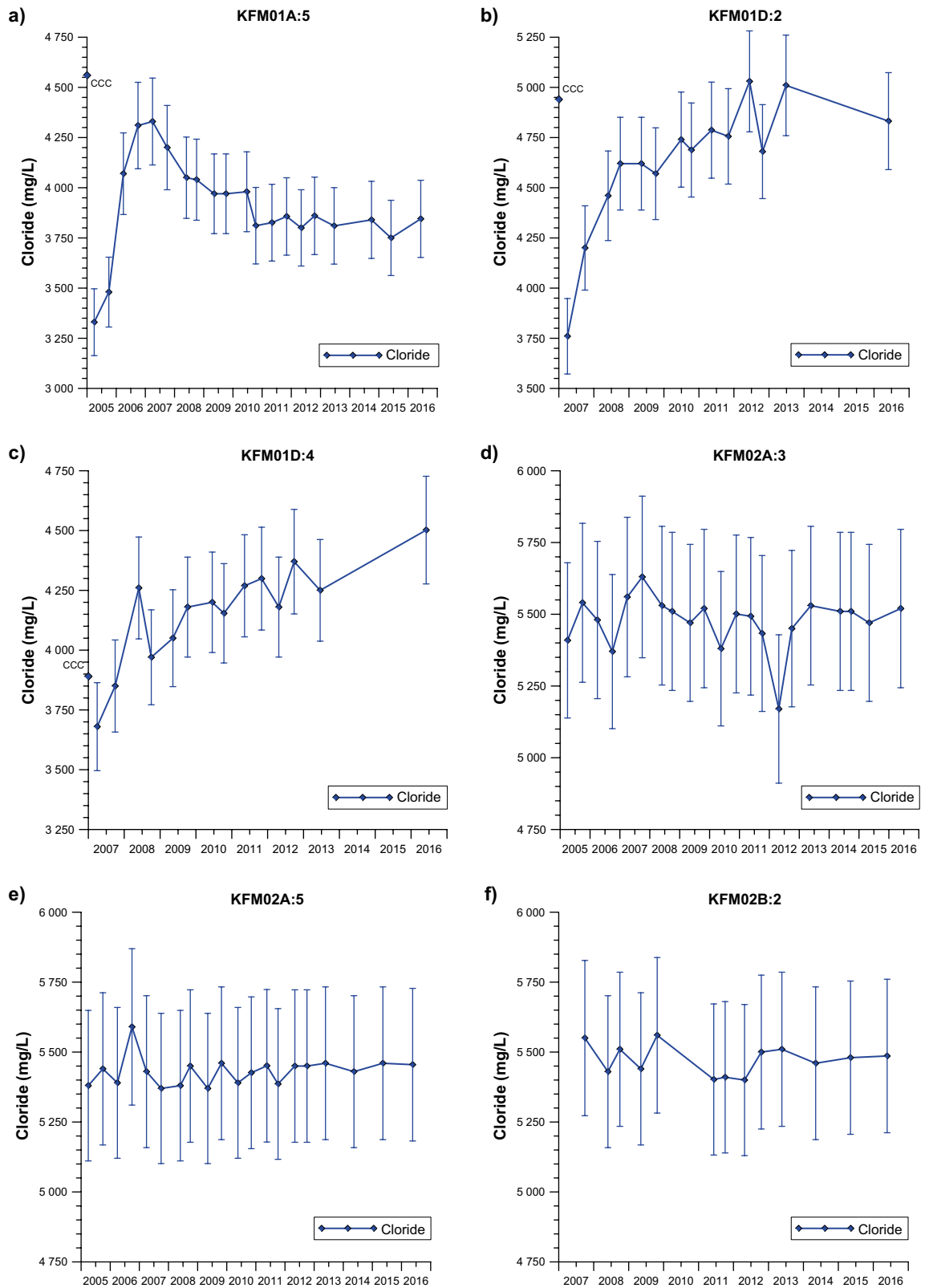
As previously observed in some of the monitored boreholes (see e.g. Ragvald 2016), high pH values are measured also in 2016. Of the eight sections that showed elevated pH values (pH above 8.5) in 2015, only four were sampled in 2016. All those four sections showed elevated pH values also this year, see Appendix 6. In three of those sections (KFM06A:3, KFM06C:3 and KFM11A:2) larger volumes than before were withdrawn before sampling. The extra pumping did not have any large effects on the pH values. Only small or no decrease of the pH values were found after the normal pumped volume, and the pH values in the last samples in the series were even higher than previous years in all three sections. In addition to the eight sections that showed elevated pH values 2015, two new sections showed elevated pH values in 2016; KFM06C:5 and KFM12A:3. Diagrams of pH values during the years in all sections with elevated pH values are presented in Appendix 6. The issue with elevated pH values are discussed in Nilsson and Sandberg (2017).

Possible effects from interference tests and injection tests, mentioned in chapter 1.3, are not evaluated or discussed in this report.

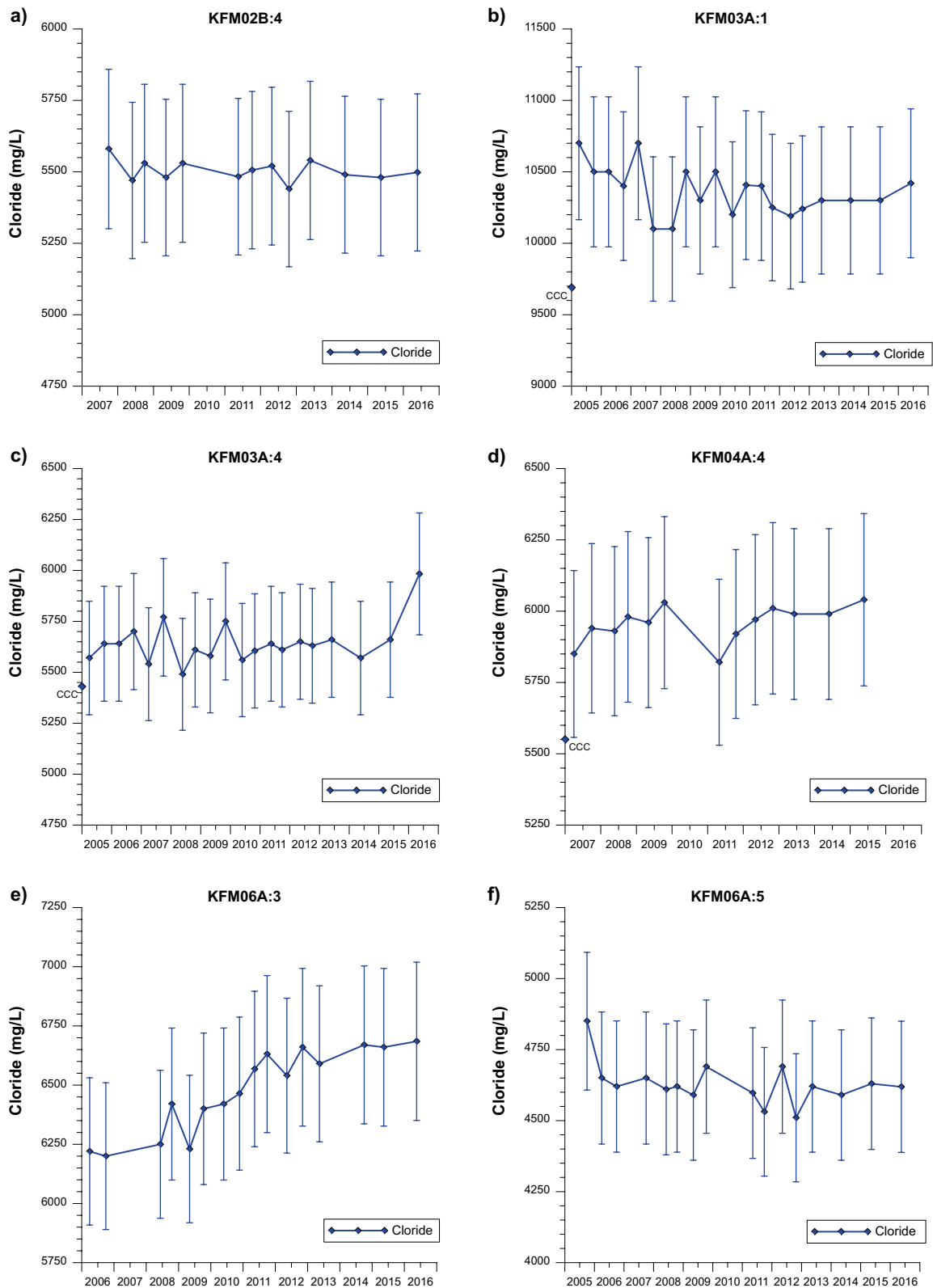
## 4.2 Chloride

Figure 4-3 to Figure 4-9 present chloride concentrations in collected samples from hydrochemical monitoring this year (2016) together with data from hydrochemical monitoring earlier years. The analytical uncertainty ( $\pm 5\%$ ) is shown as error bars in the diagrams. For some of the core drilled boreholes, data from the initial complete chemical characterisation (CCC) in corresponding borehole sections (Lindquist et al. 2012; SKB Database Sicada) are also presented. The CCC data are shown as dots on the y-axes (not corresponding to date on the x-axis). In the cases of sample series (after October 2009 and onwards), the value from the last sample in the series is presented in the diagrams. For boreholes included in the SFR Extension Project, the hydrochemical monitoring program started in 2012, but the diagrams of chloride concentrations (Figure 4-8 and Figure 4-9) also include data from earlier studies.

Within each sample series (increasing plug flow volumes), the chloride concentrations were generally quite stable. The exceptions are KFM03A:1, KFR104:1, and KFR106:1 where the chloride concentrations increase with pumped volumes. In KFR 106:1, the chloride concentration was lower than previous years, and a reason could be that the pumping time was shorter. The pumped volumes agreed with the planned plug flow volumes, but have been larger previous years. Also in KFR104:1 the chloride concentration was lower than previous years and there is a decreasing trend since 2014. As for KFR106:1 this could correlate to pumped volumes since they have also decreased since 2014 (mainly between 2014 and 2015 because the calculation of plug flow volume was changed to allow a somewhat smaller portion of the formation water and gain time).

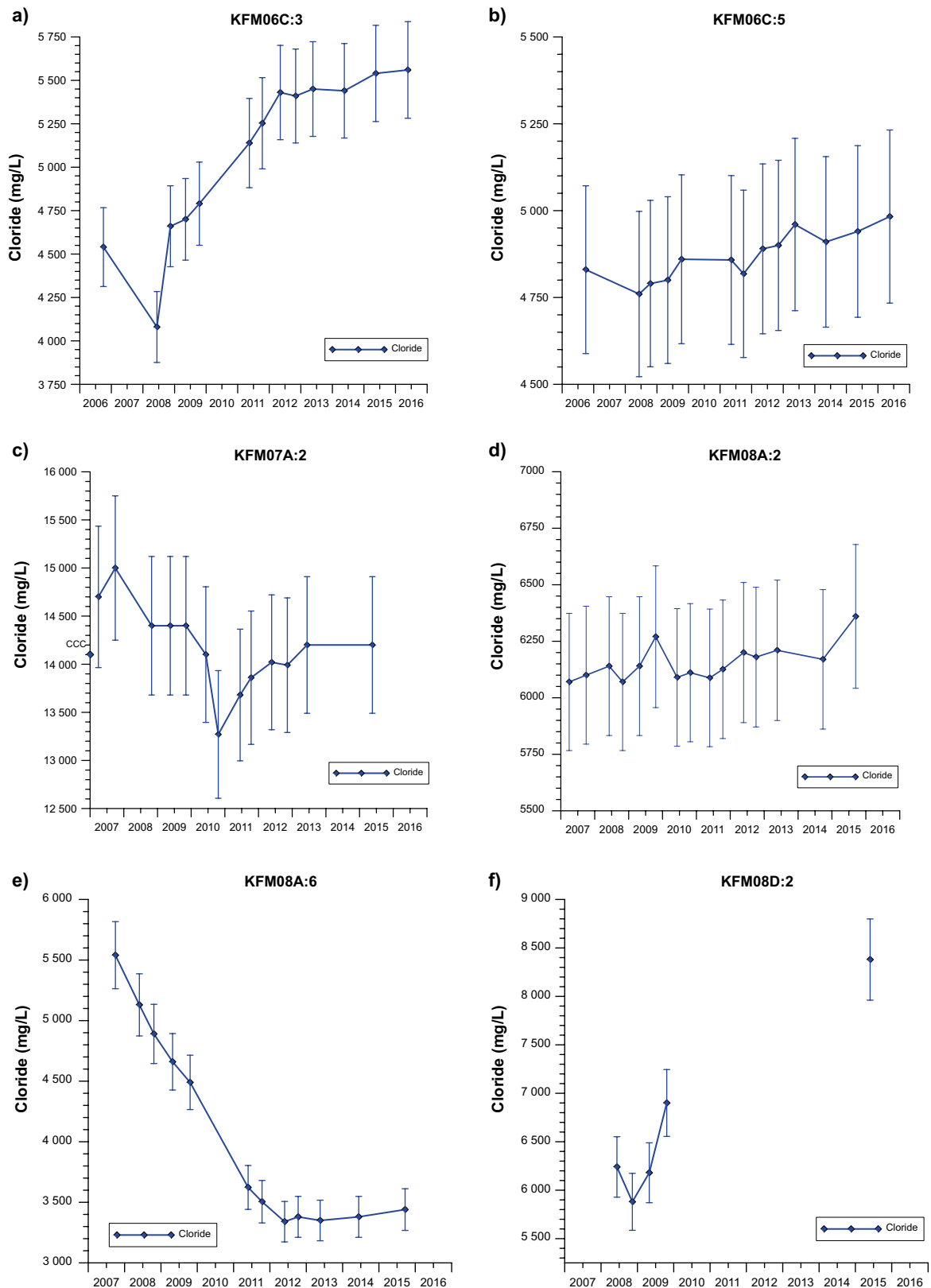


**Figure 4-3.** Chloride concentrations in collected samples from hydrochemical monitoring 2005 to 2016 and from the initial complete chemical characterisation (CCC). The CCC data points are placed on the y-axes with no correlation to date on x-axis. The last sample in the collected sample series starting from 2009 are displayed in the plots.

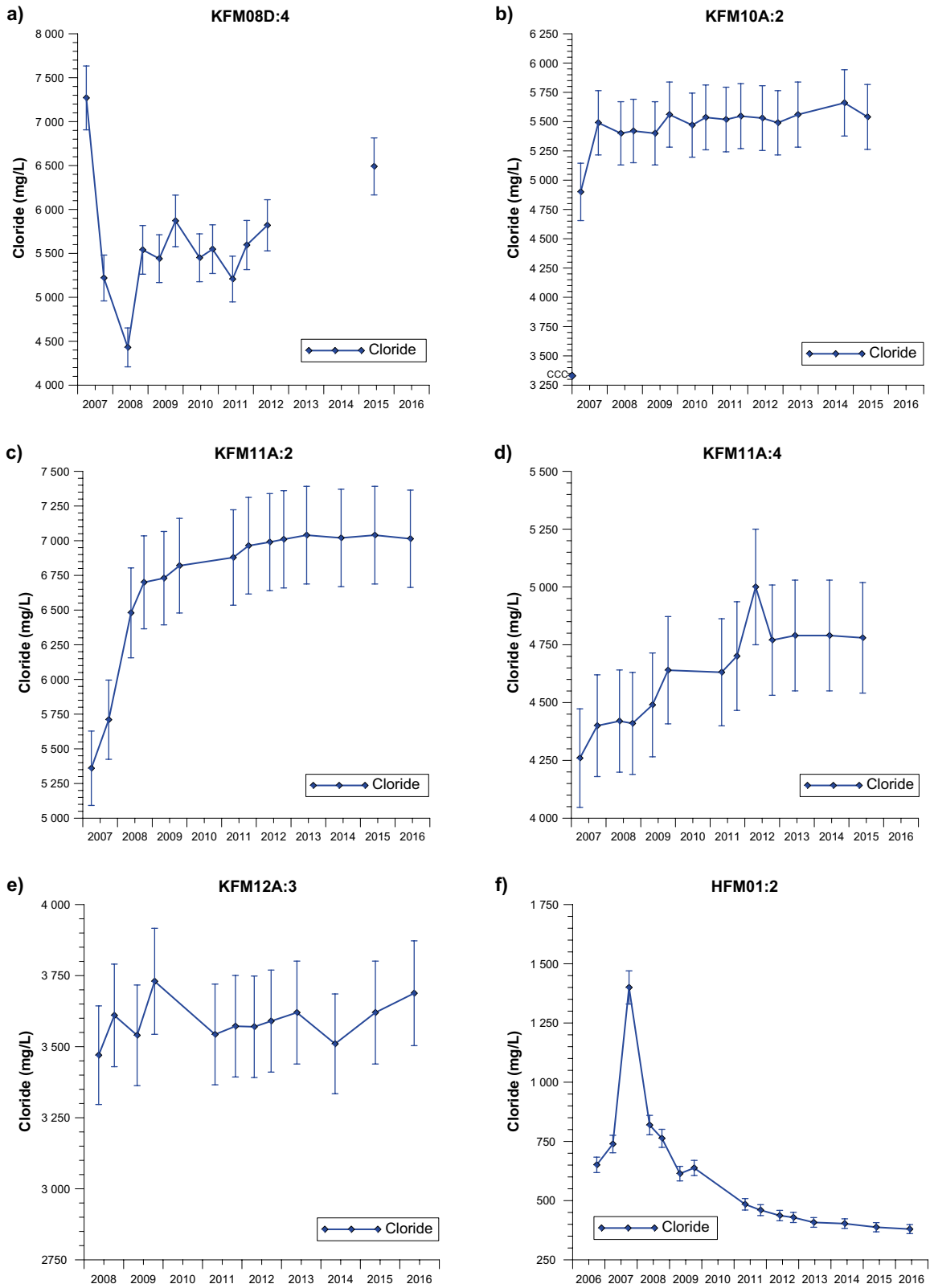


**Figure 4-4.** Chloride concentrations in collected samples from hydrochemical monitoring 2005 to 2016 and from the initial complete chemical characterisation (CCC). The CCC points are placed on the y-axes with no correlation to date on x-axis. The last sample in the collected sample series starting from 2009 are displayed in the plots.

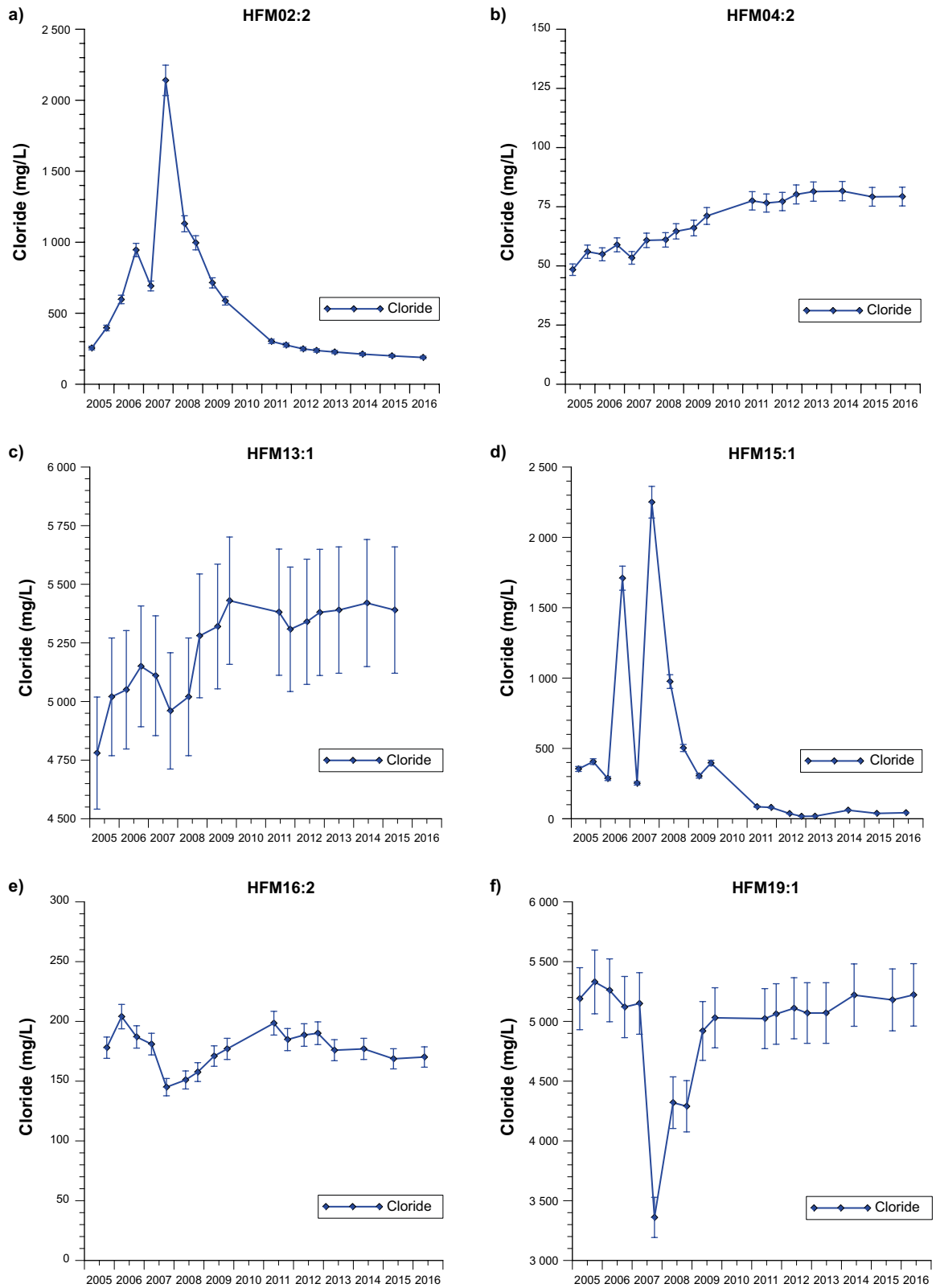




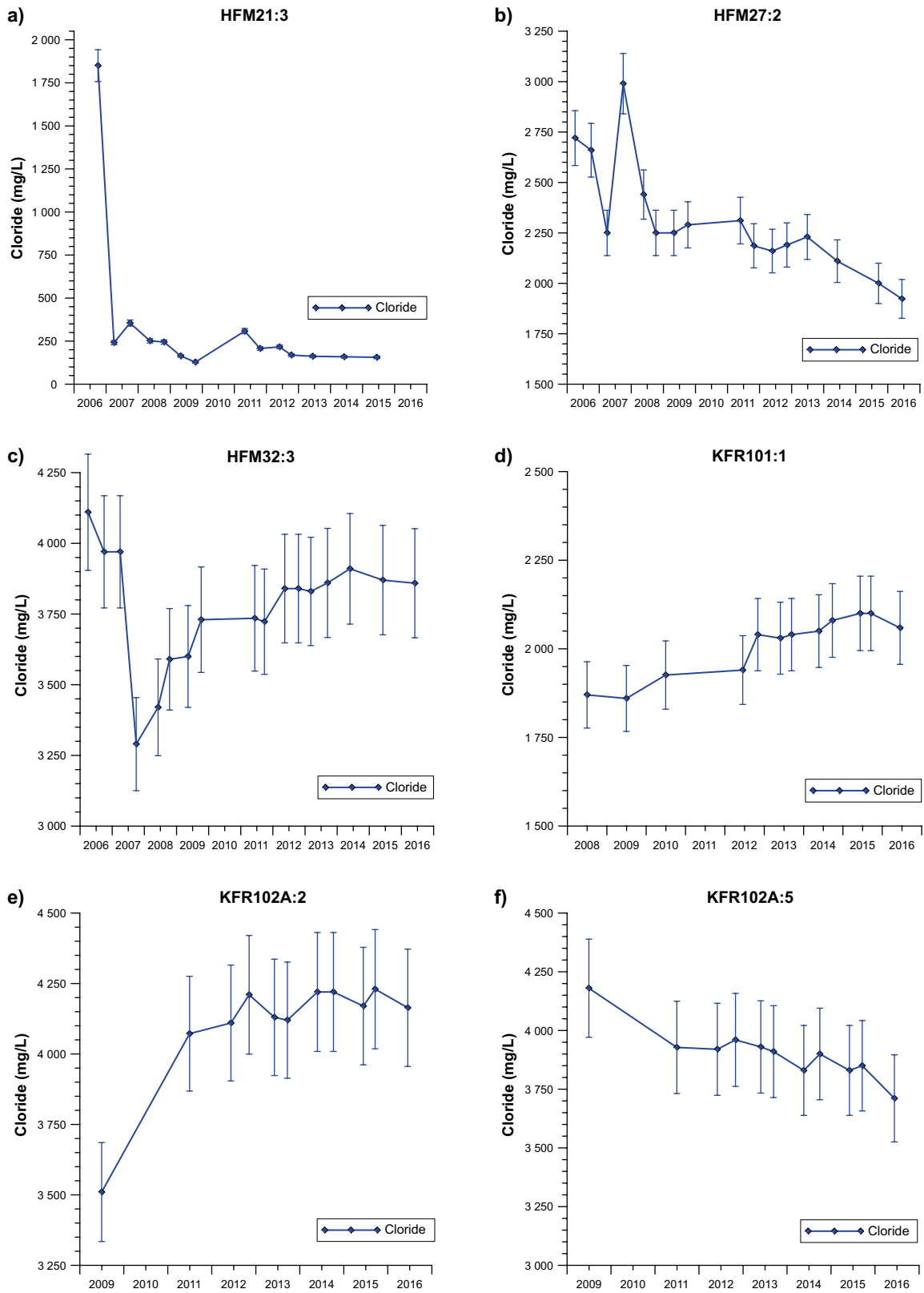
**Figure 4-5.** Chloride concentrations in collected samples from hydrochemical monitoring 2005 to 2016 and from the initial complete chemical characterisation (CCC). The CCC points are placed on the y-axes with no correlation to date on x-axis. The last sample in the collected sample series starting from 2009 are displayed in the plots.



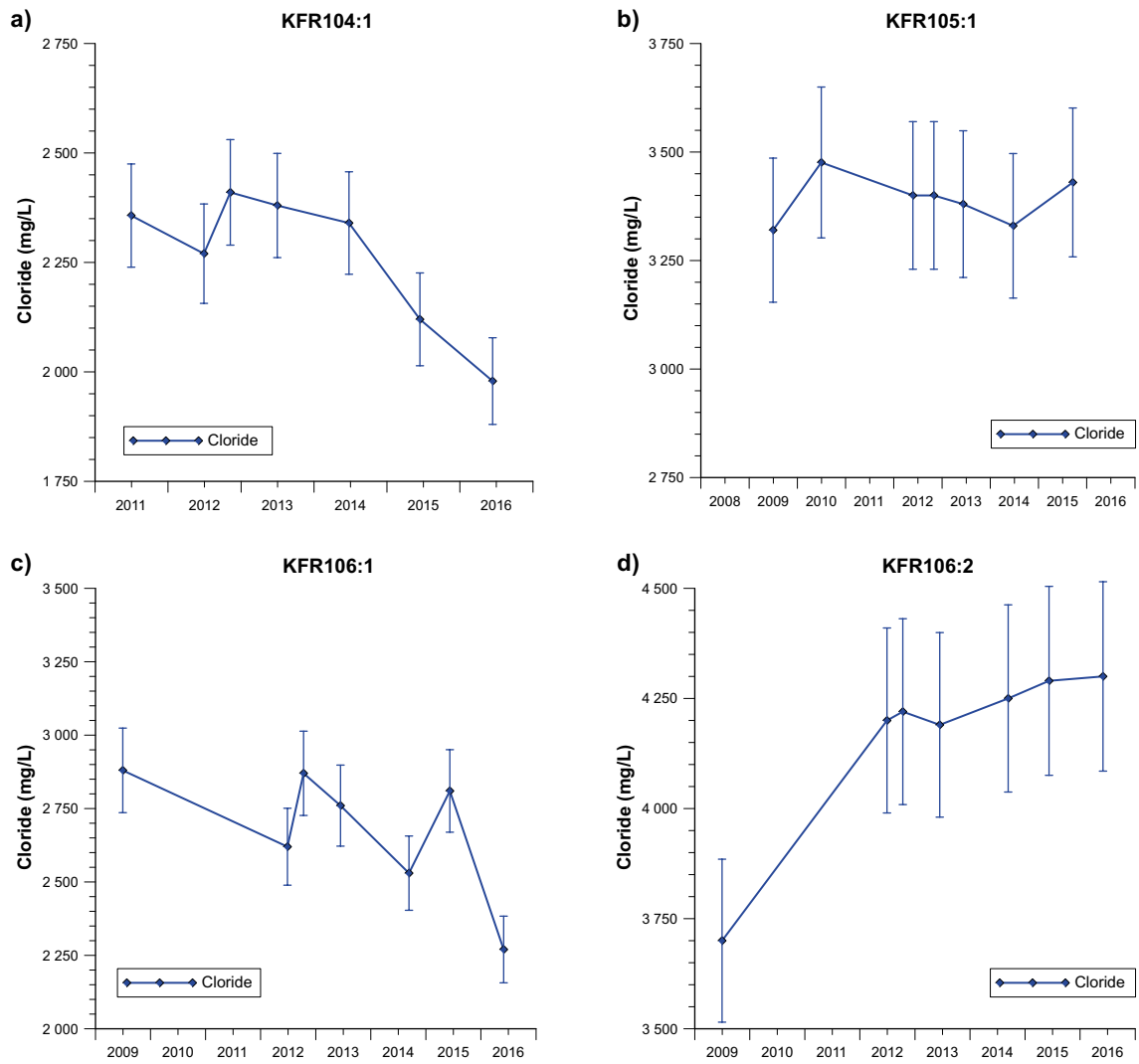
**Figure 4-6.** Chloride concentrations in collected samples from hydrochemical monitoring 2005 to 2016 and from the initial complete chemical characterisation (CCC). The CCC data points are placed on the y-axis with no correlation to date on x-axis. The last sample in the collected sample series starting from 2009 are displayed in the plots.



