P-08-55

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Hydrochemical monitoring of near surface groundwater, surface waters and precipitation

Results from sampling in the Forsmark area, August 2007–December 2007

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ISSN 1651-4416
SKB P-08-55

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Keywords: Shallow groundwater, Chemical analyses, Soil monitoring well, Stand pipe, BAT-filter tip, BAT-sampler, Private wells, Geosphere-biosphere interface zone, Water composition, Major constituents, Trace elements, Nutrient salts, Isotopes, Drinking water quality, Surface water, Lakes, Streams, Shallow bays, Sampling, Chemical analysis, Precipitation, *AP PF 400-07-040, AP PF 400-07-044, AP PF 400-07-039.*

Abstract

The site investigations in Forsmark were completed in June 2007 and a monitoring phase commenced, which among others includes regular hydrochemical sampling and analyses. The present report documents the hydrochemical monitoring of near surface groundwaters, surface waters and precipitation in Forsmark during the sampling period August 2007 to December 2007.

Near surface groundwaters were sampled and analysed twice during the reported time period from a total of ten shallow soil monitoring wells and three wells equipped with BAT filter tips. Seven of the objects belong to the GBIZ programme (Geosphere Biosphere Interface Zone), which is a special program designed to investigate the properties of this potentially important zone. Sampling from the three private wells included in the hydrochemical monitoring programme was conducted at one occasion in October 2007.

Sampling of surface waters (streams, lakes and a shallow sea bay) was performed once per month from eleven regular sampling locations together with an extra sampling object (the outlet of Lake Biotestsjön). The latter was sampled for tritium analyses in order to check eventual tritium contamination from the nuclear power plant.

Each precipitation sample was collected during a period of two months, resulting in three samples during the reported second half of 2007. Besides sampling at the Forsmark site, a last sample from a reference site (Sjötorp) was collected for tritium analyses during July–August. Sjötorp is located in the middle of Sweden far from any nuclear power plant and this sampling was conducted to allow comparison with Forsmark data and check possible effects from the adjacent nuclear power plant on the tritium content in the Forsmark samples.

The results from the near surface groundwater and surface water monitoring includes field measurements of ORP (Oxidising-Reducing Potential), pH, dissolved oxygen, electrical conductivity, and water temperature, as well as chemical analyses of major constituents, nutrient salts, carbon species, trace metals and isotopes. For surface waters the field measurements also include salinity, depth, barometric pressure, turbidity, chlorophyll, light penetration and PAR (Photosynthetic Active Radiation). Reported precipitation data include pH, electrical conductivity, major constituents, aluminium and isotopes.

Generally, the new data confirm the knowledge and conclusions presented in previous reports from earlier investigation periods. Surface waters in lakes and streams in the Forsmark area are well buffered with high alkalinity, high pH and high calcium concentrations. Furthermore, surface waters affected by brackish sea water show high sodium chloride concentrations. No observations of elevated tritium content in samples collected close to the cooling water outlet from the nuclear power plant (Lake Biotestsjön) were found during the reported time period. Elevated tritium contents have been observed at a few occasions reported earlier.

Sammanfattning

Den egentliga platsundersökningen i Forsmark avslutades i juni 2007 och övergick i en moniteringsfas som inkluderar bland annat regelbunden hydrokemisk provtagning och analys. Föreliggande rapport dokumenterar hydrokemisk övervakning av ytnära grundvatten, ytvatten och nederbörd i Forsmarksområdet under provtagningsperioden augusti 2007 till december 2007.

Den rapporterade tidsperioden omfattar två provtagningstillfällen för ytnära grundvatten i totalt tio jordborrhål samt tre BAT – rör. Sju av objekten tillhör GBIZ-programmet (Geosphere Biosphere Interface Zone), vilket är ett speciellt program för att undersöka denna potentiellt viktiga zon. Provtagning av privata brunnar som också är inkluderat i det ordinarie moniteringsprogrammet skedde vid ett tillfälle i oktober 2007.

Provtagning av ytvatten utfördes en gång per månad från elva ordinarie provpunkter (bäckar, sjöar och en grund havsvik) samt från en extra provpunkt (utloppet av Biotestsjön). Provtagningen från den extra provpunkten skedde för att kontrollera eventuell kontaminering av tritium från kärnkraftverket.

Nederbörd samlades upp under två månader och sammanförs till ett prov, vilket resulterade i tre prov under den rapporterade andra halvan av 2007. Förutom provtagningen i Forsmarksområdet har ett sista prov tagits ut vid en referenspunkt (Sjötorp) under juli till augusti. Sjötorp ligger mitt i Sverige och långt från något kärnkraftverk och provet togs för jämförelse med Forsmarksdata för att undersöka eventuell påverkan från näraliggande kärnkraftreaktorer på tritiumhalterna i Forsmarksproverna.

De erhållna resultaten från ytnära grundvatten och ytvatten omfattar fältmätningar av ORP (Oxidising-Reducing Potential), pH, löst syre, elektrisk konduktivitet och vattentemperatur samt kemiska analyser av huvudkomponenter, närsalter, kolföreningar, spårelement och isotoper. För ytvatten mäts även salinitet, djup, barometertryck, turbiditet, klorofyll, siktdjup och PAR (Photosynthetic Active Radiation). Rapporterade nederbördsdata omfattar pH, elektrisk konduktivitet, huvudkomponenter, aluminium och isotoper.

De nya data som erhållits under perioden augusti till december 2007 bekräftar i huvudsak de erfarenheter och slutsatser som presenterats i föregående rapporter från tidigare undersökningsperioder. Ytvatten i sjöar och bäckar i Forsmarksområdet är väl buffrade med hög alkalinitet, högt pH och höga kalciumkoncentrationer. Vissa ytvatten har påverkats av bräckt havsvatten och visar höga salthalter. Inga förhöjda tritiumhalter har observerats nära kylvatten-utsläppet från kärnkraftverket (Biotestsjön) under denna provtagningsperiod. Förhöjda tritiumhalter har observerats vid några tillfällen som rapporterats tidigare.

Contents

1 Introduction

The investigation phase of the site investigations in Forsmark was finished in June 2007 /1/ and a much less extensive monitoring phase commenced. This document reports the performance and results from sampling and analyses of near surface groundwater, surface waters and precipitation within the hydrochemical monitoring programme /2/ during the period July–December 2007. The report treats the three water categories in separate chapters with corresponding Appendix numbers. Earlier investigation periods are presented in /3/, /4/ and /5/ (shallow groundwater), /6/, /7/, /8/, /9/ and /10/ (surface waters) as well as /11/ and /12/ (precipitation).

The sampling objects for near surface groundwaters include shallow soil monitoring wells, wells/pipes equipped with BAT-filter tips (special sampling system described in Section 2.3.3) and private wells. Besides the regular sampling locations, the report includes also sampling locations belonging to the GBIZ programme (Geosphere Biosphere Interface Zone). The different sampling objects are presented in Table 2-1 and a map showing their location is displayed in Figure 2-1. The surface water sampling includes lake waters, stream waters and one sea water location (shallow bay) in the Forsmark area. The sampling locations are presented in Figure 3-1. Precipitation was collected at the sampler location PFM002564. The position of the samplers is shown in Figure 4-1.

The controlling documents for the activity are listed in Table 1-1. Both activity plans and method descriptions are SKB's internal controlling documents. Original data from the reported activitities are stored in the primary database Sicada. Data are traceable in Sicada by the activity plan numbers (AP PF 400-07-040, AP PF 400-07-044 and AP PF 400-07-039). Only data in databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the database may be revised, if needed. However, such revision of the database will not necessarily result in a revision of this report, although the normal procedureis that major data revisions entail also a revision of the P-report. Minor revisions are normally presented as supplements, available at www.skb.se.

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

Activity plans	Number	Version
Hydrokemiskt övervakningsprogram för ytnära grundvatten (jordrör) augusti 2007 till december 2007.	AP PF 400-07-040	1.0
Undersökningar i Forsmarksområdet: Långtidsövervakning av ytvatten. Augusti–december 2007.	AP PF 400-07-044	1.0
Hydrokemiskt övervakningsprogram för nederbörd.	AP PF 400-07-039	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för ytvattenprovtagningar vid platsunder sökningar.	SKB MB 900.004	2.0
Mätsystembeskrivning för YSI. Multiparametersystem för vattenmätningar.	SKB MD 910.003	1.0
Metodbeskrivning för provtagning och analys av nederbörd.	SKB MD 423.003	2.0
Provtagning och Provhantering.	SKB MD 452.001	4.0

Water sampling and measurement procedures are also described in SKB PIR-04-09 "Metodik för provtagning av ekologiska parametrar i hav", SKB PIR-04-06, "Metodik för provtagning av ekologiska parametrar i sjöar och vattendrag", and SKB PIR-04-12, "Översikt över provhanterings- och analysrutiner för vattenprov" (SKB internal documents).

Figure 1-1. *On the way to wintertime sampling of water stand pipes in Lake Bolundsfjärden.*

2 Near surface groundwaters

2.1 Objectives and scope

Near surface groundwaters were investigated in order to increase the understanding of processes that occur at the interface between the geosphere and the near surface ecosystem. Furthermore, sampling and analyses of groundwaters from shallow monitoring wells may be used to identify discharge areas.

The completed two years long extensive sampling campaign in order to characterise near surface groundwaters in different types of environments within the candidate area /3/ was followed by a reduced monitoring programme which started in July 2005. The site investigation of the candidate area was concluded in June 2007, but the monitoring programme continues /2/ in order to monitor the water composition and obtain long time series of data. During the reported period, objects belonging to both the monitoring programme and the GBIZ programme were sampled twice, once in August and once in October. Ten monitoring wells (stand pipes) and three pipes equipped with BAT-filter tips were sampled, all in the prioritised north-western part of the candidate area. Furthermore, three private wells were monitored in order to check the drinking water quality (sampled once a year).

The sampling of private wells is mainly performed in order to obtain initial information on the drinking water quality and to monitor eventual changes in the water composition at least until the location of the repository for spent nuclear fuel is decided. The private well data are of limited use for the chemical modelling as they are more or less affected by human activities. However, some additive information on the salinity distribution in the candidate area may be gained.

The activity included water sampling for chemical analysis as well as direct measure-ments in the field of parameters such as ORP (Oxidising Reducing Potential), pH, dissolved oxygen, electrical conductivity and water temperature. The analytical protocol included major constituents, nutrient salts, silica, carbon species as well as isotopes and trace metals, see Tables 2-2 and 2-3.

2.2 Sampling objects

The monitoring programme for near surface groundwater includes five stand pipes and one BAT-pipe. Besides these regular objects, five additional stand-pipes and two BAT-filter tips belonging to the GBIZ programme were sampled. The GBIZ programme includes seven BAT-filter tips, but only two could be sampled (see Section 2.4.4. Nonconformities). The wells/pipes are of the following types:

1. Single stand pipes made of HDPE located close to drill sites, see Appendix 2 for design, Figure A2-1.
2. Double and single stand pipes made of HDPE, see Appendix 2 for design, Figure A2-2. Double pipes meaning, one of the pipes is equipped with a permanently installed sensor for logging the groundwater level and the other pipe is intended for hydrochemical sampling.
3. Stand pipes installed in the sediment below the water layer in Lake Bolundsfjärden (Figure 1-1). These pipes are made of ordinary, non-stainless iron; see Appendix 2, Figure A2-3 for design. Stand pipes located in till below fen are of the same type.
4. Pipes equipped with BAT-filter tips as described in Section 2.3.3.

For pipe types 1) to 3), the positions of the filter/screen part, and for type 4) the position of the BAT-filter tip, correspond to the upper and lower section limits (Secup and Seclow) in the Sicada database. The section limits refer to the top of the stand pipe (Top Of Casing or TOC).

The sampled monitoring wells and their stand pipe types are listed in Table 2-1. The locations of the different sampling objects, including the three regularly sampled private wells, are displayed in Figure 2-1. Total depths and filter/screen depths, as well as coordinates for the different stand pipes, are given in Appendix 2 together with outlines of the different pipe types.

Table 2-1. List of sampling objects, type of sampling and type of object.

Idcode	Comments on sampled object	Type[a]
SFM0001	Stand pipe connected to drill site	A
SFM0023	Stand pipe in sediment below water surface (steel pipe)	C
SFM0032	Double-pipe for chemistry	B
SFM0037	Double-pipe for chemistry	B
SFM0049	Double-pipe for chemistry	B
SFM0051	BAT-system, drill site 1	D
SFM0081[c]	Stand pipe in sediment below water surface (steel pipe)	C
SFM0083[c]	BAT-system	D
SFM0084[c]	Stand pipe in till below fen (steel pipe)	C
SFM0086[b]	BAT-system	D
SFM0087[c]	Stand pipe in sand below fen	C
SFM0089[b]	BAT-system	D
SFM0091[c]	Stand pipe in till below fen (steel pipe)	C
SFM0093[b]	BAT-system	D
SFM0095[c]	Stand pipe for chemistry	B
SFM0097[b]	BAT-system	D
SFM0100[b]	BAT-system	D
SFM0102[c]	BAT-system	D
PFM000001	Drinking water well	
PFM000009	Drinking water well	
PFM006382	Drinking water well	

[a] Code used to distinguish between different types of soil monitoring wells/stand pipes included in the monitoring programme, see Table 5-1and Appendix 2.

[b] Included in the GBIZ promme but not sampled, see Section 2.4.4. Non-conformities.

[c] Included in GBIZ programme.

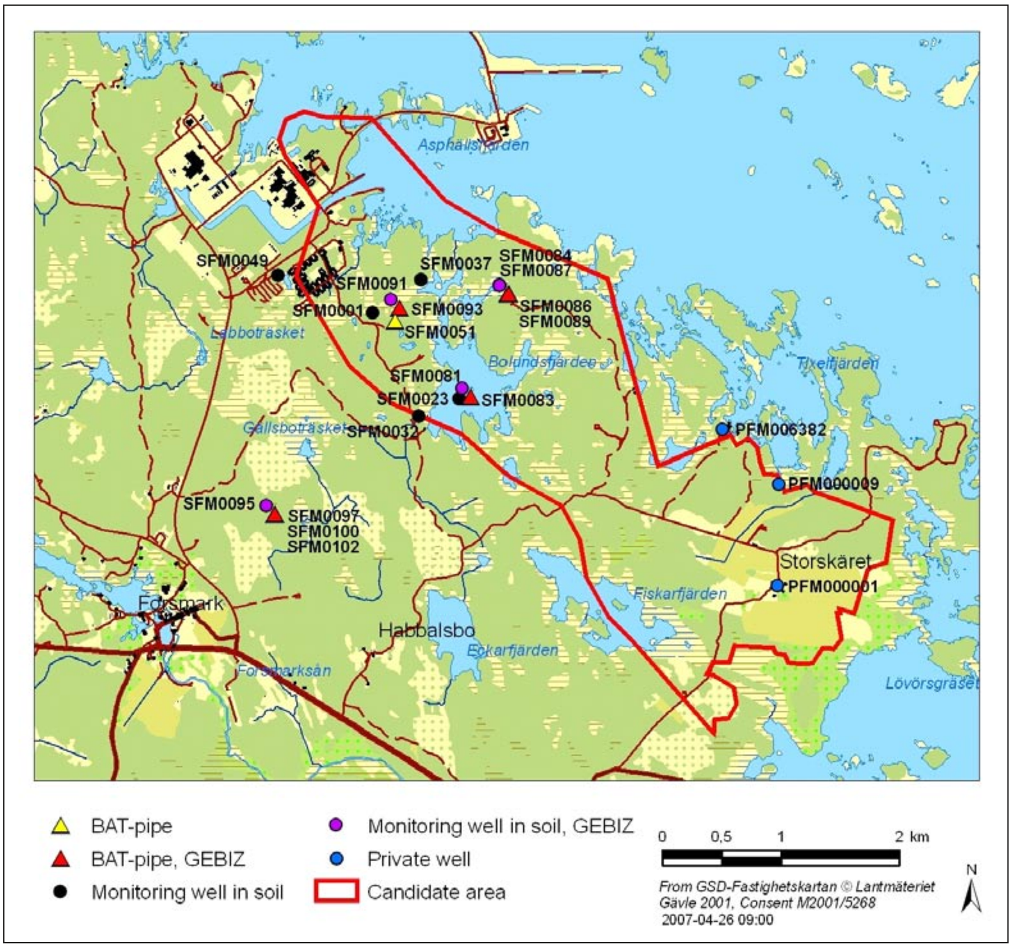


Figure 2-1. Location of sampling objects in the monitoring programme for near surface groundwaters, including different types of soil monitoring wells and private wells. Not all objects were sampled due to low water yield, cf. Table 2-1.

2.3 Equipment

2.3.1 Sampling equipment

Groundwater samples from the shallow soil monitoring stand pipes were collected using four online pumping setups, each one consisting of a submersible electrical pump (12 V, Awimex) connected to a 10–20 m long polyamide-tube (Tecalan) of 8 mm diameter. The inner metal part of the pumps was coated with Teflon. Manually operated electrical regulators (powered by 12 V, 7 Ah cells) were used to adjust the water flow to a maximum of 1 litre/minute. Disposable filters (Millipore, 0.40 µm, ∅ = 22 mm) were fitted directly to the tube from the pump when collecting the sample portions for trace metals and ferrous iron. Separate sampling set-ups were used for the stand pipes made from ordinary iron, i.e. for pipes SFM0023, 81, 84 and 91, in order to minimize the risk to contaminate other samples.

2.3.2 Multi-parameter sondes

Field measurements were performed with two multi-parameter sondes (YSI 6600 EDS and YSI 600 QS). A terminal (YSI 650 MDS) is connected to each sonde through a cable for logging data, Figure 2-2. Calibration of the sondes was conducted according to the measurement system description SKB MD 910.003, see Table 1-1. The measured parameters in near surface groundwaters included pH, water temperature, oxygen, ORP (redox potential) as well as electrical conductivity and were conducted in a simple flow-through cell constructed from a plastic bottle. The upper part of the bottle fitted tightly to the sonde and had a narrow outlet for the circulating water.

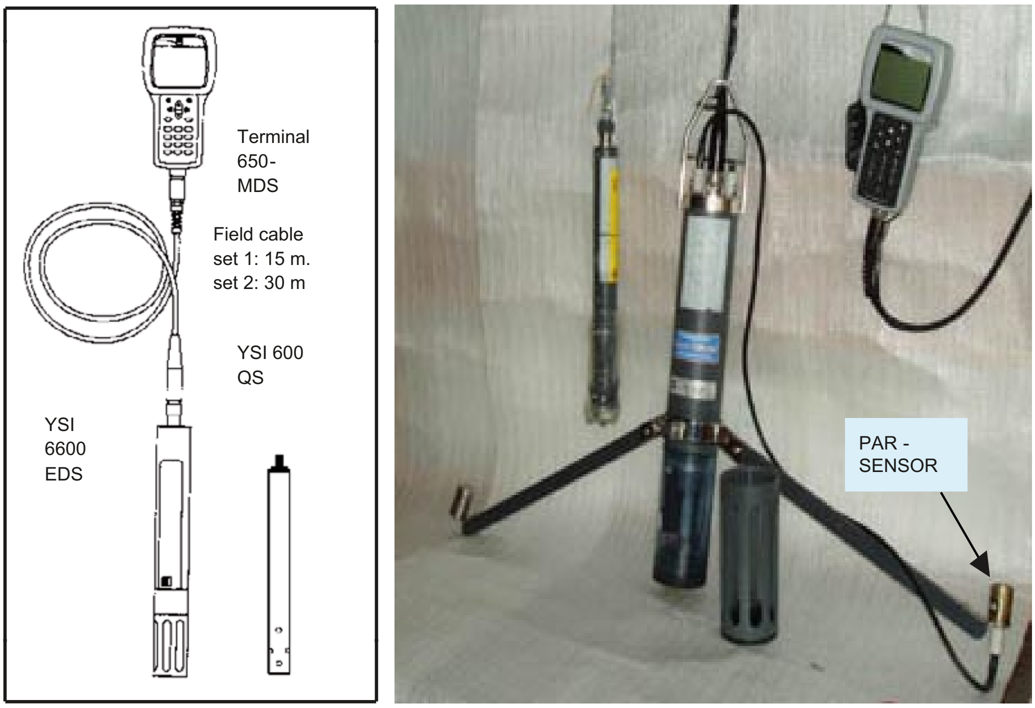


Figure 2-2. *Details of the measurement sondes.*

2.3.3 BAT-equipment

Water sampling in the stand pipes equipped with BAT-filter tips was performed by a GeoN BAT-type groundwater sampler. The sampler carries an evacuated and hermetically closed glass sample container (500 mL) and a vial. The vial is fitted with a cap with a rubber disc, similar to the disc in the filter tip. The needle of the sampler, which is “double-ended”, penetrates through the two rubber discs, thus connecting the filter tip to the vial cap, see Figure 2-3. Due to the vacuum in the vial, water will be sucked from the aquifer, through the filter and the needle, into the vial.

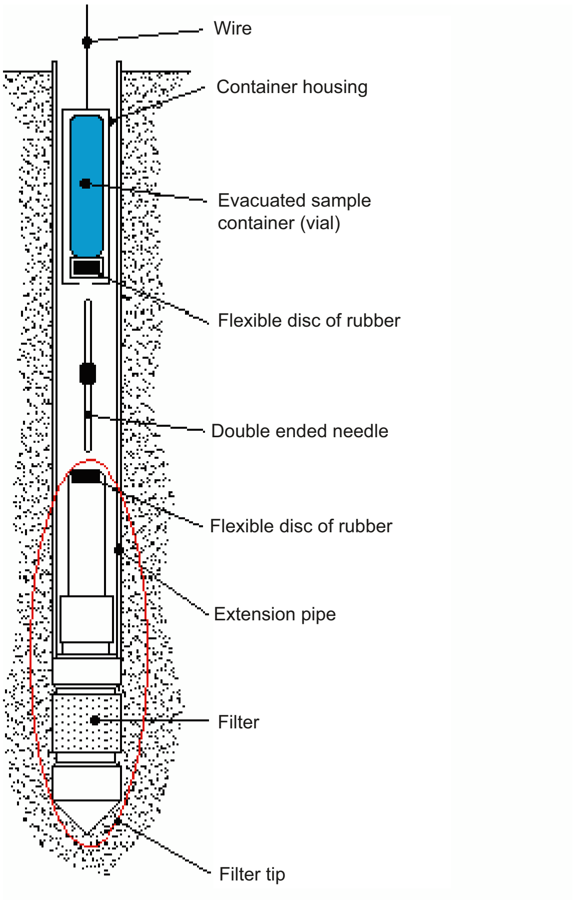


Figure 2-3. *Outline of BAT-sampler system and the BAT-filter tip.*

2.4 Performance

2.4.1 Sampling programme

2.4.1.1 Sampling scheme

The sampling scheme for the sampling programme is given in Table 2-2. The bottles filled and analysis performed according to the different SKB chemical classes (class 3 and class 5, respectively) are summarised in Table 2-3. Omitted sampling objects and the reasons for deviation from the sampling scheme are given in Table 2-4.

Table 2-2. Sampling scheme August 2007–December 2007.

Year	Month	Week	Sampling object*	Sampling and analysis class & options
2007	August	32	Shallow monitoring wells, A, B	SKB class 5
			Shallow monitoring wells, C	SKB class 3 & isotopes
			BAT-pipes, D	SKB class 5
2007	October	41	Shallow monitoring wells, A, B	SKB class 3 & isotopes
			Shallow monitoring wells, C	SKB class 3 & isotopes
			Private wells	Drinking water
			BAT-pipe, D (drill site 1)	SKB class 5
			BAT-pipes, D	SKB class 3 & isotopes

* The sampling object types A, B, C and D are defined in Table 2-1.

Table 2-3. Sample portions/bottles and preparation procedures for class 3 and class 5 /1/.

Class 3 and 5: 🟦

Class 5 🟪

Bottle volume (mL)	Number of bottles	SKB Label	Components	Preparation	Filling instructions
100	1	Green, Br/I	Br, I*		Fill up
100	1	Green, D/O	Deuterium ^{2}H, ^{18}O	–	–
250	2	Green, Anj. /Green	Anions (Br, SO$_4$, Cl, F), Alkalinity, pH, Electric conductivity	–	Fill up
500	1	Green, ^{3}H	Tritium, ^{3}H	–	Fill up from bottom, Flow over x 3
100	1	Green, N/P	Tot-N, Tot-P	–	Fill 80% of the volume
25	1	Green, T	TOC	–	Fill 80% of the volume
250	2	Green, arkiv	For the archives	–	Fill 80% of the volume
25	4	Green	Ammonia, NOx, Silicate	Filtering with syringe/0.4 µm filter	
25	2	Green, D	DOC, DIC	Filtering with syringe/0.4 µm filter	Fill 80% of the volume
125	1	Red	Major constituents; cations^{1a} and S, Si. Environmental metals^{1b}, trace metals ^{1c}, B10/B11*	Acid addition (1 mL conc. HNO$_3$) Filtering with syringe/0.4 µm	Fill up
100	2	Red, arkiv	For the archives	Acid addition (1 mL conc. HNO$_3$) Filtering with syringe/0.4 µm	Fill 80% of the volume
250	1	Red	Fe(II)/Fetot	Acid addition (2.5 mL conc. HCl) Filtering with 0.4 µm filter	Fill up
1,000	1	^{34}S	^{34}S**		Fill up
1,000	1	U/Th	U/Th-isotoper**		Fill up
1,000	1	Ra/Rn	^{226}Ra, ^{222}Rn **		Fill up
100	2	C-iso	^{13}C, pmC**		Fill up
100	1	^{37}Cl	^{37}Cl**		Fill up
100	1	^{87}Sr	^{87}Sr/^{86}Sr**		Fill up
Winkler bottles 125	2	HS	HS^{-}*	0.5 ml ZnAc + 0.5 ml NaOH and mix	Flow over x 3

1a. Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr.

1b. Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn (only class 5 samples).

1c. 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 (only class 5 samples).

* only class 5 samples.

** analyses once a year.

Table 2-4. List of collected samples during the period August 2007 to December 2007 (X = collected sample).

Id code	Name or location	Week/Year 32/07	 41/07	Sum (X)
Sonde				
YSI 600 QS		X	X	2
Soil wells				
SFM 0001	Drill site 1	X	X	2
SFM 0023	Bolundsfjärden	X	X	2
SFM 0032	SV-Bolundsfjärden	X	X	2
SFM 0037	N-Bolundsfjärden	X	X	2
SFM 0049	Bostadsområdet	X	X	2
SFM 0081	Bolundsfjärden	X	X	2
SFM 0084	Puttan	X	X	2
SFM 0087	Puttan	X	X	2
SFM 0091	–	X	X	2
SFM 0095	–	X	X	2
BAT pipes				
SFM0051	Drill site 1	X	X	2
SFM0083	Bolundsfjärden	X	X	2
SFM0102	–	X	X	2
Private wells				
PFM 000001	F3:3		X	1
PFM 000009	F3:34		X	1
PFM 006382	F3:38.Tixelfjärden		X	1
Sum (X)		**13**	**16**	**29**

2.4.1.2 Presampling preparations

Prior to the sampling campaign, sample bottles were cleaned, labelled and packed in insulated boxes/bags according to established routines (SKB MD 452.001, see Table 1-1). Acid additions were made in advance in the bottles intended for trace metal analyses. The different pumping setups were washed and rinsed with deionised water before use and all parts of equipment were kept well protected in plastic bags or in tight containers. The disposable filters (Millipore, 0.4 µm, Ø = 22 mm) were rinsed with deionised water and placed in plastic bags to prevent contamination. Calibration of the sonde was performed according to the measurement system description SKB MD 910.003.

2.4.1.3 Sampling and measurements

The groundwater sampling procedure as described below was generally applied in groundwater pipes and wells, except for the BAT-pipes and the drilled private wells where the water was collected directly from the tap.

First, the groundwater level in the pipe was established by sounding and the water volume of the pipe was calculated. The pump with its tubing was lowered carefully in order to prevent dirt from entering the pipe. The water inlet of the submersible pump (Awimex) was lowered to the filter/screen section of the pipe or just above. Pumping was then performed at a maximum flow rate of one litre per minute. The pumped water was disposed of at least 10 m away from the sampling object were it infiltrated back into the ground. The pumping phases were as follows:

- *Exchange of water volume in pipe and tubes:* The water volume was exchanged three to five times (depending on the exchange/recovery time) prior to the actual sampling.
- *Sampling:* All sample bottles, except the ones with added acid, were rinsed three times with pumped water. Disposable filters were used for filtration of water portions for trace metals, Fe(+II) and DOC/DIC. The filters were fitted directly on the outlet tube from the pump. Each filter was rinsed with sample water (approx. 30 mL) before the sample portion/filtrate was collected. The bottles containing acid were the last ones to be filled in order to prevent acid contamination in the other sample portions. Disposable plastic gloves were used during the sampling. The samples were transported back from the field in insulated bags.
- *Field measurement:* A flow-through cell was connected to the pumping setup and measurements were performed with the sonde (YSI 600 QS). The results were recorded when the electrodes and sensors in the flow-through cell showed stable values (minimum 10 minutes). A judgement of the plausibility of the values was made in the field and accepted values were noted in the field protocol.

2.4.1.4 Sampling performance using BAT-system

Sampling of the BAT-filter tip pipes followed the sampling scheme for the regular shallow soil pipes with a few days delay. The approximate time to fill one 500 mL container was 15 minutes, 5 minutes and approximately 3–4 hours for SFM0051, SFM0102 and SFM0083, respectively.

A total of four sample containers were filled from each BAT-pipe in order to obtain enough water for the analyses. In order to exchange the water volume in the BAT-pipes before sampling, the first sample container filled was not used for the analyses. The use of the sample volumes and the analyses performed are listed in Table 2-5 (SFM0051) and Table 2-6 (SFM0083 and SFM0102).

Table 2-5. Sample containers and analyses, SFM0051.

Sample container no.	Analyses and determinations			Total volume
1	Chloride, bromide, fluoride and sulphate by IC. (200 mL + 50 mL)	Alkalinity titr, pH and EC. (150 mL)	δ^2H, δ^{18}O (100 mL)	500 mL
2	Tritium (500 mL)			Approx. 500 mL
3	Fe (+II), (Fe(tot) (200 mL)	Major constituents, trace elements, ^{10}B/^{11}B by ICP AES/MS (125 mL)	5 mL of HCl was added to the container prior to sampling.	325 mL

Table 2-6. Sample containers and analyses, SFM0083 and SFM0102.

Sample container no.	Analyses and determinations			Total volume
1	Major constituents, trace elements, ^{10}B/^{11}B by ICP AES/MS (100 mL)	Chloride, bromide, fluoride and sulphate by IC. (200 mL)	Alkalinity titr, pH and EC. (100 mL)	400 mL
2	Tritium (500 mL)			Approx. 500 mL
3	N/P-tot, NO$_x$, NH$_4$–N, Silicat, PO$_4$–P TOC, DOC (250 mL)	δ^2H, δ^{18}O (100 mL)	Br/I (100 mL)	Approx. 450 mL

2.4.2 Sample handling and analyses

Measurements/analyses of $pH_{(lab)}$, electrical $conductivity_{(lab)}$ and alkalinity as well as spectrophotometric analyses of total iron and ferrous iron (Fe+II) were conducted immediately at the site in the mobile field laboratory. An overview of sample treatment and analytical routines for major constituents, minor anions, trace metals and isotopes is given in Appendix 1. The routines are applicable independent of sampling method or type of sampling object.

