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Oskarshamn site investigation

Hydrochemical logging in KLX07A

Cecilia Berg, Geosigma AB

November 2005

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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 KLX07A. The method is a fast and simple sampling technique for obtaining information about the chemical composition of the water along an open borehole. The equipment consists of an approximately 1,000 m long polyamide tube divided into units of 50 m.

The water content in each tube unit constituted one sample. Every other sample, starting with the uppermost tube unit, was analysed according to SKB chemistry class 3 (options excluded). Samples for isotope determination were collected at the time of sampling and stored in a freezer (tritium and carbon isotopes in a refrigerator); $\delta^{18}\text{O}$, deuterium ($\delta^2\text{H}$), tritium (^3H), ^{10}B , $\delta^{37}\text{Cl}$ and ^{87}Sr from odd-numbered tube units and $\delta^{34}\text{S}$ and carbon isotopes from even-numbered tube units.

The content of flushing water remaining in the borehole after drilling was below 10% in the whole sampled water column. The maximum amount of flushing water was approximately 9%, sampled at the bottom of the borehole. The relative charge balance error exceeded the acceptable limit of $\pm 5\%$ in one out of ten analysed samples, no 10346 (-7.0%), from the section at 780–830 m along the borehole.

Sammanfattning

Hydrokemisk loggning, eller så kallad slangprovtagning, har utförts i det kärnborrade borrhålet KLX07A. 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 m lång polyamidslang uppdelad i enheter om vardera 50 m.

Innehållet i en slangenhet utgör ett prov. Varannan slangenhet, med start från den översta, analyserades enligt SKB kemiklass 3 (exklusive alla tillval). Prover för bestämning av isotoptillvalen togs ut vid provtagningstillfället och sparades i frys (tritium och kolisotoper i kylskåp); $\delta^{18}\text{O}$, deuterium ($\delta^2\text{H}$), tritium (^3H), ^{10}B , $\delta^{37}\text{Cl}$ och ^{87}Sr ur udda enheter, $\delta^{34}\text{S}$ och kolisotoper ur jämna enheter.

Halten kvarvarande spolvatten i borrhålet efter borring var låg, under 10 %, längs hela den provtagna vattenpelaren. Den högsta spolvattenhalten uppmättes till cirka 9 % i botten på borrhålet. Det relativa felet i jonbalansen översteg den acceptabla nivån av $\pm 5\%$ i ett av tio analyserade prover, nummer 10346 (-7.0%), från sektion 780–830 m längs borrhålet.

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1 Introduction

This document reports the performance and results from hydrochemical logging in borehole KLX07A. The hydrochemical logging is one of the activities performed within the site investigation at Oskarshamn /1/. The work was carried out in accordance with activity plan SKB PS 400-05-037 (SKB internal controlling document). The controlling documents for the performance of this activity are listed in Table 1-1. The data is reported to the database SICADA.

Borehole KLX07A is an 844.73 m long telescopic borehole, drilled within the site investigation in the Oskarshamn area. The percussion borehole HLX10 served as the source of flushing water for the drilling of KLX07A. The location of KLX07A and HLX10 is shown in Figure 1-1.

Table 1-1. SKB internal controlling documents for the performance of the activity.

Activity plan	Number	Version
Hydrokemisk loggning i KLX07A	AP PS 400-05-037	1.0
Method descriptions	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0