**Figure 4-7.** Chloride concentrations in collected samples from hydrochemical monitoring 2005 to 2016. The last sample in the collected sample series starting from 2009 are displayed in the plots.



**Figure 4-8.** Chloride concentrations in collected samples from hydrochemical monitoring 2005 to 2016. The last sample in the collected sample series starting from 2009 are displayed in the plots.



**Figure 4-9.** Chloride concentrations in collected samples from hydrochemical monitoring 2005 to 2016. The last sample in the collected sample series starting from 2009 are displayed in the plots.



## 5 Summary and discussions

30 out of 41 borehole sections included in the monitoring program were sampled this year. The excluded sections were omitted due to other ongoing projects, the majority due to the drilling of KFM24. Only one pump stop occurred, in KFM02A:3. Gas evacuation was used in additional sections compared with previous years, which probably helped to avoid more pump stops.

According to chloride concentrations, the groundwater composition in the sampled sections is generally stable and no significant changes occur. In KFR104:1 and KFR 106:1 the chloride concentrations have decreased compared to previous years which could be due to smaller pumped volumes this year compared to previous years.

The samples with elevated pH values due to corrosion (stray currents interaction with the installed equipment in the borehole), naturally also show changes in the chemical composition. With large enough purging prior to sampling, the contribution from influenced section water present in the borehole section decreased as well as the pH, and more representative groundwater samples were obtained. Extra pumping was done this year in three of the sections with elevated pH values, but only small or no decrease of the pH values was detected after the normal pumped volume.





## References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at [www.skb.com/publications](http://www.skb.com/publications). SKBdoc documents will be submitted upon request to [document@skb.se](mailto:document@skb.se).

**Lindquist A, Nilsson A-C, 2013.** Hydrochemical groundwater monitoring. Results from water sampling at the SFR-site, spring and autumn 2012. SKBdoc 1413843 ver 1.0, Svensk Kärnbränslehantering AB.

**Lindquist A, Nilsson K, Jönsson S, 2012.** Hydrochemical monitoring of groundwaters. Results from water sampling in the Forsmark area, spring and autumn 2010. SKBdoc 1334697 ver 1.0, Svensk Kärnbränslehantering AB.

**Nilsson A-C, Sandberg B, 2017.** Elevated pH values in groundwater. Observations from SKB investigations 1976–2014 and possible causes. SKB R-16-04, Svensk Kärnbränslehantering AB.

**Nilsson A-C (ed), Berg C, Harrström J, Jönsson S, Thur P, Borgiel M, Qvarfordt S, 2010.** Forsmark site investigation. Hydrochemical monitoring of groundwaters and surface waters. Results from water sampling in the Forsmark area, January–December 2009. SKB P-10-40, Svensk Kärnbränslehantering AB.

**Ragvald J, 2016.** Hydrochemical groundwater monitoring. Results from water sampling in the Forsmark area 2015. SKBdoc 1542091 ver 1.0, Svensk Kärnbränslehantering AB.

**Sandström B, Nilsson K, Tullborg E-L, 2011.** Site investigation SFR. Fracture mineralogy including identification of uranium phases and hydrochemical characterisation of groundwater in borehole KFR106. SKP P-11-41, Svensk Kärnbränslehantering AB.

**SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.

**SKB, 2005.** Forsmark site investigation. Programme for further investigations of geosphere and biosphere. SKB R-05-14, Svensk Kärnbränslehantering AB.

**SKB, 2007.** Programme for long-term observations of geosphere and biosphere after completed site investigations. SKB R-07-34, Svensk Kärnbränslehantering AB.

**SKB, 2008.** Geovetenskapligt undersökningsprogram för utbyggnad av SFR. SKB R-08-67, Svensk Kärnbränslehantering AB. (In Swedish.)

**Wass E, 2015.** Groundwater flow measurements in permanently installed boreholes, test campaign no. 9, 2013. SKBdoc 1384642 ver 1.0, Svensk Kärnbränslehantering AB.



## Overview of the monitoring programmes 2005–2016

Table A1-1. Overview of the monitoring program in the Forsmark area 2005–2011.

Year	Number of sections included		Sampling programme		Analyses of sulphide (HS <sup>-</sup> )		Analyses of Uranium (U)		Cleaning	Exchange of water prior to sampling		Analytical protocol (general)
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn		Ordinary	Series	
2005	8	10	One sample/section	One sample/section	no	yes	no	yes	no	At least 3 section volumes	–	<b>Spring:</b> Class 3 <b>Autumn:</b> Class 5
2006	15	17	One sample/section	One sample/section	no	yes	no	yes	no	At least 3 section volumes	–	<b>Spring:</b> Class 3 <b>Autumn:</b> Class 5
2007	21	28	One sample/section	Series of 3 samples in 2 sections. One sample/section in the others	no	yes	no	yes	no	At least 3 section volumes	1 tube vol., 1 section vol., 3 section vol.	<b>Spring:</b> Class 3, some class 5 <b>Autumn:</b> Mainly class 5, some class 4
2008	33	33	One sample/section	One sample/section	in class 5	yes	in class 5	in class 5	no	At least 3 section volumes	–	<b>Spring:</b> Class 5 (in 7 sections) and class 3. <b>Autumn:</b> Mainly class 5, some class 4
2009	33	33 (13)	One sample/section	Series of 5 samples in 13 sections. One sample/section in the others	in class 4	All samples in series. Not in single samples.	no	All samples in series. Not in single samples.	Rinse pumping in 13 selected sections. No measure in other sections.	At least 5 section volumes	1 tube vol., 1 section vol., 2, 3, 5 section vol.	<b>Spring:</b> Class 3 and 4 (in 7 sections) <b>Autumn:</b> Class 3 for single samples. For series 4, 4+ and 5+)
2010	12	12	Series of 5 samples in 12 sections.	Series of 3 samples in 12 sections.	in all samples	last sample in each series	All samples.	In last sample in series in 4 sections.	Cleaning <sup>1)</sup> in all 12 sections both spring and autumn.	–	Plug flow vol. spring: (< 1, 2, 3, 4, 5) autumn: (3, 4, 5–6)	<b>Spring:</b> Class 5 <b>Autumn:</b> Class 3 and 4
2011	32 <sup>2)</sup>	32 <sup>2)</sup>	Series of 3 samples from all sections	Series of 3 samples from all sections	in all samples	in all samples	Last sample in series in KFM02A:2 and KFM03A:4.	Last sample in series in KFM02A:2 and KFM03A:4.	Cleaning <sup>1)</sup> in all sections either in spring or in autumn.	–	Plug flow volumes (1.5, 3, 5)	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 4

<sup>1)</sup> High pressure cleaning and rinse pumping.

<sup>2)</sup> KFM08D:2 was omitted.

Table A1-2. Overview of the monitoring program in the Forsmark area 2012–2016.

Year	Number of sections included		Sampling programme		Analyses of sulphide (HS <sup>-</sup> )		Analyses of Uranium (U)		Cleaning	Exchange of water prior to sampling series	Use of docking unit	Analytical protocol (general)
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn				
2012	32 <sup>3)</sup>	31 <sup>4)</sup>	Series of 3 samples from all sections	Series of 3 samples from all sections	in all samples	no	Last sample in series in KFM02A:2 and KFM03A:4.	Last sample in series in KFM02A:2 and KFM03A:4.	Cleaning <sup>1)</sup> in all sections in spring	Plug flow volumes (1.5, 3, 5)	–	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 3
2013	31 <sup>4)</sup>	1	Series of 3 samples from all sampled sections	Series of 3 samples from all sampled sections	in all samples	in all samples	last sample in series in KFM02A:2 and KFM03A:4.	no	Cleaning <sup>1)</sup> in all sections in spring	Plug flow volumes (1.5, 3, 5)	–	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 4
2014	24 <sup>5)</sup>	5	Series of 3 samples from all sampled sections	Series of 3 samples from all sampled sections	in all samples	in all samples	last sample in series in KFM02A:2 and KFM03A:4.	no	Cleaning <sup>1)</sup> in all sections except HFM32:3 either in spring or in autumn.	Plug flow volumes (1.5, 3, 5)	1 section in spring	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 4
2015	27 <sup>6)</sup>	4	Series of 3 samples from all sampled sections	Series of 3 samples from all sampled sections	in all samples	in all samples	last sample in series in KFM02A:2 and KFM03A:4.	no	Cleaning <sup>1)</sup> or cleaning <sup>2)</sup> in all sections except HFM32:3 and KFM08D:2 and 4 either in spring or in autumn.	Plug flow volumes (1.5, 3, 5)	KFM08D:2 and 4 (borehole equipment in PEEK)	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 4
2016	23 <sup>7)</sup>	0	Series of 3 samples from all sampled sections	No sampling performed during autumn	in all samples	–	last sample in series in KFM02A:3.	no	Cleaning <sup>2)</sup> in most sections <sup>8)</sup>	Plug flow volumes (1.5, 3, 5) in all sections except KFM06A:3, KFM06C:3 and KFM11A:2 <sup>9)</sup>	–	<b>Spring:</b> Class 4 <b>Autumn:</b> –

<sup>1)</sup> High pressure cleaning and rinse pumping.

<sup>2)</sup> High pressure cleaning and gas lift pumping (2 gas blows).

<sup>3)</sup> KFM08D:2 was omitted.

<sup>4)</sup> KFM08D:2 and KFM08D:4 were omitted.

<sup>5)</sup> KFM01D:2, KFM01D:4, KFM07A:2, KFM08D:2 and KFM08D:4 were omitted this year.

<sup>6)</sup> KFM01D:2 and KFM01D:4 were omitted.

<sup>7)</sup> KFM03A:4, KFM07A:2, KFM08A:6, KFM08A:2, KFM08D:4, KFM08D:2, KFM10A:2, KFM11A:4, HFM13:1 and HFM21:3 were omitted.

<sup>8)</sup> No cleaning in KFM03A:1, KFM11A:2, HFM01:2 and HFM32:3 due to various reasons.

<sup>9)</sup> Due to high pH values during earlier years, the plug flow volumes were increased during 2016.

**Table A1-3. Overview of the monitoring program at the SFR-site 2012–2016.**

Year	Number of sections included		Sampling programme		Analyses of sulphide (HS <sup>-</sup> )		Analyses of Uranium (U)		Cleaning	Exchange of water prior to sampling series	Analytical protocol (general)
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn			
2012	7	7	Series of 3 samples from all sections	Series of 3 samples from all sections	in KFR102A (2 sect.)	no	last sample in series in KFR106:1 and KFR106:2	last sample in series in KFR106:1 and KFR106:2	Cleaning <sup>1)</sup> in all sections in spring.	Plug flow volumes (1.5, 3, 5)	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 3
2013	7	3	Series of 3 samples from sampled sections	Series of 3 samples from sampled sections	in KFR102A (2 sect.) and KFR105	no	last sample in series in KFR106:1 and KFR106:2	no	Cleaning <sup>1)</sup> in all sections in spring.	Plug flow volumes (1.5, 3, 5)	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 3
2014	5	5	Series of 3 samples from sampled sections	Series of 3 samples from sampled sections	in KFR102A (2 sect.) and KFR105	no	no	last sample in series in KFR106:1 and KFR106:2	Cleaning <sup>1)</sup> in all sections in spring.	Plug flow volumes (1.5, 3, 5)	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 3
2015	6	4	Series of 3 samples from sampled sections	Series of 3 samples from sampled sections	in KFR102A (2 sect.)	KFR105	last sample in series in KFR106:1 and KFR106:2	no	Cleaning <sup>2)</sup> in all sections except KFR105 in spring.	Plug flow volumes (1.5, 3, 5)	<b>Spring:</b> Class 4 <b>Autumn:</b> Class 3
2016	7 <sup>3)</sup>	0	Series of 3 samples from sampled sections	No sampling performed during autumn	in KFR102A (2 sect.) and KFR01	–	last sample in series in KFR106:1 and KFR106:2	–	Cleaning <sup>2)</sup> in section KFR102A:5 and KFR102A:2	Plug flow volumes (1.5, 3, 5)	<b>Spring:</b> Class 4 <b>Autumn:</b> –

<sup>1)</sup> High pressure cleaning and rinse pumping.

<sup>2)</sup> High pressure cleaning and gas lift pumping (2 gas blows).

<sup>3)</sup> KFR01:1 was added to the monitoring program. KRF105:1 was not available during the sampling period due to hydraulic injection test.



## Sampling information

Table A2-1. Sampling information.

Idcode: section	Tube volume	Section volume	Length of pumping period	Medium flow rate <sup>1)</sup>	Planned removed volume <sup>2)</sup>	Pumped volume <sup>3)</sup>	Sampling date	Sample no.	Responses observed in other sections in the borehole (if yes, se Appendix 3) /Comments
	[L]	[L]		[mL/min]	[L]	[L]			
KFM01A:5	1.4	18	1 day 15 h 45 min	193	140	461	–	–	Yes
					279	139	2016-06-07	30843	
					465	375	2016-06-08	30844	
KFM01D:2	3.3	24.5	1 day 6 h 23 min	80	24	145	–	–	Yes
					48	22	2016-05-30	30828	
					80	44	2016-05-30	30829	
KFM01D:4	9	12.3	0 days 7 h 6 min	227	97	97	–	–	Yes
					27	16	2016-06-03	30840	
					54	42	2016-06-03	30841	
KFM02A:3	14.1	33.4	6 days 11 h 20 min	119	63	382	–	–	No One pump stop occurred between the first and second sample in the series
					126	62	2016-05-19	30800	
					210	209	2016-05-25	30801	
KFM02A:5	11.9	31.8	3 days 5 h 30 min	223	910	1035	–	–	No
					273	338	2016-05-18	30797	
					546	643	2016-05-19	30794	
KFM02B:2	12.8	15	1 day 5 h 45 min	331	90	591	–	–	No
					180	112	2016-05-24	30806	
					300	200	2016-05-24	30807	
						575	2016-05-25	30808	

<sup>1)</sup> The pumping period may contain pump stops. Medium flow rate and pumped volume is calculated from periods of actual pumping.

<sup>2)</sup> The first sample is planned to be collected after 1.5 plug flow, the second after 3 and third and last sample in each series after 5 plug flow volumes.

<sup>3)</sup> Pump stop has occurred causing restart of pumping during the pumping period for some sections. Volume written by each sample number represent volume pumped since restart in those cases, but total pumped volume include all pumping.

Table A2-1. Sampling information, continued.

Idcode: section	Tube volume	Section volume	Length of pumping period	Medium flow rate <sup>1)</sup>	Planned removed volume <sup>2)</sup>	Pumped volume <sup>3)</sup>	Sampling date	Sample no.	Responses observed in other sections in the borehole (if yes, see Appendix 3) /Comments
	[L]	[L]		[mL/min]	[L]	[L]			
KFM02B:4	10.5	21	1 day 8 h 57 min	485		959	–	–	No
					287	295	2016-05-23	30803	
					573	814	2016-05-24	30804	
					955	936	2016-05-24	30805	
KFM03A:1	27.7	31.5	5 days 0 h 6 min	57		410	–	–	Yes
					119	139	2016-05-30	30825	
					237	229	2016-05-31	30826	
					395	407	2016-06-02	30827	
KFM04A:4	6.8	18.7	0 days 8 h 12 min	210		103	–	–	No
					24	33	2016-05-13	30779	
					48	53	2016-05-13	30780	
					80	96	2016-05-13	30781	
KFM06A:3	21.1	13.6	2 days 22 h 36 min	48		204	–	–	Yes
					84 <sup>4)</sup>	93	2016-05-17	30789	
					140 <sup>4)</sup>	140	2016-05-18	30798	
					196 <sup>4)</sup>	201	2016-05-19	30799	
KFM06A:5	9.9	22.4	1 day 7 h 6 min	146		272	–	–	Yes
					39	40	2016-05-16	30785	
					78	76	2016-05-16	30786	
					130	265	2016-05-17	30787	
KFM06C:3	18.5	23.5	10 days 22 h 14 min	19		302	–	–	Yes
					115 <sup>4)</sup>	111	2016-05-16	30791	
					215 <sup>4)</sup>	223	2016-05-20	30792	
					315 <sup>4)</sup>	301	2016-05-23	30793	

<sup>1)</sup> The pumping period may contain pump stops. Medium flow rate and pumped volume is calculated from periods of actual pumping.

<sup>2)</sup> The first sample is planned to be collected after 1.5 plug flow, the second after 3 and third and last sample in each series after 5 plug flow volumes.

<sup>3)</sup> Pump stop has occurred causing restart of pumping during the pumping period for some sections. Volume written by each sample number represent volume pumped since restart in those cases, but total pumped volume include all pumping.

<sup>4)</sup> The planned volumes are higher than the normal plug flow volumes due to high pH values, see table table A2-2.



**Table A2-1. Sampling information, continued.**

Idcode: Section	Tube volume	Section volume	Length of pumping period	Medium flow rate <sup>1)</sup>	Planned removed volume <sup>2)</sup>	Pumped volume <sup>3)</sup>	Sampling date	Sample no.	Responses observed in other sections in the borehole (if yes, se Appendix 3) /Comments
	[L]	[L]		[mL/min]	[L]	[L]			
KFM06C:5	15.3	11.1	1 day 6 h 49 min	134		247	–	–	Yes
					42	45	2016-05-16	30782	
					83	83	2016-05-16	30783	
				139	231	2016-05-17	30784		
KFM11A:2	19.8	25.2	2 days 8 h 41 min	190		646	–	–	No
					300 <sup>4)</sup>	312	2016-06-09	30874	
					450 <sup>4)</sup>	581	2016-06-10	30875	
				600 <sup>4)</sup>	637	2016-06-10	30876		
KFM12A:3	7.9	13.6	0 days 8 h 16 min	249		123	–	–	No, but one section with non-functioning pressure measurements
					35	46	2016-05-13	30776	
					69	68	2016-05-13	30777	
				115	116	2016-05-13	30778		
HFM01:2	1.5	36.5	4 days 5 h 10 min	287		1739	–	–	Yes
					459	463	2016-06-07	30846	
					918	913	2016-06-08	30847	
				1530	1728	2016-06-10	30848		
HFM02:2	1.6	31.3	2 days 20 h 52 min	277		1 145	–	–	No
					357	338	2016-06-13	30877	
					714	680	2016-06-14	30878	
				1 190	1 134	2016-06-15	30879		
HFM04:2	2.2	26.1	1 day 5 h 40 min	301		536	–	–	No
					155	123	2016-05-24	30809	
					309	443	2016-05-25	30810	
				515	521	2016-05-25	30811		

<sup>1)</sup> The pumping period may contain pump stops. Medium flow rate and pumped volume is calculated from periods of actual pumping.

<sup>2)</sup> The first sample is planned to be collected after 1.5 plug flow, the second after 3 and third and last sample in each series after 5 plug flow volumes.

<sup>3)</sup> Pump stop has occurred causing restart of pumping during the pumping period for some sections. Volume written by each sample number represent volume pumped since restart in those cases, but total pumped volume include all pumping.

<sup>4)</sup> The planned volumes are higher than the normal plug flow volumes due to high pH values, see table A2-2.

Table A2-1. Sampling information, continued.

Idcode: section	Tube volume	Section volume	Length of pumping period	Medium flow rate <sup>1)</sup>	Planned removed volume <sup>2)</sup>	Pumped volume <sup>3)</sup>	Sampling date	Sample no.	Responses observed in other sections in the borehole (if yes, se Appendix 3) /Comments
	[L]	[L]		[mL/min]	[L]	[L]			
HFM15:1	2.9	31.8	2 days 3 h 43 min	201		624	–	–	No
					174	301	2016-06-02	30837	
					348	355	2016-06-02	30838	
					580	615	2016-06-03	30839	
HFM16:2	2	39	2 days 23 h 11 min	894		3820	–	–	No
					1260	1292	2016-05-17	30788	
					2520	2091	2016-05-18	30795	
					4200	3791	2016-05-19	30796	
HFM19:1	3.9	42.3	2 days 11 h 29 min	329		1 174	–	–	No
					305	309	2016-05-30	30831	
					609	683	2016-05-31	30832	
					1015	1 162	2016-06-01	30833	
HFM27:2	2	36.5	4 days 2 h 26 min	224		1 321	–	–	No
					333	403	2016-06-07	30849	
					666	713	2016-06-08	30850	
					1 110	1 313	2016-06-10	30851	
HFM32:3	1.4	18	0 days 7 h 56 min	371		177	–	–	No
					44	49	2016-06-01	30834	
					87	92	2016-06-01	30835	
					145	161	2016-06-01	30836	
KFR101:1	3.51	80.1	1 day 10 h 44 min	167		348	–	–	No
					110 <sup>5)</sup>	89	2016-06-13	30883	
					219 <sup>5)</sup>	285	2016-06-14	30884	
					365 <sup>5)</sup>	340	2016-06-14	30885	

<sup>1)</sup> The pumping period may contain pump stops. Medium flow rate and pumped volume is calculated from periods of actual pumping.

<sup>2)</sup> The first sample is planned to be collected after 1.5 plug flow, the second after 3 and third and last sample in each series after 5 plug flow volumes.

<sup>3)</sup> Pump stop has occurred causing restart of pumping during the pumping period for some sections. Volume written by each sample number represent volume pumped since restart in those cases, but total pumped volume include all pumping.

<sup>5)</sup> Plug flow volume representing < 100 % formation water, see table A2-3.

**Table A2-1. Sampling information, continued.**

<b>Idcode: section</b>	<b>Tube volume</b> [L]	<b>Section volume</b> [L]	<b>Length of pumping period</b>	<b>Medium flow rate<sup>1)</sup></b> [mL/min]	<b>Planned removed volume<sup>2)</sup></b> [L]	<b>Pumped volume<sup>3)</sup></b> [L]	<b>Sampling date</b>	<b>Sample no.</b>	<b>Responses observed in other sections in the borehole (if yes, se Appendix 3) /Comments</b>
KFR102A:2	12	25.6	2 days 11 h 20 min	308		1096	–	–	Yes
					291 <sup>5)</sup>	296	2016-06-13	30880	
					582 <sup>5)</sup>	648	2016-06-14	30881	
					970 <sup>5)</sup>	1084	2016-06-15	30882	
KFR102A:5	6.05	7.97	1 day 8 h 19 min	209		406	–	–	No
					78	83	2016-06-09	30855	
					156	161	2016-06-09	30856	
					260	395	2016-06-10	30857	
KFR104:1	9.42	199	7 days 0 h 20 min	42		420	–	–	Maybe
					90 <sup>5)</sup>	122	2016-06-08	30852	
					180 <sup>5)</sup>	240	2016-06-10	30853	
					300 <sup>5)</sup>	416	2016-06-13	30854	
KFR106:1	7.35	174	0 days 10 h 23 min	128		80	–	–	No
					24	28	2016-05-31	30819	
					48	46	2016-05-31	30820	
					80	74	2016-05-31	30821	
KFR106:2	4.04	490	1 day 9 h 55 min	158		322	–	–	No
					83 <sup>5)</sup>	92	2016-05-31	30822	
					165 <sup>5)</sup>	265	2016-06-01	30823	
					275 <sup>5)</sup>	315	2016-06-01	30824	

<sup>1)</sup> The pumping period may contain pump stops. Medium flow rate and pumped volume is calculated from periods of actual pumping.

<sup>2)</sup> The first sample is planned to be collected after 1.5 plug flow, the second after 3 and third and last sample in each series after 5 plug flow volumes.

<sup>3)</sup> Pump stop has occurred causing restart of pumping during the pumping period for some sections. Volume written by each sample number represent volume pumped since restart in those cases, but total pumped volume include all pumping.

<sup>5)</sup> Plug flow volume representing < 100 % formation water, see table A2-3.

**Table A2-2. Sections with larger planned pumped volumes than previous years due to high pH values.**

<b>Idcode: Section</b>	<b>Used plug flow volumes 2015</b>	<b>Used plug flow volumes 2016</b>
KFM06A:3	1.5, 3 and 5 plug flow volumes	3, 5 and 7 plug flow volumes
KFM06C:3	60 L, 115 L and 215 L	115 L, 215 L and 315 L
KFM11A:2	70 L, 125 L and 300 L	300 L, 450 L and 600 L

**Table A2-3. Plug flow volumes special.**

<b>Idcode: section</b>	<b>Used plug flow volume [L]</b>	<b>Percent formation water [%]</b>	<b>Volume needed for 100 % formation water [L]</b>
KFR101:1	73	99	17 881
KFR102A:2	194	99.9	986
KFR104:1	60	83	491
KFR106:2	55	89.4	1 450

## Water composition

Table A3-1. Water Composition.

Id code	Secup m	Seclow m	Sample no.	Sampling date	RCB %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> <sup>-</sup> mg/L	Cl <sup>-</sup> mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	SO <sub>4</sub> -S mg/L	Br <sup>-</sup> mg/L	F <sup>-</sup> mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fell mg/L	Mn mg/L	Li mg/L	Sr mg/L
HFM01	33.5	45.5	30846	2016-06-07	-0.4	401	13.0	47.8	14.3	463	363	163	57.1	1.54	2.36	5.71	0.291	-	-	0.0789	0.0133	0.274
HFM01	33.5	45.5	30847	2016-06-08	-0.7	405	13.1	48.4	14.4	458	377	169	57.3	1.52	2.36	5.74	0.303	-	-	0.0792	0.0134	0.276
HFM01	33.5	45.5	30848	2016-06-10	-1.7	397	13.0	47.5	14.1	459	380	169	56.1	1.52	2.35	5.60	0.305	0.31	0.30	0.0772	0.0131	0.272
HFM02	38.0	48.0	30877	2016-06-13	1.5	263	10.9	36.6	10.8	441	191	62.1	20.6	0.83	2.12	6.16	0.233	-	-	0.0691	0.0112	0.226
HFM02	38.0	48.0	30878	2016-06-14	1.8	262	11.0	37.3	11.0	440	189	60.8	20.5	0.82	2.05	6.22	0.253	-	-	0.0712	0.0111	0.231
HFM02	38.0	48.0	30879	2016-06-15	1.1	258	10.9	36.4	10.8	442	188	60.2	20.0	0.83	2.05	6.21	0.252	0.25	0.24	0.0705	0.0112	0.225
HFM04	57.9	65.9	30809	2016-05-24	1.7	175	6.94	35.5	8.25	409	80.7	41.4	13.5	0.35	1.76	6.44	0.363	-	-	0.0911	0.0105	0.260
HFM04	57.9	65.9	30810	2016-05-25	1.8	175	7.02	34.5	8.19	409	77.7	41.1	13.6	0.34	1.78	6.54	0.354	-	-	0.0890	0.0102	0.246
HFM04	57.9	65.9	30811	2016-05-25	1.6	175	6.92	34.0	8.19	407	79.3	41.4	13.6	0.34	1.79	6.50	0.351	0.35	0.35	0.0882	0.0097	0.236
HFM15	85.0	95.0	30837	2016-06-02	1.4	92.2	6.90	74.9	9.43	408	45.5	21.3	7.21	0.21	0.83	7.35	1.41	-	-	0.259	0.0060	0.306
HFM15	85.0	95.0	30838	2016-06-02	0.6	88.0	6.82	74.6	9.30	408	44.1	21.2	7.01	0.21	0.83	7.35	1.43	-	-	0.258	0.0060	0.304
HFM15	85.0	95.0	30839	2016-06-03	0.7	87.0	6.81	74.2	9.25	408	42.7	21.1	6.97	0.20	0.83	7.35	1.46	1.41	1.38	0.256	0.0057	0.302
HFM16	54.0	67.0	30788	2016-05-17	0.9	277	6.52	29.8	7.09	459	174	70.6	23.8	0.69	2.31	5.82	0.339	-	-	0.0664	0.0114	0.248
HFM16	54.0	67.0	30795	2016-05-18	0.3	278	6.45	30.2	7.02	456	179	79.4	25.6	0.73	2.36	5.87	0.383	-	-	0.0711	0.0112	0.247
HFM16	54.0	67.0	30796	2016-05-19	1.6	281	6.49	29.9	7.02	458	170	78.8	25.5	0.67	2.37	5.91	0.311	0.35	0.34	0.0676	0.0113	0.247
HFM19	168.0	182.0	30831	2016-05-30	-0.2	2040	48.3	980	231	122	5170	499	169	19.2	1.15	5.69	4.38	-	-	1.73	0.0611	7.36
HFM19	168.0	182.0	30832	2016-05-31	0.1	2040	48.3	983	231	124	5140	490	170	18.8	1.16	5.75	4.64	-	-	1.77	0.0618	7.36
HFM19	168.0	182.0	30833	2016-06-01	-0.8	2030	48.3	980	230	127	5220	495	169	18.9	1.18	5.81	4.84	4.79	4.74	1.80	0.0612	7.29
HFM27	46.0	58.0	30849	2016-06-07	0.5	965	32.0	320	88.7	296	1940	261	92.5	6.9	1.51	6.05	1.95	-	-	0.556	0.0333	1.95
HFM27	46.0	58.0	30850	2016-06-08	0.8	976	32.5	325	89.6	300	1950	265	94.4	7.00	1.46	6.09	1.99	-	-	0.566	0.0339	1.98
HFM27	46.0	58.0	30851	2016-06-10	0.8	961	32.3	323	88.1	298	1920	266	92.5	7.02	1.49	6.02	1.96	1.87	1.95	0.553	0.0331	1.94
HFM32	26.0	31.0	30834	2016-06-01	0.3	1900	62.5	468	161	196	3870	366	123	13.7	1.25	5.17	4.19	-	-	0.818	0.0621	2.98
HFM32	26.0	31.0	30835	2016-06-01	-0.1	1880	62.5	467	160	196	3860	368	125	13.8	1.25	5.15	4.20	-	-	0.819	0.0615	2.97
HFM32	26.0	31.0	30836	2016-06-01	0.9	1930	63.0	461	160	194	3860	367	122	14.1	1.29	5.14	4.16	3.98	4.05	0.817	0.0613	2.96
KFM01A	109.0	130.0	30843	2016-06-07	1.6	1700	19.1	742	108	67.7	3910	236	84.7	16.0	1.35	7.95	0.208	-	-	0.515	0.0416	5.67
KFM01A	109.0	130.0	30844	2016-06-08	1.8	1680	18.7	725	106	70.1	3830	235	82.3	15.6	1.36	8.24	0.332	-	-	0.540	0.0408	5.52
KFM01A	109.0	130.0	30845	2016-06-08	1.9	1690	19.2	734	105	70.4	3850	232	82.8	15.5	1.37	8.25	0.353	0.36	0.36	0.541	0.0412	5.58

RCB % = Rel. charge balance error %

- = Not analysed

&lt; "value" = value below reporting limit.

