

# Multidisciplinary perspectives on a natural attenuation zone in a PCE-contaminated aquifer

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# **Multidisciplinary perspectives on a natural attenuation zone in a PCE-contaminated aquifer**

A case study from Hagfors, Sweden

Master's thesis

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**Cover Picture:** Photo of the study area (floodplain).

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**Abstract:** The old dry-cleaner in Hagfors, is one of the most seriously tetrachloroethene (PCE) contaminated sites in Sweden. Ever since the pollution was discovered in the groundwater in the 1990s, the site has undergone remediation two times with limited success. The Geological Survey of Sweden (SGU) has estimated that tens of tonnes of PCE are still left in the subsurface, where dissolved PCE is transported via groundwater and discharged to the adjacent Örbäcken stream. In this study, I applied high-resolution direct current induced polarization (DCIP) and sampled the groundwater and the near-surface sediment for chloroethenes in a study area located adjacent to Örbäcken. The chemical results indicate that natural attenuation is an actively ongoing process in the study area, while the DCIP model result provided information about subsurface structures that correlate well with the aquifer-aquitard boundary indicated from already existing core descriptions. The different DCIP model results were displayed together with borehole data, as well as chemical reference data, in a 3D model. These combined results clearly showed two structures that are continuous throughout the study area. These two structures include one zone of high resistivity, correlating with an area of high amount of the biological degradation product *cis*-1,2-dichloroethene (*cis*DCE), and the other is a tilted zone with low resistivity upstream of the high-resistivity zone. The low-resistivity tilted zone crosses the aquifer-aquitard boundary and is interpreted as a fracture zone in the aquitard.

The work is part of the research project **Monitoring of *In situ* Remediation of CHLorinated hydrocarbon contaminants, MIRACHL** (Funder by Formas 2016-00808 and 942-2016-99, SGU and Tyréns Stiftelse). The work was also partly supported by the European Union, Eurostars Programme, together with Innovation Fund Denmark and The Swedish innovation agency Vinnova under the project “Mapping Geology in Cities” (E10096 MAGIC).

**Keywords:** DCIP, Groundwater chemistry, Tetrachlorethene, PCE, Natural attenuation

**Supervisor(s):** Sofia Åkesson, Charlotte Sparrenbom, Torlief Dahlin and Matteo Rossi

**Subject:** Quaternary Geology, Applied geology

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# Multidisciplinärt undersökning på en naturlig nedbrytningszon i en PCE-förorenad akvifär

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**Sammanfattning:** Den gamla kemtvätten i Hagfors är ett av de kraftigast tetrakloreten (PCE) förorenade områdena i Sverige. Sedan föroreningen upptäcktes i grundvattnet på 1990-talet har området genomgått två saneringar med begränsad framgång. Sveriges Geologiska Undersökning (SGU) har uppskattat att tiotals ton PCE fortfarande finns kvar under markytan. Upplöst PCE transporteras i grundvattensystemet och läcker sedan ut i den närliggande Örbäcken. Området som undersökts inom ramen för detta examensarbete ligger alldeles intill Örbäcken. Den geofysiska metoden DCIP (Direct Current Induced Polarization) har använts högupplöst inom området, tillsammans med provtagning av grundvatten och ytnära sediment, som analyserats med avseende på kloreteninnehåll. De kemiska resultaten indikerar att naturlig nedbrytning av PCE och dess nedbrytningsprodukter är en aktivt pågående process inom undersökningsområdet. De geofysiska resultaten ger information om en yta som korrelerar väl med akvifär-akvitaridgränsen. Genom att kombinera DCIP-resultaten med borrhålsdata och kemiska referensdata, har en 3D-modell konstruerats. De kombinerade resultaten visar tydligt två avvikande zoner. En av zonerna uppvisar hög resistivitet, samtidigt som höga halter nedbrytningsprodukter (*cisDCE*) detekterats i zonen. Den andra zonen är en lutande lågresistiv zon, belägen uppströms zonen med hög resistivitet. Den lågresistiva zonen bryter akvifär-akvitaridgränsen, och tolkas som en sprickzon i akvitariden.

Arbete ingår i forskningsprojektet **Monitoring of *In situ* Remediation of CHLorinated hydrocarbon contaminants, MIRACHL** (Finansierat av Formas 2016-00808 samt 942-2016-99, SGU och Tyréns Stiftelse). Arbetet stöddes också delvis av Europeiska Unionen, Eurostar Programme, tillsammans med Innovation Fund Denmark och Vinova i projektet "Mapping Geology in Cities" (E10096 MAGIC).

**Nyckelord:** DCIP, Grundvattenkemi, Tetrakloreten, PCE, Naturlig nedbrytning

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**Ämnesinriktning:** Kvartergeologi, tillämpad geologi

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# 1. Introduction

Worldwide, a large number of polluted areas are in need of remediation, where the organic solvent tetrachlorethene (PCE) is among the most problematic pollutants found in groundwater aquifers (Parker et al. 2003). In total, the Swedish Environmental Protection Agency counted 746 old dry-cleaning facilities in Sweden which are still contaminated with PCE and classified to be a huge risk for humans and the environment (Naturvårdsverket 2016). The old dry-cleaning facility located in the centre of Hagfors and studied in this work, is one of the most known and highly PCE contaminated sites in Sweden and the operation was active 1970 - 1993. Exposure to PCE has been linked to increased risk for oesophageal-, cervical cancer and non-Hodgkin's lymphoma and is an unwanted compound in water resources (IARC 1995).

For many sites contaminated with dense non-aqueous phase liquids (DNAPL) like PCE, *in situ* remediation would give an advantage over the classical remediation approach of "excavation". Then both the expensive and dangerous transports of the contaminated sediments, but also the deposition in already overused landfills, can be avoided. As PCE is denser than water it sinks through the water column by gravitational force, making it very hard to find and remediate with common excavation techniques.

Chemical or biological techniques for *in situ* remediation are available and can degrade PCE to non-toxic compounds. Such degradation would effect and alter the groundwater chemistry, changes that might be detectable with the non-destructive geophysical methods direct current resistivity and time-domain induced polarization tomography (DCIP) (Sparrenbom et al. 2017).

However, a high-resolution continuous DCIP monitoring system for *in situ* remediation is still lacking in general. Without a high-resolution spatially continuous monitoring system, the *in situ* remediation degree and degradation status cannot be verified effectively (Sparrenbom et al. 2017).

It has been suggested in earlier studies that DCIP has the capacity to detect free phase (as a separate individual liquid) DNAPL (Johansson et al. 2015, Sparrenbom et al. 2017). In theory, using DCIP it is possible to detect zones of natural attenuation, which has also been proven possible

at field scale after the injection of bio stimulating agents (Atekwana & Slater 2009).

## 1.1 MIRACHL

This master thesis is a minor part of the research project **Monitoring of *In situ* Remediation of Chlorinated hydrocarbon contaminants**, or MIRACHL ([www.mirachl.com](http://www.mirachl.com)). The vision of the project is to develop methods and methodology, for optimized planning and monitoring of *in situ* remediation of PCE, by combining DCIP with, physical and biogeochemical characterisation (PBGC) and compound-specific isotope analysis (CSIA). This means finding and monitoring the contaminant by measuring the electrical resistance and chargeability of the sediment in 3D and verifying the results with pinpointed biogeochemical and isotope analyses of sediment and water samples. The specific aim of MIRACHL is to develop and fine-tune an applicable methodology and technique for the remediation industry (MIRACHL 2017).

## 1.2 Objective

The objective of this thesis is to correlate high-resolution DCIP data with available geological and chemical data over a small part of the dissolved PCE plume, referred to as the study area. Further, the objective is to combine these results into a reasonable conceptual model. The model can potentially be used as input for remediation actions, as for example construction of active barriers or drainage actions, both to minimize the discharge of dissolved PCE to Örbäcken stream.

This thesis addresses the following questions:

- Could a DCIP investigation give a good high-resolution 2D picture of the underground, to interpret the geology/hydrogeology and the contaminant situation in the Örbäcken area?
- Do the geochemical conditions differ between the sampled wells? Do the concentrations of chlorinated aliphatic hydrocarbons (CAH) differ between sediment pits? Why do they differ? Is it possible to correlate the CAH difference in the ground with DCIP?
- Are the environmental conditions favourable for the soil microbes degrading PCE and its metabolites? What depths and what



sediment type are most favourable for degradation?

- PCE transported in the groundwater is known to enter Örbäcken. Where does recharge and discharge of groundwater take place in the examined area of Örbäcken?

## 2. Background

### 2.1 Site description

The old dry-cleaner located in Hagfors, Värmland, (Figure 1), used PCE as a solvent instead of water (Nilsen 2013). In Figure 1, an overview map of the site and the study area is presented. Since the mid-90s, the facility has been subjected to two sediment remediation actions (1995-96 and 2003-04). The objectives of these remediations were to ensure acceptable guideline values for air quality within the indoor facility to ensure the environment for the people working there. Today the Swedish Geological Survey (Sveriges geologiska undersökning, SGU) estimates that tens of tons PCE are still left in the ground,

whereas the main objective today is to stop the leakage of PCE to Örbäcken (Nilsen 2013).

Nilsen (2013) reported the contamination situation in the groundwater to be extremely high with two PCE plumes heading in a southwest direction. One plume is moving from the main building, while a secondary plume located 150 m south of the main building is identified to occur due to a drainage pipe leading from the main building into the creek area. The secondary source zone is situated on a manmade railroad bank with a steep embankment to the southeast transitioning to a lower valley where Örbäcken is located.

### 2.2 Geological setting

About 10 800 years ago, the ice margin was situated 100 km south of Hagfors and the highest shoreline was positioned around 190 – 195 m a.s.l. (Svedlund 2010). The study area located beneath the highest shoreline in a topographical low at 136 m a.s.l. Figure 2 shows the quaternary

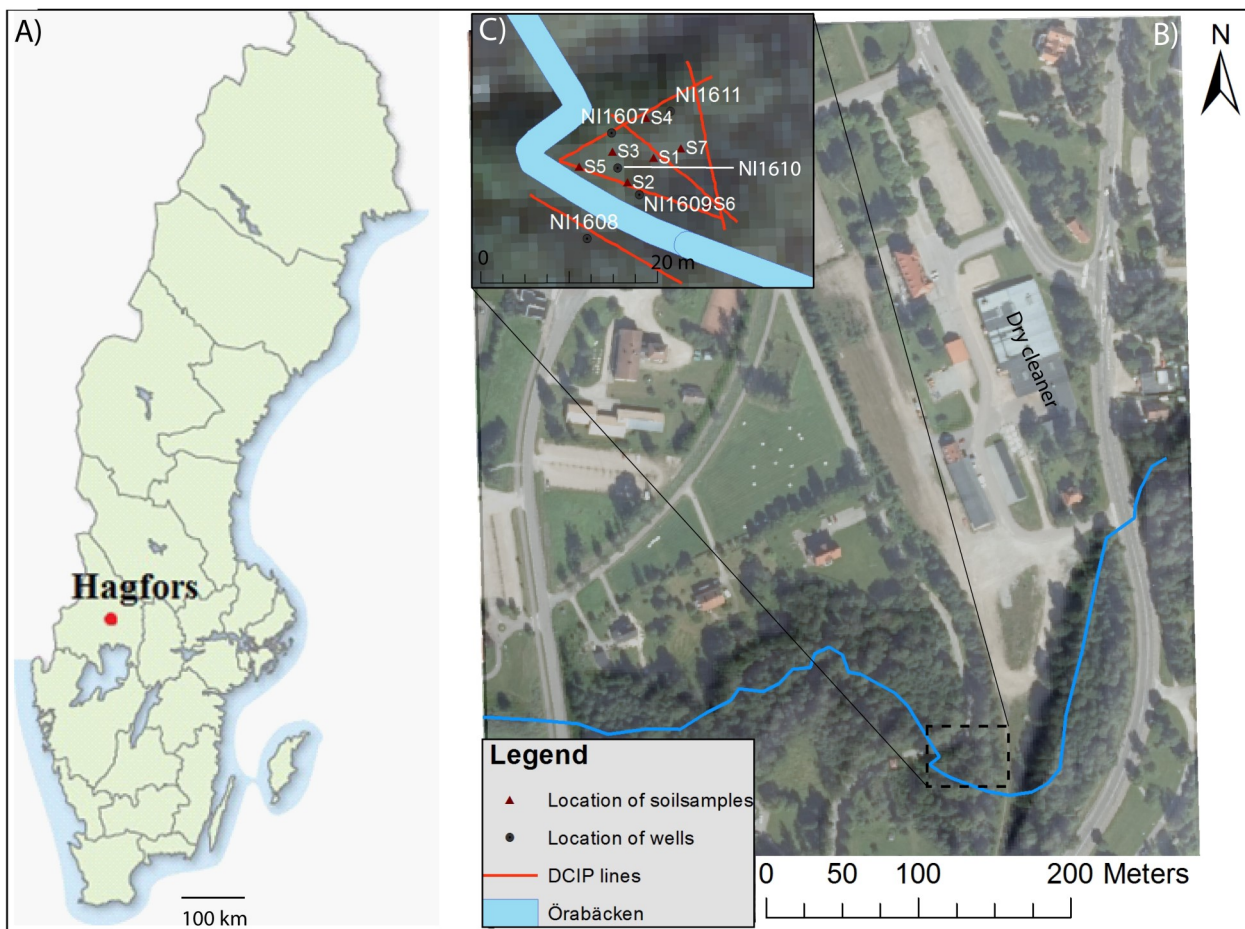


Figure 1. A) National map of Sweden with Hagfors highlighted located in the western part. B) An orthophoto over Hagfors, with the old dry-cleaner marked with a black straight line. C) South of the old dry-cleaning facility, the study area adjacent to Örbäcken is marked with a dashed black line. © Lantmäteriet.

deposit map over the Hagfors area, where a glaciofluvial deposits extend in a SW-NE direction. In between, the glaciofluvial deposits, the Örbäcken valley and the study area are located, which is marked in Figure 2 with a solid red rectangle and solid black rectangle respectively.

Glacial silt deposits cover the sides of today's Lake Värmullen (Figure 2) and extend 2 km south within the low topographical area. The glacial silt was most probably deposited in a marine environment or in a lacustrine environment. However, due to the location 50 m below the highest shoreline, Lake Värmullen has undoubtedly been in connection with a marine or brackish environment.

The sediment covering Örbäcken valley is a postglacial sand with isolated lenses of silt and gravel. The environment around the study area

has been altered by human activity in the past. The most prominent change of the landscape was the construction of a railroad embankment and the re-directing of Örbäcken through culverts in early 20<sup>th</sup> century (Larsson et al. 2017).

In the eastern part, the sediments consist of a compacted glacial silty and/or sandy till, which extends under the postglacial sand deposit in the study area (Larsson et al. 2017). In the higher areas, bedrock is exposed at the surface and consists of granites. The granites are mainly of a porphyritic texture with bigger feldspars crystals and a matrix of quartz and biotite. The bedrock originates from the Sveconorwegian orogeny (1.7 Ga) and the region is characterized by major fault and deformation zones which occur in a northwest - southeast direction (SGU 2012).

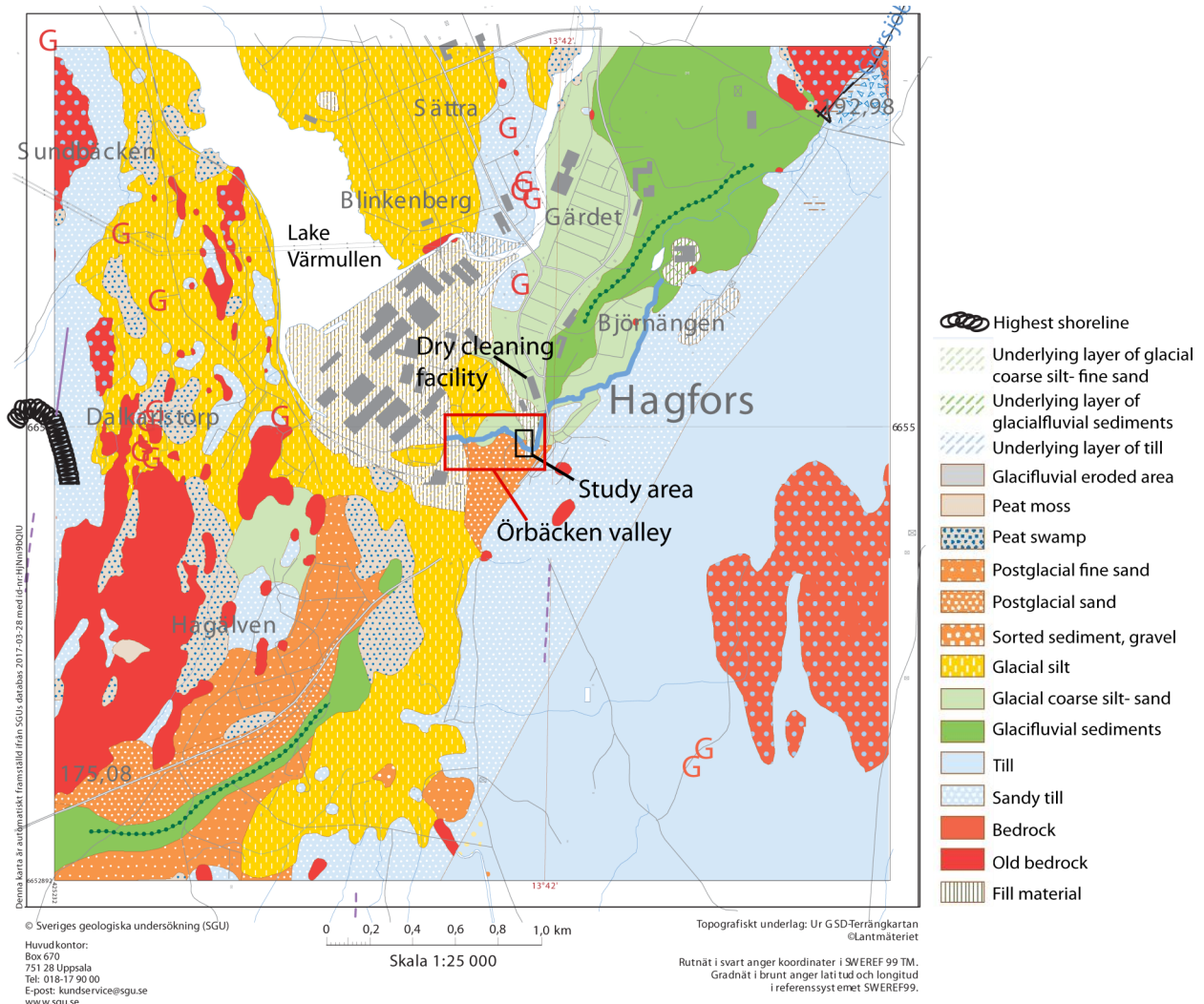


Figure 2. Quaternary deposit map over Hagfors at scale 1:25 000, mapped by SGU, showing the surface and near surface distribution of different sediment types and Örbäcken stream. The study area is marked with a solid black square and the Örbäcken valley is marked with a solid red square. © Sveriges geologiska undersökning.

In Figure 3, the study area is shown to be located at the foot of the railroad embankment, and Örbäcken flows out from a culvert in the right hand of the photo. The floodplain is small and almost triangular in shape, with about 20 m long sides.

The lithology consists of two layers, one top layer of postglacial sand with a thickness in between 3 – 4 m, which is underlain by a till with a thickness of 12 – 13 m which extends down to the bedrock (Larsson et al. 2017).

Örbäcken is a meandering stream with an average flow of ca 165 l/s (Nilsen 2013). Örbäcken displays the characteristics of repeated sequences of pool and riffle bedforms that create a topographic difference at the streambed. Örbäcken has a moderate slope (1.5 – 2 %), where the pools consist of finer sediments (sand) and riffles are composed of coarser sediments (gravel, cobble).

The recipient of Örbäcken is Lake Värmullen. Nilsen (2013) calculated the mass fluxes of PCE discharge from the aquifer to Örbäcken to be

approximately 180 kg/year, while 80 kg/year is assumed to reach Lake Värmullen (Nilsen 2013). In the past, the migration of Örbäcken and over-bank flooding, erosion and re-deposition of sediments has created a complex sediment stratigraphy that is found in the top sand unit of the study area.

### 2.3 Hydrogeology

Before 1993 the Örbäcken valley was regarded as a reserve groundwater resource for Hagfors municipality, but since the contamination was detected several surveys have been conducted to understand the hydraulic properties of the aquifer in the Örbäcken valley (Nilsen 1991, Sweco 1993-2013 and NIRAS 2013-present).

In the autumn of 1991, a pumping test was performed in the unconfined aquifer (~100 m NW, from the study area) just prior to the discovery of the contamination. At this time, Hagfors municipality wanted to examine the possibilities to re-open the old groundwater wells in the Örbäcken valley for drinking water purposes. The



Figure 3. Photo of the study area, which has almost triangular shaped sides, with Örbäcken meandering around the bend. © Robin Jansson.

pumping test was performed in well KB3 (Figure 4) by Nilsen (1991) during 14 days, pumping at a constant flow of 6 l/s. Complete drawdown (-3.5 m) of the pumped well was achieved after 100–200 min of pumping, while recovery was slow (just noted, not measured). The transmissivity (T) was calculated to c.  $6 \cdot 10^{-3}$  m<sup>2</sup>/s and the hydraulic conductivity (K) to  $5 \cdot 10^{-4}$  m/s (Nilsen 1991).

As part of the main study for Hagforstväten, Nilsen (2013) conducted a numerical groundwater modelling using the software Visual Modflow 2011.1. The objective was to improve the understanding of flow patterns within different parts of the groundwater magazine and get an estimated transport time of groundwater to the surface water recipient (Nilsen 2013). The modelling result shows that the general groundwater direction is from the northeast towards southwest. But the model does not include the aquitard in the study area. In Figure 4, a groundwater level map for the Hagfors site is presented and monitoring well B19 represents the source zone for the secondary plume (Nilsen 2013).

The groundwater table at well B19 is located about 10 m b.g.s., while in the study area about 130 m downstream, the groundwater table is situated about 0.5 m b.g.s. (Nilsen 2013) Modflow results, recharge and discharge to Örbäcken calculations are shown in Figure 5, where blue marks recharge of surface water to groundwater, which was calculated to 265 m<sup>3</sup>/d. The zone of discharge to Örbäcken from the groundwater magazine is marked with red (Figure 5) and was calculated to 880 m<sup>3</sup>/d. The measurements of the hydraulic head were performed in spring 2012 and the model reflects wet conditions for the region with a high groundwater table (Nilsen 2013).

From tracer tests with fluorescent dyes conducted by the consultancy company NIRAS in autumn 2016, the hydraulic conductivity was measured to be in range of 1–10 m/day (mean value  $1.15 \cdot 10^{-4}$ – $1.15 \cdot 10^{-5}$  m/s) for the aquifer part between B19 (secondary source zone) reaching and the edge of the study area at Örbäcken (Larsson et al. 2017).

The postglacial sand covering Örbäcken valley with interbedded silty and gravelly sediments together forms a unconfined aquifer with an average thickness of 10–12 m (Nilsen 2013). The unconfined aquifer in the study area is 3–4 m

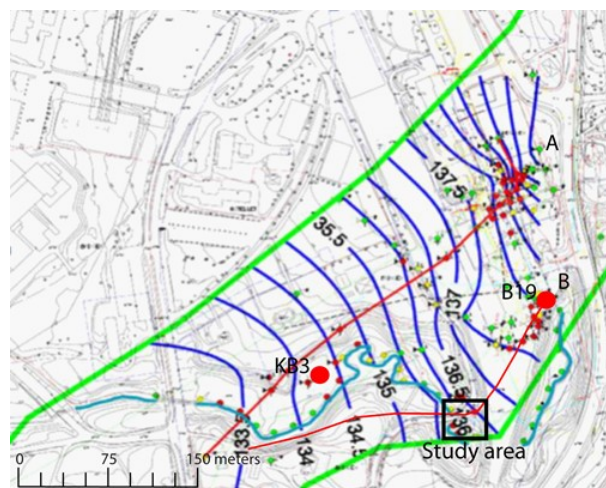


Figure 4. Groundwater flow map for the aquifer, hydraulic head plotted as isobars (blue colour) in meters above sea level. Green lines are negative hydraulic boundaries where no flow can pass and the red line represents the groundwater direction from the two source areas. Modified from Nielsen (2013), and with courtesy of J. Nilsen Sweco Environment AB.

thick and is underlain by a 12–13 m thick subglacial till referred to as the aquitard.

The hydraulic properties of the aquitard have previously been reported by Nilsen (2013) whose numerical model uses a K value of  $6 \cdot 10^{-4}$  m/s. Stephenson et al. (1988) have reported k values from a fractured silty-clayey subglacial till to be in the range  $10^{-6}$ – $10^{-9}$  m/s. As the till in Hagfors is mostly sandy and silty it is reasonable to expect K values between  $10^{-6}$ – $10^{-7}$  m/s. The Nilsen (2013) numerical model results suggest a higher hydraulic head in the aquitard, causing an discharge of groundwater to the aquifer from beneath. If Nilsen (2013) model results are correct, it might indicate the existence of a flow path and/or fractures in the aquitard where contaminated groundwater enters the aquifer.

In Figure 6A an overview map of the transect line B–B' of the secondary source zone (B19 to the study area) is presented. In Figure 6B the transect across the railroad embankment down to the creek displays the aquifer, aquitard and bedrock surface which is based on drill core logs (B19, NI1412, NI1604, NI1413, NI1611, NI1607 and NI1612) from Larson et al. (2017).

### 2.3.1 Hyporheic zone

The study site is a floodplain consisting of fluvial sand (aquifer), whereas the zone where groundwater interacts with surface water (Örbäcken) is called the hyporheic zone (Krause et al. 2011).

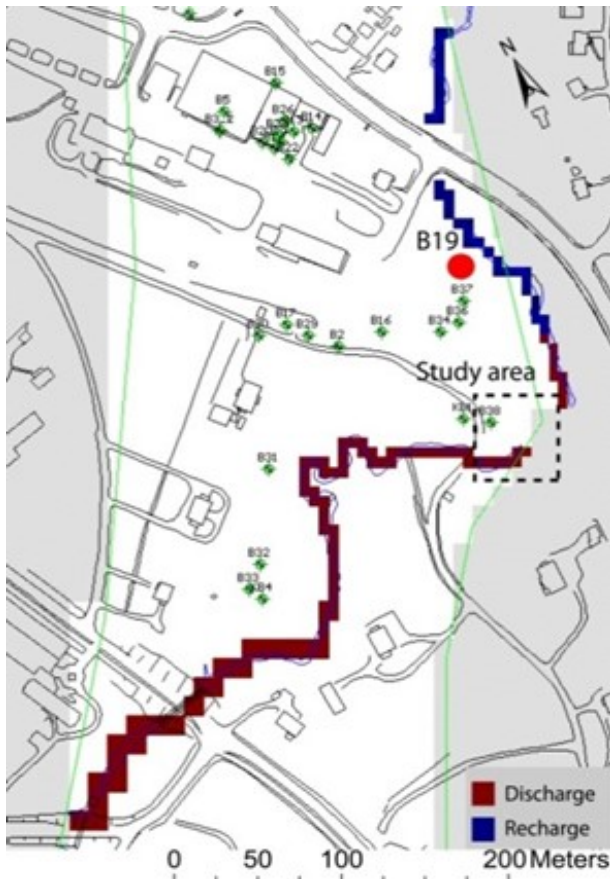


Figure 5. Recharge and discharge between the aquifer and Örbacken. Blue colour marks area of recharge and red colour marks the area where groundwater discharges to Örbacken. Well B19 marked with a red dot is the monitoring well where free phase PCE has been detected and my study area is marked with a black dashed square. Modified from Nilsen (2013), and with Courtesy of J. Nilsen Sweco Environment AB.

Along stream channels the hyporheic zone is the saturated sediments beneath and lateral to the channel, in which there is an active exchange of surface and groundwater (Jones & Mulholland 1999).

Pool-riffle channels have relatively large bedforms compared to channel depth. Such channel morphology has been shown in laboratory experiments by Tonina and Buffington (2007) and at field scale (Jones & Mulholland 1999) to cause a strong influences on the channel hydraulics and generate a complex three-dimensional flowpath lateral into the floodplain (Tonina & Buffington 2007, Buffington & Tonina 2009).

The complex three-dimensional flow paths can propagate laterally over meander bends within the floodplain or through old networks of buried paleochannels (Sophocleous 1991). The coarse sediments (riffles), hence where the sur-

face-groundwater exchange occurs, serve as a delivery corridor for nutrients (e.g. dissolved organic carbon and oxygen) into the hyporheic zone and floodplain. Steady supply of dissolved organic carbon and oxygen are important factors that enhance the aerobic microbial activity (Boano et al. 2014).

The exchange of water across a meandering bend is regulated by potential and kinetic energy near the streambed interface (Boano et al. 2014). As the hydraulic head regulates the water fluxes across the streambed, the water fluxes will be proportional to the gradient and cause a higher discharge within the morphologically deep sequences of the channel. Fundamentally the hyporheic exchange is related to the variability of hydraulic conductivity and the differences in hydraulic gradient due to the streambed morphology (Krause et al. 2011).

Therefore, it is reasonable that dissolved DNAPLs, traveling in a similar groundwater system as a contamination plume, will partially or completely discharge into surface water (Parker et al. 2008).

## 2.4 Pollution properties

Pure free-phase DNAPL e.g. PCE and its metabolites trichloroethene (TCE), dichloroethene (DCE) and vinylchlorid (VC), are hydrophobic, and hence have a low solubility in water and possess a greater density than water, see Table 1 (Amos 2007). Due to the chemical properties of PCE, it will migrate downward in the subsurface after a spill event, penetrate below the water table and onwards until it meets a non-permeable layer, and this is driven by the gravitational force (Amos 2007).

Free-phase PCE is unaffected by the groundwater flow direction and can penetrate through or into low permeability boundaries due to natural preferential pathways (Parker et al. 2004). During migration, free-phase PCE separates into isolated immobile droplets referred to as residual PCE. This is due to capillary forces in unconsolidated sediments (Amos 2007).

At the interface of low permeability boundaries or confining layers, PCE tends to pool up into high saturation zones (Amos 2007). During the downward migration, low concentrations (<200 mg/l) of PCE can dissolve into the groundwater, creating a plume fed from one or several

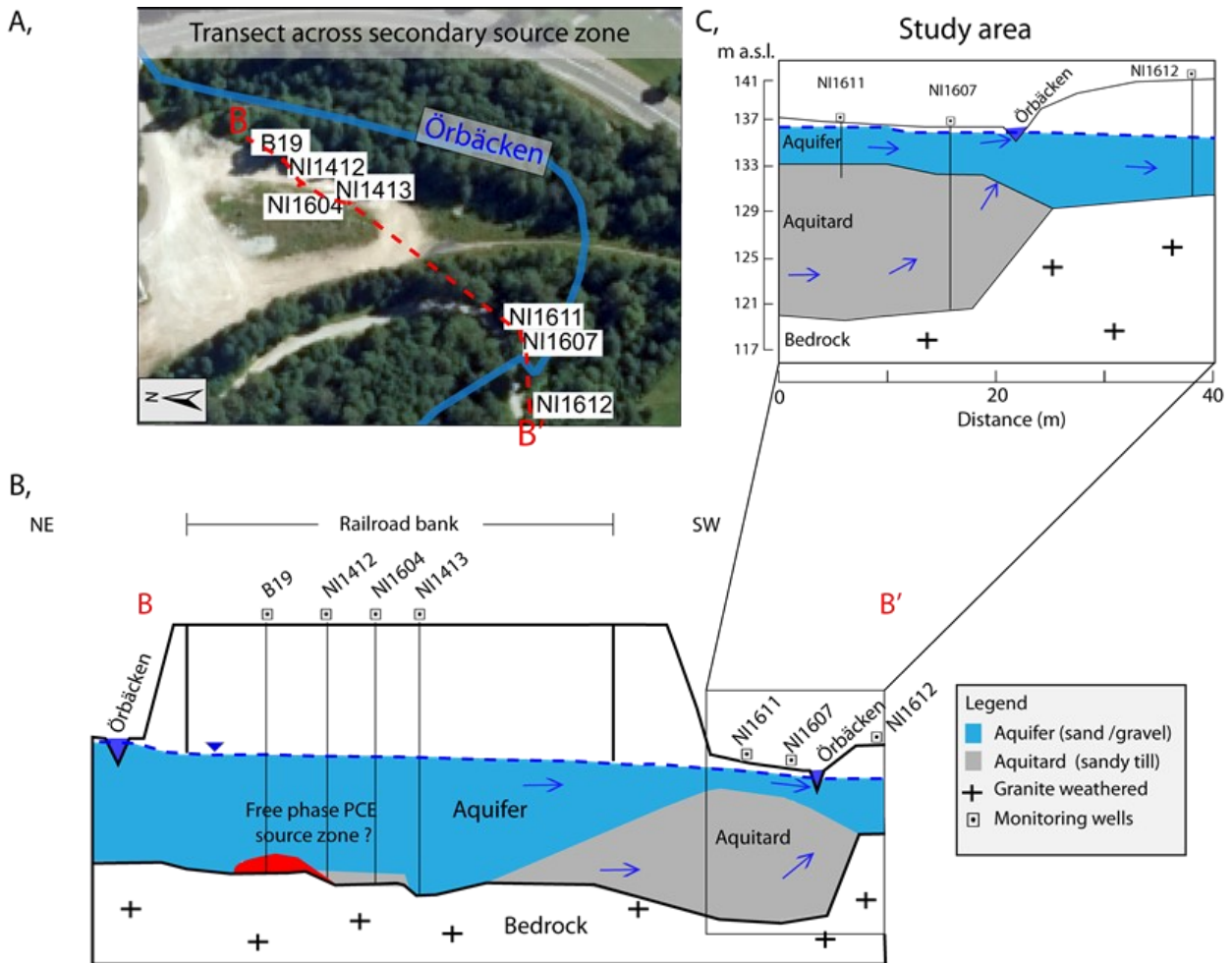


Figure 6. (A) Overview map of the transect line from B – B' across the railroad embankment down to the study area. (B) Transect with the secondary source zone located within the B19 area and a general groundwater direction towards SW in the aquifer and aquitard. Higher pore water pressure in the aquitard creates an upwards pressure to the aquifer within the study area. (C) Close-up section of the transect with the groundwater table close to ground surface and groundwater leaking into Örbäcken.

source zones (Chapman & Parker 2005). These dissolved PCE plumes follow the hydraulic gradient. Parker et al. (2004) observed that a large hydraulic gradient produces greater advection, which increases the rate of PCE migration (O'Hara et al. 2000, Parker et al. 2004). Even if the PCE source zones are remediated, back diffusion of PCE from a low permeability layer can feed a plume for many decades to centuries thereafter (Chapman & Parker 2005). Figure 7 shows a conceptual model for PCE migration in the subsurface.

#### 2.4.1 Dechlorinating microorganisms

It is evident from previous research that *in situ* bioremediation of chlorinated solvents by microorganisms is an emerging technology (Wiedemeier 1999, Das & Dash 2014). *In situ* reductive dechlorination is today regarded as the

most promising mechanism to biodegrade chloroethene contaminated sites (Löffler & Edwards 2006). Where PCE (tetrachloroethene) represents the primary contaminant, in sequence reductive dechlorination yields trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*DCE) and minor quantities of *trans*-1,2-dichloroethene (*trans*-DCE), vinyl chloride (VC) and finally the non-toxic end product ethene, see Figure 8 (Lowe et al. 2002). The known microbes that can degrade chloroethenes are anaerobes of a phylogenetically diverse origin and include *Dehalococcoides ethenogenes* (strains; 195, BAV1, FL2, VS, CBDB1, KB-1/VC, GT), *Dehalobacter restrictus*, *Dehalospirillum multivorans* and *Desulfuromonas* sp. See Lowe et al. (2002), He et al. (2003), Duhamel et al. (2004), Ritalahti & Löffler (2004), He et al. (2005), Löffler & Edwards (2006), Sung et al.