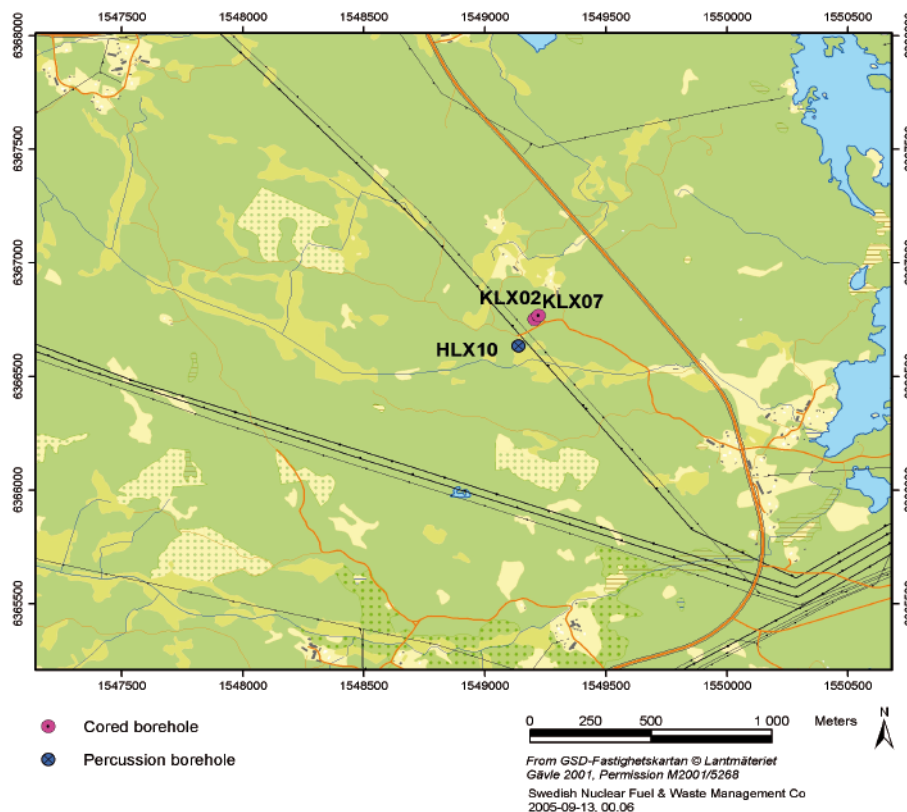


Figure 1-1. Location of the core drilled borehole KLX07A and the percussion borehole HLX10 as well as the nearby situated core drilled borehole KLX02 within the site investigation in the Oskarshamn area.

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 KLX07A. 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 optional isotopes. Sample portions intended for isotope analyses were collected at the time of sampling, but have not been analysed. The samples are stored in a freezer at SKB (except the samples collected for determination of tritium and carbon isotopes; these samples were stored in a refrigerator) until further notice. If samples from the activity are analysed for isotopes, the results from those analyses will be presented in a separate report.

3 Sampling equipment

For the hydrochemical logging an approximately 1,000 m long polyamide tube, divided into units of 50 m, was used. The equipment is described in the method description, see Table 1-1.

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 first tube lowered down the borehole has a non-return valve at the bottom to prevent water outflow while lifting the tube units. 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 and a half litres. At the lower end of the tube array, a weight is added in order to stretch the array and thereby prevent fastening.

