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Regolith in wetlands with high nature values

Additional studies

Gustav Sohlenius

Matilda Svensson

SVENSK KÄRNBRÄNSLEHANTERING AB

SWEDISH NUCLEAR FUEL
AND WASTE MANAGEMENT CO

Box 3091, SE-169 03 Solna
Phone +46 8 459 84 00
skb.se

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Gustav Sohlenius, Geological Survey of Sweden

Matilda Svensson, Svensk Kärnbränslehantering AB

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Abstract

The Forsmark area contains several wetlands with high nature values. Because of the very recent uplift above the sea level, several of these have not yet been filled with sediment and peat. In addition, many of these contain high concentrations of lime. Both these factors contribute to the high nature values in the wetlands.

The groundwater table in some of these wetlands may be lowered during the construction of the planned repository for spent nuclear fuel. This might result in the uppermost regolith being exposed to air, leading to oxidation of sulphide minerals. This oxidation might in turn result in lowering of pH causing leaching of metals in the wetlands. Lowering of the ground water table also occurs naturally during dry periods, consequently these processes can occur regularly.

Earlier work has studied wetlands that may be affected by the construction of the repository. These studies show that potentially acid sediments occur in some of these wetlands. This study focuses on regolith from three wetlands that are situated outside the area where the groundwater table might be affected by the construction of the repository. The three wetlands have high nature values and can be used as reference objects during the construction phase.

The uppermost regolith in the studied wetlands consists of thin layers of gyttja and peat that commonly are underlain by clay gyttja and sand. In the field, during sampling, pH was generally above 6 in most of the studied deposits. The acidic potential was determined in the laboratory after exposing the samples to air. The results show that potentially acid sediments occur in most of the investigated wetlands. The potentially acid deposits are to a large extent overlain by peat that may protect underlying deposits from oxidation and thereby acidification. The uppermost deposits in several of the ponds may, however, become acid if exposed to air.

The groundwater table was low during the sampling occasion and several of the ponds in the wetlands were dry without open water. The pH measurements showed, however, that field-pH was high in the uppermost sediments of the exposed ponds. However, additional measurement after exposure to air showed that these deposits are potentially acid.

Sammanfattning

I Forsmarksområdet finns flera våtmarker med höga naturvärden. En orsak till detta är att området är relativt ungt och har till största delen, genom landhöjningen, torrlagts under det senaste årtusendet. Därför finns här flera våtmarker med grunda gölar vilka ännu inte fyllts med sediment och torv. Jordarna i området innehåller dessutom i stor utsträckning kalk, vilket påverkar miljön i våtmarkerna.

Vid byggnationen av slutförvaret för använt kärnbränsle finns det en risk att grundvattennivån i vissa av dessa våtmarker sänks. Detta kan leda till att vissa sediment exponeras för luft och att sulfidmineral därmed oxiderar vilket skulle kunna förorsaka lågt pH och höga metallkoncentrationer i våtmarkernas vatten. Perioder med lågt grundvatten förekommer naturligt i området under torra perioder och processerna som beskrivs ovan skulle därför kunna uppkomma oberoende av ett förvarsbygge.

Tidigare har våtmarker som bedöms riskera en påverkan på grund av avsänkning orsakad av förvarsbygget undersökts, och det har fastslagits att det i några av dessa finns sediment där pH kan sjunka drastiskt om de skulle exponeras för luft under en längre tid. I denna undersökning har jordarter från åtta gölar i tre våtmarker med höga naturvärden undersökts. Jordarterna har beskrivits i fält och provtagits för vidare analys.

Dessa våtmarker ligger utanför det område där det bedöms finnas en risk för att grundvattenytan sänks som en följd av byggnationen av Kärnbränsleförvaret och kan därför användas som referensobjekt under byggnationen.

De ytliga jordarterna i de undersökta våtmarkerna utgörs av tunna lager av gyttja och torv vilka ofta underlagras av lergyttja och sand. Vid provtagningen mättes pH som i de flesta jordarna då låg över 6. Genom att exponera jordarna för luft har den försurande potentialen undersökts och resultaten visar att det finns potentiellt sura jordar i merparten av de undersökta våtmarkerna. Till stor del överlagras den potentiellt sura jorden av torv som eventuellt kan förhindra att dessa jordar exponeras för luft och därmed försuras. I flera av gölarna utgörs dock den ytligaste jordarten av sediment som eventuellt skulle kunna försuras om de exponeras för luft.

