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Seawater intrusion beneath the quayfront buildings of Bryggen, Bergen:

Resultats from new dipwells MB 28 and MB 29, and from repeated measurements of chloride and sulphate in quayfront dipwells during 2009

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Title:
Seawater intrusion beneath the quayfront buildings of Bryggen, Bergen: Results from new dipwells MB28 and MB29, and from repeated measurements of chloride and sulphate in quayfront dipwells during 2009.

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Summary:
Earlier studies at the quayfront of Bryggen have shown that sulphate reducing bacteria are active in the soil and have the potential to cause a comprehensive decay of organic material. When sulphate was added to soil samples in the laboratory, sulphate reduction rates of 5-24 mg SO_4/kg dry soil/day were measured, which corresponds to a yearly loss of 1-5 g organic material per kg dry soil. However, the studies also indicated that the decay rate in situ is probably limited by the supply of sulphate i.e. how far and how often new seawater penetrates into the cultural layers. A hypothesis was put forward, that in front of the buildings the exchange and decay was relatively fast in the porous layers down to -4 m above sea level (m asl) whereas beneath -4 m asl the deposits were relatively compact giving a slow sulphate supply.
In order to study this further two new dipwells were installed inside the quayfront buildings in February 2009. Soil samples from the installation were analysed, and water was sampled on the 1st of April for a full groundwater analysis. At the same time water was sampled from all dipwells at the quayfront for chloride and sulphate analysis, which was repeated eight times during 2009 at 2-6 weeks interval. In September 2009 conductivity loggers were installed in dipwells MB26 and MB29 measuring the conductivity, water-level, and temperature every hour. The results are presented and commented on in this report, with special emphasis on seawater intrusion under the buildings and sulphate reduction in the soil.
The results have confirmed that in front of the buildings the uppermost dipwell MB24 at -2.5 to -3.5 m asl was dynamic with a varying salinity and frequent supply of seawater, whereas MB26 at -3.9 to -4.9 m asl (and the deeper dipwells MB27, MB12 and MB25) were less dynamic during 2009. The multilevel sampler FB1 was only dynamic at the uppermost levels at -0.5 and -2 m asl, and had a low seawater content at all depths. For the dipwells inside the buildings the results have shown a high salt content in the soil all the way down to natural deposits, but only dipwell MB9 at 0.7 to -1.3 m asl was very dynamic. In dipwells MB28 at -2.2 to -3.2 m asl and MB29 at -2.6 to -3.6 m asl the water exchange rate was relatively slow and most of the sulphate had already been reduced when the monitoring started. The results have confirmed that sulphate reduction in the deeper compact deposits was limited by the supply of sulphate during 2009, whereas there was sufficient sulphate available in the upper porous deposits. Some sulphate reduction also took place in MB28, which is placed near the interface between the compact and the porous deposits.

An attempt has been made to calculate the actual sulphate reduction rates, but the results are still uncertain. No flooding with seawater occurred at the quayfront area during the monitoring period in 2009, which means that we may underestimate the supply of seawater to the deposits. It is therefore relevant to continue logging the conductivity and possibly repeat the groundwater sampling in the future if flooding with seawater occurs for instance at spring tide.

Henning Matthiesen	Poul Jensen
Author	Control

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Introduction

The buildings at the seaward facade of Bryggen are presently being restored. In this context it is important to assess the state of preservation and possible threats against the foundations and the cultural layers underneath the buildings. Especially the effect of seawater intrusion and sulphate reduction has been discussed (Matthiesen, 2008). The study in 2008 showed that there is a high potential effect of sulphate reduction, and rates between 5-24 mg SO_4 pr kg dry soil pr day were measured in the laboratory when sulphate was added to the soil. However, the study also showed that the sulphate reduction in situ could be limited by the supply of sulphate: the cultural deposits beneath -4 m asl were fairly compact making it difficult to have a fresh supply of seawater, whereas the deposits higher than -4 m asl were more porous. Three main questions remained after the 2008 study: How often is there a supply of new seawater to the deposits? How fast does the sulphate from the new seawater disappear? How far inland does this take place – is it for instance a problem underneath the buildings?

In order to elucidate these questions two new dipwells were installed inside the quayfront buildings in February 2009 (Figure 1). Furthermore, conductivity loggers have been installed in two dipwells (MB26 and MB29) and frequent analyses of chloride and sulphate in groundwater from all dipwells at the quayfront have been made. The National Museum of Denmark has been contracted by Riksantikvaren to evaluate the conditions of and threats to the cultural layers at these dipwells based on results from analyses of soil and water.

Site and methods

The new and old dipwells on Bryggen are shown in Figure 1.

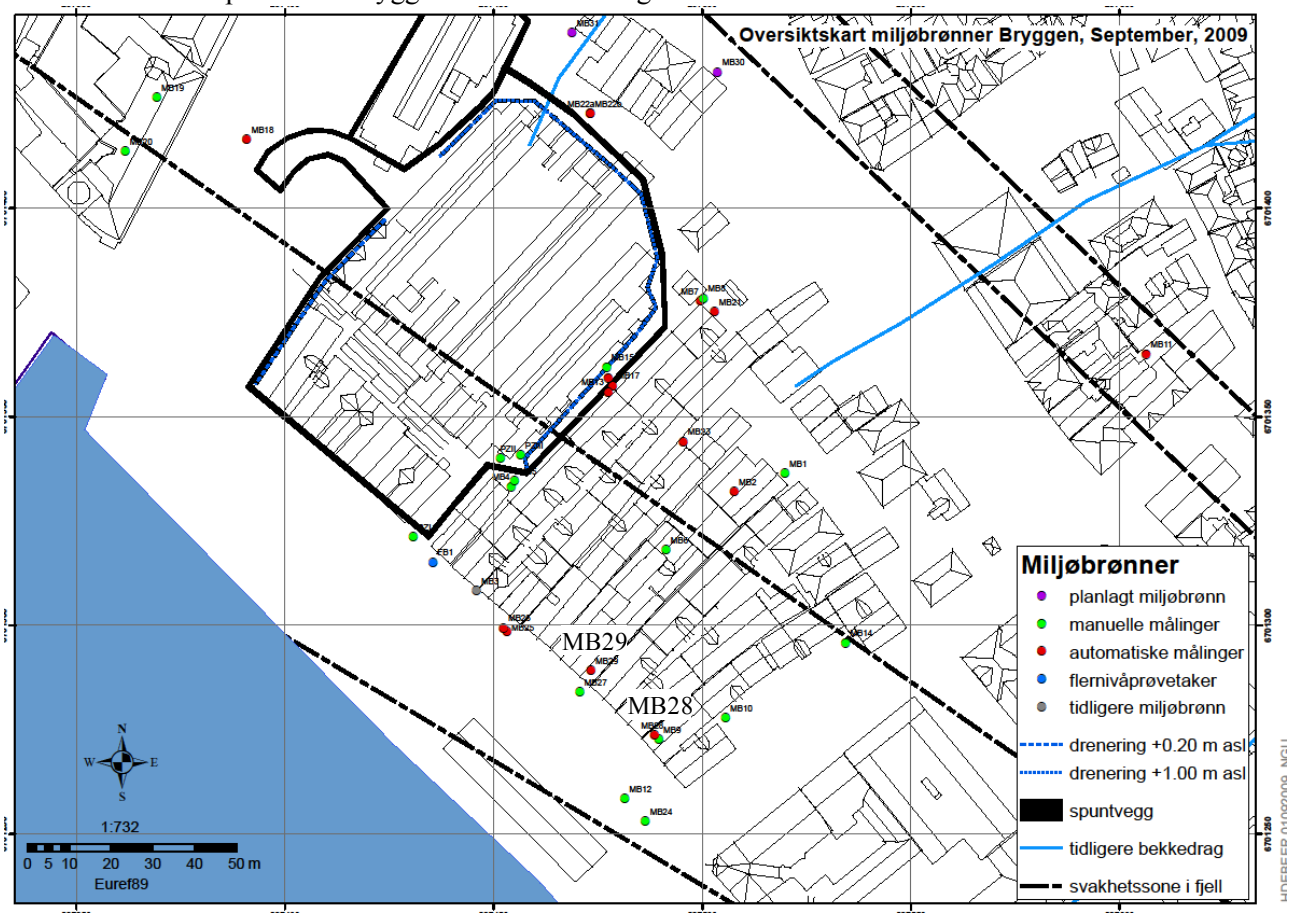

Figure 1: Map of Bryggen, showing the position of MB28 and MB29 inside the buildings at the quayfront area. Other dipwells are marked as well. Map from Hans de Beer, NGU

In February 2009 the drilling work was made by Multiconsult and archaeologist Katharina Lorvik from the Norwegian Institute for Cultural Heritage Research (NIKU). The soil stratigraphy is described in a report by Lorvik & Dunlop (2009). Twelve soil samples from MB28 and MB29 were analysed for pH, water content,

loss on ignition (LOI), water-soluble chloride, water-soluble sulphate, total sulphur and total nitrogen, and four of these were also analysed for sulphide and pyrite. The results are given in Appendix 1.

The position of the dipwells along with the level of their water intake is given in Table 1.

Dipwell	Y-COORD.	X-COORD.	Soil surface (m asl)	Top of dipwell (m asl)	Water intake – top (m asl)	Water intake – bottom (m asl)
MB28	297488.494	6701273.696	0.348	1.79	-2.215	-3.215
MB29	297473.319	6701289.209	0.876	0.88	-2.624	-3.624

Table 1: Position of dipwells (data from Multiconsult/NGU).