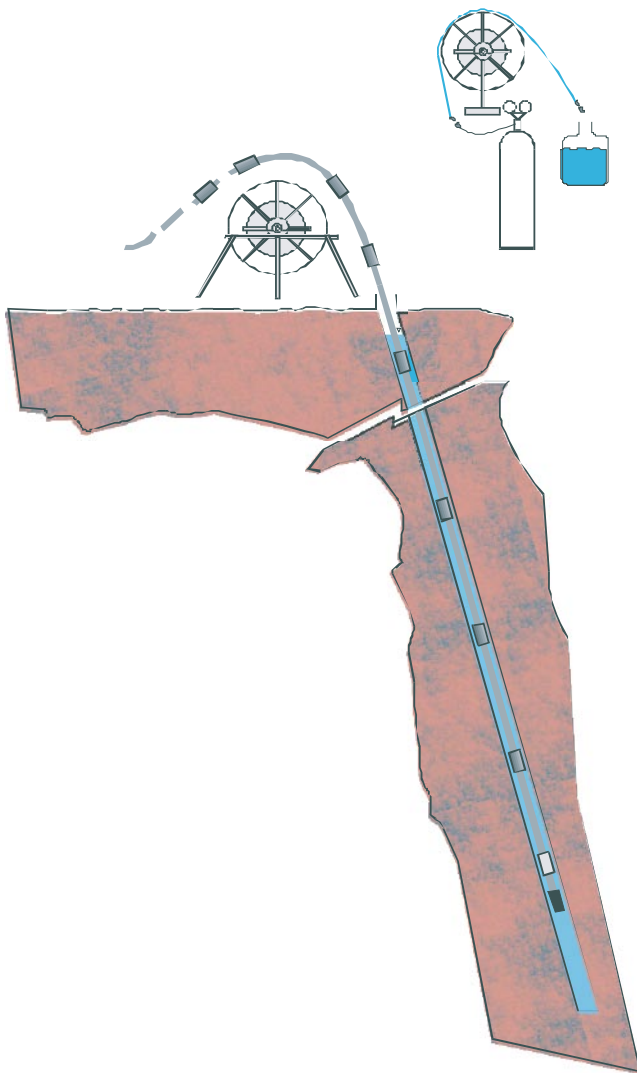


Figure 3-1. Equipment for hydrochemical logging in boreholes. At the lower end of the tube array there is a check valve and a weight connected. Each tube unit is 50 m long.

4 Performance

4.1 Hydrochemical logging

The hydrochemical logging in KLX07A was performed on June 8, 2005.

The lowering of the tube units started at 08:13. The tubes were lowered down the borehole at a rate of about five metres/minute. The equipment was lowered to a depth of 830 m, in order to avoid drilling debris sedimented at the bottom of the borehole, and thereby decrease the risk of fastening. The lifting of the tubes started at 11:07, and the last tube unit was retrieved at 12:22. The tube unit at the top of the tube array was lowered to 30 m of its length. This resulted in a not completely filled tube unit. Pressurized nitrogen gas was used to empty the tube units and the water samples were portioned into sample bottles. Each tube unit represents one sample.

The ground water level before and after the hydrochemical logging was 13.06 and 13.12 m, respectively, measured from the top of the casing.

4.2 Sample treatment and chemical analysis

An overview of sample treatment and analysis routines is given in Appendix 1. The routines are applicable irrespectively 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 at the sampling occasion but not sent for analysis. These samples are stored in a freezer at SKB (except the sample collected for tritium determination which is stored in refrigerator). The collected samples intended for isotope analysis may be sent for analysis, and in that case, the results will be presented in a separate report. The data from the hydrochemical logging are stored in the database SICADA. The SKB sample numbers are 10330–10346.

The uppermost tube unit was not completely filled, see Section 4.1. All other tube units seemed, by visual inspection, to be fully filled with sample water; only small bubbles of gas were observed during lifting. Due to the lack of water in the first tube unit, see above, bottles for isotope analysis from the upper most section as well as archive samples from the second tube unit were not obtained. Water intended for archive samples in the second unit were used to fill sample bottles for analyses of, anions from the first section (0–30 m).

Table 4-1. Overview of samples collected at the hydrochemical logging in KLX07A. Filled cells represent collected samples. Dark (blue) filling represents samples sent for analyses, light (yellow) filling represents samples collected and stored in a freezer (tritium and carbon isotopes in a refrigerator) and dashed (purple) cells represent archive samples.

Sample information			Collected sample portions											Archive
Tube unit	Length (m)	SKB no	Cond, pH, alk	Major Comp	Uranine	An-ions	³ H	δ ² H δ ¹⁸ O	δ ³⁷ Cl	¹⁰ B	⁸⁷ Sr	δ ³⁴ S	C-iso-topes	Filtered 2×250 mL
1	0-30	10330				Ж								
2	80	10331												
3	130	10332												
4	180	10333												
5	230	10334												
6	280	10335												
7	330	10336												
8	380	10337												
9	430	10338												
10	480	10339												
11	530	10340												
12	580	10341												
13	630	10342												
14	680	10343												
15	730	10344												
16	780	10345												
17	830	10346												

Ж Filled with sample water from tube unit 2.

4.3 Data handling

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

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 from **basic water analyses** are inserted into raw data tables for further evaluation. The evaluation results in a final 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 $\pm 10\%$).

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

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

All results from **special analyses of trace metals and isotopes** are inserted directly into primary data tables. In cases where the analyses are repeated or performed by more than one laboratory, a “best choice” notation will indicate the results considered most reliable.

