RAPPORT ARKEOLOGISK SERIE : 2002-1

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway (1996-2001)

Elizabeth E. Peacock

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Peacock, Elizabeth E. (2002). Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway (1996-2001). Rapport Arkeologisk Serie 2002-1.

Trondheim, May 2002

Publisher
Institute of Archaeology and Cultural History
Museum of Natural History and Archaeology
Norwegian University of Science and Technology (NTNU)
NO-7491 Trondheim
NORWAY

ISSN 0332-8546
ISBN 82-7126-635-7

Front cover
Picture postcard of Schultzgate postmarked 1909. Scene looking north toward Our Lady Church with properties 5a, 5b and 7 on the right. (Photo: Photographer unknown. Special Collections, University Library in Trondheim. Photograph Collection UbiT:VII-Uhjmz 4844)

Layout
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Gordon Turner-Walker

Printed and bound in Norway by Skipnes Trykkeri, Trondheim

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Preface

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway (1996-2001) describes the establishment and first five years of the first environmental monitoring programme in Norway developed to monitor in situ archaeological deposits at a redeveloped urban site.

This report is intended for a multidisciplinary audience including the archaeological community, cultural heritage managers, the construction industry, local authorities, and natural and conservation scientists. For this reason, the report is broader than if written specifically for the project developer, and includes background chapters that address mitigation options, monitoring parameters and technologies, and the nature of Trondheim and its history.

The international interest that has developed in this project has led to its publication in English. Many urban areas in Northwest Europe face redevelopment and preservation pressures identical to those being mitigated in Trondheim. These cities rest on archaeology that has chronological depth and good survival, and likewise are confronted with obvious development pressure. It is recognised that the Schultzgate project has an obligation to share its experience and interim results with the larger European cultural heritage community. It is hoped that this project can be used to help form strategies for other similar small residential developments in redevelopment-protected urban areas.

The work reported herein has come about with the assistance of many people and organisations at different phases of the project. In addition to Vitenskapsmuseum, Norwegian Directorate for Cultural Heritage (Riksantikvaren), Selmer AS, Hunting Technical Services (UK), The Institute of Hydrology (UK), Norwegian Institute for Cultural Heritage Research (NIKU), Trondheim Community Geotechnical Section, Riksantikvaren's District Office in Trondheim, English Heritage (UK), and the US Army Corps of Engineers Waterways Experiment Station have contributed to the project.

Mat Davis formerly of Hunting Technical Services was instrumental in the technological design of the monitoring programme. His commitment, interest, and assistance to the project far exceeded Hunting's contractual obligations. The project team and site crew from Selmer AS were helpful, professional and a pleasure to work with in the planning for and installation of the monitoring programme at the Schultzgate project site. Sam Boyle of the Institute of Hydrology was most helpful in providing long-distance training in the operation and maintenance of the neutron probe.
Special thanks are extended to Gordon Turner-Walker for equipment and site assistance from the start of the project, as well as for moral support and fruitful discussions. Numerous conservation interns have had the pleasure of at least one rainy site visit to assist in taking neutron probe readings. Roar Sæterhaug, Head of Conservation at Vitenskapsmuseum has continually supported the project.

Last but not least, I am grateful to the current residents of both Schultzgt. 3 and Schultzgt. 5-7 for facilitating access to the monitoring installations in their homes, and for their hospitality and interest in the project during site visits.

The Schultzgt. 3-7 monitoring programme has been funded by Selmer AS.

Elizabeth E. Peacock

Trondheim, Norway
April, 2002

Introduction

In preparation for the one-thousandth anniversary of the founding of Trondheim, the city embarked upon a comprehensive renovation programme leading up to the 1997 celebrations. Among other things, the city was anxious to fill numerous gaps in street frontages in the protected historic city centre. Of particular concern were two small under-developed, vacant lots located on the street *Schultzgate* and situated directly opposite the Church of Our Lady, which dates from the 13th century. The redevelopment of these lots led to the first instance of a mitigation strategy based upon long-term environmental monitoring of the buried archaeological remains to be implemented in Norway. This monitoring programme is providing the first systematic evidence on the hydrology and water quality of in situ archaeological deposits under a redeveloped site in Trondheim.

Traditionally the Norwegian Cultural Heritage Act has stipulated that developers provide for carrying out archaeological excavations prior to new development in sensitive areas. Schultzgate lies within the automatically protected precinct of medieval Trondheim. Consequently, any redevelopment within this zone must be preceded by a complete investigation of the archaeology in the affected areas, and the costs involved in such an investigation borne by the developed. Over the years, a number of watching briefs and smaller archaeological investigations had been conducted in neighbouring plots. These revealed several metres of wet cultural strata in the neighbourhood, and many well-preserved organic finds were recovered, thus establishing the archaeological sensitivity of the area.

The proposed redevelopment of this site, to be completed in time for Trondheim's jubilee, was for continued domestic use. The project consisted of two modest, two-storey timber-framed buildings of residential flats for, among others, old-age pensioners. The costs of a full-scale excavation of the archaeology prior to construction made realisation of the project financially prohibitive.

The new local authority development plan for Trondheim city centre was adopted for this section of the city in 1988, in which the Norwegian Directorate for Cultural Heritage (Riksantikvaren) provided for the possibility of redevelopment without full-scale archaeological excavation. This plan is based upon minimising ground disturbance, and construction without basements or any form of structural foundations that penetrate into underlying archaeology.

Erecting a building on top of a protected site, and without sinking structural support into the cultural strata, was unproven in Norway as a non-destructive alternative to full-scale archaeological investigation. Planning permission was eventually granted for the redevelopment of the Schultzgate plots and hinged upon adopting an agreed-upon mitigation strategy. This strategy included both an engineered solution of rafted foundations and a long-term post-construction programme of environmental monitoring of the status of the cultural strata beneath the new residential buildings, to be funded by the developer. The mitigation strategy was agreed upon as a viable alternative, even though the knowledge and experience necessary to implement such a scheme was not well established. This was especially so considering both the northerly climate and the fact that most archaeological deposits in Trondheim lie above the level of the water table.

The new buildings were constructed in the period autumn 1996 - spring 1997. The environmental monitoring programme was installed in autumn 1996. Monitoring consists of periodic measurement of the soil hydrology and soil water quality of the in situ archaeological deposits beneath the new buildings. Based upon parameters being monitored, preliminary assessments can now be made five years into the project.

The setting for the monitoring programme

The city of Trondheim

Geography and climate

Trondheim is situated on the southern shore of the Trondheim fjord in Mid-Norway, about 50km inland east of the North Atlantic Ocean (Figure 1). The city lies in a wide valley on and along the delta of the tidal Nidelva River. The historic city centre developed on the flat peninsula delta wetland, Nidarnes (Figure 2). Nidaros Cathedral is located at the highest point on the peninsula (14m above sea level) in the southernmost part of the city centre. Although seemingly flat, the terrain of the peninsula rises gradually in elevation from about 5m above sea level in the north at the fjord shore to 14m above sea level in the Cathedral precinct 1km inland (Cramer 1989). The immediate landscape surrounding the city is undulating rather than steeply mountainous in nature.

Trondheim rests on a fluvial/glaciofluvial delta formed over the last 2,500 years as the result of the interplay between the changing course of the Nidelva River and shoreline displacement (Reitan et.al. 1999, Reitan 1983). During this period the sea level has dropped approximately 13m. This has been the final stage in the transformation of the local landscape that has taken place following the retreat of the last glacial event 10,000 years ago when the level of the Trondheim fjord in the delta area was 152m above today's sea level. Shoreline displacement continues in the city and is estimated to be at a rate of 4mm/year, or 40cm per century.

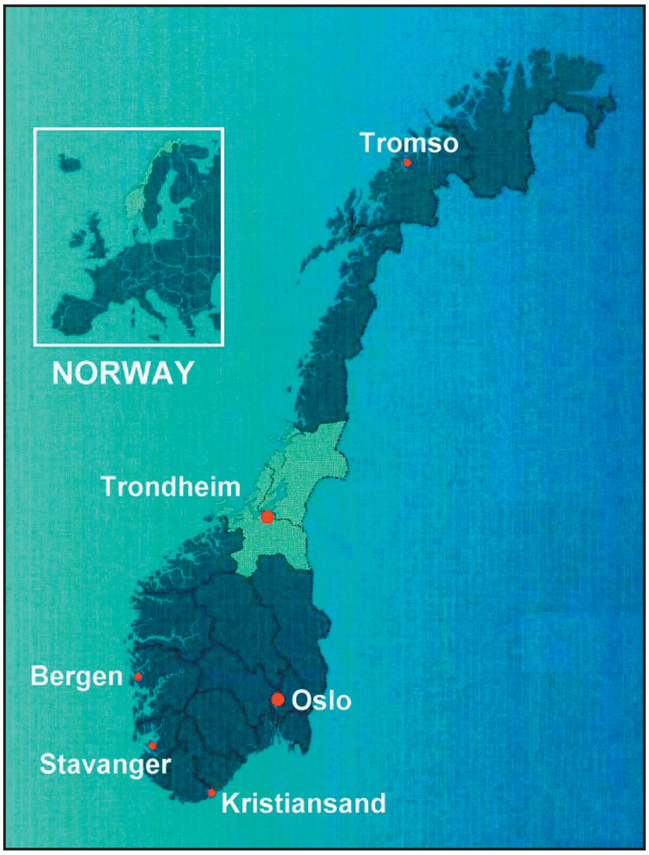


Figure 1 Map showing Trondheim in Mid-Norway with location map for Norway inset (Turner-Walker after Skogrand for Vitenskapsmuseum 1995).

Today the uppermost layers of the ground on the Trondheim peninsula consist of heterogeneous anthropogenic made ground, also called cultural levels, which vary between 2 to 6m in depth depending upon location. Below this are layers of clay, compact sand and gravel, and silt and sand deposits. Geotechnical investigations in the Cathedral precinct and further north in the city centre have revealed that the underlying sand and silt deposits extend to depths exceeding 50m. Bedrock lies at 50m depth in the eastern part of the city along the river, increasing to 125m as one moves west to the centre of the peninsula (Figure 3). The bedrock in the fjord occurs up to 800m below sea level, and this is overlain by about 300m of unconsolidated sediments deposited during the Quaternary and Holocene.

Studies show that the water table in the city centre lies at the interface between the compact sand/gravel layer and the underlying sand and silt deposits (Storemyr 1997). This is about 8m below ground level in the Cathedral precinct in the south and 3m in the north. The actual topography of the water table is irregular, and this has not been mapped across the peninsula. Soil more than two meters above the water table is scarcely affected by capillarity (Foth 1990). In general, considering the sand/gravel nature of the sub-made ground deposits of the Trondheim delta, ground water in many instances is not contributing to the water content of sub-surface layers, including the in situ archaeological deposits.

Taking into consideration its northern latitudinal position at 63°, Trondheim has a relatively mild climate. Air temperatures are strongly influenced by the North Atlantic Ocean current (Gulf Stream). That said, it is a frequently changeable, cold, maritime climate. Autumn is usually the wettest period of the year, winter is relatively cold with moderate amounts of snow, and spring is the driest period.

The annual average temperature is 4.9°C (1961-1990); however, recorded temperatures for the period 1893-1997 indicate that five of the ten warmest

Figure 2 Aerial view of Trondheim from the south showing the course of the Nidelva River and the city centre on the flat peninsula delta (after Aune Forlag AS).

years in Trondheim occurred between 1988 and 1997 when the average temperature was 6-7°C (Bjørbæk 1998). Temperature inversions are infrequent due to rather windy weather conditions. There are prolonged periods with sub-zero temperatures with an average number of days with sub-zero temperatures being around 130 (Figure 4). Consequently, Trondheim has seasonally frozen soils. The depth of the annual winter frost front varies and is moderated by snow cover. The frost front has been measured at a 1.6-1.8m depth in sand/gravel without snow cover, and Reed (1997) reports that a 2-meter deep frost front in the city is not uncommon. However, local monitoring near the city centre shows that even in a winter with numerous sub-zero events and some snow cover the temperature of the soil at 1m depth can remain above zero (Figure 5).

The city has a mean annual precipitation of 850mm (1961-1990) (Bjørbæk 1998). From December to April this falls more often as snow (Figure 6). The ion content of precipitation in Trondheim is mainly dependent upon natural constituents in the air (CO_2), dust and sea salts, while anthropogenic emissions of air pollution (distant and local sources) play a relatively minor role (Anda and Henriksen 1992). It is primarily the North Atlantic Ocean and the Trondheim fjord that provide excessive amounts of aerosols and ionic constituents (sea salt) in the precipitation falling over Trondheim. SO_2 concentrations in Trondheim are very low compared to those in Central Europe and the UK. The average concentration of SO_2 is about 5µg/m^3.

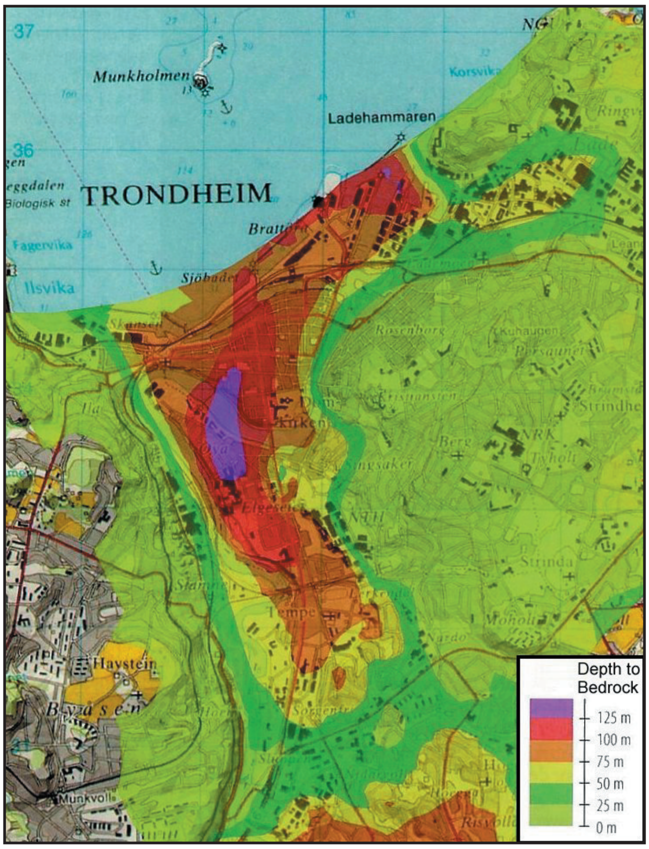


Figure 3 Geological map of the Trondheim area showing the depths to bedrock (after Reitan et al. 1999 and Statens kartverk).

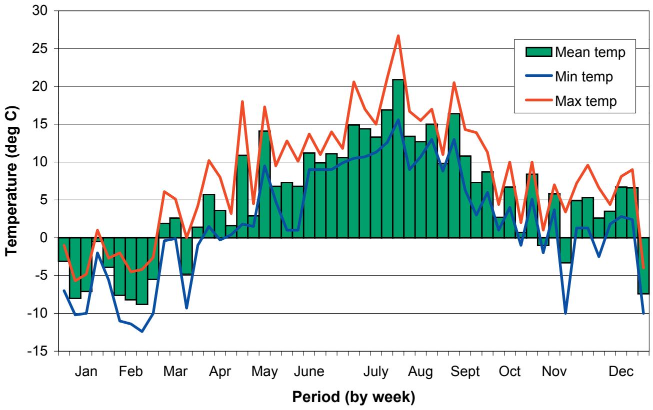


Figure 4 Weekly minimum, maximum and mean temperatures for Trondheim for 1994 (Turner-Walker after http://www.wunderground.com/history/station/01271/2001/3/31/DailyHistory.html).

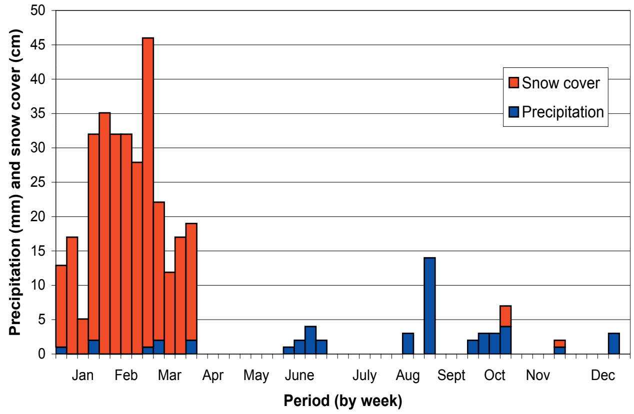


Figure 6 Weekly precipitation and snow cover for Trondheim for 1994 (Turner-Walker after http://www.wunderground.com/history/station/01271/2001/3/31/DailyHistory.html).

