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Oskarshamn site investigation

Hydrochemical logging in KAV04A

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Keywords: Core drilled borehole, Groundwater, Water sampling, Chemical analyses.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author and do not necessarily coincide with those of the client.

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Abstract

Hydrochemical logging or so called tube sampling has been performed in the core drilled borehole KAV04A. The method is a fast and simple sampling technique to obtain information about the chemical composition of the water column along an open borehole. The equipment consists of an approximately 1,000 metres long polyamide tube divided into units of 50 metres.

The water content in each tube unit constituted one sample. Every other sample, with start from the upper most unit, was analysed according to SKB chemistry class 3 (excluding isotope options). Samples for isotope determination were collected and stored in a freezer (tritium in refrigerator) at the time of sampling; $\delta^{18}\text{O}$, deuterium, ^{10}B , ^{87}Sr and $\delta^{34}\text{S}$ from odd tube units and tritium, $\delta^{37}\text{Cl}$ and carbon isotopes from even tube units. Samples for determination of tritium, $\delta^{18}\text{O}$ and deuterium were sent for analysis approximately one month after the performance of the hydrochemical logging in KAV04A. Results from the isotope determinations will be presented in a separate report.

The content of flushing water remaining in the borehole after drilling was relatively low (below 7%) in the first 400 metres. The maximum amount of flushing water was found at approximately 600 m where it was around 28%. The relative charge balance error did not exceed the acceptable limit of $\pm 5\%$ in any of the ten samples.

Sammanfattning

Hydrokemisk loggning, eller så kallad slangprovtagning, har utförts i det kärnborrade borrhålet KAV04A. Metoden är snabb och enkel att använda för att erhålla information om den kemiska sammansättningen hos grundvattnet längs ett öppet borrhål. Utrustningen består av en cirka 1 000 meter lång polyamidslang uppdelad i enheter om vardera 50 meter.

Innehållet i en slangenhet utgör ett prov. Varannan slangenhet, med start från den översta, analyserades enligt SKB kemiklass 3 (exklusive tillval). Prover för bestämning av isotop-tillvalen togs ut vid provtagningstillfället och sparades i frys (tritium i kylskåp); $\delta^{18}\text{O}$, deuterium, ^{10}B , ^{87}Sr och $\delta^{34}\text{S}$ ur udda enheter samt tritium, $\delta^{37}\text{Cl}$ och kolisotoper ur jämna enheter. Prover för bestämning av isotoperna tritium, $\delta^{18}\text{O}$ och deuterium sändes till laboratorier för analys ungefär en månad efter provtagningen i KAV04A. Resultaten av utförda isotopbestämningar kommer att presenteras i en separat P-rapport.

Halten kvarvarande spolvatten i borrhålet efter borrning var relativt låg (under 7 %) de första 400 metrarna. Den högsta spolvattenhalten uppmättes vid cirka 600 m där halten var 28 %. Det relativa felet i jonbalansen översteg inte den acceptabla nivån av $\pm 5\%$ i något av de tio analyserade proverna.

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1 Introduction

This document reports performance and results from the Hydrochemical logging in KAV04A, which is one of the activities performed within the site investigation at Oskarshamn /1/. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method description are SKB's internal controlling documents. The data is reported to SICADA in field note no. Simpevarp 356.

Borehole KAV04A is a 1,004.0 metre long telescopic borehole drilled at the site investigation in the Oskarshamn area (Simpevarp). KAV04A is of a so called SKB chemical type. The percussion borehole HSH03 served as source of flushing water for the core drilling of KAV04A. The locations of KAV04A and HSH03 are shown in Figure 1-1.

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

Activity plan	Number	Version
Hydrokemisk loggning i KAV04	AP PS 400-04-032	0.5
Method description	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0