Table 1. Chemical properties for some common chlorinated ethenes. Note that guideline values are given in µg/L.

Compound	Molecular weight <sup>a</sup>	Density <sup>b</sup> (g/mL)	Aqueous Solubility <sup>a</sup> (mg/L)	Guideline values (SLV) <sup>c</sup> (µg/L)	Guideline values (MCL) <sup>d</sup> (µg/L)
PCE	165.83	1.625	200	10*	5
TCE	131.39	1.462	1100	10*	5
cis-DCE	96.94	1.248	3500	–	70
trans-DCE	96.94	1.257	6300	–	100
1,1-DCE	96.94	1.214	2450	–	7
VC	62.49	–	6754	0.5	2
Ethene	28.05	–	90910	–	–

<sup>a</sup> Data from Yalkowsky et al. (2016).

<sup>b</sup> Data from Huling & Weaver (1991).

<sup>c</sup> Guideline values for drinking water (SLV 2001:30).\* In total summarized value (PCE+TCE).

<sup>d</sup> Maximum contamination level allowed in drinking water from US EPA (2009).

(2006). The microbial communities can perform different steps of the degradation where one population might just degrade PCE to TCE, while another community is able to degrade PCE to *cis*DCE. But detection of any or several of these microbes at a chloroethene contaminated site, is important evidence that the site is applicable for *in situ* bioremediation (Lowe et al. 2002).

#### 2.4.2 Microbial use of chlorinated solvents

In aquifers, the processes promoting biological growth is microbial catalysed redox reactions,

which can occur in both aerobic and anaerobic environments (Wiedemeier 1999). The mechanism involves the microbial transfer of an electron between an electron donor and electron acceptor. The transfer releases energy and promotes microbial growth (McCarty 1996).

During biological oxidation both the electron donors and acceptors are considered as the primary growth substrate. Both are needed for growth to take place. In aerobic environments, oxygen is primarily used as the electron acceptor because it is the most energetically favoured re-

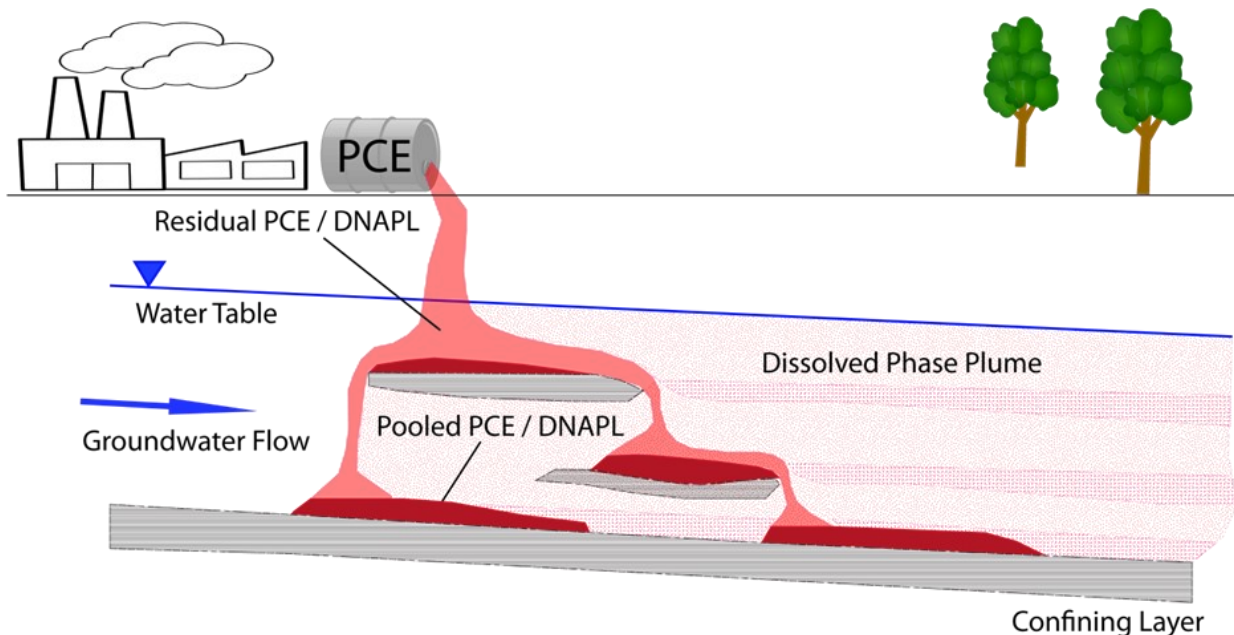


Figure 7. Conceptual DNAPL spill event, showing zones of residual DNAPL and pooled DNAPL not affected by groundwater flow. In addition, dissolved DNAPL plumes move in the groundwater direction. The figure is modified from Amos (2007).

dox reaction (Table 2). Therefore oxygen in a contaminated plume will rapidly deplete due to microbial respiration. This results in establishment of an anaerobic environment leading to a shift in microbial community and usage of alternative electron acceptors e.g. nitrate or PCE (Wiedemeier 1999).

Under anaerobic (reducing) conditions, microbes utilize an organic compound as an electron acceptor to promote biological growth. The biological reaction reductive dechlorination is a process called halorespiration. Wiedemeier (1999) suggest halorespiration to be the predominant process that governs natural biodegradation of chlorinated solvents (e.g. PCE, TCE, DCE and VC). Halorespiration requires an anaerobic environment as it uses the chlorinated solvent as an electron acceptor and transfers a hydrogen ion to an electron donor (Wiedemeier 1999). Two additional reactions of importance for degrading chlorinated solvents are fermentation and cometabolism.

Fermentation in the subsurface is a unique reaction, in the sense that it does not require an external electron acceptor, because the organic compound used acts both as the electron donor and acceptor (Wiedemeier 1999). Fermentation of glucose results in the production of hydrogen gas, carbon dioxide and acetate (Wiedemeier 1999). In anaerobic environment the hydrogen

gas ( $H_2$ ) is used as an electron donor for a wide range of microbial reactions which keep the concentration of hydrogen gas low, See Table 2.

Cometabolism is a process found in both aerobic and anaerobic environments where microbes do not receive any benefits (gain of energy) from the degradation of the compound. The contamination is instead (e.g. chlorinated solvents) degraded in the presence of an enzyme or cofactor, produced by the microbe for other purposes (Wiedemeier 1999).

Cometabolism occurs as a parallel process with redox reactions (Wiedemeier 1999). Cometabolism is a slow process and some authors even regarded it as an unimportant process during natural conditions (Wiedemeier 1999).

McCarty (1996) grouped the different reactions into the following classification system:

Use of organic compounds as a primary growth substrate:

- Growth promoting biological oxidation of the organic compound (e.g. petroleum hydrocarbons) used as an electron donor
- Growth promoting biological reduction of the organic compound (e.g. chlorinated solvents) used as an electron acceptor (halorespiration)
- Fermentation

Use of organic compounds without gaining ener-

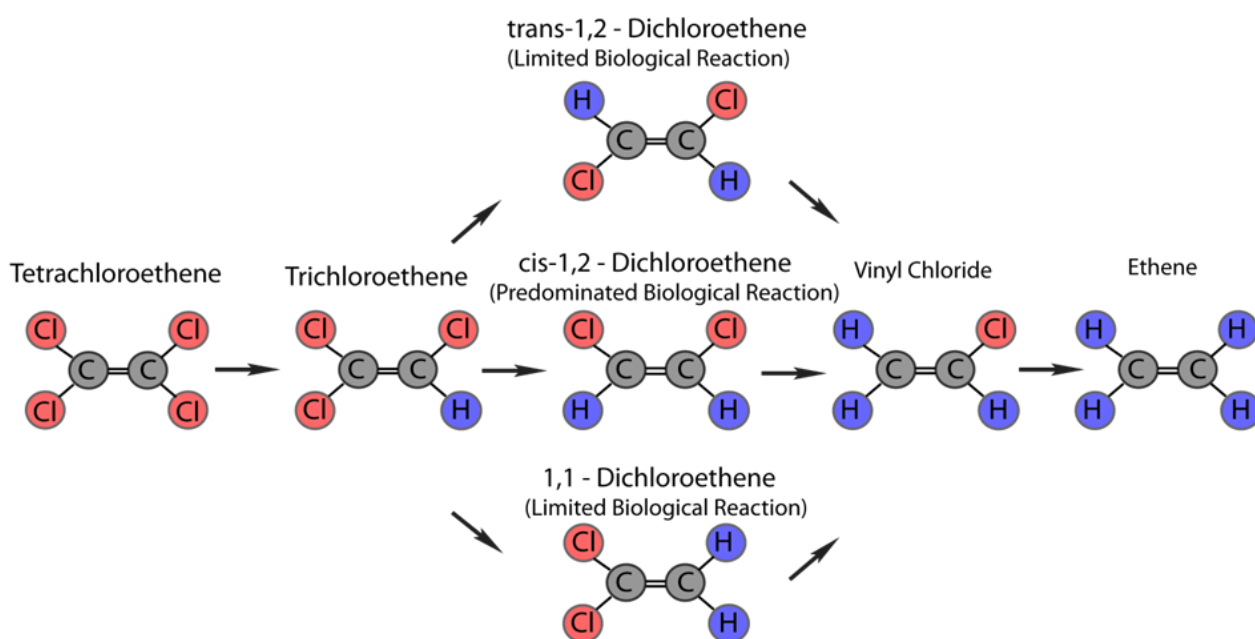


Figure 8. Degradation steps from tetrachloroethene (PCE) to ethene. As displayed, the trichloroethene (TCE) can degrade through multiply pathways, where the transformation via *cis*-1,2 Dichloroethene, is predominately the biological pathway. Figure modified from Wiedemeier (1999).



Table 2. The common redox reactions involved in transformation of chloroethenes using hydrogen as an electron donor. Data from Wiedemeier (1999).

Electron Acceptor	Reaction	$\Delta G^\circ_r$ (kcal/mol e <sup>-</sup> )
Oxygen	$\frac{1}{2}\text{O}_2 + \text{H}_2 \rightarrow \text{H}_2\text{O}$	-28.5
Nitrate	$\frac{2}{5}\text{NO}_3^- + \frac{2}{5}\text{H}^+ + \text{H}_2 \rightarrow \frac{1}{5}\text{N}_2 + \frac{6}{5}\text{H}_2\text{O}$	-27.0
Sulphate	$\frac{1}{4}\text{SO}_4^{2-} + \frac{3}{8}\text{H}^+ + \text{H}_2 \rightarrow \frac{1}{8}\text{H}_2\text{S} + \frac{1}{8}\text{HS}^- + \text{H}_2\text{O}$	-4.8
CO <sub>2</sub>	$\frac{1}{4}\text{CO}_2 + \text{H}_2 \rightarrow \frac{1}{4}\text{CH}_4 + \frac{1}{2}\text{H}_2\text{O}$	-4.1
Iron(III)	$2\text{Fe}^{3+} + \text{H}_2 \rightarrow 2\text{Fe}^{2+} + 2\text{H}^+$	-19.6
PCE	$\text{C}_2\text{Cl}_4 + \text{H}_2 \rightarrow \text{C}_2\text{HCl}_3 + \text{H}^+ + \text{Cl}^-$	-19.7
TCE	$\text{C}_2\text{HCl}_3 + \text{H}_2 \rightarrow \text{C}_2\text{H}_2\text{Cl}_2 + \text{H}^+ + \text{Cl}^-$	-19.4
DCE	$\text{C}_2\text{H}_2\text{Cl}_2 + \text{H}_2 \rightarrow \text{C}_2\text{H}_3\text{Cl} + \text{H}^+ + \text{Cl}^-$	-17.1
VC	$\text{C}_2\text{H}_3\text{Cl} + \text{H}_2 \rightarrow \text{C}_2\text{H}_4 + \text{H}^+ + \text{Cl}^-$	-18.7

gy:

- Cometabolism

## 2.5 Thermodynamics and energy release

Many biochemical reactions in the subsurface are governed by microbial growth and reproduction. During electron transfer, oxidation of an electron donor results in reduction of the electron acceptor (e.g. chlorinated solvents) and release of energy. The energy released in these oxidation-reduction reactions can be quantified with Gibbs free energy ( $\Delta G^\circ_r$ ) (Wiedemeier 1999).

Negative values of  $\Delta G^\circ_r$  indicate that the reaction is energy producing (exothermic) and will then proceed from left to right. Positive values mean that the reaction is energy consuming (endothermic) and requires energy to be put into the system for the reaction to proceed from left to right (Wiedemeier 1999), see Eq.1:

Microbes will not invest more energy than the amount of energy that can yield biological growth (Chapelle 1993). This means that reductive dechlorination of PCE will not take place before the aquifer (system) is depleted in oxygen, nitrogen and iron (III) because the energy yield from aerobic respiration, denitrification and iron reduction is higher than the energy yield from reductive dechlorination. The value of  $\Delta G^\circ_r$  (Table 2) can be used to estimate the amount of free energy either produced or consumed (Wiedemeier 1999).

Chapelle (1993) explained the coupled oxidation-reduction reaction from a thermodynamic stand point, where the oxidation-reduction reaction is expected to continue in order of the highest thermodynamical energy yield. Assume that the system has the microbial organisms capable of facilitating each reaction, then the reactions will continue and will be limited by the supply of electron donor and electron acceptors (Chapelle 1993). Stumm and Morgan (1996) draw a similar conclusion, where the reactions that yields the most energy tends to take place over reactions that yield less energy, if there is no limitations of electron acceptors or donors (Stumm & Morgan 1996).

### 2.5.1 Subsurface geochemical environment

The oxidation-reduction potential of the underground environment and the groundwater chemistry (dissolved organic carbon, major ions and pH) are the governing factors that play an essential role in determining if halo-respiration will occur at all (McCarty 1996). In groundwater, a certain amount of dissolved hydrogen is required as an electron donor for microbial reduction of chlorinated solvents (Wiedemeier 1999). Figure 9 shows possible and preferred ranges for various anaerobic reactions, where the available hydrogen concentration or are the factor that governs when the halo-respirators can start to compete with other reducers, methanogens and denitrifiers.

Wiedemeier (1999) further suggests that if sulphate is being consumed in a contaminated aquifer or if methane is produced, the environment would be suitable for reductive dechlorination and the halorespirators can receive enough energy

$$\Delta G_r^\circ = \sum \Delta G_{f, products}^\circ - \sum \Delta G_{f, reactants}^\circ \text{ (Eq.1)}$$

Where:

$\Delta G_r^\circ$  = Gibbs free energy of reaction at standard state

$\Delta G_{f, products}^\circ$  = Gibbs free energy of formation for products at standard state

$\Delta G_{f, reactants}^\circ$  = Gibbs free energy of formation for reactants at standard state

from the pollutant to compete with sulphate reducers and methanogens.

Wang et al. (1993) demonstrated that the critical redox potential (ORP) for methane formation ( $\text{CH}_4$ ) is in the range of -150 to -160 mV and can overlap with sulphate reduction. A decrease in the redox potential to -240 mV exponentially increases methane production (Wang et al. 1993). ORP values below -150 mV could then be used to indicate that the environment is suitable for methane production if hydrogen concentration is  $> 0.01 \mu\text{g/l}$  and carbon dioxide (electron acceptor) is available.

## 2.6 Direct Current Induced Polarization (DCIP) theory

### 2.6.1 Resistivity

Resistivity is defined as the ability of materials to oppose the flow of an electrical current, which is measured in the SI unit  $\Omega\text{m}$  (Reynolds 2011).

Electrical resistivity surveys have been used for many decades in hydrogeological and geotechnical investigations as well as in mining. In more recent time, they are also been implemented in environmental surveys, e.g. Manataki et al. (2014) and Sparrenbom et al. (2017).

Resistivity of the subsurface is measured by the injection of an electrical current, which causes a potential difference at the surface and is calculated from the maximum potential during the transmission of the current pulses (Loke 2001). A general sketch of a field setup is shown in Figure 10, where the two pairs of necessary

electrodes are shown. The A and B electrodes are used for current injections, while electrodes M and N are used for the potential measurement (Reynolds 2011).

The basic principle is that from the known transmitted current (I) and the measured voltage (U), the resistance (R) is calculated with Ohm's law (Eq. 2):

In an idealized case, the subsurface is homogeneous, and the current will flow through an uniformed conducting half sphere. Where the resistivity is determined by the four-electrode configuration would be the true resistivity ( $\rho$ ) (Nijland et al. 2010). In general, the subsurface is heteroge-

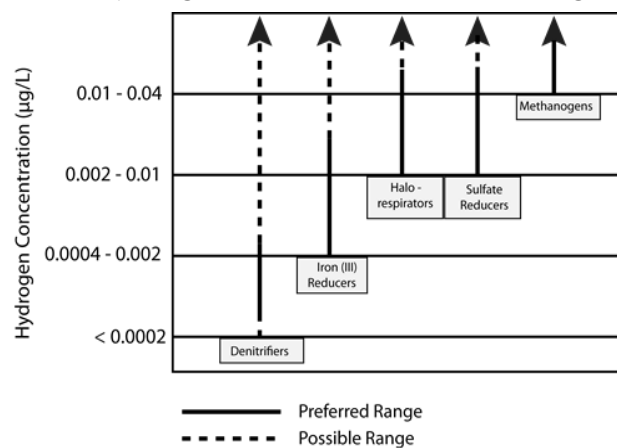


Figure 9. Preferred and possible hydrogen concentration ranges for several microbial activities. Figure modified from Wiedemeier (1999) with data from Lovley et al. (1994) and Chapelle et al. (1995).

neous and the measured resistivity is then the apparent resistivity ( $\rho_a$ ) and is calculated by (Eq. 3): Where K (m) is the geometric factor, which is dependent on the electrode array and spacing. The relationship between the "true" resistivity and the "apparent" resistivity is complex (Loke 2001). The method to determine the "true" resistivity from the "apparent" resistivity is called inversion.

The resistivity of the subsurface is strongly influenced by the occurrence of groundwater and its content of ions, which serve as an electrolyte (Nijland et al. 2010). This is especially important in porous sediments, where the mineral grains are less conductive than the groundwater (Nijland et al. 2010). Therefore, the resistivity of sediments decreases with increasing water saturation (Loke 2001).

Unconsolidated saturated sediments have in general a resistivity interval between 10 and

1000  $\Omega\text{m}$ , where the resistivity value is thought to be dependent on the porosity, the amount of dissolved ions and the clay content (Nijland et al. 2010). However, due to naturally occurring heterogeneities in the subsurface, the resistivity value itself can be misleading if used as a strict value. The resistivity value should rather be interpreted as continuous features, where zones of higher resistivity could reflect lower porosity and/or coarser sediments (e.g. gravel) and zones of lower resistivity could reflect high clay content and/or higher porosity or amount of dissolved ions. In summary, the measurement will reflect the physical parameters of underground conditions, so the interpretation of the model has to be reasonable from a geological perspective.

### 2.6.2 Inversion theory

Homogenous geological materials are very rare in reality, which makes a measured data become an apparent or pseudo data. Therefore, all measured data points together represent an apparent or pseudo model. Moreover, an inversion process is needed as this is an ill-posed and bad-conditioned mathematical problem (Tarantola 2005). Where the calculated response is a synthetic model containing the true values of depth, resistivity and chargeability, which is defined by a given set of model parameters (Loke 2001). So basically in all

$$R = \frac{U}{I} \quad (\text{Eq. 2})$$

inversion methods, we want to determine a model of the subsurface, the response of which correlates closely with the measured data (Loke 2001).

### 2.6.3 Time-domain Induced Polarization

Time-domain induced polarization (TDIP) is measured during off time between the injection of current pulses into the subsurface. Transmitted current pulses consist of cycles of square waveforms, with an alternating polarity (Figure 11

$$\rho_a = K \times \frac{U}{I} \quad (\text{Eq. 3})$$

(Johansson 2016)). Usually the measurements are repeated 2-4 times (stacks = n) to increase the accuracy of the measurement. Shown in Figure 11 with a red line, is the potential, which takes a certain time before reaching its maximum value,

similarly it also takes some time for the potential to drop back to zero during current transmission off time (Reynolds 2011, Johansson 2016).

The fundamental basis of TDIP is the electrical charge and discharge behaviour of the subsurface measured from the potential decline during the current transmission off time (Zonge et al. 1972). In Figure 12, a typical potential decay curve is displayed, which shows the immediate potential drop from primary potential ( $V_p$ ) to the secondary potential ( $V_s$ ), which appears when the current is interrupted.

The classical parameter measured in TDIP is called chargeability (Eq. 4), where the intrinsic chargeability ( $m_0$ ), was first defined by Seigel (1959) as the magnitude of the secondary potential ( $V_s$ ) over the primary potential ( $V_p$ ):

Due to practical problems measuring the secondary potential ( $V_s$ ) instantaneously after current disruption, chargeability has instead been calculated from the integration of the surface area beneath the decay curve (see Eq. 5 taken from Zonge et al. 1972) through pre-defined time windows where  $V_t$  is the potential reading at time (t):

In practice, this means that a TDIP measurement will be influenced by both the pre-defined time windows and time length of the current pulse and the current off time. This makes the comparison of integral chargeability values from different measurements strongly dependent on the measurement settings, apart from the material parameters itself. This means that if measurement settings are changed, e.g. the time length of the current pulse, the IP result from two measurements from the same line (location) will differ and cannot be compared (Johansson 2016).

### 2.6.4 Cause of IP effects

IP effects that arise in geological materials from the presence of an electric field, are results of the heterogeneity in the subsurface and can be explained from four different polarization mechanisms; electrode polarization, membrane polarization, electrochemical polarization and interfacial polarization (Marshall & Madden 1959, Johansson et al. 2015).

The varying mineral composition, grain size, microgeometry, groundwater chemistry etc., makes it difficult to understand how the polariza-

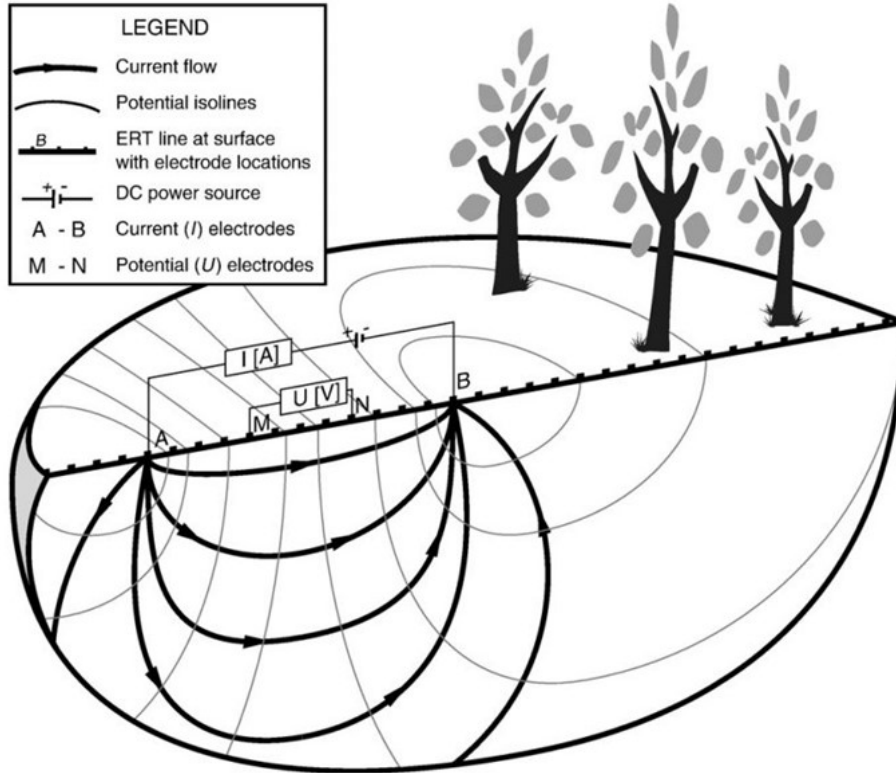


Figure 10. Conceptual sketch where an electrical field flows between two electrodes (A and B) used for current injections, while electrodes M and N are used for the potential measurement (Nijland et al. 2010). Courtesy of W. Nijland, Utrecht University.

tion mechanism works in a heterogeneous environment. The measured IP response is a result of several different polarization mechanisms occurring simultaneously in the subsurface (Lesmes & Frye 2001, Johansson 2016).

Electrode polarization is generally related to the occurrence of conductive minerals (metal, oxides or sulphides). When a conductive mineral grain is in connection with an electrolyte (e.g. water), the mineral surface becomes negatively

charged, which attracts a fixed layer of positive counter ions called the Stern layer. The ions within the Stern layer, can become either electrostatically or chemically attracted. Outside the Stern layer, a secondary diffuse layer will form due to electrostatically attracted ions and collectively, both layers are called, the electrical double layer (EDL) (Marshall & Madden 1959, Titov et al. 2002).

During the presence of an electric field, ions in an electrolyte move and accumulate at the surface of a conductive mineral. Since the electrons in the conductive mineral are redistributed due to the applied electric field, they forms a barrier for the direct ion transport (Johansson 2016). When the applied electrical field is turned off or reversed, the excessive ions will start to move back into the electrolyte, creating an IP effect (Titov et al. 2002, Johansson 2016). A conceptual sketch is shown in Figure 13.

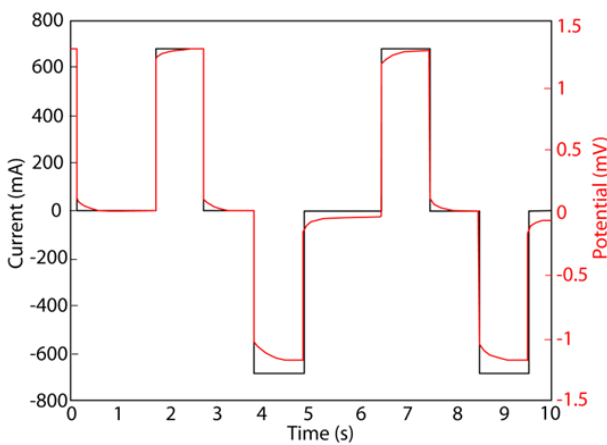


Figure 11. Current waveform (black) and potential decay (red) in TDIP measurements with 50% duty cycle (Johansson 2016). Courtesy of S. Johansson, Lund University.

$$m_0 = \frac{V_s}{V_p} \quad (\text{Eq. 4})$$

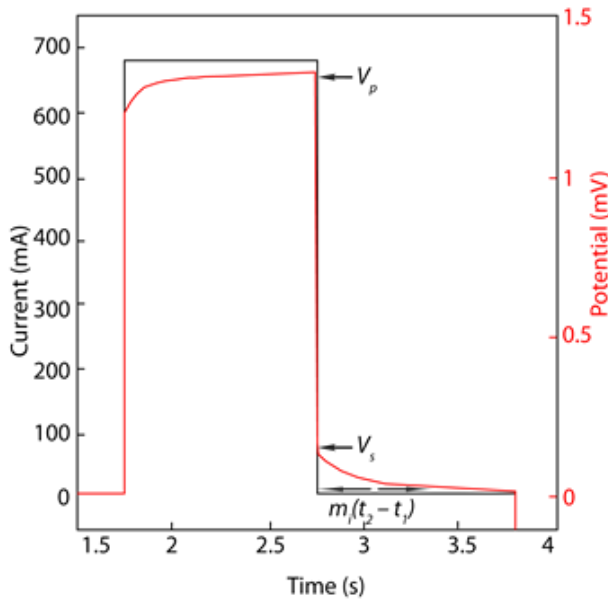


Figure 12. Black line represents the alternating current and the red line shows the potential charge and decay. Readings from the potential decay ( $V_p$  and  $V_s$ ) is used to calculate the integral chargeability (Johansson 2016). Courtesy of S. Johansson, Lund University..

Marshall and Madden (1959) formulated a theoretical model of IP response, called membrane polarization, in order to account for the background polarization which could not be explained by the EDL. In the model, sediments have series of ion selective (active) zones and nonselective (passive) zones. These zones have different concentrations of cations and anions and

$$m_i = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{V_t}{V_p} dt \quad (\text{Eq. 5})$$

transport capabilities. Ion selective zones are paths where cations can pass while anions are blocked (Titov et al. 2002, Johansson 2016). In the presence of an electrical field, a local concentration gradient will form in the pore throat, resulting in additional electrical current in the ion selective zones, while anions are blocked in front of the ion non-selective zone. In Figure 14, a conceptual sketch of the membrane polarization is shows a narrow (ion selective) pore throat and wider (non-selective) pore spaces. The membrane polarization has been proposed to explain the IP effect in clayey sediments, with narrow pore throat systems (Marshall & Madden 1959, Vinegar & Waxman 1984, Titov et al. 2002).

Electrical double layers can also form around isolating minerals like silicates (Johansson 2016). Under the influence of an electric field, ions in the EDL surrounding the grain will redistribute (Lima & Sharma 1992). Figure 15 shows a conceptual sketch of grain polarization.

### 2.6.5 Biogeophysics and groundwater flow

It is apparent from groundwater biogeochemistry studies, that microbial communities can influence both the chemical and physical properties of an aquifer due to metabolism and growth (e.g. Jones et al. 1985, Jones & Mulholland 1999, Dupin & McCarty 2000, Atekwana & Slater 2009). Atekwana and Slater (2009) call this discipline biogeophysics, which combines the fields of microbiology, biogeoscience and geophysics.

Biodegradation is one of few processes that can transform organic contaminants into non-toxic products. It is however difficult to demonstrate where degradation is taking place based on sampling concentrations alone, because monitored concentration changes can also be caused by physical processes, e.g. dilution and sorption (Hunkeler et al. 1999) as well as advection.

In recent studies it has been shown empirically, that microbial metabolism and growth can both impact the geochemical and physical properties of aquifers (Atekwana & Slater 2009, Williams et al. 2009). Microbial growth as biofilms, isolated colonies and/or aggregates, can cause clogging of pore space and alteration of mineral grains (Figure 16), leading to changes in the effective porosity, hydraulic conductivity and water chemistry (Brovelli et al. 2009). Microbial metabolism has been found to enhance weathering of mineral grains through the colonization and growth on the mineral surface (Bennet et al. 1996). Atekwana and Slater (2009) observed that the presence of a microbial colony/community enhanced mineral weathering and dissolution, which resulted in an increase of  $\text{Ca}^{2+}$  concentrations, leading to a decrease in electrical resistivity (Atekwana et al. 2004). Enhanced mineral dissolution could impose changes of the surface geometry of the mineral grains as well, leading to a secondary porosity and increased hydraulic conductivity (Atekwana & Slater 2009).

Both porosity and hydraulic conductivity are fundamental hydrogeological properties, which if changed, can cause development of new preferential flow paths, depending upon the scale of pore clogging (Kildsgaard & Engesgaard

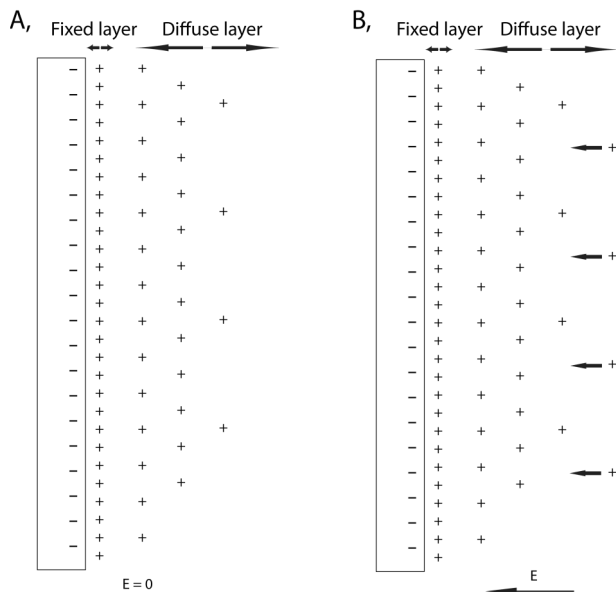


Figure 13. Conceptual sketch of the electrode polarization where (A) no electric field is present, (B) an electric field is present. As an electric field is applied, ions move and accumulate at the surface, and when the electric field is turned off, the excessive ions will move back creating an IP effect (Johansson 2016). Courtesy of S. Johansson, Lund University.

2002). A decrease in porosity due to clogging of pore spaces could increase the resistivity, if the aggregate clogging the pores causes a blockage.

Studies conducted by Markx et al. (1994) on microbes and their dielectric properties, show that microbes in general are conductive in themselves.

Brovelli et al. (2009) demonstrated that growth of biomass within pore spaces causes clogging and subsequently change the flow path.

Nutrients was injected into the pore water which promoted biomass growth, with the increasing amount of biomass it leads to a decrease in hydraulic conductivity until nutrients could no longer penetrate into the biomass zone (Brovelli et al. 2009). Due to lack of nutrients the biomass zone starts to decrease, causing an increase in hydraulic conductivity again (Kildsgaard & Engesgaard 2002, Brovelli et al. 2009).

### 3. Methodology

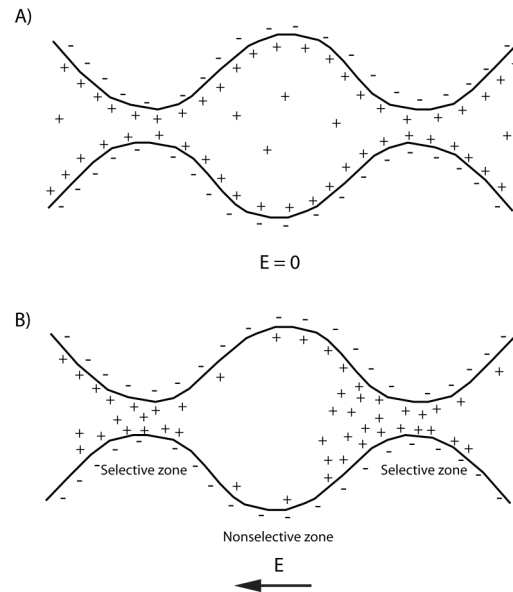


Figure 14. Conceptual sketch of the membrane polarization mechanism where (A) no electric field is present, (B) an electric field is present. In the presence of an electric field, ions accumulate in the narrow pore throats (selective zones) creating zones of ion surplus and ion deficiency within the pores (non-selective zone) (Johansson 2016). Courtesy of S. Johansson, Lund University.

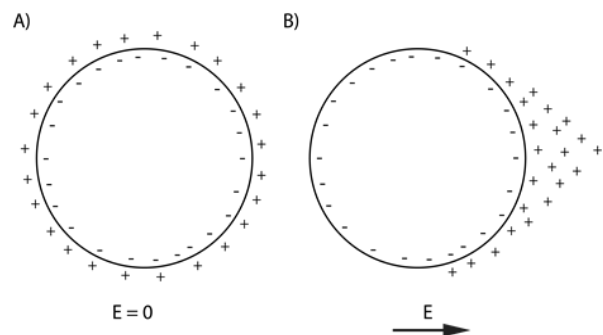


Figure 15. Conceptual sketch of the electrochemical polarization mechanism (A) no electric field present, (B) an electric field present. Under the presence of an electric field, ions around the EDL are displaced (Johansson 2016). Courtesy of S. Johansson, Lund University.

