P-05-48

Forsmark site investigation

Sampling and analyses of groundwater from percussion drilled boreholes

Results from the percussion drilled boreholes HFM20, HFM21 and HFM22

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February 2005

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Keywords: Forsmark, Percussion borehole, Groundwater, Chemical analyses, Isotope determination, Water sampling.

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 HFM20, HFM21 and HFM22 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 with this activity was to gain hydrogeochemical data to approximately 200 m depth from a number of boreholes within the north-western part of the candidate area. Water samples were collected at three occasions during the pumping period. Borehole HFM20 shows an increase in the chloride concentration during the pumping period while boreholes HFM21 and HFM22 are characterized by stable concentrations within the analytical uncertainty.

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 HFM20, HFM21 and HFM22 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). Syftet med denna aktivitet är att erhålla hydrogeokemiska data ner till ca 200 m djup från flera borrhål inom den nordvästra delen av kandidatområdet. Vattenprover togs vid tre tillfällen under pumpningen. I borrhålet HFM20 uppmättes ökande kloridkoncentration under pumpningen medan borrhålen HFM21 och HFM22 visade stabila förhållanden inom ramen för analysosäkerheten.

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

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1 Introduction

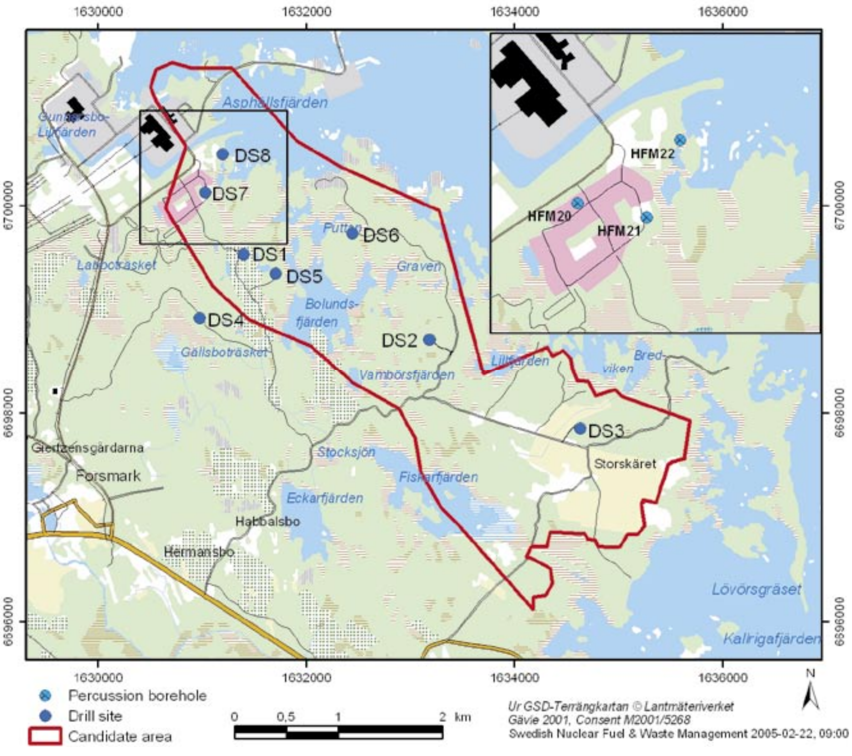
This document reports the performance and the results of the activity “Sampling of percussion boreholes after drilling”, which is one of the activities performed within the site investigation at Forsmark /1/. The work was carried out in accordance with the activity plans AP PF 400-04-75 and AP PF 400-04-91. In Table 1-1 controlling documents for conducting this activity are listed. Both activity plans and method descriptions are SKB’s internal controlling documents. The report presents hydrogeochemical data from the percussion boreholes HFM20–22. The length of the boreholes varies between 200 and 300 m /2/.

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

Samplings of the boreholes were accomplished in connection with pumping tests and flow logging carried out within the programme for hydrogeological investigations /3/.

