P-03-96

Forsmark site investigation

Hydrochemical logging in KFM03A

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December 2003

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ISSN 1651-4416
SKB P-03-96

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Keywords: groundwater, water column in open borehole, chemical analyses, isotope determinations, AP PF 400-03-01, Field notes No. Forsmark 156.

Contents

1 Introduction

This document reports performance of and results from the activity: "Hydrochemical logging in KFM03A", performed within the site investigation at Forsmark /1/. The work was conducted according to the activity plan AP PF 400-03-56 (SKB internal controlling document).

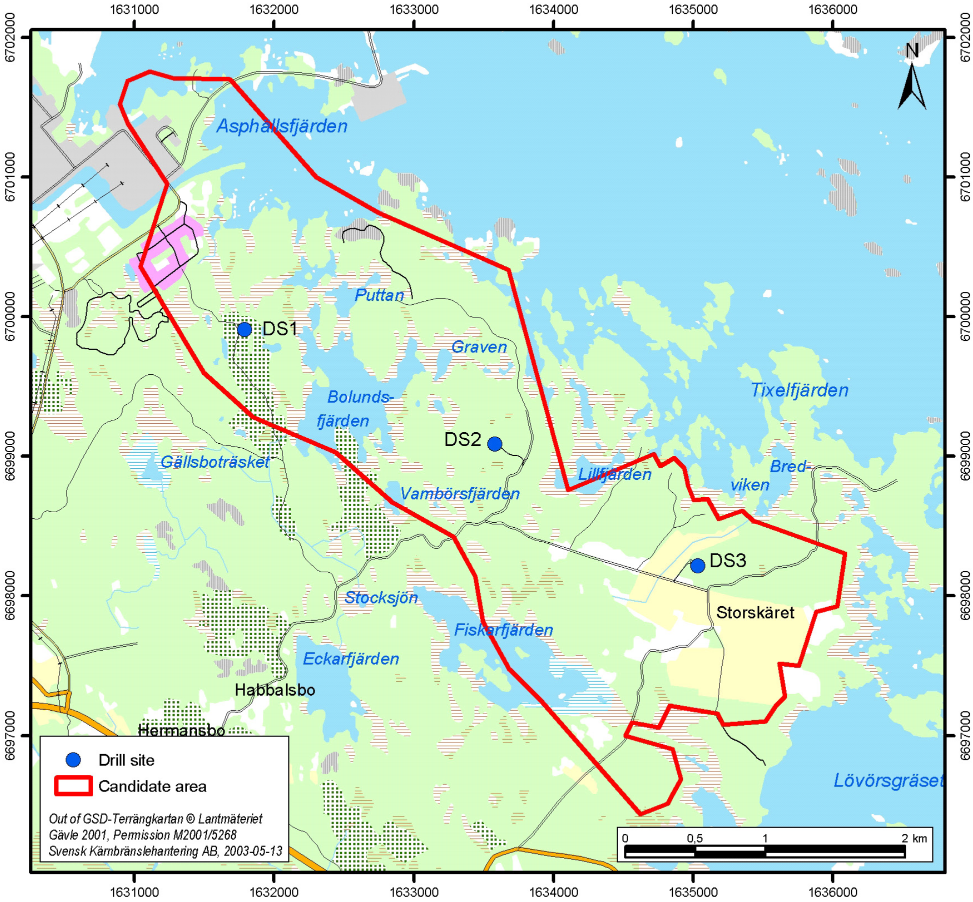
Borehole KFM03A is the third deep telescopic borehole drilled at the site investigations in the Forsmark area /2/. The location of the borehole is shown in Figure 1-1. The borehole section 0–100 m is percussion drilled. Initially this first part of the borehole was very tight and did not show any sign of water bearing fracture zones. Therefore it was cased with a stainless steel casing down to only 12 m and not the usual 100 m. Later on, during the drilling of the borehole KFM01B, some fractures seem to have opened up at a depth of between 62 and 65 m and a quite large flow of water was noted. The percussion-drilled part of the borehole has an internal diameter of 200 mm, whereas section 100–1001.2 m is core drilled with a diameter of 77 mm.

Borehole KFM03A is of the so-called SKB chemical type, see method descriptions MD 620.003 (Method description for drilling cored boreholes) and 610.003 (Method description for percussion drilling). A borehole being of SKB chemical type entails cleaning procedures of all in-hole equipment to be used in the borehole during and after drilling according to level 2 in the cleaning instructions in SKB MD 600.004 (Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning).

Basic borehole information is given in Table 1-1 below. The design of the borehole is presented in Appendix 1. A map showing the locations of the boreholes at drill site DS3 is presented in Figure 1-2.