Vid provtagningstillfället var grundvattennivåerna låga i området och flera av gölarna saknade därför vid tillfället en vattenspegel. Resultat från pH mätningarna visade dock att detta inte lett till att pH sjunkit i de sediment som utgör botten på de gölar som saknade vatten. Dessa sediment var dock inte uttorkade vid provtagningstillfället och uppföljande mätningarna efter ytterligare exponering i luft visade att dessa sediment är potentiellt sura.

Contents

1 Introduction

The present study includes investigation of stratigraphical conditions as well as the acidifying potential of regolith from 16 places in three wetlands with high nature values in the Forsmark area (Figure 1-1). Regolith, also called Quaternary deposits (in the following abbreviated QD), refers to all unconsolidated deposits overlying the bedrock. The study was performed according to the activity plan AP SFK-20-035 "Kompletterande kvartärgeologiska undersökningar inför infiltration". The methods used for the stratigraphical description are described in SKB MD 131.001, Version 1.0 (see Table 1-1) whereas the method used for pH determination is described in section 3.

The Geological Survey of Sweden (SGU) and SKB are responsible for field work and reporting.

Table 1-1 SKBs controlling documents for the performance of the activity.

Name	SKB document ID	Version number
Kompletterande kvartärgeologiska undersökningar inför infiltration (in swedish)	AP SFK-20-035	1.0
Metodbeskrivning för jordartskartering (in swedish)	SKB MD 131.001	1.0