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Table A3-1. Water composition, continued.

Id code	Secup m	Seclow m	Sample no.	Sampling date	RCB %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> <sup>-</sup> mg/L	Cl <sup>-</sup> mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	SO <sub>4</sub> -S mg/L	Br <sup>-</sup> mg/L	F <sup>-</sup> mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fell mg/L	Mn mg/L	Li mg/L	Sr mg/L
KFM01D	311.0	321.0	30840	2016-06-03	2.3	1850	19.3	1030	98.6	79.4	4470	315	108	18.8	1.41	10.5	0.464	-	-	0.489	0.0457	9.33
KFM01D	311.0	321.0	30841	2016-06-03	2.2	1850	19.0	1050	95.0	85.6	4500	317	107	19.3	1.43	10.1	0.162	-	-	0.477	0.0450	9.53
KFM01D	311.0	321.0	30842	2016-06-03	1.1	1820	19.4	1000	94.1	73.7	4500	291	99.2	19.2	1.33	10.8	0.648	0.66	0.66	0.450	0.0449	9.14
KFM01D	429.0	438.0	30828	2016-05-30	1.0	1920	24.9	1020	110	105	4790	216	69.4	24.4	1.25	9.80	< 0.1	-	-	0.433	0.0425	8.74
KFM01D	429.0	438.0	30829	2016-05-30	1.3	1910	23.6	1050	104	93.2	4780	211	70.2	24.2	1.20	10.0	< 0.1	-	-	0.403	0.0416	9.22
KFM01D	429.0	438.0	30830	2016-05-31	2.2	1880	19.1	1180	77.0	69.9	4830	175	55.3	26.9	1.16	9.96	0.020	0.02	0.03	0.286	0.0388	11.2
KFM02A	411.0	442.0	30797	2016-05-18	1.1	2040	22.2	1220	198	93.0	5410	423	140	21.9	1.33	6.94	0.762	-	-	1.74	0.738	11.6
KFM02A	411.0	442.0	30794	2016-05-19	1.3	2070	22.2	1220	198	94.2	5430	420	140	21.6	1.33	7.03	0.770	-	-	1.78	0.695	11.6
KFM02A	411.0	442.0	30790	2016-05-20	1.8	2110	22.4	1230	200	94.0	5460	415	142	21.5	1.34	7.14	0.755	0.77	0.76	1.79	0.640	11.6
KFM02A	490.0	518.0	30800	2016-05-19	-0.1	2230	39.6	974	233	109	5460	487	163	19.9	1.44	6.60	0.678	-	-	1.62	0.0451	8.08
KFM02A	490.0	518.0	30801	2016-05-25	-0.6	2230	37.2	986	233	124	5520	491	166	19.9	1.44	6.37	1.66	-	-	2.06	0.0510	8.16
KFM02A	490.0	518.0	30802	2016-05-25	0.2	2270	37.5	997	236	123	5520	491	168	19.9	1.42	6.42	1.69	1.67	1.64	2.09	0.0515	8.22
KFM02B	410.0	431.0	30803	2016-05-23	0.7	2170	25.6	1130	214	105	5510	444	151	20.6	1.43	8.34	1.89	-	-	1.98	0.0837	10.4
KFM02B	410.0	431.0	30804	2016-05-24	0.8	2150	25.4	1140	214	105	5480	444	151	20.6	1.43	8.21	1.98	-	-	2.01	0.0891	10.4
KFM02B	410.0	431.0	30805	2016-05-24	0.5	2130	25.3	1140	213	106	5500	448	150	20.9	1.44	8.19	1.98	1.97	1.98	2.01	0.0894	10.4
KFM02B	491.0	506.0	30806	2016-05-24	-0.2	2290	40.0	947	238	123	5510	492	169	19.4	1.54	8.19	3.34	-	-	1.94	0.0550	7.73
KFM02B	491.0	506.0	30807	2016-05-24	0.1	2300	39.8	944	238	124	5490	496	168	19.5	1.50	8.05	3.55	-	-	1.97	0.0555	7.73
KFM02B	491.0	506.0	30808	2016-05-25	-0.3	2250	39.2	959	239	124	5490	494	169	19.5	1.51	7.71	4.03	3.89	3.86	2.03	0.0563	7.72
KFM03A	969.5	994.5	30825	2016-05-30	0.5	2310	8.89	3790	7.36	8.2	10100	55.3	15.7	93.1	1.37	5.08	< 0.1	-	-	0.0314	0.0268	42.0
KFM03A	969.5	994.5	30826	2016-05-31	0.3	2320	9.01	3820	7.53	6.9	10300	49.2	15.9	101	1.37	4.80	< 0.1	-	-	0.0300	0.0271	42.3
KFM03A	969.5	994.5	30827	2016-06-02	0.4	2380	9.44	3870	7.77	6.5	10400	48.8	16.1	98.0	1.37	4.69	0.074	0.07	0.06	0.0305	0.0294	42.9
KFM04A	230.0	245.0	30779	2016-05-13	1.2	2030	24.9	1510	239	99.6	5950	454	163	26.9	1.00	6.21	2.25	-	-	3.05	0.0628	15.5
KFM04A	230.0	245.0	30780	2016-05-13	0.9	2030	24.8	1480	237	100	5930	454	162	26.8	1.00	6.22	2.21	-	-	3.03	0.0623	15.4
KFM04A	230.0	245.0	30781	2016-05-13	0.6	2020	24.9	1490	238	101	5980	453	162	26.6	1.02	6.17	2.21	2.16	2.17	3.02	0.0637	15.4
KFM06A	341.0	362.0	30785	2016-05-16	1.8	1600	15.2	1270	44.9	28.9	4580	117	38.8	28.3	1.13	4.74	< 0.1	-	-	0.164	0.0486	14.0
KFM06A	341.0	362.0	30786	2016-05-16	1.6	1570	12.7	1290	44.2	25.8	4590	112	37.2	28.8	1.22	5.24	0.169	-	-	0.247	0.0501	14.3
KFM06A	341.0	362.0	30787	2016-05-17	1.6	1580	10.2	1300	41.7	25.7	4620	112	35.8	29.5	1.19	5.09	0.441	0.45	0.45	0.257	0.0502	14.5

RCB % = Rel. charge balance error %

- = Not analysed

&lt; "value" = value below reporting limit

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Table A3-1. Water composition, continued.

Id code	Secup m	Seclow m	Sample no.	Sampling date	RCB %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> <sup>-</sup> mg/L	Cl <sup>-</sup> mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	SO <sub>4</sub> -S mg/L	Br <sup>-</sup> mg/L	F <sup>-</sup> mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fell mg/L	Mn mg/L	Li mg/L	Sr mg/L
KFM06A	738.0	748.0	30789	2016-05-17	2.0	1980	9.45	2190	19.4	16.9	6630	100	33.9	47.4	1.33	6.48	< 0.1	–	–	0.191	0.0386	23.5
KFM06A	738.0	748.0	30798	2016-05-18	2.7	1990	9.53	2230	19.2	15.4	6620	102	33.9	48.6	1.31	6.54	0.132	–	–	0.198	0.0382	23.8
KFM06A	738.0	748.0	30799	2016-05-19	2.0	1980	8.92	2220	17.6	12.3	6690	101	33.2	49.1	1.33	6.25	0.195	0.16	0.16	0.193	0.0376	23.8
KFM06C	531.0	540.0	30782	2016-05-16	1.9	1820	16.3	1270	80.0	35.7	4910	229	77.8	25.6	0.86	3.73	< 0.1	–	–	0.414	0.0411	12.8
KFM06C	531.0	540.0	30783	2016-05-16	2.2	1820	15.1	1290	80.5	28.9	4910	233	80.6	25.2	0.92	4.37	0.154	–	–	0.477	0.0423	13.0
KFM06C	531.0	540.0	30784	2016-05-17	1.6	1830	14.1	1290	84.3	34.2	4980	245	83.2	25.6	1.00	4.68	0.243	0.26	0.26	0.560	0.0442	13.0
KFM06C	647.0	666.0	30791	2016-05-16	2.3	1620	6.34	1860	16.0	32.9	5510	68.1	22.5	42.3	1.20	2.06	< 0.1	–	–	< 0.02	0.0330	20.3
KFM06C	647.0	666.0	30792	2016-05-20	2.1	1620	5.93	1880	18.2	23.7	5570	72.1	22.2	43.4	1.22	3.25	< 0.1	–	–	< 0.02	0.0325	20.5
KFM06C	647.0	666.0	30793	2016-05-23	2.0	1630	6.01	1860	17.7	21.5	5560	71.3	22.0	43.9	1.24	3.39	0.007	–	–	0.0263	0.0332	20.5
KFM11A	690.0	710.0	30874	2016-06-09	2.0	2070	8.69	2370	16.2	17.7	7050	97.9	34.7	52.5	1.28	4.76	< 0.1	–	–	0.0601	0.0509	28.1
KFM11A	690.0	710.0	30875	2016-06-10	2.0	2020	8.55	2400	16.5	15.1	7040	103	34.9	53.2	1.27	4.66	< 0.1	–	–	0.0659	0.0510	28.1
KFM11A	690.0	710.0	30876	2016-06-10	0.9	1990	8.75	2320	15.7	15.3	7010	98.8	33.5	52.6	1.27	4.55	0.089	0.09	0.09	0.0595	0.0509	27.5
KFM12A	270.0	280.0	30776	2016-05-13	1.9	1070	6.37	1230	31.8	35.5	3710	64.1	21.7	25.1	0.77	3.86	< 0.1	–	–	0.290	0.0412	17.3
KFM12A	270.0	280.0	30777	2016-05-13	3.0	1090	6.46	1250	32.3	27.0	3700	62.5	22.3	24.6	0.77	3.76	< 0.1	–	–	0.237	0.0433	17.7
KFM12A	270.0	280.0	30778	2016-05-13	2.3	1070	6.17	1230	33.5	25.3	3690	65.0	21.8	25.0	0.81	3.66	0.061	0.05	0.06	0.289	0.0432	17.4
KFR01	44.7	62.3	30886	2016-06-13	0.8	1530	8.55	599	115	106	3370	357	123	12.1	1.18	4.28	0.426	–	–	0.637	0.0541	7.90
KFR01	44.7	62.3	30887	2016-06-14	-0.3	1500	8.67	590	114	106	3380	360	124	11.8	1.17	4.29	0.432	–	–	0.659	0.0525	7.69
KFR01	44.7	62.3	30888	2016-06-14	0.1	1490	8.59	587	114	107	3330	364	123	12.2	1.12	4.26	0.430	0.43	0.43	0.660	0.0524	7.62
KFR101	279.5	341.8	30883	2016-06-13	2.2	818	4.63	440	32.2	63.4	1960	54.1	18.8	10.7	1.44	4.98	0.379	–	–	0.537	0.0332	6.22
KFR101	279.5	341.8	30884	2016-06-14	1.0	825	4.82	456	34.1	64.4	2050	61.3	21.7	10.7	1.44	4.99	0.424	–	–	0.558	0.0337	6.38
KFR101	279.5	341.8	30885	2016-06-14	1.5	837	4.76	462	34.6	64.5	2060	61.8	22.4	10.8	1.45	4.99	0.428	–	–	0.564	0.0335	6.44
KFR102A	214.0	219.0	30855	2016-06-09	1.7	1670	8.75	716	107	97.2	3730	310	106	14.5	1.27	4.81	0.636	–	–	0.552	0.0522	9.88
KFR102A	214.0	219.0	30856	2016-06-09	0.7	1650	8.77	712	106	96.5	3780	306	104	14.3	1.29	4.75	0.625	–	–	0.556	0.0518	9.80
KFR102A	214.0	219.0	30857	2016-06-10	2.2	1680	9.40	715	108	96.2	3710	307	104	14.4	1.29	4.83	0.631	0.62	0.62	0.566	0.0523	9.91
KFR102A	423.0	443.0	30880	2016-06-13	0.5	1430	7.67	1130	76.1	36.6	4180	249	81.9	20.4	1.35	5.02	0.963	–	–	0.563	0.0490	14.4
KFR102A	423.0	443.0	30881	2016-06-14	1.5	1470	7.74	1130	76.4	37.0	4160	242	81.6	20.2	1.35	4.99	0.956	–	–	0.563	0.0487	14.4
KFR102A	423.0	443.0	30882	2016-06-15	1.5	1460	7.70	1140	76.7	36.7	4160	241	81.5	20.3	1.35	4.98	0.952	0.95	0.93	0.563	0.0484	14.4

RCB % = Rel. charge balance error %

– = Not analysed

&lt; "value" = value below reporting limit

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Table A3-1. Water composition, continued.

Id code	Secup m	Seclow m	Sample no.	Sampling date	RCB %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> <sup>-</sup> mg/L	Cl <sup>-</sup> mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	SO <sub>4</sub> -S mg/L	Br <sup>-</sup> mg/L	F <sup>-</sup> mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	FeII mg/L	Mn mg/L	Li mg/L	Sr mg/L
KFR104	333.0	454.6	30852	2016-06-08	0.3	729	3.71	423	7.69	33.3	1810	35.2	27.1	10.8	1.53	4.60	0.161	-	-	0.0518	0.0204	6.11
KFR104	333.0	454.6	30853	2016-06-10	0.8	752	3.74	438	8.22	28.9	1850	42.4	28.7	10.5	1.55	4.47	0.044	-	-	0.0530	0.0212	6.30
KFR104	333.0	454.6	30854	2016-06-13	2.1	792	3.72	497	12.1	25.8	1980	57.9	24.9	10.8	1.51	4.70	0.048	-	-	0.0680	0.0243	6.93
KFR106	143.0	259.0	30822	2016-05-31	1.2	1800	15.5	775	169	110	4230	348.6	113	15.8	1.37	5.10	1.24	-	-	1.20	0.0572	8.62
KFR106	143.0	259.0	30823	2016-06-01	2.1	1860	15.3	796	172	103	4280	338	114	15.5	1.34	5.08	1.25	-	-	1.22	0.0587	8.82
KFR106	143.0	259.0	30824	2016-06-01	1.3	1830	15.8	791	172	106	4300	339	114	15.6	1.34	5.09	1.24	-	-	1.22	0.0579	8.82
KFR106	260.0	300.1	30819	2016-05-31	0.9	875	13.1	318	52.6	184	1850	85.8	35.7	8.34	1.42	4.69	0.064	-	-	0.215	0.0301	4.14
KFR106	260.0	300.1	30820	2016-05-31	0.9	889	13.1	355	54.4	135	1970	93.6	35.8	9.21	1.25	5.01	0.041	-	-	0.233	0.0341	4.67
KFR106	260.0	300.1	30821	2016-05-31	1.3	1010	13.1	426	63.2	122	2270	125	45.6	9.66	1.48	5.03	0.161	-	-	0.313	0.0363	5.59

RCB % = Rel. charge balance error %

- = Not analysed

&lt; "value" = value below reporting limit

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Table A3-2. Water composition 2.

Id code	Secup m	Seclow m	Sample no.	Sampling Date	pH_L	pH_F	TOC mg/L	DOC mg/L	HS mg/L	Uranine µg/L	EC_L mS/m	EC_F mS/m	NH <sub>4</sub> -N mg/L	NO <sub>2</sub> -N+NO <sub>3</sub> -N mg/L	PO <sub>4</sub> -P mg/L	PO <sub>4</sub> -P* mg/L	P mg/L	Temp_F °C
HFM01	33.5	45.5	30846	2016-06-07	7.90	7.77	10.2	10.2	0.11	0.7	223	220	–	–	–	–	–	10.3
HFM01	33.5	45.5	30847	2016-06-08	7.90	7.83	10.2	10.1	0.09	0.2	224	217	–	–	–	–	–	10.3
HFM01	33.5	45.5	30848	2016-06-10	7.86	7.87	10.2	10.2	0.09	0.5	225	224	0.706	< 0.0003	0.0555	0.0764	0.0861	7.9
HFM02	38.0	48.0	30877	2016-06-13	7.72	7.71	11.1	10.8	0.05	0.5	141	135	–	–	–	–	–	10.3
HFM02	38.0	48.0	30878	2016-06-14	7.78	7.71	11.1	10.8	0.04	0.2	140	137	–	–	–	–	–	9.2
HFM02	38.0	48.0	30879	2016-06-15	7.80	7.71	11.1	11.2	0.04	0.2	139	135	0.443	0.0004	0.0387	0.0460	0.0555	8.8
HFM04	57.9	65.9	30809	2016-05-24	7.66	7.77	9.7	9.5	0.09	0.4	97.0	94.8	–	–	–	–	–	7.9
HFM04	57.9	65.9	30810	2016-05-25	7.69	7.80	9.5	9.5	0.08	0.7	96.0	93.4	–	–	–	–	–	7.9
HFM04	57.9	65.9	30811	2016-05-25	7.68	7.82	9.5	9.6	0.07	0.8	95.0	94.5	0.523	< 0.0003	0.0125	– <sup>1)</sup>	0.0235	7.1
HFM15	85.0	95.0	30837	2016-06-02	7.12	6.72	9.9	9.9	0.23	0.9	81.0	78.7	–	–	–	–	–	9.3
HFM15	85.0	95.0	30838	2016-06-02	7.11	6.87	10.1	10.0	0.23	0.7	80.0	77.8	–	–	–	–	–	9.8
HFM15	85.0	95.0	30839	2016-06-03	7.02	6.87	9.6	9.6	0.22	0.9	78.0	76.0	0.384	0.0003	0.0008	0.0059	0.0086	12.0
HFM16	54.0	67.0	30788	2016-05-17	7.96	8.08	13.3	13.2	0.17	– <sup>2)</sup>	141	139	–	–	–	–	–	8.2
HFM16	54.0	67.0	30795	2016-05-18	7.80	8.03	13.3	13.4	0.06	1.5	141	138	–	–	–	–	–	7.5
HFM16	54.0	67.0	30796	2016-05-19	7.84	8.03	13.3	13.4	0.09	1.1	141	138	0.676	0.0019	0.0584	0.0706	0.0755	8.3
HFM19	168.0	182.0	30831	2016-05-30	7.36	7.49	1.8	1.8	0.09	1.2	1510	1510	–	–	–	–	–	8.8
HFM19	168.0	182.0	30832	2016-05-31	7.26	7.48	1.8	1.8	0.08	1.4	1520	1500	–	–	–	–	–	8.9
HFM19	168.0	182.0	30833	2016-06-01	7.34	8.72	2.0	1.9	0.12	1.2	1510	1480	2.48	0.0016	< 0.0005	0.0048	< 0.04	8.8
HFM27	46.0	58.0	30849	2016-06-07	7.45	7.32	5.7	5.7	0.03	0.3	669	648	–	–	–	–	–	14.9
HFM27	46.0	58.0	30850	2016-06-08	7.51	7.31	5.7	5.7	0.03	0.0	666	676	–	–	–	–	–	12.1
HFM27	46.0	58.0	30851	2016-06-10	7.49	7.46	5.6	5.6	0.03	0.0	662	662	1.43	< 0.0003	< 0.0005	0.0147	0.0142	10.2
HFM32	26.0	31.0	30834	2016-06-01	7.26	8.46	3.3	3.1	– <sup>3)</sup>	0.9	1200	1190	–	–	–	–	–	10.6
HFM32	26.0	31.0	30835	2016-06-01	7.27	7.29	3.3	3.5	0.11	0.7	1200	1190	–	–	–	–	–	11.1
HFM32	26.0	31.0	30836	2016-06-01	7.19	7.26	3.3	3.5	0.09	0.7	1200	1190	2.22	0.0004	< 0.0005	0.0062	0.0111	12.5
KFM01A	109.0	130.0	30843	2016-06-07	7.97	7.92	1.6	1.6	0.59	26.4	1170	1170	–	–	–	–	–	11.9
KFM01A	109.0	130.0	30844	2016-06-08	7.95	7.78	1.7	1.7	0.36	29.7	1160	1140	–	–	–	–	–	8.8
KFM01A	109.0	130.0	30845	2016-06-08	7.95	7.65	1.6	1.7	0.33	30.5	1150	1140	0.806	< 0.0003	< 0.0005	0.0005	< 0.005	11.7

PO<sub>4</sub>-P\* = P after hydrolysis

pH\_L; EC\_L = Laboratory measurements of pH and EC

pH\_F; EC\_F = Field measurements of pH and EC

– = Not analysed

&lt; "value" = value below reporting limit

<sup>1)</sup> Analysis missed at laboratory<sup>2)</sup> Non reliable result<sup>3)</sup> Not analysed due to broken sample bottles

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Table A3-2. Water composition 2, continued.

Id code	Secup m	Seclow m	Sample no.	Sampling date	pH_L	pH_F	TOC mg/L	DOC mg/L	HS <sup>-</sup> mg/L	Uranine µg/L	EC_L mS/m	EC_F mS/m	NH <sub>4</sub> -N mg/L	NO <sub>2</sub> -N+ NO <sub>3</sub> -N mg/L	PO <sub>4</sub> -P mg/L	PO <sub>4</sub> -P* mg/L	P mg/L	Temp_F °C
KFM01D	311.0	321.0	30840	2016-06-03	7.86	7.68	2.8	3.0	0.45	17.4	1340	1310	–	–	–	–	–	15.0
KFM01D	311.0	321.0	30841	2016-06-03	7.83	7.68	3.0	3.2	3.56	15.7	1340	1250	–	–	–	–	–	17.0
KFM01D	311.0	321.0	30842	2016-06-03	7.86	7.72	2.9	2.8	0.24	18.3	1320	1280	0.772	< 0.0003	0.0025	0.0049	0.0096	13.4
KFM01D	429.0	438.0	30828	2016-05-30	7.78	7.81	3.4	3.2	7.00	15.3	1390	1380	–	–	–	–	–	13.0
KFM01D	429.0	438.0	30829	2016-05-30	7.77	7.69	3.1	3.2	5.01	15.2	1380	1320	–	–	–	–	–	12.5
KFM01D	429.0	438.0	30830	2016-05-31	7.83	7.89	2.6	2.6	6.61	13.9	1390	1350	0.724	0.0055	0.0017	0.0023	< 0.005	14.7
KFM02A	411.0	442.0	30797	2016-05-18	7.46	7.46	1.3	1.3	0.31	50.2	1590	1540	–	–	–	–	–	9.2
KFM02A	411.0	442.0	30794	2016-05-19	7.39	7.48	1.2	1.2	0.24	47.3	1590	1560	–	–	–	–	–	8.7
KFM02A	411.0	442.0	30790	2016-05-20	7.40	7.45	1.2	1.2	0.20	44.7	1590	1540	1.70	< 0.0003	< 0.0005	< 0.0005	< 0.04	9.9
KFM02A	490.0	518.0	30800	2016-05-19	7.56	7.53	1.7	1.8	0.64	8.0	1600	1540	–	–	–	–	–	12.5
KFM02A	490.0	518.0	30801	2016-05-25	7.25	7.27	1.5	1.5	0.24	6.4	1610	1560	–	–	–	–	–	8.5
KFM02A	490.0	518.0	30802	2016-05-25	7.25	7.24	1.5	1.5	0.25	6.6	1610	1550	2.61	< 0.0003	< 0.0005	< 0.0005	< 0.04	8.0
KFM02B	410.0	431.0	30803	2016-05-23	7.47	7.56	1.2	1.2	0.09	4.8	1600	1550	–	–	–	–	–	13.2
KFM02B	410.0	431.0	30804	2016-05-24	7.46	7.65	1.2	1.2	0.07	4.6	1600	1530	–	–	–	–	–	9.9
KFM02B	410.0	431.0	30805	2016-05-24	7.47	7.61	1.2	1.2	0.07	4.3	1600	1570	1.98	< 0.0003	< 0.0005	< 0.0005	< 0.04	8.5
KFM02B	491.0	506.0	30806	2016-05-24	7.46	7.58	1.8	1.8	0.07	2.9	1610	1520	–	–	–	–	–	10.2
KFM02B	491.0	506.0	30807	2016-05-24	7.48	7.55	1.8	1.8	0.06	2.8	1620	1550	–	–	–	–	–	9.1
KFM02B	491.0	506.0	30808	2016-05-25	7.40	7.45	1.7	1.7	0.05	2.9	1610	1550	2.71	< 0.0003	< 0.0005	< 0.0005	< 0.04	8.2
KFM03A	969.5	994.5	30825	2016-05-30	8.30	8.19	0.8	1.1 <sup>4)</sup>	0.32	0.5	2700	2630	–	–	–	–	–	14.9
KFM03A	969.5	994.5	30826	2016-05-31	8.30	8.32	0.5	0.6	0.20	0.4	2680	2620	–	–	–	–	–	18.0
KFM03A	969.5	994.5	30827	2016-06-02	8.40	6.93	0.4	0.5	0.18	0.5	2700	2530	0.0201	0.0024	< 0.0005	0.0007	< 0.005	17.6
KFM04A	230.0	245.0	30779	2016-05-13	7.30	8.26	1.2	1.5 <sup>4)</sup>	0.12	1.7	1720	1610	–	–	–	–	–	7.6
KFM04A	230.0	245.0	30780	2016-05-13	7.28	8.72	1.1	1.2	0.10	1.9	1710	1600	–	–	–	–	–	7.5
KFM04A	230.0	245.0	30781 <sup>5)</sup>	2016-05-13	7.32	7.37	1.2	1.2	0.10	1.7	1710	1610	1.52	0.0005	< 0.0005	< 0.0005	< 0.04	7.8
KFM06A	341.0	362.0	30785	2016-05-16	9.32	9.70	1.6	1.7	0.12	17.9	1330	1300	–	–	–	–	–	8.9
KFM06A	341.0	362.0	30786	2016-05-16	8.99	9.28	1.4	1.5	0.07	17.6	1330	1300	–	–	–	–	–	7.9
KFM06A	341.0	362.0	30787	2016-05-17	8.35	8.51	1.1	1.2	0.05	16.9	1330	1320	0.189	< 0.0003	< 0.0005	< 0.0005	< 0.005	8.3

PO<sub>4</sub>-P\* = P after hydrolysis  
pH\_L; EC\_L = Laboratory measurements of pH and EC  
pH\_F; EC\_F = Field measurements of pH and EC

– = Not analysed  
< "value" = value below reporting limit

<sup>4)</sup> DOC>TOC, sample analysed twice with same results  
<sup>5)</sup> Red precipitation in sample

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Table A3-2. Water composition 2, continued.