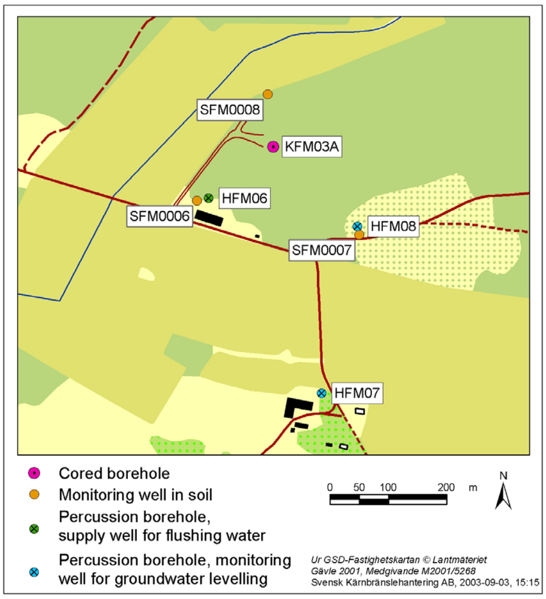
Table 1-1. Borehole information, KFM03A at drill site DS3.

Activities performed	Date of completion	Length (m)	Comment
Percussion drilling	2003-03-28	0–100	/2/, /4/
BIPS-logging	2003-03-26	0–100	–
Core drilling WL-water sampl.	2003-06-23 2003-05-06	100–1000.19 347–394	HFM06 was source of flushing water for core drilling the cored part of KFM03A. HFM06 is a SKB chemical type of borehole /2/, /3/, /5/.
Final mammoth pumping after completion of the core drilled part	–	–	Pumped volumes: 176 m^3 after completed drilling, 250 m^3 just before hydrochemical logging.
Borehole direction and coordinate surveying	2003-06-24	–	–
Hydrochemical logging	2003-06-30	100–1000	Described in this report.



Out of GSD-Terrängkartan © Lantmäteriet
Gävle 2001, Permission M2001/5268
Svensk Kärnbränslehantering AB, 2003-05-13

***Figure 1-1**. The investigation area at Forsmark (approximately the area inside the black square) including the candidate area selected for more detailed investigations. Drill sites DS1–3 are marked with blue circles.*



Ur GSD-Fastighetskartan © Lantmäteriet
Gävle 2001, Medgivande M2001/5268
Svensk Kärnbränslehantering AB, 2003-09-03, 15:15

***Figure 1-2.** Locations of the telescopic borehole KFM03A as well as percussion boreholes and shallow monitoring wells at drill site DS3.*

2 Objective and scope

Hydrochemical logging is performed in order to obtain an overview of the initial chemical composition along the open borehole KFM03A. The sampling technique is fast and simple even at great depth.

The analysis program is carried out according to SKB chemistry class 3 including isotope options. However, if the drilling water content in a sample is above 25%, the isotope determinations are omitted.

3 Sampling equipment

The sampling equipment used for the hydrochemical logging consists of an approximately 1000-metre long polyamide tube divided into units of 50 m length. The equipment is described by Nurmi and Kukkonen /6/ and in the method description SKB MD 422.001 (Metodbeskrivning för hydrokemisk loggning).

The tube units are connected with couplings. The exact length of each tube unit is given in Table 3-1. The external and internal diameters of the tube units are 10 and 8 mm respectively. The water content in each tube unit will constitute one sample and the volume of each sample will amount to at least two litres. A check valve and a weight are mounted at the bottom of the tube array to prevent water outflow and to keep it stretched in the borehole. At both ends of each tube unit there is a manual shut off valve. A schematic illustration of the equipment used for the hydrochemical logging is presented in Figure 3-1.

Table 3-1. Lengths of tube units.

Unit	Length [m]
1	49,870
2	49,620
3	49,630
4	49,300
5	49,200
6	49,220
7	49,700
8	50,620
9	50,250
10	49,670
11	49,720
12	49,570
13	49,870
14	49,850
15	50,010
16	49,970
17	49,280
18	49,770
19	50,080
20	49,710
Sum:	994,910
Coupling length	2,812
Weight length	0,817
Total tube length:	**998,539**

***Figure 3-1**. "Equipment for hydrochemical logging in boreholes". At the lower end of the tube array there is a check valve and a weight connected. Each tube unit is about 50 metres long.*

4 Performance

4.1 Hydrochemical logging

The sampling of the telescopic borehole KFM03A was performed according to activity plan AP PF 400-03-56 (SKB internal controlling document) following the method described in SKB MD 422.001 (Metodbeskrivning för hydrokemisk loggning).

