P-04-92

Forsmark site investigation

Sampling and analyses of groundwater from percussion drilled boreholes

Results from the percussion boreholes HFM09 to HFM19 and the percussion drilled part of KFM06A

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June 2004

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Keywords: Forsmark, Percussion borehole, Groundwater, Early water sampling after drilling, Chemical analyses, Isotope determinations, AP PF 400-03-95, AP PF 400-03-101, AP PF 400-04-07, AP PF 400-04-17, Field note nos 186, 187, 200, 201, 213, 214, 238, 252, 262, 265.

Abstract

Percussion boreholes are drilled as monitoring wells or as flushing water supply wells for core drilling. Further, percussion boreholes are drilled for general geological characterisation or in order to investigate specific geological features (e.g. lineaments) down to about 200 m depth in the bedrock.

Groundwater samples collected in connection with hydraulic pumping tests in the percussion drilled boreholes HFM09 to HFM19 have been analysed according to SKB class 3 level, including isotope options i.e. major constituents (except redox sensitive ones) as well as the isotopes δD, $\delta^{18}O$, $^{10}B/^{11}B$, $\delta^{34}S$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$, Tritium and ^{14}C (pmC)). The main objective was to gain hydrochemical data down to approx. 200 m depth from a number of boreholes spread all over the candidate area. Water samples were collected at three occasions during the pumping; initially, in the middle and just before terminating the pumping. In most cases the salinity increased, the longer the pumping continued and it is difficult to decide whether the analytical results are representative for the water composition of the formation penetrated by the borehole or if the pumping entails extraction of groundwater also from deeper levels in the bedrock.

The analytical results obtained are reasonable/consistent and the relative charge balance error does not exceed 5% in any of the samples.

Sammanfattning

Hammarborrhål borras dels för att övervaka grundvattennivåförändringar, dels för att utgöra spolvattenbrunnar för kärnborrning. Vidare används hammarborrhål för allmän geologisk karakterisering och för att undersöka specifika geologiska företeelser (t ex lineament) ner till ca 200 m djup i berggrunden.

Grundvattenprov tagna under hydrauliska pumptester från hammarborrhålen HFM09 till HFM19 har analyserats enligt SKB klass 3 med isotoptillägg, dvs huvudkomponenter (förutom redoxkänsliga sådana) samt isotoperna δD, $\delta^{18}O$, $^{10}B/^{11}B$, $\delta^{34}S$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$, Tritium och ^{14}C (pmC). Det huvudsakliga syftet var att erhålla hydrokemiska data ner till ca 200 m djup från ett flertal borrhål spridda inom kandidatområdet. Vattenprov togs ut vid tre tillfällen under pumpningen; i början, i mitten och innan pumpningen avslutades. I de flesta borrhål skedde en ökning av salthalten ju längre pumpningen pågick och det är därför svårt att helt avgöra om analysresultaten är representativa för vattensammansättningen i den formation som omger borrhålen eller om pumpningen åstadkommer inblandning av grundvatten även från djupare nivåer.

Analysresultaten är rimliga/konsistenta och det relativa felet i jonbalansen överskrider inte 5 % för något av proven.

Contents

1 Introduction

This document reports performance of and results from the activity: “Sampling of percussion boreholes after drilling”, performed within the site investigation at Forsmark /1/. The work was conducted according to the activity plans AP PF 400-03-95, AP PF 400-03-101, AP PF 400-04-07 and AP PF 400-04-17 (SKB internal controlling documents). The report presents hydrochemical data from a number of percussion drilled boreholes in hard rock. The length of the boreholes varies between 50 to 210 m.
The percussion boreholes are:

1. HFM09 and HFM10 at drilling site DS4 /2/
2. HFM14 and HFM15 at drilling site DS5 /3/
3. HFM16 and the percussion drilled part of KFM06A at drilling site DS6 /4/
4. The not drilling site-connected percussion drilled boreholes HFM11, HFM12, HFM13, HFM17, HFM18 and HFM19 /3, 5/. These boreholes were drilled in order to investigate specific lineaments or other geological structures.

The locations of the percussion boreholes are shown in Figure 1-1 below.

Sampling of the boreholes was accomplished in connection with pumping tests and flow logging carried out within the programme for hydrogeological investigations /6-10/. The data references to the present activity are given in Table 1-1.

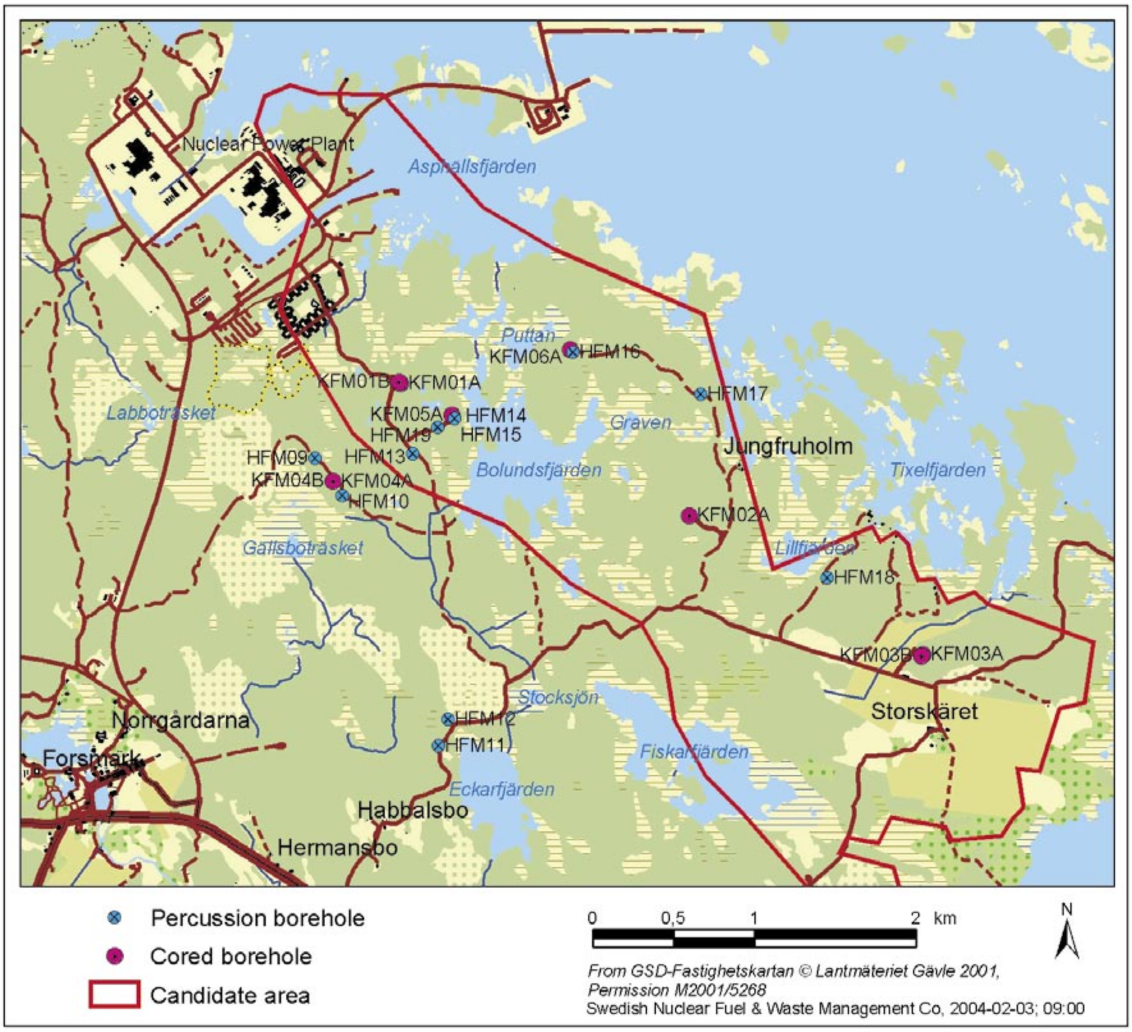

Figure 1-1. *Locations of the investigated boreholes within and just outside the Forsmark candidate area. Also the locations of core drilled boreholes are included in the map.*

Table 1-1. Data references to sampling of the percussion boreholes HFM09–HFM19 after drilling, SICADA database.

Sampling activity in borehole	Field note nos Forsmark
HFM09	262, 186
HFM10	265
HFM11	186
HFM12	187
HFM13	213
HFM14	200
HFM15	201
HFM16	214
HFM17	252
HFM18	252
HFM19	252
KFM06A	238

2 Objective and scope

Sampling and analysis of groundwater from the percussion boreholes (HFM09–19) and the percussion drilled part of KFM06A were mainly performed in order to:

- Gain data on the chemical composition of so called "first strike" groundwater, i.e. groundwater sampled before the impact of short circuiting between fractures of different hydrogeochemical character has become significant.
- Obtain area coverage of the hydrochemical data from the shallow part of the bedrock.
- Determine the suitability of some of the percussion boreholes to serve as supply wells for the flushing water needed for drilling the cored part of the telescopic boreholes. Core drilling of a 1000 m long borehole consumes approximately 1000 m^3 water. Core drilled boreholes of SKB chemical-type are of special importance and the total organic content in the flushing water must be low (<5 mg/L) in order to avoid disturbing the microbiological conditions in the borehole.

Sampling and analysis are performed according to the SKB class 3 procedure. The analyses of the last collected sample from each borehole also include isotope options.

3 Background

The percussion boreholes treated in this report are of the following types:

- Monitoring wells connected to a drilling site.
- Flushing water supply wells connected to a drilling site.
- Boreholes for special purposes like investigating specific lineaments or fracture zones.
- The percussion drilled first 100 m of a deep telescopic borehole.

3.1 Percussion boreholes at drilling site DS4

The drilling site DS4 was established in order to examine the western perimeter of the tectonical lens. Two 1000 m telescopic boreholes are planned at the drilling site but only the first one, KFM04A has been completed so far. The two percussion boreholes, HFM09 and HFM10 were drilled in order to serve as source of flushing water for the core drilling and as a monitoring well respectively. The major water bearing zone was found at a relatively shallow depth in the borehole HFM09 and the content of organic constituents was considered too high, see Table 3-2. Therefore, HFM10 was selected as flushing water supply well for KFM04A. The locations of the boreholes are presented in Figure 3-1. A schematic representation of the boreholes at drilling site DS4 and the major water bearing zones is presented in Figure 3-2. Basic borehole information concerning the two investigated/sampled percussion boreholes is given in Table 3-1.

Activities performed in boreholes HFM09 and HFM10 are presented in Table 3-2.

