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Groundwater Quality monitoring in the border area between Norway, Finland and Russia

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# REPORT

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Title:
Groundwater quality monitoring in the border area between Norway, Finland and Russia

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Summary:

The chemical composition of groundwater was monitored between October 2003 and November 2005 at Karpdalen, Svanvik and Skjellbekken in the border area between Norway, Russia and Finland. In addition 6 snow samples were collected from these stations during the winter of 2004 and 2005. The border area has been exposed to the emissions of $SO_2$ and heavy metals from the smelter in Nikel and ore roasting plant in Zapolyarniy in Russia.

All samples were analysed for cation concentrations by inductively coupled plasma-atomic emission spectrometry (ICP-AES: Si; Fe; Ti; Mg; Ca; Na; Ba; Sr; Sc), heavy metals and trace elements by inductively coupled plasma-mass spectrometry (ICP-MS: Y; Nb; Ag; In; Sb; Cs; Nd; Sm; Ho; Yb; Ta; W; Tl; Bi; Th; V; Mn; Cu; Zn; Ga; Ge; Li; Be; B; Rb; Zr; Mo; Cd; La; Ce; Pb; U; Al; Cr; Co; Ni; P; I; K; As; Se), anions by ion chromatography (IC: F; Cl; Br; $NO_3$; $NO_2$; $PO_4$; $SO_4$), alkalinity, pH, electrical conductivity, colour and turbidity with the view to assess the possible impact of the emissions on groundwater quality. The long-term groundwater monitoring data from the Nellim station in Finland has been used as reference data since the area is not exposed to deposition from the smelters.

Most elements show slight temporal variation in concentration. However, Cu concentration at Svanvik shows a slightly increasing trend during 2005. At Skjellbekken, alkalinity has been steadily decreasing since April 2004 and stabilised around June 2005, and $SO_4$ displays a generally decreasing trend from April to December 2004 followed by an increasing trend from January to October 2005. Seasonal variations are not shown in the data. Groundwater composition at all three stations reflects mostly the mineralogical composition of the Quaternary deposits and also marine influence, especially at Karpdalen. Groundwater at all three stations has not been acidified to any extent and has a high acid-neutralising capacity. A comparison of median groundwater levels of 7 toxic trace elements with reference data shows that all elements are below reference values except for Cu at Svanvik, and As and Cr at all three stations. Furthermore, all 7 trace-element concentrations in groundwater are well below the Norwegian drinking water standards. Although surface media are contaminated by emissions from Nikel smelters, as shown by higher concentration of Cd, Cu, Ni, Pb in snow compared with groundwater at Svanvik and Karpdalen, there are no clear signs of contamination of groundwater at the three monitoring stations so far.

Keywords:

| | | |
|---|---|---|
| Groundwater | Monitoring | Contamination |
| Acidification | Chemical analysis | Sampling |
| Quaternary deposits | Reference value | Report |

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# 1. INTRODUCTION

Copper-nickel ore smelting at Nickel and Zapolyarniy in the Kola Peninsula of Northwest Russia is the main source of environmental contamination in the border area between Norway, Russia and Finland, also referred to as the Pasvik area in this report. Although the impact of the emissions is most severe on the Russian side, the easternmost parts of Norway are affected by the emissions (Reimann et al., 1997). Previous studies have been carried out in the border area to investigate the environmental situation, focusing mainly on soils, air, surface water and vegetation, all of which have shown to be affected by the emissions. The studies have not focused much on the potential contamination of groundwater from airborne pollution. Indirect contamination of groundwater may occur through leaching of elements from these surface media. For example, data on snowmelt contribution to groundwater in this area suggests a possible nickel contamination (NGU unpublished data).

It is in this light that the Geological Survey of Norway (NGU) proposed a Norwegian-Finnish collaborative project to monitor groundwater quality in this vulnerable area. Following an agreement between NGU and Fylkesmannen in Finnmark, this project was started on the Norwegian side at the end of September 2003. This subproject on groundwater quality monitoring is part of a big collaborative 3-year project between Norway, Finland and Russia aimed at assessing the effects of the emissions from Nikel and Zapolyarniy on the environment in the border area and to come up with recommendations for a sound joint future monitoring program/activity in the area.

# 2. STUDY/SAMPLING AREAS

The groundwater quality monitoring study area covers the Jarfjord/Karpdalen area, the Svanvik area and the Skjellbekken area. The Jarfjord area is a about 25 km NNE of Nikel, the Svanvik area is about 7 km west of Nikel and the Skjellbekken area is about 30 km SW of Nikel.

## 2.1 Geology

The study area consists mainly of bedrock of Precambrian age and thick layers of moraine material; deposits from glaciers and watercourses cover most of it. The Pasvik area has greenstone bedrock geology while the Jarfjord area has a gneissic bedrock (Jensen & Finne, 2006; Reimann et, al., 1997) with low base content, which makes it sensitive to acidification (www.pasvikmonitoring.org , in prep). According to Caritat, 1998, the main bedrock types in the Skjellbekken area are andesite/andesitic volcaniclastic schist (40% areal cover), tholeitic basaltic tuff (30%), black schist (20%), other rock types including ultra-mafic/mafic intrusions (5%), minor carbonates and quartzite.

Figure 1 shows a simplified version of the Quaternary geology map covering the study area. The main Quaternary deposits are till, peat, glaciofluvial deposits including eskers in the Skjellbekken and Svanvik areas. Till covers 71% of the Skjellbekken catchment, glaciofluvial deposits, 15%, outcrops, 5% and water bodies, 6% (Caritat, 1998). Discontinuous till, silt and clay and outcrops of pre-Quaternary bedrock cover the Karpdalen/Jarfjord area. Till consists mainly of an unsorted mixture of rock and mineral fragments from boulders to clay (Reimann et al., 1997). The moraine in the area is mostly gravely and sandy till and also hummocky moraines. The Nellim station is also located in an area covered by Quaternary deposits. The main geological formations are till, eskers and hummocky moraines. The main bedrock formation in the Nellim area is mafic granulite.

## 2.2 Monitoring wells

Groundwater monitoring wells were established in the Skjellbekken area during previous studies in the mid-1990s and were monitored from March 1994 to November 1995. In order to extend the groundwater-monitoring network in the study area, NGU proposed to establish two more monitoring stations, one in the Svanvik area and another in Karpdalen, in addition to the one in Skjellbekken. The stations were located in the same geological setting i.e. Quaternary deposits and at varying distances and directions from the smelters. Fieldwork was carried out in the study area between 24 September and 3 October 2003 in order to establish the two new monitoring wells, check on the condition of the existing wells for monitoring purposes, identify and train a local assistant in groundwater sampling and collect the first round of groundwater samples from the 3 monitoring stations.

Out of the 3 stations in the Skjellbekken area, station 43 of the Kola Project (Caritat 1997) was chosen for groundwater monitoring and samples were collected from the deepest well, which reaches about 12.2m below ground level. It is located at UTM coordinates (596584; 7697488 in zone 35). Station 42 was considered too shallow, while station 44 has a 3 m layer of silt, which may hinder flow of water to the groundwater zone. The well was pumped clean and fitted with a small electric pump, which was left in the well for collection of samples. For the purposes of this project this will be referred to as 'Well 1' (Figure 1).

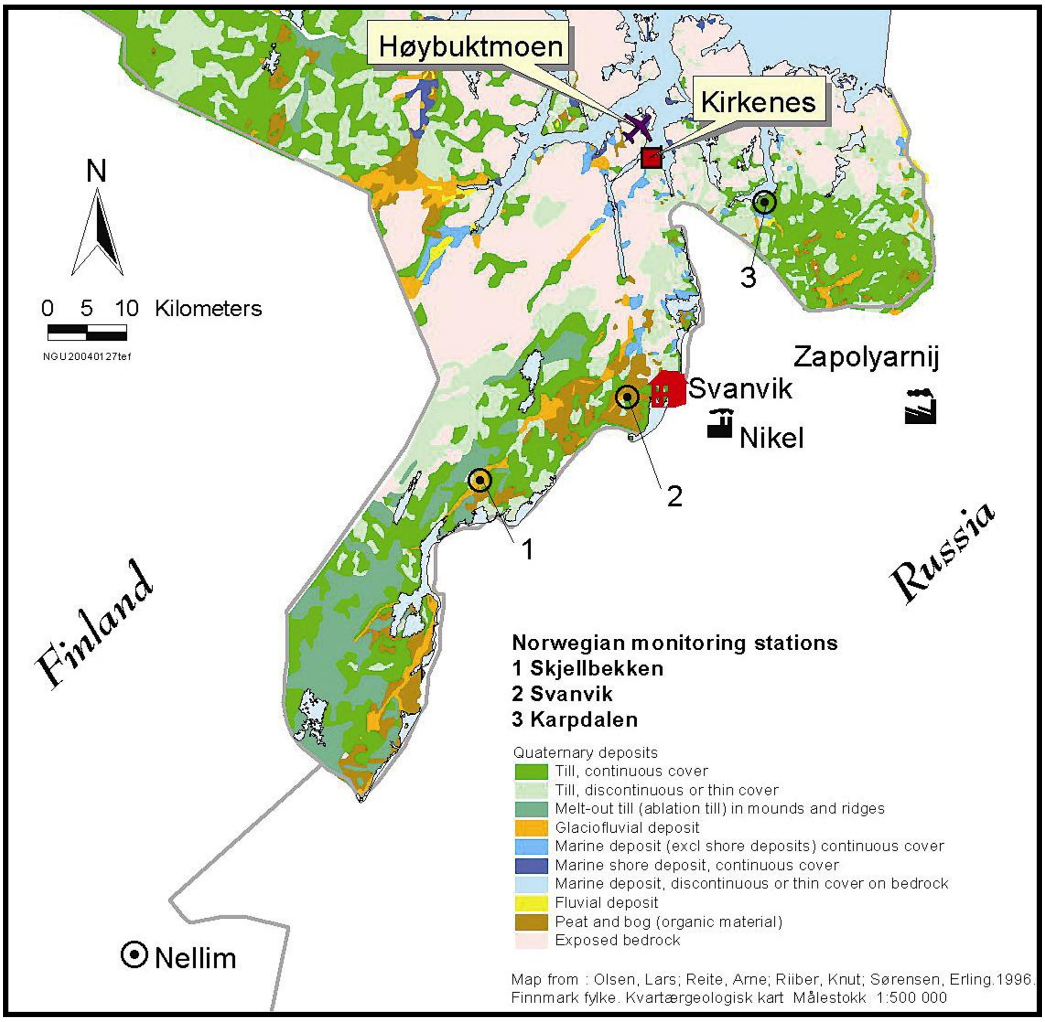


Figure 1: Location of groundwater monitoring wells in Norway and Finland and location of Nikel and Zapolyarniy industries in Russia

Following hydrogeological investigations using test drilling at several locations, two groundwater-monitoring wells were drilled in the Quaternary deposits in Svanvik ('Well 2') and Karpdalen ('Well 3') areas, respectively (Figure 1). The deposits at Svanvik consist of glacial-fluvial sediments (fine sand to sand) overlying esker sediments (gravel), while at Karpdalen marine sediments (fine sand and clay) overlay coarse sediments. Quaternary deposits in the southern part of the Karpdalen were inaccessible with the drilling rig, thus investigations were limited to the northern parts. Well 2 in Svanvik was drilled to 12.50 m at UTM coordinates (615006; 7707999 in zone 35). The well in Karpdalen (Well 3) was drilled to 11.85 m at UTM coordinates (399657; 7730782 in zone 36). The well in Skjellbekken was drilled in Quaternary deposits where sand and fine sand overlay coarse grained deposits. Each well was cased with white PEH tubing and 1 m of screen installed through the monitored interval. The annulus was sealed with bentonite. The design of the wells and the geological logs are shown in Figure 2.

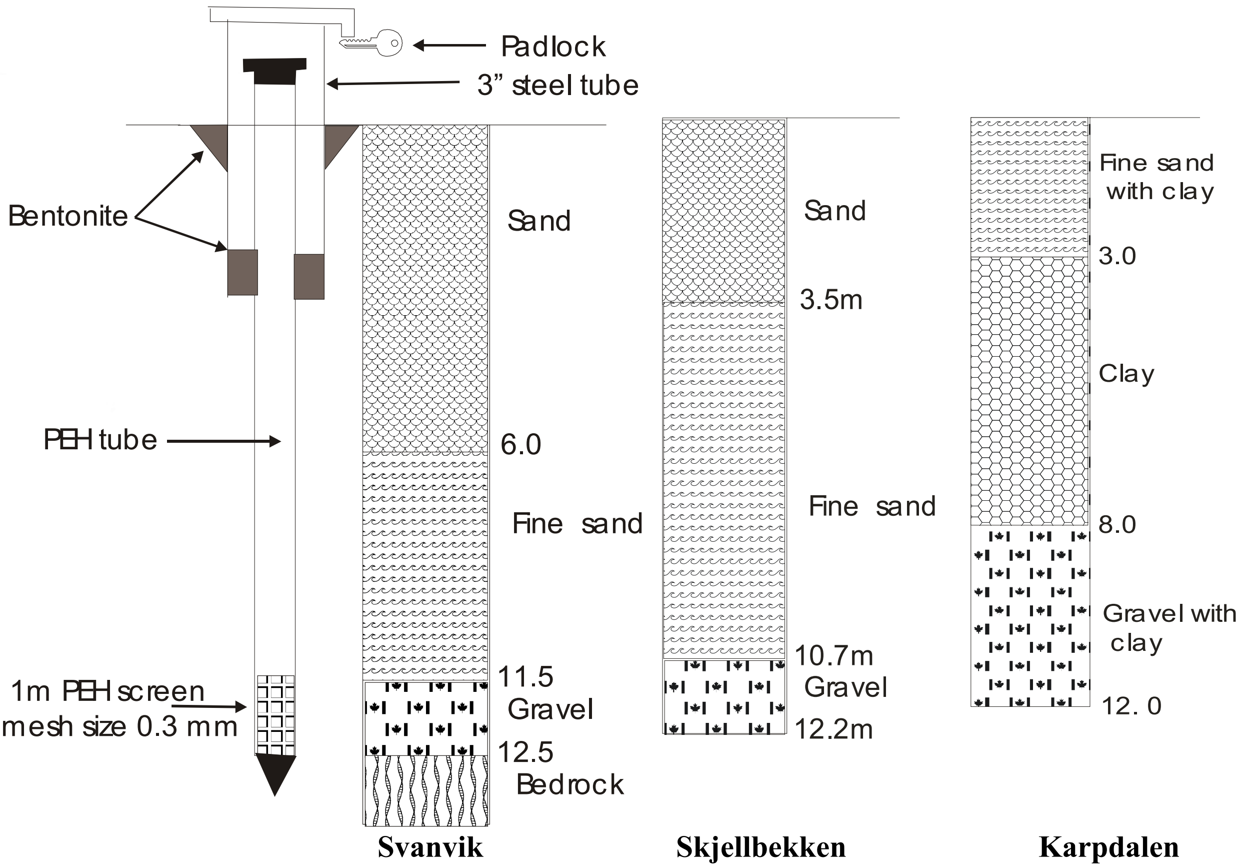


Figure 2: Well design and geological logs of monitoring wells

## 3. SAMPLING METHODS

### 3.1 Groundwater sampling

All three wells were purged or pumped clean before equipping each of them with a small electric Eijkelkamp pump and hose for groundwater sampling. The pumps and hose were left in the wells to minimize contamination as much as possible during sampling. There are widely diverging opinions on how best to avoid contamination from field equipment, especially from sampling bottles. Many researchers suggest the use of factory-new HDPE bottles, while others prefer that all field equipment should be pre-washed. We opted for factory-new white HDPE bottles and pre-acidification of these with super-pure $HNO_3$ for cation analysis samples. Brand new field equipment like syringes, filters, sample bottles and gloves were used. Sample bottles were pre-acidified in order to reduce field errors and the risk of moving around with toxic acid. However, this should usually be avoided as the acid may damage plastic and might release elements that may be in the plastic material into the water sample. Groundwater samples were collected following a standardised sampling protocol (Appendix 1).

The first groundwater samples were taken soon after establishment of the monitoring wells (first week of October 2003). Groundwater samples were collected every month in 2003 and every 5 weeks thereafter, up to November 2005, according to the sampling program for each year.

A groundwater sample from each well included three sub samples:

1) 500 ml of unfiltered, un-acidified water for analysis of physical parameters,
2) 100 ml filtered but un-acidified water for analysis of anions, and
3) 100 ml of filtered water, acidified with 1 ml super-pure (65%) nitric acid for cation and metal analysis.

Physical parameters, such as water level, EC, temperature and pH, were measured in the field.

A local assistant was identified and trained in groundwater sampling procedures in order to reduce travel costs.

### 3.2 Snow sampling

Snow was also sampled because it generally contains many impurities, which may come from natural sources, locally derived contaminants or from long distance sources of contaminants (Soveri, 1985). It therefore gives an indication of the amount of contamination that will have accumulated over a period of time when snow falls.

Snow samples were collected from sites around each of the monitoring stations towards the end of the winter season, during week 14 of 2004 and 2005 giving a total of 2 snow samples from each station. Samples were collected by pushing plexiglass samplers vertically into the snow pack. The snow samples were stored in polyethylene bags (Figure 3) and transported whilst frozen to the laboratory at Svanhovd Environmental Centre. In this lab they were melted at room temperature to liquid water, which was then transferred to sample bottles for analysis without filtering and acidifying, for analysis of physical parameters. The snow samples for cation and trace elements analysis were filtered through a 0.45µm filter membrane and transferred into pre-acidified sample bottles. Snow samples for anions were filtered but not acidified, as was the case with groundwater samples. The melt water samples were then sent to NGU laboratory for analysis. Only the filtered melt water was analysed and not the filter residue. Thus our snow data may be an underestimation of the actual element levels in snow.

### 3.3 Comparison of methods

NGU carried out the groundwater quality monitoring part of the project in collaboration with Lapland Regional Environmental Centre (LREC) in Finland. LREC provided NGU with long term monitoring reference data on groundwater quality from their Nellim station for integration with groundwater quality data from the Norwegian side through this cooperation.

Nellim station has been a part of the Finnish national groundwater-monitoring network for the past 35 years. Following a start up meeting in March 2004, at Svanhovd Environmental Centre, NGU and their Finnish counterparts decided to exchange information about their monitoring stations. A one-day joint trip to Nellim station was organised on 5 July 2004 followed by next day's visit to the 3 monitoring stations in Pasvik. The main purpose of this visit was to compare the monitoring stations in terms of hydrogeological setting and groundwater sampling procedure, sampling bottle material and analytical methods. Details about Nellim station are given in status report of 2004 (Magombedze & Jæger, NGU Report 2005.028).

Figure 3: Snow sampling equipment

### *3.3.1 Similarities in groundwater monitoring in Pasvik and at Nellim station*

- The monitoring stations are located in the same geological environment, i.e. Quaternary deposits.
- The locations are all far from direct human influence. There is a cabin close to the spring at Nellim, but since it is rarely used, the risk of anthropogenic contamination is very small.
- Sampling bottles made of the same HDPE material are used in both cases but these were not from the same manufacturer.

### *3.3.2 Differences in groundwater monitoring in Pasvik and at Nellim station*

- The groundwater monitoring point at Nellim is a spring while wells are used on the Norwegian side. However, this does not cause a big difference since wells and spring are both sources of groundwater.
- Frequency of sampling: At Nellim, groundwater samples are collected every 2 months. That means 6 samples a year. In Norway samples were collected every 5 weeks giving a total of 10 samples per station in 2004.

- Sampling methods: At Nellim, a bailer sampling method is used whereby a sample is collected directly from the well by lowering a bottle (sample collector) and then transferred to the sample bottles. On the Norwegian side, samples are collected through pumping.
- Samples from the Norwegian stations are filtered in the field and collected in factory new bottles that were washed and pre-acidified with super pure $HNO_3$ for cation analysis whereas in Finland, filtration and acidification are done in the laboratory. Sample bottles for analysis of heavy metals are pre-washed with HCl.
- Measurement of EC, pH and water level are also done in the field on the Norwegian stations whereas no field measurements are done on the Finnish station.
- Several analytical methods have been used to analyse groundwater samples in Finland. However since 2003 they use methods that are directly comparable to those used at NGU laboratory.