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

Activity plan	Number	Version
Hydrotester och vattenprovtagning i HFM20 (0–300 m) och HFM21 (0–200 m)	AP PF 400-04-75	1.0
Hydrotester och vattenprovtagning i HFM22 (0–221 m)	AP PF 400-04-91	1.0
Method descriptions	**Number**	**Version**
Vattenprovtagning i hammarborrhål efter borrning	SKB MD 423.002	1.0



Ur GSD-Terrängkartan © Lantmäteriverket Gävle 2001, Consent M2001/5268
Swedish Nuclear Fuel & Waste Management 2005-02-22, 09:00

Figure 1-1. *Locations of the investigated boreholes within the Forsmark candidate area.*

2 Objective and scope

Sampling and analysis of groundwater from the percussion boreholes (HFM20–22) 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.
- Contribute to 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 telescopic boreholes. Core drilling of a 1,000 m long borehole consumes approximately 1,000 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 of 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 boreholes included in this report are all concentrated to the north-western part of the candidate area. The percussion borehole HFM20 was drilled in order to investigate the hydraulic characteristics as well as the groundwater chemistry of the surrounding bedrock. The percussion drilled boreholes HFM21 and HFM22 are positioned at drill sites DS7 and DS8 respectively and were drilled to serve as sources for flushing water for core drilling. General information concerning the boreholes is presented in Table 3-1.

Activities performed prior to the sampling are presented in Table 3-2.

Table 3-1. Borehole information for HFM20 to HFM22 (from SICADA).

Idcode	Date of completion	Bearing (degrees)	Inclination (degrees)	Northing (m)	Easting (m)	Elevation (m a s l)	Length (m)
HFM20	2004-06-01	354.41	–85.45	6700187.5	1630776.7	2.97	301.0
HFM21	2004-06-07	88.81	–58.48	6700125.6	1631074.1	3.98	202.0
HFM22	2004-09-10	90.08	–58.85	6700456.2	1631217.6	1.54	222.0

Table 3-2. Previous activities performed in boreholes HFM20 to HFM22.

Idcode	Date	Activity	Comment
HFM20	040518–040601	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004 (SKB internal controlling document)
	040602–040602	Magnetic – accelerometer measurement	
	040615–040615	BIPS-logging	
	040615–040615	Radar logging – Dipol Antenna, one freq	
	040816–040818	Hydro tests and water sampling	
HFM21	040602–040607	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004 (SKB internal controlling document)
	040602	Magnetic – accelerometer measurement	
	040614	BIPS-logging	
	040614	Radar logging – Dipol Antenna, one freq	
	040809–040811	Hydro tests and water sampling	
HFM22	040907–040910	Percussion drilling	Cleaning procedure of drilling equipment according to SKB MD 600.004 (SKB internal controlling document)
	040921–040924	Hydro tests and water sampling	

The major water bearing zones in the boreholes are presented in Table 3-3.

Table 3-3. Major water bearing zones in boreholes HFM20 to HFM22.

Idcode	Section (m)	Transmissivity (m^2/s)
HFM20	22.5–28.0	5.73×10^{-5}
	77.0–78.0	1.78×10^{-6}
	118.0–118.5	6.16×10^{-5}
HFM21	26.0–27.0	1.01×10^{-4}
	38.9–42.9	3.54×10^{-5}
	67.0–69.0	3.43×10^{-5}
	97.5–99.0	3.01×10^{-4}
	157.0–163.0	2.08×10^{-4}
HFM22	28.0–29.0	1.49×10^{-5}
	42.0–44.0	5.16×10^{-6}
	60.5–64.0	1.44×10^{-4}

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 (Mätsystem – beskrivning 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.

