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Master’s thesis

HYDROGEOLOGY AND HYDROGEOCHEMISTRY OF THE WESTERN MARGIN OF THE VIIANKIAAPA MIRE IN SODANKYLÄ

- FACTORS AFFECTING THE DISTRIBUTION OF ENDANGERED SPECIES

University of Helsinki
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Geology
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Hydrogeology and hydrogeochemistry of the western margin of the Viiankiaapa mire in Sodankylä – Factors affecting the distribution of endangered species

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Tiivistelmä — Referat — Abstract

Viiankiaapa mire, located in the municipality of Sodankylä, has drawn public attention after mining company, AA Sakatti Mining Oy published their discovery in 2011. The discovered Ni-Cu-PGE ore deposit, Sakatti, is located mainly under the Natura 2000 protected Viiankiaapa. Viiankiaapa is Natura 2000 protected due to the several natural habitat types and plant species one of these, *H. vernicosus* is known to thrive at the areas of groundwater influence. The Sakatti deposit is in exploration phase but it is possible that mining will start in future. Knowing the hydrogeology of the area is crucial for preventing possible negative changes if the mining starts. In this study the objectives were to study 1) the influence of groundwater at the western margin of Viiankiaapa, 2) the influence of Sakatti ore deposit to the hydrogeochemistry of the area, 3) the influence of hydrology and hydrogeochemistry to the endangered *H. vernicosus* species.

The sampling was done in September and October 2016, March and April 2017 and continued in summer 2017. Samples were collected from surface water of the mire, groundwater, spring water as well as from different depth of peat pore water using mini-piezometer. EC, pH, temperature, stable isotopes, DSi, main ions, trace elements and dissolved organic carbon (DOC) were analyzed.

The groundwater influence was visible at the area of Lake Viiankijärvi and Särkikoskenmaa fluvial sediment deposit. Depth profiles of stable isotopes and main ions indicated groundwater flow in deep peat layer and mixing with surface water as the groundwater flow upwards through the peat layer. At the Sakatti ore deposit area the isotopic composition of surface water samples represented mainly season's precipitation with few exceptions. Possible groundwater discharge was visible at the area between Sakatti main deposit and River Kitinen as well as near Pahanlaaksonmaa. The isotopic chemistry of spring water samples at the bend of River Kitinen had values of mixed groundwater and surface water. It is likely that the mire water infiltrates through the peat layer and fluvial sediments and discharges to the springs and River Kitinen. The bedrock of the area is known to be weathered, which could explain surface water like isotope values in springs and in some of the bedrock groundwater observation wells.

Positive correlation was found between *H. vernicosus* ecosystems and the depth of peat. A ribbon-shaped zone of habitats and 2 – 4 m thick peat layer crosses the mire. The correlation with groundwater discharge was not clear. Ca and Mg concentrations were smaller but pH and alkalinity were higher at the areas of *H. vernicosus* ecosystems. However the Ca and Mg concentrations resembled areal spring water chemistry, which could indicate groundwater influence. Areas without the ecosystems are located mainly near the Sakatti ore deposit. The influence of the deposit in hydrogeochemistry was locally visible as elevated electric conductivity, main ion and trace element concentrations of the surface water and peat pore water. This most likely explains why the areas without the ecosystems had higher element concentrations.

Avainsanat — Nyckelord — Keywords

Hydrogeology, hydrogeochemistry, Hamatocaulis vernicosus.

Säilytyspaikka — Förvaringsställe — Where deposited

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Viiankiaavan länsireunan hydrologia ja hydrogeokemia – Vaarantuneen sammallajin levinneisyyteen vaikuttavat tekijät

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Tiivistelmä — Referat — Abstract

Sodankylässä sijaitsevan Viiankiaavan aapasuoalue on herättänyt kansallista mielenkiintoa vuoden 2011 jälkeen, AA Sakatti Mining Oy:n ilmoittaessaan suuresta malmilöydöstä. Tämä Sakatti malmina tunnettu Ni-Cu-PGE esiintymä sijaitsee Natura 2000 –alueena suojellun Viiankiaavan länsireunalla, jääden pääsääntöisesti suojelualueen alle. Viiankiaavalta on löytynyt useampi Natura 2000 luontodirektiiveihin kuuluva laji, yksi näistä on pohjavesivaikutteisessa ympäristössä viihtyvä kiiltosirppisammal (*Hamatocaulis vernicosus*). Vaikka Sakatin kaivoshanke on tänä päivänä vasta malminetsintävaiheessa, on alueen hydrogeologian tunteminen tärkeää. Tässä työssä selvitettiin 1) pohjavesivaikutusta Viiankiaavan länsireunalla, 2) Sakattimalmin vaikutusta alueen hydrogeokemiaan, 3) hydrologian ja hydrogeokemian vaikutusta vaarantuneen *H. vernicosuksen* esiintyvyyteen.

Näytteet kerättiin syys-, lokakuussa 2016, maalis-, huhtikuussa 2017 ja kesällä 2017. Näytteitä kerättiin niin pintavedestä, pohjavesiputkista, lähteistä kuin minipietsometrillä eri syvyydeltä turpeen huokosvedestä. Näytteistä analysoitiin EC, pH, lämpötila, hapen ja vedyn stabiilit isotoopit, DSi, pääionikoostumus, alkaliniteetti, hivenalkuaineita sekä liuennut orgaaninen hiili (DOC).

Pohjavesivaikutus oli selkeintä Viiankijärven ja Särkikoskenmaan fluviaalisedimenttimuodostuman välisellä alueella. Varsinkin syvät turpeen huokosvedet osoittivat pohjaveden liikettä turpeessa ja purkautumista kohti Viiankijärveä sekä turvekerroksen pintaosia sekoittuen samalla pintaveden kanssa. Sakattimalmin alueella, pintavesinäytteet sekä turveveden syvyysprofiilit kuvastivat pääsääntöisesti isotooppikoostumukseltaan vuodenaikaista sadantaa. Mahdollista pohjaveden purkautumista tapahtui kuitenkin Sakattimalmin ja Kitisen joen välissä sekä Pahanlaaksonmaan lähettyvillä. Kitisen joen reunavallien lähteiden isotooppikoostumus kuvasti sekoittunutta pinta- ja pohjavettä, jonka perusteella voidaan olettaa, että Viiankiaavan pintavettä suotautuu jokipenkan fluviaalisedimenttien läpi lähteisiin sekä Kitisen jokeen. Myös mahdollinen kallioperän rapauma ja rikkonaisuus voisi selittää pintavesien kaltaisia tuloksia lähteissä sekä osassa kallioperään ulottuvassa pohjavesiputkessa.

Positiivinen korrelaatio löydettiin *H. vernicosuksen* ja turvepaksuuden kanssa. Sammallaji oli runsaimmillaan alueilla, jossa turvepaksuus oli 2 – 4 m. Pohjaveden vaikutus *H. vernicosuksen* esiintyvyyteen ei ollut täysin selvä. Ca ja Mg pitoisuudet olivat pienempiä alueilla, joilla ekosysteemi viihtyi, mutta pH ja alkaliteetti suurempia. *H. vernicosus* esiintyvyysalueella Ca ja Mg pitoisuudet muistuttivat kuitenkin Lapin liuskekivivyöhykealueen lähdevesien pitoisuuksia, mikä voisi viitata pohjavesivaikutukseen. Alueet, mistä ekosysteemejä ei esiintynyt sijoittuivat pääsääntöisesti Sakatin malmin läheisyyteen. Malmin vaikutus näkyi alueellisesti suon pintavedessä, nostaen malmialueen pääioni- sekä hivenainepitoisuuksia ja sähkönjohtavuutta. Tämä selittänee myös miksi alueilla, jossa ekosysteemejä ei tavattu oli korkeat alkuainepitoisuudet.

Avainsanat — Nyckelord — Keywords

Hydrogeologia, hydrogeokemia, Hamatocaulis vernicosus

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Contents

1. INTRODUCTION

Viiankiaapa, a Natura 2000 protected aapamire, is located in northern Finland in municipality of Sodankylä. In 2009 a large, globally significant Ni-Cu-PGE ore deposit, named Sakatti, was discovered underneath the Viiankiaapa mire (Brownscombe *et al.* 2015). The setting of Natura 2000 protected area and a potential mine site is complicated and it has drawn a lot of public attention. There has even been discussion weather the protection should be completely or partly canceled in future if the mining begins. The Sakatti project is currently in exploration phase and environmental impact assessment of the possible mine is on progress.

Aapamire, as Viiankiaapa, is the most common mire type in northern Finland (Maunu and Virtanen 2005). So-called aapamire zone reaches from the Central Finland almost to the northernmost Lapland (Lappalainen 2004, 26). In southern Finland aapamires are rare and most dominant mire type is raised bog (Solantie, 2006). The most important factor for this distribution of aapamires and raised bogs is the ratio of areal precipitation and evapotranspiration between northern and southern Finland. In northern areas the evapotranspiration is smaller than in south and thus the amount of excess water is greater (Solantie, 2006). Bogs and fens do not only differ in hydrology but also in nutrient content that, however is very strongly affected by areal hydrology. If simplifying bogs are low in nutrients (ombrotrophic bogs), they are elevated from the ground surface and therefore only fed by rainwater. Fens are fed, in addition to rainwater, with groundwater as well as surface water runoff and spring floodings that carry high amounts of nutrients compared to rainwater (minerotrophic fens) (Lappalainen 2004, 23). Hydrological conditions do not only vary between different mire types but also within a single aapamire causing heterogeneous areas. Center of the aapamire is usually treeless, wet fen whereas dryer swamps are occasionally found from the margins. Patterns of flarks and strings are common in aapamire (Maunu and Virtanen 2005). The spatial variation in wetness, in the stability of water table and in hydrogeochemistry causes also variation in thriving plant species. The hydrology and vegetation are strongly interdependent and even minor changes in hydrology and thus in hydrochemistry might cause extensive changes in vegetation (Mitch and Gosselink, 2007). The areas of groundwater discharge within the mire and in general have often a specific kind of vegetation that mainly thrives at the areas where water chemistry has features of groundwater and surface water (Kløve *et al.* 2011). The moss species *Hamatocaulis vernicosus* and *Hamatocaulis Lapponicus,* are known to thrive in these kind of environments, indicating often the discharge of groundwater (Laitinen *et al.* 2005, Štechová *et al.* 2008).

When the vegetation is dependent on areal hydrochemistry is the hydrochemistry influenced by the areal soil and bedrock geochemistry (Lahermo *et al.* 1990). The influence of soil and bedrock geochemistry is seen both in surface water and in groundwater, yet the influence in groundwater is greater. It is studied that groundwater can transport metals from the mineral soil and the upward-discharging groundwater can elevate the metal content in peat layer (Hill and Siegel, 1991). In Finland areal hydrogeochemistry has been widely studied by Lahermo *et al.* (1990, 1996). The composition of groundwater in Finland is generally slightly acidic due to the dominant felsic bedrock. The areas with bedrock of metamorphic schists or mafic / ultramafic bedrock as the area of Central Lapland Greenstone Belt (CLGB), have usually groundwater with locally higher cation content and pH (Lahermo *et al.* 1996).

Objectives of this study were, using hydrogeochemistry (1) to find the possible groundwater discharge locations in aapamire, (2) study if the bedrock and ore body affect to the water chemistry and (3) find out whether the distribution of Hamatocaulis vernicosus ecosystems correlate with certain type of water chemistry and/or with groundwater discharge areas.

2. THE HYDROGEOLOGY AND HYDROGEOCHEMISTRY OF MIRES

2.1 Hydrogeology of mire

Two main factors are required for mires to form; the suitable climate and areal geomorphology. Climate needs to be cool and wet so the precipitation exceeds evaporation and allows excess water to accumulate to depressions of basins with relatively flat topography and poorly permeable soil (Mitch and Gosselink 2007, 108). Natural state aapamires are often affected not only with precipitation but also with groundwater discharge and flooding of nearby surface water bodies. Flooding and groundwater discharge transport nutrients to and from mires specifying the hydrogeochemical environment of the mire (Mitch and Gosselink 2007, 108). Even though all the water sources play important part in mire hydrology, is precipitation still the most important and stable source of water (Bleuten *et al.* 2006). The balance between precipitation and evaporation, groundwater discharge and recharge, possible flooding as well as surface water inflow and outflow are the main factors to determine the water budget of a mire (Fig. 1) (Mitch and Gosselink 2007, 121).

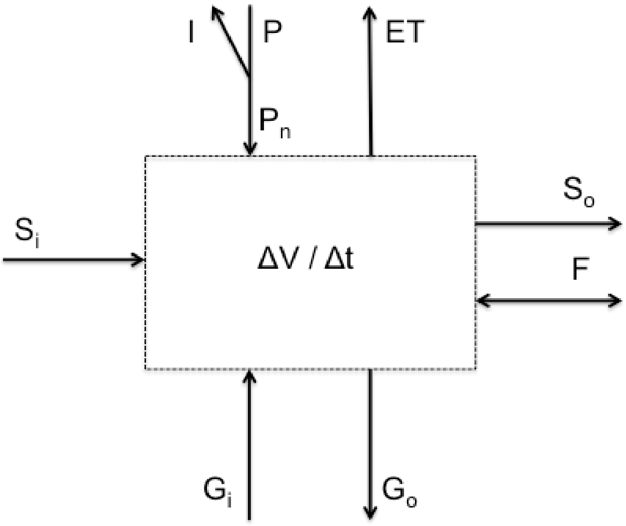


Figure 1. Simplified water budget of aapamire (modified from Mitch and Gosselink, 2007). P_n = net precipitation, I = Interception, ET = evapotranspiration, S_i = Surface water inflow, S_o = Surfacewter outflow, F = Flooding in and out, G_i = Groundwater discharge, G_o = groundwater recharge.

These multiple different water sources change hydrological as well as hydrochemical environment and are thus important factors in characterizing hydrology and hydrochemistry of mire. Besides the water sources many other factors as basal material e.g. mineral content and grain size, thickness and stage of decomposition of peat layer as well as water depth change the hydrology causing variation in water movement within a mire complex (Mitch and Gosselink 2007, 108).

The groundwater discharge occurs if the surface of mire water table is lower than the surrounding groundwater table and if the soil material is permeable (Bleuten *et al.* 2006). The discharging groundwater migrates as a vertical flow from the mineral soil towards the top of the peat layer as well as a horizontal flow through the peat (Ferlatte *et al.* 2015). However the vertical groundwater flow is minor (Reeve *et al.* 2000), and the dominant water flow direction is horizontal through the peat layer (Bleuten *et al.*). The vertical connection through the peat layer also decreases when the peat layer thickens e.g. when the distance from the dry land increases (Ferlatte *et al.* 2015). There is also lots of variation in flow flux depending on the stage of decomposition of the peat (Bleuten *et al.* 2006). Peat deposits can be roughly divided in two layers, the upper acrotelm and deeper catotelm (Ingram, 1983). Acrotelm reaches from the top of the peat to the depth of 10 to 50 cm following usually the lowest level of water table fluctuation. It is less decomposed than catotelm and therefore the water flow is faster in acrotelm than in catotelm. Catotelm is almost continuously under water, it is more decomposed than acrotelm and it reaches from the boundary of acrotelm to the mineral soil beneath the peat (Ingram, 1983). The more decomposed peat is the slower the water flow is (Mitch and Gosselink 2007). Water flow can be thousand times faster in acrotelm, where peat is still fibric and only little decomposed compared to the decomposed catotelm (Fraser *et al.* 2001, Bleuten *et al.* 2006, Mitch and Gosselink 2007). The horizontal hydraulic conductivity (K_h) for acrotelm varies from 10^{-7} ms^{-1} to 10^{-3} ms^{-1} and the speed of flow decreases with respect of the depth (Frasier *et al.* 2001). The K_h of catotelm, that is 10^{-8} ms^{-1} to 10^{-6} ms^{-1}, is much more homogenic and not as clearly depth dependent (Fraser *et al.* 2001). Because of the faster water flow, the upper layer, acrotelm, is more sensitive to changes in weather. The changes in precipitation and evaporation can change the direction of water flow in peat layer (Fraser *et al.* 2001). The annual changes in weather may also fluctuate groundwater table and have thus effect to groundwater flow direction (Fraser *et al.* 2001). These changes in groundwater table can change the areas of groundwater discharge to become areas of groundwater recharge (Fraser *et al.* 2001). At the areas where groundwater discharge is relatively stable and continuous (Mitch and Gosselink, 2007, 113) or where the peat layer is thick (Jabłońska *et al.* 2014) the changes in weather affecting water table fluctuation are minor and the water table is more stable than at the areas without stable groundwater discharge or thinner peat layer.

Some mires get occasionally extra water when they are completely or partly flooded by flooding river nearby. In addition to groundwater flooding is an important factor as a nutrient supply for the mire. In cold regions with annual snow cover, spring floods are common (Mitch and Gosselink, 2007, 132).

2.2 Hydrogeochemistry - an influence of groundwater discharge

Mires gain water from multiple different sources having their own characteristic chemical composition depending on the environment where the water originates. Ratio between these water sources dictates the chemical composition of mire water. Due to the lack of nutrients in precipitation, groundwater discharge and / or possible flooding are the most important factors of nutrient supply of mires (Bleuten *et al.* 2006). Groundwater discharge areas are relatively easy to detect with field measurements and with help of hydrogeochemistry due to the high amount of dissolved ions in it. It is studied that the periods of groundwater discharge increase the electric conductivity (Siegel *et al.* 1995, Frasier *et al.* 2001), pH (Tahvanainen *et al.* 2002) as well as the cation content of mire water (Frasier *et al.* 2001, Tahvanainen *et al.* 2002). In study of Frasier et al (2001) the positive changes of cation content at the area of groundwater discharge, even if the concentrations were relatively small, were in percentage terms much greater at the water in top peat layer of the mire, showing that even small increase of ions in surface water of mire can indicate possible groundwater discharge. Conversely, dissolved organic carbon (DOC) content is noticed to be lower at those sites of the mire that are influenced by groundwater discharge because of its absence in groundwater (Tahvanainen *et al.* 2002). In addition to water chemistry the discharge of groundwater can be detected when inspecting the peat chemistry. In study by Hill and Siegel (1991) the metal content of the peat at spring-fen site was found to be 10% greater compared to the ombrotrophic bogs where the influence of groundwater is absence.

A mire complex consists of smaller subunits with different hydrological properties. This causes spatial variation also in hydrochemistry and available nutrients within the whole complex (Tahvanainen *et al.* 2002). The major differences occur between margins and the center of the mire (Bleuten *et al.* 2006, Jabłońska *et al.* 2014) and are most likely explained with the changes in thickness of the peat, the distance from the mineral soil as well as the geomorphology of the mineral soil (Jabłońska *et al.* 2014). At the groundwater discharge areas, hydrogeochemistry of mire also can be influenced by the bedrock or mineral soil beneath the peat (Shotyk 1988, Tahvanainen 2004). Studies done in north-eastern Finland (Tahvanainen 2004) indicated that mires with waters, rich of magnesium and nutrients, are located mainly at the areas with mafic bedrock, which is more prone to chemical weathering, whereas mires with nutrient poor waters had calcium as main ion and were located within areas of felsic bedrock. These differences in water chemistry are visible in mire vegetation as shown in studies of Tahvanainen *et al.* (2002) and Bleuten *et al.* (2006). According to Tahvanainen *et al.* (2002) the variation of areas with poor or rich mire vegetation is connected to the surface water chemistry of the mire. The water chemistry at the areas of rich vegetation reflected groundwater influence having elevated electric conductivity and pH and higher Na, Mg and alkalinity content. The study was done within felsic, poorly weathered bedrock zone and the ion composition in rich mire was relatively low compared to the rich mire hydrochemistry in general. From this it is possible to draw conclusion that groundwater discharge seems to have influence in mire vegetation even the nutrient content of the water is generally low.

2.3 Groundwater and ecosystems

The areas of groundwater discharge differs hydrogeochemically from the surrounding waters having features of surface water as well as groundwater. These environments e.g. riparian and hyporheic zones, caves, estuaries as well as wetlands and mires, just to mention few, are important substrates for groundwater dependent ecosystems (GDEs) (Kløve *et al.* 2011). The importance of groundwater discharge for GDEs is mainly based on the stability of nutrient supply and temperature as well as the stable source of the water, especially if the area is otherwise arid. The groundwater discharge may be seasonal, continuous or occasional depending of the geological setting as well as the amount of annual precipitation and evaporation (Kløve *et al.* 2011).

2.3.1 Hamatocaulis vernicosus

In this study our interest is in *Hamatocaulis vernicosus,* a moss species that is known to thrive in groundwater discharge influenced environments. *H. vernicosus* (Kiiltosirppisammal in Finnish) has been common throughout Finland, especially at nutritious mires of Lapland. Due to the human activity, e.g. draining the mires, has the hydrochemistry and hydrology of the environment changed causing evanescence of *H.* vernicosus from many of its original habitats. Nowadays *H. vernicosus* is classified as vulnerable (VU) specie. (Laaka-Lindberg *et al.* 2009. 119 – 121). The habitat of *H. vernicosus* has been studied during the years and few factors specifying where *H. vernicosus* thrive, has come to the fore. According to Štechová *et al.* (2008) the optimum pH conditions of water for *H. vernicosus* are fluctuating from slightly acid to base-rich depending on the region of growth. In general the hydrogeochemical main features for *H. vernicosus* ecosystems seem to be elevated EC (Hedenäs and Kooijman 1995, Štechová *et al.* 2008), pH that is almost neutral (Štechová *et al.* 2008) or slightly elevated and higher Ca, Mg and HCO_3^- concentrations (Hedenäs and Kooijman 1995). All these are characteristic for places of groundwater discharge (Hiscock and Bense 2014, 137). The iron content of water and its effect on *H. vernicosus* has been unclear in earlier studies. Štechová and Kucera (2007) didn’t find any significant correlation with iron and occurrence of *H. vernicosus* ecosystems but in later studies of Štechová *et al.* (2012) a positive correlation was found between dissolved iron and abundance of *H. vernicosus* ecosystems. The positive correlation has also been found in study by Hedenäs and Kooijman (1995). In addition to the chemical composition also seasonal water table fluctuation and high amount of other moss species are found to be important factors affecting negatively to *H. vernicosus* ecosystems (Štechová *et al.* 2012).

3. GEOLOGICAL SETTING

3.1 Study area

Viiankiaapa (67°33’ N and 26°46’ E, WGS84) is located in municipality of Sodankylä, 20 kilometers north from the town center. Viiankiaapa mire complex consists mainly of moderate to rich mires as well as small raised bog (Metsähallitus, 2006). It covers 7 135 ha when including Eliasaapa and Käppäläaapa and its mean elevation is 190 m.a.s.l. (Lappalainen 2004, 21). According to Finnish Meteorological Institute the average temperature of Viiankiaapa in September 2016, during the field work period, was 8 °C and in October 3 °C. No average temperature data from March and April 2017 is available, but in years 1981 – 2010 the average temperature in March was -7.5 °C and in April -1.3 °C. Average temperatures in Sodankylä (years 1981 – 2010) has been below zero for four months, from November to April. The yearly precipitation in Sodankylä in 2016 was 600 – 700 mm a^{-1} (The Finnish environment institute, 2017). Precipitation in September 2016 was 76 mm and in October 9 mm, the snow depth in March 2017 was 79 cm and in April 73 cm (Finnish Meteorological Institute). The study area is located on the western margin of Viiankiaapa. Water samples were collected from the areas with and without *H. vernicosus* ecosystems, covering Sakatti deposit area and surrounding units described earlier, and reference area with bedrock of quartzite, gabbro and graphite paraschist (Fig. 2).

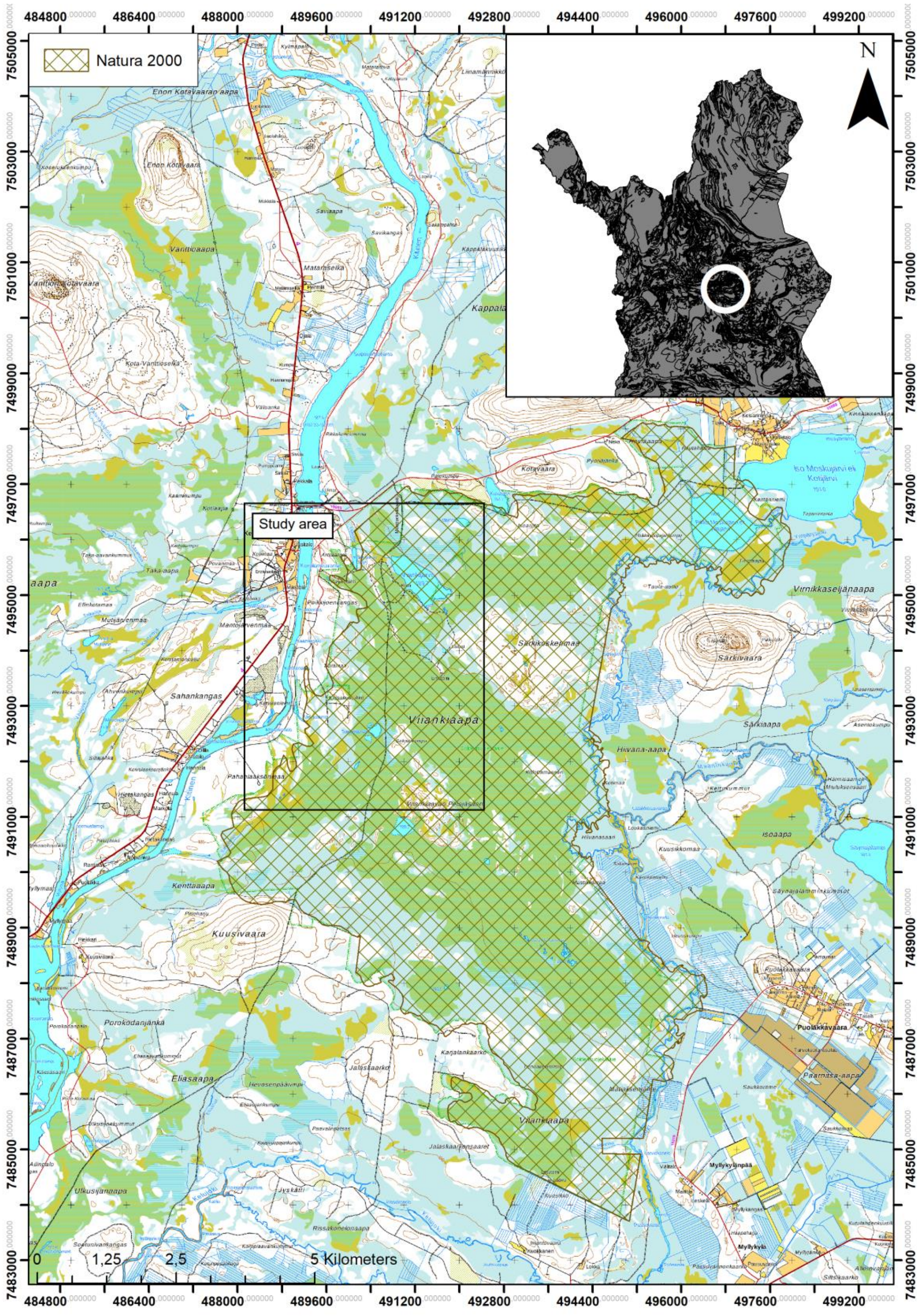


Figure 2. Study area. (General map Database © NLS 2014)

3.1.1 Definition of Natura 2000

Majority, 92%, of Viiankiaapa is protected as a Natura 2000 area and thus belongs in a nature conservation network (Metsähallitus 2006, 7) (Fig. 2). The aim of Natura 2000 network is to protect rare and threatened plant and animal species as well as rare natural habitat types that are mentioned in European Union directive: Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (European Commission 2017). Viiankiaapa is Natura 2000 protected due to the several natural habitat types and plant species as, our interest, *Hamatocaulis vernicosus* (Ympäristö.fi, 2013).

3.2 Bedrock geology of Viiankiaapa area

Viiankiaapa is located within Central Lapland Greenstone Belt (CLGB) at the Sodankylä schist area (Räsänen 2008, Hanski and Huhma 2005). CLGB crosses northern Finland from east to west when spreading from Kuusamo to Kolari. It consists of Proterozoic metasedimentary and metavolcanic rocks that are formed over Archean granite gneiss (Räsänen 2008) approximately 1.9 – 2.5 Ga ago (Brownscombe *et al.* 2015). The composition of metavolcanic rocks varies from felsic (rhyolites) to ultramafic (komatiites) (Brownscombe *et al.* 2015) while metasedimentary rocks are mainly quartzites and mica schist (Lehtonen et al 1998, Hanski and Huhma. 2005). Metasedimentary rocks are major at Sodankylä schist area but within the study area both types are equally present (Fig 3). Because of the geological history, the ore potential of CLGB is high (Lahtinen *et al.* 2012, 397). The fracturing and rifting of Archean craton during Palaeoproterozoic Era led to events where quantities of magma ascended and both mafic and ultramafic intrusions as well as extrusions were formed (Hanski, 2015, 51). These events are essential for Ni-Cu-PGE formations and explain presumably Sakatti Ni-Cu-PGE ore formation (Hanski 2015, 51). Sakatti deposit is located right at the western margin of the Viiankiaapa mire and is therefore in our interest.

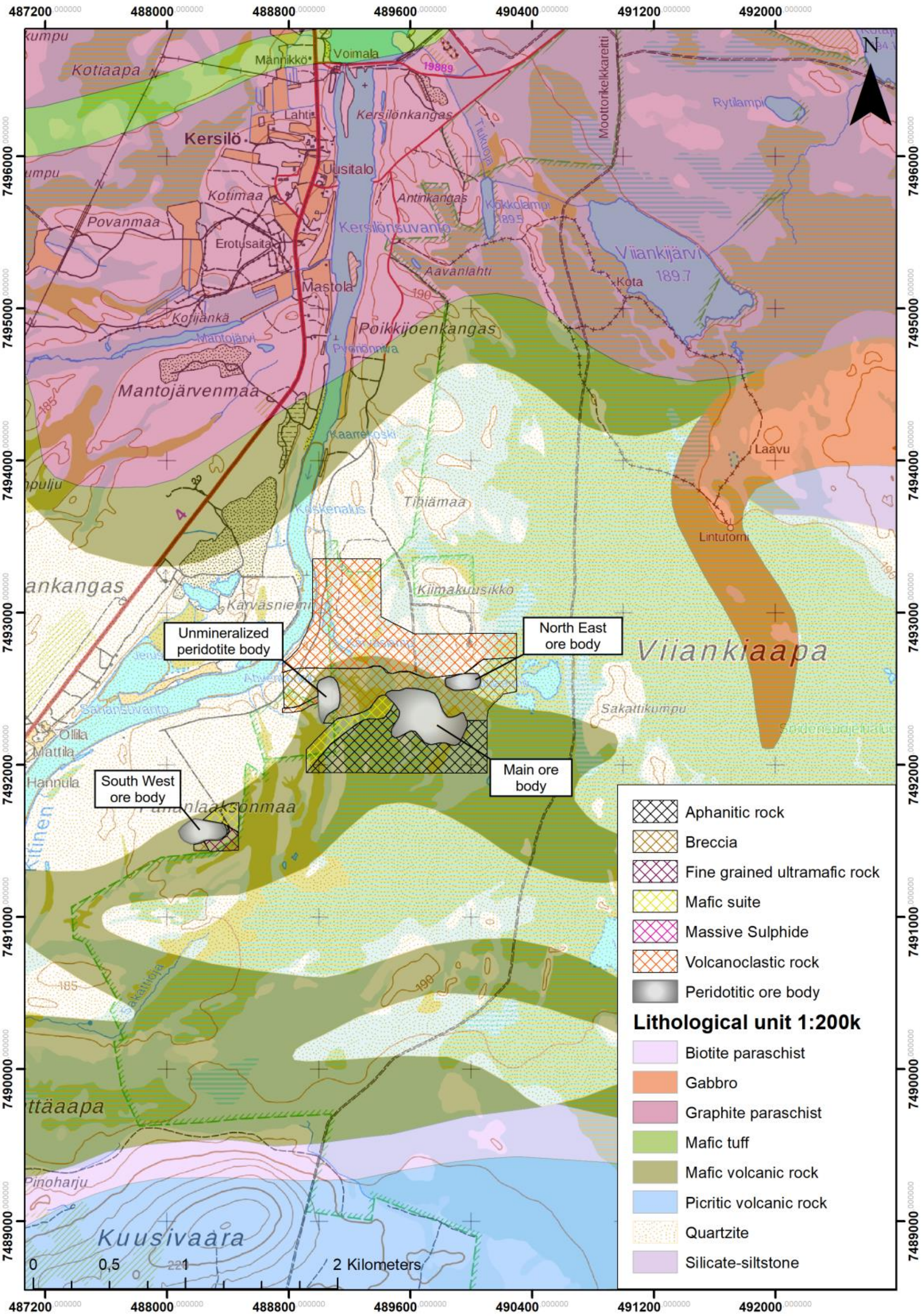


Figure 3. Bedrock of the study area. (General map Database © NLS 2014, Bedrock map Database © Geological Survey of Finland 2014. Sakatti deposits modified from Brownscombe *et al.* 2015)

Sakatti deposit was discovered in 2009 when mining company Anglo American performed drillings at the Sodankylä area (Brownscombe *et al.* 2015). The deposit consists of three different ore bodies with similar petrological qualities. The ore itself is hosted by an ultramafic olivine cumulate (peridotite unit) that is serpentinized and could technically be called as serpentinite (Brownscombe *et al.* 2015). The deposit is surrounded with aphanitic unit (most likely volcanic origin), volcanoclastic unit and breccia unit as well as with a mafic suite (Brownscombe *et al.* 2015). Whether the Sakatti deposit will be mined and when would that happen is still unknown, the exploration phase is still ongoing.

3.3 Deglaciation and surficial deposits of Sodankylä area

Northern Finland has gone through several glaciations and deglaciations during the Quaternary period (Taipale and Saarnisto 1991, 231). The most recent was last Weichselian cold stage (110 – 10.3 ka) when northern Finland was covered with ice for most of the time (Johansson *et al.* 2011). Early Weichselian (Hirvas 1991) as well as Middle Weichselian (Lunkka *et al.* 2015) deposits show however that some ice-free events have occurred in central Lapland at which time climate has resembled mostly tundra like conditions (Hirvas 1991). During the Late Weichselian glaciation the ice divide zone of stagnant cold-based glacier were located right at the north of Sodankylä causing only minor areal glacial erosion (Johansson *et al.* 2011). Nowadays the poor glacial erosion of ice divide zone is shown as presence of highly weathered bedrock that otherwise is generally lacking throughout Finland. The deglaciation of northern Finland initiated 11.6 ka ago when elevated areas, as fjelltops were first to expose under ice. Deglaciation lasted approximately 1.5 k years and Sodankylä area was ice-free 10.3 ka ago (Johansson 2007). Directly after the deglaciation Sodankylä area was covered with waters of Moskujärvi ice-lake. When ice margin retreated further, waters of Ancylus ice-lake reached Sodankylä (Johansson and Kujansuu 2005).

During glaciations and deglaciations several different sedimentation events moulded the Sodankylä area causing complex areal sedimentology (Sarala *et al.* 2015). Varying moraine deposits and basal till cover are common within Sodankylä (Sarala *et al.* 2015), till cover is also present as a base sediment of Viiankiaapa mire. However, the most common sediments under the Viiankiaapa peat layer are fluvial deposits of sands and gravels (Metsähallitus 2006, Åberg *et al.* 2017a). Also smaller areas of fine-grained, silty and sandy sediments deposited during Moskujärvi ice lake phase (Sarala *et al.* 2015) are locally found (Åberg *et al.* 2017a). There are six mapped groundwater areas near Viiankiaapa. Two of them, Kersilönkangas and Pahanlaaksonmaa, are the main groundwater recharge areas within the study area. Both of them are located parallel to River Kitinen, between the river and Viiankiaapa mire (Britschgi *et al.* 1996) (Fig. 4). According to the old classification (Britschgi *et al.* 1996) Pahanlaaksonmaa and Kersilönkangas are classified as III class aquifers. The transitional stage to new classification is still unfinished and at the moment it is unknown what the future classification is for these recharge areas when the old class III is removed. Aquifers of Viiankiaapa are hosted by fluvial sediments and are poorly connected due to the variation in sediment units and thus in hydraulic conductivity (Åberg *et al.* 2017a).

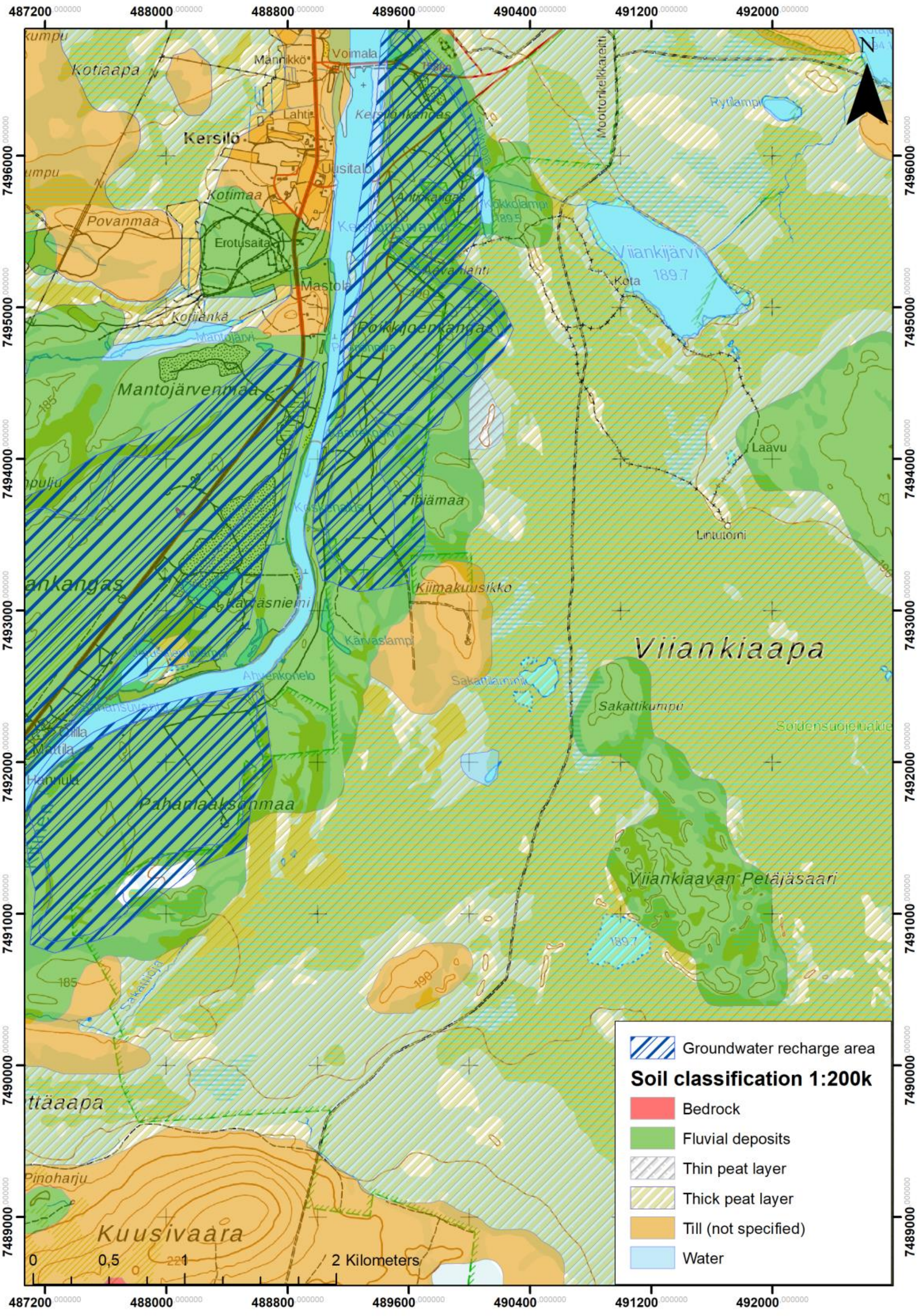


Figure 4. Soil map of the study area and nearby groundwater recharge areas. (General map Database © NLS 2014, Soil map Database © Geological Survey of Finland 2010, Open database © Finnish Environmental Institute 2014).

According to previous peat studies (Lappalainen 2004, 35) Viiankiaapa mire has gone through various phases after it became peaty ca. 8.6 ka ago. The peat layer, covering Viiankiaapa nowadays, is mainly two meters thick (Metsähallitus, 2006, Åberg *et al.* 2017b) being more than seven meters when thickest (Åberg *et al.* 2017b). The spatial division of peat thickness is uneven. Peat layer is thickest in western and northern part and thinnest in southern part of the mire (Åberg *et al.* 2017a, Åberg *et al.* 2017b). Continuously thick peat layer (≥ 4 m) crosses the mire from SW to NE starting from the southwestern corner and continuing towards Lake Viiankijärvi (Åberg *et al.* 2017a). Peat has been accumulating thousands of years in Viiankiaapa and the accumulation rate has been relatively fast, 0.3 - 0.6 mm a^{-1} (Lappalainen 2004, 36). Viiankiaapa is considered as a natural state mire, with exception of area near Moskuvaara road where natural water flow is blocked (Metsähallitus 2006, 16). However the construction of Matarakoski hydroelectric power plant at the NW end of Viiankiaapa in 1995 changed the areal hydrology and reduced annual floodings of the River Kitinen. There area altogether two hydroelectric power plants between Matarakoski power plant and artificial Lake Porttipahta.

4. MATERIAL AND METHODS

4.1 Material

Fieldwork was done in September and October of 2016 and in March/April of 2017. Total of 137 samples collected from 71 different sampling locations. Samples were taken from surface water of the mire (n = 55), peat pore water using mini-piezometer (MP) (n = 66) and groundwater (n = 16) (Appendix 1). Sampling was continued in summer 2017 when 19 additional samples were collected mainly from groundwater observation wells and springs for isotopic analyses. A profile consisting of surface water sample and one or more peat pore water samples were taken from 28 different sampling points. Single surface water or groundwater sample was taken from 44 sampling points. Sampling locations were planned to cover varying bedrock types in and outside of Sakatti deposits, with and without *Hamatocaulis vernicosus* ecosystems (Fig 5 and 6).