Scope of the survey and field campaign in the creek Örbäcken:

- Five lines of DCIP measurements, 20 m long with 0.5 m electrode spacing with a pole-dipole array.
- Nine groundwater samples by S. Åkesson, was analysed for field parameters (pH, oxygen-reduction potential, temperature,

electrical conductivity, total dissolved solids and barometric pressure) physical and chemical properties, anions, nutrients, metals, organic content and chloroethenes. Microbial and CSIA samples were also conducted but the results are not included in this thesis.

- One surface water sample (Örbäcken) taken by S. Åkesson, has been analysed for field parameters, physical and chemical properties, anions, nutrients, metals, organic content and chloroethenes.
- 10 seepage-meters were installed to measure recharge and/or discharge of groundwater in Örbäcken.
- 20 sediment samples from seven pits were analysed for chloroethenes adsorbed to sediments.

The field campaign was performed 19-27<sup>th</sup> of April 2017. The study area is located in a Örbäcken valley, approximately 300 meter southwest of the old dry cleaner where the secondary plume enters Örbäcken (Figure 1). A site photo is shown in Figure 17.

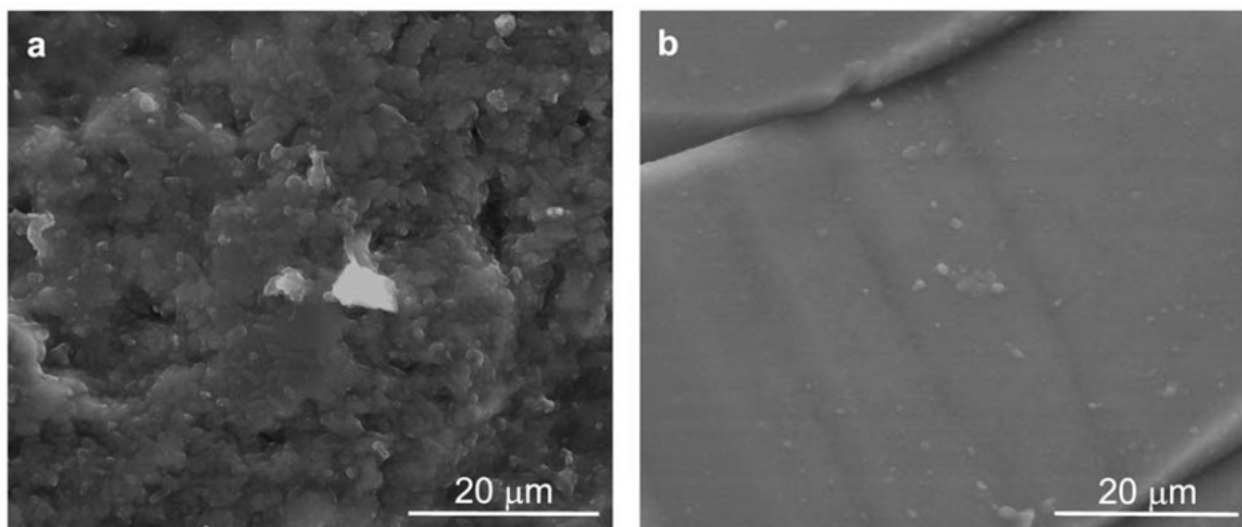


Figure 16. Environmental scanning electron microscope (ESEM) images from a growth experiment conducted on a sand grain, (a) cells of *P. aeruginosa* growing on a sand grain, versus (b) a control group on a sand grain (Atekwana and Slater 2009). Courtesy of C. Davis, University of Iowa.



Figure 17. Photo of the study area showing the location of monitoring wells and sediment pits. Red lines mark the positions of the DCIP lines. © Robin Jansson.



### 3.1 Groundwater sampling

Nine groundwater samples were collected, by Sofia Åkesson, – from different depths in nine existing filters in four monitoring wells; NI1607, NI1609, NI1610, NI1611, and one sample of surface water in Örbäcken. The samples were taken with an Eijkelkamp peristaltic pump (12 V). The samples were measured in the field with an Aquareader flowcell (AP-800 Aquaprobe®) and analysed in the laboratory by ALcontrol Laboratories. Parameters measured in the field were temperature, oxidation-reduction potential (ORP), pH, electrical conductivity (EC) and total dissolved solids (TDS). The collected groundwater and surface water samples were sent to the laboratory and were kept cold during transport. Prior to sampling, groundwater from each well was purged three times the well volume, or sampling was done when measured field parameters were stable.

#### 3.1.1 Seepage-meters

Ten seepage-meter (Figure 18A) were constructed after Lee (1977) to measure recharge and discharge of groundwater in Örbäcken. The construction is a plastic bucket (10 L) with a vent in the bottom connected to a plastic bag (2 L), filled with 0.5 L of water via a plastic pipe. A conceptual sketch is shown in Figure 18B. The seepage-meters installed in the streambed sediment, here by hand, and afterwards the plastic bag was filled with 0.5 L. After the installation the plastic tube and plastic bag were attached to the vent. The measurements started at 12:00 and continued to 8:00 the day after. The volume of water in the plastic bag was measured in the field using a standard graded kitchen jar. During the measure-

ment, two parallel lines (containing five seepage-meters each) with a 0.5 m spacing, were selected and installed in the first pool sequence. However, due to heterogeneities in the bottom sediments (large cobbles) the spacing of the seepage-meters had to be adjusted for practical reasons. The placement in Örbäcken is displayed in Figure 23. The aim was to re-install the seepage-meters twice, to create a map of discharge and recharge in the survey area. Unfortunately, the silicon seal between the vent and the plastic bucket broke after the first measurement which made re-installation impossible.

### 3.2 Sediment sampling

Seven sediment pits were dug by hand as deep as possible, and varying between 0.5 and 0.9 m. In total 20 sediment samples were collected. The samples were taken both in the unsaturated and saturated zone, or if there was a change in lithology e.g. grain size or colour shift. For each sediment pit, the lithology was documented and logs were made.

### 3.3 DCIP measurements

The DCIP survey was carried out with an ABEM Terrameter LS 2, a fully integrated data acquisition system for resistivity and IP measurements. The instrument is equipped with a constant current transmitter that delivers maximum 600V (GUIDELINEGEO, 2017). In this survey the special feature of switch polarity instantaneously without switching off the current was used, allowing a transmission of a full square waveform while recording data (Dahlin 2010).

The pole-dipole electrode configuration was used to acquire data with large penetration

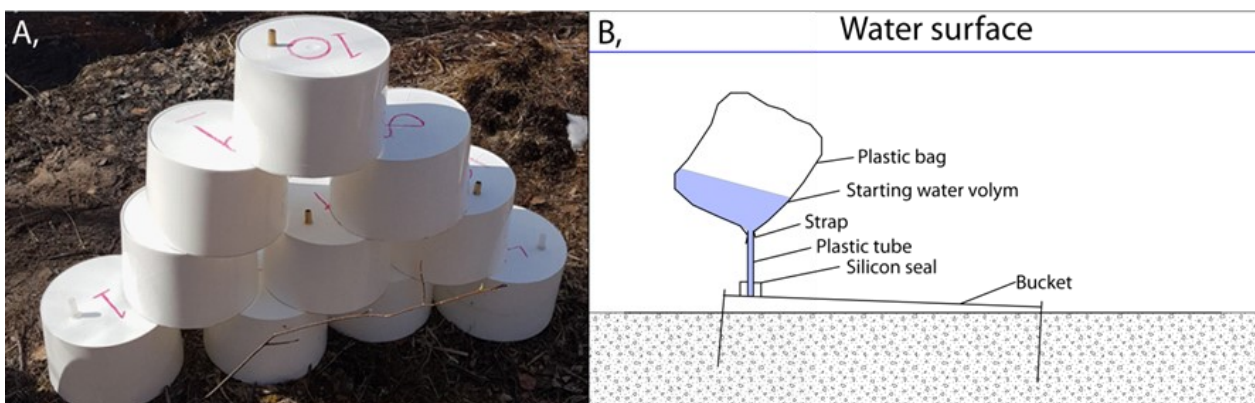


Figure 18. (A) Photo of seepage-meter without plastic bag (© Robin Jansson). (B) A conceptual sketch of an installed seepage meter in the streambed sediments Modified from Lee, (1977).

depth (6 m). Furthermore, two ABEM Imaging cables with 21 take-outs and 0.5 m spacing were used with a total of 41 electrodes for each line, to obtain a high spatial resolution of the near subsurface. The drawback using 0.5 m spacing is that the investigation depth is limited to about 6 m b.g.s.. The instrument was set to record data with a sample rate of 2 s and the measurement was stacked two times to acquire good quality data. The measurement was performed with 100% duty cycle (Olsson et al. 2015). A single cable was used for both current injection and potential measurement electrode layout, as shown in Figure 19. Prior to the measurement a “Focus One” electrode contact test was conducted before data collection for each line in order to verify a low contact resistance between the electrodes and the ground.

A Global Navigation Satellite System (GNSS) was used for collection of each electrode position and the elevation above sea level with high accuracy.

### 3.3.1 Data processing

Prior to inversions in with the Aarhus inversion code: Constant Phase Angle, all decay curves were processed in the software package Aarhus Workbench (v. 5.5.0.0), which enables processing and removing single IP gates while keeping the remaining part of the decay curves. Bad IP gates normally occur during early arrival times, which could be due to electromagnetical effects. In Figure 20, an example shows a processing step, where early arrival times with a repeated charge and discharge behaviour for individual curves have been filtered. Negative IP data (continuous charge during measurement, shown in red in Figure 20), have in general not been regarded as bad data quality as negative IP decays can occur due to geometrical distribution of chargeable bodies

in zones of negative sensitivity (Dahlin & Loke 2015).

The inversion were than performed with the constant phase angle model (Johansson et al. 2015). All DCIP models have been inverted using L2 norm with medium constraints in the lateral direction (STD: 1.3) and vertical directions (STD: 2). Auken et al. (2005) proposed that constraint values between 1.1 and 1.3 are good starting options. A constrain value of 1.1 means that model parameters are allowed to vary 10% between neighbouring cells (Auken et al. 2005).

The software package GeoScene3D (v. 10.0.13.552) provides an integrated 3D environment which can combine GIS maps with different types of geological and geophysical data e.g. DCIP models, borehole logs and chemical data in one space. In GeoScene3D the interpretation becomes more visual and it is easier to interpret and find continuous features. The inverted DCIP models were exported from Aarhus Workbench using .GBD format to GeoScene3D. The lithological and chemical data (for well NI1607, NI1608, NI1609, NI1610 and NI1611) were digitized to a database (.csv format) and plotted in GeoScene3D together.

## 4. Results

### 4.1 Groundwater chemistry

The groundwater chemistry sampling performed by Sofia Åkesson and team is with her permission, published in this thesis. The results from the groundwater analyses and measured field parameters are summarised in Table 3, where bold values are above the national guideline values (SLV 2001:30; USEPA 2009). The complete analysis protocols from the laboratory are attached in Appendix I. In Table 4 measurement results of hy-

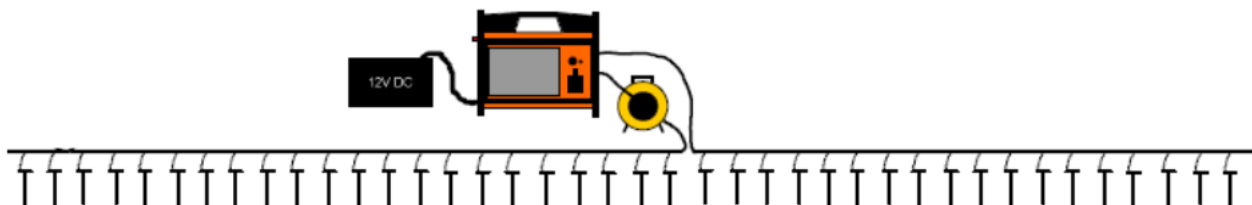


Figure 19. DCIP setup with 41 electrodes connected to the ABEM Terrameter LS2 with an external battery source. Modified from Dahlin (2010).

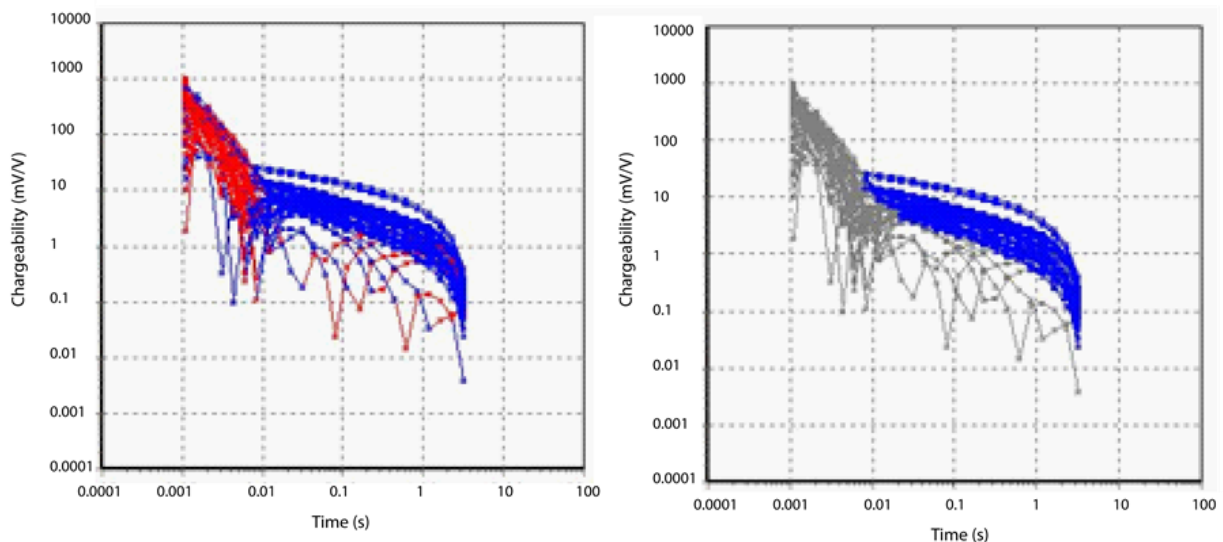


Figure 20. To the left, unprocessed IP decay curves are shown, where negative IP data are marked with red. To the right, IP curves have been processed and IP decay curves with early arrival times have been removed (grey colour). Also IP decay curves that show a charge, discharge and/or charge behaviour have been removed (grey colour). Only the blue IP decay curves to the right were used in the inversion.

draulic head in aquifer and aquitard are presented with groundwater temperatures.

PCE, TCE and DCE have been detected in all wells and the most common DCE isomer detected was *cis*DCE. This indicates primarily degradation via the predominant biological degradation pathway for TCE (Wiedemeier 1999). In two well filters located in the top of the aquitard (NI1607:2, NI1609:2, see Figure 21 or 22 for locations), vinyl chloride was detected, as well as high concentrations of *cis*DCE. As vinyl chloride easily vaporizes, the values are rather an indication of its existence, and the concentration should be considered as a minimum amount of vinyl chloride present in the aquitard.

PCE concentrations are higher in the aquifer compared to the aquitard and concentrations vary between 4000 and 11 000  $\mu\text{g/L}$ . These concentrations are much higher than the national guideline values for drinking water (SLV 2001:30). In the aquitard, the PCE concentration is still very high (29–2300  $\mu\text{g/L}$ ), but notably lower than for the aquifer. Instead, we find higher concentrations of the metabolites TCE and *cis*DCE in the aquitard. This result might indicate that the environment in the aquitard is more suitable for reductive dechlorination as described by Wiedemeier (1999) and that it is an ongoing process there.

In Figure 21 and 22 the monitoring wells (NI1607, NI1609, NI1610 and NI1611) are displayed as transects, about 15 m in length, with

selected chemical data.

About 1 m b. g. s., filter NI1607:1 (located in the aquifer) was the only filter displaying a positive oxidation reduction potential (ORP) value at 45 mV and thereby indicates aerobic conditions. In filter NI1610:1 and NI1609:1 located just 0.5 m below NI1607:1, reducing conditions were detected (ORP values -75.5–-82.8 mV).

Nitrate was detected in shallow filters in NI1607:1, NI1609:1, NI1610:1 and NI1611 (Figure 21 and 22), while the concentration is under the detection limit for the remaining sampled filters. Ammonium was also detected in filters (NI1607:1, NI1609:1, NI1610:1 and NI1611) but at concentrations 10–20 times lower. Interesting is NI1610:1 (Figure 21), where the nitrate concentration is about threefold lower compared to NI1607:1 and NI1609:1. This result could indicate that denitrification (combustion of nitrate) occurs in filter NI1610:1, while nitrification occurs in NI1607:1 and NI1609:1. Furthermore, in filters NI1607:2 and NI1609:2 all nutrients (nitrate, nitrite and ammonia) were below detection limit. The high *cis*DCE:PCE ratio makes these filters (NI1607:2 and NI1609:2) stand out, but NI1607:2 holds a relative high chloride concentration, which is not found in NI1609:2. Instead NI1609:2 shows elevated calcium concentrations, while the iron concentration is found to be about ten times greater than in NI1607:2.

In filters NI1607:3 and NI1609:3 located near the bedrock–aquitard interface about 15 m

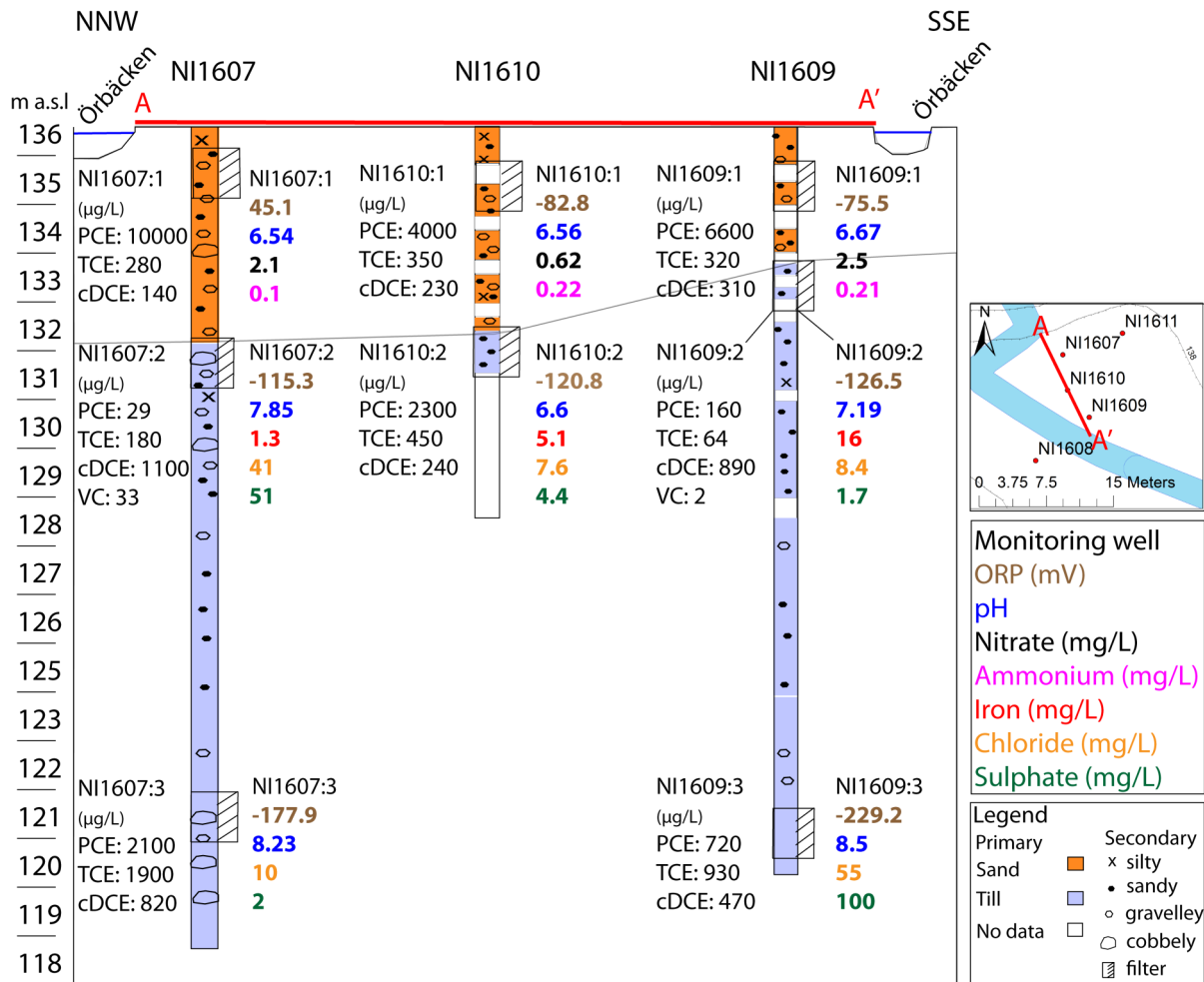


Figure 21. A–A' displays the orientation of the transect in the overview map. Drill cores NI1607, NI1610 and NI1609 are presented with chemical concentrations of PCE, TCE, *cis*DCE, VC (if detected) for each filter and ORP, pH, nitrate, ammonium, iron, chloride and sulphate in colours. All samples and measurements are from April 2017.

b.g.s. the result shows that the environment is strongly reducing with ORP values around -200 mV, which exceed the critical ORP (-150 mV) for methane formation (Wang et al. 1993). However NI1609:3 shows lower concentrations of PCE, TCE and *cis*DCE, but an accumulation of chloride and sulphate compared to NI1607:3. As NI1609:3 holds higher concentration of TCE than PCE while the chloride concentration is relatively high, it might indicate that degradation of PCE occurs close by.

In Figure 22 NI1611 displays the highest PCE concentration found in the study area with weak reducing condition (-5.7 mV) and a pH of 6.5. As the exact depth of the NI1611 filter is uncertain and the chemical data (ORP, pH and chloroethene concentrations) are similar to NI1607:1, it might propose that the filter is located in the aquifer rather than the aquitard.

The result also shows that dissolved organic content (DOC, see Table 3) in the aquifer (3.5-5.6 mg/L) and the top of the aquitard (4.1-5.8 mg/L) differ more between monitoring wells than with depth.

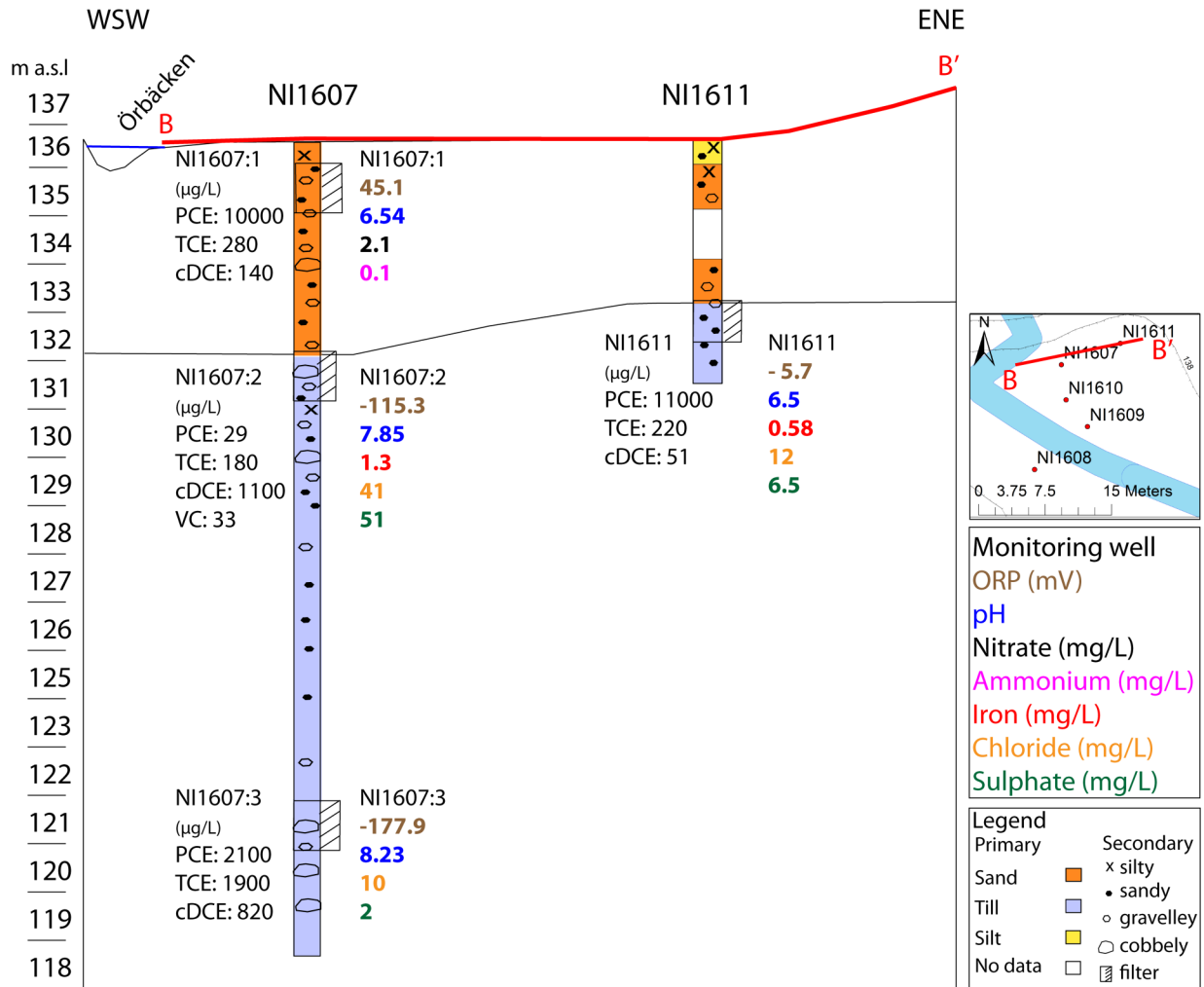


Figure 22. B – B' displays the orientation of the transect in the overview map. Drill cores NI1611 and NI1607 are presented with groundwater chemical concentrations PCE, TCE, cisDCE, VC (if detected) for each filter and ORP, pH, nitrate, ammonium, iron, chloride and sulphate in colours. All samples and measurements are from April 2017.

Table 3. Groundwater chemistry data divided into subgroups of field parameters, anions, nutrients, metals, organic content and chlorinated solvents and ratio. Bold values are above the guideline values (SLV 2001:30). The full chemical analyses are given in Appendix I. \*Uncertain filter depth. \*\*SLV 2001:30 combined together (PCE+TCE). \*\*\*US EPA 2009 guideline value.

Wells	NI1607:1	NI1607:2	NI1607:3	NI1609:1	NI1609:2	NI1609:3	NI1610:1	NI1610:2	NI1611	Örbäcken	Guideline values
Filter depth (m b.g.s.)	0.61-1.61	3.99-4.99	14.43-15.43	1-2*	2.9-3.9	14.91-15.91	1.05-2.05	3.23-4.23	2.2-3.2*		
<b>Field parameters</b>											
Temperature (°C)	4	4.6	5.9	2.9	4.1	6.1	3.7	4.1	4.8	4	-
ORP (mV)	45.1	-115.3	-177.9	-75.5	-126.5	-229.2	-82.8	-120.8	-5.7	102.1	-
pH	6.54	7.85	8.23	6.67	7.19	8.5	6.56	6.6	6.5	7.53	10.5**
Electric Conductivity (µS/cm)	338	602	220	391	449	763	350	359	296	71	2500**
Total dissolved solids (mg/L)	219	391	143	254	291	495	227	233	192	46	-
<b>Anions</b>											
Chloride, Cl (mg/L)	15	41	10	9.5	8.4	55	8.5	7.6	12	4.7	100**
Sulphate, SO4 (mg/L)	8.5	51	2	7.9	1.7	<b>100</b>	5	4.4	6.5	3	100**
<b>Nutrients</b>											
Nitrate, NO3 (mg/L)	2.1	<0.3	<1.1	2.5	<0.3	<0.3	0.62	<0.3	1.3	1.2	20**
Nitrate nitrogen, NO3-N (mg/L)	0.47	0.04	<0.25	0.56	<0.01	<0.01	0.14	<0.01	0.29	0.26	-
Nitrite nitrogen, NO2-N (mg/L)	<0.045	<0.001	<0.001	<0.045	<0.001	<0.001	0.0081	<0.001	0.012	<0.001	-
Ammonium, NH4 (mg/L)	0.1	0.17	<0.02	0.21	<0.02	0.28	0.22	0.28	0.12	0.13	0.5**
<b>Metals</b>											
Iron, Fe (mg/L)	1.6	1.3	5.6	5.9	16	1.8	3.2	5.1	2.3	1.1	30**

Manganese, Mn	(mg/L)	0.39	0.72	0.38	0.44	1.6	0.25	0.46	0.57	0.44	0.02	30**
Calcium, Ca	(mg/L)	22	20	16	31	35	28	28	30	21	3.7	
Sodium, Na	(mg/L)	11	57	7.8	10	8.8	87	7	6.9	8.2	3.8	100**
<b>Organic content</b>												
DOC	(mg/L)	3.5	4.1	2.7	4.4	4.5	1.6	5.6	5.8	4.1	13	-
TOC	(mg/L)	3.7	4.2	3	5.1	6.6	1.8	5.8	6	4.1	13	-
<b>Chloroethenes</b>												
Tetrachloroethene, PCE	(µg/L)	10000	29	2100	6600	160	720	4000	2300	11000	3.2	10**
Trichloroethene, TCE	(µg/L)	280	180	1900	320	64	930	350	450	220	0.35	10**
cis-1,2-dichloroethene, cisDCE	(µg/L)	140	1100	820	310	890	470	230	240	51	0.73	70***
trans-1,2-dichloroethene, transDCE	(µg/L)	<10	<5	<5	<10	2.1	2.8	<5	<5	<10	<0.1	100***
Vinyl Chloride, VC	(µg/L)	<20	33	<10	<20	2	<2	<10	<10	<20	<0.2	0.5**
<b>Ratio</b>												
TCE:PCE		0.03	6.21	0.9	0.05	0.4	1.29	0.09	0.2	0.02	0.11	-
cisDCE:PCE		0.0114	37.9	0.4	0.05	5.6	0.65	0.06	0.1	0.005	0.23	-

#### 4.1.1 Hydraulic head

The measurement of hydraulic head was performed by S. Åkesson. The results are presented in Table 4 and shows that the groundwater surface is located very close to the ground surface (0.09-0.53 m). The date of measurement differs by one week between first and last measurement, so fluctuations in hydraulic head are expected between NI1607, NI1609 and NI1610 as this reflects the amount of precipitation during the first week of the field campaign. The result shows that the hydraulic head in the aquitard is located 0.09-0.12 m above the hydraulic head in the aquifer. NI1609:1 shows a 1°C lower temperature than NI1607:1 and NI1610:1, while NI1609:1 is located about 1 m from the riffle bedform (Figure 23) this result might indicate recharge of surface water into the floodplain.

#### 4.1.2 Seepage-meters

Results from seepage-meters are presented in Table 5 and visualized in Figure 23. The result for seepage-meter number 1 is excluded due to an installation error, which makes the measurement unreliable. All the nine measurements show an increased volume after measurement. The results indicate discharge of groundwater to Örbäcken at all measurement locations.

A simple calculation of PCE discharge to the first pool sequence during one year resulted in 2.05 kg. Numbers are given in Table 6. This assumes

that the average discharge (calculated to 0.035 L/h) in all nine seepage meters is continuous and representative for the discharge occurring during one year (365 days). If we assume that average PCE concentrations (6867 µg/L) from filters located in the aquifer (NI1607:1, NI1609:1 and NI1610:1) are representative for every L groundwater discharging to the first pool sequence, then the total amount of PCE discharging under one year to the first pool sequence would be 2.05 kg.

## 4.2 Sediment chemistry

### 4.2.1 Lithology

Lithology logs were drawn for all seven dug pits for which locations are shown in Figure 24. PCE,

Table 5. Result from 20 hours of seepages-meter measurements in Örbäcken.

Seepage meter	Time duration (h)	Volume before (mL)	Volume after (mL)	Discharge (mL)
2	20	500	1200	700
3	20	500	1400	900
4	20	500	1500	1000
5	20	500	1300	800
6	20	500	1250	750
7	20	500	1200	700
8	20	500	1100	600
9	20	500	1200	700
10	20	500	1300	800

Table 4. Measured hydraulic head and temperature in the aquifer and aquitard. Performed by S. Åkesson in April 2017.

Aquifer	Hydraulic head (m b.g.s.)	Hydraulic head (m a.s.l.)	Temperature (°C)	Date
NI1607:1	0.2	136.3	4	2017-04-25
NI1609:1	0.45	136.18	2.9	2017-04-20
NI1610:1	0.53	136.14	3.7	2017-04-19
<b>Aquitard</b>				
NI1607:2	0.15	136.35	4.6	2017-04-25
NI1607:3	0.09	136.41	5.9	2017-04-26
NI1609:2	0.3	136.33	4.1	2017-04-20
NI1609:3	0.23	136.4	6.1	2017-04-20
NI1610:2	0.44	136.23	4.1	2017-04-19



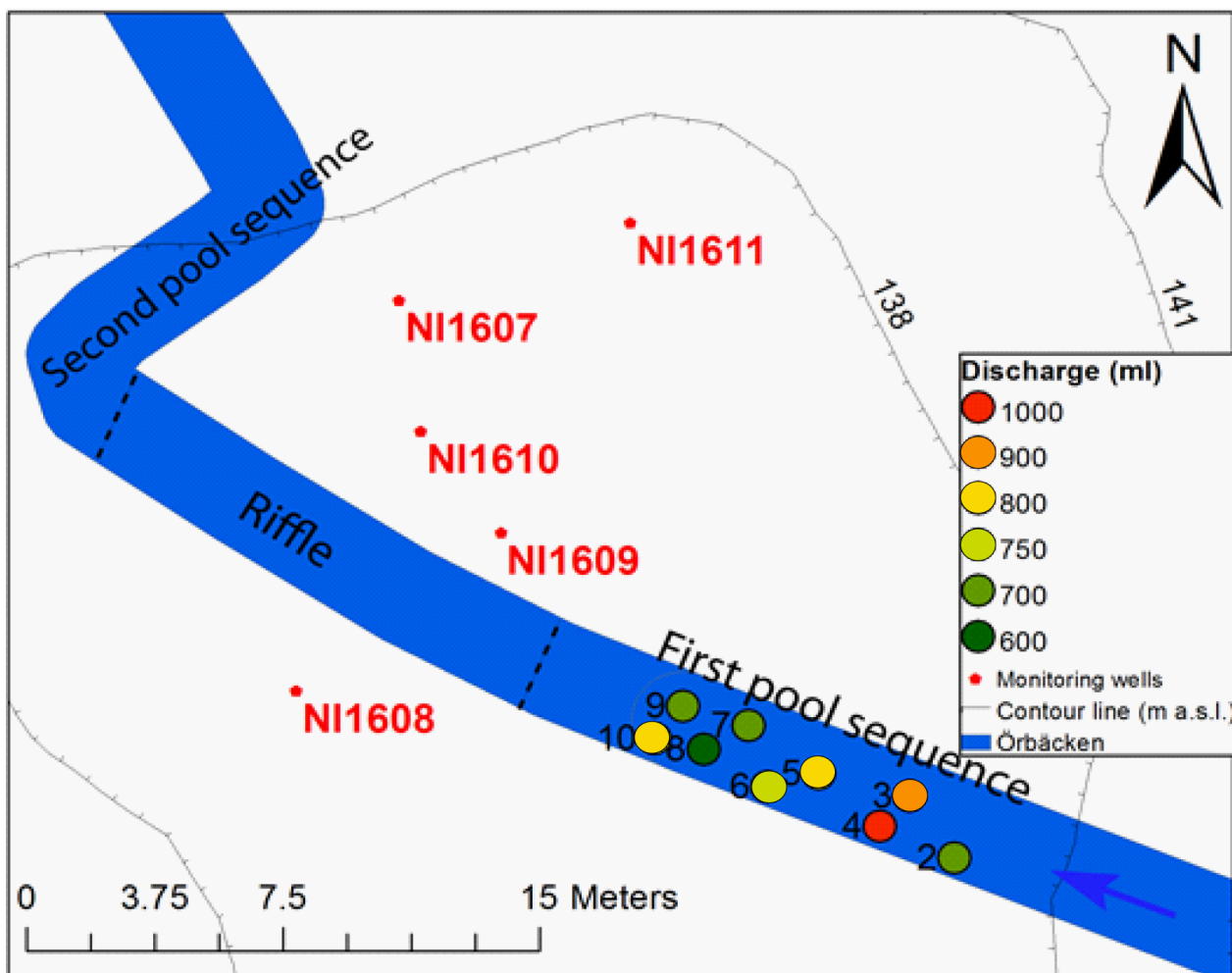


Figure 23. Location of seepage-meters in Örbäcken. Volume water discharged is displayed with different colours. Low discharge is displayed with green colour and red colour shows the highest discharge.