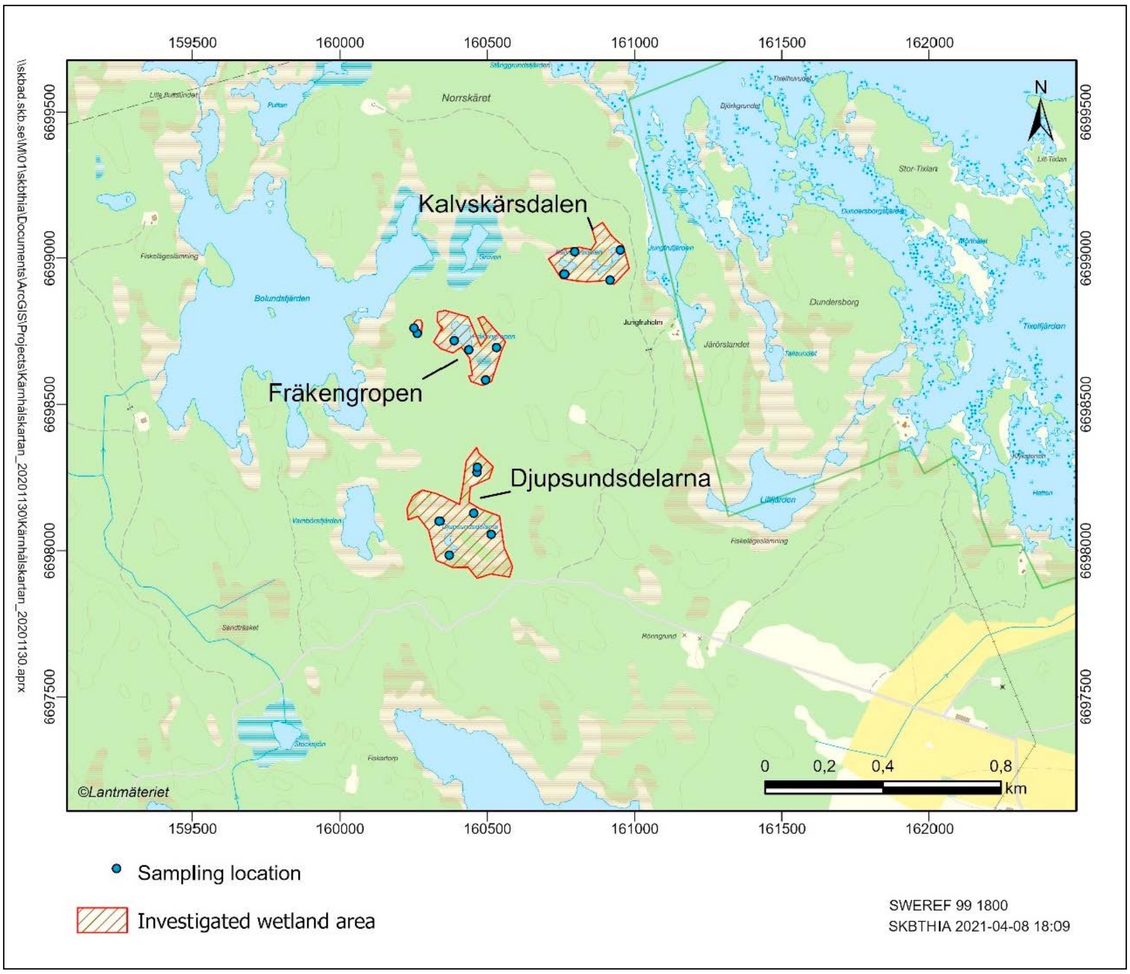

***Figure 1-1.** The studied wetlands Kalvskärsdalen, Fräkengropen and Djupsundsdelarna situated near the coast of Forsmark, northern Uppland.*

2 Objective and scope

This study aims at determining if acid sulphate soils occur in some wetlands with high nature values situated in the Forsmark area. Previous studies have shown that such deposits occur in some of the wetlands in the area (Sohlenius et al. 2020). Acid soils formed due to sulphide oxidation are called "active acid sulphate soils", whereas the reduced sulphidic sediment are called "potential acid sulphate soils". There are numerous studies describing how active acid sulphate soils forms due to oxidation of potential acid sulphates soils (e.g. Sohlenius and Öborn 2004, Åström 1997), and these acid soils are known to affect surface waters by low pH and high metal concentrations in surface waters. The acid condition develops when sulphides present in the potential acid sulphate soils oxidise. The deposits earlier found in the Forsmark area are all potential acid sulphate soils and not harmful to the environment in their present state.

Three wetlands with high nature values such as presence of valuable amphibians and orchids were studied. These wetlands are situated outside the area where the groundwater table potentially might be lowered during the construction of the repository for spent nuclear fuel (Hamrén et al. 2010). The wetlands can therefore be used as reference objects for wetlands where the groundwater table might be affected by the repository construction. The wetlands that might be affected were studied by Sohlenius et al. (2020). All the studied wetlands consist of ponds surrounded by fen areas. The ponds are shallow and may consequently be temporarily drained if the groundwater table drops during dry periods. Besides the direct negative effects of a complete drying of a pond on e.g. amphibian juveniles also indirect negative effects can arise if the reduced QD in the wetlands are oxidised and thereby cause acidic conditions making the ponds unsuitable as reproduction sites.

3 Execution

The methods used for sampling and classification of QD are described in detail in SKB MD 131.001 (see Table 1-1). Generally, the same QD classification system was used in this study as in SGU's earlier investigations in the area (Persson 1985, 1986). For an up to date nomenclature the reader is referred to SKB MD 131.001 and to the report describing the map of QD that was produced during SKB's site investigation (Sohlenius et al. 2004). The method for determination of pH is described in Becher et al. (2019).

3.1 Field work

The studied sites are shown in Figure 3-1. The aim was to spread the sites evenly around the ponds. Some sites were in ponds that lacked water during the sampling occasion. A hand driven probe and a Russian peat corer (Figure 3-2) were used for sampling and determination of the stratigraphy of shallow QD.

pH was directly measured in the field on the sampled deposits (altogether 84 measurements) according to the method described in Becher et al. (2019). Samples were taken for further analyses to determine the risk of acid conditions due to oxidation of sulphidic minerals. Altogether 36 samples were analysed in the laboratory where pH was measured after oxidizing the samples (see below).

All field data have been digitally stored in SKB's database SICADA in accordance with the SKB method description (see table 1-1).