On the 1st of April 2009 water was sampled from the dipwells by Multiconsult. The dipwells were emptied before the actual sampling, to ensure that fresh water from the cultural layers was sampled. The water samples were filtered in the field (0.45 µm Gelman high capacity in-line filter). The samples were sent to the laboratory (Eurofins) and analysed for alkalinity, salt (sodium, chloride), nutrients (ammonium, nitrate, phosphate), redox active species (sulphate, nitrate, dissolved iron, dissolved manganese, sulphide, methane), and other major ions (calcium, magnesium, potassium), which gives a good description of the chemical conditions in the ground-water. The reports from the laboratory are shown in Appendix 2.
Water samples were taken from all dipwells at the quayfront (i.e. MB9, MB12, MB24-29 and FB1) on the 1/4, 30/4, 6/5, 20/5, 4/6, 10/7, 30/9 and 5/11 2009 to measure the concentrations of chloride and sulphate. The results from these analyses are compiled in Appendix 3.
Loggers measuring conductivity, temperature and pressure were installed in two dipwells (MB26 and MB29) on the 3/9 2009, and the first dataset was downloaded on the 20/10.
No flooding of the quayfront occurred during the monitoring period. However, a very high water-level was observed in one of the buildings (Fiskebutikken) on the 20th of November, just after the sampling campaign had ended. It was due to heavy rainfall, and analysis of the water showed that it had a low chloride content (Einar Mørk, pers.com).

Results

The results from analysis of soil from MB28 and MB29 are presented in Figure 2. Results from groundwater analysis of samples taken in MB28 and MB 29 in April 2004 are presented in Figure 3, along with results from May 2008 from other dipwells at Bryggen. Time series for chloride and sulphate measurements in quayfront dipwells are presented in Figure 4. Results from conductivity loggers are given in Figure 5.
A note about the units used: Dissolved species are given as “mmol/L” to allow an easy evaluation of the ion balance in the water and a good overview of their quantitative importance. Results from soil analysis are, on the other hand, normally presented as mg / g dry soil. Where it is necessary to make a direct comparison, the recalculation is made in the text.

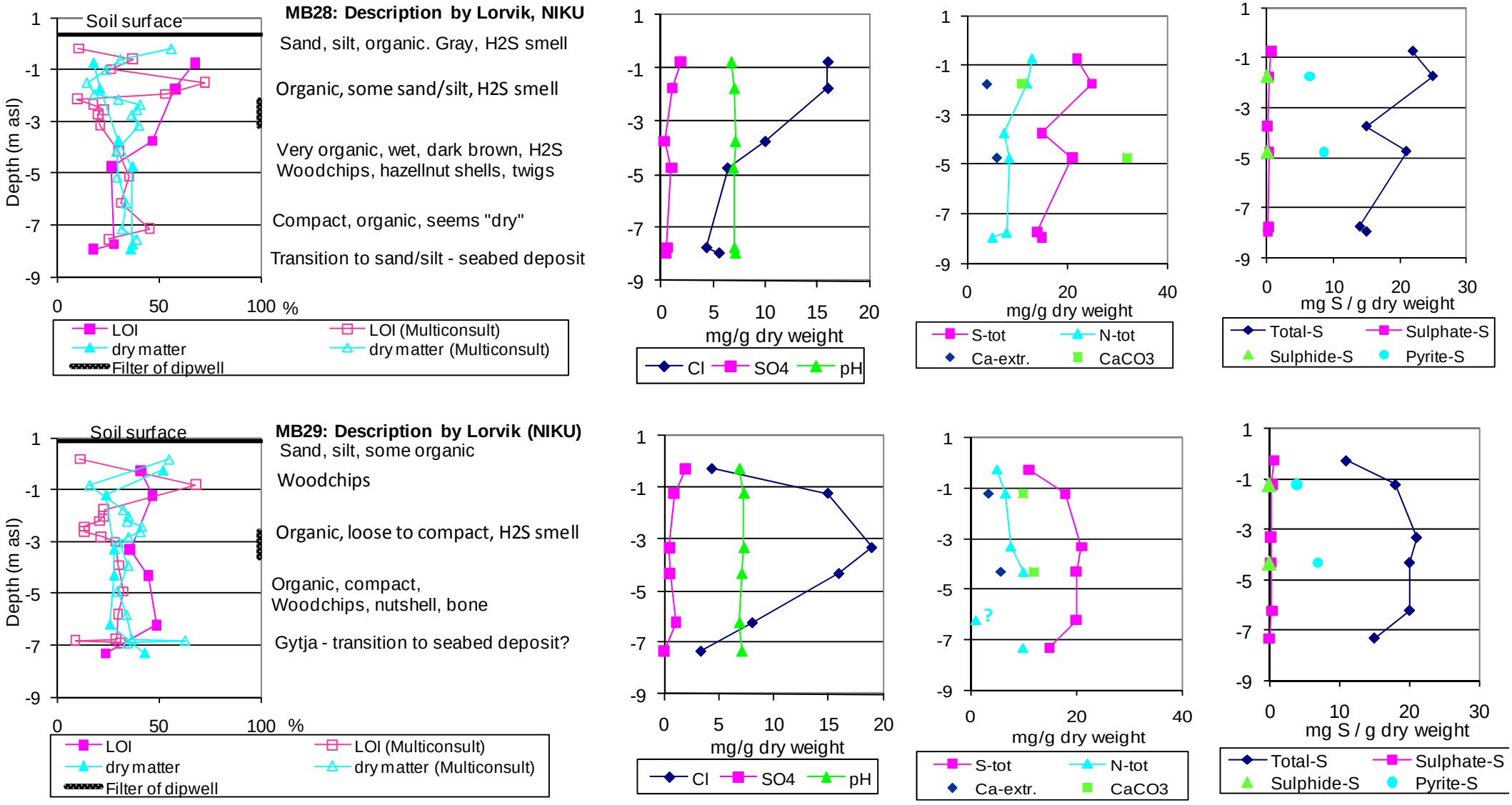

Figure 2: Description and soil analyses of drillings MB28 and MB29. Ca-extr. is Ca extractable by ammonium chloride, $CaCO_3$ is measured by adding HCl to the sample and measuring the CO_2 developed, sulphide-S is Acid volatile sulphide, sulphate-S is water extractable sulphate, and pyrite-S is calculated from pyrite-Fe, which is measured as iron extracted in boiling HNO_3 (after removal of non-pyritic iron). It took more than a month between sampling of the soil (25^{th} – 27^{th} February) to analysis in the laboratory (3^{rd} – 21^{st} April) and it cannot be excluded that some oxidation of pyrite or sulphide-S has taken place during storage, giving a production of sulphate-S.

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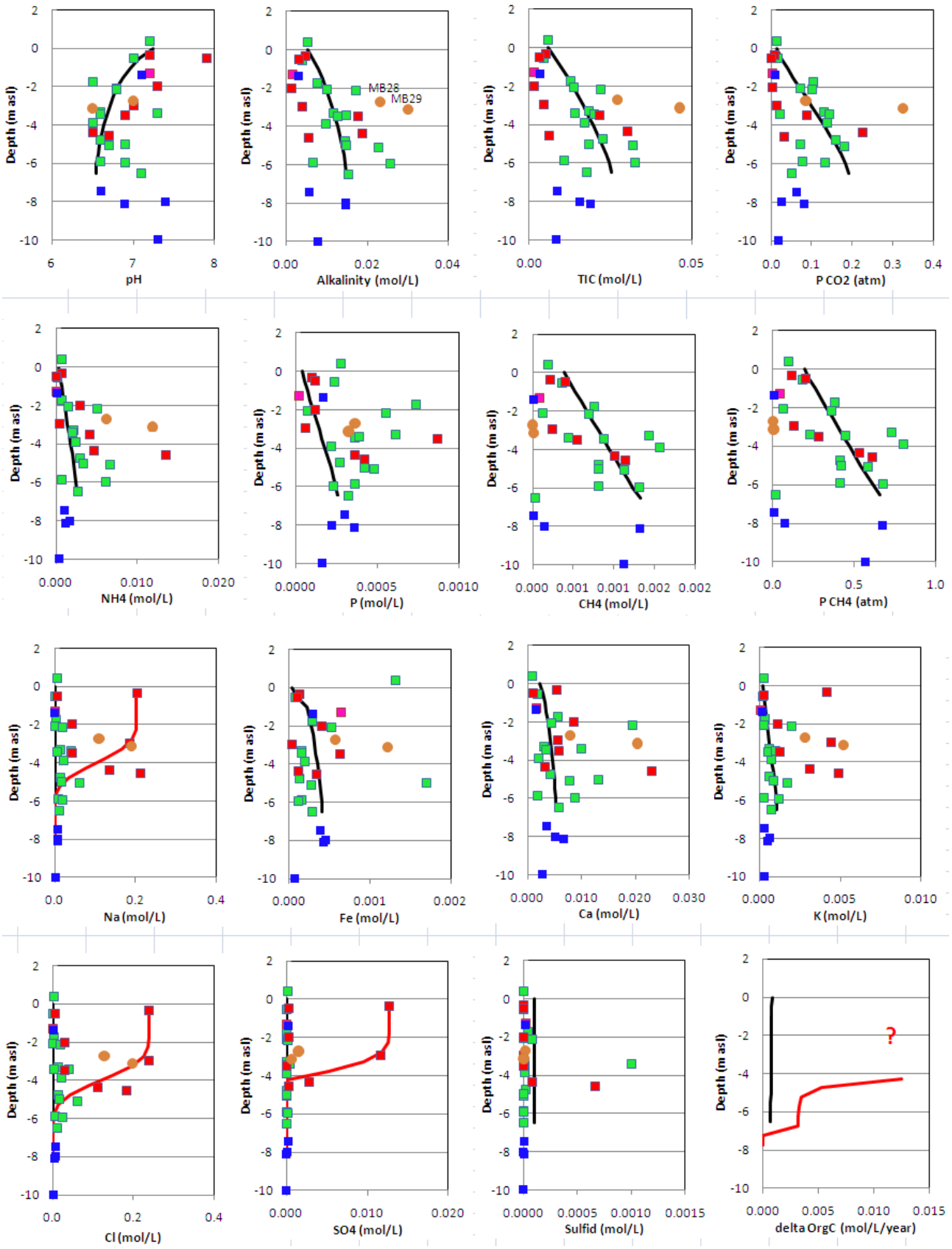