An overview of the data management is given in Figure 4-1.

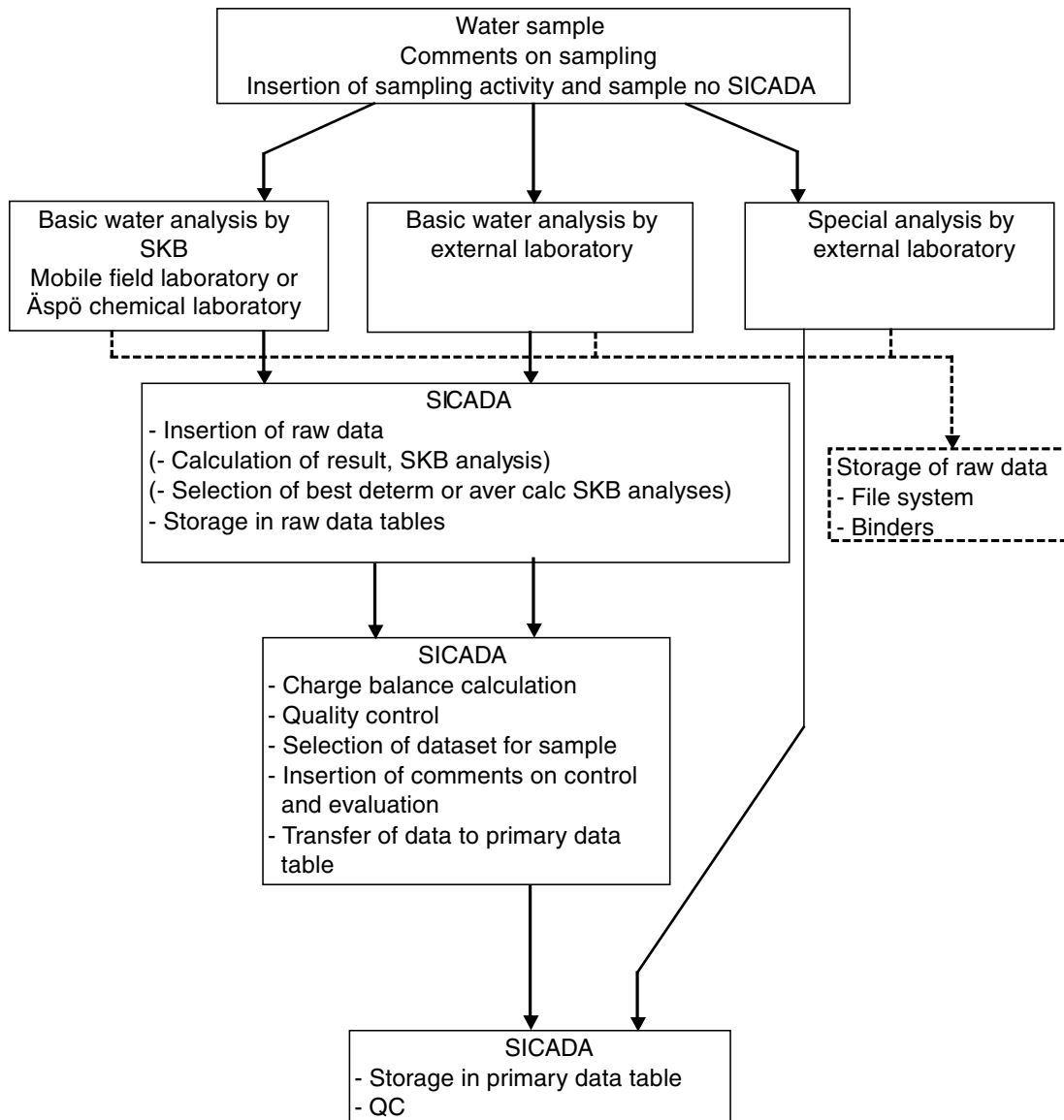


Figure 4-1. Overview of data management for hydrogeochemical data.

4.1 Nonconformities

The activity was performed without any deviations from the controlling documents of the activity that can affect the quality of the data.