Id code	Secup m	Seclow m	Sample no.	Sampling date	pH_L	pH_F	TOC mg/L	DOC mg/L	HS <sup>-</sup> mg/L	Uranine µg/L	EC_L mS/m	EC_F mS/m	NH <sub>4</sub> -N mg/L	NO <sub>2</sub> -N+ NO <sub>3</sub> -N mg/L	PO <sub>4</sub> -P mg/L	PO <sub>4</sub> -P* mg/L	P mg/L	Temp_F °C
KFM06A	738.0	748.0	30789	2016-05-17	8.72	8.63	1.1	1.2	0.03	1.2	1840	1780	–	–	–	–	–	13.4
KFM06A	738.0	748.0	30798	2016-05-18	8.53	8.83	1.1	1.1	0.07	29.6	1840	1770	–	–	–	–	–	13.3
KFM06A	738.0	748.0	30799	2016-05-19	8.40	8.54	1.0	1.3 <sup>3)</sup>	0.06	28.9	1850	1780	0.161	0.0026	< 0.0005	< 0.0005	< 0.04	13.8
KFM06C	531.0	540.0	30782	2016-05-16	9.62	10.06	1.6	1.6	0.29	47.9	1430	1400	–	–	–	–	–	7.7
KFM06C	531.0	540.0	30783	2016-05-16	8.45	8.75	1.5	1.5	0.16	47.2	1430	1380	–	–	–	–	–	8.8
KFM06C	531.0	540.0	30784	2016-05-17	8.10	8.24	1.4	1.4	0.10	48.3	1440	1400	0.447	< 0.0003	< 0.0005	< 0.0005	< 0.005	11.3
KFM06C	647.0	666.0	30791	2016-05-16	9.92	11.64	0.9	1.0	0.19	17.4	1560	1530	–	–	–	–	–	8.6
KFM06C	647.0	666.0	30792	2016-05-20	9.43	9.34	0.8	0.9	0.14	17.5	1570	1550	–	–	–	–	–	15.2
KFM06C	647.0	666.0	30793	2016-05-23	9.38	9.36	0.8	0.9	0.11	16.2	1570	1540	0.117	0.0015	0.0005	0.0009	< 0.04	28.0
KFM11A	690.0	710.0	30874	2016-06-09	9.29	9.46	0.4	0.4	0.22	0.0	1940	1900	–	–	–	–	–	9.5
KFM11A	690.0	710.0	30875	2016-06-10	9.10	9.31	0.3	0.4	0.19	0.3	1940	1890	–	–	–	–	–	10.1
KFM11A	690.0	710.0	30876	2016-06-10	9.13	9.37	0.3	0.3	0.18	0.0	1940	1920	0.0954	0.0003	< 0.0005	0.0009	< 0.04	8.7
KFM12A	270.0	280.0	30776	2016-05-13	9.18	9.55	0.9	1.1	0.45	1.6	1090	1010	–	–	–	–	–	7.4
KFM12A	270.0	280.0	30777	2016-05-13	9.31	11.29	0.9	0.9	0.37	1.5	1080	1010	–	–	–	–	–	7.1
KFM12A	270.0	280.0	30778	2016-05-13	9.15	9.71	0.9	0.9	0.24	2.7	1080	1030	0.0417	< 0.0003	< 0.0005	< 0.0005	< 0.005	7.3
KFR01	44.7	62.3	30886	2016-06-13	7.46	7.63	1.4	1.4	< 0.02	0.0	1030	1010	–	–	–	–	–	9.7
KFR01	44.7	62.3	30887	2016-06-14	7.49		1.3	1.4	< 0.02	0.0	1030	1020	–	–	–	–	–	9.5
KFR01	44.7	62.3	30888	2016-06-14	7.49	7.62	1.4	1.3	< 0.02	0.0	1040	1020	0.227	< 0.0003	< 0.0005	< 0.0005	< 0.005	9.3
KFR101	279.5	341.8	30883	2016-06-13	7.63	7.63	0.7	0.8	0.21	0.0	624	602	–	–	–	–	–	11.4
KFR101	279.5	341.8	30884	2016-06-14	7.61	7.46	1.3	1.9 <sup>4)</sup>	–	0.7	641	629	–	–	–	–	–	10.8
KFR101	279.5	341.8	30885	2016-06-14	7.59	7.30	1.2	1.0	–	0.4	645	638	0.0517	0.0004	< 0.0005	0.0007	< 0.005	11.1
KFR102A	214.0	219.0	30855	2016-06-09	7.63	7.66	1.1	1.1	0.08	0.9	1140	1150	–	–	–	–	–	8.9
KFR102A	214.0	219.0	30856	2016-06-09	7.69	7.66	1.0	1.1	0.06	0.8	1140	1140	–	–	–	–	–	11.5
KFR102A	214.0	219.0	30857	2016-06-10	7.63	7.68	1.0	1.1	0.04	0.7	1150	1150	0.0964	< 0.0003	< 0.0005	< 0.0005	< 0.005	9.1
KFR102A	423.0	443.0	30880	2016-06-13	7.52	7.47	0.6	0.7	0.04	0.1	1240	1210	–	–	–	–	–	13.9
KFR102A	423.0	443.0	30881	2016-06-14	7.55	7.41	0.6	0.6	0.02	0.0	1230	1210	–	–	–	–	–	12.0
KFR102A	423.0	443.0	30882	2016-06-15	7.48	7.37	0.6	0.7	0.02	0.0	1240	1210	0.0386	0.0006	< 0.0005	< 0.0005	< 0.005	11.8

PO<sub>4</sub>-P\* = P after hydrolysis

pH\_L; EC\_L = Laboratory measurements of pH and EC

pH\_F; EC\_F = Field measurements of pH and EC

– = Not analysed

&lt; "value" = value below reporting limit

<sup>4)</sup> DOC>TOC, sample analysed twice with same results

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Table A3-2. Water composition 2, continued.

Id code	Secup m	Seclow m	Sample no.	Sampling date	pH_L	pH_F	TOC mg/L	DOC mg/L	HS <sup>-</sup> mg/L	Uranine µg/L	EC_L mS/m	EC_F mS/m	NH <sub>4</sub> -N mg/L	NO <sub>2</sub> -N+ NO <sub>3</sub> -N mg/L	PO <sub>4</sub> -P mg/L	PO <sub>4</sub> -P* mg/L	P mg/L	Temp_F °C
KFR104	333.0	454.6	30852	2016-06-08	7.66	7.54	1.8	2.1	–	1.2	569	566	–	–	–	–	–	17.9
KFR104	333.0	454.6	30853	2016-06-10	7.72	7.73	1.0	1.1	–	1.1	581	578	–	–	–	–	–	12.1
KFR104	333.0	454.6	30854	2016-06-13	7.72	7.43	0.7	2.4 <sup>4)</sup>	–	1.4	620	619	0.0031	0.0060	0.0012	0.0013	< 0.005	19.2
KFR106	143.0	259.0	30822	2016-05-31	7.52	7.58	1.8	2.3 <sup>4)</sup>	–	0.7	1260	1270	–	–	–	–	–	9.9
KFR106	143.0	259.0	30823	2016-06-01	7.49	7.52	1.4	1.7	–	0.7	1290	1270	–	–	–	–	–	9.4
KFR106	143.0	259.0	30824	2016-06-01	7.43	7.48	1.4	1.6	–	0.6	1290	1230	0.198	0.0008	< 0.0005	< 0.0005	< 0.005	11.5
KFR106	260.0	300.1	30819	2016-05-31	7.52	7.70	8.1	7.9	–	1.4	603	632	–	–	–	–	–	10.5
KFR106	260.0	300.1	30820	2016-05-31	7.58	7.60	3.7	4.0 <sup>4)</sup>	–	1.0	628	641	–	–	–	–	–	11.0
KFR106	260.0	300.1	30821	2016-05-31	7.76	7.84	2.8	2.8	–	1.0	714	701	0.126	0.0019	0.0005	0.0005	< 0.005	12.0

PO<sub>4</sub>-P\* = P after hydrolysis

pH\_L; EC\_L = Laboratory measurements of pH and EC

pH\_F; EC\_F = Field measurements of pH and EC

– = Not analysed

&lt; "value" = value below reporting limit

<sup>4)</sup> DOC>TOC, sample analysed twice with same results

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Table A3-3. Trace elements.

Id code	Secup m	Seclow m	Sample no.	Sampling date	Al µg/L	Ba µg/L	Cd µg/L	Cr µg/L	Cu µg/L	Co µg/L	Hg µg/L	Ni µg/L	Mo µg/L	Pb µg/L	V µg/L	Zn µg/L	U µg/L
HFM01	33.5	45.5	30848	2016-06-10	5.15	20.4	0.0079	0.183	< 0.1	0.0366	< 0.002	0.159	12.9	0.0295	1.32	0.237	–
HFM02	38.0	48.0	30879	2016-06-15	2.01	22.5	0.0061	0.151	< 0.1	0.0377	< 0.002	0.147	10.2	< 0.01	1.10	3.87	–
HFM04	57.9	65.9	30811	2016-05-25	4.97	40.4	0.0204	0.812	< 0.1	0.0342	< 0.002	0.451	3.75	0.0111	0.840	2.74	–
HFM15	85.0	95.0	30839	2016-06-03	27.0	30.0	< 0.002	0.237	0.133	0.0310	< 0.002	0.255	5.35	0.0197	1.28	0.573	–
HFM16	54.0	67.0	30796	2016-05-19	1.33	23.6	0.0211	0.517	< 0.1	0.0484	< 0.002	0.278	24.6	0.0241	1.26	34.4	–
HFM19	168.0	182.0	30833	2016-06-01	< 0.7	66.3	< 0.05	0.115	< 0.5	< 0.05	< 0.002	< 0.5	4.28	< 0.3	< 0.05	< 2	–
HFM27	46.0	58.0	30851	2016-06-10	0.671	33.6	< 0.02	0.600	< 0.2	< 0.02	< 0.002	0.212	8.84	< 0.1	0.302	< 0.8	–
HFM32	26.0	31.0	30836	2016-06-01	3.41	64.8	0.0735	0.515	0.382	0.1030	< 0.002	0.537	13.1	0.214	0.164	1.59	–
KFM01A	109.0	130.0	30845	2016-06-08	< 0.3	92.5	< 0.02	0.146	< 0.2	0.0228	< 0.002	< 0.2	25.6	< 0.1	0.0462	< 0.8	–
KFM01D	429.0	438.0	30830	2016-05-31	3.47	550	< 0.02	0.558	< 0.2	0.0447	< 0.002	0.302	0.305	0.138	0.0835	7.71	–
KFM01D	311.0	321.0	30842	2016-06-03	2.14	486	< 0.02	0.166	< 0.2	0.0443	< 0.002	0.237	3.72	0.107	0.116	< 0.8	–
KFM02A	411.0	442.0	30790	2016-05-20	< 0.7	87.6	< 0.05	0.250	< 0.5	0.113	< 0.002	< 0.5	16.2	< 0.3	0.115	< 2	–
KFM02A	490.0	518.0	30802	2016-05-25	2.54	90.0	0.244	< 0.1	< 0.5	0.111	< 0.002	< 0.5	82.6	< 0.3	0.114	< 2	62.7
KFM02B	410.0	431.0	30805	2016-05-24	1.22	91.1	0.0601	1.00	< 0.5	0.127	< 0.002	0.602	7.35	< 0.3	0.0771	3.33	–
KFM02B	491.0	506.0	30808	2016-05-25	< 0.7	100	0.0531	< 0.1	7.44	0.1390	< 0.002	0.791	7.46	< 0.3	< 0.05	8.80	–
KFM03A	969.5	994.5	30827	2016-06-02	18.1	1030	< 0.02	0.0813	< 0.2	< 0.02	< 0.002	< 0.2	9.78	0.104	0.0905	7.07	–
KFM04A	230.0	245.0	30781	2016-05-13	< 0.7	97.0	0.0669	0.222	< 0.5	3.65	< 0.002	0.956	40.0	< 0.3	0.107	< 2	–
KFM06A	341.0	362.0	30787	2016-05-17	< 0.3	224	0.0972	0.291	< 0.2	0.166	< 0.002	0.330	174	< 0.1	0.111	< 0.8	–
KFM06A	738.0	748.0	30799	2016-05-19	< 0.7	370	0.295	1.48	< 0.5	< 0.05	< 0.002	0.703	403	< 0.3	0.0945	< 2	–
KFM06C	531.0	540.0	30784	2016-05-17	< 0.3	106	0.0243	0.313	< 0.2	< 0.02	< 0.002	0.388	59.5	< 0.1	0.0699	< 0.8	–
KFM06C	647.0	666.0	30793	2016-05-23	2.26	366	0.176	< 0.1	0.648	< 0.05	< 0.002	< 0.5	37.0	< 0.3	0.138	2.94	–
KFM11A	690.0	710.0	30876	2016-06-10	< 0.7	252	< 0.05	0.144	< 0.5	< 0.05	< 0.002	< 0.5	27.7	< 0.3	< 0.05	< 2	–
KFM12A	270.0	280.0	30778	2016-05-13	0.473	506	< 0.02	0.953	< 0.2	0.0372	< 0.002	0.350	13.8	< 0.1	0.0807	< 0.8	–
KFR01	44.7	62.3	30888	2016-06-14	0.563	60.4	0.0888	0.0757	< 0.2	< 0.02	< 0.002	< 0.2	5.48	< 0.1	0.0312	4.56	–
KFR101	279.5	341.8	30885	2016-06-14	10.8	647	< 0.02	0.1540	< 0.2	0.0933	< 0.002	0.547	4.93	< 0.1	0.0354	3.51	–
KFR102A	214.0	219.0	30857	2016-06-10	0.957	118	< 0.02	0.0887	< 0.2	0.0299	< 0.002	< 0.2	6.26	< 0.1	0.0308	< 0.8	–
KFR102A	423.0	443.0	30882	2016-06-15	2.94	115	< 0.02	< 0.04	< 0.2	0.0919	< 0.002	< 0.2	4.76	< 0.1	< 0.03	3.82	–
KFR104	333.0	454.6	30854	2016-06-13	7.77	276	< 0.02	0.3410	< 0.2	0.0421	< 0.002	0.400	8.85	< 0.1	0.0530	< 0.8	–
KFR106	260.0	300.1	30821	2016-05-31	6.43	281	0.0674	0.2980	0.211	0.0653	< 0.002	2.85	3.79	0.199	0.0705	13.1	29.5
KFR106	143.0	259.0	30824	2016-06-01	4.06	74.6	< 0.02	0.1730	< 0.2	0.107	< 0.002	2.31	6.04	0.157	0.0602	7.94	27.0

– = Not analysed

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**Table A3-4. Isotopes I (H-, O- and C-isotopes).**

Id code	Secup m	Seclow m	Sample no.	Sampling date	$\delta^2\text{H}$ dev SMOW	$^3\text{H}$ TU	$\delta^{18}\text{O}$ dev SMOW
HFM01	33.5	45.5	30848	2016-06-10	-75.9	3.4	-10.74
HFM02	38.0	48.0	30879	2016-06-15	-82.3	4.9	-11.51
HFM04	57.9	65.9	30811	2016-05-25	-79.1	4.3	-11.66
HFM15	85.0	95.0	30839	2016-06-03	-80.6	6.7	-11.66
HFM16	54.0	67.0	30796	2016-05-19	-79.7	3.6	-11.74
HFM19	168.0	182.0	30833	2016-06-01	-64.7	< 0.8	-8.77
HFM27	46.0	58.0	30851	2016-06-10	-73.6	1.4	-10.45
HFM32	26.0	31.0	30836	2016-06-01	-63.7	0.9	-8.52
KFM01A	109.0	130.0	30845	2016-06-08	-87.0	1.1	-11.96
KFM01D	429.0	438.0	30830	2016-05-31	-69.2	1.3	-10.06
KFM01D	311.0	321.0	30842	2016-06-03	-71.1	1.2	-10.02
KFM02A	411.0	442.0	30790	2016-05-20	-74.1	< 0.8	-10.12
KFM02A	490.0	518.0	30802	2016-05-25	-65.4	< 0.8	-10.01
KFM02B	410.0	431.0	30805	2016-05-24	-70.3	< 0.8	-10.18
KFM02B	491.0	506.0	30808	2016-05-25	-63.7	< 0.8	-8.64
KFM03A	969.5	994.5	30827	2016-06-02	-92.0	2.0	-13.37
KFM04A	230.0	245.0	30781	2016-05-13	-70.7	< 0.8	-9.27
KFM06A	341.0	362.0	30787	2016-05-17	-86.8	< 0.8	-12.14
KFM06A	738.0	748.0	30799	2016-05-19	-83.7	< 0.8	-13.22
KFM06C	531.0	540.0	30784	2016-05-17	-79.6	1.2	-11.02
KFM06C	647.0	666.0	30793	2016-05-23	-91.3	-	-13.01
KFM11A	690.0	710.0	30876	2016-06-10	-84.8	< 0.8	-11.94
KFM12A	270.0	280.0	30778	2016-05-13	-110.1	< 0.8	-14.88
KFR01	44.7	62.3	30888	2016-06-14	-72.4	3.3	-9.80
KFR101	279.5	341.8	30885	2016-06-14	-109.2	< 0.8	-14.87
KFR102A	214.0	219.0	30857	2016-06-10	-82.0	< 0.8	-11.04
KFR102A	423.0	443.0	30882	2016-06-15	-89.4	< 0.8	-12.09
KFR104	333.0	454.6	30854	2016-06-13	-104.5	2.3	-14.29
KFR106	260.0	300.1	30821	2016-05-31	-98.3	2.3	-13.46
KFR106	143.0	259.0	30824	2016-06-01	-77.8	0.8	-10.51

- = Not analysed

< "value" = result less than detection limit

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**Table A3-5. Isotopes II (U- and Th-isotopes).**

Id code	Secup m	Seclow m	Sample no.	Sampling date	$^{238}\text{U}$ mBq/kg	$^{235}\text{U}$ mBq/kg	$^{234}\text{U}$ mBq/kg	$^{232}\text{Th}$ mBq/kg	$^{230}\text{Th}$ mBq/kg
KFM02A	490.00	518.00	30802	2016-05-25	312	12	604	0.13	0.29
KFR106	260.00	300.10	30821	2016-05-31	293	9.7	922	BDL	BDL
KFR106	143.00	259.00	30824	2016-06-01	664	21.6	1384	BDL	BDL

- = Not analysed

BDL = Below detection limit

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### Pressure registrations during pumping and sampling, HMS system

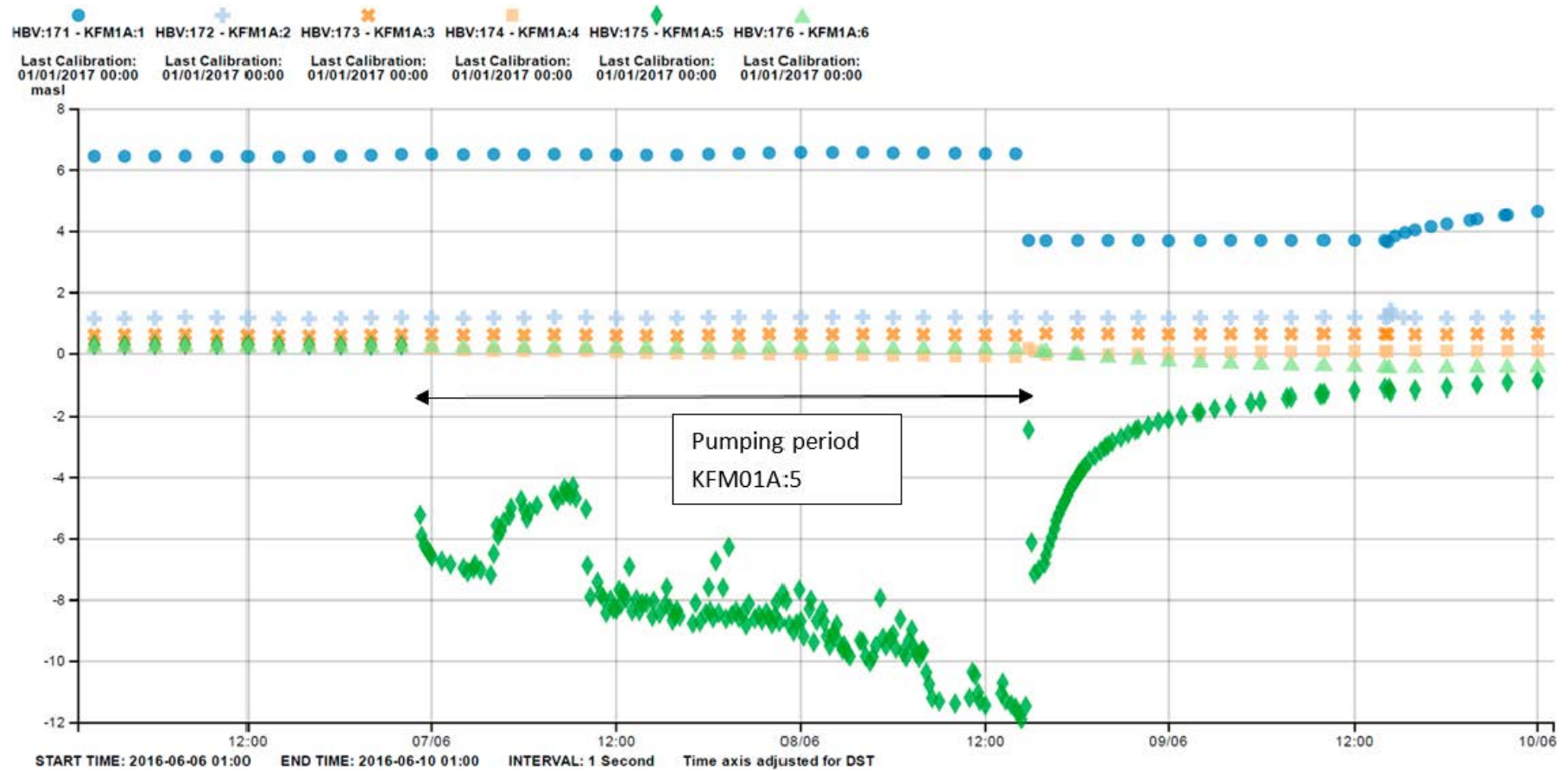


Figure A4-1. Pumping and drawdown in KFM01A:5 in June 2016. A response was observed in section 4. See next figure for a more detailed plot.

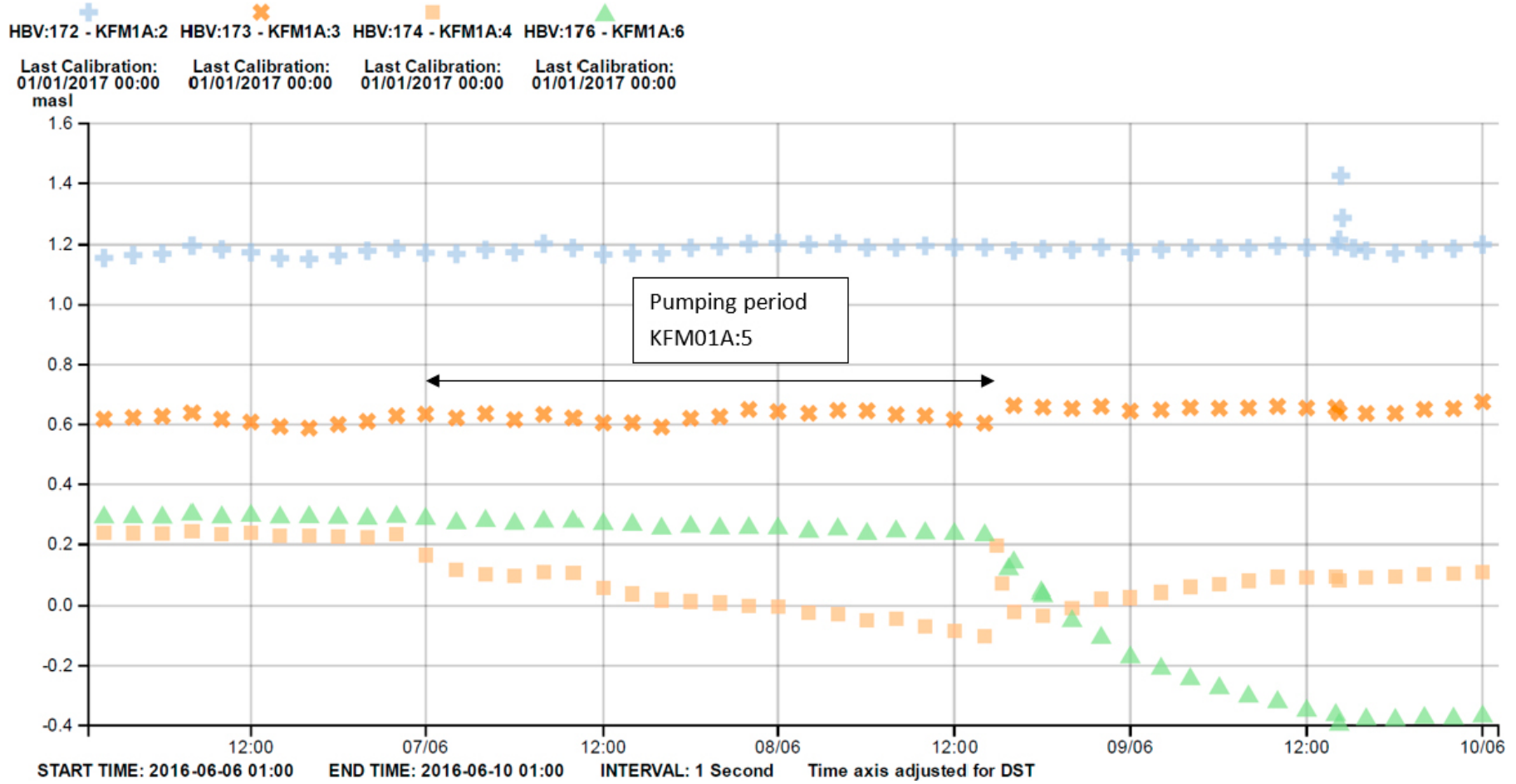
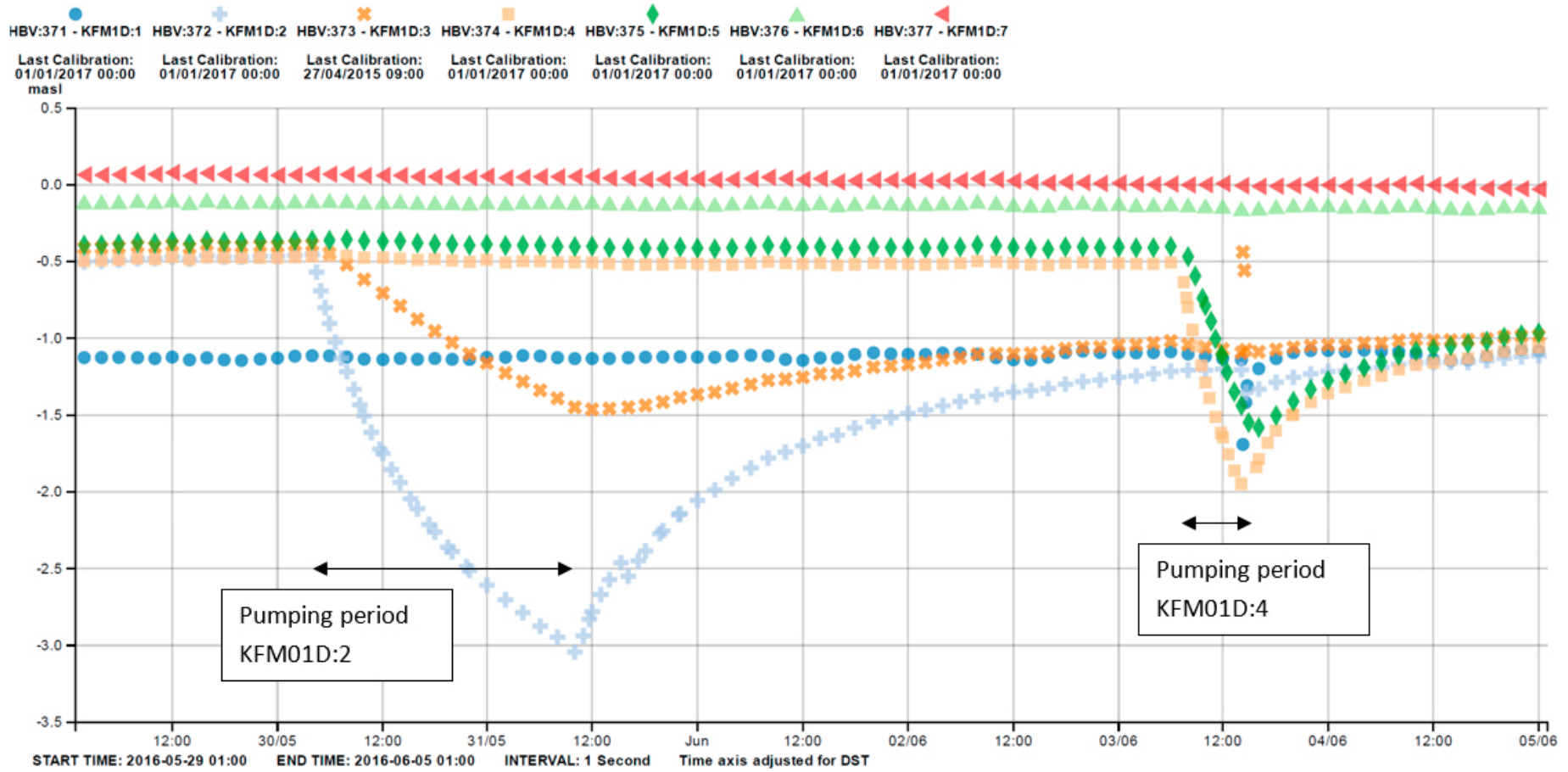


Figure A4-2. Detailed plot of pumping and drawdown in KFM01A:5 in June 2016. The pumping in KFM01A:5 causes a drawdown in KFM01A:4.





**Figure A4-3.** Pumping and drawdown in KFM01D:2 in May 2016 and in KFM01D:4 in June 2016. Section KFM01D:3 was affected by the pumping in KFM01D:2. Section KFM01D:5 was affected by the pumping in KFM01D:4.

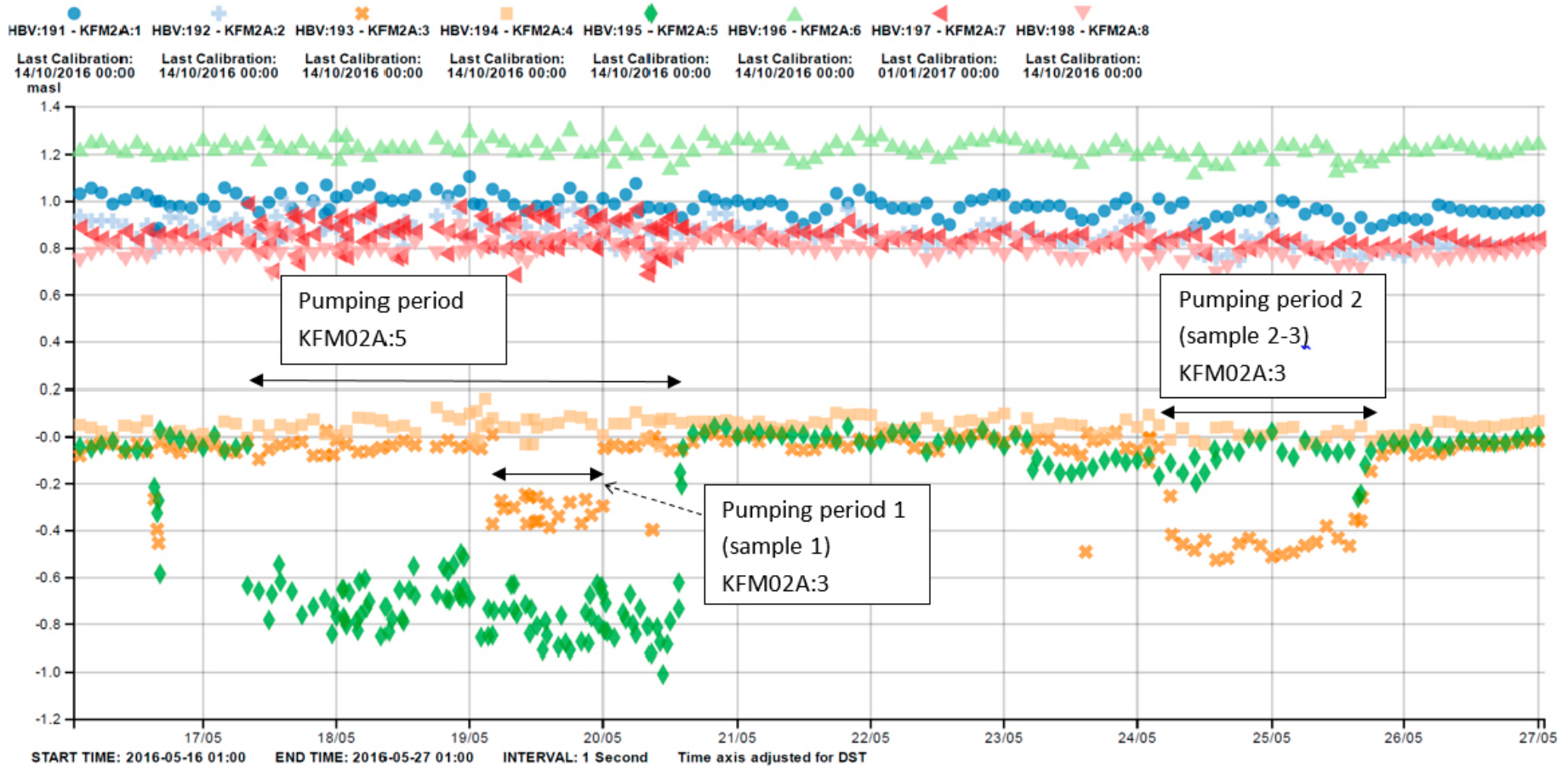


Figure A4-4. Pumping and drawdown in KFM02A:5 and KFM02A:3 in May 2016. No other sections were affected.