Figure 3: Results from groundwater analyses – data from MB28 and MB29 are shown as orange points, where MB28 is slightly higher (-2.72 m asl) than MB29 (-3.12 m asl). For comparison are shown data from sampling of all other dipwells on Bryggen in May 2008. The different colours indicate: Green – water from relatively stagnant conditions; red – influenced by seawater; pink – "young" samples very diluted by rainwater; and blue – samples from natural deposits underneath the cultural layers. The black lines are the output from a numerical groundwater geochemistry model made in PHREEQC attempting to model the stagnant condition (using a moderate vertical flow of 0.1 m/year through organic deposits). The red lines (only shown for Na, Cl, SO_4 and delta-orgC) are from a preliminary model attempting to model the conditions at the quay-front (using brackish water in the upper porous deposits, and transport by diffusion down into the lower compact layers). It must be emphasized that these models still need validation and the numbers should not be over-interpreted. Updated from Matthiesen (2009).

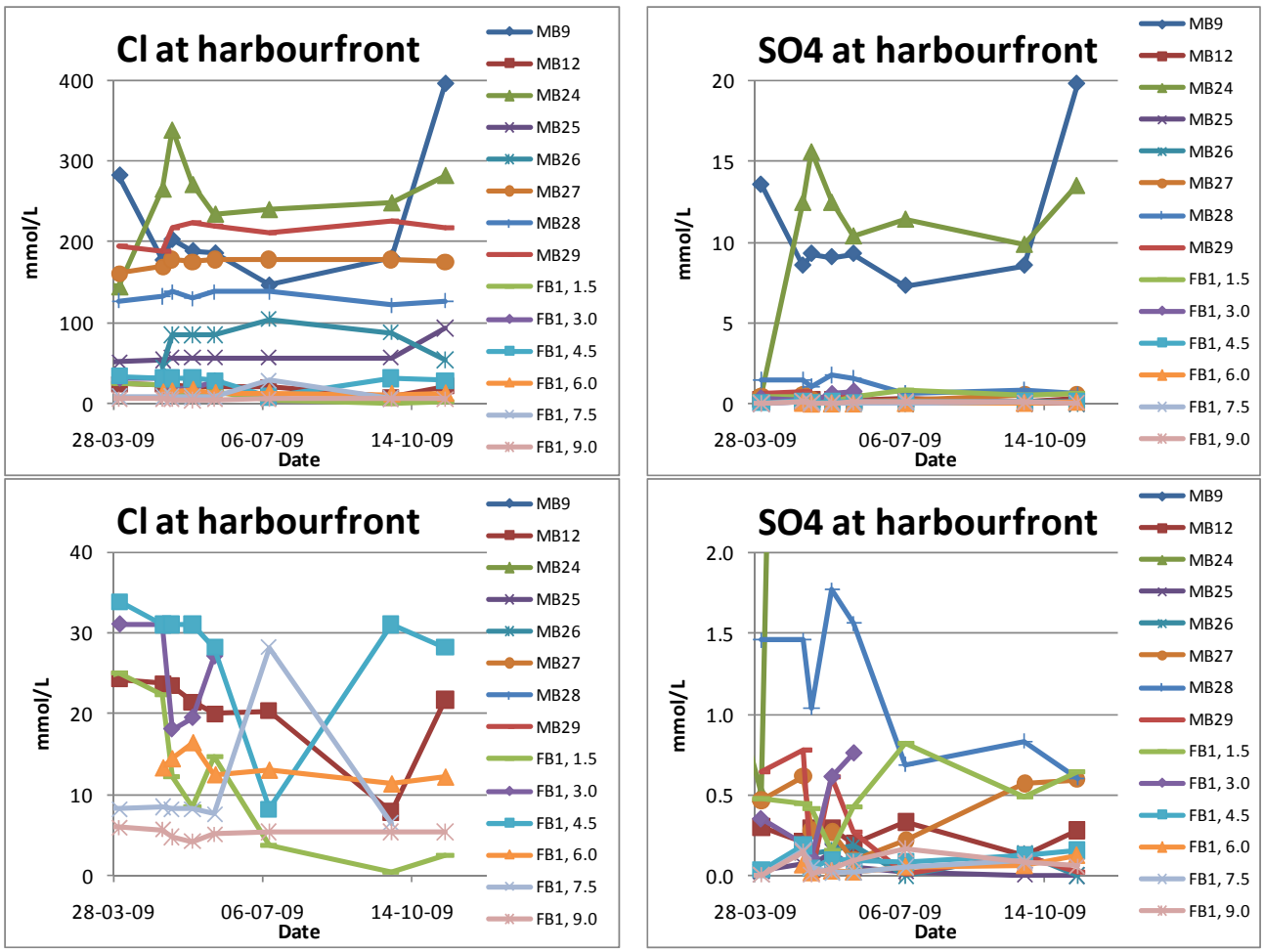

Figure 4: Time series for chloride and sulphate in dipwells from the quayfront area. Dipwells with low concentrations are also shown in the lower two figures (note different level on y-axis). The curves indicate that samples from FB1, 4.5m and 7.5 m on the 10/7 may have been interchanged by mistake, but this has not been possible to verify or falsify. The same applies for the samples from MB25 and MB26 on the 5/11.

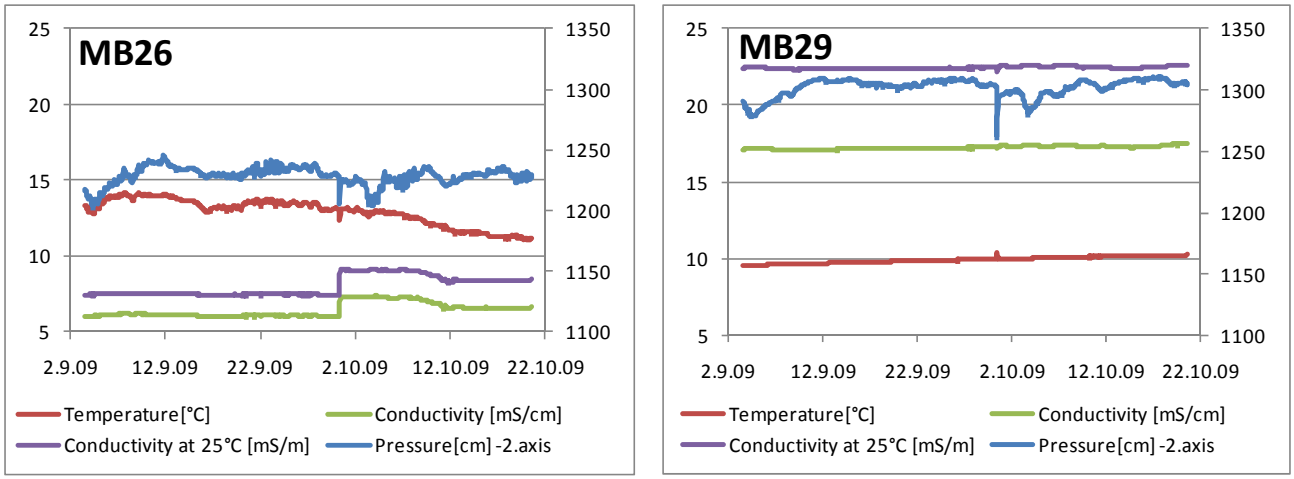

Figure 5: Results from groundwater loggers measuring the pressure, temperature and conductivity every hour. The measured conductivity has been recalculated to the conductivity at 25°C, assuming that the conductivity increases with 2% for each °C. The pressure is not compensated for variations in air-pressure. A groundwater sample is taken from both dipwells on the 30th of September, giving a sudden decrease in the pressure and (for MB26) a change in the conductivity.

Discussion

Organic content, water content and porosity

Figure 2 (left) shows the organic content and water content of soil samples from dipwell MB28 and MB29, along with a brief description of the different soil strata (taken from Lorvik & Dunlop, 2009). Open symbols are data from Multiconsult, whereas closed symbols are data from Eurofins. There is some variation between the two set of data, which could be due to a large heterogeneity of the soil making it difficult to take a representitative sample.

MB28 has a sandy/silty deposit in the uppermost meter down to approximately -0.5 m asl. Beneath this the deposits are described by Lorvik as organic to very organic with a medium to good state of preservation (C3-C4) and locally with H_2S smell. At -6 to -7.7 m asl the deposits are so compact that they feel dry. The loss on ignition data are quite variable and with large differences between Multiconsult and Eurofins, especially in the top. In the deeper deposits they are more constant at 30-40%.