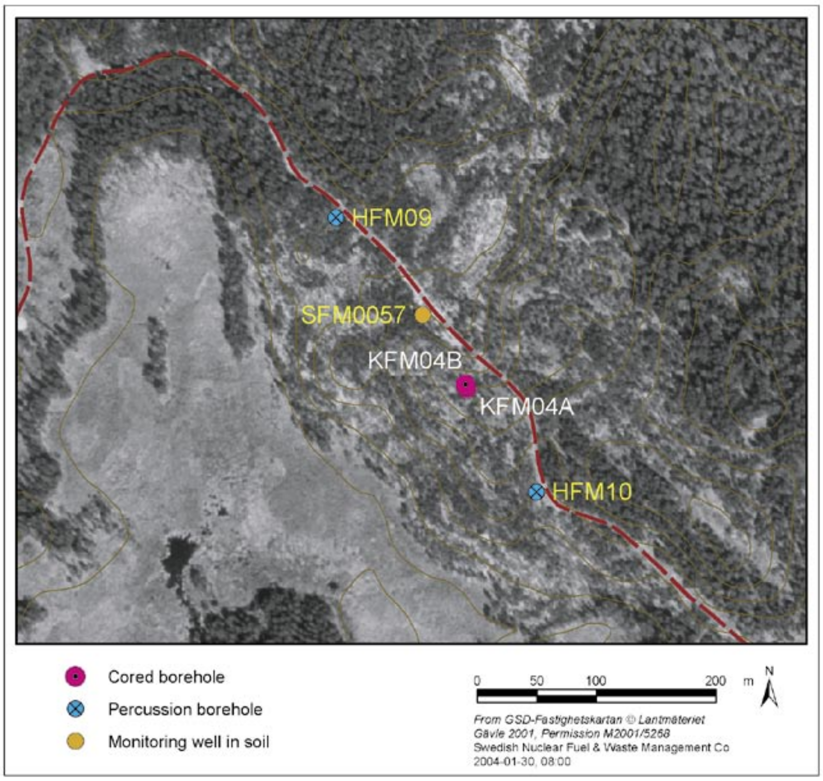

Figure 3-1. *Location of the boreholes HFM09, HFM10 and KFM04A at drilling site DS4. A second core drilled telescopic borehole (KFM04B also inclined 60°) is planned very close to KFM04A, but so far only 100 m have been drilled. Also a monitoring well in soil has been drilled at the drilling site.*

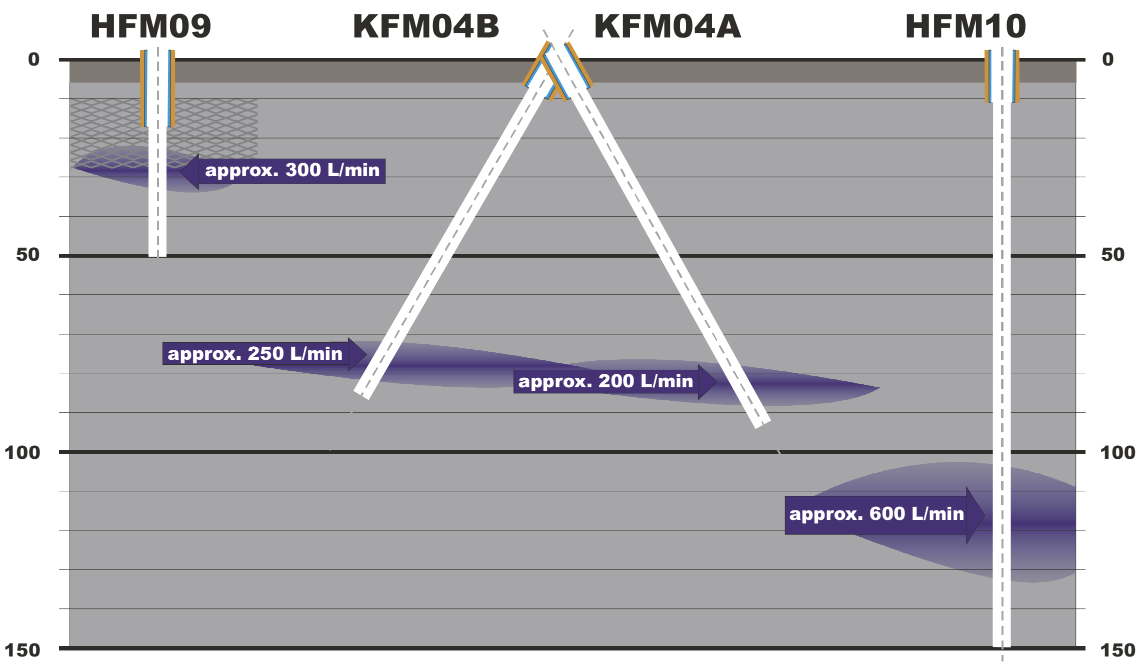

Figure 3-2. *Schematic and simplified representation of the percussion drilled parts of the telescopic boreholes KFM04A and KFM04B as well as the percussion boreholes HFM09 and HFM10 at drilling site DS4. The water yielding zones and their inflows as estimated during drilling are included.*

Table 3-1. Borehole information, drilling site DS4.

Idcode	Date of completion	Bearing (degrees)	Inlclination (degrees)	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	Length (m)
HFM09	2003-06-30	139.359	–68.8987	6699064.648	1630869.12	5.15	50.2
HFM10	2003-08-19	92.934	–68.6998	6698834.785	1631037.19	4.99	150

Table 3-2. Activities performed in boreholes HFM09 and HFM10.

Idcode	Date	Activity	Comment
HFM09	030618–030630	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004 (SKB internal controlling document)
	031029	Magnetic accelerometer measurement	
	030806	Radar-logging dipol antenna	
	030819	BIPS-logging	
	040218	Flow-logging	22.0–29.0 m 48.68 L/min, drawdown 2.69 m 45.5–49.0 m 7.14 L/min, drawdown 2.69 m
HFM10	030811–030819	Percussion drilling Magnetic accelerometer measurement Radar-logging dipol antenna BIPS-logging Flushing water during core drill	
	040225	Flow-logging	114.5–121.0 m 49.98 L/min, drawdown 2.98 m

3.2 Percussion boreholes at drilling site DS5

The drilling site DS5 was established in order to examine the geological conditions and the north-south orientated lineaments under lake Bolundsfjärden with a 1000 m telescopic borehole, KFM05A. Another purpose was to conclude possible occurrence of vuggy granite. A percussion borehole, HFM14, was drilled primary to serve as flushing water source for the core drilling of KFM05A and secondary to further examine earlier revealed block movements on the drilling site and the east-west orientated lineaments approximately 140 m north of the borehole. HFM15 was drilled for the last purpose but with another bearing and inclination. Due to low inflow and high content of organic constituents, HFM14 was considered unsuitable to serve as flushing water source and HFM13 was selected instead.

Locations of the percussion boreholes and a schematic representation of drilling site DS5 are presented in Figures 3-3 and 3-4. Basic borehole information concerning the two investigated/sampled percussion boreholes at drilling site DS5 is given in Table 3-3.

Previous activities and major water bearing zones for the boreholes are presented in Table 3-4. The percussion drilled part of KFM05A was not sampled.

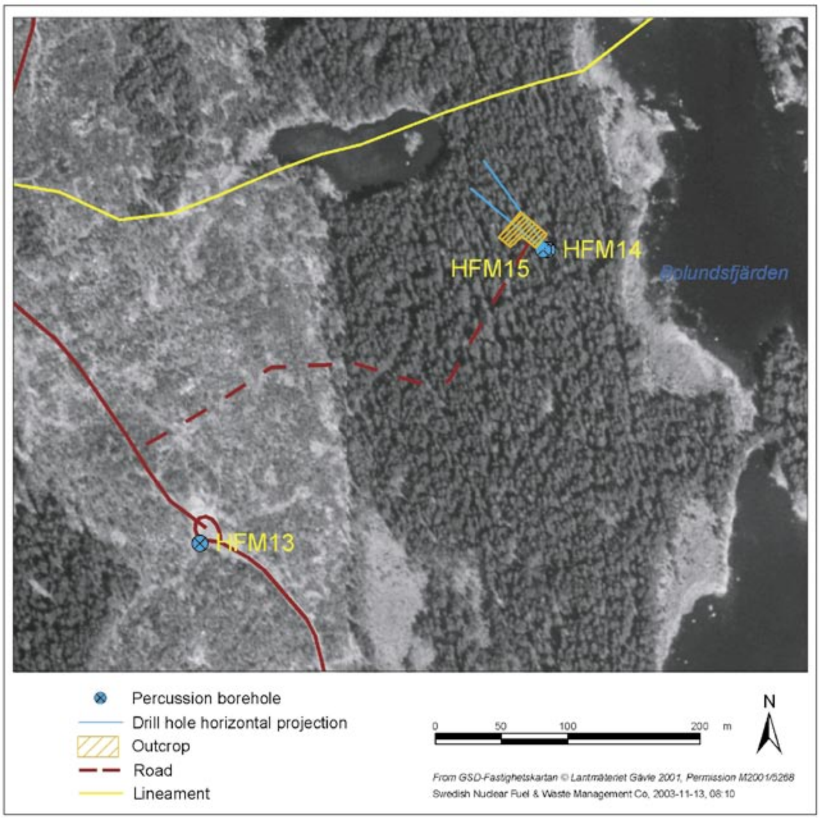

Figure 3-3. *Locations of the percussion boreholes HFM14 and HFM15 at drilling site DS5.*

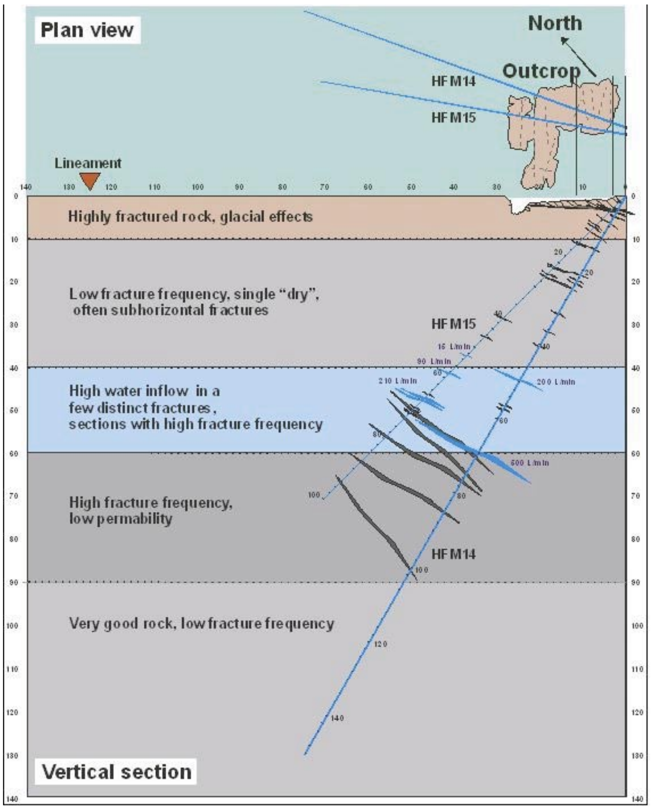

Figure 3-4. *Schematic and simplified representation of the percussion drilled boreholes HFM14 and HFM15 at drilling site DS5. The water yielding zones and their inflows as estimated during drilling are included.*

Table 3-3. Borehole information, drilling site DS5.

Idcode	Date of completion	Bearing (degrees)	Inlclination (degrees)	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	Bhlength (m)
HFM14	2003-10-09	331.7482	–59.8	6699313.139	1631734.586	3.912	150.5
HFM15	2003-10-15	314.3052	–43.7	6699312.444	1631733.081	3.878	99.5

Table 3-4. Activities performed in boreholes HFM14 and HFM15.