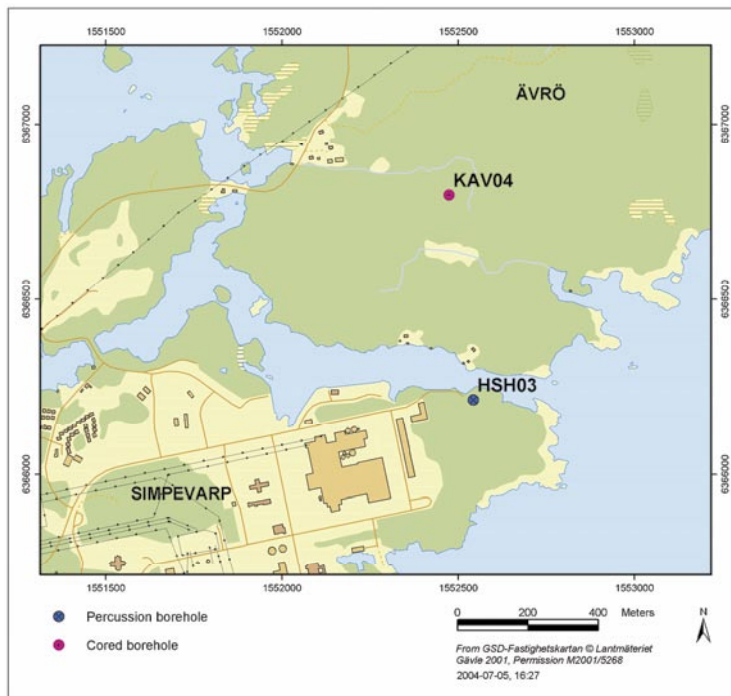


Figure 1-1. Location of the core drilled borehole KAV04A and the supply well of flushing water HSH03 at the site investigation in the Oskarshamn area (image by Fredrik Hartz).

2 Objective and scope

Hydrochemical logging was performed in order to obtain an overview of the chemical composition of the water along the open borehole KAV04A. The technique used for sampling is fast and simple even at great depth.

The analysis program was carried out according to SKB chemistry class 3 except for isotope options. Sample portions intended for isotope determinations were collected but not sent for analysis at the time of sampling. They are stored at SKB until further notice. Samples for determination of tritium, $\delta^{18}\text{O}$ and deuterium were sent for analysis at consulted laboratories approximately one month after the sampling occasion. The results from the isotope determinations will be presented in a separate report.

3 Sampling equipment

For the hydrochemical logging an approximately 1,000 metres long polyamide tube, divided into units of 50 metres, was used. The equipment is described in the method description SKB MD 422.001

A schematic picture of the equipment used for the hydrochemical logging is shown in Figure 3-1. The tube units are connected using couplings. The lengths of the tube units are 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 constitutes one sample and the volume of each sample is approximately two litres. A weight is added at the lower end of the tube array in order to keep it stretched in the borehole and to prevent fastening. The first tube lowered down the borehole has a non return valve at the bottom to prevent water outflow while lifting the tube units. At both ends of each tube unit there is a manual shut off valve.

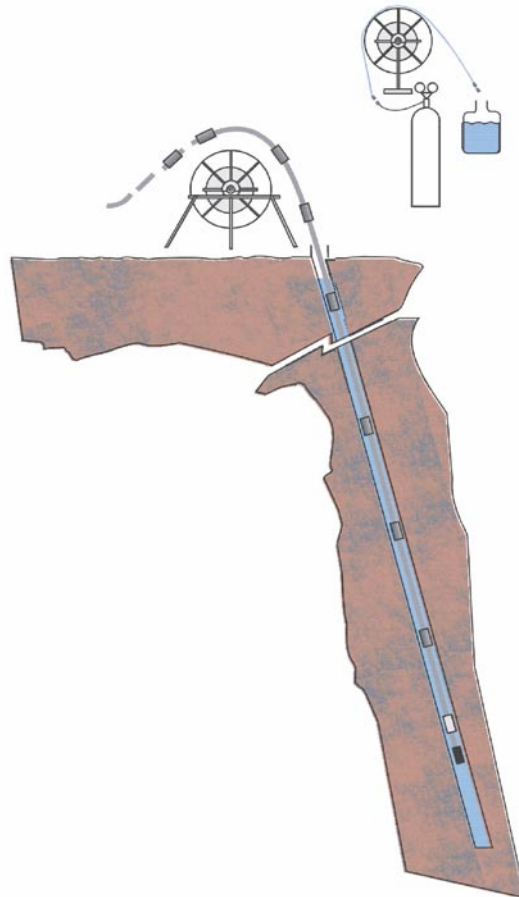


Figure 3-1. Equipment for hydrochemical logging in boreholes. At the lower end of the tube array there is a check valve and a weight connected. Each tube unit is 50 metres long.

Table 3-1. Length of tube units used at the hydro-chemical logging in KAV04A.