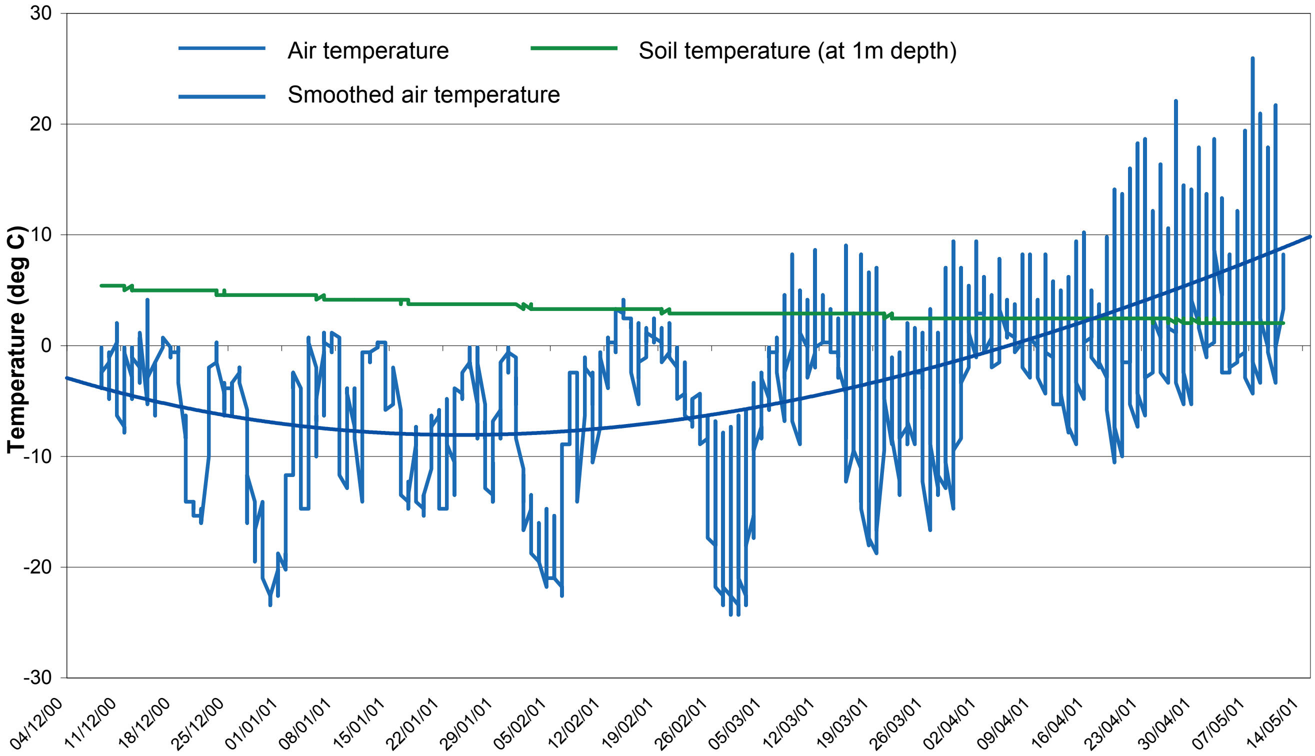


Figure 5 Daily air and soil (at 1m depth) temperatures for winter 2001 collected at Rørmyra, Trondheim.

In terms of acid rain Trondheim is a clean city. The region has not experienced the same acidification as southern Norway due to the geographical location and directions of prevailing winds. Environmental data collected for the Cathedral precinct in 1990-91 reported a mean pH of 5.5 (Anda and Henriksen 1992), This is higher than the background pH for the region, 4.9, but the readings did range between 4.2 and 7.3 (Anda and Henriksen 1992).

Development history

According to the sagas, Trondheim was founded in AD 997. It was in 996/997 that King Olav Tryggvason established a royal estate on the northeastern point of the Nidarnes peninsula at the mouth of the Nidelva River (Figure 2), and consolidated an existing marketplace just to the south. This trading settlement that grew into the medieval town of Nidaros, later Trondheim, had its loose-knit origins earlier in the mid-10th century. Archaeological evidence points to agrarian settlement on the peninsula already during the Viking Age (AD 800-1000) (Christophersen and Nordeide 1994).

Trondheim became an important political and religious centre during the early Middle Ages. The period of its founding was one of conflict in Norway between regional chieftains and the Christian kingdom's representatives. The surrounding Trøndelag district was seen as crucial in the campaign to unify the various parts of the kingdom, and the early kings focused efforts to bring Trøndelag under the control of royal authority. The trading settlement was

Figure 7 Aerial view of the Trondheim peninsula from the south with the Schultzgate project location highlighted (after Aune Forlag AS).

instrumental during this struggle, but at the same time it experienced rapid social, economic and demographic development evolving into a town.

The Monarchy and the Church did become firmly allied as the result of the canonisation of King Olav Haraldsson who suffered a martyr's death at the Battle of Stiklestad (north-east of Trondheim) in 1030. He was buried in Trondheim, and shortly after became Olav the Holy, patron saint of Norway. Through the rest of the 11th century Trondheim was the secular and religious centre of the country. It was a dynamic period of urban expansion for the town both functionally and physically.

At the end of the 11th century Trondheim became the centre for the country's bishopric, and in 1152-53 an archbishopric was established in Norway with Trondheim becoming the seat of the new archbishop. This was a decisive factor in establishing Trondheim's central role in Norwegian economic and political affairs throughout the Middle Ages. The ecclesiastical province encompassed Iceland, the Færoe Islands, Greenland, the Orkneys, the Hebrides, and the Isle of Man, in addition to Norway. The town continued to expand and develop and was an important commercial centre from the mid-12th century through the early part of the 14th century.

The town entered upon a period of dramatic decline towards the second half of the 14th century ushered in by the Black Death (1349-50), which decimated the population by as much as two thirds. Although

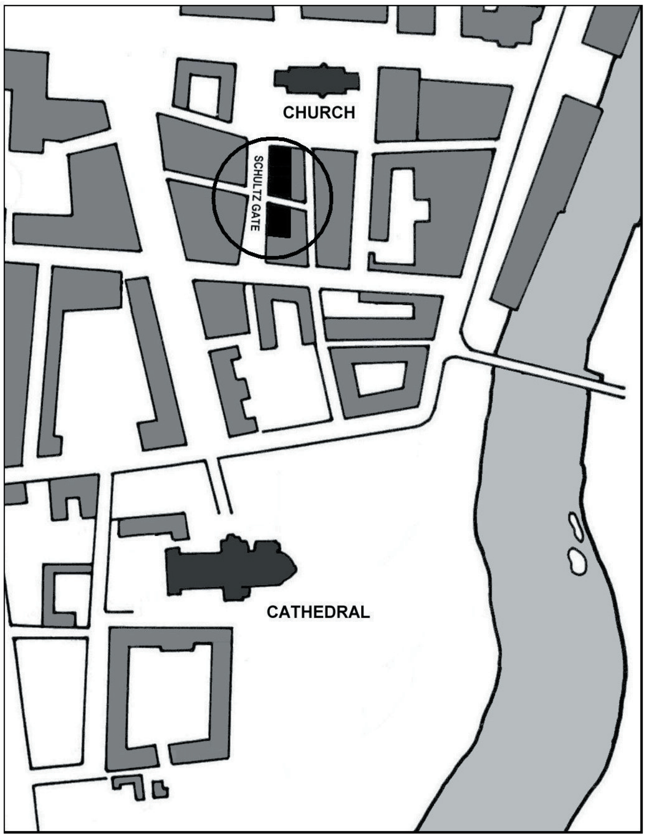


Figure 8 Map of the Trondheim city centre showing Schultzgate dissected by Munkhaugveita, and the two plots that make up the project site.

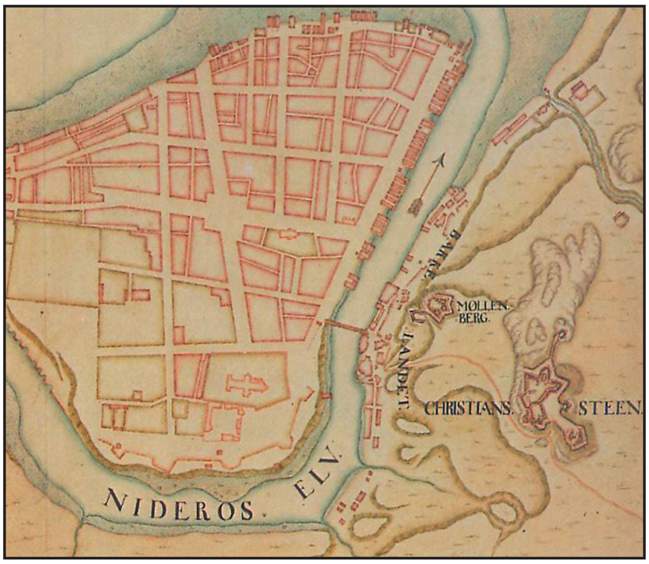


Figure 9 18th century map of Trondheim prior to the laying out of Schultzgate shows Munkhaugveita and St Jørgensveita.

Figure 10 Schultzgt. 1-7 circa 1900. (Photographer unknown. Special collections, University Library in Trondheim. Photograph Collection UbiT:X-Uhjmz 4846.)

Figure 11 Schultzgt. 7 prior to demolition in 1972. (Photographer unknown. Special collections, University Library in Trondheim. Photograph Collection UbiT:X-Uhjmz 73808.)

Figure 12 View of Schultzgate project site following pre-construction ground investigation in 1995 (E.E. Peacock).

Trondheim continued to be the religious centre of the country, the political centre shifted to Copenhagen following the Kalmar Union (1397) demoting Trondheim to a provincial centre. Norway became an increasingly unimportant part of Scandinavia politically. With the onset of the Reformation the town soon lost its religious dominance, and the last archbishop left in 1537.

Schultzgate project site

Schultzgate is a one-block street that runs between Vår Frue strete to the north to Erling Skakkes gate to the south. It is dissected midway by a narrow alley, Munkhaugveita, that runs east to west (Figures 7 and 8). The Schultzgate project site consisted of two building plots that are located on the east side of the street beginning at the corner of Vår Frue strete and straddling Munkhaugveita. Schultzgt. 5-7, the larger plot at the northern end, covers approximately 600m^2; whereas, Schultzgt. 3, the smaller plot at the southern end, covers approximately 220m^2, for a total project area of 820 m^2. Residential development boarders the project site at the south and eastern rear property boundaries. Schultzgate is not a major thoroughfare, nor is it situated near to busy traffic arteries. It lies approximately 250m from a main road (Prinsens gate).

The area around the Schultzgate project site is of medieval origin and lay on the western edge of the developing town, initially utilised to support the agricultural needs of the growing community. St. Jørgensveita, which runs parallel to Schultzgate one block east, is one of the oldest thoroughfares in the city and of medieval origin, as is Munkhaugveita (Figure 9). Both of the Schultzgate building plots would have been located within the back portions of properties fronting onto St. Jørgensveita, and would have been occupied by wood-built structures. The street plan of Schultzgate itself was not laid out until following the large city fire of 1846 that destroyed much of the area (Figure 7). As a consequence of two city fires in 1841 and 1842, the City Council in 1845 passed a resolution requiring new buildings to be constructed in brick. Small two storey buildings with full and half cellars constructed of brick and roughly hewn greystone blocks were constructed, fronting onto the new broad Schultzgate (Figure 10). The rear of these properties would have had outhouses and rubbish pits. Several of these structures were torn down in 1972 with the demolition rubble being levelled out to backfill the cellars (Figure 11). The site was thereafter levelled off with gravel and used as a car park until mid-1995 when pre-construction ground investigation was carried out as the first stage in the re-development of these two building plots (Figure 12).

Archaeological background

Trondheim is a major historic urban centre that possesses archaeological deposits with chronological depth, good preservation, and obvious development pressure from population increase and economic growth. It did not escape the explosive redevelopment of urban areas throughout Europe that began in the 1960's and that launched intensive campaigns of archaeological investigations of the Roman, Anglo-Saxon, Viking and medieval cultural levels in its cities. In Trondheim alone, over 170,000 catalogued artefacts have been recovered from 30 years of urban archaeological excavations. Through this activity Trondheim has been shown to possess a wealth of urban occupation deposits containing organic materials preserved in suboxic and anoxic (i.e., lacking oxygen) conditions.

The continued preservation of the medieval cultural strata beneath Trondheim during this era of intensive redevelopment was driven for the most part by a reactive rescue agenda of excavation (i.e., preservation by record) (Figure 13). The threat to the in situ archaeological deposits was removed by removing

Figure 13 Map of Trondheim city centre showing areas of archaeological significance (shaded red) and protected areas (outlined) (after Riksantikvaren).

the site. This was one drawback of fairly effective national laws in Europe protecting the archaeological heritage, such as the Norwegian Cultural Heritage Act that stipulated that developers provide for carrying out archaeological excavations prior to new development in sensitive areas. However, as a result, there now exists a substantial research database of archaeological and environmental finds that are witness to past human activity in the city. This database of physical evidence together with maps and documentary sources has been indispensable both in identifying areas of archaeological importance and sensitivity within the city, and in guiding development and strategic planning decisions. This database and documentary evidence were instrumental in identifying the significant archaeological potential of the neighbourhood around Schultzgt. 3-7.

In the 1990's there began to evolve a grassroots reaction in cities and towns throughout Europe and in general to the clearance schemes of the 1960's-1980's. Increasingly, citizens began to appreciate that the historic environment, including buried strata are an asset. At the same time the building materials and techniques used in the new structures of that era and which were intended to minimise impact on the archaeology that remained on the sites and in the deposits in the surrounding neighbourhoods, began to be suspect. Surveys in The City of London (Nixon 1998) and Lund (Sweden) (Larsson 1994) along with observations made in York (UK) (Oxley 1998, Kenward and Hall 2001) and Trondheim (Reed 1997) show unequivocally that extensive damage has occurred subsequent to redevelopment. In addition, recent research programmes in Sweden (Borg et al. 1994), Denmark (Madsen 1998), and in the Europe Community (Soil Archive 1998, Deterioration of Bone 1998) have activated artefact databases to study the deterioration in object preservation that takes place as a consequence of changes in the burial environment.

In 1992 representatives of twenty member states of the Council of Europe signed the revised European Convention on the Protection of the Archaeological Heritage. It was accompanied by the publication of *The Charter for the Protection and Management of the Archaeological Heritage* (Council of Europe 1993, O'Keefe 1993), which sets out the principles and guidelines to preserve in place (i.e., *in situ*) or by record (i.e., excavation) archaeological remains found either in development or research projects. This Charter is directed at local and central government planning authorities and developers throughout Europe, with the aim of producing common links and routes to achieve a successful balance between development or research work on the one hand and preservation of the archaeological heritage on the other.

This message is spreading into the consciousness of the European nations. Strategies for preserving this heritage have moved towards protecting archaeological remains where they lie, with preservation as the hoped-for result. The 1988 local authority development plan for Trondheim city centre that provides for the possibility to redevelop without full-scale archaeological excavation is one such example. This change has come about, including in Trondheim, for a variety of reasons, not the least financial. Beyond the immediate costs of removing the archaeology from a site, the costs for the huge volume of recovered material of assessing, analysing, conserving, recording, and storing for curation in perpetuity in a museum are considerable (Corfield 1996).

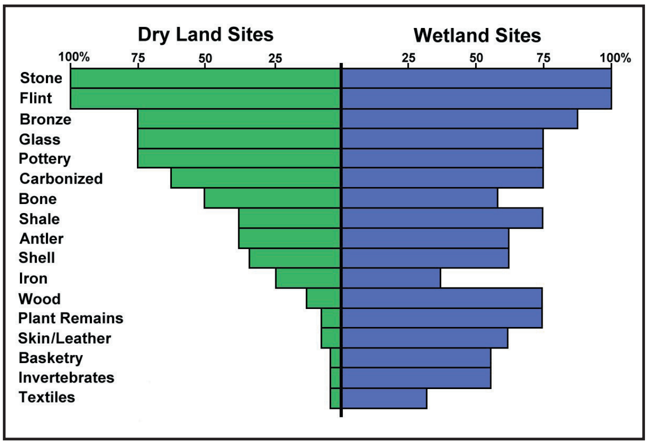
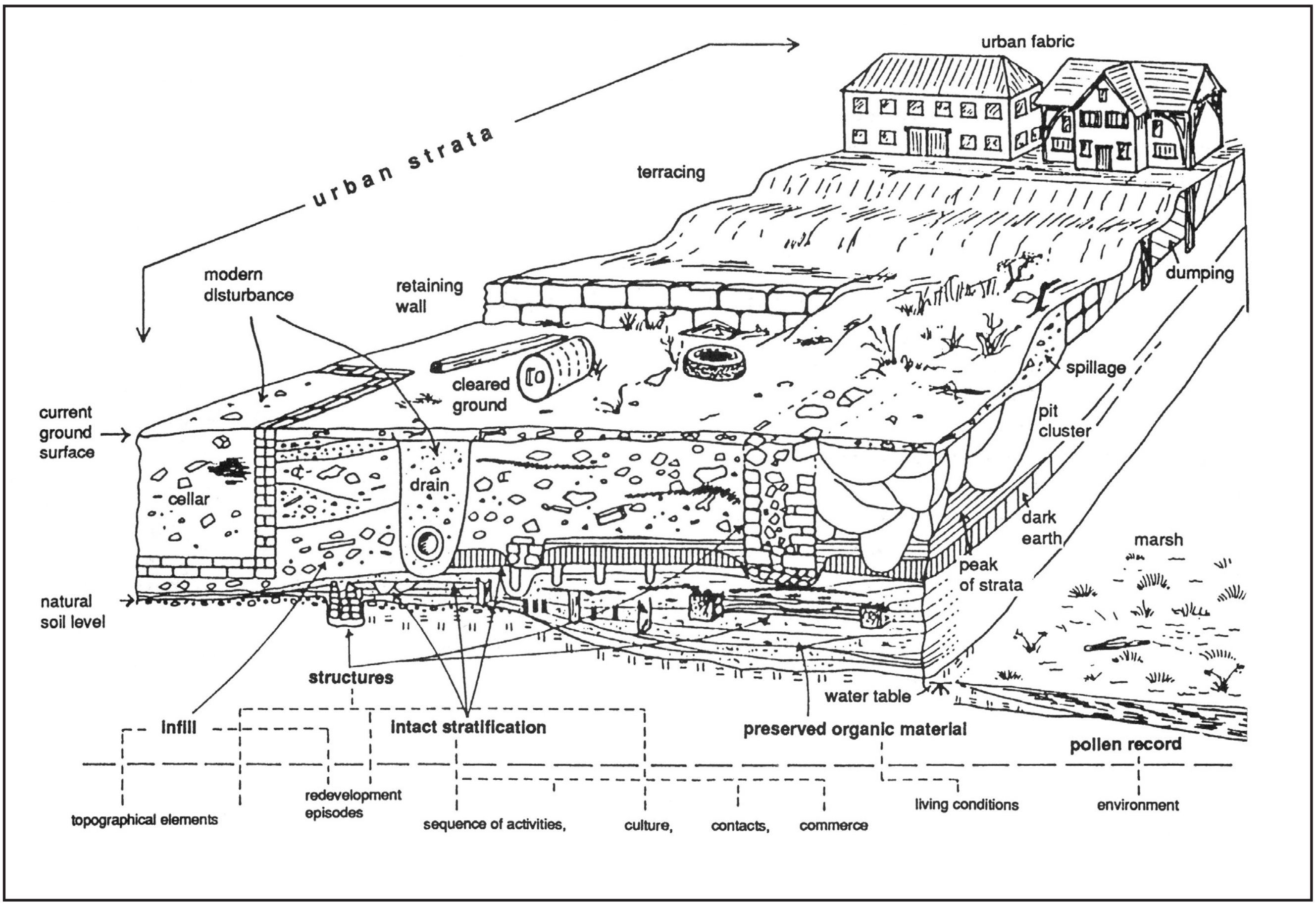


Figure 14 A general comparison of the preservation of materials on dry and wet sites (after Coles 1988).