5 Results

5.1 Analysis results

Results from the chemical analysis 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 Figures 5-1 and 5-2. Results from analyses of pH, some of the major constituents (Na, Ca and Cl⁻) and sulphate (SO₄²⁻) are shown in Figures 5-3 to 5-5. Results are plotted for the mid-length of each tube unit. For example, the first tube is plotted at 15 m.

Sulphate (SO₄²⁻) analysed by using ion chromatography (IC) is compared with sulphate determined as total sulphur using inductively coupled plasma atomic emission spectrometry (ICP-AES) in Figure 5-5. The values obtained from ICP-AES are higher than the value from IC in all samples except the one from the lowest section 780–830 m.

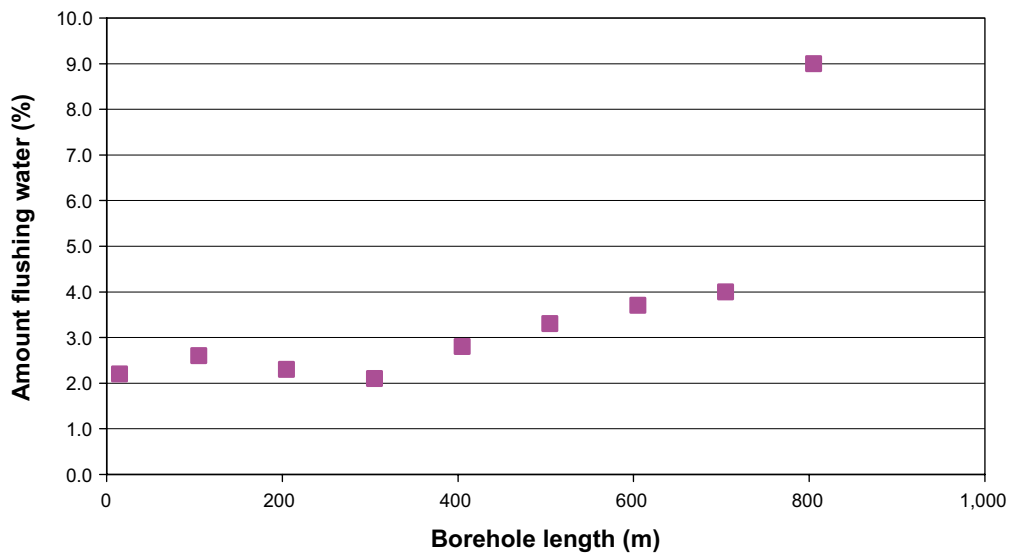


Figure 5-1. Amount of flushing water remaining at different borehole lengths at the time of the hydrochemical logging in KLX07A.