# 4. RESULTS AND ASSESSMENT

A total of 66 groundwater samples and 6 snow samples were collected from three groundwater-monitoring stations on the Norwegian side and analysed at NGU laboratory. Samples were analysed for cation concentration by inductively coupled plasma-atomic emission spectrometry (ICP-AES: Si; Fe; Ti; Mg; Ca; Na; Ba; Sr; Sc), trace elements by inductively coupled plasma-mass spectrometry (ICP-MS: Y; Nb; Ag; In; Sb; Cs; Nd; Sm; Ho; Yb; Ta; W; Tl; Bi; Th; V; Mn; Cu; Zn; Ga; Ge; Li; Be; B; Rb; Zr; Mo; Cd; La; Ce; Pb; U; Al; Cr; Co; Ni; P; I; K; As; Se), anions by ion chromatography (IC: F; Cl; Br; NO3; NO2; PO4; SO4), and alkalinity and pH by Glass electrode, electrical conductivity by a conductivity meter, colour by spectrophotometer and turbidity by a turbidity meter.

Standards and sample duplicates are normally used to check the accuracy of chemical analyses. In this project, sample blanks were used and their results were mostly below detection limit for most elements. The charge balance of major ions best indicates the quality of analytical data. The charge balance error of all the analyses were calculated by use of the geochemical software package Aq.QA (Version 1.0, 2003) and was found to be within acceptable range. All analyses have a charge balance error below 10% and 85% of the analyses have a charge balance error below 5%. Chemical analysis results are given in Appendix 2, while a statistical summary of parameters determined in groundwater and concentrations of parameters in snow are shown in Tables 1, 2 and 3. Where results below the detection limit were encountered, half the value of the detection limit was used for statistical analysis and presentation purposes.

## 4.1 Comparison of laboratory and field data

EC and pH measurements were taken both in the field and in the lab. EC measurements are particularly useful as a control on analysis and conservation of samples (Appelo & Postma, 1996). The pH of water represents the interrelated result of a number of chemical equilibria. According to Hem, 1970, the equilibria in a groundwater system are altered when water is pumped out to the surface due to degassing. Oxidation reactions may also alter equilibria conditions and as such, pH measured at the moment of sampling may represent the original equilibria conditions better than lab measurements done after some days or weeks. However, pH field measurements should be done with reliable equipment and precaution.
Figure 4 shows good agreement for EC between the field measurements and the laboratory measurements. This means that there was no major changes in the dissolved concentrations from the time samples were collected to the time they were analysed.

Figure 5 shows very poor correlation between pH field measurements and laboratory measurements. The poor correlation could be due to a number of reasons including temperature differences in the field and laboratory, sampling procedure and performance of the electrode. Quality control suggests that laboratory results for pH are more reliable than field measurements and will therefore be used in the further interpretation of the data.

Alkalinity is one parameter that should also be measured in the field. However this was not done during this study for logistical reasons.

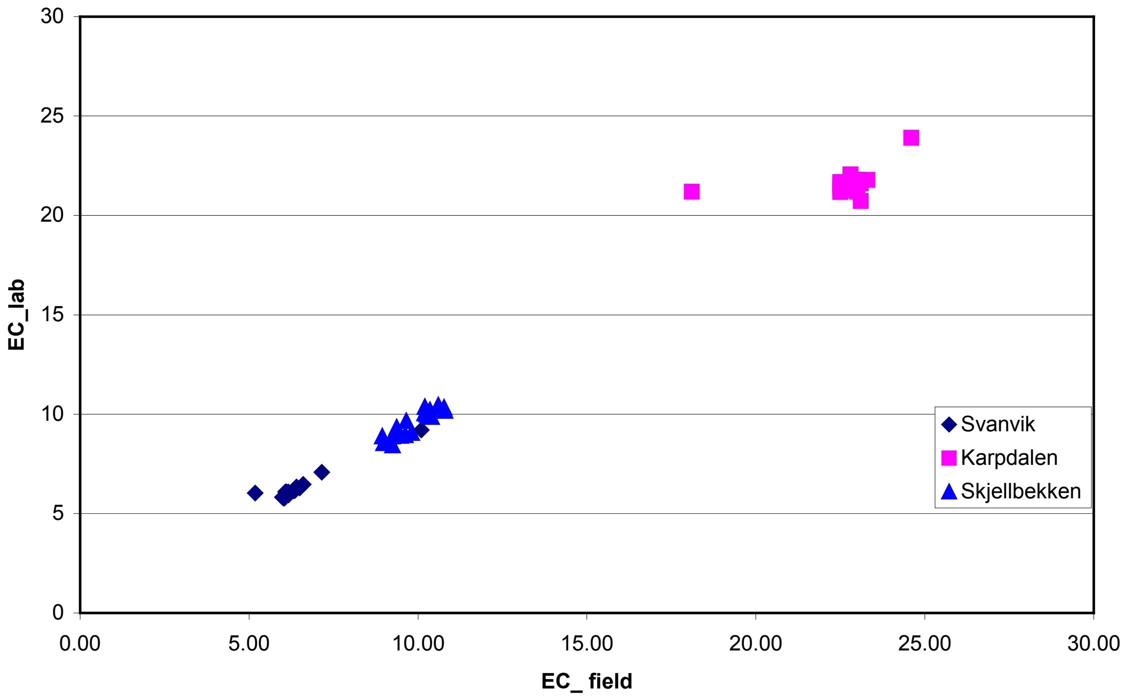


Figure 4: xy-diagram comparing EC measured in the field and in the laboratory.

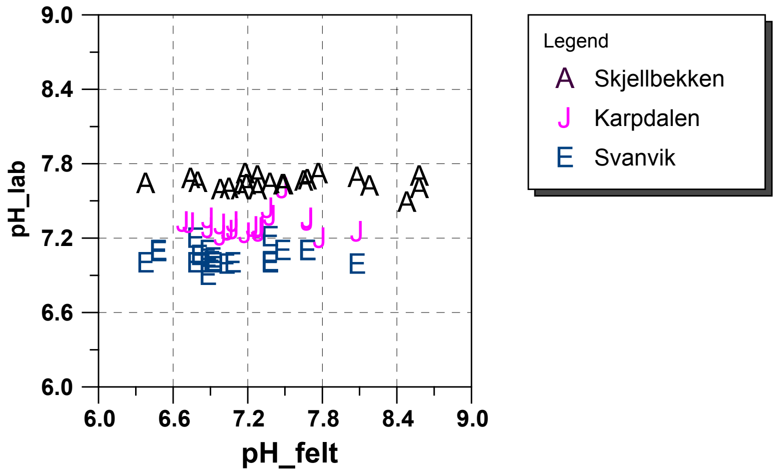


Figure 5: Comparison of field pH and laboratory pH

Table 1: Statistical summary of parameter values in groundwater and in snow at Skjellbekken and Nellim (Reference)

| Parameter | Unit | Detection limit | Min | Median | mean | St.. Dev. | Max | Snow (median) | Nellim (median) |
|---|---|---|---|---|---|---|---|---|---|
| Temp_field | °C | | 2.400 | 3.050 | 3.168 | 0.688 | 5.200 | - | - |
| EC_field | mS/m | | 8.940 | 10.000 | 9.886 | 0.592 | 10.800 | - | - |
| pH_field | | | 6.400 | 7.450 | 7.516 | 0.596 | 8.600 | - | - |
| pH_lab | | | 7.490 | 7.635 | 7.637 | 0.054 | 7.723 | 4.9597 | 6.45 |
| tAlk_lab | mmol/l | 0.04 | 0.556 | 0.672 | 0.647 | 0.066 | 0.763 | <0.04 | 0.3 |
| EC_lab | mS/m | 0.07 | 8.430 | 9.755 | 9.531 | 0.668 | 10.440 | 0.9665 | 5.6 |
| Colour | | 1.4 | <1.4 | 1.800 | 2.004 | 1.413 | 6.000 | 4.1350 | - |
| Turbidity | FTU | 0.05 | 0.060 | 0.090 | 0.106 | 0.055 | 0.320 | 0.1250 | - |
| F | mg/l | 0.05 | <0.05 | <0.05 | 0.035 | 0.023 | 0.110 | <0.05 | 0.025 |
| Cl | mg/l | 0.1 | 2.330 | 2.605 | 2.605 | 0.113 | 2.790 | 1.0400 | 3.6 |
| NO2 | mg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Br | mg/l | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | - |
| NO3 | mg/l | 0.05 | <0.05 | 0.140 | 0.171 | 0.147 | 0.500 | 0.6050 | - |
| PO4 | mg/l | 0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | 4 |
| SO4 | mg/l | 0.1 | 7.950 | 9.425 | 9.359 | 0.791 | 11.000 | 0.9150 | 3.8 |
| Si | mg/l | 0.02 | 3.750 | 4.055 | 4.095 | 0.197 | 4.620 | <0.02 | 5.6 |
| Fe | mg/l | 0.002 | <0.002 | <0.002 | 0.003 | 0.002 | 0.010 | 0.0036 | 0.0115 |
| Ti | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - |
| Mg | mg/l | 0.05 | 1.170 | 1.315 | 1.346 | 0.135 | 1.600 | 0.0670 | 1.4 |
| Ca | mg/l | 0.02 | 10.700 | 12.300 | 12.400 | 1.281 | 14.800 | 0.0565 | 5.2 |
| Na | mg/l | 0.05 | 2.190 | 2.455 | 2.548 | 0.239 | 3.260 | 0.6115 | 2.1 |
| Ba | mg/l | 0.002 | 0.033 | 0.043 | 0.113 | 0.109 | 0.283 | 0.1328 | 0.014 |
| Sr | mg/l | 0.001 | 0.025 | 0.029 | 0.029 | 0.002 | 0.035 | 0.0046 | 0.032 |
| Sc | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - |
| Y | µg/l | 0.005 | 0.008 | 0.012 | 0.012 | 0.002 | 0.015 | <0.005 | - |
| Nb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Ag | µg/l | 0.01 | <0.01 | <0.01 | 0.147 | 0.203 | 0.584 | 0.3095 | <0.02 |
| In | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | - |
| Sb | µg/l | 0.01 | <0.01 | <0.01 | 0.008 | 0.005 | 0.025 | <0.01 | <0.02 |
| Cs | µg/l | 0.002 | <0.002 | 0.002 | 0.002 | 0.001 | 0.006 | 0.0016 | - |
| Nd | µg/l | 0.01 | <0.01 | 0.010 | 0.009 | 0.003 | 0.013 | <0.01 | - |
| Sm | µg/l | 0.002 | <0.002 | 0.002 | 0.004 | 0.008 | 0.039 | 0.0015 | - |
| Ho | µg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - |
| Yb | µg/l | 0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | - |
| Ta | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | - |
| W | µg/l | 0.05 | 0.675 | 0.870 | 0.856 | 0.107 | 1.050 | <0.05 | - |
| Tl | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.08 |
| Bi | µg/l | 0.01 | <0.01 | 0.005 | 0.011 | 0.008 | 0.030 | 0.0100 | - |
| Th | µg/l | 0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | - |
| V | µg/l | 0.02 | 0.265 | 0.314 | 0.324 | 0.060 | 0.548 | 0.1220 | 0.175 |
| Mn | µg/l | 0.05 | 3.980 | 5.835 | 6.564 | 2.506 | 11.100 | 0.4170 | 5 |
| Cu | µg/l | 0.05 | 0.094 | 0.133 | 0.145 | 0.043 | 0.250 | 2.2900 | 0.44 |
| Zn | mg/l | 0.002 | 0.293 | 0.346 | 0.353 | 0.030 | 0.418 | 0.3335 | 1.1 |
| Ga | µg/l | 0.01 | <0.01 | 0.016 | 0.016 | 0.004 | 0.022 | 0.0075 | - |
| Ge | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Li | µg/l | 0.5 | <0.5 | 0.905 | 0.883 | 0.187 | 1.100 | <0.5 | 0.24 |
| Be | µg/l | 0.01 | <0.01 | 0.019 | 0.024 | 0.026 | 0.121 | 0.0285 | - |
| B | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 1.6 |
| Rb | µg/l | 0.05 | 0.888 | 1.004 | 1.008 | 0.086 | 1.200 | 0.0420 | 1.205 |
| Zr | µg/l | 0.05 | <0.05 | <0.05 | 0.035 | 0.032 | 0.170 | <0.05 | - |

Table 1 continues

| Parameter | Unit | Detection limit | Min | Median | mean | St.. Dev. | Max | Snow (median) | Nellim (median) |
|---|---|---|---|---|---|---|---|---|---|
| Mo | µg/l | 0.2 | 0.510 | 0.645 | 0.728 | 0.212 | 1.300 | <0.2 | 0.18 |
| Cd | µg/l | 0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | 0.143 | <0.03 |
| La | µg/l | 0.01 | 0.010 | 0.016 | 0.019 | 0.013 | 0.075 | <0.01 | - |
| Ce | µg/l | 0.01 | 0.004 | 0.010 | 0.013 | 0.014 | 0.070 | <0.01 | - |
| Pb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.225 | 0.110 |
| U | µg/l | 0.0005 | 0.107 | 0.127 | 0.133 | 0.017 | 0.170 | 0.001 | 0.070 |
| Al | µg/l | 2 | 5.600 | 9.245 | 9.715 | 3.567 | 18.000 | 5.050 | 12.000 |
| Cr | µg/l | 0.1 | 0.230 | 0.580 | 0.531 | 0.163 | 0.810 | 0.275 | 0.450 |
| Co | µg/l | 0.02 | <0.02 | 0.198 | 0.173 | 0.079 | 0.290 | 0.103 | - |
| Ni | µg/l | 0.2 | 0.320 | 0.455 | 0.459 | 0.075 | 0.630 | 1.435 | 3.100 |
| P | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | - |
| I | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | - |
| K | mg/l | 0.025 | 0.312 | 2.885 | 2.743 | 0.595 | 3.150 | 0.033 | 1.200 |
| As | µg/l | 0.05 | <0.05 | 0.170 | 0.180 | 0.072 | 0.440 | 0.068 | <0.05 |
| Se | µg/l | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <0.4 |
| GWL | m | | 3.150 | 3.400 | 3.423 | 0.191 | 3.800 | - | - |

Table 2: Statistical summary of parameter values in groundwater and in snow at Svanvik and Nellim (Reference)

| Parameter | Unit | Detection limit | Min | Median | mean | St.. Dev. | Max | Snow (median) | Nellim (median) |
|---|---|---|---|---|---|---|---|---|---|
| Temp_field | °C | | 2.00 | 3.00 | 2.95 | 0.72 | 5.10 | - | - |
| EC_field | mS/m | | 5.18 | 6.15 | 6.39 | 0.90 | 10.10 | - | - |
| pH_field | | | 6.40 | 6.95 | 7.08 | 0.43 | 8.10 | - | - |
| pH_lab | | | 6.87 | 7.03 | 7.04 | 0.07 | 7.21 | 5.06 | 6.45 |
| tAlk_lab | mmol/l | 0.04 | 0.29 | 0.30 | 0.31 | 0.02 | 0.38 | <0.04 | 0.30 |
| EC_lab | mS/m | 0.07 | 5.77 | 6.08 | 6.26 | 0.71 | 9.21 | 1.51 | 5.60 |
| Colour | | 1.4 | <1.4 | <1.4 | 1.71 | 1.63 | 6.60 | 3.60 | - |
| Turbidity | FTU | 0.05 | 0.18 | 0.29 | 7.45 | 32.66 | 150.00 | 0.22 | - |
| F | mg/l | 0.05 | <0.05 | <0.05 | 0.035 | 0.032 | 0.150 | <0.05 | 0.025 |
| Cl | mg/l | 0.1 | 3.63 | 3.98 | 4.15 | 0.50 | 5.40 | 2.505 | 3.6 |
| NO2 | mg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Br | mg/l | 0.1 | <0.1 | <0.1 | 0.056 | 0.021 | 0.120 | <0.1 | - |
| NO3 | mg/l | 0.05 | 0.060 | 0.400 | 0.437 | 0.222 | 0.920 | 0.675 | - |
| PO4 | mg/l | 0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | 4 |
| SO4 | mg/l | 0.1 | 6.05 | 6.45 | 6.93 | 1.97 | 15.40 | 1.385 | 3.8 |
| Si | mg/l | 0.02 | 4.37 | 4.73 | 4.74 | 0.18 | 5.08 | <0.02 | 5.6 |
| Fe | mg/l | 0.002 | <0.002 | 0.005 | 0.006 | 0.006 | 0.030 | 0.007 | 0.012 |
| Ti | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - |
| Mg | mg/l | 0.05 | 0.928 | 1.040 | 1.072 | 0.110 | 1.360 | 0.177 | 1.400 |
| Ca | mg/l | 0.02 | 5.040 | 5.665 | 5.720 | 0.472 | 7.280 | 0.152 | 5.200 |
| Na | mg/l | 0.05 | 3.390 | 3.790 | 4.045 | 1.018 | 8.370 | 1.460 | 2.100 |
| Ba | mg/l | 0.002 | 0.020 | 0.028 | 0.067 | 0.079 | 0.266 | 0.121 | 0.014 |
| Sr | mg/l | 0.001 | 0.014 | 0.016 | 0.017 | 0.002 | 0.022 | 0.003 | 0.032 |
| Sc | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - |
| Y | µg/l | 0.005 | 0.079 | 0.090 | 0.094 | 0.012 | 0.131 | <0.005 | - |
| Nb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Ag | µg/l | 0.01 | <0.01 | 0.014 | 0.144 | 0.200 | 0.563 | <0.01 | <0.02 |
| In | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | - |
| Sb | µg/l | 0.01 | <0.01 | <0.01 | 0.0060 | 0.0022 | 0.0120 | <0.01 | <0.02 |
| Cs | µg/l | 0.002 | 0.021 | 0.025 | 0.025 | 0.004 | 0.037 | 0.003 | - |