The archaeological deposits beneath Trondheim are characterised as *wet*. Wet archaeological sites are found in wetlands (e.g., bogs, swamps and marshes) and drained wetland landscapes in the countryside or along coasts and estuaries, and beneath urban centres that developed along rivers and coasts (Nicholas 2001). The significance of wet archaeological sites is that they contain a better documentation of the past than has been retrieved from desiccated and eroded landscapes (Figure 14). Wet sites provide a broader perspective of the material types and their representation. In addition, they yield immense quantities of environmental and economic data. Coles (1988) has calculated that on dry sites 80-100% of all materials found are imperishable inorganics, such as flint, pottery, and copper alloys. On wet sites these materials make up 10-25% of materials found, while organic remains such as wood, textile, leather and environmental data seldom encountered on dry sites account for 75-90% of material recovered.

Unlike wetland sites, urban archaeological deposits are complex and heterogeneous. Carver (1983) has captured this scenario in a splendid cartoon (Figure 15). Survival of organic artefacts and ecofacts is promoted by a high level of moisture and correspondingly low oxygen content. It is the anoxic wet conditions of these sites that suppress the natural fungal and bacterial decay of these

Figure 15 Characteristics of an urban archaeological site (after Carter 1983).



materials. In urban sites a mosaic develops in the buried environment with anoxic pockets interspersed with oxygenated pockets. Preservation of organic materials in the cultural strata beneath modern Trondheim is good to excellent, but not uniformly so. It varies both across and throughout the Nidarnes peninsula. It is best in deposits along the waterfront and in foundations, rubbish pits, and wells.

The heterogeneity of preservation is perhaps best illustrated by reference to the preservation of medieval human skeletal remains excavated from around the Library Site (Turner-Walker, personal communication 2002). These have been extensively studied microscopically and although they exhibit excellent preservation of the organic component, the colours and surface conditions vary considerably depending upon the sediments into which the graves had been cut and the composition of the grave fill. The best preservation was seen in bones from graves cut into clay and backfilled with rich, organic loam. Bones recovered from silt loam were also well preserved. Bones from graves that had been cut into sands and gravels had heavily demineralized and leached surfaces and were in general relatively poorly preserved. Colours of the bones varied from white, through shades of brown to black depending upon local soil conditions.

The basis for the large and small pockets of excellent preservation in Trondheim is twofold. First, the town has its physical origins and early developmental period on the northeast tip of Nidarnes at the mouth of the tidal Nidelva and along its western bank leading into the Trondheim fjord. During this period the area was riverine/estuarine in character, with areas of wetland. Second, the town rapidly became an intensively occupied area of dense human habitation where thick deposits of organic waste were allowed to accumulate over short periods of time.

Mitigating the construction impact in the urban context

Impacts that cause degradation of in situ archaeological deposits are numerous and cumulative. Impact categories range from agriculture, bioturbation, vandalism, erosion, inundation, ice and frost action, construction and development, cultural factors such as acid rain, and natural impacts such as earthquakes (US Army Corps of Engineers 1992). Those that cause site degradation in the urban environment stem predominantly from redevelopment. Redevelopment and its associated groundwork and engineering operations impact site hydrology, soil water chemistry (water quality), and ground integrity.

Protecting urban archaeological deposits where they lie is a complex mandate. There is a wide range of engineering operations employed during the course of the redevelopment of an urban site that lead to ground disturbance, and consequentially, have the potential to seriously impact the in situ archaeological deposits. An equally wide range of practical measures and technical approaches have been investigated and adopted to reduce, avoid, or limit construction damage or disturbance. Each development will require a site-specific solution commensurate with the cultural significance of the site and incorporating a range of measures with the overall aim being to minimised and confine ground disturbance. An archaeological excavation may be part of this. The make-up of the solution will hinge upon the archaeological significance of the site, physical condition of the site, nature and design of new structure(s), and financial framework. Not all urban sites or parts of sites can or will be preserved in place.

An archaeologically significant site can be protected by avoidance. To preserve a site by avoidance, all archaeologically damaging engineering operations are excluded from areas of archaeological sensitivity. Ground disturbance is avoided and the threat of construction impact on the in situ archaeological deposits is removed. This may apply to an entire site, in which case it may not be developed, or to parts of a site. In the urban context avoiding the entire site will rarely be an option, but avoiding areas of the site may, especially for sites that consist of areas of greater and lesser archaeological sensitivity. In most instances, a buffer zone around the restricted area is necessary. But there will be many sites where ground conditions (e.g., high water table) are such that a localised buffer zone cannot be effective in guarding against construction impacts to, for example, the underlying soil hydrology from engineering operations in neighbouring areas.

Numerous measures can be employed to isolate the in situ archaeological deposits from ground disturbance caused by construction activities. The undisturbed ground can be covered or practically encapsulated by the installation of membrane barriers. This containment however, may cut the deposits off from the natural soil processes that are responsible for their specific burial environment. Alternatively where construction activities are to take place above subsurface archaeological remains, new materials can be introduced at surface level to create a buffer zone. The buffer zone aims to actively maintain the burial environment conditions of the in situ deposits. The most common buffering material is soil, including any already-in-place surface ground layers that are not archaeologically significant.

Re-using existing foundations, columns, service trenches, and other features has the benefit of minimising excavation. These features have already impacted the underlying archaeological deposits, and in theory their re-use limits additional damage resulting from sinking new foundations or digging new trenches. In practice, this frequently proves fraught with complications. In particular, determining the suitability of foundations - whether existing foundations are structurally sound enough to bear the loading of the new structure (Shilston and Fletcher 1998). This is especially an issue in light of increasing requirements to guarantee structural stability in the form of more substantial foundations, and in liability issues should the old structures not bear the new load successfully. In addition, the existing arrangement may not be workable for the desired layout of the new building (Tilly 1998). Comprehensive information about the design, geometry and condition of the existing foundations and sub-surface ground conditions can be difficult to obtain. Boreholes, trial pits and trenches aid in gathering this information, but also impact the in situ archaeological deposits. Loading tests to prove the capacities of the existing foundations can be technically and financially problematic. A variation of foundation re-use is the specification and construction of new foundations with the objective of re-use in the next generation of redevelopment of the site.

Protecting in situ archaeological deposits, structures and features does not necessarily mean not uncovering them, but may entail reburial. Simply, reburial is the placing of a fill material over an exposed site. It can be temporary such as burying a feature until the remainder of a site is excavated or for the long term. The theory is that the fill layer will protect the underlying features against the impact of all phases of construction. A range of materials and techniques have been developed for the capping and reburial of sites containing important archaeological structures and features.

Preservation for public display is also a method of protecting archaeological features where they lie, but one designed for continued exposure and public access. It is a mitigation option that requires post-construction monitoring and maintenance. An excavated, but not removed, archaeological feature or structure can be incorporated into the new building as it is, or it can be physically underpinned or isolated from the underlying strata by the insertion of a barrier. In the urban context preservation for public display has most frequently been used for stone/masonry walls and floors, and mosaic features. In Trondheim, this solution was adopted during the construction of several new buildings: the public library, a bank (SpareBank1 Midt-Norge), and the Archbishop's Palace Museum. The ruins of two medieval churches that came to light during excavations at the first two sites were left in place and successfully integrated into the public areas of these buildings. The floor of the medieval mint workshop uncovered during excavations at the Archbishop's Palace is a highly complex feature of integrated levels of organic and inorganic materials with a wide range of preservation conditions. Its incorporation into the new museums standing on the site is proving an environmentally more problematic feature for *in-situ* preservation for public display (Peacock and Turner-Walker 1998).

At the core of a redevelopment is the nature of the proposed structure itself: design, materials, piling, rafting, framing, load, etc. It is within this framework that the potential technical solutions must be worked out. The range of approaches and measures is beyond the scope of this report.

Monitoring parameters and technologies

Site condition is the result of a multiplicity of factors including site type, site size, environment, climate, rainfall runoff, natural factors, and a variety of modifications brought about by human actions. The result of these factors is a site condition that is not fixed but an interval at any point in time along a continuum of change. It has always been subject to change through time along what may be termed a site-decay curve or trajectory (Schisser 1987). Site protection represents an attempt to slow the decay process at a particular point in time. It cannot preserve the current site status quo; nor can it reverse the decay curve or arrest it, but they may serve to slow it down. Simply initiating a site preservation technique does not guarantee that the decay process has been halted. The preservation technique may fail or may not provide the anticipated control (US Army Corps of Engineers 1992).

The full extent to which a mitigation strategy has been effective in protecting the in situ archaeological deposits beneath a redeveloped site can only be evaluated by excavating the site at some time in the future. At that point, if the deposits have deteriorated unnecessarily, nothing (e.g., re-introducing water) can reverse the damage incurred by the archaeological and environmental evidence. Alternatively, an environmental monitoring programme can be established in conjunction with redevelopment to track the on-going condition of the deposits over a long-term future. The aim of such a programme is to flag changes in the in situ deposits at the earliest occasion so that remedial measures can be put into place before the site's burial environment becomes seriously compromised.

An environmental monitoring programme consists of periodic or continual systematic measurement of a series of parameters that are indicative of the deposit micro-environment. There now exists a growing body of research that is identifying the physical, chemical and biological factors of the urban archaeology environment, and their relationships, that lead to the preservation, or not, of organic materials. Hydrology is the most important factor affecting preservation of the in situ archaeological deposits at wet sites. Changes to it will affect the chemical and biological processes and so alter the rates of change of buried materials. Established monitoring programmes now assess soil hydrology, soil water chemistry (i.e., quality), and soil dynamics or movement as factors important in the continued preservation of the archaeological record.

Monitoring parameters

Soil hydrology

Hydraulic conductivity

The hydraulic conductivity (*k*), or the ability of soil to transmit water, is determined by the nature and size of the spaces and pores of the soil matrix through which the water moves. As long as the physical properties of a soil (including moisture content) remain constant, so too does the hydraulic conductivity. For example, increasing the load (i.e., compression) on a soil may decrease its hydraulic conductivity. Wet urban archaeological deposits are complex, stratified soils with different physical properties that lead to differences in hydraulic conductivity between and across layers. Downward movement of water is altered when the downward moving water front encounters a layer with a different texture, i.e. different hydraulic conductivity. Moving water tends to build up and accumulate at the junction between two layers. Changes to a site that alter the hydraulic conductivity may cause the draining of previously saturated preservative pockets in the archaeological deposits.

Water quantity

Soil moisture is an indirect limitor of soil oxygen, which is essential for aerobic metabolism of soil microbes. The greater the soil moisture, the fewer air-filled pores exist and the slower the diffusion rate. As soil moisture levels are saturated and free-oxygen supplies are depleted, overall microbiological activity declines. Growth yields for anaerobic microbes are much less. However, a flooded soil is not necessarily either anoxic or highly reducing (Tate 1985). Water movement through the environment as well as diffusion of atmospheric gases into the system may prevent exhaustion of free oxygen.

Soil water quality

It has long been realised that anoxic wet sediments can provide the necessary conditions for the survival of organic archaeological and environmental materials. The complexity and diversity of burial environment chemistry has hampered identifying the general physico-chemical conditions that are conducive to the preservation of organic archaeological remains. Recent research, conducted principally in the UK, has made great strides in characterising the chemical and physical limits of environments in which archaeological organic materials are preserved. From this work a range of chemical and physical factors have been singled out as representing the most important characteristics of the burial environment. Many of them are interrelated and their combined assessment is presently seen as indicating the condition of deposits containing archaeological materials.

Acidity

The concentration in hydrogen ions (H^+) or pH, is a measure of acidity or alkalinity. pH conditions result from coupled biological, geochemical and hydrological processes. It is an important parameter in archaeological environments containing water in which the hydrogen ions are mobile. Low values (3-6) are typical of acidic conditions whereas, high values (8-11) are found in alkaline environments. In general, the pH range reflects the soil type, such as riverine silt, estuarine silt, loamy clay, and peat. The pH of urban archaeological deposits tends to be circumneutral. The stability of archaeological materials is greatly affected by pH; consequently, pH defines threshold conditions beyond which materials are unstable. Because the pH range of stability varies widely for different organic materials, a long-term change in the pH range of an archaeological deposit may lead to the deterioration of materials that otherwise were in a state of chemical balance.

Temperature

Temperature influences the rate of chemical reactions and microbiological activity. The depth of overburden of an archaeological deposit buffers against changes in temperature in the atmosphere (Figure 16). As a result, the temperature of deep in situ deposits is warmer than the air temperature during the colder seasons and cooler than the air temperature during the warmer seasons. The extent to which temperature plays a vital role in slowing down the rate of deterioration increases with northerly and arctic latitudes. Reduction of soil temperatures below freezing results in significant decline in the microbial populations with the lethal factor being the slow thawing of the soil (Tate 1995).

Redox potential

The oxidation-reduction (redox) potential (Eh) is an electrical measure of the chemical activity in an environment, and is one of the key parameters in characterising the anoxic environment. The balance between oxidation and reduction plays a major role in determining the microbiological activity leading to decomposition of organic materials. High redox values (+200mV and higher) are usually found in unsaturated and agricultural soils and indicate oxidising conditions. Under these conditions most organic materials are quickly broken down into simple constituents and decay. Low values (-200mV and lower) are characteristic of reducing environments of waterlogged soils. Under these conditions preservation of organic materials can occur.

Archaeological deposits are a three dimensional mosaic with pockets of reducing environments interspersed with more oxygenated zones. There are various levels of reducing conditions, depending on the quantity of decomposable organic matter, the amount of oxygen brought in by water, and the temperature. Like pH, redox potential defines

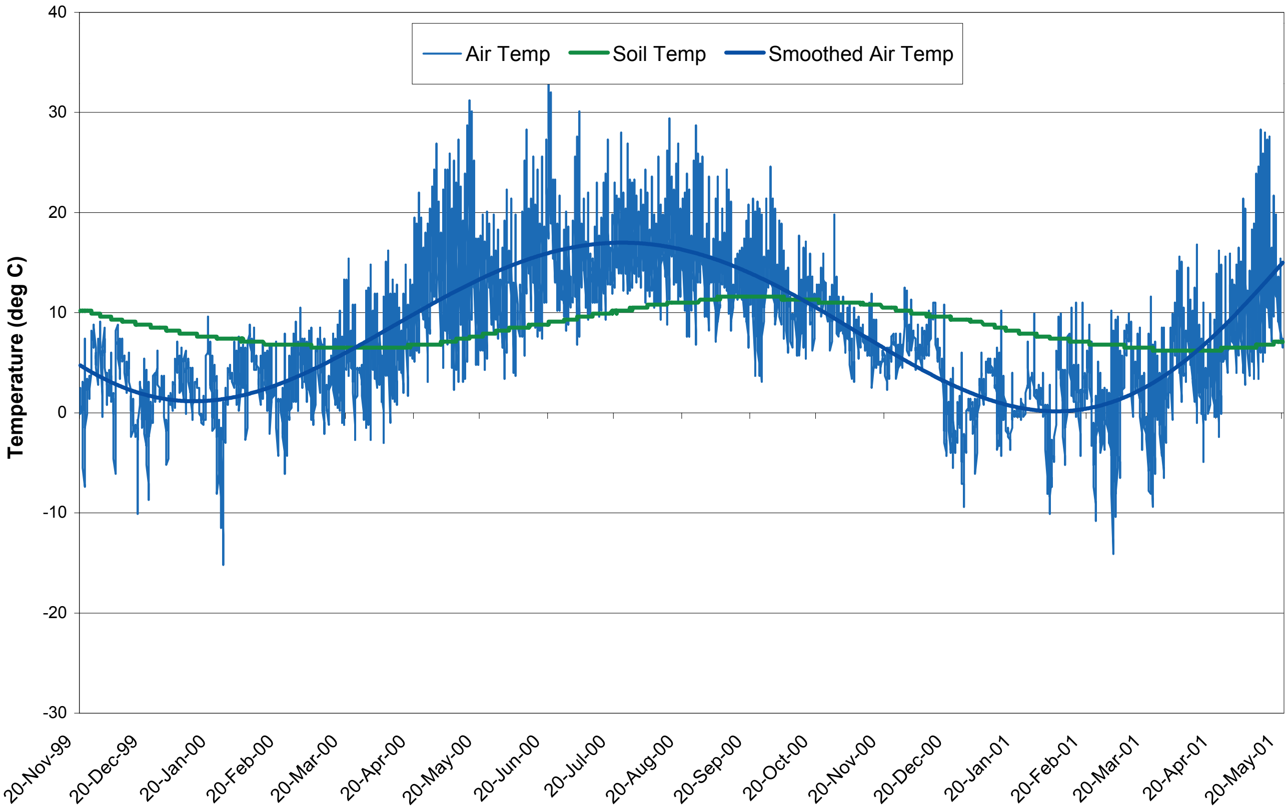


Figure 16 Differences in daily air and soil (at 1m depth) temperatures as illustrated by readings for 1999-2001 collected at Lejre, Denmark.

threshold conditions beyond which materials are unstable. Redox potentials for preserving organic archaeological deposits should be low, ideally below +200mV.