Idcode	Date	Activity	Comment
HFM14	031006–031009	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	031015	Magnetic accelerometer measurement	
	031020	Radar-logging dipol antenna	
	031021	BIPS-logging	
	031105	Flow-logging	
HFM15	031013–031015	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	031015	Magnetic accelerometer measurement	
	031020	Radar-logging dipol antenna	
	031021	BIPS-logging	
	031112	Flow-logging	22.9–24.5 m 12.78 L/min, drawdown 1.01 m 67.0–68.5 m 15.36 L/min, drawdown 1.01 m 71.9–74.5 m 12.24 L/min, drawdown 1.01 m 88.0–89.0 m 18.96 L/min, drawdown 1.01 m

3.3 Percussion boreholes at drilling site DS6

The drilling site DS6 was established in order to examine the geological conditions and the north-south orientated lineaments under the lake Bolundsfjärden with a 1000 m telescopic borehole, KFM06A. Another purpose was to conclude possible occurrence of vuggy granite. Percussion borehole, HFM16, was drilled to serve as a source of flushing water for core drilling of KFM06A. Locations of the boreholes at drilling site DS6 are presented in Figure 3-5. Figure 3-6 displays a schematic representation of the drilling site. Basic borehole information concerning the two investigated/sampled boreholes at drilling site DS6 is presented in Table 3-5.

Previous activities and major water bearing zones in HFM16 and the percussion drilled part of KFM06A are presented in Table 3-6.

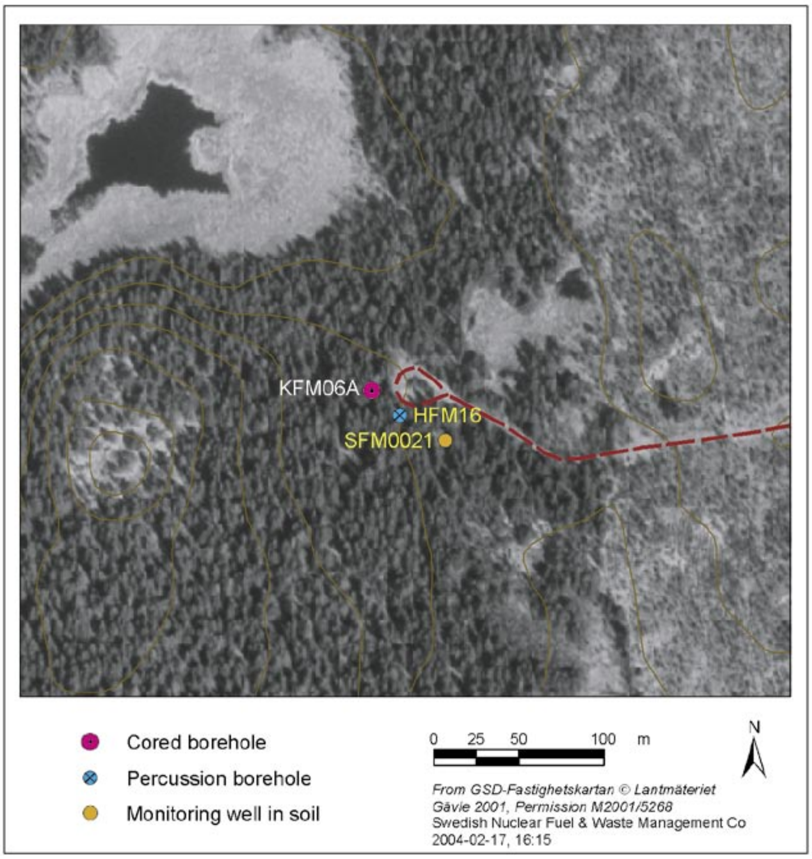

Figure 3-5. *Locations of the boreholes HFM16 and KFM06A as well as a monitoring well in soil at drilling site DS6.*

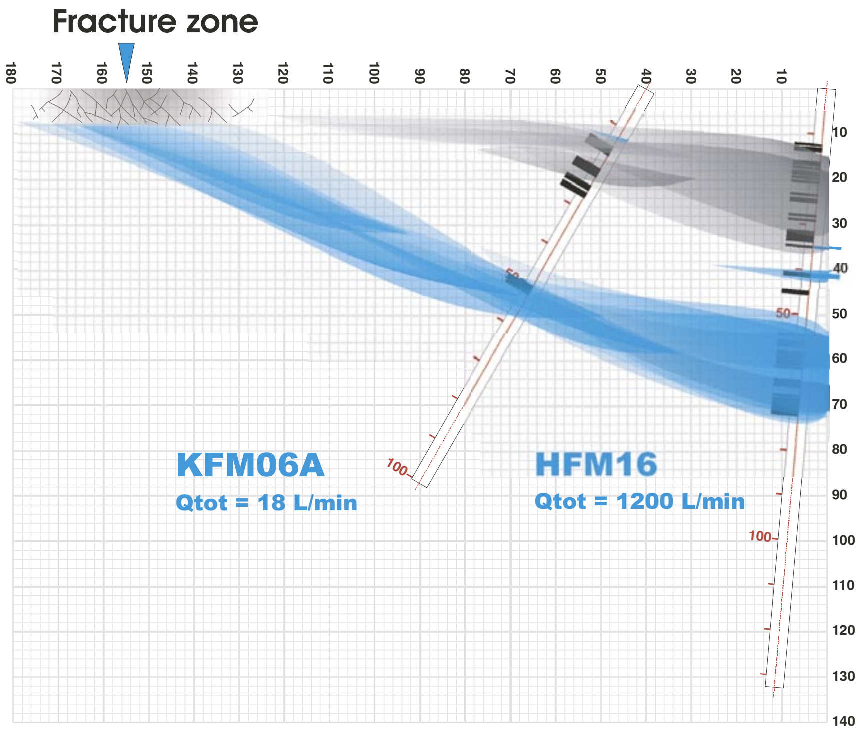

Figure 3-6. *Schematic and simplified representation of the percussion drilled borehole HFM16 and the percussion drilled part of KFM06A at drilling site DS6. The water yielding zones and their inflows as estimated during drilling are included.*

Table 3-5. Borehole information at drilling site DS6.

Idcode	Bearing (degrees)	Inlclination (degrees)	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	Bhlength (m)
HFM16	327.957	–84.2177	6699721.098	1632466.182	3.210	132.5
KFM06A	300.916	–60.2520	6699732.879	1632442.506	4.098	100.3

Table 3-6. Activities performed in boreholes HFM16 and KFM06A.

Idcode	Date	Activity	Comment
HFM16	031104–031110	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	031118	Magnetic accelerometer measurement	
	031202	Flow-logging	41.0–41.5 m 14.4 L/min, drawdown 0.82 m 56.0–56.5 m 5.0 L/min, drawdown 0.82 m 58.5–59.5 m 37.98 L/min, drawdown 0.82 m 69.0–69.5 m 7.02 L/min, drawdown 0.82 m
KFM06A	031111–031121	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	031203	Radar-logging dipol antenna	
	031203	BIPS-logging	
	031208	Flow-logging	All detected flow yielding fractures were below measurement limit

3.4 Not drilling site connected percussion boreholes

Several of the sampled percussion boreholes were drilled outside the drilling sites for deep telescopic boreholes in order to investigate different geological structures in the investigation area. The boreholes and their objectives are listed below:

- HFM11 and HFM12 were drilled in order to study the "Eckarfjärden deformation zone", Figure 3-7 and 3-8.
- HFM13 was drilled for investigation of a presumed flat-dipping structure between drilling sites DS1, DS4 and DS5 within 200 m depth. The intention was also to reveal if there was a steep lineament parallel with the road passing the borehole, Figure 3-9.
- HFM17–19 were drilled in order to investigate different lineaments of special interest in the candidate area, Figures 3-9, 3-10 and 3-11.

Basic borehole information concerning the investigated/sampled not drilling site-connected percussion boreholes is given in Table 3-7.

Previous activities and inflows into the boreholes as recognized during the flow logging are presented in Table 3-8.

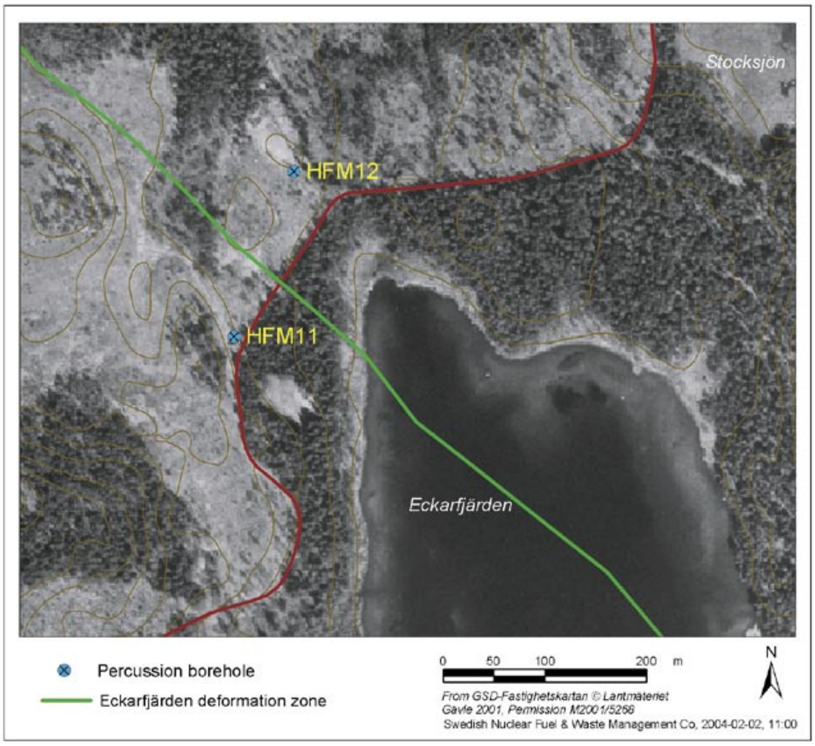

Figure 3-7. *Locations of percussion drilled boreholes HFM11 and HFM12 and the presumed orientation of the Eckarfjärden deformation zone.*

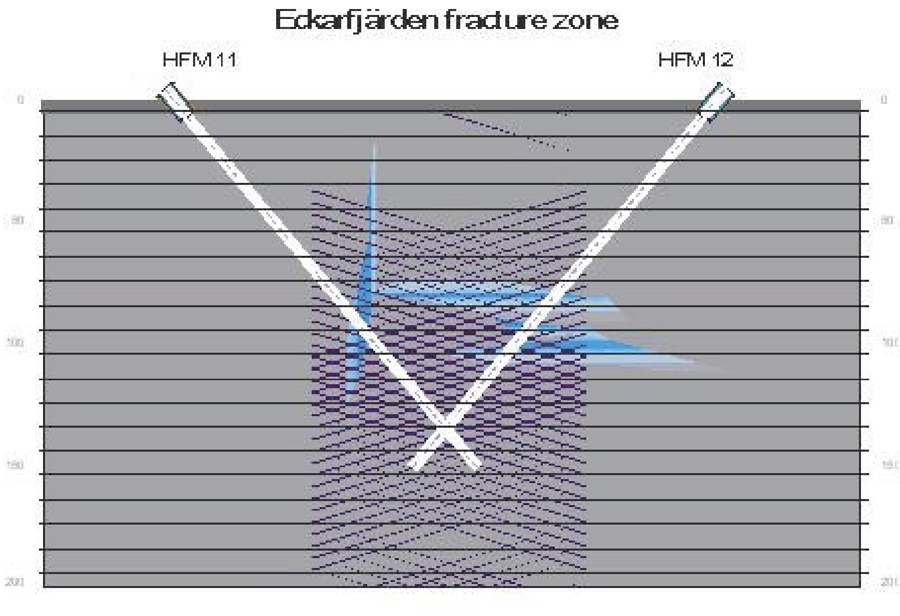

Figure 3-8. *Schematic and simplified representation of boreholes HFM11 and HFM12, the Eckarfjärden deformation zone and estimated approximate locations of water yielding zones.*