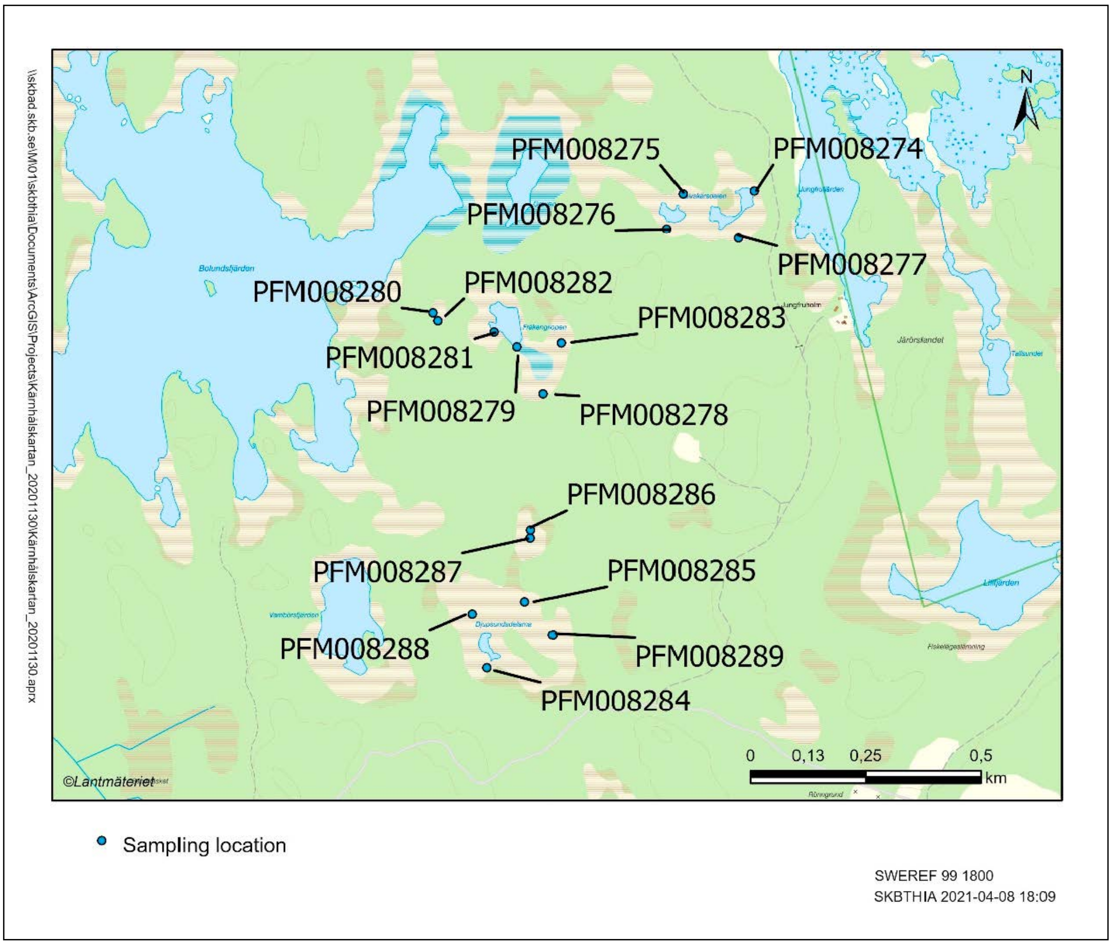

Figure 3-1. Sampling locations in the investigated wetlands.

Figure 3-2. *The hand driven probe (upper picture) and the Russian peat corer (lower picture) used for sampling.*

3.2 Analytical methods

To determine if pH drops due to sulphide oxidation 36 samples were oxidised (incubated) in the laboratory at SGU. These samples were taken to represent the different types of QD documented in the field. During incubation, the samples were kept wet by regular addition of deionized water. The exposure to oxygen in combination with moderately wet conditions makes the sulphide minerals oxidise. The pH was measured in the samples after an incubation period of 10 weeks. If the pH during this period had dropped below 4 for minerogenic samples or below 3 for peat samples, and if the pH drop was larger than 0.5 pH units compared to field-pH (i.e. measured during field sampling), the pH drop was considered to be due to sulphide mineral oxidation. However, the oxidation of sulphide minerals may continue for a longer period than 10 weeks. Some of the samples with a pH just above 4 after 10 weeks incubation were therefore re-measured after four additional weeks (Becher et al. 2019).