2.4.3 Data handling

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

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

All analytical results were stored in the Sicada database. The applied hierarchy path "Hydrochemistry/Hydrochemical investigation/Analyses/Water in the database" contains two types of tables, raw data tables and primary data tables (final data tables).

Data on *basic water analyses* are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water_composition". The evaluation is based on:

- Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
- Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable (in surface waters ± 10%).

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

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

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

An overview of the data management is given in Figure 2-4.

2.4.4 Nonconformities

No nonconformities occurred in the regular monitoring programme for near surface groundwaters during the time period concerned. The same goes for the additional five stand-pipes belonging to the GBIZ programme.

However, water sampling has not been successful from some of the stand pipes equipped with BAT filter tips in the GBIZ programme. Only two (SFM0102 and SFM0083) out of seven BAT-pipes showed sufficient water yield to allow sampling.

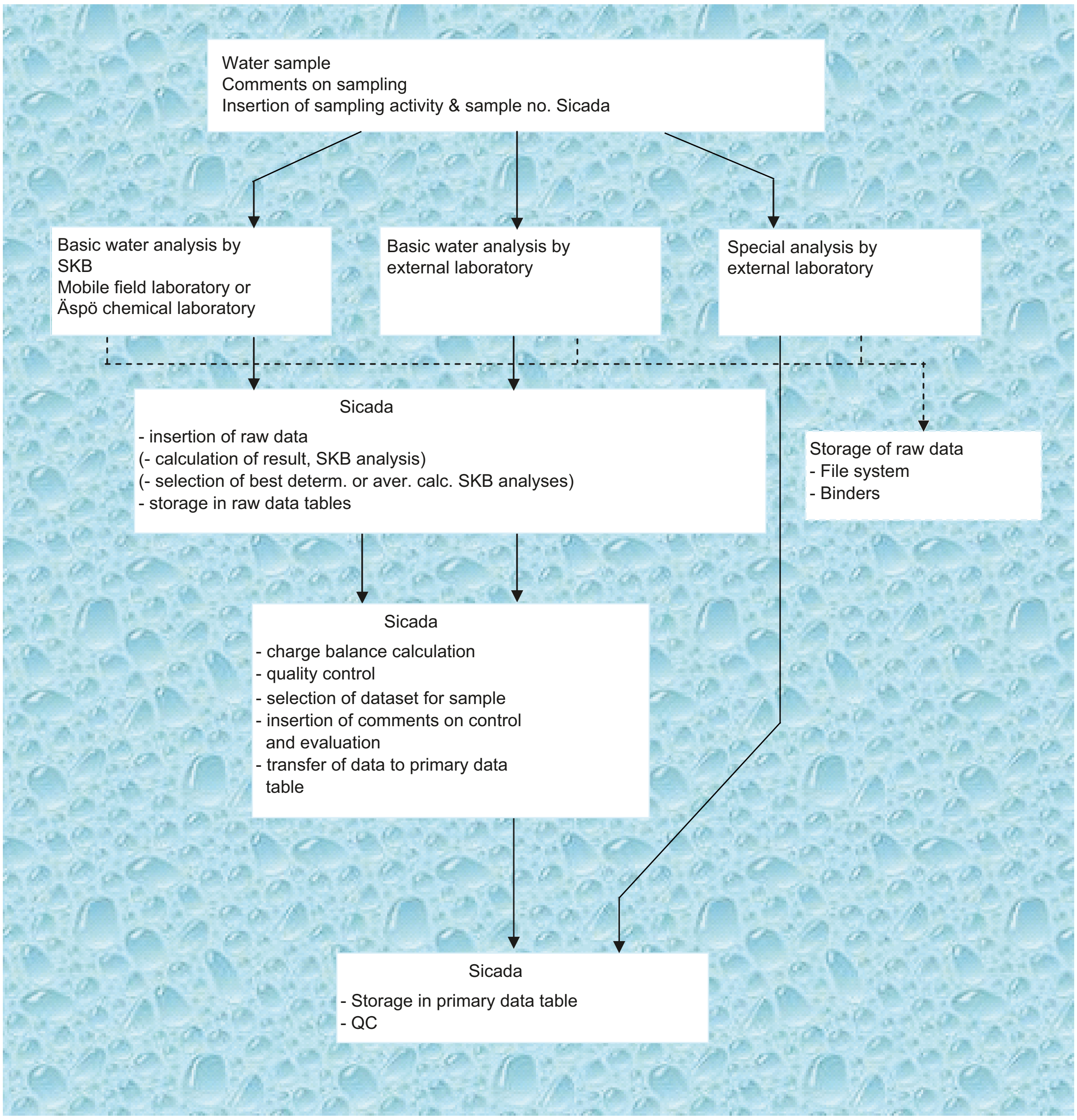


Figure 2-4. *Overview of data management for hydrochemical data.*

2.5 Results

2.5.1 Field measurements

The results from the field measurements on pH, electrical conductivity, dissolved oxygen, water temperature and redox potential (ORP) are presented in Appendix 2.

2.5.1.1 pH-measurement

Field measurements of pH are plotted against the corresponding laboratory values in Figure 2-5. Some deviation is reasonable considering the change of water temperature, and the time delay prior to the laboratory measurement. However, in a few cases, the disagreement seems to be greater than expected.

2.5.1.2 Electrical conductivity

Electrical conductivity field values are plotted versus corresponding laboratory values in Figure 2-6 and show good agreement.

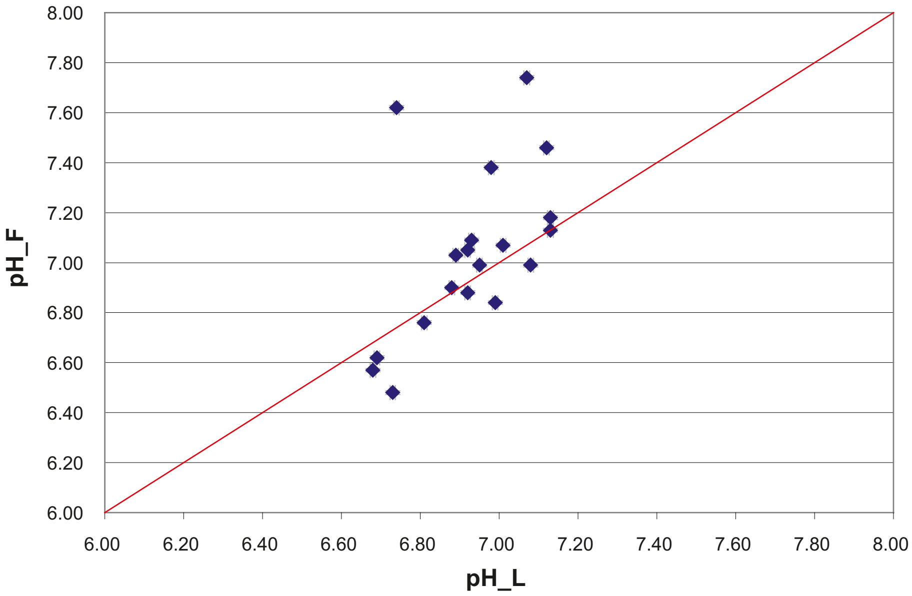


Figure 2-5. *Field-pH (pH_F) values versus laboratory-pH (pH_L) values. Field-pH and laboratory-pH values are measured at prevailing water temperature and at 25°C respectively. The measurement uncertainty (Appendix 1) is shown as hardly visible error bars.*

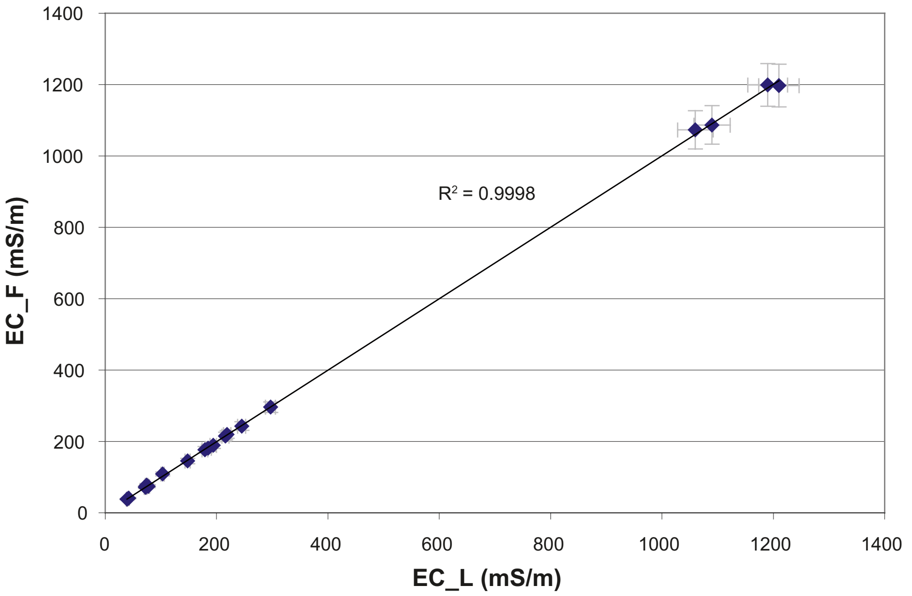


Figure 2-6. *Electrical conductivity (25°C). Field measurements (EC_F) versus laboratory values (EC_L). The measurement uncertainty (Appendix 1) is shown as error bars.*

2.5.1.3 Dissolved oxygen

The measurements of dissolved oxygen were checked in April 2005 by comparison to results from laboratory analyses /8/. This control showed that, generally, the field measurement values were somewhat higher, especially at oxygen concentrations below 4 mg/L. Field measurements of dissolved oxygen are presented in Appendix 2.

2.5.1.4 ORP-measurements and redox conditions

ORP-measurements (Oxidising-Reducing Potential) have been conducted using the multi-purpose measurement sonde. The recorded ORP-values (potential against Ag/AgCl reference electrode) should be used with great caution and merely be considered as an indication of the redox conditions in the waters. Measured ORP-values are presented in Appendix 2.

2.5.2 Water analyses

2.5.2.1 Basic components

The basic water analyses include the major constituents Na, K, Ca, Mg, Sr, S, SO_4^{2-}, Cl^-, Si and HCO_3^- as well as the minor constituents Fe, Li, Mn, Br, F, I and HS^-. Furthermore, batch measurements of pH and electrical conductivity are included. The basic water analysis data are compiled in Appendix 2. The charge balance errors give an indication of the quality and uncertainty of the analyses of major constituents. The errors exceed the acceptance limit ± 5% in a few cases. Duplicate analyses by a second laboratory or another method are conducted regularly for some of the analysed constituents as a further check of the reliability of the analyses.

The chloride concentrations are plotted against the corresponding electrical conductivity values in Figure 2-7 as a rough check and the data agree well with an assumed trend line. The bromide analyses are often uncertain. For example the detection limit of bromide by ion chromatography (< 0.2 mg/L) is often too high for fresh waters. Therefore, duplicate analyses by ICP (bromine) have been performed for most samples. Selected bromide/bromine values for each sample are plotted against the corresponding chloride concentrations in Figure 2-8 as a consistency check.

Sulphate by ion chromatography and sulphate calculated from total sulphur by ICP are compared in Figure 2-9 and most samples show a satisfactory agreement. However, several samples diverge, probably due to high sulphide concentrations. The total sulphur concentration determined by ICP increases disproportionately at high sulphide concentrations due to hydrogen sulphide gas entering the plasma. In the most obvious cases (Sample nos. 12530, 12834, 12865 and 12872) the ICP results are rejected in Sicada.

Total silicon concentrations by ICP, and SiO_4 as silicon concentrations (SiO_4–Si) by spectrophotometry, are compared in Figure 2-10. Here the values diverge, but somewhat higher total silicon concentrations may be expected since not all silicon in the water is in the form of SiO_4.

The iron concentrations determined by ICP-AES (total Fe) and by spectrophotometry (Fe(+II) and Fe-tot) are compared in Figure 2-11. In most cases, the total iron concentrations determined by ICP agree well with the results obtained by spectrophotometry.

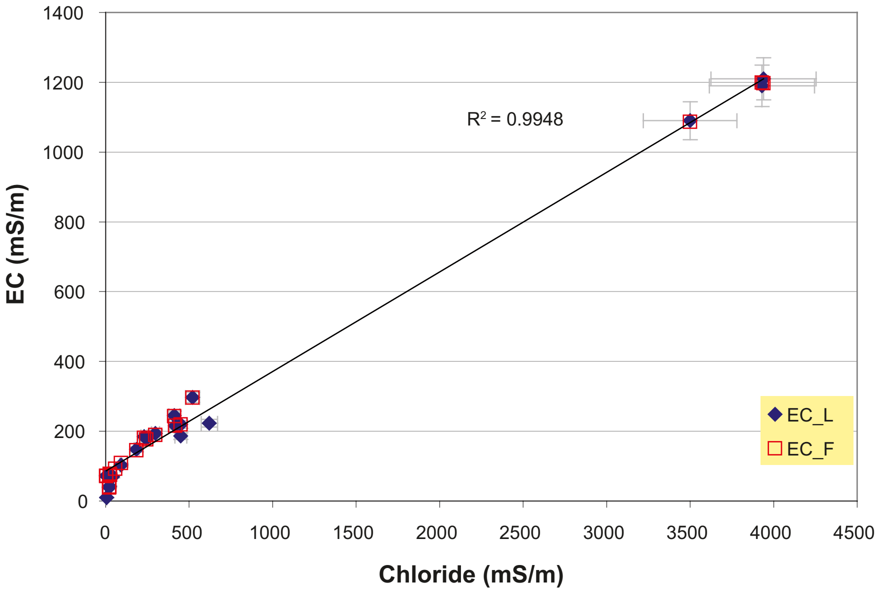


Figure 2-7. *Electrical conductivity (EC) values versus chloride concentrations. EC_L = Laboratory value, EC_F = Field value. The measurement uncertainty (Appendix 1) is shown as error bars.*

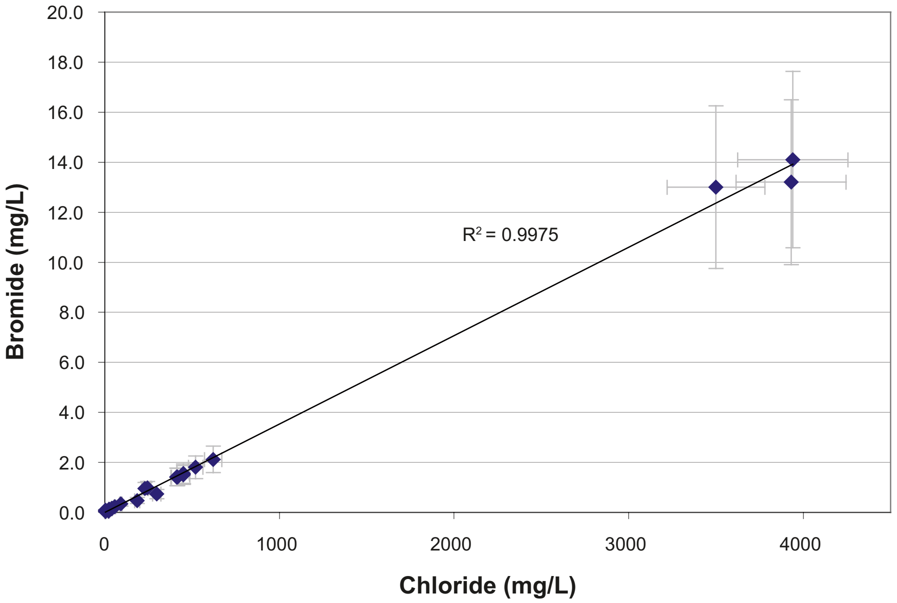


Figure 2-8. *Bromide concentrations versus chloride concentrations. The measurement uncertainty (Appendix 1) is shown as error bars.*

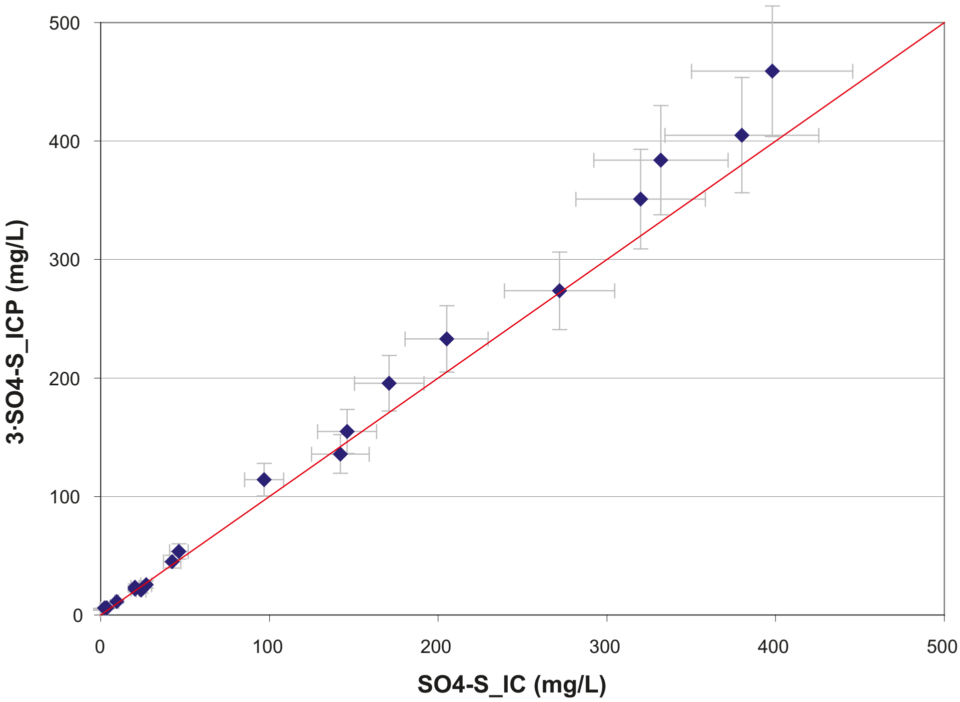


Figure 2-9. *Sulphate (SO_4 by IC) versus sulphate calculated from total sulphur (3·SO4_S) by ICP. The measurement uncertainty (Appendix 1) is shown as error bars.*

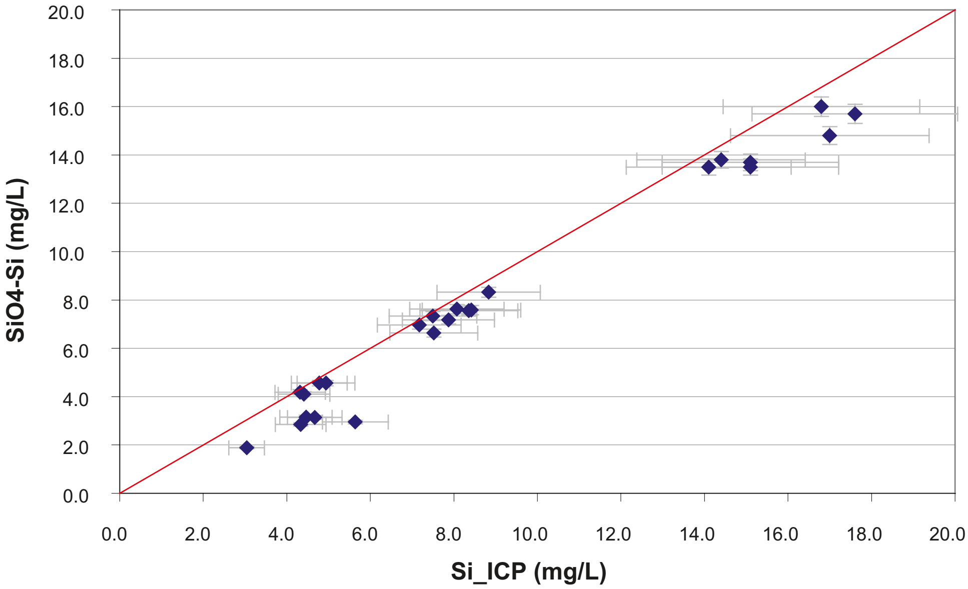


Figure 2-10. *SiO_4-Si determined by spectrophotometry versus total Si analysed by ICP. The measurement uncertainty (Appendix 1) is shown as error bars.*

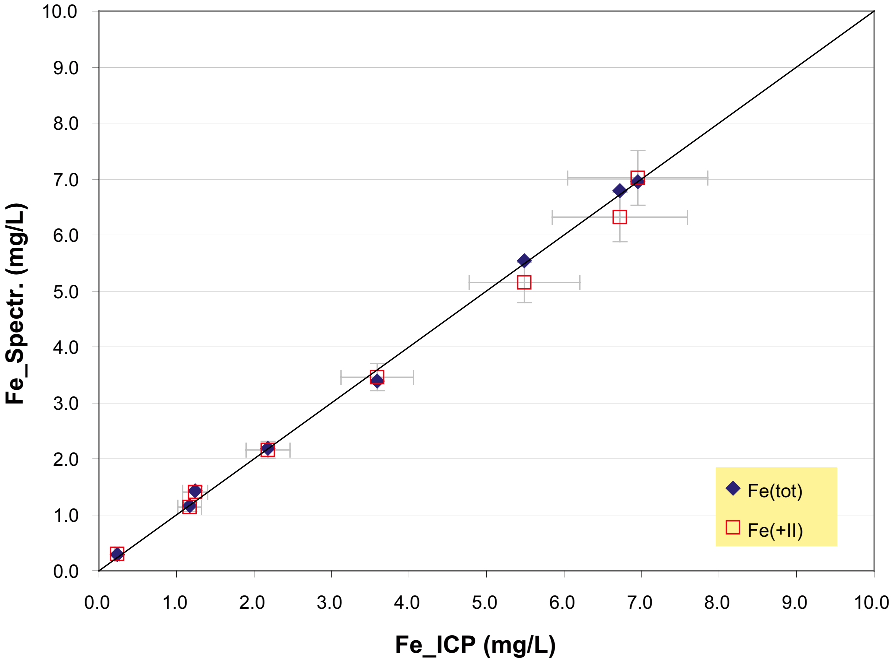


Figure 2-11. *Comparison of iron concentrations obtained by ICP and by spectrophotometry (Fetot and FeII). The measurement uncertainty (Appendix 1) is shown as error bars.*

2.5.2.2 Surface water supplements

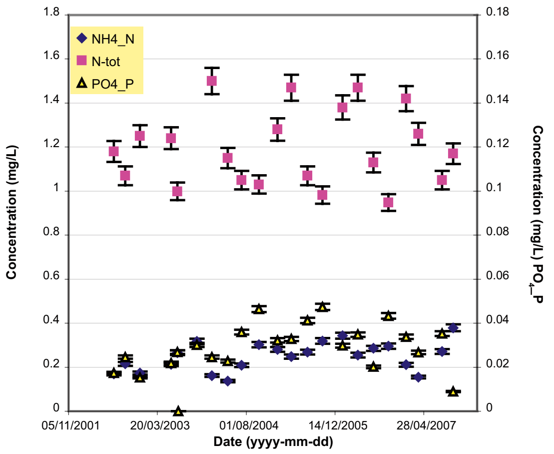
Shallow groundwater analysis includes the surface water supplements/options NH_4_N, NO_2_N, NO_3_N+NO_2_N, NO_3_N, tot-N, tot-P, PO_4_P, TOC, DOC and DIC. The analytical data are compiled in Appendix 2. The DIC values should be used with care and bicarbonate values (by alkalinity titration) are considered more reliable.

The concentrations of the different nitrogen, phosphorous and carbon compounds are expected to show seasonal variation depending on decomposition processes and varying redox conditions. However, this variation is more pronounced in surface waters than in the present shallow groundwaters. Figures 2-13 a to 2-13 e show the variations of total nitrogen, ammonium and phosphate in the sampled groundwaters from the five soil-pipes included in the long term monitoring programme. The figures show high concentrations of total nitrogen in the stand pipes SFM0032 and SFM0037 in October 2007 compared to previous measurements. It is difficult to explain these high concentrations, which are the highest ever recorded for these two pipes, but the continued monitoring will yield more information.

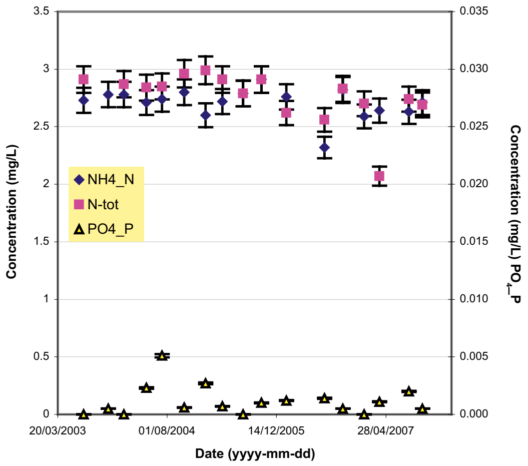
2.5.2.3 Drinking water quality (private wells)

Data on drinking water quality parameters/components for the investigated private wells are presented in Appendix 2.

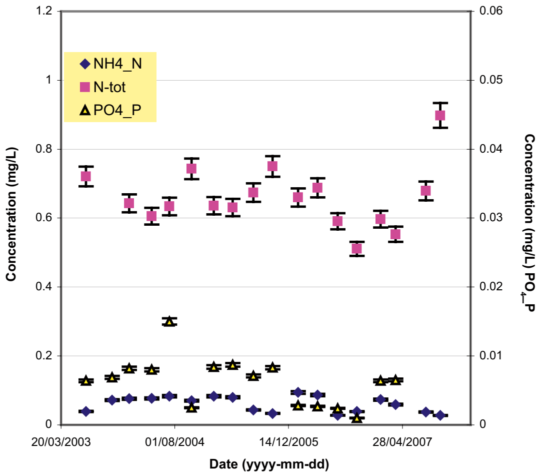
Figure 2-12. *Field measurements with the multi-parameter sonde in Lake Bolundsfjärden.*



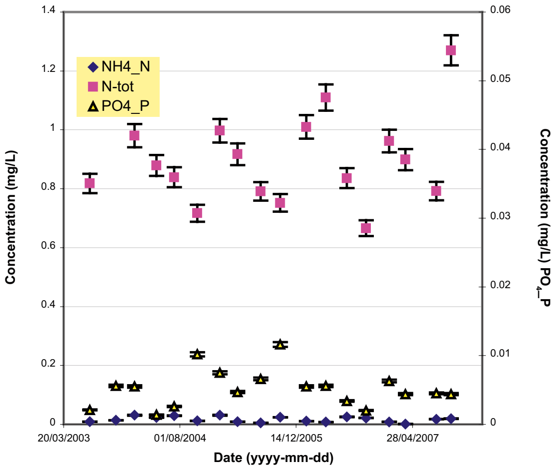
a) SFM0001



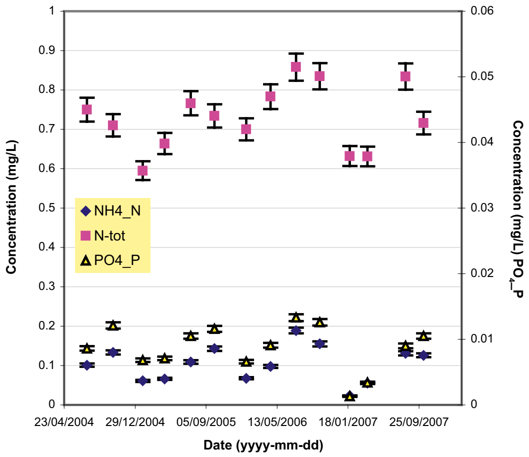
b) SFM0023



c) SFM0032



d) SFM0037



e) SFM0049

Figures 2-13 a to e. *Ammonium, total nitrogen and phosphate concentrations versus sampling date for groundwaters from the stand pipes included in the long-term monitoring programe. Note that phosphate concentrations refer to the secondary Y-axis.*

2.5.2.4 Trace metals

The analyses of trace and rare earth elements include Al, As, Sc, Cd, Cr, Cu, Co, Hg, Ni, Zn, Pb, V, U, Th , Rb, Y, Zr, Mo, In, Sb, Cs, Ba, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. The trace element data are compiled in Appendix 2.

These elements are generally present at low concentrations in the groundwater and the risk for contamination is high. Especially data on common metals such as Al, Cr, Cu, Co, Ni and Zn must be used with caution. Generally, the borehole data conform well but outliers exist.

2.5.2.5 Isotopes

Isotope determinations include the stable isotopes δD, $\delta^{18}O$ and $^{10}B/^{11}B$ as well as the radioactive isotope ^{3}H (TU). The isotope data are compiled in Appendix 2.

2.6 Summary and discussion

The chemical investigation routines for near surface groundwaters are well established after more than four years of field work, reporting and data administration and this year of the long-term monitoring programme has passed without any major nonconformities or surprises.

The statements/findings regarding the character of the near surface groundwaters remain unchanged. However, three out of 25 samples showed relative charge balance errors exceeding ± 5% (sample nos. 12833, 12530 and 12872). Furthermore, some sulphate concentrations are somewhat less certain as the ICP-results seem to be affected by high contents of sulphide and can not be used to verify the IC analyses.

The high concentrations of total nitrogen observed in the stand pipes SFM0032 and SFM0037 in October 2007 compared to previous measurements are difficult to explain but the continued monitoring will yield more information.

3 Surface waters

3.1 Objectives and scope

The ongoing surface water monitoring programme started in July 2004 and focuses on sampling locations in the prioritised northwestern part of the Forsmark candidate area /2, 13/. The main objectives are to create long-time series of data in order to obtain further information on natural variations and also to allow identification of eventual perturbation effects from the completed investigation activities. The sampling locations are presented in Figure 3-1.

The monitoring programme includes water sampling and sonde measurements in the different lake systems; Lake Bolundsfjärden, Lake Eckarfjärden and Lake Labboträsket. Measurements are being performed also in Lake Norra Bassängen in order to monitor salinity changes. One regular sampling location represents a shallow sea bay (Forslingens grund). Sampling of stream water is conducted at four localities (Kungsträsket, Bolundsskogen, Norr Eckarfjärden, Öster Gunnarsbo) and an electrical conductivity logger is installed in Lilleputt-sundet, also to monitor salinity changes. Furthermore, due to previously observed enhanced tritium contents in sea waters close to the nuclear power plant, samples for tritium analyses are collected each month close to the cooling water outlet in Lake Biotestsjön.