Unit	Length [m]
1	49.71
2	50.08
3	49.77
4	49.28
5	49.97
6	50.01
7	49.85
8	49.87
9	49.57
10	49.72
11	49.67
12	50.25
13	50.62
14	49.70
15	49.22
16	49.20
17	49.30
18	49.63
19	49.62
20	49.87
Sum:	994.91
Couplings:	2.812
Weight:	0.817
Total tube length:	998.539

4 Performance

4.1 Hydrochemical logging

The hydrochemical logging in KAV04A was performed on June 8, 2004.

The lowering of the tube units started at 08:23. The tubes were lowered down the borehole at a rate of about five metres/minute. The equipment was lowered to a depth of 995 metres, i.e. the length of the borehole subtracted by 9 metres. This was done in order to avoid suspending drilling debris gathered at the bottom of the borehole and thereby decreasing the risk of fastening. The lifting of the tubes started at 12:59 and at 14:17 the last tube was retrieved. The tube unit at the top of the tube array was lowered to 45 metres of its length. This, and the level of the ground water at the time, resulted in a not completely filled tube unit. The tube units were emptied using pressurized nitrogen gas and the water samples were portioned into sample bottles. Each tube unit represents one sample to be portioned into bottles.

The groundwater level was measured in the borehole before and after completed logging to 9.12 m and 9.36 m, respectively, below the top of the casing.

4.2 Sample treatment and chemical analysis

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

An overview showing the samples obtained at the logging occasion is given in Table 4-1. Sample portions intended for isotope analyses were collected, but not sent for immediate analysis. They are stored in freezer at SKB (tritium samples in refrigerator) until further notice. The data from the hydrochemical logging are stored in the database SICADA in field note no. Simpevarp 356. The SKB sample numbers are 7442–7461.

The uppermost tube unit was not completely filled, see section 4.1, neither was the second unit from the top. During the lifting of the tube array, the water column in the second unit slowly declined. This decline of the water column was not observed from unit three and down, i.e. all other tube units seemed by visual inspection to be fully filled with sample water, only small bubbles could be observed during lifting. Due to the lack of water in the first tube unit (see above), archive samples from the second tube unit could not be filled. Water intended for archive samples in the second unit were used to fill sample bottles for δD and $\delta^{18}O$, $^{87}Sr/^{86}Sr$, B^{10}/B^{11} and $\delta^{34}S$ from the first section (0–45 m).

Samples for determination of tritium, $\delta^{18}O$ and deuterium were sent for analysis approximately one month after sampling. Results from those analyses will be presented in a separate report.

Table 4-1. Overview of samples collected at the hydrochemical logging in KAV04A. Filled cells represent collected samples. Blue filling represents samples sent for analyses, light yellow filling represents samples collected and stored in a freezer (except for tritium samples which were stored in refrigerator) and purple dashed cells represents archive samples stored in a freezer.

Sample information			Collected sample portions											Archive
Tube unit	Length [m]	SKB no.	Cond., pH, alk.	Major Comp.	Ura-nine	An-ions	$\delta^{34}\text{S}$	$\delta\text{D}/\delta^{18}\text{O}$	^{10}B	^{87}Sr	^3H	$\delta^{37}\text{Cl}$	Carbon isotopes	Filtered 2×250 mL
1	0-45	7442					ω	ж	ж	ж				
2	95	7443												
3	145	7444												
4	195	7445												
5	245	7446												
6	295	7447												
7	345	7448												
8	395	7449												
9	445	7450												
10	495	7451												
11	545	7452												
12	595	7453												
13	645	7454												
14	695	7455												
15	745	7456												
16	795	7457												
17	845	7458												
18	895	7459												
19	945	7460												
20	995	7461												

ж filled with sample water from tube unit two

ω partly filled with sample water from tube unit two

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 constituents 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 $\pm 5\%$ are considered acceptable (in surface waters $\pm 10\%$).

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

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

All results from 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.

4.4 Nonconformities

The activity was performed without any deviations that may affect the quality of the data.