3.3 Classification of acid sulphate soils

The different types of QD at the sampled sites were classified based on their field pH and pH after the following incubation. If the material in field displayed pH < 4 for sediment and pH < 3 for peat, the deposit was classified as active acid sulphate soil. If material, having a higher field pH, after incubation displayed pH < 4 for sediment and pH < 3 for peat the deposit was classified as potential acid sulphate soil.

Sulphidic materials are defined as any soil containing ≥ 0.01 % sulphidic-S (by dry weight). In this study sulphide analyses were not performed, and the classification is entirely based on pH before and after oxidation.

4 Results

4.1 Stratigraphical field studies

The stratigraphy of QD at the 16 sites (Figure 3-1) was determined in field and the results are shown in Table 4-1. The results are comparable with results from earlier stratigraphical studies of QD in wetlands (Sohlenius and Hedenström 2009, Sohlenius et al. 2020). This stratigraphy is characterised by fen peat that in the following order is underlain by gyttja, clay gyttja, postglacial sand, glacial clay and till. The two last deposits were, however, not sampled within this study. All these deposits are, however, not found at all sites with fen peat. The layers of peat are characterised by a high water content and are generally thin. Three of the ponds lacked water during the sampling occasion and sediments from the floor of the ponds were sampled at these sites (PFM008279, PFM0081281 and PFM008286).

Table 4-1. The stratigraphical distribution of QD at the studied sites. SKB wetland ID* according to Hamrén and Collinder (2010).

Sicada Id-code	SKB Wetland ID*	Sicada Id-code of wetland	Depth (cm below ground surface)	Quaternary deposit
Kalvskärsdalen				
PFM008274	69		0.0–0.55	Fen peat
			0.55–0.85	Clay gyttja
			0.85–1.0	Postglacial sand
PFM008275	69		0.0–0.5	Fen peat
			0.5–0.75	Gyttja
			0.75–0.9	Clay gyttja
PFM008276	69		0.0–0.55	Fen peat
			0.55–0.8	Clay gyttja
PFM008277	69a	AFM001481	0.0–0.55	Fen peat
			0.55–0.8	Clay gyttja
			0.8–0.9	Clay gyttja
			0.9–0.95	Postglacial sand
Fräkengropen				
PFM008278	46a		0.0–0.25	Fen peat
			0.25–0.8	Postglacial sand
PFM008279	46b		0.0–0.25	Clay gyttja
PFM008280	46b		0.0–0.3	Fen peat
PFM008281	46b		0.0–0.01	Gyttja
			0.01–0.2	Postglacial gravelly sand
PFM008282	46b		0.0–0.1	Fen peat
			0.1–0.3	Postglacial gravelly sand
PFM008283	46a		0.0–0.25	Fen peat
			0.25–0.4	Postglacial sand
			0.4–0.8	Postglacial sand

Sicada Id-code	SKB Wetland ID*	Sicada Id-code of wetland	Depth (cm below ground surface)	Quaternary deposit
Djupsundsdelarna				
PFM008284	67		0.0–1.0	Fen peat
			1.0–1.35	Gyttja
			1.35–1.49	Postglacial sand
			1.49–1.5	Glacial clay
PFM008285	48	AFM001476	0.0–0.6	Fen peat
			0.6–0.7	Gyttja
			0.7–0.8	Postglacial sand
PFM008286	68	AFM001480	0.0–0.4	Gyttja
			0.4–0.9	Postglacial sand
PFM008287	68	AFM001480	0.0–0.3	Fen peat
			0.3–0.6	Clay gyttja
			0.6–0.7	Postglacial sand
PFM008288	48a	AFM001477	0.0–0.4	Fen peat
			0.4–0.5	Clay gyttja
			0.5–0.8	Clay gyttja
			0.8–0.85	Postglacial sand
PFM008289	48	AFM001476	0.0–0.3	Fen peat
			0.3–0.55	Gyttja
			0.55–0.9	Clay gyttja
			0.9–0.95	Postglacial sand

4.2 Results from analyses

The studied QD samples had in most cases field pH above 6 (Table 4-2), and were probably characterised by reducing conditions. An active acid sulphate soil has a pH below 4, i.e. a pH much lower than in all the deposits studied here. In many samples the pH values dropped significantly during oxidation and most samples constituting sand, gyttja or clay gyttja had pH values below 4 after 10 weeks of incubation (oxidation). These deposits are consequently classified as potentially acid sulphate soils (Table 4-2). Unexpectedly one sample with glacial clay was classified as potential acid sulphate soil. That type of clay is commonly not containing sulfide. It is, however, possible that the glacial clay has been sulfidised by overlying sediments that are rich in organic material.