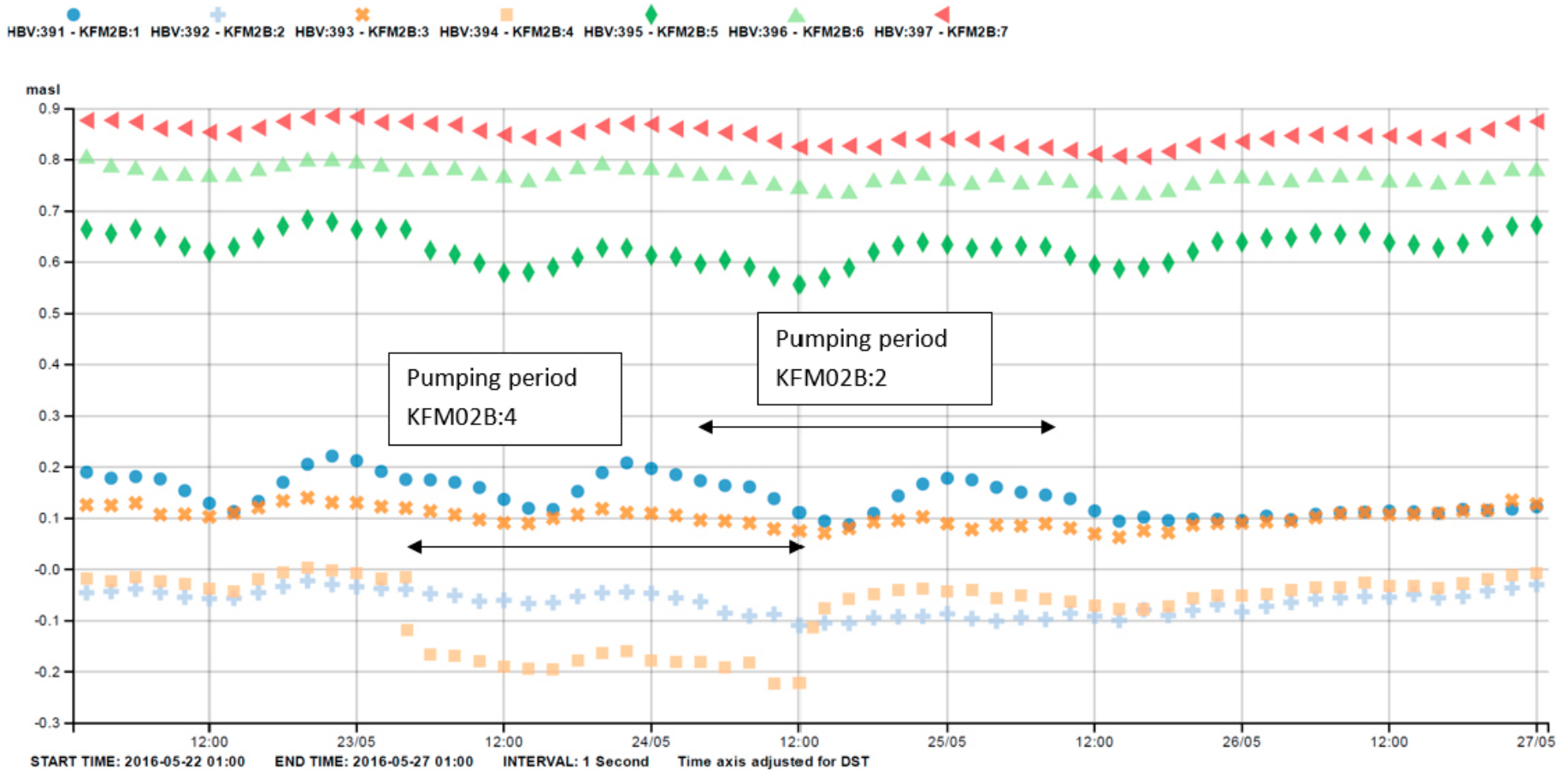
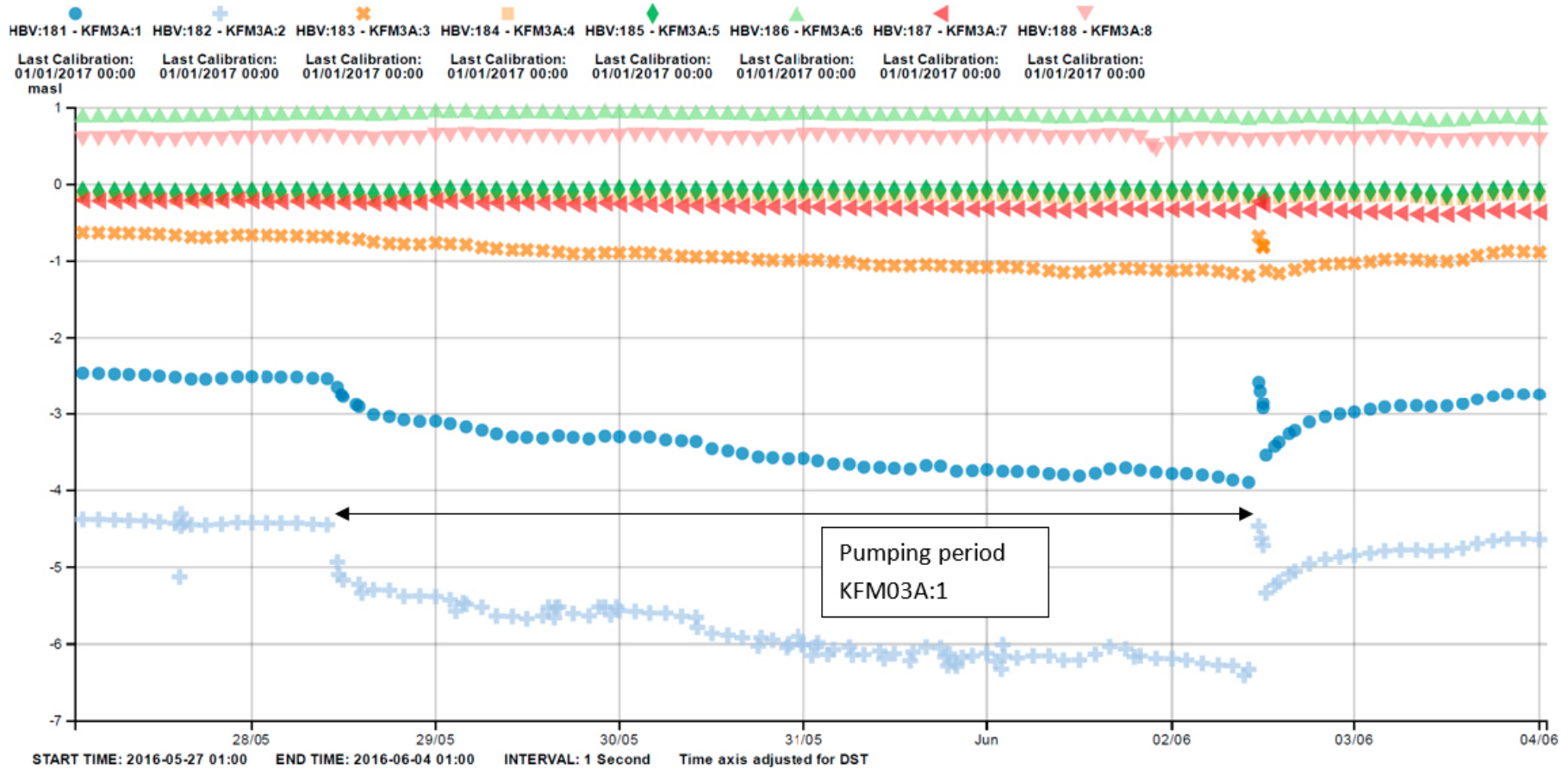
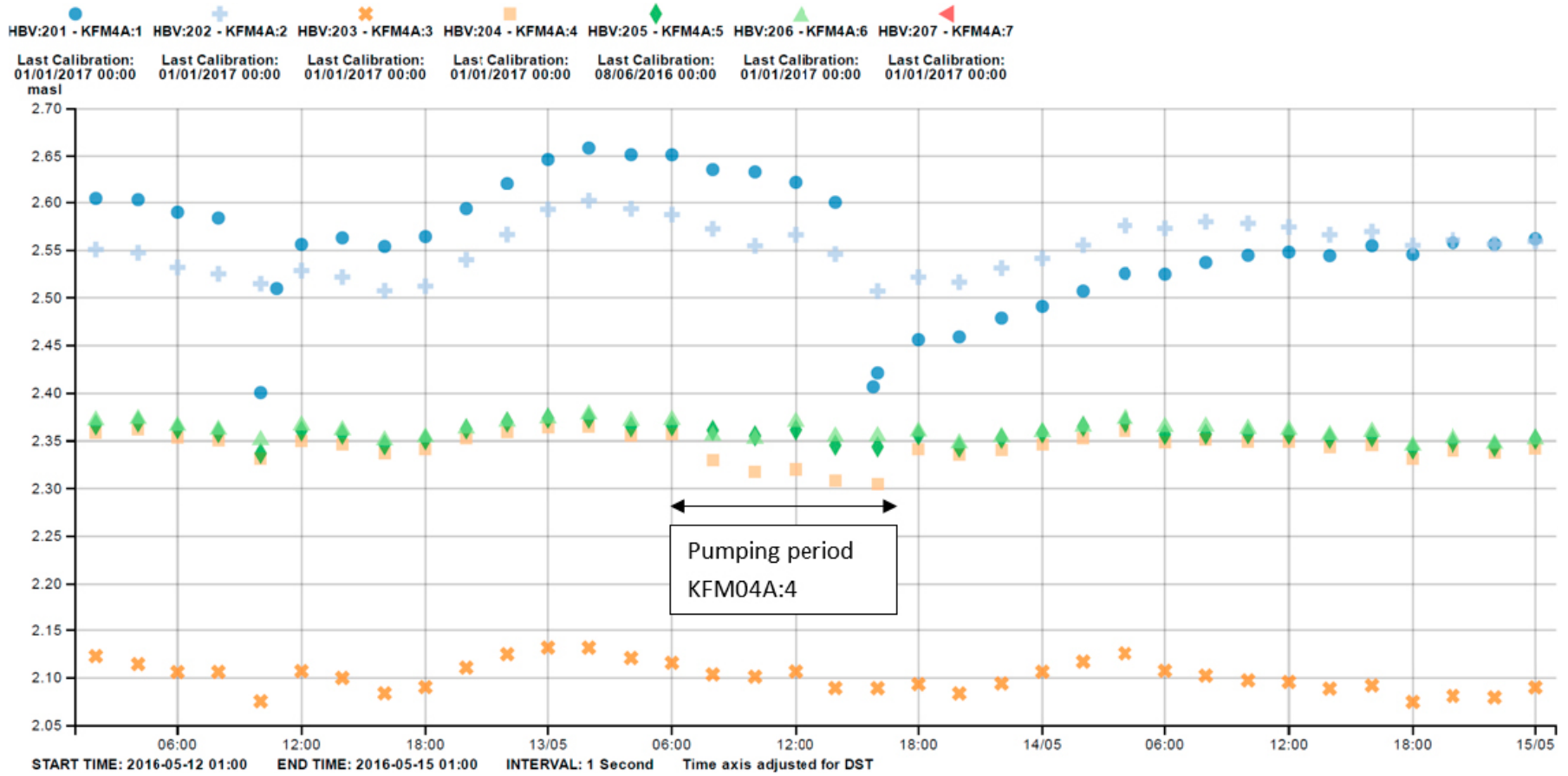


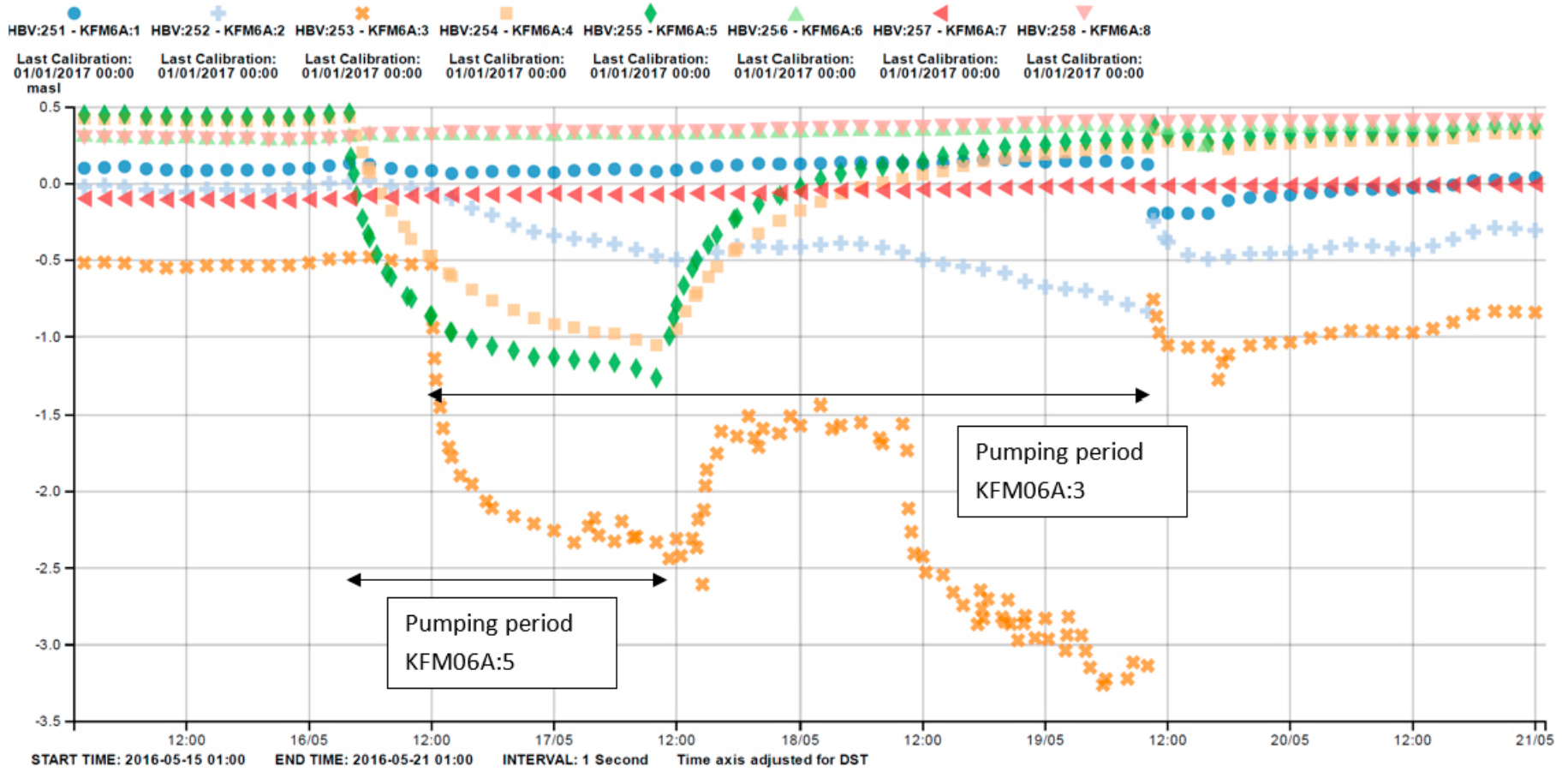
Figure A4-5. Pumping and drawdown in KFM02B:4 and KFM02B:2 in May 2016. No other sections were affected.



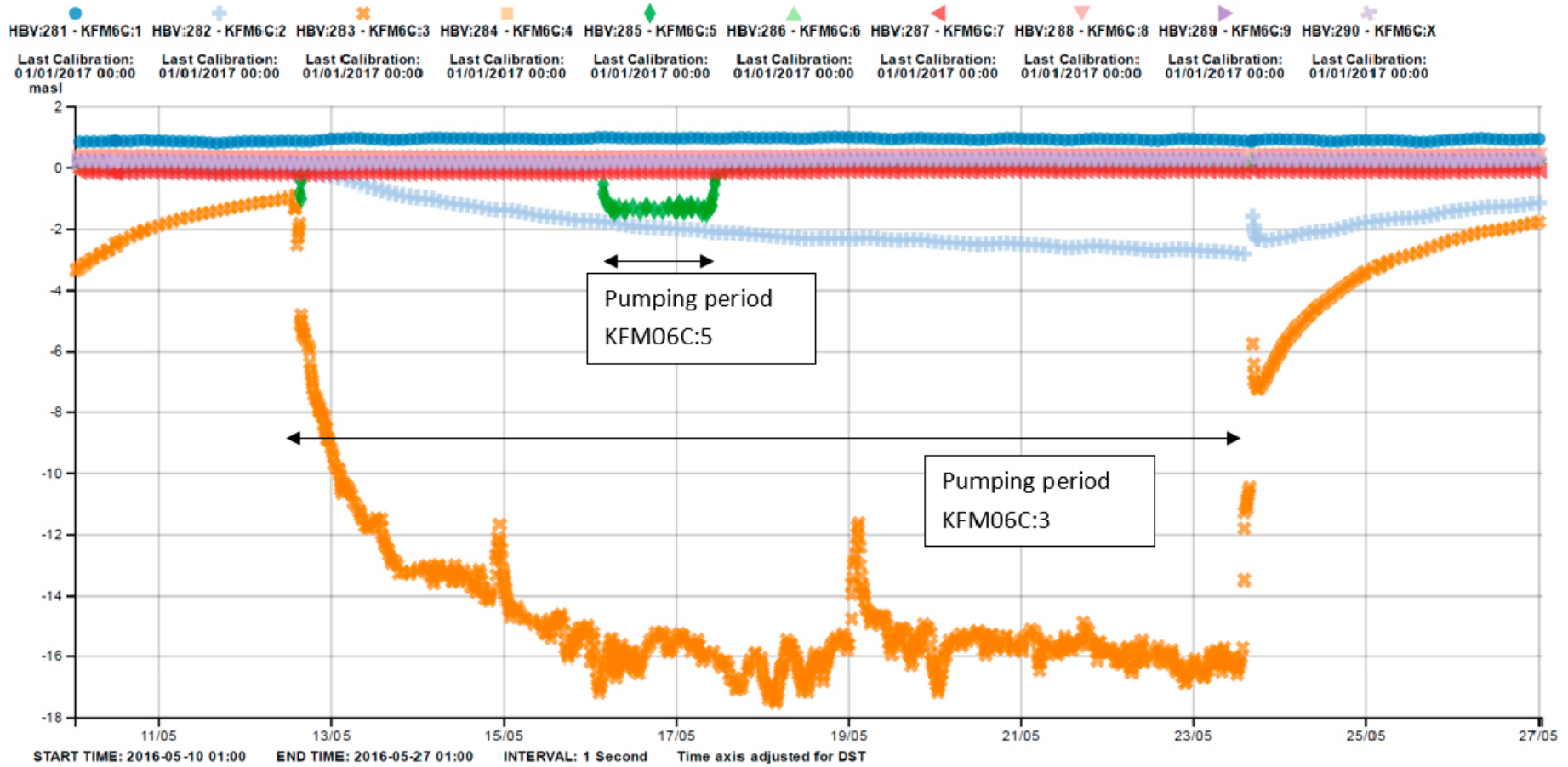
**Figure A4-6.** Pumping and drawdown in KFM03A:1 in May–June 2016. The pressure response observed in KFM03A:2 during pumping in KFM03A:1 may be caused by a leaking connection in the equipment between sections KFM03A:1 and KFM03A:2 rather than a connected fracture system. A small response was also seen in KFM03A:3.



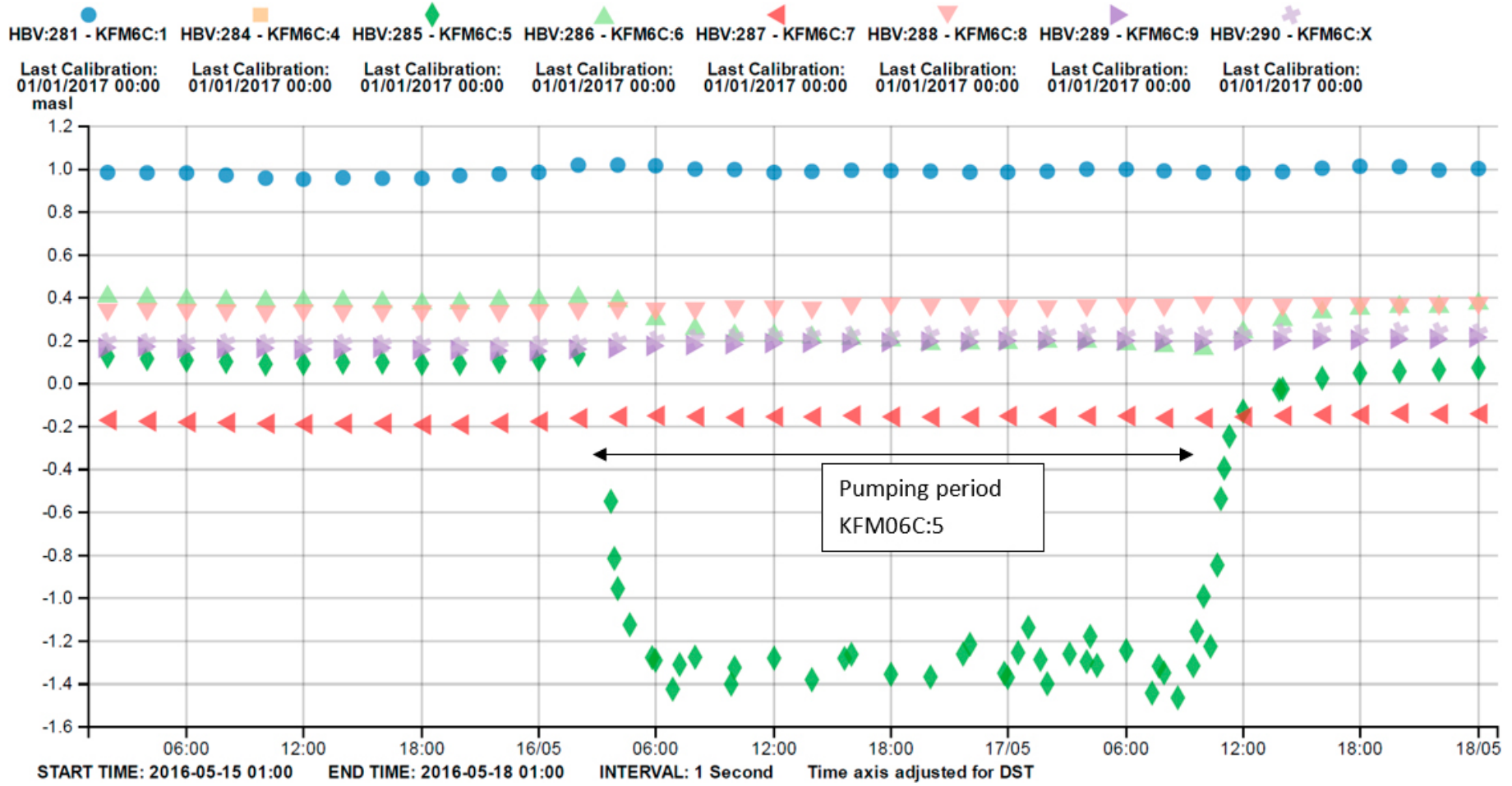
**Figure A4-7.** Pumping and drawdown in KFM04A:4 in May 2016. None of the other sections were significantly affected by the pumping. In section 7 the pressure measurements were non-functioning during the sampling period.



**Figure A4-8.** Pumping and drawdown in KFM06A:3 and KFM06A:5 in May 2016. Section KFM06A:2 was affected by the pumping in KFM06A:3. KFM06A:4 was effected by the pumping in section KFM06A:5. Temporary pressure increase due to decreased pumping flow in the middle of the pumping period in KFM06A:3.

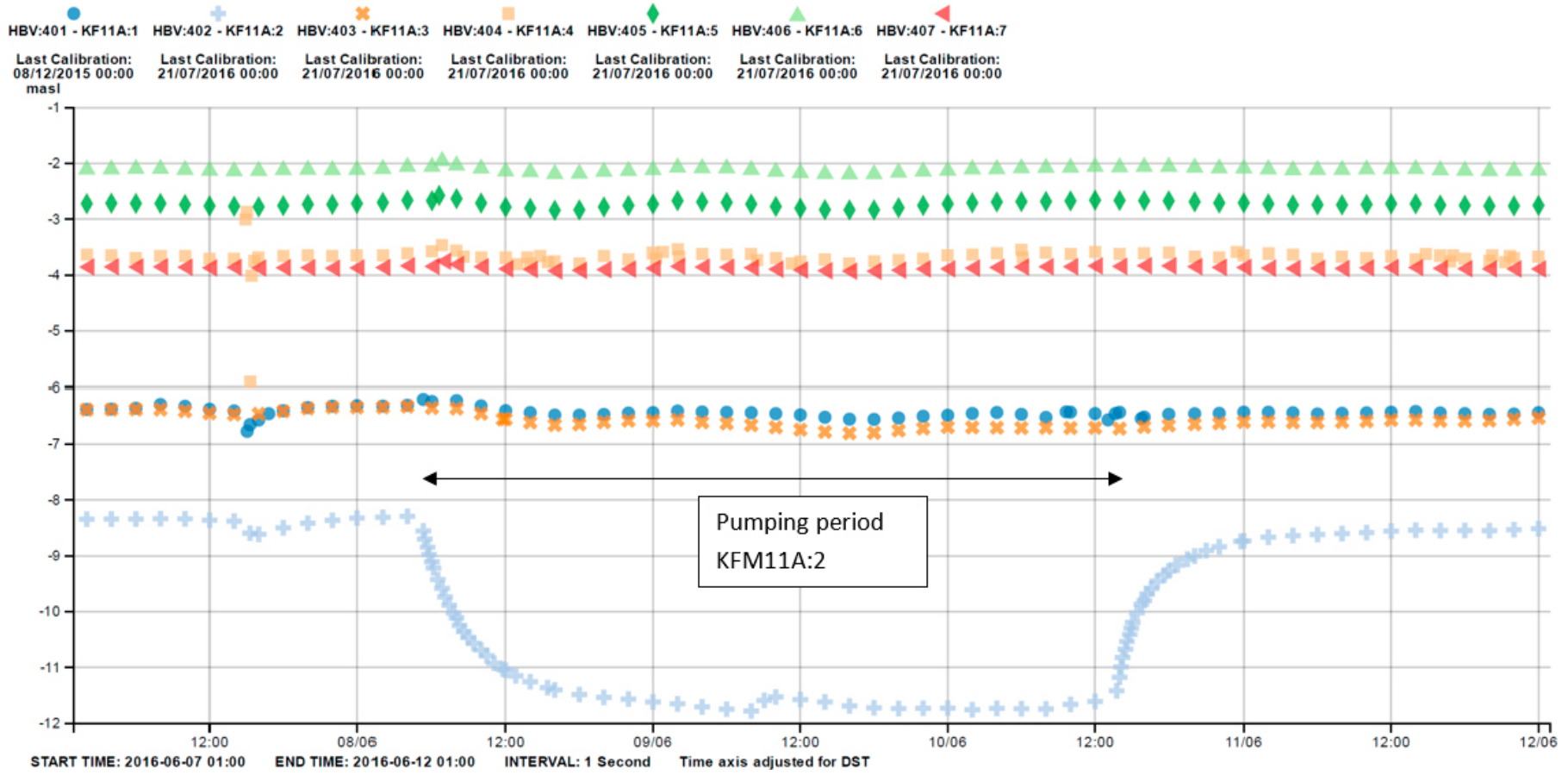


**Figure A4-9.** Pumping and drawdown in KFM06C:3 and KFM06C:5 in May 2016. Sections KFM06C:2 were affected by the pumping in section KFM06C:3. Usually, effects can be seen in KFM06C:4, but the pressure measurement in KFM06C:4 was non-functioning during this period. The pumping in section KFM06C:5 causes a response in KFM06C:6. For a more detailed plot of the pumping in KFM06C:5, see next figure.