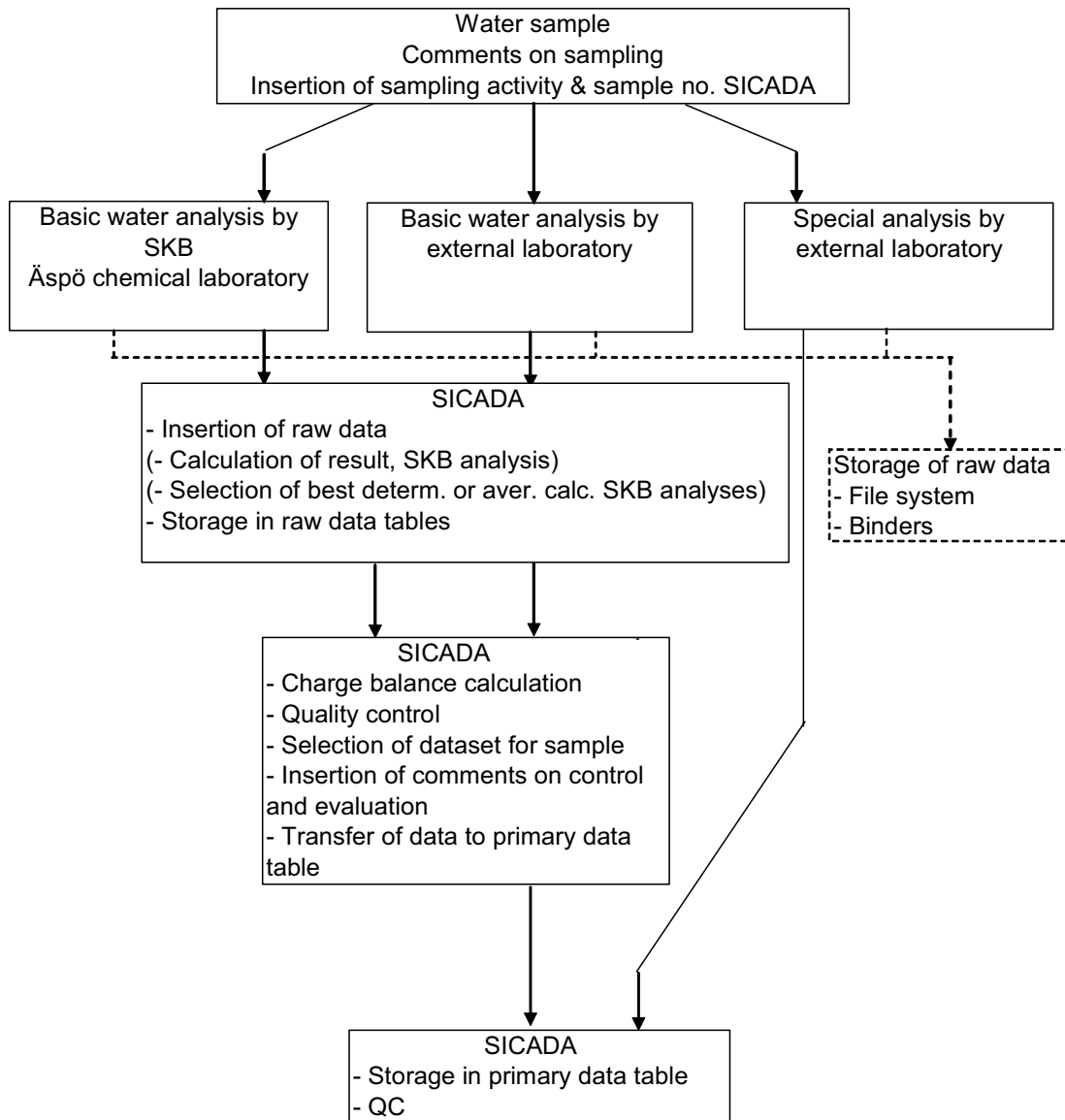


Figure 4-1. Overview of data management for hydrogeochemical data.

5 Results

5.1 Analysis results

The results from the chemical analyses are given in Appendix 2. Diagrams showing the flushing water content and the electric conductivity along the borehole at the time of the hydrochemical logging are presented in Figure 5-1 and Figure 5-2. Results from pH measurements, analysis of hydrogen carbonate and major constituents are shown in Figure 5-3 to Figure 5-5. Results are plotted for the mid-length of each tube unit. For example, the first tube is plotted at 22.5 metres.

Sulphate analysed by ion chromatography (IC) is compared to sulphate determined as total sulphur by ICP-AES in Figure 5-6. As shown, there is a satisfactory agreement.