Some samples were taken from ponds that lacked water during the sampling occasion (PFM008279, PFM008286 and PFM008289). Also, these samples had a field pH above 6 but had a pH below or slightly above 4 after incubation.

Potentially acid sulphate soils were documented at all except for three sites (PFM008280, PFM008281 and PFM008282, northeast part of Fräkengropen in Figure 3-1). The pH in the peat samples did not drop below 3, and the peat is therefore not classified as potentially acid sulphate soil.

The drop in pH during oxidation is interpreted to be an effect of sulphide oxidation. In the field the studied deposits are reduced, and wet conditions protect the sulphides from oxidation. There were, however, no measurements of sulphur or sulphides confirming the presence of sulphides in the reduced deposits studied. However, earlier studies from wetlands in the area have shown that the fine-grained potentially acid sediments contain sulphides (Sohlenius et al. 2020) and it is therefore likely that corresponding deposits studied here also contain sulphides.

Table 4-2. Results from measurements of pH and classification (PAS = Potential acid sulphate soil). The different QD layers were classified as separate units. All samples measured in field were, however, not incubated for further measurements.

Id	Depth (m)	Quaternary deposit	pH (field)	pH (after 10 weeks of oxidation)	pH (after 14 weeks of oxidation)	Classification
PFM008274	0,45	Fen peat	6.3			-
	0.65	Clay gyttja	6.9			PAS
	0.75	Clay gyttja	6.6	2.9		PAS
	0.9	Postglacial sand	6.6	2.9		PAS
PFM008275	0.4	Fen peat	6.4			-
	0.6	Gyttja	6.5	3.4		PAS
	0.7	Gyttja	6.9			PAS
	0.8	Clay gyttja	7.1			PAS
	0.9	Clay gyttja	7.2	2.9		PAS
PFM008276	0.45	Fen peat	6.3			-
	0.6	Clay gyttja	6.5			PAS
	0.7	Clay gyttja	6.6	2.9		PAS
	0.8	Clay gyttja	6.5			PAS
PFM008277	0.3	Fen peat	6.4	5.3		Not PAS
	0.6	Clay gyttja	7.1	4.0	3.5	PAS
	0.7	Clay gyttja	7.2			PAS
	0.85	Clay gyttja	7.2	3.1		PAS
PFM008278	0.15	Fen peat	5.3	5.2		Not PAS
	0.3	Postglacial sand	5.1			PAS
	0.4	Postglacial sand	5.7			PAS
	0.5	Postglacial sand	6.4			PAS
	0.6	Postglacial sand	6.5			PAS
	0.7	Postglacial sand	6.5	2.6		PAS
	0.8	Postglacial sand	6.9			PAS
PFM008279	0.05	Clay gyttja	6.6			PAS
	0.1	Clay gyttja	6.7	3.1		PAS
	0.2	Clay gyttja	7	2.5		PAS
PFM008280	0.2	Fen peat	5.1			Not PAS
	0.3	Fen peat	5.8	5.1		Not PAS
PFM008281	0	Gyttja	6.1	4.4	4.3	Not PAS
	0.15	Postglacial sand	5.9	4.8	4.9	Not PAS
PFM008282	0	Fen peat	5.7			Not PAS
	0.05	Fen peat	5.9	4.1	4.3	Not PAS
	0.2	Postglacial sand	5.9	5.1		Not PAS
	0.3	Postglacial sand	6.2			Not PAS
PFM008283	0.2	Fen peat	5.7	5.4		Not PAS
	0.3	Postglacial sand	6.2	4.3	3.9	PAS
	0.4	Postglacial sand	6.3			PAS
	0.5	Postglacial sand	6.4			PAS
	0.6	Postglacial sand	6.5	2.8		PAS
	0.7	Postglacial sand	6.6			PAS
	0.8	Postglacial sand	6.7			PAS
PFM008284	0.7	Fen peat	4.9	5.3		Not PAS
	0.9	Fen peat	5.3			Not PAS
	1.0	Fen peat	6.6			Not PAS
	1.1	Gyttja	6.8			PAS
	1.2	Gyttja	7.1	3.1		PAS
	1.3	Gyttja	7.3			PAS
	1.4	Postglacial sand	7.1	2.4		PAS
	1.5	Glacial clay	7.7	2.9		PAS

