

## **Oskarshamn site investigation**

### **Water sampling in KLX11A and KLX19A**

**Summary of analyses from water sampling  
during pumping in connection with  
Single Well Injection Withdrawal (SWIW)  
tests and Pipe String System (PSS)  
measurements**

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Geosigma AB

November 2008

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*Keywords:* Groundwater, Borehole, Chemical analyses, Isotope determinations, PSS, SWIW, AP PS 400-07-026, AP PS 400-06-144.

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

Data in SKB's database can be changed for different reasons. Minor changes in SKB's database will not necessarily result in a revised report. Data revisions may also be presented as supplements, available at [www.skb.se](http://www.skb.se).

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## **Abstract**

Water sampling within the site investigation at Oskarshamn was performed in three sections (516.5 to 519.5 m, 579.0 to 584.0 m and 598.0 to 599.0 m) in the core-drilled borehole KLX11A using the equipment for Single Well Injection Withdrawal (SWIW) tests and in two sections (495.0 to 515.0 m and 764.0 to 769.0 m) in KLX19A during pumping with the Pipe String System (PSS).

The obtained chemistry data comprise groundwater chemistry data according to SKB chemistry class 5 in all sections and also groundwater chemistry data according to SKB chemistry class 4 in KLX11A (section 516.5 to 519.5 m) and in KLX19A (section 495.0 to 515.0 m), and SKB chemistry class 3 in KLX19A (section 764.0 to 769.0 m). The data were obtained during March–July 2007 in KLX11A and November 2006–January 2007 in KLX19A.

All analytical data from the activity are stored in the Sicada database.

## Sammanfattning

Vattenprovtagning inom platsundersökningen i Oskarshamn, har utförts i tre sektioner (516,5 till 519,5 m, 579,0 till 584,0 m och 598,0 till 599,0 m) i kärnborrhålen KLX11A med hjälp av utrustningen för tester med Single Well Injection Withdrawal (SWIW) och i två sektioner (495,0 till 515,0 m och 764,0 till 769,0 m) i KLX19A vid pumpning med Pipe String System (PSS).

Resultaten från denna aktivitet inkluderar vattenkemidata enligt SKB kemiklass 5 från alla sektioner och dessutom vattenkemidata enligt SKB kemiklass 4 i KLX11A (sektion 516,5 till 519,5 m) och i KLX19A (sektion 495,0 till 515,0 m) och SKB kemiklass 3 i KLX19A (764,0 till 769,0 m). Proverna är tagna under perioden mars–juli 2007 i KLX11A och november 2006–januari 2007 i KLX19A.

Alla resultat från vattenanalyserna finns i databasen Sicada.

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# 1 Introduction

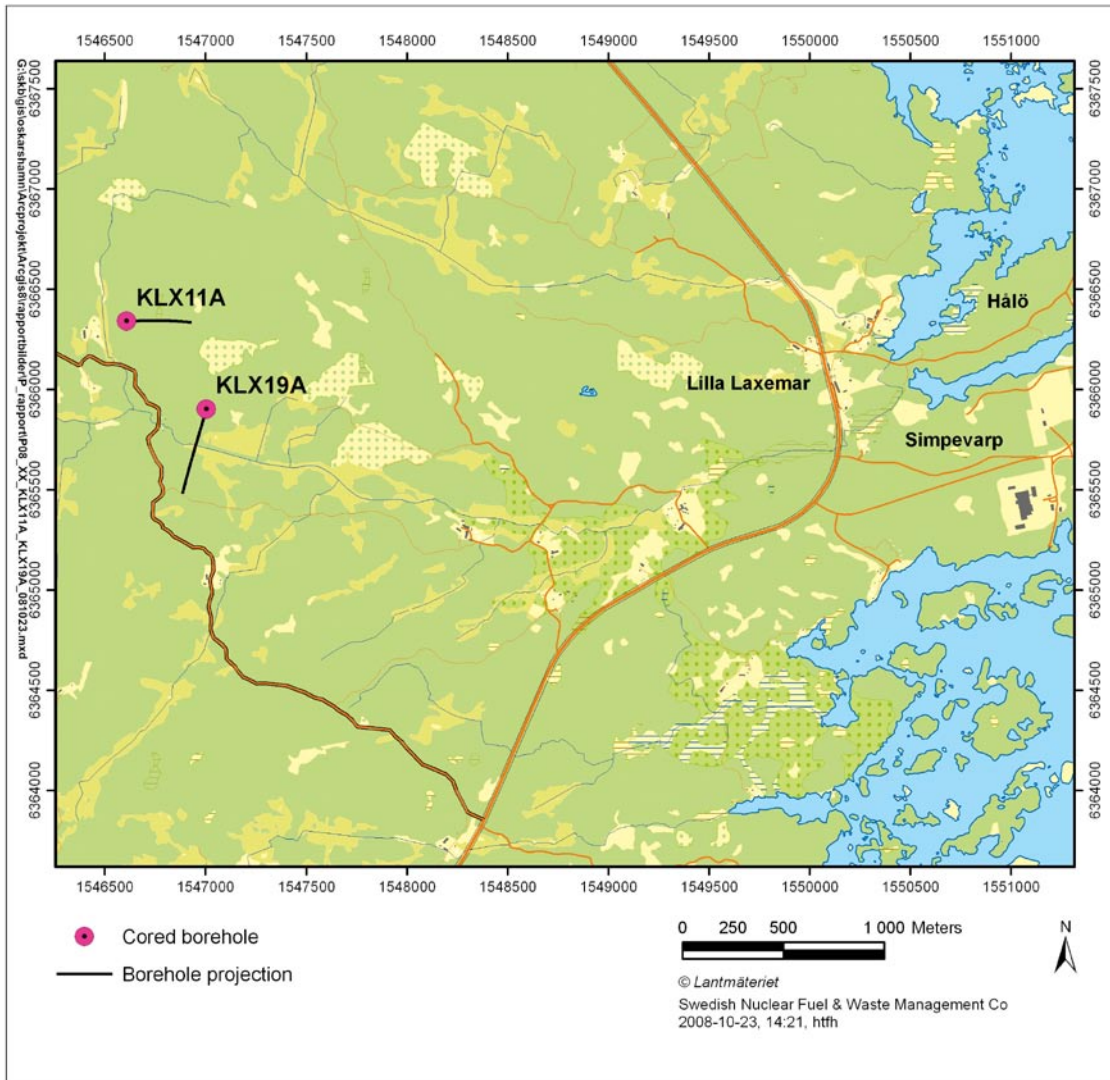
This document summarises the results gained from water sampling, a sub-activity during pumping with the Single Well Injection Withdrawal (SWIW) equipment in three sections in KLX11A and with the Pipe String System (PSS) in two sections in KLX19A, both of these are core-drilled boreholes within the site investigation at Oskarshamn. The work was conducted in accordance with activity plan SKB AP PS 400-07-026 (KLX11A) and SKB AP PS 400-06-144 (KLX19A). Controlling documents for performance of the water sampling activities are listed in Table 1-1. The activity plans as well as the method descriptions are SKB's internal controlling documents. The data were obtained during March–July 2007 in KLX11A and November 2006–January 2007 in KLX19A and are reported in the Sicada database. A map showing the investigation site and the location of the boreholes KLX11A and KLX19A is shown in Figure 1-1.

The report presents groundwater chemistry data from the following five borehole sections:

- KLX11A 516.5 to 519.5 m (SWIW)
- KLX11A 579.0 to 584.0 m (SWIW)
- KLX11A 598.0 to 599.0 m (SWIW)
- KLX19A 495.0 to 515.0 m (PSS)
- KLX19A 764.0 to 769.0 m (PSS)

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

<b>Activity plan</b>	<b>Number</b>	<b>Version</b>
Grundvattenflödesmätningar, vattenprovtagningar och SWIW-test i KLX11A	AP PS-400-07-026	1.0
Hydraulic injection tests and water sampling in borehole KLX19A	AP PS 400-06-144	1.0
<b>Method descriptions</b>	<b>Number</b>	<b>Version</b>
Mätsystembeskrivning för utspädningssond med SWIW-test utrustning – Allmän del	SKB MD 353.059	1.0
Mätsystembeskrivning för Pipe String System 3 (PSS3)	SKB MD 345.100–124	1.0
Metodbeskrivning för provtagning under pumptester i kärnbrorhål	SKB MD 430.018	1.0



**Figure 1-1.** Overview of the Oskarshamn site investigation area, showing core-drilled boreholes KLX11A and KLX19A.

## 2 Objective and scope

This report summarises the analytical results from the water chemistry samples collected during pumping with the SWIW equipment in three sections in borehole KLX11A and with the PSS in two sections in borehole KLX19A. The choice of borehole sections for sampling was based on results from differential flow logging in KLX11A and in KLX19A /1, 2/. The water sampling was performed in order to increase the quantity of chemical data from the boreholes, and carried out according to SKB chemistry class 3, 4 or 5. In all of the sections, water sampling was carried out according to SKB chemistry class 5. In addition, sampling according to SKB chemistry class 4 was performed in KLX11A (section 516.5 to 519.5 m) and in KLX19A (section 495.0 to 515.0 m). SKB chemistry class 3 sampling was carried out in KLX19A (section 764.0 to 769.0 m).

When the flushing water content is 5% or lower, a final SKB sample is normally collected. However, since the maximum pumping time for each section is 7 days, this flushing water criterion may not be achieved.