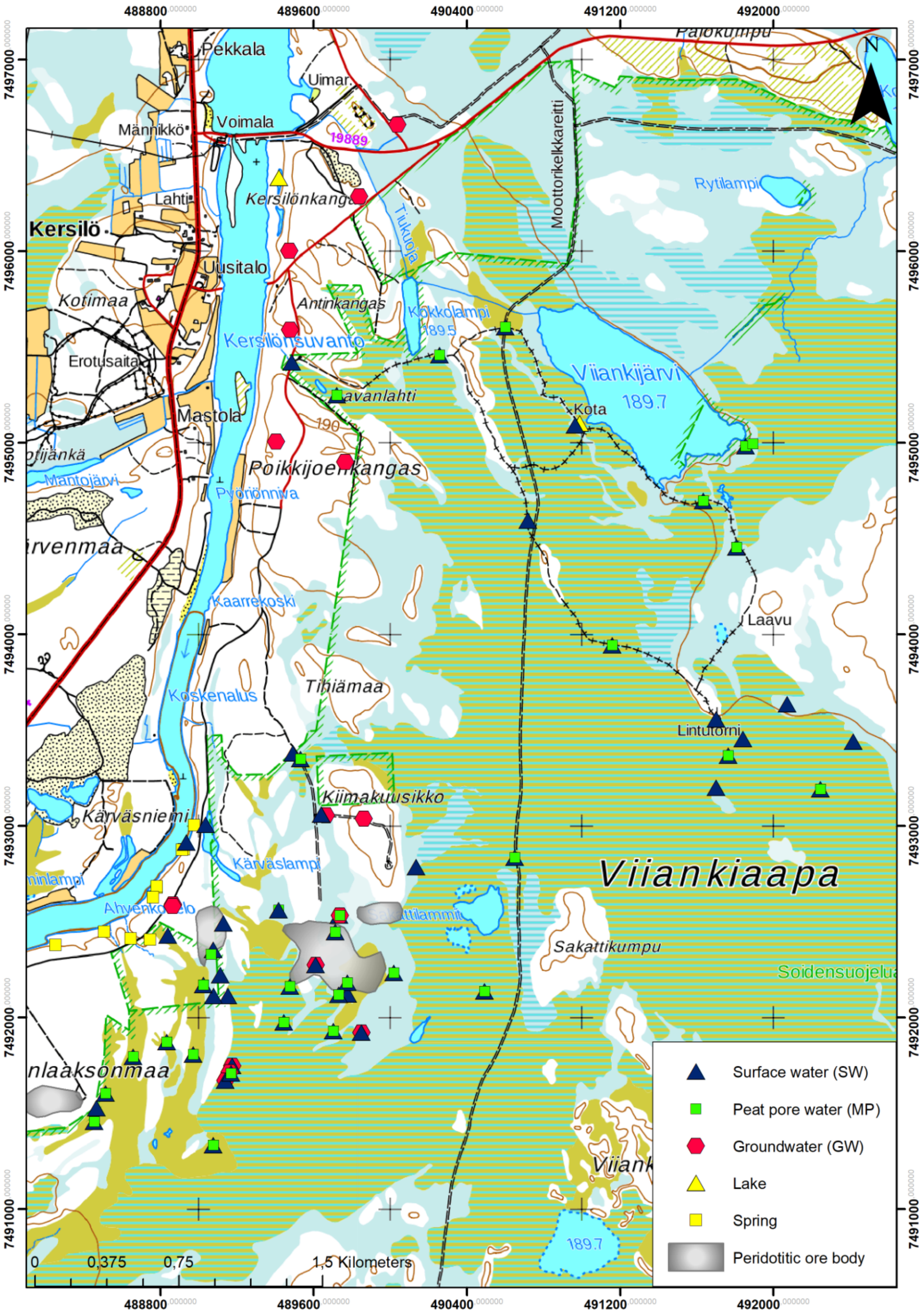


Figure 5. Surface water, peat pore water and groundwater sampling points. IDs not presented because several samples are taken from same location. (General map Database © NLS 2014)

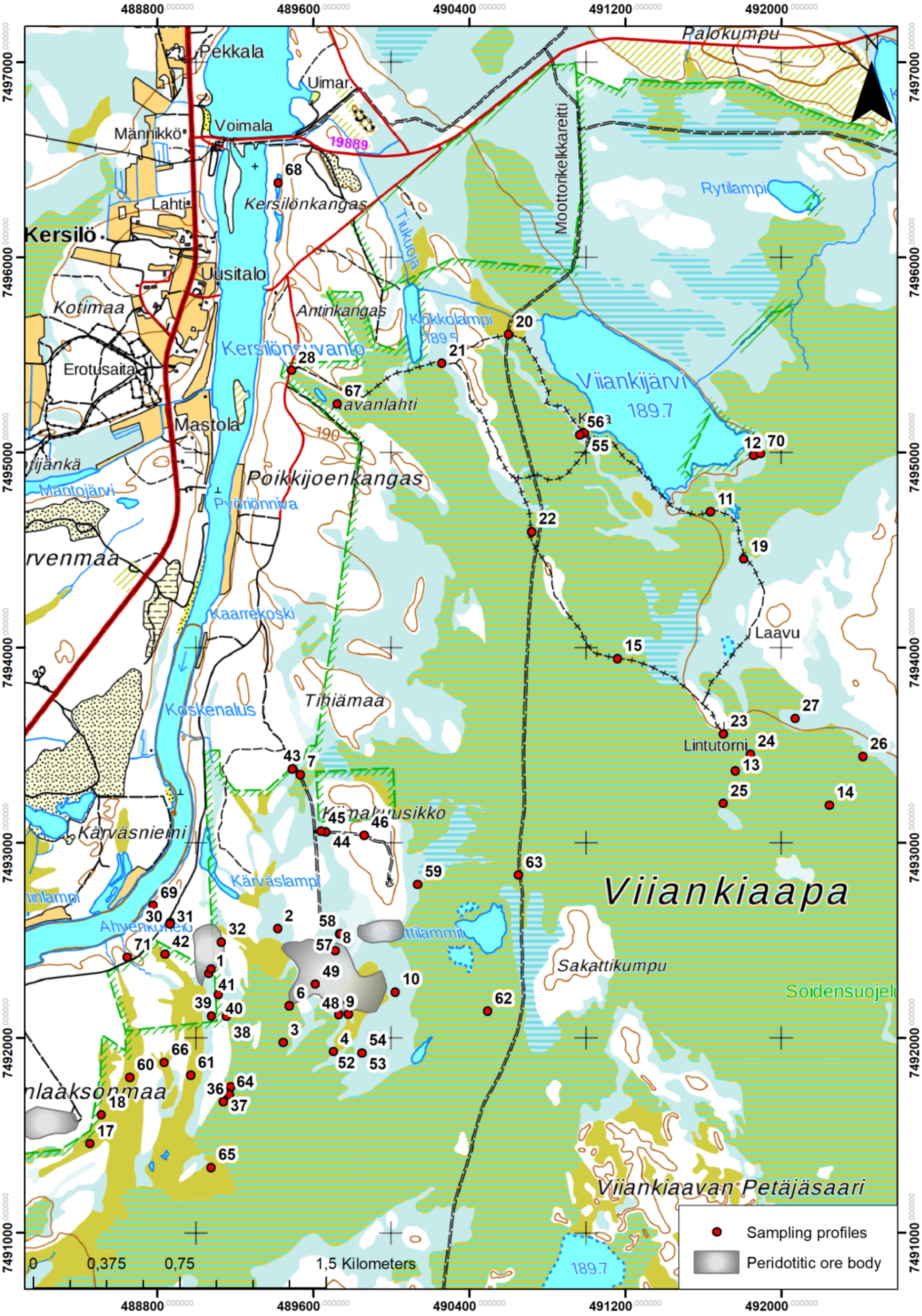


Figure 6. Sampling profiles (may contain only one surface water / groundwater sample / spring sample or both surface water sample and one or more peat pore water samples, see Appendix 1) (General map Database © NLS 2014).

4.2 Field investigations

Groundwater discharge and thus supply of dissolved elements causes measurable anomalies in surface water temperature and pH values as well as in electric conductivity (EC). Even though the pH of Finnish groundwater is generally slightly acidic is it nonetheless usually higher than the pH of surface waters (Lahermo *et al.* 1990, 21). The difference of groundwater and surface water is also seen in electric conductivity. EC for fresh groundwater is roughly ten times greater than for fresh rainwater as well as for surface water (Hiscock and Bense, 2014, 139). Because of the areal geology, Central Lapland Greenstone Belt, the EC and pH values of groundwater may locally be elevated even more than what they usually are at the areas of groundwater discharge (Lahermo *et al.* 1990, 21). The median EC (+25°C) of spring water within areas of mafic bedrock is little less than 0.1 mS cm^{-1} and in dug wells almost 0.2 mS cm^{-1}. pH at the mafic bedrock areas is approximately 6.7 (Lahermo *et al.* 1990, 55–56). The anomalies in EC and pH renders the groundwater discharge easily detected with simple field measurements (Hiscock and Bense, 2014, 139). Temperature is another parameter that is easily measurable in situ at the field. The temperature of groundwater is 2 – 4 °C in northern Finland thus it is colder or warmer than the surface water depending on the season. Problem is if the measurements are conducted during the autumn or spring, at the times when groundwater and surface water temperatures are approximately the same.

Electric conductivity, pH and temperature were measured *in situ* with portable YSI 600XLM multi probe. Electric conductivity and pH was calibrated daily with standard calibration liquids before starting the fieldwork. Surface water samples were measured placing the probe to the water near the sampling point. This method was not possible for peat pore water and groundwater samples. In these measurements, water was first collected to clean, 500mL sampling bottle with groundwater sampler or mini-piezometer and then measured. EC, temperature and pH were measured only during the September and October field work periods.

4.3 Water sampling

Samples were collected directly into the sampling bottles at field. Groundwater samples were collected using sampler after pumping the stagnant water from the observation well, surface water samples were collected by hand and peat pore water samples using mini-piezometer (Fig. 7). Samples were collected for main ion composition, stable isotopes ($\delta^{18}O$, δD), dissolved silica (DSi), dissolved organic carbon (DOC) and trace element analyses (Table 1). Also pH and EC were measured in laboratory, but the field measurements were more reliable and therefore used. Samples were collected to HDPE-bottles (high density polyethylene). Bottles were rinsed with sampling water two times before filling with the sample.) Samples for trace elements and DOC were filtered with 0.45 µm membrane filters when collected. HNO_3^- acidified syringes, filters and test tubes were used with trace element samples. Samples for stable isotopes of hydrogen and oxygen , dissolved silica, DOC and trace element were stored and transported in cold and dark. Samples for main ion were stored and transported frozen.

Table 1. Conducted analyses

Analyses	Amount of samples (n)
Trace elements	153
Stable isotopes $\delta^{18}O$, δD)	143
Dissolved silica (Dsi)	122
Dissolved organic carbon (DOC)	97
Main ions	88

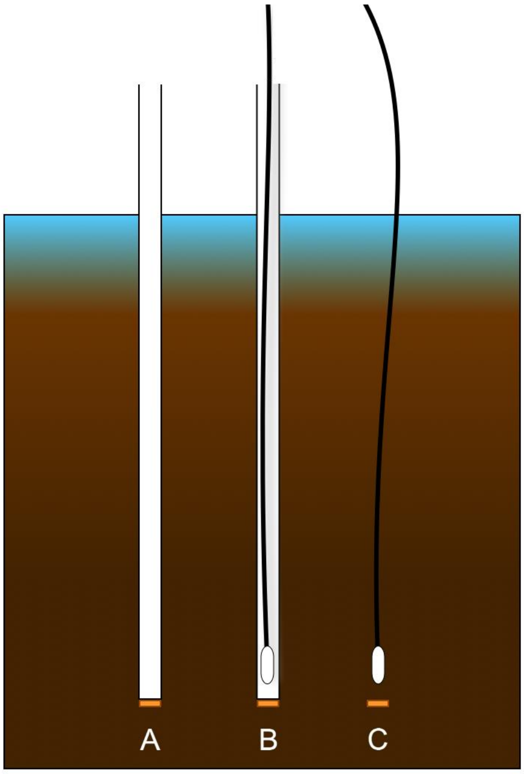


Figure 7. Installing mini-piezometer to the peat; A) Hammering an installation pipe to wanted depth (and removing wooden plug with a steel rod), B) inserting plastic tube (mini-piezometer) with a mesh tip, C) removing installation pipe. (Modified from Lee and Cherry 1987).

Mini-piezometers were used to collect peat pore water samples from different depths varying from 0.15 m to 4.82 m. Mini-piezometer consists of a thin plastic tube with a perforated end wrapped with mesh netting. They were installed manually using a method described by Lee and Cherry (1978). The water for the samples was collected with a clean syringe to sample bottles.

4.4 Water chemistry and analyzing methods

The interaction between different water sources as well as groundwater and mineral soil or bedrock were studied with stable isotopes (^{18}O and D), dissolved silica- (DSi), main ions, alkalinity and trace elements as well as dissolved organic carbon (DOC) (Appendix 1). The abundance of main ions and trace elements dissolved in groundwater reflect the chemistry of areal soil and bedrock even though it often might be hidden behind other stronger factors affecting hydrochemistry (Lahermo *et al.* 1990, 11). Main ions dissolved to groundwater are Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO_3^-. Usually they are represented as a content of mg L^{-1} or ppm (parts per million) (Fetter 2001, 373). Trace elements are represented as a content of µg L^{-1} or ppb (parts per million) with few exceptions that are more abundant and therefore represented as a content of ppm. The time of the mineral – water contact and the mineral composition as well as grain size in soil and bedrock affects to the chemical composition of groundwater (Lahermo *et al.* 1990, 11). Main ions were analyzed with ion chromatography (IC) following standards of Finnish Standards Association (SFS). Samples with total alkalinity more than 0.2 mmol L^{-1} were diluted with distilled water before measuring cations. The ratio of dilution was 1:5 or 1:10 if the alkalinity was more than 1 mmol L^{-1}. Cations were analyzed by the standard SFS EN-ISO 14911, and anions by the standard SNS EN-ISO 10304. Trace elements were analyzed with ICP-MS (Inductively Coupled Plasma Mass Spectrometry) following the standard ISO 17294-2:2003. Main ions and trace elements were analyzed at the Department of Geosciences and Geography, University of Helsinki. Measurement limits for trace elements and main ions are reported in Appendices 2 and 3.

Dissolved organic carbon (DOC) includes organic matter with size smaller than 45 µm (Drever 1997, 107). The samples were filtered with 0.45 µm membrane filters to exclude larger organic matter. In wetlands the concentration of DOC can be as high as 60 ppm while groundwater reflects the DOC concentration of rainwater that is 0.5 ppm – 1.5 ppm (Drever 1997, 107). Therefore it is a usable variable when recognizing waters with groundwater influence, the surface water at the areas of groundwater discharge are diluted with the DOC poor groundwater (Sallantaus 2006, 114). Dissolved organic carbon was analyzed according to the SFS-EN 1484:1997/OUL standard at the laboratory of Ahma Environment Ltd. in Rovaniemi.

4.4.1 Stable isotopes and dissolved silica

Isotopic compositions of oxygen and hydrogen and amount of dissolved silica are common variables when studying groundwater surface water interactions (see e.g. Landouche and Weng 2005, Rautio 2005). The isotopic composition of groundwater commonly reflects the isotopic composition of areal precipitation while the isotopic composition of surface water has gone through fractionation by the evapotranspiration

(Drever 1997, 314 – 315). The fractionation occurs when lighter oxygen isotope ^{16}O and hydrogen isotope ^{1}H evaporates easier than the heavier ^{18}O and D (^{2}H). Ongoing evaporation changes the ratio of ^{18}O / ^{16}O and D / ^{1}H and the surface water will become depleted in lighter isotopes (Drever 1997, 315). Because of the varying intensity of evaporation the isotopic composition of precipitation is not homogenous through the globe but it changes with the climate. In Northern Finland the $\delta^{18}O$ / δD is studied to be -13.04 ‰/-94.8 ‰ for precipitation and -14.26 ‰ /-104.5 ‰ for groundwater (Kortelainen 2007). Isotopic ratio is calculated with the equation 1.

$$\delta^{18}\mathrm{O} \text{ or } \delta\mathrm{D} = \frac{R_{sample} - R_{VSMOW}}{R_{VSMOW}} * 1000 \qquad \text{(Eq. 1)}$$

Deuterium excess (*d*) is also used when inspecting origin of water. It is calculated from the measured δD and $\delta^{18}O$ values using the equation 2.

$$d = \delta\mathrm{D} - 8\delta^{18}\mathrm{O} \qquad \text{(Eq. 2)}$$

D-excess is affected by the humidity, air temperature as well as surface seawater temperature (Merlivat and Jouzel, 1979). Therefore it is dependent on the season and can globally vary from -2 ‰ to 15 ‰ (Frölich *et al.* 2002). At areas of temperate climate, as in Lapland, the *d*-excess of precipitation varies from 5 ‰ to 15 ‰ (Kortelainen 2007) having an annual mean value approximately 10 ‰ (Kendall and Coplen, 2001, Kortelainen 2007). This annual mean value is also visible in groundwater. Lower *d*-excess values may indicate fractionation of the water and thus the condition where evaporation has occurred or it can show the annual variation (Kendall and Coplen, 2001).

In addition to isotopic composition dissolved silica (DSi) is used to determine groundwater discharge to surface waters (Rautio 2005). Because it’s absence in precipitation and presence in groundwater, an elevated concentration of DSi is a possible sign of a groundwater discharge. The amount of DSi in groundwater is dependent on several factors as the grain size of aquifer, amount of CO_2 in water and the retardation of groundwater in aquifer (Sandborg 1993, 33). In this study DSi is used to support results of the isotopic composition.

Isotopes were analyzed with Picarro L2120-1 analyzer following the commonly used protocol of Laboratory of the University of Helsinki, Department of Geosciences and Geography. Samples were filtered with 0.45 µm filter before analyzing. Isotope ratios are reported as per mil difference relative to VSMOW (Vienna Standard Mean Ocean Water) standard. Dissolved silica was analyzed with ICP-MS (Inductively Coupled Plasma Mass Spectrometry) following the standard protocol of the University of Helsinki, laboratory of Department of Geosciences and Geography.

4.5 Evaluation of the results: Ion balance (IB %) and DOC rich waters

Groundwater is a neutrally charged solution of dissolved anions and cations. Cation – anion balance calculations as ion balance calculation (IB %) is used to check the reliability of conducted main ion analyses. The ion concentrations are converted to units of equivalents per liter and the balance is calculated using equation 3 (Fetter 200, 373).

$$IB\ \% = \frac{(\sum cations - \sum anions)}{(\sum cations + \sum anions)} * 100 \qquad \text{(Eq. 3)}$$

The difference between negatively charged anions and positively charged cations should be less than ±5 % (Fetter 2001, 373) but the organic waters are more complex due to the dissolved organic carbon and its dissociation to organic anions. Organic compounds are generally composed of carbon skeleton and functional groups attached to it (Drever 1997, 107). The most abundant and thus the most important functional group of dissolved organic acids is carboxylic acid group: -COOH. All the carboxylic acids behave like acid in solutions, but the strength of the acid varies amongst the carboxylic acid groups (Drever 1997, 110). pK_a value of most of the carboxylic acids varies between 3.5 – 5 meaning that most of the acids are dissociated to anion and cation in pH 3.5 – 5 (Eq. 4).

$$RCOOH = RCOO^- + H^+ \qquad \text{(Eq.4)}$$

In natural waters carboxylic acids are usually completely dissociated (Drever 1997, 110). When studying mire waters, the influence of organic anions cannot be ignored. If the concentration of DOC is more than 5 ppm is it reasonable to calculate the amount of extra organic anions and include those to the sum of the inorganic anions so the ionic balance of anions and cations in water is more reliable. According to Oliver *et al.* (1983) in 1 mg of DOC equals 10 µmol of organic acid groups of which 5 µmol are strong organic acids that are dissociated in pH 4.8. In this study organic anions were calculated to the sum of all anions using presumption of Oliver *et al.* (1983) when the concentration of DOC is > 5 ppm and pH is 5 or less. The measured main ion composition and calculated ionic balance is seen in appendix 3.

4.6. Statistic methods and visualization

Different statistic and visualization methods were used to analyze and present results. The statistical analyzes as well as boxplots were done with BMI SPSS version 25. Piper diagrams were created with AquaChem version 2012.4. Tables and scatter diagrams with Microsoft Excel 2016 and maps with ESRI ArcMAP 10.3.1. Maps were modified with PDF-XChange editor.

4.6.1 Log$_{10}$-transformation, comparison of different groups (Mann Whitney U and Kruskal-Wallis -tests) and principal component analysis (PCA)

Many of the used statistical methods expect the data to be normally distributed, which is rarely the case when working with geochemical data (Reimann and Filzmoser 2000). There are several methods that can be used when transforming data normally distributed but according many (see e.g. Reimann and Filzmoser 2000, Ranta *et al.* 2012) one of the most used method is log$_{10}$ transformation that was also used in this study. Before the log$_{10}$ transformation the trace elements and main ions, under the detection limit, got a value "½ of the detection limit". That is a common transformation that must be done, before different multivariate methods can be used (Güler *et al.* 2002).

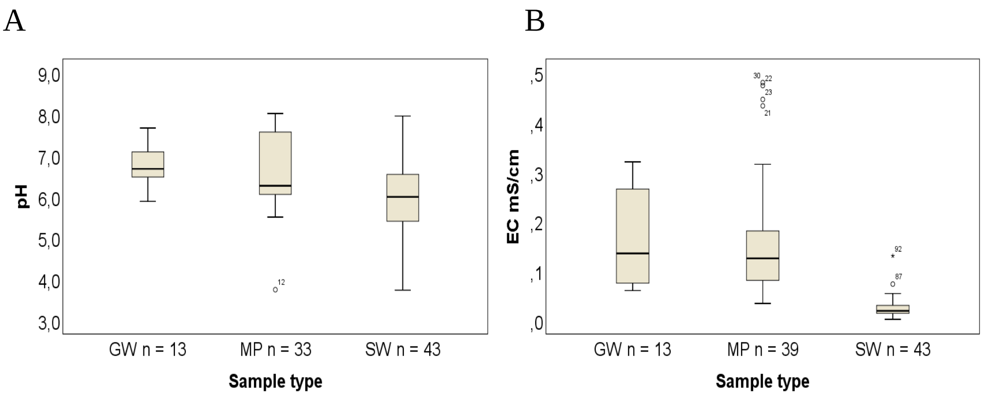
The similarities of different variables between the areas of YES/NO *H. vernicosus* habitats and between areas of shallow and deep peat layer was analyzed with Mann Whitney U –test. Mann Whitney U –test is one of the most effective test for comparing non-parametric data of two different groups (Ranta *et al.* 2012). With this analysis it was possible to find out which variables differed between the groups (YES/NO *H. vernicosus* or shallow or deep peat layer) and take those for further study. The null hypothesis (H_0) in Mann Whitney U –test is that the observations between the two different groups does not differ and the alternative hypothesis (H_1) is that these groups are not equal (Ranta *et al.* 2012). In Mann Whitney U –test the observations are arranged to the order from smallest to largest and then replaced with the ordinal numbers. The test is based to the distribution of the ordinal numbers (Ranta *et al.* 2012). Kruskal-Wallis one way analysis for variance is used when comparing non-parametric observations between several groups. In Kruskal-Wallis test the H_0 assumes that all the observations are equal between different groups and H_1 that at least one group differences from the others (Ranta *et al.* 2012). In this study Kruskal-Wallis test was used when comparing variables and areas of different bedrock.

Whit great amount of data the relationships between the variables are often impossible to detect without statistical help. The purpose of principal component analysis (PCA) is to find these relationships from large amount of data and simplify it by forming new variables e.g. principal components (PC) (Ranta *et al.* 2012). PCA is mainly used when analyzing large amount of data but can also be used for smaller datasets when strong correlation can is present as presented in Costello and Osborne (2005). In this study the dataset is relatively small for PCA, which increases the risk that PCA do not show the real connections between the variables if the data quality is not good enough (Ranta *et al.* 2012). The loadings of multiple components must be > 0.5 to qualify the use of PCA with small dataset (Costello and Osborne 2005).

5. RESULTS

5.1 Electric conductivity, pH and temperature

Variation of EC, pH and temperature (T) between groundwater (GW), peat pore water (MP) and surface water (SW) from autumn field work periods are shown in figure 8 and in Appendix 4. The clearest difference between SW, GW and MP samples was seen in electric conductivity. Electric conductivity of surface water was significantly lower compared to the GW and MP samples. The difference between EC of groundwater and peat pore water was relatively small. As clear difference between GW, SW and MP was not seen when observing pH and T values. The range of pH and temperature was greatest in SW samples being relatively stable between MP and GW samples. The EC, T and pH measurements were conducted during two different sampling periods in September and October 2016. Because of this, it is not possible to examine all the measurements together without examining first if there is a difference in results between these two sampling periods. According to the pre-examinations it was justified to examine all the pH and EC measurements together regardless of sampling periods. Only temperature values varied greatly depending on the sampling period and are thus observed separately.



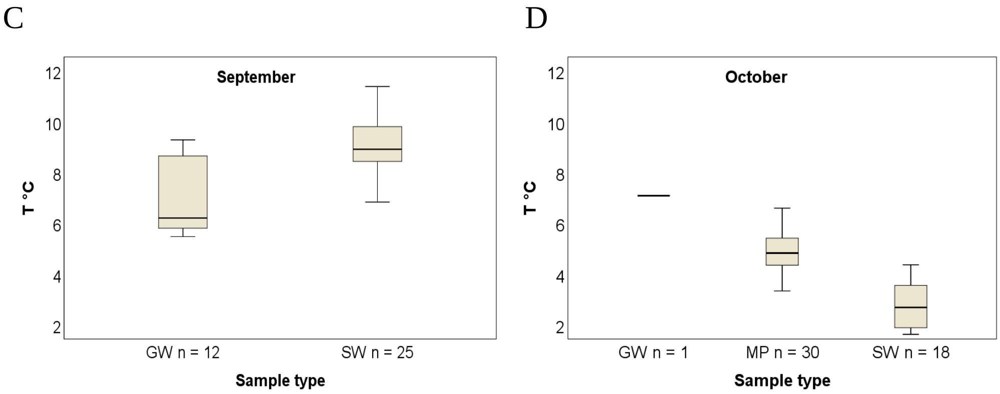


Figure 8. A) pH variation between all GW, MP and SW samples. B) EC variation between all GW, MP and SW samples. C and D) Temperature variation between GW, MP and SW samples from different autumn sampling periods.

The mean pH value (n =13) of groundwater samples was 6.70 and the overall variation 5.88 – 7.66. The mean electric conductivity of GW (n =13) was 0.169 mS cm^{-1} (variation of 0.06 – 0.32 mS cm^{-1}) and the mean temperature of GW (n =13) 6.99 °C (variatio 5.48 – 9.29 °C). Mean value of pH for surface water samples was 5.98 (variation 3.73 – 7.95). The mean electric conductivity of SW was 0.026 mS cm^{-1}, (variation 0.002 – 0.130 mS cm^{-1}). The variation of surface water temperature at research area was great (1.63 – 11.39 °C) but there was clear difference depending on the sampling period (September – October). Surface water temperature in September was generally higher (mean 8.5 °C) than in October (mean 4.2 °C). The peat pore water samples had mean pH value 6.49 (variation 3.74 – 8.01). The mean electric conductivity of all peat pore water samples was 0.16 mS cm^{-1} (variation 0.034 – 0.480 mS cm^{-1}) and the mean temperature was 4.9 °C (variation 3.3 – 6.6 °C) (Appendix 5).

Comparison of groundwater and surface water samples was not exhaustive because all the groundwater pH, EC and temperature measurements were conducted in observation wells near Sakatti ore deposits, while there were no pH, EC, T groundwater measurements done near Lake Viiankijärvi. When inspecting surroundings of Sakatti ore deposit it was possible to notice that measured pH values reflected groundwater values more at the margin of Pahanlaaksonmaa than near the main ore deposit and Kiimakuusikko (Fig. 9). pH values of surface water near Särkikoskenmaa (East side of the Lake Viiankijärvi) and Lake Viiankijärvi varied greatly. Peat pore water pH measurements had similar trend with surface water measurements almost in all profiles. Peat pore water values are not presented on maps, because there might be several samples taken from the same sampling point from varying depths. Therefore a scatter diagram profiles are much more informative when presenting MP measurements.

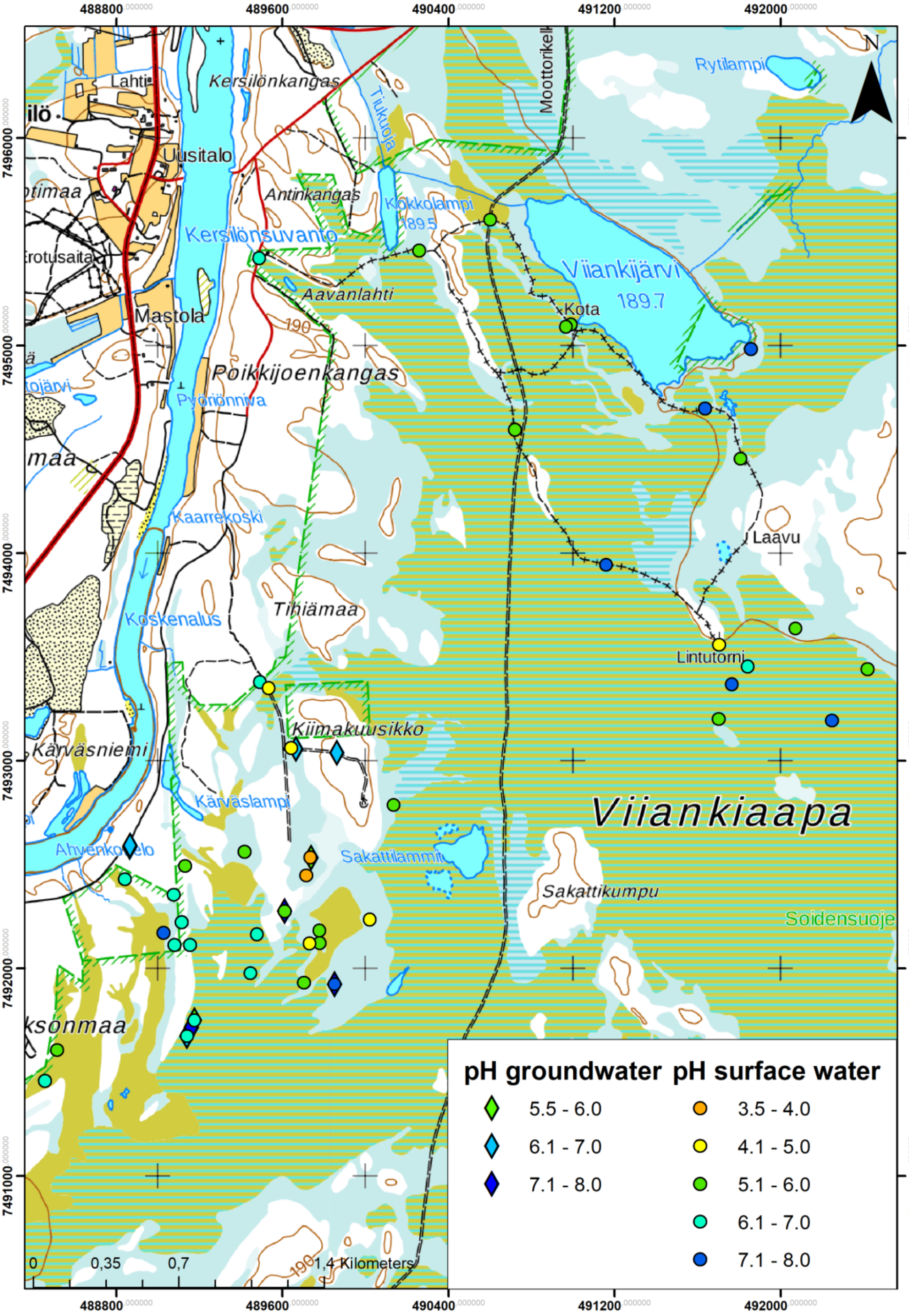


Figure 9. pH values of groundwater and surface water measurements. (General map Database © NLS 2014).

The comparison of EC between surface water samples and groundwater was not as clear as with pH measurements. Surface water values were distinctly lower than measured groundwater values (Fig. 10).

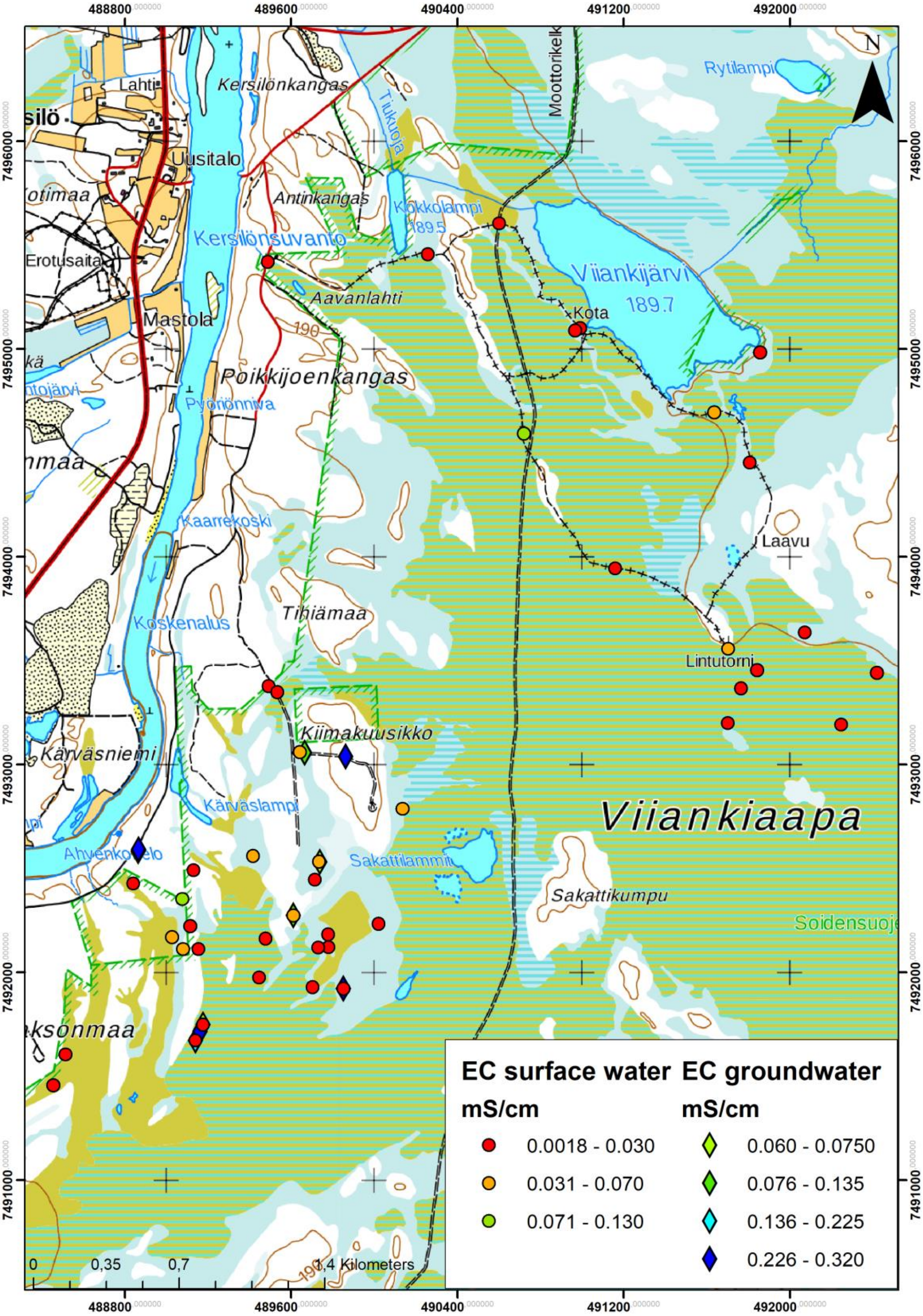


Figure 10. pH values of groundwater and surface water measurements. (General map Database © NLS 2014).

5.2 Stable isotope composition, d-excess and DSi

The measured $\delta^{18}O$, δD, *d*-excess (n = 143) and DSi (n = 122) values are presented in Appendix 4. The variation in stable isotopic composition was wide being greatest within mini-piezometer samples, following surface water samples and finally groundwater and spring water samples that were most uniform (Fig. 11). Mean values ($\delta^{18}O$, δD, *d*-excess) for all mini-piezometer samples (n = 54) was -11.82 ‰, -90.38 ‰, 4.16 ‰, for surface water samples (n = 54) -11.07 ‰, -83.61 ‰, 4.96 ‰, for groundwater samples: (n = 24 measurements from n = 19 observation wells) -12.84 ‰, -97.01 ‰, 5.73 ‰ and for spring samples (n = 8): -11.20 ‰, -91.83 ‰, 4.09 ‰ (Appendix 5).

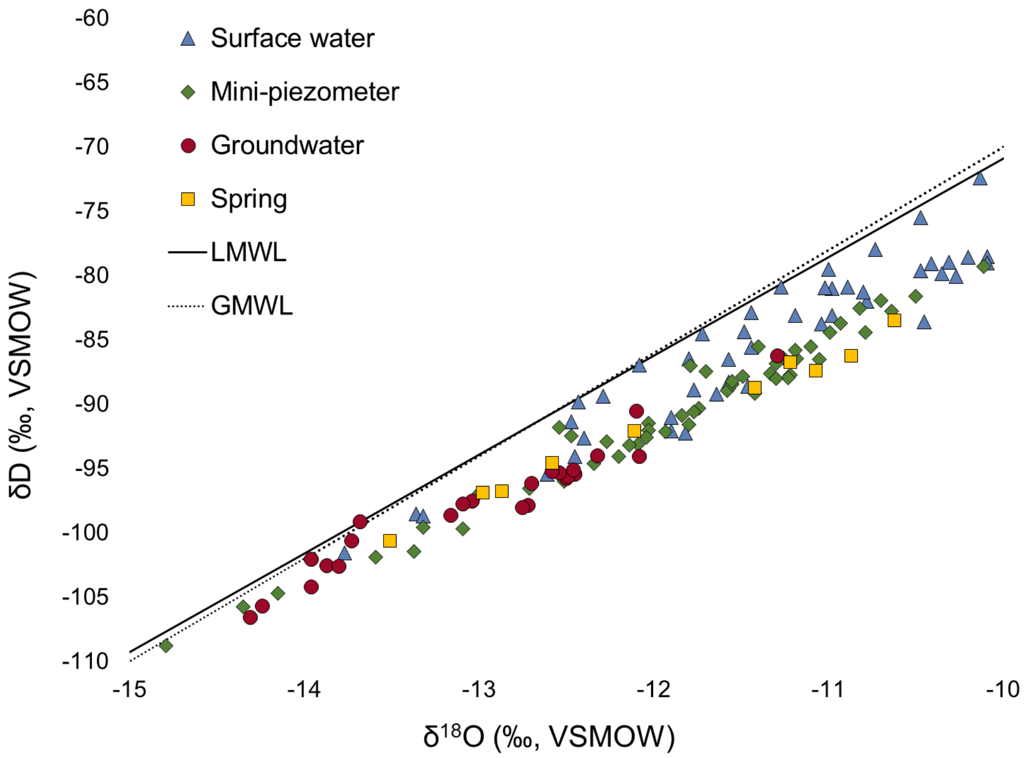


Figure 11. Isotopic composition of GW, SW, MP and spring samples.

The measured observation wells can be divided in three groups depending on the area of location. Observation wells along the river (n = 9, green circles) are mainly located near the dam and hydroelectric power plant. This is the area of fluvial sediments. The wells near the Sakatti ore deposit are located either on the dry land / at the dryer areas of the mire (n = 4, blue circle) or on the open mire at the margin of Viiankiaapa (n = 6, red circle) (Fig. 12).

Figure 12. The grouping of the groundwater observation wells by the environment. Green circle: Fluvial sediments. Blue circle: Dry land. Red circle: Open mire. (General map Database © NLS 2014).

The smallest $\delta^{18}O$ values (-14.5 – -13.5 ‰) were measured from the observation wells near hydroelectric power plant (upper green circle) as well as from wells located on dry land of Kiimakuusikko and Sakatti ore deposit area (blue circle). The highest $\delta^{18}O$ values (-11.2 – -13.5 ‰) were mainly measured from the observation wells located on the open mire south of the Sakatti ore deposit and along the river west of the Sakatti ore deposit (red and lower green circles) (Fig. 13). Similar trend was also seen with the measured δD values. The smallest *d*-excess values (*d*-excess 2.6 – 5.0 ‰) were measured from the observation wells located to the open mire, southern side of Sakatti ore deposit. The samples with highest values (7.9 – 10.3 ‰) were collected from the wells located at the dry land of Kiimakuusikko and on the riverbanks near hydroelectric power plant (Fig. 14). All the spring samples were collected from the mire side riverbank of River Kitinen, west of Sakatti ore deposit. Samples were collected mainly during the summer 2017. The smallest spring water values of $\delta^{18}O$ and δD were found from the southern part of the river bend while the highest values were measured from the springs near the mire margin as well as from the springs located at the northern part of river bend. The highest d-excess values in spring samples (6.2 – 7.5 ‰) were located correspondingly at the southern part of river bend while the samples with lowest *d*-excess (0.7 – 4.0 ‰) located near the mire margin as well as at the northern part of river bend. The variation of $\delta^{18}O$ of surface water was -13.8 – -8.6 ‰ and δD -101.6 – -68.6 ‰. Within both isotopes the variation was greatest at the area near Sakatti ore deposit and most homogenous near the hiking trail and Lake Viiankijärvi. The surface samples with smallest values ($\delta^{18}O$ -13.8 – -12.3 ‰) were systematically located near the dry land while samples with largest values ($\delta^{18}O$ -11.2 – -8.6 ‰) were scattered around the study area (Fig. 13). The *d*-excess of surface water samples was highest (6.2 – 9.7 ‰) near the Lake Viiankijärvi, at the southern side of Särkikoskenmaa and near the main ore body of Sakatti deposit. Near Kiimakuusikko and Pahanlaaksonmaa (around Sakatti ore deposit) high values of *d*-excess corresponded with the smallest values of stable isotopes as opposed to Lake Viiankijärvi and Särkikoskenmaa area (Fig. 14).