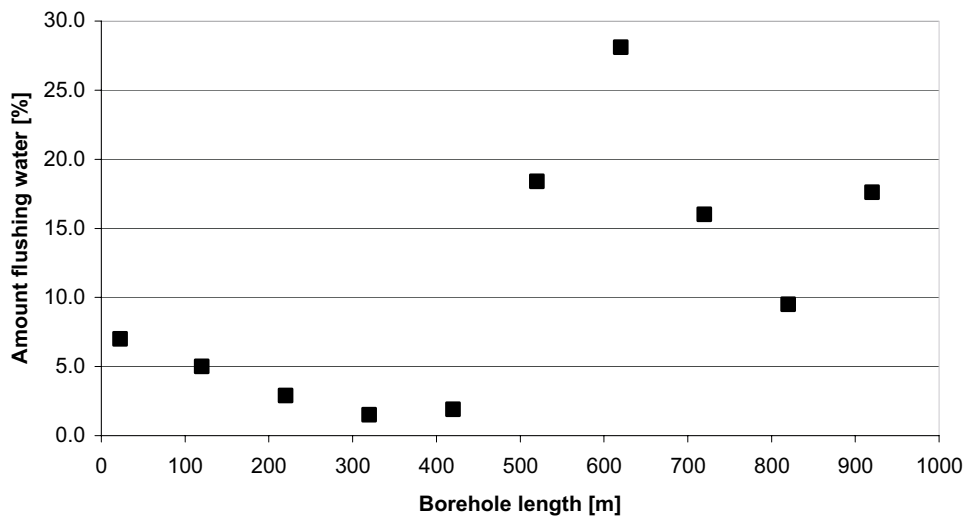


Figure 5-1. Amount of flushing water remaining at different lengths in KAV04A at the time of the hydrochemical logging.

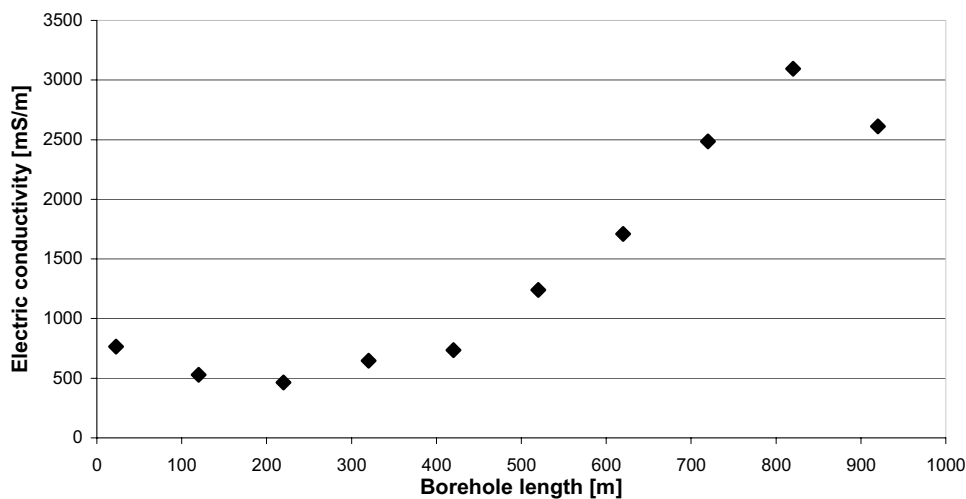


Figure 5-2. Electric conductivity values down the borehole KAV04A. Results from the hydrochemical logging.

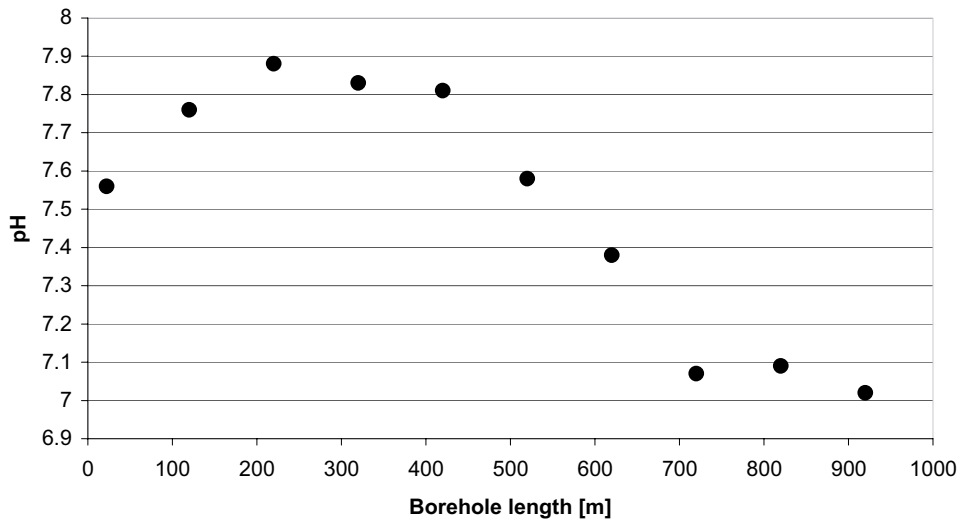


Figure 5-3. Results from pH measurements obtained from the hydrochemical logging in KAV04A.