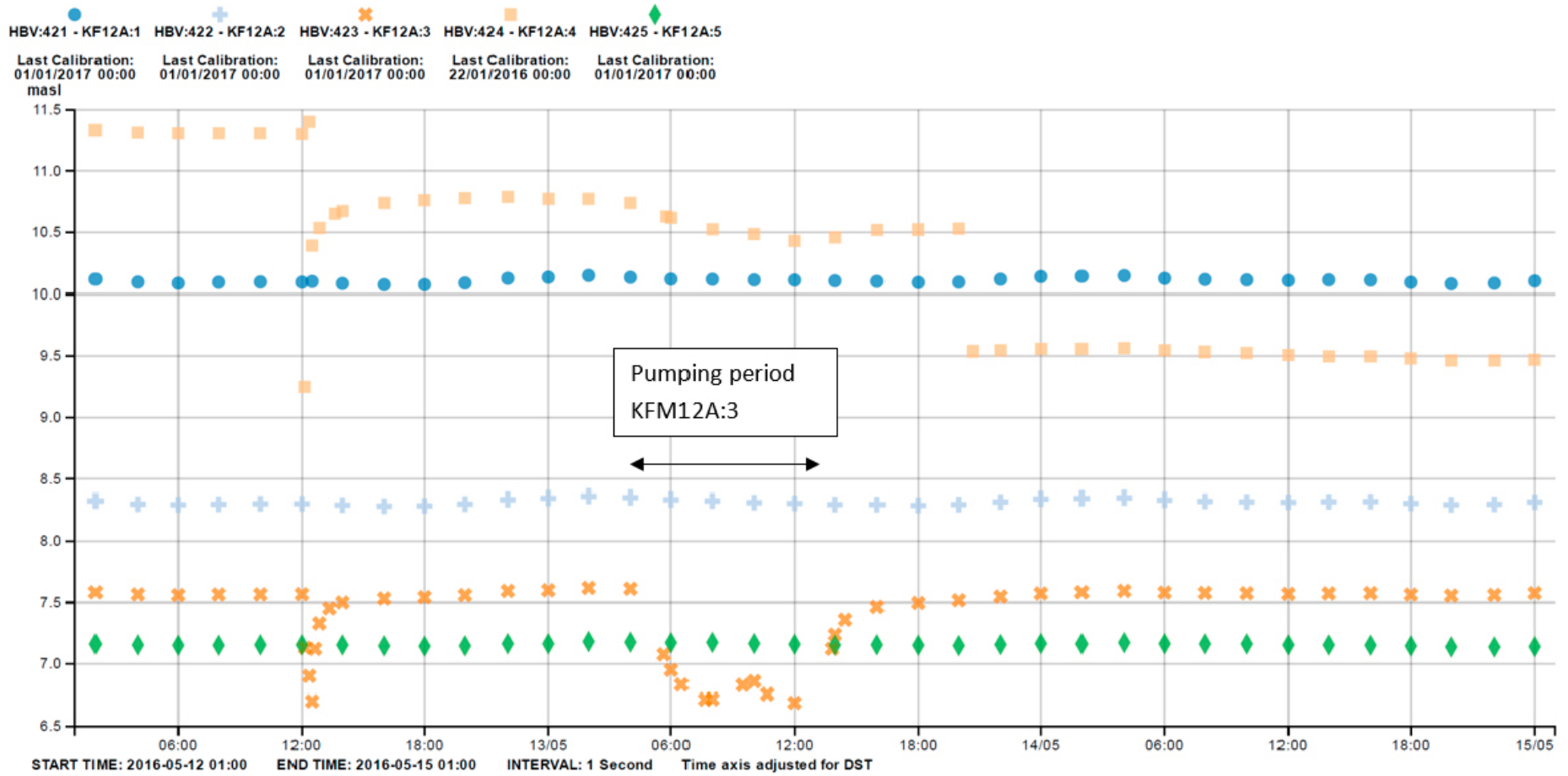


**Figure A4-10.** Detailed plot of pumping and drawdown in KFM06C:5 in May 2016. The pumping in section KFM06C:5 causes a response in KFM06C:6. The pressure measurement in KFM06C:4 was non-functioning during this period, but usually no effects caused by pumping in KFM06C:5 can be seen in KFM06C:4.





**Figure A4-11.** Pumping and drawdown in KFM11A:2 in June 2016. No other sections were affected. The pressure measurements in KFM11A:2 are not yet quality checked for this period due to uncertain manual readings of the water level which means that the absolute level is uncertain. The pressure measurements are however functioning and a change in pressure caused by pumping in KFM11A:2 would have been seen if there was one.



**Figure A4-12.** Pumping and drawdown in KFM12A:3 in May 2016. The pressure measurements in the section KFM12A:4 are not quality checked during this period. The pressure measurements in this sections are disturbed by gas and are not reliable. Normally clear effects can be seen in KFM12A:4.

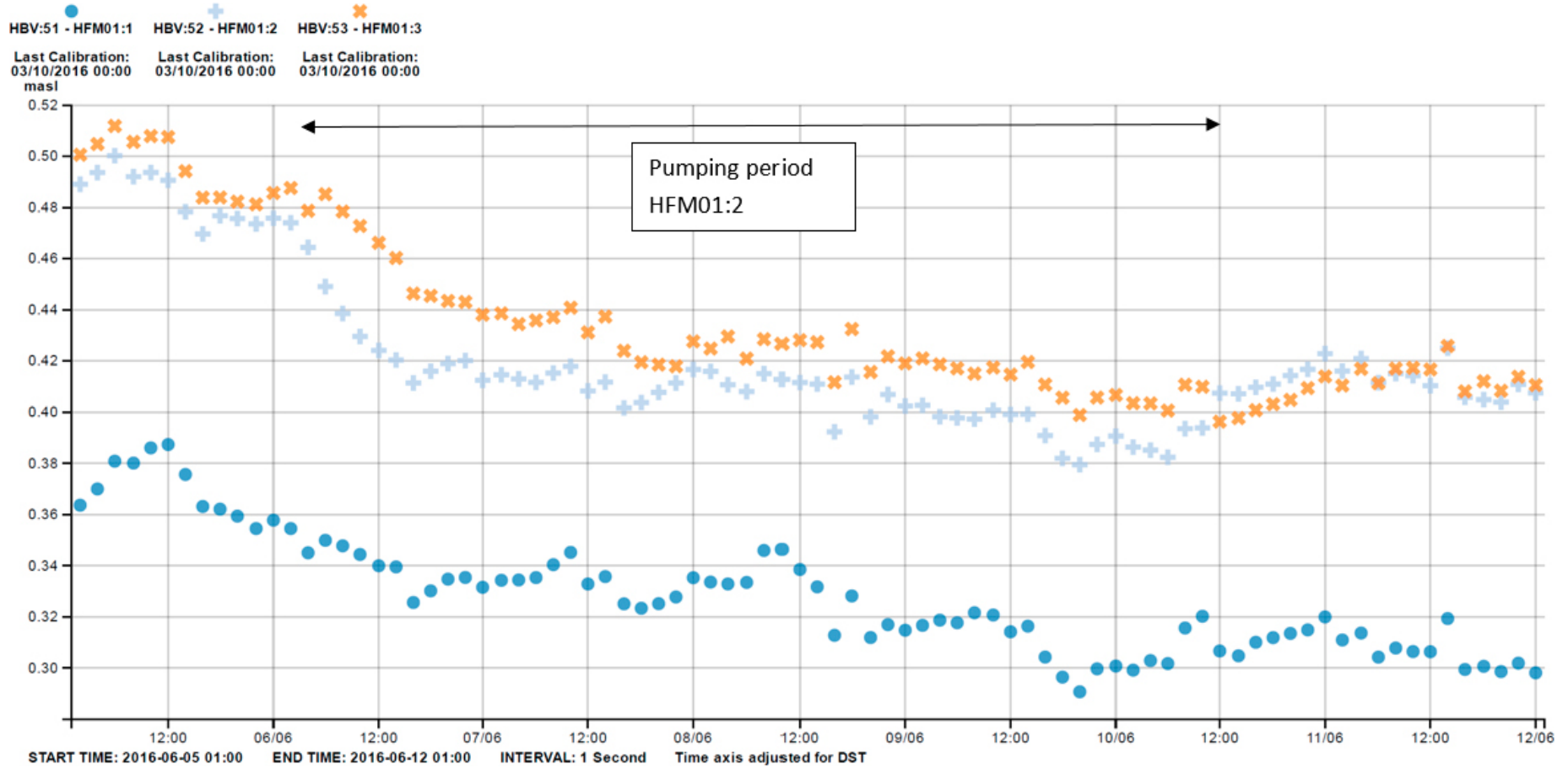


Figure A4-13. Pumping and drawdown in HFM01:2 in June 2016. A possible pressure response was observed in section HFM01:3.



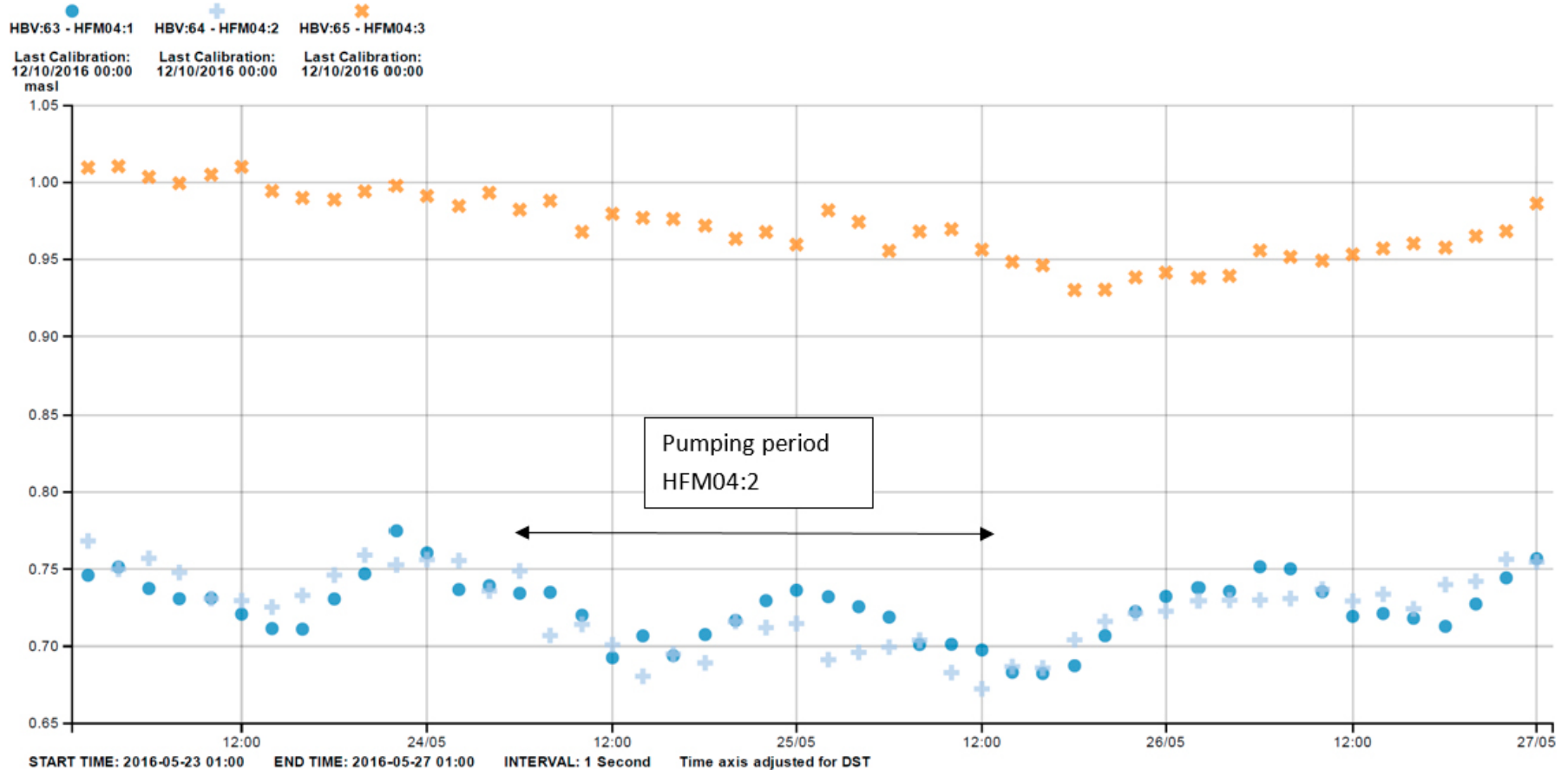


Figure A4-15. Pumping in HFM04:2 in May 2016. No significant drawdown was seen in any section at pump start.

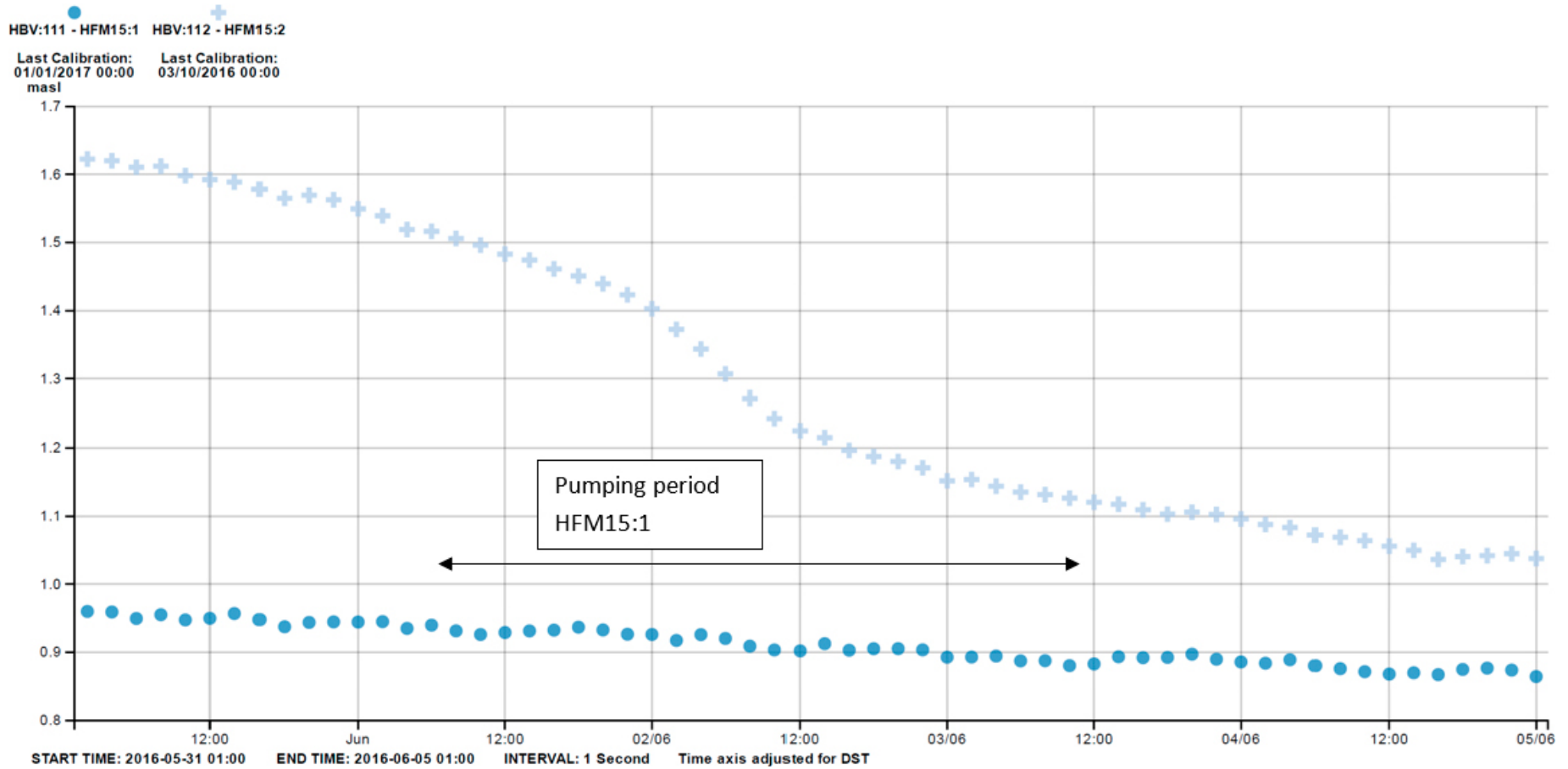


Figure A4-16. Pumping in HFM15:1 during June 2016. No significant drawdown was observed in any of the borehole sections.

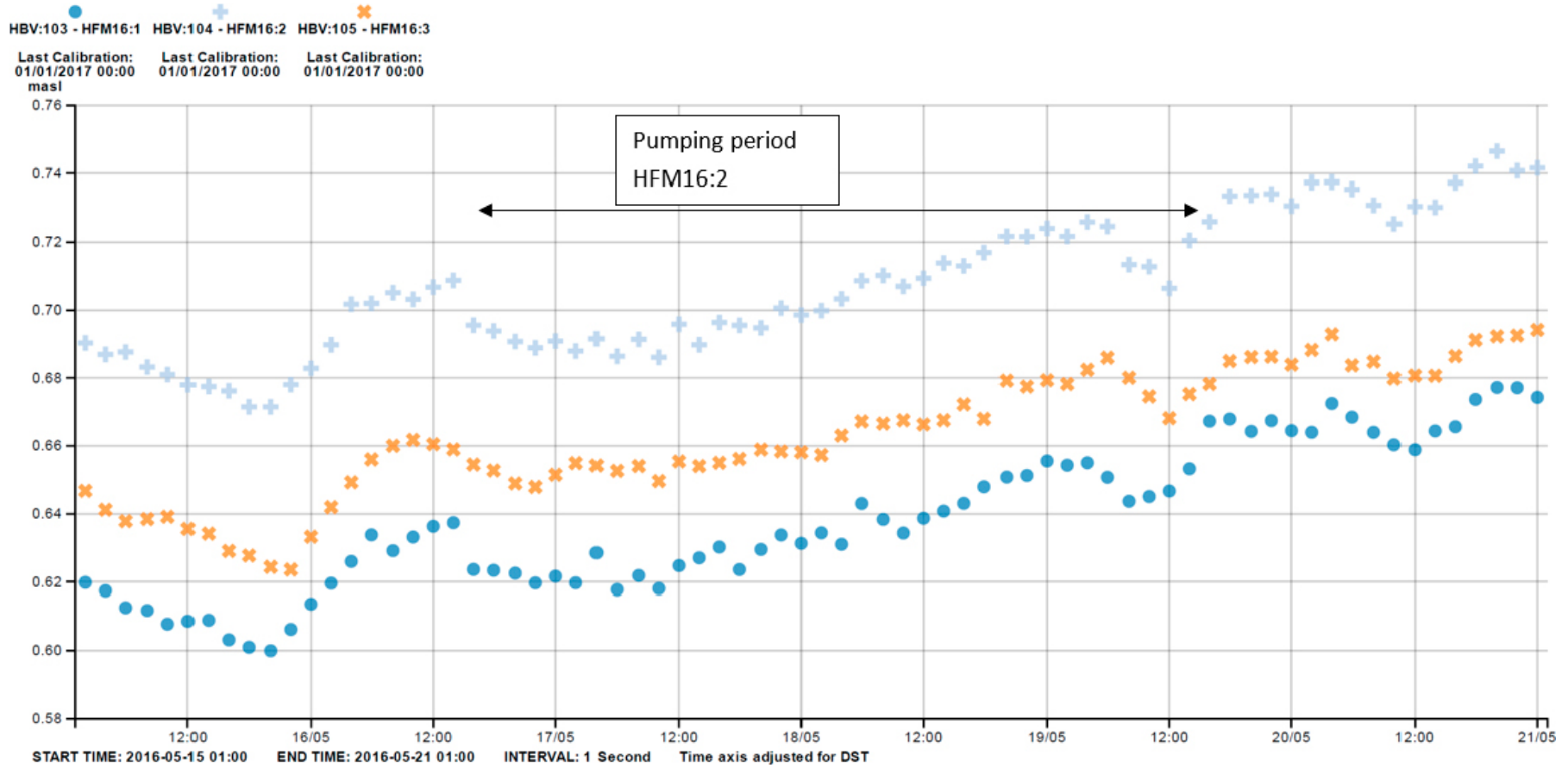


Figure A4-17. Pumping in HFM16:2 in May 2016. No significant drawdown was observed in any of the borehole sections.

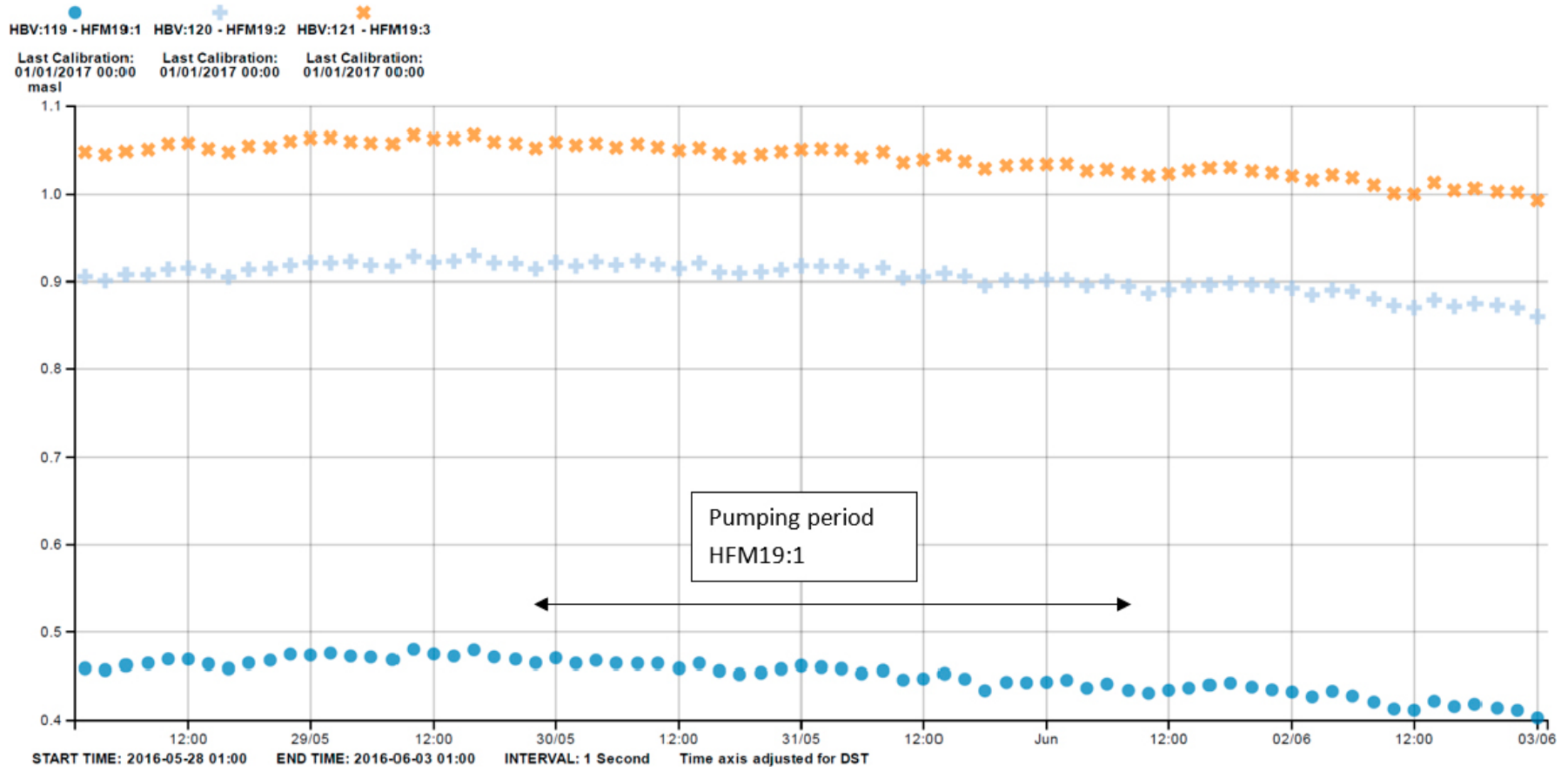


Figure A4-18. Pumping in HFM19:1 in May – June 2016. No significant drawdown was observed in any of the borehole sections.



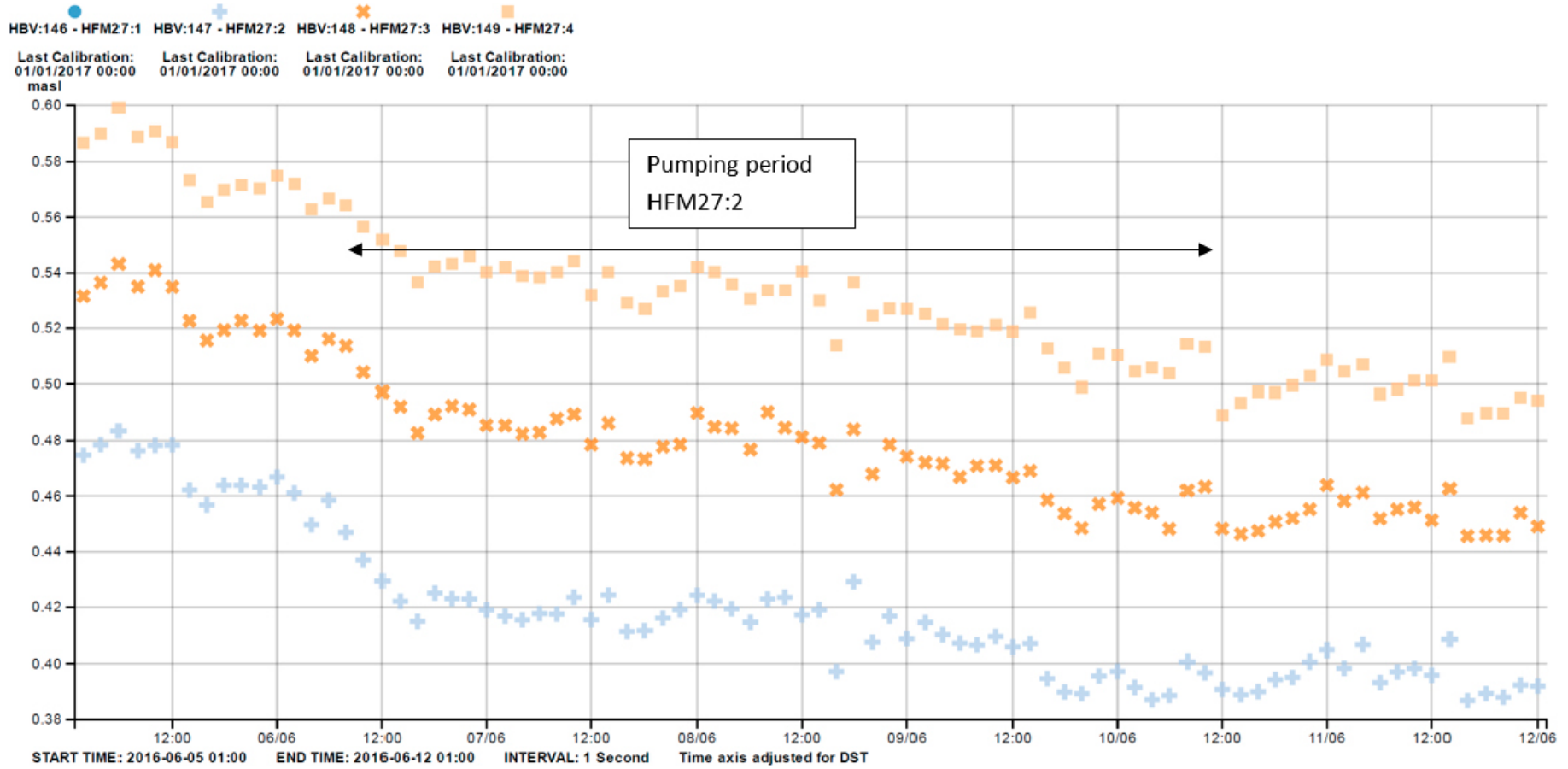


Figure A4-19. Pumping in HFM27:2 in June 2016. No significant drawdown was observed in any of the borehole sections.