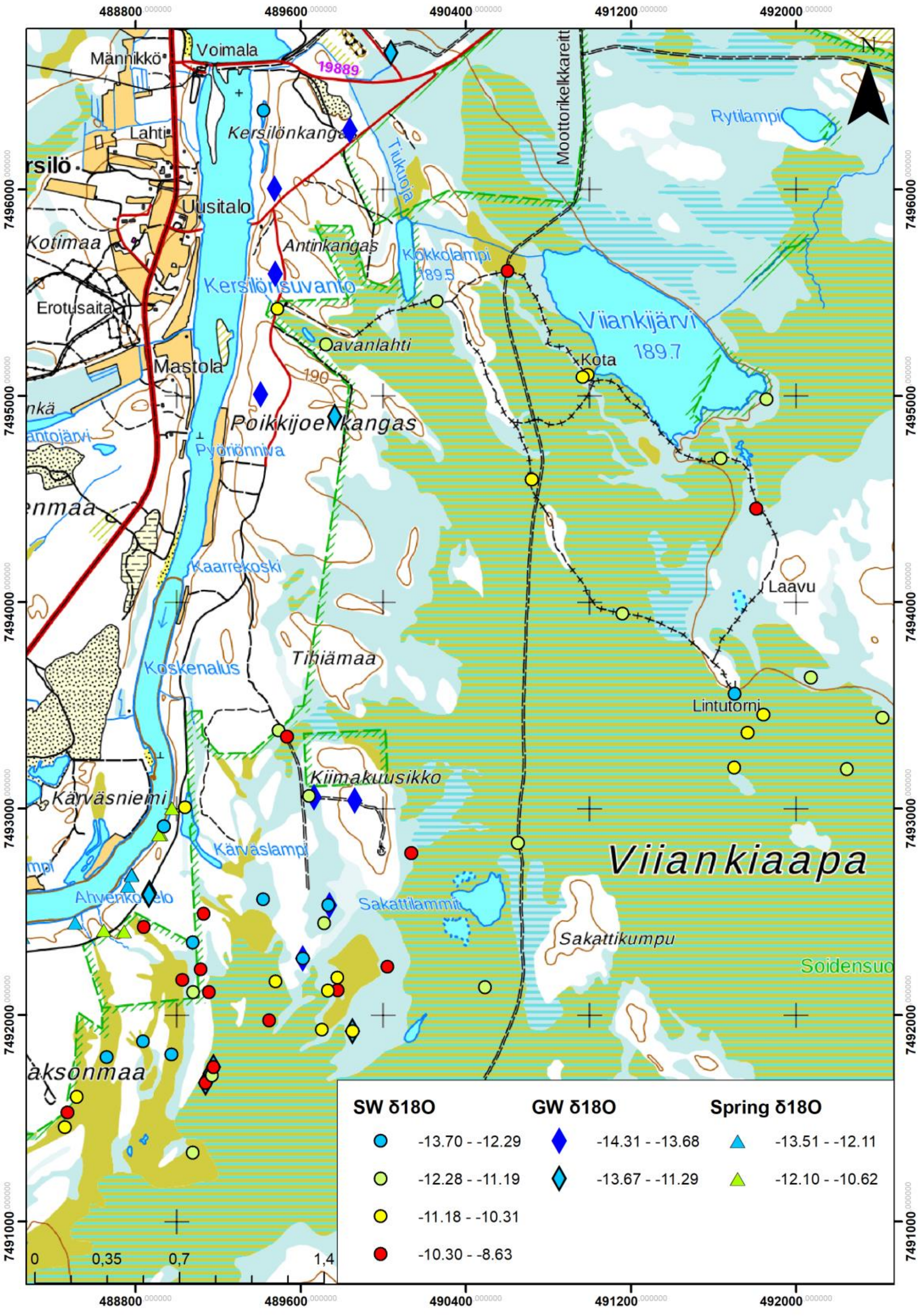


Figure 13. δ¹⁸O composition of SW, GW and spring samples. (General map Database © NLS 2014).

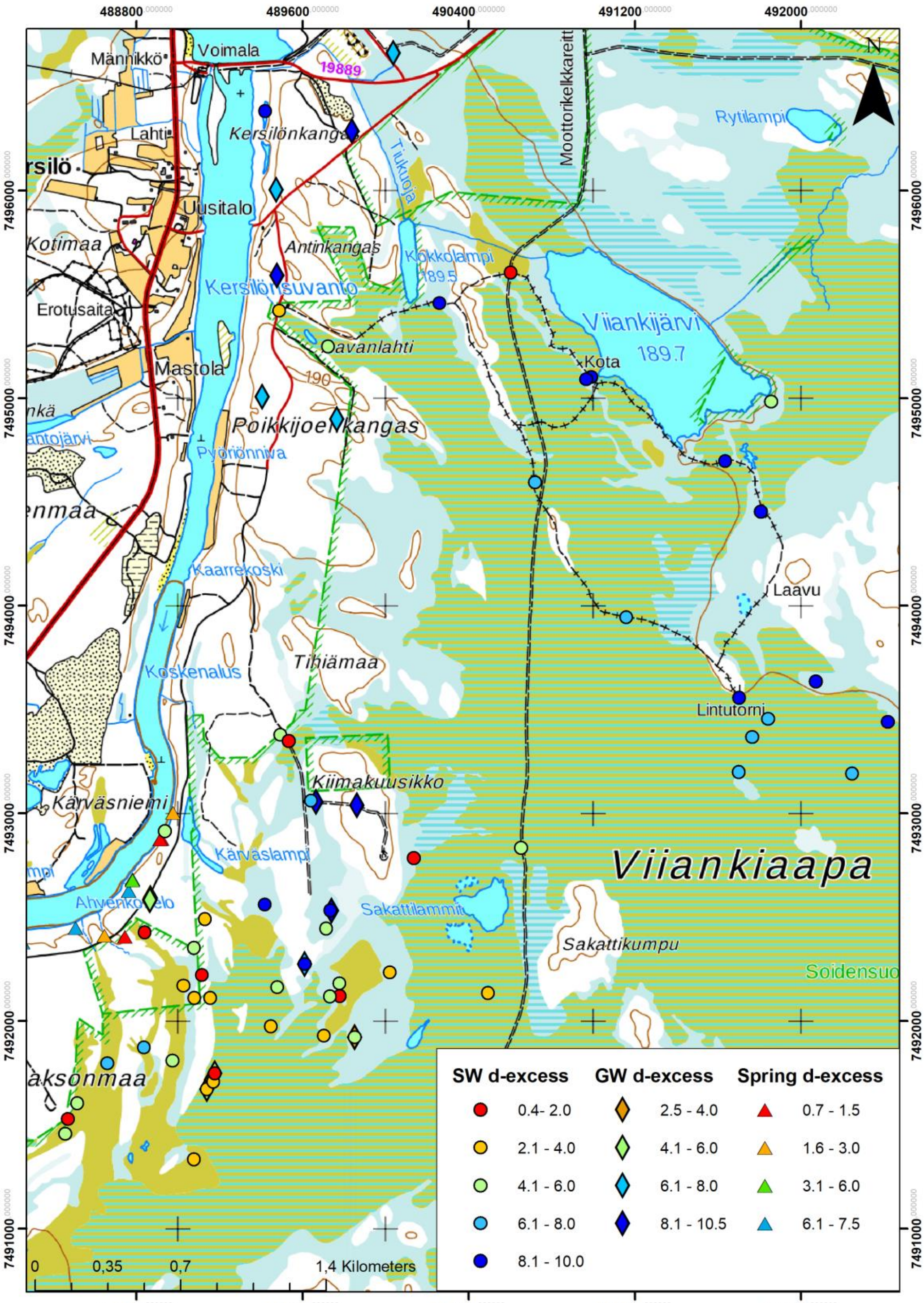


Figure 14. *d*-excess values of SW, GW and spring samples. (General map Database © NLS 2014).

The spatial distribution of isotopic composition of peat pore water is difficult to present on a map. There may be one or several samples taken from the same location but only one value from random depth, is shown on the map. More informative is to present the values in relation to depth. When changes in δ^{18}O composition were inspected, it was possible to find three different profile types; 1) strongly descending δ^{18}O values (profiles 3, 10, 11, 12, 17 and 19), 2) moderately descending or almost unchanging δ^{18}O values (profiles 4, 9, 16, 64 and 66) and 3) moderately increasing δ^{18}O values (profiles 61, 62, 63 and 65) (Fig. 15). Only profiles reaching to the depth 1 m or more were used.

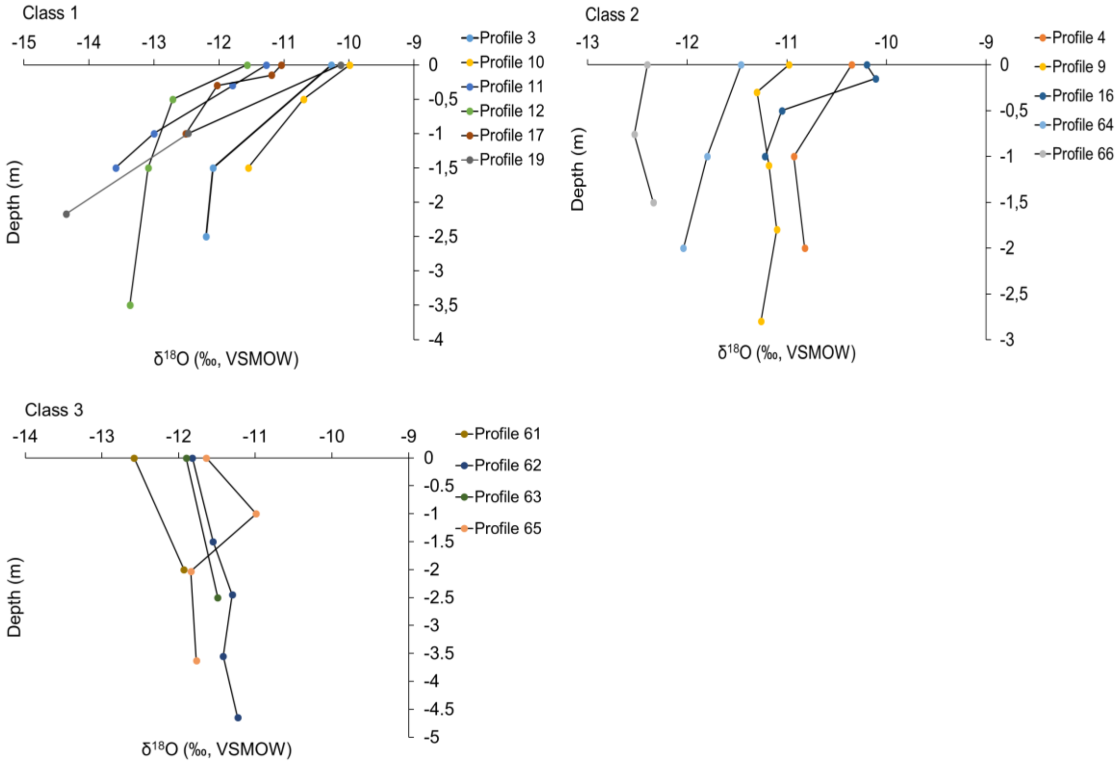


Figure 15. Change of δ^{18}O in relation to depth.

The dissolved silica was sampled with the stable isotope sampling. The mean dissolved silica of surface water samples was 3.20 ppm (variation of 0.01 – 12.59 ppm) and for groundwater samples (n = 16) 6,77 ppm (variation of 1.88 ppm – 11.70 ppm). The difference between DSi in surface water and groundwater samples was clear (Fig. 16). Profiles 11, 12 and 19 had strongly increasing DSi values when going deeper. Profiles 17, 60, 61, 63, 64 and 66 had descending values when going deeper.

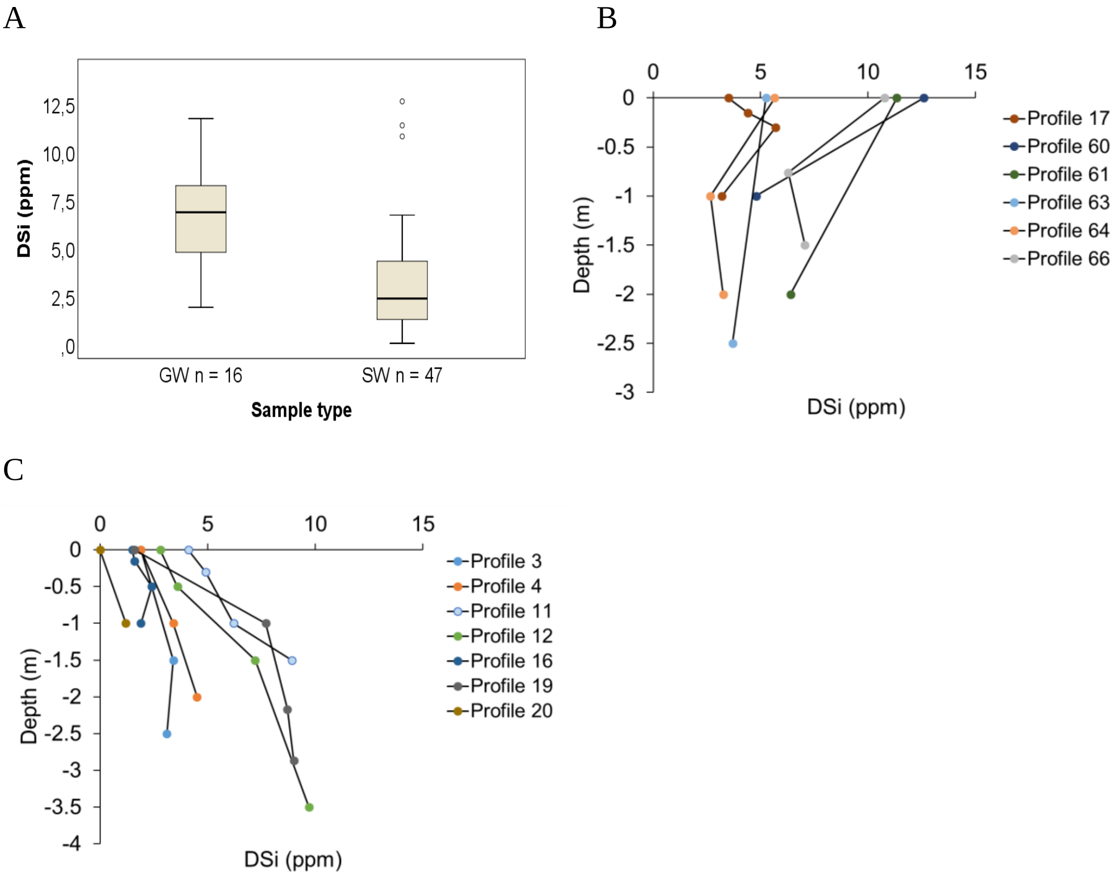


Figure 16. A) DSi in GW and SW samples. B and C) DSi concentration in relation to the depth.

5.3 Main ions

5.3.1 General features

Main ionic composition was analyzed from 87 samples. Ionic balance was calculated to ensure the reliability of the measurements. Organic anion was included to the total sum of anions as explained in Oliver *et al.* (1983) (Appendix 3). Because of the mire environment and presence of organic carbon the limit of acceptance for groundwater ionic balance in this study was 20 %, which is slightly higher than usually. Samples SAGA103, SAGA303 and SAGA400 did not meet these demands and therefore were not inspected with Piper’s diagram. For surface water samples the limit of acceptance of ionic balance was 30 % because of the higher amount of organic carbon. Four samples, SASW7, SASW17, SASW33 and SASW39 did not meet these demands. Peat pore water samples were not inspected in Piper's diagram (Fig. 17).

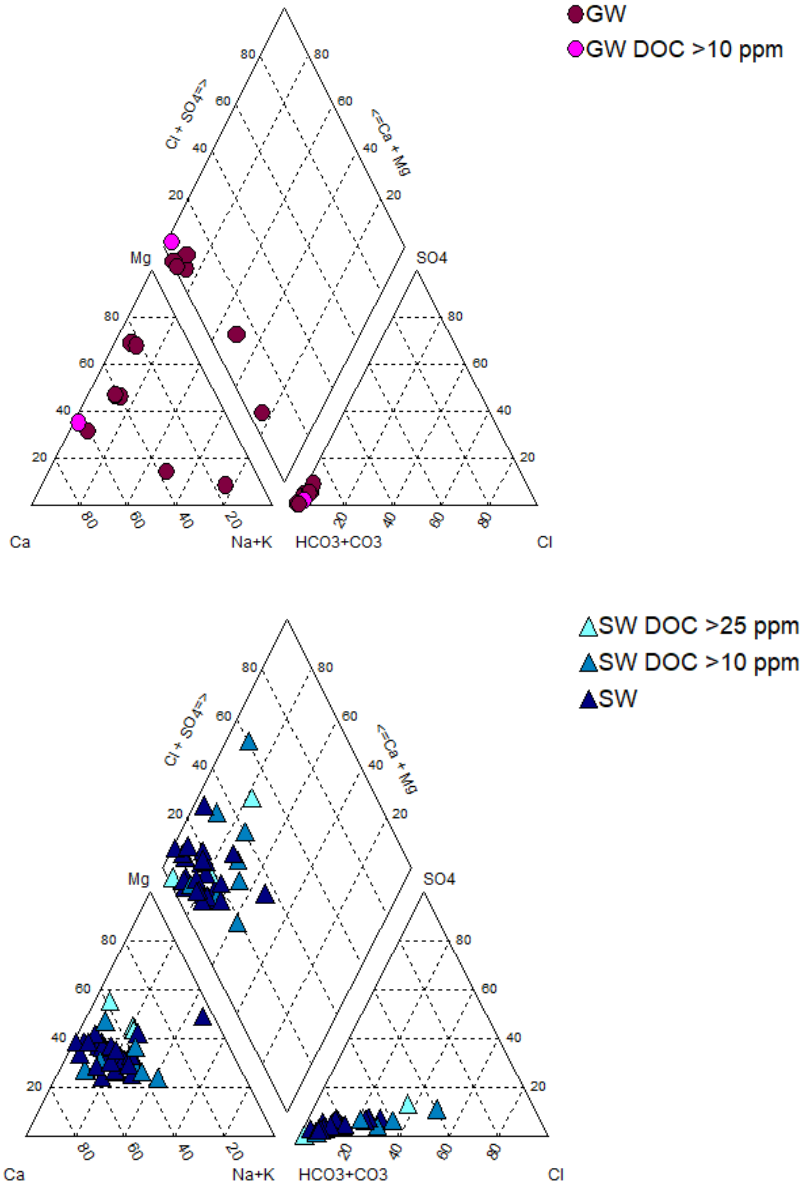


Figure 17. Piper's diagram representing the water types of GW and SW samples. Samples are color-coded depending of the amount of dissolved organic carbon (no value = < 10 ppm DOC).

General water type for surface water of the mire (n = 39) was Ca-Mg-HCO_3 (n = 18) and for groundwater (n = 9) was Mg-Ca-HCO_3 (n = 5). The variation of all water types were relatively small, changing mainly from Mg-Ca-HCO_3 type of water to Ca-Mg-HCO_3. Slight spatial variation was visible: Ca-Mg-HCO_3 –type waters located mostly around Sakatti deposit, within areas of mafic volcanic bedrock as well as South – SW – West side of the lake Viiankijärvi, where bedrock consists mostly of graphite paraschist but also mafic volcanic rocks and quartzite. The greatest variations of surface water types were found near the furthest end of Viiankiaapa hiking trail, where bedrock consists of gabbro, quartzite and siliciclastic sedimentary rock.

5.3.2 Main ions and H. vernicosus, peat depth and varying bedrock

Main ion values for surface water, groundwater and peat pore water samples are presented in Appendices 3 and 5. The statistically significant differences ($p < 0.05$) of main ion contents within the areas with and without *H. vernicosus* habitats and varying peat depth were studied with non-parametric Mann-Whitney U test for independent samples and for varying bedrock with Kruskal-Wallis test (Appendices 6 and 7). Cations were analyzed with ion chromatography (IC) as well as with inductively coupled plasma mass spectrometry (ICP-MS) together with trace element analyze. The quantity of analyzed samples was greater with ICP-MS and therefore these values are used. The IC analyses are used for anions.

Potassium was the only main ion in surface water samples having statistically significant difference ($p < 0.05$) between the areas with and without *H. vernicosus* ecosystems. The concentrations were low at areas with *H. vernicosus* ecosystems compared to the areas without the ecosystems (Fig. 18 A). Chloride had statistically significant difference between areas with different bedrock having highest values at the areas of gabbroic bedrock and graphite paraschist (Fig. 18 B). No statistically significance difference was found when main ions of surface water samples were compared with the areas of varying peat depth.

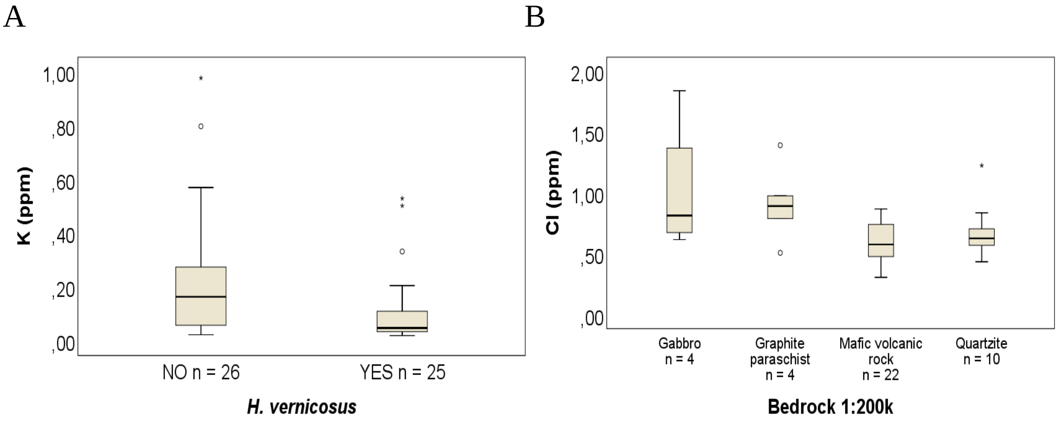


Figure 18. A) Potassium concentrations in surface water compared to areas with and without *H. vernicosus* habitats. B) Choride concentrations at the areas with varying bedrock.

In peat pore water samples Na and Cl had statistically significant differences between the areas with and without *H. vernicosus* ecosystems. Mg and Ca had statistically significant difference when comparing peat pore water with varying peat depth and Na and Ca had statistically significant difference when comparing peat pore water within areas of different bedrock (Fig. 19).

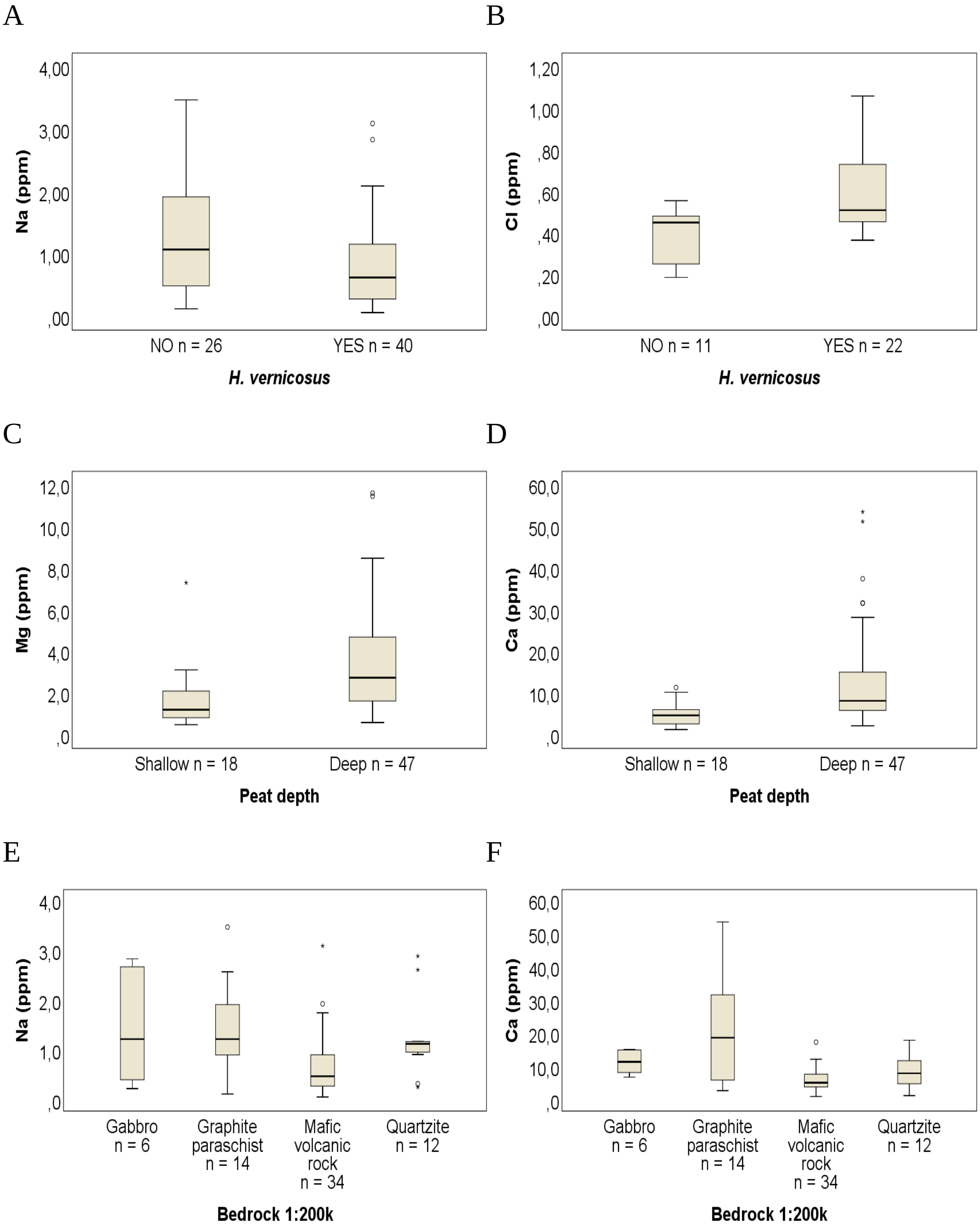
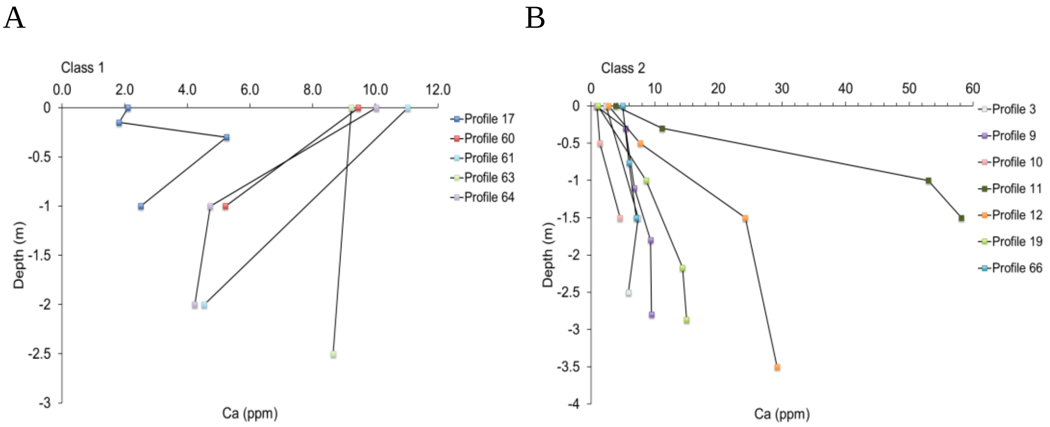


Figure 19. A and B) Na and Cl concentrations in peat pore water compared between the areas with and without *H. vernicosus* ecosystems. C and D) Mg and Ca concentrations compared between the areas of varying peat depth. E and F) Na and Ca concentrations compared between the areas of varying bedrock.

Mg and Ca values were greatest at the areas where peat depth was greater than 1.5 m. The highest Ca values of peat pore water were found from the areas of graphite paraschist. The highest Na values were found from the areas with gabbroic bedrock following graphite paraschist.

The peat pore water values of Ca and Mg were inspected with depth diagrams. These two cations are abundant in natural waters and therefore not greatly affected by the plant consumption (Lahermo *et al.* 1996). These are also good indicators of groundwater influence as the Mg and Ca bearing rocks are easily weathered (Lahermo *et al.* 1996). Profiles reaching to depth less than one meter were excluded because the changes in main ion concentrations did vary greatly in shallow depths and the overall trend was not visible in short profiles. Two different trends were found in relation to depth; descending or approximately non-changing values (class 1) and increasing values (class 2) (Fig. 20). Profiles 17, 60, 61, 62, 63 and 64 had descending or non-changing values with both variables while profiles 3, 9, 10, 11, 12. 19 and 66 had increasing Ca and Mg values. Especially in profiles 11 and 12 values increased strongly. Descending Ca profiles had greater surface water values than the increasing ones but the values were mainly similar when going deeper. This trend was also visible in Mg profiles.’



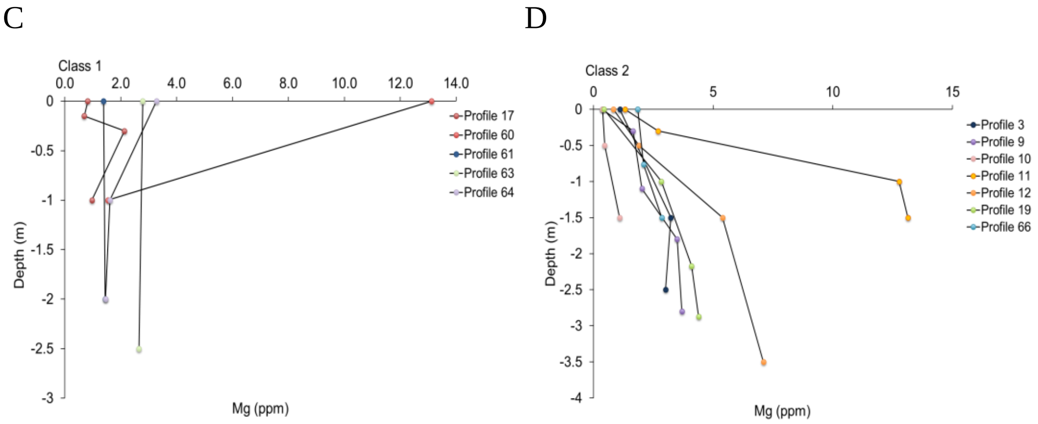
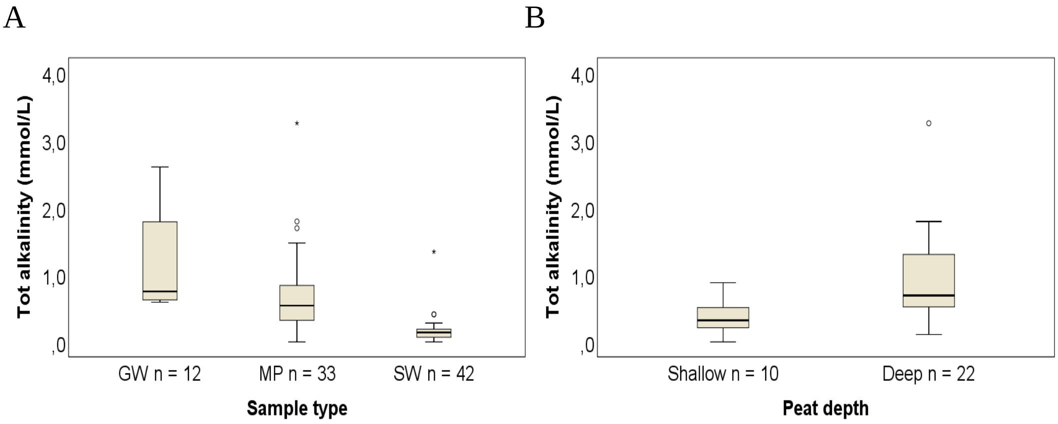


Figure 20. A and B) Ca concentrations in relation to depth. C and D) Mg concentrations in relation to depth.

5.3.4 Alkalinity

The difference of alkalinity (HCO_3^-) content of groundwater, peat pore water and surface water was clear. The greatest values and variation was seen within groundwater samples following peat pore water and finally surface water (Fig. 22 A). The mean value of total alkalinity of surface water samples was 0.171 mmol L^{-1}, variation of 0.00 – 1.34 mmol L^{-1}. There was no statistically significant difference in alkalinity neither between the areas with and without *H. vernicosus* habitats nor between the areas of varying peat depth and bedrock. The mean alkalinity of peat pore water was 0.73 ppm (variation 0.00 ppm – 3.25 ppm). There was statistically significant difference between the areas of different peat depth and varying bedrock (Appendix 7). Highest alkalinity was at areas of graphite paraschist following gabbroic bedrock. Only one sample was collected from the area of quartzite bedrock. (Fig. 21 B and C)



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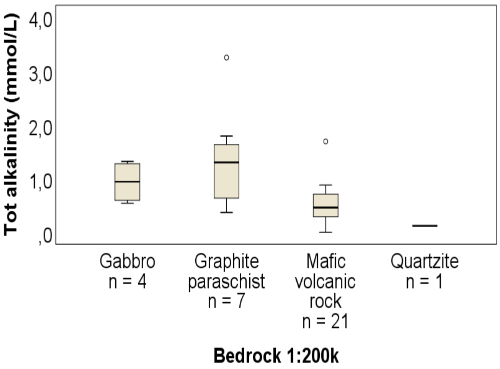


Figure 21. A) Alkalinity between the GW, MP and SW samples. B) Variation of alkalinity in peat pore water between varying peat depth. C) Variation of alkalinity in peat pore water between varying bedrock.

5.4 DOC

The difference with dissolved organic carbon in groundwater, surface water and peat pore water was clear. DOC of surface water samples had a mean value of 12.89 ppm, but the variation was large (3.10 – 65.60 ppm). Peat pore water had mean value of 14.52 ppm (variation 2.50 – 48.00 ppm) and groundwater 4.68 ppm (variation 1.30 – 12.00 ppm) (Appendix 5). There was a statistically significant difference in surface water samples between the DOC and areas with and without *H. vernicosus* ecosystems as well as between the areas of varying peat depth (Appendix 6). DOC was higher at the areas of shallow peat layer as well as near dry land (Fig. 22 and Fig. 23).

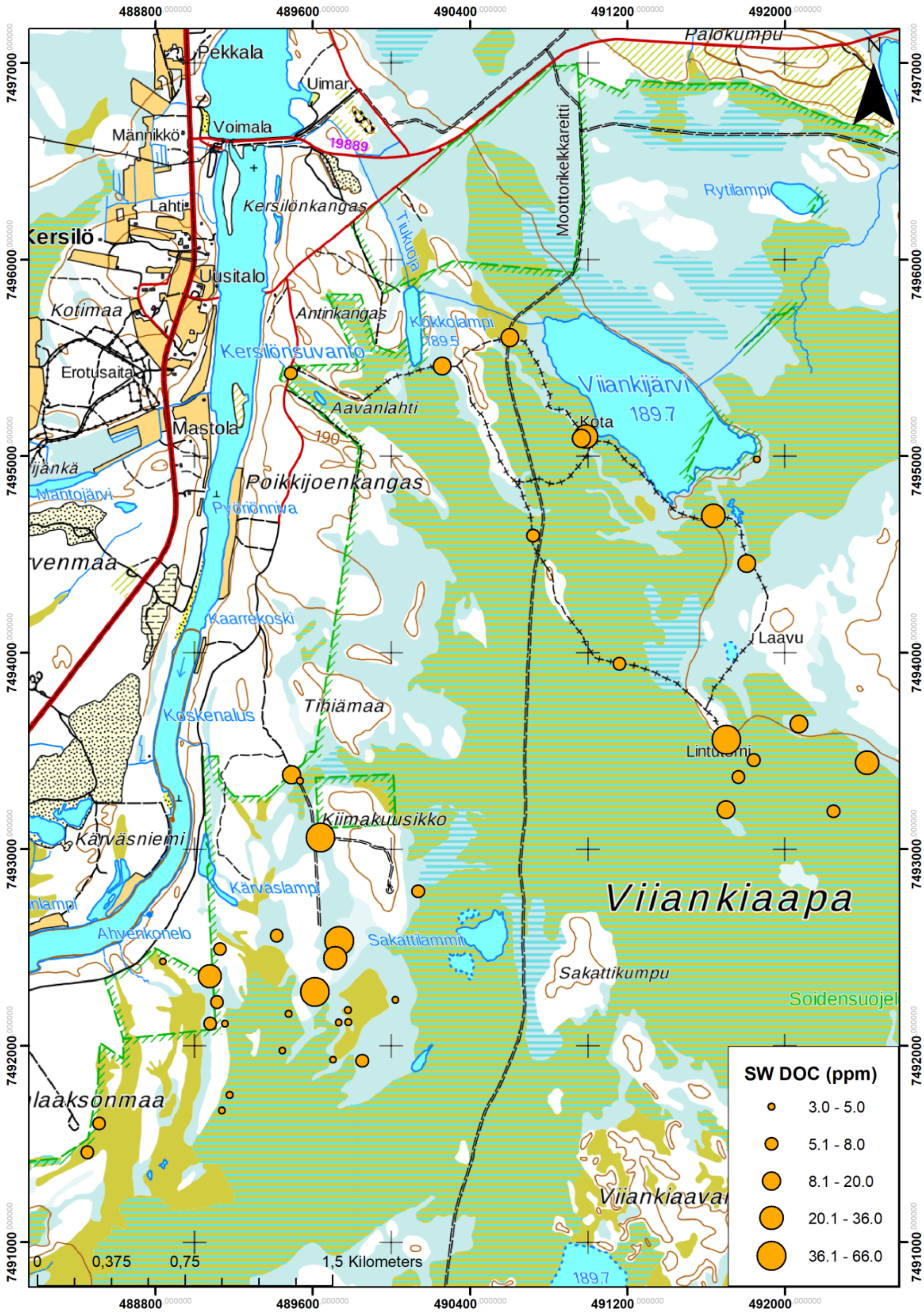


Figure 22. The distribution of DOC concentration in surface water of aapamire. (General map Database © NLS 2014)

Also the areas with the *H. vernicosus* habitats showed lower DOC concentrations (Fig. 23).

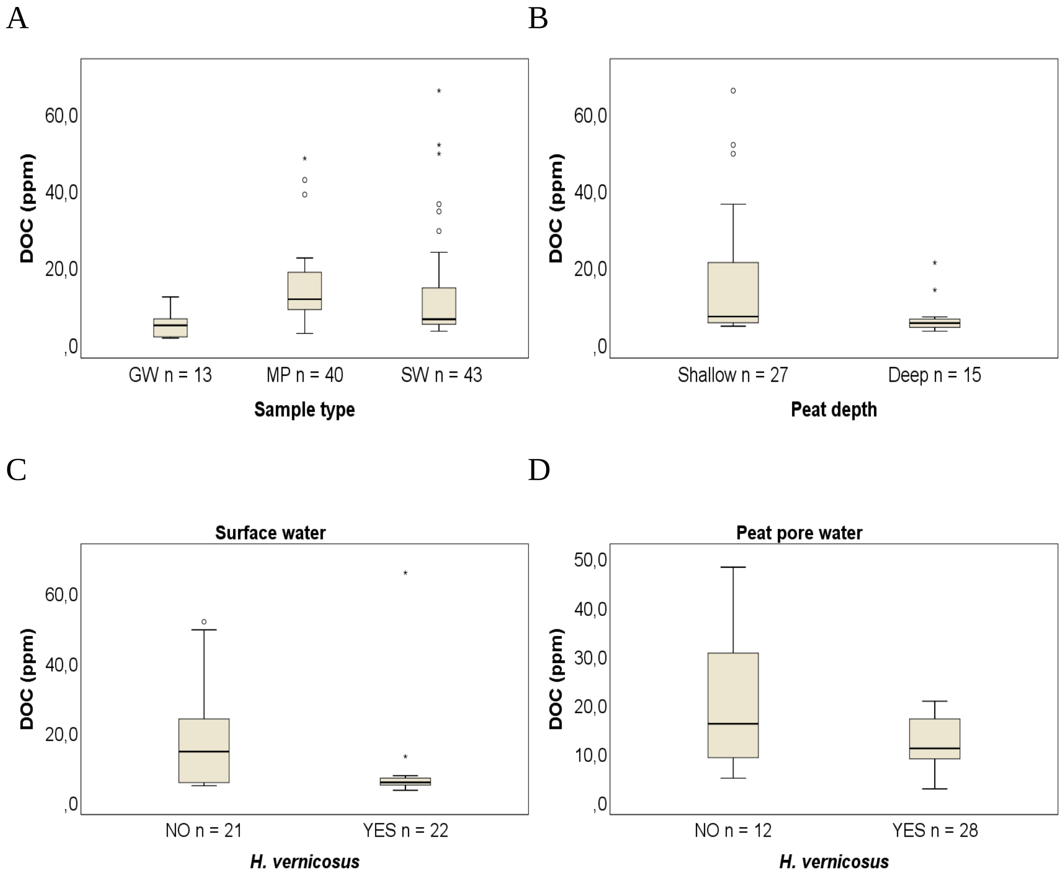


Figure 23. A) Variation of DOC concentration between GW, MP and SW samples. B) Variation of surface water DOC concentration between areas with varying peat depth. C) Variation of surface water DOC concentration between areas with and without *H. vernicosus* habitats. D) Variation of peat pore water DOC concentration between areas with and without *H. vernicosus* habitats.

5.5 Trace elements

Various trace elements were analyzed from 55 water samples. Trace elements with all concentrations under the detection limit were excluded (Appendix 2). The surface water concentrations were compared with background values presented in Lahermo *et al.* (1990). The variables with elevated concentrations were Mn, Fe, Ni, Zn, Pb, Al, As, Sb, Co and Th. Elevated consecrations were found from 24 surface water samples including lake and spring samples (Table 2.). The majority of these samples located at the margin of the mire, near dry land around Sakatti ore deposit. Samples SW23 and SW55 located near the duckboards at the hiking trail. Both lake water samples had elevated concentrations, SW47 had elevated Mn and Ni and located near hydroelectric power plant, SW24 with elevated Sb and Mn located along the hiking trail. 12 of these were located within mafic volcanic bedrock, six (6) within quartzite, five (5) within graphite paraschist and one (1) within bedrock of gabbro.