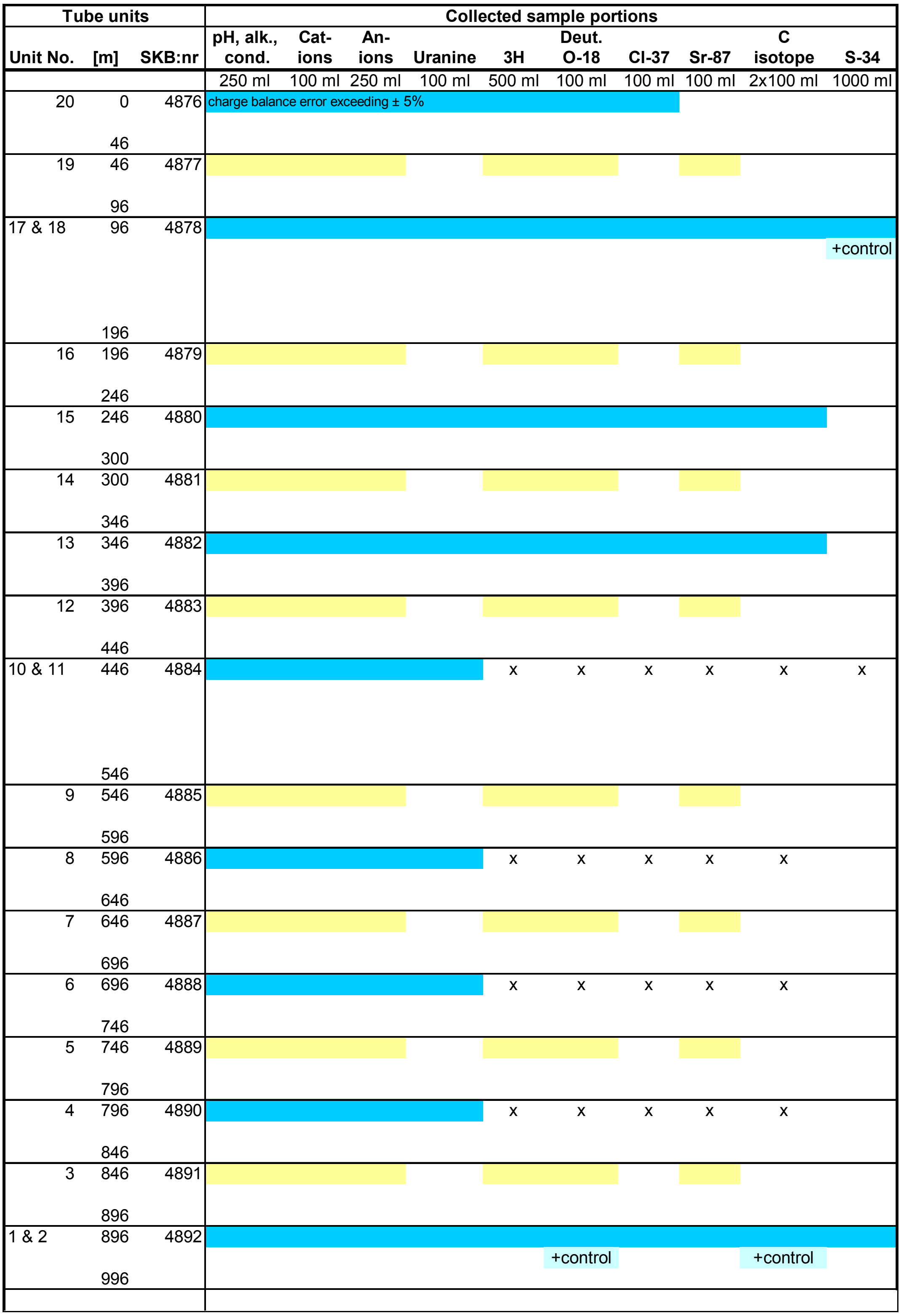
The hydrochemical logging was performed on the 30:th of June to a depth of 996 metres. The tube array was not lowered all the way down in order to decrease the risk of getting stuck and also to avoid suspending drilling debris sedimented at the bottom of the borehole. The lowering of the tubes along the borehole started at 08:10 and at 12:23 all 20 tube units had been descended. The uptake of the first tube unit started at 13:33 and at 15:02 the last tube unit was lifted up. The first tube unit at the top of the array was lowered to 46 m of its length. This, and the fact that the groundwater level was about 9 m below top of casing resulted in a tube unit that was not completely filled. The tube units were emptied using pressurised nitrogen gas and the water was portioned into plastic bottles to be analysed at different laboratories.

The ground water level in the borehole was measured before the logging, after lowering the tube array and when the logging was completed. The groundwater levels measured were 9.30 m, 8.63 m and 8.30 m respectively.

4.2 Sample treatment and chemical analyses

An overview of sample treatment and analysis routines is given in Appendix 2. The routines are applicable independent of sampling method or sampling object. An overview showing the sample portions filled at the logging occasion is given in Table 4-1. Some of the sample portions that were intended for isotope analyses were not sent to the laboratories due to their high content of remaining flushing water from the drilling. The excluded isotope samples where SKB:no 4884 to 4890. The hydrochemical data from the logging are stored in the database SICADA in field note No. 156. The SKB sample numbers are 4876–4892.

Table 4-1. Overview of sample portions collected at hydrochemical logging in KFM03A. Filled cells represent collected sample portions.