Dissolved oxygen

In archaeological deposits, voids are filled with air and water, and an indirect limitor of soil oxygen is soil moisture. The greater the soil moisture content, the less air-filled voids exist and the slower the diffusion rate of gaseous oxygen. The presence of oxygen within saturated deposits is principally due to the flow of oxygenated surface waters down through the soil. The arrest of water movement allows depletion of free oxygen by the existing aerobic bacteria and the rise of anoxic conditions. Drainage causes preserved in situ organic artefacts to deteriorate. Dissolved oxygen (DO_2) is a measure of the amount of free oxygen present in aqueous systems such as archaeological deposits, and thus an indicator of the potential presence of aerobic micro-organisms organisms which degrade organic materials. Anaerobic bacteria are less damaging to organic archaeological remains since they generally can only metabolise simple organic molecules and cannot directly degrade structural biopolymers - relying instead on much slower chemical degradation processes to release potential nutrients.

Electrical conductivity

Electrical conductivity (micro Siemens, μS) measures the extent to which a solution can conduct an electrical current and is influenced by the concentration of dissolved ions. The conductivity levels in the in situ archaeological deposits provide an indication of the level of dissolved ionic species within the soil water. Dissolved salts may have an effect on the buried archaeological materials. Conductivity can be used to monitor the type of water input into an archaeological site. Rainwater typically has conductivity levels of 10-50μS, river water and water running through undisturbed, uncultivated soil vary from 100 to 1000μS, and sea water has higher levels. Wetlands that are mostly fed by precipitation have low conductivity levels, whereas wetlands that are groundwater-fed have high conductivity levels (Caple and Dungworth 1998).

Soil movement

Soil movement in the form of shear, compaction, and settlement can occur as the result of the redevelopment of a site. Soil movements are caused by a number of processes, which rarely act on their own, to produce the effect of compression or foundation settlement. The in situ archaeological deposits can become compressed from the additional loading. This may cause localised increase in density and strength of the soil, and change the hydraulic conductivity of the deposits. Overburden can cause reduced levels of dissolved oxygen, and reduced water infiltration and movement rates. It may also bring about further physical deformation and damage to the in situ archaeological materials, such as building timbers.

Monitoring technologies

Effort is being expended to identify appropriate technologies from other disciplines that are suitable for archaeological field implementation to monitor and protect sites that are experiencing various physical and human-caused impacts. Davis (1998) has reviewed a range of technologies available for monitoring water quantity and water quality of land-based, wet archaeological deposits.

Soil hydrology

Archaeological deposits that extend below the water table provide for the possibility of direct access to groundwater through the installation of a piezometer, or dipwell. This consists of an open-ended, narrow-diameter, metal or plastic pipe that is inserted into the ground to a depth below the water table. Installation can be by hand or in the case of obtrusive soil matrices or greater depth by first creating a borehole. It is semi-permanent, simple to install and use, and sensitive to changes in ground water conditions; but it does cause some initial disturbance to the burial environment. The height of the water in the piezometer is equivalent to that of the water table. This can be measured by hand with a measuring tape with sounding device or electronic water level meter or by continuous recording using a monitoring well datalogging system. The dipwell does not provide information on the moisture content down its entire profile.

Archaeological deposits that lie above the water table require other technological solutions for assessing hydrological conditions. The simplest and most commonly used method to determine the soil moisture content directly in the field uses the tensiometer. This consists of a water-filled clear transparent plastic tube with a ceramic cup at the bottom end and a manometer at the top, alternatively with an electronic sensor giving out a continuous signal that can be read with a hand-held read-out device or a datalogger. Changes in moisture content are related to changes in pressure within the tensiometer. They come in a variety of lengths and are permanently installed directly into a pre-drilled borehole in the deposit.

There exist a range of soil moisture sensors and blocks that operate on similar principles of changes in electrical resistance or dielectric constant. They are installed directly in the deposit at various depths, and field readings are taken manually using a hand-held soil moisture meter or a datalogger.

The capacitance probe measures volumetric soil moisture content by measuring changes in the dielectric constant. There is a marked change in the dielectric constant as the water content of a deposit changes. The probe is connected to permanently installed plastic access tubes that are open-ended. Field readings are taken manually using a hand-held read-out device.

Moisture cells measure moisture content of soils by a change in electrical resistance. Cells consist of two small thin stainless steel plates that sandwich an electrical screen that provides the electrical coupling, and they can contain a thermistor to record temperature. The relationship between the soil moisture content and cell resistance must be calibrated for each deposit type. Cells are permanently installed into deposits at various depths with their wire leads channelled to the surface. Field readings of resistance (and temperature) are taken manually using a hand-held read-out device or a datalogger.

The above-described systems provide for readings of moisture content at the location of the cell or sensor. Two systems enable moisture measurement to be executed at any depth in an installed access tube: time domain reflectrometry (TDR) tube probe and the neutron probe. Time domain reflectrometry is based on measuring the propagation time of en electromagnetic pulse, the propagation time being dependent upon the moisture content of the soil. A TDR tube probe is lowered into a sealed thin-walled access tube, and measurements are immediately available. This measuring system is limited to a depth of 2 meters and 0-60% volumetric moisture content. The neutron probe is based on measuring the flux of neutrons scattered back from hydrogen atoms in the surrounding soil following introduction of a radioactive source. The portable probe is lowered down a permanently installed aluminium alloy access tube to the depth(s) from which readings are to be taken. Field data is converted into estimated volumetric moisture content using a standard calibration curve for a soil type similar to that of the deposit. This measuring system is limited to a depth of 4 meters and 0 to 100% volumetric moisture content. The soil moisture profiles generated by these devices can provide insight into the hydraulic conductivity of the site.

Soil water quality

Changes in soil water quality can be monitored in a number of ways: soil sampling and analysis; collection of soil water samples and analysis; and direct measurement in the archaeological deposits at the project site.

Monitoring based on the analysis of soil samples from archaeological deposits consists of standard laboratory soil analysis such as pH, sulphide, and organic content. This approach is seldom suitable for a long term monitoring programme because it requires repeated direct access to the archaeological deposits and because it is destructive in nature - being based on the removal of material. Soil sample analysis, however, is critical in the initial characterisation of a site. It should be conducted subsequent to the creation of trial pits and boreholes during pre-construction ground investigation, or following the installation of a monitoring system (e.g., neutron probe access tubes or water samplers), which ideally should take place during the pre-construction stage. Here soil analysis contributes to the site environment baseline data.

Long term monitoring can be carried out by analysis of the soil water. Archaeological deposits that extend below the water table provide for the possibility of direct access to groundwater through the installation of a piezometer. Water samples can be directly analysed for pH, dissolved oxygen, and other parameters in the field using portable monitoring sensors and water quality monitoring systems developed for pollution control and obtain immediate results. Laboratory-based analysis of samples can offer greater accuracy and a wider range of analyses, but may be subject to post-sampling changes. Yet another approach is the direct measurement of the ground water in a dipwell by either lowering sensors down for spot readings or installing probes for continuous monitoring using a ground-level datalogger. Caple and Dungworth (1998) question how representative dipwell soil water, which is not in intimate contact with the archaeological deposits, is of the surrounding deposits. They do note, however, that other disciplines do not question the limitations of dipwells.

Sites that lie above the water table require a different technology to access and collect soil water samples. One technology that has been developed for obtaining soil water samples from both saturated and unsaturated soils and at considerable depths is the pressure/vacuum soil water (suction) sampler. The sampler allows water to be removed from the soil matrix into the sampler by creating a vacuum inside the sampler greater than the suction holding the water in the capillary spaces. Hunting Technical Services (UK) has been in the forefront in adapting soil water sampler technology for use in monitoring water quality in wet archaeological deposits. Once collected, water samples can be analysed either on site or sent to a laboratory.

Measuring the quality of soil water in in-situ archaeological deposits can also be accomplished by inserting individual electrodes directly into deposits being monitored. These are connected to a hand-held reading device or to dataloggers that remain accessible on the ground surface. Caple and co-workers (Caple and Dungworth 1997, Caple, Dungworth and Clogg 1997, Caple and Dungworth 1998) and English Heritage (Corfield 1996, 1998) have investigated a range of probes and electrodes to monitor parameters such as temperature, pH, redox potential, and conductivity within a range of land-based wet burial environments in the UK. Similar research at Nydam Mose in Denmark has addressed the development of a suitable redox potential electrode for field measurement in wetlands (Aaby et al. 1999, Sørensen 1999). Other projects have investigated probes suitable for monitoring marine archaeological environments but will not be discussed here. Optrodes, which allow for surface-level measurement of colour changes of a chemical indicator encapsulated in a permeable membrane probe installed in archaeological deposits and connected by a fibre optic lead, offer yet another technique for monitoring some of these parameters (Corfield 1996).

The chemical composition of soil water is the result of a complex and dynamic interaction between the soil minerals, the soil atmosphere, the soil organic matter and aqueous temperature, pH and redox potential (Eh). Extracted samples are one step removed from this dynamic environment and chemical analysis either on site or in the laboratory inevitably reflects this. Direct measurement of soil water chemistry is therefore preferred; however, detailed measurement of many of the relevant soil water parameters in the field is fraught with complications of undisturbed access, robust and suitable instrumentation, and interpretation. Reproducible field measurements of such variables are notoriously difficult to achieve.

Soil movement

Soil movement resulting from redevelopment of a site can be monitored employing common engineering approaches to monitoring soil movement. These include the use of an inclinometer system in a borehole installation, in which settlement occurring in the ground surrounding the borehole is recorded as a measure of vertical deviation. A similar system is the extensometer, which is installed within a vertical access tube and records relative movement between an end anchor and reference tube (Hunting 1995).

Alternatively vertical displacement caused by soil movement is monitored using a profile gauge system, which enables measurements to be made beneath concrete and earth structures. This and similar systems rely on buried tubes installed into an excavated trench. The profile gauge uses a probe passed through the buried tube in which, if settlement has occurred, changes in level of the probe with respect to datum result in a pressure change in the instrument. Readings are processed to a profile of vertical displacement under the structure being monitored.

Mitigation strategy adopted for Schultzgt. 3-7

The mitigation strategy adopted for the redevelopment of Schultzgt. 3-7 is a monitored engineered mitigation strategy. It comprises a co-ordinated sequence of mitigation options aimed at avoiding or minimising the impact of construction activities on the in situ archaeological deposits at the site. The strategy consists of a number of components including: avoidance, an engineering solution, and a post-construction environmental monitoring programme. The mitigation strategy did not include either a limited or a localised excavation of the archaeological deposits, nor does it specify remedial measures to be put into place should the post-construction monitoring programme indicate that the in situ archaeological deposits are not adequately protected.

Trondheim city centre consists of quarters of larger commercial enterprises such as banks, hotels, and shopping precincts and public buildings interspersed by pockets of residential and small business neighbourhoods. The neighbourhood of Schultzgate is one of these pockets, consisting of small two storey buildings, mostly the 1846-era brick and stone masonry structures of the type that previously stood on the two Schultzgate building plots, but also some timber-frame buildings that pre-date these (Figure 17).

In this archaeologically sensitive quarter of the city, redevelopment has traditionally required a full-scale archaeological investigation (i.e., preservation by record) prior to construction. This is destructive, time consuming and costly. The additional requirement that only residential development is permitted effectively blocks investment-led redevelopment. Commercially, the costs of an archaeological excavation are deemed unfeasible by developers, as these jeopardise the financial viability of development. A lower cost solution is necessary if sites in this area are to be developed, and in 1988 the new local authority development plan incorporated the possibility of building without cellars to reduce the impact on the buried cultural strata.

Figure 17 Schultzgt. 5-7 circa 1900. (Photographer unknown. Special Collections, University Library in Trondheim. Photograph Collection UbiT:VII-Uhjmz 4844.)

Since demolition in the 1970's, the two building plots of the Schultzgt. 3-7 site had been the subject of several redevelopment proposals. Unlike some of these, such as the mid-1980's cultural centre complex (i.e., Olav's Hall), which were substantial multi-storey structures necessitating extensive sub-surface disturbance to guarantee structural stability, the modest character of the proposed residential retirement flats for Schultzgt. 3-7, provided room for an alternative solution to a full-scale archaeological excavation and for mitigating the impact of their construction and associated activities on the in situ archaeological deposits. Preservation of the in situ archaeological deposits by record was discounted on the projected costs of such an exercise, and preservation by protection was pursued.

Archaeological and preservation assessment

A detailed desk-based assessment carried out by the Norwegian Institute for Cultural Heritage Research (NIKU) collected and analysed historic source material and the site excavation archives of all previous archaeological investigations for both the Schultzgate site and the surrounding neighbourhood (Reed 1995, Appendix A, Peacock 1995). The purpose of this was twofold. First, to compile available evidence for the in situ archaeology and the nature of its stratigraphy, and second, to establish as full a picture as possible of the location and condition of the half and full cellars remaining from the demolished brick buildings.

There are archaeological records for about a dozen excavation events in the neighbourhood, ranging from digging holes and trenches in order to repair services (with or without a watching brief) to trial and localised excavations carried out by Riksantikvaren's excavation office in Trondheim. Summarising these records, natural deposits are reported to lie at depths between 2 to 3.8 metres below ground level. The uppermost made ground judged of no archaeological significance varies from 0.5 to 1 metre or more in thickness. Consequentially, the in situ archaeological deposits under the Schultzgt. 3-7 plots could range from approximately 1m to a little over 3m in thickness. Common for the records of the

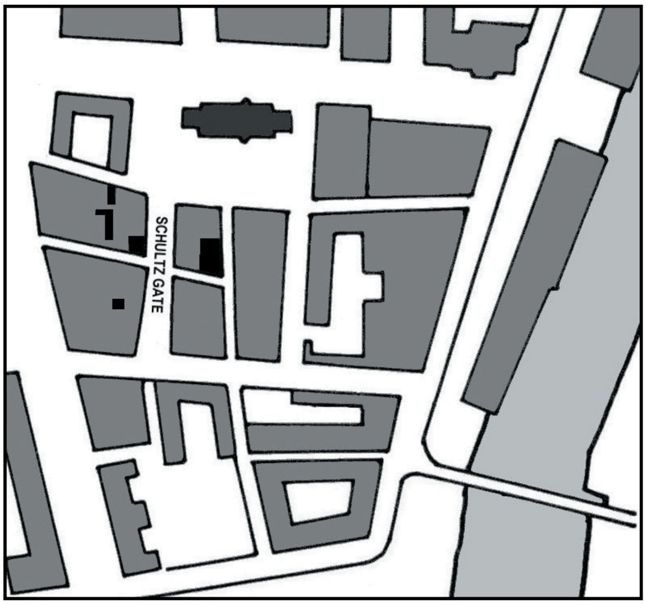


Figure 18 Map of Trondheim city centre showing the two plots that make up the project site and archaeological investigations TA 1985/12 and TA 1977/5 ('D') that yielded a range of organic artefacts.

trial and localised excavations are comments on the heterogeneous nature of the deposits, the frequency of included layers of sand/gravel/clay, and pockets of very wet deposits. Datings for some of the earliest phases ranged from AD 1000/1100. The excavation reports note well-preserved organic finds, especially wooden construction elements, floors, pavements and posts.

The desk-base assessment did not survey the range of small finds recovered from these investigations. Two of these investigations in particular, TA 1985/12 and TA 1977/5 ('D') (Figure 18), did yield artefacts covering a range of functions and material type. Schultzgt. 5-7 lies between these two sites. Site TA 1977/5 borders on the eastern property boundary of Schultzgt. 5; whereas, TA 1985/12 lies across Schultzgate from Schultzgt. 5-7. The small finds were examined for both their nature and state of preservation. A full range of well-preserved organic materials (i.e., wood, worked bone, leather, textiles and rope) was recovered from both sites and some, such as leather, in large quantities (Figure 19). A large amount of slag was also recovered, but the metal finds (mainly iron) were less well preserved. The finds recovered from TA 1985/12 point to the production of leather, worked bone and textile articles, and to metalworking. Worked bone is represented in raw materials and offcuts and a full range of items such as combs, gaming pieces, and ice skates. Stone loom weights and spindle whorls found at both sites, and bone needles in a range of sizes (at TA 1985/12) and wool fleece (at TA 1977/5) provide evidence for textile production.

The finds support the assumption that the full range of organic materials may be represented in the in situ archaeological deposits at the Schultzgate site, and that pockets of good to excellent preservation conditions within the deposits are likely. If the preserving conditions deteriorate leading to the degradation of the in situ wet organic archaeological and environmental materials, the eco- and artefact record for this area will be severely jeopardised.