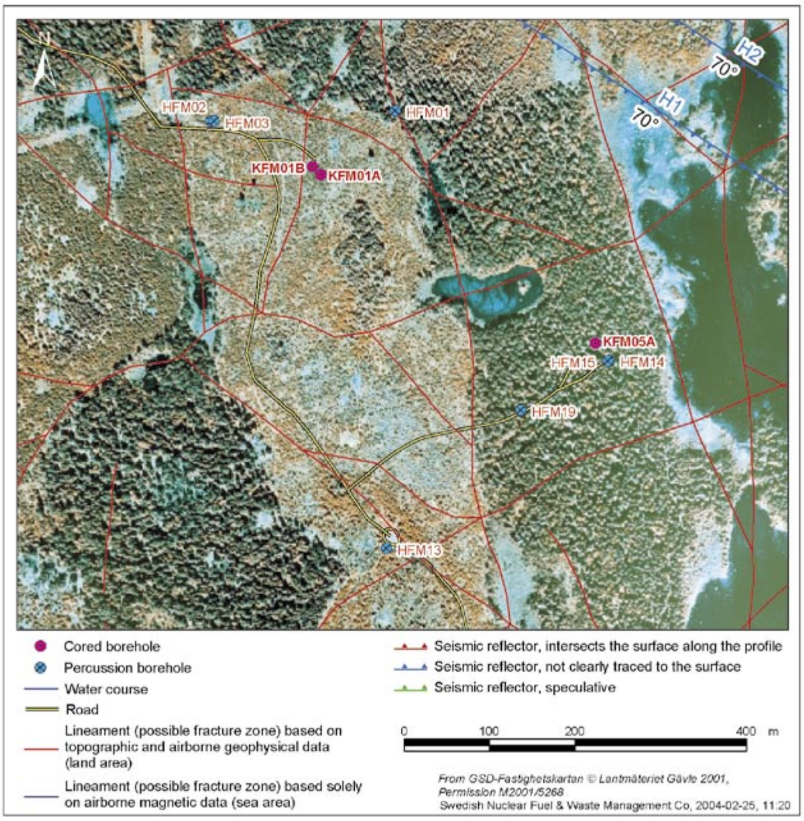

Figure 3-9. *Locations of percussion boreholes HFM13 and HFM19 as well as different lineaments in the nearby area.*

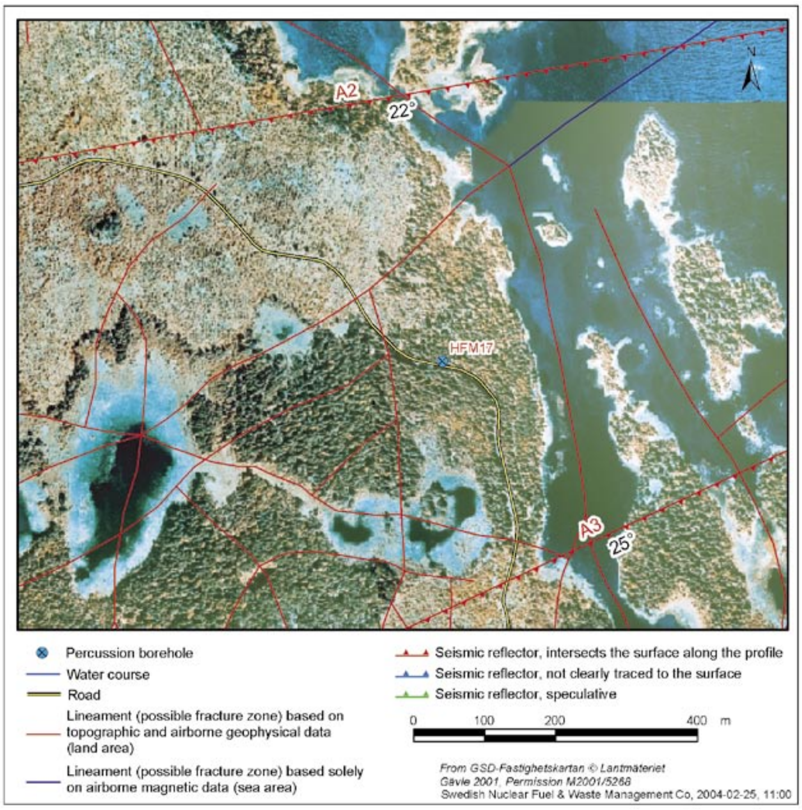

Figure 3-10. *Locations of the percussion drilled borehole HFM17 and different lineaments in the nearby area.*

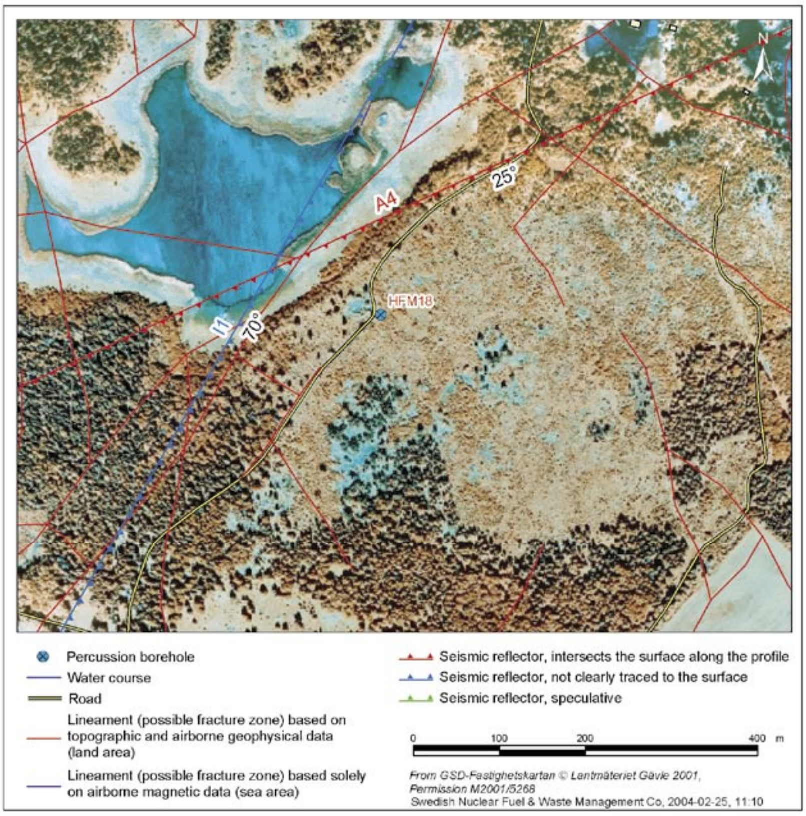

Figure 3-11. *Location of the percussion drilled borehole HFM18 and the lineaments A4 and I1.*

Table 3-7. Borehole information of the percussion boreholes drilled outside drilling site for telescopic boreholes.

Idcode	Bearing (degrees)	Inlclination (degrees)	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	Bhlength (m)
HFM11	63.5057	–49.3172	6697283.402	1631636.333	7.559	182.35
HFM12	245.1626	–49.0523	6697446.459	1631695.671	7.025	209.55
HFM13	51.1937	–58.8450	6699093.678	1631474.404	5.687	175.60
HFM17	318.5763	–84.1865	6699461.952	1633261.310	3.750	210.65
HFM18	313.2986	–59.3555	6698326.858	1634037.374	5.039	180.65
HFM19	280.9148	–58.1031	6699257.585	1631626.925	3.656	185.20

Table 3-8. Previous activities in the not drilling site connected boreholes.

Idcode	Date	Activity	Comment
HFM11	030821–030901	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	031002	Flow-logging	37.7–38.7 m 7.0 L/min, drawdown 13.47 m 40.7–43.7 m 14.6 L/min, drawdown 13.47 m 108.2–110.2 m 9.9 L/min, drawdown 13.47 m 135.7–136.7 m 2.8 L/min, drawdown 13.47 m 141.2–143.7 m 9.8 L/min, drawdown 13.47 m 146.2–147.3 m 4.8 L/min, drawdown 13.47 m
HFM12	030903–030917	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	030926	Flow-logging	110.2–112.2 m 0.96 L/min, drawdown 13.47 m 123.2–123.8 m 4.6 L/min, drawdown 13.47 m
HFM13	030918–031002	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	031022	Radar-logging dipol antenna	
	031021	BIPS-logging	
	031117	Flow-logging	105.5–106.0 m 4.3 L/min, drawdown 3.00 m 162.5–163.5 m 59.2 L/min, drawdown 3.00 m
HFM17	031201–031208	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	031211	Magnetic accelerometer measurement	
	040115	Radar-logging dipol antenna	
	040115	BIPS-logging	
	040127	Flow-logging	30.0–32.5 m 31.2 L/min, drawdown 8.97 m
HFM18	031210–031216	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	040112	Magnetic accelerometer measurement	
	040115	Radar-logging dipol antenna	
	040115	BIPS-logging	
	040210	Flow-logging	36.5–38.0 m 25.0 L/min, drawdown 6.92 m 46.0–46.5 m 19.0 L/min, drawdown 6.92 m 48.0–48.5 m 8.0 L/min, drawdown 6.92 m
HFM19	031202–031218	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004
	040113	Magnetic accelerometer measurement	
	040116	Radar-logging dipol antenna	
	040116	BIPS-logging	
	040203	Flow-logging	100.0–102.0 m 6.5 L/min, drawdown 1.53 m 148.0–150.0 m 2.5 L/min, drawdown 1.53 m 160.0–163.0 m 1.0 L/min, drawdown 1.53 m 170.0–182.5 m 44.5 L/min, drawdown 1.53 m

4 Equipment

The sampling in the percussion boreholes was performed in connection with hydraulic tests with the HTHB (HydroTester för HammarBorrhål) pump and packer equipment described in the SKB internal controlling document SKB MD 326.001 (Mätsystembeskrivning för hydrotestutrustning för hammarborrhål – HTHB). The equipment allows pumping from packed off sections in boreholes of diameter 165 mm and 140 mm (± a few millimetres) using a single- or double packer system. The in-hole equipment includes a packer system, a measurement tube, an enclosed pump, and a combined pressure sensor and data logger. An overview of the HTHB equipment is given in Figure 4-1 below.