Table 6. Values used to calculate PCE discharge in the first pool sequence.

Seepage meter PCE discharge calculation	
Discharge (average)	0.035 L/h
Area (seepage meter)	0.041 m <sup>2</sup>
Area (first pool)	40 m <sup>2</sup>
PCE (average conc.)	6867 µg/L
Discharge (first pool)	34.1 L/h
Discharge (first pool)	299122 L/year
PCE discharge (first pool)	2.05·10 <sup>9</sup> µg/year
PCE discharge (first pool)	2.05 kg/year

TCE *cis*DCE and VC concentrations were visualized, and in Figure 25, and 26, the two pits with the highest concentrations of metabolites are shown, S2 and S5. Logs for pits S1, S3, S4, S6 and S7 can be found in Appendix II. The groundwater table was visually observed and in most of

the dug pits, it stabilized about 0.1 m above the bottom of each sediment pit.

In Figure 25, the lithology log S2 is shown together with results from the chemical analyses of pollutants. The groundwater table was observed to be located at 0.5 m b.g.s. The top soil contains root systems and organic matter with a transition into medium sand at 0.1 m b.g.s. The first sample was taken at 0.2 m depth in unsaturated sand. At 0.35 m b.g.s. the sand gradually becomes coarser containing some finer gravel as well. At 0.41 m b.g.s., the colour changes from rust red to black, which can be an indication of manganese oxidation (Snoeyink & Jenkins 1980). Sample (S2:45) was derived from a black layer containing low amounts of PCE and very low amounts of metabolites. The black layer was underlain by a distinct rusty coloured red layer (S2:50) containing PCE and all metabolites (TCE, *cis*DCE and VC). The rusty to red colour might

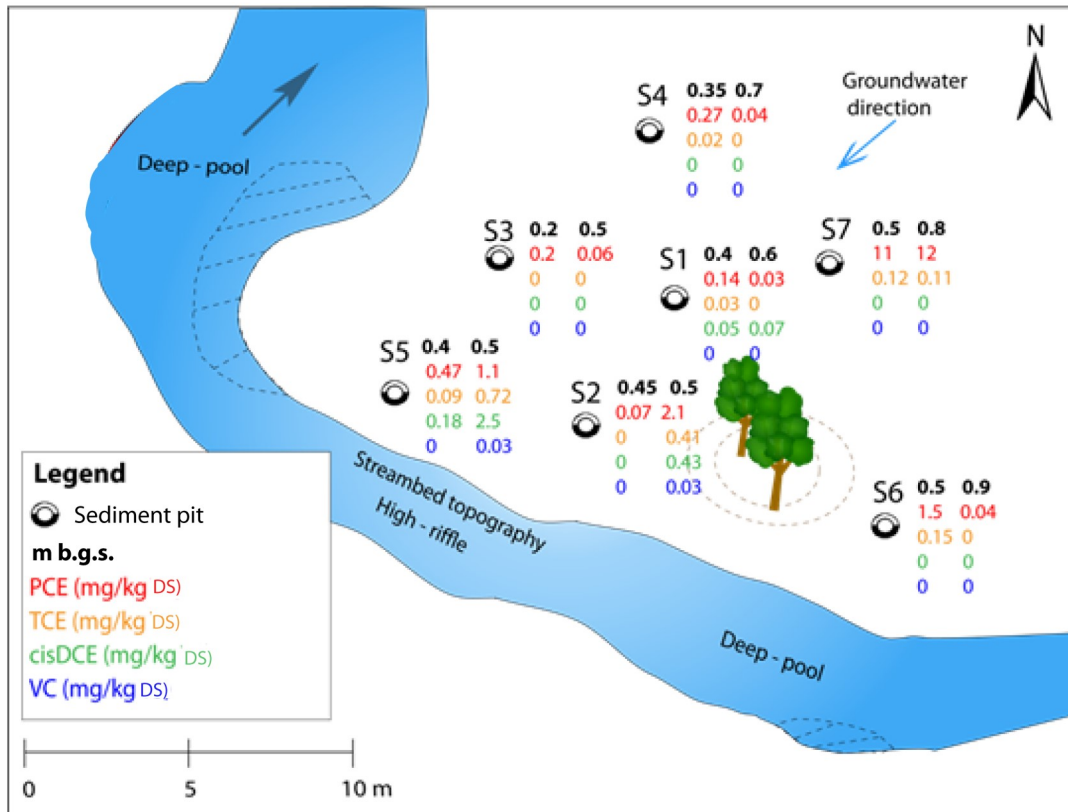


Figure 24. Sketch of the creek with locations of sediment samples displayed together with chloroethenes concentration at different elevations.

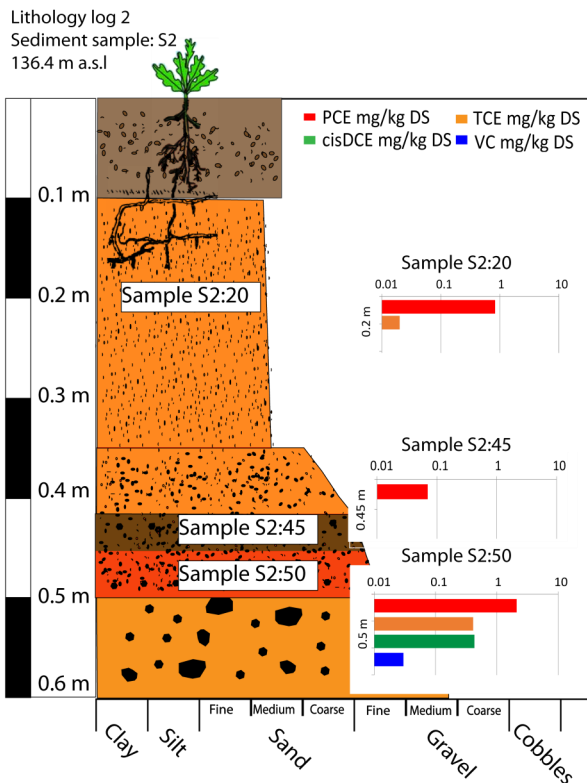


Figure 25. Lithology log and chemical data for chloroethenes for sediment pit S2.

indicate iron oxidation. At 0.5 m b.g.s. the sediment changes from coarse sand to gravel.

In Figure 26, the lithology of S5 is shown together with results from sediment chemical analyses of pollutants and observations of the groundwater table (observed at 0.4 m b.g.s). The top soil contains root system, and organic matter, which changes into a medium sand at 0.1 m b.g.s. The first sample was taken at 0.2 m depth in unsaturated sand. At 0.3 m b.g.s., the sand gradually becomes coarser and at 0.4 m b.g.s. it changes back to fine to medium sand. Within the coarser grain sections (sample at 0.35 m), PCE and metabolites show lower concentrations than observed within the fine sand layers above and below.

The results from the analysed sediment samples are summarised in Table 7. Bold values are above the general guideline values for contaminated sediment in the category less sensitive land use (MKM- *mindre känslig markanvändning*) measured in mg/kg DS (Dry Solid), which for PCE is 1.2, TCE 0.6 and *cisDCE* 0.06 MKM (Naturvårdsverket 2009). The name for each sample reflects the pit number and depth where it was collected; e.g. S2:45 is located in pit S2 at 0.45 m

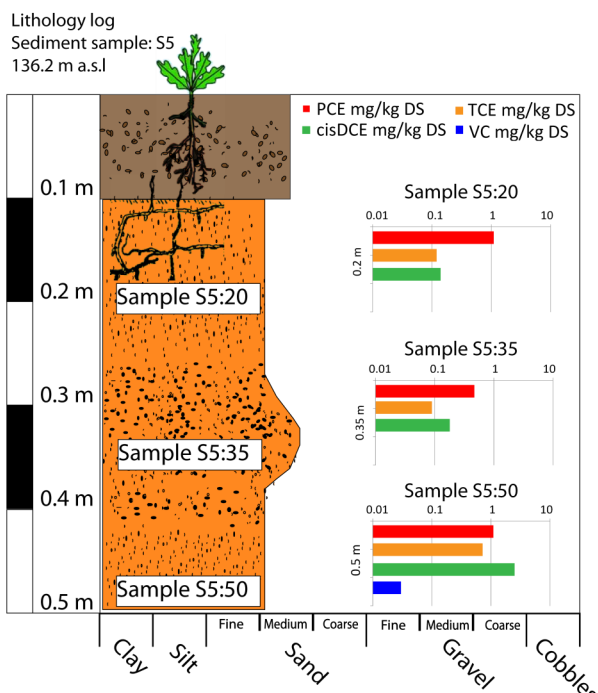


Figure 26. Lithology log and chemical data for chloroethenes for sediment pit S5.

b.g.s. The analysis protocols from the laboratory are attached in Appendix III.

PCE was detected in all analysed sediment

Table 7. Results from pollutant analyses within the sediment samples as well as MKM guideline values (less sensitive land use) (Naturvårdsverket 2009). Bold values are greater than guideline values for MKM.

		PCE	TCE	cisDCE	VC
General guideline value (MKM)	mg/kg DS	1.2	0.6	0.06	-
Soil sample	Sample depth (m)				
S1:20	0.2	0.07	0	0	0
S1:40	0.4	0.14	0.03	0.05	0
S1:60	0.6	0.03	0	<b>0.07</b>	0
S2:20	0.2	0.83	0.02	0	0
S2:45	0.45	0.07	0	0	0
S2:50	0.5	<b>2.1</b>	0.41	<b>0.43</b>	0.03
S3:20	0.2	0.2	0	0	0
S3:35	0.35	0.18	0	0	0
S3:50	0.5	0.06	0	0	0
S4:35	0.35	0.27	0.02	0	0
S4:50	0.5	0.01	0	0	0
S4:60	0.6	0.02	0	0	0
S4:70	0.7	0.04	0	0	0
S5:30	0.3	1.1	0.12	<b>0.14</b>	0
S5:40	0.4	0.47	0.09	<b>0.18</b>	0
S5:50	0.5	1.1	<b>0.72</b>	<b>2.5</b>	0.03
S6:50	0.5	<b>1.5</b>	0.15	0	0
S6:90	0.9	0.04	0	0	0
S7:50	0.5	<b>11</b>	0.12	0	0
S7:80	0.8	<b>12</b>	0.11	0	0

samples, with the highest levels of PCE (12 mg/kg DS) detected in S7 at 0.8 m b.g.s. located at the foot of the embankment. In total, four samples (S2:50, S6:50, S7:50 and S7:80) exceed the general Swedish guideline value for less sensitive land use with respect to PCE.

TCE found in ten out of twenty samples, concentrations are in general low with only S5:50 exceeding the general guideline value of 0.6 mg/kg for less sensitive land use. *cis*DCE was detected in six sediment samples out of twenty, with five samples (S1:60, S2:50, S5:30, S5:40 and S5:50) showing concentrations above the general guideline value of 0.06 mg/kg DS.

VC was detected in two sediment samples (S2:50 and S5:50), located close to the edge of the meandering bend. VC easily vaporizes, especially in an open sediment pit, so the detection is a clear indicator of dechlorination of *cis*DCE in the area.

#### 4.3 DCIP Inversion Results and Interpretation

Resistivity model results for lines 1, 2, 3, 4 and 5 are presented in Figures 28–32. IP model results show in general a very low or no IP response, therefore IP models are only presented for line 1, while IP model results for lines 2, 3, 4 and 5 have been placed in Appendix IV.

The inverted resistivity model results shown are unexpected, as the lithology is well known and from the previously defined geological models (Figure 21 and 22). The expected resistivity model result would be a two-layered model with a shift in resistivity where the sand unit (aquifer) changes to the till layer (aquitard). From the drill core information it would expect that the resistivity increases or decreases at the transition between the aquifer and the aquitard, which occurs between 2.5 and 4 m b.g.s. (Larsson et al. 2017). With the groundwater table located at 0.2–0.5 m b.g.s. (Table 3), it means that all sediments beneath 0.5 m are fully saturated, and high resistivity values close to the ground surface reflect the occurrence of unsaturated sediments. The resistivity in the till is highly dependent on the amount of fine-grained material (till type) and the degree of compaction. A silty till would be expected to have lower resistivity than a well-sorted sand, unless the electrical conductivity of the groundwater is high. Sandy and gravelly till will normally generate a resistivity response high-

er than a clean sand (personal communication with Torlief Dahlin, LTH, 2017-04-03).

The resistivity model results show a 800  $\Omega\text{m}$  boundary, which correlates quite well with the known transition depth between the aquifer-aquitard boundary throughout all five DCIP lines. The 800  $\Omega\text{m}$  boundary is a likely candidate to represent the boundary between the aquifer and the aquitard. Using such a boundary is a simplified approach and caution should be noted to this interpretation. The resistivity of the subsurface is influenced by multiple factors e.g. porosity, grain size or amount of dissolved ions (Nijland et al. 2010).

Furthermore, two anomalies have been detected ( $\gamma$ -,  $\beta$ - in Figs. 28-29 and 32-36) in the resistivity model results, both situated within the aquitard at depths between 2.5 and 6 m b.g.s. The  $\gamma$ -anomaly displays a very high-resistive zone of about 3000  $\Omega\text{m}$ , while the  $\beta$ -anomaly displays a relative low-resistive zone of about 500  $\Omega\text{m}$ . These anomalies could be artefacts from the numerical modelling in Aarhus Workbench, but it is not likely, as they are consistent throughout DCIP lines 1, 2 and 5 while the DC residual is low at 1.5–2 %.

Even if the till aquitard is heterogeneous in grain size, the geological reference data indicate some geological differences within the till layer, with more gravel and sand content adjacent to the  $\gamma$ -anomaly and more sand and silt content within the  $\beta$ -anomaly. It is possible that this variation in grain size in the till could affect the resistivity. Since the majority of the till is sandy, the till layer should generate a quite homogenous resistivity response. This type of response can be seen in line 3 (Figure 30).

As the  $\gamma$ -anomaly cannot be explained by the known geological differences or pore water conductivity, there are only three remaining reasonable interpretations available to explain the  $\gamma$ -anomaly increase in resistivity; (1) free-phase biogas in the pore space (2) internal erosion and loss of fine sediments, (3) the existence of a huge boulder (5–10 m in diameter). For the  $\beta$ -anomaly, two reasonable interpretations may explain the low-resistive zone; (1) a fracture zone in the glacial till, which would increase the porosity i.e. decrease the resistivity, (2) if the till holds a higher amount of fine sediments (silt, clay) compared to the  $\gamma$ -anomaly.

In figures 28–32, the dashed lines mark the boundary between aquifer and the aquitard, as extrapolated from the lithology data from boreholes NI1607, NI1609, NI1610 and NI1611 (Larsson et al. 2017). The DCIP outline is displayed in Figure 27, where 0 m marks the start of the line and corresponds to 0 m for each figure respectively. Geological reference data (borehole logs) are incorporated in the figures (28–32).

#### 4.3.1 DCIP Line 1

In Figure 28A, the result shows that the lithology data where the sand unit changes into till (dashed line), correlate with a resistivity boundary marked with a straight line. An exception is the  $\beta$ -anomaly between 8 and 10 m, which breaks the 800  $\Omega\text{m}$  boundary causing an tilted zone of low resistivity.

The pore water electrical conductivity in the  $\gamma$ -anomaly NI1607:2 is twofold higher (602  $\mu\text{S}/\text{cm}$  at 4.6°C) compared with NI1607:1 (338  $\mu\text{S}/\text{cm}$  at 4°C) and NI1611 (296  $\mu\text{S}/\text{cm}$  at 4.8°C), while the resistivity is about 3–5 times greater in the  $\gamma$ -anomaly next to NI1607:2. The results are unexpected as higher electric conductivity should decrease the resistivity in the zone. Furthermore, it is interesting to note the relatively low amount of PCE in the  $\gamma$ -anomaly while the *cis*DCE concentration is high.

In Figure 28B, the IP model results are presented, showing no obvious IP effects and is in the range between 1 and 3 mrad. It should also be noted, that the IP residual is high, where the

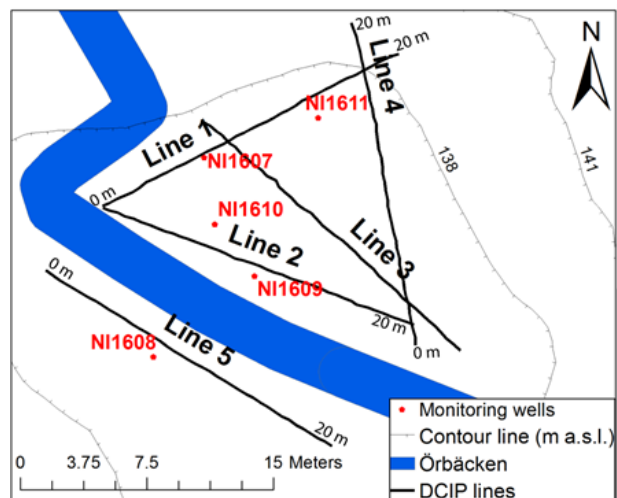


Figure 27. Overview map of the study area with monitoring wells and DCIP-lines, where 0 m corresponds to 0 m in the DCIP model result.

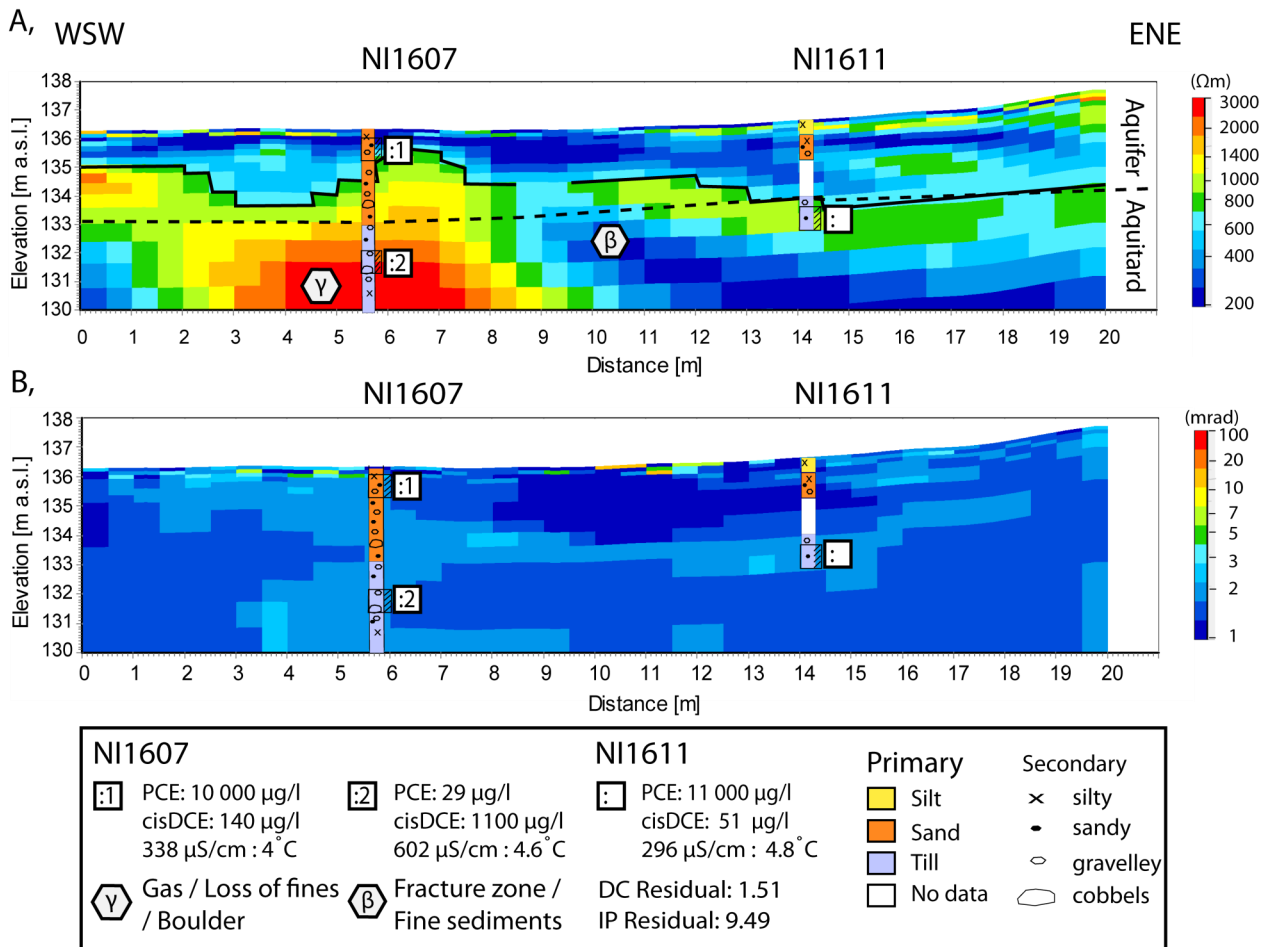


Figure 28. (A) Resistivity and (B) IP model results with borehole logs and chemical reference data for NI1607:1, NI1607:2 and NI1611 (PCE, *cis*DCE and electric conductivity in pore water). Polygons with  $\gamma$  sign mark the high resistivity anomalies and polygons with  $\beta$  sign mark low resistivity zones. The dashed line in (A) marks the aquifer-aquitard boundary extrapolated from drill cores NI1607 and NI1611, while the solid line marks the 800  $\Omega$ m resistivity boundary. (B) Shows no obvious IP effect.

measured data and the inverted model result differs by 9.49 %.

#### 4.3.2 DCIP Line 2

Line 2 is parallel to Örbäcken and is shown in Figure 29, where the resistivity model result shows that the two boundaries correlate well except in the  $\beta$ -anomaly. The  $\beta$ -anomaly (low-resistive feature) is geometrically connected and seen in DCIP line 1. Chemical reference data from the  $\beta$ -anomaly (NI1609:2) show high ratio of degradation products (*cis*DCE) compared to PCE and elevated electrical conductivity in the pore water. The  $\gamma$ -anomaly shown in Figure 29 is geometrically connected with the  $\gamma$ -anomaly in DCIP line 1. The chemical data from NI1610:2 (situated just in the outskirts of the  $\gamma$ -anomaly) show a relatively low electrical conductivity compared with NI1609:2 within the  $\beta$ -anomaly.

#### 4.3.3 DCIP Line 3

Line 3 is presented in Figure 30 and shows two distinct layers, but the 800  $\Omega$ m resistivity boundary does not correlate with the aquifer-aquitard boundary, which is located about 1–2 m below the 800  $\Omega$ m resistivity boundary. The section displays a resistivity interval between 800–1400  $\Omega$ m, a normal and expected value for the till, while resistivity values between 200 and 800  $\Omega$ m are representative for the sand unit.

#### 4.3.4 DCIP Line 4

Line 4 is presented in Figure 31 and stands almost perpendicular to the general groundwater direction. A low-resistive zone occurs at the distance 8–11 m at a depth down to 131 m a.s.l., which I propose could be due to deposition of postglacial sediments with lower compaction, in the form of an old palaeochannel from the meandering Örbäcken. At 0–2 m distance a high-resistivity

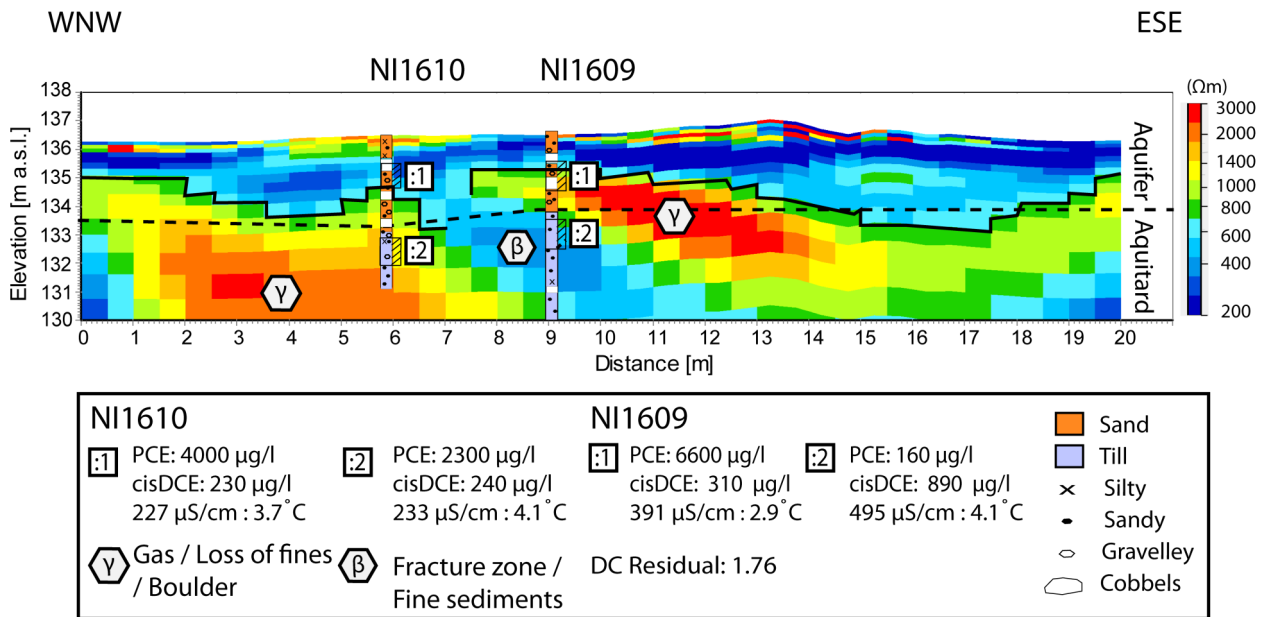


Figure 29. Resistivity model result for line 2 with borehole logs and chemical reference data for NI1609 and NI1610 (PCE, cisDCE and electric conductivity in pore water). (A) The dashed line marks the aquifer–aquitard boundary extrapolated from drill cores NI1609 and NI1610, while the solid line marks the 800 Ωm resistivity boundary.

feature occurs (135–133 m a.s.l.) which has abnormally high resistivity (>3000 Ωm) and might be caused by an artefact in the inversion process.

#### 4.3.5 DCIP Line 5

Line 5 is parallel with line 2, but placed on the other side of Örbäcken (Figure 27). In Figure 32, the resistivity boundary of 800 Ωm and the aquifer–aquitard boundary according to drill log NI1608, correlate well except between 11 and 19

m where a low-resistivity zone occurs down to 132 m a.s.l.

#### 4.4 Geoscene3D Resistivity model

Geoscene3D models are presented in Figure 33–35. Geological reference data are incorporated in the model together with chemical data for Figures 34 and 35 (ratios between PCE and cisDCE, and electrical conductivity in the groundwater).

In the overview maps the orientation of the “camera angle” is displayed together with the DCIP lines marked with purple. The grid cells are

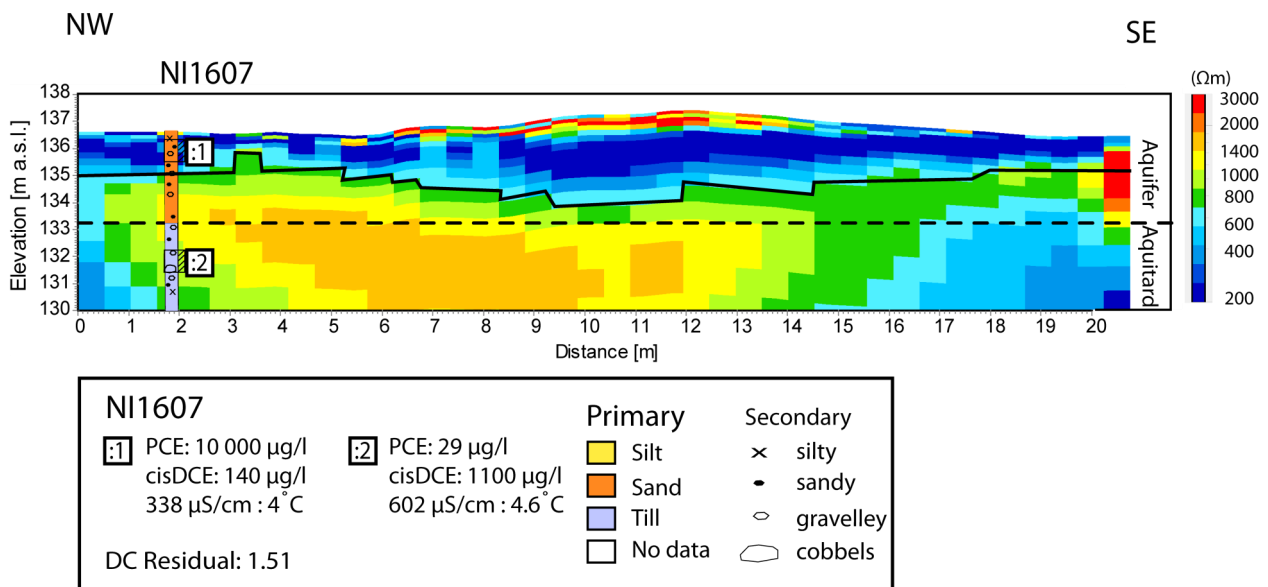


Figure 30. Resistivity model result for line 3 with borehole logs and chemical reference data for NI1607 (PCE, cisDCE and electric conductivity in pore water). The dashed line marks the aquifer–aquitard boundary extrapolated from drill cores NI1607, while the solid line marks the 800 Ωm resistivity boundary.

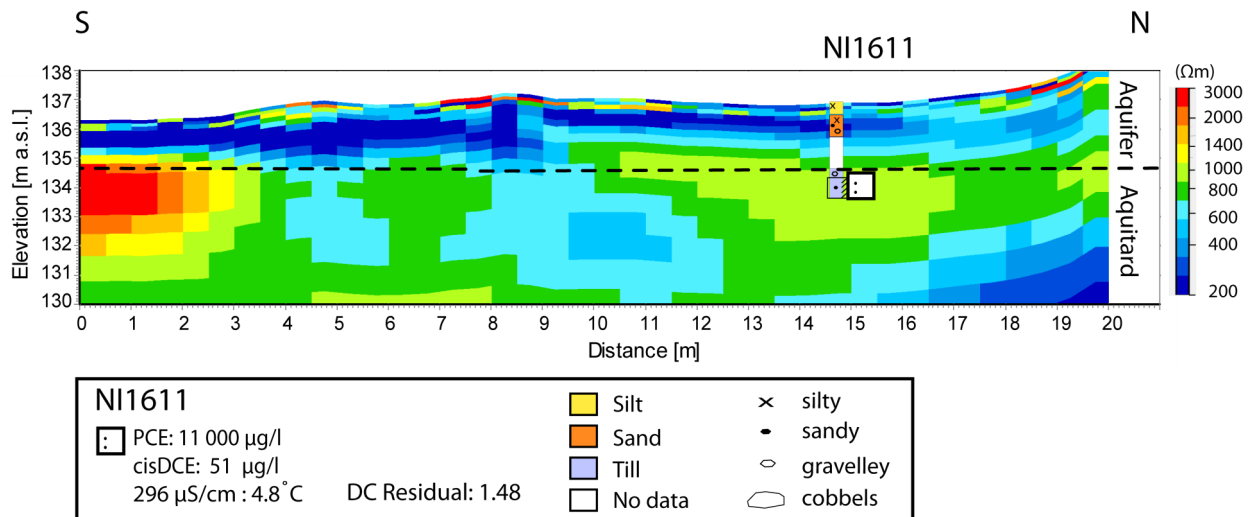


Figure 31. Resistivity model result with borehole logs for Line 4 and chemical reference data for NI1611 (PCE, cisDCE and electric conductivity in pore water). The dashed line marks the aquifer–aquitard boundary extrapolated from drill core NI1611.

1 x 1 m. Important to note is that the figures display the full resistivity model of 10 m depth, but below 130 m a.s.l. the data coverage is poor.

In Figure 33, the 3D model is displayed with geological reference data (lithology logs for NI1607, NI1608 and NI1609) and resistivity data for lines 1, 2 and 5, viewed from west towards the east. From the 3D visualization, it is clear that the  $\gamma$ -anomaly (marked with circles) found in lines 1, 2 and 5 is a geometrically connected and continuous feature.

In Figure 34, the 3D model is displayed with geological reference data from lithology logs NI1607 and NI1611 (Larsson et al. 2017), and resistivity data for lines 1, 2 and 5, viewed from the east. Furthermore, the cisDCE:PCE ratio ( $\alpha$ ) and elec-

trical conductivity ( $\sigma$ ) for monitoring wells NI1607:2 and NI1611 are displayed. The results show a clearly erosional surface interpreted as paleo channels (marked with red line at the transition between the gravelly sand and till unit). Furthermore, it show that the  $\beta$ -anomaly and the  $\gamma$ -anomaly occur in both line 1 and 2 and possibly also between them.

In Figure 35, the 3D model is displayed with geological reference data from lithology logs NI1607, NI1610 and NI1611 (Larsson et al. 2017), and resistivity data for lines 1 and 4 viewed from the southeast. The result shows a clear view of the erosional surfaces interpreted as old buried paleochannels. The  $\beta$ -anomaly appears to be continues between lines 1 and 4. The ero-

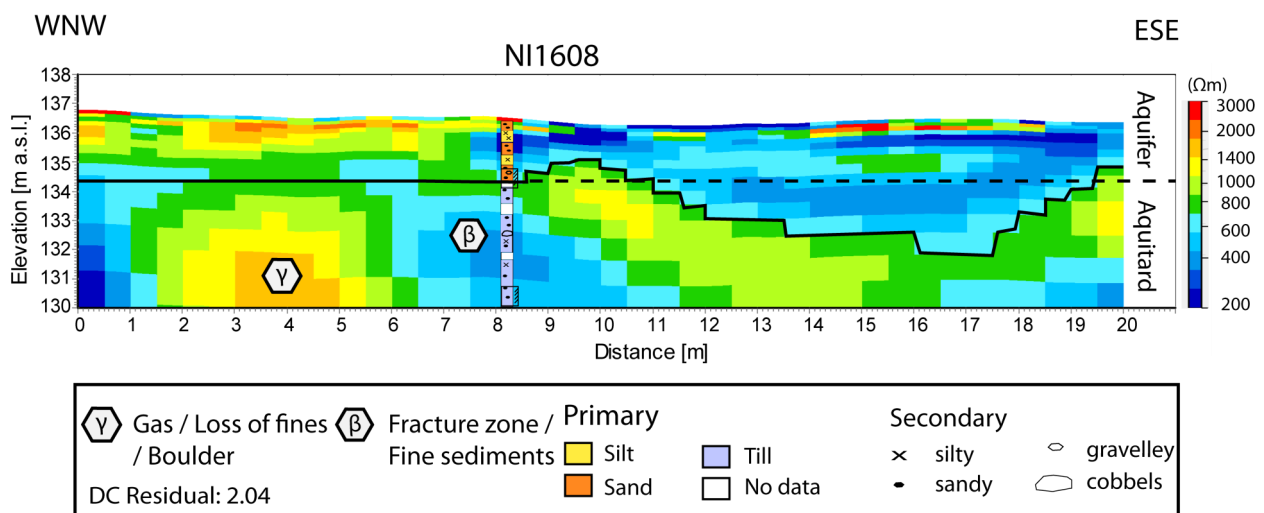


Figure 32. Displays the resistivity model result with borehole log NI1608. The dashed line marks the aquifer–aquitard boundary extrapolated from drill core NI1608, while the solid line marks the 800  $\Omega$ m resistivity boundary.