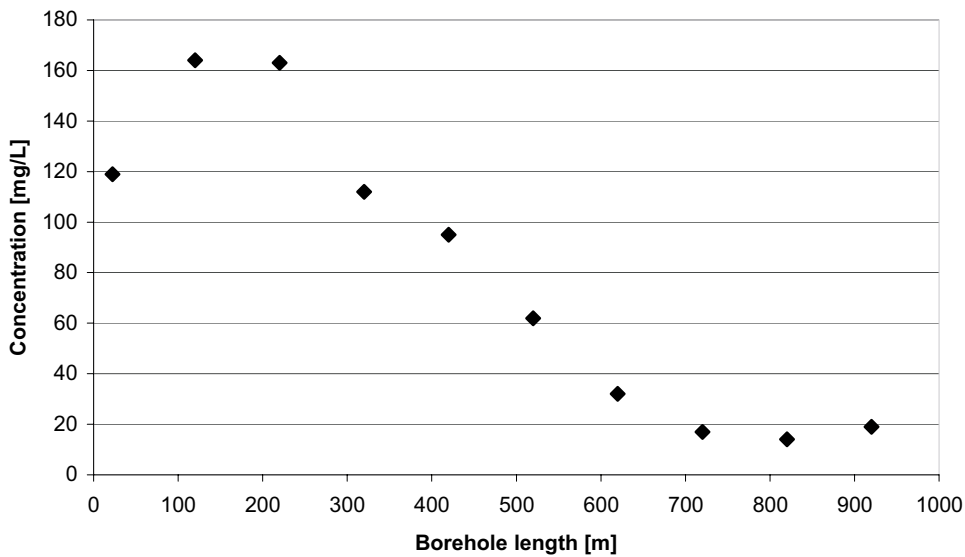


Figure 5-4. Results from hydrogen carbonate analysis of water samples collected at different lengths. Data obtained at the hydrochemical logging in KAV04A.

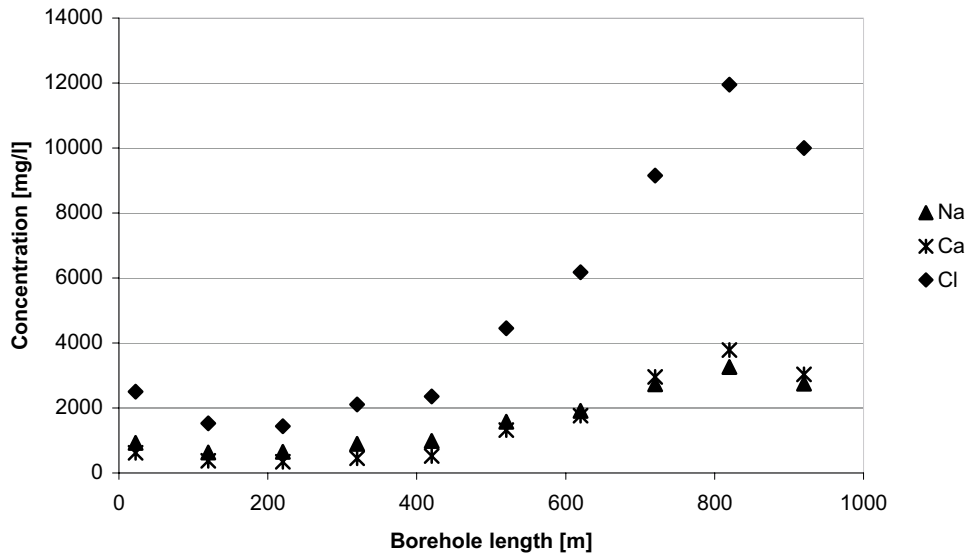


Figure 5-5. Analysis results from the major constituents Na, Ca and Cl. Results from samples collected at the hydrochemical logging in KAV04A.