MB29 has layers of sand/silt and charcoal in the uppermost meter, down to approximately -0.2 m asl. Beneath this the deposits are described by Lorvik as organic to very organic with a medium to good state of preservation (C3-C4) and locally with H_2S smell. The loss-on-ignition data are typically between 30 to 50% for most of the analysed samples.

It is thus characteristic that the deposits beneath the buildings are organic to highly organic and have a high decay and settling potential from -0.5 m asl and downwards. For comparison the deposits in front of the buildings were typically modern fill down to approximately -1 or -2 m asl. There was a moderate organic content down to -4 m asl and the state of preservation was described as poor to medium (C2-C3). Beneath -4 m asl the organic content was higher and with a medium to good state of preservation (C3-C4) (Dunlop, 2008).

The water-table at the quayfront is found approximately at 0.2 m asl, which is above the organic rich soil layers. The deposits are thus not threatened by dewatering, which we have seen leads to increased oxygen access, decay of organic material, and settling of the soil surface other places on Bryggen. Approximately 0.5 mg/L oxygen was measured in water from MB28 and MB29 (Appendix 2) but this is considered an artefact due to oxygen pollution during sampling as other species in the water indicate anoxic conditions under the water-table. The results of the groundwater analyses are similar to earlier analyses from Bryggen, and indicate that the two new dipwells fall into the category “influenced by seawater” (Figure 3).

Salt and seawater intrusion

Occasionally the quayfront area of Bryggen is flooded, which gives a very visible input of seawater (or rainwater) to the deposits. The frequency of the flooding has decreased significantly since 2007, when the sewage system was renovated and counter-valves installed in the sewage pipes to avoid backflow of seawater from the harbour into the pipes. No flooding has occurred during the monitoring period described in this report. However, even without flooding or backflow through pipes there may be a subsurface intrusion through the soil itself.

Former or current seawater intrusions are reflected in the results from soil analysis: Figure 6 shows a draft where the chloride content of 171 samples from Bryggen has been projected onto a single vertical profile. It has been updated from Matthiesen (2008) with the results from MB28 and MB29, which are situated inside two of the front buildings. It shows that the salt penetrates deep into the soil layers beneath the buildings, but does not reveal if there is a continuous supply of salt or whether it is old salt, possibly even from the formation of the deposits centuries ago.

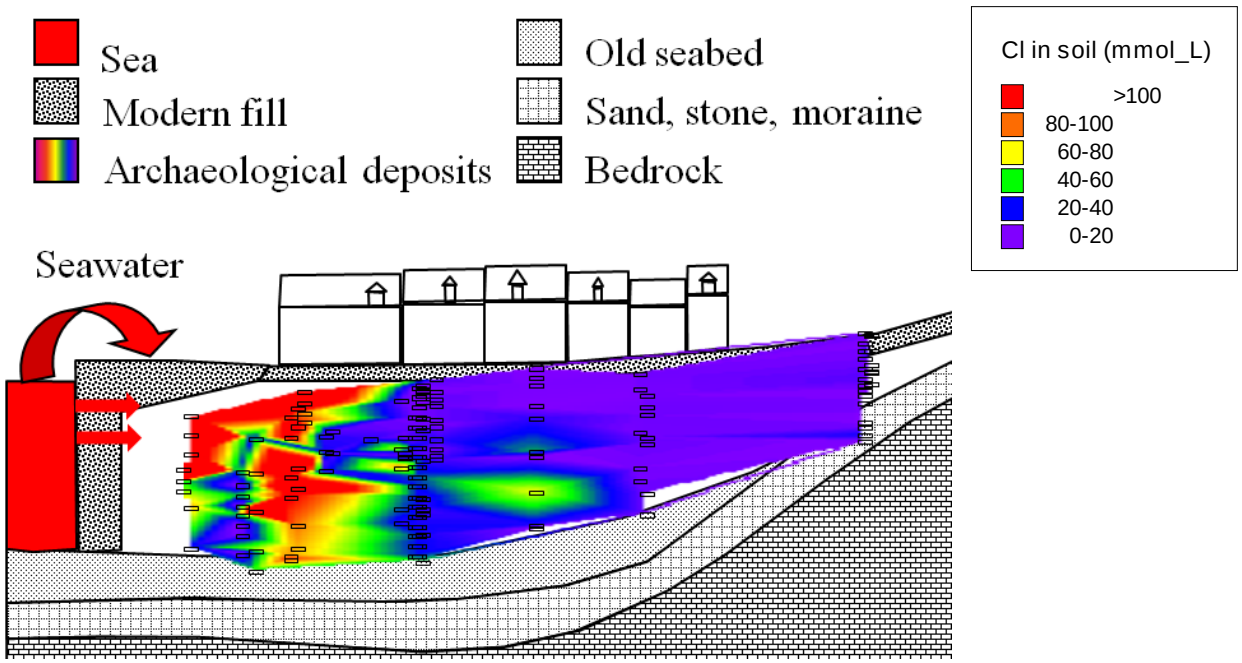

Figure 6: Draft profile of chloride concentrations measured in 171 soil samples taken beneath Bryggen 2001-2009. All data have been projected onto a single vertical profile. Individual samples are shown as rectangles. Figure updated from Matthiesen (2008).

Figure 7 shows in more detail how water-soluble chloride (and sulphate) was distributed in the soil samples from MB28 and MB29, where the results have been recalculated to mmol/L and compared to the content measured in the dipwells in April 2009. MB9, which was installed in November 2004, is placed right next to MB28 and is shown for comparison.

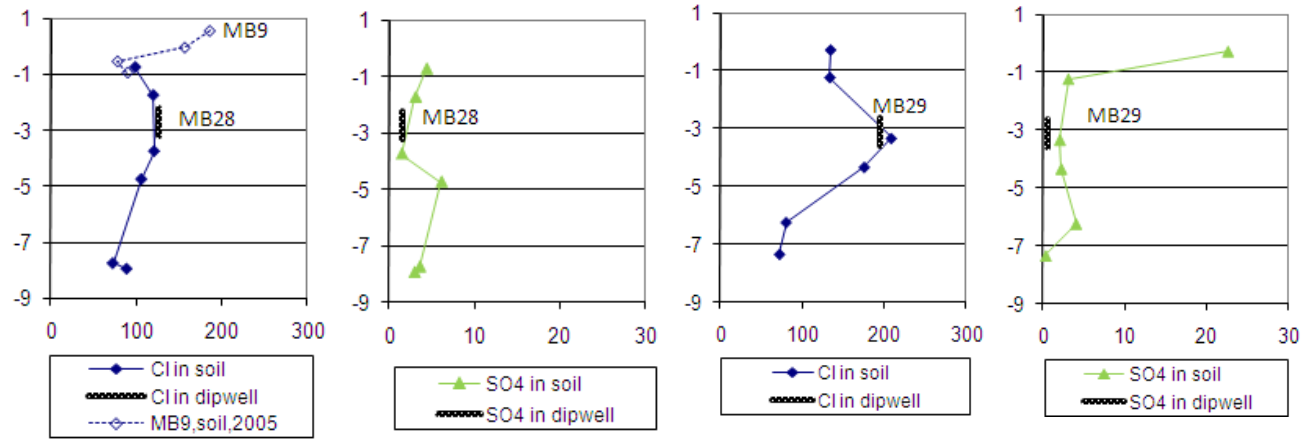

Figure 7: Measurements of water soluble chloride and sulphate in soil samples from MB28 and MB29 (MB9 is placed right next to MB28 and is shown for comparison). Recalculated to mmol/L using the water content of the soil. For comparison is also shown the concentrations measured in water from the dipwells, sampled 1st of April 2009.

If seawater with a high salt content penetrates into the soil it does not only influence the chloride content, but also species like sodium, potassium, magnesium and sulphate. Figure 3 shows the results from groundwater analyses, where red marks indicate dipwells influenced by seawater. The new dipwells are marked as orange, and they seem to fall within the "red" group, verifying that seawater is present in the cultural deposits underneath the buildings.

But one thing is the penetration – another is the dynamics. Is there an active exchange today, or is it old stagnant seawater that is observed in these dipwells? This should be possible to evaluate from the time series for chloride (Figure 4) and conductivity (Figure 5) – if there is a flooding or a sudden intrusion of seawater, the chloride content and conductivity should increase. Figure 4 show a significant variation in the chloride

concentration in MB9, MB24, FB1 1.5 and FB1 3.0, an intermediate variation in MB12, MB26 and MB29, and only a modest variation in the rest of the dipwells (the sudden variation in FB1 4.5 and FB1 7.5 on the 10th of July is possibly due to an exchange of samples). MB24, MB9 and FB1 1.5 are the most variable, which is not surprising as they are also the uppermost dipwells. MB28 is placed next to MB9, but deeper in the deposits, and only shows a modest variation. MB26 and MB29 are at the same depth as MB28 and show an intermediate variation. The multilevel sampler FB1 shows surprisingly low concentrations at all depths.

Further insight into the dynamics is given by the conductivity loggers (Figure 5). In seawater there is a close correspondence between the chloride content, salinity and conductivity, where seawater at a salinity of 35‰ contains 19.4 g Cl/kg (corresponding to 546 mmol/L) and has a conductivity of 53 mS/cm at 25°C, so the chloride content in mmol/L may be estimated from the conductivity as [Cl] (mmol/L) = 10.3*conductivity (mS/cm). The same relation may to some extent be used for mixtures of seawater and freshwater, and during the water sampling on the 30.9.2009 the following results are found:

	Conductivity at 25°C (mS/cm)	Cl(mmol/L) estimated	Cl (mmol/L) measured 30/9
MB26	7.45-9.08	77-94	87.4
MB29	22.5	232	225.7

The good correspondence indicates that in these two dipwells the conductivity is a good measure of the seawater and chloride content. The conductivity has been monitored in dipwells MB26 and MB29 for a period of two months. Figure 5 shows that there is very little variation in the conductivity, indicating stagnant conditions. The main change is observed in MB26, where the conductivity increases abruptly on the 30th of September and then slowly decreases. This is due to sampling of water for Cl and SO_4 analysis, where the dipwell is emptied a few times in order to sample fresh water from the surroundings. Ideally a dipwell should always reflect the conditions in the surroundings, but the data here shows that this is not always the case.