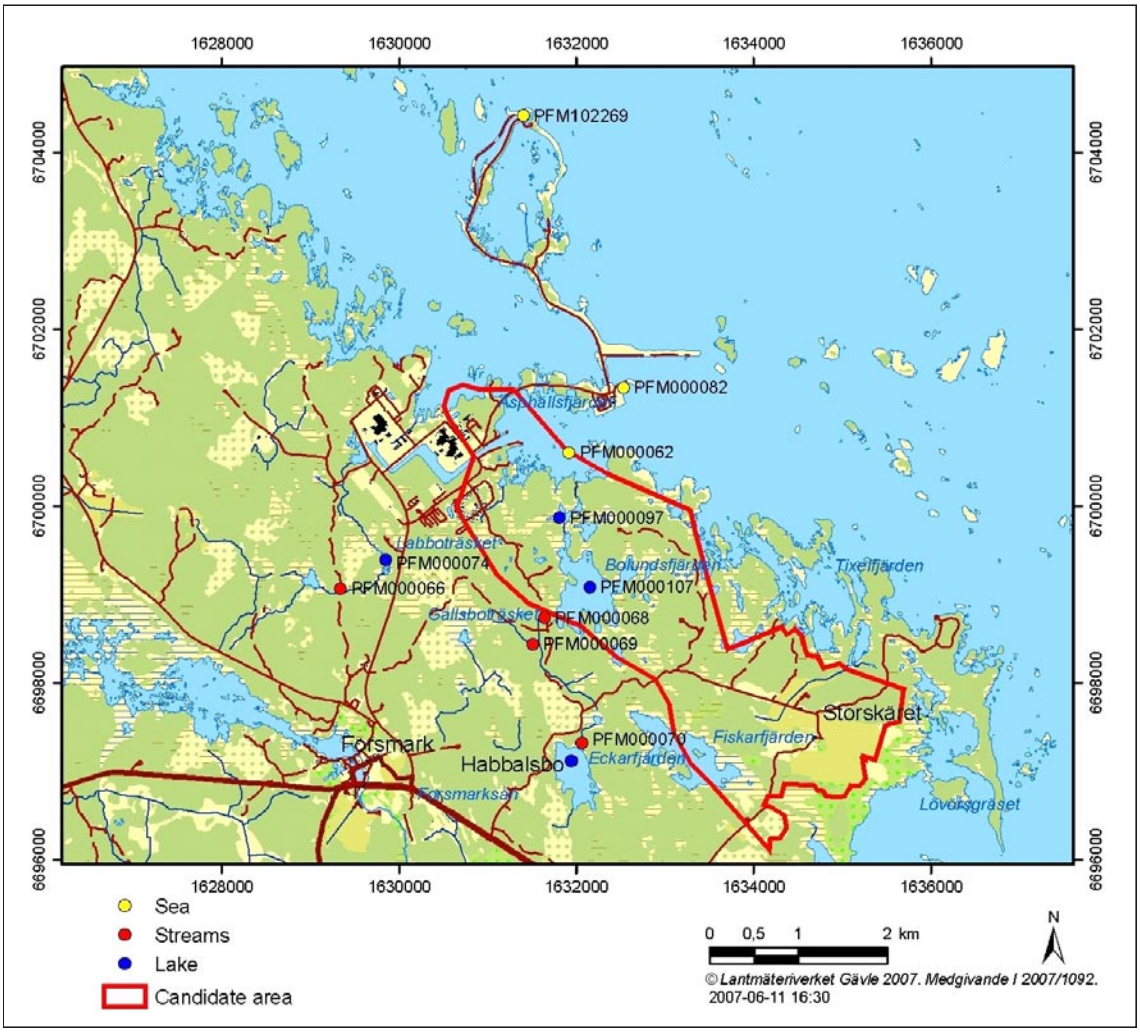


Figure 3-1. *Sampling locations within the monitoring programme. One location constitutes an alternative for a regular sampling position (see Table 3-1).*

Sampling for chemical analysis as well as direct measurements of physical and chemical parameters such as ORP (Oxidising-Reducing Potential), pH, dissolved oxygen, electrical conductivity, salinity, measurement depth, barometric pressure, turbidity, chlorophyll, light penetration, PAR (Photosynthetic Active Radiation) and water temperature were conducted at five occasions during the reported time period. The extent of the sampling varied at different occasions. Analyses of major constituents and surface water supplements (nutrient salts, chlorophyll etc) were conducted frequently (once a month) while extended analyses including also isotopes and trace elements were performed once per season, i.e. in August and October. Some special isotopes (δ^{37}Cl, δ^{13}C, ^{14}C (pmC), ^{87}Sr/^{86}Sr, δ^{34}S, U- and Th-isotopes as well as Ra- and Rn-isotopes) were determined only once, in August.

3.2 Sampling locations and sampling scheme

The monitoring programme includes four lakes, one shallow sea bay location and four streams. Furthermore, a location close to the outlet of cooling water from the nuclear power plant is sampled in order to investigate eventual tritium contamination.

The sampling locations are presented in Figure 3-1. Table 3-1 lists the location id-codes, coordinates and names together with clarifying comments. The sampling scheme for the period August 2007–December 2007 is given in Table 3-2.

Table 3-1. Sampling locations (Id-code, coordinates, name and comments).

Sampling locations	Coordinates (RT90 RHB70)	Name	Comments
Lakes			
PFM000074	16 29 854, 66 99 393	Labboträsket	
PFM000097*	16 31 814, 66 99 868	Norra bassängen	
PFM000107	16 32 065, 66 99 031	Bolundsfjärden	
PFM000117	16 31 946, 66 97 118	Eckarfjärden	
Shallow sea bays and deep sea location			
PFM000062	16 31 921, 67 00 605	SV Forslingens grund	
PFM000082	16 32 528, 67 01 336		Alternative to PFM00062
PFM102269	16 31 405, 67 04 412	Cooling water outlet, Lake Biotestsjön	Check of tritium contamination
Streams			
PFM000066	16 29 343, 66 99 064	Öster Gunnarsboträsket	
PFM000068	16 31 641, 66 98 735	Kungsträsket	
PFM000069	16 31 510, 66 98 440	Bolundsskogen	
PFM000070	16 32 061, 66 97 319	Norr Eckarfjärden	

* Only sonde measurements.

Table 3-2. Surface water sampling scheme from August 2007 to December 2007.

Year	Month	Week	Programme type*
2007	August	32	E+
2007	September	36	M
2007	October	41	E
2007	November	45	M
2007	December	49	M

* M = main programme (SKB class 3 including surface water supplements), E = extended programme (SKB class 5 including surface water supplements), E+ = extended programme with special isotopes (δ^{37}Cl, δ^{13}C, ^{14}C (pmC), ^{87}Sr/^{86}Sr, δ^{34}S, U- and Th-isotopes as well as Ra- and Rn-isotopes).

3.3 Equipment

3.3.1 Sampling equipment

Water samples were collected using an online pumping setup consisting of an electrical peristaltic pump system, PPS (ASF Thomas SR 10/100, powered by 12 VDC, 7 Ah cells), connected to 4–8 m long teflon-tubes (FEP 140) of 5 mm inner diameter. A manually operated regulator (ELFA, DCM 24-40 pwm) was used to adjust the water flow to a maximum of 1.3–2.9 litres/minute (depending on tube length, tube diameter and pumping level). The sampling equipment is presented in Figure 3-2.

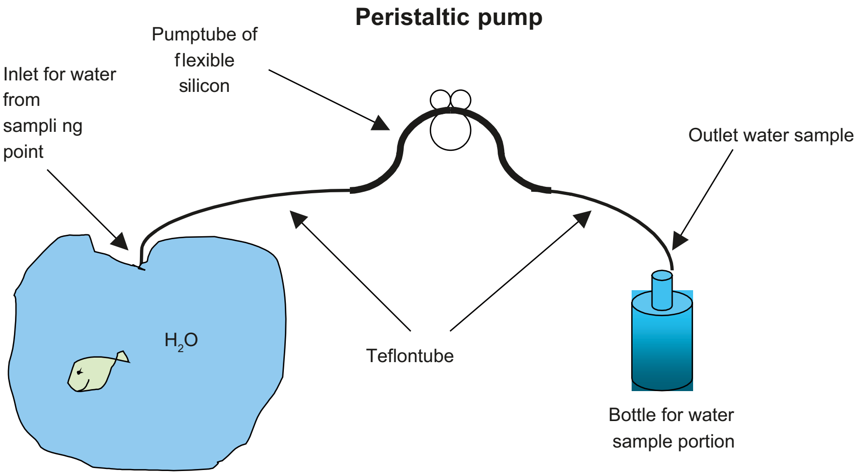


Figure 3-2. Schematic presentation of the peristaltic pump system (PPS).

3.3.2 Multiparameter sondes

Field measurements were performed using two multiparameter sondes (YSI 6600 EDS and YSI 600 QS). A terminal (YSI 650 MDS) is connected to each sonde through a cable for logging data (Figure 3-3). Calibration of the sondes was carried out according to the measurement system description SKB MD 910.003 (SKB internal controlling document, see Table 1-1). Table 3-3 describes the parameters measured by the two sondes.

Table 3-3. Parameters measured by the two different YSI sondes.

Parameter	YSI 6600 EDS	YSI 600 QS
Date/time	Yes	Yes
Temperature (°C)	Yes	Yes
pH	Yes	Yes
Dissolved oxygen (mg/L)	Yes	Yes
ORP (Redox potential, mV)	Yes	Yes
Electrical conductivity (mS/cm)	Yes	Yes
Salinity (ppt)	Yes	Yes
Depth (m)	Yes	Yes
Barometric pressure (mm Hg)	Yes	Yes
Turbidity (NTU)	Yes	No
Chlorophyll (µg/l)	Yes	No
Light/PAR* (µmoles s^{-1} m^{-2})	Yes	No

* Photosynthetic Active Radiation.

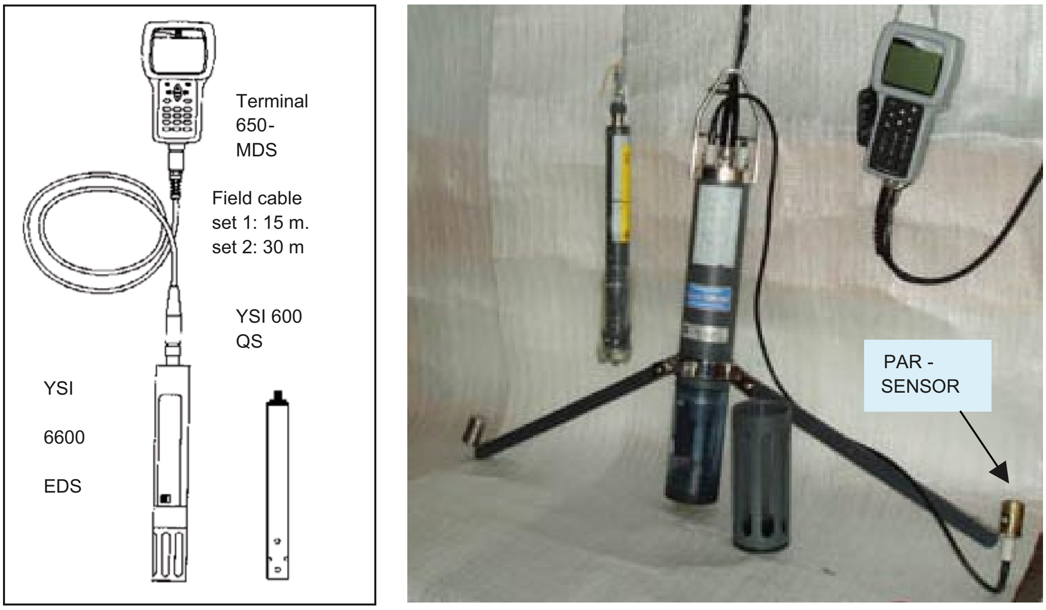


Figure 3-3. Measurement sondes used in the field investigations.

3.3.3 General field equipment

- Ruttner samplers were used as back-up if the portable pump system should fail.
- The exact locations of the sampling location positions were found using a GPS (Garmin 172C) with an average accuracy of +/– 0.5–1.0 m.
- Water depth was measured using an echo sounder (Plastimo, Echotest, LCD digital sounder) with an accuracy of +/– 0.05 m.
- Water transparency was estimated using a Secchi disc and aqua scope.
- Disposable filters (Millipore, 0.4 µm, ∅ = 22 mm) were used together with 60 mL syringes to filter specific sample portions of the sampled water in the field.
- Stopwatch (GUL), a water-filled plastic bottle (50 mL) and measuring-tape (Hultafors) were used for flow/runoff estimates in stream waters.
- Digital cameras (Nikon Coolpix 5000 and Olympus 400 mju) were used for documentation of stream waters.

Figure 3-4. *Sampling of stream water, Norr Eckarfjärden (PFM 000070).*

3.4 Performance

3.4.1 Presampling preparations

Prior to sampling, the sample bottles were cleaned (according to the routines for respective SKB class), labelled and packed in insulated boxes/bags. Acid additions were made in advance in bottles intended for trace metal analyses; these were placed in separate plastic bags to avoid contamination. The peristaltic pump system (PPS), including the Teflon tubes, was washed using acid (0.5 M HCl) and rinsed with deionised water before use. The equipment was kept well protected in plastic bags or in tight containers. The disposable filters (Millipore) were rinsed with MilliQ-water (50 mL) and placed in plastic bags to prevent contamination. Calibration of the sondes was performed according to the measurement system description SKB MD 910.003.

3.4.2 Water sampling

Water samples were collected using a peristaltic pump system, PPS, and Ruttner samplers were used as backup if the PPS-system should fail. Lake and sea water samples were collected close to the surface (at 0.5 m depth). In case of ice coverage during winter, water was also collected from approximately 0.5 m above the lake or sea bottom, in order to sample water both above and below stratification in the lake. Stream water samples were collected at approximately 0.1 m depth. The PPS-system and sample bottles were rinsed initially with water from the sampling locations prior to filling, except for bottles with acid additions. To avoid contamination, the field crew was obliged to wear rubber gloves and great care was taken not to contaminate bottles or equipment. Bottles and samples containing added acid were handled and stored separately to avoid contaminating other sample portions.

Each sample consists of several sample portions labelled with the same sample number. The preparation of the sample portions in the field differs depending on their use. Details on collected sample portions, components to be analysed and sample preparations are summarised in Table 3-4.

Figure 3-5. *Sampling from the ice-covered Lake Eckarfjärden (PFM 000117).*

Table 3-4. Sample volumes, components and preparation of samples.

🟦 Main monthly programme.
🟩 Modified performance in the extended programme.
🟦 Extended programme four times per year.
🟪 Once a year for lake and sea sites only.

Bottle volume (mL)	Number of bottles	SKB labels	Analyses	Comments	Preparation in field	Filling instructions
250	1	Green	pH, EC, Alkalinity, color determination			Fill up
250	1	Green, Anj.	Cl, SO_4, Br, F			Fill up
100	1	Green, Br	Br			Fill up
125	1	Green, HK	Major cations, SO4_S, Si	Acid washed		Fill up
2,000–2,500	1	Green	PON, POP, POC, Chlorophyll a, c and pheophytin			Fill up
100	1	Green, N/P	Tot-N, tot-P			Fill 80%
25	2	Green, D	DIC, DOC		Filtering with syringe/0.4 µm filter	Fill 80%
25	1	Green, T	TOC			Fill 80%
25	2	–	Nutrients: NH4, NO2, NO3, PO4		Filtering with syringe/0.4 µm filter	Fill up
1,000	1	Green, Susp.	Suspended material			Fill up
125^a	2	Green, O_2	O_2	calibrated Winkler, glass bottle	1 mL Mn(II) reagent + 2 mL alkaline iodine reagent and mix	Flow over 3x
125^a	2	Green, HS	HS^-	Winkler, glass bottle	1 mL ZnAc + 1 mL 1M NaOH and mix	Flow over 3x
100	1	Green, Br,I	Br, I	Additional anal. in class 5 samples		Fill up
125	1	Red, HK	Major cations, SO4_S, Si, environmental metals	Acid washed, additional anal. in class 5 samples		Fill up
25	3	–	Nutrients: NH4, NO2, NO3, PO4		Filtering with syringe/0.4 µm filter	Fill up
100	1	Green, D/O	Deuterium, ^{18}O			Fill up
500	1	Green, 3H	Tritium, ^{3}H			Flow over 3x
100	2	Red, Arkiv	Archives	Syradiskad	Filtering with syringe/0.4 µm filter	Fill up
250	2	Green, Arkiv	Archives			Fill up
125	1	Red, HK	Major cations, SO4_S, Si, environmental metals, trace metals, B, As, In, 10B/11B	Acid washed, additional anal. In class 5^+ samples		Fill up
1,000	1	Green, Ra/Rn	Ra^{226}, Rn^{222}			Fill up
1,000	1	Green, U/Th	U/Th-isotopes			Fill up
100	1	Green, 37Cl	^{37}Cl			Fill up
100	1	Green, 87Sr	$^{87}Sr/^{86}Sr$			Fill up
1,000	1	Green, 34S	^{34}S			Fill up
100	2	Green, C-iso	^{13}C/pmC			Fill up

a): Winkler samples only when sonde measurements of oxygen show values below 4 mg/L.

3.4.3 Field measurements

The multiparameter sondes were used for measurements of pH, water temperature, barometric pressure, ORP, PAR, turbidity, electrical conductivity, salinity, dissolved oxygen and chlorophyll. Light penetration was measured in lakes and at sea locations with a secchi disc according to the Swedish standard BIN SR 111. Photo documentation of stream waters was performed to facilitate evaluation of the investigation data. Photos were taken of each marked out (using a wooden stake) stream water sampling location.

In stream waters measurements were performed using a YSI 6600 EDS sonde if the water level was high enough, otherwise the smaller YSI 600 QS sonde was used. Chlorophyll, PAR and turbidity data were not reported for streams.

At lake and sea localities the multiple sonde (YSI 6600 EDS) was employed to measure a profile at each sampling point. Measurements were conducted at every metre from the surface to the bottom, see Table 3-5. In addition, PAR was logged just below the surface and during the ice season above the ice, in the air. PAR measurements were performed at discrete depths and as continuous PAR-profile loggings. PAR-profiles were obtained by setting the sonde mode to 'continuous logging'. The sonde was then submerged from surface to bottom and hoisted up again. The produced PAR-data were used for regression analyses of PAR versus depth.

A simple "floating bottle" method /14/ was used to measure water flow/runoff in the streams as a complement to the regular method using discharge weirs and gauges. The cross-section mean area of the stream was estimated, forming a rectangle, see Figure 3-6. The time for the bottle (close to neutral in weight in water) to float the distance (L) from point A to B was measured with a stopwatch. This procedure was repeated three times in each stream. The average water velocity (m/s) multiplied with the average area (m^2) resulted in a rough water runoff estimate (m^3/s).

3.4.4 Sample treatment and chemical analyses

An overview of sample treatment and analytical methods is given in Appendix 1. The routines are applicable independently of sampling method or type of sampling object.

3.4.5 Data handling/post processing

Two field protocols (activity log and sampling protocol) contain meta data (id-code, date, time, sample no., field crew etc), a few measured data and weather observations as well as comments on field conditions which may influence the analytical results. The field protocols supply basic information for creating activities and activity comments in the SKB Sicada database. In addition, the few measured parameters and weather conditions, noted on the sampling protocol, are stored as data tables in Sicada.

Table 3-5. Logging depths at sampling locations in lakes and shallow sea bays.

Sampling locations	Name	Sonde logging depth (m)											
		0.5	1.0	1.5	2.0	2.5	3.0	4.0	4.5	5.0	6.0	6.5	7.0
Lakes													
PFM000074	Labbo-träsket	X											
PFM000097	Norra bassängen	X											
PFM000107	Bolunds-fjärden	X	X										
PFM000117	Eckar-fjärden	X	X	X									
Shallow sea bays													
PFM000062	SV Forslingens grund	X	X		X		X						
PFM000082	Alternative to PFM00062	X	X		X		X	X		X	X	X	

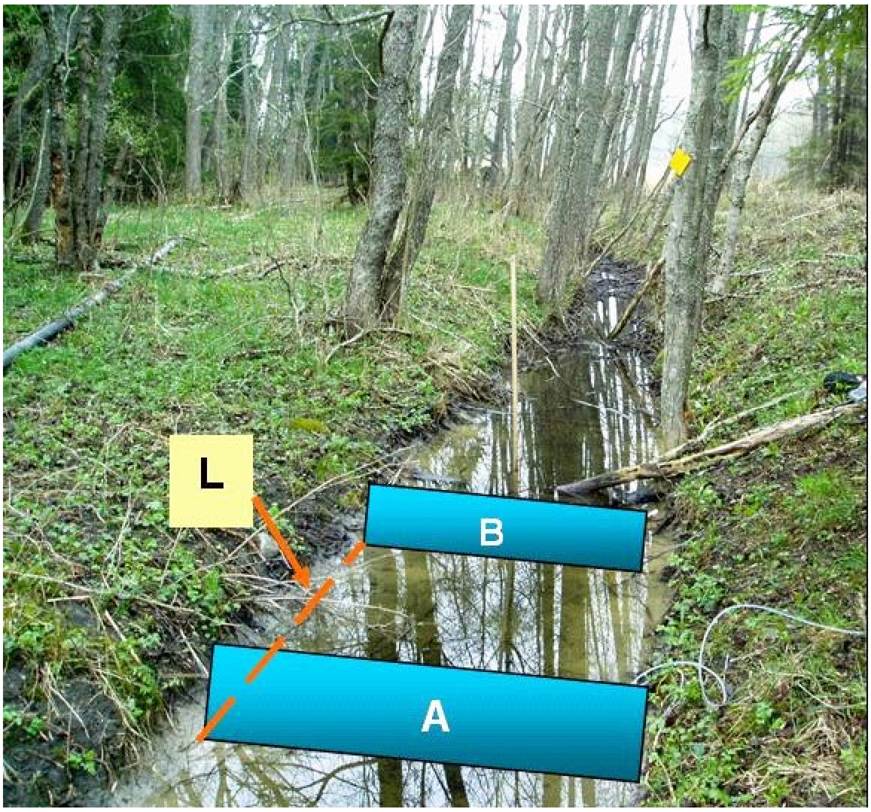


Figure 3-6. *Schematic presentation for estimating water runoff in natural stream waters (see text for explanation).*

Furthermore, eventual deviations from the sampling programme or from the normal routines are also documented in special reports/comment files. The comment files are stored in the Sicada file archive, see Table 2-4.

3.4.5.1 Chemical analytical data

The routines for quality control and data management described earlier in Section 2.4.3 are generally applied for hydrochemical analysis data, independently of sampling method or type of sampling object.

3.4.5.2 Field measurement data

The logged data from sonde measurements are exported digitally from the YSI Terminal 650-MDS to the specified Sicada data table. The original raw data file, calibration file and calibration protocol from each sonde, as well as photographs and comments on sampling and measurements, are stored in the Sicada file archive, see Table 3-6.

3.4.5.3 Other relevant information and data

Information about weather conditions and related parameters during the sampling occasions are compiled in a separate table in Sicada called "Weather_data" which contains the following columns:

Air temperature
Cloudiness
Precipitation
Wind velocity
Wind direction
Light penetration (lakes and sea)
Runoff/Water flow
Water depth
Snow/ice depth

These data are not presented in this report.

Table 3-6. File types stored in the Sicada file archive.

Type of file	Example of file name	No. per sampling session
Raw data file	L580438.dat	1 or 2*
Comments	Kommentarer V38.xls	1
Calibration data file	000113CF.txt	1 or 2*
Calibration protocol	Stora sonden V38år04.xls	1 or 2*
Photography	PFM66.jpg	1–4
Light data file	PAR-profiler V38_04.xls	1

* Depending on the number of measuring sondes used.

3.4.6 Nonconformities

The only nonconformities that occurred during the reported sampling period involve omitted sampling locations due to, for example, problems with ice or dry conditions. The reasons for deviations from the programme are compiled in Tables 3-7 and 3-8.

Table 3-7. Collected samples and conducted measurements.

	week/year	32/07	36/07	41/07	45/07	49/07	Sum (X)
Sond							
YSI 6600		X	X	X	X	X	5
YSI 600 QS							
Sea	**Name**						
PFM000062	SV-Forslingen	X	X	X	X	X	5
PFM000082	Alt PFM000062						0
PFM102269	Utloppet Biotesten	X*	X*	X*	X*	X*	5
Stream							
PFM000066	Ö-Gunnarsbo	E	E	E	X	X	2
PFM000068	Kungsträsket	X	E	X	X	X	4
PFM000069	Bolundsskogen	E	E	X	X	X	3
PFM000070	N-Eckarfjärden	E	E	E	X	X	2
Lakes							
PFM000074	Labboträsket	X	X	X	X	C	4
PFM000097	Norra bassängen	B	B	B	N	C	0
PFM00107	Bolundsfjärden	X	X	X	X	C	4
PFM00117	Eckarfjärden	X	X	X	X	C	4
Sum (X)		**6**	**5**	**7**	**9**	**6**	**33**

Explanations and abbreviations:

X: Collected sample.

B: No sample, only field measurements.

C: No sample, due to weak ice.

E: No sample, dry conditions, or too little water to collect representative samples.

N: Boat missing.

*: Only tritium and anions.

Table 3-8. Comments on measurements/water sampling.

	week/year	32/07	36/07	41/07	45/07	49/07
Sonde						
YSI 6600						
YSI 600 QS						
Sea	**Name**					
PFM000062	SV-Forslingen		J			
PFM000082	Alt PFM62					
PFM102269	Utloppet Biotesten					
Stream						
PFM000066	Ö-Gunnarsbo				H	
PFM000068	Kungsträsket	H, Z		H	H	
PFM000069	Bolundsskogen			H		
PFM000070	N-Eckarfjärden				H	H
Lakes						
PFM000074	Labboträsket			J		
PFM000097	Norra bassängen			Q		
PFM00107	Bolundsfjärden	J				
PFM00117	Eckarfjärden	J				

Explanations to codes/abbreviations:

H: Stagnant water or nearly stagnant water – no flow estimation, flow approx 0 m^3/s.

J: Incorrect PAR-values in one or several depths (mainly caused by waves, clouds, vegetation or darkness).

Q: Risk for incorrect sonde values for PAR, Turbidity and Chlorophyll, due to plants and/or particles in the water.

Z: Samples for oxygen analyses (2 Winkler bottles) were collected, due to measured low oxygen concentration.

3.5 Results

3.5.1 General

The surface water investigation period from August 2007 to December 2007 includes records of 33 water analyses (i.e. number of analysed samples) and records of 63 field measurements. Furthermore, the accompanying field documentation is quite extensive. The data are compiled in the attached Appendices and stored in the Sicada database where they are traceable by the activity plan number.

Fresh waters in the Forsmark area are well buffered with high alkalinity, high pH and high calcium concentrations. In addition, waters affected or recently affected by brackish sea water still show high sodium chloride concentrations. The relationship between the position of the coastline and the salinity of the water samples collected at the sampling locations in the area has been demonstrated in /6/. Furthermore, a detailed evaluation of surface water data from March 2002 to March 2004 was presented in /15/.

The results presented and compiled in this report are restricted to field work performed between August 2007 and December 2007. Besides results from the regular sampling objects, five new tritium results have been obtained from the location close to the cooling water outlet into Lake Biotestsjön.

3.5.2 Water analyses

3.5.2.1 Major components

The basic water analyses include the major constituents Na, K, Ca, Mg, Sr, S, SO_4^{2-}, Cl^-, Si and HCO_3^- as well as the minor constituents Fe, Li, Mn, Br, F^-, I and HS^-. Furthermore, batch measurements of pH and electrical conductivity are included. The basic water analysis data are compiled together with field measurements of pH and water temperature in Appendix 3.

The charge balance errors give an indication of the quality and uncertainty of the analyses of major constituents. None of the 33 samples/datasets show errors exceeding ± 10% and in four cases the errors exceed ± 5%.

To provide a rough check of the data, the electrical conductivity values are plotted versus the corresponding chloride concentrations in Figure 3-7. As shown, the near surface groundwater data generally agree well with a regression line.

Sulphate by ion chromatography and sulphate calculated from total sulphur by ICP are compared in Figure 3-8. As shown, within the analytical error all the sulphur is present as sulphate.

As established earlier /8/, bromide determinations by ion chromatography may be difficult at high chloride concentrations. Selected bromide values (in most cases ICP results) for each sample are plotted versus the corresponding chloride concentrations in Figure 3-9 as a consistency check. The points do not differ too much from the linear trend and the data are therefore considered acceptable.

3.5.2.2 Surface water supplements

The surface water supplements include NH_4_N, NO_2_N, $NO_3\_N+NO_2\_N$, NO_3_N, tot-N, tot-P, PO_4_P, TOC, DOC, DIC and sometimes at a few sampling occasions also dissolved oxygen. The analytical data are compiled in Appendix 3, Table A3-4. The DIC values should be used with care and bicarbonate values (by alkalinity titration) are considered more reliable.

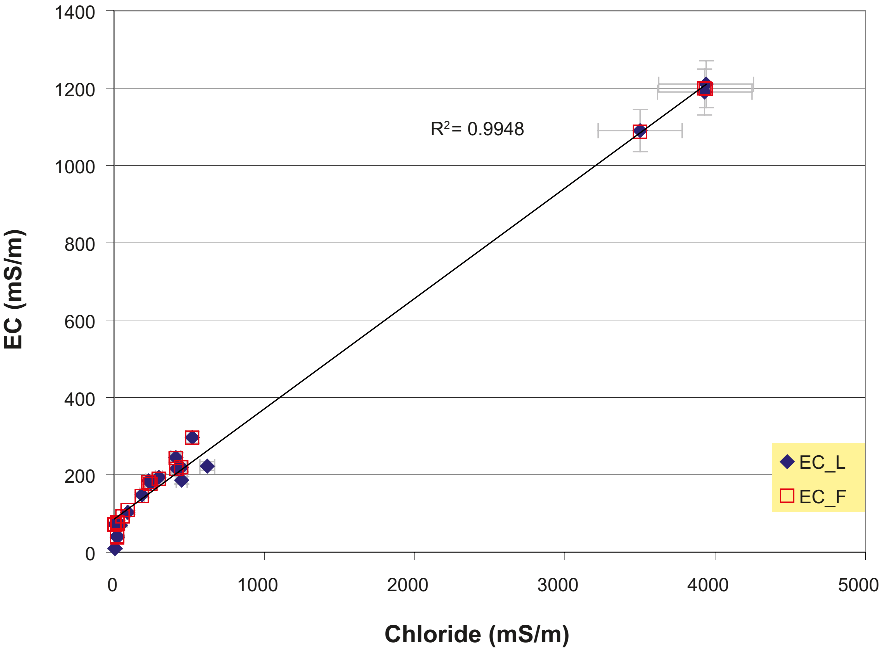


Figure 3-7. Electrical conductivity versus chloride concentrations. EC_L = Laboratory value, EC_F = Field value. The measurement uncertainty (Appendix 1) is shown as error bars.