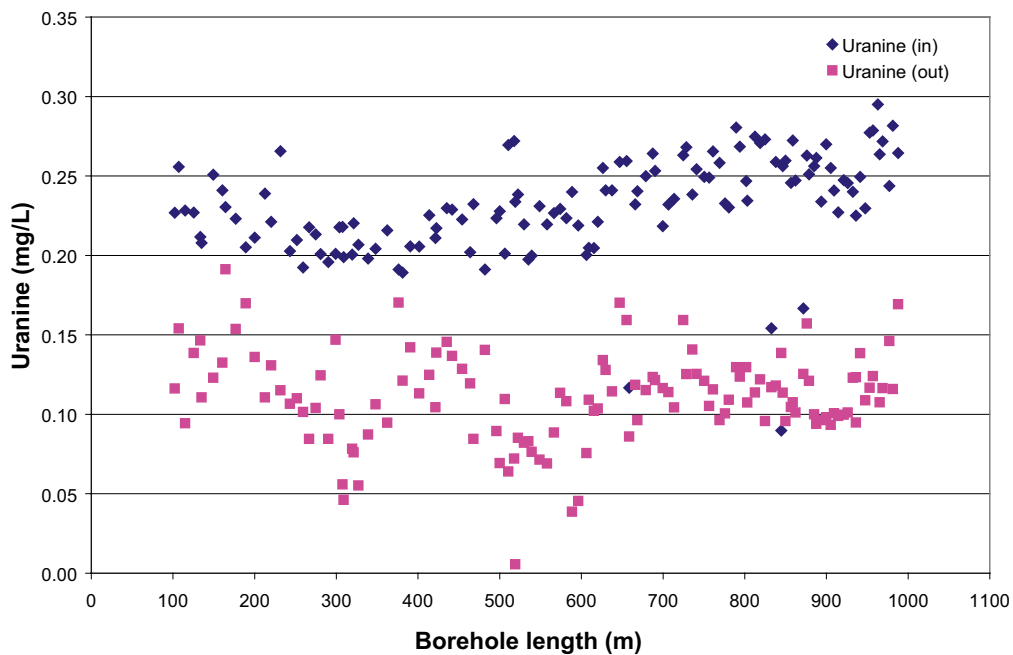
### 3 Background

#### 3.1 Flushing water history

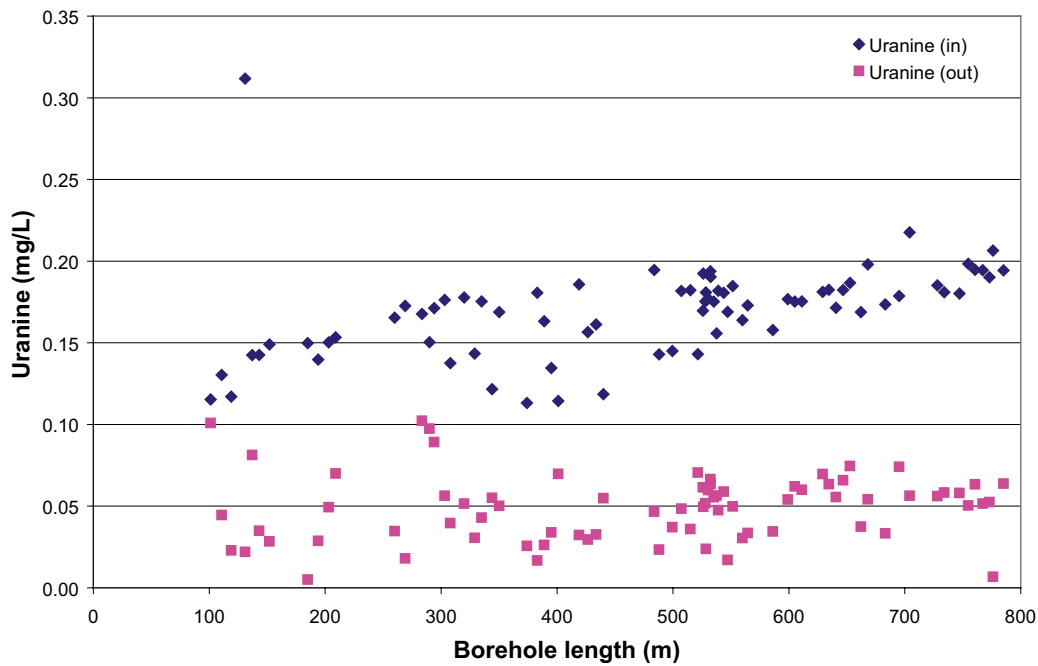
The core drilling /3/ of the 992.29 m long borehole KLX11A consumed 1,050 m<sup>3</sup> of flushing water and the volume of returned water pumped from the borehole by air-lift pumping during drilling was 1,984 m<sup>3</sup>. The core drilling /4/ of the 800.07 m long borehole KLX19A consumed 841 m<sup>3</sup> of flushing water. The volume of returned water pumped from the borehole by air-lift pumping during drilling was 2,378 m<sup>3</sup>.

Uranine was added automatically to the flushing water tank that supplies flushing water to the drilling head. The uranine concentration in the flushing water and returned water was checked regularly and of each a total of 129 and 76 samples in KLX11A and KLX19A, respectively, were analysed. The uranine concentrations in the flushing water and in the returned water in KLX11A and KLX19A are presented in Figures 3-1 and 3-2, respectively. The amounts of uranine added to the borehole via the flushing water and the estimated amount recovered in the return water, respectively, are given in Table 3-1.

The uranine budget in Table 3-1 suggests that only a few cubic metres of flushing water might have been lost to each of the boreholes and the adjacent host bedrock during drilling.



**Figure 3-1.** KLX11A, uranine concentrations in the flushing water and in the recovered water versus borehole length.



*Figure 3-2. KLX19A, uranine concentrations in the flushing water and in the recovered water versus borehole length.*

**Table 3-1. Amount of uranine added to KLX11A and KLX19A via the flushing water during core drilling and the amount recovered from the air-lift pumping.**

<b>Uranine, KLX11A</b>	<b>(g)</b>
Added, calculated from the average uranine concentration added and the total volume of flushing water.	243
Recovered, estimated from the average uranine concentration recovered and the total volume of returned water.	220
<b>Uranine, KLX19A</b>	<b>(g)</b>
Added, calculated from the average uranine concentration added and the total volume of flushing water.	142
Recovered, estimated from the average uranine concentration recovered and the total volume of returned water.	116

### 3.2 Previous activities and events in boreholes KLX11A and KLX19A.

The activities/investigations performed in KLX11A and KLX19A prior to chemistry groundwater sampling are listed in Table 3-2 below.

**Table 3-2. Activities performed in KLX11A and KLX19A prior to sampling of groundwater.**

<b>Activity in KLX11A</b>	<b>Date of completion</b>	<b>Length or section (m)</b>	<b>Reference</b>
Percussion drilling	2005-11-08	0.43–100.06	
Core drilling	2006-03-02	100.06–992.29	/3/
BIPS-logging	2006-04-05	12.00–989.40	/5/
Geophysical logging	2006-04-12	0.00–990.90	/6/
Injection tests	2006-08-11	103.00–903.00	/7/
Differential flow logging	2006-11-10	24.40–989.99	/1/
<b>Activity in KLX19A</b>	<b>Date of completion</b>	<b>Length or section (m)</b>	<b>Reference</b>
Percussion drilling	2006-05-22	0.20–99.33	
Core drilling	2006-09-20	99.33–800.07	/4/
BIPS-logging	2006-10-10	100.00–795.00	/8/
Geophysical logging	2006-10-13	0.00–796.60	/9/
Differential flow logging	2006-11-22	19.72–797.42	/2/

## 4 Equipment

### 4.1 Single Well Injection Withdrawal (SWIW)

The SKB downhole Single Well Injection Withdrawal (SWIW) system may also be used for pumping and chemical sampling. For pumping the system is designed for flow rates up to 350 mL/min. The equipment is described in SKB MD 353.059 (Mätssystem-beskrivning för Utspänningssond med SWIW-test utrustning, SKB internal controlling document).

#### 4.1.1 SWIW test equipment

The SWIW (Single Well Injection Withdrawal) test equipment constitutes a complement to the borehole dilution probe making it possible to carry out a SWIW test in the same test section as the dilution measurement, Figure 4-1. Measurements can be made in boreholes with 56 mm or

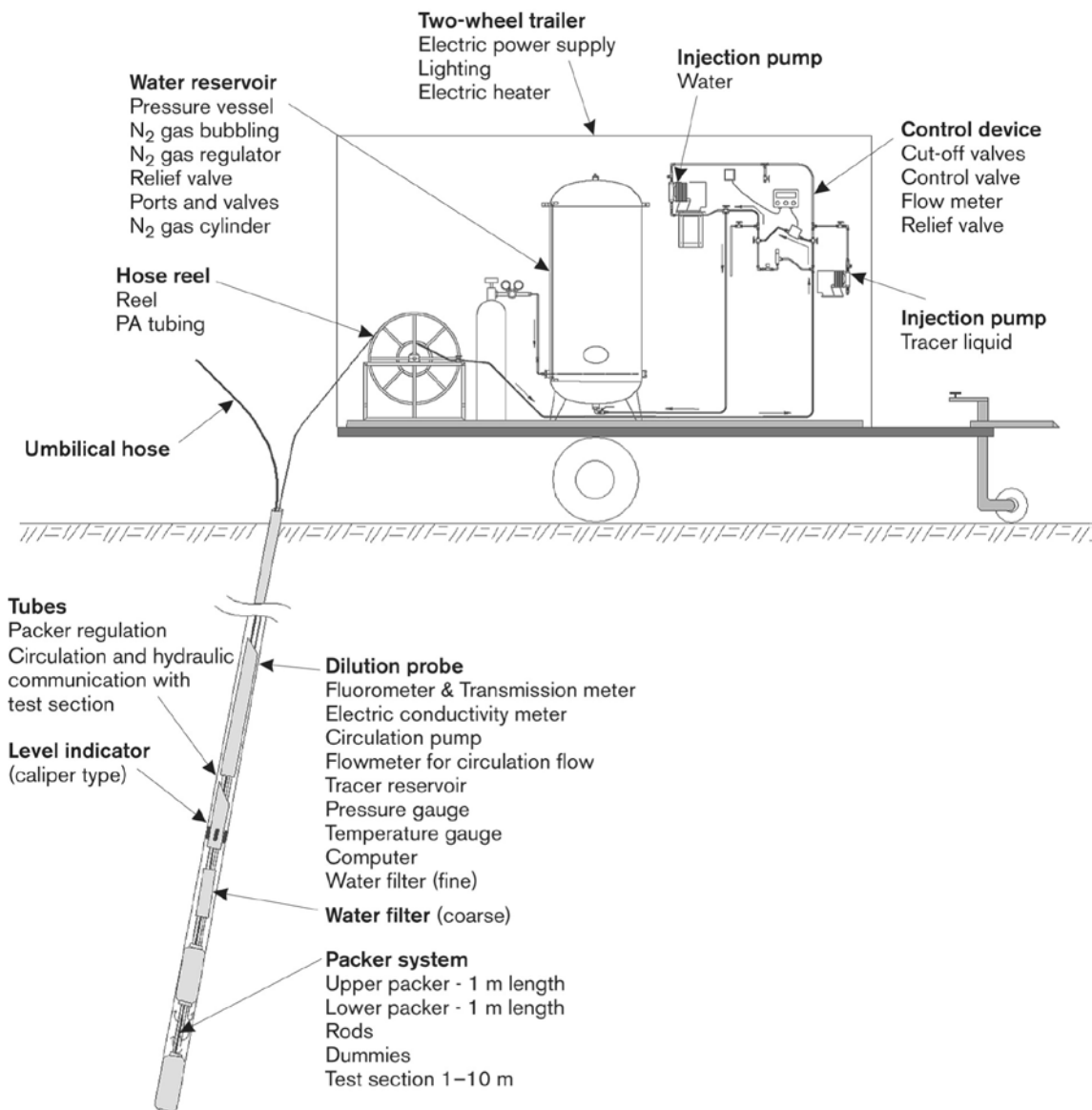


Figure 4-1. SWIW test equipment, connected to the borehole dilution probe.

76 to 77 mm diameter and the test section length can be arranged for 1, 2, 3, 4 or 5 m with an optimised special packer/dummy system for 76–77 mm boreholes. The equipment is primarily designed for measurements in the depth interval 300 to 700 m borehole length. However, measurements can be carried out at shallower depths as well as at depths larger than 700 m. The possibility to carry out a SWIW test much depends on the hydraulic transmissivity in the investigated test section and frictional loss in the tubing at tracer withdrawal pumping. Besides the dilution probe, the main parts of the SWIW test equipment are:

- Polyamide tubing constituting the hydraulic connection between SWIW test equipment at ground surface and the dilution probe in the borehole.
- Airtight vessel for storage of groundwater under anoxic conditions, i.e. N<sub>2</sub>-atmosphere.
- Control system for injection of tracer solution and groundwater (chaser fluid).
- Injection pumps for tracer solution and groundwater.

## 4.2 Pipe String system (PSS)

The SKB downhole pipe string system (PSS) is normally used for hydraulic injection tests but in this case it was used for pumping and chemical sampling. The system is designed for pumping flow rates between 5 to 40 L/min. The equipment is described in SKB MD 345.100-124 (Pipe String System, SKB internal controlling document).

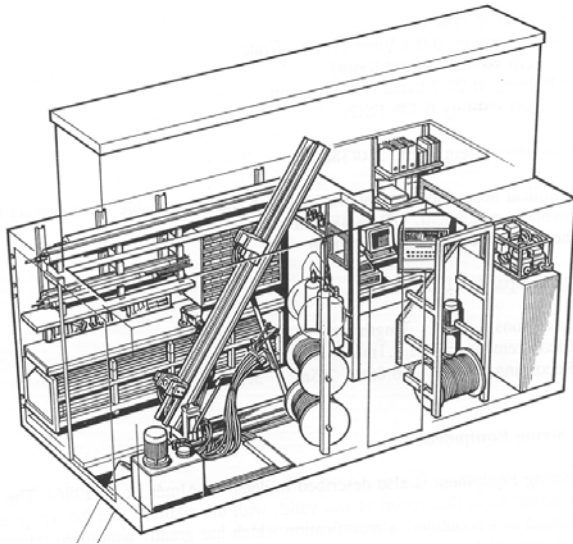
### 4.2.1 PSS equipment

The PSS is primarily designed for pumping and injection tests in packed-off borehole sections. All of the equipment needed to perform the tests is located in a self-contained steel container, which is placed on pallets in order to ensure a suitable working level in relation to the borehole casing. The container is divided into a computer-room and a workshop compartment, see Figure 4-2.