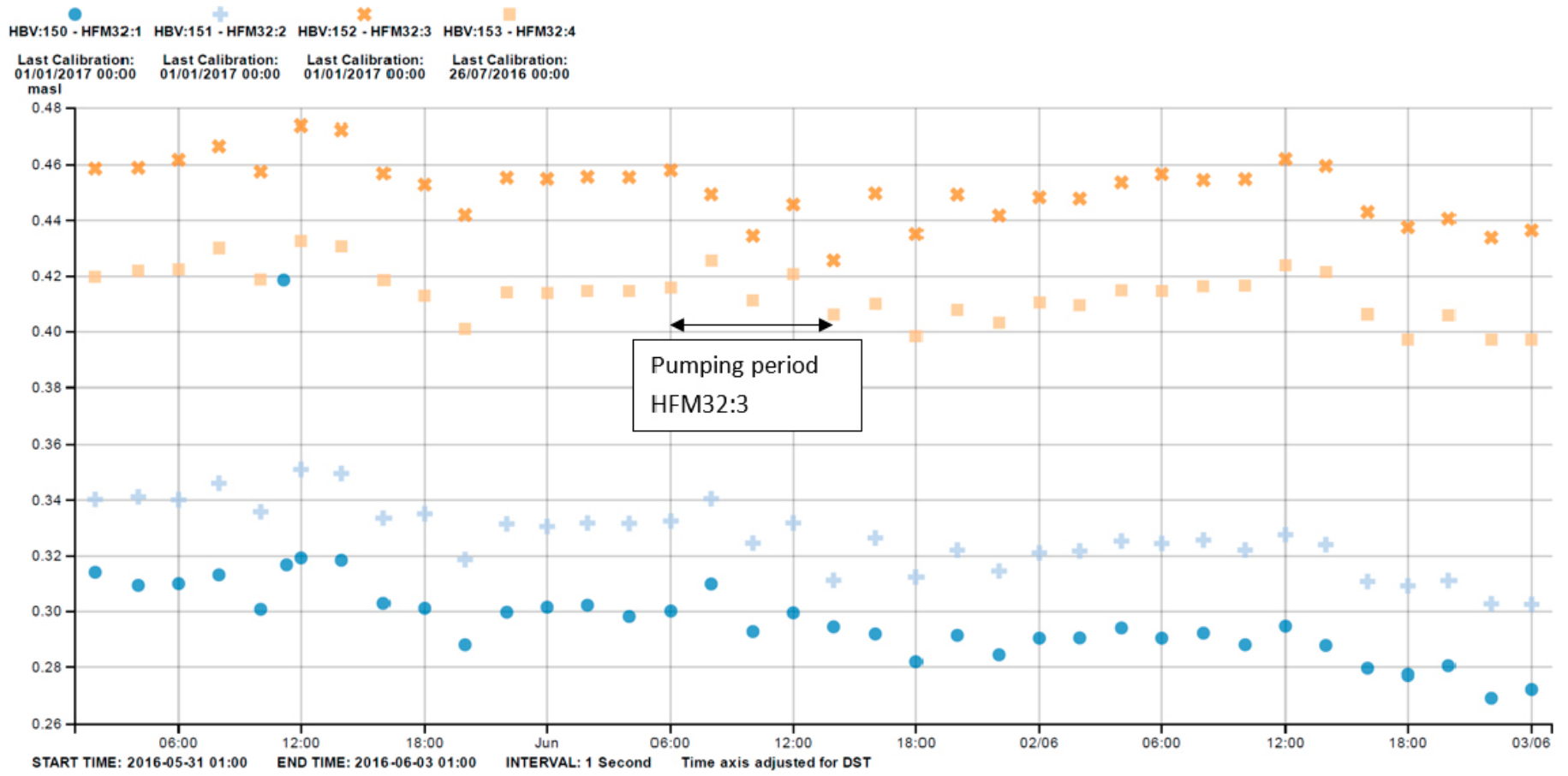
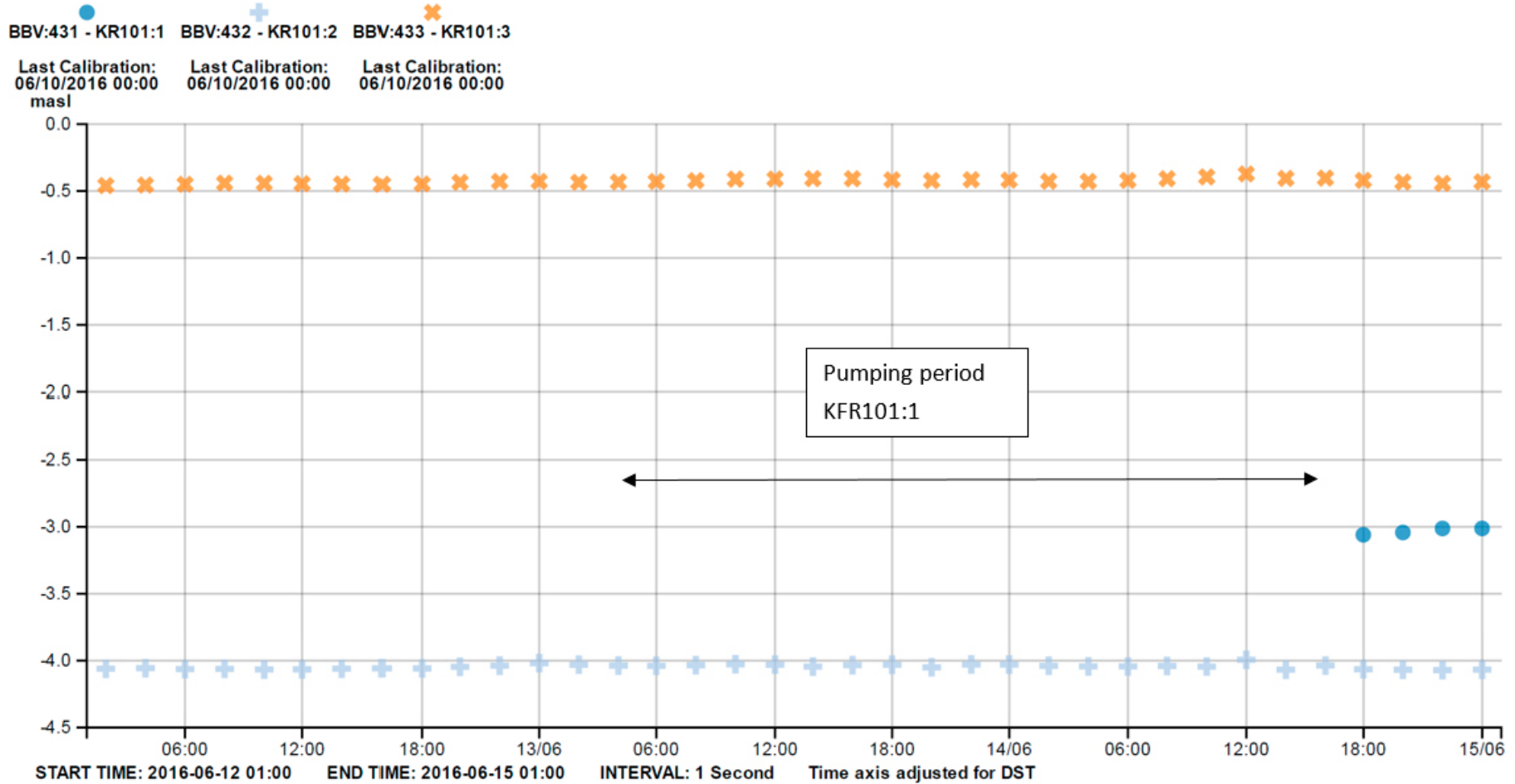


Figure A4-20. Pumping and minor drawdown in HFM32:3 in June 2016. No significant drawdown was observed in any of the borehole sections.



**Figure A4-21.** Pumping in KFR101:1 in June 2016. The pressure transducer in KFR101:1 was lifted during the pumping. No significant drawdown was noted in any other section.

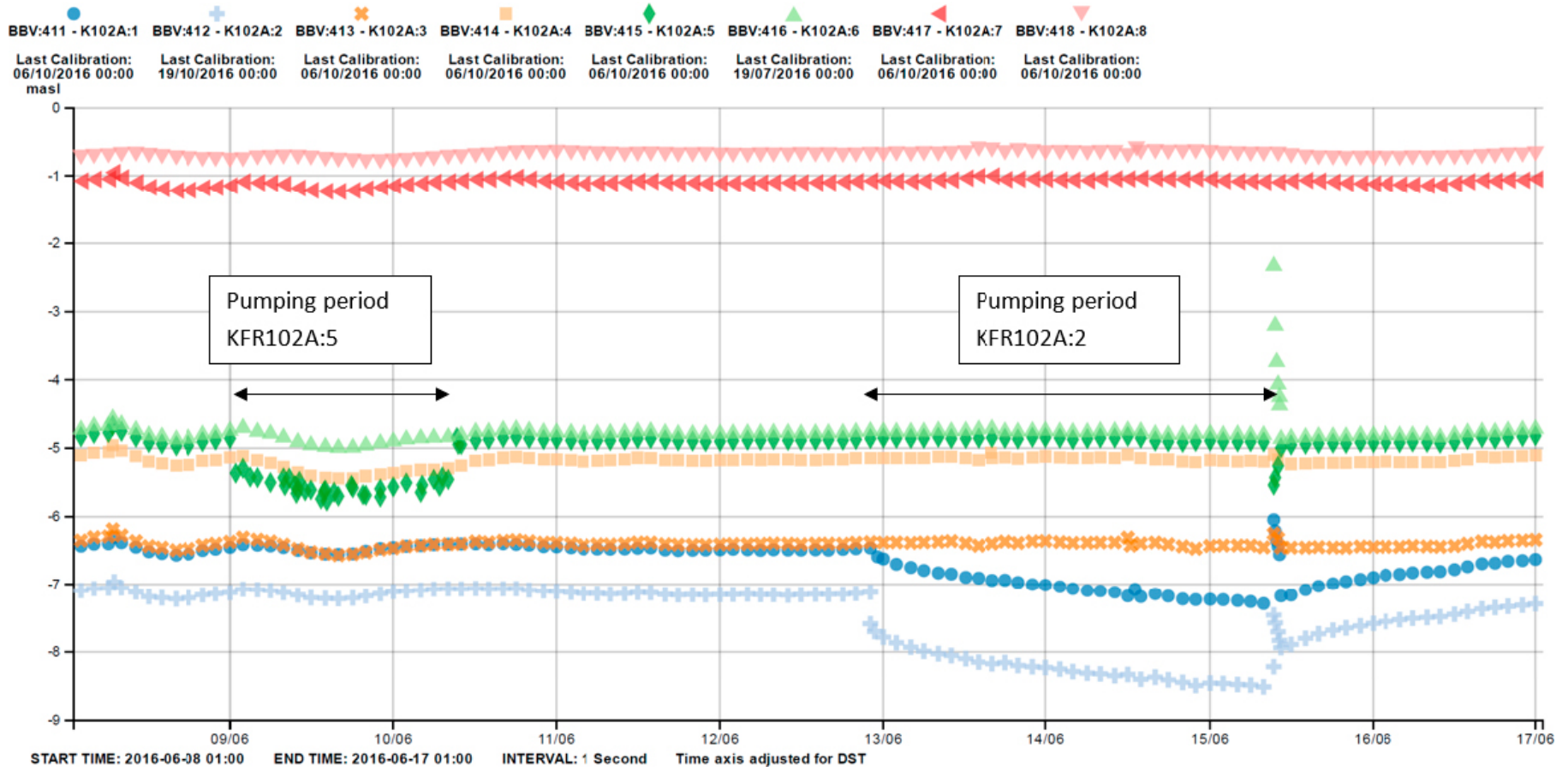


Figure A4-22. Pumping and drawdown in KFR102A:2 and KFR102A:5 in June 2016. A clear response in KFR102A:1 was observed during pumping in KFR102A:2.

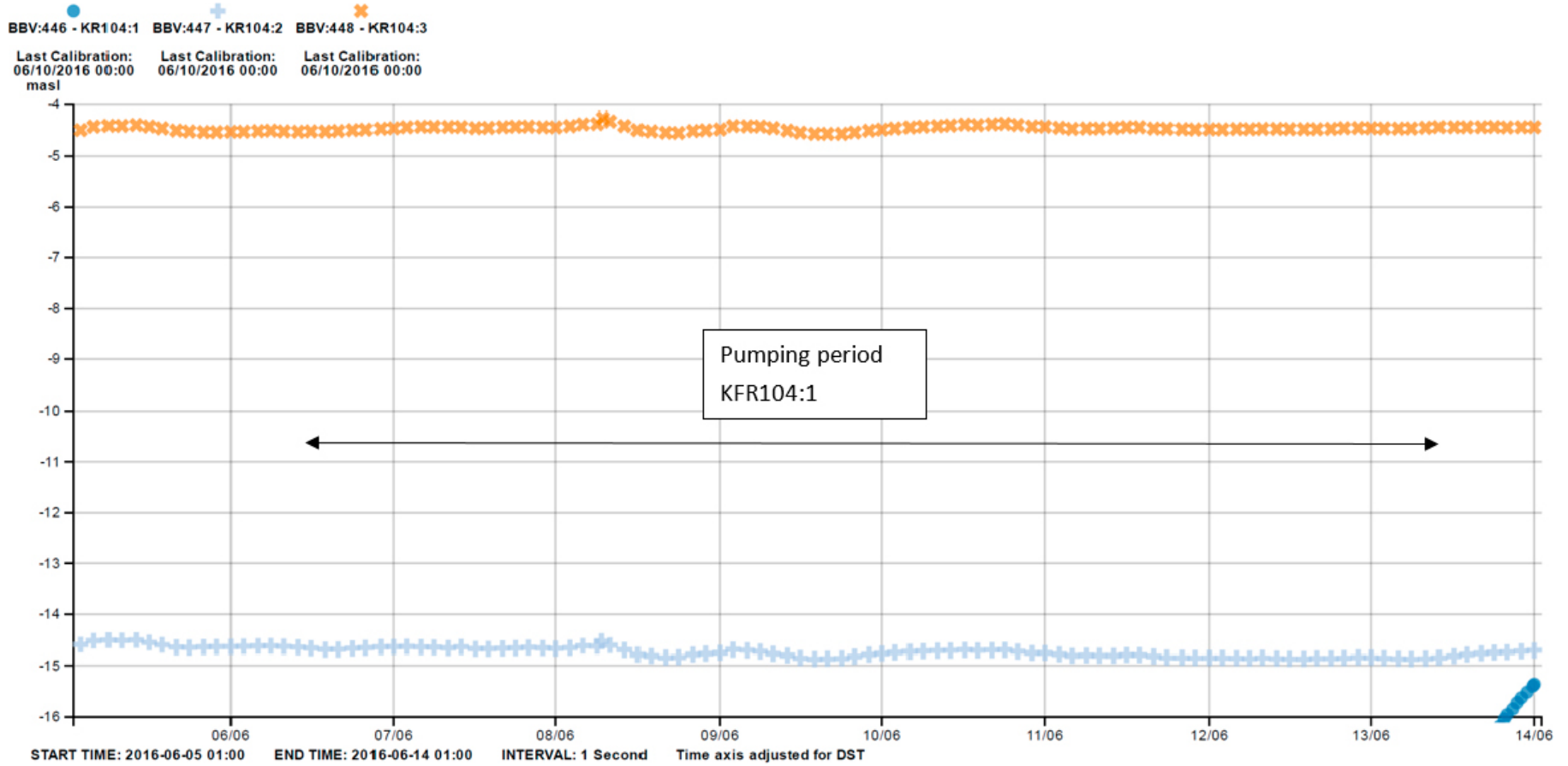


Figure A4-23. Pumping in KFR104:1 in June 2016. The pressure transducer in KFR104:1 was lifted during the pumping. A possible response was seen in section KFR104:2.

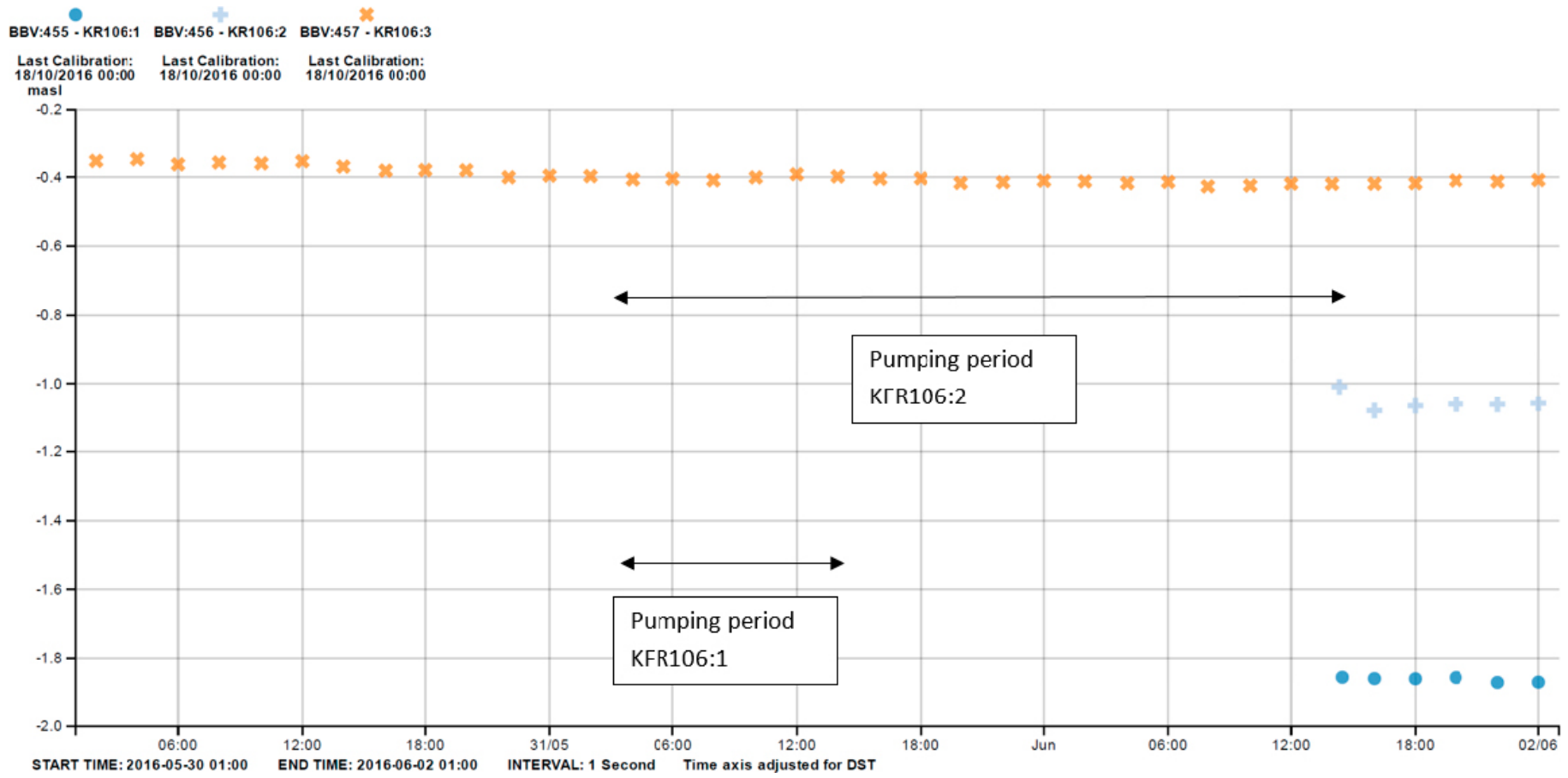


Figure A4-24. Pumping in KFR106:1 and KFR106:2 in May–June 2016. The pressure transducers in the pumped sections were lifted during the pumping. KFR106:3 was not affected.

## Sampling and analytical methods

**Table A5-1. Sample handling routines and analytical methods.**

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab
Anions 1	HCO <sub>3</sub> pH(lab) Cond (lab)	Plastic	250	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	The same day – maximum 24 hours
Anions 2	Cl, SO <sub>4</sub> , Br <sup>-</sup> , F <sup>-</sup> , I <sup>-</sup>	Plastic	100	Yes (not in the field)	No	Titration (Cl <sup>-</sup> ) IC (Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> , Br <sup>-</sup> , F <sup>-</sup> ) ISE (F <sup>-</sup> )	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	Not critical (month)
Cations, Si and S according to SKB class 3	Na, K, Ca, Mg, S(tot), Si(tot), Li, Sr	Plastic (at low conc. acid washed bottles)	100	Yes (not in the field)	Yes (not in the field, 1 mL HNO <sub>3</sub> )	ICP-AES ICP-MS	Not critical (month)
Cations, Si and S according to SKB class 4 and 5	Na, K, Ca, Mg, S(tot), Si(tot), Fe, Mn, Li, Sr	Plastic (Acid washed)	100	Yes (immediately in the field)	Yes (1 mL HNO <sub>3</sub> )	ICP-AES ICP-MS	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	500	Yes	Yes (5 mL HCl))	Spectrophotometry Ferrozine method	As soon as possible the same day
Hydrogen sulphide	HS-	Glass (Winkler)	About 120×2	No	Opt. 1 mL 1 M NaOH+ 1 mL 1 M ZnAc	Spectrophotometry	Immediately or if conserved, a few days
Environmental metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn	Plastic (Acid washed)	100	Yes	Yes (1 mL HNO <sub>3</sub> )	ICP-AES ICP-MS	Not critical (month)
Lantanoids, U, Th and so on	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Ti, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th	Plastic (Acid washed)	100	Yes	Yes (1 mL HNO <sub>3</sub> )	ICP-AES ICP-MS	Not critical (month)
Dissolved organic Carbon, dissolved inorganic Carbon	DOC, DIC	Plastic	250 25	Yes	Frozen, transported in isolated bag	UV oxidation, IR	Short transportation time
Total organic Carbon	TOC	Plastic	250 25	No	Frozen, transported in isolated bag	UV oxidation, IR	Short transportation time

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab
Environmental isotopes	$\delta^2\text{H}$ , $\delta^{18}\text{O}$	Plastic	100	No	– –	MS	Not critical (month)
Tritium, Chlorine-37	$^3\text{H}$ (enhanced) $\delta^{37}\text{Cl}$	Plastic (dry bottle) Plastic	500 100	No No	– –	LSC MS	Not critical (month)
Carbon isotopes	$^{13}\text{C}$ , $^{14}\text{C}$	Glass (brown)	100×2	No	–	(A)MS	A few days
Sulphur isotopes	$\delta^{34}\text{S}$	Plastic	500–1 000	Yes	–	Combustion, MS	No limit
Strontium-isotopes	$^{87}\text{Sr}/^{86}\text{Sr}$	Plastic	100	Yes	–	TIMS	Days or Week
Uranium and Thorium isotopes	$^{234}\text{U}$ , $^{235}\text{U}$ , $^{238}\text{U}$ , $^{230}\text{Th}$ , $^{232}\text{Th}$ ,	Plastic	50	No	–	Alfa spectroscopy	No limit
Boron isotopes	$^{10}\text{B}$	Plastic	100	Yes	Yes (1 mL $\text{HNO}_3$ )	ICP – MS	No limit
Radon and Radium isotopes	$^{222}\text{Rn}$ , $^{226}\text{Ra}$	Plastic	500	No	No	LSS	Immediate transport
Dissolved gas (content and composition)	Ar, $\text{N}_2$ , $\text{CO}_2$ , $\text{O}_2$ , $\text{CH}_4$ , $\text{H}_2$ , $\text{CO}$ , $\text{C}_2\text{H}_2$ , $\text{C}_2\text{H}_4$ , $\text{C}_2\text{H}_6$ , $\text{C}_3\text{H}_8$	Cylinder of stainless steel	200	No	No	GC	Immediate transport
Colloids	Filter series and fractionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 $\mu\text{m}$	–	$\text{N}_2$ atmosphere	ICP-AES ICP-MS	Immediate transport
Humic and fulvic acids	Fractionation	Fractions are collected in plastic bottles	250	–	$\text{N}_2$ atmosphere	UV oxidation, IR (DOC)	Immediate transport
Archive samples with acid	–	Plastic (washed in acid)	100×2**	Yes	Yes (1 mL $\text{HNO}_3$ )	–	Storage in freeze container
Archive samples without acid	–	Plastic	250×2**	Yes	No	–	Storage in freeze container
Carbon isotopes in humic and fulvic acids	$\delta^{13}\text{C}$ , $^{14}\text{C}$ (pMC)	DEAE cellulose (anion exchanger)	–	–	–	(A)MS	A few days
Nutrient salt + silicate	$\text{NO}_2$ , $\text{NO}_3$ , $\text{NO}_2+\text{NO}_3$ , $\text{NH}_4$ , $\text{PO}_4$ , $\text{SiO}_4$	Sample tubes, plastic	25×2	Yes (in the field)	No, frozen immediately***	Spectrophotometry	Short transportation time
Total concentrations of Nitrogen and Phosphorous	N-tot, P-tot	Plastic	100	No	No, frozen immediately***	Spectrophotometry	Short transportation time



Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab
Particulate Carbon, Nitrogen and Phosphorous	POC, PON, POP	Plastic	1 000	Yes (within 4 h) prepared filters. Blank filters	Filtering, the filters are frozen immediately 2 filters/sample	Elementar-analysator (N, C) own method 990121 (P)	Short transportation time
Chlorophyll	Chlorophyll a, c and pheopigment	Plastic	1 000–2 000	Yes (within 4 h)	Filtering, the filters are frozen immediately	Spectrophotometry Fluorometry	Short transportation time
Oxygen	Dissolved O <sub>2</sub>	Winkler, glass	2×ca 120	No	Mn (II) reagent Iodide reagent	Spectrophotometry SIS SS-EN 25813	Within 3 days
Archive samples for supplementary radio nuclides		Plastic	5 000	No	50 mL HNO <sub>3</sub>	–	Storage in freeze container

\* Suprapur acid is used for conservation of samples.

\*\* Minimum number. The number of archive samples can vary depending on the number of similar samples collected at the same occasion.

\*\*\* The sample is transported in frozen condition to the laboratory. It is possible that the silicate concentration can change due to polymerisation for this reason.

#### Abbreviations and definitions:

<b>IC</b>	Ion chromatograph
<b>ISE</b>	Ion selective electrode
<b>ICP-AES</b>	Inductively Coupled Plasma Atomic Emission Spectrometry
<b>ICP-MS</b>	Inductively Coupled Plasma Mass Spectrometry
<b>INAA</b>	Instrumental Neutron Activation Analysis
<b>MS</b>	Mass Spectrometry
<b>TIMS</b>	Thermal Ionization Mass Spectrometer
<b>LSC</b>	Liquid Scintillation Counting
<b>(A)MS</b>	(Accelerator) Mass Spectrometry
<b>GC</b>	Gas Chromatography
<b>LSS</b>	Liquid Scintillation Spectroscopy

**Table A5-2. Reporting limits and measurement uncertainties.**

Component	Method <sup>1)</sup>	Reporting limits (RL), detection limits (DL) or range <sup>2)</sup>	Unit	Measurement uncertainty <sup>3)</sup>
pH	Potentiometric	3–10	pH unit	±0.1
EC	Electrical Conductivity meas.	1–150 150–10 000	mS/m	5 % 3 %
HCO <sub>3</sub>	Alkalinity titration	1	mg/L	4 %
Cl <sup>-</sup> Cl <sup>-</sup>	Mohr-titration IC	≥ 70 0.5–70	mg/L	5 % 8 %
SO <sub>4</sub>	IC	0.5	mg/L	12 %
Br <sup>-</sup>	IC	DL 0.2, RL 0.5	mg/L	15 %
Br	ICP SFMS	0.001, 0.004, 0.010 <sup>4)</sup>	mg/L	25 % <sup>5)</sup>
F <sup>-</sup> F <sup>-</sup>	IC Potentiometric	DL 0.2, RL 0.5 DL 0.1, RL 0.2	mg/L	13 % 12 %
I <sup>-</sup>	ICP SFMS	0.001, 0.004, 0.010 <sup>4)</sup>	mg/L	25 % <sup>5)</sup>
Na	ICP AES	0.1	mg/L	13 %
K	ICP AES	0.4	mg/L	12 %
Ca	ICP AES	0.1	mg/L	12 %
Mg	ICP AES	0.09	mg/L	12 %
S(tot)	ICP AES	0.16	mg/L	12 %
Si(tot)	ICP AES	0.03	mg/L	14 %
Sr	ICP AES	0.002	mg/L	12 %
Li	ICP AES	0.004	mg/L	12.2 %
Fe	ICP AES	0.02	mg/L	13.3 % <sup>6)</sup>
Fe	ICP SFMS	0.0004, 0.002, 0.004 <sup>4)</sup>	mg/L	20 % <sup>6)</sup>
Mn	ICP AES	0.003	mg/L	12.1 % <sup>5)</sup>
Mn	ICP SFMS	0.00003, 0.00004, 0.0001 <sup>4)</sup>	mg/L	53 % <sup>6)</sup>
Fe(II), Fe(tot)	Spectrophotometry	DL 0.006, RL 0.02	mg/L	0.005 (0.02–0.05 mg/L) 9 % (0.05–1 mg/L) 7 % (1–3 mg/L)
HS <sup>-</sup>	Spectrophotometry, SKB	SKB DL 0.006, RL 0.02	mg/L	32 %
HS <sup>-</sup>	Spectrophotometry, external laboratory	0.01	mg/L	0.02 (0.01–0.2 mg/L) 12 % (> 0.2 mg/L)
NO <sub>2</sub> as N	Spectrophotometry	0.1	µg/L	2 %
NO <sub>3</sub> as N	Spectrophotometry	0.2	µg/L	5 %
NO <sub>2</sub> +NO <sub>3</sub> as N	Spectrophotometry	0.2	µg/L	0.2 (0.2–20 µg/L) 2 % (> 20 µg/L)
NH <sub>4</sub> as N	Spectrophotometry, SKB	11	µg/L	30 % (11–20 µg/L) 25 % (20–50 µg/L) 12 % (50–1 200 µg/L)
NH <sub>4</sub> as N	Spectrophotometry external laboratory	0.8	µg/L	0.8 (0.8–20 µg/L) 5 % (> 20 µg/L)
PO <sub>4</sub> as P	Spectrophotometry	0.7	µg/L	0.7 (0.7–20 µg/L) 3 % (> 20 µg/L)
SiO <sub>4</sub>	Spectrophotometry	1	µg/L	2.5 % (> 100 µg/L)

Component	Method <sup>1)</sup>	Reporting limits (RL), detection limits (DL) or range <sup>2)</sup>	Unit	Measurement uncertainty <sup>3)</sup>
O <sub>2</sub>	Iodometric titration	0.2–20	mg/L	5 %
Chlorophyll a, c pheopigment <sup>7)</sup>	/1/	0.5	µg/L	5 %
PON <sup>7)</sup>	/1/	0.5	µg/L	5 %
POP <sup>7)</sup>	/1/	0.1	µg/L	5 %
POC <sup>7)</sup>	/1/	1	µg/L	4 %
Tot-N <sup>7)</sup>	/1/	10	µg/L	4 %
Tot-P <sup>7)</sup>	/1/	0.5	µg/L	6 %
Al,	ICP SFMS	0.2, 0.3, 0.7 <sup>4)</sup>	µg/L	17.6 % <sup>6)</sup>
Zn	ICP SFMS	0.2, 0.8, 2 <sup>4)</sup>	µg/L	15.5, 17.7, 25.5 % <sup>6)</sup>
Ba, Cr, Mo,	ICP SFMS	0.01, 0.04, 0.1 <sup>4)</sup>	µg/L	Ba 15 % <sup>4)</sup> , Cr 22 % <sup>5)</sup> Mo 39 % <sup>6)</sup>
Pb	ICP SFMS	0.01, 0.1, 0.3 <sup>4)</sup>	µg/L	15 % <sup>6)</sup>
Cd	ICP SFMS	0.002, 0.02, 0.5 <sup>4)</sup>	µg/L	15.5 % <sup>6)</sup>
Hg	ICP AFS	0.002	µg/L	10.7 % <sup>6)</sup>
Co	ICP SFMS	0.005, 0.02, 0.05 <sup>4)</sup>	µg/L	25.9 % <sup>6)</sup>
V	ICP SFMS	0.005, 0.03, 0.05 <sup>4)</sup>	µg/L	18.1 % <sup>6)</sup>
Cu	ICP SFMS	0.1, 0.2, 0.5 <sup>4)</sup>	µg/L	14.4 % <sup>6)</sup>
Ni	ICP SFMS	0.05, 0.2, 0.5 <sup>4)</sup>	µg/L	15.8 % <sup>6)</sup>
P	ICP SFMS	1, 5, 40 <sup>4)</sup>	µg/L	16.3 % <sup>6)</sup>
As	ICP SFMS	0.01 (520 mS/m)	µg/L	59.2 % <sup>6)</sup>
La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu	ICP SFMS	0.005, 0.02, 0.05 <sup>4)</sup>	µg/L	20 %, 20 %, 25 % <sup>6)</sup>
Sc, In, Th	ICP SFMS	0.05, 0.2, 0.5 <sup>4)</sup>	µg/L	25 % <sup>6)</sup>
Rb, Zr, Sb, Cs	ICP SFMS	0.025, 0.1, 0.25 <sup>4)</sup>	µg/L	15 %, 20 %, 20 % <sup>5)</sup> , 25 % <sup>6)</sup>
Tl	ICP SFMS	0.025, 0.1, 0.25 <sup>4)</sup>	µg/L	14.3 % <sup>5)</sup> and <sup>6)</sup>
Y, Hf	ICP SFMS	0.005, 0.02, 0.05 <sup>4)</sup>	µg/L	15 %, 20 %, 20 % <sup>5)</sup> , 25 % <sup>6)</sup>
U	ICP SFMS	0.001, 0.005, 0.01 <sup>4)</sup>	µg/L	13.5 %, 14.3 %, 15.9 % <sup>5)</sup> 19.1 %, 17.9 %, 20.9 % <sup>6)</sup>
DOC	UV oxidation, IR Carbon analysator	0.5	mg/L	8 %
TOC	UV oxidation, IR Carbon analysator	0.5	mg/L	10 %
δ <sup>2</sup> H	MS	2	‰ SMOW <sup>7)</sup>	0.9 (one standard deviation)
δ <sup>18</sup> O	MS	0.1	‰ SMOW <sup>7)</sup>	0.1 (one standard dev.)
<sup>3</sup> H	LSC	0.8	TU <sup>8)</sup>	0.8
δ <sup>37</sup> Cl	A (MS)	0.2	‰ SMOC <sup>10)</sup>	0.2 <sup>17)</sup>
δ <sup>13</sup> C	A (MS)	–	‰ PDB <sup>11)</sup>	0.3 <sup>17)</sup>
<sup>14</sup> C pmc	A (MS)	–	PMC <sup>12)</sup>	0.4 <sup>17)</sup>
δ <sup>34</sup> S	MS	0.2	‰ CDT <sup>13)</sup>	0.4 (one standard dev.)