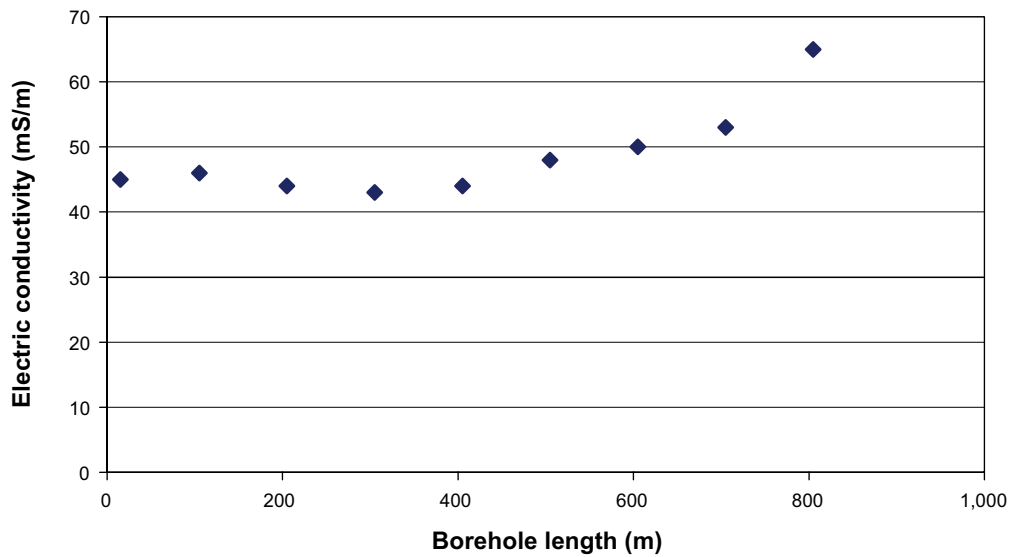


Figure 5-2. Electric conductivity values along the borehole KLX07A obtained from the hydrochemical logging.

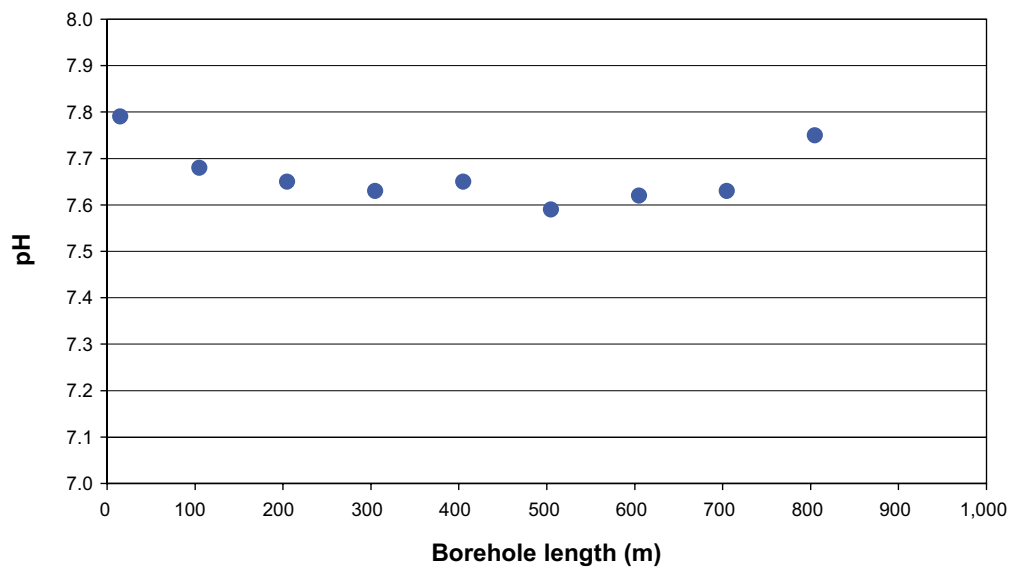


Figure 5-3. Results from pH measurements obtained from the hydrochemical logging in KLX07A.