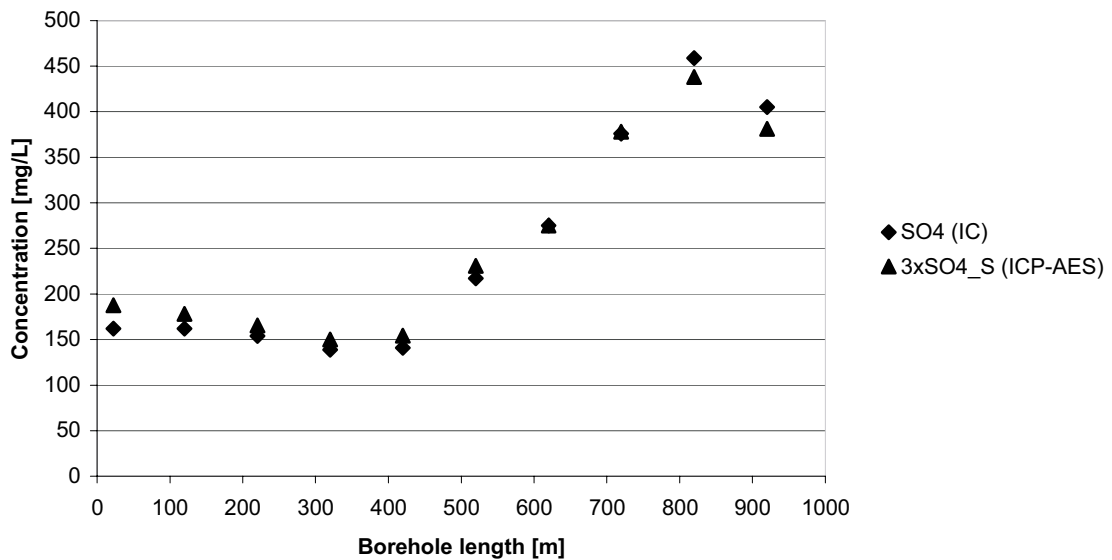


Figure 5-6. Sulphate (IC) compared to sulphate recalculated from total sulphur (ICP). Results from the hydrochemical logging in the borehole KAV04A.

5.2 Quality of the analyses

The charge balance errors give an indication of the quality and uncertainty of the analyses of major constituents. The relative charge balance errors are calculated for the selected sets of data, see Appendix 2. If the relative errors are within $\pm 5\%$ they are considered acceptable. The errors do not exceed 5% in any of the cases.

6 Conclusions

At the hydrochemical logging in KAV04A the following chemical conditions was found:

- There was a steep increase in the amount of remaining flushing water from approximately 400 m (~2%) to the maximum amount found at approximately 600 m (~28%).
- The electric conductivity showed no large variation for the first 400 metres of the borehole. From 400 metres and downwards the conductivity increased, except for a slight decrease in the deepest part (895–945 m).
- The water composition below 600 metres is significantly different from that above 600 metres. This may partly be an effect of the high amount of remaining flushing water at the deeper levels.
- The relative charge balance error, giving an indication of the quality and uncertainty of the analyses, did not exceed the acceptable limit of $\pm 5\%$ in any of the cases.

7 References

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

Sampling and analysis methods

Table A1-1. 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	Äspö's chemistry lab.	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.	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	Not critical (month)
Environmental isotopes	² H, ¹⁸ O	Plastic	100	No	–	MS	IFE	Not critical (month)
Tritium,	³ H (enhanced.)	Plastic (dry bottle) Plastic	500	No	–	LSC	Univ. Of Waterloo	Not critical (month)
Chlorine-37	Chlorine-37		100	No	–	ICP MS		
Carbon isotopes	¹³ C, ¹⁴ C	Glass (brown)	100x2	No	–	(A)MS	Univ. Of Waterloo	A few days
Sulphur isotopes	³⁴ S	Plastic	500 –1,000	Yes	–	Combustion, ICP MS	The Ångström laboratory, Uppsala IFE	No limit
Strontium-isotopes	⁸⁷ Sr/ ⁸⁶ Sr	Plastic	100	Yes	–	TIMS	IFE	Days or Week
Boron isotopes	¹⁰ B	Plastic	100	Yes	Yes (1 mL HNO ₃)	ICP – MS	Analytica AB	No limit
Archive samples without acid	–	Plastic	250x2**	Yes	No	–	–	Storage in freeze

* 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 A1-2.

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. Consulted laboratories, full name and address.