Tube units			Collected sample portions									
Unit No.	[m]	SKB:nr	pH, alk., cond.	Cat-ions	An-ions	Uranine	3H	Deut. O-18	Cl-37	Sr-87	C isotope	S-34
			250 ml	100 ml	250 ml	100 ml	500 ml	100 ml	100 ml	100 ml	2x100 ml	1000 ml
20	0 46	4876	🟦 charge balance error exceeding ± 5%	🟦	🟦	🟦	🟦	🟦	🟦			
19	46 96	4877	🟨	🟨	🟨		🟨	🟨		🟨		
17 & 18	96 196	4878	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦 +control
16	196 246	4879	🟨	🟨	🟨		🟨	🟨		🟨		
15	246 300	4880	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
14	300 346	4881	🟨	🟨	🟨		🟨	🟨		🟨		
13	346 396	4882	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
12	396 446	4883	🟨	🟨	🟨		🟨	🟨		🟨		
10 & 11	446 546	4884	🟦	🟦	🟦	🟦	x	x	x	x	x	x
9	546 596	4885	🟨	🟨	🟨		🟨	🟨		🟨		
8	596 646	4886	🟦	🟦	🟦	🟦	x	x	x	x	x	
7	646 696	4887	🟨	🟨	🟨		🟨	🟨		🟨		
6	696 746	4888	🟦	🟦	🟦	🟦	x	x	x	x	x	
5	746 796	4889	🟨	🟨	🟨		🟨	🟨		🟨		
4	796 846	4890	🟦	🟦	🟦	🟦	x	x	x	x	x	
3	846 896	4891	🟨	🟨	🟨		🟨	🟨		🟨		
1 & 2	896 996	4892	🟦	🟦	🟦	🟦	🟦	🟦 +control	🟦	🟦	🟦 +control	🟦

X= samples were collected but not analysed due to high flushing water content.
Odd sample numbers are archive samples, i.e. yellow cells.
“Control” implies that the sample was analysed by a second laboratory.

4.3 Data handling

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

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

All analytical results were 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%).

$$\text{Rel. Error (\%)} = 100\times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$$

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

All results from "biochemical" components and 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 4-1.

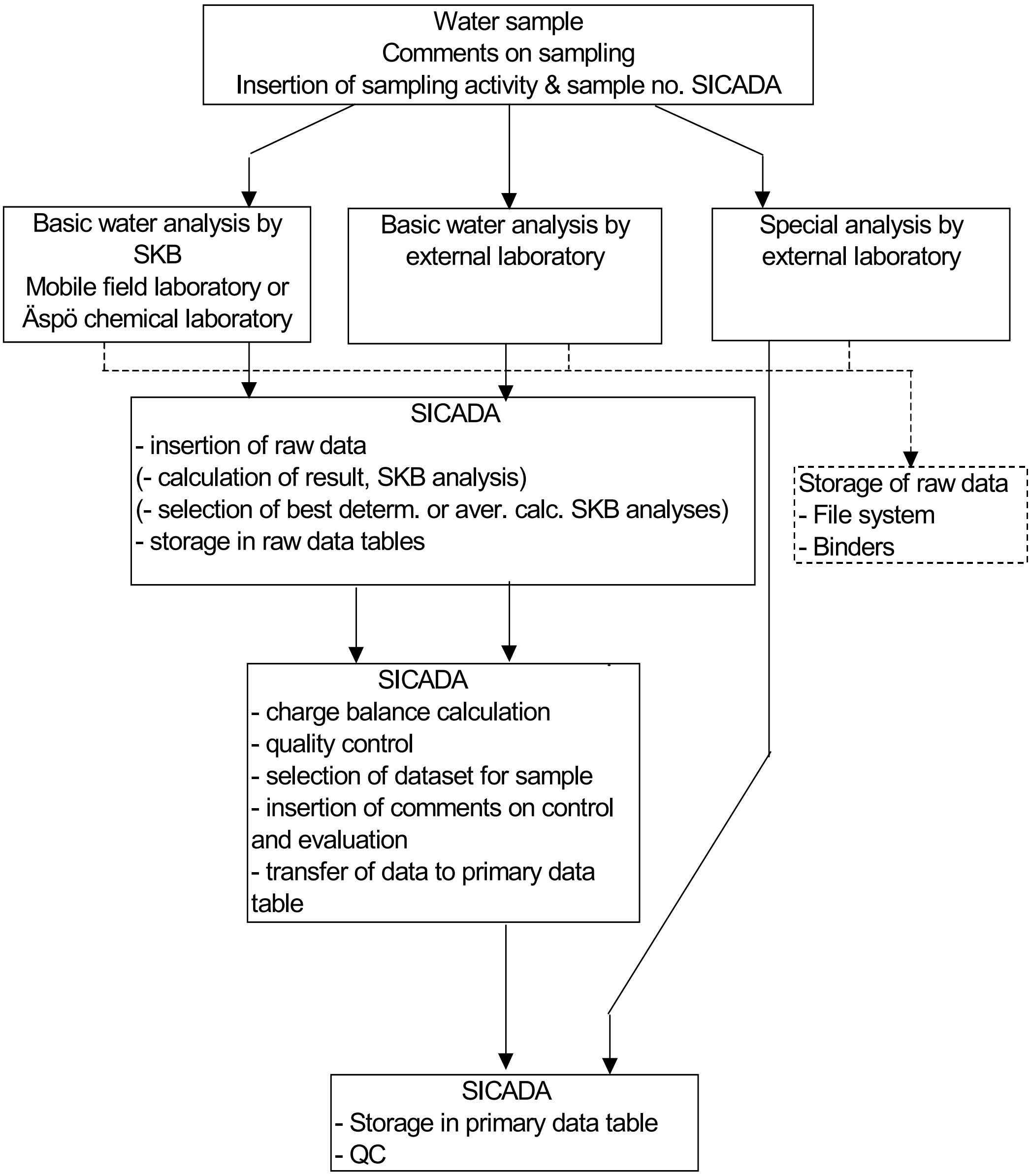


Figure 4-1. *Overview of data management for hydrogeochemical data.*

5 Results

5.1 Analysis results

The analysis data from the hydrochemical logging in borehole KFM03A are presented in Appendix 3 and 4. Diagrams showing the flushing water content and the electric conductivity plotted versus borehole length are presented in Figure 5-1 and 5-2 below. The data are plotted at the mean length of each tube unit. Isotope results are not available between 500 to 850 m along the borehole as the flushing water content in these samples exceeded 25%, see Figure 5-1.