Id	Depth (m)	Quaternary deposit	pH (field)	pH (after 10 weeks of oxidation)	pH (after 14 weeks of oxidation)	Classification
PFM008285	0.4	Fen peat	6.3			Not PAS
	0.5	Fen peat	6.3	5.4		Not PAS
	0.6	Fen peat	6.4			Not PAS
	0.65	Gyttja	6.4	3.1		PAS
	0.75	Postglacial sand	6.6	2.3		PAS
PFM008286	0	Gyttja	6.6			PAS
	0.1	Gyttja	6.6			PAS
	0.2	Gyttja	6.5	2.8		PAS
	0.3	Gyttja	6.7			PAS
	0.4	Gyttja	6.7			PAS
	0.5	Postglacial sand	6.3	2.7		PAS
	0.6	Postglacial sand	6.7			PAS
	0.7	Postglacial sand	6.9			PAS
PFM008287	0.2	Fen peat	5.7	5.1		Not PAS
	0.3	Fen peat	6.3			Not PAS
	0.4	Clay gyttja	6.4	2.8		PAS
	0.5	Clay gyttja	6.5			PAS
	0.6	Clay gyttja	6.6			PAS
	0.7	Postglacial sand	6.7	2.5		PAS
PFM008288	0.1	Fen peat	6.1			-
	0.3	Fen peat	6.3			-
	0.4	Fen peat	6.5			-
	0.5	Clay gyttja	6.8	2.8		PAS
	0.6	Clay gyttja	7			PAS
	0.7	Clay gyttja	7.1			PAS
	0.8	Clay gyttja	7.1			PAS
	0.85	Postglacial sand	6.8	2.5		PAS
PFM008289	0.4	Gyttja	6.3			-
	0.5	Gyttja	6.6			-
	0.6	Clay gyttja	6.6			PAS
	0.7	Clay gyttja	7.1			PAS
	0.8	Clay gyttja	7.2	2.8		PAS
	0.9	Clay gyttja	7.3			PAS
	0.95	Postglacial sand	7.1	2.3		PAS

5 Discussion

Potentially acid sediments were found at 13 of the studied 16 sites. These deposits are hence classified as potential acid sulphate soils and might, if exposed to air, become acid due to sulphide oxidation. In the present state these deposits are situated below the groundwater table and characterised by reducing conditions and pH values well above 6. Periods with naturally dry conditions might, however, regularly cause oxidation of the uppermost deposits and potentially a pH drop due to sulphide oxidation.

The potential acid soils documented here are at many sites covered by a layer of fen peat, which was not classified as potentially acid sulphate soil. This peat probably protects underlying sediments from oxidation during dry periods. The pH in the peat was, however, not measured at all studied sites but no peat samples in this nor in earlier studies have been classified as potential acid sulphate soil. It is therefore concluded that the peat in the area in general can be regarded as not potentially acid.

Unlike the conditions in the wetland parts there is no peat layer in the ponds overlying and protecting the potentially acid sediments, and therefore oxidation of sulphides might occur during periods when the ponds are dried out. The groundwater table was, however, low during the sampling occasion and there was almost no water in some of the ponds. Despite this, the measured in-situ pH was relatively neutral (~6.1–6.6). The sediments in the ponds were water saturated during the sampling occasion and that probably prevented oxidation of sulphides, suggesting that long periods with dry conditions are needed to obtain a low pH. It is beyond the scope of this study to estimate if such long-lasting dry conditions are likely to ever occur.

The results from the stratigraphical investigation of this study are in accordance with the general stratigraphy presented in earlier Forsmark reports (Sohlenius and Hedenström 2009, Sohlenius et al. 2020). Glacial clay is most probably present below the postglacial sand that was documented at several of the studied sites. This study was, however, focused on near-surface QD and no effort was put on sampling deeper lying deposits.

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