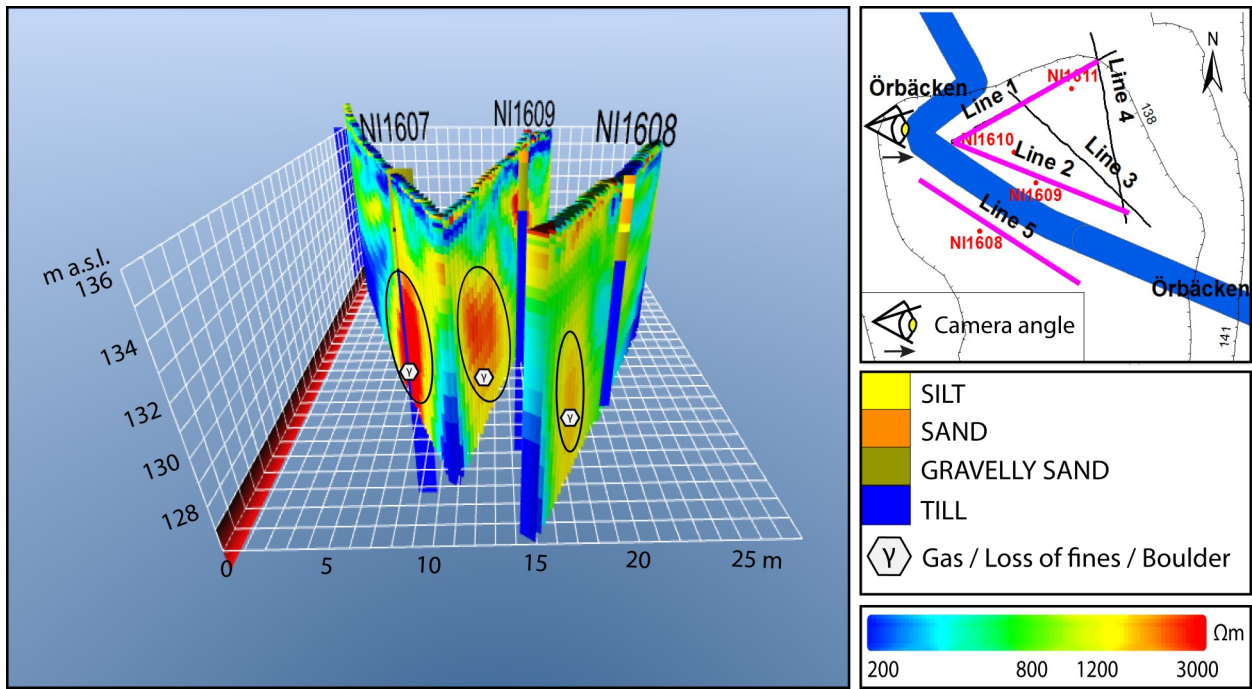


Figure 33. Geoscene3D model containing resistivity data from line 1, 2 and 5 viewed from the west together with geological data. Black circles with  $\gamma$ -anomaly mark a high-resistivity continuous feature. The grid cells are 1 x 1 m, but below 130 m a.s.l. depth the data coverage is poor.

sional surfaces are thought to be the boundary between the aquifer and aquitard, which fits the geological data from NI1611 but not NI1607.

## 5. Joint interpretation

In Figure 36, groundwater chemistry data (PCE, *cis*DCE, pH, ORP, Chloride, Sulphate, Iron and

Calcium) are displayed from filters NI1607:2, NI1609:2 and NI1609:3. Resistivity logs for the area around the monitoring wells (NI1607, NI1609, NI1610 and NI1611) are also displayed.

Within Figure 36, “Map Overview” displays a planar view of the study area where the dashed line is the joint conceptual model as dis-

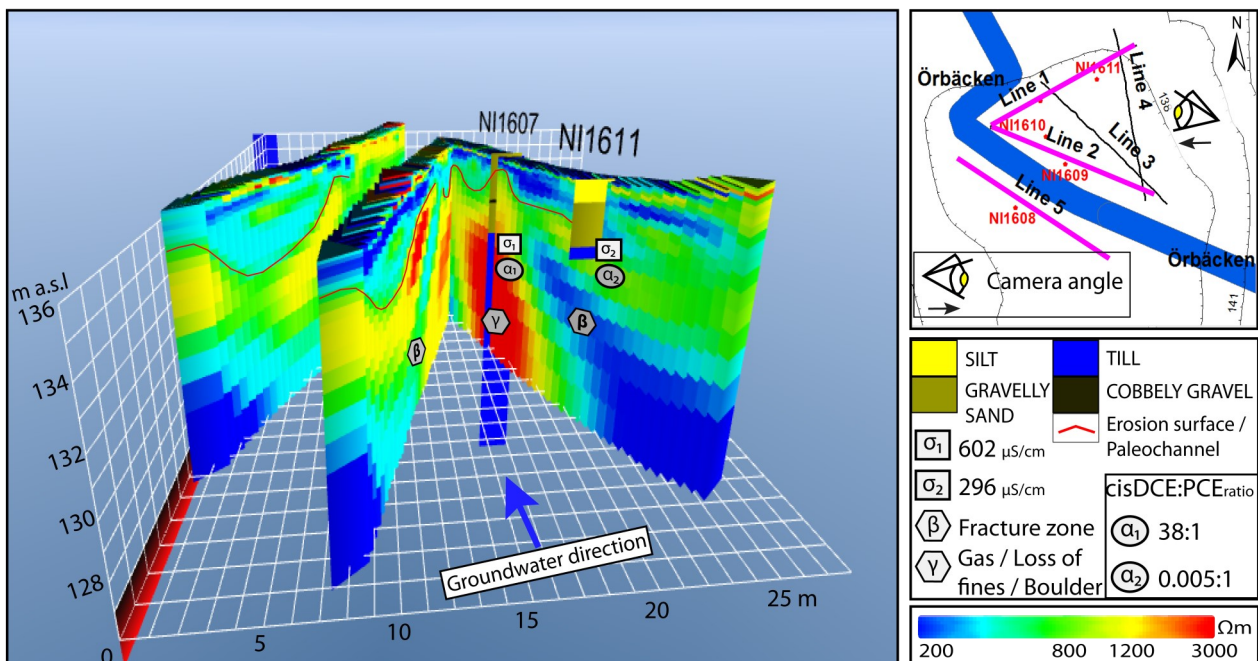


Figure 34. Geoscene3D model containing resistivity data lines 1, 2 and 5 viewed from the east together with geological data and chemical reference data for NI1607:2 and NI1611. The grid cells are 1 x 1 m, but below 130 m a.s.l. depth the data coverage is poor.



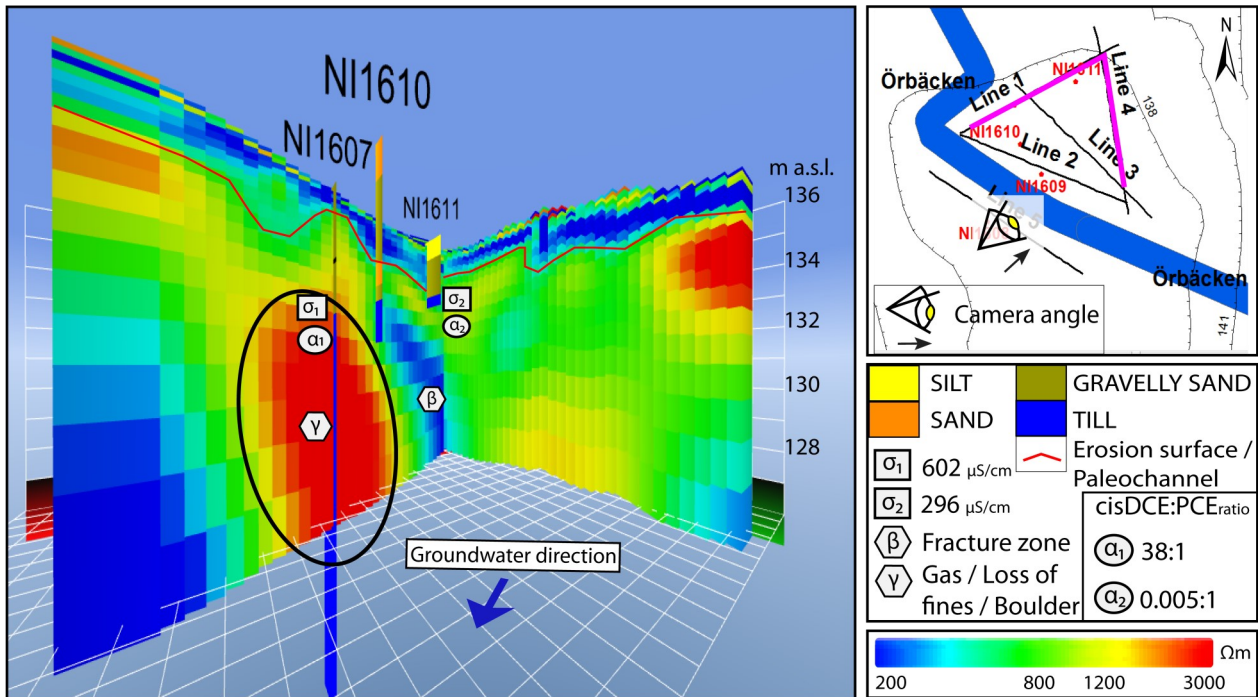


Figure 35. Geoscience3D model containing resistivity data line 1 and 4 viewed from the southeast together with geological data and chemical reference data for NI1607:2 and NI1611.

played, while the solid line shows the true positions of borehole data. Therefore, the geological model should be considered as conceptual, showing what kind of features are expected to occur within the aquifer.

The combined results show that the highest concentrations of PCE (in Figure 36 presented as average concentrations for NI1607:1, NI1609:1 and NI1610:1) are located in the sand unit (aquifer) within the top 3–5 m b.g.s. The highest concentrations of *cis*DCE are found in the aquitard (till unit). In the joint conceptual model (Figure 36), it can be noted that the changes in lithology and resistivity do not correspond in the same ways; for monitoring wells NI1608, NI1609 and NI1611 the resistivity increases to about 800 Ωm, at the sand/till transition. In the area of monitoring wells NI1607 and NI1610, the resistivity increases above the transition zone between sand and till.

In Figure 36, shaded in red, three interpreted PCE degradation zones (1, 2 and 3) are plotted. These zones display high concentrations of PCE metabolites (TCE and *cis*DCE) and a reducing environment (-115 – -230 mV).

Zone 1 is located in the  $\gamma$ -anomaly and shows a *cis*DCE:PCE ratio of 38:1 and displays elevated chloride and sulphate concentrations, which is indicative of reductive dechlorination (Weidermeier 1999).

Zone 2 is located in the  $\beta$ -anomaly and displays a *cis*DCE:PCE ratio of 5:1 and elevated iron and calcium concentrations, while chloride and sulphate concentrations are low.

Zone 3 is located near the bedrock and displays both high TCE and *cis*DCE concentrations, with elevated chloride and sulphate concentrations, which is indicative of reductive dechlorination (Weidermeier 1999).

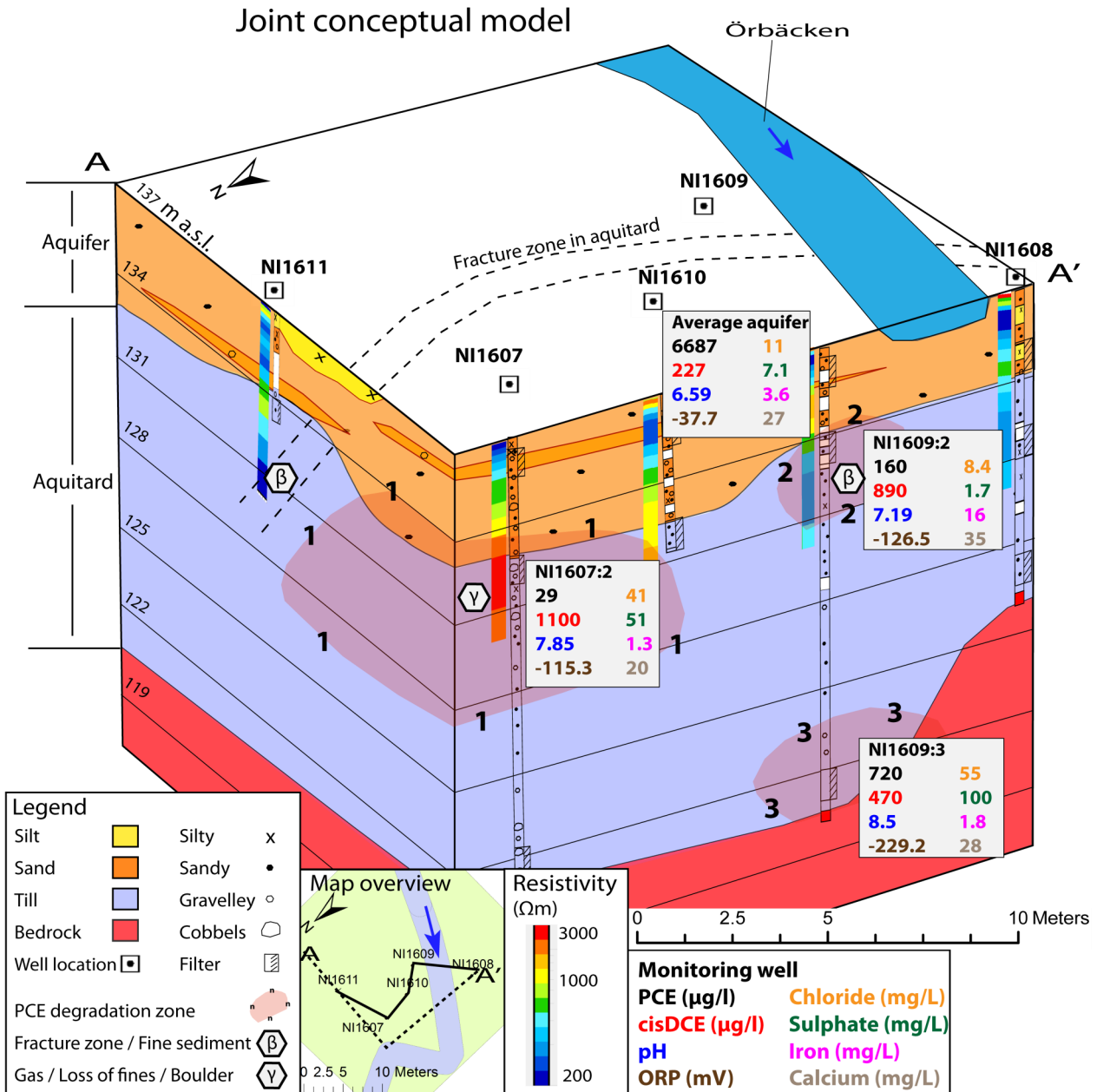


Figure 36. Joint conceptual geological model of the study area. In the “Map overview”, the dashed line represents the transect A–A’ while the black line represents the true transect with correct distances between boreholes. Resistivity logs is presented at each borehole NI1607, NI1608, NI1609, NI1610 and NI1611 respectively. Dashed black lines represent the proposed fracture zone in the aquitard. The red shaded zones (1, 2 and 3) represent the proposed PCE degradation zones.

## 6. Discussion

The resistivity results give a high-resolution view of the subsurface and show a quite homogenous response in the aquifer with small high-resistivity zones (lenses of coarser sediments) and a resistivity boundary (about 800  $\Omega\text{m}$ ) where the lithology changes to till. The boundary is not straight, which most probably is caused by old paleo channel networks that have eroded the till surface. In the Geoscene3D models it is visually clear that these features and the  $\beta$ -,  $\gamma$ -anomalies hold a geometric connection.

The IP model results show no obvious IP effects in the subsurface. This might indicate that there are no IP effects from microbial biomass, or that the total biomass in the subsurface is too low to generate a measurable IP effect. But the absence of IP effects could also be due to the measurement settings, as two seconds of current pulse might be too short to record the spectral parameters.

Furthermore, the absence of IP effects might indicate that the clay content is generally low in the study area, which in turn may support the interpretation of a fracture zone ( $\beta$ -anomaly).

### 6.1 $\gamma$ -anomaly and PCE degradation zone 1

The  $\gamma$ -anomaly displays a significantly higher resistivity than the surrounding till unit, while the measured electrical conductivity in the pore water (NI1607:2) is relatively high. This is a contradictory result, and three reasonable geological explanations are found for this  $\gamma$ -anomaly (Figure 33–35). The  $\gamma$ -anomaly in the resistivity model seems to be a continuous feature between three separate DCIP measurements. As the DC residual is low ( $<2$ ), the DCIP inversion result should be reliable.

One possible explanation is the existence of free phase biogas in the pore space, which would generate a high resistivity response. The groundwater chemistry results corresponding to the  $\gamma$ -anomaly (NI1607:2) show high *cis*DCE and chloride concentrations, which is the microbial pathway degrading PCE (Wiedemeier 1999). The high *cis*DCE and chloride concentrations indicate that microbial activity is an ongoing process within the area of the  $\gamma$ -anomaly marked in Figure 36 as PCE degradation zone 1. Microbial metabolism creates biofilms and aggregates during

growth, which can clog the pores and temporarily reduce the hydraulic conductivity ( $K$ ) in the sediments (Kildsgaard & Engesgaard 2002). Microbes themselves are in general conductive and cannot explain the  $\gamma$ -anomaly (Markx et al. 1994).

Methanogenesis requires a very reducing environment  $< -150$  mV (Wang et al. 1993), which is found at the bottom of the aquitard in filters NI1609:3 (ORP,  $-229.2$  mV) and NI1607:3 (ORP,  $-177.6$  mV). Methane has a low density ( $0.656$  kg/m<sup>3</sup>) and due to its density difference compared with water ( $1$  kg/m<sup>3</sup>), it will migrate towards the surface, if not dissolved. As biofilms and aggregates can change the hydraulic properties of sediments (Kildsgaard & Engesgaard 2002), it is reasonable to expect that biofilms and aggregates can act as a “biocap” sealing the methane gas and trapping it under ground. Migration of biogas (methane and/or carbon dioxide) has previously been proposed to increase resistivity in landfills (Rosqvist et al. 2007). High methane production rates have been reported from several natural floodplain systems, from tropical to arctic environments (Neue et al. 1997, van Huissteden et al. 2005). The dissolution potential of methane in water is dependent on temperature, pressure and salinity. At 1 bar pressure in pure water, the dissolution potential for methane is in the range of 20–40 mg/L water, when temperature is 0–30°C (Duan & Mao 2006). This means that the production rate of methane has to be above the dissolution potential for free-phase methane to exist in the subsurface. The production rate of methane in an arctic floodplain setting has been shown to be in the order of 12.5–23.4 mg m<sup>-2</sup> h<sup>-1</sup> for saturated sites (van Huissteden et al. 2005).

With the groundwater table located at about 0.2–0.5 m b.g.s., most of the sediments are saturated, with established reducing conditions close to the ground surface. The study area is probably favourable for production of free-phase methane. In future investigations, methane and carbon dioxide measurements could verify or dismiss this interpretation.

The second possible explanation for the  $\gamma$ -anomaly, is internal erosion and loss of fine sediments due to hydrologically active zones. The loss of fines in a silty till has been observed to cause a tenfold increase in resistivity in dams (Sjödahl et al. 2008). As the study area is located just outside the distal part of an esker, prior to the

deposition of the postglacial sand (aquifer), the till was most probably in connection with a water body, as the study area is situated below the highest shoreline. The  $\gamma$ -anomaly is located within a depression in the till (Figure 36). Even with the location in the depression, it is not reasonable to assume that the  $\gamma$ -anomaly was that hydrologically active at the time it was in connection with a water body that internal erosion of fine sediment could occur. As the till in drill core NI1607 was visually classified as silty sandy and cobbley sandy between 4–6 m b.g.s. (Larsson et al. 2017), the specific grain size distribution of this section is unknown. If loss of fine sediment causes the  $\gamma$ -anomaly it would also cause an increase in hydraulic conductivity initiating a higher transport rate for chloroethenes in the aquitard.

The third possible explanation for the  $\gamma$ -anomaly is the existence of a very large boulder (> 5 m), which would generate a high resistivity response. But, as monitoring well NI1607 is located right through the  $\gamma$ -anomaly without intersecting any boulder, it is more likely that the  $\gamma$ -anomaly is due to biogas or loss of fines. However, no measurements of methane/carbon dioxide have been conducted and dissolved biogas in the groundwater would decrease pH if the gas is carbon dioxide (Cahill et al. 2017), but not if the gas is methane, our chemical results do not indicate any decrease in pH, which make methane gas or loss of fines the most reasonable explanation. Additional DCIP measurements could bring clarity to this result. If the  $\gamma$ -anomaly is caused by biogas, it would be temporally and spatially shifting, and a reduction or increase in size due to e.g. seasonal variations. These changes could probably be detectable if the DCIP time-lap technique were applied.

## 6.2 $\beta$ -anomaly and PCE degradation zone 2

The  $\beta$ -anomaly marks the proposed fracture zone in the aquitard, illustrated with a dashed line in Figure 36, which is one reasonable geological solution to explain the continuous  $\beta$ -anomaly seen in Figures 34 and 35.

The  $\beta$ -anomaly displays a significantly lower resistivity than the surrounding till unit, which could also reflect higher contents of fine-grained sediments. Drill core NI1609 intersects

(2.5–6 m b.g.s.) the  $\beta$ -anomaly along DCIP line 2 (Figure 29). The lithology is known and visually classified as a sandy till (Larsson et al. 2017), which makes it less likely that high amount of fine-grained sediments causes the low resistivity response. But still, no thorough grain size analysis has been performed of the mentioned till section within the  $\beta$ -anomaly, and slight differences in grain size distribution could have been overlooked during the geological classification.

If we assume that the geological classification is correct and applicable for the  $\beta$ -anomaly, the reasonable interpretation for the  $\beta$ -anomaly, is a fracture zone in the till. This interpretation is also supported by the mapping and photo documentations of the drill core (Personal communication with Sofia Åkesson, LU, 2018-04-17). Higher porosity due to fractures would cause a decrease in resistivity, as long as no internal erosion of finer sediments had occurred. Resistivity in porous sediments is influenced by the volume of groundwater within the pores and the amount of fine sediments (Nijland et al. 2010). A fracture zone (macro pore) in the aquitard would give higher porosity than the surrounding till, and therefor hold a higher amount of groundwater. This would in turn cause a decrease in the resistivity within the “fracture zone”, possibly generating a groundwater flowpath between the aquitard and aquifer.

An interpretation of the hydrogeology based on the DCIP models alone is not possible, as two contradictory explanations are found to explain the  $\beta$ -anomaly that might generate either a lower or higher K-value compared to the surrounding sediments and also the adjacent  $\gamma$ -anomaly. From a hydrogeological standpoint, it would be of interest in the future to determine the hydraulically conductivity in the  $\beta$ -anomaly and  $\gamma$ -anomaly, this could be done by a slug test in monitoring wells NI1609:2 and NI1607:2.

Our measurements of the groundwater table (Table 4), show a slightly higher hydraulic head in the aquitard than in the aquifer, which supports the study of Nilsen (2013) and their Visual Modflow simulation. Nilsen’s (2013) results display a higher hydraulic head in the aquitard compared with the aquifer, where groundwater might move from the aquitard to the aquifer. Suggestively, the groundwater movement occurs through the proposed fracture zone ( $\beta$ -anomaly).

PCE degradation zone 2 (Figure 36) locat-

ed within the  $\beta$ -anomaly, displays low amounts of chloride ions and high concentrations of *cis*DCE, iron, negative ORP and pH 7.19. These are interesting results. As the degradation of PCE releases chloride ions, and I would expect to find an accumulation of chloride ions in the zone. This could indicate several things. Firstly it could be possible that degradation occurs somewhere else and *cis*DCE is transported into zone 2. Secondly degradation may occur within zone 2, but chloride ions rapidly diffuse and are transported out of the zone, and if so, it might indicate a higher groundwater flow. The third option would be that degradation has occurred, but is now inactive, whereas *cis*DCE diffuses less rapidly than chloride. Still, the high concentration of *cis*DCE is indicative of reductive dechlorination (Wiedermeier 1999), but it is not necessary that degradation occurs within the proposed PCE degradation zone 2. As microbial samples were collected from NI1609:2, these results will possibly bring clarity to the status of PCE degradation zone 2.

#### 6.4 Geoscene3D

When combining the 2D DC resistivity models into a 3D environment using Geoscene3D, the reliability of the model results increases as continuous features are far more visible. The result shows a clear resistivity boundary, which correlates fairly well with the transition between lithological units (sand–till) from borehole data. A perfect alignment between the mentioned boundaries cannot be expected for a certain resistivity value, where multiple factors such as grain size, porosity and dissolved ions effect the resistivity measurements. For the sand deposit, grain size distributions have been described to change between silt and cobble (Larsson et al. 2017). For this reason, it is possible to yield overlapping resistivity values.

With the present knowledge, it is not possible to interpret the hydrogeology from the resistivity model results only, but it is very likely that the  $\gamma$ -anomaly and  $\beta$ -anomaly display differences in hydraulic properties, as the deviation in resistivity is high. The next step would be to distinguish the hydraulic conductivity between the  $\beta$ - and  $\gamma$ -anomalies and construct a detailed groundwater model of the study area.

Even if the resistivity models provide a high-resolution picture of the subsurface, they do not give additional information to interpret the

contamination situation in the study area. We do find high and low concentrations of PCE, TCE and *cis*DCE in both high- and low resistive zone. At the point where the chloroethenes are diluted in the groundwater, as in the study area, the contaminants are found in very low concentrations ( $<11\ 000\ \mu\text{g/L}$ ) compared to total dissolved solids (TDS) ( $>100\ 000\ \mu\text{g/L}$ ) and therefore their resistivity response would be concealed, if it even exists.

#### 6.5 PCE degradation zones, groundwater and sediment chemistry

The groundwater and sediment chemistry results show that there are large differences in concentrations of chlorinated solvents (PCE, TCE, *cis*DCE and VC), both between different wells and between and within sediment pits. One reason why we find the highest concentrations of PCE (S7 and NI1611) at the foot of the railroad embankment and more metabolites (*cis*DCE and VC) at the edge of the floodplain (S2, S5, NI1607:2 and NI1609:2), is that degradation of PCE occurs in the short distance (10 m) between sediment pits and monitoring wells.

As biodegradation of PCE is not possible under aerobic conditions and the measured hydraulic head in the aquifer is between 0.2 and 0.5 m b.g.s., while just four out of twenty sediment samples were taken below 0.5 m, it is reasonable to believe that the sediment samples reflect aerobic conditions. However, this is not known, as no measurements of oxygen concentrations were performed. But, if we assume aerobic conditions, the findings of PCE metabolites in the sediment pits suggest that metabolites are transported from deeper parts to the ground as indicated by the difference in hydraulic head as well.

Three different zones (Figure 36) have been identified, where degradation of PCE might occur, as the chemical results show an increase in *cis*DCE or TCE concentrations compared to PCE. However, these zones show marked differences in groundwater chemistry, as zone 1 (NI1607:2) and 3 (NI1609:3) displays elevated concentrations in chloride, sulphate and sodium, while zone 2 (NI1609:2) displays elevated iron and calcium concentrations. These different results might reflect the difference in activity of biodegradation, where elevated chloride concentration suggests active and ongoing degradation, while the elevated iron and calcium concentration might reflect a

cease in former microbial activity. The elevated calcium and iron concentrations could be caused by weathering of sediments, where weathering products diffuse from the once active zone, but this is speculative. Still, microbial activity has been observed to enhance weathering and mineral dissolution from aquifer sediments, causing an elevation in calcium concentrations in groundwater (Atekwana & Slater 2009).

Furthermore, the chemical results show that sulphate concentrations are very high in zone 1 (51 mg/l at 4.5 m b.g.s.) and zone 3 (100 mg/l at 15.5 m b.g.s.) compared to filter zone 2 (1.7 mg/L at 3.5 m b.g.s.) and NI1607:3 (2 mg/L at 15 m b.g.s.). The high difference in the sulphate concentration between filters located both in the top and bottom of the aquitard, is an indication of sulphate reduction, which means that the environmental conditions in the Örbäcken area are probably suitable for halorespiration and biodegradation of PCE (Wiedemeier 1999).

Dissolved organic carbon (DOC) concentration differences are small in the top of the aquitard and within the aquifer (+/- 1 mg/L), but it is notable that filter NI1610:1 (5.6 mg/L) and NI1610:2 (5.8 mg/L) hold the highest DOC concentrations, without any indications of PCE degradation occurring. As DOC is important for hydrogen production, which governs halorespiration (Wiedemeier 1999), the zone around well NI1610 should in theory be more favourable for reductive dechlorination, but this is not what the results indicate. The results might instead reflect that DOC is to a higher extent fermented (used) for hydrogen production in filter zones 1 (NI1607:2, 4.1 mg/L) and 2 (NI1609:2, 4.5 mg/L), holding the two highest *cis*DCE ratios, and therefore the DOC concentration is lowered within the groundwater in these filters. This interpretation is speculative, with data from only one survey. To be able to draw better conclusions about the differences in DOC concentrations, monitoring the groundwater chemistry (chloroethenes, DOC, pH, ORP, chloride and EC) for an extended period is needed. My suggestion is that monitoring could be performed together with repetitive DCIP measurement.

It is not possible to correlate the DC resistivity model results with different geochemical conditions. We find that the filters (NI1607:2 and NI1609:2) with high amounts of degradation products (*cis*DCE), display either an increase or a

decrease in resistivity. This is a contradictory result, suggesting that other factors, e.g. porosity and grain size influence the resistivity measurements far more than the dechlorination process itself at these concentration levels. Still, it is an unexpected result as every step of degradation releases one chloride ion, which decreases the resistivity of the electrolyte (groundwater).

It is not likely that the DC resistivity model anomalies are a direct measurement of any biodegradation zone. Instead, they could possibly be an indirect effect of the biodegradation zone's existence, if a "biocap" produced by halorespirators and free-phase gas is occupying the pores in the zone of biodegradation. This would generate a zone of higher resistivity. With additional DCIP measurements and groundwater samples, it would be possible to perform a better correlation and understand if the resistivity of the subsurface is fixed or temporally changing. This is because a zone where biodegradation occurs, would most likely be spatially and temporally changing, due to the cycle biomass growth until no nutrients (e.g. PCE) can penetrate into the biodegrading zone (Wiedemeier 1999, Brovelli *et al.* 2009).

The IP model results were not possible to correlate with any zone of degradation. In theory, it is expected that a zone with ongoing biodegradation and high biomass content, would generate an IP response (Atekwana & Slater 2009).

In summary, from a thermodynamic standpoint, we expect that *cis*DCE would accumulate, because of the lower energy yield compared to degrading PCE or TCE. As mentioned before, this type of accumulation is found in zone 1 and zone 2, where *cis*DCE concentrations are about 38 and 5 times higher than PCE concentrations respectively. Zone 3 shows an accumulation of TCE, something that might suggest different species of halorespirators in the top and bottom of the aquitard, but not necessarily. Due to the high variations in values, it will be of great interest to see the results from the planned microbial genome sequencing from collected samples during the field campaign in April 2017 (to be performed by S. Åkesson).

## 6.5 Seepage-meters

The method for estimating in/outflow of groundwater in the Örbäcken stream with seepage-meters, was not properly designed to work in the conditions of Örbäcken. In the future, the method

used by Larsson et al. (2017) measuring the bottom sediment temperature during summer or winter would be preferred. When the temperature difference between surface water and groundwater is at the annual maximum, this method would be recommended for future surveys to locate zones of groundwater discharge.

The seepage-meter results show that discharge occurs in the first pool sequence (Figure 23), which was the only sequence measured. This is supported by previous Modflow result and streambed temperature results (Nilsen 2013, Larsson et al. 2017).

The calculated amount of PCE discharging to Örbäcken should be regarded as an approximation as it is based on assumptions and averaged discharge of nine seepage meters during 20 h. The calculated fluxes could be misleading, as seasonal variation influences the amount of discharge. Also, I assumed that the total discharge to the first pool sequence of 33.7 L/h is representative for one year. However, the discharge is more dependent on the hydraulic head, which varies throughout the year, as well as the streambed morphology, which changes spatially and temporally due to natural erosion by the water flow. Furthermore, I assumed that every litre of groundwater discharging would contain 6867 µg/L, which is not likely, as our measurement could reflect a period of either a high or low PCE concentration as dissolution potential for PCE is affected by temperature. The result of 2.05 kg per year is, however, a “low” but reasonable number entering the first pool sequence (for this small part of Örbäcken), when comparing our results to Nilsen (2013), with a total discharge of 180 kg/year to Örbäcken.

From the groundwater chemistry results, one indication of recharge from the riffle bedform was noticed from the 1°C lower temperature measured in well NI1609:1 (Table 4), when comparing temperature differences between monitoring wells (NI1607:1 and NI1610:1) close to the ground surface. However, temperatures in the aquifer are temporal, where the temperature difference between the groundwater and surface water is very small under the snow-melt period in the spring. This makes temperature differences during this season a poor indicator.

In summary, with the background from Jones & Mulholland (1999) and Woessner (2000), it is expected that the hydrodynamics in

Örbäcken would have similarities with other pool-riffle streams. Discharge of groundwater to the stream is most likely to occur in the deeper pools, while surface water enters the sediment beneath and lateral to the riffle bedform (Figure 37) (Woessner 2000). Visually, I can conclude that the second pool sequence was deeper than the first pool sequence, and it is probably where the highest amount of groundwater discharge occurs (Figure 23). This is an assumption that is also supported by Larsson’s et al. (2017) streambed temperature investigation results from Örbäcken.

## 7. Conclusions and suggestions

The results from this study indicate that natural attenuation occurs preferably in two zones, zone 1 and 3 (Figure 36), while zone 2 is regarded as inactive. However, it is still unknown if these zones are connected with each other and an additional DCIP survey perpendicular to line 1, with a 2 m electrode separation could bring clarity to this question.

This study has shown that:

- The aquifer is heavily contaminated with PCE.
- The aquitard holds high concentration of degradation products, mostly TCE and *cis*DCE, which confirms that natural attenuation occurs.
- The chemical results suggest that the environmental conditions in the Örbäcken area are suitable for biodegradation.
- The DC resistivity method was shown to be very useful in providing details of the subsurface structures.
- Integrating DC resistivity models and lithology data with groundwater chemistry using GeoScene3D enhanced the reliability of the data creating a visual model, where continuous features are more easily found.
- 2.05 kg per year of PCE was calculated to discharge to Örbäcken in the first pool sequence.