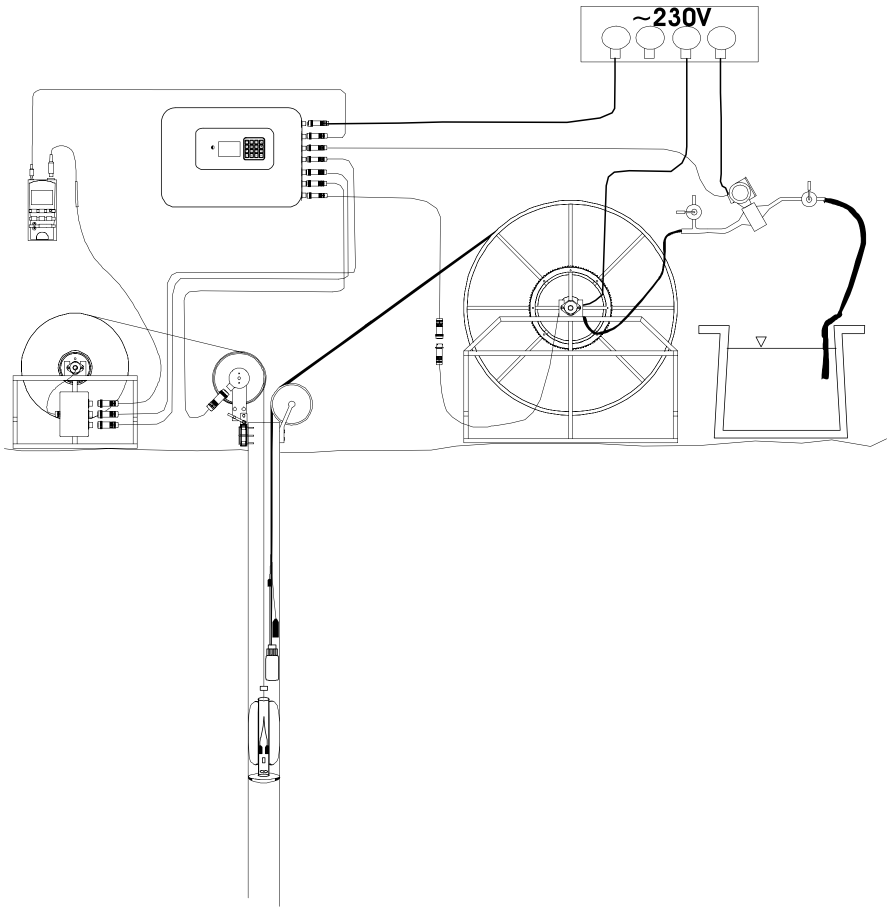

Figure 4-1. The HTHB (HydroTester för HammarBorrhål) equipment, configured for pumping at "open hole" conditions in combination with flow logging.

5 Performance

5.1 Sampling

Sampling of the percussion boreholes was performed according to activity plans AP PF 400-03-95, AP PF 400-03-101, AP PF 400-04-07 and AP PF 400-04-17 following the method described in SKB MD 423.002 (Metodbeskrivning för vattenprovtagning i hammarborrhål efter borrning, SKB internal controlling document).

Generally, pumping was performed during 10 hours, and samples were collected three times during the pumping period. In the percussion drilled part of KFM06A, only two samples were collected due to the low water yield of the borehole. Table 5-1 presents the general sampling information from the pumping tests.

Table 5-1. Pumping information and collected samples.

Borehole	Section	Pump start	Pump stop	Sampling time	Pumped vol [m^3]	Sample no
HFM09	17.0–50.5	040218 10:11	040218 20:13	040218 12:40	10.3	8333
				040218 15:45	20.5	8334
				040218 19:40	30.8	8335
HFM10	12.00–150.0	040225 09:48	040218 19:50	040225	4.2	8336
				040225	15.9	8337
				040225	28.9	8338
HFM11	12.0–182.4	031002 09:19	031002 19:19	031002 10:39	4.4	8036
				031002 15:00	16	8037
				031002 18:51	27	8038
HFM12	14.9–209.5	030926 07:05	030926 18:20	030926 08:00	1.0	8020
				030926 11:15	3.0	8019
				030926 16:30	7.0	8018
HFM13	14.9–175.6	031117 08:21	031117 18:21	031117 10:31	7.7	8130
				031117 14:30	24	8129
				031117 17:56	36	8128
HFM14	3.0–150.5	031105 08:48	031105 18:55	031105 10:24	5.4	8095
				031105 15:09	18	8094
				031105 18:40	36	8093
HFM15	6.0–99.5	031112 08:40	031112 18:46	031112 09:10	1.8	8125
				031112 15:00	23	8126
				031112 18:30	35	8127
KFM06A	12.3–100.3	031208 09:20	031208 19:21	031208 17:07	1.7	8186
				031208 18:53	2.0	8187
HFM16	12.02–132.5	031202 09:04	031202 19:04	031202 10:38	6.2	8162
				031202 15:26	25	8163
				031202 18:41	38	8164
HFM17	8.0–210.65	040127 08:32	040127 18:32	040127 10:17	4.4	8257
				040127 14:17	12.4	8258
				040127 17:53	19.3	8246
HFM18	9.0–180.65	040210 09:20	040210 19:21	040210 10:47	4.66	8324
				040210 14:35	16.5	8325
				040210 18:40	29.4	8250
HFM19	12.0–185.2	040203 08:18	040203 18:22	040203 09:09	2.8	8259
				040203 13:17	16.4	8260
				040203 18:11	32.7	8247

Sampling and analyses were performed according to SKB class 3 but isotope options were included only for the last sample collected from each borehole. Total organic carbon (TOC) was determined in order to investigate the suitability of some of the boreholes as sources for flushing water.

5.2 Sample treatment and chemical analyses

An overview of sample treatment and analysis routines is given in Appendix 1. The routines are applicable independent of sampling method or type of sampling object.

5.3 Data handling

The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independently of sampling method or type of sampling object.

Several components are determined by more than one method and/or laboratory. Moreover, duplicate analyses by an independent laboratory are performed as a standard procedure on each fifth or tenth collected sample.

All analytical results are stored in the SICADA database. The applied hierarchy path “Hydrochemistry/Hydrochemical investigation/Analyses/Water in the database” contains two types of tables, raw data tables and primary data tables (final data tables).

Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named “water_composition”. The evaluation is based on:

- Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
- Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable (in surface waters ± 10%).

$$rel\ error\ (\%) = 100 \times \frac{\sum cations(equivalents) - \sum anions(equivalents)}{\sum cations(equivalents) + \sum anions(equivalents)}$$

- General expert judgement of plausibility based on earlier results and experiences.

All results from special analyses of trace metals and isotopes are inserted directly into primary data tables. In those cases where the analyses are repeated or performed by more than one laboratory, a “best choice” notation will indicate those results which are considered most reliable. An overview of the data management is given in Figure 5-1.

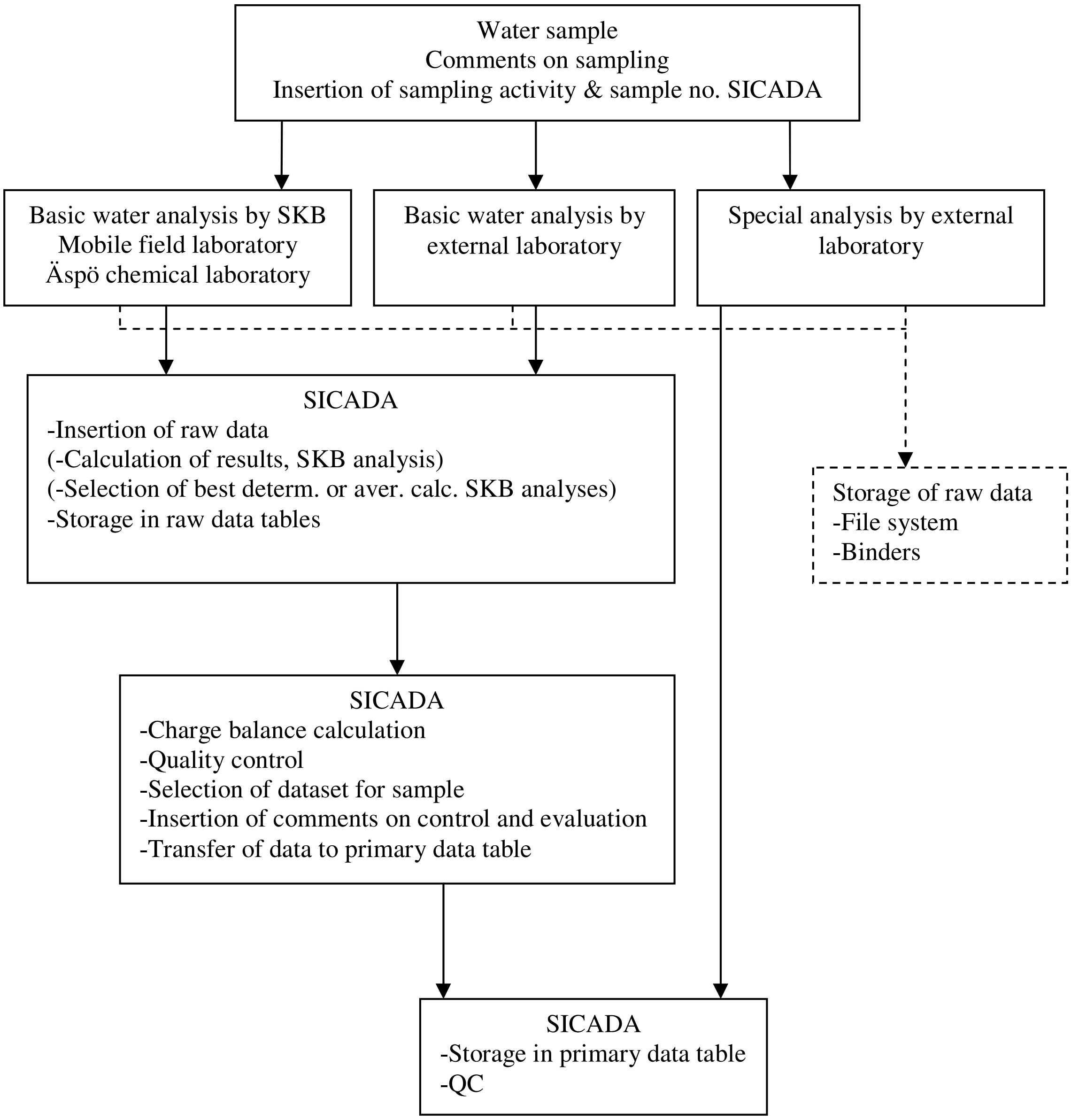

Figure 5-1. *Overview of data management for hydrogeochemical data.*

6 Nonconformities

According to SKB MD 423.002 and /1/, the sampling of groundwater was planned to take place immediately after completion of each percussion borehole. Due to logistic problems this has very seldom been possible. The main problem has been a tight schedule for the different tests in the boreholes. Further, the HTHB equipment has not always been available and there are no other suitable equipment for pumping and sampling of groundwater in percussion boreholes so far.

KFM06A was sampled only twice and not three times due to low inflow into the borehole.

7 Results

7.1 Basic water analysis

The basic water analyses include the major components Na, K, Ca, Mg, S, SO_4^{2-}, Cl^-, Si and HCO_3^- as well as the minor constituents Li, Br and F. Furthermore, batch measurements of pH and electric conductivity are included. TOC is included in case the borehole is to serve as a flushing water supply well for core drilling. The basic water analysis data and relative charge balance errors are compiled in Appendix 2.