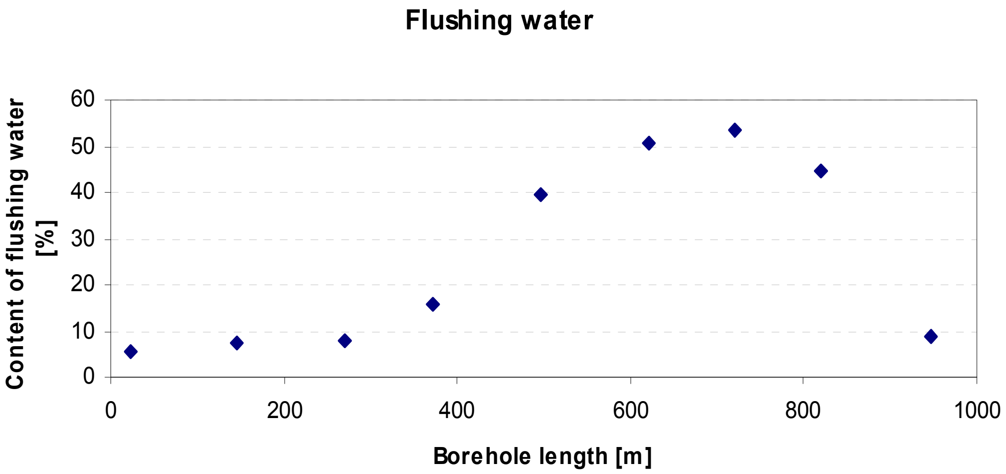


Figure 5-1. *Flushing water content*

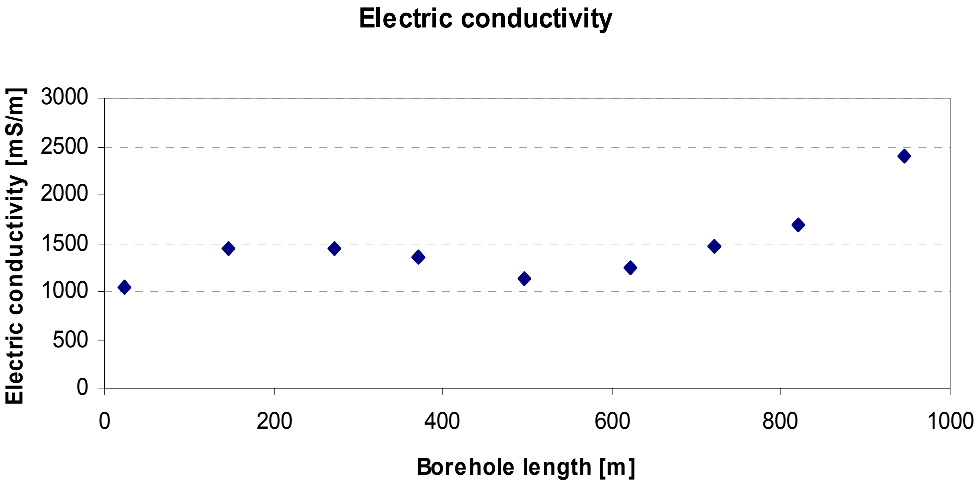


Figure 5-2. *Electric conductivity*

5.2 Quality of the analyses

Comparison of results from different laboratories and methods indicates that the agreement is acceptable in most cases. Generally the difference in concentrations between each controlled component is less than 10%.

The charge balance errors give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance errors are calculated for the selected sets of data, see Appendix 3. The errors exceed ± 5% in one case out of nine.

6 Conclusions

The hydrochemical logging in KFM03A revealed the initial chemical conditions in the borehole. The following was found:

- The flushing water content was relatively high in the middle part of the borehole but acceptable the first 400 m and at the bottom. Therefore isotopes were determined in the first four samples and in the last sample.

- The low flushing water content at the bottom of the borehole was the first indication of water bearing fractures at depth. This was confirmed by the results from the difference flow logging that was conducted later on /7/. Two water bearing fracture zones were found below 900 m.

- The electric conductivity in the flushing water from HFM06 amounted at about 400 mS/m. The contribution from the flushing water decreases the electric conductivity in the samples numbered SKB 4884 to SKB 4890.

- The chloride concentration/electric conductivity in the water at the bottom of the borehole was found to be lower than expected at this depth (9800 mg/L or 2500 mS/m). However, sampling in an open borehole soon after the drilling may result in samples that are not representative for the groundwater at the actual depth. The electric conductivity logging that was conducted later on, in connection with the difference flow logging, showed an electric conductivity value of about 3500 mS/m which based on investigations at the corresponding depth in other areas, seemed more reasonable. At the time of writing this report, the ongoing chemical characterisation in the borehole section at 980–1000 m however confirms the low values from the hydrochemical logging.