The DC resistivity model results support the hypothesis of a fracture zone in the aquitard and this indicates that there is a flowpath for groundwater through the aquitard to the aquifer. However, if

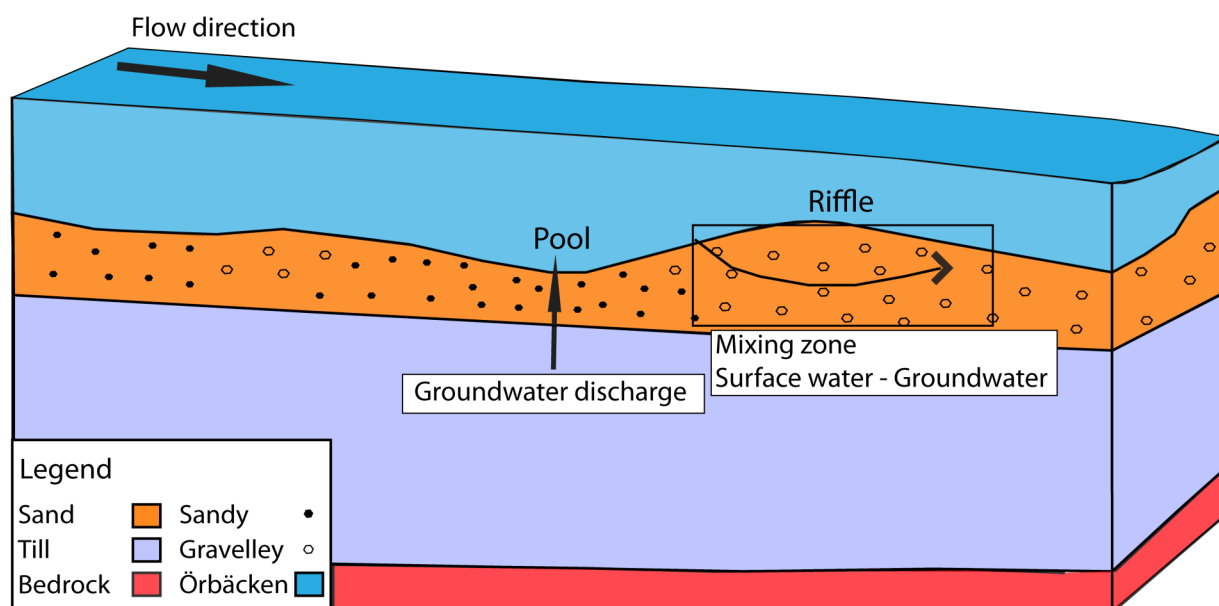


Figure 37. Conceptual model for discharge and recharge in a pool-riffle sequence like Örbäcken. According to Woessner (2000).

groundwater is transported through the proposed fracture zone to the aquifer, is not verified.

## 8. Acknowledgement

Hereby I want to give my warmest thanks to my supervisors Charlotte Sparrenbom, Torlief Dahlin, Matteo Rossi and Sofia Åkesson. Sofia deserves to be mentioned once more as you has been an awesome supervisor and inspiring factor. Also, I want to thank the MIRACHL group, Formas, SGU and Tyréns Stiftelse. Also I would like to thank Eurostars Programme, together with Innovation Fund Denmark and The Swedish innovation agency Vinnova which partly funded this project, furthermore I would like to thank I-GIS, Aarhus Geosoftware and Beth Parker from which I gained support and a lot of knowledge and new perspectives from. A special thank I would like to give Kristoffer Hellman and Sara Johansson for the time you have given me to discuss various aspect of the fundamentals about the DCIP technique. I would also like to thank my girlfriend Johanna Grünfeld and Viktor Ahrenstedt for a first brief review.

## 9. References

Amos, B.K., 2007: *Evaluation of microbial reductive dechlorination in tetrachloroethene (PCE) Dense Nonaqueous Phase Liquid*

(DNAPL) source zones. Ph. D. Thesis. Georgia Institute of Technology, Georgia, USA. 287pp.

Atekwana, E.A., Atekwana E.A., Werkema D.D., Allen J.P., Smart L.A., Duris J.W., Cassidy D.P., Sauck W.A. & Rossbach S., 2004: Evidence for microbial enhanced electrical conductivity in hydrocarbon contaminated sediments. *Geophysical Research Letters* 31. 1-4.

Atekwana, E.A. & Slater, L.D., 2009: Biogeophysics: A new frontier in earth science research. *Reviews of Geophysics* 47, RG4004. doi:10.1029/2009RG000285.

Auken, E., Christiansen, A.V., Jacobsen, B.H., Foged, N. & Sørensen, K.I., 2005: Piecewise 1D laterally constrained inversion of resistivity data. *Geophysical Prospecting* 53, 497-506.

Bennet, P.C., Hiebert, F.K. & Choi, W.J., 1996: Microbial colonization and weathering of silicates in petroleum contaminated groundwater. *Chemical Geology* 132, 45-53.

Boano, F., Harvey, J.W., Marion, A., Packman, A.I., Revelli, R., Ridolfi, L. & Worman, A., 2014: Hyporheic flow and transport processes: Mechanisms, models, and biogeochemical implications. *Reviews of Geophysics* 52, 603-679.

Brovelli, A., Malaguerra, F. & Barry, D., 2009:



- Bioclogging in porous media: Model development and sensitivity to initial conditions. *Environmental Modelling & Software* 24, 611-626.
- Buffington, J.M. & Tonina, D., 2009: Hyporheic exchange in mountain rivers II: Effects of channel morphology on mechanics, scales, and rates of exchange. *Geography Compass* 3, 1038-1062.
- Cahill, A.G., Steelman, C.M., Forde, O., Kuloyo, O., Ruff, S.E., Mayer, B., Mayer, K.U., Strous, M., Ryan, M.C., Cherry, J.A. & Parker, B.L., 2017: Mobility and persistence of methane in groundwater in a controlled-release field experiment. *Nature Geoscience* 10, 289-294.
- Chapelle, F., 1993: *Ground-water microbiology and geochemistry*. John Wiley & Sons, New York. 424pp.
- Chapelle, F.H., McMahon, P.B., Dubrovsky, N.M., Fujii, R.F., Oaksford, E.T. & Vroblesky, D.A., 1995: Deducing the distribution of terminal electron-accepting processes in hydrologically diverse groundwater systems. *Water resources research* 31, 359-371.
- Chapman, S.W. & Parker, B.L., 2005: Plume persistence due to aquitard back diffusion following dense nonaqueous phase liquid source removal or isolation. *Water resources research* 41. W12411. doi:10.1029/2005WR004224.
- Dahlin, T. & Loke, M.-H., 2015: Negative apparent chargeability in time-domain induced polarisation data. *Journal of Applied Geophysics* 123, 322-332.
- Dahlin, T & Leroux, V., 2010: 'Full Wave-form Time-domain IP Data Acquisition' Paper presented at 16th European Meeting of Environmental and Engineering Geophysics, 2010, Zürich, Switzerland, 2010/09/06 - 2010/09/08, pp. P42.
- Das, S. & Dash H.R., 2014: Microbial Biodegradation and Bioremediation, England. In S. Das (eds.): *Microbial Biodegradation and Bioremediation*, 1-21. Elsevier, Oxford.
- Duan, Z. & Mao, S., 2006: A thermodynamic model for calculating methane solubility, density and gas phase composition of methane-bearing aqueous fluids from 273 to 523K and from 1 to 2000bar. *Geochimica et Cosmochimica Acta* 70, 3369-3386.
- Duhamel, M., Mo K. & Edwards, E.A., 2004: Characterization of a highly enriched Dehalococcoides-containing culture that grows on vinyl chloride and trichloroethene. *Applied and Environmental Microbiology* 70, 5538-5545.
- Dupin, H.J. & McCarty, P.L., 2000: Impact of colony morphologies and disinfection on biological clogging in porous media. *Environmental science & technology* 34, 1513-1520.
- Fiandaca, G., Ramm, J., Binley, A., Gazoty, A., Christiansen A.V. & Auken, E., 2013: Resolving spectral information from time domain induced polarization data through 2-D inversion. *Geophysical Journal International* 192, 631-646.
- GUDIELINEGEO, 2017: ABEM Terrameter LS 2 product leaflet, Malå. Downloaded 2018-03-12 from [https://www.guidelinegeo.com/wp-content/uploads/2016/09/ABEM-Terrameter-LS-2\\_TechSpec\\_FINAL.pdf](https://www.guidelinegeo.com/wp-content/uploads/2016/09/ABEM-Terrameter-LS-2_TechSpec_FINAL.pdf)
- He, J., Ritalahti, K.M., Yang, K.-L., Koenigsberg S.S. & Löffler, F.E., 2003: Detoxification of vinyl chloride to ethene coupled to growth of an anaerobic bacterium. *Nature* 424, 62-65.
- He, J., Sung, Y., Krajmalnik, Brown, R., Ritalahti K.M. & Löffler, F.E., 2005: Isolation and characterization of Dehalococcoides sp. strain FL2, a trichloroethene (TCE) and 1, 2-dichloroethene-respiring anaerobe. *Environmental Microbiology* 7, 1442-1450.
- Huling, S.G. & Weaver, J.W., 1991: *Dense nonaqueous phase liquids*. Superfund Technology Support Center for Ground Water, Robert S. Kerr Environmental Research Laboratory. Ada, Oklahoma, USA. 21pp.
- Hunkeler, D., Aravena R. & Butler, B., 1999: Monitoring microbial dechlorination of tetrachloroethene (PCE) in groundwater using compound-specific stable carbon isotope ratios: microcosm and field studies. *Environmental science & technology* 33, 2733-2738.
- IARC, 1995: *Dry Cleaning, Some Chlorinated Solvents and Other Industrial Chemicals*. International Agency for Research on Cancer, Lyon, France. 481pp.
- Janknecht, P. & Melo, L.F., 2003: Online Biofilm Monitoring. *Reviews in Environmental Sci-*

- ence and Biotechnology* 2, 269-283.
- Johansson, S., 2016: From microstructure to sub-surface characterization - Spectral information from field scale time domain induced polarization. Licentiate Thesis. Lund University. Lund, Sweden. 54pp.
- Johansson, S., Fiandaca G. & Dahlin, T., 2015: Influence of non-aqueous phase liquid configuration on induced polarization parameters: Conceptual models applied to a time-domain field case study. *Journal of Applied Geophysics* 123, 295-309.
- Jones, J. B. & Mulholland, P.J., 1999: *Streams and ground waters*. Academic Press. San Diego, USA. 425 pp.
- Jones, J. G., Berner, R.A., Meadows, P.S., Durand B. & Eglinton, G., 1985: Microbes and Microbial Processes in Sediments [and Discussion]. *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences* 315, 3-17.
- Kildsgaard, J. & Engesgaard, P., 2002: Tracer Tests and Image Analysis of Biological Clogging in a Two Dimensional Sandbox Experiment. *Groundwater Monitoring & Remediation* 22, 60-67.
- Krause, S., Hannah, D., Fleckenstein, J., Heppell, C., Kaeser, D., Pickup, R., Pinay, G., Robertson A. & Wood, P., 2011: Interdisciplinary perspectives on processes in the hyporheic zone. *Ecohydrology* 4, 481-499.
- Larsson, N., Christensen, A.G., Steffensen, H.E., Lilbæk, G., Sandberg, Y., Nilsson, F., Hunner, B.A., Baden, K., Hemdroff, A., Arvidsson, K. & Åkesson, S., 2017: *HAG-FORSTVÄTTEN Resultatrapport från undersökningar dec 2013 – jan 2017*. [Unpublished consulting report.] NIRAS Sweden AB, Malmö. 54pp.
- Lee, D. R., 1977: A device for measuring seepage flux in lakes and estuaries. *Limnology and Oceanography* 22, 140-147.
- Lesmes, D.P. & Frye, K.M., 2001: Influence of pore fluid chemistry on the complex conductivity and induced polarization responses of Berea sandstone. *Journal of Geophysical Research: Solid Earth* 106, 4079-4090.
- Lima, O.A. & Sharma, M.M., 1992: A generalized Maxwell-Wagner theory for membrane polarization in shaly sands. *Geophysics* 57, 431-440.
- Löffler, F.E. & Edwards, E.A., 2006: Harnessing microbial activities for environmental cleanup. *Current Opinion in Biotechnology* 17, 274-284.
- Loke, M.-H., 2001: *Tutorial: 2-D and 3-D Electrical Imaging Surveys*. 122pp.
- Lovley, D.R., Chapelle F.H. & Woodward, J.C., 1994: Use of dissolved H<sub>2</sub> concentrations to determine distribution of microbially catalyzed redox reactions in anoxic groundwater. *Environmental science & technology* 28, 1205-1210.
- Lowe, M., Madsen, E.L., Schindler, K., Smith, C., Emrich, S., Robb F. & Halden, R.U., 2002: Geochemistry and microbial diversity of a trichloroethene-contaminated Superfund site undergoing intrinsic in situ reductive dechlorination. *FEMS Microbiology Ecology* 40, 123-134.
- Manataki, M., Papadopoulos, N. , Sarris, A., Agapiou, A., Themistocleous K. & Hadjimitsis, D.G., 2014: Monitoring of Water Leakages from Pipes through Geophysical Imaging Methods. In D. G. Hadjimitsis (eds.): *Integrated Use of Space, Geophysical and Hyperspectral Technologies Intended for Monitoring Water Leakages in Water Supply Networks*. 37-56. InTech, London.
- Markx, G.H., Huang, Y., Zhou X.-F. & Pethig, R., 1994: Dielectrophoretic characterization and separation of micro-organisms. *Microbiology* 140, 585-591.
- Marshall, D.J. & Madden, T.R., 1959: Induced polarization, a study of its causes. *Geophysics* 24, 790-816.
- McCarty, P.L., 1996: Biotic and abiotic transformations of chlorinated solvents in ground water. *Symposium on Natural Attenuation of Chlorinated Organics in Ground Water*. 5-9.
- Naturvårdsverket, 2009: Riktvärden för förorenad mark – modellbeskrivning och vägledning. *Report 5976*. Naturvårdverket, Stockholm. 270pp.
- Naturvårdsverket, 2016: Contaminated sites – selected industries. Downloaded 2017-09-12 from <http://www.naturvardsverket.se/Sa-mar-miljon/Statistik-A-O/Fororenade-omraden-branscher-i-urval/>
- Neue, H.U., Gaunt, J.L., Wang, Z.P., Becker-Heidmann, P. & Quijano, C., 1997: Carbon

- in tropical wetlands. *Geoderma* 79, 163-185.
- Nijland, W., van der Meijde, M., Addink, E.A. & de Jong, S.M., 2010: Detection of soil moisture and vegetation water abstraction in a Mediterranean natural area using electrical resistivity tomography. *Catena* 81, 209-216.
- Nilsen, J., 1991. *Reservvattentäkt för Hagfors*. [Unpublished consulting report.] VBB VIAK AB, Karlstad. 3pp.
- Nilsen, J., 2013. *Hagforstvätten, Huvudstudie*. Report. Sweco Environment AB, Karlstad. 270pp.
- O'Hara, S.K., Parker, B.L., Jorgensen P.R. & Cherry, J.A., 2000: Trichloroethene DNAPL flow and mass distribution in naturally fractured clay; evidence of aperture variability. *Water resources research* 36, 135-147.
- Olsson, P.-I., Dahlin, T., Fiandaca G. & Auken, E., 2015: Measuring time-domain spectral induced polarization in the on-time: decreasing acquisition time and increasing signal-to-noise ratio. *Journal of Applied Geophysics* 123, 316-321.
- Parker, B., Cherry, J., Chapman S. & Guilbeault, M., 2003: Review and analysis of chlorinated solvent dense nonaqueous phase liquid distributions in five sandy aquifers. *Vadose Zone Journal* 2, 116-137.
- Parker, B.L., Chapman S.W. & Guilbeault, M.A., 2008: Plume persistence caused by back diffusion from thin clay layers in a sand aquifer following TCE source-zone hydraulic isolation. *Journal of Contaminant Hydrology* 102, 86-104.
- Parker, B.L., Cherry J.A. & Chapman, S.W., 2004: Field study of TCE diffusion profiles below DNAPL to assess aquitard integrity. *Journal of Contaminant Hydrology* 74, 197-230.
- Prodan, C., Mayo, F., Claycomb, J.R., Miller J.H. & Benedik, M.J., 2004: Low-frequency, low-field dielectric spectroscopy of living cell suspensions. *Journal of Applied Physics* 95, 3754-3756.
- Reynolds, J.M., 2011: *An introduction to applied and environmental geophysics*. John Wiley & Sons Ltd, Chichester, West Sussex, England. 712pp.
- Ritalahti, K.M. & Löffler, F.E., 2004: Populations implicated in anaerobic reductive dechlorination of 1, 2-dichloropropane in highly enriched bacterial communities. *Applied and Environmental Microbiology* 70, 4088-4095.
- Rosqvist, H., Dahlin, T., Linders, F. & Meijer, J.-E., 2007: 'Detection of water and gas migration in a bioreactor landfill using geoelectrical imaging and a tracer test' Paper presented at SARDINIA 2007 Eleventh International Waste Management and Landfill Symposium, Italy, 0001/01/02, pp. P267.
- SGU, 2012: Sveriges Berggrund 1:1 1 000 000 [Kartografiskt material]. K423. Sveriges geologiska undersökning, Uppsala. Downloaded 2017-06-01 from: <http://resource.sgu.se/produkter/k/k423-karta.pdf>.
- Sjödahl, P., Dahlin, T., Johansson, S. & Loke, M.H., 2008: Resistivity monitoring for leakage and internal erosion detection at Hällby embankment dam. *Journal of Applied Geophysics* 65, 155-164.
- SLV, 2001: Livsmedelsverkets föreskrifter om dricksvatten, *SLVFS 2001:30*. Svenska livsmedelsverket./National food agency, Sweden. 33pp.
- Snoeyink, V.L. & Jenkins, D., 1980: *Water chemistry*. Wiley, New York, USA. 480pp.
- Sophocleous, M. A., 1991: Stream-floodwave propagation through the Great Bend alluvial aquifer, Kansas; field measurements and numerical simulations. *Journal of Hydrology* 124, 207-228.
- Sparrenbom, C.J., Akesson, S., Johansson, S., Hagerberg D. & Dahlin, T., 2017: Investigation of chlorinated solvent pollution with resistivity and induced polarization. *Science of the Total Environment* 575, 767-778.
- Stephenson, D.A., Fleming, A.H. & Mickelson, D.M., 1988: Glacial deposits. In W. Back., J.S. Rosenshein. & P.R. Seaber (eds.): *Hydrogeology: the geology of North America*, 301-314.
- Stumm, W. & Morgan, J.J., 1996: *Aquatic chemistry : chemical equilibria and rates in natural waters*. Wiley-Interscience, New York, USA. 1040pp.
- Sung, Y., Ritalahti, K.M., Apkarian R.P. & Löffler, F.E., 2006: Quantitative PCR confirms purity of strain GT, a novel trichloroethene

- to-ethene-respiring Dehalococcoides isolate. *Applied and Environmental Microbiology* 72, 1980-1987.
- Svedlund, J.-O., Hedenström, A., 2010: Beskrivning till jordartskartan, 11D Munkfors NO. *Serie K, Nr 282*. Geological Survey of Sweden (SGU), Uppsala.
- Tarantola, A., 2005: *Inverse Problem Theory and Methods for Model Parameter Estimation*. SIAM, Philadelphia, USA. 332 pp.
- Titov, K., Komarov, V., Tarasov V. & Levitski, A., 2002: Theoretical and experimental study of time domain-induced polarization in water-saturated sands. *Journal of Applied Geophysics* 50, 417-433.
- Tonina, D. & Buffington, J.M., 2007: Hyporheic exchange in gravel bed rivers with pool-riffle morphology: Laboratory experiments and three-dimensional modeling. *Water resources research* 43, W01421. doi:10.1029/2005WR004328
- U.S. EPA, 2009: National Primary Drinking Water Regulations. Downloaded 2017-09-12 from: <https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#Organic>
- van Huissteden, J., Maximov T.C. & Dolman, A.J., 2005: High methane flux from an arctic floodplain (Indigirka lowlands, eastern Siberia). *Journal of Geophysical Research: Biogeosciences* 110, G02002. doi:10.1029/2005JG000010.
- Vinegar, H.J. & Waxman, M.H., 1984: Induced polarization of shaly sands. *Geophysics* 49, 1267-1287.
- van Voorhis, G.D., Nelson P.H. & Drake, T.L., 1973: Complex resistivity spectra of porphyry copper mineralization. *Geophysics* 38, 49-60.
- Wang, Z.P., DeLaune, R.D., Patrick W.H. & Masscheleyn, P.H., 1993: Soil Redox and pH Effects on Methane Production in a Flooded Rice Soil. *Soil Science Society of America Journal* 57, 382-385.
- Wiedemeier, T. H., 1999: *Natural attenuation of fuels and chlorinated solvents in the subsurface*. John Wiley & Sons, New York. 580pp.
- Williams, K.H., Kemna, A., Wilkins, M.J., Druhan, J., Arntzen, E., N'Guessan, A.L., Long, P.E., Hubbard S.S. & Banfield, J.F., 2009: Geophysical monitoring of coupled microbial and geochemical processes during stimulated subsurface bioremediation. *Environmental science & technology* 43, 6717-6723.
- Woessner, W.W., 2000: Stream and fluvial plain ground water interactions; rescaling hydrogeologic thought. *Groundwater* 38, 423-429.
- Yalkowsky, S. H., He Y. & Jain, P., 2016: *Handbook of aqueous solubility data*. CRC press, Taylor & Francis Group, Boca Raton, USA. 1367pp.
- Zonge, K. L., Sauck W.A. & Sumner, J. S., 1972: Comparison of time, frequency, and phase measurements in induced polarization. *Geophysical Prospecting* 20, 626-648.

## 10. Appendix I

Collected groundwater samples were sent to the laboratory ALcontrol Laboratories and were kept cold in a cooler during transport. The samples were analysed for physical and chemical properties (HCO<sub>3</sub>, colour, hardness, conductivity, pH, turbidity), anions (Br, F, Cl, SO<sub>4</sub>), nutrients (NH<sub>4</sub>, NH<sub>4</sub>-N, PO<sub>4</sub>-P, NO<sub>3</sub>, NO<sub>3</sub>-N, NO<sub>2</sub>-N, NO<sub>2</sub>-N), metals (Fe, K, Si, Mg, Na, Al, Ca, Mn, Na, B, Cu), organic content (DOC, TOC, COD-Mn) and chlorinated solvents (1,1-dichloroethane, 1,2-dichloroethane, dichloro-methane, trans-1,2-dichloroethene, cis-1,2-dichloro-ethene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, tetrachloroethene, tetrachloromethane, trichloroethene, trichloromethane, monochlorobenzene, dichlorobenzene, 1,2-dichloropropane, 1,1-dichloroethene and vinyl chloride).

**ALcontrol AB**

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**RAPPORT**

Sida 1 (3)

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**Rapport Nr 17129472**
*Uppdragsgivare*

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*Avser*
**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 0950
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI1607:1		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Akesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.48	±0.05	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	0.68	±0.07	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	22	±2.2	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	2.5	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	7.1	±0.71	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.39	±0.04	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	11	±1.1	mg/l
Beräknad	Hårdhet tyska grader	4.7	±0.71	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	0.012	±0.004	mg/l
SS-EN ISO 17294-2:2005	Bor, B	14	±1.4	µg/l
ISO 17294, syrauppslutet	Bor, B	<150	±23	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	7.1	±0.71	mg/l
ISO 11885, syrauppslutet	Kisel, Si	10	±2.0	mg/l
ISO 11885, syrauppslutet	Natrium, Na	11	±1.1	mg/l
ISO 11885, syrauppslutet	Kalium, K	3.2	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	1.6	±0.16	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	7.7	±0.8	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	380	±57	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	1.7	±0.26	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	38	±5.7	FNU
SS-EN ISO 7887:2012C mod	Färg	10	±2	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	23.0	±2.30	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	6.6	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	93	±14	mg/l

Analys av metaller: provet är uppslutet med HNO3 (mikrovågsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

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 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-28
Provtagnings tidpunkt	: -	Ankomsttidpunkt	: 0950
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provet märkning	: NI1607:1		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	2.0	±0.50	mg/l
ISO 15923-1:2013 B beräknad	Ammoniumkväve, NH4-N	0.080	±0.008	mg/l
ISO 15923-1:2013 C beräknad	Ammonium, NH4	0.10	±0.01	mg/l
ISO 15923-1:2013 D beräknad	Nitrat + nitritkväve, NO23-N	0.47	±0.047	mg/l
SS-EN ISO 10304-1:2009	Nitratkväve, NO3-N	0.47		mg/l
SS-EN ISO 10304-1:2009	Nitrat, NO3	2.1		mg/l
SS-EN ISO 10304-1:2009	Nitritkväve, NO2-N	< 0.045	±0.0045	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.22	±0.045	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	15	±2.3	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	8.5	±1.3	mg/l
GC/MS	1,1-dikloreten (1)	< 10	±2.3	µg/l
GC/MS	1,2-dikloreten (1)	< 10	±1.5	µg/l
GC/MS	Diklormetan (1)	< 50	±16	µg/l
GC/MS	trans-1,2-dikloreten (1)	< 10	±3.1	µg/l
GC/MS	cis-1,2-dikloreten (1)	140	±43	µg/l
GC/MS	1,1,1-trikloreten (1)	< 10	±4.1	µg/l
GC/MS	1,1,2-trikloreten (1)	< 10	±2.7	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	10000	±3100	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	< 10	±3.1	µg/l
GC/MS	Triklloreten (1)	280	±87	µg/l
GC/MS	Triklormetan (Kloroform) (1)	< 10	±3.1	µg/l
GC/MS	Monoklorbensen (1)	< 10	±3.1	µg/l
GC/MS	Diklorbensener (1)	2.1	±0.65	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr LO28

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)



ALcontrol Laboratories

**ALcontrol AB**

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Akred. nr 1006  
Provning  
ISO/IEC 17025



**RAPPORT**

Sida 3 (3)

utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory

**Rapport Nr 17129472**

Uppdragsgivare

Lunds Universitet  
Geologiska Institutionen  
Rapportmottagare  
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221 00 LUND

Avser

**Grundvatten**

Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 0950
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI1607:1		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 10	± 2.6	µg/l
GC/MS	1,1-dikloreten (1)	< 10	± 3.3	µg/l
GC/MS	Vinylklorid (1)	< 20		µg/l
SS-EN 1484 utg 1	DOC	3.5	± 0.53	mg/l
SS-EN 1484 utg 1	TOC	3.7	± 0.56	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO<sub>3</sub>.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

**Kommentar**

Förhöjd rapporteringsgräns för Bor, B, Nitritkväve, NO<sub>2</sub>-N på grund av störningar från andra ämnen i provet. Detta medför också att mätosäkerheten är högre än vad som angivits ovan.

På grund av nödvändig spädning så är en del rapportgränser förhöjda. Detta medför också att mätosäkerheten är högre än vad som angivits ovan.

Linköping 2017-05-15

Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.se

Emil Johansson  
Analysansvarig

Kontrollnr 2781 6420 8076 0956

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



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 Provning  
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**RAPPORT**

Sida 1 (3)

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**Rapport Nr 17129466**

Uppdragsgivare

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## Avser

**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI 1607:2		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Akesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.09	±0.02	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	1.2	±0.12	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	20	±2.0	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	3.5	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	6.5	±0.65	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.72	±0.07	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	57	±5.7	mg/l
Beräknad	Hårdhet tyska grader	4.3	±0.64	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	0.075	±0.008	mg/l
SS-EN ISO 17294-2:2005	Bor, B	35	±3.5	µg/l
ISO 17294, syrauppslutet	Bor, B	32	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	7.9	±0.79	mg/l
ISO 11885, syrauppslutet	Kisel, Si	7.9	±1.6	mg/l
ISO 11885, syrauppslutet	Natrium, Na	59	±5.9	mg/l
ISO 11885, syrauppslutet	Kalium, K	4.0	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	1.3	±0.13	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	7.0	±0.7	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	700	±110	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	<0.5	±0.18	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	4.1	±0.61	FNU
SS-EN ISO 7887:2012C mod	Färg	30	±3	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	44.5	±4.45	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	7.8	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	120	±18	mg/l

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

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Sida 2 (3)

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REPORT issued by an Accredited Laboratory**Rapport Nr 17129466**

Uppdragsgivare

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## Avser

**Grundvatten**Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI 1607:2		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	3.1	±0.78	mg/l
ISO 15923-1:2013 B beräknad	Ammoniumkväve, NH4-N Ammonium, NH4	0.13 0.17	±0.013 ±0.02	mg/l mg/l
ISO 15923-1:2013 C Beräknad beräknad	Nitrat + nitritkväve, NO23-N Nitratkväve, NO3-N Nitrat, NO3	0.037 0.04 <0.3	±0.005	mg/l mg/l mg/l
ISO 15923-1:2013 D	Nitritkväve, NO2-N	<0.001	±0.0009	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.58	±0.087	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	41	±6.1	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	51	±7.6	mg/l
GC/MS	1,1-dikloreten (1)	<5.0	±1.2	µg/l
GC/MS	1,2-dikloreten (1)	<5.0	±0.75	µg/l
GC/MS	Diklormetan (1)	<25	±7.8	µg/l
GC/MS	trans-1,2-dikloreten (1)	<5.0	±1.6	µg/l
GC/MS	cis-1,2-dikloreten (1)	1100	±340	µg/l
GC/MS	1,1,1-trikloreten (1)	<5.0	±2.1	µg/l
GC/MS	1,1,2-trikloreten (1)	<5.0	±1.4	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	29	±9.0	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	<5.0	±1.6	µg/l
GC/MS	Triklloreten (1)	180	±56	µg/l
GC/MS	Triklormetan (Kloroform) (1)	<5.0	±1.6	µg/l
GC/MS	Monoklorbensen (1)	<5.0	±1.6	µg/l
GC/MS	Diklorbensener (1)	<0.6	±0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO3 (mikrovågsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

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Provning  
ISO/IEC 17025**RAPPORT**

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REPORT issued by an Accredited Laboratory**Rapport Nr 17129466**

Uppdragsgivare

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## Avser

**Grundvatten**Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-28
Provtagnings tidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI 1607:2		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 5.0	± 1.3	µg/l
GC/MS	1,1-dikloreten (1)	< 5.0	± 1.7	µg/l
GC/MS	Vinylklorid (1)	33		µg/l
SS-EN 1484 utg 1	DOC	4.1	± 0.61	mg/l
SS-EN 1484 utg 1	TOC	4.2	± 0.63	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO<sub>3</sub>.Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.**Kommentar***Tiden mellan provtagning och ankomst till laboratoriet har överskridit 2 dygn, vilket kan ha påverkat analysresultatet.**På grund av nödvändig spädning så är en del rapportgränser förhöjda.**Resultatet av TOC är lägre än DOC, skillnaden ligger dock inom mätosäkerheten.*

Linköping 2017-06-02

Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.seFrida Björklund  
Analysansvarig

Kontrollnr 3383 1629 8779 0850



## ALcontrol AB

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Akred. nr 1006  
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## RAPPORT

Sida 1 (3)

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 REPORT issued by an Accredited Laboratory

## Rapport Nr 17129460

Uppdragsgivare

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 Rapportmottagare  
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## Avser

## Grundvatten

Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum	: 2017-04-27	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: Backen		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.27	±0.03	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	0.53	±0.05	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	3.7	±0.37	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	< 2	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	< 0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	1.7	±0.17	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.02	±0.003	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	3.8	±0.38	mg/l
Beräknad	Hårdhet tyska grader	0.90	±0.14	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	< 0.01	±0.004	mg/l
SS-EN ISO 17294-2:2005	Bor, B	10	±1.0	µg/l
ISO 17294, syrauppslutet	Bor, B	< 30	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	3.9	±0.39	mg/l
ISO 11885, syrauppslutet	Kisel, Si	4.4	±0.88	mg/l
ISO 11885, syrauppslutet	Natrium, Na	4.0	±0.40	mg/l
ISO 11885, syrauppslutet	Kalium, K	< 2.5	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	1.1	±0.11	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	1.9	±0.2	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	58	±8.7	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	0.94	±0.18	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	1.6	±0.24	FNU
SS-EN ISO 7887:2012C mod	Färg	130	±13	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	5.77	±0.600	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	7.0	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	13	±2.0	mg/l

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

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Provning  
ISO/IEC 17025**RAPPORT**

Sida 2 (3)

utfärdad av ackrediterat laboratorium

REPORT issued by an Accredited Laboratory

**Rapport Nr 17129460**

Uppdragsgivare

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Rapportmottagare  
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Avser

**Grundvatten**Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-27	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: Backen		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosakerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	18	± 4.5	mg/l
ISO 15923-1:2013 B beräknad	Ammoniumkväve, NH4-N	0.10	± 0.010	mg/l
	Ammonium, NH4	0.13	± 0.01	mg/l
ISO 15923-1:2013 C Beräknad	Nitrat + nitritkväve, NO23-N	0.26	± 0.026	mg/l
	Nitratkväve, NO3-N	0.26		mg/l
beräknad	Nitrat, NO3	1.2		mg/l
ISO 15923-1:2013 D	Nitritkväve, NO2-N	< 0.001	± 0.0009	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.13	± 0.045	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	4.7	± 0.90	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	3.0	± 0.90	mg/l
GC/MS	1,1-dikloreten (1)	< 0.1	± 0.02	µg/l
GC/MS	1,2-dikloreten (1)	< 0.1	± 0.02	µg/l
GC/MS	Diklormetan (1)	< 0.5	± 0.16	µg/l
GC/MS	trans-1,2-dikloreten (1)	< 0.1	± 0.03	µg/l
GC/MS	cis-1,2-dikloreten (1)	0.73	± 0.23	µg/l
GC/MS	1,1,1-trikloreten (1)	< 0.1	± 0.04	µg/l
GC/MS	1,1,2-trikloreten (1)	< 0.1	± 0.03	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	3.2	± 0.99	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	< 0.1	± 0.03	µg/l
GC/MS	Triklormetan (1)	0.35	± 0.11	µg/l
GC/MS	Triklormetan (Kloroform) (1)	< 0.1	± 0.03	µg/l
GC/MS	Monoklorbensen (1)	< 0.2	± 0.06	µg/l
GC/MS	Diklorbensener (1)	< 0.6	± 0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosakerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosakerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING



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**RAPPORT**

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**Rapport Nr 17129460**

Uppdragsgivare

Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

Avser

**Grundvatten**

Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-27	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: Backen		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	<0.2	±0.05	µg/l
GC/MS	1,1-dikloreten (1)	<0.1	±0.03	µg/l
GC/MS	Vinylklorid (1)	<0.2		µg/l
SS-EN 1484 utg 1	DOC	13	±2.0	mg/l
SS-EN 1484 utg 1	TOC	13	±2.0	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	<1	±0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO<sub>3</sub>.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-12

Rapporten har granskats och godkänts av

Kopia sänds till  
 charlotte.sparrenbom@geol.lu.se

Ingrid Södersten  
 Granskningsansvarig

Kontrollnr 3985 1622 8677 0954

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

 Box 1083, 581 10 Linköping - Tel: 013-25 49 00 - Fax: 013-12 17 28  
 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Proving  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (3)

utfärdad av ackrediterat laboratorium

REPORT issued by an Accredited Laboratory

**Rapport Nr 17129464**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
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## Avser

**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-26	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI1607:3		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	1.1	±0.11	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	1.9	±0.19	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	16	±1.6	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	4.2	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	5.8	±0.58	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.38	±0.04	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	7.8	±0.78	mg/l
Beräknad	Hårdhet tyska grader	3.6	±0.54	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	0.13	±0.013	mg/l
SS-EN ISO 17294-2:2005	Bor, B	4.5	±0.45	µg/l
ISO 17294, syrauppslutet	Bor, B	<150	±23	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	14	±1.4	mg/l
ISO 11885, syrauppslutet	Kisel, Si	27	±5.4	mg/l
ISO 11885, syrauppslutet	Natrium, Na	9.1	±0.91	mg/l
ISO 11885, syrauppslutet	Kalium, K	6.5	±0.65	mg/l
ISO 11885, syrauppslutet	Järn, Fe	5.6	±0.56	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	6.8	±0.7	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	420	±63	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	3.4	±0.51	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	230	±35	FNU
SS-EN ISO 7887:2012C mod	Färg	5	±2	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	17.6	±1.76	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	8.0	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	74	±11	mg/l

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)



## ALcontrol AB

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## RAPPORT

Sida 2 (3)

utfärdad av ackrediterat laboratorium

REPORT issued by an Accredited Laboratory

## Rapport Nr 17129464

Uppdragsgivare

Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

## Grundvatten

Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum	: 2017-04-26	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI1607:3		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	1.4	±0.50	mg/l
ISO 15923-1:2013 B	Ammoniumkväve, NH4-N	<0.25	±0.025	mg/l
beräknad	Ammonium, NH4	<0.02	±0.01	mg/l
ISO 15923-1:2013 C	Nitrat + nitritkväve, NO23-N	<0.25	±0.025	mg/l
Beräknad	Nitratkväve, NO3-N	<0.25		mg/l
beräknad	Nitrat, NO3	<1.1		mg/l
ISO 15923-1:2013 D	Nitritkväve, NO2-N	<0.001	±0.0009	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.51	±0.077	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	10	±1.5	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	2.0	±0.90	mg/l
GC/MS	1,1-dikloreten (1)	<5.0	±1.2	µg/l
GC/MS	1,2-dikloreten (1)	<5.0	±0.75	µg/l
GC/MS	Diklormetan (1)	<25	±7.8	µg/l
GC/MS	trans-1,2-dikloreten (1)	<5.0	±1.6	µg/l
GC/MS	cis-1,2-dikloreten (1)	820	±250	µg/l
GC/MS	1,1,1-trikloreten (1)	<5.0	±2.1	µg/l
GC/MS	1,1,2-trikloreten (1)	<5.0	±1.4	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	2100	±650	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	<5.0	±1.6	µg/l
GC/MS	Trikloreten (1)	1900	±590	µg/l
GC/MS	Triklormetan (Kloroform) (1)	<5.0	±1.6	µg/l
GC/MS	Monoklorbensen (1)	<5.0	±1.6	µg/l
GC/MS	Diklorbensener (1)	<0.6	±0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



## ALcontrol AB

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## RAPPORT

Sida 3 (3)

utfärdad av ackrediterat laboratorium  
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## Rapport Nr 17129464

Uppdragsgivare

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## Avser

## Grundvatten

Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum	: 2017-04-26	Ankomstdatum	: 2017-04-28
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 8 °C
Provets märkning	: NI1607:3		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 5.0	± 1.3	µg/l
GC/MS	1,1-dikloreten (1)	< 5.0	± 1.7	µg/l
GC/MS	Vinylklorid (1)	< 10		µg/l
SS-EN 1484 utg 1	DOC	2.7	± 0.50	mg/l
SS-EN 1484 utg 1	TOC	3.0	± 0.50	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO<sub>3</sub>.Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

## Kommentar

På grund av nödvändig spädning så är en del rapportgränser förhöjda.  
Detta medför också att mätosäkerheten är högre än vad som angivits ovan.