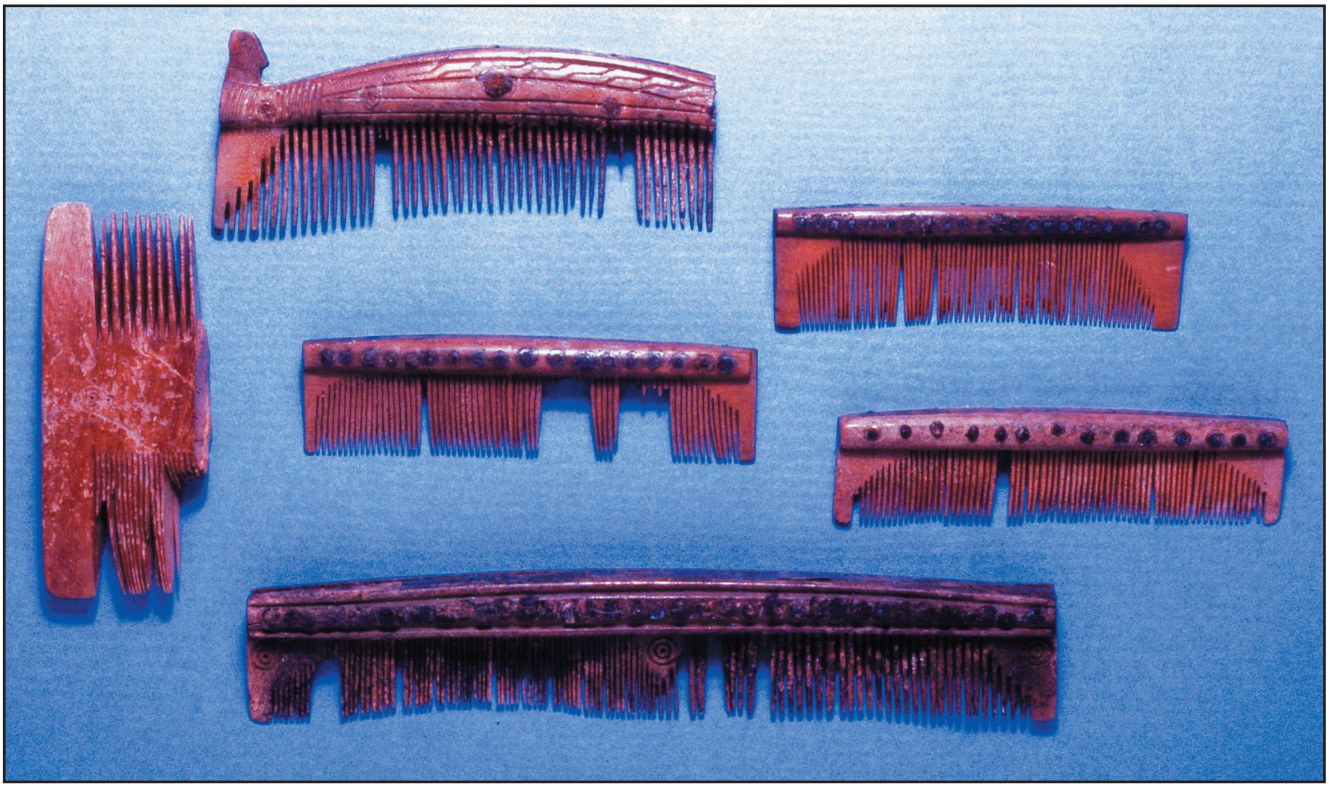


Figure 19 Selection of worked bone artefacts recovered during archaeological excavations at Schultzgate (TA 1985/12) across the street from the Schultzgt. 5-7 building site (E.E. Peacock).

Figure 20 View of site from Vår Frue strete looking south following field evaluation (E.E. Peacock).

The desk-based assessment was only partially successful in identifying and precisely locating the earlier cellars and foundation walls. It was then followed by an archaeological and geotechnical field evaluation of the project site in August 1995 (Reed 1995, Appendix A, Peacock 1995) (Figure 20). The purpose of this exercise was twofold. First, to map the geometry and near-surface condition of the foundations of the demolished buildings. Second, to identify at what sub-surface depths the archaeological strata began.

Under the archaeological supervision of NIKU, the modern overburden of gravel that formed the car park surface and sealed the demolition rubble was mechanically removed to expose the underlying made ground. Some of this demolition rubble was inadvertently disturbed and removed as well. The mapping proved difficult because much of the surface was covered with masonry rubble. Moreover the cellars had been backfilled with debris of similar construction material and for the most part it was not possible to differentiate between surviving foundation walls and backfill. It was not possible to located the filled-in cellars in Schultzgt. 3-5A. An unregistered cellar in Schultzgt. 5B was discovered and a known cellar in Schultzgt. 7 was found to be larger than earlier registered. Only with trial pits and trenches would the foundations be precisely located and their condition evaluated, and the geotechnical properties of the archaeological deposits ascertained. But such intervention would disrupt precisely the archaeology that was intended to be protected where it lay. Consequentially, the field evaluation was not supplemented by any further exploratory work such as a geophysical survey or field evaluation by trenching.

Engineering solution

The tailor-made engineering solution that was proposed comprised a rafted foundation with a modern timber-frame superstructure. One building was proposed for each plot. The location of these buildings lies on the street and alley frontages (i.e., Schultzgate, Vår Frue strete and Munkhaugveita) on the site of the earlier structures and extended into the plots approximately 7-metres from the frontages corresponding to the earlier buildings. The design leaves an open interior courtyard and a row of connecting outhouses along the rear (east) property boundary, similar to the mid-19th century layout of the plots (Figure 21, Appendix B). This lightweight, timber construction consisted of two storeys plus loft set on a ground wall with crawl space (Figure 22). Beams, flooring, outer walls and clapboard were all specified in wood. In order to make use of the earlier foundation walls, the width of the new structures was kept to that of the demolished masonry buildings.

The design of the rafts carries the buildings over much of the archaeology. For the most part, the open interior courtyards lie over areas of the plots that, for the most part, have not been disturbed by masonry cellars, thus avoiding building over cultural strata that have not been similarly compromised. The

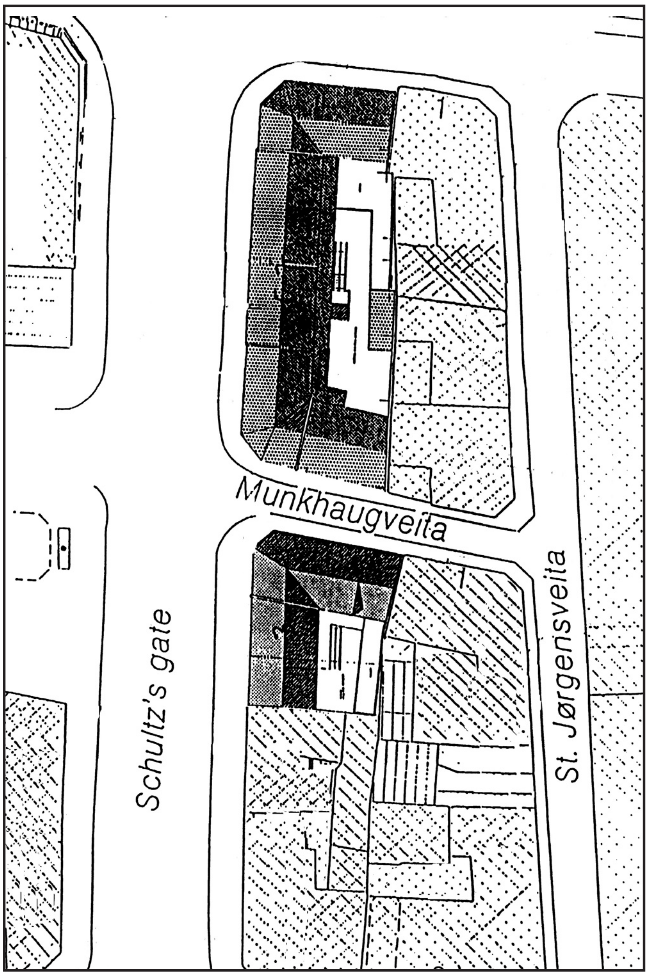


Figure 21 Design of the new buildings at Schultzgt. 3-7 in relation to neighbouring properties (after Selmer AS).

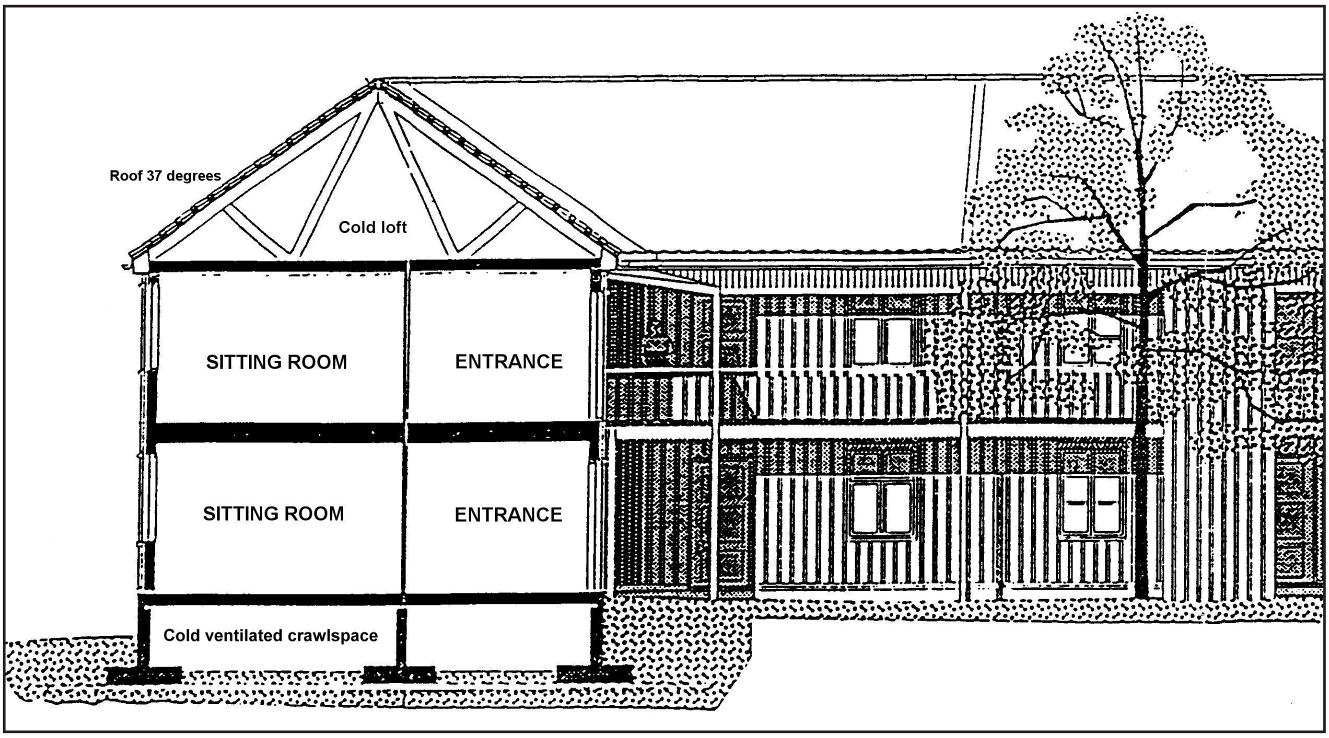


Figure 22 Details taken from engineer's drawings for Schultzgt. 5-7.

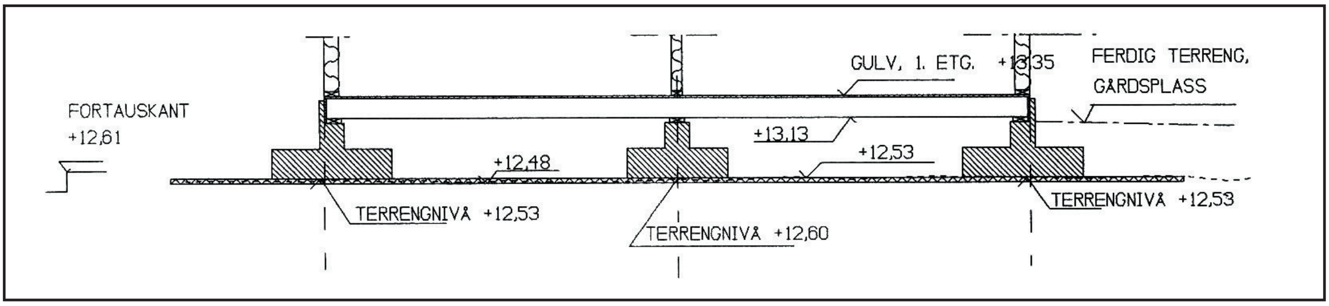


Figure 23 Details taken from engineering's drawings for the rafting.

new structures were to be set on new, cast concrete footings that rested on the earlier foundation walls (Figure 23). The footings would support the outer frame of the building. For additional support another footing would be cast inside this outer footing framework, and run parallel to the long axis of the building, connecting the two narrower exterior walls. The footing would have a 1-metre wide base and extend into the made ground 0.5-1.0m. The made ground (i.e., demolition rubble) in between the footings would be removed to form the crawl spaces. The finished ground floor would stand 0.5m higher than the pre-construction ground level. Following construction the rafted foundation allowed for the ventilated crawl space under the ground floor to accommodate services such as electricity, mains water and wastewater. Furthermore, the crawl space provided access to the in situ archaeological deposits should this prove necessary at some later date.

The ground had already been compromised through supporting the load from the brick masonry buildings constructed in the mid-19th century. Although the underlying levels would have experienced some unloading since the these buildings were demolished in 1972, they were currently bearing the load from their demolition waste and car parking. During the archaeological and geotechnical field evaluation the gravel car park surface was removed. Loadings from the removed surface and the cars were calculated for the areas to be affected by the new structures. These were estimated at 6.7 and 7.4kN/m^2 for Schultzgt. 3 and Schultzgt. 5-7 respectively.

Loadings for the new structures including full snow cover on the roofs and full occupancy loading were calculated at 16.8 and 18kN/m^2 for the smaller and larger plot respectively. Taking into account the loadings of the removed gravel and cars, the increase in loading would be 10.1 and 10.6kN/m^2 respectively. However, the final additional loadings would be in fact lower because 0.5-1m of demolition rubble was later removed from the crawl spaces. The remaining deposits of rubble covering the plots and which had no significance would function as a buffer zone, a form of capping, between the new structures and the underlying archaeological deposits.

The design incorporated re-using the existing frontage foundations from the 1846-era structures to minimise the need for excavation and hence the effects on the in situ archaeological deposits. However, problems would have been presented both technically in proving load-bearing capacity of the earlier foundations and financially in carrying out load tests. The calculated additional loadings from the projected structures were small in comparison with the perceived loadings from the previous masonry buildings. Ultimately, the existing foundation arrangement was judged suited to the design arrangement of the proposed new buildings.

The calculated loadings of the timber-frame superstructures would be spread between and along the three parallel footing walls. These walls were designed to impose a maximum load of $35kN/m^2$ (equal to the impact of a footstep of a walking adult or 30% of the loading of a car wheel) at ground level and fanning out with depth. Taking into account the reduced surface loading resulting from removal of the crawl space debris, it was calculated that the full loadings of the new buildings would marginally exceed the pre-construction car park loading, but not the loading imposed by the previous masonry structures.

Selected monitoring systems

Selection requirements and constraints

The monitoring programme developed for Schultzgate is based on technologies available in 1996. As previously described, a number of technologies were available that could be installed at a saturated or wet urban site of archaeological interest to monitor the sub-surface conditions of the in situ archaeological deposits, and to provide data on the stability of the site. These technologies were already being researched and developed for application to archaeological environments, in particular in the UK; however, these technologies had not been tested in Norway or a similar northerly climate.

A number of overriding factors severely limited the technologies that could be considered for the Schultzgate monitoring programme. The water table at Schultzgate is located deep within the natural deposits that lie beneath the site. (A geotechnical investigation was not carried out to specifically map its location and topography across the site.) The in situ archaeological deposits lie several metres above the water table with the consequence that there is no direct access to groundwater. The use of open-ended standpipes to monitor changes in the water table and to provide access points for the retrieval of water samples was therefore not an option. The fact that the water table lies well beneath the archaeology indicated that it was not a driving factor that keeps the water-retaining, preserving pockets wet. Consequently, monitoring the water table at Schultzgate is of less importance than at an urban site where the in situ archaeology is fed by groundwater; but, monitoring the moisture content throughout the deposits is critical.

The in situ archaeology at Schultzgate was not exposed and would not be exposed during pre-construction and construction activities, whether by trial pits, foundation trenches or rescue excavation. The implications from this were that at no time would there be direct access to soil profiles where probes and sensors used in conjunction with hand-held meters or dataloggers could be directly installed. The lack of exposed profiles also ruled out adequately determining the optimum depths and locations for installation of water samplers.

The lack of a survey of the stratigraphic make-up of the in situ archaeology substantially increased the probability that some instrumentation would become installed in deposits that were not the water-retaining preserving pockets the programme sought to monitor. For example, installing a water sampler in backfill. This likelihood was further increased by the complexity and heterogeneity typically found in urban archaeological deposits.

The monitoring programme was to operate for 10-20 years with no possibility to replace access tubes or buried (i.e., installed) sensors that may malfunction or that had a limited or unproven operating life span. The desired monitoring depth of moisture content was 4 metres and for soil water recovery was 3 metres, which eliminated technologies designed for near-surface application.