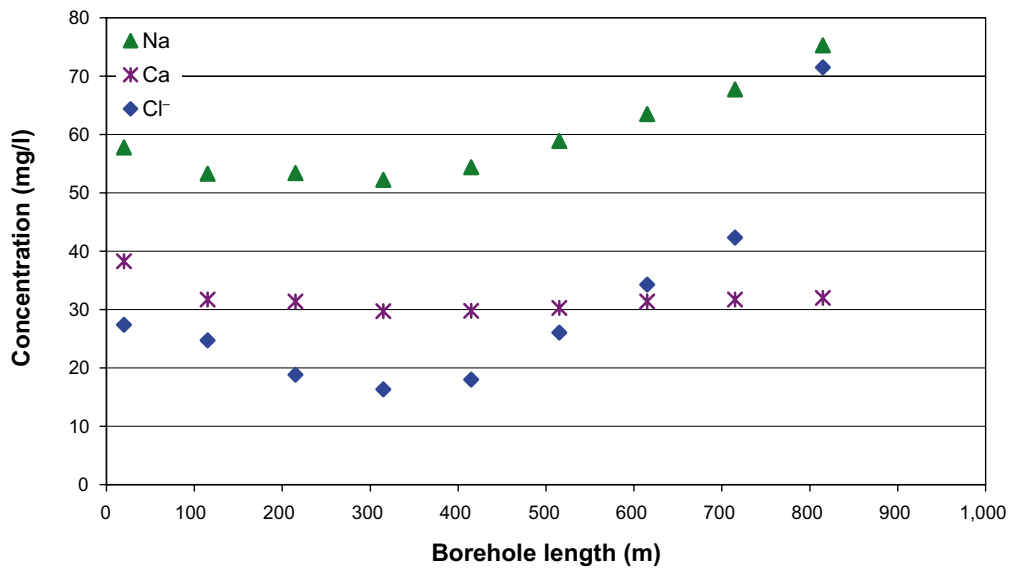


Figure 5-4. Results from analysis of the constituents Na, Ca and Cl⁻ in water samples obtained from the hydrochemical logging in KLX07A.

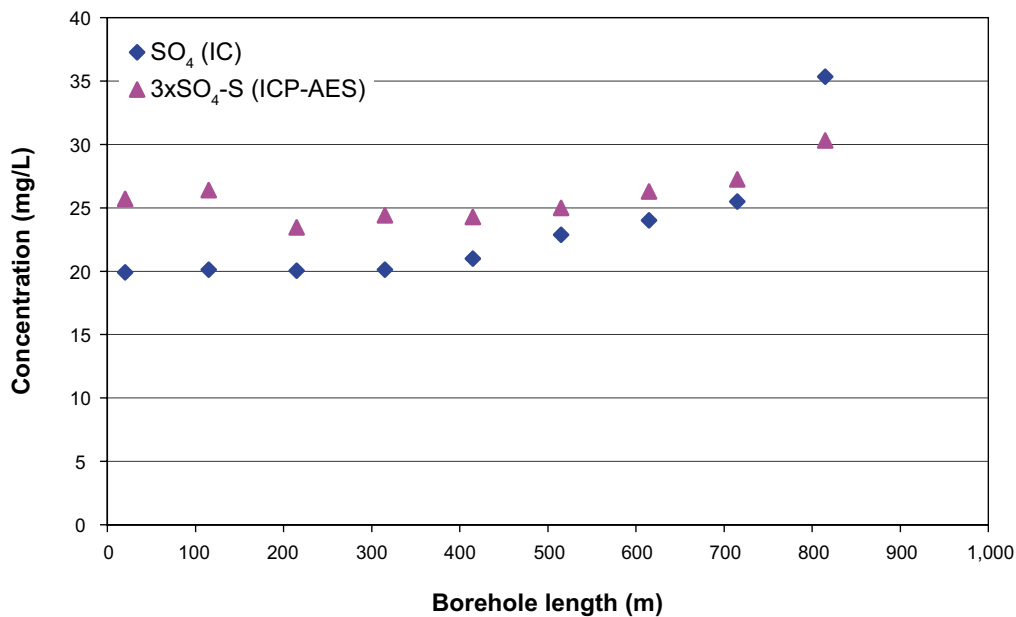


Figure 5-5. Sulphate (IC) compared to total sulphur (ICP-AES), results from the hydrochemical logging in KLX07A.

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 were calculated for the selected sets of data, see Appendix 2. If the relative errors are within $\pm 5\%$ they are considered acceptable. The errors did exceed 5% in one out of ten cases, no 10346 (from section 780–830 m).

6 Conclusions

At the hydrochemical logging in KLX07A, the following chemical conditions were found:

- The amount of remaining flushing water at the time of the hydrochemical logging was low; all samples had an amount below 10%. The highest value was found the deepest sampled section, 780–830 m, where the remaining flushing water content reached 9.0%.
- The charge balance error, giving an indication of the quality and uncertainty of the analyses, exceeded the acceptable level one case, sample 10346 (–7.0%). The sample was collected from the lowest section, 780–830 m, in the borehole.
- The electric conductivity and the chloride concentration increased only slightly down the borehole. The highest values were 64.8 mS/m and 71.5 mg/L, respectively (both values from the deepest part sampled along the borehole).