Äspö waterchemical laboratory (SKB)

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)

Instituttveien 18
P.O Box 40
2027 Kjeller
NORGE

The Ångström laboratory

Box 534
Se-751 21 Uppsala

Appendix 2

Water composition

Idcode	Secup m	Seclow m	Sample no.	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO ₃ ⁻ mg/L	Cl ⁻ mg/L	SO ₄ ²⁻ mg/L	SO ₄ -S mg/L	Br ⁻ mg/L	F ⁻ mg/L	Si mg/L	Fe mg/L	Mn mg/L	Li mg/L	Sr mg/L
KAV04A	0	45	7442	-2.4	924	6.01	625	27.0	119	2,500	162	62.6	18.1	2.55	4.10	0.449	0.307	0.459	10.5
KAV04A	45	95	7443	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	95	145	7444	-2.3	630	3.90	376	20.0	163	1,520	162	59.4	11.0	3.25	4.72	0.264	0.203	0.276	6.36
KAV04A	145	195	7445	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	195	245	7446	0.3	654	3.60	342	24.8	164	1,440	154	55.2	8.5	3.20	4.98	0.232	0.206	0.237	5.67
KAV04A	245	295	7447	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	295	345	7448	-0.3	898	4.60	455	36.9	111	2,110	139	50.1	11.3	2.50	4.98	0.063	0.275	0.300	7.41
KAV04A	345	395	7449	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	395	445	7450	0.2	982	4.97	526	41.1	95	2,360	141	51.4	13.0	2.30	4.95	0.207	0.302	0.344	8.56
KAV04A	445	495	7451	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	495	545	7452	2.4	1,580	13.6	1,320	51.4	61	4,450	217	76.9	33.5	1.65	4.54	0.342	0.444	0.952	21.2
KAV04A	545	595	7453	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	595	645	7454	-1.8	1,910	17.2	1,760	56.3	31	6,180	275	91.6	51.3	1.10	4.27	<0.10	0.526	1.290	30.3
KAV04A	645	695	7455	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	695	745	7456	0.3	2,730	14.0	2,960	49.7	17	9,150	376	126	77.9	0.90	3.53	0.63	0.435	1.940	51.7
KAV04A	745	795	7457	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	795	845	7458	-2.2	3,260	14.2	3,780	45.1	13	12,000	459	146	101.0	0.80	3.08	0.963	0.428	2.330	66.1
KAV04A	845	895	7459	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KAV04A	895	945	7460	-3.2	2,750	13.7	3,030	46.1	19	10,000	405	127	86.6	<0.20	3.11	1.43	0.511	1.940	53.1
KAV04A	945	945	7461	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- = Not analysed

A = results will be reported later

x= No result due to sampling problems

xx= No result due to analytical problems

xxx= Sample stored in freezer/refrigerator

< = below detection limit

ChargeBal % = Relative charge balance error %

Idcode	Secup m	Seclow m	Sample no.	pH	Drill_water %	EiCond mS/m	$\delta^3\text{H}$ dev SMOW	$\delta^{18}\text{O}$ dev SMOW	^3H TU	$\delta^{37}\text{Cl}$ dev SMOC	$^{10}\text{B}/^{11}\text{B}$ no unit	$^{87}\text{Sr}/^{86}\text{Sr}$ no unit	$\delta^{34}\text{S}$ dev CDT	$\delta^{13}\text{C}$ dev PDB	^{14}C pmC
KAV04A	0	45	7442	7.56	7.00	765	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	45	95	7443	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	95	145	7444	7.76	5.04	529	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	145	195	7445	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	195	245	7446	7.88	2.89	463	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	245	295	7447	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	295	345	7448	7.83	1.45	646	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	345	395	7449	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	395	445	7450	7.81	1.94	735	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	445	495	7451	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	495	545	7452	7.58	18.30	1,240	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	545	595	7453	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	595	645	7454	7.38	28.1	1,710	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	645	695	7455	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	695	745	7456	7.07	16.0	2,490	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	745	795	7457	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	795	845	7458	7.09	9.52	3,100	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	845	895	7459	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx
KAV04A	895	945	7460	7.02	17.6	2,620	xxx	xxx	-	-	xxx	xxx	xxx	-	-
KAV04A	895	945	7461	-	-	-	-	-	xxx	xxx	-	-	-	xxx	xxx

- = Not analysed

A = results will be reported later

x= No result due to sampling problems

xx= No result due to analytical problems

xxx= Sample stored in freezer/refrigerator

< = below detection limit

ChargeBal % = Relative charge balance error %