At the time of selection, none of the available technologies had been investigated for application to archaeological problems in northerly climates, such as that of Trondheim, where near-surface levels can be

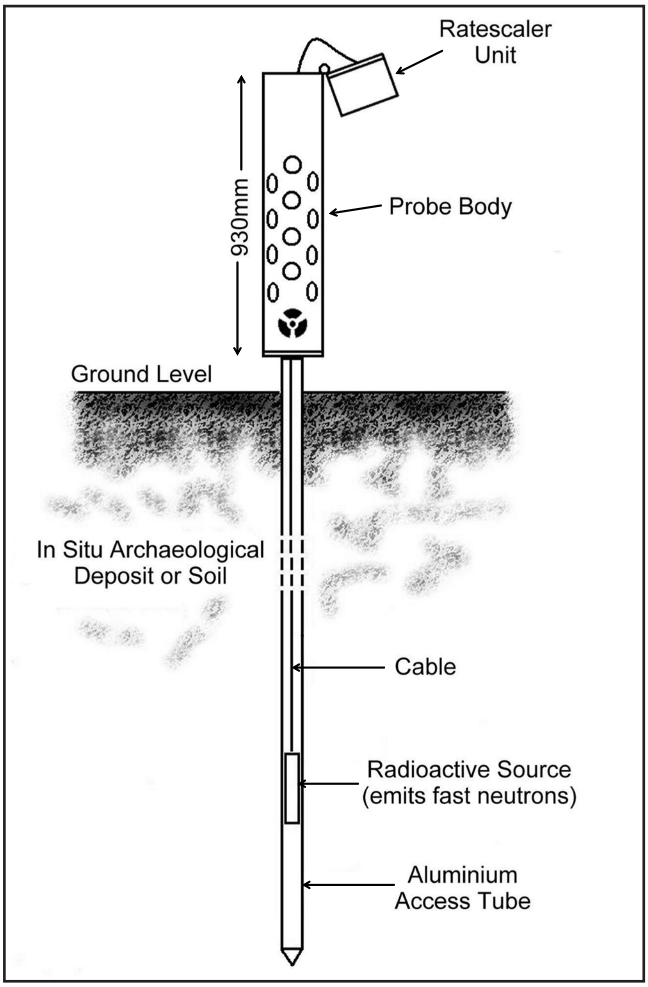


Figure 24 Schematic diagram of neutron probe in use situated atop an aluminium access tube (after Davis 1998).

subjected to freezing, perhaps for prolonged periods, during the winter. The winter climate would also present extreme working conditions for monitoring personnel and compromise access to monitoring points located out-of-doors.

Consultation with the environmental specialists Hunting Technical Services (UK) led to the selection of two monitoring technologies to provide long-term soil hydrology and water quality information: the neutron probe system to monitor soil hydrology, and water suction samplers to collect and monitor soil water quality. No provision was made for monitoring load compression.

Soil hydrology by the neutron probe system

Instrumentation

The neutron probe is designed as a portable field instrument for measuring in situ the volumetric moisture content of both the soil and the underlying unsaturated zone (Institute of Hydrology 1981). Developed for use in agriculture, it has been successfully adapted for use on wet archaeological sites by Hunting Technical Services (UK) (Davis 1998). Measurement is made by means of a probe that is lowered into an aluminium access tube that has been previously installed vertically into the soil profile (Figure 24). Soil moisture is determined at specific depth intervals down the tube to provide a soil moisture profile.

The permanent aluminium alloy access tubes are sealed at the lower end with a nose cone and require great care in installation to ensure close contact between the tube and the surrounding soil. The probe contains a sealed Americium-Beryllium (Am-Be) radioactive source from which fast neutrons are emitted into the soil. On collision with hydrogen atoms these neutrons scatter, decrease in speed, and lose energy. The resulting cloud of slow neutrons can then be sensed by a neutron detector. A Boron trifluoride detector contained in the probe registers the density of the 'cloud' of slowed neutrons. The mean count rate at the depth of the Am-Be radioactive source is recorded electronically by the probe's ratescaler. The count rate is linearly related to the volumetric moisture content of the deposit; the wetter the deposit, the higher the count rate.

A calibration curve based upon the textural character of the deposits is used to convert the field readings for each depth into estimated volumetric moisture content. The converted readings for a profile can then be plotted to form a moisture profile. Although archaeological deposits are highly variable, it is judged that the adoption of standard calibration curves is likely to introduce less error than special deposit-specific calibrations (Institute of Hydrology 1981).

The method is capable of producing consistently high quality data. Its use is best suited in situations where repeated measurements of soil water change are required over an extended period of time. This is because a standard water count rate must be calculated for each field session, calibration curves must be selected for each soil composition and the access tubes are a permanent and precise installation. However, the neutron probe system is robust and obtaining field data is straightforward, albeit time consuming. Both the system and site installation require minimal maintenance.

Methodology

The water quantity field data obtained using the portable neutron probe system consists of readings taken following installation in November 1996, and data collected during quarterly field visits conducted between November 1998 and September 2001. These took place in February/March, May/June, August/September and November/December with the exception of March 2001 due to extreme cold over a longer period. Although the probe system has been used at temperatures below −10°C, the system is not designed for operation below −10°C (Institute of Hydrology 1981). Field readings in November 1996 were taken by Hunting using one of their neutron probes. All readings made during 1998 - 2001 were taken using Vitenskapsmuseum's probe and operated by the same investigator.

Readings are taken at 100mm intervals up each access tube beginning at 3.8 - 3.9 meters and ending at 200mm below the top of the access tube. The soil/air interface greatly affects readings in the uppermost 250mm and the standard calibration curves do not apply in the sub-surface zone (Institute of Hydrology 1981). Field data collected in November 1996 consists of three readings per interval over a 16 sec count rate; whereas, the 1998 - 2001 readings consist of one reading per interval over a 64 sec count rate.

Field readings are converted into an estimated volumetric moisture content using a soil/deposit calibration curve and a standard water count (Rs). A standard water count is calculated for the neutron probe for each field session according to established procedures employing a water drum standard (Institute of Hydrology 1981).

Table I Standard calibration curves for principal soil types (after Institute of Hydrology 1981)

Deposit description	*Moisture volume fraction**
Sand, silt and gravel soil	0.790 x (R/Rs) – 0.024
Loam soil	0.867 x (R/Rs) – 0.016
Clay and peat soil	0.958 x (R/Rs) – 0.012

* R = mean count rate, Rs = water standard mean

The soil texture character of the deposit profile for each access tube was determined from the contents of the borehole (Appendix C after Hunting 1997). Standard calibration curves provided by the Institute of Hydrology (1981) for the three principal soil types recorded for the profiles (Table I) were evaluated for use with the Schultzgate field data (Hunting 1997).

Table II Estimated volumetric moisture contents from Access Tube 1 (after Hunting 1997)

Recording depth (m)	*Description of deposit*	*Estimated volumetric moisture content (%)*			*Lab. moisture content on disturbed sample (%)**
		Loam calibration curve	*Sand/silt/gravel calibration curve*	*Clay/peat calibration curve*	
2.20 – 2.80	Coarse sandy loam/ loamy sand	16 - 22	14 -19	18 - 25	11
3.40 – 3.90	Organic clay	53 - 60	48 - 52	59 - 65	32

* gravimetric method of determination

These three curves were applied to a sample of the neutron probe field data obtained for Access Tube 1 following installation in 1996, and the results are presented in Table II. The laboratory determination of moisture content for the recovered soil samples from these same levels is also presented. Based upon the comparative analysis, the *loam* calibration curve was selected for the standard calibration curve for the Schultzgate neutron probe field data (Hunting 1997).

To determine the reproducibility of taking readings down an access tube with the neutron probe, four successive runs were carried out for Access Tube 4, which is located outdoors. The resulting estimated volumetric moisture content profile indicates that the measurements are highly consistent (Figure 25).

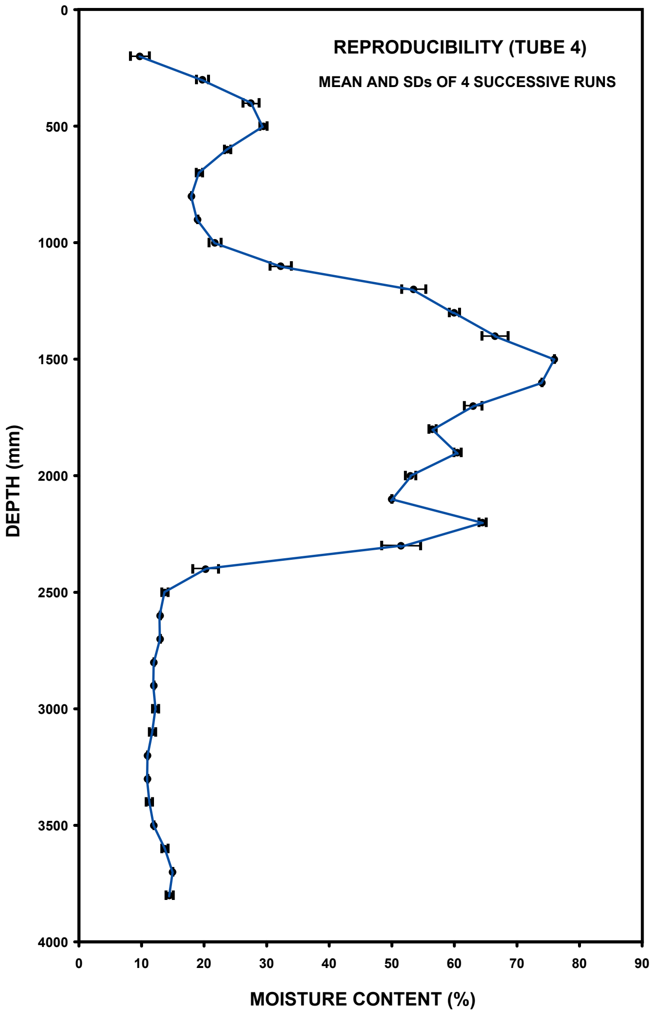


Figure 25 Estimated volumetric moisture content profile and deviations for four successive series of full profile measurement for Access Tube 4.

Soil water quality by water sampler recovery

Instrumentation

Pressure-vacuum soil water samplers (suction sampler) were developed for obtaining soil water samples from both saturated and unsaturated soils at depths ranging up to a hundred metres. The system allows water to be removed from the soil by creating a vacuum inside the sampler greater than the soil suction holding the water within the soil matrix.

Each suction sampler consists of a plastic (PVC) tube body with a porous ceramic cup bonded to the lower end (Soilmoisture Equipment Corp. 1997). The other, serviceable, end of the sampler is completely sealed and two tube connectors protrude from the top. Two polyethylene access tubes are connected to these connectors and are used for pressurising and evacuating the sampler, and for recovering the collected sample. A vacuum is established with a simple hand pump to pull water from the surrounding soil through the porous cup into the sampler body. The collected water is then pumped to the surface and into a container.

Soil water samplers are installed down an unlined borehole to the depth from which water samples are to be collected (Figure 26). The borehole can be created with a mechanical auger or rotary drill. A precision-cored borehole is not essential, but good contact between the porous cup of the sampler and the surrounding soil is. To establish this, the bottom of the cored hole is first filled with a slurry made from sifted excavated soil, and then the sampler is lowered into this. The remaining area around the sampler is backfilled with sifted soil to ensure complete sealing of the cored hole.

Methodology

Recovery

Field visits for soil water recovery took place following installation in November 1996 and in June 1997, followed by quarterly visits conducted between

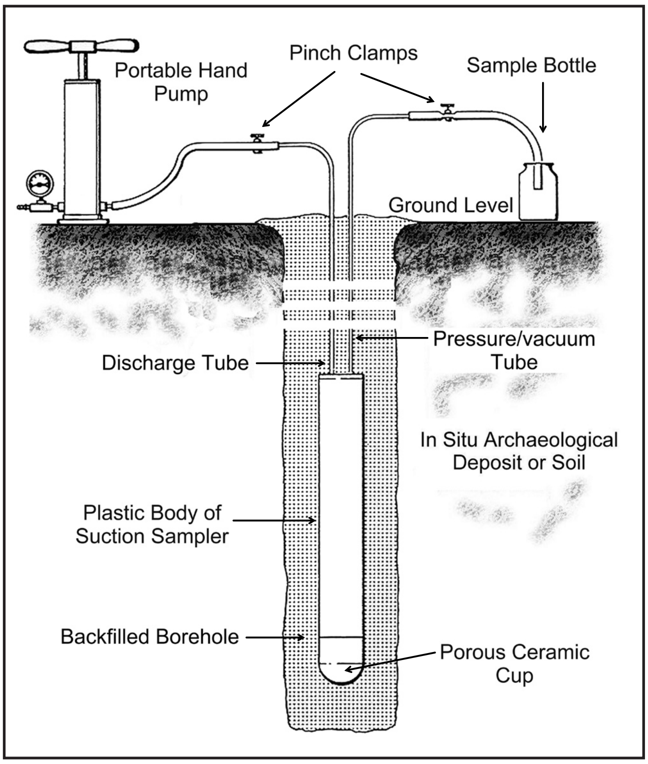


Figure 26 Schematic diagram of an installed water suction sampler and collection method (after Davis 1998).

November 1998 and September 2001. These took place in February/March, May/June, August/September and November/December. Although soil water recovery is carried out in outdoor temperatures below –10°C, the sub-surface transfer system (from suction sampler location in the courtyard across to the collection point) is not deep enough to avoid occasional freezing of the water sample in the duct.

Field visits consist of several sessions during a 48-hour period during which a vacuum of approximately 60 centibars is set on the sampler system by the use of a portable hand pump. The same hand pump is used to apply pressure to the system to force the accumulated soil water up through the polyethylene discharge tube. When collecting samples in the autumn-winter season the exposed ends of both the vacuum and discharge tubes require warming up in order to be able to manipulate them. Samples are recovered in 50ml brown glass bottles with polyethylene bung and screw cap. The temperature of the water, if recorded, is measured immediately.

Analysis

Costly, high quality, water analysis with a processing turn-around of three months was available at a local research institute. Because the Schultzgate monitoring programme aims to map trends in the soil water chemistry, immediacy in carrying out analysis once samples are collected has been prioritised over high quality analysis.

Site measurement of soil water chemistry was ruled out based upon climate conditions. A measurement regime consisting of summer site measurement and winter laboratory analysis could introduce an undesired discrepancy in the data. Consequently, chemical analysis is carried out at the Conservation Laboratory at Vitenskapsmuseum, a short walk from the site, the same day as the samples are collected. All soil water analysis carried out during the 1998-2001 monitoring period has been undertaken by the same personnel.

Soil water samples from Schultzgate are analysed once they have reached ambient room temperature. Dissolved oxygen (DO_2), redox potential (Eh) and electrical conductivity are measured electrochemically using conventional meters and selective electrodes. Instruments are calibrated prior to analysis. Sulphite (SO_2^{-2}), nitrate (NO^{-3}), nitrite (NO^{-2}) and pH are measured using a remission photometer to evaluate chemical-specific reflectrometric test strips developed for environmental water quality. Non-reflectometric test strips are employed to evaluate sulphate (SO_4^{-2}).

Establishing the monitoring programme

Installation of the monitoring systems

When planning permission was granted for redevelopment of Schultzgate, the window of opportunity prior to the onset of winter ruled out both installing the monitoring system and initiating the monitoring prior to development of the site. Construction needed to reach a certain phase before the onset of winter; otherwise, it could not be started until the following spring, the point in time for which the city wanted a presentable street front. As a critical result, this time factor precluded the opportunity to gather, prior to disturbance, vital pre-development, baseline soil moisture content and chemistry data for later comparison.

Installation was carried out in three phases. The first, and major work, was conducted 12-14 November 1996 after construction work had commenced but before the new buildings began to take shape. During the course of installation the wooden framework at Schultzgt. 3 was raised, and the ground wall at Schultzgt. 5-7 was cast. Installation work was directed by Hunting Technical Services with the assistance of staff from the Institute of Hydrology, Vitenskapsmuseum, Trondheim Community Geotechnical Section, NIKU, and Selmer AS. Selmer AS undertook the second phase, and Hunting and Vitenskapsmuseum completed the third phase. Twelve monitoring locations were established: five at Schultzgt. 3 and seven at Scultzgt. 5-7 (Figures 27 and 28, Appendix B). There are six stations for data and sample collection from these locations: two at Schultzgt. 3 and four at Scultzgt. 5-7. Three are sheltered and three are located outdoors.

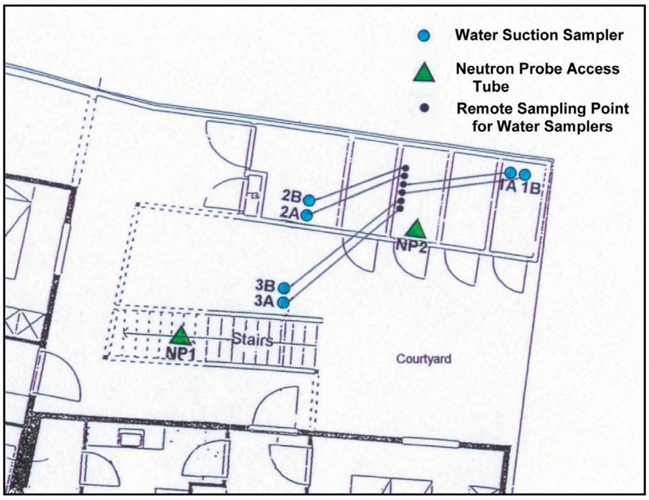


Figure 27 Building plans for Schultzgt. 3 showing the locations of neutron probe aluminium access tubes, water suction samplers, and collection points (after Hunting 1997 and Selmer AS).