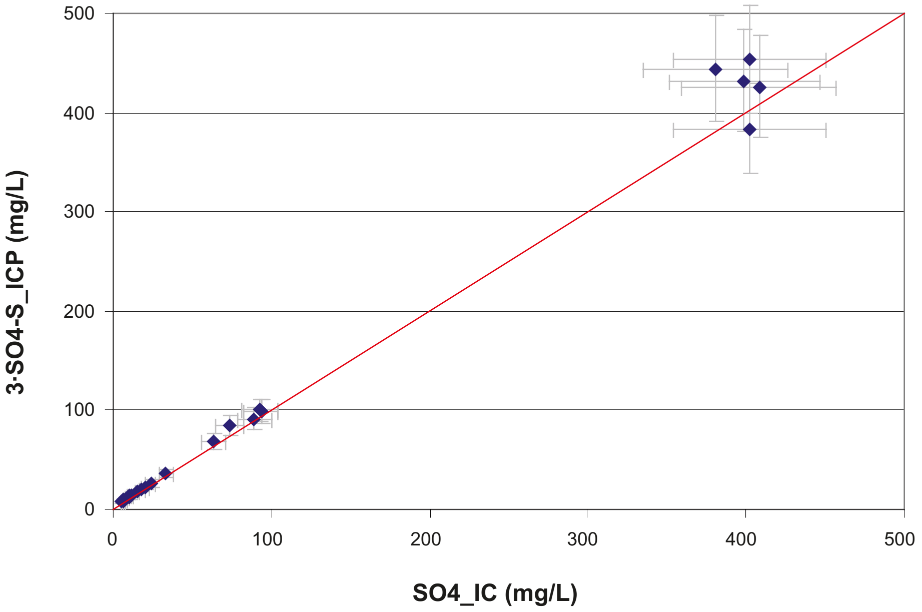


Figure 3-8. *Sulphate (SO_4 by IC) versus sulphate calculated from total sulphur (3·SO4-S) by ICP. The measurement uncertainty (Appendix 1) is shown as error bars.*

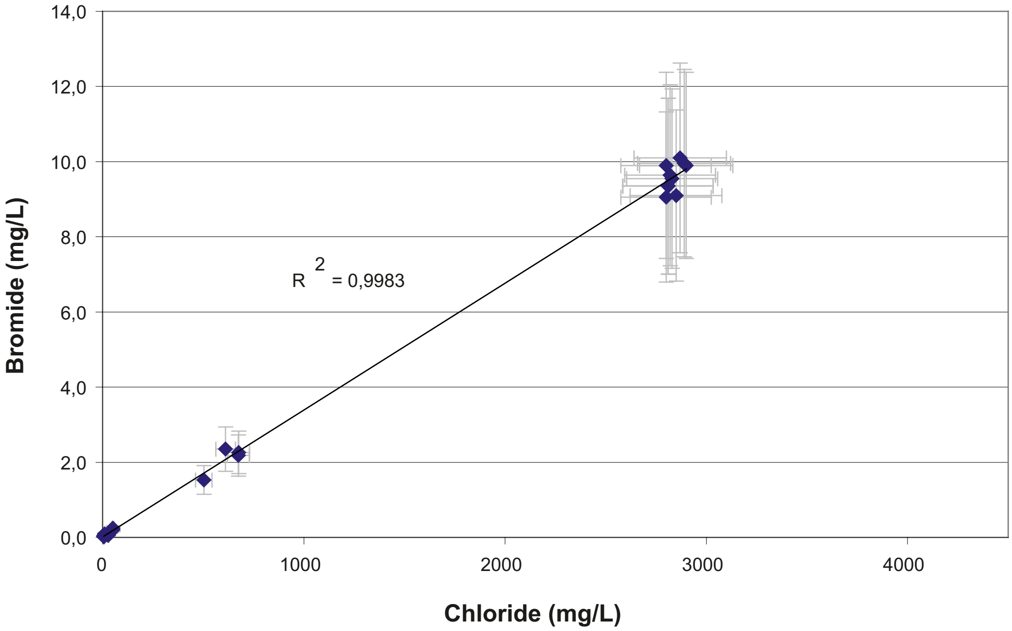


Figure 3-9. *Bromide versus chloride. The measurement uncertainty (Appendix 1) is shown as error bars.*

3.5.2.3 Isotopes

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

3.5.2.4 Tritium

It has been suggested that the adjacent nuclear power plant may have influenced the natural content of tritium and ^{14}C isotopes /8/. Some relation between the concentrations of these isotopes and distance from the nuclear power reactors was observed during March 2004–June 2005. In order to better understand the tritium data, repeated tritium determinations from close to the outlet of reactor cooling water commenced in July 2005. One very high tritium value was observed in July 2005 /9/ and three of the samples collected during July 2006–June 2007 also revealed enhanced tritium concentration (16.5, 40.12 and 17.5 TU) /10/. These circumstances indicate that contamination from the nuclear power plant does occur at times. During the present sampling period (August 2007–December 2007), the tritium concentrations measured in samples from the outlet of cooling water were comparable to concentrations from the regular sampling locations.

3.5.2.5 Trace metals

The analyses of trace elements include Al, As, Cd, Cr, Cu, Co, Hg, Ni, Zn, Pb, V, Mo, and Ba. The trace element data are compiled in Appendix 3, Table A3-4. These elements are generally present at low concentrations in the surface waters and the risk for contamination is high. Especially data on common metals like Al, Cr, Cu, Co, Ni and Zn must be used with caution. Generally, the distribution of data is location specific but outliers do exist; significantly large deviating concentrations for a sampling location are rejected in the Sicada database.

3.5.3 Field measurements

The field measurement data including redox potential, pH, dissolved oxygen, electrical conductivity, salinity, measurement depth, barometric pressure, turbidity, chlorophyll, light penetration, PAR (Photosynthetic Active Radiation) and water temperature are compiled in Appendix 3, Table A3-1. The PAR-profile logs are presented as diagrams including regression constants in Appendix 3, Table A3-2. Three sets of data are of lower quality; 1) water flow rate estimations by the float method, 2) sonde measurements (YSI 6600 EDS) of chlorophyll, and 3) turbidity measurements also by the sonde.

- The water flow rate estimations by the float method /12/ are of low accuracy compared to measurements using discharge weirs and gauges. They were performed in order to allow comparison between early data obtained when there was no other available method and new data from installed measurement stations (Appendix 3, Table A3-3).
- The chlorophyll measurements have been problematic, possibly due to the fact that humic substances and chlorophyll have similar fluorescence in the wavelength used by the sonde. Since the inland waters show high concentrations of humic substances and the sonde interprets humus as chlorophyll, the amount of chlorophyll tends to be overestimated.
- The turbidity measurements performed in the sea and in lakes often display negative values. This may be due to bad probe sensitivity in clear waters (turbidity weak waters) or calibration problems.

Comments on the low quality of chlorophyll and turbidity data as well as explanations to these circumstances are stored in the Sicada database.

3.5.4 Water composition

Both in freshwater and in the sea the major cations are generally calcium, magnesium, sodium and potassium. Sulphate and chloride are the major anions in sea water and also in freshwater together with bicarbonate. The relative proportions between these major constituents differ between sea water and freshwater and also between different freshwater bodies. In the investigated lakes and streams, bicarbonate is by far the most common anion, which is explained by the limestone-rich surroundings. Lake Bolundsfjärden (PFM000107) is however characterised by saltwater inflow and the water is more similiar in composition to the sea site (PFM000062) than the water in other lakes and streams. Figures 3-10 and 3-11 show the relative proportions of cations and anions, respectively.

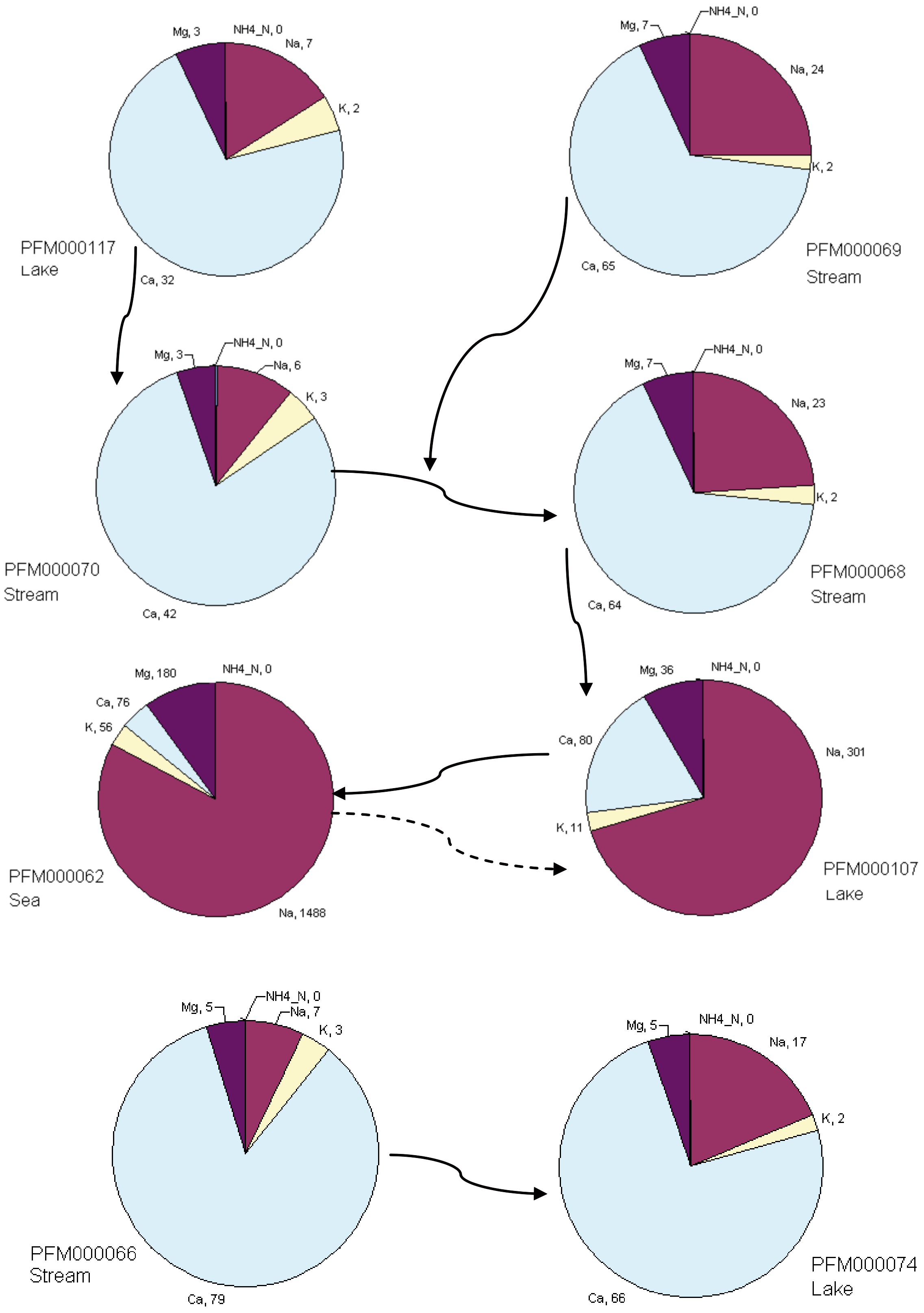


Figure 3-10. *Relative proportions of the cations Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4_N based on average values during the sampling period. The average values (mg/L) are displayed after each cation in the diagrams. The arrows show the path of the surface water between the lakes and streams. The occasional inflow of sea water into Lake Bolundsfjärden (PFM 000107) is indicated by a dotted arrow. The lake Labboträsket (PFM000074) and the stream PFM000066 belong to a different catchments area.*

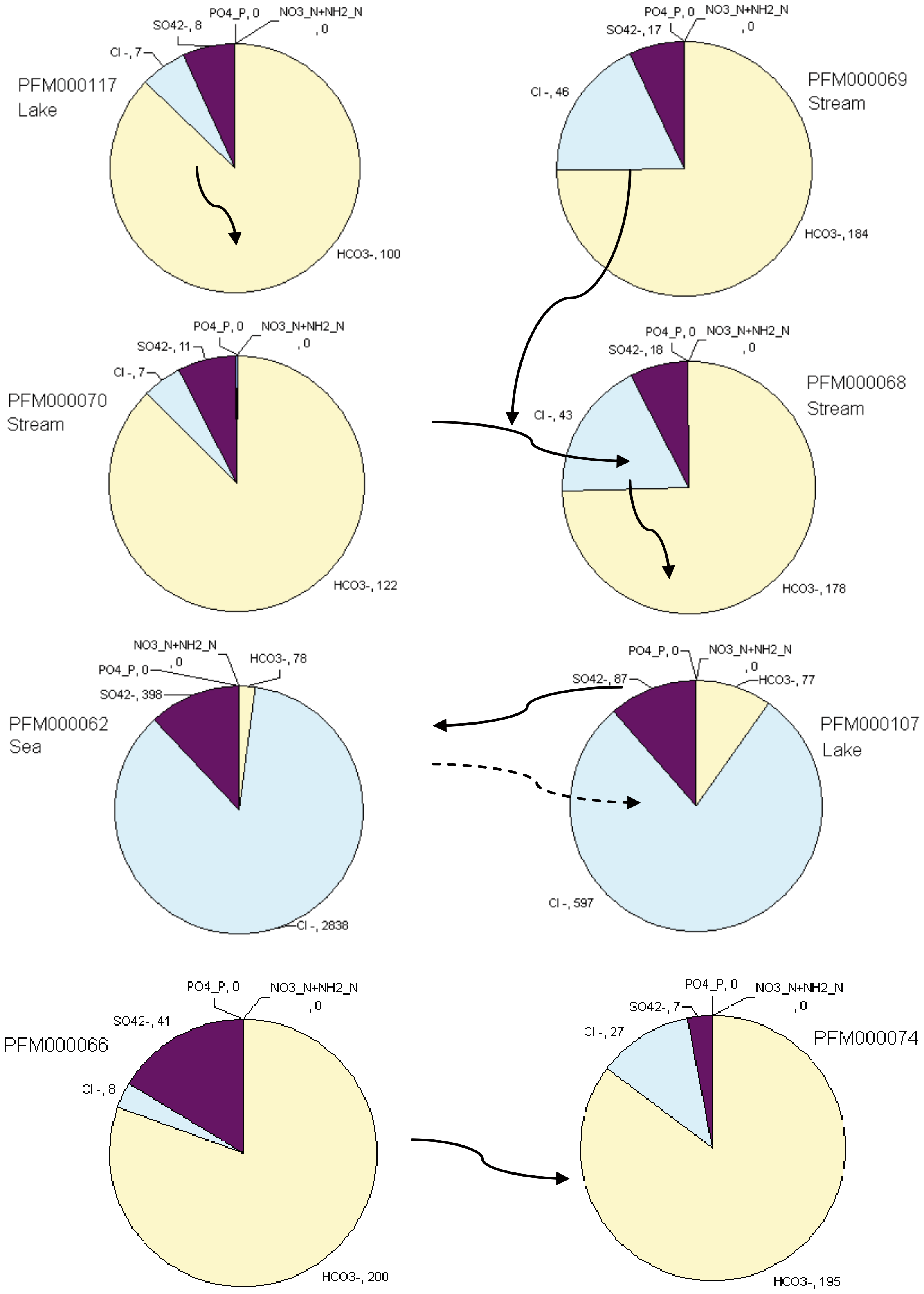


Figure 3-11. *Relative proportions of the anions Cl^-, HCO^{3-}, SO_4^{2-}, PO_4^{2-}_P, NO_3_N+ NH_2_N based on the average values (given in the diagrams in mg/L) during the sampling period. The arrows show the path of the surface water between the lakes and streams. The occasional inflow of sea water into Lake Bolundsfjärden (PFM 000107) is indicated by a dotted arrow. The lake Labbo-träsket (PFM000074) and the stream PFM000066 belong to a different catchments area.*

3.5.5 The NP-ratio in the surface water

The nutrients, nitrogen and phosphorus, are often the limiting factors for the primary production. Primary producers such as plants and phytoplankton use nitrogen and phosporus in a ratio of about 16 mol nitrogen to 1 mol phosphorous (also know as the Redfield ratio) or 7:1 in terms of mass. A ratio deviating from 16 (or 7) indicates that the primary production is limited by either nitrogen or phosphorus. When nitrogen is present in excess the ratio will be higher than 16, indicating that lack of phosphorus is limiting the growth. On the contrary, lower ratios indicate nitrogen limitations, which may favour growth of blue green algae able to use nitrogen from the air. In fresh water, phosphorus is usually the limiting nutrient, whereas in the oceans it is usually nitrogen. Figure 3-12 shows the relationship between nitrogen and phosphorous in the surface water of the investigated streams, lakes and coastal bays in the Forsmark area. The lakes and streams are phosporus limited with high concentrations of nitrogen. The coastal bay in the Baltic Sea (PFM000062) is also phosphorous limited although the ratio is much lower.

3.6 Summary and discussion

The chemical investigation routines for surface waters are well established after more than five years of field work, reporting and data administration and this period of the long-term surface water monitoring programme has passed without any major nonconformities or surprises. Sampling performed close to the outlet of cooling water from the power plant for tritium analyses did not reveal any enhanced values during the reported time period. The deviation from the Redfield ratio (7:1) indicated that the primary production in all the waters was limited by the phosphorus concentration.

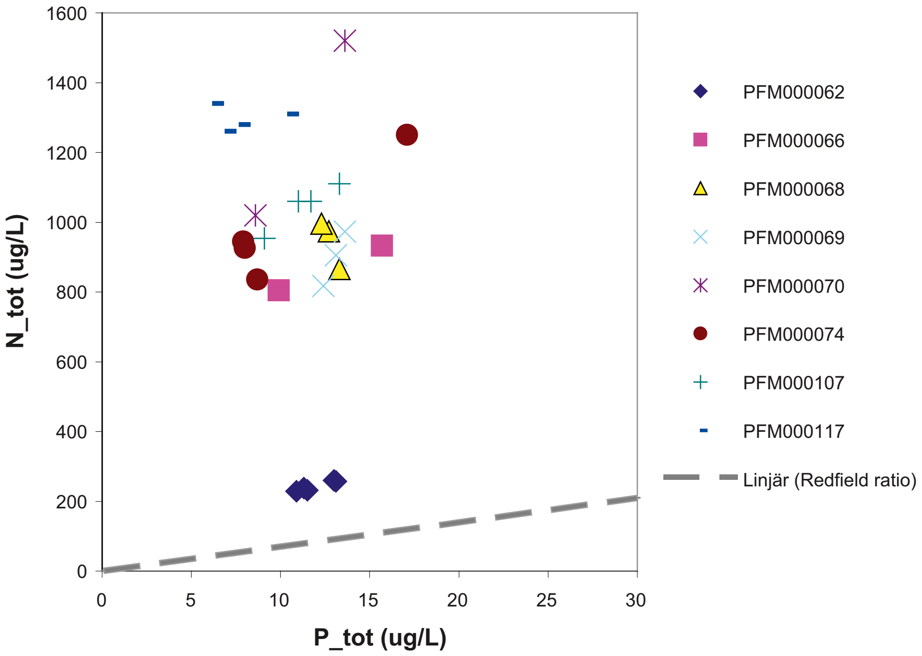


***Figure 3-12.** The relationship between nitrogen and phosphorus in the surface water of the investigated streams, lakes and coastal bays in the Forsmark area. The Redfield ratio (7:1) is indicated. Values above and below the line indicate phosphorus limitation and nitrogen limitation, respectively.*

4 Precipitation

4.1 Objective and scope

Information on the chemical composition of precipitation and its variation in Forsmark is useful in the following context:

- to improve the understanding of groundwater formation and other hydogeological conditions at the site,
- as boundary conditions conditions for chemical modelling purposes,
- possible use as reference water in mixing calculations.

Sampling and analysis of precipitation are mainly performed according to the SKB class 3 /1/. However, aluminium and iron are also included in the analytical protocol.

Besides the regular sampling point at the Forsmark area, Figure 4-1, a reference sampling point for tritium samples was introduced in August 2006. This point, PFM102271, is located in Sjötorp close to Lake Vänern and it was selected due to the long distance to any nuclear power plant. It was observed that the tritium content in precipitation and surface waters close to the nuclear power plants at Oskarshamn and Forsmark varied more than expected and a possible reason was occasional conta-mination from the nuclear power plants. Therefore, samples from an inland position were needed for comparison. To complete a one year cycle of tritium sampling at the reference point, one sample from PFM102271 was collected in July–August.

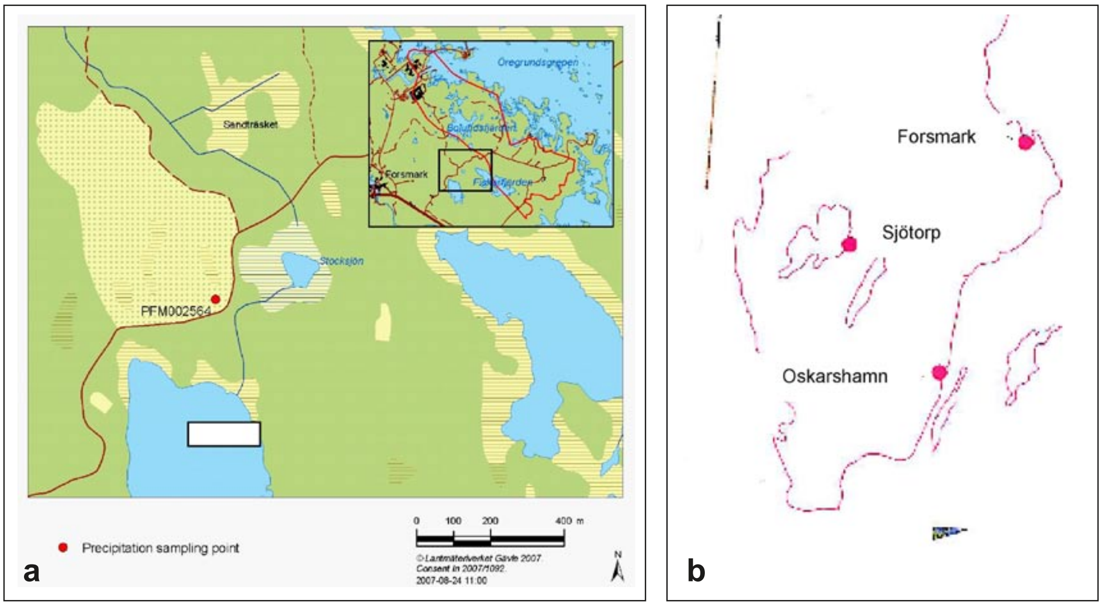


Figure 4-1. *a) Location of the samplers for precipitation, PFM002564, within the Forsmark investigation area (the area of the map). b) Map showing the southern part of Sweden with the location of the small village Sjötorp were the reference point is situated.*

4.2 Equipment

Two different setup's of samplers for precipitation were used during the period, the summer setup (July to October), Figure 4-2, and the winter setup (November to December), Figure 4-3. Both samplers are from NILU, Norway. Two samplers of each type were used simultaneously for collecting precipitation. At the reference point a different type of equipment was uses, Figure 4-4. This equipment type was initially delivered from IVL (Institutet för vatten och luftvård) and used at the site investigation in Forsmark until April 2007.

Figure 4-2. *Precipitation sampler, summer setup. Two sampler setups were used simultaneously in order to increase the collected volume of the precipitation.*

Figure 4-3. *Precipitation sampler, winter setup. Two sampler setups were used simultaneously in order to increase the collected volume of the precipitation.*

Figure 4-4. *Precipitation sampler used at the reference point in Sjötorp.*

4.3 Performance

4.3.1 Sampling

Sampling of precipitation within the Forsmark area was carried out according to activity plan AP PF 400-07-039 following the method described in SKB MD 423.003 (Provtagning och analys av nederbörd), see Table 1-1, both, SKB internal controlling documents.

4.3.1.1 Sampling during summer

During summer the risk for biased isotope analyses due to evaporation was larger. Therefore collection of precipitation water was conducted more frequently and the necks of the sampler bottles were narrow compared to the bottles for winter use. The sampler bottles were removed from their stands every week and the contents were pooled together with water from previous weeks and stored in a refrigerator. The collected precipitation from a two months period was then portioned into smaller bottles for distribution to the different analytical laboratories, see Figure 4-5, for a schematic outline of the sampling procedure. The bottle belonging to the equipment employed in Sjötorp was used together with a thin inside plastic bag, which was replaced after each sample collection.

4.3.1.2 Sampling during winter

During winter time the samplers were fetched from the field every second week and placed indoors in order to let the snow melt. Otherwise, the procedure was the same as for the summer samples.

4.3.2 Sample treatment and chemical analyses

An overview of sample treatment and analysis routines is given in Appendix 1. The routines are applicable independent of sampling method or type of sampling object. The sub-samples and analyses are listed in Table 4-1.

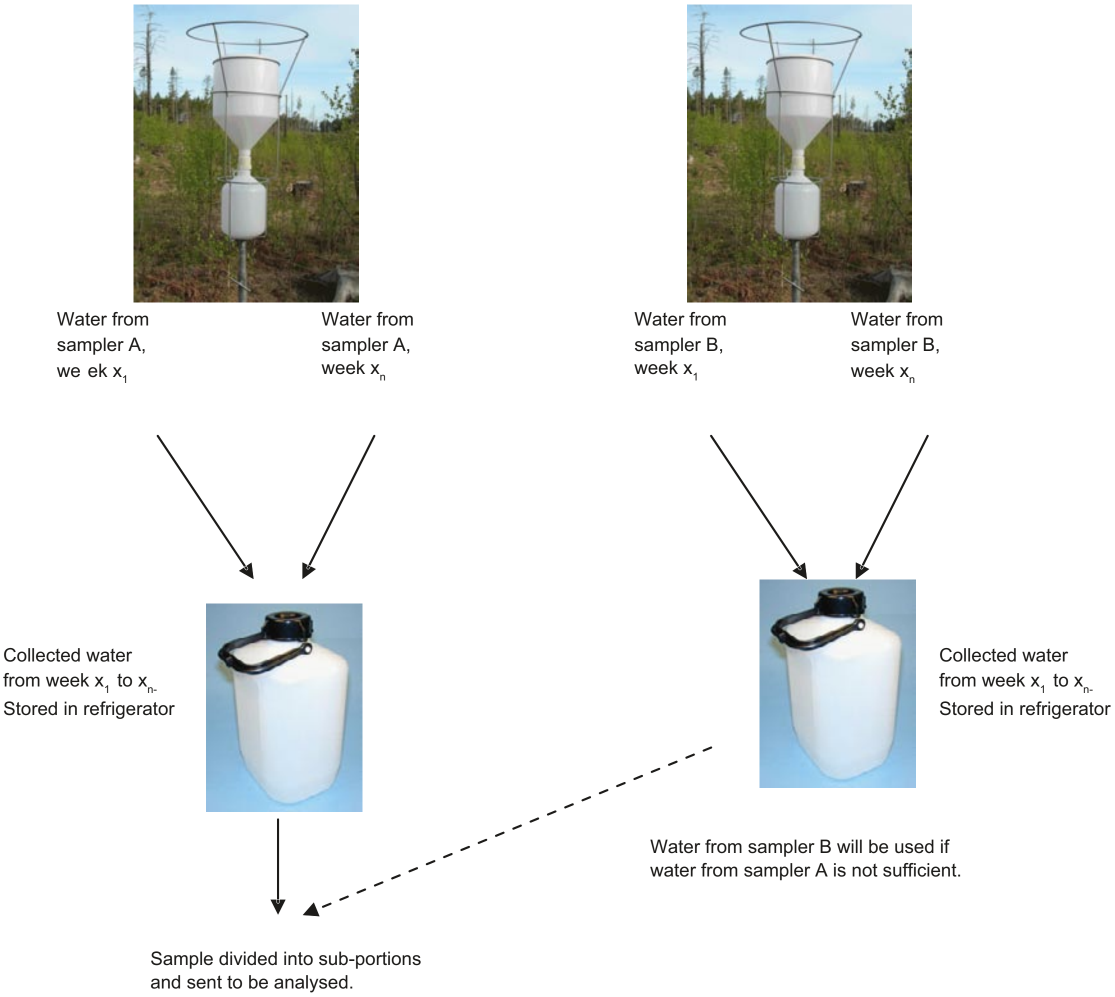


Figure 4-5. *Schematic outline of sample handling procedure.*

Table 4-1. Sampling volumes and analysed components.

Sub-sample volume [mL]	Components
250	HCO_3^-, pH, Electric conductivity (EC)
125*	Na, K, Ca, Mg, Mn, Sr, Si, Li, Al, Fe, SO_4–S,
100	Br^-
250	Cl^-, Br^-, SO_4^{2-}
500	^3H
100	δD, $\delta^{18}O$

* Filtered 0.4 µm, 1% HNO_3.

4.3.3 Data handling

The handling of hydrochemical data follow the same routine for quality control and data management data independently of sampling method or type of sampling object. For description of data handling see Section 2.4.3.

4.3.4 Nonconformities

By mistake, one aluminum analysis was omitted since, by mistake, it was not ordered from the consulted laboratory.

4.4 Results

4.4.1 Basic water analyses

The basic water analyses include the major components Na, K, Ca, Mg, S, SO_4^{2-}, Cl^-, Si and HCO_3^- and as well as the minor constituents Li, Mn, Sr and Br^-. Furthermore, aluminium analyses and measurements of pH and electric conductivity (EC) were conducted. The basic water analysis data are compiled in Appendix 4, Table A4-1.

Calculations of the relative charge balance error may give an indication of the quality and uncertainty of the major constituents data also for precipitation. Normally, for surface waters, a relative charge balance error within ± 10% is considered acceptable. However, the concentrations in precipitation samples are much lower and close to or below the reporting limit for many constituents. Therefore, analytical errors have a large impact on the charge balance, and the precipitation samples often exceed this limit, see Figure 4-6.

4.4.2 Isotoper analysis

The isotope determinations include the stable isotopes δD and , $\delta^{18}O$ as well as the radioactive isotope ^3H (Tritiuim). The isotope data are compiled in Appendix 4, Table A4-2. Sampling for isotope determinations may be biased by evaporation during summer time. The diagram for $\delta^{18}O$ (deviation from Standard Mean Ocean Water) versus δD (dev. SMOW) in Figure 4-7, corresponds well with the "Global meteoric water line" which is based on precipitation data from around the world /16/.

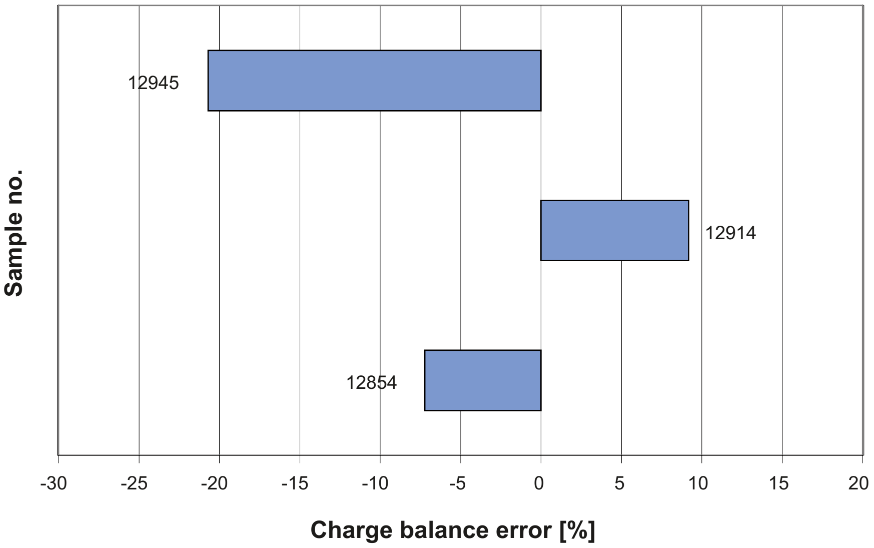


Figure 4-6. Charge balance errors for the three precipitation samples collected during the reported time period.