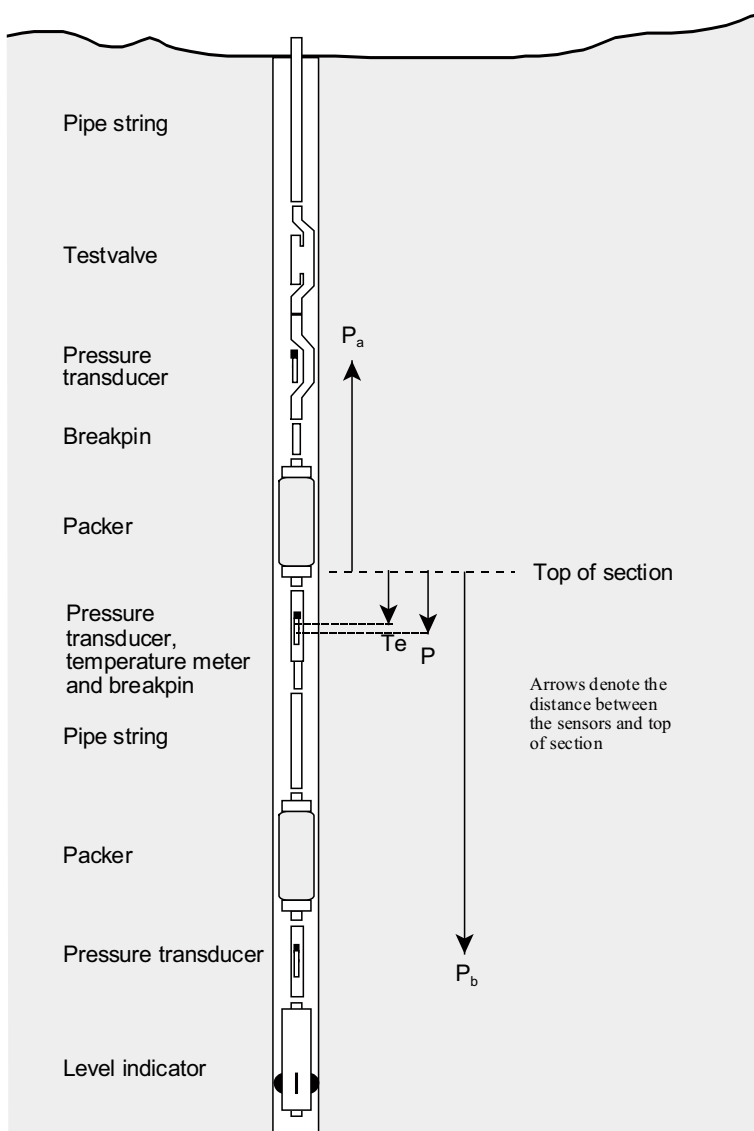
The hoisting rig is of a hydraulic chain-feed type. The jaws, holding the pipe string, are opened hydraulically and closed mechanically using springs. The rig is equipped with a load transmitter, maximum 22 kN, and a limiting value for the load may be adjusted.

Water filled pressure vessels operate the packers and the test valve. Expansion and release of packers as well as opening and closing of the test valve is done by magnetic valves controlled by the software in the data acquisition system.

A schematic drawing of the downhole equipment is shown in Figure 4-3. The pipe string consists of aluminium pipes of 3 m lengths and with an inner diameter of 21 mm, connected by stainless steel taps sealed with double o-rings. The test section is constructed using 5 m pipe lengths which can be adjusted to investigate 5, 20 or 100 m borehole sections, corresponding to available lengths of electric cable. Pressure is measured above ( $P_a$ ), within ( $P$ ) and below ( $P_b$ ) the test section which is isolated by two packers. The groundwater temperature in the test section is also measured. The hydraulic connection between the pipe string and the test section can be closed or opened by a test valve operated from the equipment facility container. At the lower end of the borehole equipment, a level indicator (caliper type) gives a signal when the reference length marks along the borehole are passed.



*Figure 4-2. Outline of the PSS equipment facility container.*



*Figure 4-3. Schematic drawing of the downhole equipment in the PSS system.*

## 5 Performance

### 5.1 General

Dilution tests were performed before the pumping and water sampling in KLX11A section 579.0 to 584.0 m (SKB chemistry class 5), and in KLX11A section 516.5 to 519.5 m (SKB chemistry class 4) /10/. For other sections the pumping and water sampling was performed prior to other tests /10, 11/. The sampling was performed in accordance with the method description SKB MD 430.018 (Metodbeskrivning för provtagning under pumptester i kärnbråhåll, SKB internal controlling document), see Table 1-1.

The main objective of the pumping was to sample water from three sections in KLX11A and two sections in KLX19A. A final SKB sample is normally collected when the flushing water content is 5% or lower, according to the Activity Plan. However, since the maximum pumping time for each section is 7 days, this flushing water content criterion may not be achieved. The collected samples were immediately brought to the Äspö chemistry laboratory for further preparation and conservation.

### 5.2 Performance in KLX11A

Samples for uranine analyses were collected and analysed once a day until the flushing water content was 5% or lower (1% if possible within the time restrictions). Then, the final water sample, an SKB chemistry class 4 or 5 chemistry sample, was collected. The decision when to collect the final water sample in each section was made by the SKB Activity Leader for hydrogeochemistry at Oskarshamn. In addition to the final SKB chemistry class 5 water sample, a control sample was taken from each of the sections in KLX11A.

The plan was to carry out a SKB chemistry class 4 sampling in the lowest section (598.0 to 599.0 m) and a SKB chemistry class 5 sampling in the other two sections (516.5 to 519.5 m and 579.0 to 584.0 m), see Nonconformities. The pumping periods during the sampling campaign in KLX11A are listed in Table 5-1.

**Table 5-1. Pumping times in KLX11A.**

Section [m]	Start date and time	Stop date and time
516.5–519.5	2007-04-05 08:37	2007-04-11 11:02
516.5–519.5	2007-07-17 08:32	2007-07-24 11:38
516.5–519.5	2007-07-24 18:28	2007-07-31 08:06
579.0–584.0	2007-03-26 21:24	2007-04-02 16:08
598.0–599.0	2007-05-02 07:13	2007-05-08 14:00
598.0–599.0	2007-06-07 23:36	2007-06-13 13:56
598.0–599.0	2007-06-28 04:40	2007-07-09 07:04

### 5.2.1 Section 516.5 to 519.5 metres

In addition to sampling for uranine, one SKB chemistry class 4 sample and two SKB chemistry class 5 samples were collected from this section. The first SKB chemistry class 5 sample was analysed for SKB chemistry class 5 parameters with all options and density. Archive samples were stored in a freezer. The second sample was collected as a control sample and was analysed for  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{F}^-$ , Fe-tot,  $\text{Fe}^{2+}$ ,  $\text{NH}_4^+$ ,  $\text{HS}^-$ , pH, electrical conductivity, uranine and the isotopes  $^{226}\text{Ra}$  and  $^{222}\text{Rn}$ . The rest of the control sample, and the archive samples, were stored in a freezer (tritium in a refrigerator). All of the archive samples are listed in Appendix 2.

Water samples collected during the pumping period are listed in Table 5-2.

### 5.2.2 Section 579.0 to 584.0 metres

In addition to sampling for uranine, two SKB chemistry class 5 samples from this section were collected and analysed. The first SKB chemistry class 5 sample was analysed for class 5 parameters with all options and density. Archive samples were stored in a freezer. The second sample was collected as a control sample and was analysed for  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{F}^-$ , Fe-tot,  $\text{Fe}^{2+}$ ,  $\text{NH}_4^+$ ,  $\text{HS}^-$ , pH, electrical conductivity, uranine, density and the isotopes  $^{226}\text{Ra}$ ,  $^{222}\text{Rn}$ ,  $^{238}\text{U}$ ,  $^{235}\text{U}$ ,  $^{234}\text{U}$ ,  $^{232}\text{Th}$  and  $^{230}\text{Th}$ . The rest of the control sample, and the archive samples, were stored in a freezer (tritium in a refrigerator).

Water samples collected during the pumping period are listed in Table 5-3.

**Table 5-2. Sampling performed in section 516.5 to 519.5 m in KLX11A**

Date and time	Sampling activity	SKB:no
2007-04-10 12:18	Water sampling: Uranine	11807
2007-04-11 09:40	Water sampling: Class 4	11808
2007-07-17 21:34	Water sampling: Uranine	15001
2007-07-18 07:08	Water sampling: Uranine	15002
2007-07-19 07:30	Water sampling: Uranine	15003
2007-07-20 07:45	Water sampling: Uranine	15004
2007-07-21 00:00	Water sampling: Uranine	15005
2007-07-22 00:00	Water sampling: Uranine	15006
2007-07-23 07:32	Water sampling: Uranine	15007
2007-07-24 08:54	Water sampling: Class 5	15010
2007-07-24 09:56	Water sampling: Class 5 (Control sample)	15011

**Table 5-3. Sampling performed in section 579.0 to 584.0 m in KLX11A.**

Date and time	Sampling activity	SKB:no
2007-03-28 08:39	Water sampling: Uranine	11800
2007-03-30 13:45	Water sampling: Uranine	11799
2007-04-02 11:16	Water sampling: Class 5 (Control sample)	11802
2007-04-02 11:16	Water sampling: Class 5	11801



### 5.2.3 Section 598.0 to 599.0 metres

In addition to sampling for uranine, two SKB chemistry class 5 samples were collected from this section. The first SKB chemistry class 5 sample was analysed for class 5 parameters with all options and density. Archive samples were stored in a freezer. The second sample was collected as a control sample and was analysed for  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{F}^-$ , Fe-tot,  $\text{Fe}^{2+}$ ,  $\text{NH}_4^+$ ,  $\text{HS}^-$ , pH, electrical conductivity, uranine and the isotopes  $^{226}\text{Ra}$  and  $^{222}\text{Rn}$ . The rest of the control sample, and the archive samples, were stored in a freezer (tritium in a refrigerator).

Water samples collected during the pumping period are listed in Table 5-4.

## 5.3 Performance in KLX19A

Samples for analysis of uranine were collected once a day after pumping commenced (twice a day when the flushing water content was 10% or lower). The maximum value of 5% flushing water content was not reached in any of the three sections and the decision to stop pumping and collect the final water sample was taken by the SKB Activity Leader. The pumping periods during the sampling campaign in KLX19A are listed in Table 5-5.

### 5.3.1 Section 495.0 to 515.0 metres

In addition to sampling for uranine, one SKB chemistry class 4 sample (reduced) and two SKB chemistry class 5 samples were collected from this section. The first class 5 sample included all options and density. Archive samples were stored in a freezer. The second sample was collected as a control sample and was analysed for  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{F}^-$ , Fe-tot,  $\text{Fe}^{2+}$ ,  $\text{NH}_4^+$ ,  $\text{HS}^-$ , pH, electrical conductivity, uranine, density and the isotopes  $^{226}\text{Ra}$  and  $^{222}\text{Rn}$ . The rest of the control sample, and the archive samples, were stored in a freezer (tritium in a refrigerator).

Water samples collected during the pumping period are listed in Table 5-6.

**Table 5-4. Sampling performed in section 598.0 to 599.0 m in KLX11A.**

Date and time	Sampling activity	SKB:no
2007-05-02 13:00	Water sampling: Uranine	11839
2007-05-04 11:30	Water sampling: Uranine	11840
2007-05-07 11:45	Water sampling: Uranine	11841
2007-06-11 08:46	Water sampling: Uranine	11916
2007-06-12 07:40	Water sampling: Uranine	11919
2007-06-13 07:30	Water sampling: Class 5 (Control sample)	11922
2007-06-13 08:40	Water sampling: Class 5	11921

**Table 5-5. Pumping times in KLX19A.**

Section [m]	Start date and time	Stop date and time
495.0–515.0	2006-12-07 15:38	2007-01-09 08:52
764.0–769.0	2006-11-28 20:33	2006-12-05 13:10

**Table 5-6. Sampling performed in section 495.0 to 515.0 m in KLX19A.**

Date and time	Sampling activity	SKB:no
2006-12-11 09:45	Water sampling: Uranine	11584
2006-12-12 10:06	Water sampling: Uranine	11586
2006-12-13 10:00	Water sampling: Uranine	11589
2006-12-14 09:00	Water sampling: Uranine	11590
2006-12-15 08:34	Water sampling: Uranine	11592
2006-12-18 08:54	Water sampling: Uranine	11594
2006-12-19 09:10	Water sampling: Uranine	11595
2006-12-20 08:45	Water sampling: Uranine	11597
2006-12-21 08:10	Water sampling: Class 4	11598
2006-12-22 08:40	Water sampling: Uranine	11600
2007-01-03 08:24	Water sampling: Uranine	11601
2007-01-04 08:15	Water sampling: Uranine	11602
2007-01-08 08:17	Water sampling: Class 5	11604
2007-01-08 08:46	Water sampling: Class 5 (Control sample)	11605

### 5.3.2 Section 764.0 to 769.0 metres

In addition to sampling for uranine, one SKB chemistry class 3 sample (reduced) and two SKB chemistry class 5 samples were collected from this section. The first class 5 sample included all options and density. Archive samples were stored in a freezer. The second sample was collected as a control sample and was analysed for  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{F}^-$ , Fe-tot,  $\text{Fe}^{2+}$ ,  $\text{NH}_4^+$ ,  $\text{HS}^-$ , pH, electrical conductivity, uranine, density and the isotopes  $^{226}\text{Ra}$  and  $^{222}\text{Rn}$ . The rest of the control sample, and the archive samples, were stored in a freezer (tritium in a refrigerator).