Table 2 continues

| Parameter | Unit | Detection limit | Min | Median | mean | St.. Dev. | Max | Snow (median) | Nellim (median) |
|---|---|---|---|---|---|---|---|---|---|
| Nd | µg/l | 0.01 | 0.183 | 0.233 | 0.240 | 0.038 | 0.342 | 0.008 | - |
| Sm | µg/l | 0.002 | 0.028 | 0.037 | 0.038 | 0.006 | 0.058 | 0.002 | - |
| Ho | µg/l | 0.001 | 0.002 | 0.002 | 0.002 | 0.000 | 0.003 | <0.001 | - |
| Yb | µg/l | 0.002 | 0.003 | 0.004 | 0.004 | 0.001 | 0.006 | <0.002 | - |
| Ta | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | - |
| W | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Tl | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.08 |
| Bi | µg/l | 0.01 | <0.01 | 0.0120 | 0.0122 | 0.0081 | 0.0300 | <0.01 | - |
| Th | µg/l | 0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | - |
| V | µg/l | 0.02 | 0.321 | 0.375 | 0.409 | 0.069 | 0.545 | 0.265 | 0.175 |
| Mn | µg/l | 0.05 | 0.110 | 0.630 | 0.990 | 0.959 | 3.440 | 2.520 | 5.000 |
| Cu | µg/l | 0.05 | 2.820 | 3.830 | 3.908 | 0.815 | 6.750 | 17.400 | 0.440 |
| Zn | mg/l | 0.002 | 0.259 | 0.345 | 0.343 | 0.032 | 0.398 | 0.345 | 1.100 |
| Ga | µg/l | 0.01 | <0.01 | 0.014 | 0.016 | 0.007 | 0.034 | 0.008 | - |
| Ge | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Li | µg/l | 0.5 | <0.5 | 0.540 | 0.464 | 0.180 | 0.860 | <0.5 | 0.240 |
| Be | µg/l | 0.01 | <0.01 | 0.017 | 0.025 | 0.026 | 0.107 | 0.025 | - |
| B | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | 1.6 |
| Rb | µg/l | 0.05 | 1.930 | 2.105 | 2.171 | 0.243 | 3.090 | 0.138 | 1.205 |
| Zr | µg/l | 0.05 | <0.05 | <0.05 | 0.044 | 0.030 | 0.140 | <0.05 | - |
| Mo | µg/l | 0.2 | 0.840 | 0.985 | 0.988 | 0.165 | 1.600 | <0.2 | 0.180 |
| Cd | µg/l | 0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | 0.036 | <0.03 |
| La | µg/l | 0.01 | 0.168 | 0.192 | 0.206 | 0.035 | 0.314 | 0.008 | - |
| Ce | µg/l | 0.01 | 0.029 | 0.041 | 0.062 | 0.076 | 0.396 | 0.008 | - |
| Pb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.375 | 0.110 |
| U | µg/l | 0.0005 | 0.065 | 0.089 | 0.089 | 0.013 | 0.114 | 0.001 | 0.070 |
| Al | µg/l | 2 | 10.700 | 22.000 | 25.450 | 18.625 | 93.800 | 12.400 | 12.000 |
| Cr | µg/l | 0.1 | 0.360 | 0.680 | 0.657 | 0.152 | 1.000 | 0.365 | 0.450 |
| Co | µg/l | 0.02 | <0.02 | 0.184 | 0.166 | 0.093 | 0.380 | 0.332 | - |
| Ni | µg/l | 0.2 | 1.200 | 1.400 | 1.487 | 0.250 | 2.000 | 12.550 | 3.100 |
| P | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | - |
| I | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | - |
| K | mg/l | 0.025 | 0.250 | 0.638 | 0.632 | 0.102 | 0.812 | 0.085 | 1.200 |
| As | µg/l | 0.05 | <0.05 | 0.102 | 0.100 | 0.024 | 0.140 | 0.295 | <0.05 |
| Se | µg/l | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <0.4 |
| GWL | m | | 6.83 | 7.05 | 7.03 | 0.09 | 7.15 | - | - |

Table 3: Statistical summary of parameter values in groundwater and in snow at Karpdalen and Nellim (Reference)

| Parameter | Unit | Detection limit | Min | Median | mean | St.. Dev. | Max | Snow (median) | Nellim (median) |
|---|---|---|---|---|---|---|---|---|---|
| Temp_field | $^{o}C$ | | 1.9 | 3.8 | 3.771 | 0.628 | 4.8 | - | - |
| EC_field | mS/m | | 18.1 | 22.8 | 22.677 | 1.113 | 24.6 | - | - |
| pH_field | - | | 6.7 | 7.23 | 7.257 | 0.349 | 8.1 | - | - |
| pH_lab | - | | 7.20 | 7.29 | 7.31 | 0.09 | 7.60 | 5.08 | 6.45 |
| tAlk_lab | mmol/l | 0.04 | 1.54 | 1.59 | 1.60 | 0.07 | 1.87 | <0.04 | 0.30 |
| EC_lab | mS/m | 0.07 | 20.73 | 21.61 | 21.64 | 0.59 | 23.90 | 2.46 | 5.60 |
| Colour | - | 1.4 | 1.60 | 3.00 | 4.42 | 4.52 | 23.40 | 3.59 | - |
| Turbidity | FTU | 0.05 | 5.40 | 8.60 | 27.04 | 72.19 | 345.00 | 0.22 | - |
| F | mg/l | 0.05 | 0.17 | 0.245 | 0.247 | 0.034 | 0.32 | <0.05 | 0.025 |
| Cl | mg/l | 0.1 | 10.100 | 10.750 | 10.723 | 0.446 | 11.700 | 4.805 | 3.600 |
| NO2 | mg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Br | mg/l | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | - |
| NO3 | mg/l | 0.05 | 0.050 | 0.160 | 0.171 | 0.070 | 0.290 | 0.375 | - |
| PO4 | mg/l | 0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | 4.000 |
| SO4 | mg/l | 0.1 | 11.400 | 13.050 | 13.064 | 0.756 | 15.000 | 2.080 | 3.800 |
| Si | mg/l | 0.02 | 5.450 | 6.105 | 6.072 | 0.307 | 6.770 | <0.02 | 5.600 |
| Fe | mg/l | 0.002 | 0.250 | 1.685 | 1.590 | 0.463 | 2.140 | 0.022 | 0.012 |
| Ti | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - |
| Mg | mg/l | 0.05 | 6.100 | 6.375 | 6.438 | 0.258 | 7.140 | 0.337 | 1.400 |
| Ca | mg/l | 0.02 | 19.600 | 20.400 | 20.768 | 0.990 | 24.200 | 0.284 | 5.200 |
| Na | mg/l | 0.05 | 10.300 | 11.300 | 11.359 | 0.492 | 12.400 | 2.720 | 2.100 |
| Ba | mg/l | 0.002 | 0.033 | 0.045 | 0.105 | 0.101 | 0.286 | 0.126 | 0.014 |
| Sr | mg/l | 0.001 | 0.092 | 0.097 | 0.097 | 0.004 | 0.110 | 0.007 | 0.032 |
| Sc | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - |
| Y | µg/l | 0.005 | 0.050 | 0.090 | 0.091 | 0.028 | 0.145 | 0.011 | - |
| Nb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Ag | µg/l | 0.01 | <0.01 | 0.122 | 0.238 | 0.256 | 0.656 | <0.01 | <0.02 |
| In | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | - |
| Sb | µg/l | 0.01 | <0.01 | <0.01 | 0.027 | 0.060 | 0.276 | 0.008 | <0.02 |
| Cs | µg/l | 0.002 | 0.003 | 0.004 | 0.006 | 0.005 | 0.028 | 0.002 | - |
| Nd | µg/l | 0.01 | 0.060 | 0.110 | 0.124 | 0.064 | 0.324 | 0.023 | - |
| Sm | µg/l | 0.002 | 0.010 | 0.017 | 0.020 | 0.009 | 0.047 | 0.003 | - |
| Ho | µg/l | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | 0.004 | <0.001 | - |
| Yb | µg/l | 0.002 | 0.004 | 0.006 | 0.006 | 0.002 | 0.009 | <0.002 | - |
| Ta | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | - |
| W | µg/l | 0.05 | <0.05 | 0.038 | 0.042 | 0.018 | 0.070 | <0.05 | - |
| Tl | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.08 |
| Bi | µg/l | 0.01 | <0.01 | <0.01 | 0.010 | 0.006 | 0.020 | 0.008 | - |
| Th | µg/l | 0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | - |
| V | µg/l | 0.02 | 0.218 | 0.592 | 0.650 | 0.326 | 1.740 | 0.232 | 0.175 |
| Mn | µg/l | 0.05 | 79.700 | 89.250 | 89.927 | 6.599 | 104.000 | 1.915 | 5.000 |
| Cu | µg/l | 0.05 | <0.05 | 0.054 | 0.092 | 0.149 | 0.721 | 19.750 | 0.440 |
| Zn | mg/l | 0.002 | 0.276 | 0.335 | 0.335 | 0.024 | 0.376 | 0.330 | 1.100 |
| Ga | µg/l | 0.01 | <0.01 | 0.010 | 0.016 | 0.029 | 0.142 | 0.008 | - |
| Ge | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - |
| Li | µg/l | 0.5 | 2.300 | 2.795 | 2.810 | 0.276 | 3.300 | <0.5 | 0.240 |
| Be | µg/l | 0.01 | <0.01 | 0.021 | 0.032 | 0.041 | 0.189 | 0.017 | - |
| B | µg/l | 5 | <5 | 19.000 | 18.418 | 3.908 | 23.000 | <5 | 1.600 |
| Rb | µg/l | 0.05 | 0.966 | 1.030 | 1.127 | 0.317 | 2.470 | 0.058 | 1.205 |
| Zr | µg/l | 0.05 | <0.05 | 0.099 | 0.088 | 0.053 | 0.240 | <0.05 | - |

Table 3 continues

| Parameter | Unit | Detection limit | Min | Median | mean | St.. Dev. | Max | Snow (median) | Nellim (median) |
|---|---|---|---|---|---|---|---|---|---|
| Mo | µg/l | 0.2 | 2.890 | 3.735 | 3.692 | 0.310 | 4.320 | <0.2 | 0.180 |
| Cd | µg/l | 0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | 0.073 | <0.03 |
| La | µg/l | 0.01 | 0.050 | 0.099 | 0.113 | 0.063 | 0.338 | 0.030 | - |
| Ce | µg/l | 0.01 | 0.080 | 0.174 | 0.201 | 0.131 | 0.731 | 0.038 | - |
| Pb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 1.586 | 0.110 |
| U | µg/l | 0.0005 | 2.970 | 4.840 | 8.500 | 11.498 | 55.400 | 0.002 | 0.070 |
| Al | µg/l | 2 | 5.200 | 10.350 | 23.002 | 43.300 | 210.000 | 12.550 | 12.000 |
| Cr | µg/l | 0.1 | 0.240 | 0.650 | 0.648 | 0.198 | 1.000 | 0.355 | 0.450 |
| Co | µg/l | 0.02 | <0.02 | 0.298 | 0.294 | 0.120 | 0.534 | 0.412 | - |
| Ni | µg/l | 0.2 | 0.517 | 0.800 | 0.949 | 0.393 | 1.900 | 15.555 | 3.100 |
| P | µg/l | 5 | <5 | 10.355 | 9.969 | 3.518 | 15.000 | <5 | - |
| I | µg/l | 5 | <5 | 5.400 | 4.645 | 2.107 | 8.500 | <5 | - |
| K | mg/l | 0.025 | 0.734 | 3.615 | 3.506 | 0.703 | 4.700 | 0.112 | 1.200 |
| As | µg/l | 0.05 | <0.05 | 0.606 | 0.614 | 0.167 | 0.909 | 0.390 | <0.05 |
| Se | µg/l | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <0.4 |
| GWL | m | | 1.45 | 2 | 2.027 | 0.399 | 2.9 | - | - |

## 4.2 Time Series

The aim of this study was to improve our understanding of temporal variability of element concentration in groundwater and seasonal effects to determine whether the emissions from Nikel and Zapolyarniy have an impact on groundwater quality. Time series plots have been prepared to assess any changes in groundwater element concentrations with time. $NO_2$, Br, $PO_4$, Ti, Sc, Nb, In, Sb, Ta, Tl, Th, Ge, Cd, Pb and Se have concentrations lower than detection limit for all groundwater samples from all 3 stations and time series plots will not be shown for these elements except for Cd and Pb. Boron is below detection limit at Skjellbekken and Svanvik stations.

Figures 6-14 shows time series plots of elements and parameters discussed in this report. Each plot displays data on element concentrations in groundwater at each station as well as in snow samples. Focus is on the concentration levels of the most important contamination indicators (pH, alkalinity, Cu, Ni, $SO_4$, Pb, Cd, As, Sr) and their temporal variation.

### *4.2.1 pH/ groundwater acidification*

Groundwater acidification occurs generally in the same areas where surface media acidification is a problem and this is reflected by the pH of groundwater. Time series plots for pH (Figure 6) show neutral to alkaline water at all stations with no significant temporal variation (median pH: Svanvik=7.04; Karpdalen=7.29; Skjellbekken=7.64). This indicates that the load of acids reaching the groundwater is low or that there is a high degree of buffering from weathering of parent material.

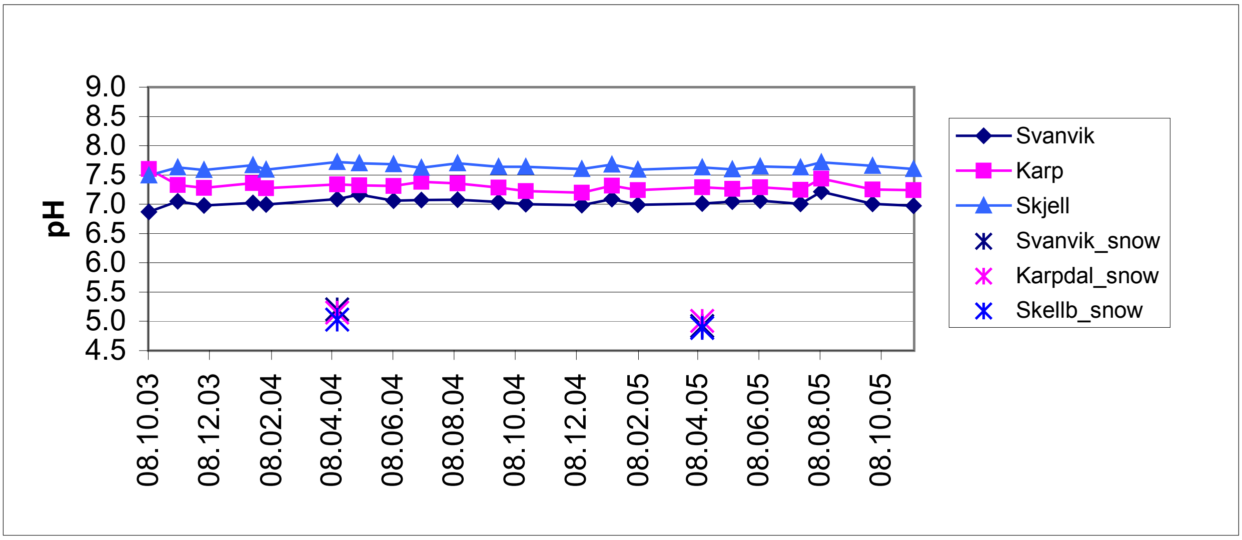

Figure 6: Temporal variation of pH in groundwater and in snow

The pH of snow and rain are only slightly affected by airborne anthropogenic emissions (snow pH = 4.89-5.2; Data from NILU shows Karpbukt rainwater median pH= 4.89 and median $SO_4$ in rainwater=0.9 mg/l). The pH of rainfall and snow is close to the background value of natural precipitation (pH = 5.5). Therefore the influence of basic substrate is important at all three stations.

### *4.2.2 Alkalinity /Acid neutralising capacity*

Alkalinity is the capacity to neutralise acidity. Alkalinity of groundwater at Svanvik is equal to reference values at Nellim, while the alkalinity at Karpdalen and Skjellbekken was higher than the reference values (Figure 7). Thus there is high acid buffering capacity from weathering of parent material thereby replenishing cations. Groundwater alkalinity is highest at Karpdalen probably due to marine influence. There is insignificant temporal variation in alkalinity at Karpdalen and Svanvik throughout the investigation period while there is a gently decreasing trend at Skjellbekken, starting April 2004 and stabilising around June 2005. This could be a first sign that the buffering capacity is being consumed at Skjellbekken. There is therefore a need for continued monitoring.

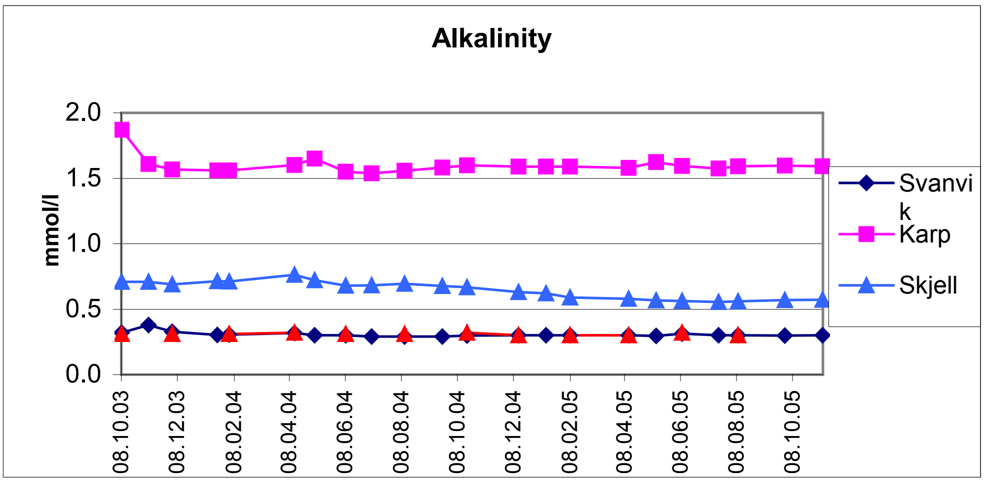

Figure 7: Alkalinity of groundwater

Acidification is defined as loss of alkalinity and according to Henriksen & Kirkhusmo, 1986 it is calculated as follows:

$$Aci = 0.93(Ca^{2+} + Mg^{2+}) - 14 - Alk + Al$$

where all concentrations are expressed in µeq/l.

Acid neutralising capacity (ANC) is defined as the difference between base cations and acid anions. It is basically alkalinity expressed in µeq/l. According to Stumm, 1992, it is calculated as follows:

$$ANC = \left(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}\right) - \left(NO_3^{-} + SO_4^{2-} + Cl^{-}\right),$$

where all concentrations are expressed in µeq/l

Figure 8 gives an overview of acidification and ANC at the three monitoring stations.
It shows low acidification at Svanvik and Skjellbekken and even negative values for acidification at Karpdalen. ANC is still positive (ranging from 300 µeq/l at Svanvik to about 1600 µeq/l at Karpdalen suggesting that there is still potential to neutralise acid at all stations. The high acid neutralising capacity shown by the plot supports the fact that groundwater has not been significantly acidified, as also shown by pH values in Figure 6 above. The geology (Quaternary deposits) provides effective neutralisation of acidity in the three areas.

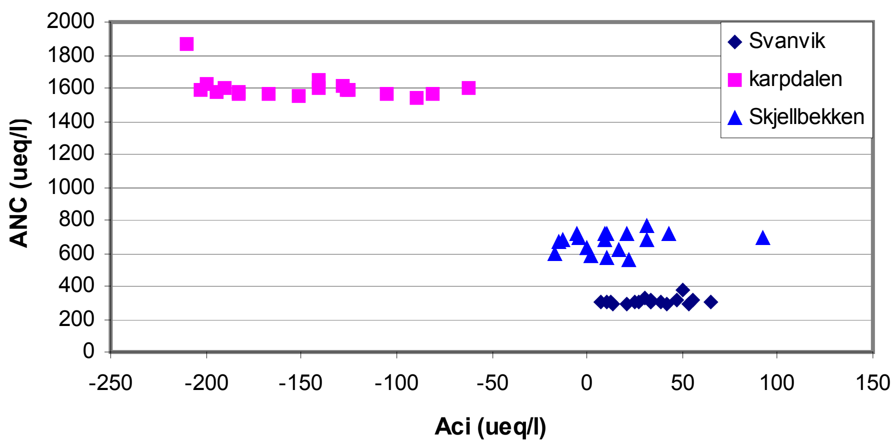


Figure 8: Relationship of acidification to ANC of groundwater

### *4.2.3 Sulphate ($SO_4$)*

$SO_4$ concentration in groundwater is a result of oxidation of sulphide minerals or/and infiltration of anthropogenic $SO_4$ from the surface. Figure 9 shows that $SO_4$ concentrations in groundwater are above reference levels at all stations (Svanvik by a factor of 1.5; Skjellbekken by a factor of 2-2.5 times; Karpdalen by 3-3.5 times), suggesting three possible sources; geogenic (from natural mineralisation), marine (from seaspray aerosols in precipitation and former higher sea-levels) and anthropogenic (oxidation of $SO_2$ from the smelters). $SO_4$ concentration shows slight and insignificant variation with time at Svanvik (range = 6.05- 6.93 mg/l, median = 6.45 mg/l) as from 2004. Slight temporal variation is also shown for Karpdalen (range=11.4-15 mg/l, median $SO_4$ is 13 mg/l). Skjellbekken displays an increasing trend from October 2003 to Feb 2004 and a decreasing trend from April 2004 to about Dec 2004. $SO_4$ concentration increases again from Jan 2005 to October 2005 ($SO_4$ range=7.95-11 mg/l, median=9.43 mg/l). Snow has median $SO_4$ concentrations of 2.08 mg/l at Karpdalen, 1.39 mg/l at Svanvik and 0.92 mg/l in Skjellbekken. Rainwater has median $SO_4$ of 0.9 mg/l at Karpdalen

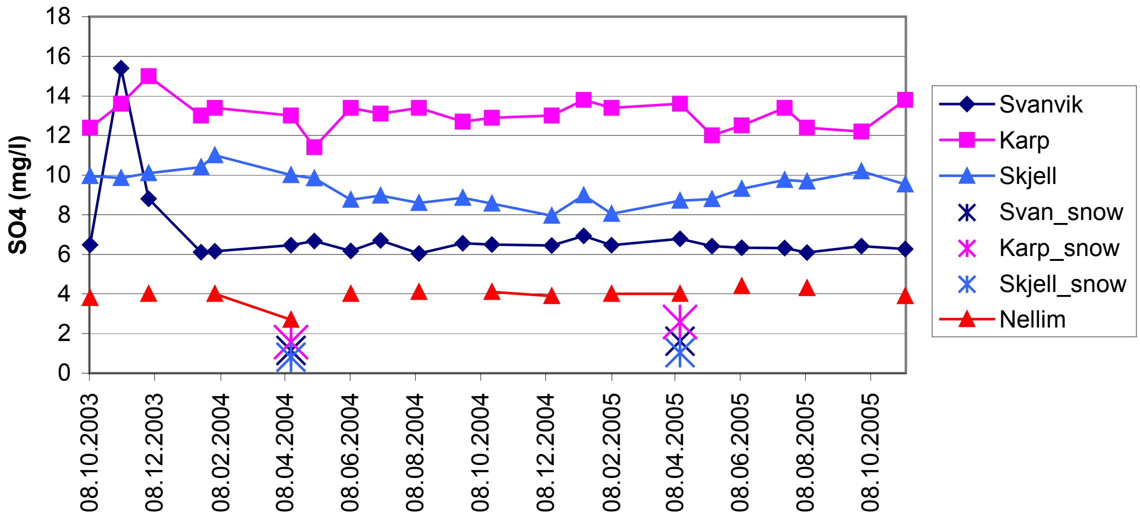


Figure 9: $SO_4$ concentrations in groundwater and snow

The $SO_4$ system is a complex one since it is not a closed system. So many factors may cause an increase or a decrease in $SO_4$ concentration e.g. it is a source of nutrition for plants and is removed from the system this way. However, an attempt has been made to distinguish between marine $SO_4$, and non-marine $SO_4$ and biotic factors have been ignored.