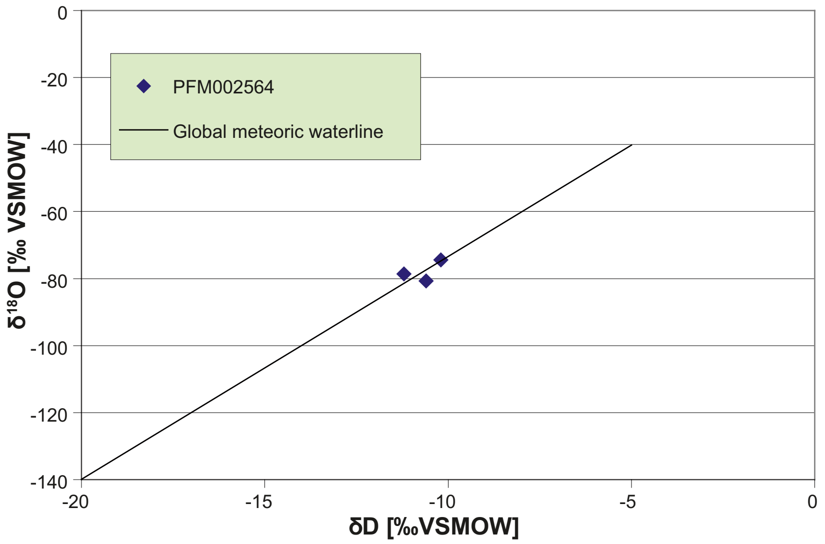


Figure 4-7. *δ18O plotted versus δD and compared with the "global meteoric water line". PFM002564 = sampling location at the Forsmark site.*

The tritium content in precipitation from Forsmark, July 2005 to December 2007, is displayed in Figure 4-8 together with the contents in the few samples from Sjötorp. As seen, the values follow more or less the same trend.

4.5 Summary and discussion

The sampling and analysis routines for precipitation have developed and improved with time and are by now well established after several years of sampling, reporting and data administration. The change to the new type of sampler setups (since April 2007) and thereby the use of a more robust and handy equipment has facilitated the sampling. The results from the sampling and analyses performed during the reported time period do not reveal any significant changes from previous years. The tritium contents in the precipitation in Forsmark and in Sjötorp were reasonably similar and followed more or less the same trends during the time period in question.

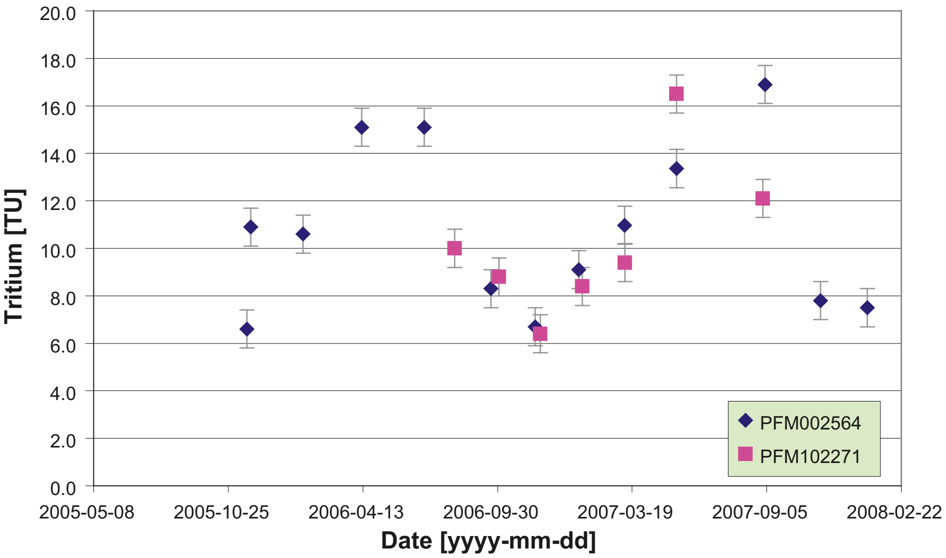


Figure 4-8. *Tritium contents in precipitation collected at the Forsmark site and at the reference location in Sjötorp. PFM002564 = sampling location in Forsmark, PFM102271= sampling location in Sjötorp.*

5 Summary conclusion

The results from the sampling and analyses of near surface groundwater, surface waters and precipitation performed during the reported time period do not reveal any significant changes from previous years. A few observations worth mentioning are listed below.

- Some monitoring wells in soil show erroneously high concentrations of total sulphur. This is probably due to enhanced sulphide concentrations (not analysed) which interfere with the ICP AES analyses of sulphur.
- The sampling in Lake Biotestsjön, close to the cooling water outlet from the nuclear power plant, did not reveal any enhanced tritium contents during the reported time period. High tritium contents have been reported a few times before, see in /9/ and /10/.
- The tritium contents in the precipitation in Forsmark and in Sjötorp were reasonably similar and followed more or less the same trend during the reported time period. Therefore, from the time series in question, it is not possible to observe any significant tritium contamination from the nuclear power plant in Forsmark.

Figure 5-1. *Exchange of water volume by pumping in a stand pipe.*

6 References

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

/2/ **SKB, 2007.** Programme for long-term observations of geosphere and biosphere after completed site investigations. SKB R-07-34, Svensk Kärnbränslehantering AB

/3/ **Nilsson A-C, Borgiel M, 2005.** Forsmark site investigation. Sampling and analyses of near surface groundwaters. Results from sampling of shallow soil monitoring wells, BAT pipes, a natural spring and private wells, May 2003–April 2005. SKB P-05-071, Svensk Kärnbränslehantering AB.

/4/ **Nilsson A-C, Borgiel M, 2005.** Forsmark site investigation. Sampling and analyses of near surface groundwaters. Results from sampling of shallow soil monitoring wells, BAT pipes, a natural spring and private wells, July 2005–April 2006. SKB P-06-304, Svensk Kärnbränslehantering AB.

/5/ **Nilsson A-C, Borgiel M, 2005.** Forsmark site investigation. Sampling and analyses of near surface groundwaters. Results from sampling of shallow soil monitoring wells, BAT pipes, a natural spring and private wells, July 2006–April 2007. SKB P-07-124, Svensk Kärnbränslehantering AB.

/6/ **Nilsson A-C, Karlsson S, Borgiel M, 2003.** Forsmark site investigation. Sampling and analyses of surface waters. Results from sampling in the Forsmark area, March 2002 to March 2003. SKB P-03-27, Svensk Kärnbränslehantering AB.

/7/ **Nilsson A-C, Borgiel M, 2004.** Forsmark site investigation. Sampling and analyses of surface waters. Results from sampling in the Forsmark area, March 2003 to March 2004. SKB P-04-146, Svensk Kärnbränslehantering AB.

/8/ **Nilsson A-C, Borgiel M, 2005.** Forsmark site investigation. Sampling and analyses of surface waters. Results from sampling in the Forsmark area, March 2004 to June 2005. SKB P-05-274, Svensk Kärnbränslehantering AB.

/9/ **Nilsson A-C, Borgiel M, 2007.** Forsmark site investigation. Sampling and analyses of surface waters. Results from sampling in the Forsmark area, July 2005 to June 2006. SKB P-07-095, Svensk Kärnbränslehantering AB.

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/11/ **Nilsson D, 2005.** Forsmark site investigation. Sampling and analysis of precipitation, years 2002 to 2005. SKB P-05-143, Svensk Kärnbränslehantering AB.

/12/ **Berg C, 2007.** Forsmark site investigation. Sampling and analysis of precipitation, September 2005 to June 2007. SKB P-07-170, Svensk Kärnbränslehantering AB.

/13/ **SKB, 2005.** Forsmark site investigation. Programme for further investigations of geosphere and biosphere. SKB R-05-14, Svensk Kärnbränslehantering AB.

/14/ **Johansson P-O, 2005.** Forsmark site investigation. Manual discharge measurements in brooks, April 2002–April 2005. SKB P-05-153, Svensk Kärnbränslehantering AB.

/15/ **Sonesten L, 2004.** Evaluation of surface water chemistry data from the Forsmark area. March 2002–March 2004. SKB R-05-41, Svensk Kärnbränslehantering AB.

/16/ **Craig H, 1961.** Isotopic variations in meteoric waters. Science 133, pp. 1702-1703.

Appendix 1

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.
Anions 1.	HCO_3 pH(lab) cond (lab)	Plastic	250	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	The same day – maximum 24 hours
Anions 2	Cl, SO_4, Br^-, F^-, I^-	Plastic	100	Yes (not in the field)	No	Titration (Cl^-) IC (Cl^-, SO4, Br^-, F^-) ISE (F^-)	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	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	Not critical (month)
Cations, Si and S according to SKB class 4 and 5	Na, K, Ca, Mg, S(tot), Si(tot), Fe, Mn, Li, Sr	Plastic (Acid washed)	100	Yes (immediately in the field)	Yes (1mL HNO_3)	ICP-AES ICP-MS	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	500	Yes	Yes (5 mL HCl))	Spectrophotometry Ferrozine method	As soon as possible the same day
Hydrogen sulphide	HS-	Glass (Winkler)	About 120×2	No	Ev 1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	Immediately or if conserved, a few days
Environmental metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn	Plastic (Acid washed)	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	Not critical (month)
Lantanoids, U, Th and so on.	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th	Plastic (Acid washed)	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	Not critical (month)
Dissolved organic Carbon, dissolved inorganic Carbon	DOC, DIC	Plastic	250 25	Yes	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Short transportation time

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.
Total organic Carbon	TOC	Plastic	250 25	No	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Short transportation time
Environmental isotopes	^{2}H, ^{18}O	Plastic	100	No	– –	MS	Not critical (month)
Tritium,	^{3}H (enhanced.)	Plastic (dry bottle)	500	No	–	LSC	Not critical (month)
Chlorine-37	Chlorine-37	Plastic	100	No	–	MS	
Carbon isotopes	^{13}C, ^{14}C	Glass (brown)	100×2	No	–	(A)MS	A few days
Sulphur isotopes	^{34}S	Plastic	500–1,000	Yes	–	Combustion, MS	No limit
Strontium-isotopes	$^{87}Sr/^{86}Sr$	Plastic	100	Yes	–	TIMS	Days or Week
Uranium and Thorium isotopes	^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{230}Th,	Plastic	50	Nej	–	Alfa spectroscopy	No limit
Boron isotopes	^{10}B	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP – MS	No limit
Radon and Radium isotopes	^{222}Rn, ^{226}Ra	Plastic	500	No	No	LSS	Immediate transport
Dissolved gas (content and composition)	Ar, N_2, CO_2, O_2, CH_4, H_2, CO, C_2H_2, C_2H_4, C_2H_6, C_3H_8	Cylinder of stainless steel	200	No	No	GC	Immediate transport
Colloids	Filter series and fractionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 µm	–	N_2 atmosphere	ICP-AES ICP-MS	Immediate transport
Humic and fulvic acids	Fractionation	Fractions are collected in plastic bottles	250	–	N_2 atmosphere	UV oxidation, IR (DOC)	Immediate transport
Archive samples with acid	–	Plast (washed in acid)	100×2 **	Yes	Yes (1 mL HNO_3)	–	Storage in freeze container
Archive samples without acid	–	Plastic	250×2 **	Yes	No	–	Storage in freeze container
Carbon isotopes in humic and fulvic acids	^{13}C, ^{14}C (pmc)	DEAE cellulose (anion exchanger)	–	–	–	(A)MS	A few days
Nutrient salt + silicate	NO_2, NO_3, NO_2+NO_3, NH_4, PO_4, SiO_4	Sample tubes, plastic	25×2	Yes (in the field)	No, frozen immediately***	Spectrophotometry	Short transportation time

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.
Total concentrations of Nitrogen and Phosphorous	N-tot, P-tot	Plastic	100	No	No, frozen immediately***	Spectrophotometry	Short transportation time
Particulate Carbon, Nitrogen and Phosphorous	POC, PON, POP	Plastic	1,000	Yes (within 4 h) prepared filters. Blank filters	Filtering, the filters are frozen immediately 2 filters/sample	Elementar-analysator (N, C) own method 990121 (P)	Short transportation time
Chlorophyll	Chlorophyll a, c and pheopigment	Plastic	1,000–2,000	Yes (within 4 h)	Filtering, the filters are frozen immediately	Spectrophotometry Fluorometry	Short transportation time
Oxygen	Dissolved O_2	Winkler, glass	2×ca 120	No	Mn (II) reagent Iodide reagent	Spectrophotometry SIS SS-EN 25813	Within 3 days
Archive samples for supplementary radio nuclides		Plastic	5,000	No	50 mL HNO_3	–	Storage in freeze container

* Suprapur acid is used for conservation of samples.

** Minimum number. The number of archive samples can vary depending on the number of similar samples collected at the same occasion.

*** The sample is transported in frozen condition to the laboratory. It is possible that the silicate concentration can change due to polymerisation for this reason.

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
TIMS	Thermal Ionization Mass Spectrometer
LSC	Liquid Scintillation Counting
(A)MS	(Accelerator) Mass Spectrometry
GC	Gas Chromatography
LSS	Liquid Scintillation Spectroscopy

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

Component	Method[1]	Reporting limits (RL), detection limits (DL) or range[2]	Unit	Measurement uncertainty[3]
pH	Potentiometric	3–10	pH unit	±0.1
EC	Electrical Conductivity meas.	1–150	mS/m	5%
		150–10,000		3%
HCO_3	Alkalinity titration	1	mg/L	4%
Cl^-	Mohr- titration	≥ 70	mg/L	5%
Cl^-	IC	0.5–70		8%
SO_4	IC	0.5	mg/L	12%
Br^-	IC	DL 0.2, RL 0.5	mg/L	15%
Br	ICP SFMS	0.001, 0.004, 0.010[4]	mg/L	25%[5]
F^-	IC	DL 0.2, RL 0.5	mg/L	13%
F^-	Potentiometric	DL 0.1, RL 0.2		12%
I^-	ICP SFMS	0.001, 0.004, 0.010[4]	mg/L	25%[5]
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	0.004	mg/L	12.2%
Fe	ICP AES	0.02	mg/L	13.3%[6]
Fe	ICP SFMS	0.0004, 0.002, 0.004[4]	mg/L	20%[6]
Mn	ICP AES	0.003	mg/L	12.1%[5]
Mn	ICP SFMS	0.00003, 0.00004, 0.0001[4]	mg/L	53%[6]
Fe(II), Fe(tot)	Spectrophotometry	DL 0.006, RL 0.02	mg/L	0.005 (0.02–0.05 mg/L) 9% (0.05–1 mg/L) 7% (1–3 mg/L)
HS^-	Spectrophotometry, SKB	SKB DL 0.006, RL 0.02	mg/L	25%
HS^-	Spectrophotometry, external laboratory	0.01	mg/L	0.02 (0.01–0.2 mg/L) 12% (> 0.2 mg/L)
NO_2 as N	Spectrophotometry	0.1	µg/L	2%
NO_3 as N	Spectrophotometry	0.2	µg/L	5%
NO_2+NO_3 as N	Spectrophotometry	0.2	µg/L	0.2 (0.2–20 µg/L) 2% (> 20 µg/L)
NH_4 as N	Spectrophotometry, SKB	11	µg/L	30% (11–20 µg/L) 25% (20–50 µg/L) 12% (50–1200 µg/L)
NH_4 as N	Spectrophotometry external laboratory	0.8	µg/L	0.8 (0.8–20 µg/L) 5% (> 20 µg/L)
PO_4 as P	Spectrophotometry	0.7	µg/L	0.7 (0.7–20 µg/L) 3% (> 20 µg/L)
SiO_4	Spectrophotometry	1	µg/L	2.5% (> 100 µg/L)
O_2	Iodometric titration	0.2–20	mg/L	5%
Chlorophyll a, c pheopigment[7]	/1/	0.5	µg/L	5%
PON[7]	/1/	0.5	µg/L	5%
POP[7]	/1/	0.1	µg/L	5%
POC[7]	/1/	1	µg/L	4%
Tot-N[7]	/1/	10	µg/L	4%

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

Component	Method[1]	Reporting limits (RL), detection limits (DL) or range2	Unit	Measurement uncertainty 3
Tot-P[7]	/1/	0.5	µg/L	6%
Al,	ICP SFMS	0.2, 0.3, 0.7[4]	µg/L	17.6%[6]
Zn	ICP SFMS	0.2, 0.8, 2[4]	µg/L	15.5, 17.7, 25.5%[6]
Ba, Cr, Mo,	ICP SFMS	0.01, 0.04, 0.1[4]	µg/L	Ba 15%[4], Cr 22%[5] Mo 39%[6]
Pb	ICP SFMS	0.01, 0.1, 0.3[4]	µg/L	15%[6]
Cd	ICP SFMS	0.002, 0.02, 0.5[4]	µg/L	15.5%[6]
Hg	ICP AFS	0.002	µg/L	10.7%[6]
Co	ICP SFMS	0.005, 0.02, 0.05[4]	µg/L	25.9%[6]
V	ICP SFMS	0.005, 0.03, 0.05[4]	µg/L	18.1%[6]
Cu	ICP SFMS	0.1, 0.2, 0.5[4]	µg/L	14.4%[6]
Ni	ICP SFMS	0.05, 0.2, 0.5[4]	µg/L	15.8%[6]
P	ICP SFMS	1, 5, 40[4]	µg/L	16.3%[6]
As	ICP SFMS	0.01 (520 mS/m)	µg/L	59.2%[6]
La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu	ICP SFMS	0.005, 0.02, 0.05[4]	µg/L	20%, 20%, 25%[6]
Sc, In, Th	ICP SFMS	0.05, 0.2, 0.5[4]	µg/L	25%[6]
Rb, Zr, Sb, Cs	ICP SFMS	0.025, 0.1, 0.25[4]	µg/L	15%, 20%, 20%[5], 25%[6]
Tl	ICP SFMS	0.025, 0.1, 0.25[4]	µg/L	14.3%[5 and 6]
Y, Hf	ICP SFMS	0.005, 0.02, 0.05[4]	µg/L	15%, 20%, 20%[5], 25%[6]
U	ICP SFMS	0.001, 0.005, 0.01[4]	µg/L	13.5%, 14.3%, 15.9%[5] 19.1%, 17.9%, 20.9%[6]
DOC	UV oxidation, IR Carbon analysator	0.5	mg/L	8%
TOC	UV oxidation, IR Carbon analysator	0.5	mg/L	10%
$\delta^{2}H$	MS	2	‰ SMOW[8]	0.9 (one standard deviation)
$\delta^{18}O$	MS	0.1	‰ SMOW[8]	0.1 (one standard dev.)
^{3}H	LSC	0.8	TU[9]	0.8
$\delta^{37}Cl$	A (MS)	0.2	‰ SMOC[10]	0.2[17]
$\delta^{13}C$	A (MS)	–	‰ PDB[11]	0.3[17]
^{14}C pmc	A (MS)	–	PMC[12]	0.4[17]
$\delta^{34}S$	MS	0.2	‰ CDT[13]	0.4 (one standard dev.)
$^{87}Sr/^{86}Sr$	TIMS	–	No unit (ratio)[14]	0.00002
$^{10}B/^{11}B$	ICP SFMS	–	No unit (ratio)[14]	–
^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{230}Th	Alfa spectr.	0.0001	Bq/L[15]	≤ 5% (Counting statistics uncertainty)
^{222}Rn, ^{226}Ra	LSS	0.015	Bq/L	≤ 5% (Count. stat. uncert.)

1. 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.
2. 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).
3. Measurement uncertainty reported by the laboratory, generally as ± percent of measured value in question at 95% confidence interval.
4. Reporting limits at electrical cond. 520 mS/m, 1,440 mS/m and 3810 mS/m respectively.
5. Measurement uncertainty at concentrations 100×RL
6. Measurement uncertainty at concentrations 10×RL

7. Determined only in surface waters. PON, POP and POC refers to Particulate Organic Nitrogen, Phosphorous and Carbon, respectively
8. Per mille deviation[16] from SMOW (Standard Mean Oceanic Water).
9. TU=Tritium Units, where one TU corresponds to a tritium/hydrogen ratio of 10^{-18} (1 Bq/L Tritium = 8.45 TU).
10. Per mille deviation[16] from SMOC (Standard Mean Oceanic Chloride).
11. Per mille deviation[16] from PDB (the standard PeeDee Belemnite).
12. 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[16] 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 ^{238}U, 1 ppm Th = 3.93 Bq/kg ^{232}Th.
16. Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:
    $\delta yI = 1{,}000 \times (K_{sample} - K_{standard)} / K_{standard}$, where K= the isotope ratio and $^{y}I = {}^{2}H$, ^{18}O, ^{37}Cl, ^{13}C or ^{34}S etc.
17. SKB estimation from duplicate analyses by the contracted laboratory

Appendix 2

Near surface groundwater

Table A2-1. Sampling object coordinates, depth to the upper (SECUP) and lower (SECLOW) limits of the filter sections and total depths.

Sampling object*	Coordinates (RT90–RHB70)**			Depths		
IDCODE	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	SECUP*** (m)	SECLOW*** (m)	Depth**** (m)
SFM0001	6699713	1631335	1.1	3.95	4.95	4.95
SFM0023	6698983	1632064	1.1	4.42	5.42	5.42
SFM0032	6698838	1631726	1.6	3	4	5
SFM0037	6699992	1631744	1.5	2	3	4
SFM0049	6700028	1630533	4	4	5	6
SFM0051	6699600	1631488	2.2	5.02	5.18	5.27
SFM0081	6698999	1632093	1.31	4.85	5.25	5.25
SFM0083	6699000	1632093	1.36	2.54	2.7	2.75
SFM0084	6699868	1632106	1.23	3.7	4.1	4.1
SFM0086	6699869	1632406	1.69	3.09	3.25	3.3
SFM0087	6699868	1632406	1.31	2	2.2	2.35
SFM0089	6699868	1632406	1.06	2.09	2.25	2.3
SFM0091	6699745	1631490	1.41	1.9	2.3	2.3
SFM0093	6699745	1631490	1.31	1.55	1.71	1.76
SFM0095	6698015	1630437	12.1	5	6	7.1
SFM0097	6698015	1630438	11.49	3.09	3.25	3.3
SFM0100	6698015	1630437	11.48	2.09	2.25	2.3
SFM0102	6698015	1630438	12.03	2.09	2.25	2.3
PFM000001	6697373	1634709	–	45	–	–
PFM000009	6698227	1634724	–	70	–	–
PFM006382	6698691	1634249	–	–	–	–

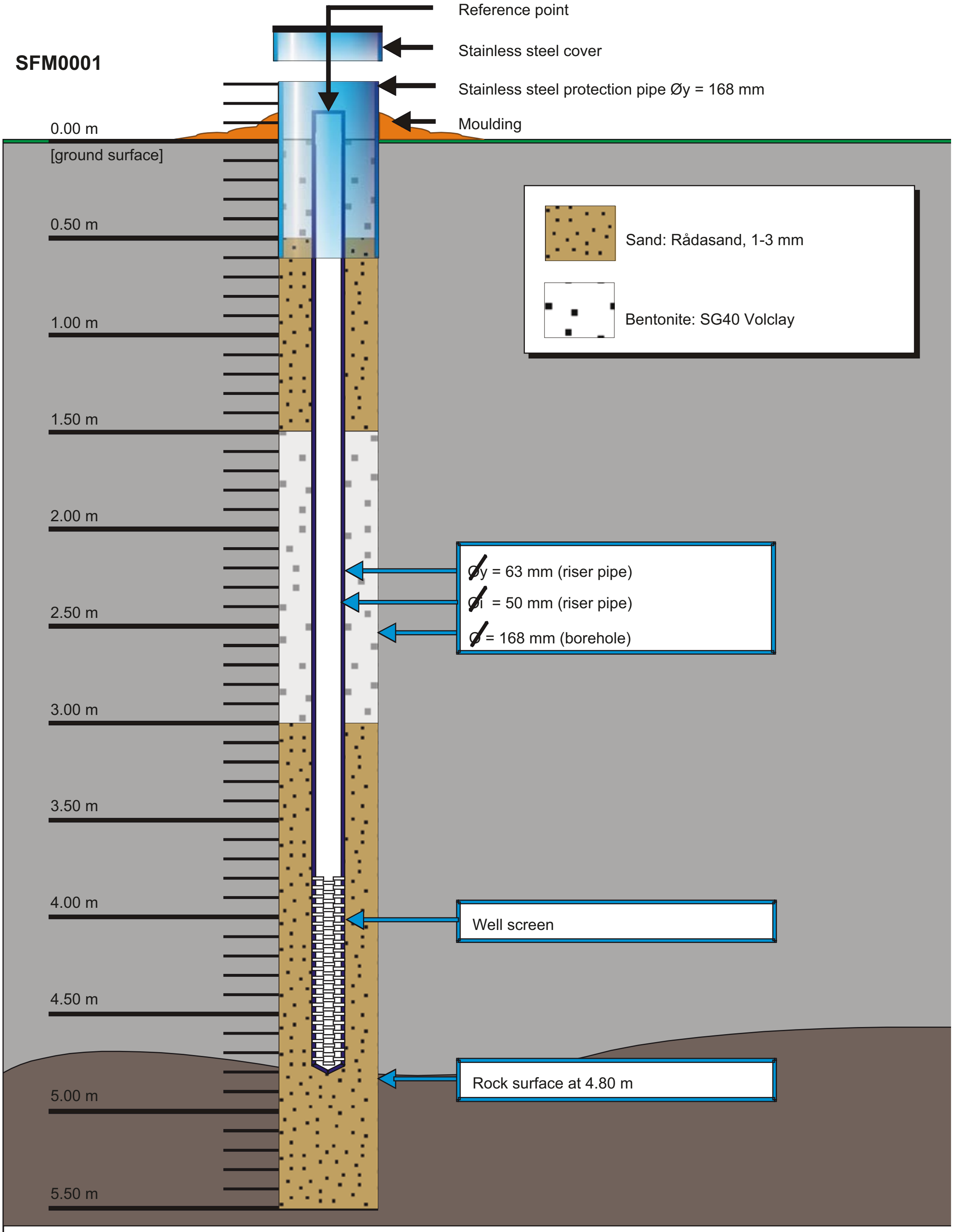
* The designs of the different types (A, B and C) of monitoring wells/stand pipes are presented in Figures A2-1 to A2-3. Typ D= BAT filter tip installation is described in section 4.3.

** Northing, easting and elevation for the reference point TOC (Top of Casing).

*** SECUP = length from TOC to filter/screen part of the pipe (upper section limit).

*** SECLOW = length from TOC to end of filter/screen part of the pipe (lower section limit).

**** Length/depth of casing/pipe from TOC.



Installation date:

2002-05-23

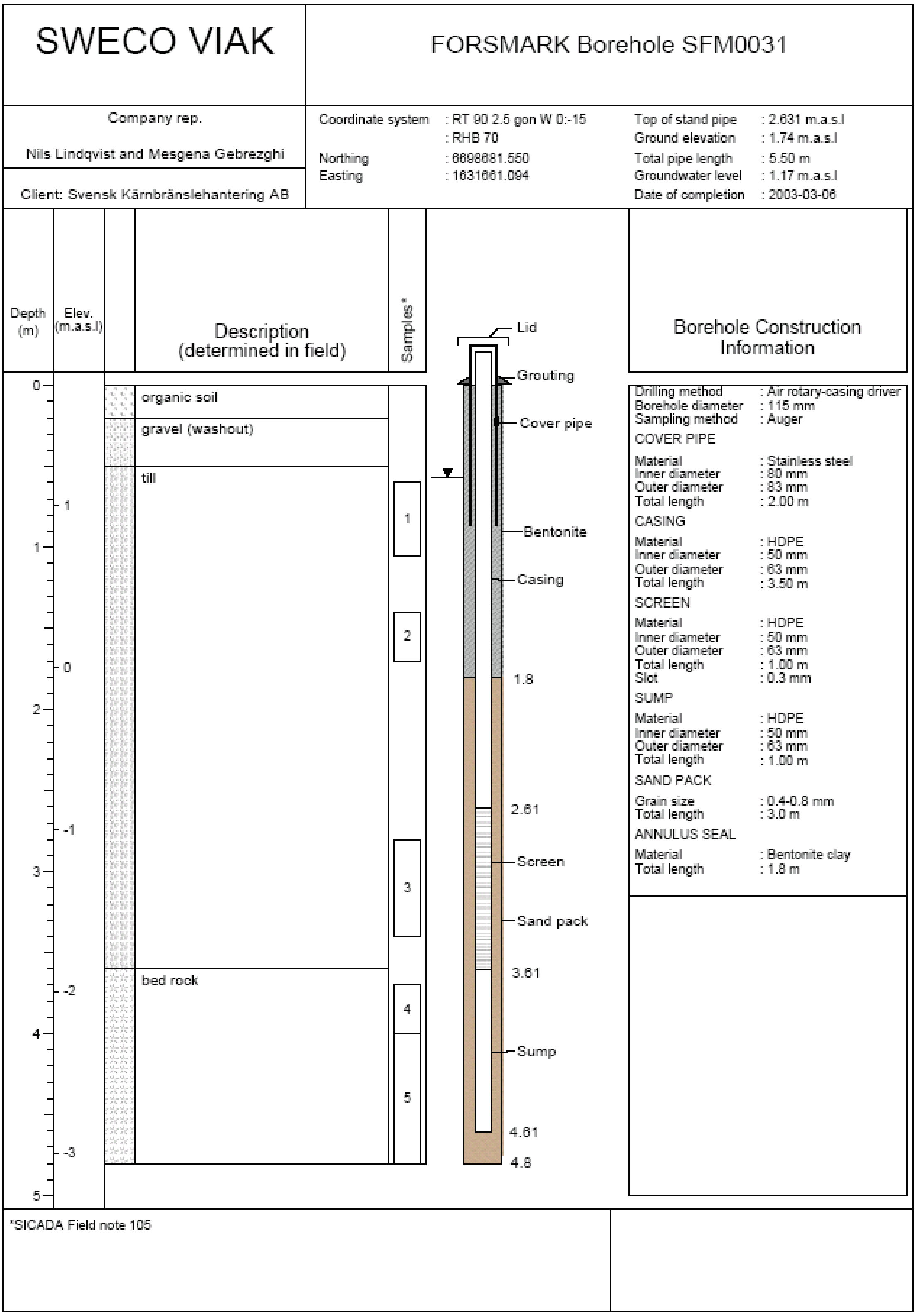
Reference point

Northing: 6699713.313 (m), RT90 2.5 gon V 0:-15

Easting: 1631335.440 (m), RT90 2.5 gon V 0:-15

Elevation: 1,104 (m), RHB 70

Figure A2-1. *Design of an A-type, drill site connected shallow soil monitoring well (e.g. SFM0001). The filter/screen section is placed at the bottom of the pipe. Note that all length information given in the database Sicada refers to the reference point as zero point.*