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	No	No	Titration Pot. meas, Cond. meas	Åspö's chemistry lab	The same day – maximum 24 hours
Anions 2	Cl ⁻ , SO ₄ ²⁻ , Br ⁻ , F ⁻ , I ⁻	Plastic	250	Yes (not in the field)	No	Titration (Cl ⁻) IC (Cl ⁻ , SO ₄ ²⁻ , Br ⁻ , F ⁻) ISE (F ⁻)	Åspö'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	Yes (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)	500	No	–	LSC	Univ Of Waterloo	Not critical (month)
Chlorine-37	Chlorine-37	Plastic	500	No	–	ICP MS	Univ Of Waterloo	Not critical (month)
Carbon isotopes	¹³ C, ¹⁴ C	Glass (brown), or plastic	100x4	No	–	(A)MS	Univ Of Waterloo The Ångström laboratory, Uppsala	A few days
Sulphur isotopes	³⁴ S	Plastic	1,000	No	–	Combustion, ICP MS	IFE	No limit
Strontium-isotopes	⁸⁷ Sr/ ⁸⁶ Sr	Plastic	100	No	–	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 chromatography
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)
Insittutveien 18
P.O Box 40
2027 Kjeller
NORGE
The Ångström laboratory
Box 534
Se-751 21 Uppsala

Appendix 2

Water composition

Compilation August 2005

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	pH
KLX07	0	30	10330	4.06	57.8	3.43	38.3	5.8	195	27.4	19.9	8.57	< 0.2	2.15	7.63	0.892	0.240	0.011	0.289	7.79
KLX07	30	80	10331	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	80	130	10332	-1.23	53.3	3.47	31.7	5.8	197	24.7	20.1	8.80	< 0.2	2.25	8.17	0.869	0.252	0.011	0.213	7.68
KLX07	130	180	10333	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	180	230	10334	-1.48	53.4	3.26	31.4	5.7	210	18.9	20.0	7.82	< 0.2	2.44	8.35	0.892	0.270	0.010	0.222	7.65
KLX07	230	280	10335	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	280	330	10336	-2.89	52.2	3.16	29.7	5.6	212	16.4	20.1	8.14	< 0.2	2.53	8.35	0.622	0.275	0.109	0.209	7.63
KLX07	330	380	10337	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	380	430	10338	-2.15	54.4	3.23	29.8	5.6	211	18.0	21.0	8.09	< 0.2	2.59	8.63	0.798	0.280	0.011	0.213	7.65
KLX07	430	480	10339	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	480	530	10340	-2.24	58.9	3.29	30.3	5.6	211	26.0	22.9	8.33	< 0.2	2.62	8.55	0.751	0.276	0.011	0.221	7.59
KLX07	530	580	10341	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	580	630	10342	-2.05	63.5	3.46	31.4	5.8	211	34.3	24.0	8.76	< 0.2	2.66	8.75	0.884	0.282	0.012	0.236	7.62
KLX07	630	680	10343	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	680	730	10344	-1.79	67.7	3.58	31.7	6.2	210	42.3	25.5	9.08	< 0.2	2.58	9.81	1.650	0.303	0.013	0.25	7.63
KLX07	730	780	10345	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX07	780	830	10346	-6.97	75.3	3.63	32.0	6.1	214	71.5	35.3	10.10	0.44	2.80	9.30	1.800	0.288	0.014	0.271	7.75

Compilation August 2005

Idcode	Secup m	Seclow m	Sample no	Drill_water %	EiCond mS/m	$\delta^2\text{H}$ 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
KLX07	0	30	10330	2.21	45.4	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	30	80	10331	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	80	130	10332	2.63	45.5	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	130	180	10333	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	180	230	10334	2.32	43.9	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	230	280	10335	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	280	330	10336	2.13	43.4	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	330	380	10337	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	380	430	10338	2.83	44.4	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	430	480	10339	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	480	530	10340	3.33	47.8	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	530	580	10341	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	580	630	10342	3.69	50.0	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	630	680	10343	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	680	730	10344	4.03	52.8	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX07	730	780	10345	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX07	780	830	10346	8.99	64.8	xxx	xxx	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 = Stored in freezer/refrigerator

< = result below detection limit

Charge Bal % = Relative charge balance error %