Sulphate reduction

Sulphate reduction is the process where sulphate is used by bacteria to oxidise organic material:

$SO_4^{2-} + 2\ CH_2O \rightarrow HS^- + 2\ HCO_3^- + H^+$

presented here as a complete oxidation of organic matter (with the brutto formula CH_2O) all the way to bicarbonate/carbon dioxide. The process only gives a small energy output to the bacteria, and it is seldom considered problematic for the preservation of archaeological remains. However, the extent and effect of sulphate reduction on urban archaeological deposits has actually never been investigated in any detail. Seawater contains both chloride and sulphate, at a fixed molar ratio of 0.052 SO_4:Cl (28 mM SO_4 and 546 mM Cl at a salinity of 35 ‰). This means that whenever the quayfront area is flooded with seawater, or there is a subsurface intrusion, sulphate enters the soil pore water along with the chloride. It is possible to calculate a theoretical sulphate concentration from the chloride content and compare this with the measured sulphate content. The difference between these numbers gives the sulphate depletion, which may be used as an indicator for the extent of sulphate reduction (assuming that there are no other sources or sinks of chloride and sulphate). Figure 8 gives the temporal variation in these numbers for the 14 dipwells/piezometers at the quayfront.

*Figure 8: Temporal variation in 14 dipwells/piezometers in the sulphate concentration measured [SO_4^{2-}], along with the theoretical concentration (0.052 * [Cl]) and the sulphate depletion ([SO_4^{2-}] – 0.052*[Cl^-]), where 0.052 is the SO_4:Cl ratio normally found in seawater.*

In order to study sulphate reduction the ideal situation would be to begin when the area is flooded with seawater supplying both chloride and sulphate to the deposits, and then measure over time whether the sulphate disappears faster than the chloride. This should in principle give an increasing "sulphate depletion" over time. However, no flooding occurred during the monitoring period and for most of the dipwells hardly any sulphate is found in the water – for instance the FB1 multilevel sampler is almost sulphate free at all levels, and the same is the case for MB12, MB25, MB26, MB27 and MB29. Obviously if no sulphate is available no sulphate reduction can take place.

On the other hand MB9 and MB24 have high concentrations of sulphate, but here the water exchange seems to be so fast that it is difficult to observe any sign of sulphate reduction before the water is exchanged again –

obviously the sulphate reduction is not limited by the supply of sulphate in these two dipwells. There is a single period (from the 10/7 to the 30/9) where the sulphate concentration in MB24 decreases while the chloride content increases, which changes the sulphate depletion from -1 to -3 mM in 80 days. A consumption of 2 mM in 80 days corresponds to 9.1 mM SO_4/year, which may oxidise 18 mM organic carbon/year if used by sulphate reducing bacteria (the real rate is probably even higher as there may well have been a fresh supply of seawater during these 80 days).
MB 28 contains a small amount of sulphate during the first sampling in April 2009 and also here the sulphate concentration decreases while the chloride concentration remains constant. The rate may be estimated from the slope of the curve to approximately to 5 mM SO_4/year which may oxidise 10 mM organic carbon/year. However, the sulphate is used up during the monitoring period, and the average rate for the whole year may be limited by the supply of sulphate.
Both estimates are the same order of magnitude as the results from a preliminary geochemical model for the quayfront area which indicates a decay rate of 13 mM organic carbon/year just beneath the porous soil layers (Figure 3 bottom right and Matthiesen, 2009). It must be emphasised that the geochemical model is far from optimised and cannot estimate the rates in the upper porous layers. It must also be emphasised that the estimates from the time series of chloride and sulphate are uncertain due to the difficulty in quantifying the seawater intrusion. Still the estimates indicate that sulphate reduction is locally important at the quayfront and that the in situ rate at most dipwells is limited by the sulphate supply. Repeated measurements after a flooding with seawater could make the picture clearer.

As for the accumulated effect over time, sulphate reduction leads to formation of sulphide, and parts of this sulphide will normally precipitate as acid volatile sulphide or as pyrite, as already discussed in Matthiesen (2008). Just like the other dipwells from the quayfront the soil samples from MB28 and MB29 have low C/S ratios (between 6 and 19) which could indicate accumulation of reduced sulphur. The pyrite content has been measured in four of the samples, showing contents between 4 and 9 g pyrite-S per kg dry soil, which is a substantial percentage of the total sulphur in the soil (Figure 2). If this pyrite stems from sulphate reduction it corresponds to the oxidation of 4 to 9 g organic matter per kg dry soil. However, some of the sulphide produced may be re-oxidised instead of accumulating, which will lead to an underestimating of the total sulphate reduction – Zaggia et al (2007) thus find in a study from Venice that only 10-25% of the sulphide produced actually precipitates. In principle, the pyrite measured in the soil samples could also stem from weathered rock, but lower pyrite contents of 2 g pyrite-S per kg dry soil were found in soil samples from MB15 and MB33 further away from the quay front (only two samples analysed).

Preservation conditions
The main threat against the cultural layers at the quayfront is the sulphate reduction, as there is no risk of dewatering of these low lying deposits. The purpose of this study was to estimate how fast and how far inland sulphate reduction takes place. This is to a large extent controlled by the sulphate supply, which is again influenced by seawater flooding the quayfront (which didn't occur during the study) or intruding through the soil (which is difficult to quantify). Figure 8 tries to sum up the current model for the situation at the quayfront:

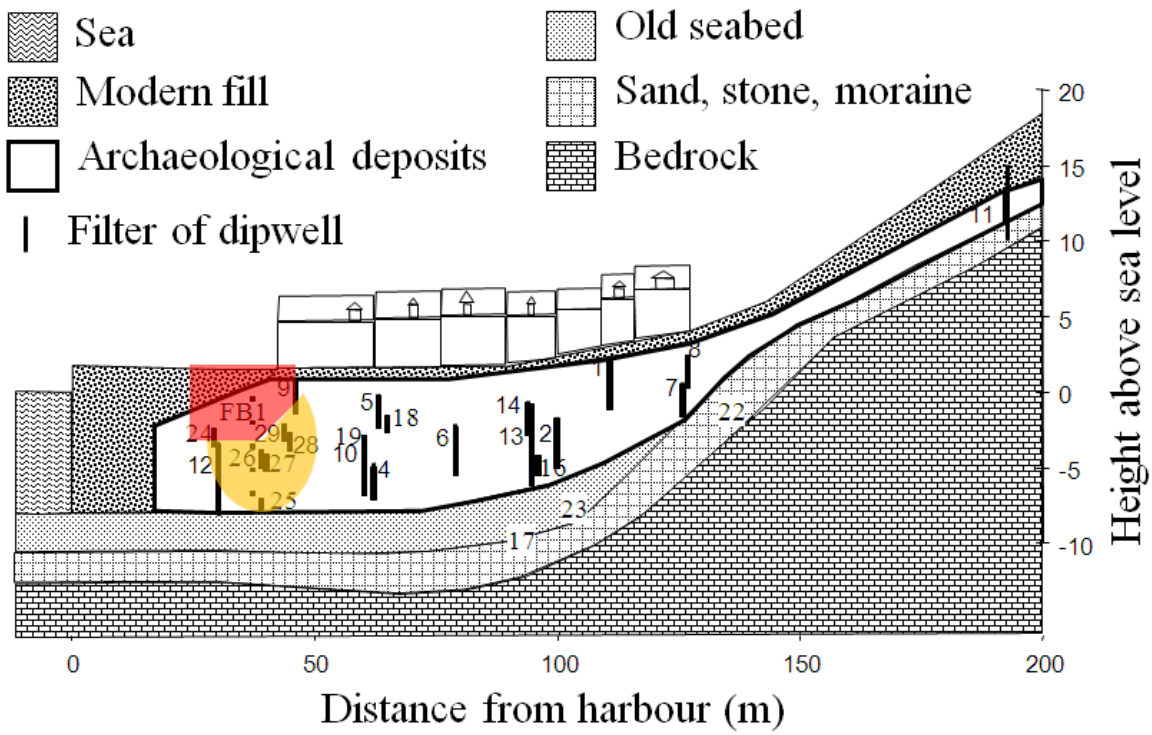

Figure 8: Profile of Bryggen showing the different dipwells. The colours at the front roughly indicate the seawater intrusion: the red area (covering dipwells MB9 and MB24) is dynamic where there is a frequent supply of seawater and enough sulphate for sulphate reduction – this is also the area with the worst state of preservation (preservation index C2-C3 according to Lorvik & Dunlop 2009). The yellow area (covering dipwells MB 25-29) has a high salt content, but relatively stagnant conditions and all the sulphate has been reduced already – here the preservation index is typically C3-C4. Dipwell MB12 and piezometers FB1 are characterised by relatively low salt contents.