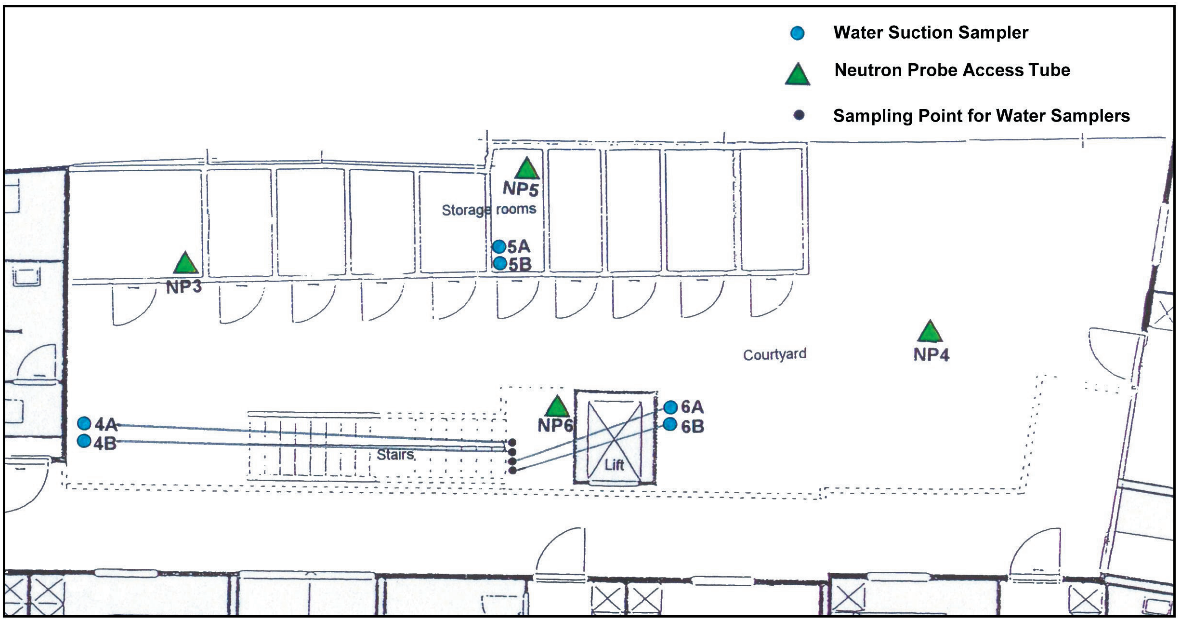


Figure 28 Building plans for Schultzgt. 5-7 showing the locations of neutron probe aluminium access tubes, water suction samplers, and collection points (after Hunting 1997 and Selmer AS).

Phase one (November 1996)

The first phase of installation entailed creating boreholes for and installing both the neutron probe aluminium access tubes and the water suction samplers. No access points were installed in areas that would be under the finished main buildings (i.e. crawl spaces) even though there are in situ archaeological deposits beneath the underlying 19th century cellars. Installation would have required boring through these cellar floors. Although the water samplers can be activated some distance from their installation points, location beneath a private residence would render investigative diagnosis impractical should they malfunction. Also impractical, would be taking readings with the portable neutron probe which must be set directly atop the access tubes.

Neutron probe

Six neutron probe aluminium access tubes were installed: two (Access Tubes 1 and 2) at the smaller plot (Schultzgt. 3) and four (Access Tubes 3, 4, 5 and 6) at the larger plot (Schultzgt. 5-7). One was situated in each of the two courtyards and the others were located in outhouses (Figures 27 and 28). The installation was carried out by staff of the Institute of Hydrology and Hunting.

In order to form the precise diameter of borehole for the aluminium access tube, a hand-held auger system was employed to core the boreholes (Figure 29). However, the high stone content of the first metre of made ground necessitated using a rotary auger system to core the uppermost section for tubes 2, 4, 5, and 6. The hand-held auger system was used for the remaining depth and for the entire coring for tubes 1 and 3. Core deposit samples were recovered during the coring and described in a log of the borehole profile (Figure 30, Appendix C). Once cored, the aluminium access tube was immediately hand installed in the borehole (Figure 31) Each tube passed to a minimum depth of 4.48 metres below ground level, and allowing for the nose cone, the total depth of each tube available for moisture content readings is 3.98 metres (Hunting 1997). Immediately following installation, the first neutron probe readings were successfully taken (Figure 32).

Water suction samplers

Twelve water suction samplers were installed - six at each plot. These were installed in pairs at two different depths in both the courtyards and under the outhouses (Figures 27 and 28). Drawing upon the desk-based assessment and 1995 site survey of

Figure 29 Coring of borehole with hand-held auger system for neutron probe aluminium access tube (E. E. Peacock).

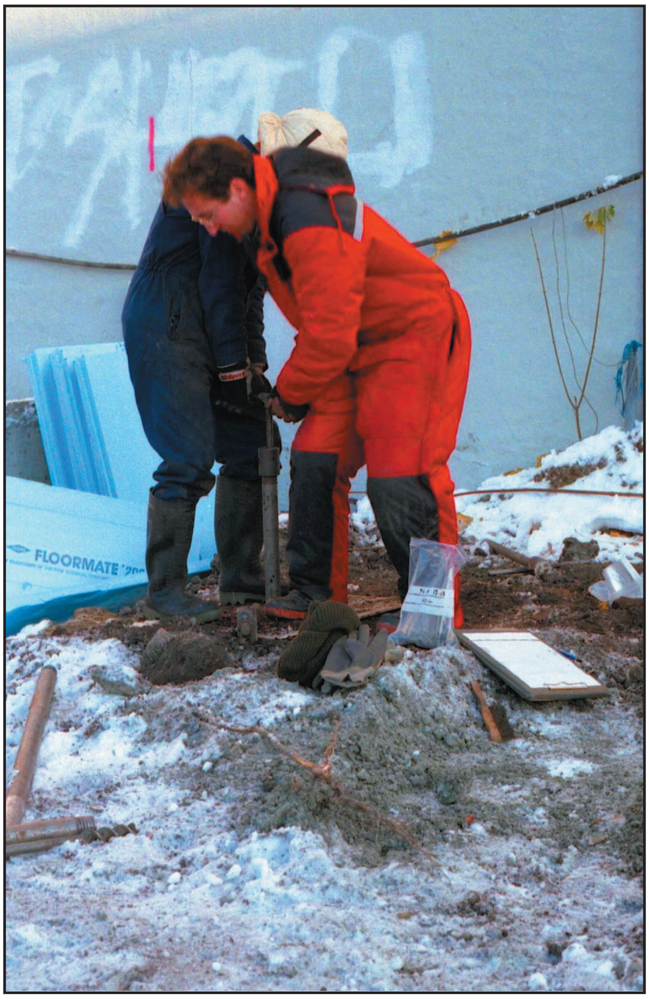


Figure 30 Recovery of core deposit samples for textural description and laboratory analysis (E. E. Peacock).

Figure 31 Installation of neutron probe aluminium access tube (E. E. Peacock).

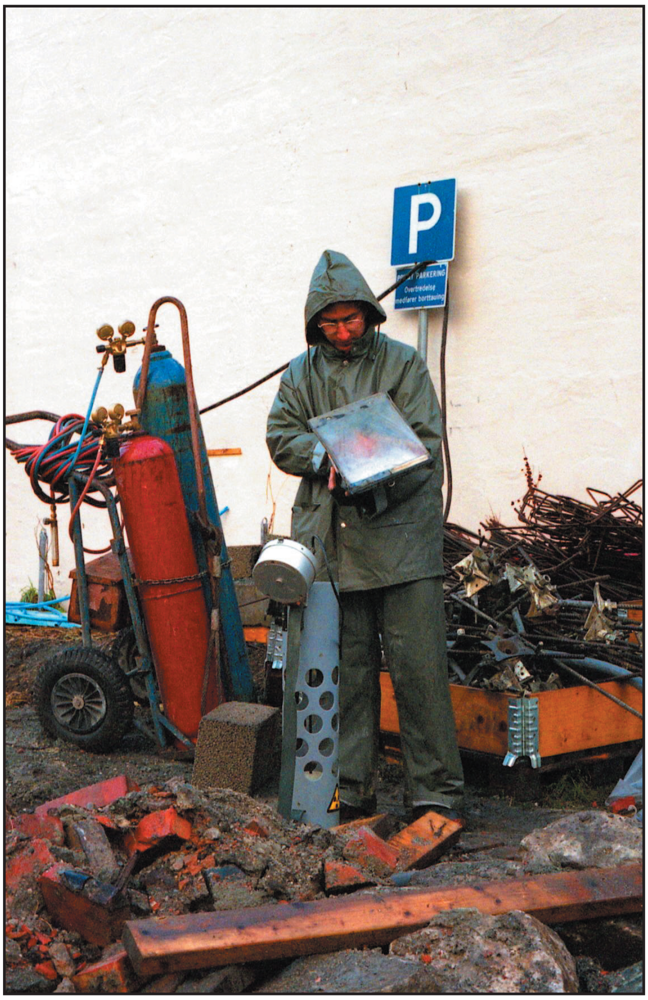


Figure 32 The first readings being taken with the neutron probe directly following installation in November 1996 (E. E. Peacock).

the in situ archaeological deposits, pair depths of 2 and 3m were selected. However, due to problematic ground conditions in the made ground encountered during coring and based upon a visual examination of the cores as they were extracted for archaeological deposit textural characteristics, the actual depths vary from these.

Boreholes were created with a track-mount mechanical rotary auger rig (Figure 33). This rig permitted a more rapid, although less precise, coring than the hand-held auger used for neutron probe access tube borehole drilling. In addition, the rig was able to penetrate the made ground despite encountering stone, wood and other obstructions. One-metre sleeved core samples were recovered during the coring, and this allowed for recording soil texture characteristics during boring to aid in targeting the samplers into wet, organic-rich pockets (Appendix C). However, problematic ground conditions frequently prevented the complete recovery of each metre of sample.

In preparation for installation, the exposed lengths of polyethylene tubing protruding from the top of the suction sampler body were run through a length of protective plastic pipe slightly longer than the installation depth of each sampler. This sampler-pipe assembly unit was eased down the borehole. The installation of water sampler 1B down the borehole was not successful leading to dislocation of the recovery polyethylene tubes. A slurry of removed core material (from the same depth) was poured into the borehole before and after installation of the suction samplers and protective pipes. The remaining depth was backfilled with recovered spoil and clean sand to near ground level, and capped with a slurry of bentonite (sodium montmorilonite) to form an impenetrable seal. The sand was of similar chemical and textural characteristic as that underlying the made ground (Table III).

Table III Laboratory analysis of suction sampler borehole backfill sand (after Hunting 1997)

Sand sample	*pH*	*Electrical conductivity (µS/cm)*
Selmer supplied	7.7	2230
VM supplied	7.7	2230

Immediately following installation, the soil water suction samplers were tested. Although no water was recovered, the sound of escaping air indicated the devices had been installed correctly and were functioning as designed.

Figure 33 Use of track-mounted mechanical auger for creation of water sampler boreholes (E. E. Peacock).

Phase two (spring 1997)

Once the buildings were completed, Selmer's site team completed the ground-level protection and cross-courtyard ducting for the access points. Permanent, protective concrete access chambers were constructed around each neutron probe access tube and each set of protruding suction sampler tubing (Figure 34). Secure lids and locking units were provided for access tubes located either in the courtyards or in outhouses that are accessible to the residents (e.g. rubbish bay). Beneath the exterior paving, protective plastic ducting was laid to provide for running the suction sampler tubing from exit points to central locations in outhouses where water samples could be recovered (Figures 35 and 36). This tubing was not insulated.

Phase three (summer 1997)

The water suction samplers were once again tested by Hunting during a site visit in the spring. Water was recovered from six samplers and the sound of escaping air was noted from the remaining five. The polyethylene tubing from the water samplers was threaded through the ducting to the central collection points in the outhouses (Figure 37).

Commencement of regular monitoring

The commencement of regular quarterly monitoring upon completion of construction became delayed until autumn 1998 due to several factors. Negatiations had been initiated in 1996 to purchase a new neutron probe from its sole producers Dipcot Instrument Company (UK). Production of neutron probes was by special order only. They were produced several at a time and production did not begin until all units were pre-sold. Production ceased altogether shortly after installation, and it took more than a year to acquire a certified used model. Chemical analisis of water samples had initially been planned for a local laboratory; however, the cost and three-month turnaround processing time together with the measurement immediacy of some of the parameters such as dissolved oxygen forced re-evaluating out-of-house processing. Instead an in-house water chemistry analysis programme was developed.

Analysis of recovered borehole soil samples

Logs were created of soil and deposit textural characteristics during creation of the boreholes for both the neutron probe access tubes and the water suction samplers (Appendix C after Hunting 1997). The sleeved condition of the former cores made viewing difficult for detailed on-site logging. The water table was not identified within borehole profiles, nor was its depth on site ascertained.

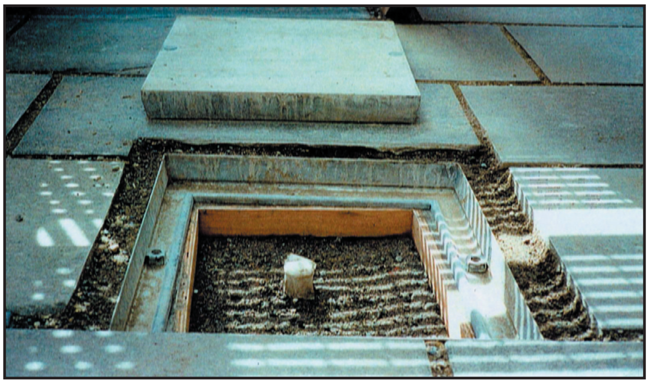


Figure 34 Protective chamber around neutron probe access tube (Hunting 1997).

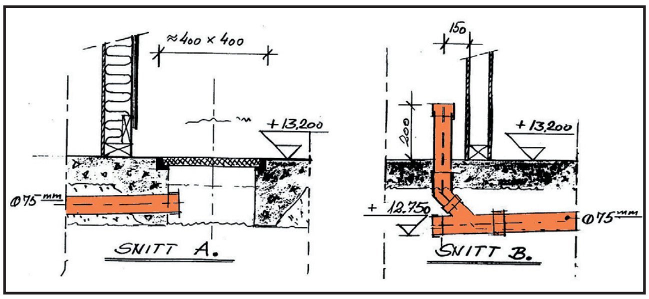


Figure 35 Schematic drawing of ducting system for water sampler plastic tubing (after Selmer AS).

Neutron probe boreholes

Interpretation of the logs for the neutron probe boreholes (Appendix C) indicates a greater depth of in situ archaeological deposits within Schultzgt. 3 that thins progressively to the north in Schultzgt. 5-7 (Hunting 1997). The archaeological deposits were in places very wet and contained material consistent with the development history of both the plots. They overlaid the naturally deposited sandy gravel soils; although the boundary between these deposits was gradual and often difficult to ascertain.

During augering of the neutron probe boreholes, 21 disturbed samples were collected from various depths from holes 1, 2, 3, and 6. These were subjected to laboratory analysis for: receipt moisture content by the gravimetric method, and organic matter content by both loss on ignition and wet oxidation methods (Appendix D after Hunting 1997). These results together with the deposit profile from the borehole log was used to arrive at the conversion calibration standard for use with the Schultzgate neutron probe field data. Although receipt moisture content is different from the volumetric moisture content reported by the neutron probe, the laboratory results are compared with the converted November 1996 neutron probe field data in Figure 38. The trends between the two sets of results are complementary for each access tube borehole; although, the estimated volumetric moisture contents are consistently greater than the respective receipt moisture contents.

Water suction sampler boreholes

During mechanical augering of the water suction sampler boreholes problematic ground conditions prevented recovering complete 1-metre core samples. Nine undisturbed core samples were subjected to laboratory analysis for: receipt moisture content (gravimetric method), organic matter content (loss on ignition and wet oxidation method), pH, electrical conductivity, sulphate and sulphide content (Appendix D after Hunting 1997). The relationship between the depth of the sampler base and depth of analysed corresponding soil sample is shown in Table IV. Four samples are from the same depth as the sampler, three are from just above or below, two are out of range, and three sampler cores were not analysed.

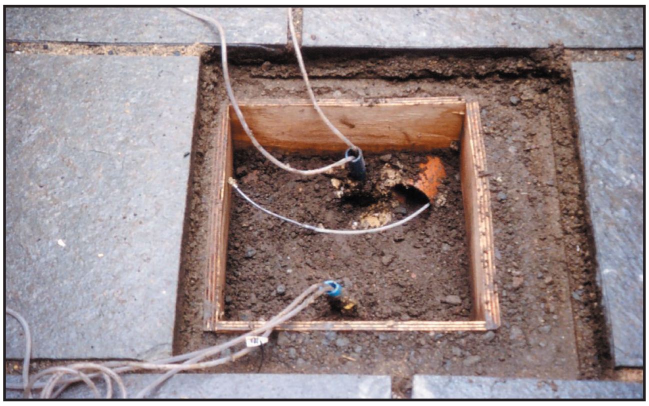


Figure 36 Chamber around water samplers showing the plastic vacuum/pressure tubes (blue) emerging from the protective pipes (orange) and the cross-courtyard ducting (E. E. Peacock).

Table IV Proximity of soil water suction samplers and laboratory analysed soil samples

Suction sampler	*Depth of base of sampler (m)*	*Depth of core sample analysed (m)*
1A	2.45	3.1-3.9 (out of range)
1B	1.45	1.5-2.3 (below)
2A	2.86	2.3-3.1 (in range)
2B	1.99	1.4-2.3 (in range)
3A	3.09	Not analysed
3B	2.11	Not analysed
4A	3.00	2.6-3.4 (in range)
4B	1.95	1.0-1.8 (above)
5A	2.92	1.8-2.8 (above)
5B	2.00	0.9-1.7 (out of range)
6A	2.10	Not analysed
6B	2.00	1.3-2.1 (in range)

Figure 37 Central collection points in outhouses for water sampler plastic tubing (Hunting 1997).