Non-marine $SO_4$ can be determined as follows:

$$SO_{4\,non-marine} = SO_{4\,meas} - \left( Cl_{meas} \times \frac{SO_{4\,sea}}{Cl_{sea}} \right)$$

where $meas$ = measured, $SO_{4\ sea}$ = 2700 mg/l and $Cl_{sea}$ = 19000 mg/l

This formula is based on the assumption that there are no other sources of Cl than marine input.

Table 4: Marine and non-marine $SO_4$ in groundwater and snow

| **Station** | **Groundwater (median (mg/l))** | | | **Snow (Median (mg/l))** | | |
|---|---|---|---|---|---|---|
| | Total | Non-marine | Marine | Total | Non-marine | marine |
| Svanvik | 6.45 | 5.88 | 0.57 | 1.39 | 1.03 | 0.36 |
| Karpdalen | 13.05 | 11.60 | 1.45 | 2.08 | 1.40 | 0.68 |
| Skjellbekken | 9.43 | 9.06 | 0.37 | 0.92 | 0.77 | 0.15 |

Table 4 above shows that marine influence on the $SO_4$ content in groundwater and snow is generally small though it may occasionally be quite substantial (≈ 33% of snow at Karpdalen).

This is due to its close proximity to the Barents Sea. Groundwater $SO_4$ at the three stations has probably mostly a geogenic source since $SO_4$ in snow is minimal. This is in agreement with the finding that Quaternary deposits and bedrock in the Skjellbekken area are rich in S (Pavlov et. al in Caritat et, al., 1998).

### *4.2.4 Copper (Cu)*

Figure 10 below shows Cu levels in snow and groundwater. Note the log scale. Cu concentration in groundwater is below reference levels at Skjellbekken (ranges from 0.09-0.25 µg/l, median= 0.133 µg/l and at Karpdalen (range: <0.05-0.721 µg/l, median= 0.054 µg/l), suggesting mostly geogenic origin. There is a decreasing trend at Karpdalen from October 2003 to July 2004. After this time, the Cu concentrations are mostly below the detection limit. Generally Cu in groundwater at Skjellbekken shows a decreasing trend. Cu in groundwater at Svanvik ranges from 2.82-6.75 µg/l with a median of 3.83 µg/l. It is above reference levels by a factor of about 10. It shows a slightly increasing trend from April 2005 to October 2005. Prior to that, it was stable.

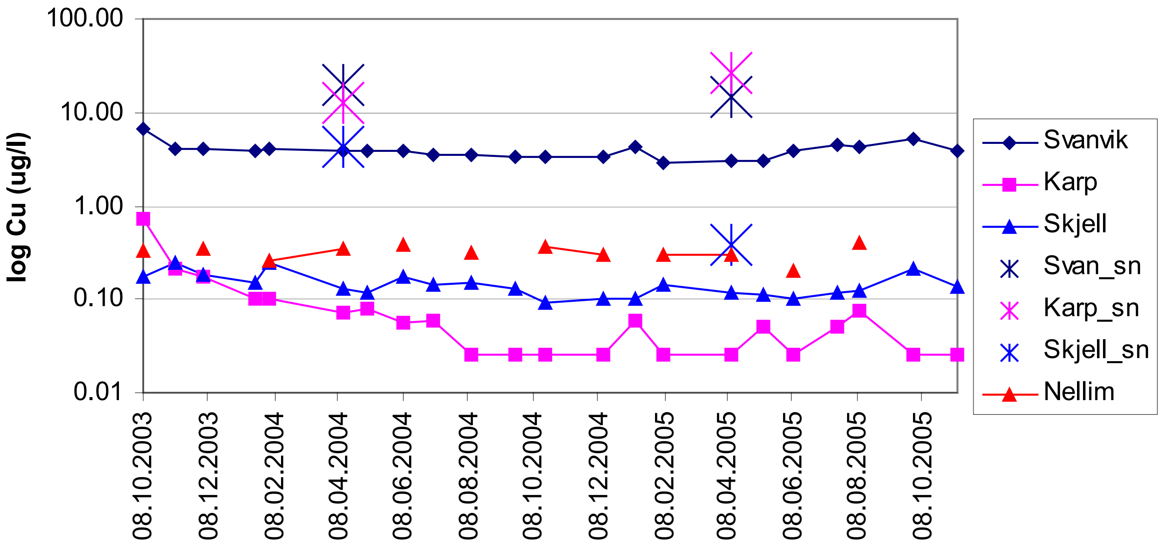


Figure 10: Cu content in groundwater and snow

The relatively high Cu concentrations in groundwater at Svanvik could be explained by 1) its proximity to Nikel relative to the other stations meaning more deposition at Svanvik. As a result the soil is saturated with $H^+$ and Cu is leached out to the groundwater. 2) The bedrock or the Quaternary deposits here are richer in Cu that at the other stations. The geochemistry of Quaternary deposits has not been studied and this is important missing information. The high Cu concentration in snow is an indication that airborne anthropogenic contamination could be a more important source than geology at Svanvik and Karpdalen. Svanvik is only 7 km from Nikel and Karpdalen is located along the prevailing wind direction from Nikel (S-N). Despite the high Cu levels in snow, there is not much Cu in groundwater at Karpdalen. This could be due to 1) lithological stratigraphy (Figure 2): the clay layer at Karpdalen may act as a barrier to flow while the sand at Svanvik will easily let the elements seep through. 2) solubility and mobility of Cu is controlled by soil and water pH. The high pH at Skjellbekken and Karpdelen causes Cu to be retained in the soil. Acid impact is normally felt when precipitation pH values are around 4.5 or below. Rainwater pH at Karpdalen is 4.8 while snow pH = 5.1 and are close to the value for natural precipitation (5.5). Therefore the impact of smelters on groundwater is limited here.

### *4.2.5 Nickel (Ni)*

Figure 11 below shows that Ni concentration in snow is relatively high at Karpdalen (median value =15.55 µg/l) and Svanvik (median value = 12.55 µg/l). Ni levels in groundwater are more or less stable throughout the project period at Skjellbekken and have a generally decreasing trend at Karpdalen. However, Ni in groundwater is relatively high at Svanvik (median=1.4 µg/l) compared to Karpdalen (0.8 µg/l) and Skjellbekken (0.46 µg/l). As with Cu the relatively high levels could be attributed to the proximity of Svanvik to Nikel. Jensen & Finne, 2006 also reported that Ni deposition in the humus layer plays a larger role in Pasvik compared to Jarfjord (partly due to the shorter distance from Nikel to Svanvik than to Jarfjord). Thus Ni load on surface media at Svanvik is higher compared to the other two stations and may eventually leach to the groundwater. However, compared to Cu, Ni has lower concentration levels in groundwater. Thus Ni is more effectively immobilised in the upper layers of the unsaturated zone than Cu.

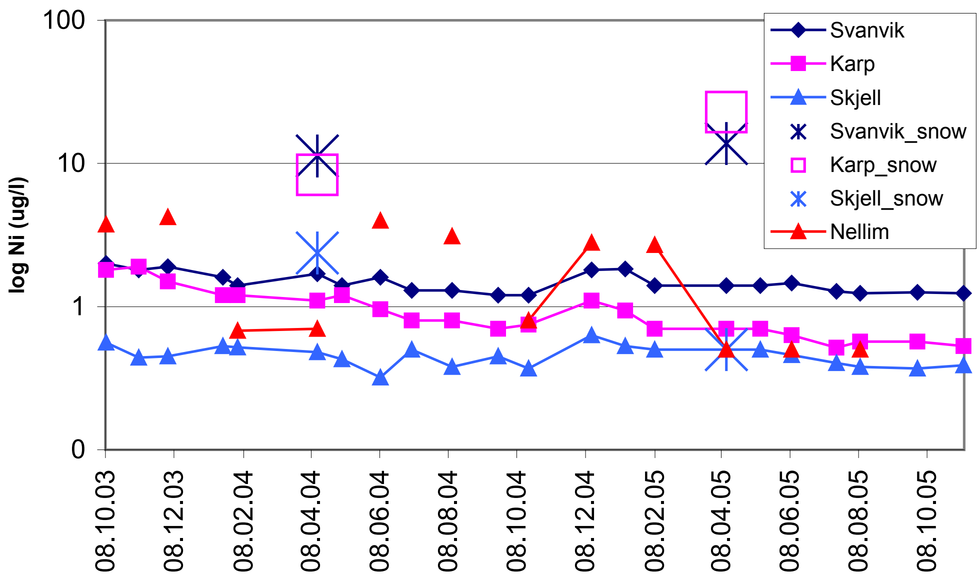


Figure 11: Temporal variation of Ni in groundwater and snow

### *4.2.6 Molybdenum (Mo)*

All analyses of molybdenum in groundwater are above the reference level at all three stations (Figure 12). Mo is not emitted in large quantities at Nikel as supported by very low concentrations in snow even at Svanvik, which is close to the emission source. The elevated molybdenum concentrations could be related to geology and marine sediments at Karpdalen. Reimann et al., 1997 showed that B and C-horizons had rather high Mo levels. The average Mo in ocean water is 10 µg/l and 0.5 µg/l in stream water. However, the highly alkaline environment at Karpdalen is probably the main explanation for the high Mo content here. Mo is more mobile in alkaline environments. Marine influence may explain the decreasing trend in Mo concentration in groundwater from Karpdalen to Nellim. Svanvik and Skjellbekken display generally a decreasing trend during the project period.

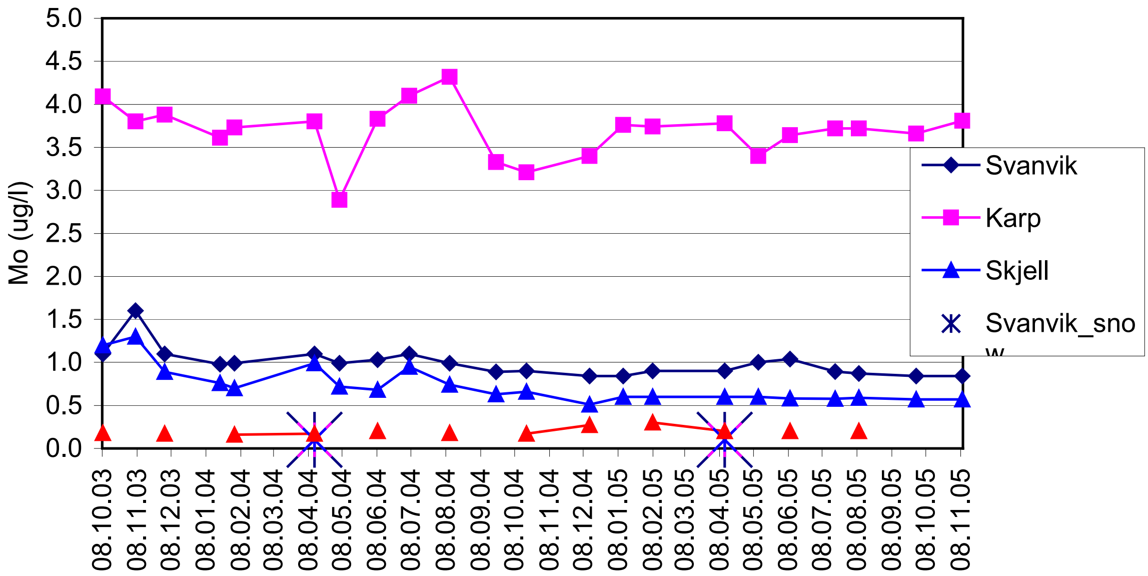


Figure 12: Temporal variation of Mo in groundwater and snow

### *4.2.7 Strontium (Sr)*

Groundwater Sr is below reference levels at Svanvik and Skjellbekken (Figure 13). Sr cannot originate from the smelters as is also supported by the low concentrations in snow. Thus Sr has a geogenic and marine origin. The high levels at Karpdalen are due to marine sediments and sea spray. Sr behaves chemically like calcium and has a positive correlation of 0.94 with this element. Strontium is a common trace element in nature and should not be confused with the radioactive isotope $^{90}$Sr, a by-product of nuclear bombs.

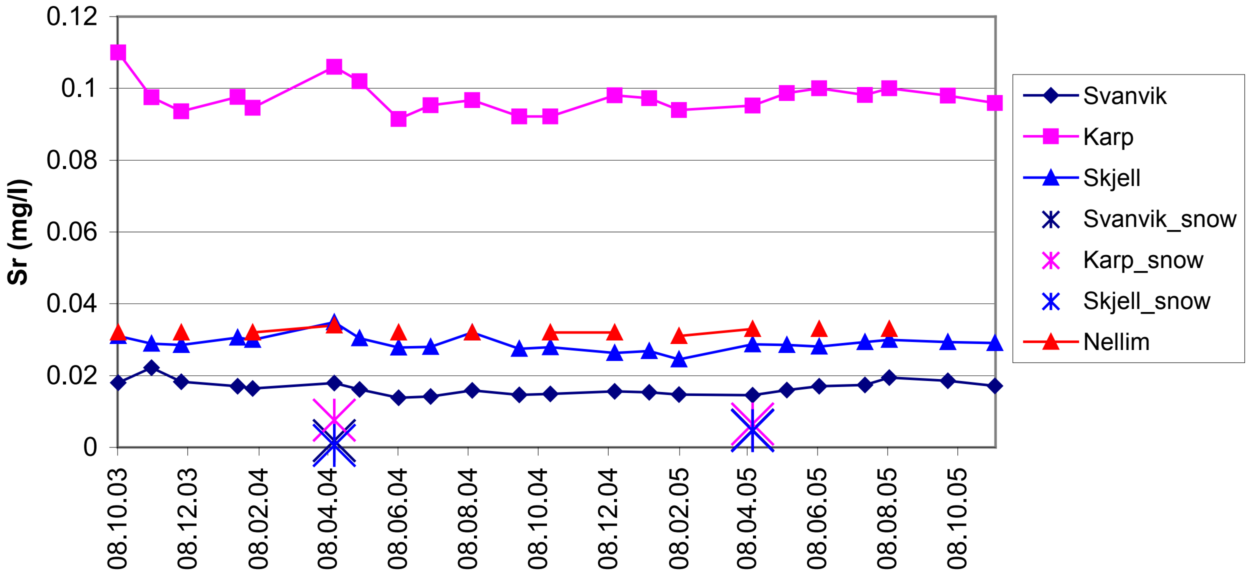


Figure 13: Sr concentration in groundwater and snow

### *4.2.8 Arsenic (As)*

Arsenic is a toxic heavy non-metallic element found in groundwater. It is emitted in substantial quantities from the Nikel smelters and Zapolyarni ore roasting plants. There have been fears and speculation that airborne As from the smelters in Russia could be deposited in Norway (Caritat et al., 1998). Figure 14 shows that arsenic concentrations are above the reference level at all three stations. Actually, at Nellim (Reference) it is below detection limit. However the differences (with the exception of Karpdalen) are insignificant. The high values (>0.25 µg/l) from Karpdalen could be attributed to the local geology (more arsenopyrite in the Karpdalen area) and the more alkaline environment prevailing at Karpdalen. Caritat et al., 1996, Chekushin et al., 1998 and Caritat, 1997, concluded that As in the Skjellbekken area is primarily of geogenic origin and that anthropogenic contribution is of secondary importance.

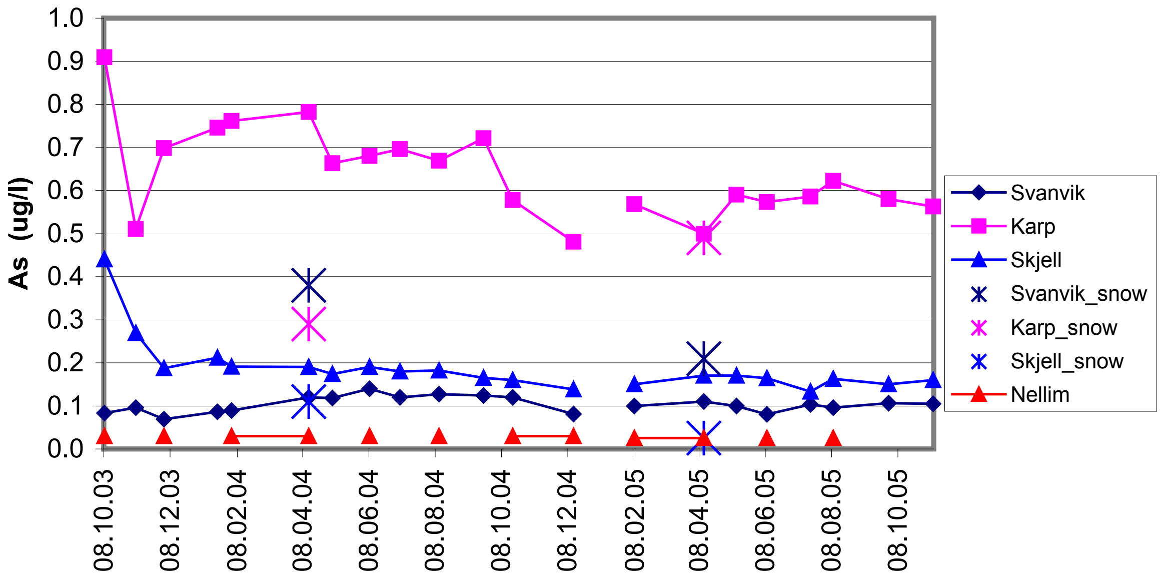


Figure 14: As concentration in groundwater and snow

### *4.2.9 Lead (Pb) and Cadmium (Cd)*

Pb and Cd are some of the elements of the emission spectrum from the smelters. Despite the significant concentrations in snow, Pb and Cd concentration in groundwater are below detection limit (Pb<0.05 µg/l; Cd<0.03 µg/l) (See Appendix 3). The soil has thus probably capacity to retain Pb and Cd and these trace elements do not yet reach the groundwater. The sudden increase in the Cd level at all three stations in Nov 2003, Dec 2004 and Jan 2005 are more likely due to analytical errors.