The estimates of the actual sulphate reduction rates are still very uncertain, but may be improved by repeating the study after a flooding with seawater. The currently best estimates are: in the porous deposits (red area) the rate is at least 18 mM organic carbon/year; in the top of the compact deposits where sulphate can be supplied by diffusion from above (interface between red and yellow area) it is 10 mM organic carbon/year; and deeper in the compact deposits it is lower and limited by the sulphate supply. If we consider a deposit with 42% dry weight (average value on Bryggen) the estimated degradation rates of at least 18 mM/year in the upper soil layers correspond to a yearly loss of at least 0.8 g organic material per kg dry soil, or 80 g within a century. The estimated rate of 10 mM/year at the top of the compact layers corresponds to a yearly loss of 0.4 g organic material per kg dry soil, or 40 g within a century. For comparison the total amount of organic material varies from 100 to 700 g pr kg dry soil (LOI of 10-70%), with an average value of 280 g organic material/kg. The estimated degradation rates are significantly higher than our estimates for the central, stagnant areas on Bryggen, but lower than the decay rates in the drained area next to the hotel. They are also slightly lower than the first estimates of sulphate reduction that were based on laboratory experiments (5-24 mg SO_4/kg/day corresponding to a yearly loss of 1-5 g organic material per kg dry soil).

Conclusions and future work

It has been shown that

- The new dipwells MB28 and MB29 inside the quayfront buildings had a high salt content in all soil samples, all the way down to the natural deposits
- The conditions in MB28 and MB29 were relatively stable during the monitoring period, and very dynamic conditions were only found in the uppermost dipwells MB24, MB9 and FB1.
- It has been verified that sulphate reduction is locally important for decay at the quayfront

    - In the upper soil layers (down to -4 m asl in front of the buildings and down to maybe -1 m asl inside the buildings) the soil is somewhat porous and there is plenty of sulphate available to sustain a high sulphate reduction rate.
    - Underneath the soil layers are more compact with stagnant conditions, but at the top of these compact layers sulphate may be supplied by diffusion from above
    - Deeper in the compact soil layers the sulphate reduction rate is limited by a very low sulphate supply
- The decay rate in the porous soil layers has been estimated to a yearly loss of at least 0.8 g organic material per kg dry soil, but the estimates are still uncertain and need to be verified
- It still cannot be recommended to use seawater to raise the water table or spray the foundations at other places on Bryggen, as this may increase the sulphate supply

Further studies may include

- Continued logging of the salinity in the dipwells at the quayfront
- If a change in salinity indicates seawater intrusion, new measurements of chloride and sulphate content in the dipwells should be made
- Combined modelling of the geochemical and hydrological data to verify the decay rates
- Literature survey on sulphate reduction to find alternative ways for quantifying the rates in situ

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Appendix 1

Results from soil analysis of 12 soil samples from MB28 and MB29

Eurofins Miljø A/S
Smedeskovvej 38
8464 Galten
Telefon: 7022 4266
CVR/VAT: DK-2884 8196

TEST Reg.nr. 168

Multiconsult

Nesttunbrekka 95
5221 Nesttun
Norge
Att.: Ove Steinestø

Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443401

Modt. dato: 2009.04.03

Sidenr.: 1 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443401**			
	Prøve ID: **Fiskebutik**	Detekt.		RSD
	Prøvemærke: **PR 1**	grænse	Metoder	(%)
pH	**6.8 pH**		*DS 287 mod.	
Tørstof	**18 %**	0.05	DS 204 mod.	10
Glødetab, total	**12.5 %**	0.002	DS 204	10
Glødetab på tørstof	**68 % i ts.**	0.10	DS 204	5
Kvælstof, total	**1.3 % i ts.**	0.03	ISO 13878	10
Chlorid, vandopløselig	**16000 mg/kg ts.**	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**1900 mg/kg ts.**	1	*SM 17 udg. 4500	10
Svovl, total	**22000 mg/kg ts.**	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:				
Prøvedybde	**1.0-1.2 m**		*	

*) Ikke omfattet af akkrediteringen.

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5221 Nesttun
Norge
Att.: Ove Steinestø

Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443402

Modt. dato: 2009.04.03

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: 77443402 Prøve ID: Fiskebutik Prøvemærke: PR 1	Detekt. grænse	Metoder	RSD (%)
Calciumcarbonat, kalkvirkning	**1.1 % i ts.**	0.50	*PD. FAJ. III 5	10
pH	**7.1 pH**		*DS 287 mod.	
Tørstof	**21 %**	0.05	DS 204 mod.	10
Glødetab, total	**12.1 %**	0.002	DS 204	10
Glødetab på tørstof	**58 % i ts.**	0.10	DS 204	5
Kvælstof, total	**1.2 % i ts.**	0.03	ISO 13878	10
Chlorid, vandopløselig	**16000 mg/kg ts.**	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**1100 mg/kg ts.**	1	*SM 17 udg. 4500	10
Svovl, total	**25000 mg/kg ts.**	50.0	DS259/SM3120ICP	15
Sulfid-S	**13 mg/kg ts.**	0.05	*DS 280 mod	15
Calciumtal	**410 mg/100g**	50.00	*PD III 18B	
Pyrit, FeS2	**1.2 % i ts.**	0.01	*SM3120 mod.	
Frit Pyrit	**<0.01 % i ts.**	0.01	*Beregning	

Oplysninger fra rekvirenten:

Prøvedybde	**2.0-2.2 m**		*

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5221 Nesttun
Norge
Att.: Ove Steinestø

Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443403

Modt. dato: 2009.04.03

Sidenr.: 3 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443403**			
	Prøve ID: **Fiskebutik**	Detekt.		RSD
	Prøvemærke: **PR 1**	grænse	Metoder	(%)
pH	**7.2 pH**		*DS 287 mod.	
Tørstof	**30** %	0.05	DS 204 mod.	10
Glødetab, total	**13.9** %	0.002	DS 204	10
Glødetab på tørstof	**47** % i ts.	0.10	DS 204	5
Kvælstof, total	**0.75** % i ts.	0.03	ISO 13878	10
Chlorid, vandopløselig	**10000** mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**330** mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	**15000** mg/kg ts.	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:				
Prøvedybde	**4.0-4.2** m		*	

*) Ikke omfattet af akkrediteringen.

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Att.: Ove Steinestø

Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443404

Modt. dato: 2009.04.03

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: 77443404 Prøve ID: Fiskebutik Prøvemærke: PR 1	Detekt. grænse	Metoder	RSD (%)
Calciumcarbonat, kalkvirkning	**3.2 % i ts.**	0.50	*PD. FAJ. III 5	10
pH	**7.0 pH**		*DS 287 mod.	
Tørstof	**37 %**	0.05	DS 204 mod.	10
Glødetab, total	**10.7 %**	0.002	DS 204	10
Glødetab på tørstof	**27 % i ts.**	0.10	DS 204	5
Kvælstof, total	**0.85 % i ts.**	0.03	ISO 13878	10
Chlorid, vandopløselig	**6400 mg/kg ts.**	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**990 mg/kg ts.**	1	*SM 17 udg. 4500	10
Svovl, total	**21000 mg/kg ts.**	50.0	DS259/SM3120ICP	15
Sulfid-S	**31 mg/kg ts.**	0.05	*DS 280 mod	15
Calciumtal	**610 mg/100g**	50.00	*PD III 18B	
Pyrit, FeS2	**1.6 % i ts.**	0.01	*SM3120 mod.	
Frit Pyrit	**<0.01 % i ts.**	0.01	*Beregning	

Oplysninger fra rekvirenten:

Prøvedybde	**5.0-2.5 m**		*	

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Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443405

Modt. dato: 2009.04.03

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ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443405**			
	Prøve ID: **Fiskebutik**	Detekt.		RSD
	Prøvemærke: **PR 1 38**	grænse	Metoder	(%)
pH	**7.1 pH**		*DS 287 mod.	
Tørstof	**37 %**	0.05	DS 204 mod.	10
Glødetab, total	**10.0 %**	0.002	DS 204	10
Glødetab på tørstof	**28 % i ts.**	0.10	DS 204	5
Kvælstof, total	**0.80 % i ts.**	0.03	ISO 13878	10
Chlorid, vandopløselig	**4400 mg/kg ts.**	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**580 mg/kg ts.**	1	*SM 17 udg. 4500	10
Svovl, total	**14000 mg/kg ts.**	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:				
Prøvedybde	**8.0-8.2 m**		*	

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Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443406

Modt. dato: 2009.04.03

Sidenr.: 6 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443406**			
	Prøve ID: **Fiskebutik**	Detekt.		RSD
	Prøvemærke: **PR 1 39**	grænse	Metoder	(%)
pH	**7.2 pH**		*DS 287 mod.	
Tørstof	**36** %	0.05	DS 204 mod.	10
Glødetab, total	**8.05** %	0.002	DS 204	10
Glødetab på tørstof	**18** % i ts.	0.10	DS 204	5
Kvælstof, total	**0.52** % i ts.	0.03	ISO 13878	10
Chlorid, vandopløselig	**5600** mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**500** mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	**15000** mg/kg ts.	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:				
Prøvedybde	**8.2-8.4** m		*	

*) Ikke omfattet af akkrediteringen.