- It may be necessary to carry out extra “clean up” pumping in the borehole prior to the chemical characterisation activity in order to obtain representative samples.

7 References

/1/ **SKB, 2001.** Generellt genomförande program för platsundersökningar. SKB R- 01-10, Svensk Kärnbränslehantering AB.

/2/ **Claesson L-Å, Nilsson G, 2003.** Forsmark site investigation. Drilling of the telescopic borehole KFM03A at drillsite DS3. SKB P-03-59, Svensk Kärnbränslehantering AB.

/3/ **Claesson L-Å, Nilsson G, 2003.** Forsmark site investigation. Drilling of a flushing water well, HFM06, and two groundwater monitoring wells, HFM07 and HFM08, at drillsite DS3. SKB P-03-58, Svensk Kärnbränslehantering AB.

/4/ **Ludvigsson J-E, Källgården J, 2003.** Forsmark site investigation. Pumping tests and flow logging. Boreholes KFM03A (0–100 m), HFM06, HFM07 and HFM08. SKB P-03-36, Svensk Kärnbränslehantering AB.

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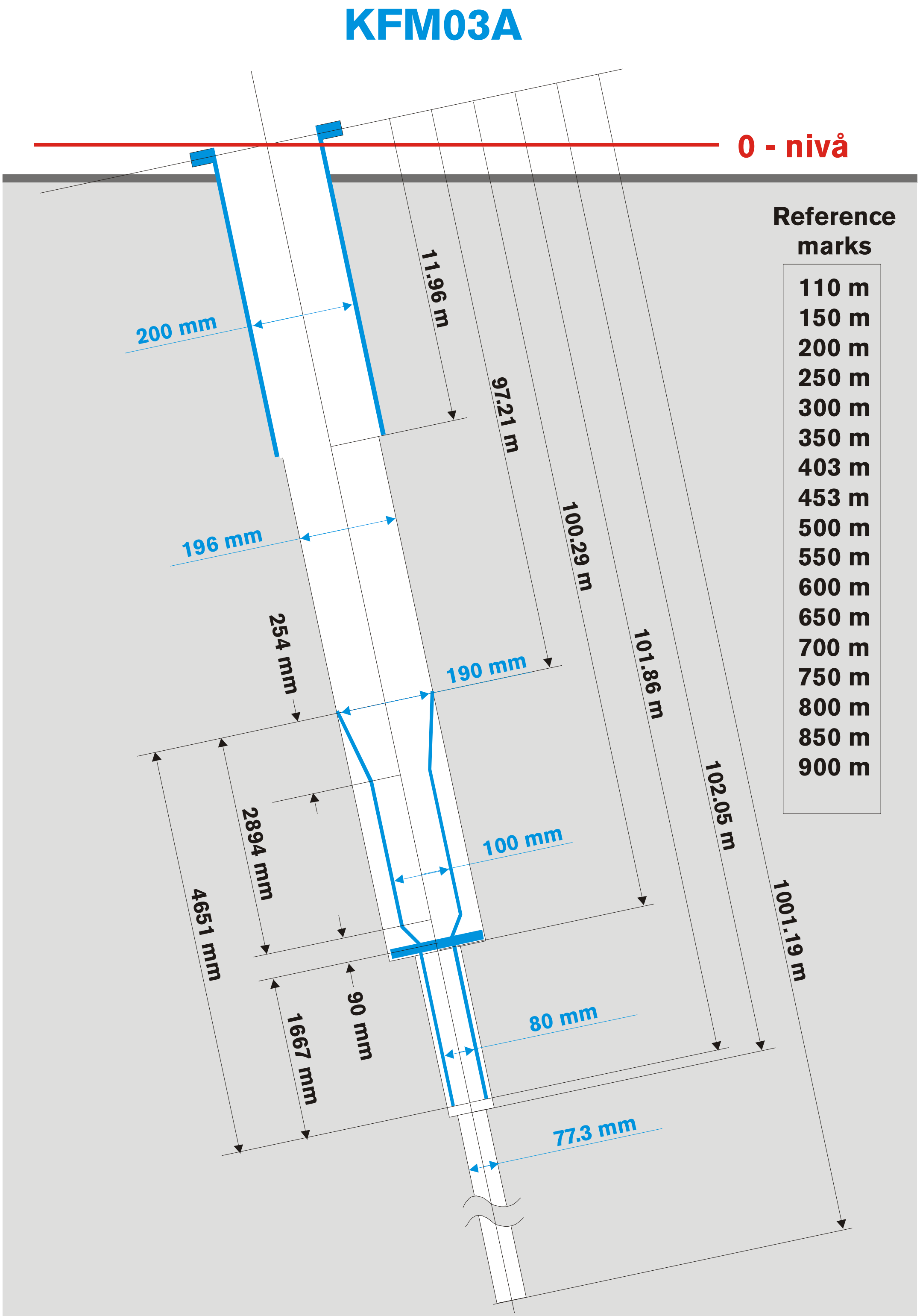
/6/ **Nurmi P, Kukkonen I, 1986.** A new technique for sampling water and gas from deep drill holes. Canadian Journal of Earth Sciences, Volume 23, Number 9, 1986, pp 1450–1454.