### *4.2.10 Other elements*

Na, Mg, Ca, Mn, Fe, Si, Sr, Mo and Li are elements of primarily geogenic origin. Their presence in groundwater is due to rock-water interaction over time and/or weathering of silicate and carbonate minerals in particular. The relatively higher abundance of typical marine elements (Mo, Na, Sr, Mg) at Karpdalen is due to its proximity to the Barents Sea. The results are presented graphically in appendix 3.

## 5. COMPARISON WITH PREVIOUS DATA

Table 5 below compares groundwater concentrations for selected elements from this study and NGU's unpublished data from the 1994/95-groundwater quality monitoring study at Skjellbekken.

Table 5: Comparison of element concentrations in groundwater from this study and the 1994/95 study

| Element/parameter | Unit | Skjellbekken (1994/95) median | Skjellbekken (2003-2005) median |
|---|---|---|---|
| pH | | 7.3 | 7.6 |
| EC | mS/m | 10.4 | 9.75 |
| As | µg/l | 0.56 | 0.17 |
| Cd | µg/l | <0.02 | <0.03 |
| Cu | µg/l | 0.97 | 0.133 |
| Ni | µg/l | 0.925 | 0.455 |
| Pb | µg/l | 0.06 | <0.05 |
| Zn | µg/l | 0.346 | 1.97 |
| SO4 | µg/l | 6.4 | 9.43 |
| Cl | µg/l | 2.32 | 2.61 |
| Sr | µg/l | 31.1 | 29 |
| Mo | µg/l | 0.16 | 0.645 |
| Al | µg/l | 7.83 | 9.23 |
| | | | |

Generally, as shown in Table 5 our median data are significantly lower than 1994/95 data for As (3.2 times), Cu (7.3 times), Ni (2 times), and higher for Zn (5.7 times), SO4 (1.5 times) and Mo (4 times). However, different laboratories were used for the analysis of samples from the two projects. The 1994/95 samples were analysed at GTK in Finland while our samples were all analysed at NGU lab, making comparability of the analytical results a bit unreliable. However, if these data are anything to go by, there is clear evidence that it takes a long time to recognise a change in the chemistry of groundwater. We don’t see any significant changes in the groundwater quality during this three-year project but such a huge difference for some elements, 10 years later from 1994. This emphasises the need for continued long term monitoring. The high Zn values in our data could be attributed to the sample bottle material, which was shown to release mainly Zn and Ba (Reimann in prep.).

## 6. COMPARISON WITH DRINKING WATER STANDARDS

Trace elements may be important for human health but only when taken in certain quantities above which most of them become toxic and cause disease. In order to protect human life and the environment countries have set limits and action levels for their waters depending on the use. Table 6 shows a comparison of the median background values of 7 toxic trace elements content in groundwater, drinking water standards for Norway and the median content in groundwater at each of the three stations in Pasvik.

Table 6: Comparison of groundwater concentrations with drinking water standards

| Element | Nellim (Reference) Median (µg/l) | Svanvik Median (µg/l) | Karpdalen Median (µg/l) | Skjellbekken Median (µg/l) | Norwegian Drinking water Standards (Maximum allowable concentrations (µg/l) |
|---|---|---|---|---|---|
| As | <0.05 | 0.102 | 0.61 | 0.17 | 10 |
| Cd | <0.03 | <0.03 | <0.03 | <0.03 | 5 |
| Cr | 0.45 | 0.68 | 0.65 | 0.58 | 50 |
| Cu | 0.36 | 3.83 | 0.05 | 0.13 | 100 |
| Ni | 2.12 | 1.40 | 0.8 | 0.46 | 20 |
| Pb | 0.06 | <0.05 | <0.05 | <0.05 | 10 |
| Zn | 0.5 | 0.345 | 0.335 | 0.346 | - |

Table 6 shows that only Cu at Svanvik and As at all 3 stations exceed the reference values from Nellim station. Cu is higher by a factor of 9, while As is higher by factors of 4; 23 and 6 at Svanvik, Karpdalen and Skjellbekken respectively. However, all elements have concentrations well below the recommended limits for drinking water in Norway and do not pose any danger to human health.

## 7. CONCLUSIONS

- Analytical data does not show significant temporal variations in concentrations for most parameters except for decreasing alkalinity at Skjellbekken and increasing Cu at Svanvik during 2005.

- High element concentrations in groundwater at Karpdalen are mainly due to contribution from:
    - marine sediments and sea spray and
    - the alkaline environment

  whereas the high values in snow are attributed to high deposition load due to Karpdalen's on-wind location (S-N) and due to Svanvik's close proximity to the source of the emissions.

- Groundwater is not acidified and still has high acid neutralising capacity (ANC). The ANC may be decreasing at Skjellbekken

- Compared to 1994/95 groundwater quality data, Ni, Cu, As, are significantly reduced in 2005.

- Although surface media have been affected by the emissions; there are no clear indications of anthropogenic contamination in groundwater. The elements from the contaminated media are expected to subsequently leach to the groundwater. However, there seems to be an attenuation of pollutants in the unsaturated zone as water infiltrates to the groundwater zone.

# 8. RECOMMENDATIONS FOR A JOINT MONITORING PROGRAM

The different surface and subsurface media of airborne pollution are part of the whole hydrological cycle and are interrelated. None of these media should be treated individually if we are to understand better the effects of the emissions on the environment. This then creates the need for an integrated monitoring program. From our findings and experiences in this study, we have come up with the following recommendations.

- Snow elemental concentration data and other surface media data have shown anthropogenic contribution from the smelters in Russia. However this is not yet reflected in the groundwater. This may be attributed to the fact that the heavy metals are not mobilised effectively through the soil layers. However as the deposition on the soils accumulate with time, the soils will become saturated with trace elements and will eventually leach out these (e.g. Cu and Ni) to the groundwater. It is therefore recommended to consider long term monitoring of groundwater quality since it may be a question of time before the effect of airborne pollution from the smelters is detected in groundwater.
  The decreasing alkalinity at Skjellbekken could also be considered as a first sign that buffering capacity is being consumed; hence the need for continued monitoring. Groundwater quality monitoring for the purposes of this project ended at the end of 2005. NGU however continues monitoring groundwater quality in the Pasvik area as part of its national groundwater monitoring network (LGN).

- With regards to the above argument, it is also recommended to consider depth profiling/pore water studies in order to monitor the movement of heavy metals in the unsaturated zone and also determine the present position of the pollution front and monitor how fast it is moving.

- The load of contaminants decreases with distance from the source and is also influenced by the wind direction (Kalabin & Svelle, 1994). The surroundings of the smelters receive the largest amounts of contaminants. In order to delimit the extent of the influence of smelters on groundwater quality, it is recommended to monitor groundwater quality in a transect from the Norwegian side across the border to Nikel.

- The geochemistry of the Quaternary deposits at each station, including the reference station should be studied to help in assessing the possible sources of elements found in groundwater.

- The three monitoring stations are not easily comparable because of the probably different geochemistry of the Quaternary deposits in these areas and the different distances to the coast. It is therefore suggested to increase the number of stations in each station area to get a regional picture of each of the three study areas.

- There are no seasonal trends displayed by the present data, which is probably due to the spaced sampling frequency (once every 5 weeks). It is therefore recommended to increase the sampling frequency in the future, especially during snowmelt, in order to pick up any seasonal variation and for earlier detection of changes in groundwater chemistry.

- It is recommended to use one laboratory for analysing samples from the same media to avoid differences in analytical methods for comparability. Ring tests of the laboratories involved may also be carried out.

- The use of factory new transparent HDPE sample bottles from the same manufacturer is recommended.

- Samples should be acidified in the field through the use of acid in Teflon drip bottles.

- Filtered melt water as well as the filter residual from snow samples should be analysed separately.

- Alkalinity, pH and EC should be measured in the field as well as in the laboratory.

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## APPENDIX 1: Groundwater sampling protocol for the Pasvik Project 2003 - 2006

**Contamination must be minimized as much as possible!**

1) Remember the keys for opening locks on wells

2) Measure the water level to the top of the casing. Note the result in the field notebook/form.

3) Measure the height of the casing above the ground and note it in the field notebook/form.

4) Lower the pump, mounted to hose and electric cable in the well.

**5)** Raise the pump a little from the bottom of the well and connect the electric cable to the battery. (**N.B each well must have it's own pump to avoid contamination)**

6) Pump out standing water in the well monitoring field parameters (pH, EC, and temperature) periodically during pumping process. When purge volume is equal to 3 casing volumes, and/or when field parameters are more or less constant, within plus or minus five percent (± 5%) over successive readings the well is ready for sampling.

7) Record the last EC, pH, Temperature readings and the volume pumped out

– **Taking a sample:**
  - rinse a 500ml bottle 2 to 3 times with water to be sampled and fill it up for analysis of EC, pH, temperature, turbidity, colour, and alkalinity. Label the samples with: BH/sample ID, location and date sampled

  - filter sample water through 0.45µm Millipore filtering membrane. Rinse a small non pre-acidified bottle (100ml), 2 to 3 times with filtered water. Fill it with filtered water and close it tightly for analysis of anions and silica. Label the samples.

    **N.B Rinse the filtering unit with deionised water after use and then rinse it with sample water prior to collection of sample at each new sampling point. Use new filter paper for each new sample.**

  - **Do not** rinse the small pre-acidified bottle (100ml). Fill it up with filtered water and close it tightly for analysis of cations and metals. Label the samples.

  - **Keep the sample bottles upright in a cool place.**

8) When it's very cold it is difficult to filter in the field. So take an extra 500mml bottle of water and filter in the lab/home. The filtration should be done the same day the sample was collected. Remember to rinse the bottle with sample water before collecting a sample.

9) If the water is too dirty, it maybe difficult to filter. Filter a small volume of water. (This will be enough for analysis even if flask is $\frac{1}{4}$ full.)

10) Disconnect electric cable from battery. Pump with hose and cable can be left in the well until next sampling round.

**Samples should be sent to the laboratory for analysis as soon as possible**.

## APPENDIX 2: Parameter values in groundwater
## SKJELLBEKKEN

| Parameter | Enhet | DL | 27.09.03 | 06.11.03 | 02.12.03 | 20.01.04 | 02.03.04 | 01.04.04 | 05.05.04 | 11.06.04 | 06.07.04 | 18.08.04 | 21.09.04 | 27.10.04 | 02.12.04 | 12.01.05 | 23.02.05 | 05.04.05 | 12.05.05 | 16.06.05 | 19.07.05 | 18.08.05 | 29.09.05 | 09.11.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp_field | | | 2.7 | 2.4 | 2.7 | 2.5 | 2.4 | 2.7 | 3.7 | 3.3 | 3.6 | 3.8 | 3.2 | 2.9 | 2.6 | 2.8 | 2.4 | 3.2 | 3.4 | 4.1 | 5.2 | 3.7 | 3.6 | 2.8 |
| EC_field | mS/m | | 10.35 | 10.35 | 10.34 | 10.8 | 10.2 | 10.6 | 10.77 | 10.4 | 10.19 | 10.3 | 10.26 | 9.65 | 9.37 | 9.81 | 9.48 | 9.19 | 8.98 | 8.94 | 9.25 | 9.25 | 9.62 | 9.39 |
| pH_field | | | 8.50 | 7.50 | 7.30 | 7.70 | 7.00 | 7.20 | 8.60 | 8.10 | 8.20 | 7.30 | 7.40 | 6.40 | 8.60 | 6.76 | 7.16 | 7.51 | 7.07 | 6.82 | 7.21 | 7.79 | 7.67 | 7.56 |
| pH_lab | | | 7.49 | 7.63 | 7.59 | 7.67 | 7.59 | 7.72 | 7.70 | 7.69 | 7.62 | 7.70 | 7.64 | 7.64 | 7.60 | 7.68 | 7.59 | 7.63 | 7.60 | 7.65 | 7.63 | 7.72 | 7.66 | 7.60 |
| tAlk_lab | mmol/l | 0.04 | 0.71 | 0.71 | 0.69 | 0.71 | 0.71 | 0.76 | 0.72 | 0.68 | 0.68 | 0.69 | 0.68 | 0.67 | 0.63 | 0.62 | 0.59 | 0.58 | 0.57 | 0.56 | 0.56 | 0.56 | 0.57 | 0.57 |
| EC_lab | mS/m | 0.07 | 10.2 | 10 | 9.91 | 10.2 | 10.4 | 10.4 | 10.3 | 9.86 | 10.1 | 10.1 | 9.98 | 9.65 | 9.33 | 9.06 | 8.92 | 8.57 | 8.55 | 8.88 | 8.89 | 8.43 | 8.95 | 9.08 |
| Colour | | 1.4 | 6 | 1.6 | 2.8 | 2.0 | < 1.4 | 2.0 | < 1.4 | < 1.4 | < 1.4 | 3.2 | < 1.4 | < 1.4 | 2.80 | 2.40 | 3.20 | 1.60 | 2.3 | < 1.4 | 3.1 | < 1.4 | 4.4 | 1.1 |
| Turbidity | FTU | 0.05 | 0.32 | 0.12 | 0.13 | 0.07 | 0.07 | 0.10 | 0.08 | 0.14 | 0.09 | 0.09 | 0.10 | 0.11 | 0.11 | 0.08 | 0.08 | 0.08 | 0.09 | 0.08 | 0.06 | | 0.07 | 0.15 |
| F | mg/l | 0.05 | <0.05 | <0.05 | < 0.05 | 0.07 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | <0.05 | <0.05 | <0.05 | < 0.05 | 0.11 | 0.06 | < 0.05 | < 0.05 | 0.08 |
| Cl | mg/l | 0.1 | 2.57 | 2.61 | 2.68 | 2.72 | 2.76 | 2.59 | 2.62 | 2.60 | 2.58 | 2.56 | 2.44 | 2.64 | 2.65 | 2.79 | 2.63 | 2.71 | 2.56 | 2.77 | 2.50 | 2.54 | 2.45 | 2.33 |
| NO2 | mg/l | 0.05 | <0.05 | <0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | <0.05 | <0.05 | <0.05 | < 0.05 | < 0.05 | 0.06 | < 0.05 | 0.11 | < 0.05 |
| Br | mg/l | 0.1 | <0.1 | <0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | 0.29 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | <0.1 | <0.1 | <0.1 | < 0.1 | < 0.1 | < 0.1 | 0.17 | 0.23 | < 0.1 |
| NO3 | mg/l | 0.05 | 0.11 | <0.05 | < 0.05 | < 0.05 | 0.19 | < 0.05 | 0.08 | < 0.05 | < 0.05 | 0.13 | 0.09 | 0.39 | 0.31 | 0.25 | 0.21 | 0.50 | 0.18 | 0.24 | 0.15 | 0.29 | 0.46 | < 0.05 |
| PO4 | mg/l | 0.2 | <0.2 | <0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | <0.2 | 0.29 | <0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| SO4 | mg/l | 0.1 | 9.96 | 9.86 | 10.1 | 10.4 | 11.0 | 10.0 | 9.84 | 8.75 | 8.97 | 8.60 | 8.86 | 8.57 | 7.95 | 8.99 | 8.05 | 8.71 | 8.79 | 9.31 | 9.76 | 9.68 | 10.2 | 9.54 |
| Si | mg/l | 0.02 | 3.9 | 4.01 | 4.11 | 4.43 | 4.12 | 4.32 | 3.97 | 4.02 | 4.22 | 4.62 | 3.95 | 4.07 | 4.38 | 4.12 | 3.98 | 3.99 | 3.93 | 3.97 | 3.75 | 4.13 | 4.05 | 4.06 |
| Fe | mg/l | 0.002 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0095 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.0028 | 0.0029 | <0.002 | <0.002 |
| Ti | mg/l | 0.001 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Mg | mg/l | 0.05 | 1.45 | 1.51 | 1.47 | 1.46 | 1.39 | 1.58 | 1.45 | 1.40 | 1.44 | 1.60 | 1.32 | 1.30 | 1.31 | 1.270 | 1.180 | 1.170 | 1.170 | 1.21 | 1.21 | 1.24 | 1.26 | 1.22 |
| Ca | mg/l | 0.02 | 14.1 | 13.3 | 12.6 | 13.7 | 13.2 | 14.8 | 13.6 | 12.8 | 13.3 | 14.6 | 12.4 | 12.2 | 11.7 | 11.90 | 10.70 | 10.90 | 10.8 | 10.9 | 11.3 | 11.3 | 11.4 | 11.3 |
| Na | mg/l | 0.05 | 2.81 | 2.68 | 2.67 | 2.72 | 2.44 | 2.90 | 2.53 | 2.73 | 2.54 | 3.26 | 2.35 | 2.19 | 2.65 | 2.40 | 2.35 | 2.33 | 2.46 | 2.42 | 2.42 | 2.39 | 2.37 | 2.45 |
| Ba | mg/l | 0.002 | 0.041 | 0.0439 | 0.0427 | 0.0442 | 0.0433 | 0.0506 | 0.0368 | 0.0380 | 0.0357 | 0.0415 | 0.0364 | 0.0368 | 0.0331 | 0.0400 | 0.0369 | 0.2780 | 0.281 | 0.245 | 0.266 | 0.283 | 0.270 | 0.255 |
| Sr | mg/l | 0.001 | 0.031 | 0.0289 | 0.0285 | 0.0306 | 0.0300 | 0.0349 | 0.0304 | 0.0278 | 0.0280 | 0.0320 | 0.0275 | 0.0279 | 0.0263 | 0.0268 | 0.0245 | 0.0287 | 0.0285 | 0.0281 | 0.0293 | 0.0300 | 0.0293 | 0.0291 |
| Sc | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Y | µg/l | 0.005 | 0.0120 | 0.012 | 0.010 | 0.012 | 0.01 | 0.0117 | 0.012 | 0.011 | 0.012 | 0.0115 | 0.01 | 0.0113 | 0.0077 | 0.015 | 0.011 | 0.011 | 0.012 | 0.012 | 0.0150 | 0.0120 | 0.0120 | 0.0110 |
| Nb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Ag | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | 0.012 | <0.01 | <0.01 | 0.384 | 0.48 | 0.536 | 0.356 | 0.341 | 0.215 | 0.205 | 0.584 | 0.07 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| In | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Sb | µg/l | 0.01 | 0.025 | 0.013 | <0.01 | <0.01 | 0.011 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | 0.01 | <0.01 | 0.01 | 0.01 | 0.0120 | <0.01 | <0.01 | <0.01 |
| Cs | µg/l | 0.002 | 0.0024 | 0.0026 | <0.002 | <0.002 | 0.0021 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | <0.002 | 0.0022 | 0.0021 | 0.0056 |
| Nd | µg/l | 0.01 | 0.012 | 0.011 | 0.012 | 0.010 | <0.01 | 0.011 | 0.012 | <0.01 | 0.011 | <0.01 | <0.01 | 0.011 | <0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | <0.01 | 0.011 | <0.01 | 0.013 |
| Sm | µg/l | 0.002 | 0.0028 | 0.0024 | 0.0386 | 0.0027 | 0.0022 | 0.0023 | <0.002 | 0.0022 | <0.002 | 0.0024 | <0.002 | 0.003 | <0.002 | 0.002 | 0.002 | 0.002 | 0.003 | 0.002 | 0.0021 | 0.0024 | 0.0024 | 0.0028 |
| Ho | µg/l | 0.001 | <0.001 | <0.001 | 0.0002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