SWECO VIAK

FORSMARK Borehole SFM0031

Company rep.
Nils Lindqvist and Mesgena Gebrezghi

Client: Svensk Kärnbränslehantering AB

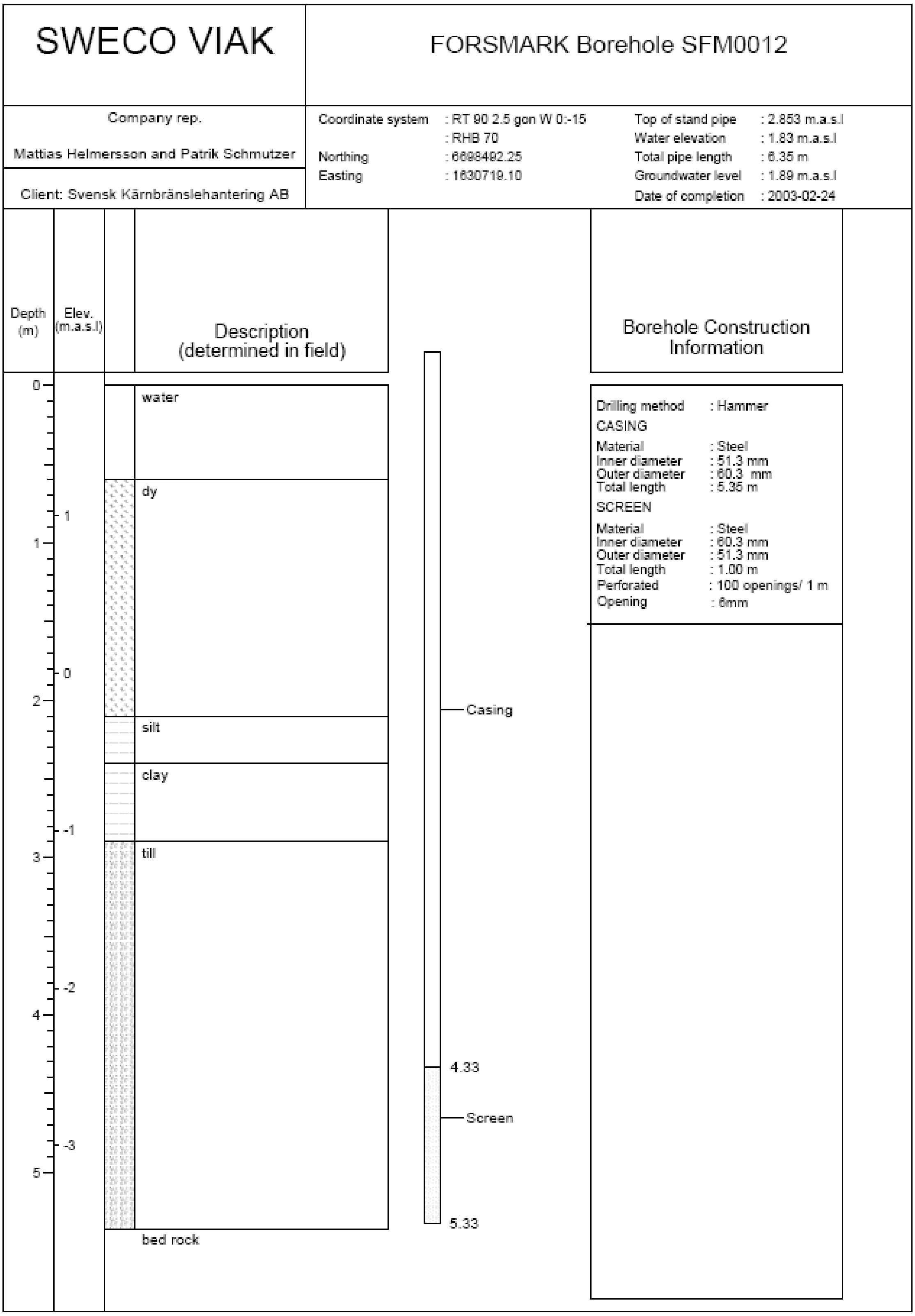
Coordinate system	: RT 90 2.5 gon W 0:-15 : RHB 70	Top of stand pipe	: 2.631 m.a.s.l
		Ground elevation	: 1.74 m.a.s.l
Northing	: 6698681.550	Total pipe length	: 5.50 m
Easting	: 1631661.094	Groundwater level	: 1.17 m.a.s.l
		Date of completion	: 2003-03-06

Borehole Construction Information

Drilling method	: Air rotary-casing driver
Borehole diameter	: 115 mm
Sampling method	: Auger
COVER PIPE	
Material	: Stainless steel
Inner diameter	: 80 mm
Outer diameter	: 83 mm
Total length	: 2.00 m
CASING	
Material	: HDPE
Inner diameter	: 50 mm
Outer diameter	: 63 mm
Total length	: 3.50 m
SCREEN	
Material	: HDPE
Inner diameter	: 50 mm
Outer diameter	: 63 mm
Total length	: 1.00 m
Slot	: 0.3 mm
SUMP	
Material	: HDPE
Inner diameter	: 50 mm
Outer diameter	: 63 mm
Total length	: 1.00 m
SAND PACK	
Grain size	: 0.4-0.8 mm
Total length	: 3.0 m
ANNULUS SEAL	
Material	: Bentonite clay
Total length	: 1.8 m

*SICADA Field note 105

***Figure A2-2.** Design of a B-type, double stand pipe for sampling of water. The filter section is placed one metre up from the bottom of the pipe. Note that all length information given in the database Sicada refers to Top Of Casing as zero point.*



SWECO VIAK

FORSMARK Borehole SFM0012

Company rep.
Mattias Helmersson and Patrik Schmutzer

Client: Svensk Kärnbränslehantering AB

Coordinate system : RT 90 2.5 gon W 0:-15
: RHB 70
Northing : 6698492.25
Easting : 1630719.10

Top of stand pipe : 2.853 m.a.s.l
Water elevation : 1.83 m.a.s.l
Total pipe length : 6.35 m
Groundwater level : 1.89 m.a.s.l
Date of completion : 2003-02-24

Borehole Construction Information

Drilling method : Hammer

CASING

Material : Steel
Inner diameter : 51.3 mm
Outer diameter : 60.3 mm
Total length : 5.35 m

SCREEN

Material : Steel
Inner diameter : 60.3 mm
Outer diameter : 51.3 mm
Total length : 1.00 m
Perforated : 100 openings/ 1 m
Opening : 6mm

Figure A2-3. Design of a C-type, stand pipe in sediment layer below open water. Note that all length information given in the database Sicada refers to Top Of Casing as zero point.

Table A2-2. Field measurements

Idcode	Start_date yyyy/mm/dd hh:mm	Stop_date yyyy/mm/dd hh:mm	Water temp. (°C)	pH	EC (mS/m)	Salinity (%)	ORP (mV)	O_2 diss. (mg/L)	Oxygen (%)
SFM0001	8/9/2007 9:17	8/9/2007 10:20	7.66	7.18	243.1	1.26	–129.00	0.80	6.7
SFM0001	10/10/2007 16:35	10/10/2007 16:52	8.46	7.13	296.3	1.55	–106.40	0.23	2.0
SFM0023	8/10/2007 9:45	8/10/2007 10:15	15.06	7.09	1,087.0	6.20	–213.00	1.12	11.6
SFM0023	10/12/2007 8:40	10/12/2007 9:05	11.98	7.38	1,073.0	6.10	–208.60	0.23	2.2
SFM0032	8/9/2007 20:00	8/9/2007 21:00	11.62	6.90	74.5	0.37	–137.00	0.61	5.6
SFM0032	10/11/2007 15:27	10/11/2007 15:47	9.67	7.03	77.9	0.38	–90.20	0.22	1.9
SFM0037	8/8/2007 17:10	8/8/2007 18:25	11.79	6.88	189.6	0.97	–100.00	0.92	8.6
SFM0037	10/10/2007 15:20	10/10/2007 15:55	9.59	7.07	145.2	0.73	–100.80	0.23	2.0
SFM0049	8/8/2007 10:50	8/8/2007 12:18	13.62	6.62	41.1	0.20	–142.00	0.63	6.0
SFM0049	10/10/2007 19:47	10/10/2007 20:07	10.71	6.76	38.1	0.18	–81.40	0.39	3.5
SFM0081	8/10/2007 9:00	8/10/2007 9:40	16.48	7.74	1,197.0	6.88	–295.00	0.69	7.4
SFM0081	10/10/2007 18:00	10/10/2007 18:29	11.25	7.62	1,199.0	6.87	–230.30	0.29	2.8
SFM0084	8/10/2007 16:30	8/10/2007 18:00	9.08	7.42	92.5	0.46	–171.00	0.37	3.2
SFM0084	10/12/2007 10:10	10/12/2007 10:47	8.54	7.46	109.1	0.54	–167.20	0.23	2.0
SFM0087	8/8/2007 13:34	8/8/2007 15:40	10.19	6.48	181.1	0.92	–167.00	2.35	21.1
SFM0087	10/9/2007 11:30	10/9/2007 12:03	9.50	6.57	176.6	0.90	–218.30	1.25	11.0
SFM0091	8/10/2007 14:40	8/10/2007 15:40	10.10	6.99	215.5	1.11	–245.00	0.58	5.2
SFM0091	10/11/2007 16:50	10/11/2007 17:20	7.72	6.84	219.7	1.13	–260.10	0.10	0.9
SFM0095	8/9/2007 15:20	8/9/2007 16:40	6.87	7.05	71.5	0.35	–135.00	0.48	3.9
SFM0095	10/9/2007 16:00	10/9/2007 16:29	6.60	6.99	72.1	0.35	–177.00	0.23	1.9

Table A2-3a. Water composition

Idcode	Secup m	Seclow m	Date yyyy-mm-dd	Sample No.	RCB %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO3 mg/L	Cl mg/L	SO4 mg/L	SO4-S mg/L	Br mg/l	F– mg/L	Si mg/L	Fe mg/L	Fe(tot) mg/L	Fe(+II) mg/L	Mn mg/L
SFM0001	3.80	4.80	8/9/2007	12836	–2.01	331	20.6	109	49.7	552	411	205	77.7	1.42	0.81	8.42	2.18	2.19	2.16	0.218
SFM0001	3.80	4.80	10/10/2007	12867	–0.13	445	27.8	118	66.4	677	520	272	91.2	1.81	0.62	8.83				
SFM0023	3.32	4.32	8/10/2007	12840	–4.07	1,410	62.4	503	159	174	3,500	332	128	13.0	0.95	4.67				
SFM0023	3.32	4.32	10/12/2007	12873	–0.90	1,570	70.1	468	158	136	3,500	320	117	12.4	0.78	4.33				
SFM0032	1.94	2.94	8/9/2007	12837	1.67	28.0	6.35	133	10.2	336	27.5	96.8	38.1	0.11	0.71	8.36	3.59	3.39	3.46	0.322
SFM0032	1.94	2.94	10/11/2007	12871	–0.59	23.5	4.88	118	8.3	262	24.4	142	45.3	0.13		7.50				
SFM0037	1.10	2.10	8/8/2007	12835	–1.79	209	12.8	157	32.3	499	298	171	65.2	0.74	0.78	7.87	1.24	1.43	1.41	0.245
SFM0037	1.10	2.10	10/10/2007	12868	–1.30	161	11.5	123	27.2	464	185	146	51.6	0.48	0.81	7.17				
SFM0049	2.90	3.90	8/8/2007	12833	**5.37**	14.4	3.66	70.8	5.4	213	22.3	2.3	1.94	0.05	0.38	4.41	1.17	1.16	1.14	0.144
SFM0049	2.90	3.90	10/10/2007	12870	1.85	14.3	3.05	60.2	4.7	197	20.4	3.5	1.99	0.08	0.31	4.32				
SFM0051	4.32	4.48	8/10/2007	12846	0.73	18.0	4.91	124	8.0	367	39.7	20.3	7.78	0.15	0.59	8.14	6.95	6.95	7.02	0.260
SFM0051	4.32	4.48	10/10/2007	12876	2.78	20.0	5.63	119	7.8	352	40.8	20.4	7.30	0.16	0.57	8.30	6.72	6.79	6.32	0.252
SFM0081	4.85	5.25	8/10/2007	12839	–2.34	1,800	78.1	325	261	169	3,940	398	153	14.1	1.35	4.46				
SFM0081	4.85	5.25	10/10/2007	12869	–0.66	1,920	85.5	289	242	133	3,930	380	135	13.2	1.12	3.04				
SFM0083	2.54	2.70	8/8/2007	12531	–2.88	233	12.6	65.6	34.5	268	450	23.9	7.04	1.50	0.34	17.0	0.021			0.092
SFM0083	2.54	2.70	10/9/2007	12530	**–8.41**	307	11.7	79.5	36.3	164	621	68.8	🟥	2.12	0.35	8.07				
SFM0084	3.70	4.10	8/10/2007	12842	–0.14	38.2	13.2	104	29.7	421	57.6	46.3	17.9	0.23	0.42	5.64				
SFM0084	3.70	4.10	10/12/2007	12874	0.74	54.5	15.1	117	29.3	446	91.5	42.4	15.0	0.35	0.41	7.52				
SFM0087	2.00	2.20	8/8/2007	12834	–1.13	191	20.3	110	61.0	795	230	1.9	🟥	0.96	0.45	15.1	0.236	0.288	0.302	0.552
SFM0087	2.00	2.20	10/9/2007	12865	–3.85	201	22.2	103	57.9	768	244	4.8	🟥	0.99	0.41	14.4				
SFM0091	1.90	2.30	8/10/2007	12841	–2.46	263	17.6	96.0	58.1	625	416	27.0	8.55	1.42	0.51	17.6				
SFM0091	1.90	2.30	10/11/2007	12872	**–6.24**	284	19.0	92.2	56.9	577	449	37.3	🟥	1.55	0.45	16.8				
SFM0095	5.00	6.00	8/9/2007	12838	–1.50	28.2	8.01	89.9	28.1	507	4.5	9.5	3.77	0.04	0.39	15.1	5.49	5.54	5.15	0.442
SFM0095	5.00	6.00	10/9/2007	12866	–1.81	31.9	8.58	84.2	27.6	496	4.0	3.6	1.95	0.09	0.35	14.1				
SFM0102	2.09	2.25	8/9/2007	12532		3.1	1.58	15.3	2.9		6.0	–0.2	1.68	0.05	–0.20	4.94	0.362			0.038
SFM0102	2.09	2.25	10/9/2007	12875		3.0	1.23	14.2	2.7		5.9	–0.2	1.57	0.08	–0.20	4.78				

🟥 rejected due to erroneously high values

< "value" = result below detection or reporting limit

RCB % = Relative charge balance error %

EC = Electrical Conductivity

SICADA: water_composition

Table A2-3a. Water composition

Idcode	Secup m	Seclow m	Date yyyy-mm-dd	Sample No.	Li mg/L	Sr mg/L	pH (lab)	EC (lab) mS/m	HS^- mg/L	I^- mg/L
SFM0001	3.80	4.80	8/9/2007	12836	0.021	0.439	7.13	245	0.050	0.011
SFM0001	3.80	4.80	10/10/2007	12867	0.025	0.577	7.13	297		
SFM0023	3.32	4.32	8/10/2007	12840	0.057	3.44	6.93	1,090		0.050
SFM0023	3.32	4.32	10/12/2007	12873	0.058	3.53	6.98	1,060		
SFM0032	1.94	2.94	8/9/2007	12837	0.008	0.235	6.88	77.4	0.110	0.007
SFM0032	1.94	2.94	10/11/2007	12871	0.011	0.200	6.89	74.3		
SFM0037	1.10	2.10	8/8/2007	12835	0.017	0.395	6.92	194	0.025	0.005
SFM0037	1.10	2.10	10/10/2007	12868	0.014	0.339	7.01	148		
SFM0049	2.90	3.90	8/8/2007	12833	0.003	0.093	6.69	42.1	0.199	0.004
SFM0049	2.90	3.90	10/10/2007	12870	0.004	0.081	6.81	38.9		
SFM0051	4.32	4.48	8/10/2007	12846	0.008	0.175	7.08	69.8		0.009
SFM0051	4.32	4.48	10/10/2007	12876	0.005	0.176	7.16	69.0		
SFM0081	4.85	5.25	8/10/2007	12839	0.054	2.83	7.07	1,210		0.050
SFM0081	4.85	5.25	10/10/2007	12869	0.053	2.80	6.74	1,190		
SFM0083	2.54	2.70	8/8/2007	12531	0.008	0.292	6.85	186		0.019
SFM0083	2.54	2.70	10/9/2007	12530	0.009	0.397	6.92	223		
SFM0084	3.70	4.10	8/10/2007	12842	0.011	0.415	7.36	93.1		0.009
SFM0084	3.70	4.10	10/12/2007	12874	0.013	0.451	7.12	103		
SFM0087	2.00	2.20	8/8/2007	12834	0.021	0.586	6.73	185		0.026
SFM0087	2.00	2.20	10/9/2007	12865	0.023	0.574	6.68	179		
SFM0091	1.90	2.30	8/10/2007	12841	0.023	0.536	7.08	216		0.014
SFM0091	1.90	2.30	10/11/2007	12872	0.023	0.546	6.99	219		
SFM0095	5.00	6.00	8/9/2007	12838	0.011	0.336	6.92	72.5	0.185	0.012
SFM0095	5.00	6.00	10/9/2007	12866	0.012	0.339	6.95	72.2		
SFM0102	2.09	2.25	8/9/2007	12532	0.002	0.037	4.31	9.8		0.017
SFM0102	2.09	2.25	10/9/2007	12875	–0.004	0.037	4.42	9.7		

🟥 rejected due to erroneously high values

< "value" = result below detection or reporting limit

RCB % = Relative charge balance error %

EC = Electrical Conductivity

SICADA: water_composition

Table A2-3b. Drinking water

Id code		PFM000001	PFM000009	PFM006382
Date	yyyy/mm/dd	10/11/2007	10/11/2007	10/11/2007
Kbact	no/100mL	1	< 1	3
Microbes	no/100mL	2,200	44	120
Ecoli	no/100mL	1	< 1	< 1
Temp.	_Field	–	–	–
Smell	_Lab	No smell	No smell	No smell
Colour	(number)	82	62	89
pH_L		7.2	7.4	7.1
Temp_pH	(°C)	25	25	25
Alk	mg/L	680	64	360
EC_L	mS/m	123	1,300	245
Ca	mg/L	190	780	230
Cl	mg/L	55	5,300	690
COD	mg/L	7.6	–	–
Cu	mg/L	< 0.02	< 0.02	< 0.02
F	mg/L	0.8	1	0.58
Fe	mg/L	1.7	2.8	1.8
Hardness	_German	34	151	40
K	mg/L	48	28	13
Mg	mg/L	32	180	36
Mn	mg/L	0.22	0.86	0.14
Na	mg/L	40	1,800	290
NH_4_N	mg/L	5.9	1.5	0.033
NH_4	mg/L	7.6	1.9	0.042
NO_3_N	mg/L	< 0.1	< 0.1	< 0.1
NO_3	mg/L	< 0.44	< 0.44	< 0.44
NO_2_N	mg/L	< 0.002	< 0.002	< 0.002
NO_2	mg/L	< 0.007	< 0.007	< 0.007
PO_4_P	mg/L	< 0.005	< 0.005	< 0.005
PO_4	mg/L	< 0.02	< 0.02	< 0.02
SO_4	mg/L	110	320	160

Explanations:

Kbact	Number of coliform bacteria
Ecoli	Number of escherichia coli bacteria at 35 °C
Sediment	Ocular inspection of sediment
EC_L	Electrical conductivity

Table A2-3c. Surface water supplements

Id code	Secup m	Seclow m	Date	Sample No.	NH_4-N mg/L	NO_2-N mg/L	NO_3-N+NO_2-N mg/L	NO_3-N mg/L	N-tot mg/L	P-tot mg/L	PO4-P mg/L	SiO_4-Si mg/L	TOC mg/L	DOC mg/L	DIC mg/L
SFM0001	3.80	4.80	8/9/2007	12836	0.271	0.0004	0.0008	0.0003	1.050	0.046	0.0353	7.58	24.6	24.4	99.3
SFM0001	3.80	4.80	10/10/2007	12867	0.379		0.0015		1.170	0.051	0.0090	8.32	22.8	22.9	124
SFM0023	3.32	4.32	8/10/2007	12840	2.63	0.0060	0.0089	0.0030	2.740	0.014	0.0020	3.14	4.20	5.00	21.7
SFM0023	3.32	4.32	10/12/2007	12873	2.71		0.0006		2.690	0.005	0.0005	2.85	3.60	3.80	14.9
SFM0032	1.94	2.94	8/9/2007	12837	0.0374	–0.0002	0.0004	0.0003	0.679	0.014	0.0023	7.56	20.9	21.1	61.4
SFM0032	1.94	2.94	10/11/2007	12871	0.0273		0.0009		0.898	0.014	0.0077	7.33	26.5	26.9	48.9
SFM0037	1.10	2.10	8/8/2007	12835	0.0174	0.0003	0.0018	0.0014	0.792	0.066	0.0045	7.18	22.9	22.0	91.0
SFM0037	1.10	2.10	10/10/2007	12868	0.0190		0.0033		1.270	0.111	0.0044	6.97	30.2	29.2	86.7
SFM0049	2.90	3.90	8/8/2007	12833	0.131	0.0004	0.0013	0.0009	0.834	0.016	0.0090	4.10	23.3	23.5	44.4
SFM0049	2.90	3.90	10/10/2007	12870	0.126		0.0009		0.716	0.014	0.0105	4.18	19.5	19.4	43.4
SFM0081	4.85	5.25	8/10/2007	12839	2.18	–0.0002	–0.0003	–0.0003	2.310	0.009	0.0006	3.15	3.70	6.20	22.9
SFM0081	4.85	5.25	10/10/2007	12869	2.11		–0.0003		2.180	0.018	0.0005	1.89	3.10	3.70	19.3
SFM0083	2.54	2.70	8/8/2007	12531	4.29	–0.0002	0.0021	0.0020	5.250	0.021	0.0016	14.8	17.1	15.5	45.9
SFM0083	2.54	2.70	10/9/2007	12530	2.25	0.0002	–0.0003	–0.0003	3.180	0.019	0.0012	7.62	14.1	14.1	27.0
SFM0084	3.70	4.10	8/10/2007	12842	0.217	–0.0002	0.0007	0.0007	0.779	0.770	–0.0005	2.95	14.0	15.2	77.1
SFM0084	3.70	4.10	10/12/2007	12874	0.282		0.0066		0.864	1.500	0.0009	6.63	13.6	16.4	69.0
SFM0087	2.00	2.20	8/8/2007	12834	0.00470	–0.0002	0.0010	0.0009	0.741	0.066	0.0538	13.5	19.7	19.7	145
SFM0087	2.00	2.20	10/9/2007	12865	0.00480		0.0005		0.803	0.067	0.0558	13.8	19.9	19.8	150
SFM0091	1.90	2.30	8/10/2007	12841	0.0492	–0.0002	0.0009	0.0009	0.520	0.099	0.0029	15.7	13.9	14.4	112
SFM0091	1.90	2.30	10/11/2007	12872	0.0557		0.0005		0.601	0.102	0.0061	16.0	10.8	14.2	96.8
SFM0095	5.00	6.00	8/9/2007	12838	1.73	–0.0002	0.0005	0.0004	2.00	0.143	0.0228	13.7	20.0	20.3	84.2
SFM0095	5.00	6.00	10/9/2007	12866	1.64		0.0009		1.92	0.127	0.0176	13.5	18.6	19.4	88.7
SFM0102	2.09	2.25	8/9/2007	12532	0.145	0.0011	0.0061	0.0051	2.96	0.116	0.0177	4.56	125	125	12.6
SFM0102	2.09	2.25	10/9/2007	12875	0.130		0.0032		2.98	0.114	0.0152	4.56	138	132	5.80

< “value” = below reporting limit

x = No result due to analytical problems

SICADA: biochemistry_supplements

Table A2-3d. Isotops I

Id code	Secup m	Seclow m	Date yyyy-mm-dd	Sample No.	$^{10}B/^{11}B$	δ D (‰ SMOW)	Tritium (TU)	$\delta^{18}O$ (‰ SMOW)
SFM0001	3.80	4.80	8/9/2007	12836	0.2374	–76.3	11.4	–10.5
SFM0001	3.80	4.80	10/10/2007	12867		–74.6	10.2	–10.1
SFM0023	3.32	4.32	8/10/2007	12840		–67.5	4.0	–8.8
SFM0023	3.32	4.32	10/12/2007	12873		–69.5	4.0	–8.6
SFM0032	1.94	2.94	8/9/2007	12837	0.2419	–78.8	12.0	–11.0
SFM0032	1.94	2.94	10/11/2007	12871		–75.7	10.1	–10.6
SFM0037	1.10	2.10	8/8/2007	12835	0.2399	–70.1	12.0	–9.6
SFM0037	1.10	2.10	10/10/2007	12868		–73.1	10.4	–10.2
SFM0049	2.90	3.90	8/8/2007	12833	0.2413	–69.6	12.2	–8.7
SFM0049	2.90	3.90	10/10/2007	12870		–71.2	11.9	–8.9
SFM0051	4.32	4.48	8/10/2007	12846	0.2465	–86.9	9.1	–12.9
SFM0051	4.32	4.48	10/10/2007	12876		–88.2	10.1	–12.1
SFM0081	4.85	5.25	8/10/2007	12839		–64.6	2.8	–8.2
SFM0081	4.85	5.25	10/10/2007	12869		–65.5	1.7	–8.2
SFM0083	2.54	2.70	8/8/2007	12531	0.2405	–57.7	8.5	–6.5
SFM0083	2.54	2.70	10/9/2007	12530		–48.6	10.8	–5.0

A: Results to be reported

SICADA: Isotopes_1

Table A2-3e. Trace metals I

IDCODE	Secup m	Seclow m	Date	Sample No.	Al µg/L	As µg/L	Cd µg/L	Cr µg/L	Cu µg/L	Co µg/L	Hg µg/L	Ni µg/L	Zn µg/L	Pb µg/L	V µg/L	Mo µg/L	Ba µg/L
SFM0001	3.80	4.80	8/9/2007	12836	31.7		0.0123	0.303	0.195	0.313	–0.002	1.39	2.34	0.304	1.72	1.46	63.4
SFM0032	1.94	2.94	8/9/2007	12837	24.3		0.0062	0.358	–0.1	0.093	–0.002	0.616	0.365	0.0308	2.13	2.85	63.2
SFM0037	1.10	2.10	8/8/2007	12835	51.5		0.0482	0.475	2.24	0.416	–0.002	2.56	3.56	0.566	4.47	2.94	121
SFM0049	2.90	3.90	8/8/2007	12833	731		0.0091	0.315	0.179	0.167	0.003	0.478	26.3	0.412	1.38	0.095	35.9
SFM0051	4.32	4.48	8/10/2007	12846	120		0.0186	2.16	2.81	0.210	–0.002	1.99	9.68	0.631	2.73	1.04	89.3
SFM0051	4.32	4.48	10/11/2007	12876	80.9	1.9	0.0047	1.15	0.840	0.099	–0.002	1.08	2.91	0.214	2.40	1.12	91.7
SFM0083	2.54	2.70	8/9/2007	12531	73.1		0.0022	0.359	0.114	0.065	–0.002	0.882	2.14	5.52	0.300	–0.05	51.2
SFM0087	2.00	2.20	8/8/2007	12834	80.3		0.0063	0.471	–0.1	0.102	–0.002	0.213	2.38	0.162	3.26	–0.05	129
SFM0095	5.00	6.00	8/9/2007	12838	9.7		0.0047	0.270	–0.1	0.089	–0.002	0.170	0.606	0.0114	1.67	0.266	93.3
SFM0102	2.09	2.25	8/9/2007	12532	189		0.0637	0.477	48.9	0.521	0.005	13.8	124	2.84	0.380	0.062	10.6

< “value” = below reporting limit

SICADA: trace_elements_1

Table A2-3f. Trace metals II

Idcode	Secup m	Seclow m	Date yyyy/mm/dd	Sample No.	U µg/L	Th µg/L	Sc µg/L	Rb µg/L	Y µg/L	Zr µg/L	Sb µg/L	Cs µg/L	La µg/L	Hf µg/L	Tl µg/L	Ce µg/L
SFM0001	3.80	4.80	8/9/2007	12836	5.00	0.149	0.0921	4.91	1.69	5.79	0.0630	–0.03	1.42	0.0933	–0.05	3.62
SFM0032	1.94	2.94	8/9/2007	12837	4.13	0.140	0.0776	2.09	2.45	4.11	0.0532	–0.03	2.07	0.0758	–0.005	2.56
SFM0037	1.10	2.10	8/8/2007	12835	28.3	0.183	0.152	8.23	2.87	5.78	0.133	–0.03	2.09	0.1100	–0.05	3.61
SFM0049	2.90	3.90	8/8/2007	12833	0.323	0.160	0.0999	5.46	1.00	0.514	0.0388	–0.03	1.99	0.0164	–0.005	3.57
SFM0051	4.32	4.48	8/10/2007	12846	0.736	0.142	0.102	1.41	0.822	5.99	0.0336	–0.03	0.461	0.0788	–0.005	0.945
SFM0051	4.32	4.48	10/10/2007	12876	0.885	0.0558	0.0855	1.57	0.782	5.54	0.0434	0.0368	0.351	0.0767	–0.005	0.704
SFM0083	2.54	2.70	8/8/2007	12531	0.125	–0.02	–0.05	7.56	0.236	0.293	0.0203	–0.03	0.241	0.0063	–0.005	0.375
SFM0087	2.00	2.20	8/8/2007	12834	0.0344	0.0210	–0.05	4.65	0.448	1.51	0.0142	–0.03	0.194	0.0288	–0.005	0.299
SFM0095	5.00	6.00	8/9/2007	12838	1.29	0.0570	–0.05	1.74	1.30	3.20	0.0147	–0.03	0.288	0.0433	–0.005	0.525
SFM0102	2.09	2.25	8/9/2007	12532	0.0181	–0.02	–0.05	1.75	0.0690	0.190	0.0929	0.0311	0.0585	–0.005	–0.005	0.149

< "value" = below reporting limit

SICADA: trace_elements_2

Table A2-3f. Trace metals II

Idcode	Secup m	Seclow m	Date yyyy/mm/dd	Sample No.	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	Yb µg/L	Lu µg/L
SFM0001	3.80	4.80	8/9/2007	12836	0.307	1.29	0.256	0.0282	0.275	0.0359	0.242	0.0479	0.159	0.0199	0.144	0.0217
SFM0032	1.94	2.94	8/9/2007	12837	0.448	1.83	0.310	0.0403	0.347	0.0450	0.304	0.0600	0.200	0.0272	0.187	0.0295
SFM0037	1.10	2.10	8/8/2007	12835	0.475	1.99	0.393	0.0441	0.423	0.0595	0.408	0.0855	0.286	0.0401	0.282	0.0417
SFM0049	2.90	3.90	8/8/2007	12833	0.421	1.60	0.287	0.0348	0.246	0.0323	0.199	0.0358	0.107	0.0136	0.0921	0.0120
SFM0051	4.32	4.48	8/10/2007	12846	0.105	0.469	0.102	0.0125	0.111	0.0155	0.110	0.0238	0.0830	0.0135	0.117	0.0252
SFM0051	4.32	4.48	10/10/2007	12876	0.0966	0.378	0.0868	0.0070	0.0950	0.0139	0.0999	0.0258	0.0822	0.0149	0.109	0.0220
SFM0083	2.54	2.70	8/8/2007	12531	0.0553	0.230	0.0437	–0.005	0.0431	0.0058	0.0500	0.0071	0.0217	–0.005	0.0206	–0.005
SFM0087	2.00	2.20	8/8/2007	12834	0.0442	0.205	0.0464	–0.005	0.0600	0.0077	0.0552	0.0117	0.0415	0.0058	0.0453	0.0070
SFM0095	5.00	6.00	8/9/2007	12838	0.0670	0.317	0.0767	0.0088	0.109	0.0176	0.130	0.0323	0.117	0.0182	0.135	0.0235
SFM0102	2.09	2.25	8/9/2007	12532	0.0196	0.0858	0.0164	–0.005	0.0155	–0.005	0.0174	–0.005	0.0066	–0.005	0.0065	–0.005