Component	Method <sup>1)</sup>	Reporting limits (RL), detection limits (DL) or range <sup>2)</sup>	Unit	Measurement uncertainty <sup>3)</sup>
<sup>87</sup> Sr/ <sup>86</sup> Sr	TIMS	–	No unit (ratio) <sup>14)</sup>	0.00002
<sup>10</sup> B/ <sup>11</sup> B	ICP SFMS	–	No unit (ratio) <sup>14)</sup>	–
<sup>234</sup> U, <sup>235</sup> U, <sup>238</sup> U, <sup>232</sup> Th, <sup>230</sup> Th	Alfa spectr.	0.0001	Bq/L <sup>15)</sup>	≤ 5 % (Counting statistics uncertainty)
<sup>222</sup> Rn, <sup>226</sup> Ra	LSS	0.015	Bq/L	≤ 5 % (Count. stat. uncert.)

1) Many elements may be determined by more than one ICP technique depending on concentration range. The most relevant technique and measurement uncertainty for the concentrations normally encountered in groundwater are presented. In cases where two techniques were frequently used, both are displayed.

2) Reporting limits (RL), generally 10 × standard deviation, if nothing else is stated. Measured values below RL or DL are stored as negative values in SICADA (i.e. –RL value and –DL value).

3) Measurement uncertainty reported by the laboratory, generally as ± percent of measured value in question at 95 % confidence interval.

4) Reporting limits at electrical cond. 520 mS/m, 1440 mS/m and 3810 mS/m respectively.

5) Measurement uncertainty at concentrations 100 × RL.

6) Measurement uncertainty at concentrations 10 × RL.

7) Determined only in surface waters. PON, POP and POC refers to Particulate Organic Nitrogen, Phosphorous and Carbon, respectively.

8) Per mille deviation<sup>16)</sup> from SMOW (Standard Mean Oceanic Water).

9) TU=Tritium Units, where one TU corresponds to a tritium/hydrogen ratio of 10<sup>-18</sup> (1 Bq/L Tritium = 8.45 TU).

10) Per mille deviation<sup>16)</sup> from SMOC (Standard Mean Oceanic Chloride).

11) Per mille deviation<sup>16)</sup> from PDB (the standard PeeDee Belemnite).

12) The following relation is valid between pmC (percent modern carbon) and Carbon-14 age:  
 $pmC = 100 \times e^{((1950-y)-1.03t)/8274}$  where y = the year of the C-14 measurement and t = C-14 age.

13) Per mille deviation<sup>16)</sup> from CDT (the standard Canyon Diablo Troilite).

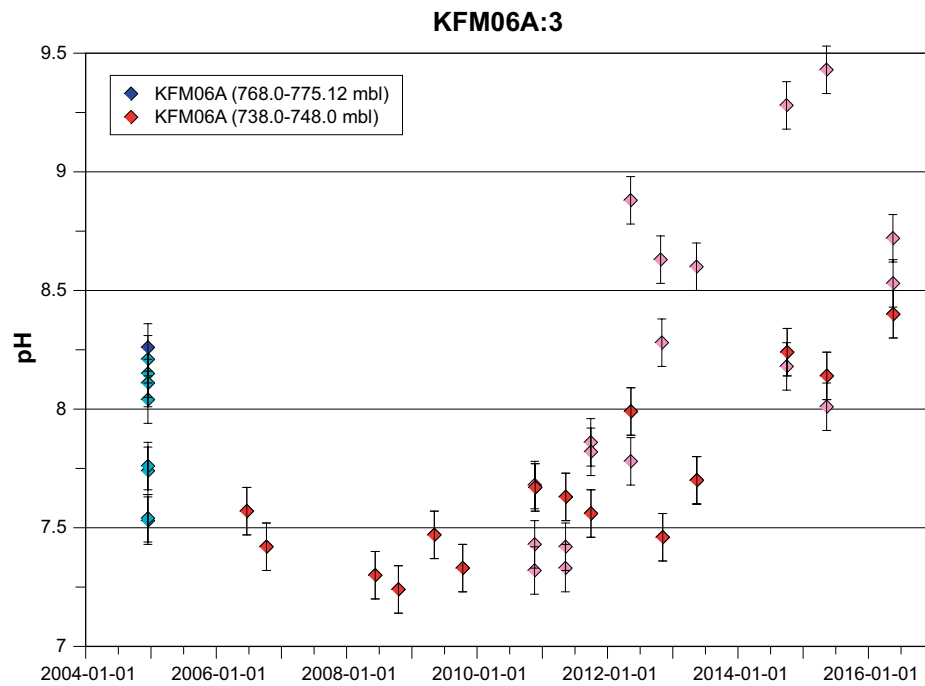
14) Isotope ratio without unit.

15) The following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232:  
 1 ppm U = 12.4 Bq/kg<sup>238</sup>U, 1 ppm Th = 3.93 Bq/kg<sup>232</sup>Th.

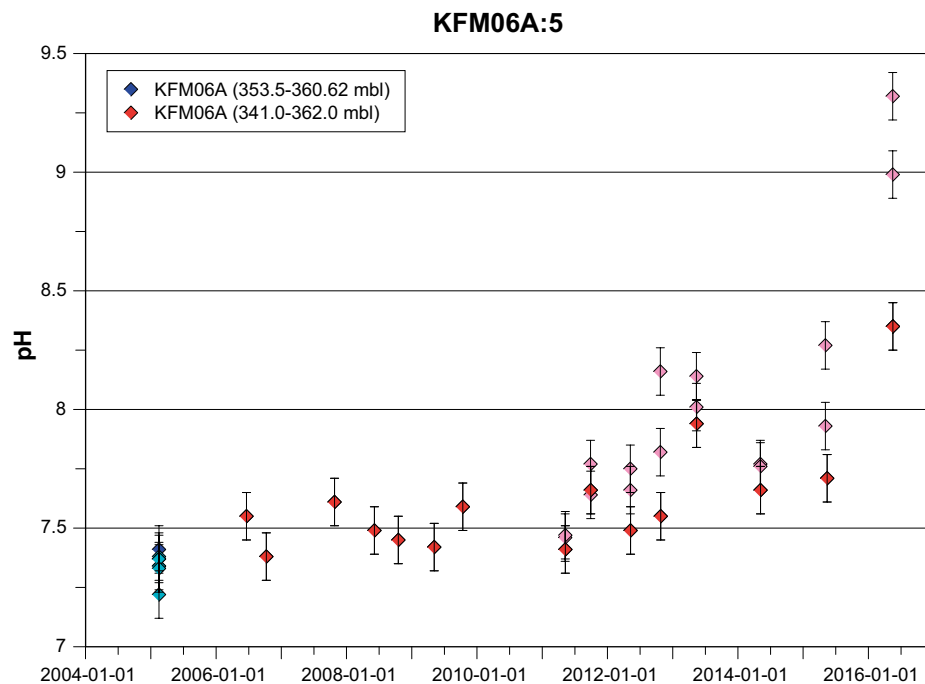
16) Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:  
 $\delta y = 1000 \times (K_{\text{sample}} - K_{\text{standard}}) / K_{\text{standard}}$ , where K= the isotope ratio and y = <sup>2</sup>H, <sup>18</sup>O, <sup>37</sup>Cl, <sup>13</sup>C or <sup>34</sup>S etc.

17) SKB estimation from duplicate analyses by the contracted laboratory.

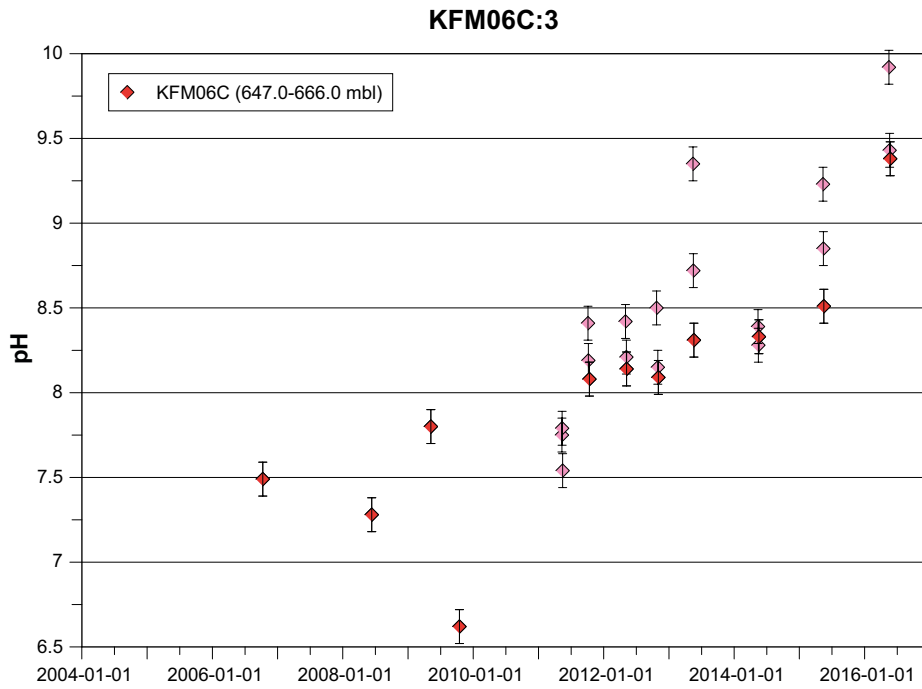
## pH trends in some of the core drilled boreholes



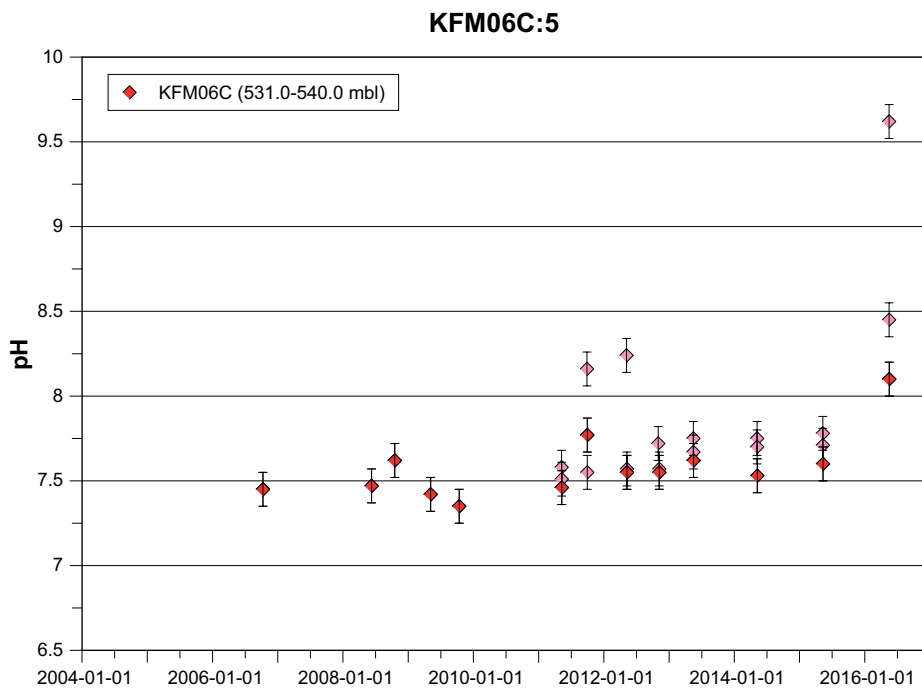
**Figure A6-1.** Comparison between initial pH-values from complete chemical characterisation during PLU (blue points) and later measurements in the ongoing monitoring programme (red points) for KFM06A:3. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from 2013 which are from field measurements.



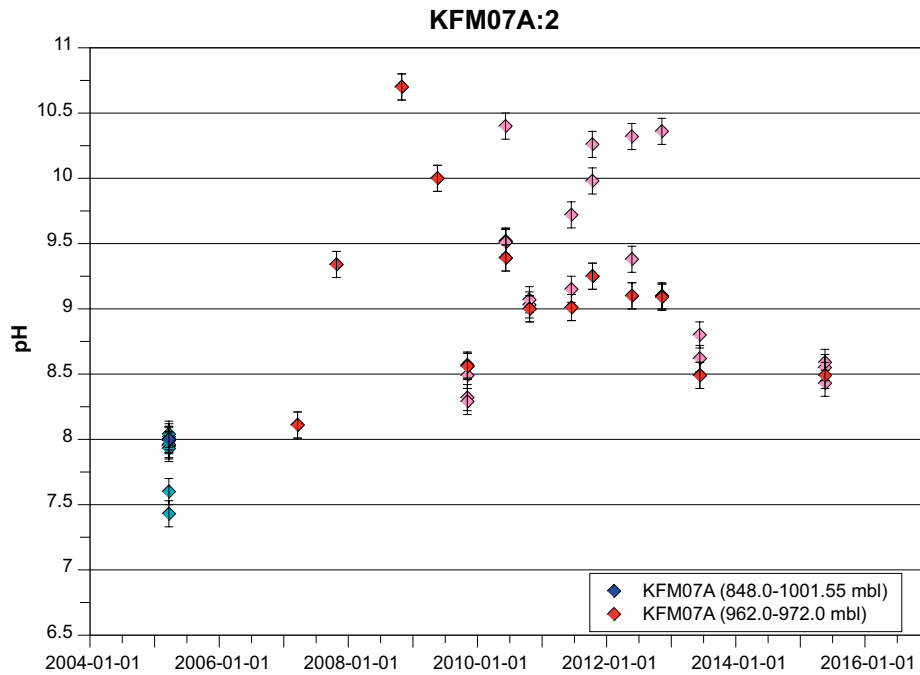
**Figure A6-2.** Comparison between initial pH-values from complete chemical characterisation during PLU (blue points) and later measurements in the ongoing monitoring programme (red points) for KFM06A:5. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from 2013 which are from field measurements.



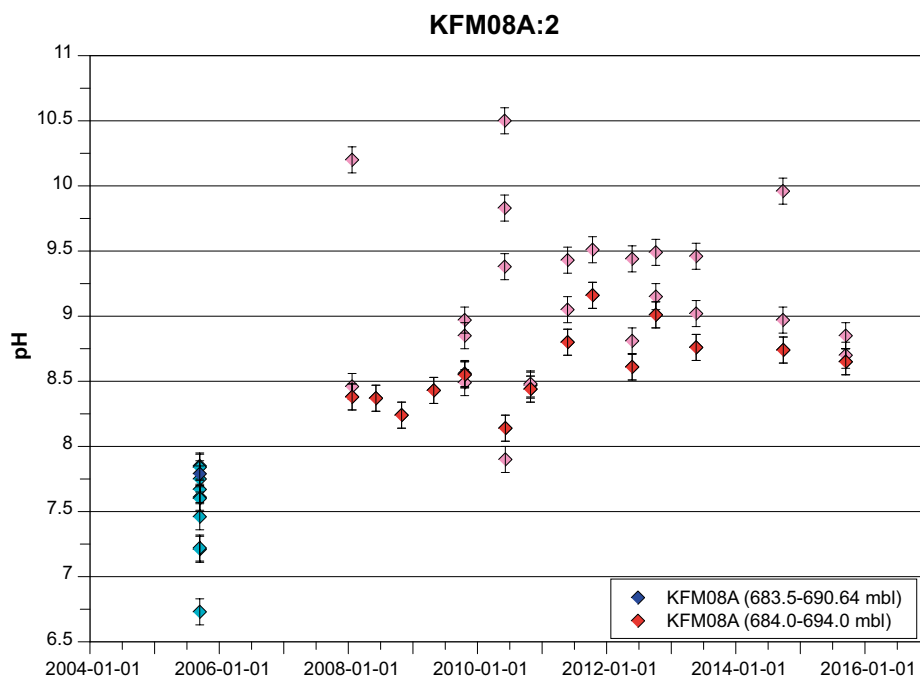
**Figure A6-3.** Measurements of pH-values from the ongoing monitoring programme (red points) for KFM06C:3. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from 2013 and the last sample from 2015 which are from field measurements.



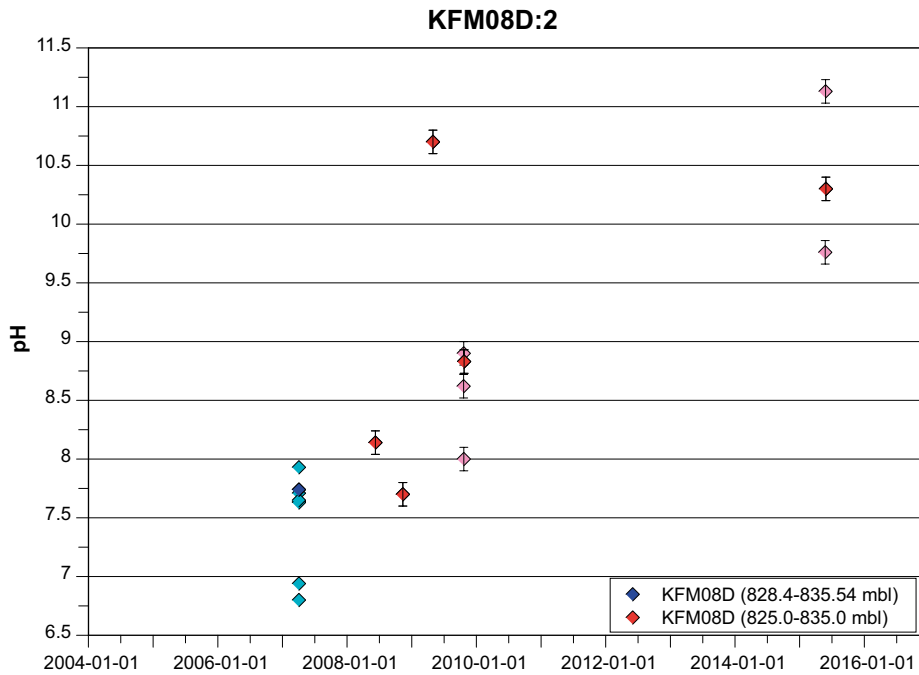
**Figure A6-4.** Measurements of pH-values from the ongoing monitoring programme (red points) for KFM06C:5. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from which are from field measurements.



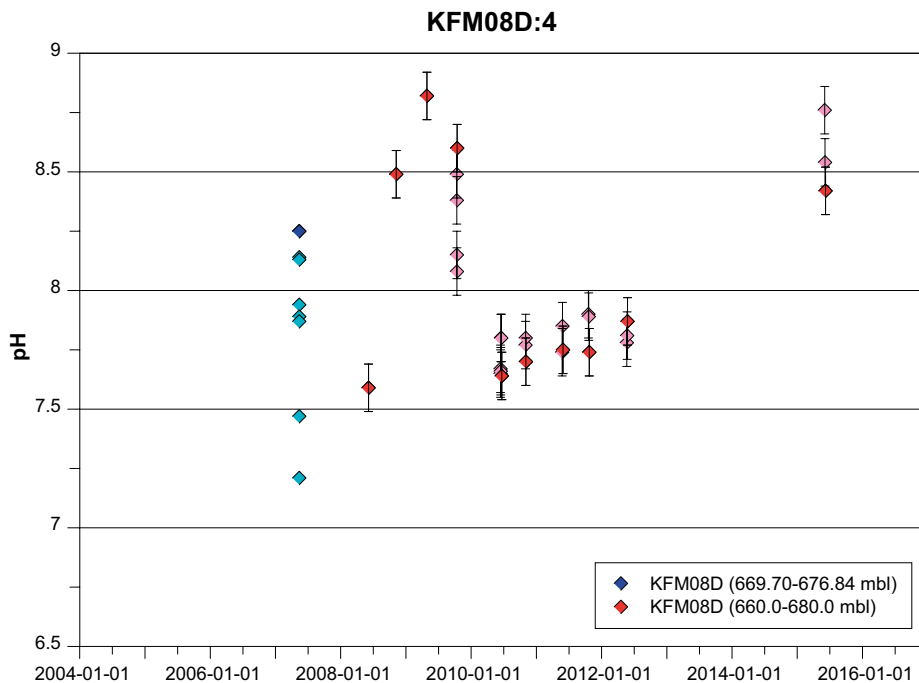
**Figure A6-5.** Comparison between initial pH-values from complete chemical characterisation during PLU (blue points) and later measurements in the ongoing monitoring programme (red points) for KFM07A:2. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from 2013 and 2015 which are from field measurements. No sampling of this section 2016 due to drilling of KFM24.



**Figure A6-6.** Comparison between initial pH-values from complete chemical characterisation during PLU (blue points) and later measurements in the ongoing monitoring programme (red points) for KFM08A:2. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from 2013 which are from field measurements. No sampling of this section 2016 due to drilling of KFM24.

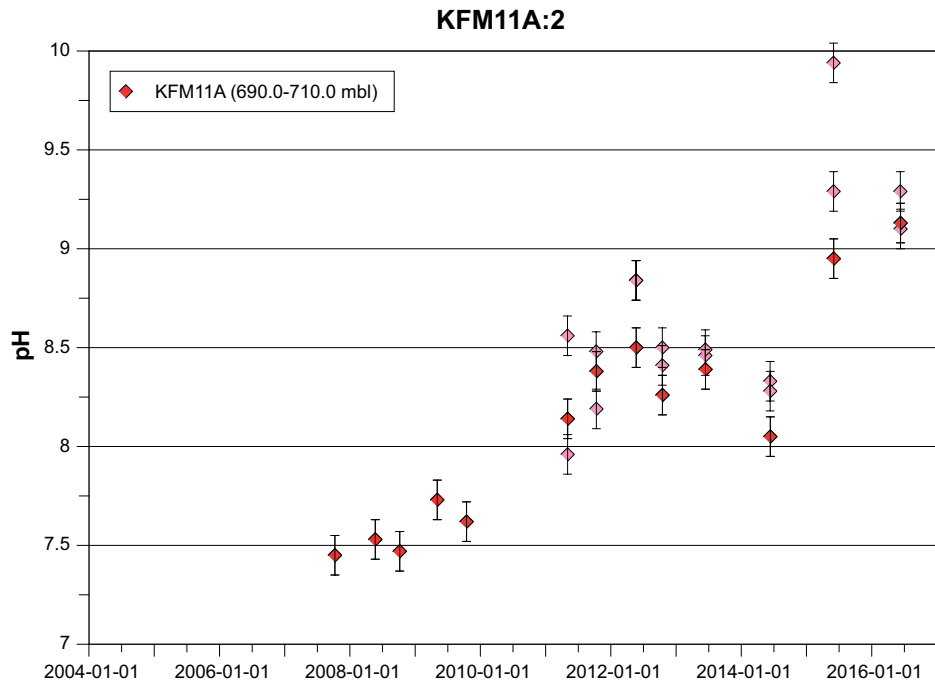


**Figure A6-7.** Comparison between initial pH-values from complete chemical characterisation during PLU (blue points) and later measurements in the ongoing monitoring programme (red points) for KFM08D:2. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C. This section has been omitted from the monitoring program for many years due to corrosion problem. After reinstallation of borehole equipment it was sampled again 2015. No sampling of this section 2016 due to drilling of KFM24.

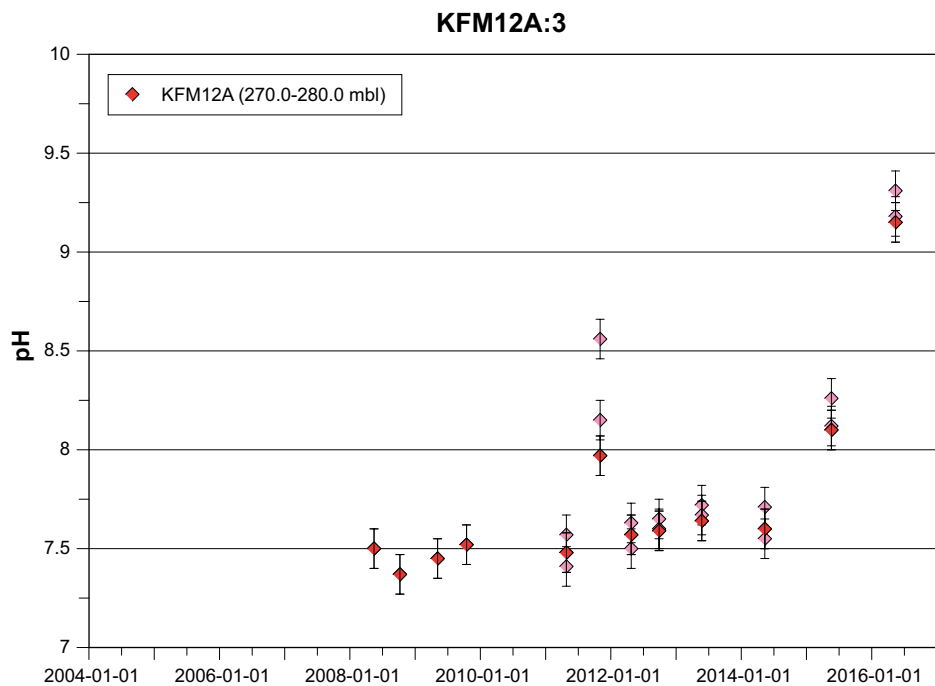


**Figure A6-8.** Comparison between initial pH-values from complete chemical characterisation during PLU (blue points) and later measurements in the ongoing monitoring programme (red points) for KFM08D:4. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C. This section has been omitted from the monitoring program for 2013–2014 due to corrosion problem. After reinstallation of borehole equipment it was sampled again 2015. No sampling of this section 2016 due to drilling of KFM24.





**Figure A6-9.** Measurements of PH-values from the ongoing monitoring programme (red points) for KFM11A:2. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from 2013 which are from field measurements.



**Figure A6-10.** Measurements of PH-values from the ongoing monitoring programme (red points) for KFM12A:3. The last sample in the series (or the only sample if no series) is marked with a darker red colour. All the presented pH-values are measured in the laboratory at 25 °C, except those from 2013 and 2015 which are from field measurements.

SKB is responsible for managing spent nuclear fuel and radioactive waste produced by the Swedish nuclear power plants such that man and the environment are protected in the near and distant future.

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