/7/ **Rouhiainen P, Pöllänen J, 2003 in prep.** Difference flow logging of borehole KFM03A. SKB P-04-16, Svensk Kärnbränslehantering AB.

Appendix 1

Design of the telescopic borehole KFM03A

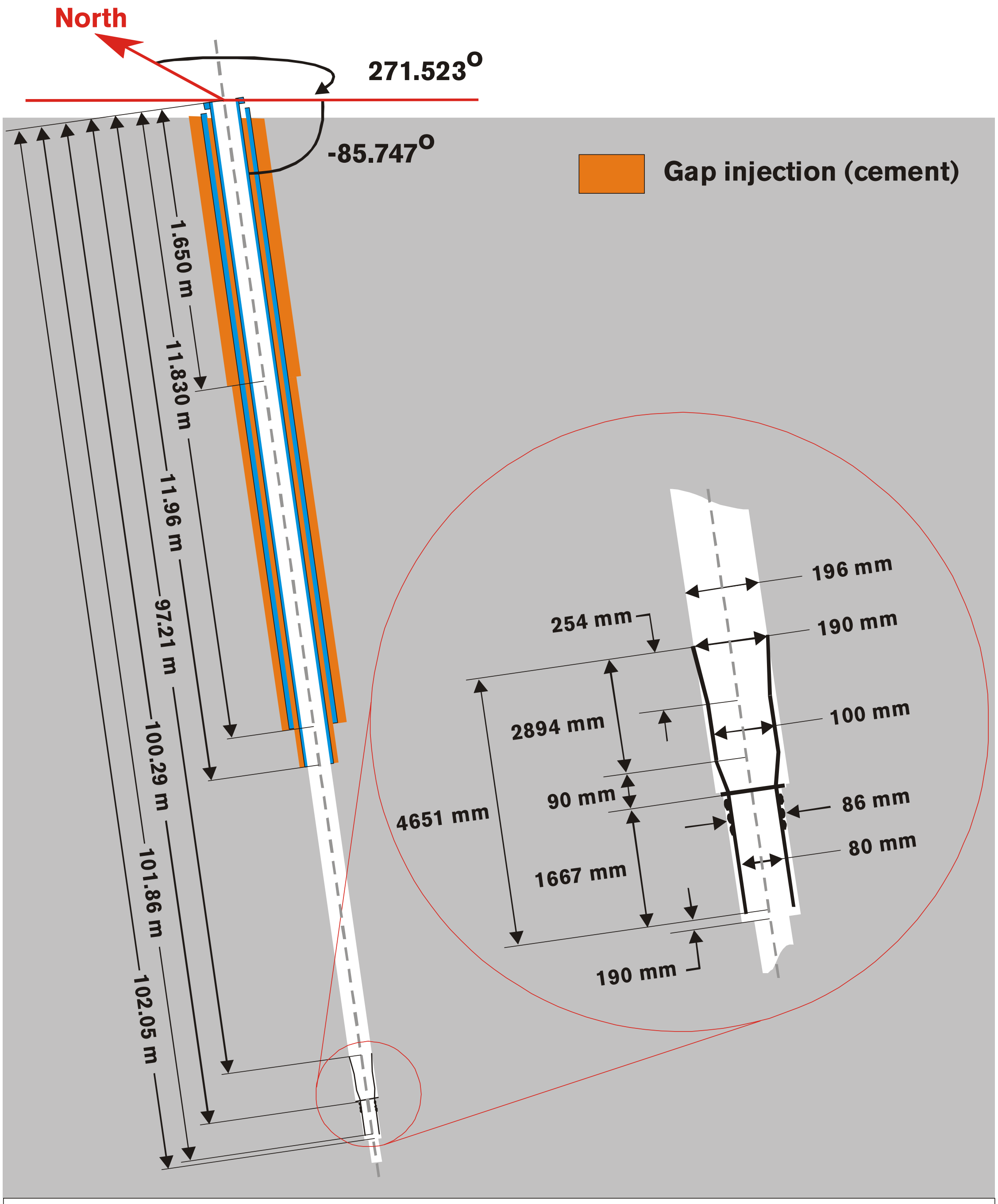


Drilling period
Drilling start date: 2002-04-16
Drilling stop date: 2003-06-23

Drilling reference point
Northing: 6697852.096 (m), RT90 2,5 gon V 0:-15
Easting: 1634630.737 (m), RT90 2,5 gon V 0:-15
Elevation: 8.285 (m), RHB 70

Technical data

Borehole KFM03A



Drilling reference point

Northing: 6697852.096 (m), RT90 2,5 gon V 0:-15
Easting: 1634630.737 (m), RT90 2,5 gon V 0:-15
Elevation: 8.285 (m), RHB 70
Borehole length: 1001,19 m