< "value" = below reporting limit

SICADA: trace_elements_2

Appendix 3

Surface waters

Table A3-1. Field measurements

Idcode	Start date	Stop date	Measured depth (m)	Water depth (m)	Sno	Temp. (º C)	pH	EC (mS/m)	Salinity (per mill)	Turb* (NTU)	Light (µmol/m²s)	O_2 diss. (mg/l)	Chlorophyll (ug/l)	ORP (mV)	Atm. Pressure (hPa)
PFM000062	2007/08/06 08:00:00	2007/08/06 20:00:00	0.5	4.0	12826	17.1	8.09	896	5.04	–0.3	1,325	10.9	0.4	125	
PFM000062	2007/08/06 08:00:00	2007/08/06 20:00:00	1.0	4.0		17.0	8.09	897	5.04	–0.1	1,106	10.1	0.9	126	
PFM000062	2007/08/06 08:00:00	2007/08/06 20:00:00	2.0	4.0		16.9	8.10	898	5.04	–0.4	443	10.0	2.2	126	
PFM000062	2007/08/06 08:00:00	2007/08/06 20:00:00	3.0	4.0		16.9	8.10	898	5.05	–0.4	258	10.0	2.2	127	
PFM000062	2007/09/03 08:00:00	2007/09/03 18:00:00	0.5	4.0	12832	14.5	8.18	901	5.07	–0.2	672	10.0	1.2	202	
PFM000062	2007/09/03 08:00:00	2007/09/03 18:00:00	1.0	4.0		14.5	8.19	907	5.10	–0.2	149	10.0	1.5	198	
PFM000062	2007/09/03 08:00:00	2007/09/03 18:00:00	2.0	4.0		14.5	8.20	908	5.11	–0.4	408	10.0	1.7	195	
PFM000062	2007/09/03 08:00:00	2007/09/03 18:00:00	3.0	4.0		14.5	8.20	908	5.11	–0.2	218	10.0	1.9	192	
PFM000062	2007/10/08 09:00:00	2007/10/08 20:00:00	0.5	4.0	12862	11.6	7.92	908	5.10	–0.5	292	10.4	1.2	197	1,007.4
PFM000062	2007/10/08 09:00:00	2007/10/08 20:00:00	1.0	4.0		11.6	7.93	909	5.11	–0.6	238	10.4	1.1	194	1,007.9
PFM000062	2007/10/08 09:00:00	2007/10/08 20:00:00	2.0	4.0		11.6	7.93	909	5.11	–0.6	164	10.4	1.7	193	1,008.4
PFM000062	2007/10/08 09:00:00	2007/10/08 20:00:00	3.0	4.0		11.6	7.94	910	5.11	–0.6	127	10.4	2.2	189	1,009.0
PFM000062	2007/11/05 08:30:00	2007/11/05 19:30:00	0.5	3.9	12907	7.0	7.88	898	5.01	–0.4	151	12.1	1.8	200	1,019.4
PFM000062	2007/11/05 08:30:00	2007/11/05 19:30:00	1.0	3.9		7.0	7.90	904	5.05	–0.4	113	12.1	2.1	196	1,019.7
PFM000062	2007/11/05 08:30:00	2007/11/05 19:30:00	2.0	3.9		7.0	7.90	904	5.04	–0.6	61	12.1	2.5	194	1,019.8
PFM000062	2007/11/05 08:30:00	2007/11/05 19:30:00	3.0	3.9		7.0	7.90	904	5.05	–0.4	35	12.1	2.1	192	1,020.1
PFM000062	2007/12/03 09:00:00	2007/12/03 18:00:00	0.5	4.0	12916	3.1	7.75	916	5.06	0.1	35	13.3	0.8	207	977.3
PFM000062	2007/12/03 09:00:00	2007/12/03 18:00:00	1.0	4.0		3.1	7.76	916	5.06	–0.1	26	13.3	1.2	205	977.2
PFM000062	2007/12/03 09:00:00	2007/12/03 18:00:00	2.0	4.0		3.1	7.76	917	5.06	0.0	13	13.3	1.4	204	977.4
PFM000062	2007/12/03 09:00:00	2007/12/03 18:00:00	3.0	4.0		3.1	7.77	917	5.06	–0.1	8	13.3	0.9	202	977.6
PFM000066	2007/11/05 08:30:00	2007/11/05 19:30:00	0.2	0.2	12906	2.8	7.39	44	0.21			7.7		106	1,011.2
PFM000066	2007/12/03 09:00:00	2007/12/03 18:00:00	0.2	0.2	12922	1.8	7.44	34	0.16			10.0		121	977.1
PFM000068	2007/08/07 07:00:00	2007/08/07 17:00:00	0.2	0.3	12830	16.1	7.27	51	0.25			1.1		25	
PFM000068	2007/10/08 09:00:00	2007/10/08 20:00:00	0.5	0.5	12864	7.6	7.41	50	0.24			5.3		115	1,011.9
PFM000068	2007/11/05 08:30:00	2007/11/05 19:30:00	0.3	0.4	12909	2.6	7.42	45	0.21			9.4		79	1,011.5
PFM000068	2007/12/03 09:00:00	2007/12/03 18:00:00	0.4	0.5	12921	2.5	7.28	43	0.21			8.9		77	977.6
PFM000069	2007/10/08 09:00:00	2007/10/08 20:00:00	0.3	0.1	12858	7.4	7.57	50	0.24			8.3		99	1,011.6
PFM000069	2007/11/05 08:30:00	2007/11/05 19:30:00	0.2	0.2	12861	2.6	7.39	45	0.22			9.9		86	1,012.2
PFM000069	2007/12/03 09:00:00	2007/12/03 18:00:00	0.3	0.3	12919	2.3	7.25	49	0.23			7.4		91	977.7
PFM000070	2007/11/05 08:30:00	2007/11/05 19:30:00	0.1	0.1	12908	3.0	7.37	26	0.13			8.5		–68	1,012.8
PFM000070	2007/12/03 09:00:00	2007/12/03 18:00:00	0.2	0.2	12923	1.7	7.59	25	0.12			10.5		174	977.4
PFM000074	2007/08/07 07:00:00	2007/08/07 17:00:00	0.5	0.6	12828	21.3	7.72	42	0.20	0.0	536	10.4	6.0	67	
PFM000074	2007/09/04 07:00:00	2007/09/04 15:00:00	0.4	0.5	12851	12.3	8.02	40	0.19	–1.1	114	9.4	5.2	229	
PFM000074	2007/10/09 07:00:00	2007/10/09 15:00:00	0.5	0.7	12857	6.4	7.85	42	0.20	11.8	407	9.7	6.8	43	1,020.5

Table A3-1. Field measurements

Idcode	Start date	Stop date	Measured depth (m)	Water depth (m)	Sno	Temp. (º C)	pH	EC (mS/m)	Salinity (per mill)	Turb* (NTU)	Light (µmol/m²s)	O_2 diss. (mg/l)	Chlorophyll (ug/l)	ORP (mV)	Atm. Pressure (hPa)
PFM000074	2007/11/06 07:00:00	2007/11/06 15:00:00	0.5	0.7	12910	3.4	7.96	41	0.20	0.8	11	12.8	9.2	123	997.8
PFM000097	2007/08/07 07:00:00	2007/08/07 17:00:00	0.5	0.6		21.6	8.75	230	1.18	–0.3	401	9.2	2.0	106	
PFM000097	2007/09/04 07:00:00	2007/09/04 15:00:00	0.5	0.6		12.0	8.76	256	1.33	–0.6	103	9.5	2.4	196	
PFM000097	2007/10/09 07:00:00	2007/10/09 15:00:00	0.5	0.7		6.0	7.76	382	2.01	0.2	76	11.1	3.4	–90	1,016.5
PFM000107	2007/08/06 08:00:00	2007/08/06 20:00:00	0.5	1.7	12827	22.7	9.45	189	0.96	–0.8	591	11.8	1.3	118	
PFM000107	2007/08/06 08:00:00	2007/08/06 20:00:00	1.0	1.7		21.5	9.54	193	0.98	–1.1	254	13.6	0.7	129	
PFM000107	2007/09/03 08:00:00	2007/09/03 18:00:00	0.5	1.7	12848	14.4	9.57	222	1.15	–1.0	89	12.2	1.0	184	
PFM000107	2007/09/03 08:00:00	2007/09/03 18:00:00	1.0	1.7		14.4	9.57	222	1.15	–1.1	55	12.2	0.9	179	
PFM000107	2007/10/08 09:00:00	2007/10/08 20:00:00	0.5	1.7	12859	9.2	8.02	249	1.29	–1.0	547	10.5	1.3	246	1,010.7
PFM000107	2007/10/08 09:00:00	2007/10/08 20:00:00	1.0	1.7		9.2	8.04	249	1.29	–1.1	392	10.7	1.5	243	1,011.2
PFM000107	2007/11/05 08:30:00	2007/11/05 19:30:00	0.5	1.8	12860	2.6	8.04	251	1.28	–1.3	67	13.9	2.0	252	1,016.8
PFM000107	2007/11/05 08:30:00	2007/11/05 19:30:00	1.0	1.8		2.6	8.04	251	1.28	–1.3	49	13.8	1.9	250	1,016.9
PFM000117	2007/08/06 08:00:00	2007/08/06 20:00:00	0.5	2.0	12825	23.3	8.89	20	0.10	0.0	431	11.0	1.8	130	
PFM000117	2007/08/06 08:00:00	2007/08/06 20:00:00	1.0	2.0		23.2	8.91	20	0.10	–0.3	224	10.9	2.6	135	
PFM000117	2007/08/06 08:00:00	2007/08/06 20:00:00	1.5	2.0		21.3	9.01	20	0.09	–0.7	296	12.4	0.4	138	
PFM000117	2007/09/03 08:00:00	2007/09/03 18:00:00	0.5	2.1	12847	14.6	9.05	21	0.10	–0.7	130	11.5	1.7	200	
PFM000117	2007/09/03 08:00:00	2007/09/03 18:00:00	1.0	2.1		14.7	9.04	21	0.10	–0.7	81	11.5	1.7	198	
PFM000117	2007/09/03 08:00:00	2007/09/03 18:00:00	1.5	2.1		14.6	9.04	21	0.10	–0.5	60	11.5	1.3	197	
PFM000117	2007/10/08 09:00:00	2007/10/08 20:00:00	0.5	2.0	12863	9.6	8.43	22	0.11	–0.8	130	11.1	3.1	169	1,010.4
PFM000117	2007/10/08 09:00:00	2007/10/08 20:00:00	1.0	2.0		9.6	8.43	22	0.11	–0.9	88	11.1	2.4	167	1,010.7
PFM000117	2007/10/08 09:00:00	2007/10/08 20:00:00	1.5	2.0		9.6	8.44	22	0.11	–0.8	57	11.1	1.7	165	1,010.8
PFM000117	2007/11/05 08:30:00	2007/11/05 19:30:00	0.5	2.1	12905	2.7	8.37	24	0.11	–1.1	6	13.8	3.8	315	1,014.7
PFM000117	2007/11/05 08:30:00	2007/11/05 19:30:00	1.0	2.1		2.7	8.36	24	0.11	–1.1	3	13.8	3.3	313	1,014.8
PFM000117	2007/11/05 08:30:00	2007/11/05 19:30:00	1.5	2.1		2.7	8.37	24	0.11	–1.1	2	13.8	3.5	310	1,015.0
PFM102269	2007/08/07 07:00:00	2007/08/07 17:00:00	0.5		12824	28.7	8.09	908	5.05	–0.8	1061	9.3	–0.3	125	
PFM102269	2007/09/04 07:00:00	2007/09/04 15:00:00	0.5		12852	24.1	8.16	907	5.07	–0.6	352	8.8	1.5	211	
PFM102269	2007/10/09 07:00:00	2007/10/09 15:00:00	0.5		12877	21.0	7.97	908	5.09	–0.5	635	9.8	1.3	123	1,020.7
PFM102269	2007/11/06 07:00:00	2007/11/06 15:00:00	0.5		12894	16.9	7.91	890	5.00	–0.8	43	11.1	1.1	156	999.1
PFM102269	2007/12/04 07:00:00	2007/12/04 15:00:00	0.5		12915	13.2	7.85	897	5.04	–0.6	19	12.4	1.2	185	990.9

Sno = Corresponding water sample no

NTU = Nephelometric Turbidiy Unit

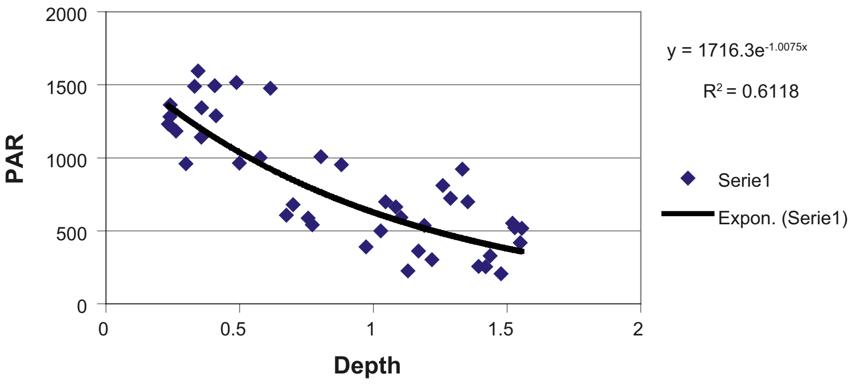
* Measurements with low reliability

EC = Electrical conductivity

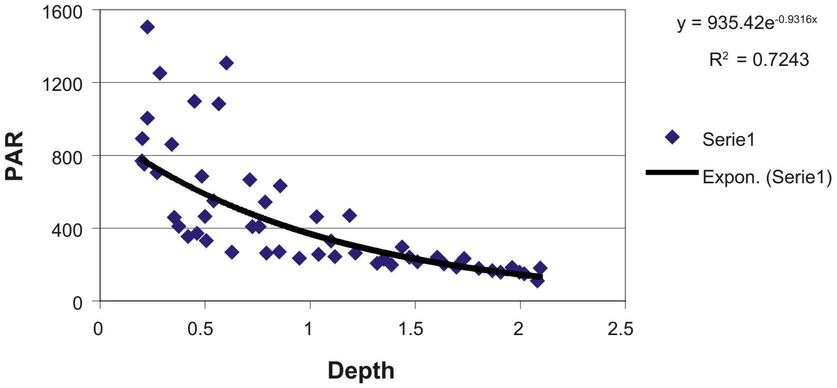
ORP = Oxidising Reducing Potential

Table A3-2. PAR-profil logs

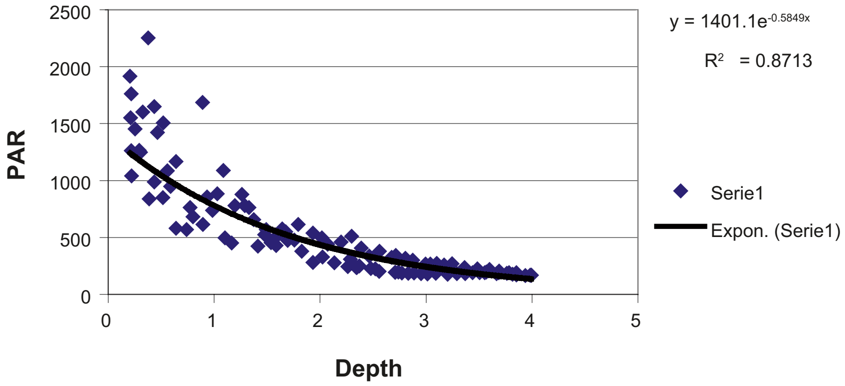
PAR vs Depth: PFM 107, v 32-07

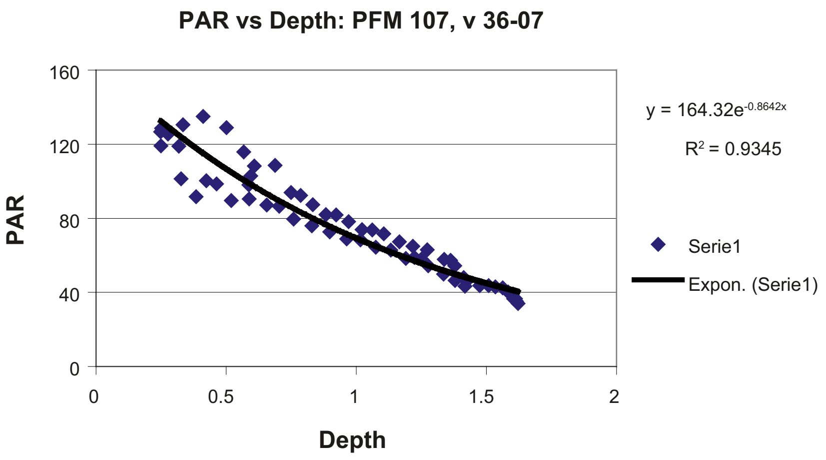


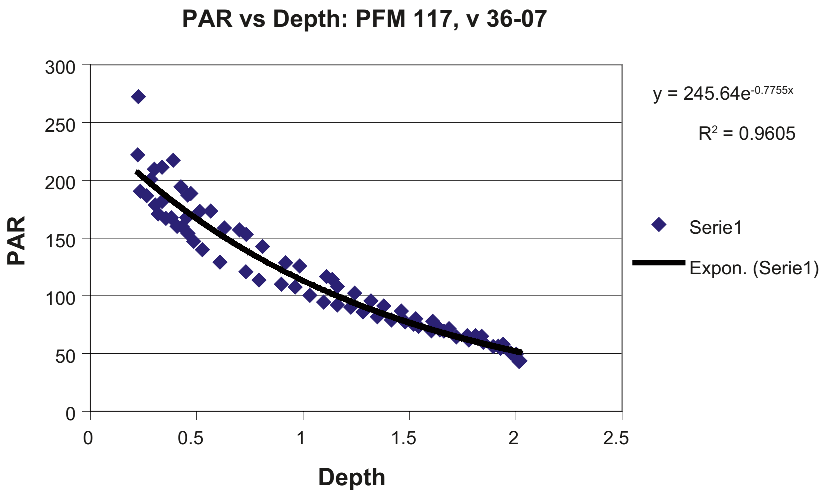
PAR vs Depth: PFM 117, v 32-07

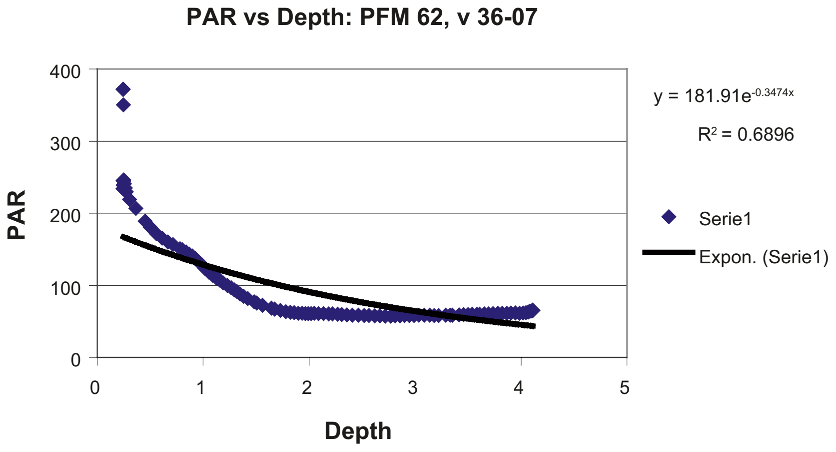


PAR vs Depth: PFM 62, v 32-07

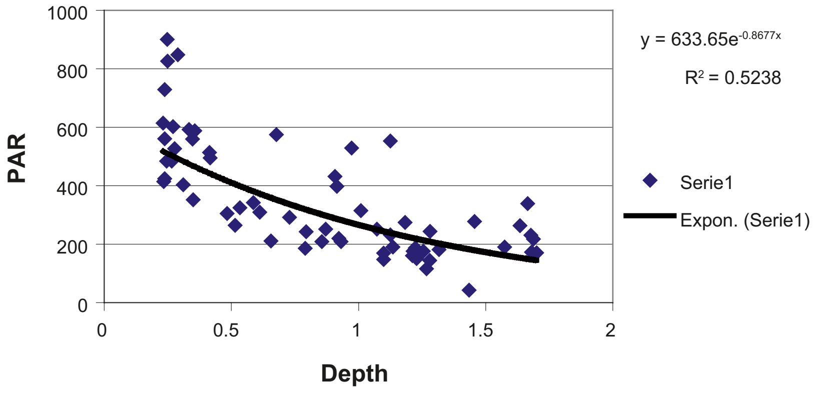



PAR vs Depth: PFM 107, v 36-07
160
120
80
40
0
PAR
0
0.5
1
1.5
2
Depth
y = 164.32e^-0.8642x
R² = 0.9345
Serie1
Expon. (Serie1)

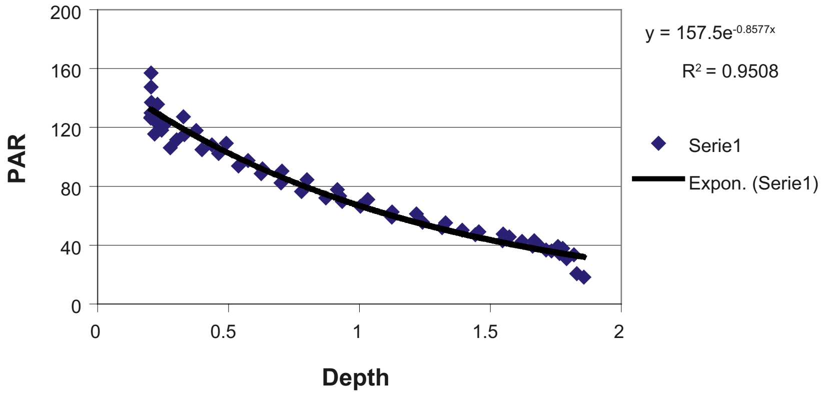

PAR vs Depth: PFM 117, v 36-07
300
250
200
150
100
50
0
PAR
0
0.5
1
1.5
2
2.5
Depth
y = 245.64e^-0.7755x
R² = 0.9605
Serie1
Expon. (Serie1)


PAR vs Depth: PFM 62, v 36-07
400
300
200
100
0
PAR
0
1
2
3
4
5
Depth
y = 181.91e^-0.3474x
R² = 0.6896
Serie1
Expon. (Serie1)

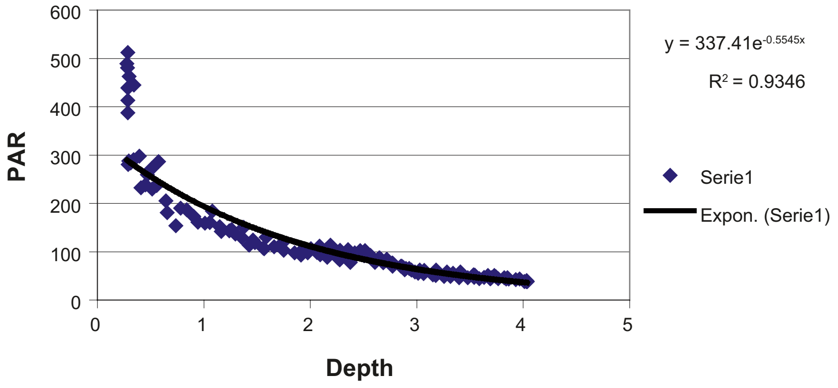
PAR vs Depth: PFM 107, v 41-07



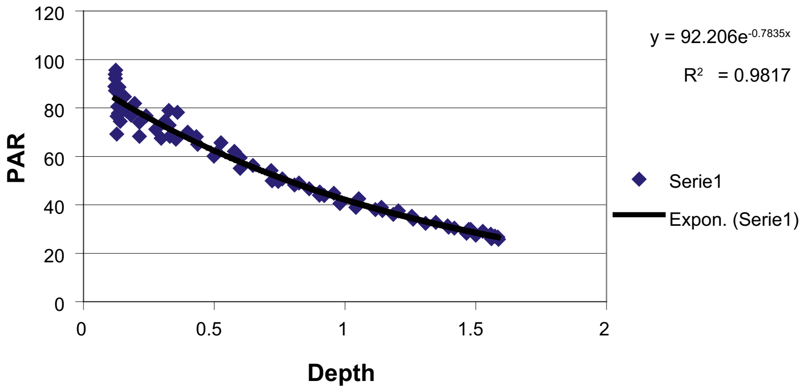
PAR vs Depth: PFM 117, v 41-07



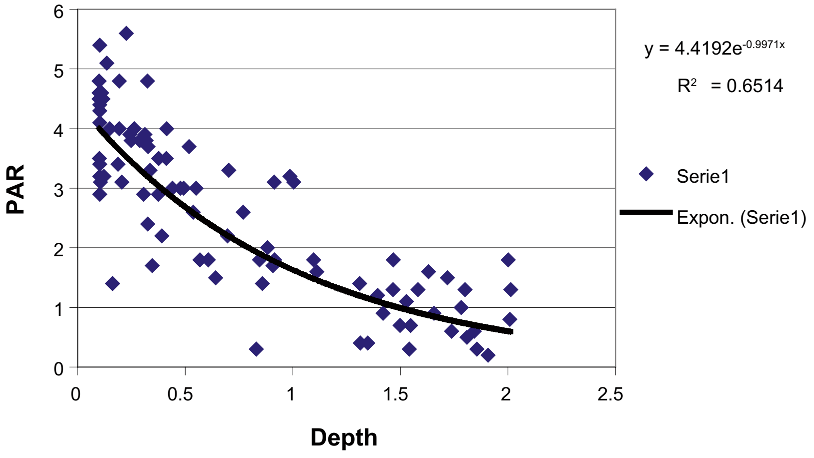
PAR vs Depth: PFM 62, v 41-07



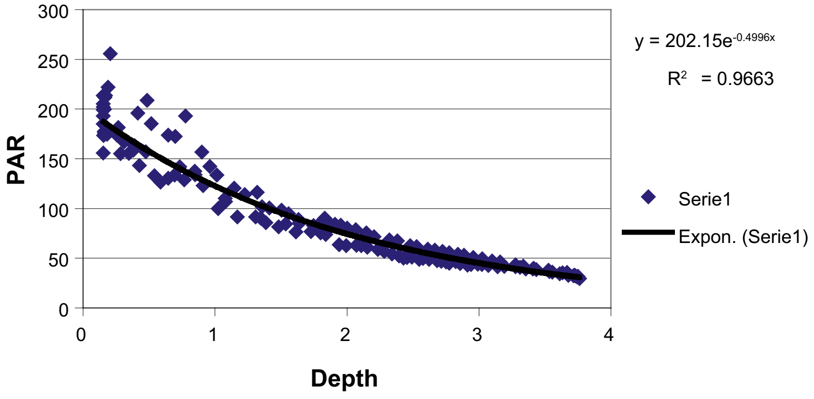
PAR vs Depth: PFM 107, v 45-07



PAR vs Depth: PFM 117, v 45-07



PAR vs Depth: PFM 62, v 45-07



PAR vs Depth: PFM 62, v 49-07

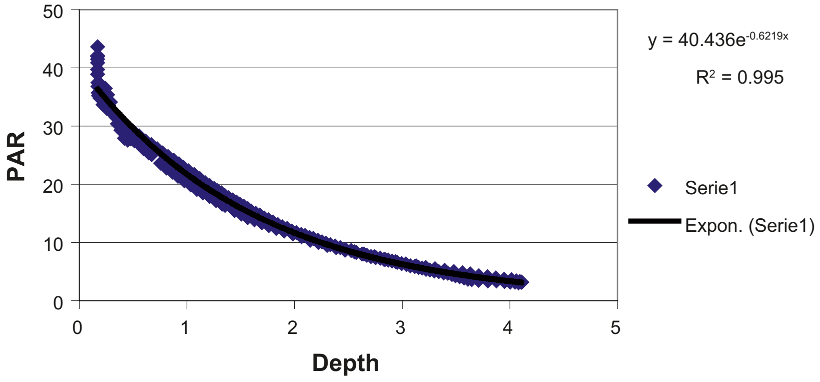


Table A3-3. Water flow measurements

Idcode	Start date	Stop date	Simple flow rate (m^3/s)	Code
PFM000062	8/6/2007 8:00	8/6/2007 20:00		N
PFM000062	8/6/2007 8:00	8/6/2007 20:00		N
PFM000062	8/6/2007 8:00	8/6/2007 20:00		N
PFM000062	8/6/2007 8:00	8/6/2007 20:00		N
PFM000062	9/3/2007 8:00	9/3/2007 18:00		N
PFM000062	9/3/2007 8:00	9/3/2007 18:00		N
PFM000062	9/3/2007 8:00	9/3/2007 18:00		N
PFM000062	9/3/2007 8:00	9/3/2007 18:00		N
PFM000062	10/8/2007 9:00	10/8/2007 20:00		N
PFM000062	10/8/2007 9:00	10/8/2007 20:00		N
PFM000062	10/8/2007 9:00	10/8/2007 20:00		N
PFM000062	10/8/2007 9:00	10/8/2007 20:00		N
PFM000062	11/5/2007 8:30	11/5/2007 19:30		N
PFM000062	11/5/2007 8:30	11/5/2007 19:30		N
PFM000062	11/5/2007 8:30	11/5/2007 19:30		N
PFM000062	11/5/2007 8:30	11/5/2007 19:30		N
PFM000062	12/3/2007 9:00	12/3/2007 18:00		N
PFM000062	12/3/2007 9:00	12/3/2007 18:00		N
PFM000062	12/3/2007 9:00	12/3/2007 18:00		N
PFM000062	12/3/2007 9:00	12/3/2007 18:00		N
PFM000066	8/6/2007 8:00	8/6/2007 20:00		G
PFM000066	9/3/2007 8:00	9/3/2007 18:00		G
PFM000066	10/8/2007 9:00	10/8/2007 20:00		G
PFM000066	11/5/2007 8:30	11/5/2007 19:30		K
PFM000066	12/3/2007 9:00	12/3/2007 18:00	2,86E–02	L
PFM000068	8/7/2007 7:00	8/7/2007 17:00		K
PFM000068	9/3/2007 8:00	9/3/2007 18:00		G
PFM000068	10/8/2007 9:00	10/8/2007 20:00		K
PFM000068	11/5/2007 8:30	11/5/2007 19:30		K
PFM000068	12/3/2007 9:00	12/3/2007 18:00	3,54E–02	L
PFM000069	8/7/2007 7:00	8/7/2007 17:00		G
PFM000069	9/3/2007 8:00	9/3/2007 18:00		G
PFM000069	10/8/2007 9:00	10/8/2007 20:00	3,43E–05	L
PFM000069	11/5/2007 8:30	11/5/2007 19:30	8,18E–03	L
PFM000069	12/3/2007 9:00	12/3/2007 18:00	2,70E–02	L
PFM000070	8/7/2007 7:00	8/7/2007 17:00		G
PFM000070	9/3/2007 8:00	9/3/2007 18:00		G
PFM000070	10/8/2007 9:00	10/8/2007 20:00		G
PFM000070	11/5/2007 8:30	11/5/2007 19:30		K
PFM000070	12/3/2007 9:00	12/3/2007 18:00		K
PFM000074	8/7/2007 7:00	8/7/2007 17:00		N
PFM000074	9/4/2007 7:00	9/4/2007 15:00		N
PFM000074	10/9/2007 7:00	10/9/2007 15:00		N
PFM000074	11/6/2007 7:00	11/6/2007 15:00		N
PFM000074	12/4/2007 7:00	12/4/2007 15:00		N
PFM000097	8/7/2007 7:00	8/7/2007 17:00		N
PFM000097	9/4/2007 7:00	9/4/2007 15:00		N
PFM000097	10/9/2007 7:00	10/9/2007 15:00		N
PFM000097	11/6/2007 7:00	11/6/2007 15:00		N
PFM000097	12/4/2007 7:00	12/4/2007 15:00		N
PFM000107	8/6/2007 8:00	8/6/2007 20:00		N
PFM000107	8/6/2007 8:00	8/6/2007 20:00		N

Table A3-3. Water flow measurements

Idcode	Start date	Stop date	Simple flow rate (m3/s)	Code
PFM000107	9/3/2007 8:00	9/3/2007 18:00		N
PFM000107	9/3/2007 8:00	9/3/2007 18:00		N
PFM000107	10/8/2007 9:00	10/8/2007 20:00		N
PFM000107	10/8/2007 9:00	10/8/2007 20:00		N
PFM000107	11/5/2007 8:30	11/5/2007 19:30		N
PFM000107	11/5/2007 8:30	11/5/2007 19:30		N
PFM000107	12/3/2007 9:00	12/3/2007 18:00		N
PFM000107	12/3/2007 9:00	12/3/2007 18:00		N
PFM000117	8/6/2007 8:00	8/6/2007 20:00		N
PFM000117	8/6/2007 8:00	8/6/2007 20:00		N
PFM000117	8/6/2007 8:00	8/6/2007 20:00		N
PFM000117	9/3/2007 8:00	9/3/2007 18:00		N
PFM000117	9/3/2007 8:00	9/3/2007 18:00		N
PFM000117	9/3/2007 8:00	9/3/2007 18:00		N
PFM000117	10/8/2007 9:00	10/8/2007 20:00		N
PFM000117	10/8/2007 9:00	10/8/2007 20:00		N
PFM000117	10/8/2007 9:00	10/8/2007 20:00		N
PFM000117	11/5/2007 8:30	11/5/2007 19:30		N
PFM000117	11/5/2007 8:30	11/5/2007 19:30		N
PFM000117	11/5/2007 8:30	11/5/2007 19:30		N
PFM000117	12/3/2007 9:00	12/3/2007 18:00		N
PFM000117	12/3/2007 9:00	12/3/2007 18:00		N
PFM000117	12/3/2007 9:00	12/3/2007 18:00		N
PFM102269	8/7/2007 7:00	8/7/2007 17:00		N
PFM102269	9/4/2007 7:00	9/4/2007 15:00		N
PFM102269	10/9/2007 7:00	10/9/2007 15:00		N
PFM102269	11/6/2007 7:00	11/6/2007 15:00		N
PFM102269	12/4/2007 7:00	12/4/2007 15:00		N

Simple flow rate = based on simple “floating bottle” method.