Water samples collected during the pumping period are listed in Table 5-7.

## 5.4 Water sample treatment and analyses

An overview of sample treatment and analytical routines is given in Appendix 1.

**Table 5-7. Sampling performed in section 764.0 to 769.0 m in KLX19A.**

Date and time	Sampling activity	SKB:no
2006-11-28 21:00	Water sampling: Uranine	11498
2006-11-29 09:30	Water sampling: Uranine	11499
2006-11-30 09:22	Water sampling: Uranine	11565
2006-12-01 09:05	Water sampling: Class 3	11566
2006-12-04 10:30	Water sampling: Uranine	11568
2006-12-05 06:44	Water sampling: Class 5	11569
2006-12-05 06:50	Water sampling: Class 5 (Control sample)	11574

## 5.5 Handling of water analytical data

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

Some of the constituents are determined by more than one method and/or by more than one laboratory. 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 the 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.
- Calculation of charge balance errors, equation (1). Relative errors within  $\pm 5\%$  are considered acceptable.

$$\text{Relative error (\%)} = 100 \times \frac{\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)}}{\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)}} \quad (1)$$

- General judgement of plausibility based on earlier results and experience.

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 indicates the results that are considered most reliable.

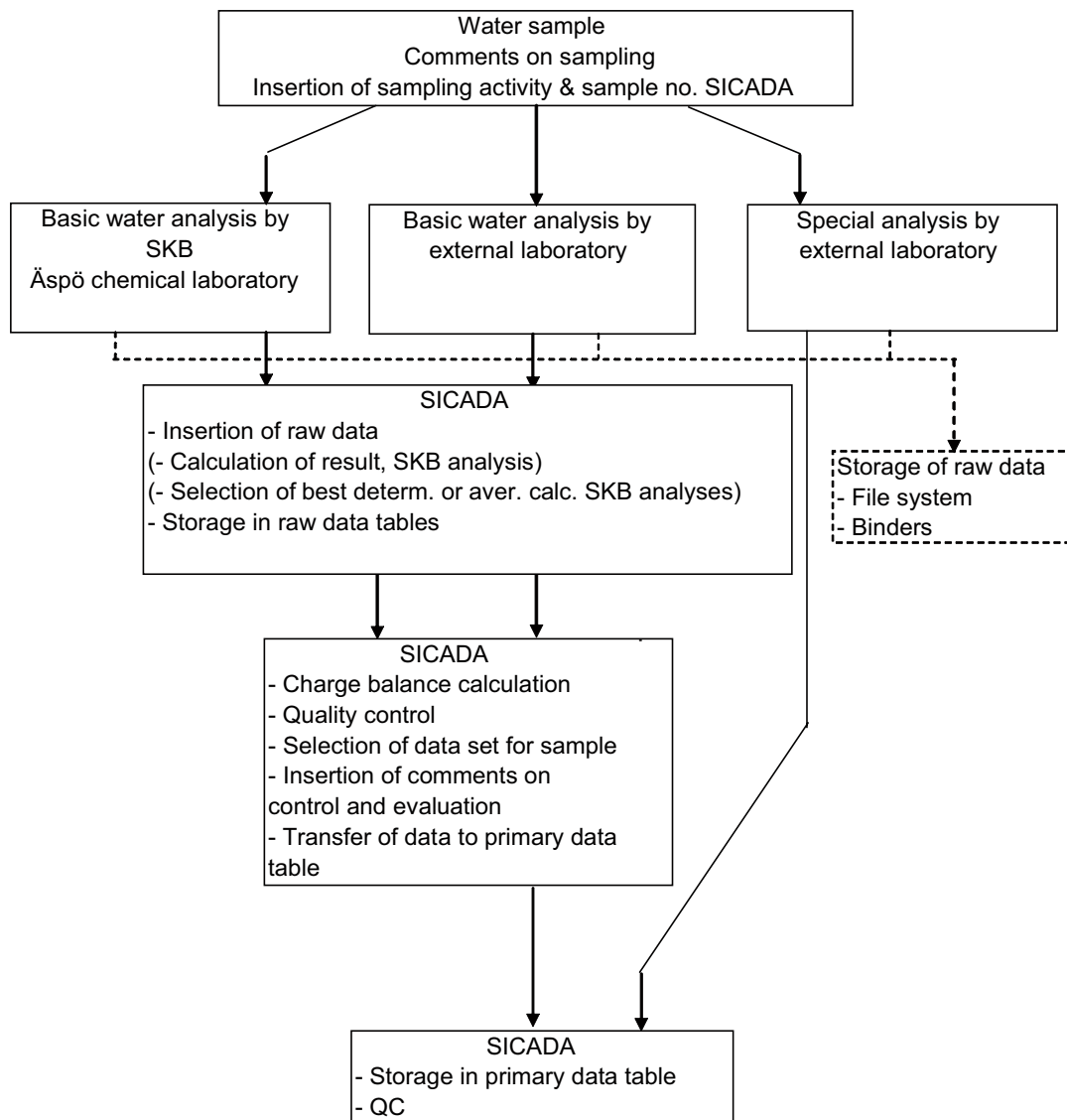
An overview of the data management is given in Figure 5-1.

## 5.6 Nonconformities

The freezer storage for sample bottles had thawed on 2008-02-28, which means that all of the archive samples stored in connection with groundwater sampling have been affected (SKB Dok id 1168893; SKB internal meeting record). The reason for this was lack of power in connection with malfunctioning of the alarm.

KLX11A

- Pump stop due to power failure causing delay of the sampling for c. 4 hours.
- A leakage of denatured ethanol due to malfunctioning of an O-ring. The leakage did not occur within the borehole section, but while lifting the equipment.
- When sampling in section 516.5 to 519.5 m on 2007-04-11, neither of the two Winkler flasks for hydrogen sulphide analysis could be opened, hence no results are available for SKB sample number 11808.
- The water sample from section 516.5 to 519.5 m on 2007-04-11 was sampled as an SKB chemistry class 4 sample instead of SKB chemistry class 5, according to the Activity Plan.
- The planned sampling in section 598.0 to 599.0 m on 2007-05-09 was cancelled due to a thunderstorm that caused equipment damages.
- Sampling (one SKB chemistry class 5 and one control sample) was performed twice in section 598.0 to 599.0 m, on 2007-06-12 and 2007-06-13. Only the sample from 2007-06-13 was analysed, as the flushing water content was the same in both of the samples.
- The SKB chemistry class 5 sample in section 598.0 to 599.0 m was taken inadvertently. No sampling should have been performed according to the revised plan.
- The flushing water content in section 598.0 to 599.0 m had been stable for several days and therefore the pumping period was reduced to five days (instead of seven).



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

## 6 Results

The results from the chemical analysis are presented below and in Appendix 3.

Original data from the reported activity are stored in the primary database Sicada. Data are traceable in Sicada by the Activity Plan number (AP PS 400-07-026 and AP PS 400-06-144.). Only data in Sicada database are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the Sicada database may be revised, if needed. However, such revision of the Sicada database will not necessarily result in a revision of this report, although the normal procedure is that major data revisions entail a revision of P-reports. Minor data revisions are normally presented as supplements, available at [www.skb.se](http://www.skb.se).

Water sampling in KLX11A and KLX19A was performed according to Table 6-1. SKB chemistry class 5 sampling in KLX11A section 598.0 to 599.0 m and all of the sampling in KLX19A were performed in spite of flushing water contents above 5%.

### 6.1 Basic water analyses

The basic water analyses include Na, K, Ca, Mg, Fe, Li, Mn, S, Sr, P,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , Si,  $\text{HCO}_3^-$ ,  $\text{Br}^-$ ,  $\text{F}^-$ ,  $\text{I}^-$ ,  $\text{HS}^-$ ,  $\text{NH}_4^+$ ,  $\text{NO}_2^-$ ,  $\text{NO}_3^-$ , TOC and DOC. Furthermore, measurements are made of pH, electrical conductivity, flushing water content and density. The basic water analysis data and relative charge balance errors are compiled in Appendix 3, Table A3-1, and Appendix 3, Table A3-2, for KLX11A and KLX19A, respectively.

The flushing water content in the samples collected during the pumping/measurement periods in the borehole sections are presented in Figure 6-1 for KLX11A and Figure 6-2 for KLX19A.

**Table 6-1. Water sampling in KLX11A and KLX19A performed according to SKB chemistry class 3, 4 and 5.**

KLX11A Section (m)	Water sample SKB chemistry class	KLX19A Section (m)	Water sample SKB chemistry class
516.5–519.5	4 and 5	495.0–515.0	4 and 5
579.0–584.0	5	764.0–769.0	3 and 5
598.0–599.0	5		

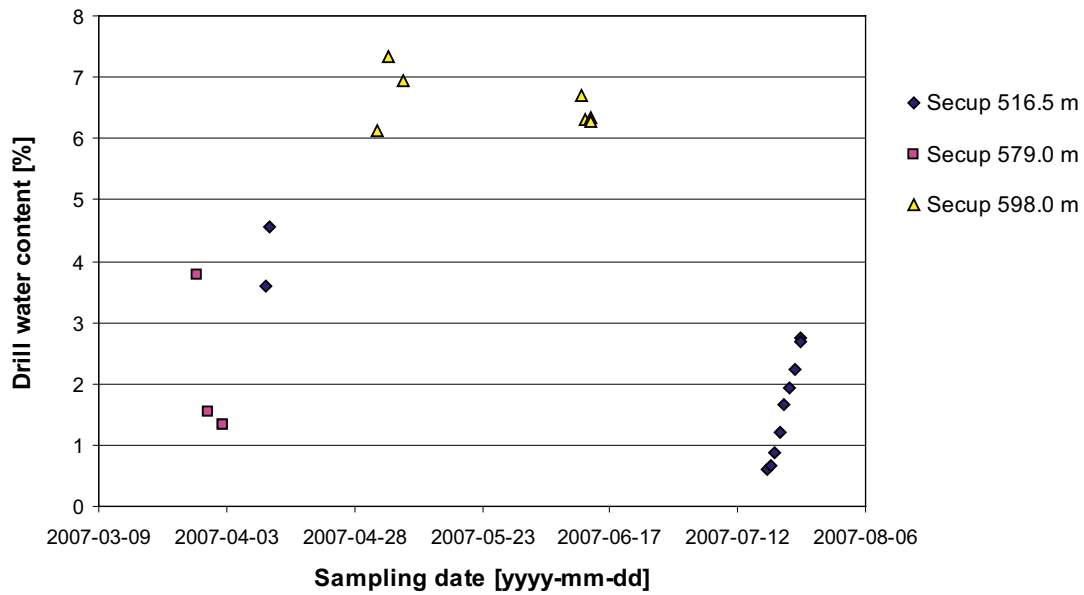


Figure 6-1. Flushing water content in samples collected from three sections in KLX11A using the SWIW equipment.