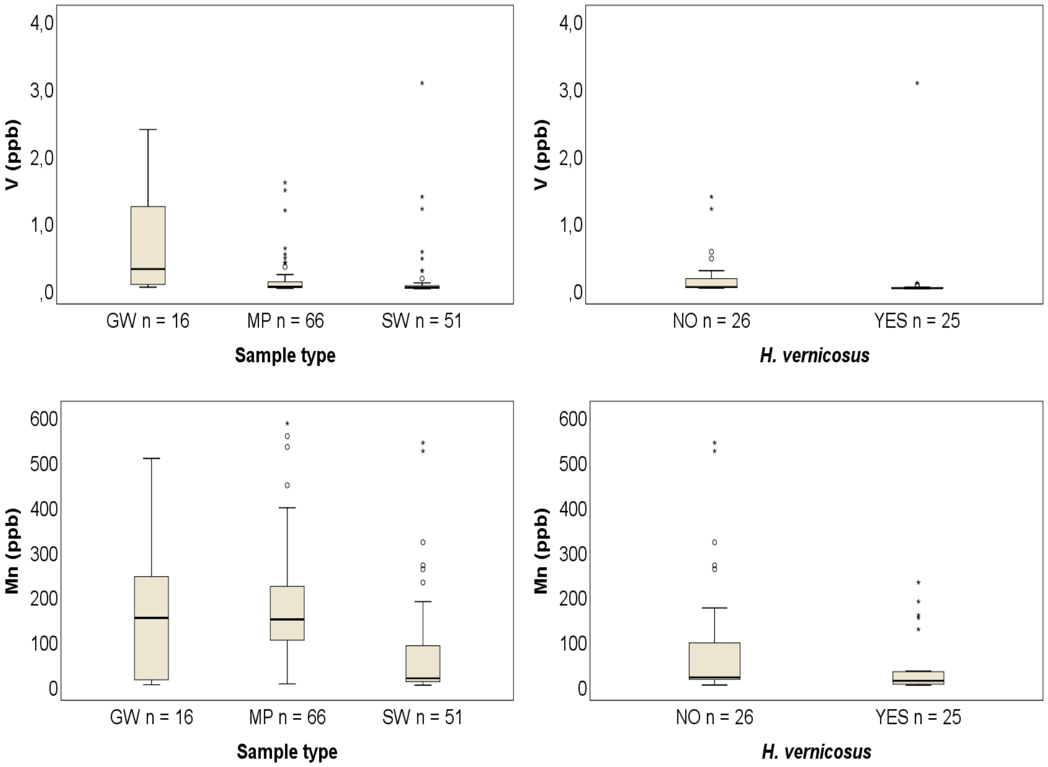
Table 2. Samples with elevated trace element concentrations. Background values to compare are based on Lahermo *et al.* 1990)

ID	CLASS	PROFILE	Mn > 150ppb	Fe > 3 ppm	Ni > 1.5 ppb	Zn > 15 ppb
SW2	SW	23		x	x	x
SW5	SW	26				
SW9	SW	34	x			
SW10	SW	37		x		
SW12	SW	39			x	
SW14	SW	41	x	x		
SW16	SW	43				
SW17	SW	45			x	
SW18	SW	47			x	
SW19	SW	49	x		x	
SW21	SW	54				
SW22	SW	21			x	
SW24	Lake	55	x	x		
SW33	SW	8				
SW36	SW	59	x	x		
SW37	SW	11		x		
SW45	Lake	68	x		x	
SW47	Spring	71	x	x	x	
SW48	SW	60	x	x	x	
SW49	SW	61	x		x	
SW50	SW	62	x	x		x
SW51	SW	63	x	x		
SW54	SW	66	x	x	x	
SW55	SW	67	x	x		

ID	CLASS	PROFILE	Pb > 0.5 ppb	Al > 50 ppb	As > 3 ppb	Sb > 0.02 ppb	Co > 1.5 ppb	Th > 0.05 ppb
SW2	SW	23		x		x	x	x
SW5	SW	26		x				
SW9	SW	34						
SW10	SW	37					x	
SW12	SW	39		x				
SW14	SW	41		x		x	x	
SW16	SW	43		x				
SW17	SW	45		x		x		
SW18	SW	47	x	x		x		
SW19	SW	49		x		x	x	
SW21	SW	54				x		
SW22	SW	21		x			x	
SW24	Lake	55				x		
SW33	SW	8		x		x		
SW36	SW	59						
SW37	SW	11						
SW45	Lake	68						
SW47	Spring	71					x	x
SW48	SW	60	x			x	x	

SW49	SW	61	x			
SW50	SW	62			x	x
SW51	SW	63				
SW54	SW	66		x	x	x
SW55	SW	67	x		x	x

In surface water samples of the mire Al, V, Mn, Fe, Co, Ni, Zn, As, Sb, Pb and Th had statistically significant difference ($p < 0.05$) between the areas with and without *H. vernicosus* ecosystems (Fig. 24). Al, V, Cr and Ni had statistically significant difference between the areas of varying peat depth (Fig. 25). No statistically significant differences were found in surface waters between the areas of different bedrock (Appendix 6). More exact inspection was done to those variables with clear difference in concentration between groundwater, peat pore water and surface water. With this inspection it was possible to say if the trace element content indicates groundwater discharge at the areas of *H. vernicosus* habitats or not. Al, Pb, Th, Zn and Co did not show significant differences in concentrations between groundwater and surface water samples. There was higher concentrations of Co in peat pore water samples, but this can be explained with the higher amount of organic carbon (Lahermo *et al.* 1996).



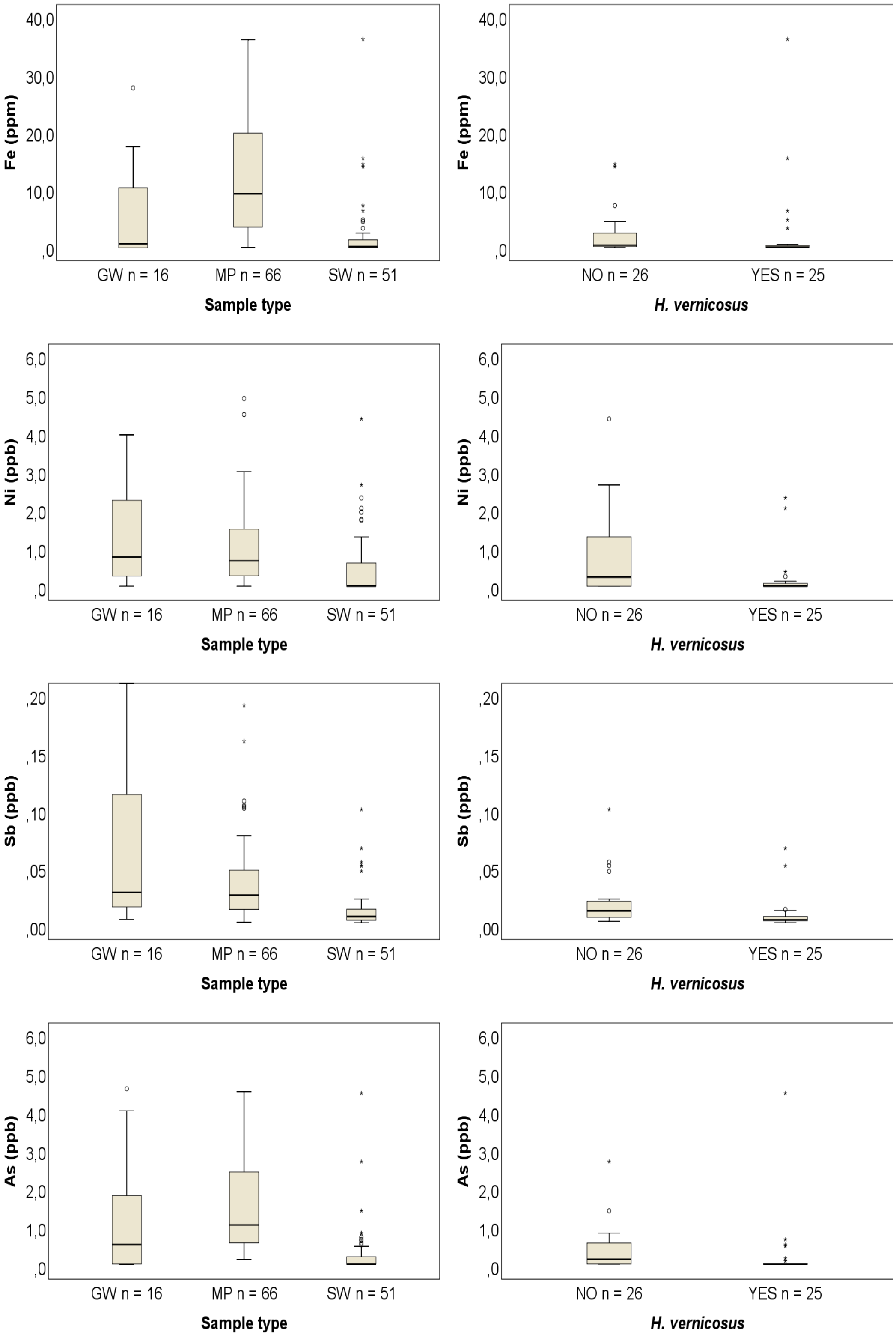


Figure 24. Left side pictures: Concentrations of several trace elements between GW, MP and SW. Right side pictures: Concentrations of several trace elements between the areas with and without *H. vernicosus* habitats.

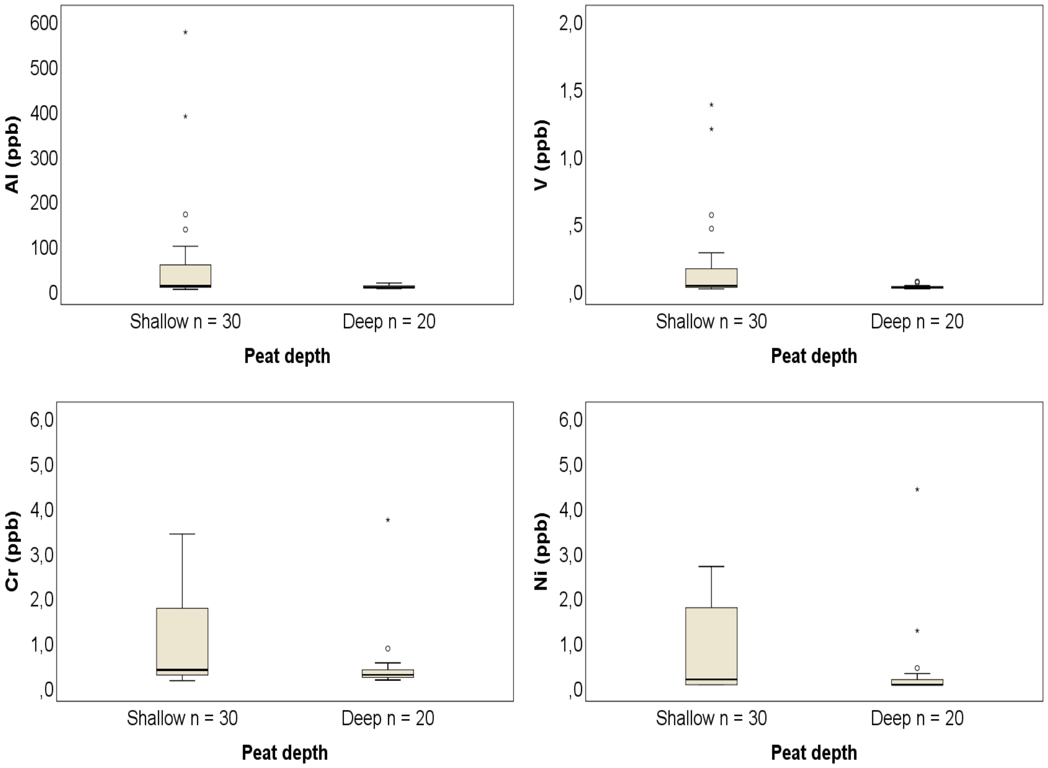


Figure 25. Surface water concentrations of Al, V, Cr and Ni between the areas of varying peat depth.

Generally all the concentrations were higher in groundwater samples following peat pore water samples and finally surface water samples. The values were also greater at areas without *H. vernicosus* ecosystems and at the areas of shallow (< 1.5 m) peat depth.

In peat pore water samples statistically significant difference between the areas with and without *H. vernicosus* was found with Co, Ni, Cr, Mo and Pd. Depth profiles were created with Co, Ni and Cr because in several samples Mo and Pd values were less than the detection limit. Profiles reaching at least to the depth of 1.5 m were included. Two different of trends were visible 1) curved profiles with small surface water values that rapidly increased when going deeper (after 0.5 m – 1 m almost all of the values stabilized or began to descend) and 2) Descending values with higher surface water values (Fig. 26). Over all the surface water values in class 2 were higher than the highest values of in class 1 profiles.

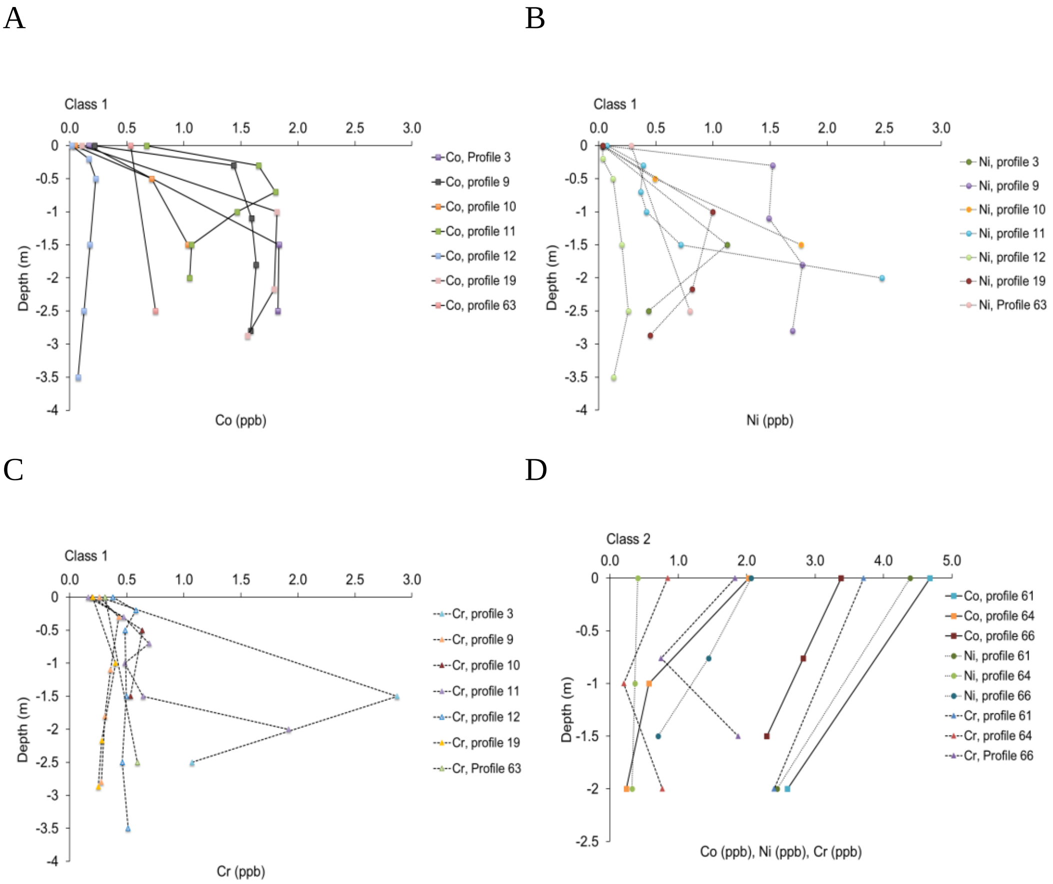
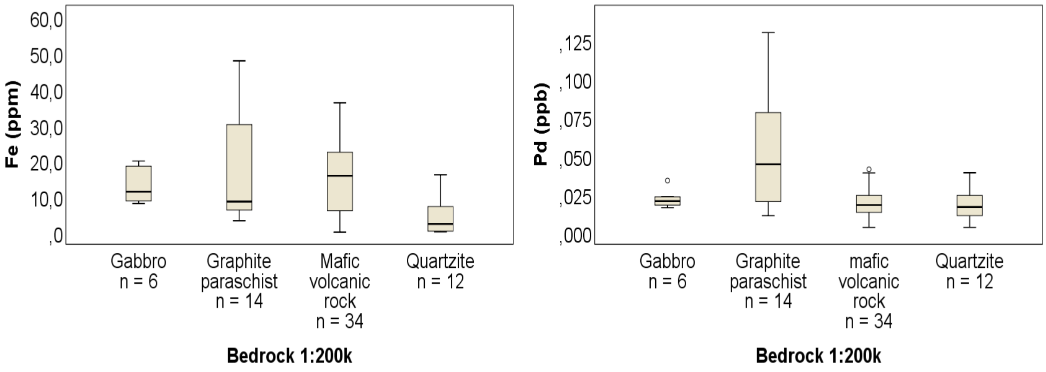


Figure 26. A, B and C) Co, Ni and Cr concentrations in relation to depth (Class 1). D) Co, Ni, Cr concentrations in relation to depth (Class 2).

Al, Mn, Pd and Pt concentrations in peat pore water samples had statistically significant difference between the areas of varying peat depth. Fe, Co, Zn, Pd and Sb had statistically significant difference between the areas of varying bedrock. Concentration difference within the varying bedrock were inspected further to see if the underlying bedrock had influence in peat pore water chemistry (Fig. 27).



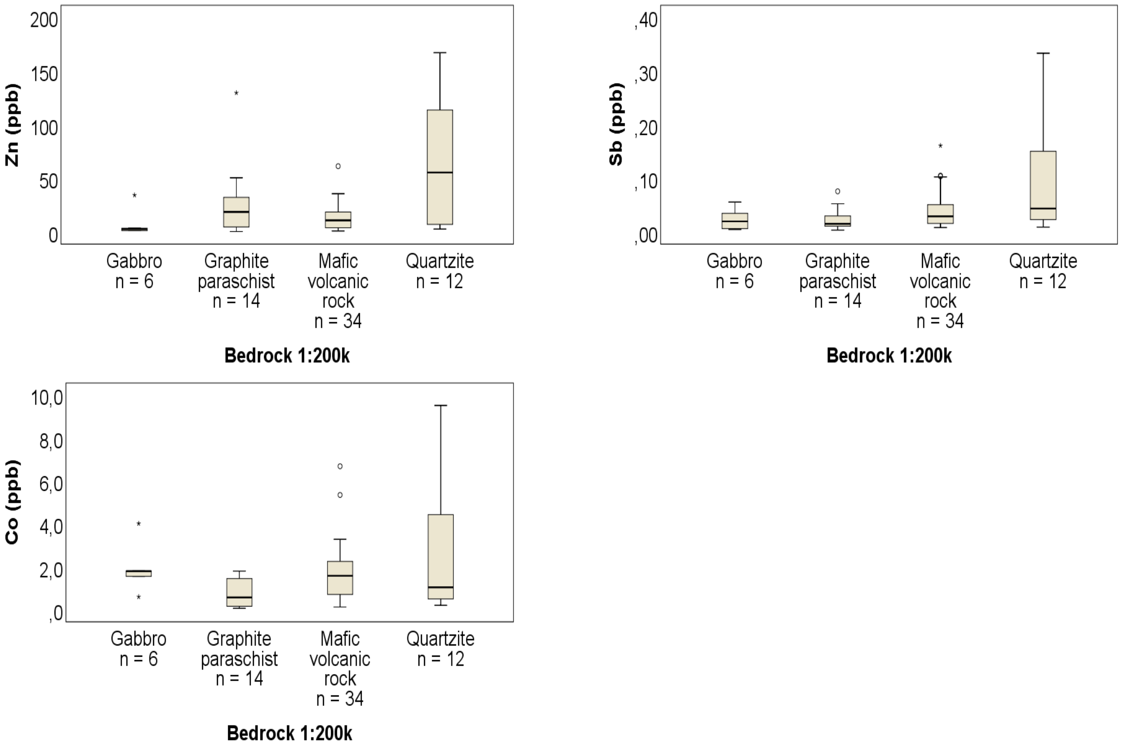


Figure 27. Several trace element concentrations in peat pore water within the varying bedrock.

Co, Zn and Sb values were greater at the areas of quartzite bedrock while Fe and Pd had higher concentrations at the areas of graphite paraschist.

5.8 Sources of error

Due to high alkalinity some of the samples were diluted with ultrapure water to 1/5 or 1/10 before measuring main cations with ion chromatography. The results were multiplied afterwards, which increase the possibility of error. Main anions where measured without dilution.

6. DISCUSSION

6.1 Hydrogeochemistry; areas of groundwater discharge and influence of the bedrock

6.1.1 Groundwater discharge

According to *d*-excess values and stable isotopes of surface water samples of the mire, possible groundwater discharge occurs between Särkikoskenmaa and Lake Viiankijärvi as well as around the bird observation tower near the Lake Viiankijärvi. Surface water near the main ore body of Sakatti had $\delta^{18}O$ and *d*-excess values that could represent possible local groundwater discharge but mainly indicated precipitation of the season (Kortelainen 2007) (Fig. 28). Depth profiles of $\delta^{18}O$ and DSi composition (presented in Ch. 5.2) support the hypothesis of groundwater movement in peat layer between the Särkikoskenmaa and Lake Viiankijärvi, mixing with the surface water when migrating upwards. In addition the main ion profiles (see Ch. 5.3.2) showed higher main ion concentrations deeper in the peat layer near Lake Viiankijärvi, which indicated the groundwater flow horizontally through the peat layer. The groundwater discharge areas, presented in Fig. 28 support earlier results by Korkka-Niemi *et al.* (2017) where groundwater discharge of the area was studied with thermal infrared survey.

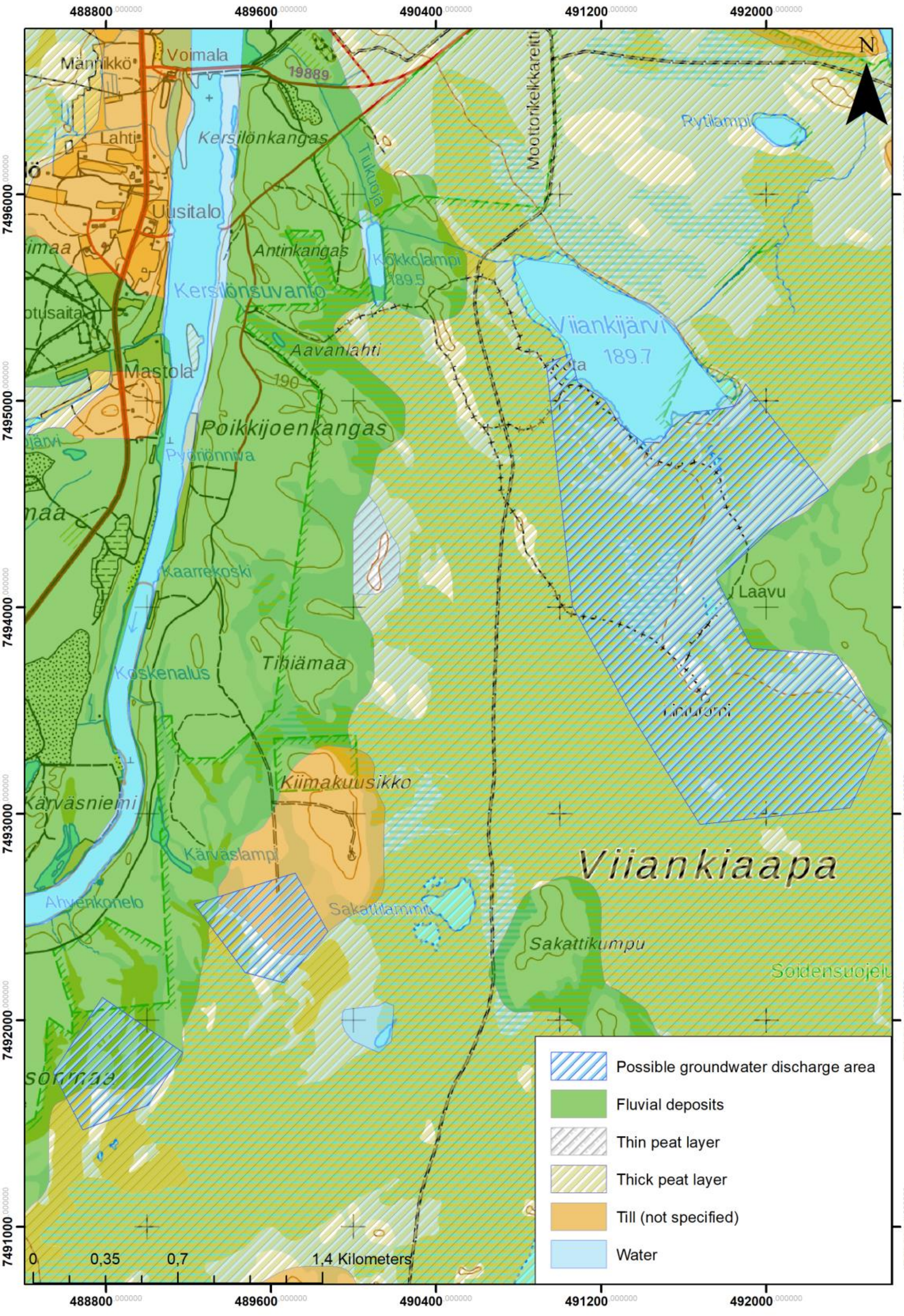


Figure 28. Possible areas for groundwater discharge according the stable isotope and main ion results of surface water samples in aapamire. (General map Database © NLS 2014, Soil map Database © Geological Survey of Finland 2010, Open database © Finnish Environmental Institute 2014).

Even though the depth profiles supported groundwater movement and discharge on the eastern side of Lake Viiankijärvi, was groundwater influence only slightly visible in surface water chemistry. There were still differences when surface and peat pore water chemistry of Lake Viiankijärvi and Sakatti area were compared (Fig. 29). Higher pH of surface water and peat pore water as well as the higher cation content of peat pore water and significantly higher electric conductivity of peat pore water around Lake Viiankijärvi area indicate groundwater discharge and movement in peat layer. Also the δ^{18}O and *d*-excess values show groundwater influence at the Lake Viiankijärvi area, while Sakatti area had mainly values that indicated precipitation of the season or stagnant waters that have been exposed to evaporation. The higher electric conductivity of surface water near the Sakatti area could be a sign of individual groundwater discharge areas. However it most probably is a result of slightly higher main ion and trace element content in surface waters around Sakatti, as seen in Fig 30 and in Fig 34 presented in chapter 6.1.2. These high element concentrations around Sakatti deposit were most likely explained with the presence of ultramafic ore body but also with the discharging groundwater at least near the mire margin where the aquifer in fluvial sand deposit possibly discharges to the mire.

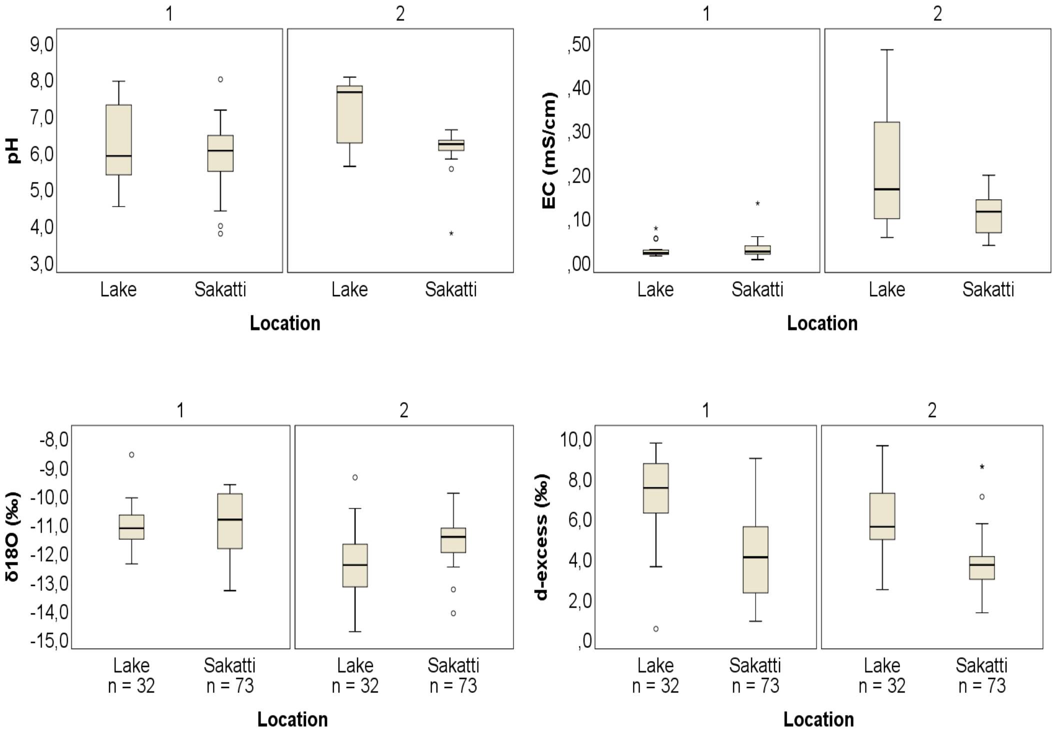


Figure 29. The differences in surface water (1) and peat pore water (2) chemistry between the areas of Lake Viiankijärvi and Sakatti ore deposit.

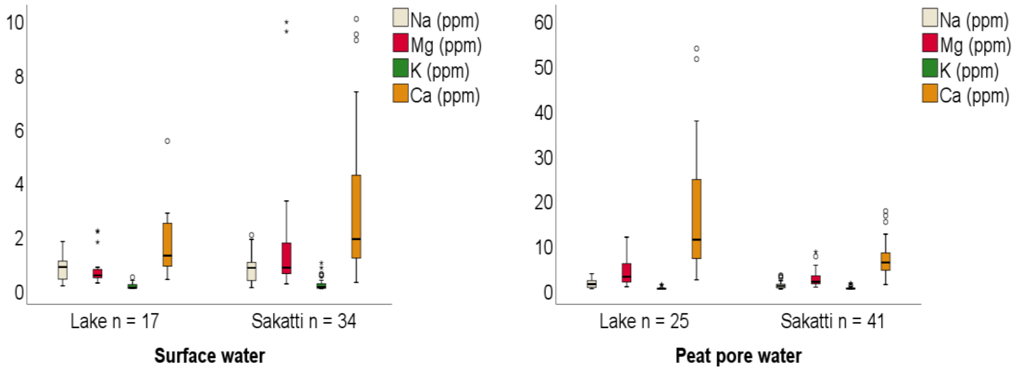


Figure 30. Surface water and peat pore water main ion concentrations between the areas of Lake Viiankijärvi and Sakatti ore deposit.

This kind of comparison of the areas is highly simplifying and shows only the major local variation not the minor. The area around Sakatti deposit is more heterogeneous in peat depth and therefore has more changing hydraulic properties than the Lake Viiankijärvi site. The possible individual groundwater discharge areas could therefore be hidden behind all the other geochemical data. It is also clear that rapid groundwater discharge cannot be expected, at least not near the Lake Viiankijärvi area. Because of the high peat thickness and state of decomposition the K values might be as low as 10^{-8} ms^{-1} – 10^{-6} ms^{-1} (Fraser *et al.* 2001) and therefore the groundwater seepage must be slight. However the lateral groundwater input is known to be an important source of a mire hydrology (Ferlatte *et al.* 2015) and near the area of Särkikoskenmaa sand-gravel formation, the groundwater most likely discharges under the Viiankiaapa peat layer as seen in peat pore water chemistry and depth profiles taken from the eastern side of Lake Viiankijärvi. The discharging groundwater slowly migrates towards the top of the peat layer and is most likely diluted with the horizontally flowing mire water, representing more surface water like chemistry (Bleuten *et al.* 2006).

The isotopic composition of groundwater measured from the observation wells and springs along the western margin of Viiankiaapa, reflected mainly the typical isotopic composition of annual mean precipitation in Middle Lapland area (Kortelainen 2007) but few exceptions needed more inspection. The isotopic values in observation wells presented in Figure 31 indicated influence of either evaporated surface water or season’s rainwater. The lowest (< 5 ‰) *d*-excess values could be a sign of evaporation considering the time of year when sampling was done. In northern Finland *d*-excess of precipitation during summer and autumn is calculated to be approximately 5 - 10 ‰ (Kortelainen 2007). During the fieldwork the autumn in Lapland was relatively dry and warm (Finnish Meteorological Institute, 2018).

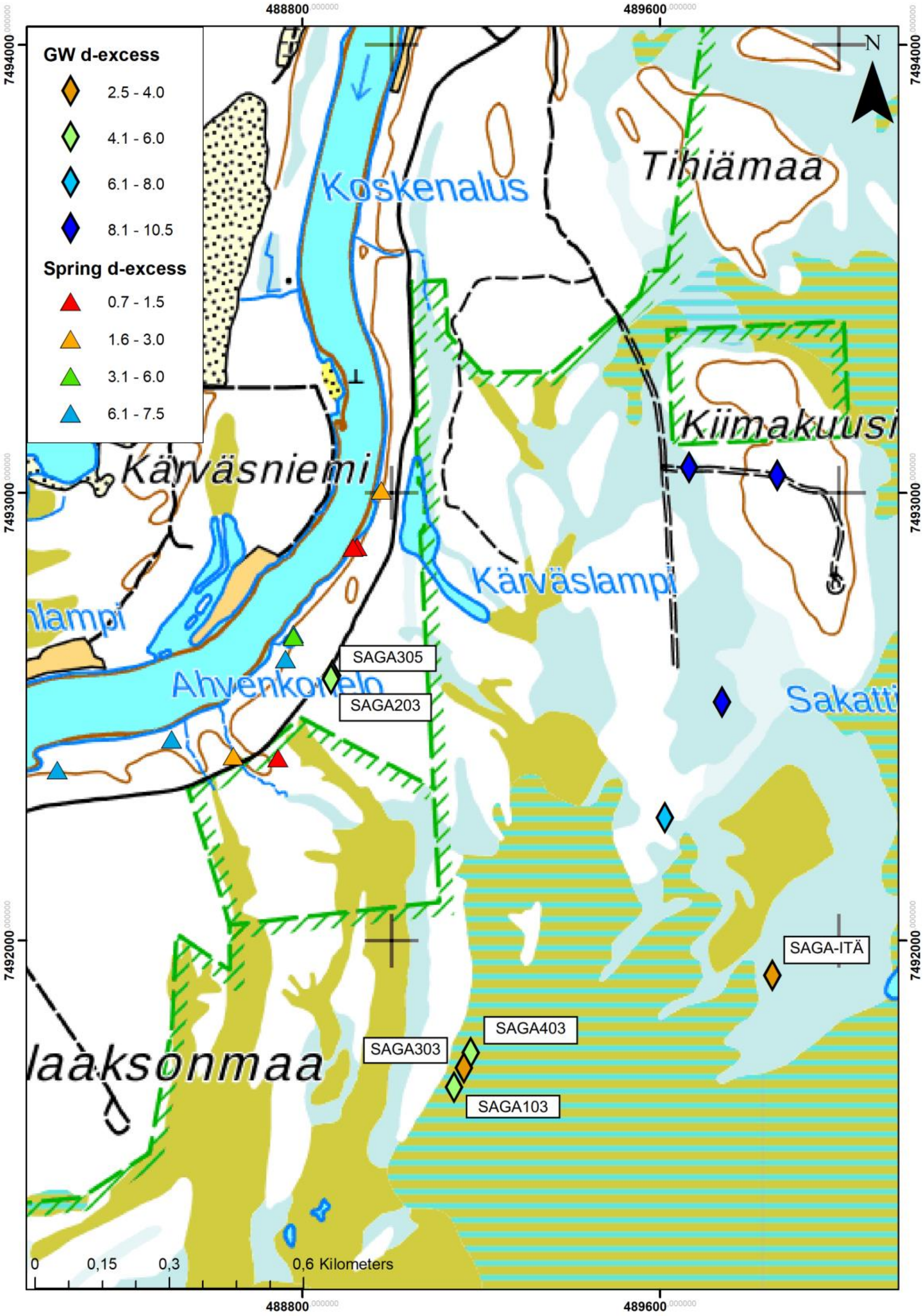


Figure 31. The groundwater observation wells with surface water like stable isotope composition. (General map Database © NLS 2014)

One or two of the surface water like values may be explained with the bad condition of the observation well i.e. surface water contamination, and some with the bottom depth of the observation well. For example observation well SAGA-Itä did not penetrate the peat layer and therefore it is obvious that the measured values are more peat pore water like than groundwater like. Other observation wells reached either to the moraine and gravel or to the bedrock that is known to be weathered at least at the eastern side of Pahanlaaksonmaa.

From pH and electrical conductivity diagrams (Fig 32 and 33) it is possible to see that half of these observation wells with evaporated waters have pH and EC values that resembles groundwater values (Lahermo *et al.* 1990, 1996). However observation wells SAGA-Itä, SAGA103, SAGA203 and SAGA305 had surface water like pH and EC values.

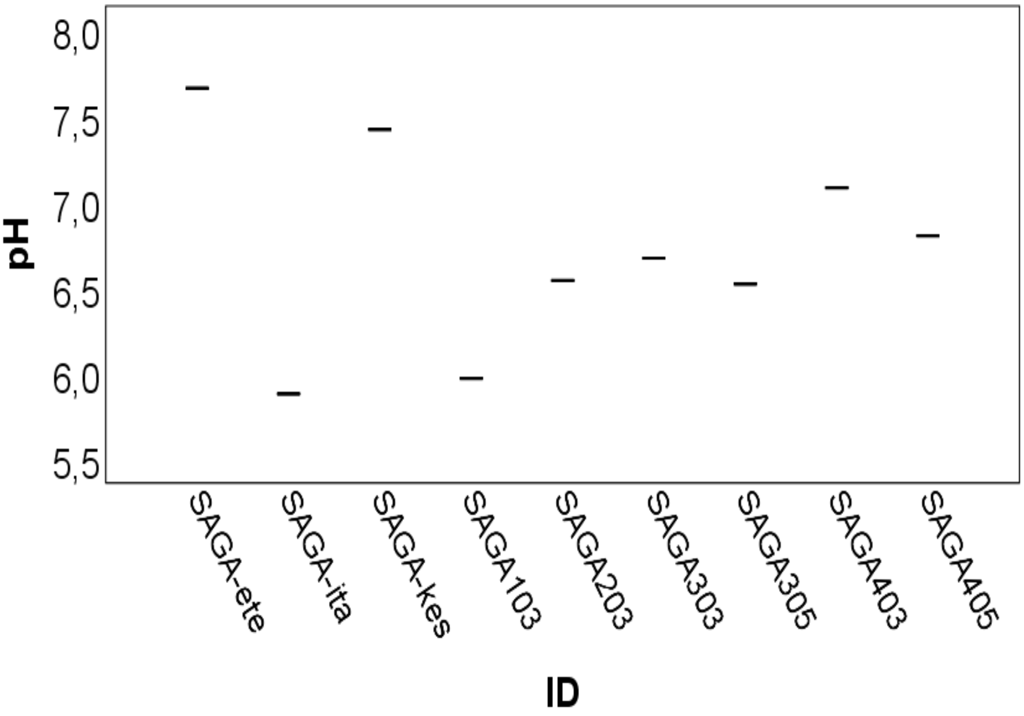


Figure 32. pH values of the groundwater samples with surface water like stable isotope compositions.

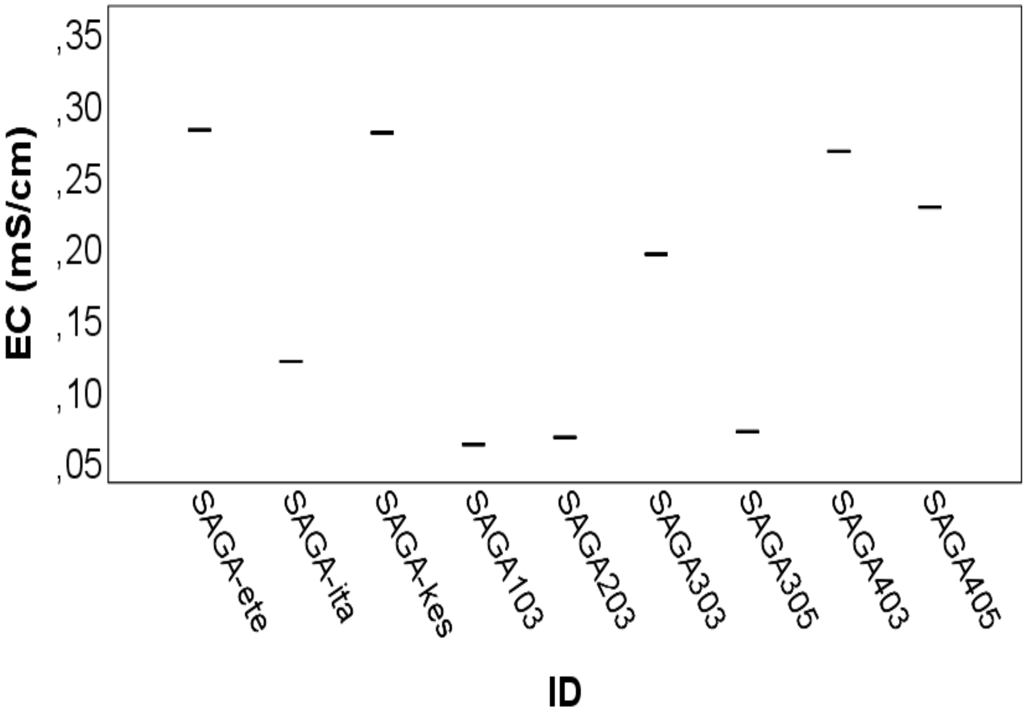


Figure 33. EC values of the groundwater samples with surface water like stable isotope compositions.

The stable isotope composition and *d-excess* of many groundwater and spring water samples between Sakatti main ore body and River Kitinen show most likely mixing of groundwater and season's precipitation. This could be explained with the groundwater flow direction. The soil beneath the peat layer at the margin of the mire consists of fluvial sediments (Åberg *et al.* 2017a) having high hydraulic conductivity. It is possible that the fen mire water infiltrates from the mire through the fluvial soil, mixes with the groundwater and discharges to the springs and river Kitinen. Also the water body altitude presented in Åberg *et al.* (2017b) supports the flow direction from Viiankiaapa to River Kitinen. This could explain especially the mixed values in springs and observation wells at the steepest bend of River Kitinen, where the dry land between Kitinen and Viiankiaapa is less than 200 m.

6.1.2 Hydrogeochemistry and bedrock of study area

The metal content of groundwater reflects in large scale the geochemistry of areal bedrock (Lahermo *et al.* 1990, Tahvanainen et al 2002). The influence of bedrock might also be visible in surface water chemistry and peat chemistry as the metals migrate with groundwater flow (Hill and Siegel 1991). The migration depends on how these metals behave in environments of changing redox, pH and present organic carbon. The ultramafic olivine cumulate Sakatti ore deposit, containing many trace metals, is prone to weathering in low temperature and low-pressure environment. These metals may locally affect water chemistry and even indicate groundwater discharge elevating the metal concentrations in surface water and in peat. The metal content of surface water and peat pore water between Sakatti ore deposit area and Lake Viiankijärvi area was inspected to see the areal difference (Fig 34). Metals V, Cr, Co, Cu and Ni are abundant in ultramafic rocks while As is more common in sulfides (Lahermo *et al.* 1996). The difference between Sakatti and Lake Viiankijärvi areas was clear. The Sakatti ore deposit area had higher Co, Cr and Ni content both in surface water as in peat pore water values. The difference with Cu and V was not as clear. The Lake Viiankijärvi area had significantly higher Arsenic content in peat pore water while the difference was minor in surface water. This can be explained with the behavior of the metals. Arsenic behaves differently compared to the others. When Co, Cr and Ni are more soluble in acid conditions, is arsenic more soluble in neutral or slightly basic conditions (Lahremo *et al.* 1996). The peat pore water around Lake Viiankijärvi had higher pH as presented in chapter 6.1.1.