Samples were collected three times in each borehole (except for KFM06A); 1) when borehole water reaches the surface, 2) in the middle and 3) in the end of the pumping period. Chloride concentrations in the samples of each borehole are compared in Figures 7-1 to 7-3. It can be noted that the concentrations usually increase during the pumping period. A few boreholes show stable concentration levels (HFM17, HFM10 and HFM19) within the analytical uncertainty. Although uncertain, the last sample in each series may be considered as the most representative for the groundwater.

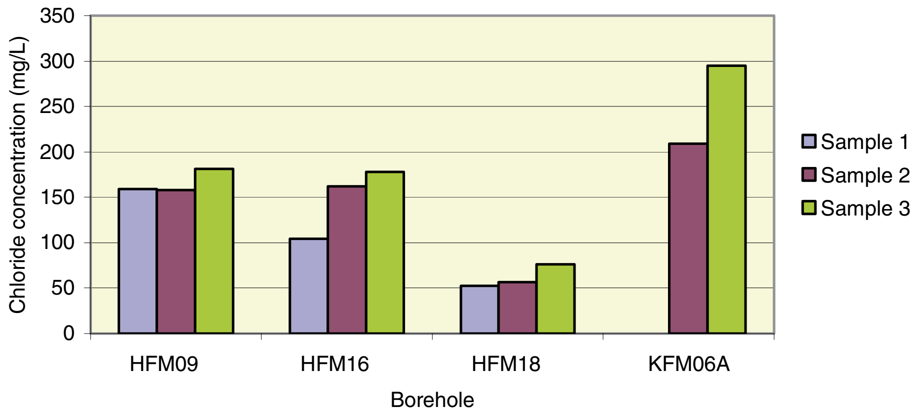

Figure 7-1. *Chloride concentration series for boreholes HFM09, HFM16, HFM18 and the percussion drilled part of KFM06A.*

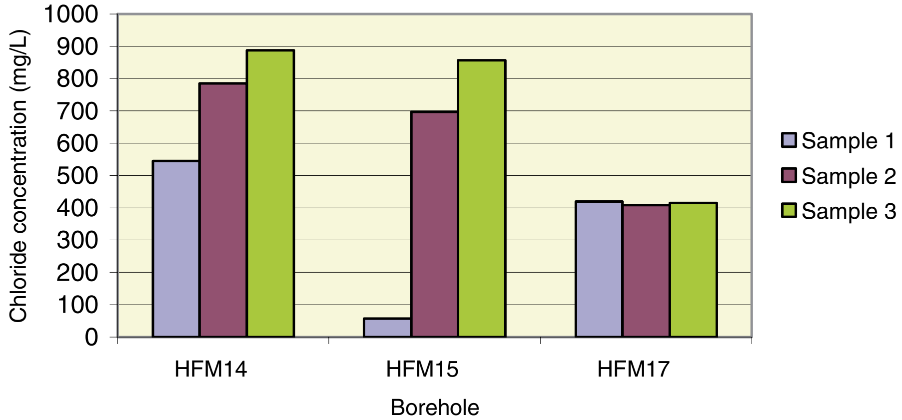

Figure 7-2. *Chloride concentration series for boreholes, HFM14, HFM15 and HFM17.*

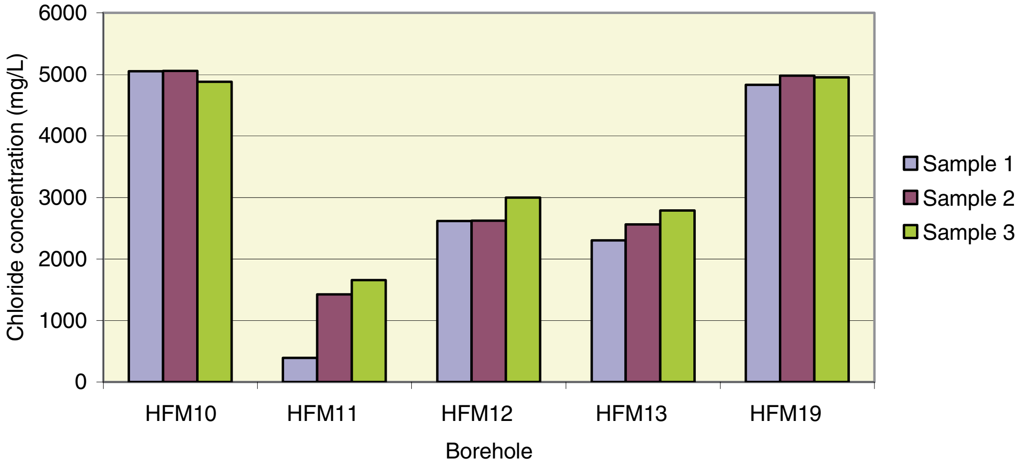

***Figure 7-3.** Chloride concentration series for boreholes HFM10, HFM11, HFM12, HFM13 and HFM19.*

The charge balance errors give an indication of the quality and uncertainty of the analyses of major components. The errors do not exceed ± 3% in any case except for the first sample in HFM15.

The chloride concentrations are plotted versus the corresponding electric conductivity values in Figure 7-4. The plot gives a rough check that the values are reasonable. In this case the correlation is very good.

Sulphate analysed by IC is plotted versus sulphate recalculated from total sulphur analysed by ICP technique in Figure 7-5. The agreement is satisfactory.

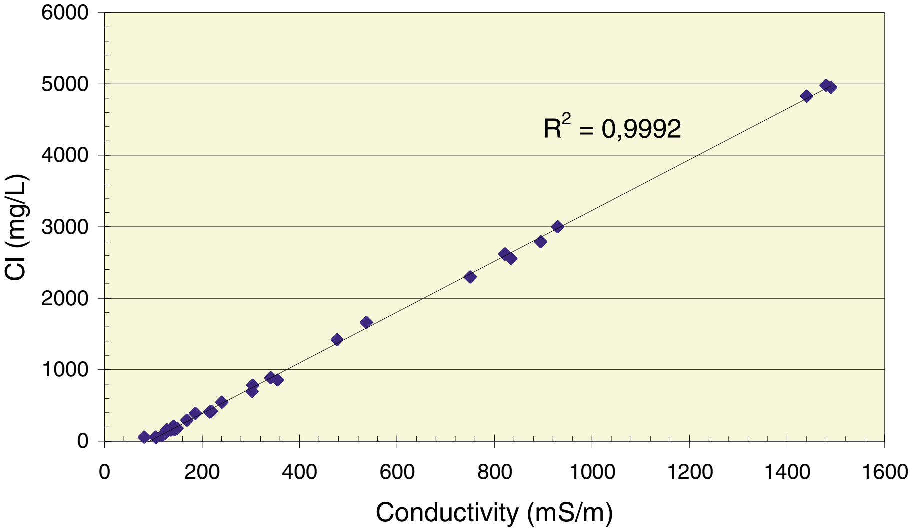

Figure 7-4. *Chloride concentration versus electric conductivity.*

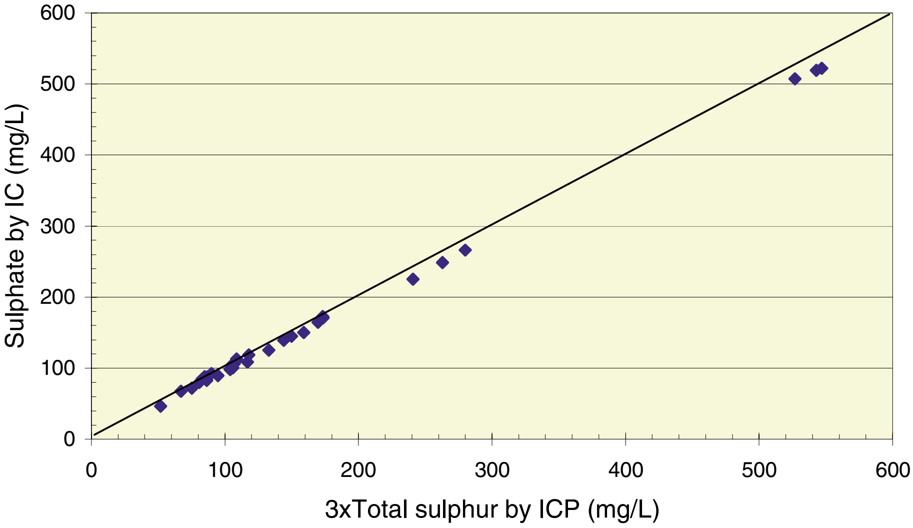

Figure 7-5. *Sulphate (IC) versus sulphate recalculated from total sulphur (ICP).*

7.2 Isotope analysis

The isotope determinations include the stable isotopes δD, $\delta^{18}O$, $^{10}B/^{11}B$, $\delta^{34}S$, $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ as well as the radioactive isotopes Tr (TU) and ^{14}C (pmC). The available isotope data at the printing date are compiled in Appendix 3. The late data will be included in a version no 2 of this report.

The tritium and $\delta^{18}O$ results for groundwater from the boreholes are plotted versus chloride concentration in Figure 7-6. The tritium content was below the detection limit (0.8 Tritium Units) in two of the most saline samples. The $\delta^{18}O$ ratios are below minus ten in all boreholes except the two most saline ones with a more marine signature.

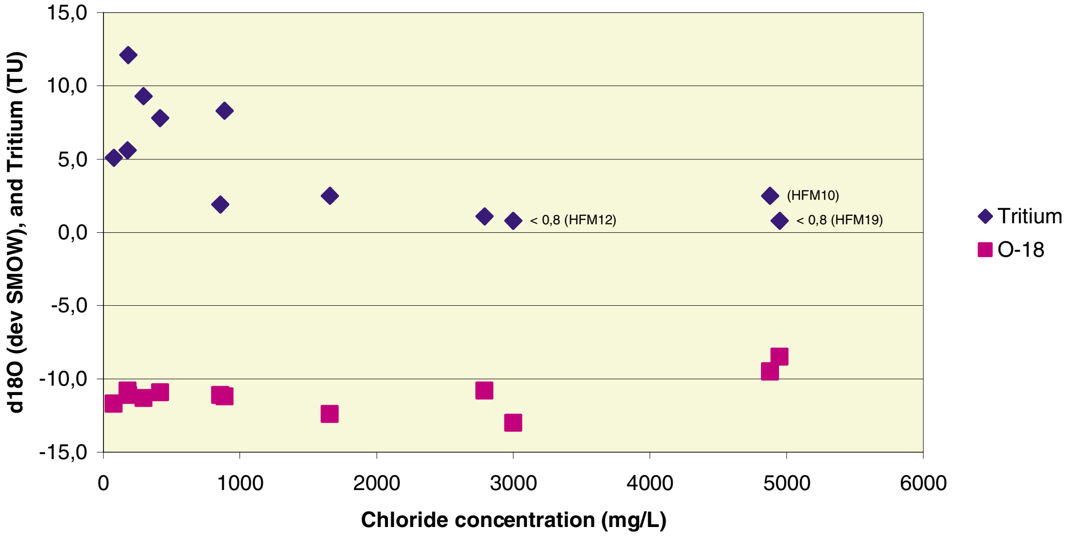

Figure 7-6. *Tritium and $\delta^{18}O$ versus chloride concentrations.*

8 Summary and discussion

The sampling of groundwater from percussion drilled boreholes HFM09 to HFM19 have been conducted in connection with hydraulic pumping tests performed in the boreholes between September 2003 and March 2004. The experimental results can be summarized as follows:

- The salinity generally increased with pumping time in the three samples collected from each borehole. A few boreholes show stable concentration levels (HFM17, HFM10 and HFM19) within the analytical uncertainty. Although uncertain, the last sample in each series may be considered as the most representative for the groundwater.
- The quality of the analytical data appears to be good. The relative charge balance error is below 5% for all the collected samples. Consistencies check/plotting of the data show no outliers.