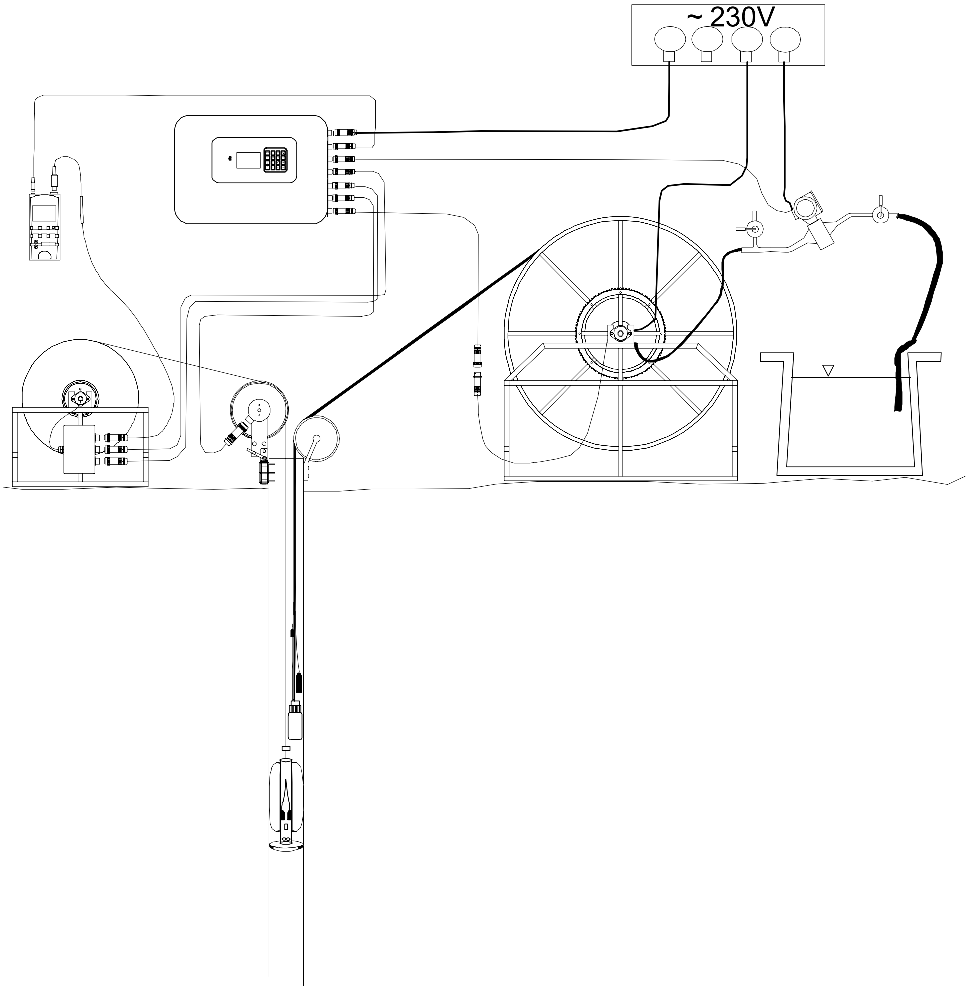


***Figure 4-1.** The HTHB (HydroTester för HammarBorrhål) equipment, configured for pumping at "open hole" conditions in combination with flow logging.*

5 Execution

5.1 Sampling

Sampling of the percussion boreholes was carried out according to activity plans AP PF 400-04-75 and AP PF 400-04-91 following the method described in SKB MD 423.002 (Metodbeskrivning för vattenprovtagning i hammarborrhål efter borrning, SKB internal controlling document).

Generally, the pumping proceeded during 10 hours, and samples were collected three times during the pumping period. Table 5-1 presents the general sampling information from the pumping tests.

Table 5-1. Pumping information and collected samples.

Borehole	Section (m)	Pump start	Pump stop	Sampling time	Pumped vol (m^3)	Sample no
HFM20	12.00–301.0	040817 08:27	040817 18:49	040817 10:10	6.4	8604
				040817 15:15	26.5	8606
				040817 18:15	38.3	8619
HFM21	12.03–201.0	040810 10:13	040810 21:03	040810 11:05	3.0	8613
				040810 15:15	19.0	8614
				040810 20:05	36.8	8615
HFM22	12.00–222.0	040923 14:23	040924 12:22	040924 08:20	53.9	8642
				040924 10:10	59.2	8644

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 the boreholes HFM21 and HFM22 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%).

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

- 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.