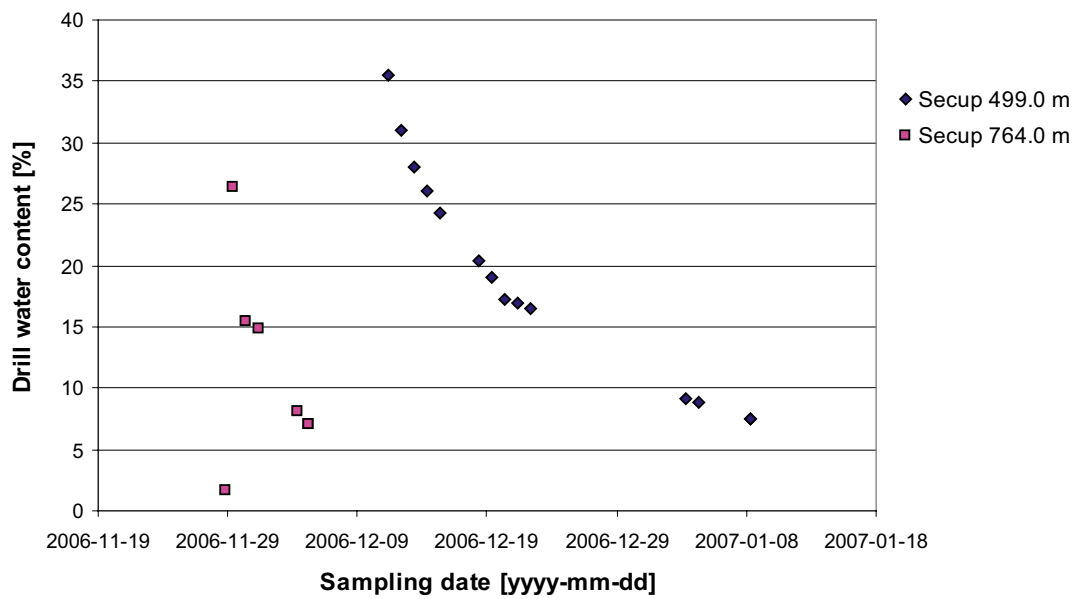
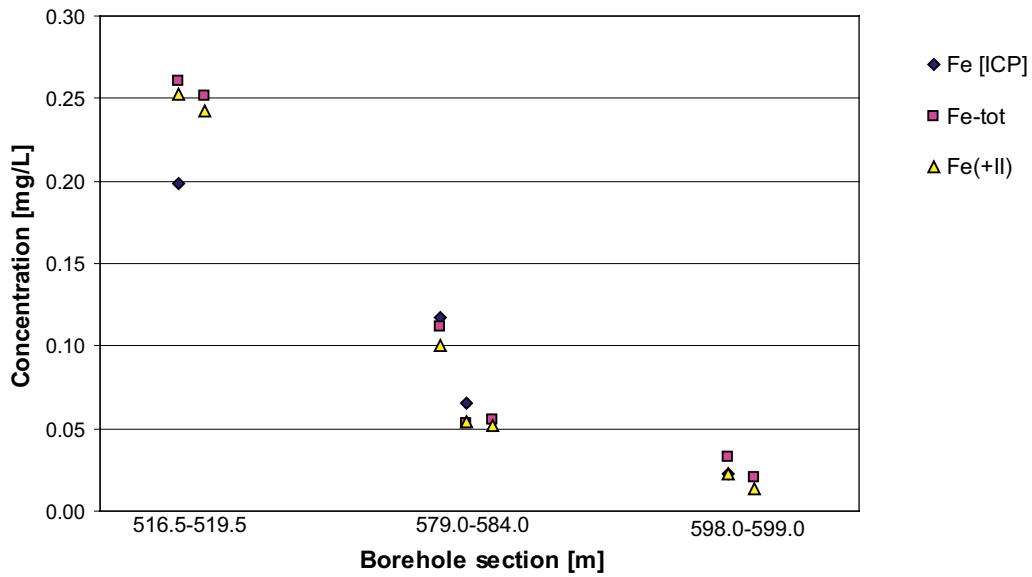
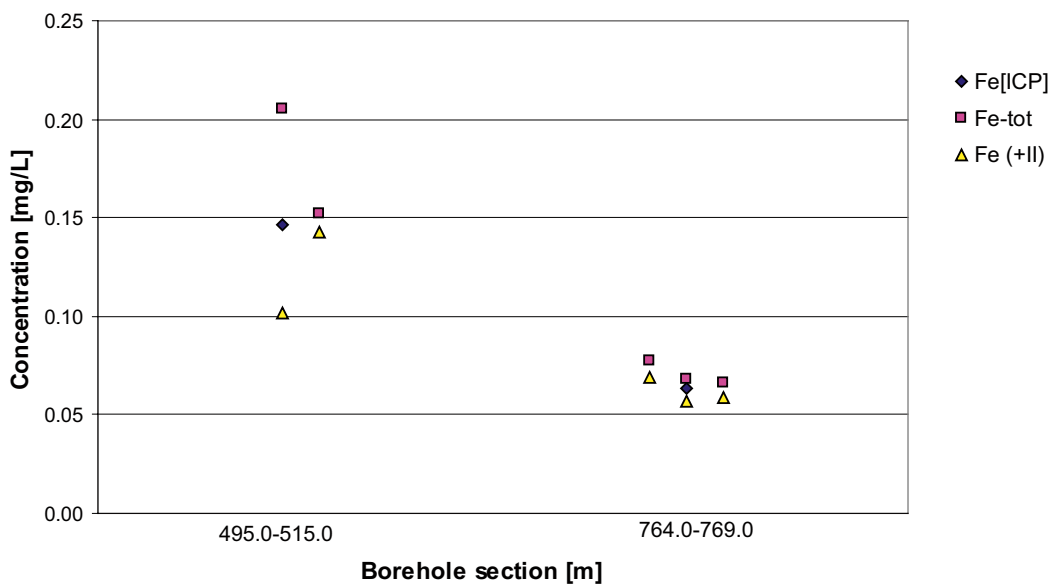


Figure 6-2. Flushing water content in samples collected from two sections in KLX19A using the PSS equipment.

The iron concentrations determined by ICP-AES (total Fe) and by spectrophotometry ( $\text{Fe}^{2+}$  and Fe-tot) are compared in Figures 6-3 and 6-4 for three sections in KLX11A and two sections in KLX19A, respectively. The discrepancies are within the measurement uncertainties.

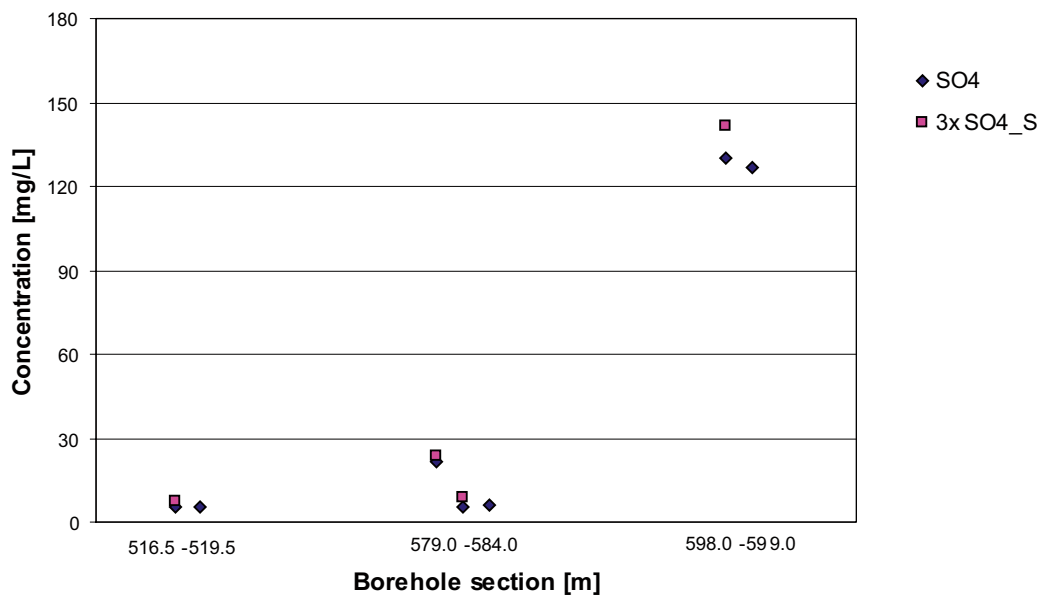


**Figure 6-3.** Comparison of iron concentrations obtained by ICP-AES and spectrophotometry, in three borehole sections in KLX11A. The control sample from each section is presented to the right. The SKB chemistry class 4 sample in section 579.0 to 584.0 m is presented to the left.

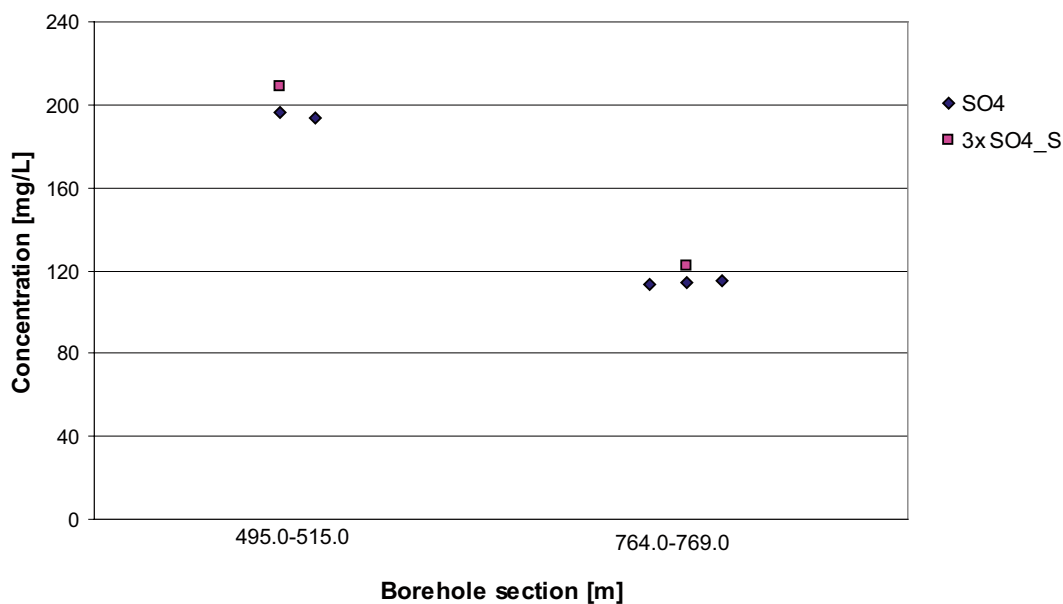


**Figure 6-4.** Comparison of iron concentrations obtained by ICP-AES and spectrophotometry, in two borehole sections in KLX19A. The control sample from each section is presented to the right. The SKB chemistry class 4 sample in section 764.0 to 769.0 m is presented to the left.

Sulphate ( $\text{SO}_4^{2-}$ ) analysed using ion chromatography (IC) is compared with sulphate determined as total sulphur using inductively coupled plasma atomic emission spectrometry (ICP-AES) in Figure 6-5 (KLX11A) and Figure 6-6 (KLX19A). There is a satisfactory agreement in this case as well.



**Figure 6-5.** Sulphate ( $SO_4$  by IC) compared to sulphate calculated from total sulphur ( $3 \times SO_4-S$  by ICP) for three sections investigated in KLX11A. The control sample from each section is presented to the right. The SKB chemistry class 4 sample in section 579.0 to 584.0 m is presented to the left.

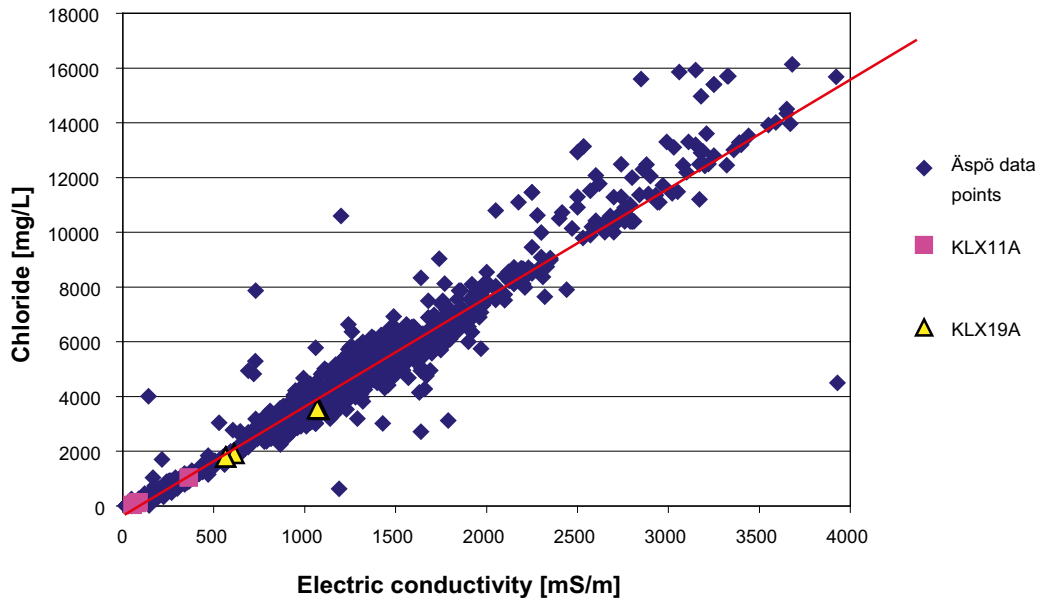


**Figure 6-6.** Sulphate ( $SO_4$  by IC) compared to sulphate calculated from total sulphur ( $3 \times SO_4-S$  by ICP) for two sections investigated in KLX19A. The control sample from each section is presented to the right. The SKB chemistry class 4 sample in section 764.0 to 769.0 m is presented to the left.