## SKJELLBEKKEN continues

| Parameter | Enhet | DL | 27.09.03 | 06.11.03 | 02.12.03 | 20.01.04 | 02.03.04 | 01.04.04 | 05.05.04 | 11.06.04 | 06.07.04 | 18.08.04 | 21.09.04 | 27.10.04 | 02.12.04 | 12.01.05 | 23.02.05 | 05.04.05 | 12.05.05 | 16.06.05 | 19.07.05 | 18.08.05 | 29.09.05 | 09.11.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yb | µg/l | 0.002 | <0.002 | <0.002 | 0.0005 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| Ta | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| W | µg/l | 0.05 | 0.675 | 0.821 | 0.920 | 0.943 | 0.931 | 0.874 | 0.952 | 0.759 | 0.901 | 0.911 | 1.02 | 1.02 | 0.830 | 0.705 | 0.757 | 0.742 | 1.05 | 0.867 | 0.788 | 0.750 | 0.747 | 0.872 |
| Tl | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Bi | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.016 | 0.013 | 0.015 | 0.017 | 0.015 | 0.015 | 0.021 | 0.03 | 0.03 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Th | µg/l | 0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| V | µg/l | 0.02 | 0.548 | 0.377 | 0.344 | 0.334 | 0.315 | 0.301 | 0.31 | 0.314 | 0.322 | 0.296 | 0.323 | 0.268 | 0.265 | 0.399 | 0.296 | 0.267 | 0.273 | 0.326 | 0.283 | 0.303 | 0.342 | 0.313 |
| Mn | µg/l | 0.05 | 11.1 | 11.1 | 8.07 | 11.0 | 8.63 | 9.79 | 9.3 | 6.82 | 6.2 | 5.99 | 6.06 | 5.23 | 4.22 | 5.68 | 4.52 | 4.51 | 4.79 | 4.11 | 4.45 | 3.98 | 4.45 | 4.41 |
| Cu | µg/l | 0.05 | 0.17 | 0.24 | 0.18 | 0.15 | 0.25 | 0.13 | 0.12 | 0.17 | 0.143 | 0.15 | 0.132 | 0.094 | 0.10 | 0.1 | 0.14 | 0.12 | 0.11 | 0.10 | 0.118 | 0.126 | 0.209 | 0.134 |
| Zn | mg/l | 0.002 | 0.293 | 0.328 | 0.329 | 0.336 | 0.346 | 0.348 | 0.370 | 0.346 | 0.346 | 0.380 | 0.339 | 0.362 | 0.328 | 0.362 | 0.343 | 0.321 | 0.342 | 0.398 | 0.386 | 0.405 | 0.418 | 0.344 |
| Ga | µg/l | 0.01 | 0.016 | 0.022 | 0.017 | 0.017 | 0.013 | 0.015 | 0.014 | 0.014 | 0.014 | 0.015 | 0.017 | 0.014 | <0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.016 | 0.016 | 0.017 | 0.017 |
| Ge | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Li | µg/l | 0.5 | 1.1 | 0.96 | 0.83 | 1.1 | 0.9 | 0.98 | 0.92 | 0.84 | 0.9 | 0.89 | 0.95 | 0.99 | 0.910 | 0.89 | 1.1 | 1.0 | 1.0 | 0.567 | <0.5 | 0.80 | 0.78 | 0.77 |
| Be | µg/l | 0.01 | 0.018 | 0.033 | 0.020 | 0.023 | 0.022 | 0.025 | 0.026 | 0.042 | 0.018 | 0.031 | 0.012 | 0.023 | 0.062 | 0.121 | 0.01 | 0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.010 | <0.01 |
| B | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Rb | µg/l | 0.05 | 0.950 | 0.947 | 0.962 | 0.953 | 0.997 | 0.927 | 0.918 | 0.901 | 0.888 | 0.948 | 1.01 | 0.907 | 1.01 | 1.12 | 1.20 | 1.04 | 1.11 | 1.07 | 1.04 | 1.07 | 1.12 | 1.09 |
| Zr | µg/l | 0.05 | 0.17 | <0.05 | <0.05 | <0.05 | 0.055 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Mo | µg/l | 0.2 | 1.2 | 1.3 | 0.89 | 0.76 | 0.7 | 0.99 | 0.72 | 0.68 | 0.95 | 0.74 | 0.63 | 0.66 | 0.51 | 0.6 | 0.6 | 0.6 | 0.6 | 0.579 | 0.576 | 0.59 | 0.57 | 0.57 |
| Cd | µg/l | 0.03 | <0.03 | 0.045 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | 0.05 | 0.06 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| La | µg/l | 0.01 | 0.075 | 0.027 | 0.016 | 0.022 | 0.014 | 0.016 | 0.019 | 0.016 | 0.013 | 0.016 | 0.016 | 0.012 | 0.010 | 0.01 | 0.01 | 0.02 | 0.01 | 0.0180 | 0.0180 | 0.021 | 0.019 | 0.017 |
| Ce | µg/l | 0.01 | 0.070 | 0.029 | 0.010 | 0.011 | <0.01 | 0.012 | 0.015 | 0.012 | <0.01 | 0.011 | <0.01 | 0.01 | 0.004 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.010 | <0.01 | <0.01 |
| Pb | µg/l | 0.05 | 0.090 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.006 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| U | µg/l | 0.0005 | 0.125 | 0.122 | 0.153 | 0.155 | 0.158 | 0.17 | 0.159 | 0.121 | 0.125 | 0.139 | 0.134 | 0.124 | 0.107 | 0.138 | 0.126 | 0.126 | 0.135 | 0.125 | 0.127 | 0.113 | 0.112 | 0.1420 |
| Al | µg/l | 2 | 10 | 9.8 | 11.3 | 6.8 | 6.9 | 18 | 6.7 | 12 | 13 | 8.7 | 9.79 | 5.6 | 14.3 | 10.1 | 7.2 | 6.3 | 6.0 | 7.42 | 7.51 | 17.5 | 11.9 | 6.9 |
| Cr | µg/l | 0.1 | 0.46 | 0.44 | 0.62 | 0.58 | 0.48 | 0.29 | 0.3 | 0.23 | 0.38 | 0.34 | 0.47 | 0.39 | 0.81 | 0.78 | 0.7 | 0.6 | 0.6 | 0.690 | 0.699 | 0.62 | 0.58 | 0.62 |
| Co | µg/l | 0.02 | 0.256 | 0.290 | 0.156 | 0.16 | 0.15 | 0.089 | 0.09 | 0.1 | 0.13 | 0.11 | 0.249 | 0.19 | <0.02 | <0.02 | 0.241 | 0.239 | 0.241 | 0.209 | 0.237 | 0.224 | 0.225 | 0.206 |
| Ni | µg/l | 0.2 | 0.56 | 0.44 | 0.45 | 0.53 | 0.52 | 0.48 | 0.43 | 0.32 | 0.5 | 0.38 | 0.45 | 0.37 | 0.63 | 0.53 | 0.5 | 0.5 | 0.5 | 0.460 | 0.404 | 0.38 | 0.37 | 0.39 |
| P | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| I | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| K | mg/l | 0.025 | 2.890 | 2.950 | 3.010 | 3.110 | 3.020 | 3.110 | 3.150 | 3.150 | 3.050 | 3.140 | 3.120 | 2.790 | 2.880 | 0.312 | 2.500 | 2.640 | 2.520 | 2.700 | 2.810 | 2.49 | 2.48 | 2.53 |
| As | µg/l | 0.05 | 0.44 | 0.269 | 0.187 | 0.212 | 0.191 | 0.19 | 0.174 | 0.19 | 0.18 | 0.182 | 0.165 | 0.16 | 0.138 | <0.05 | 0.15 | 0.17 | 0.17 | 0.164 | 0.133 | 0.163 | 0.150 | 0.160 |
| Se | µg/l | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| GWL | m | | 3.28 | 3.22 | 3.20 | 3.4 | 3.50 | 3.55 | 3.45 | 3.15 | 3.21 | 3.40 | 3.45 | 3.45 | 3.50 | 3.60 | 3.75 | 3.80 | 3.80 | 3.20 | 3.40 | 3.30 | 3.40 | 3.30 |

## SVANVIK

| Parameter | Enhet | DL | 04.10.03 | 06.11.03 | 02.12.03 | 20.01.04 | 02.03.04 | 01.04.04 | 05.05.04 | 11.06.04 | 06.07.04 | 18.08.04 | 21.09.04 | 27.10.04 | 02.12.04 | 12.01.05 | 23.02.05 | 05.04.05 | 12.05.05 | 16.06.05 | 19.07.05 | 18.08.05 | 29.09.05 | 09.11.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp_field | | | 3 | 2.4 | 2.6 | 2.2 | 2.3 | 2.1 | 3.4 | 3.3 | 3.4 | 3.7 | 3.1 | 2.7 | 2.3 | 2.1 | 2.0 | 3.1 | 3.0 | 3.5 | 5.1 | 3.5 | 3.5 | 2.7 |
| EC_field | mS/m | | 6.6 | 10.1 | 7.15 | 6.5 | 6.4 | 6.4 | 6.32 | 6.36 | 6.17 | 6.12 | 6.08 | 6.12 | 6.1 | 6.13 | 6.12 | 6.17 | 6.11 | 6.36 | 5.18 | 6.05 | 6.02 | 5.99 |
| pH_field | | | 6.90 | 7.70 | 7.10 | 7.40 | 6.90 | 7.50 | 6.80 | 7.70 | 6.50 | 6.90 | 6.80 | 6.40 | 8.10 | 6.50 | 7.05 | 6.93 | 6.94 | 6.83 | 6.95 | 7.40 | 7.40 | 7.10 |
| pH_lab | | | 6.87 | 7.05 | 6.98 | 7.02 | 6.99 | 7.09 | 7.17 | 7.06 | 7.07 | 7.08 | 7.04 | 7.00 | 6.99 | 7.09 | 6.99 | 7.01 | 7.04 | 7.06 | 7.00 | 7.21 | 7.01 | 6.97 |
| tAlk_lab | mmol/l | 0.04 | 0.32 | 0.38 | 0.33 | 0.30 | 0.31 | 0.32 | 0.30 | 0.30 | 0.29 | 0.29 | 0.29 | 0.30 | 0.3 | 0.30 | 0.30 | 0.30 | 0.30 | 0.31 | 0.30 | 0.30 | 0.30 | 0.30 |
| EC_lab | mS/m | 0.07 | 6.47 | 9.21 | 7.08 | 6.29 | 6.34 | 6.25 | 6.14 | 6.15 | 6.08 | 6.02 | 6.10 | 6.03 | 6.06 | 6.00 | 6.07 | 5.93 | 5.92 | 6.21 | 6.03 | 5.79 | 5.77 | 5.82 |
| Colour | | 1.4 | 6.6 | 2 | 2.8 | 2.4 | < 1.4 | < 1.4 | < 1.4 | < 1.4 | < 1.4 | < 1.4 | < 1.4 | < 1.4 | <1.4 | <1.4 | 2.00 | 2.40 | < 1.4 | < 1.4 | 2.1 | < 1.4 | 2.7 | 5.6 |
| Turbidity | FTU | 0.05 | 150 | 1.1 | 0.32 | 0.41 | 0.42 | 0.24 | 0.23 | 0.37 | 0.24 | 0.37 | 0.27 | 0.36 | 0.29 | 0.23 | 0.19 | 0.23 | 0.19 | 0.19 | 0.18 | | 0.29 | 0.35 |
| F | mg/l | 0.05 | <0.05 | <0.05 | < 0.05 | < 0.05 | 0.15 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | <0.05 | <0.05 | <0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | 0.11 |
| Cl | mg/l | 0.1 | 5 | 5.4 | 5.20 | 4.40 | 4.39 | 4.35 | 4.54 | 4.23 | 4.14 | 3.95 | 3.91 | 4.00 | 3.95 | 4.05 | 3.77 | 3.89 | 3.76 | 3.74 | 3.70 | 3.63 | 3.65 | 3.75 |
| NO2 | mg/l | 0.05 | <0.05 | <0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | <0.05 | 0.06 | <0.05 | < 0.05 | 0.12 | 0.12 | < 0.05 | 0.20 | < 0.05 |
| Br | mg/l | 0.1 | <0.1 | <0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | 0.12 | <0.1 | <0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | 0.12 | < 0.1 |
| NO3 | mg/l | 0.05 | 0.32 | 0.38 | 0.37 | 0.30 | 0.25 | 0.06 | 0.28 | 0.17 | 0.24 | 0.43 | 0.40 | 0.92 | 0.42 | 0.51 | 0.49 | 0.91 | 0.38 | 0.54 | 0.40 | 0.53 | 0.45 | 0.87 |
| PO4 | mg/l | 0.2 | <0.2 | <0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | <0.2 | 0.23 | <0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| SO4 | mg/l | 0.1 | 6.48 | 15.4 | 8.81 | 6.10 | 6.15 | 6.46 | 6.68 | 6.17 | 6.71 | 6.05 | 6.56 | 6.49 | 6.44 | 6.93 | 6.46 | 6.78 | 6.41 | 6.34 | 6.31 | 6.09 | 6.41 | 6.27 |
| Si | mg/l | 0.02 | 4.6 | 4.67 | 4.84 | 5.08 | 4.71 | 4.94 | 4.73 | 4.78 | 4.76 | 5.08 | 4.58 | 4.65 | 5.07 | 4.73 | 4.58 | 4.53 | 4.67 | 4.88 | 4.37 | 4.82 | 4.73 | 4.58 |
| Fe | mg/l | 0.002 | 0.03 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.0041 | 0.0063 | 0.0049 | 0.0069 | 0.0063 | 0.0064 | 0.0046 | 0.0043 | 0.0034 | 0.0037 | <0.002 | 0.0046 | 0.0043 | 0.0041 | 0.0045 | 0.0056 |
| Ti | mg/l | 0.001 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.0012 | 0.0011 | <0.001 |
| Mg | mg/l | 0.05 | 1.19 | 1.36 | 1.22 | 1.29 | 0.928 | 1.16 | 1.07 | 1.06 | 1.05 | 1.10 | 0.997 | 1.01 | 1.06 | 1.030 | 0.986 | 1.000 | 0.995 | 1.08 | 1.03 | 1.01 | 1.01 | 0.941 |
| Ca | mg/l | 0.02 | 6.21 | 7.28 | 5.98 | 6.01 | 5.84 | 6.18 | 5.81 | 5.67 | 5.66 | 5.84 | 5.31 | 5.27 | 5.70 | 5.59 | 5.28 | 5.35 | 5.30 | 5.97 | 5.66 | 5.56 | 5.34 | 5.04 |
| Na | mg/l | 0.05 | 3.94 | 8.37 | 4.93 | 3.84 | 3.63 | 4.21 | 3.73 | 3.73 | 3.65 | 4.38 | 3.54 | 3.39 | 3.87 | 3.65 | 3.59 | 3.67 | 3.79 | 3.87 | 3.88 | 3.85 | 3.79 | 3.70 |
| Ba | mg/l | 0.002 | 0.028 | 0.0288 | 0.0272 | 0.0300 | 0.0278 | 0.0320 | 0.0212 | 0.0234 | 0.0214 | 0.0237 | 0.0255 | 0.0212 | 0.0201 | 0.0256 | 0.0227 | 0.0246 | 0.112 | 0.106 | 0.128 | 0.262 | 0.266 | 0.207 |
| Sr | mg/l | 0.001 | 0.018 | 0.0222 | 0.0183 | 0.0170 | 0.0164 | 0.0179 | 0.0161 | 0.0138 | 0.0142 | 0.0159 | 0.0146 | 0.0149 | 0.0156 | 0.0153 | 0.0147 | 0.0145 | 0.0160 | 0.0170 | 0.0174 | 0.0194 | 0.0185 | 0.0171 |
| Sc | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Y | µg/l | 0.005 | 0.131 | 0.107 | 0.0870 | 0.103 | 0.102 | 0.0995 | 0.0899 | 0.0867 | 0.0929 | 0.0862 | 0.0914 | 0.0865 | 0.0841 | 0.115 | 0.0915 | 0.0870 | 0.0787 | 0.0943 | 0.0900 | 0.0890 | 0.0860 | 0.0850 |
| Nb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Ag | µg/l | 0.01 | <0.01 | 0.013 | 0.019 | <0.01 | 0.014 | 0.012 | 0.563 | 0.505 | 0.491 | 0.248 | 0.316 | 0.158 | 0.195 | 0.499 | 0.08 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| In | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Sb | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.0120 | <0.01 | <0.01 | <0.01 |
| Cs | µg/l | 0.002 | 0.0247 | 0.0373 | 0.0267 | 0.0259 | 0.0249 | 0.0267 | 0.0234 | 0.0224 | 0.0239 | 0.0214 | 0.023 | 0.0226 | 0.0221 | 0.0325 | 0.0239 | 0.0215 | 0.0254 | 0.0261 | 0.0259 | 0.0243 | 0.0224 | 0.0249 |
| Nd | µg/l | 0.01 | 0.342 | 0.253 | 0.232 | 0.281 | 0.313 | 0.284 | 0.231 | 0.224 | 0.263 | 0.218 | 0.234 | 0.232 | 0.217 | 0.234 | 0.233 | 0.209 | 0.246 | 0.240 | 0.190 | 0.183 | 0.198 | 0.222 |
| Sm | µg/l | 0.002 | 0.0584 | 0.0383 | 0.0372 | 0.0432 | 0.0472 | 0.0427 | 0.0403 | 0.0363 | 0.041 | 0.0347 | 0.0371 | 0.0397 | 0.0337 | 0.0417 | 0.0352 | 0.0282 | 0.0359 | 0.0373 | 0.0331 | 0.0333 | 0.0333 | 0.0368 |
| Ho | µg/l | 0.001 | 0.0034 | 0.0021 | 0.0022 | 0.0024 | 0.0025 | 0.0021 | 0.0021 | 0.0019 | 0.0021 | 0.002 | 0.0023 | 0.0021 | 0.0017 | 0.003 | 0.002 | 0.002 | 0.002 | 0.003 | 0.0020 | 0.0021 | 0.0018 | 0.0022 |