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Norge
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Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443407

Modt. dato: 2009.04.03

Sidenr.: 7 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443407**			
	Prøve ID: **Svensgård**	Detekt.		RSD
	Prøvemærke: **PR 2 04**	grænse	Metoder	(%)
pH	**6.9 pH**		*DS 287 mod.	
Tørstof	**52** %	0.05	DS 204 mod.	10
Glødetab, total	**11.0** %	0.002	DS 204	10
Glødetab på tørstof	**41** % i ts.	0.10	DS 204	5
Kvælstof, total	**0.50** % i ts.	0.03	ISO 13878	10
Chlorid, vandopløselig	**4400** mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**2000** mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	**11000** mg/kg ts.	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:				
Prøvedybde	**1.1-1.2** m		*	

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Att.: Ove Steinestø

Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443408

Modt. dato: 2009.04.03

Sidenr.: 8 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443408** Prøve ID: **Svensgård** Prøvemærke: **PR 2 09**	Detekt. grænse	Metoder	RSD (%)
Calciumcarbonat, kalkvirkning	**1.0 % i ts.**	0.50	*PD. FAJ. III 5	10
pH	**7.3 pH**		*DS 287 mod.	
Tørstof	**24 %**	0.05	DS 204 mod.	10
Glødetab, total	**11.0 %**	0.002	DS 204	10
Glødetab på tørstof	**47 % i ts.**	0.10	DS 204	5
Kvælstof, total	**0.66 % i ts.**	0.03	ISO 13878	10
Chlorid, vandopløselig	**15000 mg/kg ts.**	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**940 mg/kg ts.**	1	*SM 17 udg. 4500	10
Svovl, total	**18000 mg/kg ts.**	50.0	DS259/SM3120ICP	15
Sulfid-S	**6.6 mg/kg ts.**	0.05	*DS 280 mod	15
Calciumtal	**340 mg/100g**	50.00	*PD III 18B	
Pyrit, FeS2	**0.72 % i ts.**	0.01	*SM3120 mod.	
Frit Pyrit	**<0.01 % i ts.**	0.01	*Beregning	

Oplysninger fra rekvirenten:

Prøvedybde	**2.0-2.2 m** *

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Att.: Ove Steinestø

Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443409

Modt. dato: 2009.04.03

Sidenr.: 9 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443409**				
	Prøve ID: **Svensgård**		Detekt.		RSD
	Prøvemærke: **PR 2 18**		grænse	Metoder	(%)
pH	**7.3**	**pH**		*DS 287 mod.	
Tørstof	**28**	**%**	0.05	DS 204 mod.	10
Glødetab, total	**12.2**	**%**	0.002	DS 204	10
Glødetab på tørstof	**36**	**% i ts.**	0.10	DS 204	5
Kvælstof, total	**0.76**	**% i ts.**	0.03	ISO 13878	10
Chlorid, vandopløselig	**19000**	**mg/kg ts.**	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**510**	**mg/kg ts.**	1	*SM 17 udg. 4500	10
Svovl, total	**21000**	**mg/kg ts.**	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:					
Prøvedybde	**4.0-4.4**	**m**		*	

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Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443410

Modt. dato: 2009.04.03

Sidenr.: 10 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443410**			
	Prøve ID: **Svensgård**	Detekt.		RSD
	Prøvemærke: **PR 2 21**	grænse	Metoder	(%)
Calciumcarbonat, kalkvirkning	**1.2 % i ts.**	0.50	*PD. FAJ. III 5	10
pH	**7.1 pH**		*DS 287 mod.	
Tørstof	**28 %**	0.05	DS 204 mod.	10
Glødetab, total	**14.7 %**	0.002	DS 204	10
Glødetab på tørstof	**45 % i ts.**	0.10	DS 204	5
Kvælstof, total	**1.0 % i ts.**	0.03	ISO 13878	10
Chlorid, vandopløselig	**16000 mg/kg ts.**	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**550 mg/kg ts.**	1	*SM 17 udg. 4500	10
Svovl, total	**20000 mg/kg ts.**	50.0	DS259/SM3120ICP	15
Sulfid-S	**21 mg/kg ts.**	0.05	*DS 280 mod	15
Calciumtal	**580 mg/100g**	50.00	*PD III 18B	
Pyrit, FeS2	**1.3 % i ts.**	0.01	*SM3120 mod.	
Frit Pyrit	**<0.01 % i ts.**	0.01	*Beregning	

Oplysninger fra rekvirenten:

Prøvedybde	**5.0-5.4 m**		*

*) Ikke omfattet af akkrediteringen.

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Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443411

Modt. dato: 2009.04.03

Sidenr.: 11 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443411**			
	Prøve ID: **Svensgård**	Detekt.		RSD
	Prøvemærke: **PR 2 29**	grænse	Metoder	(%)
pH	**6.9 pH**		*DS 287 mod.	
Tørstof	**26** %	0.05	DS 204 mod.	10
Glødetab, total	**14.2** %	0.002	DS 204	10
Glødetab på tørstof	**49** % i ts.	0.10	DS 204	5
Kvælstof, total	**0.10** % i ts.	0.03	ISO 13878	10
Chlorid, vandopløselig	**8100** mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**1100** mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	**20000** mg/kg ts.	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:				
Prøvedybde	**7.0-7.2** m		*	

*) Ikke omfattet af akkrediteringen.

Tegnforklaring:
RSD : Relativ Analyseusikkerhed.
< : mindre end. i.p.: ikke påvist.
> : større end. i.m.: ikke målelig.
: ingen af parametrene er påvist.

Eurofins Miljø A/S
Smedeskovvej 38
8464 Galten
Telefon: 7022 4266
CVR/VAT: DK-2884 8196

DANAK TEST Reg.nr. 168

eurofins

Multiconsult

Nesttunbrekka 95
5221 Nesttun
Norge
Att.: Ove Steinestø

Registernr.: 774434
Kundenr.: 623522
Ordrenr.: 407419
Prøvenr.: 77443412

Modt. dato: 2009.04.03

Sidenr.: 12 af 12

ANALYSERAPPORT

Rekvirent.....: Multiconsult
Nesttunbrekka 95, 5221 Nesttun, Norge
Prøvested.....: **Fiskebutikken og Svensgården**
Prøvetype.....: Jord ,
Prøveudtagning...:
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.03 - 2009.04.21

	Prøvenr.: **77443412**			
	Prøve ID: **Svensgård**	Detekt.		RSD
	Prøvemærke: **PR 2 36**	grænse	Metoder	(%)
pH	**7.1 pH**		*DS 287 mod.	
Tørstof	**43** %	0.05	DS 204 mod.	10
Glødetab, total	**10.1** %	0.002	DS 204	10
Glødetab på tørstof	**24** % i ts.	0.10	DS 204	5
Kvælstof, total	**0.99** % i ts.	0.03	ISO 13878	10
Chlorid, vandopløselig	**3400** mg/kg ts.	5	*SM 17 udg. 4500	10
Sulfat,vandopløselig	**43** mg/kg ts.	1	*SM 17 udg. 4500	10
Svovl, total	**15000** mg/kg ts.	50.0	DS259/SM3120ICP	15
Oplysninger fra rekvirenten:				
Prøvedybde	**8.0-8.4** m		*	

*) Ikke omfattet af akkrediteringen.

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: ingen af parametrene er påvist.

22. april 2009

Kundecenter: tlf.70224267 Hanne Jensen
Kontaktperson Kvalitetssikring

Appendix 2

Results from analysis of groundwater sampled from MB28 and MB29 on the 1st of April 2009

Eurofins Miljø A/S
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8464 Galten
Telefon: 7022 4266
CVR/VAT: DK-2884 8196

Nationalmuseet
Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej
2800 Kgs. Lyngby

Att.: Henning Matthiesen

Registernr.: A00996
Kundenr.: 82983
Ordrenr.: 603361

Sagsnr.: MB28
Modt. dato: 2009.04.01

Sidenr.: 1 af 2

ANALYSERAPPORT

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej, 2800 Kgs. Lyngby
Prøvested.....:
Prøvetype.....: Andet
Prøveudtagning...: 2009.04.01
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.01 - 2009.04.20

Prøvenr.:	89637101			
Prøve ID:			Detekt.	
Prøvemærke:		Enheder	grænse	Metoder
Coliforme bakterier 37 °C	**<1**	ant./100ml	1	Colilert®
E. coli	**<1**	ant./100ml	1	Colilert®
Kimtal ved 22 °C, GEA	**>3000**	Antal/ml	1	DS/EN/ISO 6222
Kimtal ved 37 °C, GEA	**>3000**	Antal/ml	1	DS/EN ISO 6222
pH	**7.0**	pH		DS 287:1978
Ledningsevne	**1500**	mS/m	0.1	DS/EN 27888
Hårdhed, total	**84.5**	H grader	0.5	SM3120-ICP
Calcium (Ca)	**310**	mg/l	0.50	SM3120-ICP
Magnesium (Mg)	**180**	mg/l	0.10	SM3120-ICP
Kalium (K)	**110**	mg/l	0.20	SM3120-ICP
Natrium (Na)	**2500**	mg/l	0.10	SM3120-ICP
Jern (Fe)	**32**	mg/l	0.010	SM3120-ICP
Mangan (Mn)	**3.6**	mg/l	0.005	SM3120-ICP
Ammonium	**110**	mg/l	0.006	SM 17 udg. 4500
Nitrit	**<0.005**	mg/l	0.005	SM 17 udg. 4500
Nitrat	**<0.50**	mg/l	0.50	SM 17 udg. 4500
Total-P	**11**	mg/l	0.005	DS/EN I 6878aut
Chlorid	**4500**	mg/l	1.00	SM 17 udg. 4500
Fluorid	**0.20**	mg/l	0.050	SM 17 udg. 4500
Sulfat	**140**	mg/l	0.50	SM 17 udg. 4500
Aggressiv kuldioxid	**<2**	mg/l	2	DS 236:1977
Hydrogencarbonat	**1400**	mg/l	3.0	DS/EN I 9963
Turbiditet	**340**	FTU	0.10	DS/EN I 7027
Farvetal, Pt	**28**	mgPt/l	1.0	DS/EN I 6271-2
Inddampningsrest	**8700**	mg/l	10	DS 204:1980
Iltindhold	**0.3**	mg/l	0.1	DS/EN 25814
Sulfid-S	**0.53**	mg/l	0.02	DS 280:1976
NVOC, ikke-flygt.org.kulstof	**46**	mg/l	0.10	DS/EN 1484
Methan	**0.014**	mg/l	0.005	GC/FID