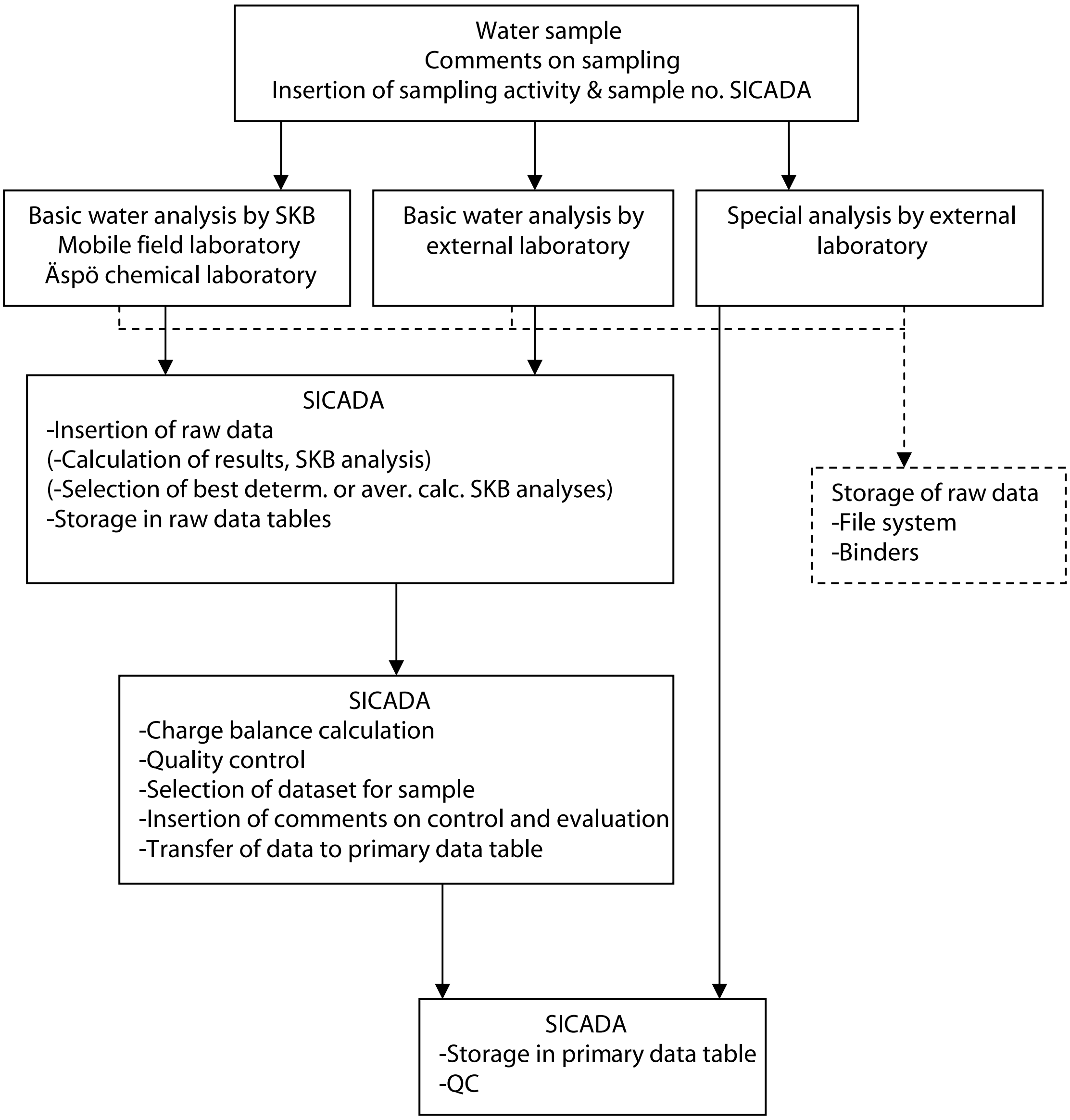


Figure 5-1. *Overview of data management for hydrogeochemical data.*

5.4 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 no other suitable equipment exists for pumping and sampling of groundwater in percussion boreholes.

HFM22 was sampled only twice and not three times as stated in activity plan AP PF 400-04-91 and the first sampling was performed after 18 hours of pumping. The second sampling was carried out 2 days after completion of the hydro tests.