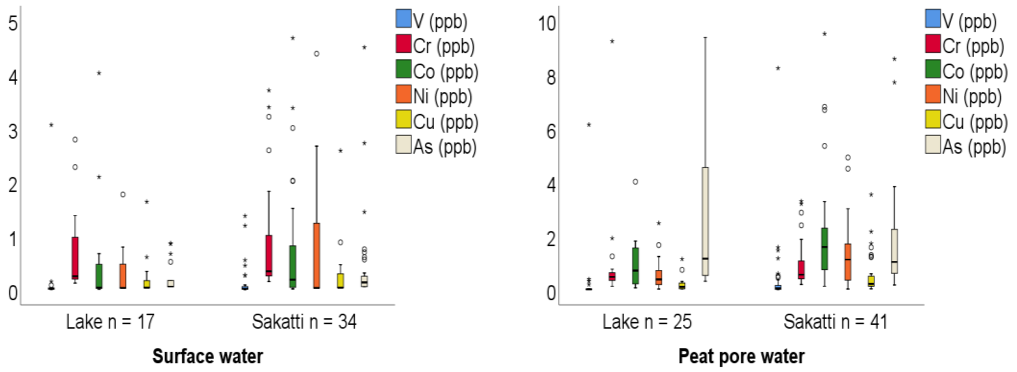


Figure 34. The trace element concentrations of surface water and peat pore water between the areas of Lake Viiankijärvi and Sakatti ore deposit.

The Sakatti ore deposit area had varying surface water metal concentrations. The areas of higher metal content were located near the dry land, around the ore bodies and had generally more groundwater like isotopic composition or were known to be groundwater fed rivers or springs even though the isotopic composition was surface water like (as sampling point SASW47). Lake Viiankijärvi area had only few locations with high metal content but the reason for these content were not as clear as near Sakatti ore deposit (Fig. 35).

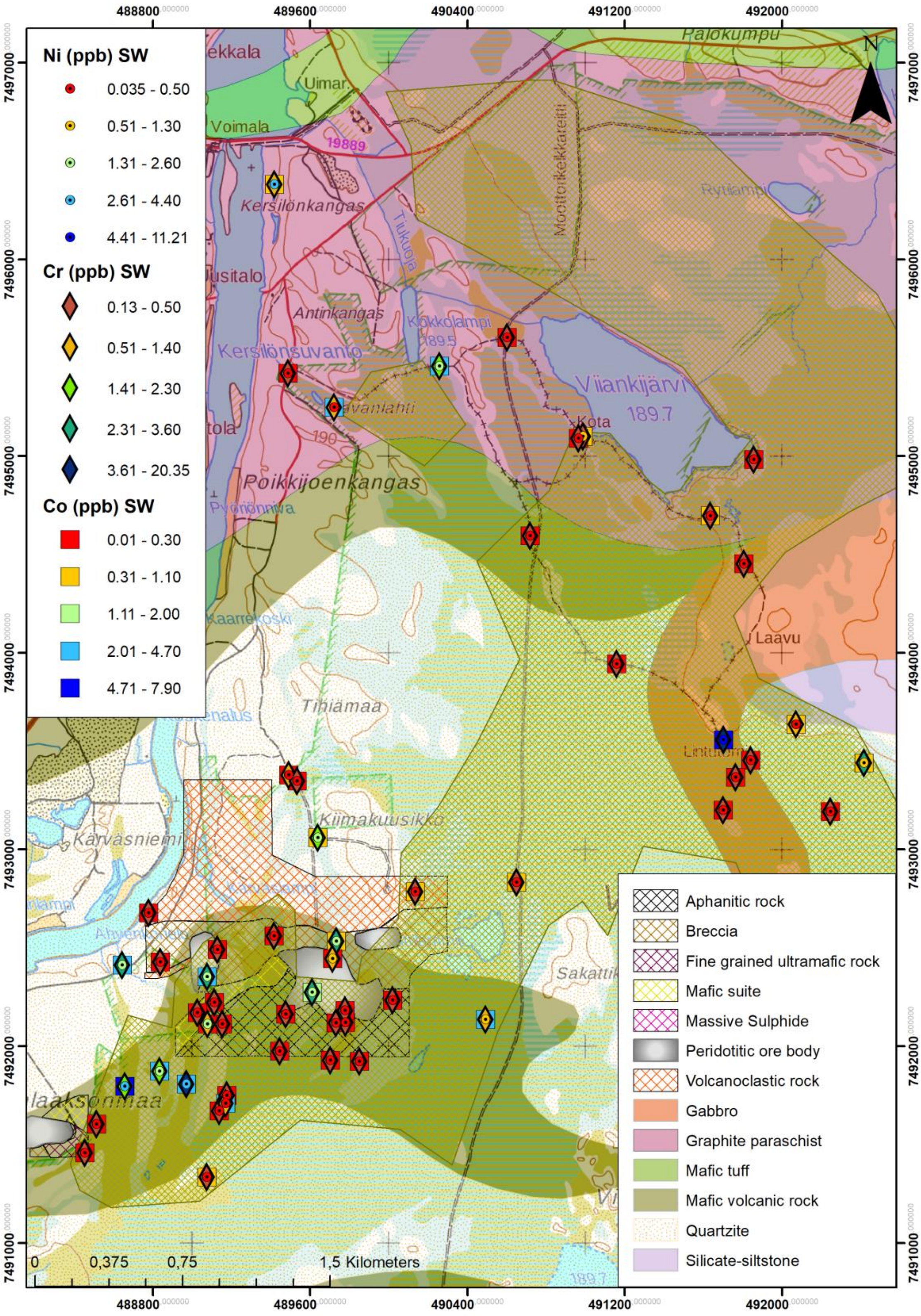


Figure 35. The Ni, Cr and Co concentrations of surface water.

The higher trace element concentrations near the main ore body correlated with the highest DOC concentrations but also with the most groundwater like isotopic chemistry. Profile 9, at the southern margin of main ore body had elevated metal concentrations when going deeper (see Ch. 5.5), but this was not seen in surface water chemistry. Profiles 66 and 60 between the main ore body and South West ore body had high surface water concentrations, but the profiles were descending. All the profiles with descending values (see Ch. 5.5) were sampled during the wintertime. The highest metal values were found near the bird observation tower, at the southern end of duckboard trail near Lake Viiankijärvi. No clear reason for this was found.

6.2 *Hamatocaulis vernicosus* and hydrogeochemistry

According to Finnish environment institute (Endangered species dataset © Hertta information system 24.9.2015) the main *H. vernicosus* habitats (ca. 2000 observations) cross the mire as a South West – North East orientated belt spreading also to the northern side of Lake Viiankijärvi (Fig 36).

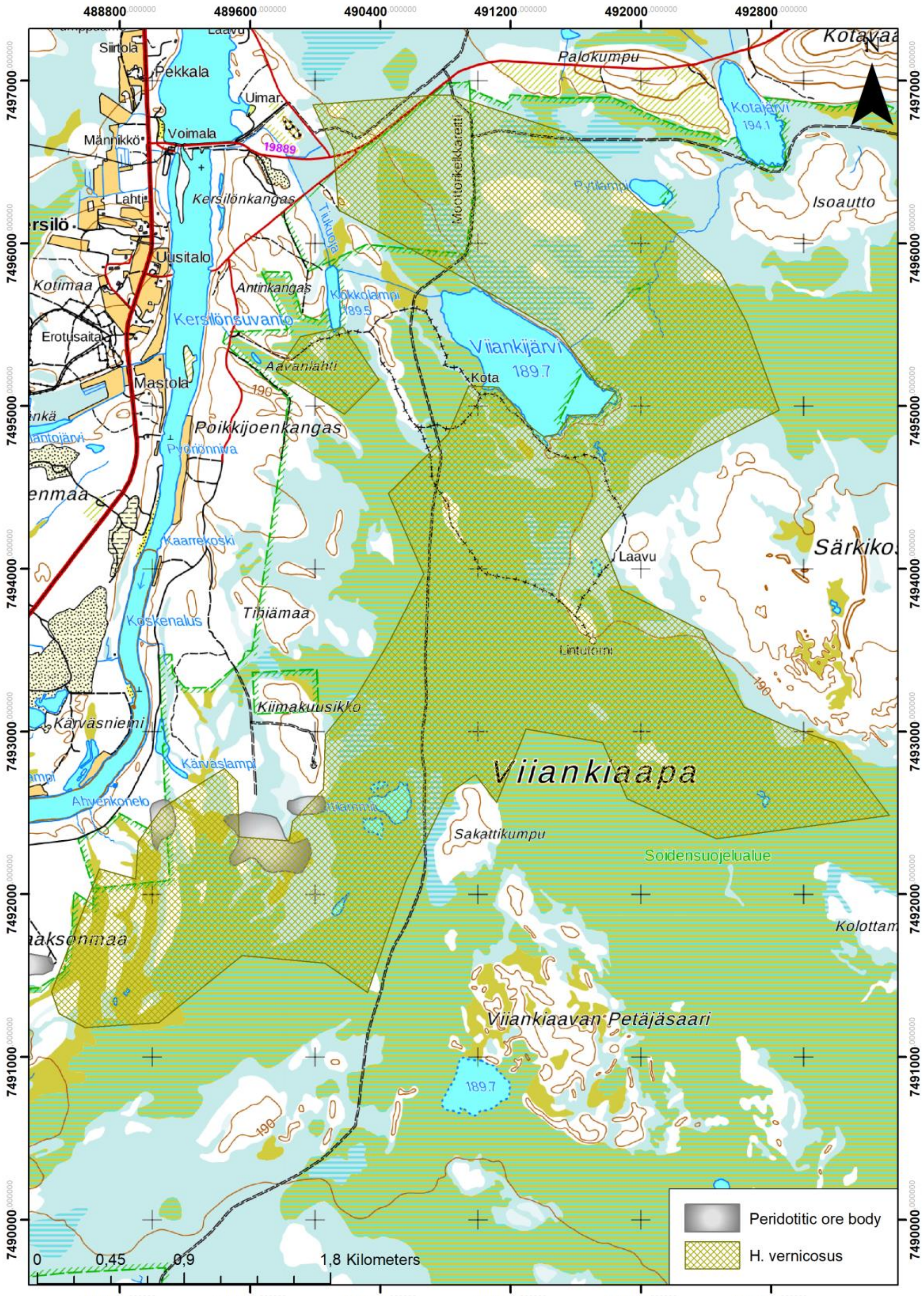


Figure 36. Areas of *H. vernicosus* habitats according to Finnish Environment Institute (FEI). (General map Database © NLS 2014, Endangered species dataset © Hertta information system of FEI 24.9.2015).

The areas with *H. vernicosus* ecosystems had smaller variation in surface water pH and higher mean pH than the areas without the ecosystems. The correlation of *H. vernicosus* and near neutral pH is discovered in several studies (see e.g. Hedenäs and Kooijman 1995 and Štechová *et al.* 2008). Electric conductivity of surface water samples was lower at the areas of *H. vernicosus* ecosystems but the values corresponded with the values presented in Štechová and Kučera (2007) (Fig. 37).

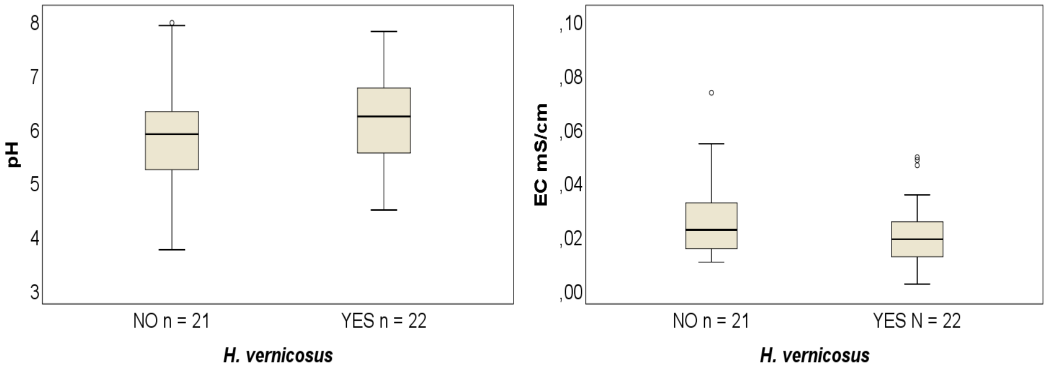


Figure 37. Changes in surface water pH and EC between the areas with and without *H. vernicosus* habitats.

The Ca, Mg and Fe concentrations of surface water samples were lower at the areas of *H. vernicosus* ecosystems while the total alkalinity was higher (Fig. 38). These variables have been discovered to correlate positively with *H. vernicosus* ecosystems (see eg. Hedenäs and Kooijman 1995, Štechová and Kučera 2012) even though the correlation of iron and abundance of *H. vernicosus* ecosystems has not been found in Štechová and Kučera (2007) and Štechová *et al.* (2010). The contradiction of higher alkalinity but lower Ca and Mg concentration at areas with *H. vernicosus* is explained with the amount of conducted analyzes. Alkalinity was analyzed from the samples that were collected for ion chromatography analysis (main ion samples). In these samples Sakatti ore deposit area was not as well represented. Ca and Mg were analyzed with ion chromatography as well as with ICP-MS (with trace elements). The amount of ICP-MS analyzed samples was greater and therefore used. Within these samples the Sakatti ore deposit area without *H. vernicosus* ecosystems is well represented. This elevates the Ca and Mg concentrations among the samples taken from “NO *H. vernicosus*” areas, as the Sakatti area had more elevated element concentrations in surface water as presented in Ch. 6.1.1 and 6.1.2. When Sakatti area was excluded and Ca as well as Mg was compared between the areas with and without *H. vernicosus* ecosystems the result was different and areas with the ecosystems had slightly higher concentrations. However the measured Ca and Mg concentrations of areas with *H. vernicosus* ecosystems corresponded with the concentrations presented in Štechová *et al.* (2010) but were lower that presented in Hedenäs and Kooijman (1995). The iron concentration corresponded with the values presented in Hedenäs and Kooijman (1995) while the alkalinity was clearly lower.

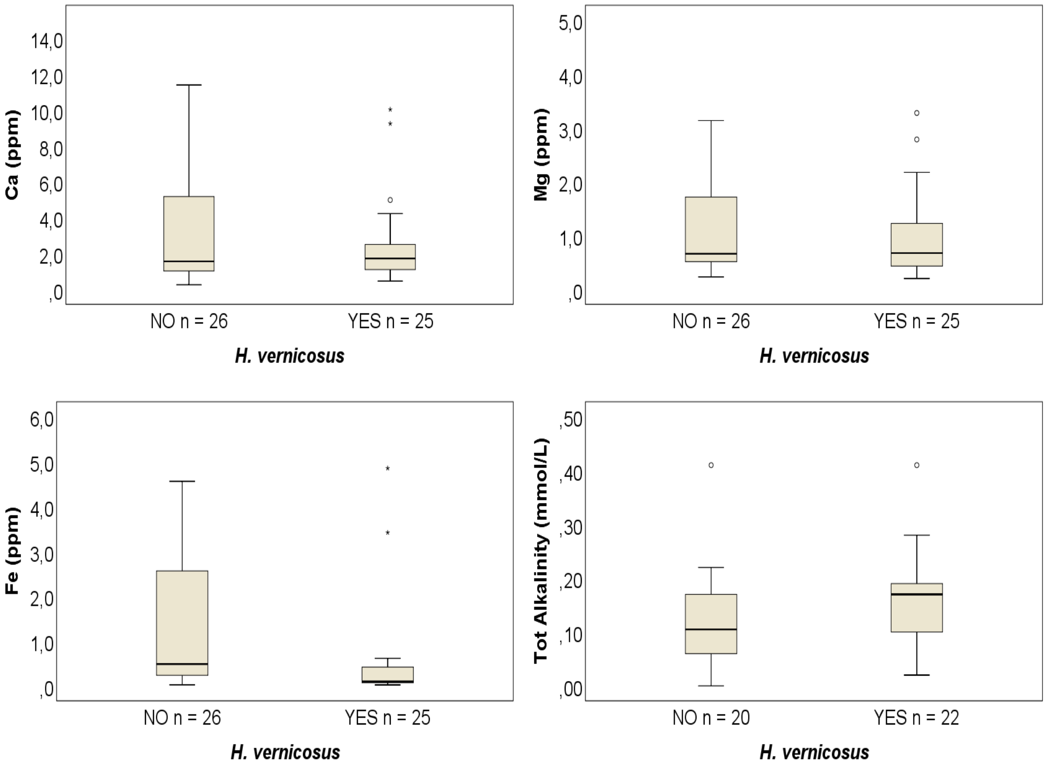


Figure 38. Ca, Mg, Fe and total alkalinity of surface water samples at the areas with and without *H. vernicosus* habitats. Ca, Mg and Fe are analyzed with ICP.

The purpose was to conduct sampling at the areas with and without *H. vernicosus* ecosystems near Lake Viiankijärvi and around the Sakatti ore body. However many of the “NO ecosystems” areas near Lake Viiankijärvi changed to “YES ecosystems” areas after we received the final biological data collected from the mire. This is why the “NO” areas located mainly around the Sakatti ore body and were under-represented near Lake Viiankijärvi. The higher main ion and trace element concentration in surface water around Sakatti was most likely explained with the ore body as presented in Ch. 6.1.2. Therefore the electric conductivity, main ion as well as the trace element concentrations were higher at the areas without *H. vernicosus* ecosystems (Fig. 39).

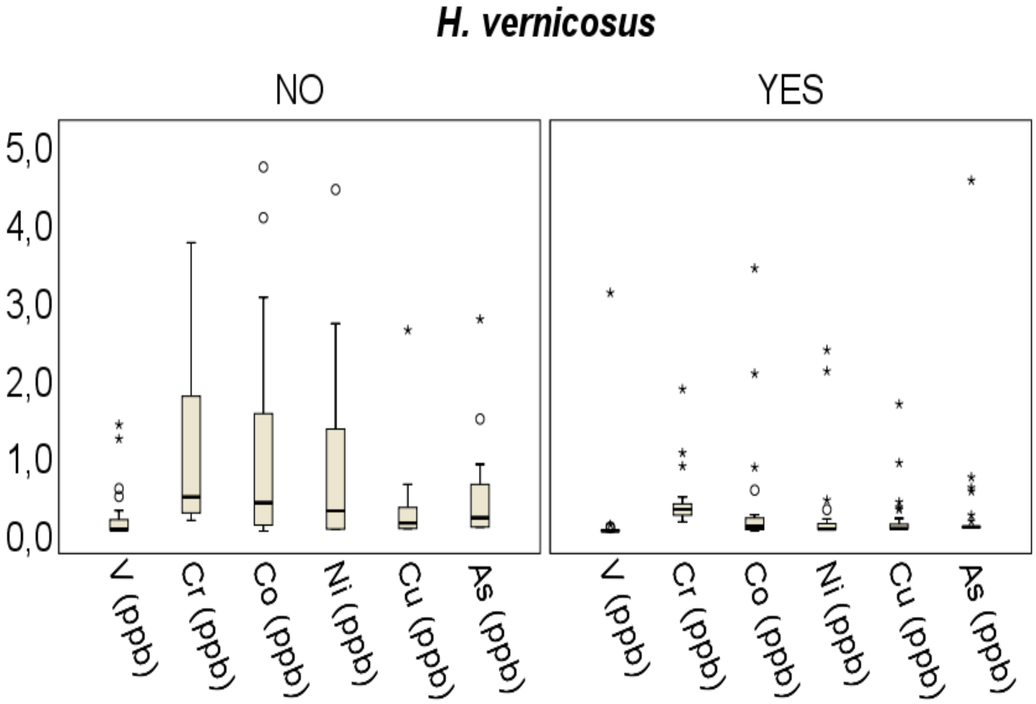


Figure 39. Trace element concentration of surface water samples between the areas with and *H. vernicosus* ecosystems.

However the concentrations of the Ca, Mg, alkalinity and pH at the areas with the ecosystems were similar with the areal spring water chemistry presented in Lahermo *et al.* (1990) indicating possible groundwater influence. The stable isotopic composition and *d*-excess values did not show clear groundwater discharge at the areas of ecosystems, on contrary the values resembled slightly more groundwater like values at the areas without the ecosystems (Fig 40 A and B). But as seen in Ch. 6.1.1 the stable isotopic composition may not be the unambiguous way to investigate groundwater discharge at the Viiankiaapa environment. The groundwater influence at areas with the *H. vernicosus* habitats could be seen when inspecting dissolved organic carbon and dissolved silica of the surface water samples (Fig. 40 C and D). The high groundwater influence is often seen with low DOC values, as presented in Tahvanainen *et al.* (2002) The areas with the ecosystems had considerably lower DOC content than the areas without the systems. The mean value of DOC at the area of ecosystems were 8.3 ppm while it was 17.7 ppm at the areas without the ecosystems. The higher DSi concentration could also indicate groundwater flow while the DSi concentration of water increases along the time of groundwater retardation (Sandborg 1993, 33).

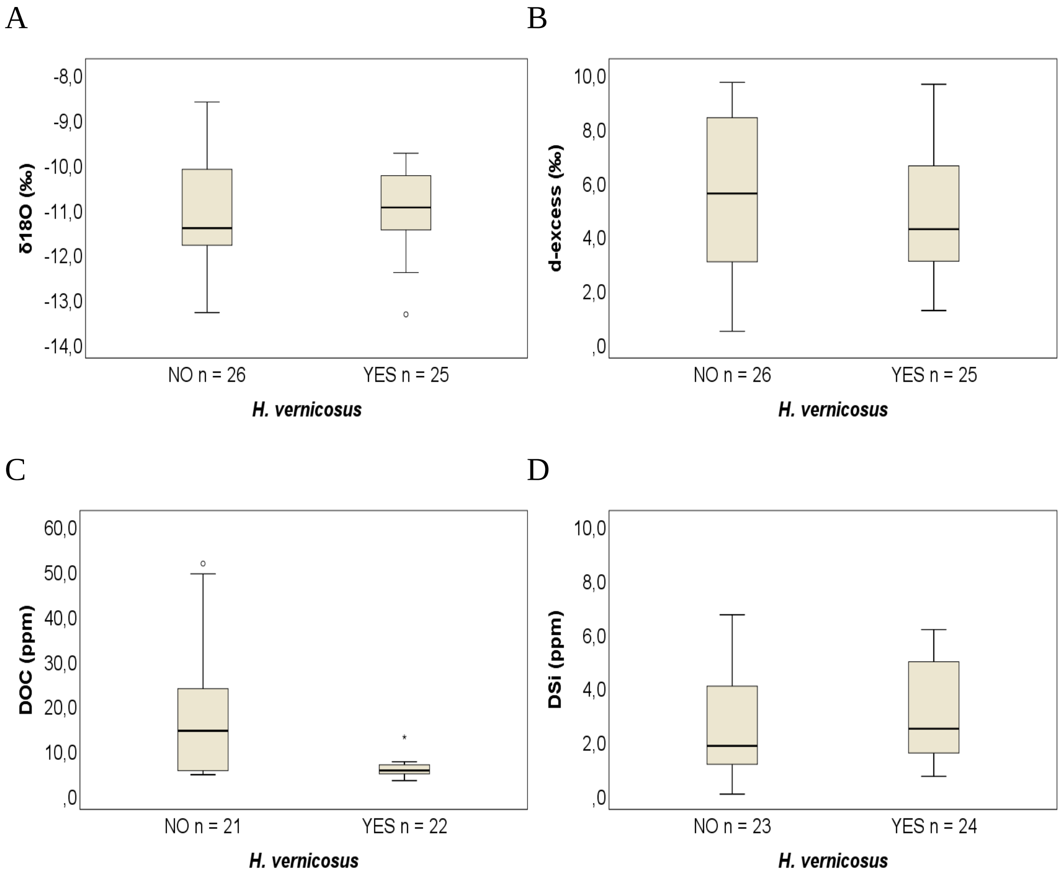


Figure 40. A and B) The $\delta^{18}O$ and *d*-excess values between the areas without *H. vernicosus* habitats. C and D) the DOC and DSi values between the areas with and without *H. vernicosus* habitats.

DOC, pH, alkalinity, DSi and main ion results at the areas of *H. vernicosus* ecosystems could indicate the groundwater discharge even though it does not show in stable isotopes. The variation of different elements and parameters was smaller at the areas where the ecosystems thrive. This could be the result of groundwater discharge as it is known that the wetlands and mires where groundwater discharges have more stable environment in nutrient and water supply (Mitch and Gosselink, 2007, 113).

6.2.1 Principal component analysis, surface water and H. vernicosus

Even the surface water concentrations of dissolved elements were low there was statistically significant differences between the areas with and without *H. vernicosus* ecosystems (Appendix 6). A principal component analysis (PCA) was done with surface water samples to determine major variables that influence surface water chemistry. Variables were included based on the correlation matrix and the analysis was conducted for major ions, EC, pH, DOC and isotopes as well as for most of the trace elements. First five principal components (Eigenvalue > 1) explained 79.5 % of the total variance. The principal component groups (PC1 – PC5) are presented in Table 3 Variable loadings are seen in Appendix 8.

Table 3. Principal component groups.

PC1	PC2	PC3	PC4	PC5
DOC	Tot-Alkalinity	$\delta^{18}O$	pH	Na
Cl	Mg	δD	Cd	K
Al	Ca	DSi		
V	Ba	SO_4^{2-}		
Mn				
Fe				
Co				
Ni				
Zn				
As				
Sb				
Pb				

Factor loadings of PC2 and PC3 were greater at the areas of *H. vernicosus* ecosystems while PC1 and PC5 had lower loadings (Fig. 41). PC4 did not have significant difference between the areas of with and without *H. vernicosus* ecosystems.

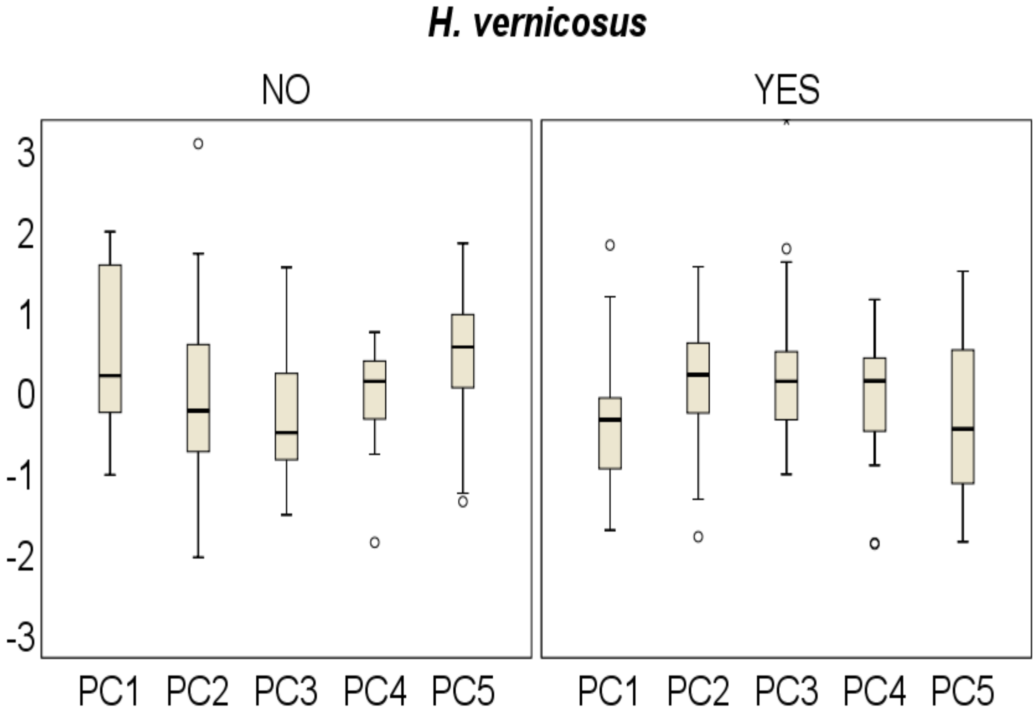


Figure 41. Factor loadings of surface water samples.

The loadings of PC2 and PC3 were higher in surface water samples from areas of *H. vernicosus* ecosystems. While the loadings of PC1 and PC5 were lower at the areas of ecosystems. According to the principal component analysis *H. vernicosus* seem to prefer areas of Ca, Mg and DSi bearing waters with higher alkalinity. In other hand it seems to avoid areas of high DOC concentrations and elements connected to the presence of organic carbon. These results indicate the groundwater influence at the areas of *H. vernicosus* habitats.

6.3 *Hamatocaulis vernicosus* and the depth of mire

The correlation of *H. vernicosus* ecosystems and thickness of peat layer is presented in report by Korkka-Niemi *et al.* (2017). The report shows that *H. vernicosus* ecosystems thrive at the areas where peat thickness is between 2 – 4 m, while fewer ecosystems were found at the areas of thinner and thicker peat layer. In this study the sampling points were divided in two different categories depending on the thickness of the peat layer; shallow (< 2 m) and deep (> 2 m) areas. The peat thickness presented in Åberg et al (2017) was used in this categorization.

The differences in pH, DOC, Mg and Ca between shallow and deep peat depth are presented in figure 42 The differences in chemistry between varying peat thickness were clear. The areas with peat depth > 2 m peat had higher pH values and higher Ca, Mg and alkalinity surface water concentrations as well as lower DOC concentrations.

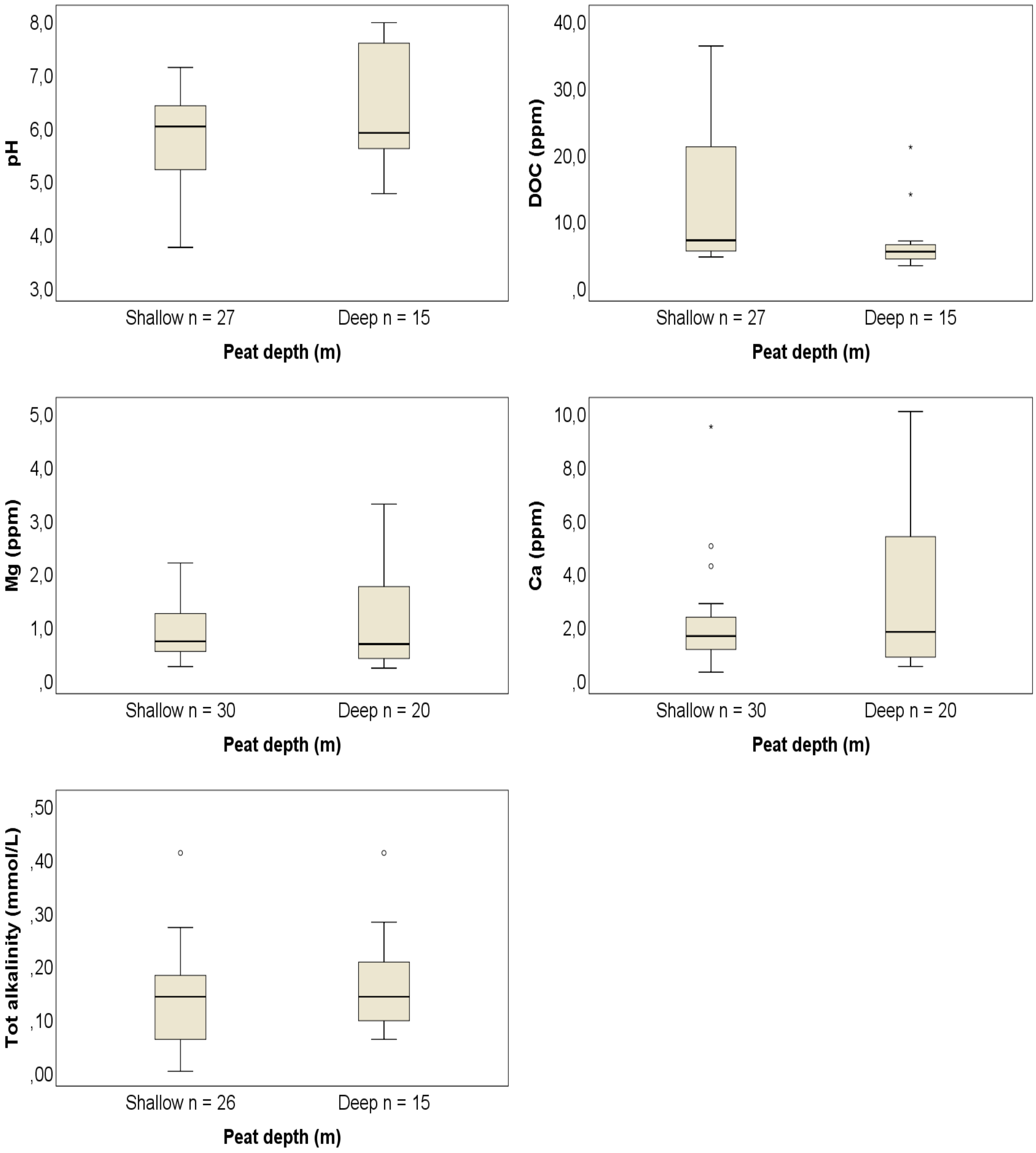


Figure 42. Surface water concentrations between the areas of deep and shallow peat layer.

These results indicate that the water chemistry at the areas of deeper peat layer is more suitable for *H. vernicosus* habitats. The deeper peat layer is known to have less water table fluctuation, which is one of the main factors affecting positively to the size of *H. vernicosus* ecosystems (Štechová and Kučera 2012).

7. CONCLUSIONS

According to the results few possible groundwater discharge areas were detected. The groundwater movement between Särkikoskenmaa and Lake Viiankijärvi can be seen in *d*-excess, pH results and depth profiles of sable isotopes and main ions. However the groundwater discharge was not as clear around Sakatti ore body, where isotopic composition of surface water samples represented mainly season's precipitation. Still some locations near Sakatti main ore deposit and Pahanlaaksonmaa had indications of groundwater discharge. The stable isotope composition of spring and groundwater samples near Sakatti ore deposit, at the area where the dry land between River Kitinen and Viiankiaapa is narrowest, indicated mixing of season's precipitation and groundwater. Most probably the mire water infiltrates through the peat layer and the fluvial sand deposits, mixing with the groundwater, finally discharging to the springs and River Kitinen. It is also possible that there is a good local hydraulic conductivity at that area, caused by bedrock fracturing. The bedrock is observed to be weathered at least around SAGA403 observation pipe. This weathered bedrock could possibly create good hydraulic connection and allow the surface water influence bedrock groundwater also near the other observation wells. The Sakatti ore body seems to have influence to the areal hydrogeochemistry. Many of the trace element contents (especially Cr, Co and Ni) as well as main ions were elevated in peat pore water and surface water near the ore body. The highest metal contents correlated with the high DOC concentration as expected.

There was no single factor in Viiankiaapa mire creating a favorable environment for *H. vernicosus.* Clearest correlation was found with *H. vernicosus* habitats and the thickness of peat layer. A ribbon-shaped zone of habitats and 2 – 4 m thick peat layer crossed the mire from South West to North East and to the northern side of Lake Viiankijärvi. It is highly possible that the zone with certain peat thickness creates environment of stable water table that is neither too low nor too high. The positive correlation between *H.*

vernicosus ecosystems and high Mg and Ca concentrations has been found in earlier studies. In this study the correlation was not plain because the hydrogeochemistry of Sakatti ore deposit area complicated the interpretation. The areas with the *H. vernicosus* ecosystems seemed to have lower Ca and Mg concentrations. When Sakatti area was excluded and areas with and without *H. ecosystems* were re-compared were the results reverse and areas with *H. vernicosus* ecosystems seemed to have slightly higher Ca and Mg concentrations. It seems that the high element concentrations at the area of Sakatti ore deposit twist the results and one must be careful when making interpretation. Interpretation is more difficult knowing that most of the samples taken from the area without *H. vernicosus* ecosystems are located near Sakatti ore deposit. Even though the Ca and Mg seemed to be low at the areas with the *H. vernicosus* ecosystems, the concentrations did represented areal spring water chemistry, as did the measured pH and alkalinity values. This could indicate possible groundwater influence at the areas of the ecosystems. The groundwater migration through the peat layer might be very slow and therefore the water will be diluted with the surface water. This hinders the detection of groundwater in hydrogeochemical analyzes. Many measured factors had smaller variation at the areas of *H. vernicosus* ecosystems than at the areas without the ecosystems. This could indicate more stable environment and supply of nutrients and therefore the influence of groundwater discharge.

The sampling campaign was planned before additional *H. vernicosus* mapping results collected during summer 2016. Therefore the samples taken from the areas without *H. vernicosus* habitats are under-represented and located mainly within small area near Sakatti ore deposit. Because of the specific hydrogeochemistry of the Sakatti area, the comparison between areas with and without *H. vernicosus* habitats has to be done with care. Sampling was conducted during autumn and springtime, which affected to the concentration differences in samples. The winter sample profiles had certain kind of trend in trace element, main ions and stable isotope chemistry that differed from the profiles sampled in autumn.