Table A2-1. Overview of general 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. Alcontrol	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. Alcontrol	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	Paavo Ristola OY SGAB Analytica,	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	SGAB Analytica, SLU, Umeå	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	SGAB Analytica, SLU, Umeå	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	Alcontrol 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. Alcontrol	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	SGAB Analytica, Alcontrol	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, Alcontrol	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	^{2}H, ^{18}O	Plastic	100	No	- -	MS	IFE	Not critical (month)
Tritium, Chlorine-37	^{3}H (enhanced.) Chlorine-37	Plastic (dry bottle) Plastic	500 100	No No	- -	LSC ICP MS	Univ. Of Waterloo	Not critical (month)
Carbon isotopes	^{13}C, ^{14}C	Glass (brown)	100×2	No	-	(A)MS	Univ. Of Waterloo	A few days
Sulphur isotopes	^{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	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP – MS	SGAB Analytica	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	SGAB Analytica	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	^{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 A2-2. 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]
δ^{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	-

[1.] Reporting limits at salinity ≤ 0.4 % (520 mS/m) and ≤ 3.5 % (3810 mS/m) respectively.

[2.] Measurement uncertainty reported by consulted laboratory

[3.] Estimated total uncertainty by experience (includes effects of sampling and sample handling)

[4.] Per mill 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 mill deviation[11] from SMOC (Standard Mean Oceanic Chloride)

[7.] Per mill deviation[11] from PDB (the standard PeeDee Belemnite)

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

[9.] Per mill 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.

Table A2-3. Consulted laboratories, full name and address

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

Water composition, compilation of basic water analysis data

Appendix 3

Idcode	Secup m	Seclow m	Sample no.	Date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO3 mg/L	Cl mg/L	SO4 mg/L	SO4-S mg/L	Br mg/l	F^- mg/L	Si mg/L	Li mg/L	Sr mg/L	pH	ElCond mS/m	Flush.Water %
KFM03A	0	46	4876	2003-06-30	-9,15	1370	29,1	648	141	138	3920	374	199	13,2	0,43	5,4	-0,05	6,16	7,6	1053	5,5
KFM03A	46	96	4877	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	96	196	4878	2003-06-30	-2,19	1890	42,0	813	201	134	4750	425	168	17,1	1,32	6,5	0,045	7,48	7,5	1451	7,5
KFM03A	196	246	4879	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	246	296	4880	2003-06-30	-1,85	1910	42,2	832	198	131	4790	423	162	18,2	1,32	6,7	0,044	7,74	7,5	1446	8
KFM03A	296	346	4881	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	346	396	4882	2003-06-30	-1,34	1770	34,3	862	159	125	4500	361	134	18,5	1,21	6,9	0,039	8,23	7,5	1356	16
KFM03A	396	446	4883	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	446	546	4884	2003-06-30	-0,7	1280	19,9	974	62,4	116	3710	189	75,9	23,7	0,48	6,6	0,024	10,5	7,4	1139	39,5
KFM03A	546	596	4885	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	596	646	4886	2003-06-30	0,74	1250	19,0	1240	42,5	115	4000	150	58,9	28,8	1,13	6,1	0,020	13,3	7,3	1236	50,5
KFM03A	646	696	4887	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	696	746	4888	2003-06-30	0,19	1320	18,6	1680	31,7	100	4930	114	45,8	42,7	0,78	6,1	0,021	17,6	7,4	1470	53,5
KFM03A	746	796	4889	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	796	846	4890	2003-06-30	0,76	1460	17,1	1980	25,8	79,0	5790	98,2	39,5	52,7	0,78	6,6	0,021	22,5	7,4	1679	44,5
KFM03A	846	896	4891	2003-06-30		_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	xxx
KFM03A	896	996,0	4892	2003-06-30	-1,42	1880	18,5	3130	18,1	46,0	8663	61,8	23,6	82,8	1,25	4,8	0,025	35,6	6,9	2390	9

- = Archive sample
x = No result due to sampling problems
xx = No result due to analytical problems
xxx = not performed
negative value = value below detection limit
ChargeBal % = Relative charge balance error %

SICADA: water_composition, 031031

Isotopes, compilation of H-, O-, B-, S-, Cl- and C-isotopes and isotope ratios

Appendix 4

Idcode	Secup m	Seclow m	Sample no	Date	D dev SMOW	Tr TU	O-18 dev SMOW	$^{10}B/^{11}B$ no unit	S-34 dev CDT	Cl-37 dev SMOC	C-13 dev PDB	$^{87}Sr/^{86}Sr$ no unit	C-14 pmC
KFM03A	0	46	4876	2003-06-30	-55,8	41.0	-9,40	A	_	A	A	_	A
KFM03A	96	196	4878	2003-06-30	-71,0	8,0	-9,20	A	25,7	A	A	0,718535	A
KFM03A	246	296	4880	2003-06-30	-73,5	13,0	-9,20	A	_	A	A	0,718464	A
KFM03A	346	396	4882	2003-06-30	-74,9	10,0	-9,60	A	_	A	A	0,718180	A
KFM03A	896	996	4892	2003-06-30	-95,8	-0,80	-13,3	A	23,1	A	A	0,717843	A

- = Not analysed
A = results will be reported later
x = No result due to sampling problems
xx = No result due to analytical problems
SICADA: h_o_isotopes, b_s_cl_sr_isotopes, c_s_isotopes 031201