Förhöjd rapporteringsgräns för Bor, B, Ammoniumkväve, NH<sub>4</sub>-N och Nitrat + nitritkväve, NO<sub>2</sub>-N på grund av störningar från andra ämnen i provet.  
Detta medför också att mätosäkerheten är högre än vad som angivits ovan.

Linköping 2017-05-15

Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.seEmil Johansson  
Analysansvarig

Kontrollnr 3580 1623 8879 0150

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



ALcontrol Laboratories

**ALcontrol AB**

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Akred. nr 1006  
Provning  
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**RAPPORT**

utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory

Sida 1 (3)

**Rapport Nr 17129469**

Uppdragsgivare

Lunds Universitet  
Geologiska Institutionen  
Rapportmottagare  
Box 188  
221 00 LUND

Avser

**Grundvatten**

Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-25
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1030
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: NI1609:1		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.45	±0.05	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	4.9	±0.49	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	31	±3.1	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	3.2	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	9.2	±0.92	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.44	±0.04	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	10	±1.0	mg/l
Beräknad	Hårdhet tyska grader	6.4	±0.96	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	<0.01	±0.004	mg/l
SS-EN ISO 17294-2:2005	Bor, B	23	±2.3	µg/l
ISO 17294, syrauppslutet	Bor, B	<30	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	10	±1.0	mg/l
ISO 11885, syrauppslutet	Kisel, Si	12	±2.4	mg/l
ISO 11885, syrauppslutet	Natrium, Na	10	±1.0	mg/l
ISO 11885, syrauppslutet	Kalium, K	4.2	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	5.9	±0.59	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	9.4	±0.9	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	470	±71	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	1.3	±0.20	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	64	±9.6	FNU
SS-EN ISO 7887:2012C mod	Färg	40	±4	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	27.9	±2.79	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	6.8	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	130	±20	mg/l

Kisel är uppslutet med HNO3. Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

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**RAPPORT**

Sida 2 (3)

utfärdad av ackrediterat laboratorium

REPORT issued by an Accredited Laboratory

 **Rapport Nr 17129469** 

Uppdragsgivare

 Lunds Universitet  
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## Avser

**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-25
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1030
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: NI1609:1		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	3.4	±0.85	mg/l
ISO 15923-1:2013 B	Ammoniumkväve, NH4-N	0.16	±0.016	mg/l
beräknad	Ammonium, NH4	0.21	±0.02	mg/l
ISO 15923-1:2013 C	Nitrat + nitritkväve, NO23-N	0.56	±0.056	mg/l
Beräknad	Nitratkväve, NO3-N	0.56		mg/l
beräknad	Nitrat, NO3	2.5		mg/l
ISO 15923-1:2013 D	Nitritkväve, NO2-N	< 0.045	±0.0045	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.27	±0.045	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	9.5	±1.4	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	7.9	±1.2	mg/l
GC/MS	1,1-dikloreten (1)	< 10	±2.3	µg/l
GC/MS	1,2-dikloreten (1)	< 10	±1.5	µg/l
GC/MS	Diklormetan (1)	< 50	±16	µg/l
GC/MS	trans-1,2-dikloreten (1)	< 10	±3.1	µg/l
GC/MS	cis-1,2-dikloreten (1)	310	±96	µg/l
GC/MS	1,1,1-trikloreten (1)	< 10	±4.1	µg/l
GC/MS	1,1,2-trikloreten (1)	< 10	±2.7	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	6600	±2000	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	< 10	±3.1	µg/l
GC/MS	Trikloreten (1)	320	±99	µg/l
GC/MS	Triklormetan (Kloroform) (1)	< 10	±3.1	µg/l
GC/MS	Monoklorbensen (1)	< 10	±3.1	µg/l
GC/MS	Diklorbensener (1)	< 0.6	±0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Kisel är uppslutet med HNO3. Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)



ALcontrol Laboratories

**ALcontrol AB**

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ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING



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**RAPPORT**

Sida 3 (3)

utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory

**Rapport Nr 17129469**

Uppdragsgivare

Lunds Universitet  
Geologiska Institutionen  
Rapportmottagare  
Box 188  
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Avser

**Grundvatten**

Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-25
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1030
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: NI1609:1		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 10	± 2.6	µg/l
GC/MS	1,1-dikloreten (1)	< 10	± 3.3	µg/l
GC/MS	Vinylklorid (1)	< 20		µg/l
SS-EN 1484 utg 1	DOC	4.4	± 0.66	mg/l
SS-EN 1484 utg 1	TOC	5.1	± 0.76	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Kisel är uppslutet med HNO<sub>3</sub>. Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

**Kommentar**

Tiden mellan provtagning och ankomst till laboratoriet har överskridit 1 dygn, vilket kan ha påverkat analysresultatet.

Förhöjd rapporteringsgräns för Nitritkväve, NO<sub>2</sub>-N på grund av störningar från andra ämnen i provet. Detta medför också att mätosäkerheten är högre än vad som angivits ovan.

På grund av nödvändig spädning så är en del rapportgränser förhöjda.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till  
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Frida Björklund  
Analysansvarig

Kontrollnr 3089 1621 8276 0859

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**Avser**
**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomststidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11609:2		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.38	±0.04	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	16	±1.6	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	35	±3.5	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	4.2	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	9.7	±0.97	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	1.6	±0.16	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	8.8	±0.88	mg/l
Beräknad	Hårdhet tyska grader	7.1	±1.1	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	<0.2	±0.020	mg/l
SS-EN ISO 17294-2:2005	Bor, B	16	±1.6	µg/l
ISO 17294, syrauppslutet	Bor, B	<30	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	12	±1.2	mg/l
ISO 11885, syrauppslutet	Kisel, Si	11	±2.2	mg/l
ISO 11885, syrauppslutet	Natrium, Na	8.8	±0.88	mg/l
ISO 11885, syrauppslutet	Kalium, K	4.7	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	16	±1.6	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	9.8	±1.0	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	1700	±260	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	<0.5	±0.18	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	79	±12	FNU
SS-EN ISO 7887:2012C mod	Färg	20	±2	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	28.9	±2.89	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	7.0	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	150	±23	mg/l

Kisel är uppslutet med HNO3. Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2.

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)



## ALcontrol AB

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING



Akred. nr 1006  
 Proving  
 ISO/IEC 17025



## RAPPORT

Sida 2 (3)

utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

## Rapport Nr 17129461

Uppdragsgivare

Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

## Grundvatten

Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum : 2017-04-20 Ankomstdatum : 2017-04-24  
 Provtagningsstidpunkt : - Ankomsttidpunkt : 1000  
 Temperatur vid provtagning : - Temperatur vid ankomst : 5 °C  
 Provets märkning : N11609:2  
 Provtagare : SA/NBH  
 Fakturareferens : Sofia Åkesson  
 Projektkod : 124573-TD

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	4.8	± 1.2	mg/l
ISO 15923-1:2013 B beräknad	Ammoniumkväve, NH4-N Ammonium, NH4	< 0.25 < 0.02	± 0.025 ± 0.01	mg/l mg/l
ISO 15923-1:2013 C Beräknad beräknad	Nitrat + nitritkväve, NO23-N Nitratkväve, NO3-N Nitrat, NO3	< 0.01 < 0.01 < 0.3	± 0.005	mg/l mg/l mg/l
ISO 15923-1:2013 D	Nitritkväve, NO2-N	< 0.001	± 0.0009	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.33	± 0.050	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	8.4	± 1.3	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	1.7	± 0.90	mg/l
GC/MS	1,1-dikloreten (1)	< 1.0	± 0.23	µg/l
GC/MS	1,2-dikloreten (1)	< 1.0	± 0.15	µg/l
GC/MS	Diklormetan (1)	< 5.0	± 1.6	µg/l
GC/MS	trans-1,2-dikloreten (1)	2.1	± 0.65	µg/l
GC/MS	cis-1,2-dikloreten (1)	890	± 280	µg/l
GC/MS	1,1,1-trikloreten (1)	< 1.0	± 0.41	µg/l
GC/MS	1,1,2-trikloreten (1)	< 1.0	± 0.27	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	160	± 50	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	< 1.0	± 0.31	µg/l
GC/MS	Triklöreten (1)	64	± 20	µg/l
GC/MS	Triklormetan (Kloroform) (1)	< 1.0	± 0.31	µg/l
GC/MS	Monoklorbensen (1)	< 1.0	± 0.31	µg/l
GC/MS	Diklorbensener (1)	0.90	± 0.28	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Kisel är uppslutet med HNO3. Analys av metaller: provet är uppslutet med HNO3 (mikrovågsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



ALcontrol Laboratories

**ALcontrol AB**

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Provning  
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**RAPPORT**

Sida 3 (3)

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**Rapport Nr 17129461**

Uppdragsgivare

Lunds Universitet  
Geologiska Institutionen  
Rapportmottagare  
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221 00 LUND

Avser

**Grundvatten**

Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum : 2017-04-20      Ankomstdatum : 2017-04-24  
Provtagningstidpunkt : -      Ankomsttidpunkt : 1000  
Temperatur vid provtagning : -      Temperatur vid ankomst : 5 °C  
Provet märkning : N11609:2  
Provtagare : SA/NBH  
Fakturareferens : Sofia Åkesson  
Projektkod : 124573-TD

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 1.0	± 0.26	µg/l
GC/MS	1,1-dikloreten (1)	< 1.0	± 0.33	µg/l
GC/MS	Vinylklorid (1)	2		µg/l
SS-EN 1484 utg 1	DOC	4.5	± 0.67	mg/l
SS-EN 1484 utg 1	TOC	6.6	± 0.99	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Kisel är uppslutet med HNO<sub>3</sub>. Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovägsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

**Kommentar**

Tiden mellan provtagning och ankomst till laboratoriet har överskridit 1 dygn, vilket kan ha påverkat analysresultatet.

Förhöjd rapporteringsgräns för Fosfatfosfor, PO<sub>4</sub>-P och Ammoniumkväve, NH<sub>4</sub>-N på grund av störningar från andra ämnen i provet.

Detta medför också att mätosäkerheten är högre än vad som angivits ovan.

På grund av nödvändig spädning så är en del rapportgränser förhöjda.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.se

Frida Björklund  
Analysansvarig

Kontrollnr 3886 1626 8872 0754

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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**RAPPORT**

Sida 1 (3)

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Uppdragsgivare

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## Avser

**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11609:3		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.67	±0.07	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	1.1	±0.11	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	28	±2.8	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	4.1	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	8.6	±0.86	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.25	±0.03	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	87	±8.7	mg/l
Beräknad	Hårdhet tyska grader	5.9	±0.89	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	0.18	±0.018	mg/l
SS-EN ISO 17294-2:2005	Bor, B	58	±5.8	µg/l
ISO 17294, syrauppslutet	Bor, B	59	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	15	±1.5	mg/l
ISO 11885, syrauppslutet	Kisel, Si	15	±3.0	mg/l
ISO 11885, syrauppslutet	Natrium, Na	88	±8.8	mg/l
ISO 11885, syrauppslutet	Kalium, K	5.1	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	1.8	±0.18	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	9.0	±0.9	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	280	±42	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	0.53	±0.18	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	970	±150	FNU
SS-EN ISO 7887:2012C mod	Färg	10	±2	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	64.0	±6.40	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	8.2	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	130	±20	mg/l

Kisel är uppslutet med HNO3. Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.





## ALcontrol AB

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## RAPPORT

Sida 2 (3)

utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory

## Rapport Nr 17129471

Uppdragsgivare

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Avser

## Grundvatten

Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provet märkning	: N11609:3		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	1.1	±0.50	mg/l
ISO 15923-1:2013 B beräknad	Ammoniumkväve, NH <sub>4</sub> -N	0.22	±0.022	mg/l
	Ammonium, NH <sub>4</sub>	0.28	±0.03	mg/l
ISO 15923-1:2013 C Beräknad	Nitrat + nitritkväve, NO <sub>2</sub> -N	<0.01	±0.005	mg/l
	Nitratkväve, NO <sub>3</sub> -N	<0.01		mg/l
beräknad	Nitrat, NO <sub>3</sub>	<0.3		mg/l
ISO 15923-1:2013 D	Nitritkväve, NO <sub>2</sub> -N	<0.001	±0.0009	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.61	±0.092	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	55	±8.3	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO <sub>4</sub>	100	±15	mg/l
GC/MS	1,1-dikloreten (1)	<1.0	±0.23	µg/l
GC/MS	1,2-dikloreten (1)	<1.0	±0.15	µg/l
GC/MS	Diklormetan (1)	<5.0	±1.6	µg/l
GC/MS	trans-1,2-dikloreten (1)	2.8	±0.87	µg/l
GC/MS	cis-1,2-dikloreten (1)	470	±150	µg/l
GC/MS	1,1,1-trikloreten (1)	<1.0	±0.41	µg/l
GC/MS	1,1,2-trikloreten (1)	<1.0	±0.27	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	720	±220	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	<1.0	±0.31	µg/l
GC/MS	Triklloreten (1)	930	±290	µg/l
GC/MS	Triklormetan (Kloroform) (1)	<1.0	±0.31	µg/l
GC/MS	Monoklorbensen (1)	<1.0	±0.31	µg/l
GC/MS	Diklorbensener (1)	<0.6	±0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Kisel är uppslutet med HNO<sub>3</sub>. Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovägsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)



ALcontrol Laboratories

**ALcontrol AB**

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ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING



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**RAPPORT**

Sida 3 (3)

utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory

**Rapport Nr 17129471**

Uppdragsgivare

Lunds Universitet  
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221 00 LUND

Avser

**Grundvatten**

Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11609:3		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 1.0	± 0.26	µg/l
GC/MS	1,1-dikloreten (1)	< 1.0	± 0.33	µg/l
GC/MS	Vinylklorid (1)	< 2		µg/l
SS-EN 1484 utg 1	DOC	1.6	± 0.50	mg/l
SS-EN 1484 utg 1	TOC	1.8	± 0.50	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Kisel är uppslutet med HNO<sub>3</sub>. Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

**Kommentar**

Tiden mellan provtagning och ankomst till laboratoriet har överskridit 1 dygn, vilket kan ha påverkat analysresultatet.

På grund av nödvändig spädning så är en del rapportgränser förhöjda.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

Frida Björklund  
Analysansvarig

Kontrollnr 2881 6126 8476 0753

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

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 Provning  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (3)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129462**
*Uppdragsgivare*

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

**Avser**
**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-19	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11610:1		
Provtagare	: SÅ/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.12	±0.02	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	2.9	±0.29	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	28	±2.8	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	2.4	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	8.1	±0.81	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.46	±0.05	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	7.0	±0.70	mg/l
Beräknad	Hårdhet tyska grader	5.7	±0.86	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	<0.01	±0.004	mg/l
SS-EN ISO 17294-2:2005	Bor, B	15	±1.5	µg/l
ISO 17294, syrauppslutet	Bor, B	<30	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	6.7	±0.67	mg/l
ISO 11885, syrauppslutet	Kisel, Si	6.9	±1.4	mg/l
ISO 11885, syrauppslutet	Natrium, Na	7.0	±0.70	mg/l
ISO 11885, syrauppslutet	Kalium, K	2.6	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	3.2	±0.32	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	8.3	±0.8	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	470	±71	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	0.76	±0.18	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	9.4	±1.4	FNU
SS-EN ISO 7887:2012C mod	Färg	50	±5	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	24.8	±2.48	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	6.7	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	120	±18	mg/l

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)



## ALcontrol AB

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## RAPPORT

Sida 2 (3)

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## Rapport Nr 17129462

Uppdragsgivare

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## Avser

## Grundvatten

Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum : 2017-04-19 Ankomstdatum : 2017-04-24  
 Provtagningsstidpunkt : - Ankomsttidpunkt : 1000  
 Temperatur vid provtagning : - Temperatur vid ankomst : 5 °C  
 Provets märkning : N11610:1  
 Provtagare : SA/NBH  
 Fakturareferens : Sofia Åkesson  
 Projektkod : 124573-TD

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	4.2	± 1.1	mg/l
ISO 15923-1:2013 B beräknad	Ammoniumkväve, NH4-N	0.17	± 0.017	mg/l
ISO 15923-1:2013 C Beräknad	Ammonium, NH4	0.22	± 0.02	mg/l
ISO 15923-1:2013 C beräknad	Nitrat + nitritkväve, NO23-N	0.15	± 0.015	mg/l
ISO 15923-1:2013 D beräknad	Nitratkväve, NO3-N	0.14		mg/l
ISO 15923-1:2013 D beräknad	Nitrat, NO3	0.62		mg/l
SS-EN ISO 10304-1:2009	Nitritkväve, NO2-N	0.0081	± 0.0009	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.20	± 0.045	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	8.5	± 1.3	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	5.0	± 0.90	mg/l
GC/MS	1,1-dikloreten (1)	< 5.0	± 1.2	µg/l
GC/MS	1,2-dikloreten (1)	< 5.0	± 0.75	µg/l
GC/MS	Diklormetan (1)	< 25	± 7.8	µg/l
GC/MS	trans-1,2-dikloreten (1)	< 5.0	± 1.6	µg/l
GC/MS	cis-1,2-dikloreten (1)	230	± 71	µg/l
GC/MS	1,1,1-trikloreten (1)	< 5.0	± 2.1	µg/l
GC/MS	1,1,2-trikloreten (1)	< 5.0	± 1.4	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	4000	± 1200	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	< 5.0	± 1.6	µg/l
GC/MS	Triklloreten (1)	350	± 110	µg/l
GC/MS	Triklormetan (Kloroform) (1)	< 5.0	± 1.6	µg/l
GC/MS	Monoklorbensen (1)	< 5.0	± 1.6	µg/l
GC/MS	Diklorbensener (1)	< 0.6	± 0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**Box 1083, 581 10 Linköping · Tel: 013-25 49 00 · Fax: 013-12 17 28  
ORG.NR 556152-0916 · STYRELSENS SÄTE: LINKÖPINGAckred. nr 1006  
Provning  
ISO/IEC 17025**RAPPORT**Sida 3 (3)  
utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory**Rapport Nr 17129462**

Uppdragsgivare

Lunds Universitet  
Geologiska Institutionen  
Rapportmottagare  
Box 188  
221 00 LUND

Avser

**Grundvatten**Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-19	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11610:1		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 5.0	± 1.3	µg/l
GC/MS	1,1-dikloreten (1)	< 5.0	± 1.7	µg/l
GC/MS	Vinylklorid (1)	< 10		µg/l
SS-EN 1484 utg 1	DOC	5.6	± 0.84	mg/l
SS-EN 1484 utg 1	TOC	5.8	± 0.87	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovägsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO<sub>3</sub>.Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.**Kommentar**

Tiden mellan provtagning och ankomst till laboratoriet har överskridit 1 dygn, vilket kan ha påverkat analysresultatet.

På grund av nödvändig spädning så är en del rapportgränser förhöjda.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.seFrida Björklund  
Analysansvarig

Kontrollnr 3786 1626 8472 0456

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Provning  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (3)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129470**

Uppdragsgivare

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## Avser

**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-19	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11610:2		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.10	±0.02	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	5.0	±0.50	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	30	±3.0	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	2.5	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	8.5	±0.85	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.57	±0.06	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	6.9	±0.69	mg/l
Beräknad	Hårdhet tyska grader	6.1	±0.91	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	0.016	±0.004	mg/l
SS-EN ISO 17294-2:2005	Bor, B	16	±1.6	µg/l
ISO 17294, syrauppslutet	Bor, B	<30	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	7.0	±0.70	mg/l
ISO 11885, syrauppslutet	Kisel, Si	7.1	±1.4	mg/l
ISO 11885, syrauppslutet	Natrium, Na	6.6	±0.66	mg/l
ISO 11885, syrauppslutet	Kalium, K	2.7	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	5.1	±0.51	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	8.3	±0.8	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	560	±84	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	<0.5	±0.18	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	11	±1.7	FNU
SS-EN ISO 7887:2012C mod	Färg	70	±7	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	24.8	±2.48	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	6.7	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	130	±20	mg/l

Kisel är uppslutet med HNO3. Analys av metaller: provet är uppslutet med HNO3 (mikrovägsugn) SS EN ISO 15587-2.

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

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**RAPPORT**

Sida 2 (3)

utfärdad av ackrediterat laboratorium

REPORT issued by an Accredited Laboratory

 **Rapport Nr 17129470** 

Uppdragsgivare

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## Avser

**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-19	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provet märkning	: N11610:2		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	4.2	± 1.1	mg/l
ISO 15923-1:2013 B	Ammoniumkväve, NH <sub>4</sub> -N	0.22	± 0.022	mg/l
beräknad	Ammonium, NH <sub>4</sub>	0.28	± 0.03	mg/l
ISO 15923-1:2013 C	Nitrat + nitritkväve, NO <sub>2</sub> -N	< 0.01	± 0.005	mg/l
Beräknad	Nitratkväve, NO <sub>3</sub> -N	< 0.01		mg/l
beräknad	Nitrat, NO <sub>3</sub>	< 0.3		mg/l
ISO 15923-1:2013 D	Nitritkväve, NO <sub>2</sub> -N	< 0.001	± 0.0009	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.20	± 0.045	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	7.6	± 1.1	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO <sub>4</sub>	4.4	± 0.90	mg/l
GC/MS	1,1-dikloreten (1)	< 5.0	± 1.2	µg/l
GC/MS	1,2-dikloreten (1)	< 5.0	± 0.75	µg/l
GC/MS	Diklormetan (1)	< 25	± 7.8	µg/l
GC/MS	trans-1,2-dikloreten (1)	< 5.0	± 1.6	µg/l
GC/MS	cis-1,2-dikloreten (1)	240	± 74	µg/l
GC/MS	1,1,1-trikloreten (1)	< 5.0	± 2.1	µg/l
GC/MS	1,1,2-trikloreten (1)	< 5.0	± 1.4	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	2300	± 710	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	< 5.0	± 1.6	µg/l
GC/MS	Triklloreten (1)	450	± 140	µg/l
GC/MS	Triklormetan (Kloroform) (1)	< 5.0	± 1.6	µg/l
GC/MS	Monoklorbensen (1)	< 5.0	± 1.6	µg/l
GC/MS	Diklorbensener (1)	< 0.6	± 0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Kisel är uppslutet med HNO<sub>3</sub>. Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2.

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

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ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPINGAckred. nr 1006  
Provning  
ISO/IEC 17025**RAPPORT**

Sida 3 (3)

utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory**Rapport Nr 17129470**

Uppdragsgivare

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Box 188  
221 00 LUND*Avser***Grundvatten**Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-19	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provet märkning	: N11610:2		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 5.0	± 1.3	µg/l
GC/MS	1,1-dikloreten (1)	< 5.0	± 1.7	µg/l
GC/MS	Vinylklorid (1)	< 10		µg/l
SS-EN 1484 utg 1	DOC	5.8	± 0.87	mg/l
SS-EN 1484 utg 1	TOC	6.0	± 0.90	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Kisel är uppslutet med HNO<sub>3</sub>. Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2.Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.**Kommentar**

Tiden mellan provtagning och ankomst till laboratoriet har överskridit 1 dygn, vilket kan ha påverkat analysresultatet.

På grund av nödvändig spädning så är en del rapportgränser förhöjda.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.seFrida Björklund  
Analysansvarig

Kontrollnr 2981 6021 8773 0955

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



**ALcontrol AB**

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 Provning  
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**RAPPORT**

Sida 1 (3)

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**Rapport Nr 17129468**
*Uppdragsgivare*

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 Box 188  
 221 00 LUND

*Avser*
**Grundvatten**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Grundvatten  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-24
Provtagningsstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11611		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-EN ISO 11885-2:2009	Aluminium, Al	0.34	±0.03	mg/l
SS-EN ISO 11885-2:2009	Järn, Fe	0.58	±0.06	mg/l
SS-EN ISO 11885-2:2009	Kalcium, Ca	21	±2.1	mg/l
SS-EN ISO 11885-2:2009	Kalium, K	2.6	±0.80	mg/l
SS-EN ISO 11885-2:2009	Koppar, Cu	<0.02	±0.008	mg/l
SS-EN ISO 11885-2:2009	Magnesium, Mg	7.3	±0.73	mg/l
SS-EN ISO 11885-2:2009	Mangan, Mn	0.44	±0.04	mg/l
SS-EN ISO 11885-2:2009	Natrium, Na	8.2	±0.82	mg/l
Beräknad	Hårdhet tyska grader	4.6	±0.69	°dH
ISO 15923-1:2013 F	Fosfatfosfor, PO4-P	<0.01	±0.004	mg/l
SS-EN ISO 17294-2:2005	Bor, B	15	±1.5	µg/l
ISO 17294, syrauppslutet	Bor, B	<30	±18	µg/l
SS-EN ISO 11885-2:2009	Kisel, Si	7.1	±0.71	mg/l
ISO 11885, syrauppslutet	Kisel, Si	11	±2.2	mg/l
ISO 11885, syrauppslutet	Natrium, Na	8.5	±0.85	mg/l
ISO 11885, syrauppslutet	Kalium, K	2.9	±0.63	mg/l
ISO 11885, syrauppslutet	Järn, Fe	2.3	±0.23	mg/l
ISO 11885, syrauppslutet	Magnesium, Mg	7.8	±0.8	mg/l
ISO 17294, syrauppslutet	Mangan, Mn	470	±71	µg/l
ISO 17294, syrauppslutet	Koppar, Cu	3.0	±0.45	µg/l
SS-EN ISO 7027-1:2016	Turbiditet FNU	23	±3.5	FNU
SS-EN ISO 7887:2012C mod	Färg	10	±2	mg/l Pt
SS-EN 27888-1	Konduktivitet 25 °C	21.1	±2.11	mS/m
SS-EN ISO 10523:2012	pH vid 20 °C	6.7	±0.2	
SS-EN ISO 9963-2, utg 1	Alkalinitet, HCO3	89	±13	mg/l

Analys av metaller: provet är uppslutet med HNO3 (mikrovågsgugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

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Provning  
ISO/IEC 17025**RAPPORT**

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REPORT issued by an Accredited Laboratory**Rapport Nr 17129468**

Uppdragsgivare

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221 00 LUND

## Avser

**Grundvatten**Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-24
Provtagningstidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provet märkning	: N11611		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
fd SS028118-1	Kemisk syreförbrukn. COD-Mn	2.4	±0.60	mg/l
ISO 15923-1:2013 B beräknad	Ammoniumkväve, NH4-N	0.095	±0.010	mg/l
	Ammonium, NH4	0.12	±0.01	mg/l
ISO 15923-1:2013 C Beräknad	Nitrat + nitritkväve, NO23-N	0.30	±0.030	mg/l
	Nitratkväve, NO3-N	0.29		mg/l
	Nitrat, NO3	1.3		mg/l
ISO 15923-1:2013 D	Nitritkväve, NO2-N	0.012	±0.0012	mg/l
SS-EN ISO 10304-1:2009	Fluorid, F	0.24	±0.045	mg/l
SS-EN ISO 10304-1:2009	Klorid, Cl	12	±1.8	mg/l
SS-EN ISO 10304-1:2009	Sulfat, SO4	6.5	±0.98	mg/l
GC/MS	1,1-dikloreten (1)	< 10	±2.3	µg/l
GC/MS	1,2-dikloreten (1)	< 10	±1.5	µg/l
GC/MS	Diklormetan (1)	< 50	±16	µg/l
GC/MS	trans-1,2-dikloreten (1)	< 10	±3.1	µg/l
GC/MS	cis-1,2-dikloreten (1)	51	±16	µg/l
GC/MS	1,1,1-trikloreten (1)	< 10	±4.1	µg/l
GC/MS	1,1,2-trikloreten (1)	< 10	±2.7	µg/l
GC/MS	Tetrakloreten(perkloretylen) (1)	11000	±3400	µg/l
GC/MS	Tetraklormetan (koltetrakl.) (1)	< 10	±3.1	µg/l
GC/MS	Triklloreten (1)	220	±68	µg/l
GC/MS	Triklormetan (Kloroform) (1)	< 10	±3.1	µg/l
GC/MS	Monoklorbensen (1)	< 10	±3.1	µg/l
GC/MS	Diklorbensener (1)	< 0.6	±0.19	µg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO3 (mikrovågsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO3.

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

(forts.)

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

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Provning  
ISO/IEC 17025**RAPPORT**

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REPORT issued by an Accredited Laboratory

**Rapport Nr 17129468**

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Box 188  
221 00 LUND

## Avser

**Grundvatten**Rubrik 1 : Hagfors  
Rubrik 2 : Grundvatten  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-24
Provtagnings tidpunkt	: -	Ankomsttidpunkt	: 1000
Temperatur vid provtagning	: -	Temperatur vid ankomst	: 5 °C
Provets märkning	: N11611		
Provtagare	: SA/NBH		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
GC/MS	1,2-diklorpropan (1)	< 10	± 2.6	µg/l
GC/MS	1,1-dikloreten (1)	< 10	± 3.3	µg/l
GC/MS	Vinylklorid (1)	< 20		µg/l
SS-EN 1484 utg 1	DOC	4.1	± 0.61	mg/l
SS-EN 1484 utg 1	TOC	4.1	± 0.61	mg/l
SS-EN ISO 10304-1:2009	Bromid, Br	< 1	± 0.20	mg/l

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Analys av metaller: provet är uppslutet med HNO<sub>3</sub> (mikrovågsugn) SS EN ISO 15587-2. Kisel är uppslutet med HNO<sub>3</sub>.Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.**Kommentar**

Tiden mellan provtagning och ankomst till laboratoriet har överskridit 2 dygn, vilket kan ha påverkat analysresultatet.

På grund av nödvändig spädning så är en del rapportgränser förhöjda.  
Detta medför också att mätosäkerheten är högre än vad som angivits ovan.