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Appendix 1 Conducted water sample analyses

ID	Y	X	CLASS	Date	Profile	EC	pH	T °C	Trace el.	Isotopes	DSi	DOC	Main ions	Bedrock	Bedrock (Anglo American)
SASW1	7494595	490720	SW	13.9.2016	22	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SASW2	7493558	491703	SW	13.9.2016	23	x	x	x	x	x	x	x	x	Gabbro	
SASW3	7493455	491842	SW	13.9.2016	24	x	x	x	x	x	x	x	x	Quarzite/Gabbro	
SASW4	7493201	491702	SW	13.9.2016	25	x	x	x	x	x	x	x	x	Gabbro	
SASW5	7493442	492419	SW	13.9.2016	26	x	x	x	x	x	x	x	x	Quarzite	
SASW6	7493637	492072	SW	13.9.2016	27	x	x	x	x	x	x	x	x	Quartzite	
SASW7	7495421	489488	SW	13.9.2016	28	x	x	x	x	x	x	x	x	Graphite paraschist	
SAGA405	7492591.823	488867.0841	GW	13.9.2016	29	x	x	x	x	x	x	x	x	Quarzite	Breccia
SAGA305	7492588.244	488865.7046	GW	13.9.2016	30	x	x	x	x	x	x	x	x	Quarzite	Breccia
SAGA203	7492584.016	488864.6851	GW	13.9.2016	31	x	x	x	x	x	x	x	x	Quarzite	Breccia
SASW8	7492492	489130	SW	14.9.2016	32	x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
SAGA103	7491750	489177	GW	14.9.2016	33	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SASW9	7491750	489177	SW	14.9.2016	34	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SAGA403	7491716	489162	GW	14.9.2016	35	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SAGA303	7491673	489140	GW	14.9.2016	36	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SASW10	7491673	489140	SW	14.9.2016	37	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SASW11	7492113	489155	SW	14.9.2016	38	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
SASW12	7492113	489079	SW	14.9.2016	39	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
SASW13	7492223	489115	SW	14.9.2016	40	x	x	x	x	x	x	x	x	Mafic volcanic rock	Mafic suite
SASW14	7492354	489077	SW	14.9.2016	41	x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
SASW15	7492429	488840	SW	14.9.2016	42	x	x	x	x	x	x	x	x	Quarzite	Breccia
SASW16	7493379	489493	SW	14.9.2016	43	x	x	x	x	x	x	x	x	Quarzite	
SAGA201	7493057	489665	GW	14.9.2016	44	x	x	x	x	x	x	x	x	Quarzite	
SASW17	7493061	489641	SW	14.9.2016	45	x	x	x	x	x	x	x	x	Quarzite	
SAGA400	7493039	489862	GW	14.9.2016	46	x	x	x	x	x	x	x	x	Quarzite	
SASW18	7492534	489735	SW	14.9.2016	47	x	x	x	x	x	x	x	x	Mafic volcanic rock	Breccia
SAGA202	7492275	489611	GW	14.9.2016		x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
SASW19	7492275	489611	SW	14.9.2016	48	x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
SASW20	7492122	489780	SW	14.9.2016	49	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
SAGA-itä	7491923	489851	GW	14.9.2016	50	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SAGA-keski	7491923	489851	GW	14.9.2016	51	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SAGA-etelä	7491923	489851	GW	14.9.2016	52	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SASW21	7491923	489851	SW	14.9.2016	53	x	x	x	x	x	x	x	x	Mafic volcanic rock	
YSI meas	7495473	490296	SW	15.9.2016	54	x	x	x						Graphite paraschist	
SASW22	7495458	490259	SW	15.9.2016		x	x	x	x	x	x	x	x	Graphite paraschist	
MP1	7495458	490259	MP	15.9.2016	21					x		x		Graphite paraschist	
SASW23	7495605	490602	SW	15.9.2016	20	x	x	x	x	x	x	x	x	Graphite paraschist	

Appendix 1 Conducted water sample analyses

ID	Y	X	CLASS	Date	Profile	EC	pH	T °C	Trace el.	Isotopes	DSi	DOC	Main ions	Bedrock	Bedrock (Anglo American)
MP2	7495605	490602	MP	15.9.2016	20	x	x		x	x	x	x	x	Graphite paraschist	
SASW24	7495101	490990	SW	15.9.2016		x	x	x	x	x	x	x	x	Graphite paraschist	
SASW25	7495091	490966	SW	15.9.2016		x	x	x	x	x	x	x	x	Graphite paraschist	
SASW26	7494454	491808	SW	15.9.2016	19	x	x	x	x	x	x	x	x	Gabbro	
MP3	7494454	491808	MP	15.9.2016	19	x	x		x	x	x	x	x	Gabbro	
MP4	7494454	491808	MP	15.9.2016	19	x	x		x	x	x	x	x	Gabbro	
MP5	7494454	491808	MP	15.9.2016	19	x	x		x	x	x	x	x	Gabbro	
MP6	7492330	489066	MP	17.10.2016	1	x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
MP7	7492561	489418	MP	18.10.2016	2	x	x	x	x	x	x	x	x	Mafic volcanic rock	Breccia
SASW27	7492561	489418	SW	18.10.2016	2	x	x	x	x	x	x	x	x	Mafic volcanic rock	Breccia
SASW28	7491976	489447	SW	18.10.2016	3	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP8	7491976	489447	MP	18.10.2016	3	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP9	7491976	489447	MP	18.10.2016	3	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
SASW29	7491930	489704	SW	18.10.2016	4	x	x	x	x	x	x	x	x	Mafic volcanic rock	
MP10	7491930	489704	MP	18.10.2016	4	x	x	x	x	x	x	x	x	Mafic volcanic rock	
MP11	7491930	489704	MP	18.10.2016	4	x	x	x	x	x	x	x	x	Mafic volcanic rock	
SASW30	7492183	489778	SW	18.10.2016	5	x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
MP12	7492183	489778	MP	18.10.2016	5	x		x	x	x	x	x	x	Mafic volcanic rock	Peridotite
SW31	7492164	489478	SW	18.10.2016	6	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP13	7492164	489478	MP	18.10.2016	6	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
SASW32	7493350	489534	SW	19.10.2016	7	x	x	x	x	x	x	x	x	Quarzite	
MP14	7493350	489534	MP	19.10.2016	7	x	x	x	x	x	x	x	x	Quarzite	
GA300	7492533	489739	GW	19.10.2016		x	x	x	x	x	x	x	x	Mafic volcanic rock	Breccia
MP15	7492533	489739	MP	19.10.2016					x	x	x	x	x	Mafic volcanic rock	Breccia
SASW33	7492447	489715	SW	19.10.2016	8	x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
MP16	7492447	489715	MP	19.10.2016	8	x	x	x	x	x	x	x	x	Mafic volcanic rock	Peridotite
SASW34	7492120	489732	SW	19.10.2016	9	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP17	7492120	489732	MP	19.10.2016	9	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP18	7492120	489732	MP	19.10.2016	9	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP19	7492120	489732	MP	19.10.2016	9	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP20	7492120	489732	MP	19.10.2016	9	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
SASW35	7492235	490021	SW	19.10.2016	10	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP21	7492235	490021	MP	19.10.2016	10	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
MP22	7492235	490021	MP	19.10.2016	10	x	x	x	x	x	x	x	x	Mafic volcanic rock	Aphanitic
SASW36	7492787	490136	SW	19.10.2016		x	x	x	x	x	x	x	x	Quarzite	Volcanioclastic

Appendix 1 Conducted water sample analyses

ID	**Y**	**X**	**CLASS**	**Date**	**Profile**	**EC**	**pH**	**T °C**	**Trace el.**	**Isotopes**	**DSi**	**DOC**	**Main ions**	**Bedrock**	**Bedrock (Anglo American)**
SASW37	7494697	491636	SW	20.10.2016	11	x	x	x	x	x	x	x	x	Graphite paraschist	
MP23	7494697	491636	MP	20.10.2016	11				x					Graphite paraschist	
MP24	7494697	491636	MP	20.10.2016	11	x	x	x	x	x	x	x	x	Graphite paraschist	
MP25	7494697	491636	MP	20.10.2016	11	x	x	x	x	x	x	x	x	Graphite paraschist	
MP26	7494697	491636	MP	20.10.2016	11	x	x	x	x					Graphite paraschist	
MP27	7494697	491636	MP	20.10.2016	11	x	x	x	x	x	x	x	x	Graphite paraschist	
YSI meas	7494697	491636		20.10.2016	11	x	x	x						Graphite paraschist	
SASW38	7494984	491857	SW	20.10.2016	12	x	x	x	x	x	x	x	x	Graphite paraschist	
MP28	7494984	491857	MP	20.10.2016	12	x	x	x	x	x	x	x	x	Graphite paraschist	
MP29	7494984	491857	MP	20.10.2016	12	x			x					Graphite paraschist	
MP30	7494984	491857	MP	20.10.2016	12	x	x	x	x	x	x	x	x	Graphite paraschist	
MP31	7494984	491857	MP	20.10.2016	12	x	x	x	x	x	x	x	x	Graphite paraschist	
MP32	7494984	491857	MP	20.10.2016	12	x		x	x					Graphite paraschist	
SASW39	7493368	491765	SW	20.10.2016	13	x	x	x	x	x	x	x	x	Gabbro	
MP33	7493368	491765	MP	20.10.2016	13	x			x					Gabbro	
MP34	7493368	491765	MP	20.10.2016	13	x	x	x	x	x	x	x	x	Gabbro	
MP35	7493368	491765	MP	20.10.2016	13	x	x	x	x					Gabbro	
SASW40	7493193	492247	SW	20.10.2016	14	x	x	x	x	x	x	x	x	Quarzite	
MP36	7493193	492247	MP	20.10.2016	14				x			x		Quarzite	
MP37	7493193	492247	MP	20.10.2016	14				x			x		Quarzite	
MP38	7493193	492247	MP	20.10.2016	14				x			x		Quarzite	
MP39	7493193	492247	MP	20.10.2016	14				x			x		Quarzite	
SASW41	7493944	491160	SW	20.10.2016	15	x	x	x	x	x	x	x	x	Quarzite	
MP40	7493944	491160	MP	20.10.2016	15				x	x	x	x		Quarzite	
SASW42	7492171	489027	SW	21.10.2016	16	x	x	x	x	x	x	x	x	Mafic volcanic rock	Mafic suite
MP41	7492171	489027	MP	21.10.2016	16				x					Mafic volcanic rock	Mafic suite
MP42	7492171	489027	MP	21.10.2016	16	x			x					Mafic volcanic rock	Mafic suite
MP43	7492171	489027	MP	21.10.2016	16	x	x	x	x	x	x	x	x	Mafic volcanic rock	Mafic suite
YSI meas	7492171	489027			16	x	x	x						Mafic volcanic rock	Mafic suite
MP44	7492171	489027	MP	21.10.2016	16	x	x	x	x	x	x	x	x	Mafic volcanic rock	Mafic suite
SASW43	7491458	488456	SW	21.10.2016	17	x	x	x	x	x	x	x	x	Mafic volcanic rock	Fine grained ultramafic
MP45	7491458	488456	MP	21.10.2016	17	x	x	x	x	x	x	x	x	Mafic volcanic rock	Fine grained ultramafic
MP46	7491458	488456	MP	21.10.2016	17	x	x	x	x	x	x	x	x	Mafic volcanic rock	Fine grained ultramafic
MP47	7491458	488456	MP	21.10.2016	17	x	x	x	x	x	x	x	x	Mafic volcanic rock	Fine grained ultramafic
SASW44	7491605	488515	SW	21.10.2016	18	x	x	x	x	x	x	x	x	Mafic volcanic rock	
MP48	7491605	488515	MP	21.10.2016	18	x			x	x	x	x		Mafic volcanic rock	
SASW45	7496382.659	489419.697	LAKE	27.3.2017	68					x	x	x	x		
SAGA405B	7492591.823	488867.0841	GW	27.3.2017	29					x	x	x	x		
SAGA305B	7492588.244	488865.7046	GW	27.3.2017	30					x	x	x	x		
SAGA203B	7492584.016	488864.6851	GW	27.3.2017	31					x	x	x	x		

Appendix 1 Conducted water sample analyses

ID	Y	X	CLASS	Date	Profile	EC	pH	T °C	Trace el.	Isotopes	DSi	DOC	Main ions	Bedrock	Bedrock (Anglo American)
SASW46	7492679.493	488780.94	SPRING	27.3.2017	69					x	x	x	x		
MP49	7494993.7	491893.493	MP	29.3.2017	70					x	x	x	x		
SASW47	7492412.999	488645.944	SPRING	29.3.2017	71					x	x	x	x		
SASW48	7491797.046	488658.679	SW	29.3.2017	60					x	x	x	x		
MP50	7491797.046	488658.679	MP	29.3.2017	60					x	x	x	x		
SASW49	7491809.094	488972.918	SW	29.3.2017	61					x	x	x	x		
MP51	7491809.094	488972.918	MP	29.3.2017	61					x	x	x	x		
SASW50	7492137.024	490493.775	SW	31.3.2017	62					x	x	x			
MP52	7492137.024	490493.775	MP	31.3.2017	62					x	x	x	x		
MP53	7492137.024	490493.775	MP	31.3.2017	62					x	x	x	x		
MP54	7492137.024	490493.775	MP	31.3.2017	62					x	x	x	x		
MP55	7492137.024	490493.775	MP	31.3.2017	62					x	x	x	x		
SASW51	7492834.98	490651.92	SW	31.3.2017	63					x	x	x	x		
MP56	7492834.98	490651.92	MP	31.3.2017	63					x	x	x	x		
SASW52	7491710.167	489171.17	SW	1.4.2017	64					x	x	x	x		
MP57	7491710.167	489171.17	MP	1.4.2017	64					x	x	x	x		
MP58	7491710.167	489171.17	MP	1.4.2017	64					x	x	x	x		
SASW53	7491335.963	489076.686	SW	1.4.2017	65					x	x	x			
MP59	7491335.963	489076.686	MP	1.4.2017	65					x	x	x	x		
MP60	7491335.963	489076.686	MP	1.4.2017	65								x		
MP61	7491335.963	489076.686	MP	1.4.2017	65					x	x	x	x		
MP62	7491335.963	489076.686	MP	1.4.2017	65					x	x	x	x		
MP63	7491335.963	489076.686	MP	1.4.2017	65					x	x	x	x		
SASW54	7491874.329	488836.35	SW	1.4.2017	66					x	x	x	x		
MP64	7491874.329	488836.35	MP	1.4.2017	66					x	x	x	x		
MP65	7491874.329	488836.35	MP	1.4.2017	66					x	x	x	x		
SASW55	7495248.757	489723.391	SW	2.4.2017	67					x	x	x	x		
MP66	7495248.757	489723.391	MP	2.4.2017	67					x	x	x	x		
17HYDO22/P8	7495590	489477	GW	Summer						x	x	x			
17GA405	7492591.823	488867.0841	GW	Summer						x	x	x			
17GA203	7492584.016	488864.6851	GW	Summer						x	x	x			
17HYDO16/P9	7495007	489405	GW	Summer						x	x	x			
17HYDO21/P7	7496003	489474	GW	Summer						x	x	x			
17HYDO20/P6	7496286	489839	GW	Summer						x	x	x			
17HYDO15/P4	7494899.5	489766.1	GW	Summer						x	x	x			
17HYDO19/P5	7496662	490037	GW	Summer						x	x	x			
17SPRING1	7492880	488923	SPRING	Summer						x	x	x			
17SPRING2	7492878	488914	SPRING	Summer						x	x	x			
17SPRING3	7493006	488977	SPRING	Summer						x	x	x			
17SPRING4	7492685	488781	SPRING	Summer						x	x	x			
17SPRING5	7492629	488763	SPRING	Summer						x	x	x			
17SPRING6	7492381	488253	SPRING	Summer						x	x	x			
17SPRING7	7492450	488508	SPRING	Summer						x	x	x			
17SPRING8	7492408	488746	SPRING	Summer						x	x	x			
17RIVER1	7492915	488937	SW	Summer						x	x	x			

Appendix 1 Conducted water sample analyses

ID	Y	X	CLASS	Date	Profile	EC	pH	T °C	Trace el.	Isotopes	DSi	DOC	Main ions	Bedrock	Bedrock (Anglo American)
17SUO1	7491529	488469	SW	Summer						x	x	x			
17Kärväslampi	7493007	489039	SW	Summer						x	x	x			

Appendix 2. Trace element

Sample Name	23 Na [1] Conc. [ppm]	24 Mg [1] Conc. [ppm]	27 Al [1] Conc. [ppb]	39 K [1] Conc. [ppm]	44 Ca [1] Conc. [ppm]	51 V [1] Conc. [ppb]	52 Cr [1] Conc. [ppb]	55 Mn [1] Conc. [ppb]	56 Fe [1] Conc. [ppm]	59 Co [1] Conc. [ppb]	60 Ni [1] Conc. [ppb]	63 Cu [1] Conc. [ppb]	66 Zn [1] Conc. [ppb]	75 As [1] Conc. [ppb]	95 Mo [1] Conc. [ppb]	101 Ru [2] Conc. [ppb]	105 Pd [2] Conc. [ppb]	107 Ag [2] Conc. [ppb]	111 Cd [2] Conc. [ppb]	121 Sb [2] Conc. [ppb]	137 Ba [2] Conc. [ppb]	189 Os [2] Conc. [ppb]	193 Ir [2] Conc. [ppb]	195 Pt [2] Conc. [ppb]	208 Pb [2] Conc. [ppb]	232 Th [2] Conc. [ppb]	238 U [2] Conc. [ppb]
Detection limit 10σ	0.02	0.00	0.92	0.01	0.01	0.004	0.11	0.1	0.0001	0.01	0.0709	0.0837	0.04	0.122	0.0980	0.0037	0.0065	0.0069	0.0126	0.001	0.04	0.0072	0.0015	0.0005	0.0049	0.0013	0.0022
Sample																											
SW1	0.2	0.3	5.4	0.03	0.78	0.02	0.25	**12.2**	0.15	0.03	<0.0709	<0.0837	1.66	<0.1220	0.14	<0.0037	<0.0065	<0.0069	<0.0126	0.007	1.6	<0.0072	<0.0015	0.0027	0.0285	<0.0013	<0.0022
SW2	**1.8**	**2.2**	**963.3**	0.33	2.82	**3.06**	20.35	**125.0**	**6.42**	**7.88**	**11.21**	**1.64**	**71.24**	**0.52**	<0.0980	<0.0037	0.038	<0.0069	**0.044**	**0.053**	**8.5**	<0.0072	<0.0015	0.0044	**0.4142**	0.232	0.035
SW3	1.3	0.7	3.7	0.03	1.73	0.01	0.13	0.7	0.06	0.02	<0.0709	0.10	**1.86**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.005	2.1	<0.0072	<0.0015	0.0016	0.0132	<0.0013	<0.0022
SW4	0.1	0.4	6.9	0.05	0.60	0.03	0.25	**11.7**	**0.42**	0.12	0.10	0.17	**2.28**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.011	0.5	<0.0072	<0.0015	0.0015	0.0248	<0.0013	<0.0022
SW5	1.1	0.8	**54.9**	0.02	1.25	0.09	**2.79**	**17.5**	**0.79**	**0.48**	**0.80**	<0.0837	**1.95**	**0.18**	<0.0980	<0.0037	0.007	<0.0069	<0.0126	0.015	3.6	<0.0072	<0.0015	0.0016	0.0501	0.014	<0.0022
SW6	1.0	0.5	16.0	0.08	1.02	0.04	**1.38**	**14.4**	**0.49**	**0.45**	**0.48**	<0.0837	1.29	0.13	<0.0980	<0.0037	<0.0065	<0.0069	0.013	0.013	2.3	<0.0072	<0.0015	0.0013	0.0211	0.004	<0.0022
SW7	0.3	0.4	6.4	0.18	1.27	0.02	0.22	**13.3**	0.07	0.04	<0.0709	<0.0837	**3.60**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.007	1.5	<0.0072	<0.0015	0.0014	0.0079	<0.0013	<0.0022
GA405	1.9	**10.0**	5.6	0.83	**21.78**	0.31	0.79	**241.3**	**9.53**	**0.18**	0.40	<0.0837	0.58	1.64	0.18	<0.0037	0.041	<0.0069	<0.0126	0.006	31.4	<0.0072	<0.0015	0.0020	<0.0049	<0.0013	0.009
GA305	1.6	**4.0**	6.7	0.54	5.36	0.03	0.27	1.5	0.02	0.06	0.19	0.30	1.07	<0.1220	<0.0980	<0.0037	0.027	<0.0069	<0.0126	0.016	5.3	<0.0072	<0.0015	0.0014	0.0060	<0.0013	0.007
GA203	1.6	**3.8**	6.6	0.50	5.18	0.07	0.31	4.8	0.00	0.05	<0.0709	0.18	1.61	<0.1220	<0.0980	<0.0037	0.028	<0.0069	<0.0126	0.052	3.8	<0.0072	<0.0015	0.0005	0.0098	<0.0013	0.019
SW8	0.8	0.8	11.1	0.27	2.06	0.03	0.37	**15.8**	0.28	0.09	0.14	<0.0837	**2.01**	<0.1220	<0.0980	<0.0037	0.008	<0.0069	<0.0126	0.007	3.0	<0.0072	<0.0015	0.0015	0.0106	<0.0013	<0.0022
GA103	0.7	1.4	10.5	0.07	4.52	0.04	0.24	**74.6**	**6.20**	**0.52**	0.10	<0.0837	1.49	0.49	<0.0980	<0.0037	0.017	<0.0069	<0.0126	0.016	9.8	<0.0072	<0.0015	0.0011	0.0102	<0.0013	<0.0022
SW9	0.9	0.9	4.6	0.19	2.10	0.01	0.20	0.7	0.16	0.03	<0.0709	<0.0837	0.96	<0.1220	<0.0980	<0.0037	0.008	<0.0069	<0.0126	0.005	3.8	<0.0072	<0.0015	0.0013	0.0334	<0.0013	<0.0022
GA403	3.4	**7.7**	8.4	0.97	**26.06**	2.37	6.34	**197.5**	**17.56**	0.49	1.04	<0.0837	0.71	4.62	0.31	<0.0037	0.078	<0.0069	<0.0126	0.019	45.8	<0.0072	<0.0015	0.0024	0.0183	0.003	0.055
GA303	2.3	**5.3**	26.9	0.64	**16.06**	4.70	11.20	**425.9**	**27.76**	2.94	3.47	0.10	2.70	4.05	0.27	<0.0037	0.073	<0.0069	<0.0126	0.098	88.0	<0.0072	<0.0015	0.0021	0.0301	0.052	0.234
SW10	0.8	0.4	5.1	0.11	1.10	0.02	0.18	7.1	0.08	0.07	<0.0709	<0.0837	**3.34**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.005	2.7	<0.0072	<0.0015	0.0008	<0.0049	<0.0013	<0.0022
SW11	0.9	0.7	5.2	0.17	1.31	0.02	0.35	8.0	0.07	0.03	<0.0709	<0.0837	**2.12**	<0.1220	<0.0980	<0.0037	0.007	<0.0069	<0.0126	0.007	2.5	<0.0072	<0.0015	<0.0005	0.0052	<0.0013	<0.0022
SW12	1.1	**2.1**	**52.6**	**0.53**	**4.23**	0.09	**1.01**	**30.5**	0.20	**0.18**	**2.33**	**0.29**	0.54	<0.1220	<0.0980	<0.0037	0.024	<0.0069	<0.0126	0.007	**8.0**	<0.0072	<0.0015	0.0009	0.0167	0.020	0.012
SW13	0.8	0.7	8.7	0.16	1.55	0.02	0.34	1.4	0.13	0.03	<0.0709	<0.0837	**3.03**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.006	3.3	<0.0072	<0.0015	<0.0005	0.0092	<0.0013	<0.0022
SW14	1.5	**9.6**	**133.7**	**0.98**	**11.39**	**1.37**	**3.22**	**522.4**	**4.56**	**3.01**	**1.32**	**0.43**	**7.33**	**0.61**	<0.0980	<0.0037	0.054	<0.0069	0.013	0.020	**15.3**	<0.0072	<0.0015	<0.0005	**0.2550**	0.041	0.013
SW15	0.9	0.7	7.5	0.15	1.48	0.02	0.21	**83.5**	0.19	**0.22**	<0.0709	<0.0837	1.61	0.14	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.005	2.8	<0.0072	<0.0015	<0.0005	<0.0049	<0.0013	<0.0022
SW16	1.1	0.8	**50.4**	0.06	1.84	**0.27**	**0.79**	**13.2**	**0.48**	**0.20**	**0.31**	<0.0837	**2.71**	**0.18**	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.011	1.9	<0.0072	<0.0015	<0.0005	**0.1551**	0.003	<0.0022
GA201	**26.7**	1.2	6.3	1.02	3.34	1.26	0.35	**20.3**	0.01	**0.50**	1.42	0.12	0.23	0.64	0.33	<0.0037	0.024	<0.0069	<0.0126	0.720	15.0	<0.0072	<0.0015	<0.0005	<0.0049	<0.0013	0.237
SW17	0.9	0.6	**385.9**	0.05	0.86	**0.55**	**1.74**	**14.7**	**1.15**	**0.82**	**1.75**	**0.31**	**7.09**	**0.24**	<0.0980	<0.0037	0.011	0.011	0.014	**0.056**	6.0	<0.0072	<0.0015	0.0005	**0.4501**	0.025	<0.0022
GA400	1.9	2.3	6.2	0.62	6.50	0.07	0.36	**2.2**	0.00	0.01	<0.0709	0.11	0.11	<0.1220	<0.0980	<0.0037	0.027	<0.0069	<0.0126	0.013	4.2	<0.0072	<0.0015	<0.0005	0.0078	<0.0013	0.054
MP10	0.1	**3.3**	14.3	0.05	**12.28**	0.09	0.31	**291.8**	**31.88**	**2.73**	**0.51**	<0.0837	**2.98**	**1.25**	<0.0980	<0.0037	0.039	<0.0069	<0.0126	0.016	**18.9**	<0.0072	<0.0015	0.0011	0.0204	<0.0013	<0.0022
MP11	0.1	**1.7**	7.4	0.05	**7.66**	0.04	0.38	**216.5**	**26.82**	**2.26**	0.17	<0.0837	1.07	**0.98**	<0.0980	<0.0037	0.026	<0.0069	<0.0126	0.016	**13.2**	<0.0072	<0.0015	0.0006	0.0149	<0.0013	<0.0022
SW30	0.2	0.2	4.2	0.02	0.47	0.01	0.16	10.5	0.02	**0.12**	<0.0709	<0.0837	**2.32**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.004	0.8	<0.0072	<0.0015	<0.0005	<0.0049	<0.0013	<0.0022
MP12	0.5	1.3	**28.4**	**0.59**	3.54	0.07	**0.55**	**188.3**	**23.34**	**2.15**	**1.57**	**0.59**	**21.34**	**2.00**	**0.27**	<0.0037	0.011	<0.0069	0.019	**0.036**	7.4	<0.0072	<0.0015	0.0027	0.0350	<0.0013	0.003
MP12?	0.2	**3.1**	10.6	0.04	**10.18**	0.04	**0.58**	**362.4**	**36.13**	**3.28**	**4.92**	0.18	**26.60**	**1.32**	<0.0980	<0.0037	0.032	<0.0069	**0.028**	**0.105**	**23.1**	<0.0072	<0.0015	0.0019	0.0169	<0.0013	<0.0022
SW31	0.2	0.9	3.9	0.03	2.03	0.01	0.29	0.6	0.03	0.02	<0.0709	<0.0837	**1.87**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.005	2.6	<0.0072	<0.0015	<0.0005	0.0055	<0.0013	<0.0022
SW32	0.4	0.6	6.4	0.02	1.06	0.02	0.24	**12.9**	0.24	**0.23**	<0.0709	<0.0837	**2.18**	**0.18**	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.009	1.3	<0.0072	<0.0015	<0.0005	0.0109	<0.0013	<0.0022

Appendix 2. Trace element

	23 Na [1]	24 Mg [1]	27 Al [1]	39 K [1]	44 Ca [1]	51 V [1]	52 Cr [1]	55 Mn [1]	56 Fe [1]	59 Co [1]	60 Ni [1]	63 Cu [1]	66 Zn [1]	75 As [1]	95 Mo [1]	101 Ru [2]	105 Pd [2]	107 Ag [2]	111 Cd [2]	121 Sb [2]	137 Ba [2]	189 Os [2]	193 Ir [2]	195 Pt [2]	208 Pb [2]	232 Th [2]	238 U [2]
Sample Name	Conc. [ppm]	Conc. [ppm]	Conc. [ppb]	Conc. [ppm]	Conc. [ppm]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppm]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]
MP14	0.3	0.5	19.6	0.07	1.29	0.06	0.38	**59.8**	**7.59**	**1.12**	**0.28**	0.21	**2.85**	**1.12**	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.009	1.8	<0.0072	<0.0015	<0.0005	0.0450	<0.0013	<0.0022
GA300	**10.8**	1.3	**48.8**	0.72	5.90	1.19	2.04	**390.8**	**0.41**	3.20	3.38	**15.29**	**861.25**	0.29	0.13	<0.0037	0.079	<0.0069	0.045	0.131	31.4	<0.0072	<0.0015	0.0014	0.2513	0.074	0.206
MP15	1.4	0.5	**565.5**	0.08	1.04	**1.17**	**3.20**	**14.2**	**1.15**	**0.72**	**2.01**	**0.40**	**16.11**	**0.31**	<0.0980	<0.0037	0.016	<0.0069	0.016	**0.049**	5.8	<0.0072	<0.0015	0.0017	**0.6169**	0.046	0.019
SW33	0.1	0.4	**96.7**	0.02	0.25	0.27	**1.11**	**17.8**	**0.50**	**0.30**	**1.01**	**0.28**	**3.88**	0.15	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	**0.024**	1.0	<0.0072	<0.0015	<0.0005	**0.1879**	0.009	<0.0022
MP16	0.4	0.6	**233.3**	0.10	1.21	**0.52**	**1.54**	**16.7**	**1.20**	**0.66**	**1.79**	**0.48**	**9.98**	**0.26**	<0.0980	<0.0037	0.010	<0.0069	**0.022**	**0.034**	5.3	<0.0072	<0.0015	<0.0005	**1.0516**	0.014	0.003
SW34	0.2	0.5	14.7	0.03	1.16	0.02	0.26	**32.0**	0.18	**0.22**	<0.0709	<0.0837	**2.71**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.011	2.0	<0.0072	<0.0015	0.0034	0.0146	<0.0013	<0.0022
MP17	0.4	**3.0**	20.8	0.08	**7.78**	0.01	0.28	**223.9**	**18.21**	**1.59**	**1.70**	<0.0837	**3.98**	**3.84**	<0.0980	<0.0037	0.019	<0.0069	<0.0126	0.012	**12.6**	<0.0072	<0.0015	0.0029	0.0200	<0.0013	<0.0022
MP18	0.3	**3.0**	18.9	0.04	**7.77**	0.02	0.31	**220.8**	**18.03**	**1.63**	**1.78**	0.22	**4.53**	**3.75**	<0.0980	<0.0037	0.019	<0.0069	<0.0126	0.018	**13.5**	<0.0072	<0.0015	0.0019	0.0966	<0.0013	<0.0022
MP19	0.3	**1.7**	**23.4**	0.04	**5.95**	0.03	0.36	**217.5**	**16.79**	**1.59**	**1.49**	0.10	**4.05**	**1.21**	<0.0980	<0.0037	0.014	<0.0069	<0.0126	0.019	**8.5**	<0.0072	<0.0015	0.0018	0.0458	<0.0013	<0.0022
MP20	0.3	1.5	6.4	0.21	**5.18**	0.02	0.43	**197.6**	**15.80**	**1.44**	**1.52**	<0.0837	**10.49**	**0.97**	<0.0980	<0.0037	0.013	<0.0069	<0.0126	0.019	**6.9**	<0.0072	<0.0015	0.0007	0.0550	<0.0013	<0.0022
SW35	0.1	0.3	2.7	0.02	0.72	0.01	0.20	10.3	0.07	0.05	<0.0709	<0.0837	**2.22**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.009	0.8	<0.0072	<0.0015	<0.0005	0.0068	<0.0013	<0.0022
MP21	0.1	1.0	16.3	0.03	**4.65**	0.03	**0.53**	**133.3**	**19.69**	**1.04**	**1.77**	<0.0837	**18.72**	**2.93**	<0.0980	<0.0037	0.014	<0.0069	<0.0126	0.009	**7.3**	<0.0072	<0.0015	0.0014	0.0214	<0.0013	<0.0022
MP22	0.1	0.6	5.5	0.12	2.11	0.02	**0.64**	**100.7**	**14.80**	**0.72**	**0.49**	<0.0837	**10.31**	**1.68**	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.017	3.4	<0.0072	<0.0015	<0.0005	0.0529	<0.0013	<0.0022
SW36	0.3	1.2	4.2	0.04	2.40	0.02	0.33	**186.9**	**4.85**	**0.83**	0.17	<0.0837	**1.82**	**0.21**	<0.0980	<0.0037	0.007	<0.0069	<0.0126	0.005	2.4	<0.0072	<0.0015	<0.0005	0.0554	<0.0013	<0.0022
SW37	0.4	**1.7**	6.1	0.06	**5.50**	0.02	0.16	**93.4**	**7.34**	**0.67**	0.07	<0.0837	**7.09**	**0.87**	<0.0980	<0.0037	0.013	<0.0069	<0.0126	0.014	**6.6**	<0.0072	<0.0015	<0.0005	0.0117	<0.0013	<0.0022
MP23	**3.5**	**8.5**	10.9	0.17	**37.48**	**0.40**	**1.92**	**446.0**	**30.05**	**1.05**	**2.48**	0.14	**25.26**	**10.79**	**0.39**	<0.0037	0.102	<0.0069	<0.0126	0.012	**21.5**	<0.0072	<0.0015	0.0012	0.0252	0.006	0.006
MP24	**2.6**	**11.6**	8.0	0.03	**53.59**	0.04	**0.64**	**555.4**	**26.68**	**1.07**	**0.72**	<0.0837	1.69	**9.37**	<0.0980	<0.0037	0.130	<0.0069	<0.0126	0.004	**30.0**	<0.0072	<0.0015	0.0013	0.0052	0.002	<0.0022
MP25	1.4	**11.5**	9.7	0.05	**51.24**	0.03	**0.48**	**531.5**	**47.84**	**1.47**	**0.42**	<0.0837	**50.63**	**11.40**	<0.0980	<0.0037	0.124	<0.0069	0.013	0.011	**34.2**	<0.0072	<0.0015	0.0010	0.0112	<0.0013	<0.0022
SW19	1.1	0.6	**573.3**	0.07	1.00	**1.19**	**2.59**	**17.5**	**1.29**	**0.79**	**1.97**	**0.46**	**6.79**	**0.22**	<0.0980	<0.0037	0.012	<0.0069	**0.072**	**0.048**	**7.8**	<0.0072	<0.0015	0.0008	**0.8679**	0.051	0.006
SW20	**3.8**	**8.1**	12.3	**1.47**	**9.53**	0.54	0.22	**219.6**	0.02	**0.89**	**3.97**	0.15	0.27	<0.1220	0.10	<0.0037	0.036	<0.0069	<0.0126	**0.028**	**20.0**	<0.0072	<0.0015	0.0008	0.0145	<0.0013	**0.066**
SW19	1.3	**1.7**	**167.3**	0.33	2.11	0.45	**3.39**	**172.6**	**2.56**	**1.51**	**1.96**	0.20	**5.65**	**0.25**	<0.0980	<0.0037	0.013	<0.0069	<0.0126	**0.022**	4.2	<0.0072	<0.0015	0.0092	**0.2517**	0.037	0.007
SW20	0.5	0.2	4.0	0.03	0.66	0.01	0.17	**16.4**	**0.10**	**0.12**	<0.0709	<0.0837	1.47	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.004	1.1	<0.0072	<0.0015	0.0006	<0.0049	<0.0013	<0.0022
ITÄ	0.3	2.8	96.8	0.05	8.88	2.03	0.80	**197.9**	**16.96**	**1.48**	0.56	0.09	12.29	1.76	<0.0980	<0.0037	0.026	<0.0069	<0.0126	0.038	11.7	<0.0072	<0.0015	0.0008	0.4123	0.017	0.047
KESKI	**4.2**	**16.9**	4.8	1.42	**23.03**	0.29	0.61	**505.9**	**7.11**	0.53	2.83	<0.0837	1.00	2.40	0.29	<0.0037	0.064	<0.0069	<0.0126	0.018	62.1	<0.0072	<0.0015	0.0016	0.0085	<0.0013	0.043
ETELÄ	**3.5**	**20.8**	2.9	1.97	**21.98**	0.13	0.42	**103.1**	**0.96**	0.10	1.28	<0.0837	4.39	1.24	0.36	<0.0037	0.076	<0.0069	<0.0126	0.134	47.1	<0.0072	<0.0015	0.0017	0.0132	<0.0013	0.014
SW21	1.0	0.6	4.7	0.24	1.65	0.03	0.36	9.0	0.39	**0.09**	<0.0709	0.24	**2.89**	**0.16**	<0.0980	<0.0037	0.007	<0.0069	<0.0126	**0.102**	2.6	<0.0072	<0.0015	<0.0005	0.0158	<0.0013	<0.0022
SW22	0.9	0.5	**58.3**	0.30	1.21	0.15	**2.28**	**33.8**	**1.49**	**2.10**	**1.77**	0.18	**2.17**	**0.86**	<0.0980	<0.0037	0.009	<0.0069	<0.0126	0.013	3.3	<0.0072	<0.0015	0.0012	0.0390	0.016	<0.0022
SW23	0.5	0.2	6.2	0.10	0.37	0.02	0.14	**32.1**	0.02	0.01	<0.0709	<0.0837	**2.68**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.008	0.3	<0.0072	<0.0015	0.0005	0.0181	<0.0013	<0.0022
MP3	**1.9**	**4.2**	10.6	0.09	**15.22**	0.01	0.28	**223.0**	**8.75**	**1.79**	**0.82**	0.23	**2.76**	**0.48**	0.13	<0.0037	0.023	<0.0069	0.015	**0.056**	**13.8**	<0.0072	<0.0015	0.0020	0.0438	<0.0013	<0.0022
MP1	**1.9**	0.6	**254.4**	0.23	2.81	**6.14**	**9.24**	**91.3**	**21.33**	**0.75**	**0.68**	**0.28**	0.57	**3.21**	<0.0980	<0.0037	0.021	<0.0069	<0.0126	0.015	**13.9**	<0.0072	<0.0015	0.0017	0.0304	0.123	0.032
MP2	0.1	1.0	7.3	0.15	**5.91**	0.02	0.14	**99.3**	**3.24**	**0.41**	0.20	<0.0837	1.09	**0.38**	<0.0980	<0.0037	0.015	<0.0069	<0.0126	0.008	**7.3**	<0.0072	<0.0015	0.0008	0.0228	<0.0013	0.002
SW24	1.1	1.1	**40.6**	0.56	**4.93**	**0.26**	**0.47**	**301.7**	**3.35**	**0.41**	**0.60**	**2.33**	***13.08***	**0.30**	<0.0980	<0.0037	0.016	0.016	**0.028**	**0.032**	**10.0**	<0.0072	<0.0015	<0.0005	0.1200	0.004	<0.0022
SW25	0.4	0.5	7.7	0.17	2.10	0.03	0.31	**30.2**	0.30	0.04	<0.0709	<0.0837	**1.95**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.014	2.0	<0.0072	<0.0015	0.0008	0.0289	<0.0013	<0.0022
SW26	1.4	0.4	5.6	0.16	0.86	0.02	0.20	**15.7**	0.24	**0.11**	<0.0709	**0.35**	**3.52**	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.014	0.8	<0.0072	<0.0015	<0.0005	0.0189	<0.0013	<0.0022

Appendix 2. Trace element

	23 Na [1]	24 Mg [1]	27 Al [1]	39 K [1]	44 Ca [1]	51 V [1]	52 Cr [1]	55 Mn [1]	56 Fe [1]	59 Co [1]	60 Ni [1]	63 Cu [1]	66 Zn [1]	75 As [1]	95 Mo [1]	101 Ru [2]	105 Pd [2]	107 Ag [2]	111 Cd [2]	121 Sb [2]	137 Ba [2]	189 Os [2]	193 Ir [2]	195 Pt [2]	208 Pb [2]	232 Th [2]	238 U [2]
Sample Name	Conc. [ppm]	Conc. [ppm]	Conc. [ppb]	Conc. [ppm]	Conc. [ppm]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppm]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]	Conc. [ppb]
MP4	0.5	**3.0**	**28.4**	0.08	**9.16**	0.02	0.40	**149.6**	**8.04**	**1.82**	**1.00**	**0.30**	**3.63**	**0.46**	<0.0980	<0.0037	0.018	<0.0069	<0.0126	**0.035**	**10.9**	<0.0072	<0.0015	0.0016	0.0326	<0.0013	<0.0022
MP5	**2.7**	**4.5**	6.1	0.33	**15.06**	0.01	0.25	**228.1**	**10.04**	**1.56**	**0.45**	<0.0837	1.50	**0.32**	<0.0980	<0.0037	0.022	<0.0069	<0.0126	0.005	**12.5**	<0.0072	<0.0015	0.0013	0.0420	<0.0013	<0.0022
MP6	**1.6**	**7.3**	**40.4**	0.11	**11.31**	**1.47**	**3.29**	**318.5**	**15.76**	**2.18**	**1.84**	0.24	**4.32**	**1.92**	0.11	<0.0037	0.038	<0.0069	<0.0126	**0.079**	**15.5**	<0.0072	<0.0015	0.0010	0.0388	0.021	0.007
MP7	**3.1**	**8.3**	9.4	**1.32**	**17.40**	0.17	0.56	3.4	**0.51**	**0.28**	0.23	0.19	1.63	**0.53**	<0.0980	<0.0037	0.031	<0.0069	<0.0126	**0.027**	**7.4**	<0.0072	<0.0015	0.0012	0.0382	<0.0013	<0.0022
SW27	**1.8**	**1.7**	11.2	0.16	1.88	0.03	**0.45**	0.4	0.09	0.03	<0.0709	<0.0837	0.64	<0.1220	<0.0980	<0.0037	0.010	<0.0069	<0.0126	0.006	2.8	<0.0072	<0.0015	<0.0005	0.0139	<0.0013	<0.0022
SW28	0.6	1.1	4.6	0.08	2.67	0.02	0.26	**28.0**	**0.61**	**0.17**	<0.0709	<0.0837	1.48	0.14	<0.0980	<0.0037	0.009	<0.0069	<0.0126	0.004	3.6	<0.0072	<0.0015	0.0006	<0.0049	<0.0013	<0.0022
MP8	1.1	**3.4**	**22.3**	0.27	**7.44**	0.60	**1.07**	**229.2**	**15.02**	**1.82**	**0.44**	0.15	**28.21**	**1.04**	<0.0980	<0.0037	0.024	<0.0069	<0.0126	**0.033**	**11.5**	<0.0072	<0.0015	0.0012	0.0217	0.003	<0.0022
MP9	0.8	**3.3**	**272.1**	0.16	**7.35**	**1.58**	**2.87**	**191.2**	**11.93**	**1.83**	**1.12**	**1.58**	**27.04**	**0.90**	<0.0980	<0.0037	0.024	<0.0069	<0.0126	**0.103**	**10.9**	<0.0072	<0.0015	0.0038	**0.5810**	0.049	0.026
SW29	0.2	0.5	2.5	0.03	1.55	0.01	0.29	**20.2**	0.08	**0.12**	<0.0709	<0.0837	1.19	<0.1220	<0.0980	<0.0037	0.007	<0.0069	<0.0126	0.003	3.1	<0.0072	<0.0015	<0.0005	0.0065	<0.0013	<0.0022
MP26	0.3	**7.2**	6.3	0.07	**31.65**	0.02	**0.69**	**327.7**	**83.50**	**1.80**	**0.37**	<0.0837	**45.37**	**14.71**	<0.0980	<0.0037	0.078	<0.0069	<0.0126	0.015	**27.6**	<0.0072	<0.0015	0.0014	0.0150	<0.0013	<0.0022
MP27	0.2	**2.8**	7.7	0.18	**13.05**	0.03	**0.47**	**225.6**	**84.03**	**1.66**	**0.39**	<0.0837	**129.65**	**12.20**	<0.0980	<0.0037	0.033	<0.0069	<0.0126	**0.023**	**11.3**	<0.0072	<0.0015	0.0010	0.0808	<0.0013	<0.0022
SW38	0.9	0.7	4.0	0.05	2.45	0.01	0.38	1.5	0.08	0.02	<0.0709	<0.0837	0.40	<0.1220	<0.0980	<0.0037	0.007	<0.0069	<0.0126	0.006	1.1	<0.0072	<0.0015	0.0010	0.0079	<0.0013	<0.0022
MP28	**2.1**	**7.0**	5.8	**0.95**	**31.61**	0.03	**0.51**	**239.3**	**8.64**	0.07	0.13	**0.31**	**4.85**	**0.47**	<0.0980	<0.0037	0.074	<0.0069	<0.0126	0.007	**21.8**	<0.0072	<0.0015	0.0007	0.0222	<0.0013	<0.0022
MP29	**1.8**	**6.2**	**23.8**	**0.80**	**28.20**	0.03	**0.46**	**215.4**	**6.75**	**0.12**	**0.26**	0.11	**14.99**	**0.44**	<0.0980	<0.0037	0.064	<0.0069	<0.0126	**0.030**	**19.5**	<0.0072	<0.0015	0.0030	0.0202	<0.0013	<0.0022
MP30	**1.7**	**5.1**	5.2	0.32	**24.44**	0.02	**0.50**	**205.3**	**8.50**	**0.18**	0.20	<0.0837	**22.75**	**0.67**	<0.0980	<0.0037	0.055	<0.0069	<0.0126	0.015	**19.0**	<0.0072	<0.0015	0.0006	0.0262	<0.0013	<0.0022
MP31	1.0	**1.8**	12.3	0.11	**8.11**	0.01	**0.48**	**118.7**	**5.48**	**0.23**	0.13	<0.0837	**32.34**	**1.16**	<0.0980	<0.0037	0.020	<0.0069	<0.0126	**0.046**	5.2	<0.0072	<0.0015	0.0014	0.0152	<0.0013	<0.0022
MP32	0.9	0.9	10.6	0.21	**5.05**	0.01	**0.58**	**92.8**	**3.41**	**0.17**	<0.0709	0.12	**30.01**	**0.62**	<0.0980	<0.0037	0.011	<0.0069	<0.0126	**0.053**	3.7	<0.0072	<0.0015	0.0010	0.1081	<0.0013	<0.0022
SW39	0.9	0.3	3.9	0.04	0.78	0.01	0.14	10.2	0.15	0.03	<0.0709	<0.0837	0.76	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.006	0.6	<0.0072	<0.0015	<0.0005	<0.0049	<0.0013	<0.0022
MP33	**2.8**	**5.7**	**33.4**	**1.07**	**13.81**	0.20	**1.25**	**584.0**	**19.89**	**4.02**	**1.67**	**1.14**	**34.48**	**10.72**	<0.0980	<0.0037	0.034	<0.0069	**0.035**	**0.031**	**15.8**	<0.0072	<0.0015	0.0026	0.1364	0.005	0.004
MP34	0.2	**2.7**	4.9	0.04	**8.28**	0.02	**0.58**	**217.5**	**18.45**	**1.81**	**0.55**	0.12	**2.94**	**2.27**	<0.0980	<0.0037	0.018	<0.0069	<0.0126	0.007	**9.5**	<0.0072	<0.0015	0.0007	0.0483	<0.0013	<0.0022
MP35	0.4	**2.3**	6.1	0.07	**6.87**	0.02	0.31	**118.6**	**12.65**	**0.61**	0.16	<0.0837	1.35	**0.74**	<0.0980	<0.0037	0.016	<0.0069	<0.0126	0.009	4.2	<0.0072	<0.0015	0.0010	0.1089	<0.0013	<0.0022
SW40	0.8	0.4	3.3	0.03	1.05	0.01	0.23	3.5	0.10	0.03	<0.0709	<0.0837	0.65	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.005	0.9	<0.0072	<0.0015	<0.0005	<0.0049	<0.0013	<0.0022
MP36	1.2	**2.2**	16.6	0.18	**8.19**	0.33	**0.53**	**113.7**	0.13	**0.44**	**1.24**	**0.75**	**81.43**	**4.55**	**0.50**	<0.0037	0.014	<0.0069	<0.0126	**0.026**	**10.0**	<0.0072	<0.0015	0.0018	0.0386	<0.0013	<0.0022
MP37	1.1	**2.3**	**24.9**	0.07	**7.60**	0.02	0.31	**120.6**	**1.26**	**0.58**	**0.75**	**0.27**	**6.58**	**2.00**	<0.0980	<0.0037	0.015	<0.0069	<0.0126	**0.048**	**10.1**	<0.0072	<0.0015	0.0025	0.0186	<0.0013	<0.0022
MP38	1.2	1.6	11.4	0.09	**5.68**	0.02	0.26	**94.3**	**0.58**	**0.41**	**0.28**	<0.0837	**3.97**	**1.02**	<0.0980	<0.0037	0.011	<0.0069	<0.0126	0.015	**8.6**	<0.0072	<0.0015	0.0022	0.0084	<0.0013	<0.0022
MP39	1.0	1.1	12.7	0.11	**4.00**	0.04	0.35	**70.4**	0.15	**0.21**	<0.0709	0.26	**7.92**	**0.54**	<0.0980	<0.0037	0.007	<0.0069	<0.0126	**0.021**	6.1	<0.0072	<0.0015	0.0015	0.0145	<0.0013	<0.0022
SW41	0.3	0.7	3.3	0.04	2.50	0.01	0.21	3.0	0.08	0.03	<0.0709	<0.0837	0.98	<0.1220	<0.0980	<0.0037	0.007	<0.0069	<0.0126	0.006	2.2	<0.0072	<0.0015	<0.0005	<0.0049	<0.0013	<0.0022
MP40	0.3	**4.9**	11.6	0.12	**17.98**	0.01	0.41	**396.0**	**16.05**	**0.99**	0.18	0.10	7.86	**0.78**	<0.0980	<0.0037	0.039	<0.0069	<0.0126	**0.030**	**12.9**	<0.0072	<0.0015	0.0010	0.0433	<0.0013	<0.0022
SW42	0.7	0.7	<0.9234	0.06	1.66	0.01	0.36	2.7	0.05	0.03	<0.0709	<0.0837	0.91	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.007	2.5	<0.0072	<0.0015	0.0006	<0.0049	<0.0013	<0.0022
MP41	0.8	1.1	**33.1**	**0.84**	**3.71**	**0.46**	**0.82**	**100.7**	**3.25**	**0.60**	**0.95**	**1.21**	**18.88**	**1.41**	<0.0980	<0.0037	0.018	<0.0069	<0.0126	**0.064**	**10.3**	<0.0072	<0.0015	0.0035	0.0385	0.002	<0.0022
MP42	0.3	1.2	**32.4**	0.17	**4.47**	0.02	0.42	**139.5**	**6.03**	**1.55**	**1.37**	0.21	**14.45**	**0.69**	<0.0980	<0.0037	0.015	<0.0069	0.015	**0.051**	**11.7**	<0.0072	<0.0015	0.0062	0.0240	<0.0013	<0.0022
MP43	0.5	1.4	4.5	0.12	**4.52**	0.03	0.41	**144.5**	**28.62**	**1.62**	0.30	<0.0837	**11.98**	**2.25**	<0.0980	<0.0037	0.014	<0.0069	<0.0126	0.013	**9.6**	<0.0072	<0.0015	0.0010	0.0109	<0.0013	<0.0022
MP44	0.5	0.8	**60.0**	0.31	2.56	0.03	**0.50**	**108.1**	**6.33**	**0.72**	0.12	0.13	**11.43**	**0.43**	<0.0980	<0.0037	0.009	<0.0069	<0.0126	0.019	4.4	<0.0072	<0.0015	0.0016	0.0290	<0.0013	<0.0022
SW43	0.1	0.9	3.9	0.06	2.31	0.00	0.27	2.0	0.02	0.03	<0.0709	<0.0837	**2.40**	<0.1220	<0.0980	<0.0037	0.008	<0.0069	<0.0126	0.006	4.6	<0.0072	<0.0015	0.0007	<0.0049	<0.0013	<0.0022