9 References

/1/ **SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29. Svensk Kärnbränslehantering AB.

/2/ **Claesson L-Å, Nilsson G, 2004.** Forsmark site investigation. Drilling of a flushing water well, HFM10, a groundwater monitoring well, HFM09 and a groundwater monitoring well in soil SFM0057, at drillsite DS4. SKB P-04-76. Svensk Kärnbränslehantering AB.

/3/ **Claesson L-Å, Nilsson G, 2004.** Forsmark site investigation. Drilling of a flushing water well, HFM13, two groundwater monitoring wells in solid bedrock, HFM14–15, and one groundwater monitoring well in soil, SFM0058, at and close to drilling site DS5. SKB P-04-85. Svensk Kärnbränslehantering AB.

/4/ **Claesson L-Å, Nilsson G, 2004.** Forsmark site investigation. Drilling of a monitoring well, HFM16, at drilling site DS6. SKB P-04-94. Svensk Kärnbränslehantering AB.

/5/ **Claesson L-Å, Nilsson G, 2004.** Forsmark site investigation. Drilling of five percussion boreholes, HFM11–12 and HFM 17–19, on different lineaments. SKB P-04-106. Svensk Kärnbränslehantering AB.

/6/ **Ludvigsson J-E, Jönsson S, Jönsson J, 2004.** Forsmark site investigation. Pumping tests and flow logging. Boreholes HFM11 and HFM12. SKB P-04-64. Svensk Kärnbränslehantering AB.

/7/ **Ludvigsson J-E, Jönsson S, Hjerne C, 2004.** Forsmark site investigation. Pumping tests and flow logging. Boreholes KFM06A (0–100 m) and HFM16. SKB P-04-65. Svensk Kärnbränslehantering AB.

/8/ **Ludvigsson J-E, Jönsson S, Jönsson J, 2004.** Forsmark site investigation. Pumping tests and flow logging. Boreholes HFM13, HFM14 and HFM15. SKB P-04-71. Svensk Kärnbränslehantering AB.

/9/ **Ludvigsson J-E, Kjällgården, Hjerne C, 2004.** Forsmark site investigation. Pumping tests and flow logging. Boreholes HFM17, HFM18 and HFM19. SKB P-04-72. Svensk Kärnbränslehantering AB.

/10/ **Ludvigsson J-E, Kjällgården, Jönsson J, 2004.** Forsmark site investigation. Pumping tests and flow logging. Boreholes HFM09 and HFM10. SKB P-04-74. Svensk Kärnbränslehantering AB.

Appendix 1

Sampling and analysis methods

Table A6-1. Sample handling routines and analysis methods.

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Laboratory***	Analysis within - or delivery time to lab.
Anions 1.	HCO_3 pH(lab) cond (lab)	Plastic	250	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	Mobile field lab. AnalyCen	The same day – maximum 24 hours
Anions 2	Cl, SO_4, Br^-, F^-, I^-	Plastic	100	Yes (not in the field)	No	Titration (Cl^-) IC (Cl^-, SO4, Br^-, F^-) ISE (F^-)	Äspö:s chemistry lab. AnalyCen	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	Paavo Ristola OY Analytica AB,	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_3)	ICP-AES ICP-MS	Analytica AB, AnalyCen	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 (1mL HNO_3)	ICP-AES ICP-MS	Analytica AB, AnalyCen	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	500	Yes	Yes (5 mL HCl))	Spectrophotometry Ferrozine method	Mobile field lab.	As soon as possible the same day
Hydrogen sulphide	HS^-	Glass (Winkler)	About 120×2	No	Ev 1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	AnalyCen l Äspö:s chemistry lab.	Immediately or if conserved, a few days
Nutrient salts	NO_2, NO_3+NO_2, NH_4, PO_4	Plastic	250	No	No	Spectrophotometry	Äspö:s chemistry lab. AnalyCen l	Maximum 24 hours
Environmental metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	Analytica AB, AnalyCen	Not critical (month)
Lantanoids, U, Th and so on.	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	SGAB Analytica, AnalyCen	Not critical (month)

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Laboratory***	Analysis within - or delivery time to lab.
Dissolved organic Carbon, dissolved inorganic Carbon	DOC, DIC	Plastic	250 25	Yes	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Paavo Ristola OY Dept. of System ecology, SU	Short transportation time
Total organic Carbon	TOC	Plastic	250 25	No	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Paavo Ristola OY Dept. of System ecology, SU	Short transportation time
Environmental isotopes	∂^2H, $\partial^{18}O$	Plastic	100	No	- -	MS	IFE	Not critical (month)
Tritium, Chlorine-37	^3H (enhanced.) $\partial^{37}Cl$	Plastic (dry bottle) Plastic	500 100	No No	- -	LSC ICP MS	Univ. of Waterloo	Not critical (month)
Carbon isotopes	$\partial^{13}C$, pmC (^{14}C)	Glass (brown)	100×2	No	-	(A)MS	Univ. of Waterloo	A few days
Sulphur isotopes	$\partial^{34}S$	Plastic	500 –1000	Yes	-	Combustion, ICP MS	IFE	No limit
Strontium-isotopes	$^{87}Sr/^{86}Sr$	Plastic	100	Yes	-	TIMS	IFE	Days or Week
Uranium and Thorium isotopes	^{234}U, ^{235}U, ^{238}U, ^{232} Th, ^{230}Th,	Plastic	50	Nej	-	Chemical separat. Alfa/gamma spectrometry	IFE	No limit
Boron isotopes	$^{10}B/^{11}B$	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP – MS	Analytica AB	No limit
Radon and Radium isotopes	^{222}Rn, ^{226}Ra	Plastic	500	No	No	EDA, RD-200	IFE	Immediate transport
Dissolved gas (content and composition)	Ar, N_2, CO_2, O_2, CH_4, H_2, CO, C_2H_2, C_2H_4, C_2H_6, C_3H_8	Cylinder of stainless steel	200	No	No	GC	Paavo Ristola OY	Immediate transport
Colloids	Filter series and fractionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 µm	-	N_2 atmosphere	ICP-AES ICP-MS	Analytica AB	Immediate transport
Humic and fulvic acids	Fractionation	Fractions are collected in plastic bottles	250	-	N_2 atmosphere	UV oxidation, IR (DOC)	Paavo Ristola OY	Immediate transport
Archive samples with acid	-	Plast (washed in acid)	100×2 **	Yes	Yes (1 mL HNO_3)	-	-	Storage in freeze container
Archive samples without acid	-	Plastic	250×2 **	Yes	No	-	-	Storage in freeze container

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Laboratory***	Analysis within - or delivery time to lab.
Carbon isotopes in humic and fulvic acids	$\partial^{13}C$, pmC (^{14}C)	DEAE cellulose (anion exchanger)	-	-	-	(A)MS	The Ångström laboratory, Uppsala	A few days

* Suprapur acid is used for conservation of samples.
** Minimum number, the number of archive samples can vary depending on how many similar samples that are collected at the same occasion.
*** Full name and address is given in Table A2-3.

Abbreviations and definitions:

IC	Ion chromatograph
ISE	Ion selective electrode
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
INAA	Instrumental Neutron Activation Analysis
MS	Mass Spectrometry
LSC	Liquid Scintillation Counting
(A)MS	(Accelerator) Mass Spectrometry
GC	Gas Chromatography

Table A6-2. Reporting limits and measurement uncertainties.

Component	Method	Detection limit	Reporting limit or range	Unit	Measurement uncertainty[2]	"Total" uncertainty[3]
HCO_3	Alkalinity titration	0.2	1	mg/L	4 %	<10 %
Cl^- Cl^-	Mohr titration IC	5 0.2	70 0.5	mg/L	5 % 6 %	<10 % 10 %
SO_4	IC	0.2	0.5	mg/L	6 %	15 %
Br^- Br^-	IC ICP	0.2 -	0.7 0.001 – 0.010[1]	mg/L	9 % 15 %	20 %
F^- F^-	IC Potentiometri	0.2 -	0.6 -	mg/L	10 % -	20 % -
I^-	ICP	-	0.001 – 0.010[1]	mg/L	15 %	20 %
Na	ICP	-	0.1	mg/L	4 %	10 %
K	ICP	-	0.4	mg/L	6 %	15 %
Ca	ICP	-	0.1	mg/L	4 %	10 %
Mg	ICP	-	0.09	mg/L	4 %	10 %
S(tot)	ICP	-	0.160	mg/L	10 %	15 %
Si(tot)	ICP	-	0.03	mg/L	4 %	15 %
Sr	ICP	-	0.002	mg/L	4 %	15 %
Li	ICP	-	0.2 - 2[1]	µg/L	10 %	20 %
DOC	See tab. 1	-	0.5	Mg/L	8 %	30 %
TOC	See tab. 1	-	0.5	Mg/L	10 %	30 %
δ^2H	MS	-	2	‰ SMOW[4]	1.0 ‰	-
$\delta^{18}O$	MS	-	0.1	‰ SMOW[4]	0.2 ‰	-
^3H	LSC	-	0.8 or 0.1	TU[5]	0.8 or 0.1 TU	-
$\delta^{37}Cl$	ICP MS	-	0.2 ‰ (20 mg/L)	‰ SMOC[6]	-	-
$\delta^{13}C$	A (MS)	-	>20 mg Carbon	‰ PDB[7]	-	-
pmC (^{14}C)	A (MS)	-	>20 mg kol	PmC[8]	-	-

Component	Method	Detection limit	Reporting limit or range	Unit	Measurement uncertainties [2]	"Total" uncertainties [3]
$\delta^{34}S$	ICP MS	-	0.2 ‰	‰ CDT[9]	0.2 ‰	-
$^{87}Sr/^{86}Sr$	MS	-	-	No unit (ratio) [10]	0.000020	-
$^{10}B/^{11}B$	ICP MS	-	-	No unit (ratio) [10]	0,0020	-
^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{230}Th	Alfa spectr.	-	0.05	Bq/L[12]	0.05 Bq/L	Right order of magnitude
^{222}Rn, ^{226}Rn	LSC	-	0.1	Bq/L	0.05 Bq/L	

1. Reporting limits at salinity ≤ 0.4 % (520 mS/m) and ≤ 3.5 % (3810 mS/m) respectively.
2. Measurement uncertainty reported by consulted laboratory, generally 95 % confidence interval.
3. Estimated total uncertainty by experience (includes effects of sampling and sample handling).
4. Per mille deviation[11] from SMOW (Standard Mean Oceanic Water).
5. TU=Tritium Units, where one TU corresponds to a Tritium/hydrogen ratio of 10^{-18} (1 Bq/L Tritium = 8.45 TU).
6. Per mille deviation[11] from SMOC (Standard Mean Oceanic Chloride).
7. Per mille deviation[11] from PDB (the standard PeeDee Belemnite).
8. 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.
9. Per mille deviation[11] from CDT (the standard Canyon Diablo Troilite).
10. Isotope ratio without unit.
11. Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:
    $\delta^{y}I = 1000\times(K_{sample}-K_{standard})/K_{standard}$, where K= the isotope ratio and $^{y}I = {}^{2}H$, ^{18}O, ^{37}Cl, ^{13}C or ^{34}S etc.
12. Following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232:
    1 ppm U = 12.4 Bq/kg^{238}U
    1 ppm Th = 3.93 Bq/kg^{232}Th

Table A6-3. Participant laboratories.