## SVANVIK continues

| Parameter | Enhet | DL | 04.10.03 | 06.11.03 | 02.12.03 | 20.01.04 | 02.03.04 | 01.04.04 | 05.05.04 | 11.06.04 | 06.07.04 | 18.08.04 | 21.09.04 | 27.10.04 | 02.12.04 | 12.01.05 | 23.02.05 | 05.04.05 | 12.05.05 | 16.06.05 | 19.07.05 | 18.08.05 | 29.09.05 | 09.11.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yb | µg/l | 0.002 | 0.0058 | 0.0046 | 0.0040 | 0.0043 | 0.0056 | 0.0043 | 0.0039 | 0.0039 | 0.0049 | 0.0043 | 0.0048 | 0.0047 | 0.0041 | 0.005 | 0.004 | 0.003 | 0.004 | 0.005 | 0.0037 | 0.0036 | 0.0034 | 0.0044 |
| Ta | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| W | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Tl | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Bi | µg/l | 0.01 | <0.01 | 0.012 | <0.01 | <0.01 | 0.012 | <0.01 | 0.016 | 0.012 | 0.018 | 0.016 | 0.016 | 0.015 | 0.021 | 0.03 | 0.03 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Th | µg/l | 0.02 | 0.058 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| V | µg/l | 0.02 | 0.545 | 0.532 | 0.333 | 0.321 | 0.357 | 0.362 | 0.368 | 0.428 | 0.428 | 0.468 | 0.442 | 0.407 | 0.355 | 0.544 | 0.375 | 0.364 | 0.354 | 0.365 | 0.432 | 0.357 | 0.492 | 0.374 |
| Mn | µg/l | 0.05 | 2.90 | 3.44 | 2.17 | 1.97 | 1.8 | 1.48 | 1.4 | 1.19 | 1.05 | 0.85 | 0.691 | 0.568 | 0.384 | 0.41 | 0.33 | 0.23 | 0.11 | 0.16 | 0.160 | 0.218 | 0.148 | 0.121 |
| Cu | µg/l | 0.05 | 6.75 | 3.98 | 4.07 | 3.79 | 4.04 | 3.79 | 3.83 | 3.94 | 3.49 | 3.56 | 3.34 | 3.32 | 3.30 | 4.28 | 2.82 | 3.07 | 3.09 | 3.83 | 4.45 | 4.18 | 5.09 | 3.96 |
| Zn | mg/l | 0.002 | 0.319 | 0.325 | 0.350 | 0.351 | 0.336 | 0.338 | 0.339 | 0.331 | 0.373 | 0.351 | 0.336 | 0.358 | 0.330 | 0.387 | 0.302 | 0.299 | 0.259 | 0.352 | 0.352 | 0.398 | 0.395 | 0.362 |
| Ga | µg/l | 0.01 | 0.034 | 0.028 | <0.01 | 0.015 | 0.016 | 0.015 | 0.013 | 0.019 | 0.019 | 0.022 | 0.014 | 0.013 | 0.010 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.014 | 0.012 | 0.024 | 0.013 |
| Ge | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Li | µg/l | 0.5 | 0.55 | 0.56 | <0.5 | 0.55 | 0.52 | 0.56 | 0.55 | 0.54 | <0.5 | 0.51 | 0.56 | 0.86 | 0.540 | <0.5 | 0.6 | 0.6 | 0.7 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Be | µg/l | 0.01 | <0.01 | 0.034 | <0.01 | 0.017 | 0.017 | 0.038 | 0.034 | 0.036 | 0.042 | 0.024 | 0.017 | <0.01 | 0.085 | 0.107 | 0.02 | 0.01 | 0.01 | <0.01 | <0.01 | 0.010 | 0.011 | <0.01 |
| B | µg/l | 5 | <5 | 5.1 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Rb | µg/l | 0.05 | 2.45 | 3.09 | 2.29 | 2.21 | 2.28 | 2.11 | 1.98 | 1.94 | 2.022 | 1.93 | 1.96 | 2.1 | 2.18 | 2.08 | 2.19 | 2.09 | 2.33 | 2.16 | 2.08 | 2.12 | 2.10 | 2.08 |
| Zr | µg/l | 0.05 | 0.050 | 0.14 | <0.05 | 0.063 | 0.1 | 0.085 | <0.05 | <0.05 | 0.05 | <0.05 | <0.05 | 0.059 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.0510 | 0.05 | <0.05 | <0.05 | <0.05 |
| Mo | µg/l | 0.2 | 1.1 | 1.6 | 1.1 | 0.98 | 0.99 | 1.1 | 0.99 | 1.03 | 1.1 | 0.99 | 0.89 | 0.9 | 0.84 | 0.84 | 0.9 | 0.9 | 1.0 | 1.04 | 0.893 | 0.87 | 0.84 | 0.84 |
| Cd | µg/l | 0.03 | <0.03 | 0.056 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | 0.08 | 0.07 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| La | µg/l | 0.01 | 0.314 | 0.267 | 0.188 | 0.236 | 0.251 | 0.229 | 0.208 | 0.203 | 0.209 | 0.215 | 0.183 | 0.196 | 0.200 | 0.185 | 0.177 | 0.173 | 0.168 | 0.180 | 0.181 | 0.186 | 0.186 | 0.186 |
| Ce | µg/l | 0.01 | 0.396 | 0.073 | 0.029 | 0.068 | 0.089 | 0.063 | 0.043 | 0.05 | 0.054 | 0.042 | 0.04 | 0.054 | 0.041 | 0.04 | 0.03 | 0.03 | 0.03 | 0.0340 | 0.0370 | 0.035 | 0.038 | 0.038 |
| Pb | µg/l | 0.05 | 0.088 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.012 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | **<0.05** | <0.05 | <0.05 | <0.05 |
| U | µg/l | 0.0005 | 0.0664 | 0.105 | 0.0651 | 0.0742 | 0.114 | 0.098 | 0.096 | 0.08 | 0.099 | 0.101 | 0.0869 | 0.0829 | 0.0796 | 0.0929 | 0.0867 | 0.0833 | 0.0902 | 0.0999 | 0.0990 | 0.0767 | 0.0777 | 0.0999 |
| Al | µg/l | 2 | 50.3 | 93.8 | 21.9 | 23.1 | 39.5 | 42.8 | 17.2 | 27.2 | 25.9 | 25.3 | 28.5 | 22.7 | 15.9 | 15.7 | 11.3 | 11.0 | 11.5 | 10.7 | 11.8 | 15.1 | 22.1 | 16.6 |
| Cr | µg/l | 0.1 | 0.70 | 0.61 | 0.77 | 0.79 | 0.7 | 0.51 | 0.41 | 0.57 | 0.5 | 0.36 | 0.68 | 0.61 | 0.93 | 1 | 0.7 | 0.8 | 0.6 | 0.684 | 0.698 | 0.64 | 0.68 | 0.51 |
| Co | µg/l | 0.02 | 0.321 | 0.380 | 0.236 | 0.262 | 0.18 | 0.09 | 0.065 | 0.077 | 0.076 | 0.06 | 0.187 | 0.18 | <0.02 | <0.02 | 0.19 | 0.19 | 0.18 | 0.202 | 0.172 | 0.195 | 0.208 | 0.187 |
| Ni | µg/l | 0.2 | 2.0 | 1.8 | 1.9 | 1.6 | 1.4 | 1.7 | 1.4 | 1.6 | 1.3 | 1.3 | 1.2 | 1.2 | 1.8 | 1.83 | 1.4 | 1.4 | 1.4 | 1.46 | 1.28 | 1.24 | 1.26 | 1.24 |
| P | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| I | µg/l | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| K | mg/l | 0.025 | 0.692 | 0.812 | 0.700 | 0.643 | 0.719 | 0.694 | 0.681 | 0.691 | 0.641 | 0.676 | 0.686 | 0.593 | 0.588 | 0.250 | 0.599 | 0.620 | 0.593 | 0.622 | 0.635 | 0.596 | 0.585 | 0.593 |
| As | µg/l | 0.05 | 0.083 | 0.096 | 0.069 | 0.086 | 0.089 | 0.12 | 0.118 | 0.14 | 0.12 | 0.127 | 0.124 | 0.12 | 0.081 | <0.05 | 0.10 | 0.11 | 0.10 | 0.0800 | 0.103 | 0.096 | 0.106 | 0.105 |
| Se | µg/l | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| GWL | m | | 7.05 | 7.05 | 7.00 | 7.05 | 7.10 | 7.15 | 7.15 | 6.90 | 6.83 | 6.90 | 6.95 | 6.95 | 7.00 | 7.05 | 7.15 | 7.15 | 7.15 | 7.05 | 7.00 | 7.00 | 7.05 | 6.95 |

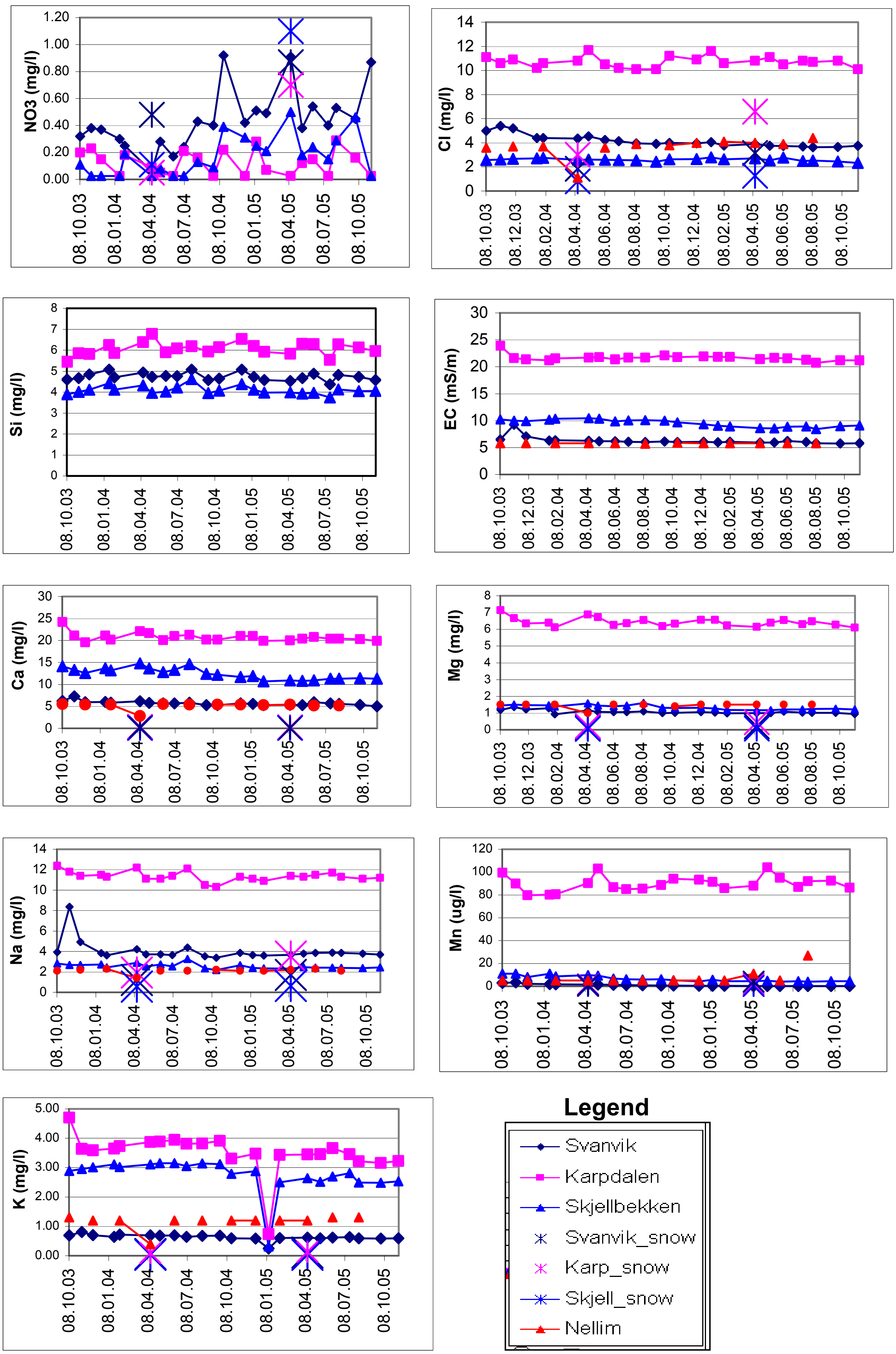
## KARPDALEN

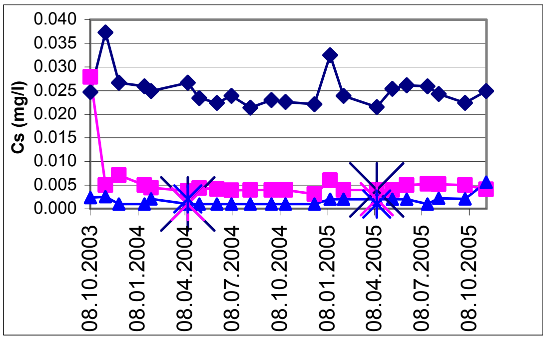
| Parameter | Enhet | DL | 04.10.03 | 07.11.03 | 03.12.03 | 21.01.04 | 25.02.04 | 02.04.04 | 06.05.04 | 12.06.04 | 06.07.04 | 18.08.04 | 20.09.04 | 28.10.04 | 01.12.04 | 11.01.05 | 24.02.05 | 04.04.05 | 13.05.05 | 16.06.05 | 20.07.05 | 18.08.05 | 30.09.05 | 08.11.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp_field | | | 3.4 | 3.7 | 3.5 | 3.6 | 3.0 | 3.1 | 4.8 | 4.4 | 3.7 | 4.2 | 3.9 | 3.7 | 3.4 | 1.9 | 3.9 | 3.8 | 4.2 | 4.4 | 4.5 | 4.1 | 4.0 | |
| EC_field | mS/m | | 24.6 | 22.9 | 22.5 | 22.5 | 22.5 | 22.7 | 23.3 | 22.6 | 22.5 | 22.6 | 22.8 | 23 | 22.8 | 22.8 | 22.9 | 22.8 | 23.1 | 23 | 22.8 | 23.1 | 18.1 | 23 |
| pH_field | | | 7.50 | 7.10 | 7.30 | 7.70 | 7.10 | 7.70 | 6.70 | 7.00 | 7.40 | 6.90 | 6.90 | 7.00 | 7.80 | 6.75 | 7.20 | 7.31 | 7.06 | 7.26 | 7.31 | 7.38 | 8.10 | 7.18 |
| pH_lab | | | 7.6 | 7.33 | 7.28 | 7.36 | 7.27 | 7.34 | 7.33 | 7.31 | 7.38 | 7.36 | 7.28 | 7.22 | 7.20 | 7.32 | 7.24 | 7.29 | 7.26 | 7.29 | 7.25 | 7.44 | 7.25 | 7.24 |
| tAlk_lab | mmol/l | 0.04 | 1.87 | 1.61 | 1.57 | 1.56 | 1.56 | 1.60 | 1.65 | 1.55 | 1.54 | 1.56 | 1.58 | 1.60 | 1.59 | 1.59 | 1.59 | 1.58 | 1.62 | 1.59 | 1.57 | 1.59 | 1.60 | 1.59 |
| EC_lab | mS/m | 0.07 | 23.9 | 21.6 | 21.4 | 21.2 | 21.5 | 21.7 | 21.8 | 21.4 | 21.7 | 21.7 | 22.1 | 21.8 | 21.9 | 21.80 | 21.80 | 21.40 | 21.6 | 21.6 | 21.3 | 20.7 | 21.2 | 21.2 |
| Colour | | 1.4 | 23.4 | 6.8 | 2.3 | 5.8 | 2.1 | 2.8 | 2.0 | 6.0 | 1.6 | 3.2 | 2.8 | 4.9 | 2 | 4.90 | 3.20 | 5.20 | 3.8 | 1.6 | 2.7 | 2.4 | 5.3 | 2.4 |
| Turbidity | FTU | 0.05 | 345 | 68 | 16 | 6.7 | 5.7 | 5.4 | 5.8 | 8.9 | 7.8 | 8.5 | 9.7 | 9.6 | 13 | 7.1 | 11 | 8.7 | 6.6 | 7.5 | 5.4 | 8.5 | 14 | 16 |
| F | mg/l | 0.05 | 0.25 | 0.24 | 0.26 | 0.26 | 0.17 | 0.26 | 0.23 | 0.24 | 0.24 | 0.23 | 0.23 | 0.23 | 0.17 | 0.32 | 0.24 | 0.30 | 0.26 | 0.23 | 0.26 | 0.28 | 0.28 | 0.26 |
| Cl | mg/l | 0.1 | 11.1 | 10.6 | 10.9 | 10.2 | 10.6 | 10.8 | 11.7 | 10.5 | 10.2 | 10.1 | 10.1 | 11.2 | 10.9 | 11.60 | 10.60 | 10.80 | 11.1 | 10.5 | 10.8 | 10.70 | 10.8 | 10.1 |
| NO2 | mg/l | 0.05 | <0.05 | <0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | <0.05 | <0.05 | <0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 | < 0.05 |
| Br | mg/l | 0.1 | <0.1 | <0.1 | < 0.1 | < 0.1 | 0.31 | 0.13 | < 0.1 | 0.27 | < 0.1 | < 0.1 | 0.11 | < 0.1 | < 0.1 | 0.12 | 0.14 | <0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | 0.11 | < 0.1 |
| NO3 | mg/l | 0.05 | 0.2 | 0.23 | 0.15 | < 0.05 | 0.18 | 0.09 | 0.05 | < 0.05 | 0.21 | 0.16 | < 0.05 | 0.22 | < 0.05 | 0.28 | 0.07 | <0.05 | 0.12 | 0.15 | < 0.05 | 0.29 | 0.16 | < 0.05 |
| PO4 | mg/l | 0.2 | <0.2 | <0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | <0.2 | <0.2 | <0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| SO4 | mg/l | 0.1 | 12.4 | 13.6 | 15.0 | 13.0 | 13.4 | 13.0 | 11.4 | 13.4 | 13.1 | 13.4 | 12.7 | 12.9 | 13.0 | 13.80 | 13.40 | 13.60 | 12.0 | 12.5 | 13.4 | 12.4 | 12.2 | 13.8 |
| Si | mg/l | 0.02 | 5.45 | 5.85 | 5.82 | 6.24 | 5.86 | 6.38 | 6.77 | 5.90 | 6.08 | 6.19 | 5.93 | 6.14 | 6.53 | 6.20 | 5.92 | 5.83 | 6.30 | 6.29 | 5.54 | 6.28 | 6.13 | 5.95 |
| Fe | mg/l | 0.002 | 0.25 | 0.611 | 1.22 | 1.36 | 1.44 | 1.66 | 2.11 | 1.63 | 1.60 | 1.65 | 1.77 | 1.84 | 1.41 | 1.76 | 1.71 | 1.2 | 2.14 | 2.04 | 1.79 | 2.05 | 1.98 | 1.75 |
| Ti | mg/l | 0.001 | 0.0138 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.0015 | 0.0012 | 0.0011 |
| Mg | mg/l | 0.05 | 7.14 | 6.67 | 6.35 | 6.39 | 6.12 | 6.88 | 6.73 | 6.27 | 6.36 | 6.55 | 6.19 | 6.33 | 6.57 | 6.570 | 6.230 | 6.150 | 6.400 | 6.56 | 6.31 | 6.48 | 6.28 | 6.10 |
| Ca | mg/l | 0.02 | 24.2 | 21.1 | 19.6 | 21.1 | 20.2 | 22.1 | 21.7 | 20.1 | 21.0 | 21.3 | 20.2 | 20.2 | 21.0 | 21.00 | 19.90 | 20.00 | 20.4 | 20.8 | 20.4 | 20.4 | 20.3 | 19.9 |
| Na | mg/l | 0.05 | 12.4 | 11.8 | 11.4 | 11.5 | 11.3 | 12.2 | 11.1 | 11.1 | 11.4 | 12.1 | 10.5 | 10.3 | 11.3 | 11.10 | 10.90 | 11.40 | 11.3 | 11.5 | 11.7 | 11.3 | 11.1 | 11.2 |
| Ba | mg/l | 0.002 | 0.053 | 0.0453 | 0.0446 | 0.0445 | 0.0458 | 0.0363 | 0.0391 | 0.0333 | 0.0387 | 0.0327 | 0.0396 | 0.0431 | 0.0342 | 0.0381 | 0.0343 | 0.1360 | 0.237 | 0.265 | 0.225 | 0.286 | 0.283 | 0.274 |
| Sr | mg/l | 0.001 | 0.11 | 0.0975 | 0.0936 | 0.0976 | 0.0946 | 0.106 | 0.102 | 0.0915 | 0.0953 | 0.0967 | 0.0922 | 0.0922 | 0.0981 | 0.0973 | 0.0940 | 0.0952 | 0.0987 | 0.100 | 0.0982 | 0.100 | 0.0980 | 0.0959 |
| Sc | mg/l | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Y | µg/l | 0.005 | 0.113 | 0.0501 | 0.0617 | 0.0610 | 0.0708 | 0.0671 | 0.128 | 0.078 | 0.0778 | 0.0796 | 0.0914 | 0.0932 | 0.0624 | 0.103 | 0.0894 | 0.0600 | 0.145 | 0.145 | 0.105 | 0.133 | 0.0990 | 0.0940 |
| Nb | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Ag | µg/l | 0.01 | <0.01 | <0.01 | 0.020 | 0.026 | 0.032 | 0.584 | 0.656 | 0.561 | 0.543 | 0.489 | 0.479 | 0.326 | 0.226 | 0.563 | 0.211 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| In | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Sb | µg/l | 0.01 | 0.276 | 0.101 | 0.066 | 0.031 | 0.017 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.01 | <0.01 | <0.01 | <0.01 |
| Cs | µg/l | 0.002 | 0.0279 | 0.0050 | 0.0071 | 0.0050 | 0.0045 | 0.0038 | 0.0044 | 0.0042 | 0.0039 | 0.004 | 0.004 | 0.004 | 0.0031 | 0.006 | 0.004 | 0.004 | 0.004 | 0.005 | 0.0053 | 0.0052 | 0.0050 | 0.0041 |
| Nd | µg/l | 0.01 | 0.324 | 0.060 | 0.088 | 0.064 | 0.075 | 0.076 | 0.147 | 0.093 | 0.102 | 0.104 | 0.12 | 0.141 | 0.065 | 0.117 | 0.106 | 0.07 | 0.218 | 0.230 | 0.113 | 0.164 | 0.121 | 0.124 |
| Sm | µg/l | 0.002 | 0.0468 | 0.0125 | 0.0161 | 0.0132 | 0.015 | 0.013 | 0.025 | 0.015 | 0.0173 | 0.0173 | 0.0201 | 0.0241 | 0.0105 | 0.016 | 0.017 | 0.010 | 0.0318 | 0.0339 | 0.0201 | 0.0305 | 0.0196 | 0.0197 |
| Ho | µg/l | 0.001 | 0.0042 | 0.0015 | 0.0020 | 0.0018 | 0.0017 | 0.0017 | 0.003 | 0.0021 | 0.0023 | 0.0021 | 0.0026 | 0.0026 | 0.0014 | 0.003 | 0.002 | 0.002 | 0.004 | 0.004 | 0.0020 | 0.0030 | 0.0018 | 0.0024 |