Appendix 2. Trace element

Sample Name	23 Na [1] Conc. [ppm]	24 Mg [1] Conc. [ppm]	27 Al [1] Conc. [ppb]	39 K [1] Conc. [ppm]	44 Ca [1] Conc. [ppm]	51 V [1] Conc. [ppb]	52 Cr [1] Conc. [ppb]	55 Mn [1] Conc. [ppb]	56 Fe [1] Conc. [ppm]	59 Co [1] Conc. [ppb]	60 Ni [1] Conc. [ppb]	63 Cu [1] Conc. [ppb]	66 Zn [1] Conc. [ppb]	75 As [1] Conc. [ppb]	95 Mo [1] Conc. [ppb]	101 Ru [2] Conc. [ppb]	105 Pd [2] Conc. [ppb]	107 Ag [2] Conc. [ppb]	111 Cd [2] Conc. [ppb]	121 Sb [2] Conc. [ppb]	137 Ba [2] Conc. [ppb]	189 Os [2] Conc. [ppb]	193 Ir [2] Conc. [ppb]	195 Pt [2] Conc. [ppb]	208 Pb [2] Conc. [ppb]	232 Th [2] Conc. [ppb]	238 U [2] Conc. [ppb]
MP45	0.5	1.3	**31.2**	0.05	**4.71**	0.10	0.38	**100.9**	**8.63**	**0.83**	**0.33**	<0.0837	**2.04**	**0.62**	<0.0980	<0.0037	0.015	<0.0069	<0.0126	0.015	**9.2**	<0.0072	<0.0015	0.0007	<0.0049	<0.0013	<0.0022
MP46	0.2	**2.4**	5.0	0.08	**7.34**	0.02	0.41	**155.2**	**19.77**	**1.42**	**0.39**	<0.0837	**3.91**	**0.89**	<0.0980	<0.0037	0.023	<0.0069	<0.0126	0.015	**14.3**	<0.0072	<0.0015	0.0012	0.0661	<0.0013	<0.0022
MP47	0.3	0.8	6.1	0.34	2.47	0.03	0.53	**54.7**	**3.61**	**0.45**	0.12	<0.0837	**13.85**	**0.18**	<0.0980	<0.0037	0.008	<0.0069	<0.0126	**0.040**	**6.9**	<0.0072	<0.0015	<0.0005	0.0318	<0.0013	<0.0022
SW44	0.2	0.5	<0.9234	0.04	1.21	0.01	0.34	5.1	0.03	0.03	<0.0709	<0.0837	0.94	<0.1220	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	0.008	2.7	<0.0072	<0.0015	0.0005	<0.0049	<0.0013	<0.0022
MP48	0.2	0.5	10.2	0.16	2.09	0.07	0.29	**27.8**	**0.82**	**0.14**	<0.0709	**0.41**	**5.83**	**0.19**	<0.0980	<0.0037	<0.0065	<0.0069	<0.0126	**0.057**	**6.6**	<0.0072	<0.0015	0.0009	0.0347	<0.0013	<0.0022

Groundwater samples are marked with green color. Bolded values are over the background values.

Background values (Lahermo et al. 1990 and 1996):

	Na (ppm)	Mg (ppm)	Al (ppb)	K (ppm)	Ca (ppm)	V (ppb)	Cr (ppb)	Mn (ppb)	Fe (ppb)	Ni (ppb)	Cu (ppb)	Zn (ppb)	As (ppb)	Mo (ppb)	Ag (ppb)	Cd (ppb)	Sb (ppb)	Ba (ppb)	Pb (ppb)	U (ppb)
Surface water	1.5-1.8	1.6-2.3	21	0.38-0.45	3.6-5.1	0.20-0.25	0.44-0.48	11.6-18.4	0.41-0.6	0.25-0.32	0.26-0.35	1.8-2.4	0.16-0.25	0.22-0.34	55-56	<0.02	<0.02	6.3-8.5	0.13-0.16	0.04-0.07
Ground water	3.5-5.4	2.8		2.6-3.2	10-12			0.02	0.05-0.1		4-6	50-70								

Appendix 3 main ions and ion balance

ID	Y	X	CLASS	PROF	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	F (ppm)	Cl (ppm)	NO3 (ppm)	PO4 (ppm)	SO4 (ppm)	tot-Alk mmol/l	IB%	IB% (with organic anion)
SW1	7494595	490720	SW	22	0.194	0.149	0.907	0.338	0.011	0.362	0.05	0.025	0.273	0.080	-6	
SW2	7493558	491703	SW	23	1.649	0.514	2.738	2.083	0.024	1.837	0.05	0.025	0.895	0.070	47	-9
SW3	7493455	491842	SW	24	1.262	0.129	2.612	0.835	0.034	0.436	0.050	0.025	0.273	0.180	13	
SW4	7493201	491702	SW	25	0.100	0.129	0.786	0.509	0.010	0.896	0.050	0.025	0.272	0.020	26	-13
SW5	7493442	492419	SW	26	1.164	0.125	1.567	0.917	0.021	1.224	0.050	0.025	0.302	0.060	34	-3
SW6	7493637	492072	SW	27	0.953	0.164	1.102	0.440	0.024	0.623	0.050	0.025	0.281	0.060	24	-7
SW7	7495421	489488	SW	28	0.325	0.194	1.364	0.423	0.013	0.509	0.050	0.025	0.273	0.010	60	
GA405	7492592	488867.1	GW	29												
GA305	7492588	488865.7	GW	30	1.575	0.515	5.850	4.000	0.025	0.769	0.050	0.025	1.664	0.640	0	
GA203	7492584	488864.7	GW	31	1.535	0.500	5.490	3.755	0.039	0.798	0.050	0.025	1.613	0.610	0	
SW8	7492492	489130	SW	32	0.782	0.285	2.181	0.799	0.017	0.573	0.050	0.025	0.274	0.200	-2	
GA103	7491750	489177	GW	33	0.700	0.125	3.475	1.255	0.018	0.594	0.050	0.025	0.296	0.810	-46	
SW9	7491750	489177	SW	34	0.851	0.225	2.112	0.980	0.015	0.548	1.105	0.025	0.283	0.220	-6	
GA403	7491716	489162	GW	35	3.390	0.960	25.910	8.150	0.047	0.746	0.050	0.025	0.575	2.600	-10	
GA303	7491673	489140	GW	36	2.710	1.120	22.220	11.080	0.087	0.768	0.399	0.025	33.941	0.670	21	
SW10	7491673	489140	SW	37	0.861	0.163	1.757	0.559	0.016	0.545	0.050	0.025	0.272	0.150	1	
SW11	7492113	489155	SW	38	0.936	0.257	1.571	0.724	0.014	0.804	0.050	0.025	0.273	0.140	5	
SW12	7492113	489079	SW	39	1.170	0.495	4.815	2.165	0.019	0.625	0.050	0.025	0.277	0.410	5	
SW13	7492223	489115	SW	40	0.871	0.213	1.591	0.684	0.017	0.583	0.050	0.025	0.277	0.180	-6	
SW14	7492354	489077	SW	41	1.535	0.980	11.395	9.990	0.034	0.855	0.050	0.025	0.342	1.340	4	-2
SW15	7492429	488840	SW	42	0.798	0.129	1.623	0.709	0.016	0.517	0.050	0.025	0.273	0.170	-4	
SW16	7493379	489493	SW	43	1.107	0.680	1.907	0.902	0.018	0.685	0.050	0.025	0.273	0.130	20	2
GA201	7493057	489665	GW	44	30.205	1.055	5.330	1.750	0.109	0.624	0.050	0.386	3.614	1.590	2	
SW17	7493061	489641	SW	45	0.827	0.053	0.970	0.707	0.007	0.837	0.050	0.025	0.461	0.000	62	-32
GA400	7493039	489862	GW	46	2.120	1.010	17.250	4.860	0.034	0.824	0.050	0.025	2.583	0.690	28	
GA202	7492275	489611	GW	48	3.860	3.840	14.810	10.395	0.116	0.611	0.050	0.072	2.363	1.320	15	
SW19	7492275	489611	SW	49	1.188	0.444	2.109	1.695	0.018	0.868	0.050	0.025	0.288	0.140	28	-7
SW20	7492122	489780	SW	50	0.441	0.040	1.246	0.319	0.010	0.400	0.050	0.025	0.287	0.090	0	
GA-itä	7491923	489851	GW	51	0.195	0.200	6.710	2.270	0.020	0.557	0.050	0.025	0.565	0.590	-7	
GA-keski	7491923	489851	GW	52	3.900	1.320	9.000	16.590	0.038	0.834	0.050	0.025	0.280	1.980	0	
GA-etelä	7491923	489851	GW	53	3.230	1.820	11.610	20.630	0.078	0.904	0.050	0.034	0.281	2.500	-1	
SW21	7491923	489851	SW	54	0.851	0.139	1.533	0.646	0.017	0.549	0.050	0.025	0.273	0.170	-6	
SW22	7495458	490259	SW	21	0.748	0.293	1.153	0.499	0.014	0.885	0.050	0.025	0.366	0.070	15	
SW23	7495605	490602	SW	20	0.428	0.115	0.040	0.276	0.007	0.790	0.050	0.025	0.284	0.050	-26	
MP2	7495605	490602	MP	20	0.085	0.145	6.390	1.095	0.015	0.221	0.050	0.025	0.289	0.370	4	
SW24	7495101	490990	LAKE	55	0.940	0.502	3.868	0.938	0.010	1.305	0.050	0.025	0.379	0.170	20	-8
SW25	7495091	490966	SW	56	0.339	0.158	2.242	0.593	0.008	1.390	0.050	0.025	0.273	0.090	14	-8
SW26	7494454	491808	SW	19	1.308	0.257	1.077	0.444	0.017	0.618	0.050	0.025	0.281	0.100	11	
MP4	7494454	491808	MP	19	3.990	0.055	8.660	2.835	0.066	0.489	0.050	0.025	0.286	0.650	11	

Appendix 3 main ions and ion balance

ID	Y	X	CLASS	PROF	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	F (ppm)	Cl (ppm)	NO3 (ppm)	PO4 (ppm)	SO4 (ppm)	tot-Alk mmol/l	IB%	IB% (with organic anion)
MP3	7494454	491808	MP	19	1.700	0.080	14.350	4.100	0.080	0.298	0.050	0.025	0.279	1.230	-5	
MP5	7494454	491808	MP	19	2.465	0.320	15.010	4.390	0.090	0.283	0.050	0.025	0.277	1.320	-4	
MP6	7492330	489066	MP	1	1.030	0.000	7.170	4.470	0.028	0.475	0.050	0.025	0.305	0.880	-8	
MP7	7492561	489418	MP	2	3.230	1.250	15.610	8.280	0.082	0.862	0.050	0.025	0.277	1.690	-3	
SW27	7492561	489418	SW	2	1.940	0.335	2.615	1.980	0.027	0.725	0.050	0.025	0.905	0.280	9	
SW28	7491976	489447	SW	3	0.550	0.110	2.355	1.105	0.017	0.582	0.050	0.025	0.274	0.270	-11	
MP8	7491976	489447	MP	3	0.980	0.210	5.855	3.010	0.022	0.447	0.050	0.025	0.273	0.670	-8	
MP9	7491976	489447	MP	3	0.670	0.115	7.385	3.230	0.024	0.455	0.050	0.025	0.284	0.620	2	
SW29	7491930	489704	SW	4	1.181	0.033	1.554	0.528	0.016	0.782	0.050	0.025	0.304	0.140	1	
MP10	7491930	489704	MP	4	0.015	0.020	10.070	2.970	0.025	1.060	0.050	0.025	0.301	0.840	-8	
MP11	7491930	489704	MP	4	0.075	0.000	8.150	1.930	0.021	1.059	0.050	0.025	0.291	0.540	-1	
SW30	7492183	489778	SW	5	0.224	0.095	0.392	0.193	0.011	0.742	0.050	0.025	0.306	0.060	-30	
MP12	7492183	489778	MP	5	0.260	0.375	2.545	0.950	0.012	0.366	0.050	0.025	0.282	0.290	-15	
SW31	7492164	489478	SW	6	0.250	0.545	2.350	1.015	0.014	0.309	1.537	0.025	0.406	0.270	-16	
MP13	7492164	489478	MP	6	0.110	0.000	8.705	2.980	0.039	0.731	0.050	0.025	0.287	0.780	-8	
SW32	7493350	489534	SW	7	0.364	0.220	1.334	0.532	0.013	0.571	0.050	0.025	0.448	0.110	-2	
MP14	7493350	489534	MP	7	0.300	0.007	1.462	0.596	0.012	0.494	0.050	0.025	0.271	0.120	-2	
GA300	7492533	489739	GW	57	8.350	0.705	5.705	1.335	0.036	0.693	0.050	0.025	2.908	0.610	6	
MP15	7492533	489739	MP	58	1.418	0.053	1.298	0.567	0.013	0.451	0.050	0.025	0.407	0.000	78	-6
SW33	7492447	489715	SW	8	0.157	0.124	0.179	0.366	0.005	0.479	0.050	0.025	0.475	0.000	34	-55
MP16	7492447	489715	MP	8	0.418	0.189	1.465	0.652	0.009	0.460	0.050	0.025	0.503	0.000	72	-18
SW34	7492120	489732	SW	9	0.148	0.163	0.840	0.369	0.010	0.746	0.050	0.025	0.273	0.110	-25	-32
MP17	7492120	489732	MP	9	0.435	0.125	9.490	3.695	0.014	0.519	2.009	0.025	0.273	0.770	-1	
MP18	7492120	489732	MP	9	0.240	0.000	9.350	3.495	0.013	0.501	1.642	0.025	0.273	0.710	1	
MP19	7492120	489732	MP	9	0.265	0.025	6.785	2.025	0.014	0.437	0.050	0.025	0.291	0.460	4	
MP20	7492120	489732	MP	9	0.310	0.275	5.420	1.650	0.014	0.565	0.050	0.025	0.272	0.390	2	
SW35	7492235	490021	SW	10	0.039	0.064	0.916	0.376	0.010	0.698	0.050	0.025	0.270	0.060	-4	
MP21	7492235	490021	MP	10	0.085	0.065	4.550	1.095	0.015	0.502	0.050	0.025	0.274	0.330	-4	
MP22	7492235	490021	MP	10	0.105	0.110	1.390	0.467	0.014	0.493	0.050	0.025	0.273	0.110	-6	
SW36	7492787	490136	SW	59	0.281	0.189	2.492	1.245	0.013	0.632	0.050	0.025	0.321	0.190	6	
SW37	7494697	491636	SW	11	0.595	1.025	3.875	1.320	0.024	0.976	0.050	0.025	0.324	0.410	-11	
MP24	7494697	491636	MP	11	2.520	0.000	58.180	13.140	0.143	0.187	0.050	0.025	0.373	3.250	11	
MP25	7494697	491636	MP	11	1.350	0.140	52.990	12.770	0.071	0.190	0.050	0.025	0.279	1.300	48	
MP27	7494697	491636	MP	11	0.155	0.245	11.140	2.695	0.027	0.556	0.050	0.025	0.277	0.750	1	
SW38	7494984	491857	SW	12	0.741	0.091	2.755	0.837	0.026	0.899	0.050	0.025	0.750	0.190	2	
MP28	7494984	491857	MP	12	1.990	0.890	29.230	7.100	0.060	0.986	0.050	0.025	0.275	1.790	8	
MP30	7494984	491857	MP	12	1.640	0.400	24.230	5.390	0.050	0.876	0.050	0.025	0.275	1.470	7	
MP31	7494984	491857	MP	12	0.960	0.125	7.720	1.900	0.036	0.377	0.050	0.025	0.276	0.520	4	
SW39	7493368	491765	SW	13	0.680	0.570	0.905	0.445	0.049	0.733	0.050	0.025	0.313	0.220	-33	

Appendix 3 main ions and ion balance

ID	Y	X	CLASS	PROF	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	F (ppm)	Cl (ppm)	NO3 (ppm)	PO4 (ppm)	SO4 (ppm)	tot-Alk mmol/l	IB%	IB% (with organic anion)
MP34	7493368	491765	MP	13	0.135	0.000	6.910	2.580	0.056	0.577	0.050	0.025	0.279	0.540	0	
SW40	7493193	492247	SW	14	0.770	0.170	1.251	0.504	0.030	0.706	0.050	0.025	0.274	0.100	6	
SW41	7493944	491160	SW	15	0.179	0.049	2.167	0.719	0.023	0.571	0.050	0.025	0.273	0.180	-7	
SW42	7492171	489027	SW	16	0.360	0.162	1.179	0.557	0.013	0.495	0.050	0.025	0.297	0.160	-18	
MP43	7492171	489027	MP	16	0.385	0.115	3.390	1.150	0.019	0.540	0.050	0.025	0.273	0.320	-9	
MP44	7492171	489027	MP	16	0.410	0.230	1.900	0.685	0.016	0.472	0.050	0.025	0.278	0.210	-14	
SW43	7491458	488456	SW	17	0.025	0.032	2.102	0.820	0.015	0.433	0.050	0.025	0.272	0.180	-7	
MP45	7491458	488456	MP	17	0.325	0.000	2.510	0.970	0.013	0.456	0.050	0.025	0.296	0.320	-22	
MP46	7491458	488456	MP	17	0.110	0.005	5.250	2.130	0.020	0.592	0.050	0.025	0.279	0.510	-9	
MP47	7491458	488456	MP	17	0.155	0.270	1.820	0.695	0.017	0.395	1.706	0.025	0.300	0.210	-22	
SW44	7491605	488515	SW	18	0.068	0.099	1.037	0.439	0.012	0.472	0.050	0.025	0.272	0.110	-16	

Appendix 4 Field measurements, stable isotopes, DSi and DOC

ID	Y	X	CLASS	Date	PROF	Depth (m)	EC mS/cm	pH	T °C	DOC (ppm)	$\delta^{18}O$	δ D	*d*-excess	DSi
SASW1	7494595	490720	SW	13.9.2016	22	0	0.073	5.83	8.44	6.8	-10.89	-80.92	6.2	0.66863
SASW2	7493558	491703	SW	13.9.2016	23	0	0.049	4.47	8.92	65.6	-12.43	-89.83	9.61	5.39742
SASW3	7493455	491842	SW	13.9.2016	24	0	0.019	6.19	8.88	6.3	-10.98	-81	6.84	4.2423
SASW4	7493201	491702	SW	13.9.2016	25	0	0.012	5.1	11.32	12.8	-10.73	-77.96	7.88	2.34083
SASW5	7493442	492419	SW	13.9.2016	26	0	0.018	5.16	9.74	23.6	-12.08	-86.96	9.68	3.97774
SASW6	7493637	492072	SW	13.9.2016	27	0	0.015	5.22	9.69	14.5	-11.72	-84.52	9.24	2.59828
SASW7	7495421	489488	SW	13.9.2016	28	0	0.013	6.3	8.75	5.7	-10.31	-78.95	3.53	0.785
SAGA405	7492591.82	488867.08	GW	13.9.2016	29		0.226	6.8	5.48	3.8	-12.45	-95.42	4.18	7.59375
SAGA305	7492588.24	488865.70	GW	13.9.2016	30		0.069	6.52	5.64	1.3	-13.04	-97.52	6.8	4.76364
SAGA203	7492584.02	488864.69	GW	13.9.2016	31		0.065	6.54	6.12	1.9	-13.16	-98.66	6.62	4.70693
SASW8	7492492	489130	SW	14.9.2016	32	0	0.022	6	6.84	5.3	-10.09	-78.51	2.21	1.38738
SAGA103	7491750	489177	GW	14.9.2016	33		0.06	5.97	8.75	6.6	-12.5	-95.79	4.21	2.45545
SASW9	7491750	489177	SW	14.9.2016	34	0	0.023	6.85	7.51	4.8	-9.84	-77.04	1.68	1.14149
SAGA403	7491716	489162	GW	14.9.2016	35		0.265	7.08	5.86	5.6	-12.08	-94.04	2.6	10.57159
SAGA303	7491673	489140	GW	14.9.2016	36		0.193	6.67	6.9	5.6	-12.32	-94.03	4.53	6.14446
SASW10	7491673	489140	SW	14.9.2016	37	0	0.02	6.74	8.69	4.8	-9.955	-77.445	2.195	1.23
SASW11	7492113	489155	SW	14.9.2016	38	0	0.018	6.13	8.25	4.4	-9.97	-76.74	3.02	1.1061
SASW12	7492113	489079	SW	14.9.2016	39	0	0.048	6.4	8.47	6.9	-11.9	-92.1	3.1	3.46149
SASW13	7492223	489115	SW	14.9.2016	40	0	0.018	6.38	8.18	5.4	-9.88	-77.6	1.44	1.20754
SASW14	7492354	489077	SW	14.9.2016	41	0	0.13	6.64	8.59	34.2	-12.45	-94.08	5.52	4.84111
SASW15	7492429	488840	SW	14.9.2016	42	0	0.019	6.87	8.4	4.8	-9.9	-78.38	0.82	1.35238
SASW16	7493379	489493	SW	14.9.2016	43	0	0.022	6.13	9.66	14.2	-11.77	-88.88	5.28	3.6333
SAGA201	7493057	489665	GW	14.9.2016	44		0.097	7	9.29	1.6	-13.68	-99.14	10.3	6.85884
SASW17	7493061	489641	SW	14.9.2016	45	0	0.04	4.35	10.86	49.2	-11.8	-86.46	7.94	2.39347
SAGA400	7493039	489862	GW	14.9.2016	46		0.32	6.47	8.56	1.3	-13.96	-102.08	9.6	4.72568
SASW18	7492534	489735	SW	14.9.2016	47	0	0.054	3.94	8.36	51.5	-12.29	-89.4	8.92	2.84704
SAGA202	7492275	489611	GW	14.9.2016	48		0.135	7.15	5.76	1.6	-14.31	-106.57	7.91	8.12881
SASW19	7492275	489611	SW	14.9.2016	49	0	0.032	5.9	9.43	36.1	-12.47	-91.39	8.37	4.31663
SASW20	7492122	489780	SW	14.9.2016	50	0	0.01	5.64	10.12	3.8	-9.78	-77.03	1.21	
SAGA-itä	7491923	489851	GW	14.9.2016	51		0.118	5.88	9.16	12	-11.29	-86.26	4.06	1.88337
SAGA-keski	7491923	489851	GW	14.9.2016	52		0.278	7.42	6.3	4.6	-12.72	-97.87	3.89	11.6974

Appendix 4 Field measurements, stable isotopes, DSi and DOC

ID	**Y**	**X**	**CLASS**	**Date**	**PROF**	**Depth (m)**	**EC mS/cm**	**pH**	**T °C**	**DOC (ppm)**	**δ^{18}O**	**δ D**	***d*-excess**	**DSi**
SAGA-etelä	7491923	489851	GW	14.9.2016	53		0.28	7.66	5.94	6.3	-12.75	-98.05	3.95	11.44007
SASW21	7491923	489851	SW	14.9.2016	54	0	0.018	7.95	11.25	5.3	-10.47	-79.65	4.11	
YSI meas	7495473	490296	SW	15.9.2016		0	0.04	4.65	8.99					
SASW22	7495458	490259	SW	15.9.2016	21	0	0.013	5.63	9.74	18.3	-11.44	-82.86	8.66	1.28
MP1	7495458	490259	MP	15.9.2016	21	-0.5				22.1	-12.03	-91.5	4.74	5.1949
SASW23	7495605	490602	SW	15.9.2016	20	0	0.01	5.46	9.81	8.2	-8.63	-68.6	0.44	0.01277
MP2	7495605	490602	MP	15.9.2016	20	-1	0.052	5.67		17.4	-9.42	-79.55	-4.19	1.17343
SASW24	7495101	490990	LAKE	15.9.2016	55		0.028	5.83	10.21	32.3	-11	-79.51	8.49	1.0824
SASW25	7495091	490966	SW	15.9.2016	56		0.022	5.6	10.3	15	-10.47	-75.51	8.25	0.36836
SASW26	7494454	491808	SW	15.9.2016	19	0	0.015	5.88	11.39	13.8	-10.13	-72.41	8.63	1.64183
MP4	7494454	491808	MP	15.9.2016	19	-1	0.095	6.02		20.9	-12.47	-92.45	7.31	7.67948
MP3	7494454	491808	MP	15.9.2016	19	-2.17	0.151	6.21		14.3	-14.35	-105.74	9.06	8.66807
MP5	7494454	491808	MP	15.9.2016	19	-2.87	0.162	6.34		9	-14.79	-108.77	9.55	8.99
MP6	7492330	489066	MP	17.10.2016	1	-1.3	0.176	6.55	4.72	10.9	-11.33	-87.61	3.03	5.6046
MP7	7492561	489418	MP	18.10.2016	2	-0.5	0.169	6.26	4.5	2.5	-14.15	-104.68	8.52	6.51469
SASW27	7492561	489418	SW	18.10.2016	2	0	0.035	5.8	1.89	5.8	-13.36	-98.5	8.38	6.1293
SASW28	7491976	489447	SW	18.10.2016	3	0	0.0018	6.37	2.05	3.7	-10.27	-80.07	2.09	1.91127
MP8	7491976	489447	MP	18.10.2016	3	-2.5	0.066	6.25	4.83	9	-12.2	-94.05	3.55	3.10898
MP9	7491976	489447	MP	18.10.2016	3	-1.5	0.097	6.26	5.22	8.3	-12.09	-93.1	3.62	3.36051
SASW29	7491930	489704	SW	18.10.2016	4	0	0.02	5.53	2.09	3.1	-10.35	-79.83	2.97	1.91299
MP10	7491930	489704	MP	18.10.2016	4	-2	0.185	6.07	5.47	20.3	-10.82	-82.57	3.99	4.46714
MP11	7491930	489704	MP	18.10.2016	4	-1	0.143	5.96	5.8	19.6	-10.93	-83.73	3.71	3.42391
SASW30	7492183	489778	SW	18.10.2016	5	0	0.009	5.34	1.7	3.5	-10.41	-79.05	4.23	1.00064
MP12	7492183	489778	MP	18.10.2016	5	-0.5	0.117		3.58	12.6	-11.58	-88.96	3.68	
SASW31	7492164	489478	SW	18.10.2016	6	0	0.021	6.23	1.78	4.6	-10.78	-82.02	4.22	1.56712
MP13	7492164	489478	MP	18.10.2016	6	-0.5	0.194	6.18	4.63	14.4	-10.79	-84.41	1.91	1.2899
SASW32	7493350	489534	SW	19.10.2016	7	0	0.014	4.62	3.84	5	-9.67	-76.16	1.2	1.10562
MP14	7493350	489534	MP	19.10.2016	7	-0.5	0.037	5.5	4.35	6.7	-9.97	-78.52	1.24	3.63554
SAGA300	7492533	489739	GW	19.10.2016	57		0.075	5.96	7.09	8.6	-13.73	-100.61	9.23	6.79343
MP15	7492533	489739	MP	19.10.2016	58	-0.3				48	-12.54	-91.82	8.5	6.55785
SASW33	7492447	489715	SW	19.10.2016	8	0	0.028	3.73	4.37	29.1	-11.44	-85.55	5.97	1.80464

Appendix 4 Field measurements, stable isotopes, DSi and DOC

ID	**Y**	**X**	**CLASS**	**Date**	**PROF**	**Depth (m)**	**EC mS/cm**	**pH**	**T °C**	**DOC (ppm)**	**δ^{18}O**	**δ D**	***d*-excess**	**DSi**
MP16	7492447	489715	MP	19.10.2016	8	-0.25	0.034	3.74	5.13	38.6	-11.4	-85.53	5.67	3.2933
SASW34	7492120	489732	SW	19.10.2016	9	0	0.014	4.74	4.23	4.8	-10.98	-83.12	4.72	1.16082
MP17	7492120	489732	MP	19.10.2016	9	-2.8	0.138	5.87	5.8	9	-11.26	-86.41	3.67	1.32886
MP18	7492120	489732	MP	19.10.2016	9	-1.8	0.134	6.07	6.17	8.7	-11.1	-85.53	3.27	1.35306
MP19	7492120	489732	MP	19.10.2016	9	-1.1	0.109	6.05	6.03	11.1	-11.18	-86.45	2.99	1.29668
MP20	7492120	489732	MP	19.10.2016	9	-0.3	0.088	6.05	5.37	8.7	-11.3	-86.87	3.53	1.30854
SASW35	7492235	490021	SW	19.10.2016	10	0	0.012	4.79	3.66	4.4	-9.99	-76.87	3.05	0.67263
MP21	7492235	490021	MP	19.10.2016	10	-1.5	0.091	5.77	6.6	10.5	-11.55	-88.46	3.94	1.11792
MP22	7492235	490021	MP	19.10.2016	10	-0.5	0.068	5.57	5.24	11.8	-10.7	-81.95	3.65	0.85372
SASW36	7492787	490136	SW	19.10.2016	59	0	0.046	5.79	3.56	6.2	-9.77	-76.24	1.92	2.01519
SASW37	7494697	491636	SW	20.10.2016	11	0	0.05	7.9	2.33	20.9	-11.27	-80.89	9.27	4.07363
MP23	7494697	491636	MP	20.10.2016	11	-2								
MP24	7494697	491636	MP	20.10.2016	11	-1.5	0.433	7.77	5.19	4.7	-13.59	-101.9	6.82	8.93133
MP25	7494697	491636	MP	20.10.2016	11	-1	0.474	7.85	5.16	8.8	-13	-96.94	7.06	6.17714
MP26	7494697	491636	MP	20.10.2016	11	-0.7	0.446	7.64	4.8					
MP27	7494697	491636	MP	20.10.2016	11	-0.3	0.315	7.62	3.78	42.4	-11.79	-87.01	7.31	4.9176
YSI meas	7494697	491636		20.10.2016	11	-0.15	0.293	7.61	3.49					
SASW38	7494984	491857	SW	20.10.2016	12	0	0.025	7.79	2.8	5	-11.57	-86.52	6.04	2.8036
MP28	7494984	491857	MP	20.10.2016	12	-3.5	0.239	7.96	4.23	5.9	-13.37	-101.44	5.52	9.73461
MP29	7494984	491857	MP	20.10.2016	12	-2.5	0.229							
MP30	7494984	491857	MP	20.10.2016	12	-1.5	0.188	8.01	4.6	7.4	-13.09	-99.69	5.03	7.22
MP31	7494984	491857	MP	20.10.2016	12	-0.5	0.075	7.59	4.25	13.2	-12.71	-96.54	5.14	3.60519
MP32	7494984	491857	MP	20.10.2016	12	-0.2	0.48		3.98					
SASW39	7493368	491765	SW	20.10.2016	13	0	0.014	7.05	3.26	6.7	-11.02	-80.97	7.19	4.751
MP33	7493368	491765	MP	20.10.2016	13	-1	0.133							
MP34	7493368	491765	MP	20.10.2016	13	-0.5	0.111	7.61	5.04	20.5	-11.7	-87.44	6.16	6.77952
MP35	7493368	491765	MP	20.10.2016	13	-0.2	0.086	7.56	4.58					
SASW40	7493193	492247	SW	20.10.2016	14	0	0.015	7.68	3.47	5.7	-11.48	-84.39	7.45	5.11952
MP36	7493193	492247	MP	20.10.2016	14	-2.4				16.4				
MP37	7493193	492247	MP	20.10.2016	14	-1.4				17.3				
MP38	7493193	492247	MP	20.10.2016	14	-0.9				11.7				

Appendix 4 Field measurements, stable isotopes, DSi and DOC

ID	**Y**	**X**	**CLASS**	**Date**	**PROF**	**Depth (m)**	**EC mS/cm**	**pH**	**T °C**	**DOC (ppm)**	**$\delta^{18}O$**	**δ D**	***d*-excess**	**DSi**
MP39	7493193	492247	MP	20.10.2016	14	-0.6				9				
SASW41	7493944	491160	SW	20.10.2016	15	0	0.019	7.45	2.95	5.2	-11.19	-83.1	6.42	2.3192
MP40	7493944	491160	MP	20.10.2016	15	-0.6				19.8	-10.5	-81.61	2.39	2.69827
SASW42	7492171	489027	SW	21.10.2016	16	0	0.034	7.11	2.58	7.3	-10.2	-78.56	3.04	1.51635
MP41	7492171	489027	MP	21.10.2016	16	-1.5							0	
MP42	7492171	489027	MP	21.10.2016	16	-1	0.133				-11.22	-87.73	2.03	1.86907
MP43	7492171	489027	MP	21.10.2016	16	-0.5	0.125	6.57	5.58	18.1	-11.05	-86.53	1.87	2.35946
YSI meas	7492171	489027			16	-0.3	0.123	7.3	4.62					
MP44	7492171	489027	MP	21.10.2016	16	-0.15	0.048	6.47	3.61	7	-10.11	-79.29	1.59	1.56915
SASW43	7491458	488456	SW	21.10.2016	17	0	0.013	6.43	1.63	5.3	-11.04	-83.77	4.55	3.54246
MP45	7491458	488456	MP	21.10.2016	17	-1	0.063	6.27	5.53	10.1	-12.51	-96	4.08	3.23044
MP46	7491458	488456	MP	21.10.2016	17	-0.3	0.113	6.46	4.36	18.7	-12.03	-92.02	4.22	5.7221
MP47	7491458	488456	MP	21.10.2016	17	-0.15	0.037	6.3	3.34	8.6	-11.19	-85.8	3.72	4.35562
SASW44	7491605	488515	SW	21.10.2016	18	0	0.009	5.99	1.86	6.6	-10.8	-81.26	5.14	2.54695
MP48	7491605	488515	MP	21.10.2016	18	-0.3	0.037			6.8	-10.64	-82.78	2.34	2.89343
SASW45	7496382.66	489419.7	LAKE	27.3.2017	68	0					-13.77	-101.56	8.6	6.569473
SAGA405B	7492591.82	488867.08	GW	27.3.2017	29						-12.49	-95.6	4.32	8.286044
SAGA305B	7492588.24	488865.7	GW	27.3.2017	30						-12.46	-95.11	4.57	7.491798
SAGA203B	7492584.02	488864.69	GW	27.3.2017	31						-12.54	-95.34	4.98	4.764454
SASW46	7492679.49	488780.94	SPRING	27.3.2017	69	0					-12.11	-92.08	4.8	4.927495
MP49	7494993.7	491893.49	MP	29.3.2017	70	-3					-12.27	-92.93	5.23	3.531596
SASW47	7492413	488645.94	SPRING	29.3.2017	71	0					-11.22	-86.73	3.03	4.025969
SASW48	7491797.05	488658.68	SW	29.3.2017	60	0					-13.32	-98.7	7.86	12.59098
MP50	7491797.05	488658.68	MP	29.3.2017	60	-1					-11.74	-90.32	3.6	4.791536
SASW49	7491809.09	488972.92	SW	29.3.2017	61	0					-12.58	-95.05	5.59	11.34002
MP51	7491809.09	488972.92	MP	29.3.2017	61	-2					-11.93	-92.12	3.32	6.391444
SASW50	7492137.02	490493.78	SW	31.3.2017	62	0					-11.82	-92.24	2.32	
MP52	7492137.02	490493.78	MP	31.3.2017	62	-4.65					-11.23	-87.95	1.89	3.069787
MP53	7492137.02	490493.78	MP	31.3.2017	62	-3.55					-11.42	-89.16	2.2	4.011009
MP54	7492137.02	490493.78	MP	31.3.2017	62	2.45					-11.3	-88.02	2.38	4.636007
MP55	7492137.02	490493.78	MP	31.3.2017	62	-1.5					-11.55	-88.22	4.18	4.105422

Appendix 4 Field measurements, stable isotopes, DSi and DOC

ID	Y	X	CLASS	Date	PROF	Depth (m)	EC mS/cm	pH	T °C	DOC (ppm)	δ^{18}O	δ D	*d*-excess	DSi
SASW51	7492834.98	490651.92	SW	31.3.2017	63	0					-11.9	-91.03	4.17	5.25303
MP56	7492834.98	490651.92	MP	31.3.2017	63	-2.5					-11.49	-87.81	4.11	3.704584
SASW52	7491710.17	489171.17	SW	1.4.2017	64	0					-11.46	-88.61	3.07	5.656201
MP57	7491710.17	489171.17	MP	1.4.2017	64	-2					-12.04	-92.58	3.74	3.261435
MP58	7491710.17	489171.17	MP	1.4.2017	64	-1					-11.8	-91.58	2.82	2.664786
SASW53	7491335.96	489076.69	SW	1.4.2017	65	0					-11.64	-89.23	3.89	
MP59	7491335.96	489076.69	MP	1.4.2017	65	-4.82					-13.32	-99.55	7.01	9.738708
MP60	7491335.96	489076.69	MP	1.4.2017	65	-4								9.372833
MP61	7491335.96	489076.69	MP	1.4.2017	65	-3.63					-11.77	-90.58	3.58	4.358373
MP62	7491335.96	489076.69	MP	1.4.2017	65	-2.03					-11.84	-90.88	3.84	4.732726
MP63	7491335.96	489076.69	MP	1.4.2017	65	-1					-10.99	-84.43	3.49	2.765694
SASW54	7491874.33	488836.35	SW	1.4.2017	66	0					-12.4	-92.62	6.58	10.77444
MP64	7491874.33	488836.35	MP	1.4.2017	66	-1.5					-12.34	-94.59	4.13	7.064249
MP65	7491874.33	488836.35	MP	1.4.2017	66	-0.76					-12.53	-95.48	4.76	6.287451
SASW55	7495248.76	489723.39	SW	2.4.2017	67	0					-11.57	-88.25	4.31	6.679336
MP66	7495248.76	489723.39	MP	2.4.2017	67						-12.14	-93.19	3.93	3.787875
17HYDO22/P8	7495590	489477	GW	Summer							-13.87	-102.56	8.4	
17GA405	7492591.82	488867.08	GW	Summer							-12.7	-96.14	5.46	
17GA203	7492584.02	488864.69	GW	Summer							-12.58	-95.23	5.41	
17HYDO16/P9	7495007	489405	GW	Summer							-13.8	-102.62	7.78	
17HYDO21/P7	7496003	489474	GW	Summer							-13.96	-104.22	7.46	
17HYDO20/P6	7496286	489839	GW	Summer							-14.24	-105.68	8.24	
17HYDO15/P4	7494899.5	489766.1	GW	Summer							-13.09	-97.78	6.94	
17HYDO19/P5	7496662	490037	GW	Summer							-12.1	-90.52	6.28	
17SPRING1	7492880	488923	SPRING	Summer							-10.87	-86.23	0.73	
17SPRING2	7492878	488914	SPRING	Summer							-11.07	-87.38	1.18	
17SPRING3	7493006	488977	SPRING	Summer							-11.42	-88.72	2.64	
17SPRING4	7492685	488781	SPRING	Summer							-12.87	-96.76	6.2	
17SPRING5	7492629	488763	SPRING	Summer							-12.58	-94.56	6.08	
17SPRING6	7492381	488253	SPRING	Summer							-13.51	-100.63	7.45	
17SPRING7	7492450	488508	SPRING	Summer							-12.98	-96.85	6.99	