Äspö water chemical laboratory (SKB) Mobile field laboratory, Forsmark (SKB)
Inainööritoimisto Paavo Ristola Oy Teollisuus-ja Voimalaitoskemia Rajantorpantie 8, C-talo 01600 Vantaa FINLAND
Dept. of System ecology Stockholm University 10691 Stockholm
Analytica AB Aurorum 10 977 75 Luleå (Nytorpsvägen 16 Box 511 183 25 Täby)
Environmental Isotope Laboratory Dep. Of earth sciences University of Waterloo Waterloo, Ontario N2L 3G1 CANADA
Institutt for energiteknik (IFE) Insituttveien 18 P.O Box 40 2027 Kjeller NORGE
AlnalyCen Nordic AB Box 905 531 19 Lidköping
The Ångström laboratory Box 534 Se-751 21 Uppsala

Appendix 2

Water composition

Compilation June 2004-06-23

Idcode	Secup	Seclow	Date	Time	Sample no.	Charge bal.	Na	K	Ca	Mg	HCO3	Cl	SO4	SO4-S	Br	F-	Si	Li	Sr	pH	ElCond	TOC
	m	m				%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L		mS/m	mg/L
HFM09	17.02	50.25	2004-02-18	12:40	8333	-2.18	253	5.28	33.0	6.1	466	159	80.9	26.7	0.60	1.70	6.7	0.012	0.30	7.98	128	6.7
HFM09	17.02	50.25	2004-02-18	15:45	8334	0.64	265	5.42	37.4	6.8	465	158	83.1	28.3	0.51	1.35	6.7	0.012	0.34	7.94	136	6.7
HFM09	17.02	50.25	2004-02-18	19:40	8335	0.3	274	5.60	41.1	7.5	465	181	85.1	29.3	0.57	1.60	6.7	0.014	0.38	7.91	144	6.7
HFM10	11.8	150	2004-02-25	11:10	8336	-3.24	1630	21.9	1120	201	147	5050	447	138	28.2	-0.2	8.5	0.046	12.2	7.17	1470	2.4
HFM10	11.8	150	2004-02-25	15:16	8337	-3.68	1630	22	1100	200	144	5060	450	137	28.5	-0.2	8.5	0.048	12	7.13	1470	2.4
HFM10	11.8	150	2004-02-25	19:50	8338	-3.69	1600	21.7	1040	191	144	4880	433	132	26.4	-0.2	8.4	0.047	11.6	7.12	1420	2.3
HFM11	12.0	182.35	2003-10-02	10:40	8036	-1.73	229	5.71	128	13.8	355	389	67.2	22.4	1.69	1.12	5.3	0.011	1.37	7.38	187	7.6
HFM11	12.0	182.35	2003-10-02	15:00	8037	-1.77	436	5.54	468	29.2	276	1421	87.2	29.4	7.25	1.11	5.2	0.022	5.61	7.27	477	5.9
HFM11	12.0	182.35	2003-10-02	18:30	8038	-1.67	482	5.63	550	32.6	261	1658	90.0	30.8	8.61	0.89	5.2	0.025	6.62	7.27	537	5.3
HFM12	14.9	209.55	2003-09-26	08:00	8020	-1.27	783	6.34	779	63.0	176	2617	174	57.5	12.1	1.00	5.2	0.036	9.02	7.44	821	4.6
HFM12	14.9	209.55	2003-09-26	11:15	8019	-1.34	780	5.74	785	62.4	183	2622	174	57.0	12.1	1.06	5.1	0.036	9.21	7.50	822	5.0
HFM12	14.9	209.55	2003-09-26	16:30	8018	-1.11	846	5.72	917	73.2	163	3000	170	54.9	15.1	0.99	5.2	0.041	10.8	7.29	930	3.8
HFM13	14.9	175.6	2003-11-17	10:30	8130	-1.07	899	14.7	506	91.2	255	2300	241	75.0	7.71	1.07	6.5	0.036	4.49	7.50	750	6.0
HFM13	14.9	175.6	2003-11-17	14:30	8129	-0.49	1010	15.8	555	102	231	2560	263	82.8	8.72	0.98	6.4	0.035	5.00	7.51	834	5.6
HFM13	14.9	175.6	2003-11-17	17:56	8128	-1.13	1080	16.8	591	111	226	2790	280	88.7	9.52	1.04	6.3	0.036	5.25	7.50	895	6.1
HFM14	3.0	150.5	2003-11-05	10:30	8095	0.42	276	9.27	176	25.5	332	545	104	33.0	1.95	0.83	4.4	0.012	0.70	7.14	241	14
HFM14	3.0	150.5	2003-11-05	15:00	8094	-2.19	381	10.8	188	28.8	308	785	133	41.8	2.65	1.25	5.0	0.015	0.79	7.07	304	13
HFM14	3.0	150.5	2003-11-05	19:00	8093	-2.85	438	12.1	189	32.6	318	887	150	48.2	3.46	1.11	3.6	0.013	0.93	7.18	341	11
HFM15	6.0	199.5	2003-11-12	09:10	8125	10.11	33.3	4.51	128	8.30	271	57.1	51.8	15.5	0.17	0.59	4.3	0.006	0.17	7.06	81.3	16.4
HFM15	6.0	199.5	2003-11-12	15:00	8126	0.64	420	11.8	160	28.6	359	697	144	46.5	2.30	1.68	5.2	0.017	0.84	7.44	303	11.8
HFM15	6.0	199.5	2003-11-12	18:30	8127	-2.04	466	12.7	175	32.9	366	857	159	50.1	2.72	1.04	5.3	0.018	0.96	7.42	355	10.6
HFM16	12.0	132.5	2003-12-02	10:40	8162	1.00	244	5.67	23.6	5.9	442	104	94.9	29.8	0.39	2.53	5.6	0.009	0.21	7.90	123	13
HFM16	12.0	132.5	2003-12-02	15:35	8163	0.48	275	5.80	30.5	7.5	450	162	104	32.6	0.59	2.56	5.7	0.009	0.27	7.91	144	13
HFM16	12.0	132.5	2003-12-02	18:41	8164	0.29	282	5.93	32.7	8.1	450	178	106	33.6	0.61	2.56	5.8	0.010	0.29	7.94	149	15
HFM17	8.0	202.65	2004-01-27	10:18	8257	-1.98	402	12.9	41.2	13.3	450	419	118	39.5	1.39	2.62	6.4	0.011	0.24	7.89	219	13.0
HFM17	8.0	202.65	2004-01-27	14:17	8258	-1.63	398	12.6	41.4	13.2	454	409	109	37.6	1.26	2.61	6.4	0.011	0.25	7.91	216	13.0
HFM17	8.0	202.65	2004-01-27	17:53	8246	-1.92	399	12.7	42.2	13.5	461	415	109	37.0	1.07	2.54	6.4	0.011	0.25	7.92	218	14.0
HFM18	9.0	180.65	2004-02-10	10:58	8324	-0.95	204	9.41	25.2	8.6	454	52.4	117	36.2	0.14	2.1	8.2	0.010	0.16	7.89	106	6.5
HFM18	9.0	180.65	2004-02-10	14:30	8325	-0.90	206	9.32	23.9	8.2	449	56.5	106	35.2	0.14	2.18	7.9	0.011	0.15	7.88	105	6.2
HFM18	9.0	180.65	2004-02-10	18:40	8250	-0.09	217	9.39	27.6	9.0	447	76.4	107	35.3	0.23	2.46	7.7	0.011	0.19	7.89	118	6.2
HFM19	12.0	185.2	2004-02-03	09:09	8259	-1.93	1830	47.4	875	233	146	4830	527	169	20.1	-0.2	6.0	0.052	6.15	7.30	1440	2.9
HFM19	12.0	185.2	2004-02-03	13:17	8260	-1.97	1880	48.6	901	240	136	4980	547	174	19.5	-0.2	6.0	0.053	6.35	7.29	1480	2.4
HFM19	12.0	185.2	2004-02-03	18:11	8247	-1.91	1870	48.4	893	242	137	4950	543	173	19.9	-0.2	6.0	0.053	6.31	7.29	1490	2.1
KFM06A	12.3	100.30	2003-12-08	17:20	8186	1.70	247	8.22	46.8	9.6	374	209	75.3	24.0	0.76	1.52	9.4	0.011	0.34	8.22	142	13
KFM06A	12.3	100.30	2003-12-08	18:58	8187	0.54	285	8.71	55.3	11.9	370	295	86.4	27.5	1.03	1.43	8.7	0.011	0.43	8.09	169	13

Appendix 3

Isotopes (H, O-, B-, S-, Sr- and C-isotopes)

Compilation June 2004

Idcode	Secup	Seclow	Date	Time	Sample	D	Tr	O-18	$^{10}B/^{11}B$	S-34	Cl-37	$^{87}Sr/^{86}Sr$	C-13	C-14	Age
	m	m			no	dev SMOW	TU	dev SMOW	no unit	dev CDT	dev SMOC	no unit	dev PDB	pmC	years
HFM09	17.02	50.3	2004-02-18	19:40	8335	-80.6	12.1	-11.1	0.2373	18.7	*	0.719654	*	*	*
HFM10	11.8	150	2004-02-25	19:50	8338	-71.8	2.5	-9.5	0.2414	25.1	*	0.717312	*	*	*
HFM11	12.0	182.4	2003-10-02	18:30	8038	-91.4	2.5	-12.4	0.2339	30.2	*	0.716741	-11.86	*	*
HFM12	14.9	209.6	2003-09-26	16:30	8018	-96.7	-0.8	-13.0	0.2384	30.9	*	0.716788	-8.65	*	*
HFM13	14.9	175.6	2003-11-17	17:56	8128	-76.5	1.1	-10.8	0.2317	24.0	*	0.718368	-10.78	*	*
HFM14	3.0	150.5	2003-11-05	19:00	8093	-78.1	8.3	-11.2	0.2403	19.0	*	0.722974	-11.00	*	*
HFM15	6.0	199.5	2003-11-12	18:30	8127	-77.5	1.9	-11.1	0.2371	17.9	*	0.722296	-10.68	*	*
HFM16	12.0	132.5	2003-12-02	18:41	8164	-81.9	5.6	-10.8	0.2387	14.8	*	0.718978	-10.66	*	*
HFM17	8.0	202.7	2004-01-27	17:53	8246	-80.0	7.8	-10.9	0.2384	20.9	*	0.722675	-9.75	*	*
HFM18	9.0	180.7	2004-02-10	18:40	8250	-85.4	5.1	-11.7	0.2374	2.9	*	0.721590	-12.46	*	*
HFM19	12.0	185.2	2004-02-03	18:11	8247	-64.5	-0.8	-8.5	0.2363	24.3	*	0.722375	-7.04	*	*
KFM06A	12.3	100.3	2004-12-08	18:58	8187	-84.1	9.3	-11.3	0.2368	19.1	*	0.719319	-11.56	*	*

* Results will be reported later