The chloride concentrations are plotted versus the corresponding electric conductivity values in Figure 6-7. The plot gives an approximate indication that the values are reasonable. The data from the borehole sections agree well with earlier data from the Äspö Hard Rock Laboratory.

The charge balance error gives an indication of the quality and uncertainty of the analyses of major constituents. The charge balance error does not exceed the acceptable level of  $\pm 5\%$  in any of the samples.





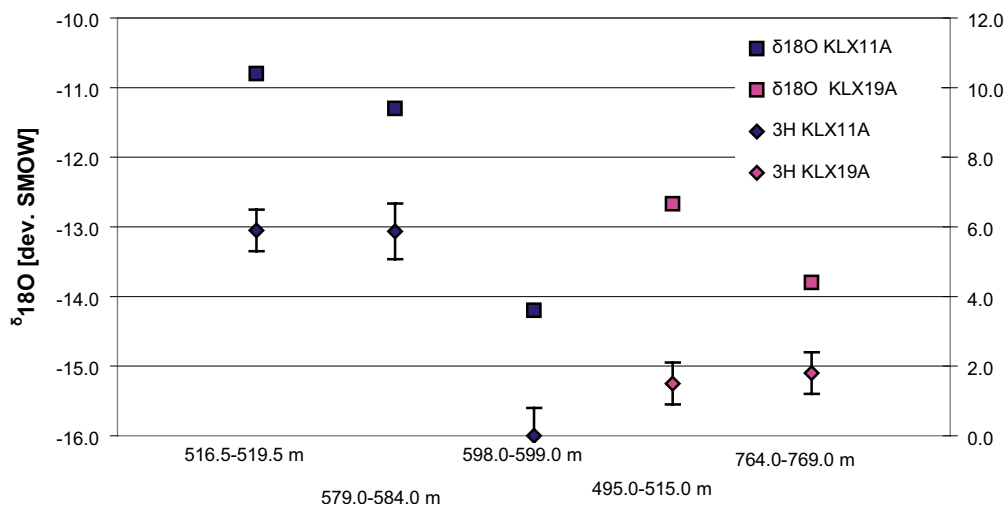
**Figure 6-7.** Chloride concentration versus electrical conductivity. Data from earlier investigations at the Äspö Hard Rock Laboratory are used to show the overall trend.

## 6.2 Trace elements (rare earth metals and others)

The analyses of trace and rare earth metals include U, Th, As, Sc, Cd, Hg, V, Rb, Y, Zr, In, Cs, Ba, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. Commonly occurring metals, such as Cu, Zn, Pb, Sb and Mo are not included in the analytical programme due to contamination considerations. The trace element data are compiled in Appendix 3, Table A3-3.

## 6.3 Stable and radioactive isotopes

The isotope determinations include the stable isotopes  $\delta^2\text{H}$ ,  $\delta^{18}\text{O}$ ,  $^{10}\text{B}/^{11}\text{B}$ ,  $\delta^{34}\text{S}$ ,  $\delta^{13}\text{C}$ ,  $\delta^{37}\text{Cl}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  as well as the radioactive isotopes  $^3\text{H}$  (TU),  $^{14}\text{C}$  (pmC),  $^{238}\text{U}$ ,  $^{235}\text{U}$ ,  $^{234}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{230}\text{Th}$ ,  $^{226}\text{Ra}$  and  $^{222}\text{Rn}$ . The isotope data are compiled in Appendix 3, Table A3-4 and Table A3-5. The  $^3\text{H}$  and  $\delta^{18}\text{O}$  results are presented in Figure 6-8.



**Figure 6-8.**  $^3\text{H}$  and  $\delta^{18}\text{O}$  (‰ SMOW) data versus sampling data, KLX11A and KLX19A.

## 7 Summary

- In general, comparison of the results from different laboratories and/or methods showed agreement.
- The charge balance error did not exceed the acceptable level of  $\pm 5\%$  in any of the samples.
- General judgement of plausibility based on earlier results and experience indicated reasonable values in most cases.

## 8 References

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- /10/ **Thur P, Nordqvist R, Gustafsson E, 2007.** Oskarshamn site investigation. Groundwater flow measurements and SWIW tests in borehole KLX11A. SKB P-07-180, Svensk Kärnbränslehantering AB.
- /11/ **Enachescu C, Böhner J, Wolf P, 2007.** Oskarshamn site investigation. Pumping tests and hydraulic injection tests in borehole KLX19A, Subarea Laxemar. SKB P-07-90, Svensk Kärnbränslehantering AB.

## Sampling and analytical methods

Table A1-1. Sample handling routines and analytical methods.

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab.
Drill water	Uranine	Plastic (brown)	100	No	No	Spectrofluorometry	–
Anions	HCO <sub>3</sub> <sup>-</sup>	Plastic	250	No	No	Titration	The same day – maximum 24 hours
	pH (lab)					Pot. meas.	
	Cond. (lab)					Cond. meas.	
	Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> , Br <sup>-</sup> , F <sup>-</sup>	Plastic	250	Yes (in connection to the analysis)	No	Titration (Cl <sup>-</sup> ) IC (Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> , Br <sup>-</sup> , F <sup>-</sup> ) ISE (F <sup>-</sup> )	Not critical (month)
	Br <sup>-</sup> (control sample to external laboratory)	Plastic	100	Yes	No	ICP MS	Not critical (month)
	I <sup>-</sup>	Plastic	100	Yes	No	ICP MS	Not critical (month)
Cations etc.	Na, K, Ca, Mg, S(tot), Si(tot), Fe, Mn, Li, Sr	Plastic (acid washed)	100	Yes	Yes (1 mL HNO <sub>3</sub> )	ICP AES ICP MS	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic-PEH (acid washed)	500	Yes	Yes (5 mL HCl)	Spectrophotometry Ferrozine method	As soon as possible the same day
Hydrogen sulphide	HS <sup>-</sup>	Glass (Winkler)	About 120×2	Yes	1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	Immediately or if conserved, a few days
Nutrient salts	NO <sub>2</sub> -N, NO <sub>3</sub> -N+NO <sub>2</sub> -N, PO <sub>4</sub> -P	Plastic	250	Yes	Frozen, transported in isolated bag	Spectrophotometry	Short transportation time
	NH <sub>4</sub> -N	Glass (measuring flask)	50	No	No	Spectrophotometry	Maximum 24 hours
Environmental metals etc.	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn, In	Plastic	100	Yes	Yes (1 mL HNO <sub>3</sub> )	ICP AES ICP MS	Not critical (month)
Lanthanoids, U, Th, etc.	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 <sub>3</sub> )	ICP AES ICP MS	Not critical (month)

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab.
Dissolved organic Carbon	DOC	Plastic	250	Yes	Frozen, transported in isolated bag	UV oxidation, IR	Short transportation time
Total organic Carbon	TOC	Plastic	250	No	Frozen, transported in isolated bag	UV oxidation, IR	Short transportation time
Environmental isotopes	$\delta^2\text{H}$ , $\delta^{18}\text{O}$	Plastic	100	No	–	MS	Not critical (month)
Tritium	$^3\text{H}$ (enhanced.)	Plastic (dry bottle)	500	No	–	LSC	Not critical (month)
Chlorine-37	$\delta^{37}\text{Cl}$	Plastic	500	No	–	ICP MS	Not critical (month)
Carbon isotopes	$\delta^{13}\text{C}$ , pmC ( $^{14}\text{C}$ )	FLPE	125×2	No	–	(A)MS	A few days
Sulphur isotopes	$\delta^{34}\text{S}$	Plastic	1,000	No	–	Combustion, ICP MS	No limit
Strontium-isotopes	$^{87}\text{Sr}/^{86}\text{Sr}$	Plastic	100	No	–	TIMS	Days or Week
Uranium and Thorium isotopes	$^{234}\text{U}$ , $^{235}\text{U}$ , $^{238}\text{U}$ , $^{232}\text{Th}$ , $^{230}\text{Th}$ ,	HDPE	1,000	No	–	Chemical separat. Alfa/ gamma spectrometry	No limit
Boron isotopes	$^{10}\text{B}/^{11}\text{B}$	Plastic	100	Yes	Yes (1 mL $\text{HNO}_3$ )	ICP MS	No limit
Radon and Radium isotopes	$^{222}\text{Rn}$ , $^{226}\text{Ra}$	HDPE	1,000	No	No	LSC	Immediate transport
Dissolved gas (content and composition)	Ar, He, $\text{N}_2$ , $\text{CO}_2$ , $\text{O}_2$ , $\text{CH}_4$ , $\text{H}_2$ , $\text{CO}$ , $\text{C}_2\text{H}_6$ , $\text{C}_2\text{H}_4$ , $\text{C}_2\text{H}_2$ , $\text{C}_3\text{H}_8$ , $\text{C}_3\text{H}_6$	Cylinder of stainless steel	200	No	No	GC	Immediate transport

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab.
Colloids	Filter series and fractionation (Analysis of cations and environmental metals)	Polycarbonate filters	2.0, 0.4, 0.2 and 0.05 µm	–	Ar atmosphere	ICP AES ICP MS	Immediate transport
Density	Density	Plastic	250	No	–	Pycnometer	–
Archive samples with acid	–	Plastic (washed in acid)	100×2 **	Yes	Yes (1 mL HNO <sub>3</sub> )	–	Storage in freeze container
Archive samples without acid	–	Plastic	250×2 **	Yes	No	–	Storage in freeze container

\* Suprapur acid is used for conservation of samples.

\*\* Minimum number, the number of archive samples can vary depending on how many similar samples collected at the same occasion.

**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
IR	Infra Red detection
MS	Mass Spectrometry
LSC	Liquid Scintillation Counting
(A)MS	(Accelerator) Mass Spectrometry
TIMS	Thermal Ionization Mass Spectrometry
GC	Gas Chromatography