Code	Code description
A	Blocked flow; no measurement
B	Too much water vegetation, no measurement
C	Water compleately frosen, no measurement
D	Too much ice, no measurement
E	Flow rate too high, no measurement
F	Flow rate too low, no measurement
G	Dry conditions, no measurements
H	Measurement not possible, estimated value
I	Measurement not possible, see protocol
K	Comment missing
L	Flow rate value available
M	Low water level
N	Lake, Sea, no measurement
O	Too much wind, no measurement
P	Stationary water

Table A3-4a. Water composition – Compilation of hydrochemical data from water analyses

Idcode	Sample no.	Depth (m)	Sampling date	RCB (%)	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)
PFM000062	12826	0.5	8/6/2007	–3.03	1,470	55.5	78.5	183	78.0	2,800	381	148	9.06	0.32	0.45	–0.002	0.0071
PFM000062	12832	0.5	9/3/2007	–5.22	1,420	61.6	80.4	192	77.5	2,890	402	151	10.0	–	0.45	–	–
PFM000062	12862	0.5	10/8/2007	0.27	1,640	62.7	77.1	183	77.5	2,870	399	144	10.1	0.32	0.51	0.006	0.0020
PFM000062	12907	0.5	11/5/2007	–4.35	1,460	48.2	67.7	163	78.6	2,820	402	128	9.64	0.32	0.45	–	–
PFM000062	12916	0.5	12/3/2007	–3.79	1,450	53.7	74.9	180	79.0	2,810	408	142	9.35	0.32	0.59	–	–
PFM000066	12906	0.1	11/5/2007	3.30	8.0	3.89	97.8	5.5	226	9.1	63.5	23.1	0.095	0.24	6.38	–	–
PFM000066	12922	0.1	12/3/2007	1.48	5.3	2.71	59.3	3.5	174	6.2	18.1	6.71	0.045	–0.2	4.25	–	–
PFM000068	12830	0.1	8/7/2007	3.37	26.9	2.38	65.9	6.9	189	50.5	7.4	3.50	0.204	0.36	3.51	–	–
PFM000068	12864	0.1	10/8/2007	4.56	31.0	2.15	68.6	7.6	196	51.4	10.7	4.83	0.210	0.29	7.18	–	–
PFM000068	12909	0.1	11/5/2007	0.27	20.0	2.50	60.3	6.4	173	40.2	20.2	7.36	0.178	0.27	5.56	–	–
PFM000068	12921	0.1	12/3/2007	1.42	15.5	2.36	62.1	5.6	155	30.6	33.5	12.1	0.121	0.26	5.32	–	–
PFM000069	12858	0.1	10/8/2007	2.15	29.1	1.78	65.3	7.2	194	51.2	11.8	4.88	0.244	0.30	6.77	–	–
PFM000069	12861	0.1	11/5/2007	1.37	23.2	1.83	60.8	6.6	173	45.5	15.2	5.95	0.187	0.26	6.24	–	–
PFM000069	12919	0.1	12/3/2007	1.22	20.4	2.37	67.6	6.2	185	39.9	23.5	8.74	0.149	0.28	6.09	–	–
PFM000070	12908	0.1	11/5/2007	4.27	5.9	2.67	44.8	3.1	131	6.8	9.6	3.95	0.031	–0.2	3.98	–	–
PFM000070	12923	0.1	12/3/2007	2.74	5.2	2.51	39.2	2.5	113	6.9	11.6	4.42	0.029	–0.2	4.02	–	–
PFM000074	12828	0.5	8/7/2007	5.09	17.0	1.98	67.6	4.9	188	28.0	8.4	3.81	0.060	0.31	7.59	0.022	0.0107
PFM000074	12851	0.5	9/4/2007	3.31	16.8	2.02	62.4	4.7	186	26.4	6.9	3.15	0.077	0.30	9.08	–	–
PFM000074	12857	0.5	10/9/2007	3.33	17.9	1.97	66.3	4.7	201	27.1	5.4	2.52	0.074	0.27	8.20	0.020	0.0040
PFM000074	12910	0.5	11/6/2007	1.47	15.1	1.83	66.8	4.5	205	26.0	6.2	2.71	0.070	0.25	6.71	–	–
PFM000107	12827	0.5	8/6/2007	–1.18	248	9.59	62.6	31.7	73.1	503	73.6	28.0	1.530	0.36	0.82	0.045	0.0061
PFM000107	12848	0.5	9/3/2007	–1.68	295	10.9	70.7	35.3	63.2	611	89.0	30.4	2.35	0.37	1.50	–	–
PFM000107	12859	0.5	10/8/2007	–1.62	349	11.9	91.5	37.8	77.2	675	92.5	33.3	2.18	0.39	0.24	0.049	0.0040
PFM000107	12860	0.5	11/5/2007	–1.88	312	10.7	96.1	38.9	92.5	676	93.3	32.9	2.26	0.38	0.10	–	–
PFM000117	12825	0.5	8/6/2007	6.67	7.0	2.13	30.8	3.1	89.3	7.0	8.2	3.36	0.021	0.21	1.00	0.003	0.0013
PFM000117	12847	0.5	9/3/2007	2.18	7.0	2.25	28.6	3.0	93.0	7.4	8.2	3.25	0.035	0.23	2.04	–	–
PFM000117	12863	0.5	10/8/2007	5.67	8.0	2.36	33.8	3.1	104	7.1	7.0	2.92	0.043	0.20	2.12	0.004	0.0010
PFM000117	12905	0.5	11/5/2007	3.35	6.9	1.99	36.4	3.1	115	7.2	6.9	2.80	0.040	–0.2	2.08	–	–
PFM102269	12824	0.5	8/7/2007	–	–	–	–	–	77.9	2,800	388	–	9.90	0.33	–	–	–
PFM102269	12852	0.5	9/4/2007	–	–	–	–	–	78.9	2,900	395	–	9.90	0.33	–	–	–
PFM102269	12877	0.5	10/9/2007	–	–	–	–	–	78.8	2,850	400	–	9.10	0.32	–	–	–
PFM102269	12894	0.5	11/6/2007	–	–	–	–	–	79.1	2,830	410	–	9.55	0.34	–	–	–
PFM102269	12915	0.5	12/4/2007	–	–	–	–	–	78.6	2,810	407	–	9.35	0.32	–	–	–

Table A3-4a. Water composition – Compilation of hydrochemical data from water analyses

Idcode	Sample no.	Depth (m)	Sampling date	Li (mg/L)	Sr (mg/L)	I^- (mg/L)	pH_L	pH_F	Temp_F (ºC)	EC_L (mS/m)
PFM000062	12826	0.5	8/6/2007	0.027	1.17	0.008	7.97	8.09	17.1	907
PFM000062	12832	0.5	9/3/2007	0.028	1.22	–	7.99	8.18	14.5	912
PFM000062	12862	0.5	10/8/2007	0.003	1.21	0.009	7.91	7.92	11.6	909
PFM000062	12907	0.5	11/5/2007	0.021	0.974	–	7.81	7.88	7.0	907
PFM000062	12916	0.5	12/3/2007	0.024	1.09	–	7.76	7.75	3.1	895
PFM000066	12906	0.1	11/5/2007	–0.004	0.107	–	7.36	7.39	2.8	51.5
PFM000066	12922	0.1	12/3/2007	–0.004	0.063	–	7.36	7.44	1.8	33.0
PFM000068	12830	0.1	8/7/2007	–0.004	0.118	0.015	7.63	7.27	16.1	48.5
PFM000068	12864	0.1	10/8/2007	0.004	0.121	0.008	7.40	7.41	7.6	49.7
PFM000068	12909	0.1	11/5/2007	–0.004	0.105	–	7.32	7.42	2.6	45.2
PFM000068	12921	0.1	12/3/2007	–0.004	0.099	–	7.21	7.28	2.5	42.4
PFM000069	12858	0.1	10/8/2007	0.005	0.114	0.009	7.53	7.57	7.4	49.6
PFM000069	12861	0.1	11/5/2007	0.005	0.099	–	7.32	7.39	2.6	46.2
PFM000069	12919	0.1	12/3/2007	0.004	0.106	–	7.18	7.25	2.3	47.1
PFM000070	12908	0.1	11/5/2007	–0.004	0.049	–	7.12	7.37	3.0	26.6
PFM000070	12923	0.1	12/3/2007	–0.004	0.039	–	7.04	7.59	1.7	24.0
PFM000074	12828	0.5	8/7/2007	0.003	0.092	0.009	7.97	7.72	21.3	41.1
PFM000074	12851	0.5	9/4/2007	–0.004	0.088	–	7.84	8.02	12.3	39.5
PFM000074	12857	0.5	10/9/2007	–0.004	0.089	0.006	7.67	7.85	6.4	42.0
PFM000074	12910	0.5	11/6/2007	–0.004	0.085	–	7.89	7.96	3.4	43.3
PFM000107	12827	0.5	8/6/2007	0.008	0.309	0.008	9.30	9.45	22.7	189
PFM000107	12848	0.5	9/3/2007	0.008	0.407	–	9.15	9.57	14.4	221
PFM000107	12859	0.5	10/8/2007	0.009	0.511	0.006	7.89	8.02	9.2	246
PFM000107	12860	0.5	11/5/2007	0.009	0.500	–	7.83	8.04	2.6	246
PFM000117	12825	0.5	8/6/2007	0.001	0.046	0.005	8.74	8.89	23.3	19.8
PFM000117	12847	0.5	9/3/2007	–0.004	0.045	–	8.67	9.05	14.6	20.0
PFM000117	12863	0.5	10/8/2007	0.005	0.048	0.005	8.32	8.43	9.6	21.5
PFM000117	12905	0.5	11/5/2007	–0.004	0.047	–	8.05	8.37	2.7	23.2
PFM102269	12824	0.5	8/7/2007	–	–	–	7.97	8.09	28.7	907
PFM102269	12852	0.5	9/4/2007	–	–	–	7.89	8.16	24.1	909
PFM102269	12877	0.5	10/9/2007	–	–	–	7.89	7.97	21.0	913
PFM102269	12894	0.5	11/6/2007	–	–	–	7.70	7.91	16.9	909
PFM102269	12915	0.5	12/4/2007	–	–	–	7.74	7.85	13.2	902

RCB = Relative Charge Balance error

pH_L = lab. pH

pH_F = field pH

Temp_F = water temperature in the field

EC = Electrical Conductivity

< ”value” = below detection limit

Table A3-4b. Surface water suppliments

Idcode	Sample no.	Sampling date	Depth (m)	NH$_4$_N (mg/L)	NH$_2$_N (mg/L)	NO$_3$_N+NH$_2$_N (mg/L)	N TOT (mg/L)	P TOT (mg/L)	PO$_4$_P (mg/L)	POP (mg/L)	PON (mg/L)	SIO$_2$_SI (mg/L)	Chl. C (ug/L)	Chl. A (ug/L)	Pheop. (ug/L)
PFM000062	12826	8/6/2007	0.5	0.0034	–0.0002	0.0003	0.260	0.0130	–0.0005	0.0069	0.0523	0.382	2.3	0.3	0.3
PFM000062	12832	9/3/2007	0.5	0.0008	–	0.0004	0.257	0.0131	0.0006	0.0069	0.0553	0.346	2.3	0.2	0.3
PFM000062	12862	10/8/2007	0.5	0.0039	0.0003	0.0020	0.232	0.0115	0.0016	0.0049	0.0373	0.458	2.1	0.3	0.6
PFM000062	12907	11/5/2007	0.5	0.0039	–	0.0077	0.229	0.0109	0.0019	0.0044	0.0421	0.452	2.4	0.2	0.4
PFM000062	12916	12/3/2007	0.5	0.0029	–	0.0326	0.238	0.0113	0.0046	0.0048	0.0231	0.502	1.4	–0.2	0.4
PFM000066	12906	11/5/2007	0.1	0.0043	–	0.0449	0.933	0.0157	0.0025	0.0033	0.0334	5.82	–	–	–
PFM000066	12922	12/3/2007	0.1	0.0106	–	0.0551	0.805	0.0099	0.0012	0.0048	0.0376	4.05	–	–	–
PFM000068	12830	8/7/2007	0.1	0.0488	–	0.0072	1.160	0.0759	0.0309	0.0159	0.0726	3.26	–	–	–
PFM000068	12864	10/8/2007	0.1	0.0142	0.0004	0.0045	0.974	0.0127	0.0028	0.0041	0.0280	6.68	–	–	–
PFM000068	12909	11/5/2007	0.1	0.0173	–	0.0161	0.866	0.0133	0.0022	0.0035	0.0321	5.42	–	–	–
PFM000068	12921	12/3/2007	0.1	0.0185	–	0.1290	0.996	0.0123	0.0018	0.0029	0.0324	5.11	–	–	–
PFM000069	12858	10/8/2007	0.1	0.0133	0.0008	0.0123	0.973	0.0136	0.0021	0.0028	0.0205	6.58	–	–	–
PFM000069	12861	11/5/2007	0.1	0.0223	–	0.0063	0.905	0.0131	0.0023	0.0035	0.0281	5.95	–	–	–
PFM000069	12919	12/3/2007	0.1	0.0140	–	0.0240	0.817	0.0124	0.0020	0.0039	0.0242	5.88	–	–	–
PFM000070	12908	11/5/2007	0.1	0.0343	–	0.1170	1.02	0.0086	0.0012	0.0039	0.0297	3.92	–	–	–
PFM000070	12923	12/3/2007	0.1	0.3300	–	0.3280	1.52	0.0136	0.0013	0.0077	0.0711	3.94	–	–	–
PFM000074	12828	8/7/2007	0.5	0.0075	–	–0.0030	1.25	0.0171	0.0023	0.0115	0.1640	6.97	15.2	1.8	1.0
PFM000074	12851	9/4/2007	0.5	0.0151	–	0.0017	0.945	0.0079	0.0013	0.0033	0.0485	7.97	2.7	–0.2	0.4
PFM000074	12857	10/9/2007	0.5	0.0254	0.0003	0.0004	0.926	0.0080	0.0017	0.0086	0.2330	7.87	10.1	0.6	5.5
PFM000074	12910	11/6/2007	0.5	0.0157	–	0.0023	0.836	0.0087	0.0016	0.0038	0.0545	6.38	2.1	–0.2	1.6
PFM000107	12827	8/6/2007	0.5	0.0132	–	0.0004	1.11	0.0133	0.0020	0.0022	0.0454	0.731	–0.2	–0.2	0.4
PFM000107	12848	9/3/2007	0.5	0.0120	–	0.0006	1.06	0.0117	0.0015	0.0045	0.0405	1.36	0.8	–0.2	–0.2
PFM000107	12859	10/8/2007	0.5	0.0676	–0.0002	0.0013	1.06	0.0110	0.0008	0.0059	0.0372	0.228	1.0	0.2	0.3
PFM000107	12860	11/5/2007	0.5	0.0610	–	0.0016	0.954	0.0091	0.0009	0.0033	0.0337	0.094	0.8	–0.2	–0.2
PFM000117	12825	8/6/2007	0.5	0.0128	–	0.0014	1.31	0.0104	0.0016	0.0035	0.0527	0.916	2.3	0.3	–0.2
PFM000117	12847	9/3/2007	0.5	0.0150	–	0.0010	1.26	0.0069	0.0012	0.0033	0.0418	1.96	1.5	–0.2	–0.2
PFM000117	12863	10/8/2007	0.5	0.0616	–0.0002	0.0042	1.28	0.0077	0.0014	0.0033	0.0526	2.03	2.0	0.2	0.4
PFM000117	12905	11/5/2007	0.5	0.1590	–	0.0051	1.34	0.0062	0.0014	0.0032	0.0417	2.02	2.4	0.2	0.2

Table A3-4b. Surface water suppliments

Idcode	Sample no.	Sampling date	POC (mg/L)	TOC (mg/L)	DOC (mg/L)	DIC (mg/L)	O_2 (mg/L)	Abs. coeff. (1/m)
PFM000062	12826	8/6/2007	0.37	3.9	4.0	11.0	–	0.14
PFM000062	12832	9/3/2007	0.38	4.0	4.0	12.7	–	0.14
PFM000062	12862	10/8/2007	0.25	3.8	3.6	11.5	–	0.20
PFM000062	12907	11/5/2007	0.29	3.7	3.7	14.8	–	0.28
PFM000062	12916	12/3/2007	0.21	3.6	3.7	14.1	–	0.18
PFM000066	12906	11/5/2007	0.25	20.1	19.6	31.8	–	2.68
PFM000066	12922	12/3/2007	0.27	17.1	17.1	32.0	–	1.90
PFM000068	12830	8/7/2007	0.80	25.4	24.8	27.0	–	5.72
PFM000068	12864	10/8/2007	0.51	23.6	23.3	24.3	–	4.32
PFM000068	12909	11/5/2007	0.26	20.4	20.7	27.7	–	3.38
PFM000068	12921	12/3/2007	0.24	22.4	23.4	28.4	–	3.80
PFM000069	12858	10/8/2007	0.18	21.9	22.0	24.9	–	3.86
PFM000069	12861	11/5/2007	0.23	20.5	20.6	27.8	–	3.14
PFM000069	12919	12/3/2007	0.20	19.2	19.2	34.3	–	2.74
PFM000070	12908	11/5/2007	0.24	22.3	21.9	19.6	–	3.02
PFM000070	12923	12/3/2007	0.51	17.2	16.7	21.4	–	1.60
PFM000074	12828	8/7/2007	1.10	23.4	22.1	27.4	5.30	2.20
PFM000074	12851	9/4/2007	0.38	19.2	19.2	33.2	–	1.72
PFM000074	12857	10/9/2007	2.09	19.1	18.3	30.0	–	1.64
PFM000074	12910	11/6/2007	0.45	17.0	16.7	28.1	–	1.58
PFM000107	12827	8/6/2007	18.60	18.8	7.7	–	–	0.76
PFM000107	12848	9/3/2007	0.30	14.4	18.0	8.4	–	0.60
PFM000107	12859	10/8/2007	0.26	15.9	15.4	10.6	–	0.56
PFM000107	12860	11/5/2007	0.27	14.6	14.8	11.5	–	0.48
PFM000117	12825	8/6/2007	0.46	21.4	20.8	12.7	–	0.74
PFM000117	12847	9/3/2007	0.34	20.5	20.7	14.0	–	0.68
PFM000117	12863	10/8/2007	0.47	19.5	20.5	16.9	–	0.60
PFM000117	12905	11/5/2007	0.36	19.7	19.5	15.1	–	0.56

Chl. A = Chlorophyll a.

Chl. C = Chlorophyll c.

Pheop. = Pheopigment.

Abs. Coeff. = Absorption Coefficient 436 nm (colour).

Table A3-4c. Isotops I (H-, B-, S- and C-isotopes)

Idcode	Sample no.	Sampling date	Depth m	^{14}C pmC	δ^{13}C ‰ PDB	δ^{34}S ‰ CDT	δ^{37}Cl ‰ SMOC	^{37}Sr/^{38}Sr	δ^{2}H ‰ SMOW	^{3}H TU	δ^{18}O ‰ SMOW
PFM000062	12826	8/6/2007	0.5	105.22	–0.28	16.9	0.66	0.70948	–62.1	10.6	–8.1
PFM000062	12862	10/8/2007	0.5	–	–	–	–	–	–60.7	11.8	–7.9
PFM000068	12830	8/7/2007	0.1	–	–	–	–	–	–70.0	11.0	–9.0
PFM000068	12864	10/8/2007	0.1	–	–	–	–	–	–74.4	11.2	–9.8
PFM000069	12858	10/8/2007	0.1	–	–	–	–	–	–73.0	12.4	–9.7
PFM000074	12828	8/7/2007	0.5	115.39	–6.14	16.9	1.23	0.72256	–59.2	12.4	–6.6
PFM000074	12857	10/9/2007	0.5	–	–	–	–	–	–59.8	11.7	–6.7
PFM000107	12827	8/6/2007	0.5	108.85	–9.28	4.1	0.90	0.71827	–47.9	10.6	–4.4
PFM000107	12859	10/8/2007	0.5	–	–	–	–	–	–46.1	11.3	–4.3
PFM000117	12825	8/6/2007	0.5	107.77	–1.96	8.1	0.86	0.72407	–53.5	12.5	–5.3
PFM000117	12863	10/8/2007	0.5	–	–	–	–	–	–50.5	12.0	–4.8
PFM102269	12824	8/7/2007	0.5	–	–	–	–	–	–	11.8	–
PFM102269	12852	9/4/2007	0.5	–	–	–	–	–	–	11.5	–
PFM102269	12877	10/9/2007	0.5	–	–	–	–	–	–	12.4	–
PFM102269	12894	11/6/2007	0.5	–	–	–	–	–	–	12.0	–
PFM102269	12915	12/4/2007	0.5	–	–	–	–	–	–	10.5	–

The units are explained in Appendix 1.

Table A3-4d. Trace elements

Idcode	Sample no.	Sampling date	Depth m	Al (ug/L)	Cd (ug/L)	Cr (ug/L)	Cu (ug/L)	Co (ug/L)	Hg (ug/L)	Ni (ug/L)	Zn (ug/L)	Pb (ug/L)	V (ug/L)	Mo (ug/L)	Nb (ug/L)	Ba (ug/L)
PFM000062	12826	2007/08/06	0.5	3.60	–0.02	0.101	0.67	0.049	–0.002	0.921	1.22	0.314	0.19	1.62	–	14.9
PFM000062	12862	2007/10/08	0.5	0.98	–0.02	–0.04	0.62	–0.02	–0.002	0.930	–0.8	–0.1	0.17	1.64	–	17.2
PFM000074	12828	2007/08/07	0.5	7.20	0.0033	0.053	0.28	0.035	0.0059	0.265	2.17	0.057	0.22	0.35	–	29.6
PFM000074	12857	2007/10/09	0.5	10.40	–0.002	0.038	0.13	0.028	0.0025	0.243	0.80	0.023	0.21	0.18	–	27.5
PFM000107	12827	2007/08/06	0.5	21.40	0.0058	0.113	0.68	0.073	–0.002	0.447	3.09	0.490	0.53	0.89	–	24.5
PFM000107	12859	2007/10/08	0.5	8.22	0.0022	0.102	0.30	0.045	–0.002	0.377	0.99	0.181	0.28	1.01	–	37.7
PFM000117	12825	2007/08/06	0.5	6.17	0.0036	–0.01	0.35	0.032	–0.002	0.206	1.05	0.011	0.25	0.21	–	7.9
PFM000117	12863	2007/10/08	0.5	6.40	0.0020	0.043	0.39	0.030	0.0036	0.210	3.66	0.049	0.31	0.21	–	10.4

Idcode	Sample no.	Sampling date	Depth m	As (ug/L)	U (ug/L)	Th (ug/L)	Sc (ug/L)	Rb (ug/L)	Y (ug/L)	Zr (ug/L)	Sb (ug/L)	Cs (ug/L)	La (ug/L)	Hf (ug/L)	Tl (ug/L)	Ce (ug/L)
PFM000062	12826	2007/08/06	0.5	–	0.538	–0.2	–0.4	16.2	0.027	–0.1	–0.1	–0.1	–0.02	–0.02	–0.03	–0.02
PFM000062	12862	2007/10/08	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
PFM000074	12828	2007/08/07	0.5	–	1.330	–0.02	–0.1	2.1	0.043	0.09	0.04	–0.03	0.0183	–0.005	–0.005	0.018
PFM000074	12857	2007/10/09	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
PFM000107	12827	2007/08/06	0.5	–	2.150	–0.02	–0.1	5.4	0.041	0.10	0.10	0.0321	0.0412	–0.005	–0.005	0.066
PFM000107	12859	2007/10/08	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
PFM000117	12825	2007/08/06	0.5	–	0.862	–0.002	–0.1	2.3	0.019	0.08	0.08	–0.03	–0.005	–0.005	–0.005	–0.005
PFM000117	12863	2007/10/08	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–

Idcode	Sample no.	Sampling date	Depth m	Pr (ug/L)	Nd (ug/L)	Sm (ug/L)	Eu (ug/L)	Gd (ug/L)	Tb (ug/L)	Dy (ug/L)	Ho (ug/L)	Er (ug/L)	Tm (ug/L)	Yb (ug/L)	Lu (ug/L)	In (ug/L)
PFM000062	12826	2007/08/06	0.5	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	0.320	–
PFM000062	12862	2007/10/08	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
PFM000074	12828	2007/08/07	0.5	–0.005	0.0256	0.0051	–0.005	0.0056	–0.005	–0.0070	–0.005	0.0054	–0.005	0.0061	–0.005	–
PFM000074	12857	2007/10/09	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
PFM000107	12827	2007/08/06	0.5	0.0111	0.0421	0.0076	–0.005	0.0143	–0.005	0.0923	–0.005	–0.005	–0.005	–0.005	–0.005	–
PFM000107	12859	2007/10/08	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
PFM000117	12825	2007/08/06	0.5	–0.005	0.0076	–0.005	–0.005	–0.005	–0.005	–0.005	–0.005	–0.005	–0.005	–0.005	–0.005	–
PFM000117	12863	2007/10/08	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–

< "value" = below reporting limit.

Yellow marked values are probably affected by contamination.

Table A3-4e. Isotopes II (U-, Th-, Ra- and Rn-isotopes)

Idcode	Sample no.	Sampling date	Depth m	^{238}U mBq/kg	^{234}U mBq/kg	Th^{230} mBq/kg	Ra^{226} Bq/l	Rn^{222} Bq/l
PFM000062	12826	8/6/2007	0.5	7.00	9.00	3.16	–0.02	0.01
PFM000074	12828	8/7/2007	0.5	17.30	18.20	0.46	–0.02	0.01
PFM000107	12827	8/6/2007	0.5	29.70	36.20	0.37	–0.02	0.04
PFM000117	12825	8/6/2007	0.5	12.10	12.60	0.29	–0.02	0.01

Precipitation

Table A4-1. Water Composistion

Idcode		Sampling date and time	Sample no.	Al µg/L	Br mg/l	Ca mg/L	Cl^- mg/L	EC_L mS/m	Fe mg/L	HCO_3^- mg/L	K mg/L	Mg mg/L	Na mg/L	pH_L	SO4_S mg/L	SO4 mg/L	Mn mg/L	Li mg/L	Sr mg/L
PFM002564	6/26/2007	9/3/2007	12854	0.003	0.003	0.21	0.800	1.02	0.005	< 1	< 0.4	< 0.09	0.38	5.17	0.218	0.76	0.00228	< 0.004	< 0.002
PFM002564	9/3/2007	11/12/2007	12914	–	0.003	0.17	0.600	1.45	< 0.02	< 1	< 0.4	< 0.09	0.34	4.72	0.301	0.79	< 0.003	< 0.004	< 0.002
PFM002564	11/12/2007	1/10/2008	12945	< 0.06	0.004	0.10	0.900	2.25	< 0.02	< 1	< 0.4	< 0.09	0.65	4.39	0.606	1.47	< 0.003	< 0.004	< 0.002

Table A4-2. Isotopes (H- and O-isotopes)

Idcode		Sampling date	Sample no.	d^2H dev SMOW	^3H TU	$d^{18}O$ dev SMOW
PFM102271	6/26/2007	8/31/2007	12853	–	12.1	–
PFM002564	6/26/2007	9/3/2007	12854	–74.4	16.9	–10.2
PFM002564	9/3/2007	11/12/2007	12914	–78.6	7.8	–11.2
PFM002564	11/12/2007	1/10/2008	12945	–80.7	7.5	–10.6