6 Results

6.1 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 as well as TOC 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 HFM22); 1) when borehole water reaches the surface, 2) in the middle and 3) in the end of the pumping period. Chloride concentrations from all three boreholes are compared in Figure 6-1. Borehole HFM20 shows an increase in the chloride concentration during the pumping period, while boreholes HFM21 and HFM22 display stable concentrations within the frame of the analytical uncertainty. Although uncertain, the last sample in each series may be considered as the most representative for the groundwater.

The charge balance errors give an indication of the quality and uncertainty of the analyses of major components. The errors do not exceed ± 5% in any case.

The chloride concentrations are plotted versus the corresponding electric conductivity values in Figure 6-2. The plot provides a rough check that the values are reasonable.

Sulphate analysed by IC is plotted versus sulphate recalculated from total sulphur analysed by ICP technique in Figure 6-3. The agreement is satisfactory.

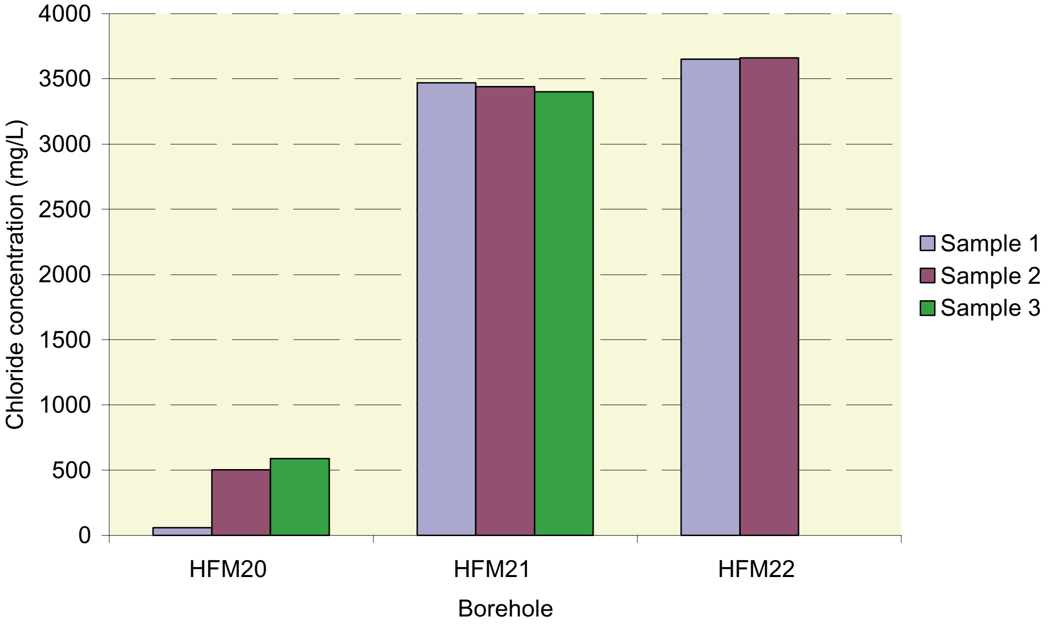


Figure 6-1. *Chloride concentration series for boreholes HFM20 to HFM22.*

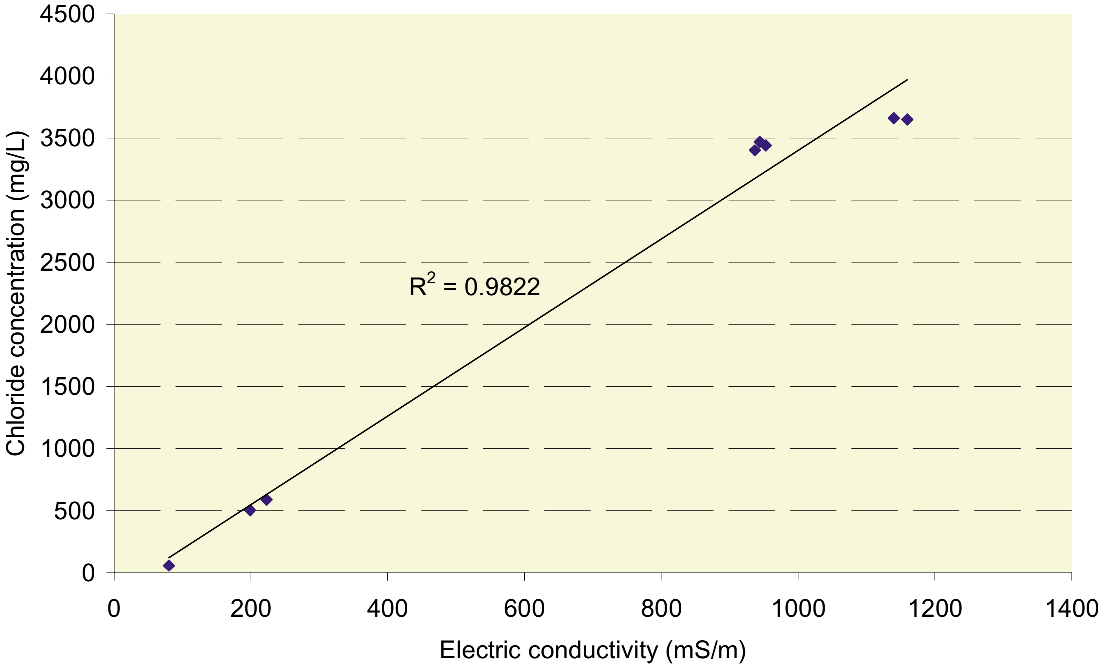


Figure 6 2. *Electric conductivity versus chloride concentration.*

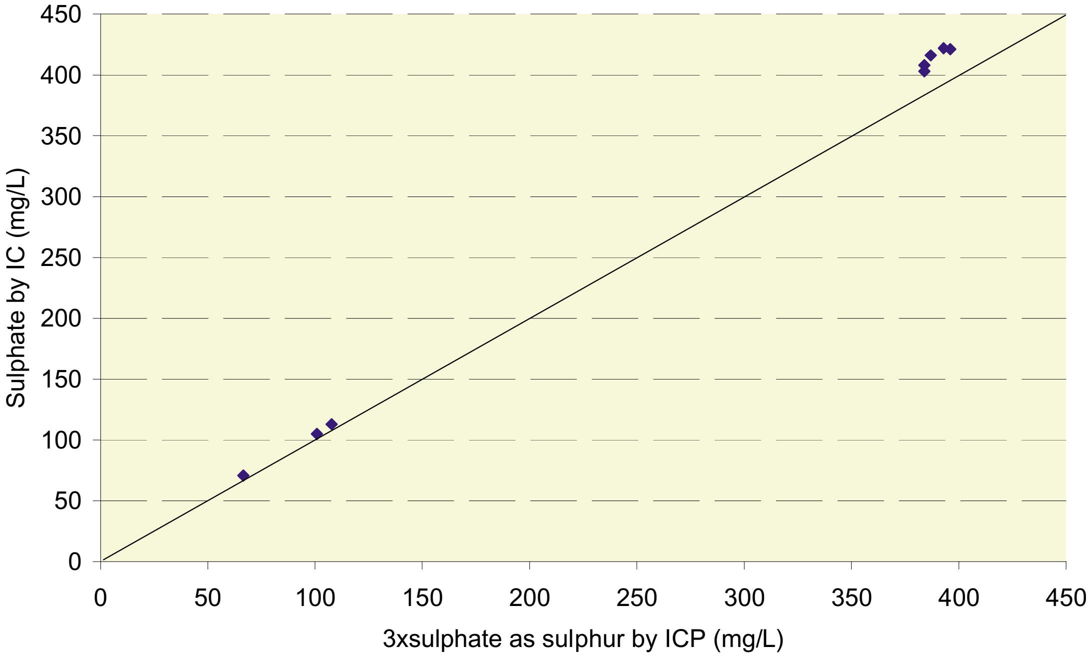


Figure 6-3. *Sulphate (IC) versus sulphate (ICP) recalculated from sulphate as sulphur.*

6.2 Isotope analysis

The isotope determinations include the stable isotopes δD, $\delta^{18}O$, $^{10}B/^{11}B$, $\delta^{34}S$, $\delta^{13}C$ and $^{87}Sr/^{87}Sr$ as well as the radioactive isotopes ^{3}H (TU) and ^{14}C (pmC). The isotope data are compiled in Appendix 3. The ^{3}H results for borehole HFM20 indicates water of shallow origin.