Linköping 2017-05-09

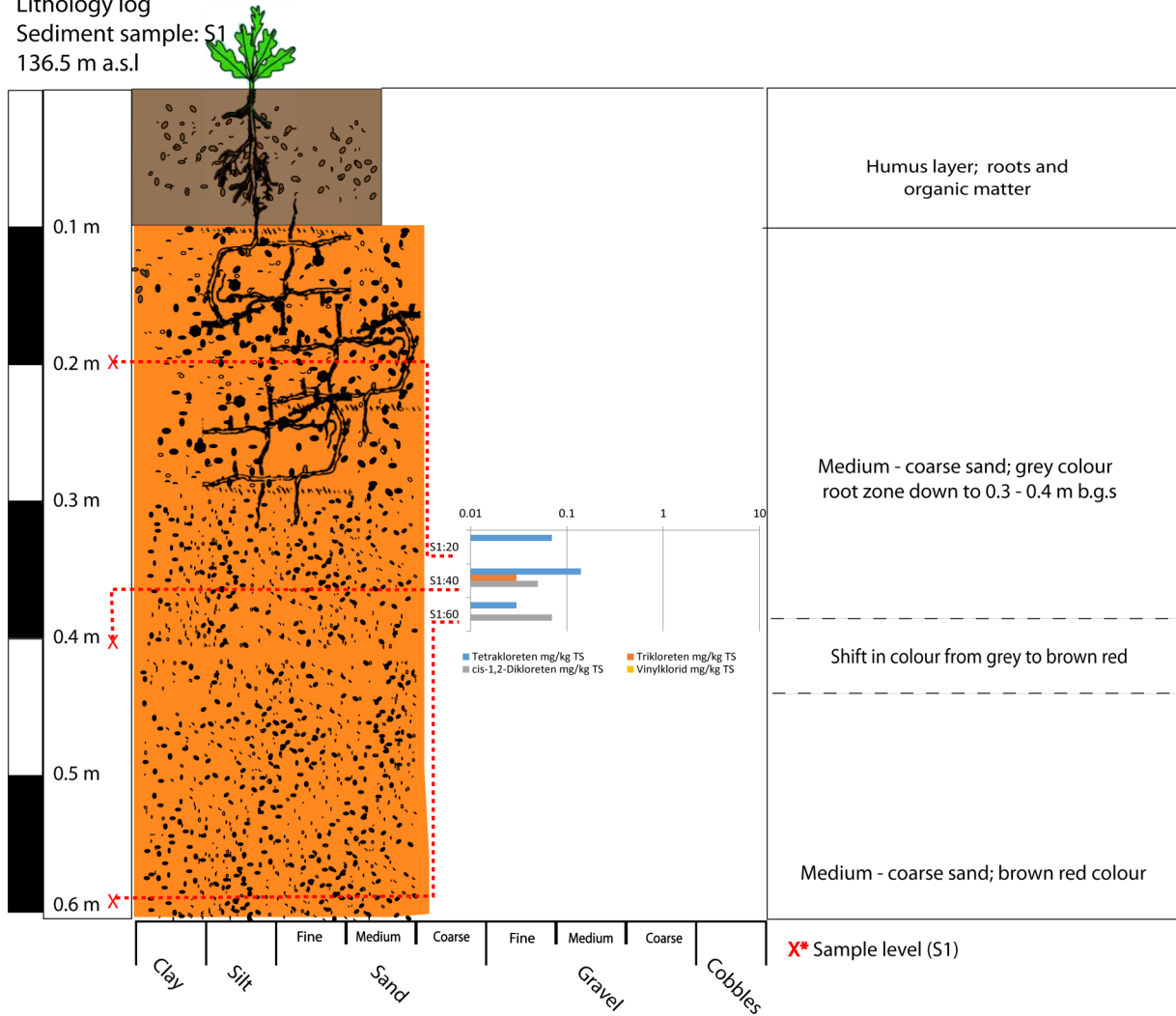
Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.seIngrid Södersten  
Granskningsansvarig

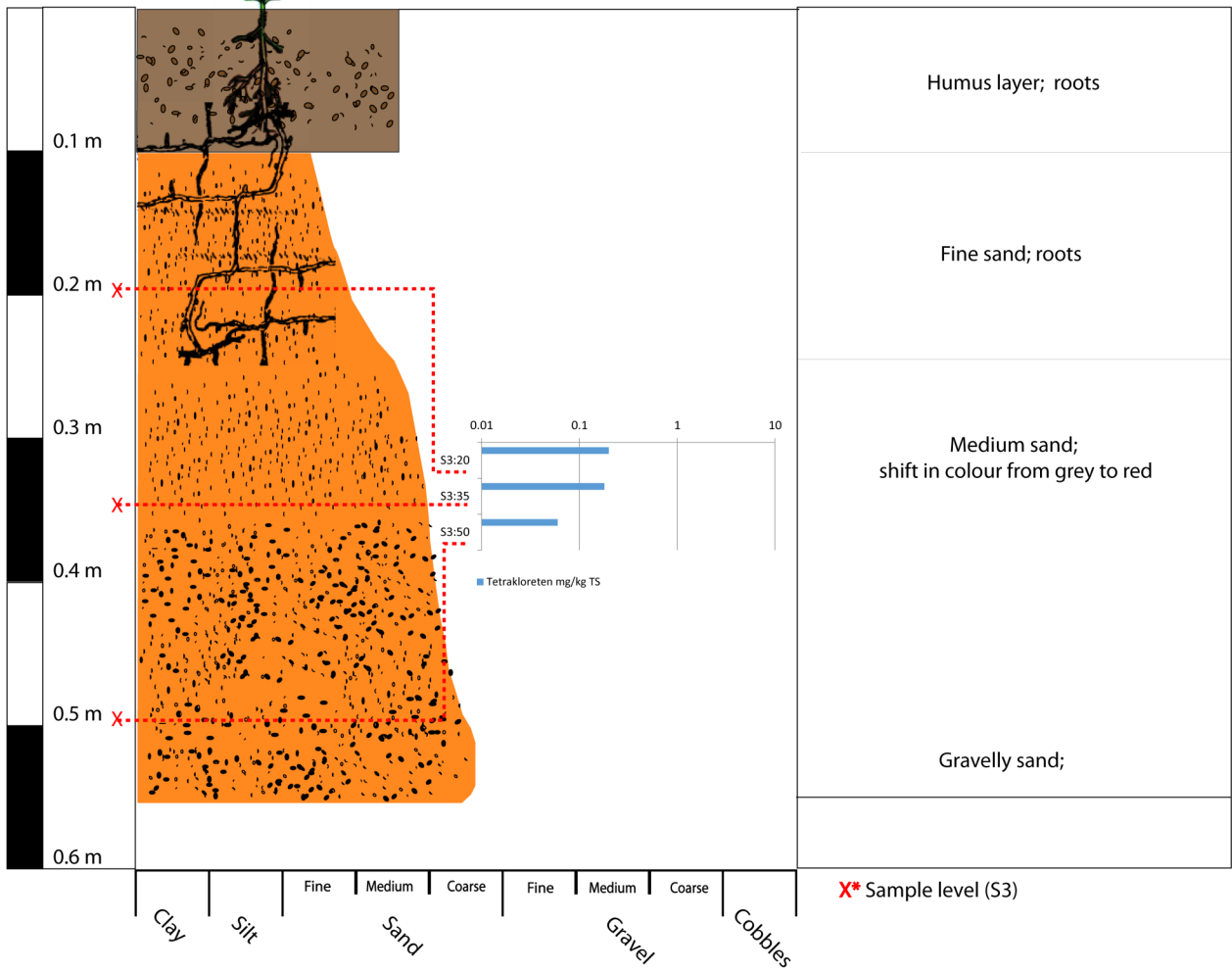
Kontrollnr 3186 1628 8876 0259

# Appendix II

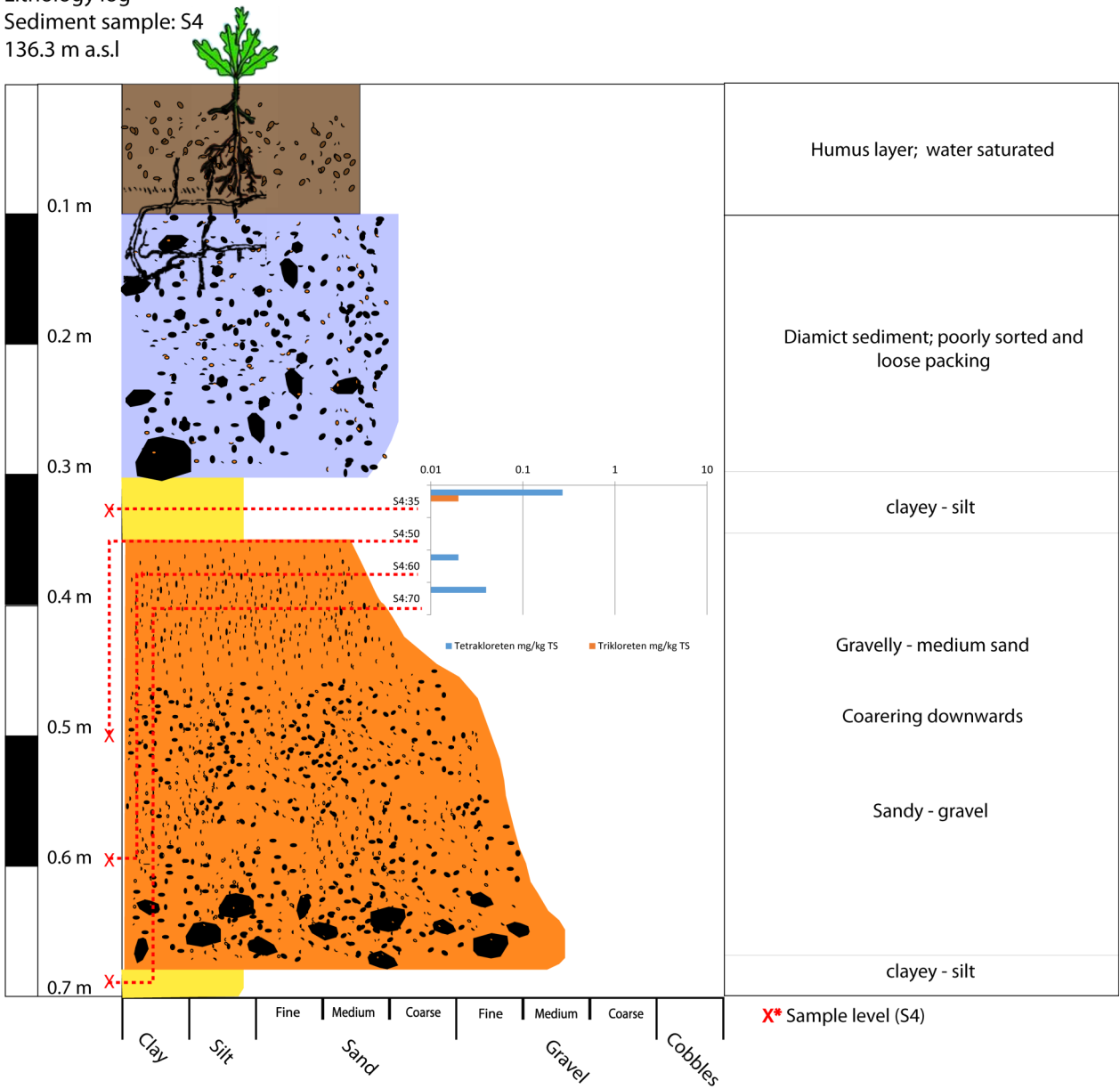
Lithology log  
 Sediment sample: S1  
 136.5 m a.s.l



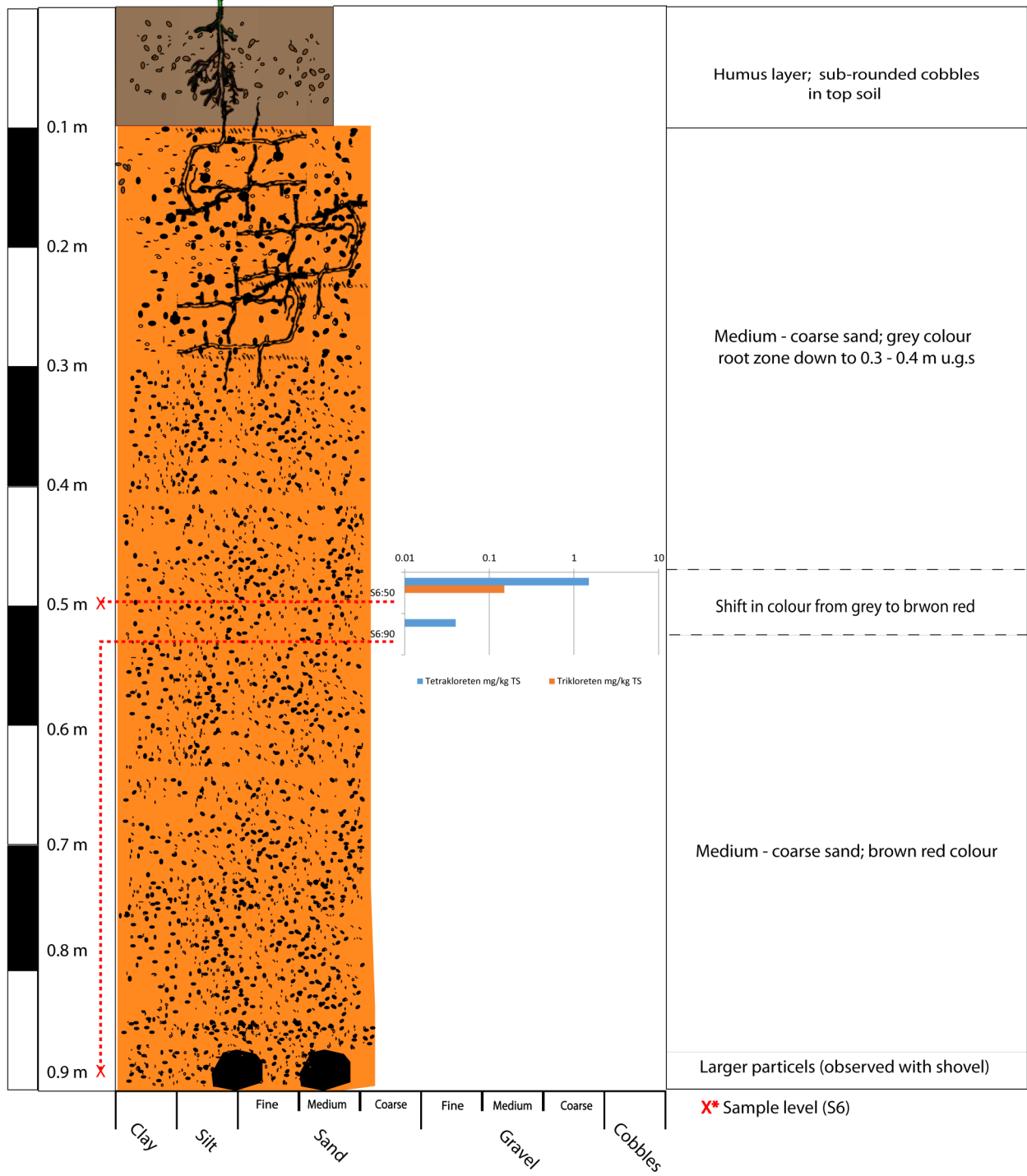
Lithology log  
 Sediment sample: S3  
 136.3 m a.s.l



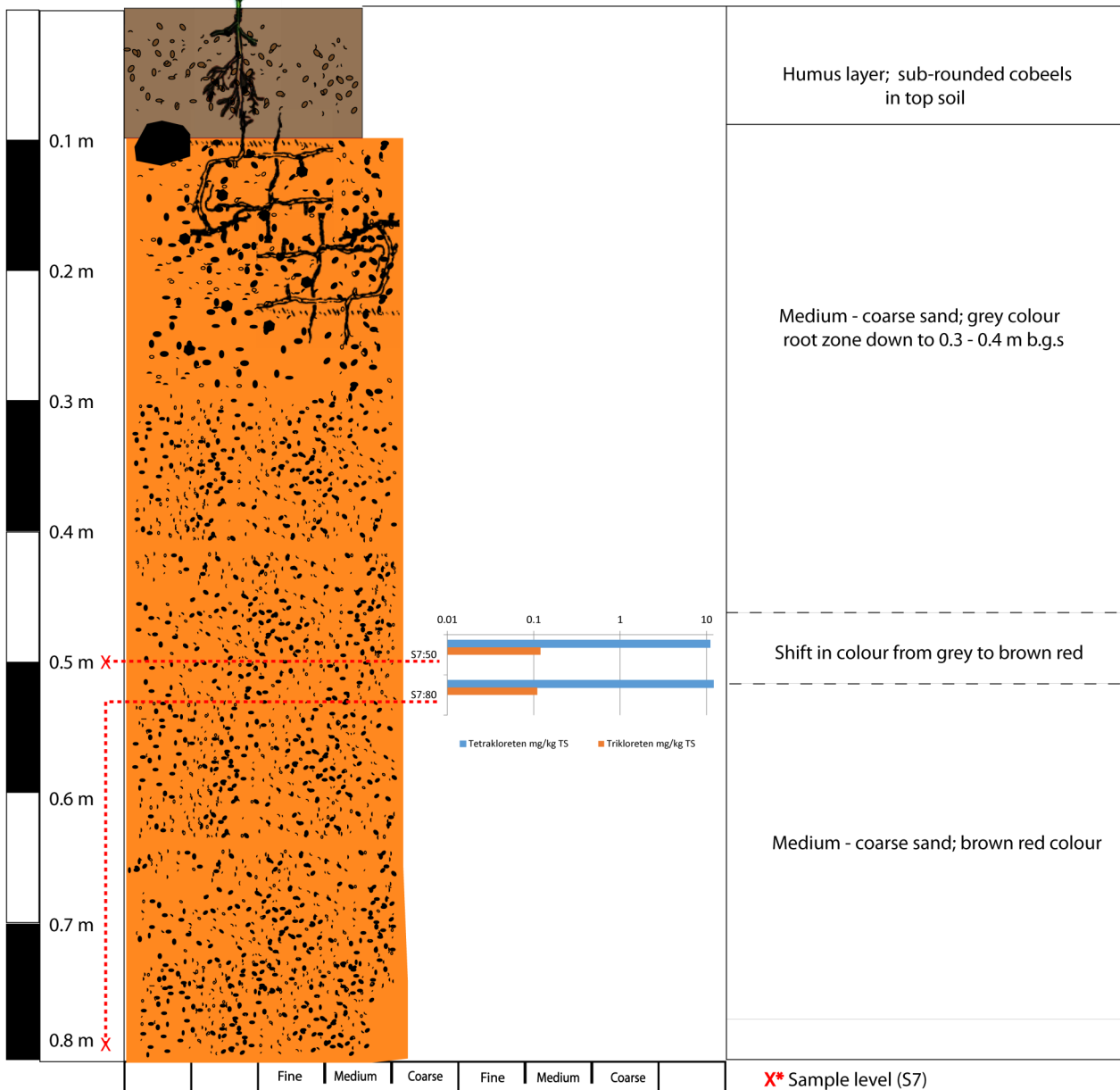
Lithology log  
 Sediment sample: S4  
 136.3 m a.s.l



Lithology log  
 Sediment sample: S6  
 136.5 m a.s.l



Lithology log  
 Sediment sample: S7  
 136.5 m a.s.l





## Appendix III

The collected soil samples were sent to the laboratory, ALcontrol Laboratories, Linköping. Samples were kept cold in a cooler during transport. The soil samples were analysed for chlorinated solvents: (Dichloromethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,2-dichloromethane, trans-1,2-dichloroethene, *cis*-1,2-dichloroethene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, Tetrachloroethene, Tetrachloromethane, Trichloroethene, Trichloromethane, Monochlorobenzene, 1,2-dichlorobenzenes, 1,3-dichlorobenzenes, 1,4-dichlorobenzenes, 1,2,3-trichlorobensen, 1,2,4-trichlorobensen and vinyl chloride).

**ALcontrol AB**

 Box 1083, 581 10 Linköping · Tel: 013-25 49 00 · Fax: 013-12 17 28  
 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Provning  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129450**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

**Avser**
**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.2 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 1	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	78.6	± 7.86	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	0.07	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

 Kopia sänds till  
 charlotte.sparrenbom@geol.lu.se

 Frida Björklund  
 Analysansvarig

Kontrollnr 4986 2164 8379 0852

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Akkred. nr 1006  
 Proving  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129444**

Uppdragsgivare

 Lunds Universitet  
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 Rapportmottagare  
 Box 188  
 221 00 LUND

Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.4 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 1	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	72.3	± 7.23	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloretan	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloretan	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	0.14	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromdiklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Angiven mätosäkerhet är beräknad med täckningsfaktor k = 2. Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

 Frida Björklund  
 Analysansvarig

Kontrollnr 5583 2416 8370 0458

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Akred. nr 1006  
 Provning  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129456**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
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 Box 188  
 221 00 LUND

## Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-20	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.6 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 1	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	69.3	± 6.93	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	0.07	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklöreten	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloreten	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloreten	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklöreten	0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

 Ingrid Södersten  
 Granskningsansvarig

Kontrollnr 4380 2164 8577 0456

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Proving  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129453**
*Uppdragsgivare*

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

**Avser**
**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.2 m	Ankomsttidpunkt	: 1030
Provet märkning	: Jordprov 2	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	75.7	± 7.57	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloretan	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloretan	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloretan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloretan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	0.83	± 0.21	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenborj@geol.lu.se

 Ingrid Södersten  
 Granskningsansvarig

Kontrollnr 4686 2169 8371 0756

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**Rapport Nr 17129451**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.45 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 2	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	77.3	± 7.73	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklloreten	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Triklloreten	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Triklloreten	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklloreten	0.07	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

 Frida Björklund  
 Analysansvarig

Kontrollnr 4886 2165 8673 0752

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Proving  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

 **Rapport Nr 17129452** 

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

**Avser**
**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.5 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 2	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	74.3	± 7.43	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	0.43	± 0.13	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	0.41	± 0.10	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	2.1	± 0.53	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	0.03	± 0.02	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr LO28

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

 Frida Björklund  
 Analysansvarig

Kontrollnr 4785 2167 8674 0757

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Akred. nr 1006  
 Provning  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129454**
*Uppdragsgivare*

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

**Avser**
**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.2 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 3	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	78.4	± 7.84	%
SS-EN ISO 22155:2016 mod	Diklormetan	<0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	<0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	<0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	<0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	<0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	<0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	<0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	<0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	<0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	<0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	<0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	0.20	± 0.05	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	<0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	<0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	<0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	<0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	<0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	<0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	<0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	<0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	<0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	<0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

Ingrid Södersten

Granskningsansvarig

Kontrollnr 4589 2168 8078 0956

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Proving  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129455**

Uppdragsgivare

 Lunds Universitet  
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 Box 188  
 221 00 LUND

## Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.35 m	Ankomsttidpunkt	: 1030
Provet märkning	: Jordprov 3	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	78.9	± 7.89	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	0.18	± 0.05	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr LO28

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

 Kopia sänds till  
 charlotte.sparrenbom@geol.lu.se

 Ingrid Södersten  
 Granskningsansvarig

Kontrollnr 4489 2165 8073 0458

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



## ALcontrol AB

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING



Akred. nr 1006  
 Proving  
 ISO/IEC 17025



## RAPPORT

Sida 1 (1)

utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129440**

Uppdragsgivare

Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

## Mark

Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.5 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 3	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torssubstans	74.7	± 7.47	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklloreten	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Triklloreten	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Triklloreten	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	0.06	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr LO28

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

Frida Björklund  
 Analysansvarig

Kontrollnr 5981 2516 8774 0751

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



## ALcontrol AB

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Akred. nr 1006  
 Provning  
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## RAPPORT

Sida 1 (1)

utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

## Rapport Nr 17129445

Uppdragsgivare

Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

## Mark

Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.35 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 4	Temperatur vid ankomst	: 5 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	77.1	± 7.71	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	0.27	± 0.07	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

Frida Björklund  
 Analysansvarig

Kontrollnr 5487 2616 8276 0354

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

*Avser*
**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.50 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 4	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	86.3	±8.63	%
SS-EN ISO 22155:2016 mod	Diklormetan	<0.01	±0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	<0.003	±0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	<0.05	±0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	<0.01	±0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	<0.05	±0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	<0.05	±0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	<0.02	±0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	<0.02	±0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	<0.1	±0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	<0.03	±0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	<0.01	±0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	0.01	±0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	<0.01	±0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	<0.05	±0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	<0.03	±0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	<0.1	±0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	<0.1	±0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	<0.07	±0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	<0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	<0.05	±0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	<0.05	±0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	<0.02	±0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

 Frida Björklund  
 Analysansvarig

Kontrollnr 5689 2816 8970 0755

 Kopia sänds till  
 charlotte.sparrenbom@geol.lu.se

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



## ALcontrol AB

Box 1083, 581 10 Linköping · Tel: 013-25 49 00 · Fax: 013-12 17 28  
 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING



Akred. nr 1006  
 Proving  
 ISO/IEC 17025



## RAPPORT

Sida 1 (1)

utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129442**

Uppdragsgivare

Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

## Mark

Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

## Information om provet och provtagningen

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.6 m	Ankomsttidpunkt	: 1030
Provet märkning	: Jordprov 4	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

## Analysresultat

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torssubstans	79.9	± 7.99	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklloreten	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Triklloreten	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Triklloreten	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr LO28

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

Frida Björklund  
 Analysansvarig

Kontrollnr 5785 2216 8775 0858

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Provnings  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129441**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.7 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 4	Temperatur vid ankomst	: 2 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	76.0	± 7.60	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	0.04	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

 Kopia sänds till  
 charlotte.sparrenbom@geol.lu.se

 Frida Björklund  
 Analysansvarig

Kontrollnr 5889 2116 8878 0854

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



## ALcontrol AB

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING



Akred. nr 1006  
 Proving  
 ISO/IEC 17025



## RAPPORT

Sida 1 (1)

utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129449**

Uppdragsgivare

Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

**Mark**

Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.3 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 5	Temperatur vid ankomst	: 5 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	69.8	± 6.98	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	0.14	± 0.04	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	0.12	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	1.1	± 0.28	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräkнад	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbor@geol.lu.se

Frida Björklund  
 Analysansvarig

Kontrollnr 5089 2016 8477 0254

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Akred. nr 1006  
 Provnings  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129446**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.4 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 5	Temperatur vid ankomst	: 5 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	64.5	± 6.45	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	0.18	± 0.05	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	0.09	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	0.47	± 0.12	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

 Kopia sänds till  
 charlotte.sparrenbom@geol.lu.se

 Frida Björklund  
 Analysansvarig

Kontrollnr 5384 2616 8879 0353

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.



**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Proving  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129447**
*Uppdragsgivare*

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

*Avser*
**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-25	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.5 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 5	Temperatur vid ankomst	: 5 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torssubstans	65.9	± 6.59	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	2.5	± 0.75	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklloreten	0.72	± 0.18	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Triklloreten	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Triklloreten	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloreten	1.1	± 0.28	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	0.03	± 0.02	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr LO28

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

Frida Björklund

Analysansvarig

Kontrollnr 5287 2216 8576 0757

**ALcontrol AB**Box 1083, 581 10 Linköping · Tel: 013-25 49 00 · Fax: 013-12 17 28  
ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPINGAckred. nr 1006  
Provning  
ISO/IEC 17025**RAPPORT**

Sida 1 (1)

utfärdad av ackrediterat laboratorium  
REPORT issued by an Accredited Laboratory**Rapport Nr 17129448**

Uppdragsgivare

Lunds Universitet  
Geologiska Institutionen  
Rapportmottagare  
Box 188  
221 00 LUND

## Avser

**Mark**Rubrik 1 : Hagfors  
Rubrik 2 : Mark  
Rubrik 3 : Kemisk**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-26	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.50 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 6	Temperatur vid ankomst	: 5 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	73.4	± 7.34	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	0.15	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	1.5	± 0.38	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till  
charlotte.sparrenbom@geol.lu.seFrida Björklund  
Analysansvarig

Kontrollnr 5185 2116 8575 0353

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

 Box 1083, 581 10 Linköping - Tel: 013-25 49 00 - Fax: 013-12 17 28  
 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Ackred. nr 1006  
 Proving  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (1)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129439**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-26	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.90 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 6	Temperatur vid ankomst	: 5 °C
Provtagare	: PJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	65.4	± 6.54	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Trikloretan	< 0.02	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Trikloretan	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Trikloretan	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetrakloretan	0.04	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

Linköping 2017-05-08

Rapporten har granskats och godkänts av

Kopia sänds till

charlotte.sparrenbom@geol.lu.se

 Frida Björklund  
 Analysansvarig

Kontrollnr 6083 2481 6275 0950

Denna rapport får endast återges i sin helhet, om inte utfärdande laboratorium i förväg skriftligen godkänt annat.

**ALcontrol AB**

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 ORG.NR 556152-0916 STYRELSENS SÄTE: LINKÖPING

 Akred. nr 1006  
 Provnings  
 ISO/IEC 17025

**RAPPORT**

Sida 1 (2)

 utfärdad av ackrediterat laboratorium  
 REPORT issued by an Accredited Laboratory

**Rapport Nr 17129457**

Uppdragsgivare

 Lunds Universitet  
 Geologiska Institutionen  
 Rapportmottagare  
 Box 188  
 221 00 LUND

## Avser

**Mark**

 Rubrik 1 : Hagfors  
 Rubrik 2 : Mark  
 Rubrik 3 : Kemisk

**Information om provet och provtagningen**

Provtagningsdatum	: 2017-04-26	Ankomstdatum	: 2017-04-27
Provtagningsdjup	: 0.50 m	Ankomsttidpunkt	: 1030
Provets märkning	: Jordprov 7	Temperatur vid ankomst	: 5 °C
Provtagare	: RJ		
Fakturareferens	: Sofia Åkesson		
Projektkod	: 124573-TD		

**Analysresultat**

Metodbeteckning	Analys/Undersökning av	Resultat	Mätosäkerhet	Enhet
SS-ISO 11465-1:1995	Torrsubstans	78.4	± 7.84	%
SS-EN ISO 22155:2016 mod	Diklormetan	< 0.01	± 0.005	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dibrometan	< 0.003	± 0.0009	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1-Dikloreten	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-Dikloreten	< 0.01	± 0.007	mg/kg TS
SS-EN ISO 22155:2016 mod	cis-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2013 mod	trans-1,2-Dikloreten	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklormetan (Kloroform)	< 0.02	± 0.006	mg/kg TS
SS-EN ISO 22155:2016 mod	Triklöreten	0.12	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,1-Triklöreten	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,1,2-Triklöreten	< 0.03	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklormetan (koltetrakl.)	< 0.01	± 0.002	mg/kg TS
SS-EN ISO 22155:2016 mod	Tetraklöreten	11	± 2.8	mg/kg TS
SS-EN ISO 22155:2016 mod	Bromdiklormetan	< 0.01	± 0.003	mg/kg TS
SS-EN ISO 22155:2016 mod	Dibromklormetan	< 0.05	± 0.02	mg/kg TS
SS-EN ISO 22155:2016 mod	Monoklorbensen	< 0.03	± 0.008	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2-diklorbensen	< 0.1	± 0.03	mg/kg TS
SS-EN ISO 22155:2016 mod	1,3-diklorbensen	< 0.1	± 0.04	mg/kg TS
SS-EN ISO 22155:2016 mod	1,4-diklorbensen	< 0.07	± 0.02	mg/kg TS
Beräknad	S:a Mono- och Diklorbensener	< 0.1		mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,3-triklorbensen	< 0.05	± 0.01	mg/kg TS
SS-EN ISO 22155:2016 mod	1,2,4-triklorbensen	< 0.05	± 0.01	mg/kg TS
HS-GC-MS	Vinylklorid (1)	< 0.02	± 0.01	mg/kg TS

(1) Resultat levererat av ALcontrol B.V.NL. RvA acknr L028

 Angiven mätosäkerhet är beräknad med täckningsfaktor  $k = 2$ . Mätosäkerheten för ackrediterade mikrobiologiska analyser kan erhållas från laboratoriet efter begäran.

## Kommentar

(forts.)

## Appendix IV

Inversion settings example Line 1:

eLayerCount=20

eRefDist=0

eNumberOfCPU=1

cbXContanimatedLatFactor=0.2

edXTiltSTD=1

cbxAltApri=30

cbxAltApriSTD=2

cbxAltLatSTD=0.3

cbAutoRes=1

DOINLayers=20

DOIDepth1=0.26

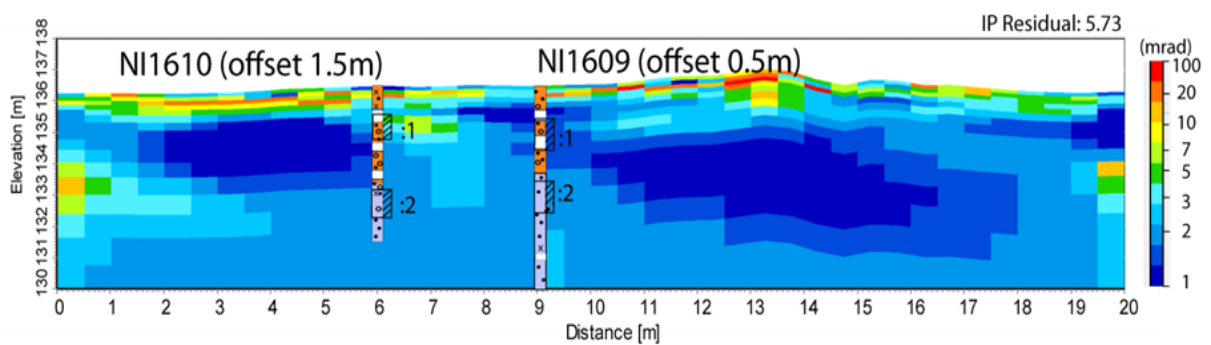
DOIDepthN=10.74

LogData=0

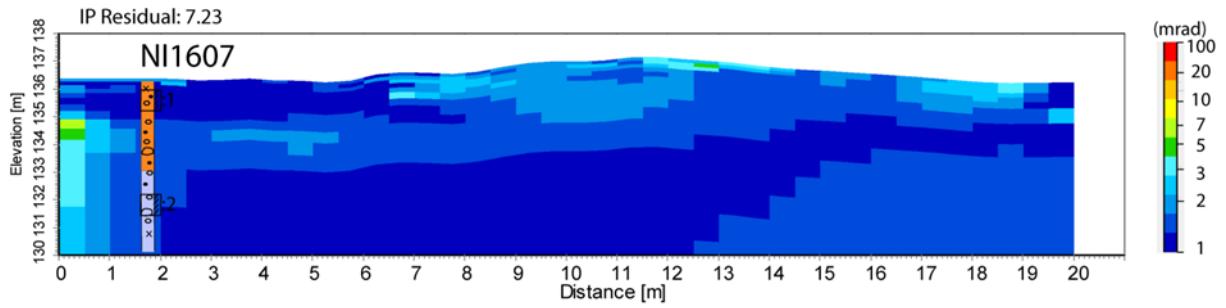
LogDepth=0

DepthRef=1

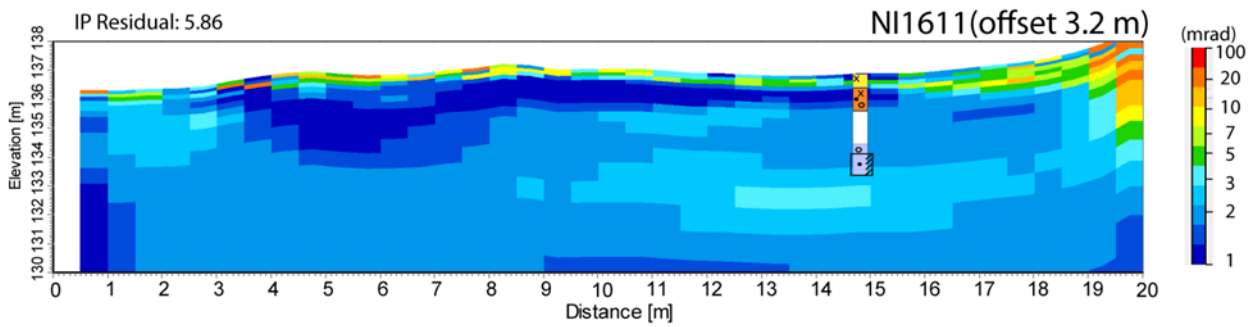
IP model for DCIP line 2



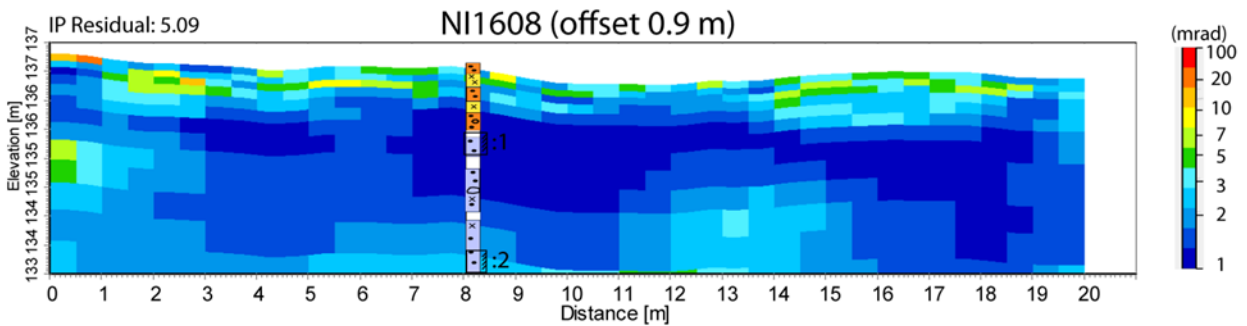
IP model for DCIP line 3



IP model for DCIP line 4



IP model for DCIP line 5



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Lunds universitet  
Sölvegatan 12, 223 62 Lund