Appendix 4 Field measurements, stable isotopes, DSi and DOC

ID	Y	X	CLASS	Date	PROF	Depth (m)	EC mS/cm	pH	T °C	DOC (ppm)	$\delta^{18}O$	δ D	*d*-excess	DSi
17SPRING8	7492408	488746	SPRING	Summer							-10.62	-83.49	1.47	
17RIVER1	7492915	488937	SW	Summer							-12.61	-95.42	5.46	
17SUO1	7491529	488469	SW	Summer							-10.09	-79	1.72	
17Kärväslampi	7493007	489039	SW	Summer							-10.45	-83.58	0.02	

Appendix 5 Mean and median values for all the water samples

Surface water samples		**EC mS/cm**	**pH**	**T °C**	**DOC, ppm**	**Dsi**	**F (ppm)**	**Cl (ppm)**	**tot-Alk mmol/l**	**Na (ppm)**	**Mg (ppm)**	**Al (ppb)**	**K (ppm)**	**Ca (ppm)**	**V (ppb)**	**Cr (ppb)**
N	**Valid**	43	43	43	43	47	42	42	42	51	51	51	51	51	51	51
	Missing	8	8	8	8	4	9	9	9	0	0	0	0	0	0	0
Mean		***0.03***	***5.98***	***6.55***	***12.89***	***3.20***	***0.02***	***0.70***	***0.17***	***0.75***	***1.54***	***55.57***	***0.17***	***3.09***	***0.16***	***1.16***
Median		***0.02***	***5.99***	***8.25***	***6.20***	***2.34***	***0.02***	***0.63***	***0.14***	***0.81***	***0.66***	***6.18***	***0.08***	***1.66***	***0.02***	***0.33***
Std. Deviation		0.02	1.03	3.41	14.43	2.78	0.01	0.28	0.21	0.48	2.50	162.39	0.20	3.88	0.49	2.90
Minimum		0.00	3.73	1.63	3.10	0.01	0.01	0.31	0.00	0.06	0.20	0.45	0.02	0.25	0.00	0.13
Maximum		0.13	7.95	11.39	65.60	12.59	0.05	1.84	1.34	2.01	13.11	963.27	0.98	21.48	3.06	20.35

Surface water samples		**Mn (ppb)**	**Fe (ppm)**	**Co (ppb)**	**Ni (ppb)**	**Cu (ppb)**	**Zn (ppb)**	**As (ppb)**	**Pd (ppb)**	**Cd (ppb)**	**Sb (ppb)**	**Ba (ppb)**	**Pt (ppb)**	**Pb (ppb)**	**Th (ppb)**	**U (ppb)**
N	**Valid**	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean		***72.12***	***4.37***	***0.91***	***0.75***	***0.23***	***5.02***	***0.36***	***0.01***	***0.07***	***0.02***	***5.71***	***0.00***	***0.14***	***0.01***	***0.00***
Median		***15.76***	***0.24***	***0.12***	***0.04***	***0.04***	***2.28***	***0.06***	***0.01***	***0.01***	***0.01***	***2.74***	***0.00***	***0.02***	***0.00***	***0.00***
Std. Deviation		122.88	11.35	1.77	1.75	0.43	10.17	0.75	0.01	0.36	0.02	7.14	0.00	0.32	0.03	0.01
Minimum		0.35	0.02	0.01	0.04	0.04	0.40	0.06	0.00	0.01	0.00	0.29	0.00	0.00	0.00	0.00
Maximum		540.74	56.92	7.88	11.21	2.59	71.24	4.51	0.07	2.59	0.10	27.27	0.01	1.77	0.23	0.04

Mini-piezometer samples		**EC mS/cm**	**pH**	**T °C**	**DOC, ppm**	**Dsi**	**F (ppm)**	**Cl (ppm)**	**tot-Alk mmol/l**	**Na (ppm)**	**Mg (ppm)**	**Al (ppb)**	**K (ppm)**	**Ca (ppm)**	**V (ppb)**	**Cr (ppb)**
N	**Valid**	39	33	31	40	54	33	33	33	66	66	66	66	66	66	66
	Missing	27	33	35	26	12	33	33	33	0	0	0	0	0	0	0
Mean		***0.16***	***6.49***	***4.89***	***14.52***	***4.45***	***0.03***	***0.53***	***0.73***	***1.02***	***2.96***	***36.59***	***0.25***	***10.48***	***0.36***	***1.06***
Median		***0.13***	***6.26***	***4.83***	***11.40***	***3.90***	***0.02***	***0.49***	***0.54***	***0.87***	***2.27***	***15.08***	***0.13***	***7.52***	***0.03***	***0.53***
Std. Deviation		0.12	0.92	0.80	9.70	2.46	0.03	0.22	0.65	0.84	2.50	83.57	0.31	10.56	1.27	1.79
Minimum		0.03	3.74	3.34	2.50	0.85	0.01	0.19	0.00	0.06	0.47	2.95	0.03	1.04	0.01	0.14
Maximum		0.48	8.01	6.60	48.00	9.74	0.14	1.06	3.25	3.47	11.62	565.54	1.32	53.59	8.24	11.39

Mini-piezometer samples		**Mn (ppb)**	**Fe (ppm)**	**Co (ppb)**	**Ni (ppb)**	**Cu (ppb)**	**Zn (ppb)**	**As (ppb)**	**Pd (ppb)**	**Cd (ppb)**	**Sb (ppb)**	**Ba (ppb)**	**Pt (ppb)**	**Pb (ppb)**	**Th (ppb)**	**U (ppb)**
N	**Valid**	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean		***179.58***	***14.83***	***1.99***	***0.98***	***0.38***	***39.52***	***2.44***	***0.03***	***0.11***	***0.05***	***14.18***	***0.00***	***0.09***	***0.01***	***0.00***
Median		***147.01***	***9.39***	***1.43***	***0.69***	***0.18***	***11.71***	***1.08***	***0.02***	***0.01***	***0.03***	***11.43***	***0.00***	***0.04***	***0.00***	***0.00***
Std. Deviation		121.08	16.13	3.39	0.97	0.59	135.97	3.32	0.03	0.46	0.06	11.46	0.00	0.17	0.02	0.01
Minimum		3.39	0.04	0.07	0.04	0.04	0.57	0.18	0.00	0.01	0.00	1.77	0.00	0.00	0.00	0.00
Maximum		583.99	84.03	25.49	4.92	3.54	1094.43	14.71	0.13	3.32	0.33	81.53	0.01	1.05	0.12	0.04

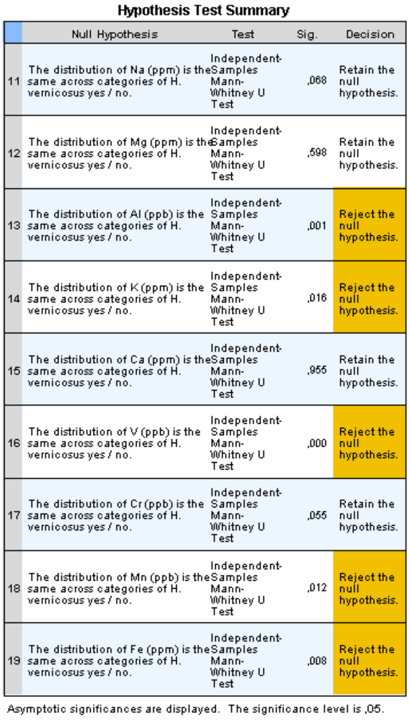
Appendix 5 Mean and median values for all the water samples

Groundwater samples		**EC mS/cm**	**pH**	**T °C**	**DOC, ppm**	**Dsi**	**F (ppm)**	**Cl (ppm)**	**tot-Alk mmol/l**	**Na (ppm)**	**Mg (ppm)**	**Al (ppb)**	**K (ppm)**	**Ca (ppm)**	**V (ppb)**	**Cr (ppb)**
N	**Valid**	13	13	13	13	16	12	12	12	16	16	16	16	16	16	16
	Missing	3	3	3	3	0	4	4	4	0	0	0	0	0	0	0
Mean		***0.17***	***6.70***	***6.99***	***4.68***	***6.77***	***0.05***	***0.73***	***1.22***	***4.26***	***7.00***	***15.90***	***0.83***	***12.78***	***0.85***	***1.67***
Median		***0.14***	***6.67***	***6.30***	***4.60***	***6.83***	***0.04***	***0.76***	***0.75***	***2.02***	***4.91***	***6.45***	***0.77***	***9.21***	***0.30***	***0.52***
Std. Deviation		0.10	0.56	1.44	3.26	2.89	0.03	0.11	0.77	6.43	5.77	24.56	0.50	8.31	1.26	2.95
Minimum		0.06	5.88	5.48	1.30	1.88	0.02	0.56	0.59	0.25	1.19	2.90	0.05	3.34	0.03	0.22
Maximum		0.32	7.66	9.29	12.00	11.70	0.12	0.90	2.60	26.65	20.83	96.79	1.97	26.06	4.70	11.20

Groundwater samples		**Mn (ppb)**	**Fe (ppm)**	**Co (ppb)**	**Ni (ppb)**	**Cu (ppb)**	**Zn (ppb)**	**As (ppb)**	**Pd (ppb)**	**Cd (ppb)**	**Sb (ppb)**	**Ba (ppb)**	**Pt (ppb)**	**Pb (ppb)**	**Th (ppb)**	**U (ppb)**
N	**Valid**	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	Missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean		***169.38***	***6.12***	***0.78***	***1.33***	***1.33***	***57.72***	***1.21***	***0.04***	***0.22***	***0.10***	***26.68***	***0.00***	***0.08***	***0.01***	***0.07***
Median		***150.33***	***0.68***	***0.49***	***0.80***	***0.11***	***1.43***	***0.56***	***0.04***	***0.01***	***0.03***	***17.53***	***0.00***	***0.01***	***0.00***	***0.05***
Std. Deviation		162.84	8.47	0.99	1.35	3.78	214.42	1.45	0.02	0.84	0.18	24.21	0.00	0.13	0.02	0.08
Minimum		1.45	0.00	0.01	0.04	0.04	0.11	0.05	0.02	0.01	0.01	3.57	0.00	0.00	0.00	0.00
Maximum		505.94	27.76	3.20	3.97	15.29	861.25	4.62	0.08	3.38	0.72	88.01	0.01	0.41	0.07	0.24

Appendix 6 Mann-Whitney U –test and Kruskal-Wallis test for surface water samples

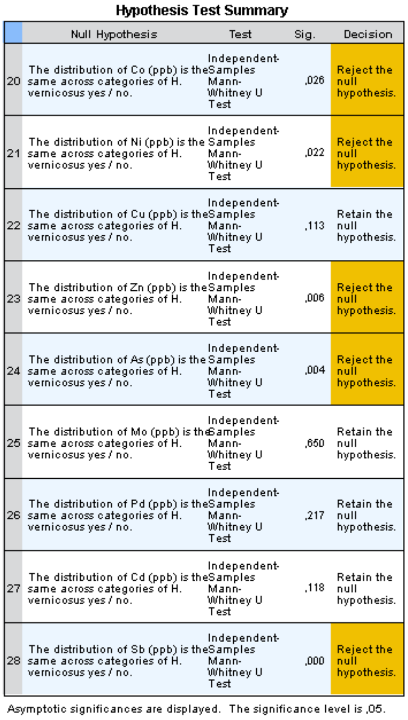
Mann-Whitney U –test for surface water samples. Differences of main ion and trace element content between the areas with and without *H. vernicosus* habitats.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
11	The distribution of Na (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,068	Retain the null hypothesis.
12	The distribution of Mg (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,598	Retain the null hypothesis.
13	The distribution of Al (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,001	Reject the null hypothesis.
14	The distribution of K (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,016	Reject the null hypothesis.
15	The distribution of Ca (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,955	Retain the null hypothesis.
16	The distribution of V (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.
17	The distribution of Cr (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,055	Retain the null hypothesis.
18	The distribution of Mn (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,012	Reject the null hypothesis.
19	The distribution of Fe (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,008	Reject the null hypothesis.

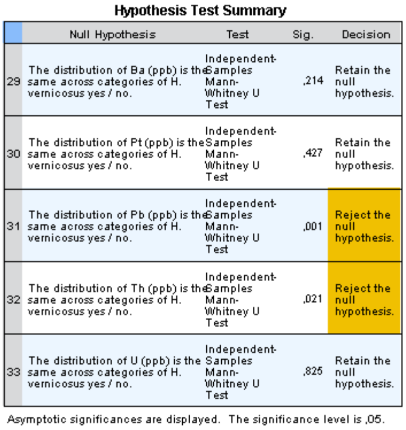
Asymptotic significances are displayed. The significance level is ,05.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
20	The distribution of Co (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,026	Reject the null hypothesis.
21	The distribution of Ni (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,022	Reject the null hypothesis.
22	The distribution of Cu (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,113	Retain the null hypothesis.
23	The distribution of Zn (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,006	Reject the null hypothesis.
24	The distribution of As (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,004	Reject the null hypothesis.
25	The distribution of Mo (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,650	Retain the null hypothesis.
26	The distribution of Pd (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,217	Retain the null hypothesis.
27	The distribution of Cd (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,118	Retain the null hypothesis.
28	The distribution of Sb (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.



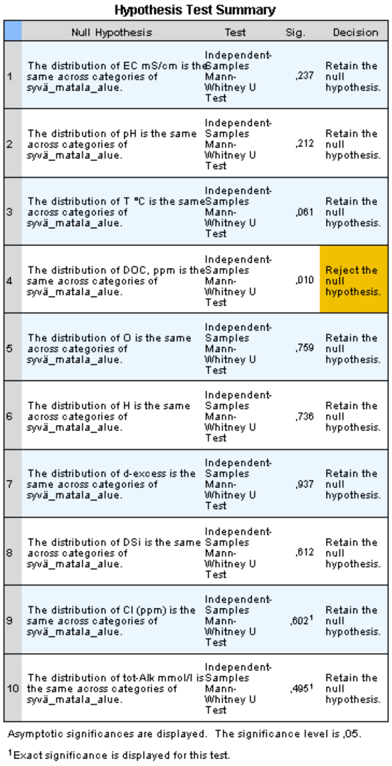
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
29	The distribution of Ba (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,214	Retain the null hypothesis.
30	The distribution of Pt (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,427	Retain the null hypothesis.
31	The distribution of Pb (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,001	Reject the null hypothesis.
32	The distribution of Th (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,021	Reject the null hypothesis.
33	The distribution of U (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,825	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Appendix 6 Mann-Whitney U –test and Kruskal-Wallis test for surface water samples

Mann-Whitney U –test for surface water samples. Differences of main ion and trace element content between the areas with shallow and deep peat depth.

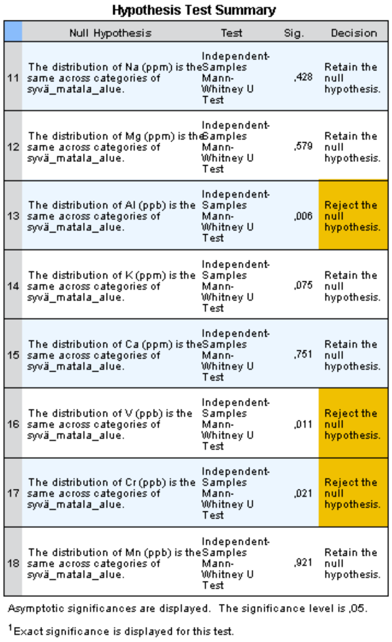


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of EC mS/cm is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,237	Retain the null hypothesis.
2	The distribution of pH is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,212	Retain the null hypothesis.
3	The distribution of T °C is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,061	Retain the null hypothesis.
4	The distribution of DOC, ppm is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,010	Reject the null hypothesis.
5	The distribution of O is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,759	Retain the null hypothesis.
6	The distribution of H is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,736	Retain the null hypothesis.
7	The distribution of d-excess is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,937	Retain the null hypothesis.
8	The distribution of DSi is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,612	Retain the null hypothesis.
9	The distribution of Cl (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,602[1]	Retain the null hypothesis.
10	The distribution of tot-Alk mmol/l is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,495[1]	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

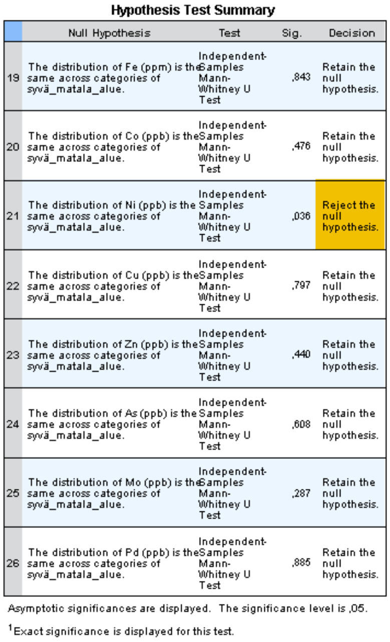


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
11	The distribution of Na (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,428	Retain the null hypothesis.
12	The distribution of Mg (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,579	Retain the null hypothesis.
13	The distribution of Al (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,006	Reject the null hypothesis.
14	The distribution of K (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,075	Retain the null hypothesis.
15	The distribution of Ca (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,751	Retain the null hypothesis.
16	The distribution of V (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,011	Reject the null hypothesis.
17	The distribution of Cr (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,021	Reject the null hypothesis.
18	The distribution of Mn (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,921	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

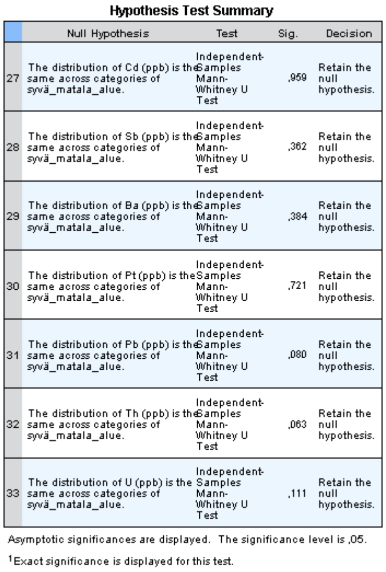


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
19	The distribution of Fe (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,843	Retain the null hypothesis.
20	The distribution of Co (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,476	Retain the null hypothesis.
21	The distribution of Ni (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,036	Reject the null hypothesis.
22	The distribution of Cu (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,797	Retain the null hypothesis.
23	The distribution of Zn (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,440	Retain the null hypothesis.
24	The distribution of As (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,608	Retain the null hypothesis.
25	The distribution of Mo (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,287	Retain the null hypothesis.
26	The distribution of Pd (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,885	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
27	The distribution of Cd (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,959	Retain the null hypothesis.
28	The distribution of Sb (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,362	Retain the null hypothesis.
29	The distribution of Ba (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,384	Retain the null hypothesis.
30	The distribution of Pt (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,721	Retain the null hypothesis.
31	The distribution of Pb (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,080	Retain the null hypothesis.
32	The distribution of Th (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,063	Retain the null hypothesis.
33	The distribution of U (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,111	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

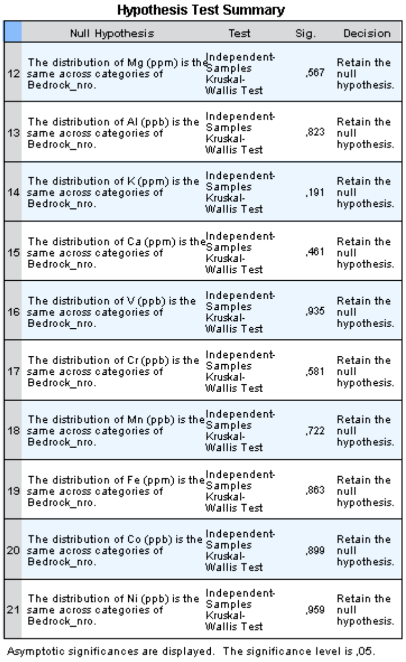
Appendix 6 Mann-Whitney U –test and Kruskal-Wallis test for surface water samples

Kruskal-Wallis -test for surface water samples. Differences of main ion and trace element content between the areas with varying bedrock.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of EC mS/cm is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,890	Retain the null hypothesis.
2	The distribution of pH is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,779	Retain the null hypothesis.
3	The distribution of T °C is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,091	Retain the null hypothesis.
4	The distribution of DOC, ppm is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,074	Retain the null hypothesis.
5	The distribution of O is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,943	Retain the null hypothesis.
6	The distribution of H is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,501	Retain the null hypothesis.
7	The distribution of d-excess is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,046	Reject the null hypothesis.
8	The distribution of DSi is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,453	Retain the null hypothesis.
9	The distribution of Cl (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,018	Reject the null hypothesis.
10	The distribution of tot-Alk mmol/l is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,337	Retain the null hypothesis.
11	The distribution of Na (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,505	Retain the null hypothesis.

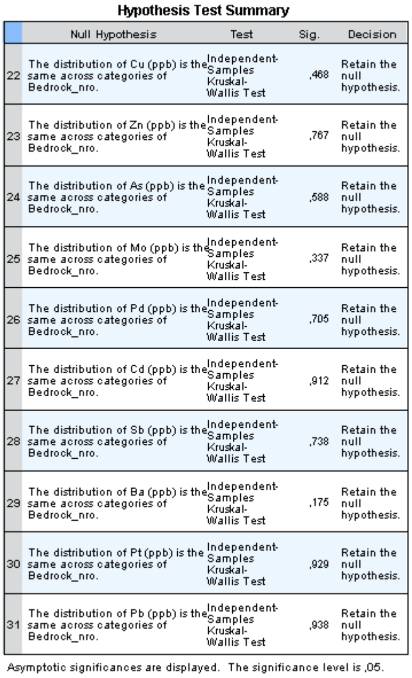
Asymptotic significances are displayed. The significance level is ,05.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
12	The distribution of Mg (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,567	Retain the null hypothesis.
13	The distribution of Al (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,823	Retain the null hypothesis.
14	The distribution of K (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,191	Retain the null hypothesis.
15	The distribution of Ca (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,461	Retain the null hypothesis.
16	The distribution of V (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,935	Retain the null hypothesis.
17	The distribution of Cr (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,581	Retain the null hypothesis.
18	The distribution of Mn (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,722	Retain the null hypothesis.
19	The distribution of Fe (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,863	Retain the null hypothesis.
20	The distribution of Co (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,899	Retain the null hypothesis.
21	The distribution of Ni (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,959	Retain the null hypothesis.

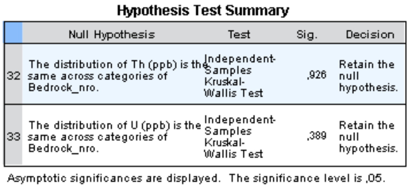
Asymptotic significances are displayed. The significance level is ,05.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
22	The distribution of Cu (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,468	Retain the null hypothesis.
23	The distribution of Zn (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,767	Retain the null hypothesis.
24	The distribution of As (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,588	Retain the null hypothesis.
25	The distribution of Mo (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,337	Retain the null hypothesis.
26	The distribution of Pd (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,705	Retain the null hypothesis.
27	The distribution of Cd (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,912	Retain the null hypothesis.
28	The distribution of Sb (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,738	Retain the null hypothesis.
29	The distribution of Ba (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,175	Retain the null hypothesis.
30	The distribution of Pt (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,929	Retain the null hypothesis.
31	The distribution of Pb (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,938	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.



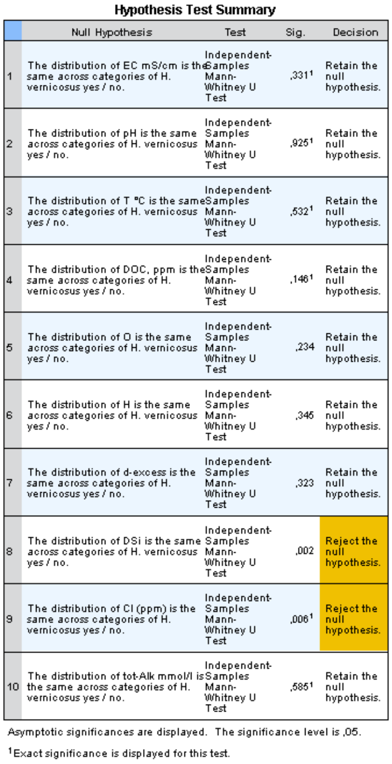
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
32	The distribution of Th (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,926	Retain the null hypothesis.
33	The distribution of U (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,389	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

Appendix 7 Mann-Whitney U –test and Kruskal-Wallis test for peat pore water samples

Mann-Whitney U –test for peat pore water samples. Differences of main ion and trace element content between the areas with and without *H. vernicosus* habitats.

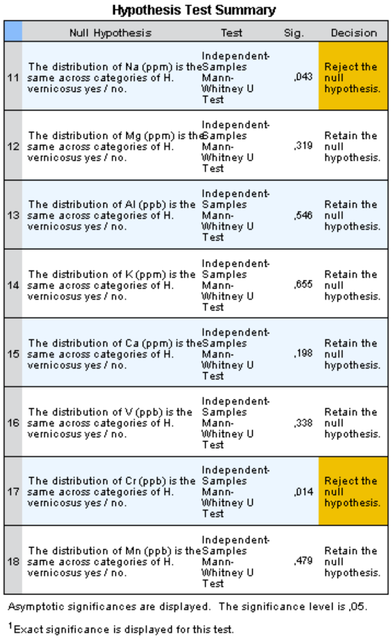


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of EC mS/cm is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,331[1]	Retain the null hypothesis.
2	The distribution of pH is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,925[1]	Retain the null hypothesis.
3	The distribution of T °C is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,532[1]	Retain the null hypothesis.
4	The distribution of DOC, ppm is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,146[1]	Retain the null hypothesis.
5	The distribution of O is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,234	Retain the null hypothesis.
6	The distribution of H is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,345	Retain the null hypothesis.
7	The distribution of d-excess is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,323	Retain the null hypothesis.
8	The distribution of DSi is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,002	Reject the null hypothesis.
9	The distribution of Cl (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,006[1]	Reject the null hypothesis.
10	The distribution of tot-Alk mmol/l is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,585[1]	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

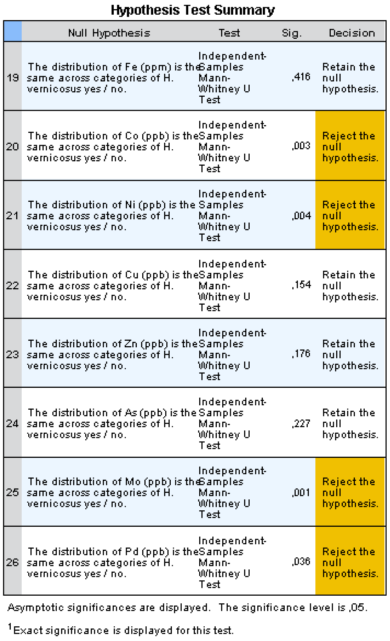


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
11	The distribution of Na (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,043	Reject the null hypothesis.
12	The distribution of Mg (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,319	Retain the null hypothesis.
13	The distribution of Al (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,546	Retain the null hypothesis.
14	The distribution of K (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,655	Retain the null hypothesis.
15	The distribution of Ca (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,198	Retain the null hypothesis.
16	The distribution of V (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,338	Retain the null hypothesis.
17	The distribution of Cr (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,014	Reject the null hypothesis.
18	The distribution of Mn (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,479	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.



Hypothesis Test Summary

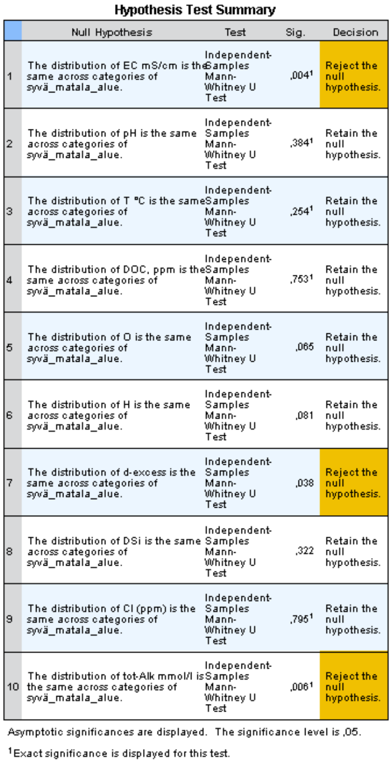
	Null Hypothesis	Test	Sig.	Decision
19	The distribution of Fe (ppm) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,416	Retain the null hypothesis.
20	The distribution of Co (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,003	Reject the null hypothesis.
21	The distribution of Ni (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,004	Reject the null hypothesis.
22	The distribution of Cu (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,154	Retain the null hypothesis.
23	The distribution of Zn (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,176	Retain the null hypothesis.
24	The distribution of As (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,227	Retain the null hypothesis.
25	The distribution of Mo (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,001	Reject the null hypothesis.
26	The distribution of Pd (ppb) is the same across categories of H. vernicosus yes / no.	Independent-Samples Mann-Whitney U Test	,036	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

Appendix 7 Mann-Whitney U –test and Kruskal-Wallis test for peat pore water samples

Mann-Whitney U –test for peat pore water samples. Differences of main ion and trace element content between the areas with shallow and deep peat depth.

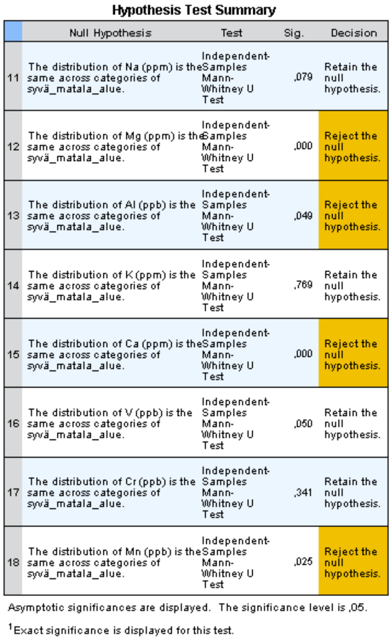


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of EC mS/cm is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,004[1]	Reject the null hypothesis.
2	The distribution of pH is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,384[1]	Retain the null hypothesis.
3	The distribution of T °C is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,254[1]	Retain the null hypothesis.
4	The distribution of DOC, ppm is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,753[1]	Retain the null hypothesis.
5	The distribution of O is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,065	Retain the null hypothesis.
6	The distribution of H is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,081	Retain the null hypothesis.
7	The distribution of d-excess is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,038	Reject the null hypothesis.
8	The distribution of DSi is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,322	Retain the null hypothesis.
9	The distribution of Cl (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,795[1]	Retain the null hypothesis.
10	The distribution of tot-Alk mmol/l is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,006[1]	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

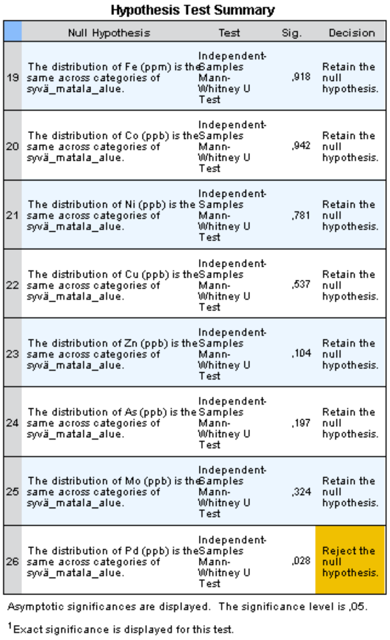


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
11	The distribution of Na (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,079	Retain the null hypothesis.
12	The distribution of Mg (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.
13	The distribution of Al (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,049	Reject the null hypothesis.
14	The distribution of K (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,769	Retain the null hypothesis.
15	The distribution of Ca (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,000	Reject the null hypothesis.
16	The distribution of V (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,050	Retain the null hypothesis.
17	The distribution of Cr (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,341	Retain the null hypothesis.
18	The distribution of Mn (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,025	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

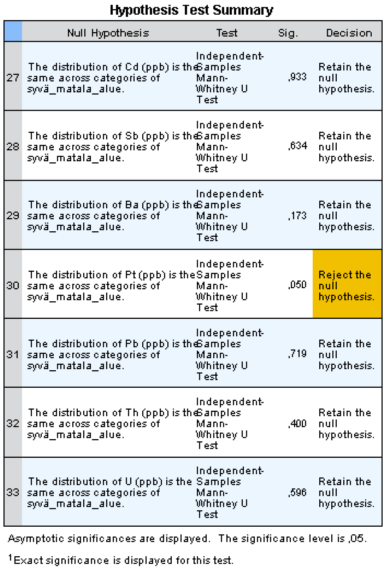


Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
19	The distribution of Fe (ppm) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,918	Retain the null hypothesis.
20	The distribution of Co (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,942	Retain the null hypothesis.
21	The distribution of Ni (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,781	Retain the null hypothesis.
22	The distribution of Cu (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,537	Retain the null hypothesis.
23	The distribution of Zn (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,104	Retain the null hypothesis.
24	The distribution of As (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,197	Retain the null hypothesis.
25	The distribution of Mo (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,324	Retain the null hypothesis.
26	The distribution of Pd (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,028	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
27	The distribution of Cd (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,933	Retain the null hypothesis.
28	The distribution of Sb (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,634	Retain the null hypothesis.
29	The distribution of Ba (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,173	Retain the null hypothesis.
30	The distribution of Pt (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,050	Reject the null hypothesis.
31	The distribution of Pb (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,719	Retain the null hypothesis.
32	The distribution of Th (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,400	Retain the null hypothesis.
33	The distribution of U (ppb) is the same across categories of syvä_matala_alue.	Independent-Samples Mann-Whitney U Test	,596	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

[1] Exact significance is displayed for this test.

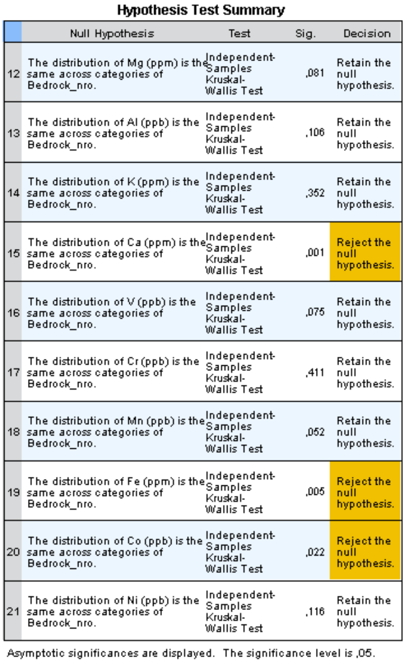
Kruskal-Wallis -test for peat pore water samples. Differences of main ion and trace element content between the areas with varying bedrock.

Appendix 7 Mann-Whitney U –test and Kruskal-Wallis test for peat pore water samples

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of EC mS/cm is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,008	Reject the null hypothesis.
2	The distribution of pH is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,004	Reject the null hypothesis.
3	The distribution of T °C is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,177	Retain the null hypothesis.
4	The distribution of DOC, ppm is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,618	Retain the null hypothesis.
5	The distribution of O is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,006	Reject the null hypothesis.
6	The distribution of H is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,022	Reject the null hypothesis.
7	The distribution of d-excess is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,001	Reject the null hypothesis.
8	The distribution of DSi is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,005	Reject the null hypothesis.
9	The distribution of Cl (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,567	Retain the null hypothesis.
10	The distribution of tot-Alk mmol/l is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,024	Reject the null hypothesis.
11	The distribution of Na (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,019	Reject the null hypothesis.

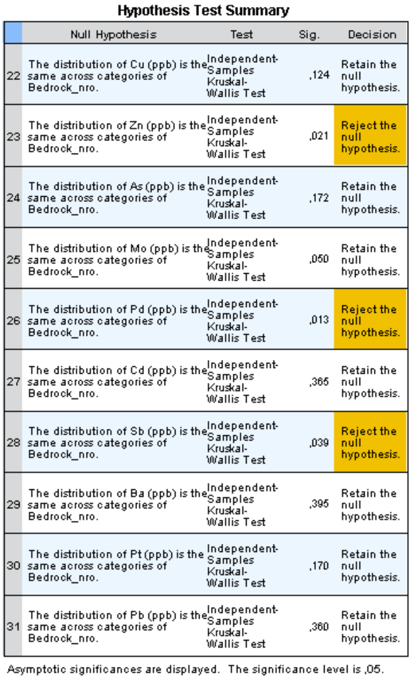
Asymptotic significances are displayed. The significance level is ,05.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
12	The distribution of Mg (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,081	Retain the null hypothesis.
13	The distribution of Al (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,106	Retain the null hypothesis.
14	The distribution of K (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,352	Retain the null hypothesis.
15	The distribution of Ca (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,001	Reject the null hypothesis.
16	The distribution of V (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,075	Retain the null hypothesis.
17	The distribution of Cr (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,411	Retain the null hypothesis.
18	The distribution of Mn (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,052	Retain the null hypothesis.
19	The distribution of Fe (ppm) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,005	Reject the null hypothesis.
20	The distribution of Co (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,022	Reject the null hypothesis.
21	The distribution of Ni (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,116	Retain the null hypothesis.

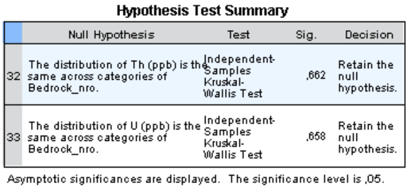
Asymptotic significances are displayed. The significance level is ,05.



Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
22	The distribution of Cu (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,124	Retain the null hypothesis.
23	The distribution of Zn (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,021	Reject the null hypothesis.
24	The distribution of As (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,172	Retain the null hypothesis.
25	The distribution of Mo (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,050	Retain the null hypothesis.
26	The distribution of Pd (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,013	Reject the null hypothesis.
27	The distribution of Cd (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,365	Retain the null hypothesis.
28	The distribution of Sb (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,039	Reject the null hypothesis.
29	The distribution of Ba (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,395	Retain the null hypothesis.
30	The distribution of Pt (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,170	Retain the null hypothesis.
31	The distribution of Pb (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,360	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.



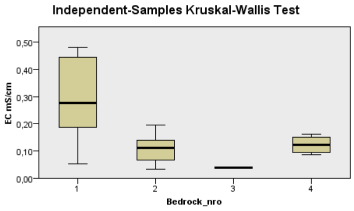
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
32	The distribution of Th (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,662	Retain the null hypothesis.
33	The distribution of U (ppb) is the same across categories of Bedrock_nro.	Independent-Samples Kruskal-Wallis Test	,658	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

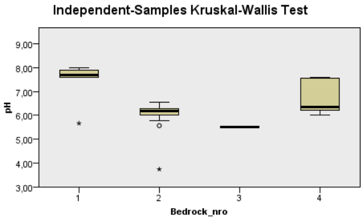
1 = graphic paraschist, 2 = mafic volcanic rock, 3 = quartzite, 4 = gabbro

Appendix 7 Mann-Whitney U –test and Kruskal-Wallis test for peat pore water samples



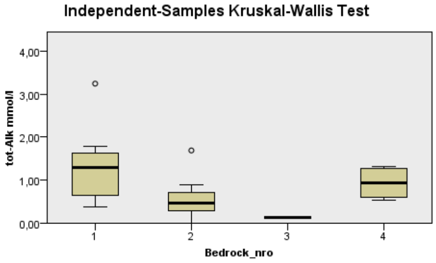
Total N	39
Test Statistic	11,939
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	,008

1. The test statistic is adjusted for ties.



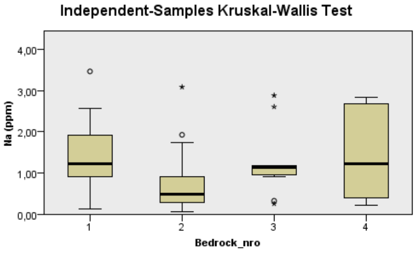
Total N	33
Test Statistic	13,350
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	,004

1. The test statistic is adjusted for ties.



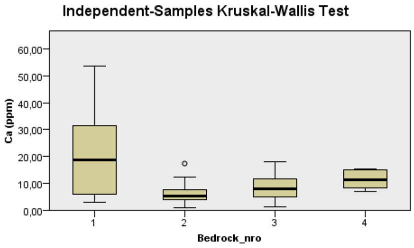
Total N	33
Test Statistic	9,411
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	,024

1. The test statistic is adjusted for ties.



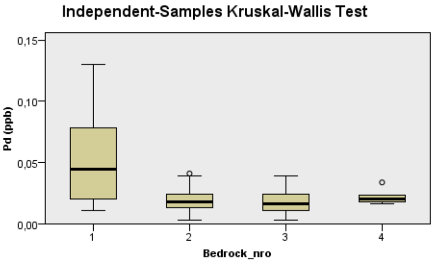
Total N	66
Test Statistic	9,991
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	,019

1. The test statistic is adjusted for ties.



Total N	66
Test Statistic	17,433
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	,001

1. The test statistic is adjusted for ties.



Total N	66
Test Statistic	10,854
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	,013

1. The test statistic is adjusted for ties.

Varimax-rotated PCA factor loadings of standardized (log-transformed) geochemical variables.

Loadings above 0.63 are bolded.

Rotated Component Matrix[a,b]

	Component				
	1	2	3	4	5
logEC	0.204	0.539	0.220	0.168	0.203
Log DOC	**0.784**	0.058	0.297	0.217	0.303
O	-0.278	-0.247	**-0.875**	-0.049	-0.082
H	-0.164	-0.401	**-0.829**	-0.074	-0.085
DSi	0.209	0.269	**0.822**	-0.110	0.111
logCl	**0.652**	-0.207	0.296	0.109	0.165
SO4 (ppm)	-0.049	0.067	**0.654**	0.410	0.119
log_totAlk	-0.086	**0.817**	0.140	-0.255	0.099
Log Na	0.185	0.185	0.349	-0.106	**0.787**
Log Mg	0.329	**0.817**	0.301	0.130	0.191
Log Al	**0.670**	0.143	0.330	0.371	0.358
Log K	0.271	0.395	-0.070	0.192	**0.766**
Log Ca	0.206	**0.897**	0.202	-0.038	0.112
Log V	**0.715**	0.223	0.285	0.369	0.387
Log Cr	0.605	0.202	0.439	0.428	0.262
Log Mn	**0.852**	0.136	-0.254	0.042	0.001
Log Fe	**0.869**	0.323	0.109	0.008	0.081
Log Co	**0.873**	0.265	0.118	0.223	-0.010
Log Ni	**0.709**	0.203	0.332	0.304	0.288
Log Cu	0.486	0.158	0.196	0.477	0.427
Log Zn	0.596	0.099	-0.136	0.584	0.062
Log As	**0.825**	0.336	0.125	0.028	-0.011
Log Cd	0.391	0.149	0.283	**0.658**	0.173
Log Sb	**0.742**	-0.032	0.251	0.406	0.210
Log Ba	0.262	**0.841**	0.161	0.181	0.087
Log Pb	**0.673**	0.120	0.207	0.374	0.279
pH	-0.286	0.410	0.052	**-0.667**	0.229

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 8 iterations.

b. Only SW samples