7 Summary and discussions

The sampling of groundwater from percussion drilled boreholes HFM20, HFM21 and HFM22 have been conducted in connection with hydraulic pumping tests performed in the boreholes in August and September, 2004. The experimental results can be summarized as follows:

- The salinity of the three samples increases with time for borehole HFM20 while boreholes HFM21 and HFM22 show stable concentrations.
- Although uncertain, the last sample in each series may be considered as the most representative for the groundwater in each borehole.
- The quality of the analytical data appears to be good. The relative charge balance error is below 5% for all collected samples and the checks by plotting show no outliers.
- Tritium results for HFM20 indicate water of shallow origin.

References

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

/2/ **Claesson L-Å, Nilsson G, 2004.** Forsmark site invenstigation. Drilling of two flushing water wells, HFM21 and HFM22, one groundwater monitoring well in solid bedrock, HFM20, and one groundwater monitoring well in soil, SFM0076. SKB P-04-245. Svensk Kärnbränslehantering AB.

/3/ **Jönsson J, Hjerne C, Ludvigson J-E, 2004.** Forsmark site invenstigation. Pumping tests and flow logging. Boreholes HFM20, HFM21 and HFM22. SKB P-05-14. Svensk Kärnbränslehantering AB.

Appendix 1

Sampling and analysis methods

Table A1-1. 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^-, SO_4, 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 (1 mL 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 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	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	δ^2H, ∂^{18}O	Plastic	100	No	– –	MS	IFE	Not critical (month)
Tritium, Chlorine-37	^{3}H (enhanced) δ^{37}Cl	Plastic (dry bottle) Plastic	500 100	No No	– _	LSC ICP MS	Univ. of Waterloo	Not critical (month)
Carbon isotopes	δ^{13}C, pmC (^{14}C)	Glass (brown)	100×2	No	–	(A)MS	Univ. of Waterloo	A few days
Sulphur isotopes	δ^{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	No	–	Chemical separat. Alfa/gamma spectrometry	IFE SUERC	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 SUERC	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

Component group	**Component/element**	**Sample container (material)**	**Volume (mL)**	**Filtering**	**Preparation/ Conservation***	**Analysis method**	**Laboratory*****	**Analysis within – or delivery time to lab.**
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	δ13C, pmC (14C)	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 A1-3.

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 A1-2. 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^-	Mohr titration	5	70	mg/L	5%	< 10%
	IC		0.5		6%	
Cl^-		0.2				10%
SO_4	IC	0.2	0.5	mg/L	6%	15%
Br^-	IC	0.2	0.7	mg/L	9%	20%
Br^-	ICP	–	0.001–0.010[1]		15%	
F^-	IC	0.2	0.6	mg/L	10%	20%
F^-	Potentiometri	–	–		–	–
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%
Fe	ICP	–	0.4–4[1]	µg/L	6%	10%
Mn	ICP	–	0.03–0.1[1]	µg/L	8%	10%
Fe (II), Fe(tot)	Spectrophotometry	5	20	µg/L	15% (> 30 µg/L)	20%
DOC	See tab. 1	–	0.5	Mg/L	8%	30%
TOC	See tab. 1	–	0.5	Mg/L	10%	30%
δ^{2}H	MS	–	2	‰ SMOW[4]	1.0‰	–
δ^{18}O	MS	–	0.1	‰ SMOW[4]	0.2‰	–
^{3}H	LSC	–	0.8 or 0.1	TU[5]	0.8 or 0.1 TU	–
Component	Method	Detection limit	Reporting limit or range	Unit	Measurement uncertainties[2]	"Total" uncertainties[3]
δ^{37}Cl	ICP MS	–	0.2‰ (20 mg/L)	‰ SMOC[6]	–	–
δ^{13}C	A (MS)	–	> 20 mg Carbon	‰ PDB[7]	–	–
pmC (^{14}C)	A (MS)	–	> 20 mg kol	PmC[8]	–	–
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	–
^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{230}Th	Alfa spectr.	–	0.0005	Bq/L	0.05 Bq/L	Right order of magnitude
^{222}Rn, ^{226}Rn	LSC	–	0.0005	Bq/L	0.05 Bq/L	

[1] Reporting limits at salinity ≤ 0.4% (520 mS/m) and ≤ 3.5% (3,810 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[12] 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[12] from SMOC (Standard Mean Oceanic Chloride).