**Table A1-2. Reporting limits and measurement uncertainties (updated in 2008).**

Component	Method <sup>1</sup>	Reporting limits (RL), detection limits (DL) or range <sup>2</sup>	Unit	Measurement uncertainty <sup>3</sup>
HCO <sub>3</sub> <sup>-</sup>	Alkalinity titration	1	mg/L	4%
pH	Potentiometric	3–10	pH unit	±0.10 pH units
Cond.	Electrical Conductivity Meas.	1–150 150–10,000	mS/m	5% 3%
Cl <sup>-</sup>	Mohr titration	IC	mg/L	5%
Cl <sup>-</sup>		≥70 0.5–70		8%
SO <sub>4</sub> <sup>2-</sup>	IC	0.5	mg/L	12%
Br <sup>-</sup>	IC	DL 0.2, RL 0.5	mg/L	15%
Br <sup>-</sup>	ICP SFMS	0.001, 0.004, 0.010 <sup>4</sup>		25%
F <sup>-</sup>	IC	DL 0.2, RL 0.5	DL 0.1, mg/L	13%
F <sup>-</sup>	ISE	RL 0.2		12%
I <sup>-</sup>	ICP SFMS	0.001, 0.004, 0.010 <sup>4</sup>	mg/L	25% <sup>5</sup>
Na	ICP AES	0.1	mg/L	13%
K	ICP AES	0.4	mg/L	12%
Ca	ICP AES	0.1	mg/L	12%
Mg	ICP AES	0.09	mg/L	12%
S(tot)	ICP AES	0.16	mg/L	12%
Si(tot)	ICP AES	0.03	mg/L	14%
Sr	ICP AES	0.002	mg/L	12%
Li	ICP AES	4	µg/L	12%
Fe	ICP AES	0.02	mg/L	13.3% <sup>6</sup>
Fe	ICP SFMS	0.0004, 0.002, 0.004 <sup>4</sup>	µg/L	20% <sup>6</sup>
Mn	ICP AES	0.003	µg/L	12% <sup>5</sup>
Mn	ICP SFMS	0.00003, 0.00004, 0.0001 <sup>4</sup>	mg/L	53% <sup>6</sup>
Fe(II), Fe(tot)	Spectrophotometry	DL 0.006, RL 0.02	µg/L	0.005 (0.02–0.05 mg/L) 9% (0.05–1 mg/L) 7% (1–3 mg/L)
HS <sup>-</sup>	Spectrophotometry	DL 0.006, RL 0.02	µg/L	25%
NO <sub>2</sub> -N	Spectrophotometry	0.1	µg/L	2%
NO <sub>2</sub> -N +NO <sub>3</sub> -N	Spectrophotometry	0.2	µg/L	0.2 (0.2–20µg/L) 2%(> 20 µg/L)
NH <sub>4</sub> -N	Spectrophotometry	11	µg/L	30% (11–20 µg/L) 25% (20–50 µg/L) 12% (50– 1,200 µg/L)
PO <sub>4</sub> -P	Spectrophotometry	0.7	µg/L	0.7 (0.7–20µg/L) 3% (> 20 µg/L)
Al	ICP SFMS	0.2, 0.3, 0.7 <sup>4</sup>	µg/L	18% <sup>6</sup>
Zn	ICP SFMS	0.2, 0.8, 2 <sup>4</sup>	µg/L	16, 18, 26% <sup>6</sup>
Ba, Cr, Mo	ICP SFMS	0.01, 0.04, 0.1 <sup>4</sup>	µg/L	Ba 15% <sup>4</sup> , Cr 22% <sup>5</sup> Mo 39% <sup>6</sup>
Pb	ICP SFMS	0.01, 0.1, 0.3 <sup>4</sup>	µg/L	15% <sup>6</sup>
Cd	ICP SFMS	0.002, 0.02, 0.5 <sup>4</sup>	µg/L	16% <sup>6</sup>
Hg	ICP AFS	0.002	µg/L	11% <sup>6</sup>
Co	ICP SFMS	0.005, 0.02, 0.05 <sup>4</sup>	µg/L	26% <sup>6</sup>
V	ICP SFMS	0.005, 0.03, 0.05 <sup>4</sup>	µg/L	18% <sup>6</sup>
Cu	ICP SFMS	0.1, 0.2, 0.5 <sup>4</sup>	µg/L	14% <sup>6</sup>
Ni	ICP SFMS	0.05, 0.2, 0.5 <sup>4</sup>	µg/L	16% <sup>6</sup>
P	ICP SFMS	1, 5, 40 <sup>4</sup>	µg/L	16% <sup>6</sup>
As	ICP SFMS	0.01 (520 mS/m)	µg/L	59% <sup>6</sup>

Component	Method <sup>1</sup>	Reporting limits (RL), detection limits (DL) or range <sup>2</sup>	Unit	Measurement uncertainty <sup>3</sup>
La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu	ICP SFMS	0.005, 0.02, 0.05 <sup>4</sup>	µg/L	20%, 20%, 25% <sup>6</sup>
Sc, In, Th	ICP SFMS	0.05, 0.2, 0.5 <sup>4</sup>	µg/L	25% <sup>6</sup>
Rb, Zr, Sb, Cs	ICP SFMS	0.025, 0.1, 0.25 <sup>4</sup>	µg/L	15%, 20%, 20% <sup>5</sup> , 25% <sup>6</sup>
Tl	ICP SFMS	0.025, 0.1, 0.25 <sup>4</sup>	µg/L	14% <sup>5,6</sup>
Y, Hf	ICP SFMS	0.005, 0.02, 0.05 <sup>4</sup>	µg/L	15%, 20%, 20% <sup>5</sup> , 25% <sup>6</sup>
U	ICP SFMS	0.001, 0.005, 0.01 <sup>4</sup>	µg/L	14%, 16% <sup>5</sup> , 19%, 18%, 21% <sup>6</sup>
DOC	UV oxidation, IR Carbon analyser	0.5	mg/L	8%
TOC	UV oxidation, IR Carbon analyser	0.5	mg/L	10%
δ <sup>2</sup> H	MS	2	‰ SMOW <sup>8</sup>	0.9 (one standard dev.)
δ <sup>18</sup> O	MS	0.1	‰ SMOW <sup>8</sup>	0.1 (one standard dev.)
<sup>3</sup> H	LSC	0.8	TU <sup>9</sup>	0.8 TU
δ <sup>37</sup> Cl	ICP MS	0.2	‰ SMOC <sup>10</sup>	0.2 <sup>17</sup>
δ <sup>13</sup> C	A (MS)	–	‰ PDB <sup>11</sup>	0.3 <sup>17</sup>
pmC ( <sup>14</sup> C)	A (MS)	–	pmC <sup>12</sup>	0.4 <sup>17</sup>
δ <sup>34</sup> S	MS	0.2	‰ CDT <sup>13</sup>	0.4 (one standard dev.)
<sup>87</sup> Sr/ <sup>86</sup> Sr	TIMS	–	No unit (ratio) <sup>14</sup>	0.00002
<sup>10</sup> B/ <sup>11</sup> B	ICP SFMS	–	No unit (ratio) <sup>10</sup>	–
<sup>234</sup> U, <sup>235</sup> U, <sup>238</sup> U, <sup>232</sup> Th, <sup>230</sup> Th	Alfa spectr.	0.0001	Bq/L <sup>15</sup>	≤5% (Counting statistics uncertainty)
<sup>222</sup> Rn, <sup>226</sup> Ra	LSC	0.015	Bq/L	≤5% (Counting statistics uncertainty)

- Many elements may be determined by more than one ICP technique depending on concentration range. The most relevant technique and measurement uncertainty for the concentrations normally encountered in groundwater are presented. In cases where two techniques were frequently used, both are displayed.
- Reporting limits (RL), generally 10×standard deviation, if nothing else is stated. Measured values below RL or DL are stored as negative values in SICADA (i.e. –RL value and –DL value).
- Measurement uncertainty reported by the laboratory, generally as ± percent of measured value in question at 95% confidence interval.
- Reporting limits at electrical cond. 520 mS/m, 1440 mS/m and 3,810 mS/m respectively.
- Measurement uncertainty at concentrations 100×RL.
- Measurement uncertainty at concentrations 10×RL.
- Determined only in surface waters. PON, POP and POC refers to Particulate Organic Nitrogen, Phosphorous and Carbon, respectively.
- Per mille deviation<sup>16</sup> from SMOW (Standard Mean Oceanic Water).
- TU=Tritium Units, where one TU corresponds to a tritium/hydrogen ratio of 10<sup>-18</sup> (1 Bq/L Tritium=8.45 TU).
- Per mille deviation<sup>16</sup> from SMOC (Standard Mean Oceanic Chloride).
- Per mille deviation<sup>16</sup> from PDB (the standard PeeDee Belemnite).
- The following relation is valid between pmC (percent modern carbon) and Carbon-14 age:  

$$\text{pmC} = 100 \times e^{((1.950 - y - 1.03t)/8.274)}$$
where y=the year of the C-14 measurement and t=C-14 age.



13. Per mille deviation<sup>16</sup> from CDT (the standard Canyon Diablo Troilite).
14. Isotope ratio without unit.
15. The following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232: 1 ppm U=12.4 Bq/kg<sup>238</sup>U, 1 ppm Th=3.93 Bq/kg<sup>232</sup>Th.
16. Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:  
 $\delta^i = 1,000 \times (K_{\text{sample}} - K_{\text{standard}}) / K_{\text{standard}}$ , where K= the isotope ratio and <sup>i</sup>I =<sup>2</sup>H, <sup>18</sup>O, <sup>37</sup>Cl, <sup>13</sup>C or <sup>34</sup>S etc.
17. SKB estimation from duplicate analyses by the contracted laboratory.

## Appendix 2

### Archive Samples

SKB no.	Date	Main components	B10 env. met, I-lant. trace.	Nutr.	DOC	TOC	Deut O18	Sr87	Trit.	Cl-37	C13 pmC	S34	U Th	Archive 250ml (no)	Archive 100ml (no)	Archive 5,000ml (no)
11808	070411													2	2	1
11921	070613													2	2	1
11922	070613	1	1	1	1	1	1	1	1	1	2	1	1	2	2	1
11922	070613													2	2	1
15010	070724													2	1	1
15011	070724	1	1	1	1	1	1	1	1	1	2	1	1	2	2	1
15011	070724													2	2	1
11801	070402													2	2	1
11802	070402	1	1	1	1	1	1	1	1	1	2	1	1	2	2	1
11802	070402													2	2	1
11569	061205													2	2	
11574	061205													2	2	
11598	061221													2	2	
11604	070108													2	2	
11605	070108													2	2	

## Compilation of water analysis data

Table A3-1. Water Composition, KLX11A.

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> <sup>-</sup> mg/L	Cl <sup>-</sup> mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	SO <sub>4</sub> -S mg/L	Br <sup>-</sup> mg/l	F <sup>-</sup> mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fe(II) mg/L	Mn mg/L	Li mg/L	Sr mg/L
KLX11A	516.50	519.50	11807	2007-04-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	11808	2007-04-11	-0.42	147	3.40	28.7	4.5	218	145	21.4	7.91	0.650	3.88	8.62	0.117	0.112	0.100	0.0997	0.018	0.270
KLX11A	516.50	519.50	15001	2007-07-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15002	2007-07-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15003	2007-07-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15004	2007-07-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15005	2007-07-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15006	2007-07-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15007	2007-07-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15011	2007-07-24	-	-	-	-	-	247	105	5.74	-	0.505	4.30	-	-	0.055	0.052	-	-	-
KLX11A	516.50	519.50	15010	2007-07-24	0.08	124	3.18	31.6	4.7	248	105	5.66	2.85	0.520	4.31	8.61	0.0657	0.053	0.054	0.102	0.017	0.250
KLX11A	579.00	584.00	11799	2007-03-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	579.00	584.00	11800	2007-03-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	579.00	584.00	11802	2007-04-02	-	-	-	-	-	256	35.2	5.46	-	<0.2	3.09	-	-	0.251	0.242	-	-	-
KLX11A	579.00	584.00	11801	2007-04-02	-0.22	85.5	2.73	26.5	4.2	256	35.1	5.48	2.53	<0.2	3.03	8.78	0.198	0.261	0.253	0.155	0.013	0.221
KLX11A	598.00	599.00	11839	2007-05-02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11840	2007-05-04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11841	2007-05-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11916	2007-06-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11919	2007-06-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11921	2007-06-13	-0.64	656	1.75	81.8	1.7	42.6	1040	130	47.1	5.88	4.00	6.42	0.0228	0.033	0.022	0.0186	0.061	1.35
KLX11A	598.00	599.00	11922	2007-06-13	-	-	-	-	-	42.6	1040	127	-	5.98	3.85	-	-	0.020	0.013	-	-	-

- = Not analysed

x = Not analysed due to analytical problems

< "value" = result less than detection limit

ChargeBal % = Rel. charge balance error %

SICADA: p\_water\_chemistry

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Γ <sup>-</sup> mg/L	pH	DOC mg/L	TOC mg/L	HS <sup>-</sup> mg/L	Drill water %	ElCond mS/m	NH <sub>4</sub> -N mg/L	NO <sub>2</sub> -N mg/L	NO <sub>3</sub> -N mg/L	NO <sub>2</sub> -N+NO <sub>3</sub> -N mg/L	PO <sub>4</sub> -P mg/L	P mg/L	Density g/mL
KLX11A	516.50	519.50	11807	2007-04-10	-	-	-	-	-	3.60	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	11808	2007-04-11	0.010	8.37	5.1	-	x	4.56	88.3	0.0275	<0.0002	0.0002	0.0003	0.0053	0.0065	-
KLX11A	516.50	519.50	15001	2007-07-17	-	-	-	-	-	0.59	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15002	2007-07-18	-	-	-	-	-	0.65	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15003	2007-07-19	-	-	-	-	-	0.89	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15004	2007-07-20	-	-	-	-	-	1.20	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15005	2007-07-21	-	-	-	-	-	1.66	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15006	2007-07-22	-	-	-	-	-	1.93	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15007	2007-07-23	-	-	-	-	-	2.24	-	-	-	-	-	-	-	-
KLX11A	516.50	519.50	15011	2007-07-24	-	8.30	-	-	1.46	2.74	75.8	0.0076	-	-	-	-	-	-
KLX11A	516.50	519.50	15010	2007-07-24	0.012	8.31	9.6	9.6	1.46	2.69	75.3	0.0077	0.0003	<0.0003	0.0005	0.0052	0.0135	0.9973
KLX11A	579.00	584.00	11799	2007-03-30	-	-	-	-	-	1.53	-	-	-	-	-	-	-	-
KLX11A	579.00	584.00	11800	2007-03-28	-	-	-	-	-	3.78	-	-	-	-	-	-	-	-
KLX11A	579.00	584.00	11802	2007-04-02	-	8.00	-	-	0.384	1.32	54.0	0.0166	-	-	-	-	-	0.9976
KLX11A	579.00	584.00	11801	2007-04-02	0.008	7.99	7.5	7.6	0.511	1.34	54.2	0.0173	0.0002	<0.0003	<0.0003	0.0021	0.0017	0.9971
KLX11A	598.00	599.00	11839	2007-05-02	-	-	-	-	-	6.13	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11840	2007-05-04	-	-	-	-	-	7.34	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11841	2007-05-07	-	-	-	-	-	6.93	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11916	2007-06-11	-	-	-	-	-	6.70	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11919	2007-06-12	-	-	-	-	-	6.30	-	-	-	-	-	-	-	-
KLX11A	598.00	599.00	11921	2007-06-13	0.047	8.54	2.3	2.3	0.403	6.35	363	0.0150	<0.0002	0.0016	0.0017	<0.0005	0.454	0.9984
KLX11A	598.00	599.00	11922	2007-06-13	-	8.54	-	-	0.432	6.27	363	0.0205	-	-	-	-	-	-