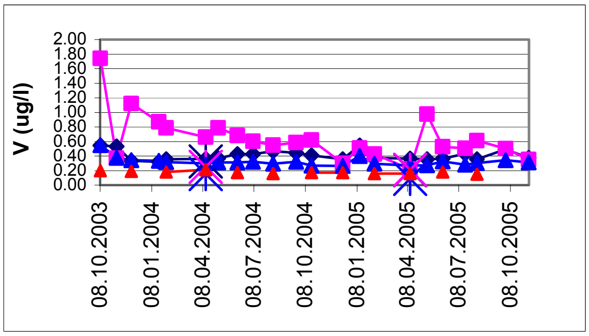
## KARPDALEN continues

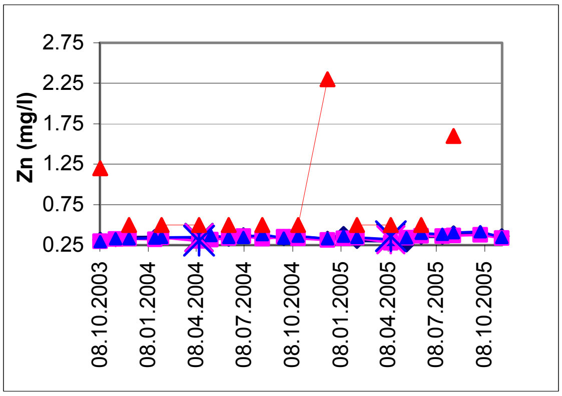
| Parameter | Enhet | DL | 04.10.03 | 07.11.03 | 03.12.03 | 21.01.04 | 25.02.04 | 02.04.04 | 06.05.04 | 12.06.04 | 06.07.04 | 18.08.04 | 20.09.04 | 28.10.04 | 01.12.04 | 11.01.05 | 24.02.05 | 04.04.05 | 13.05.05 | 16.06.05 | 20.07.05 | 18.08.05 | 30.09.05 | 08.11.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yb | µg/l | 0.002 | 0.0079 | 0.0035 | 0.0051 | 0.0045 | 0.0044 | 0.0051 | 0.007 | 0.0048 | 0.0054 | 0.005 | 0.0057 | 0.007 | 0.0035 | 0.007 | 0.005 | 0.004 | 0.009 | 0.009 | 0.0063 | 0.0068 | 0.0058 | 0.0060 |
| Ta | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| W | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.056 | <0.05 | 0.055 | 0.062 | 0.064 | 0.064 | 0.07 | <0.05 | <0.05 | 0.05 | <0.05 | <0.05 | 0.05 | 0.056 | <0.05 | 0.056 | 0.065 |
| Tl | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Bi | µg/l | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.014 | 0.014 | 0.016 | 0.019 | 0.012 | 0.017 | 0.013 | 0.019 | 0.02 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Th | µg/l | 0.02 | 0.152 | 0.024 | 0.033 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | 0.02 | 0.02 | <0.02 | 0.03 | 0.03 | <0.02 | <0.02 | <0.02 | <0.02 |
| V | µg/l | 0.02 | 1.74 | 0.368 | 1.12 | 0.871 | 0.789 | 0.66 | 0.785 | 0.68 | 0.601 | 0.548 | 0.583 | 0.619 | 0.300 | 0.511 | 0.426 | 0.218 | 0.976 | 0.527 | 0.507 | 0.612 | 0.501 | 0.350 |
| Mn | µg/l | 0.05 | 99.500 | 89.9000 | 79.7000 | 80.2 | 80.5 | 90.3 | 103 | 86.8 | 85.1 | 85.5 | 88.6 | 94.2 | 93.30 | 91.3 | 85.8 | 88.0 | 104 | 95.00 | 86.90 | 92.1000 | 92.4000 | 86.3 |
| Cu | µg/l | 0.05 | 0.721 | 0.21 | 0.17 | 0.099 | 0.1 | 0.07 | 0.079 | 0.056 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | 0.06 | <0.05 | <0.05 | 0.05 | <0.05 | 0.052 | 0.076 | <0.05 | <0.05 |
| Zn | mg/l | 0.002 | 0.299 | 0.324 | 0.331 | 0.323 | 0.344 | 0.301 | 0.316 | 0.336 | 0.360 | 0.331 | 0.351 | 0.334 | 0.312 | 0.332 | 0.340 | 0.276 | 0.342 | 0.364 | 0.362 | 0.368 | 0.376 | 0.339 |
| Ga | µg/l | 0.01 | 0.142 | 0.023 | 0.021 | 0.010 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.013 | <0.01 | 0.011 | <0.01 |
| Ge | µg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Li | µg/l | 0.5 | 3.3 | 2.9 | 2.7 | 2.7 | 2.79 | 2.9 | 3 | 2.7 | 2.6 | 2.73 | 2.8 | 3.1 | 3.200 | 2.85 | 3.1 | 3.0 | 3.2 | 2.60 | 2.50 | 2.43 | 2.41 | 2.30 |
| Be | µg/l | 0.01 | <0.01 | 0.034 | 0.033 | 0.016 | 0.021 | 0.034 | 0.037 | 0.033 | 0.035 | 0.036 | 0.033 | 0.011 | 0.105 | 0.189 | 0.02 | 0.01 | 0.01 | <0.01 | <0.01 | 0.012 | 0.020 | <0.01 |
| B | µg/l | 5 | 21 | 20 | <5 | 19 | 18 | 20 | 17 | 18 | 19 | 19 | 17 | 17.8 | 21 | 23 | 21.3 | 20.7 | 20.2 | 18.9 | 19.6 | 18.0 | 17.5 | 16.7 |
| Rb | µg/l | 0.05 | 2.47 | 1.45 | 1.20 | 1.11 | 1.09 | 1.09 | 1.07 | 0.993 | 1.03 | 1.03 | 0.998 | 1.03 | 0.984 | 1.14 | 1.07 | 0.981 | 1.02 | 1.04 | 0.966 | 1.02 | 1.01 | 1.00 |
| Zr | µg/l | 0.05 | 0.24 | 0.088 | <0.05 | 0.11 | 0.1 | 0.104 | 0.146 | 0.098 | 0.11 | 0.13 | 0.11 | 0.13 | 0.05 | 0.08 | <0.05 | <0.05 | <0.05 | 0.119 | 0.101 | 0.067 | <0.05 | <0.05 |
| Mo | µg/l | 0.2 | 4.09 | 3.8 | 3.88 | 3.61 | 3.73 | 3.8 | 2.89 | 3.83 | 4.1 | 4.32 | 3.33 | 3.21 | 3.4 | 3.76 | 3.74 | 3.78 | 3.40 | 3.64 | 3.72 | 3.72 | 3.66 | 3.81 |
| Cd | µg/l | 0.03 | <0.03 | 0.048 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | 0.07 | 0.09 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| La | µg/l | 0.01 | 0.338 | 0.070 | 0.096 | 0.051 | 0.07 | 0.065 | 0.162 | 0.076 | 0.088 | 0.102 | 0.097 | 0.115 | 0.064 | 0.1 | 0.09 | 0.05 | 0.156 | 0.181 | 0.104 | 0.183 | 0.115 | 0.119 |
| Ce | µg/l | 0.01 | 0.731 | 0.131 | 0.195 | 0.113 | 0.124 | 0.128 | 0.221 | 0.133 | 0.156 | 0.183 | 0.189 | 0.206 | 0.116 | 0.159 | 0.161 | 0.08 | 0.267 | 0.294 | 0.165 | 0.299 | 0.186 | 0.193 |
| Pb | µg/l | 0.05 | 0.084 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.009 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| U | µg/l | 0.0005 | 55.4 | 22.7 | 16.1 | 10.2 | 9.35 | 5.82 | 5.22 | 5.05 | 5.49 | 4.63 | 5.44 | 5.61 | 3.18 | 4.3 | 3.91 | 3.44 | 3.31 | 4.34 | 3.69 | 3.08 | 2.97 | 3.78 |
| Al | µg/l | 2 | 210 | 37.4 | 55.5 | 21.7 | 15 | 5.8 | 9.7 | 10 | 13 | 9.6 | 11.5 | 8.3 | 13.9 | 10.2 | 7.7 | 5.2 | 9.3 | 10.5 | 8.34 | 13.8 | 12.6 | 7.0 |
| Cr | µg/l | 0.1 | 0.98 | 0.58 | 0.78 | 0.71 | 0.78 | 0.24 | 0.49 | 0.34 | 0.41 | 0.32 | 0.73 | 0.72 | 0.83 | 1 | 0.8 | 0.6 | 0.8 | 0.644 | 0.616 | 0.65 | 0.65 | 0.59 |
| Co | µg/l | 0.02 | 0.473 | 0.534 | 0.461 | 0.293 | 0.318 | 0.252 | 0.289 | 0.224 | 0.217 | 0.23 | 0.3 | 0.349 | <0.02 | <0.02 | 0.318 | 0.322 | 0.347 | 0.322 | 0.294 | 0.295 | 0.312 | 0.292 |
| Ni | µg/l | 0.2 | 1.8 | 1.9 | 1.5 | 1.2 | 1.2 | 1.1 | 1.2 | 0.96 | 0.8 | 0.8 | 0.7 | 0.75 | 1.1 | 0.94 | 0.7 | 0.7 | 0.7 | 0.630 | 0.517 | 0.57 | 0.57 | 0.53 |
| P | µg/l | 5 | 7.9 | <5 | 9.4 | 11 | 14 | 11 | 13 | 12 | 15 | 15 | 12 | 9.3 | <5 | 8.8 | 8 | 5 | 12 | 12.6 | 9.71 | 12.7 | 7.6 | 8.3 |
| I | µg/l | 5 | 8.5 | 6.1 | 7.4 | 6.8 | 7 | 6.2 | 6.1 | 6 | 5.5 | <5 | <5 | 5.7 | <5 | 6.6 | <5 | <5 | <5 | <5 | <5 | 5.3 | <5 | <5 |
| K | mg/l | 0.025 | 4.700 | 3.640 | 3.590 | 3.650 | 3.730 | 3.870 | 3.890 | 3.940 | 3.810 | 3.820 | 3.910 | 3.310 | 3.47 | 0.734 | 3.430 | 3.450 | 3.460 | 3.660 | 3.460 | 3.22 | 3.16 | 3.23 |
| As | µg/l | 0.05 | 0.909 | 0.511 | 0.698 | 0.746 | 0.761 | 0.782 | 0.663 | 0.68 | 0.696 | 0.669 | 0.721 | 0.578 | 0.481 | <0.05 | 0.568 | 0.50 | 0.590 | 0.573 | 0.586 | 0.622 | 0.580 | 0.563 |
| Se | µg/l | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| GWL | m | | 1.81 | 1.53 | 1.60 | 2.08 | 2.37 | 2.55 | 2.20 | 1.55 | 1.81 | 2.20 | 2.05 | 1.75 | 1.95 | 2.25 | 2.60 | 2.90 | 2.60 | 1.70 | 2.10 | 1.70 | 1.85 | 1.45 |

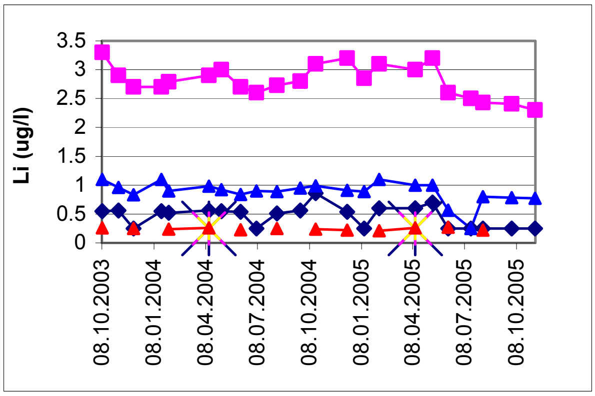
# APPENDIX 3: Temporal variation of elemental concentration in groundwater and Snow

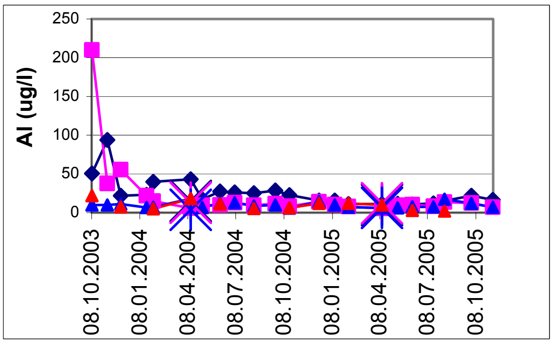


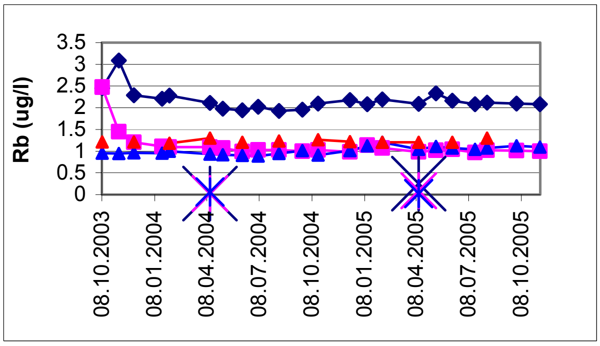

Cs (mg/l)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

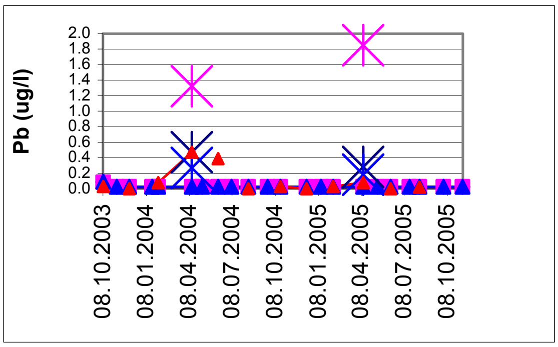

V (ug/l)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

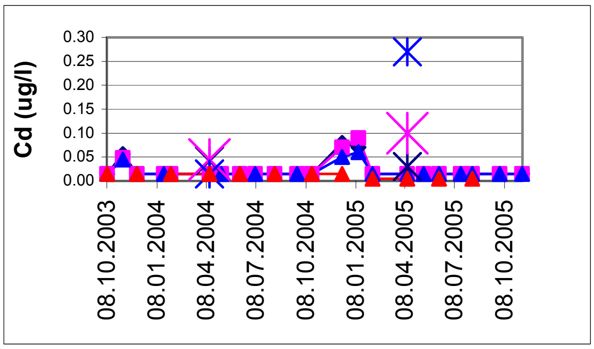

Zn (mg/l)
2.75
2.25
1.75
1.25
0.75
0.25
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

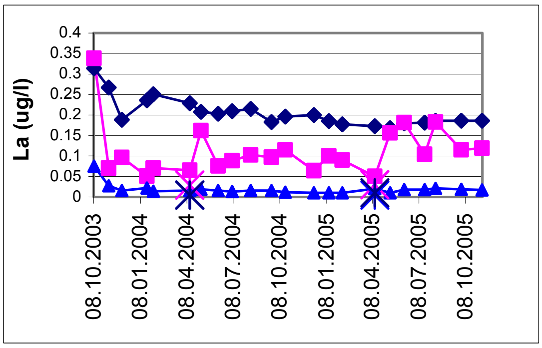

Li (ug/l)
3.5
3
2.5
2
1.5
1
0.5
0
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

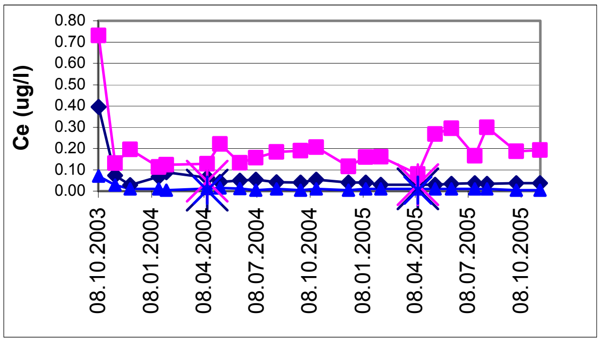

Al (ug/l)
250
200
150
100
50
0
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

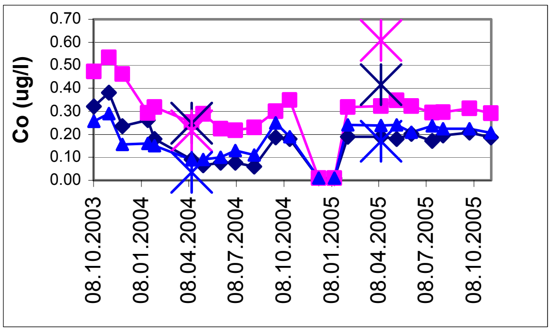

Rb (ug/l)
3.5
3
2.5
2
1.5
1
0.5
0
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

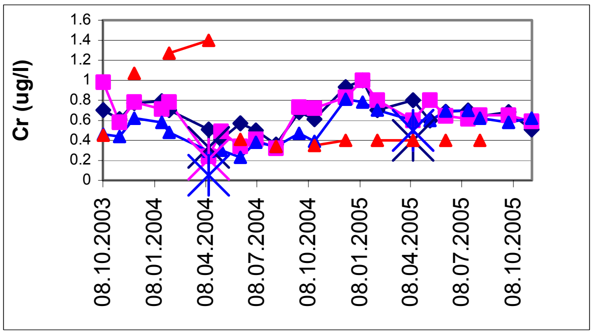

Pb (ug/l)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

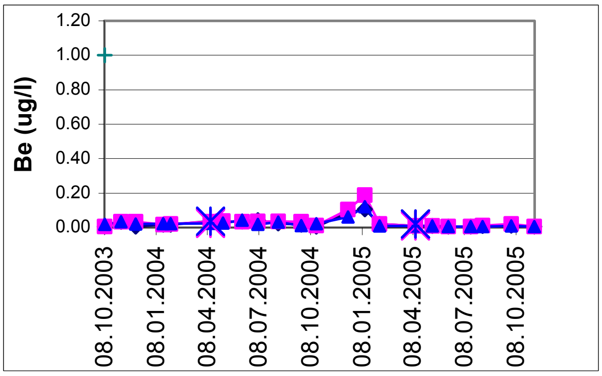

Cd (ug/l)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005

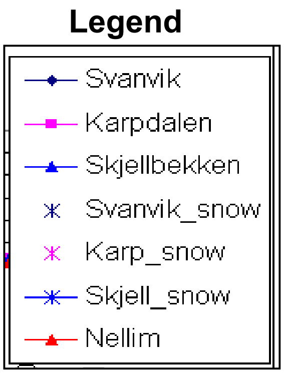

La (ug/l)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005


Ce (ug/l)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005


Co (ug/l)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005


Cr (ug/l)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005


Be (ug/l)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
08.10.2003
08.01.2004
08.04.2004
08.07.2004
08.10.2004
08.01.2005
08.04.2005
08.07.2005
08.10.2005


Legend
Svanvik
Karpdalen
Skjellbekken
Svanvik_snow
Karp_snow
Skjell_snow
Nellim