[7] Per mille deviation[12] from PDB (the standard PeeDee Belemnite).

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

[9] Per mille deviation[12] from CDT (the standard Canyon Diablo Troilite).

[10] Isotope ratio without unit.

[11] The 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

[12] 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 A1-3. Participant laboratories.

Äspö water chemical laboratory (SKB)
Mobile field laboratory, Forsmark (SKB)

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Appendix 2

Water composition

Compilation February 2005-03-01

Idcode	Secup m	Seclow m	Date	Time	Sample no	Chrg.bal. %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO_3 mg/L	Cl mg/L	SO_4 mg/L	SO_4-S mg/L
HFM20	12	301	2004-08-17	10:10	8604	–1.8	71.5	8.37	110	13.8	441	59.1	70.8	22.2
HFM20	12	301	2004-08-17	15:15	8606	–1.5	245	10.1	180	29.9	411	502	105	33.6
HFM20	12	301	2004-08-17	18:15	8619	–1.4	282	10.7	192	32.7	405	588	113	35.9
HFM21	12.03	200	2004-08-10	11:05	8613	0.5	1500	31.8	646	150	216	3470	416	129
HFM21	12.03	200	2004-08-10	15:15	8614	0.6	1500	31.8	637	148	220	3440	408	128
HFM21	12.03	200	2004-08-10	20:05	8615	0.8	1490	31.5	632	148	224	3400	403	128
HFM22	12	221	2004-09-24	08:20	8642	–2.7	1510	40.5	577	154	171	3650	421	132
HFM22	12	221	2004-09-24	10:10	8644	–3.0	1500	40.3	575	153	173	3660	422	131

Idcode	Secup m	Seclow m	Date	Time	Sample no	Br mg/l	F mg/L	Si mg/L	Li mg/L	Sr mg/L	pH	ElCond mS/m	TOC mg/L
HFM20	12	301	2004-08-17	10:10	8604	0.315	0.62	5.32	0.016	0.368	7.21	80.3	9.0
HFM20	12	301	2004-08-17	15:15	8606	3.74	0.63	5.71	0.018	0.898	7.11	199	8.7
HFM20	12	301	2004-08-17	18:15	8619	2.03	0.58	5.80	0.021	0.996	7.09	223	8.5
HFM21	12.03	200	2004-08-10	11:05	8613	12.0	1.20	6.05	0.049	4.42	7.37	944	3.9
HFM21	12.03	200	2004-08-10	15:15	8614	12.2	1.20	6.37	0.052	4.37	7.43	953	4.1
HFM21	12.03	200	2004-08-10	20:05	8615	11.7	1.25	6.46	0.049	4.33	7.40	937	4.0
HFM22	12	221	2004-09-24	08:20	8642	12.6	–0.2	5.79	0.053	3.24	7.42	1160	3.3
HFM22	12	221	2004-09-24	10:10	8644	12.5	–0.2	5.75	0.053	3.22	7.40	1140	3.1

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

Compilation February 2005-03-01

Idcode	Secup m	Seclow m	Date	Time	Sample no	δD dev SMOW	^{3}H TU	δ^{18}O dev SMOW	^{10}B/^{11}B no unit	δ^{34}S dev CDT	δ^{37}Cl dev SMOC	^{87}Sr/^{87}Sr no unit	δ^{13}C dev PDB	^{14}C pmC	^{14}C-age years
HFM20	12	301	2004-08-17	18:15	8619	–85.3	10.1	–11.5	0.2402	12.9	–2.53	0.721241	–12.51	86.34	1127
HFM21	12.03	200	2004-08-10	20:05	8615	–71.9	2.6	–9.4	0.2373	24	–0.33	0.721598	–8.06	35.63	8236
HFM22	12	221	2004-09-24	10:10	8644	–67.9	1.6	–8.9	0.2392	21.7	–0.32	0.72229	–6.14	*	*

* Will be reported later.