-- = Not analysed

x = Not analysed due to analytical problems

< "value" = result less than detection limit

ChargeBal % = Rel. charge balance error %

SICADA: p\_water\_chemistry

**Table A3-2. Water Composition, KLX19A.**

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> <sup>-</sup> mg/L	Cl <sup>-</sup> mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	SO <sub>4</sub> -S mg/L	Br <sup>-</sup> mg/l	F <sup>-</sup> mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fe(II) mg/L	Mn mg/L	Li mg/L	Sr mg/L
KLX19A	495.00	515.00	11584	2006-12-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11586	2006-12-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11589	2006-12-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11590	2006-12-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11592	2006-12-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11594	2006-12-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11595	2006-12-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11597	2006-12-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11598	2006-12-21	-	-	-	-	-	32.8	1910	113	-	10.1	2.54	-	-	0.077	0.069	-	-	-
KLX19A	495.00	515.00	11600	2006-12-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11601	2007-01-03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11602	2007-01-04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11604	2007-01-08	-4.49	933	5.26	151.0	8.8	38.5	1780	114	40.6	9.60	3.08	6.14	0.063	0.068	0.057	0.0710	0.080	2.58
KLX19A	495.00	515.00	11605	2007-01-08	-	-	-	-	-	38.7	1780	115	-	9.12	2.84	-	-	0.066	0.059	-	-	-
KLX19A	764.00	769.00	11498	2006-11-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11499	2006-11-29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11565	2006-11-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11566	2006-12-01	-	-	-	-	-	19.0	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11568	2006-12-04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11569	2006-12-05	-2.07	1580	6.66	628.0	2.5	55.3	3520	196	69.7	23.1	2.27	7.54	0.146	0.205	0.102	0.0364	0.125	10.9
KLX19A	764.00	769.00	11574	2006-12-05	-	-	-	-	-	55.1	3540	194	-	23.4	2.19	-	-	0.152	0.143	-	-	-

- = Not analysed  
x = Not analysed due to analytical problems  
< "value" = result less than detection limit  
ChargeBal % = Rel. charge balance error %  
SICADA: p\_water\_chemistry

Idcode	Secup m	Seclow m	Sample no.	Γ <sup>-</sup> mg/L	pH	DOC mg/L	TOC mg/L	HS <sup>-</sup> mg/L	Drill water %	ElCond mS/m	NH <sub>4</sub> -N mg/L	NO <sub>2</sub> -N mg/L	NO <sub>3</sub> -N mg/L	NO <sub>2</sub> -N+NO <sub>3</sub> -N mg/L	PO <sub>4</sub> -P mg/L	P mg/L	Density g/mL
KLX19A	495.00	515.00	11584	-	-	-	-	-	35.5	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11586	-	-	-	-	-	31.0	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11589	-	-	-	-	-	28.0	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11590	-	-	-	-	-	26.0	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11592	-	-	-	-	-	24.2	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11594	-	-	-	-	-	20.3	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11595	-	-	-	-	-	19.0	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11597	-	-	-	-	-	17.2	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11598	-	8.19	-	-	<0.006	17.0	612	0.0299	-	-	-	-	-	0.9995
KLX19A	495.00	515.00	11600	-	-	-	-	-	16.5	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11601	-	-	-	-	-	9.15	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11602	-	-	-	-	-	8.90	-	-	-	-	-	-	-	-
KLX19A	495.00	515.00	11604	0.066	8.23	1.5	1.5	0.003	7.50	566	0.0267	0.0002	0.0011	0.0013	0.0017	<0.005	0.9993
KLX19A	495.00	515.00	11605	-	8.25	-	-	0.004	7.51	564	0.0198	-	-	-	-	-	0.9993
KLX19A	764.00	769.00	11498	-	-	-	-	-	1.69	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11499	-	-	-	-	-	26.3	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11565	-	-	-	-	-	15.5	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11566	-	7.99	-	-	-	14.8	1150	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11568	-	-	-	-	-	8.07	-	-	-	-	-	-	-	-
KLX19A	764.00	769.00	11569	0.158	7.97	3.1	2.7	0.003	7.04	1080	0.0096	<0.0002	<0.0003	<0.0003	0.0006	<0.005	1.0016
KLX19A	764.00	769.00	11574	-	7.96	-	-	0.006	7.01	1070	-	-	-	-	-	-	1.0015

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- = Not analysed  
x = Not analysed due to analytical problems  
< "value" = result less than detection limit  
ChargeBal % = Rel. charge balance error %  
SICADA: p\_water\_chemistry

**Table A3-3. Trace Elements.**

Idcode	Secup m	Seclow m	Sample no.	Sampling date	U µg/L	Th µg/L	As µg/L	Sc µg/L	Cd µg/L	Hg µg/L	V µg/L	Rb µg/L	Y µg/L	Zr µg/L	In µg/L	Cs µg/L	Ba µg/L
KLX11A	516.50	519.50	15010	2007-07-24	0.749	<0.02	<0.1	<0.05	<0.003	<0.002	0.537	5.12	0.193	0.102	<0.05	0.160	109
KLX11A	579.00	584.00	11801	2007-04-02	0.855	0.0511	0.133	<0.05	0.0111	<0.002	0.758	4.19	0.493	4.91	<0.05	0.111	29.8
KLX11A	598.00	599.00	11921	2007-06-13	0.0243	<0.02	<0.1	<0.05	0.0479	<0.002	0.0777	4.60	0.0433	<0.03	<0.05	0.467	89.0
KLX19A	495.00	515.00	11604	2007-01-08	0.0353	<0.2	<0.5	<0.4	<0.02	<0.002	0.138	13.7	0.0394	<0.1	<0.2	0.406	85.0
KLX19A	764.00	769.00	11569	2006-12-05	0.0827	<0.2	<10	<0.4	<0.02	<0.002	0.210	21.2	0.105	<0.1	<0.2	1.16	65.6

< "value" = result less than detection limit

SICADA: p\_water\_chemistry

Idcode	Secup m	Seclow m	Sample no.	Sampling date	La μg/L	Hf μg/L	Tl μg/L	Ce μg/L	Pr μg/L	Nd μg/L	Sm μg/L	Eu μg/L	Gd μg/L	Tb μg/L	Dy μg/L	Ho μg/L	Er μg/L	Tm μg/L
KLX11A	516.50	519.50	15010	2007-07-24	0.154	<0.005	<0.005	0.245	0.0305	0.119	0.0207	<0.005	0.0215	<0.005	0.0201	0.0052	0.0175	<0.005
KLX11A	579.00	584.00	11801	2007-04-02	0.267	1.09	<0.005	0.451	0.0566	0.263	0.0533	0.0062	0.0654	0.0083	0.0558	0.0129	0.0423	0.0058
KLX11A	598.00	599.00	11921	2007-06-13	0.0404	<0.005	<0.005	0.0472	<0.005	0.0192	<0.005	0.0091	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
KLX19A	495.00	515.00	11604	2007-01-08	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
KLX19A	764.00	769.00	11569	2006-12-05	0.115	<0.02	<0.03	0.117	<0.02	0.0595	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

< "value" = result less than detection limit  
SICADA: p\_water\_chemistry



Idcode	Secup m	Seclow m	Sample no.	Sampling date	Yb μg/L	Lu μg/L
KLX11A	516.50	519.50	15010	2007-07-24	0.0184	<0.005
KLX11A	579.00	584.00	11801	2007-04-02	0.0407	0.0067
KLX11A	598.00	599.00	11921	2007-06-13	<0.005	<0.005
KLX19A	495.00	515.00	11604	2007-01-08	<0.02	<0.02
KLX19A	764.00	769.00	11569	2006-12-05	<0.02	<0.02

< "value" = result less than detection limit  
SICADA: p\_water\_chemistry

**Table A3-4. Isotopes I (H-, O-, B-, S-, C-, Sr- and Cl-isotopes).**

Idcode	Secup m	Seclow m	Sample no	Sampling date	$\delta^2\text{H}$ dev SMOW	$^3\text{H}$ TU	$\delta^{18}\text{O}$ dev SMOW	$^{10}\text{B}/^{11}\text{B}$ no unit	$\delta^{34}\text{S}$ dev CDT	$\delta^{13}\text{C}$ dev PDB	$^{87}\text{Sr}/^{86}\text{Sr}$ no unit	$^{14}\text{C}$ pmC	$\delta^{37}\text{Cl}$ dev SMOC
KLX11A	516.50	519.50	15010	2007-07-24	-82.1	5.87	-11.3	0.2372	28.7	-17.30	0.717120	64.7	0.77
KLX11A	579.00	584.00	11801	2007-04-02	-78.0	5.90	-10.8	0.2384	27.0	-17.30	0.717131	65.7	0.19
KLX11A	598.00	599.00	11921	2007-06-13	-107.6	<0.8	-14.2	0.2340	14.0	-19.80	0.715140	49.6	0.41
KLX19A	495.00	515.00	11604	2007-01-08	-102.4	1.80	-13.8	0.2447	22.6	-15.10	0.715456	29.9	0.21
KLX19A	764.00	769.00	11569	2006-12-05	-96.4	1.50	-12.7	0.2389	18.6	-15.85	0.715706	46.8	0.74

< "value" = result less than detection limit

SICADA: p\_water\_chemistry

**Table A3-5. Isotopes II (U- Th, Ra- and Rn-isotopes).**

Idcode	Secup m	Seclow m	Sample no.	Sampling date	<sup>238</sup> U mBq/L	<sup>235</sup> U mBq/L	<sup>234</sup> U mBq/L	<sup>232</sup> Th mBq/L	<sup>230</sup> Th mBq/L	<sup>226</sup> Ra Bq/L	<sup>222</sup> Rn	<sup>222</sup> Rn
											Bq/L	Bq/L
											At time of analysis	At time of collection
KLX11A	516.50	519.50	15011	2007-07-24						<0.015	0.517	14.1
KLX11A	516.50	519.50	15010	2007-07-24	13.4	0.74	14.5	0.27	0.81	<0.015	0.533	14.2
KLX11A	579.00	584.00	11802	2007-04-02	14.0	0.70	15.0	0.20	0.40	<0.015	14.3	24.5
KLX11A	579.00	584.00	11801	2007-04-02	11.0	0.50	14.0	0.30	1.60	<0.015	13.8	22.7
KLX11A	598.00	599.00	11921	2007-06-13	0.30	0.15	0.60	0.14	0.26	0.015	15.9	27.3
KLX11A	598.00	599.00	11922	2007-06-13						<0.015	15.0	26.4
KLX19A	495.00	515.00	11604	2007-01-08	0.60	0.07	2.10	0.11	0.09	0.036	35.0	144
KLX19A	495.00	515.00	11605	2007-01-08						0.015	28.1	119
KLX19A	764.00	769.00	11569	2006-12-05	0.50	0.03	1.10	0.35	0.78	0.437	39.0	76.0
KLX19A	764.00	769.00	11574	2006-12-05						0.363	42.0	85.0

- = Not analysed

\* = Sample stored in freezer/refrigerator

< "value" = result less than detection limit

SICADA: p\_water\_chemistry