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Nationalmuseet
Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej
2800 Kgs. Lyngby

Att.: Henning Matthiesen

Registernr.: A00996
Kundenr.: 82983
Ordrenr.: 603361

Sagsnr.: MB28
Modt. dato: 2009.04.01

ANALYSERAPPORT

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej, 2800 Kgs. Lyngby
Prøvested.....:
Prøvetype.....: Andet
Prøveudtagning...: 2009.04.01
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.01 - 2009.04.20

Prøvenr.: **89637101**
Prøve ID:

Prøvemærke:		Enheder	Detekt. grænse	Metoder
Oplysninger fra prøvetageren:				
Prøvens farve	**mørk grå**			VISUEL
Prøvens klarhed	**m. uklar**			VISUEL
Prøvens lugt	**jord**			ORGANOLEP

Tegnforklaring:
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20. april 2009

Kundecenter: tlf.72187295
Kontaktperson

Sys Bisgaard Hansen
Kvalitetssikring

Eurofins Miljø A/S
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CVR/VAT: DK-2884 8196

Nationalmuseet
Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej
2800 Kgs. Lyngby

Att.: Henning Matthiesen

Registernr.: A00997
Kundenr.: 82983
Ordrenr.: 603361

Sagsnr.: MB29
Modt. dato: 2009.04.06

Sidenr.: 1 af 2

ANALYSERAPPORT

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej, 2800 Kgs. Lyngby
Prøvested.....:
Prøvetype.....: Andet
Prøveudtagning...: 2009.04.01
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.06 kl. 13:49 - 2009.04.23

Prøvenr.:	89637001			
Prøve ID:			Detekt.	
Prøvemærke:		Enheder	grænse	Metoder
Coliforme bakterier 37 °C	**>200**	ant./100ml	1	Colilert®
E. coli	**1**	ant./100ml	1	Colilert®
Kimtal ved 22 °C, GEA	**>3000**	Antal/ml	1	DS/EN/ISO 6222
Kimtal ved 37 °C, GEA	**>3000**	Antal/ml	1	DS/EN ISO 6222
pH	**6.5**	pH		DS 287:1978
Ledningsevne	**2300**	mS/m	0.1	DS/EN 27888
Hårdhed, total	**165**	H grader	0.5	SM3120-ICP
Calcium (Ca)	**800**	mg/l	0.50	SM3120-ICP
Magnesium (Mg)	**230**	mg/l	0.10	SM3120-ICP
Kalium (K)	**200**	mg/l	0.20	SM3120-ICP
Natrium (Na)	**4300**	mg/l	0.10	SM3120-ICP
Jern (Fe)	**67**	mg/l	0.010	SM3120-ICP
Mangan (Mn)	**8.1**	mg/l	0.005	SM3120-ICP
Ammonium	**210**	mg/l	0.006	SM 17 udg. 4500
Nitrit	**<0.005**	mg/l	0.005	SM 17 udg. 4500
Nitrat	**<0.50**	mg/l	0.50	SM 17 udg. 4500
Total-P	**9.8**	mg/l	0.005	DS/EN I 6878aut
Chlorid	**6900**	mg/l	1.00	SM 17 udg. 4500
Fluorid	**2.1**	mg/l	0.050	SM 17 udg. 4500
Sulfat	**62**	mg/l	0.50	SM 17 udg. 4500
Aggressiv kuldioxid	**4**	mg/l	2	DS 236:1977
Hydrogencarbonat	**1810**	mg/l	3.0	DS/EN I 9963
Turbiditet	**35**	FTU	0.10	DS/EN I 7027
Farvetal, Pt	**56**	mgPt/l	1.0	DS/EN I 6271-2
Inddampningsrest	**13000**	mg/l	10	DS 204:1980
Iltindhold	**0.5**	mg/l	0.1	DS/EN 25814
NVOC, ikke-flygt.org.kulstof	**35**	mg/l	0.10	DS/EN 1484
Sulfid-S	**0.05**	mg/l	0.02	DS 278:1/1976
Methan	**0.14**	mg/l	0.005	GC/FID

Tegnforklaring:
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I.C.Modewegs vej
2800 Kgs. Lyngby

Att.: Henning Matthiesen

Registernr.: A00997
Kundenr.: 82983
Ordrenr.: 603361

Sagsnr.: MB29
Modt. dato: 2009.04.06

ANALYSERAPPORT

Rekvirent.....: Nationalmuseet, Bevaringsafdelingen, Arkæologi
I.C.Modewegs vej, 2800 Kgs. Lyngby
Prøvested.....:
Prøvetype.....: Andet
Prøveudtagning...: 2009.04.01
Prøvetager.....: Rekvirenten
Kundeoplysninger.:
Analyseperiode...: 2009.04.06 kl. 13:49 - 2009.04.23

Prøvenr.: **89637001**
Prøve ID:

Prøvemærke:		Enheder	Detekt. grænse	Metoder
Oplysninger fra prøvetageren:				
Prøvens farve	**sort**			VISUEL
Prøvens klarhed	**m. uklar**			VISUEL
Prøvens lugt	**ubehag.**			ORGANOLEP

Analysekommentarer:
Ionbalancen kan ikke forventes at passe indenfor +/- 5 %, da prøven indeholder udfældninger
Prøven indeholder store mængder bundfald(jord) dekanteres til alle analyser

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23. april 2009

Kundecenter: tlf.70224267
Kontaktperson

Annette Vendel
Kvalitetssikring

Appendix 3

Results from chloride and sulphate analysis in water sampled on several dates from dipwells at the quayfront (Eurofins). All results are given in mmol/L

	Dipwell	Depth (m asl)	m from harbour	Date: 09-06-05	20-05-08	01-04-09	30-04-09	06-05-09	20-05-09	04-06-09	10-07-09	30-09-09	05-11-09
Cl	MB9	-0.35	46	129.8	234.1	282.1	177.7	203.1	189.0	186.2	146.7	180.5	394.9
	MB12	-5.95	30	20.0	24.3	24.3	23.7	23.4	21.4	20.0	20.3	7.9	21.7
	MB24	-2.96	29		234.1	143.9	265.2	338.5	270.8	234.1	239.8	248.2	282.1
	MB25	-7.46	39		8.7	50.8	53.6	56.4	56.4	56.4	56.4	56.4	93.1
	MB26	-4.36	39		110.0		45.1	84.6	84.6	84.6	104.4	87.4	53.6
	MB27	-4.57	40		180.5	160.8	169.3	177.7	174.9	177.7	177.7	177.7	174.9
	MB28	-2.72	44			126.9	132.6	138.2	129.8	138.2	138.2	121.3	126.9
	MB29	-3.12	45			194.6	189.0	217.2	222.8	220.0	211.6	225.7	217.2
	FB1, 1.5	-0.5	37		5.1	25.1	22.3	12.1	8.5	14.7	3.7	0.4	2.5
	FB1, 3.0	-2.0	37		31.0	31.0	31.0	18.1	19.5	27.1			
	FB1, 4.5	-3.5	37		31.0	33.9	31.0	31.0	31.0	28.2	8.2	31.0	28.2
	FB1, 6.0	-5.0	37		16.6		13.3	14.4	16.4	12.4	13.0	11.3	12.1
	FB1, 7.5	-6.5	37		11.6	8.2	8.5	8.2	8.2	7.6	28.2	6.5	
	FB1, 9.0	-8.0	37		7.3	5.9	5.6	4.8	4.2	5.1	5.4	5.4	5.4
SO4	MB9	-0.35		4.16	12.49	13.53	8.54	9.27	9.06	9.27	7.29	8.54	19.78
	MB12	-5.95		0.17	0.17	0.30	0.21	0.29	0.29	0.20	0.33	0.12	0.28
	MB24	-2.96			11.45	0.51	12.49	15.62	12.49	10.41	11.45	9.89	13.53
	MB25	-7.46			0.19	0.03	0.07	0.06	0.15	0.05	0.02	0.00	0.00
	MB26	-4.36			2.81		0.15	0.14	0.16	0.19	0.00	0.14	0.00
	MB27	-4.57			0.35	0.47	0.61	0.28	0.27	0.10	0.22	0.57	0.59
	MB28	-2.72				1.46	1.46	1.04	1.77	1.56	0.69	0.83	0.60
	MB29	-3.12				0.65	0.78	0.00	0.61	0.27	0.01	0.12	0.02
	FB1, 1.5	-0.5			0.36	0.48	0.45	0.42	0.16	0.43	0.82	0.49	0.65
	FB1, 3.0	-2.0			0.28	0.35	0.20	0.11	0.61	0.76			
	FB1, 4.5	-3.5			0.07	0.04	0.19	0.05	0.10	0.09	0.08	0.12	0.16
	FB1, 6.0	-5.0			0.06		0.07	0.02	0.03	0.02	0.06	0.06	0.12
	FB1, 7.5	-6.5			0.05	0.01	0.16	0.05	0.02	0.02	0.05	0.09	
	FB1, 9.0	-8.0			0.07	0.01	0.15	0.01	0.04	0.09	0.17	0.08	0.06