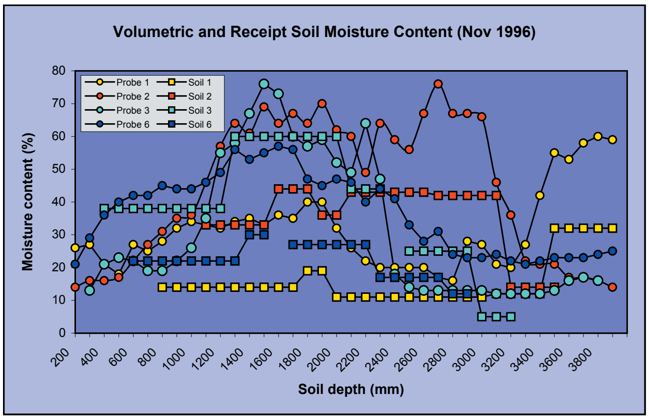


Figure 38 Comparison of estimated volumetric moisture contents by neutron probe and receipt moisture contents (gravimetric method) of core samples from access tube boreholes (receipt moisture content data from Hunting 1997).

The archaeological deposits range from very wet and highly organic loamy peat deposits (moisture content 30-54%, and maximum loss on ignition of 33%), to sandy deposits containing moisture and organic matter contents as low as 7% and 1% respectively (Hunting 1997). The loamy deposits (e.g. 1B and 4B) were organic with high moisture retention and typically had high electrical conductivities, high sulphate and, from one sample, high sulphide contents. This contrasted with the lower values of the same parameters recorded for the sandier deposits (e.g. 4A), possibly due to the lower organic matter content, poor moisture retention, and greater loss of salts in solution (Hunting 1997).

The range of pH values (4.9) 5.8 – 7.7 were wide; however, the same as electrochemical pH determinations made on soil samples (by soil suspension) recovered from deposit profiles during 1985 excavations at the Library Site

Figure 39 Proximity of Schultzgate project site and the Library Site excavations' site.

(Folkebibliotekstomten) in Trondheim, approximately 210 m NE of the Schultzgate project site (Figure 39). Those pH values ranged from 5.6 to 7.5 (Peacock 1985). It is noted that the Schultzgate pH values did not reflect the textural character of the respective archaeological deposits, for example low values typical of anaerobic environments were recorded for both loamy peat (4.9) and sandy samples (5.8) (Hunting 1997).

Monitoring programme field results

Soil moisture content

The estimated volumetric moisture contents for the Schultzgate access tubes over the five years (1996-2001) of water quantity monitoring are presented in Appendix E, and moisture content profiles are illustrated in Figure 40. The profiles differ both across each plot, i.e. Schultzgt. 3 and Schultzgt. 5-7, as well as between the two plots. Comparison with the soil texture characterisation for each profile (Appendix C), shows close agreement.

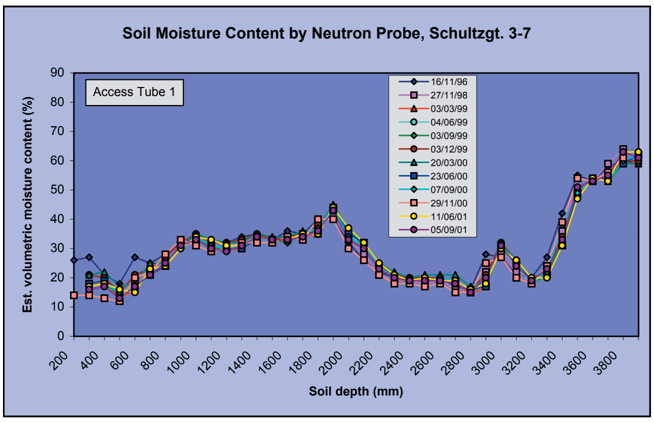
Each profile exhibits a wet zone (greater than 40% volumetric moisture content) of at least 1 m in thickness. This thickness approaches 2 m for Access Tubes 2 (Schultzgt. 3), 3, 5 and 6 (Schultzgt. 5-7). These zones begin at depths between 500 and 1200mm and end between 2300 and 3200mm. The exception is Access Tube 1 (Schultzgt. 3) which does not encounter a wet zone until a depth of 3.4 metres. Below these wet zones are dry lower layers with low unsaturated hydraulic conductivity levels (Access Tube 1 and 6 excepted). The drop in moisture content between these saturated and unsaturated layers is steep and abrupt.

Quarterly moisture data for each access tube location is in general consistently similar (Figure 41). The moisture contents vary, reflecting textural variability within the deposits. The contents fluctuate up and down at each level with few exhibiting decreasing trends. The top 400mm of the courtyard tubes are sensitive to meteorological changes. Seasonal patterns of fluctuations in moisture content are not readily apparent.

The results of the previously described reproducibility exercise (Figure 25) indicate that the close fit of the moisture profiles is real. Access Tubes 1 and 2 have several levels that experienced a noticeable change in moisture content between November 1996 and November 1998. For Access Tube 1 (outdoors) these levels are the uppermost 400mm plus 600, 2900 and 3400mm, all of which now have lower moisture contents. Since November 1998 however, these levels have fluctuated similarly to the rest of the profile. For Access Tube 2 (sheltered) this level is at 2600mm which experienced a slight drop in moisture content. This level has fluctuated similarly to the rest of the profile since November 1998 as well. In mid-2000 the post-installation shrinkage gap that developed at ground level was filled with bentonite clay, and this is reflected in the higher moisture contents recorded for the uppermost 400mm thereafter.

Access Tubes 3, 4 and 6 do not exhibit noticeable changes in deposit profile moisture contents since installation in November 1996. The upper 1300mm of Access Tube 6 (sheltered) and 500mm of Access Tube 4 (outdoors) have been respectively marginally and markedly wetter since November 1996. Access Tube 5 has several levels that experienced a marked decrease in moisture content between November 1996 and November 1998. These levels are at 1100-1200, 1900-2000 and 2300mm. All these levels have fluctuated similarly to the rest of the profile since November 1998. These drier pockets are located within thick, organic loamy sections (ref. Appendices C and E).

Hughes (1999) has called for threshold levels for significant changes in preservation parameters such as temperature and moisture content. For changes in the percent moisture content of archaeological deposits, he has proposed: 0-5% (green), 6-10% (amber) and 11% and greater (red) threshold levels.



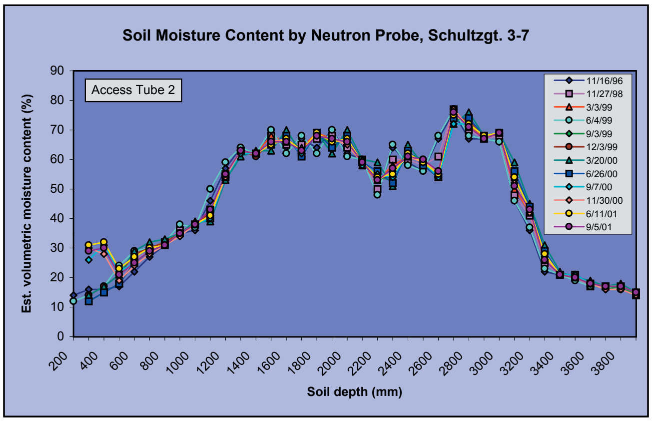


Figure 40a Estimated volumetric moisture content (%) for Access Tubes 1 & 2 (Schultzgt. 3) for the period 1996-2001.

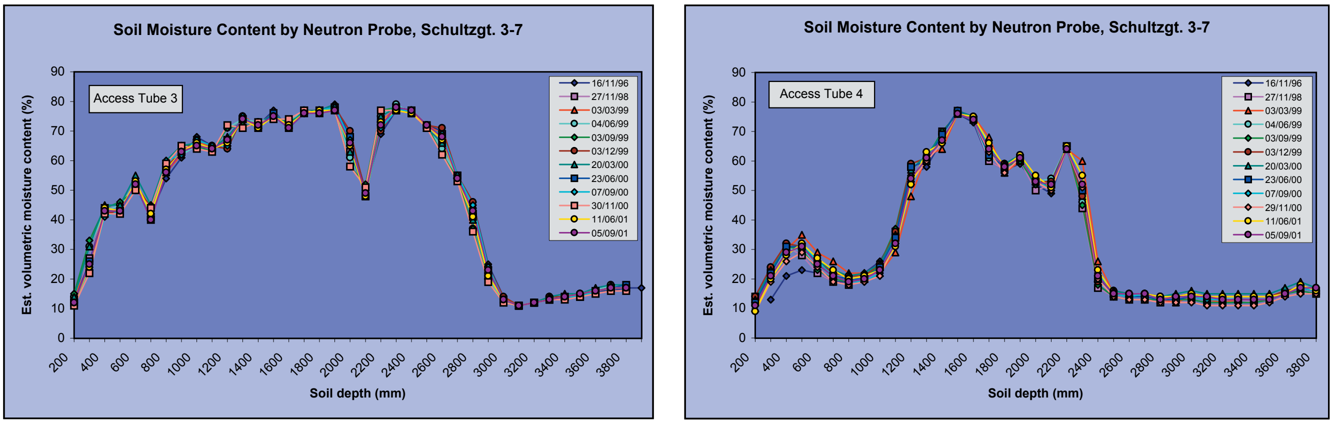


Figure 40b Estimated volumetric moisture content (%) for Access Tubes 3 & 4 (Schultzgt. 5-7) for the period 1996-2001.

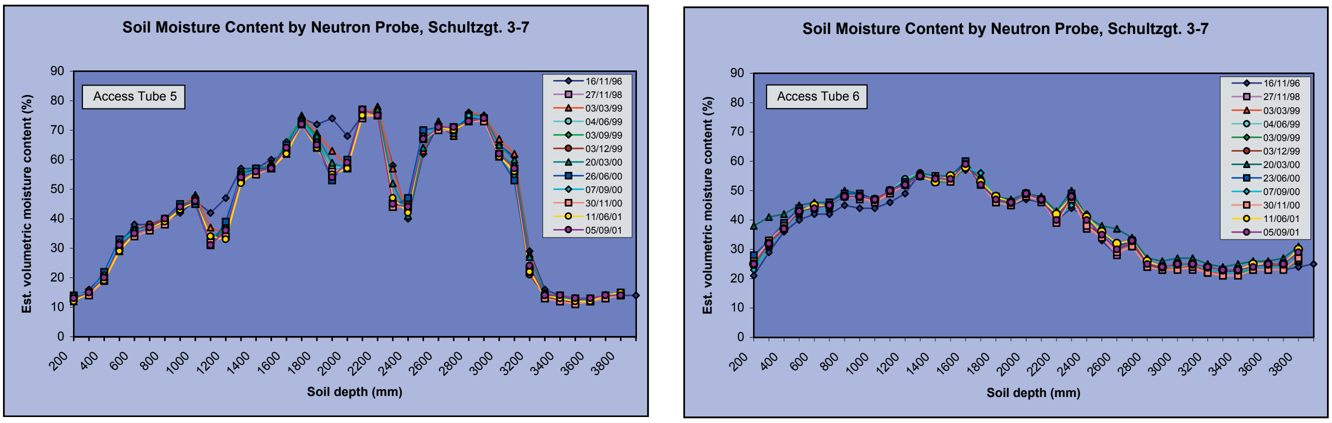


Figure 40c Estimated volumetric moisture content (%) for Access Tubes 5 & 6 (Schultzgt. 5-7) for the period 1996-2001.

The colours indicate the level of concern with red being the trigger value. For the Schultzgate data, the changes in percent estimated moisture content of the two drier pockets of Access Tube 5 lie in the red zone, but this event occurred between Novembers 1996 and 1998. Since then the profile has been stable. Since November 1998 the profiles of all the access tubes exhibit fluctuations, but none exhibits a permanent change in character. For the most part the moisture contents of the six profiles at Schultzgate have a fluctuation range within the 0-5% (green) zone. Six levels (i.e. 100mm intervals) have a fluctuation range of 11% or greater indicating the red zone. These are Access Tube 1 (3400-3500mm), Access Tube 2 (2200-2300, and 2600mm) and Access Tube 5 (2300mm). A total of 41 levels have a fluctuation range that lies in the amber zone.

Rainfall levels for the years that have been monitored have varied widely. Levels for 1996 and 2000 were well below the annual average of 892mm (Værnes), whereas 2001 was above average. A study was made of a possible direct effect of rainfall on the deposits at Schultzgate by comparing the estimated volumetric moisture contents of the access tube profiles with the rainfall levels for the corresponding monitoring months, using monthly precipitation data from the Norwegian Meteorological Station at Værnes Airport (30km NE of Trondheim). The overall patterns of change show there is little direct response to rainfall (Figure 42). The pattern of change for the rainfall levels is dramatic compared to the moisture profiles, ranging widely between 3.6mm for November 2000 to 121mm for March 2000. It is these two extremes that are just barely mirrored in the moisture profiles, which are otherwise unaffected.

Soil water quality

Soil water recovery

During the period November 1996 - September 2001, soil water recovery was conducted on 15 occasions. Both the frequency of successful recovery and the amount of sample recovered vary. Figure 43 shows the frequency of recovery for the 12 suction samplers. Of the 12 installed samplers water has been collected from nine. No samples were recovered following installation in November 1996 and six were recovered during the site visit in June 1997. Figure 44 presents an overview of the history of recovery for the monitoring period 1996-2001. Two samplers do not function (1B and 3A, both at Schultzgt. 3), one has always been empty (3B), and three others have low frequency of collection (2A, 5B, and 6B). Of the three samplers that most frequently contain water (1A, 4B, and 6A), only one (1A) is consistently full.

An empty water suction sampler is one that when put under pressure (following the vacuum procedure)

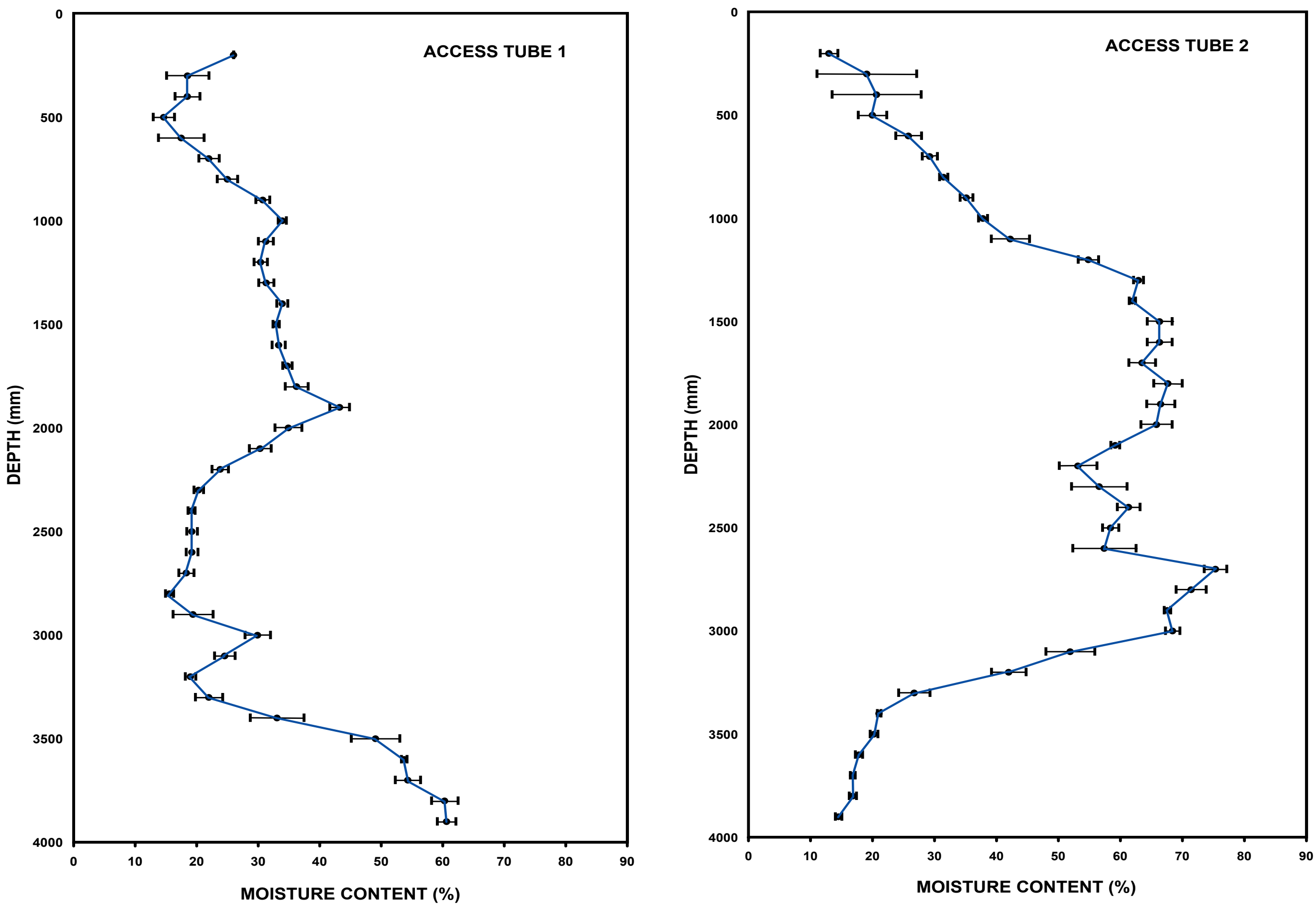


Figure 41a Variation in moisture profiles for Access Tubes 1 & 2 (Schultzgt. 3) for the period 1996-2001.

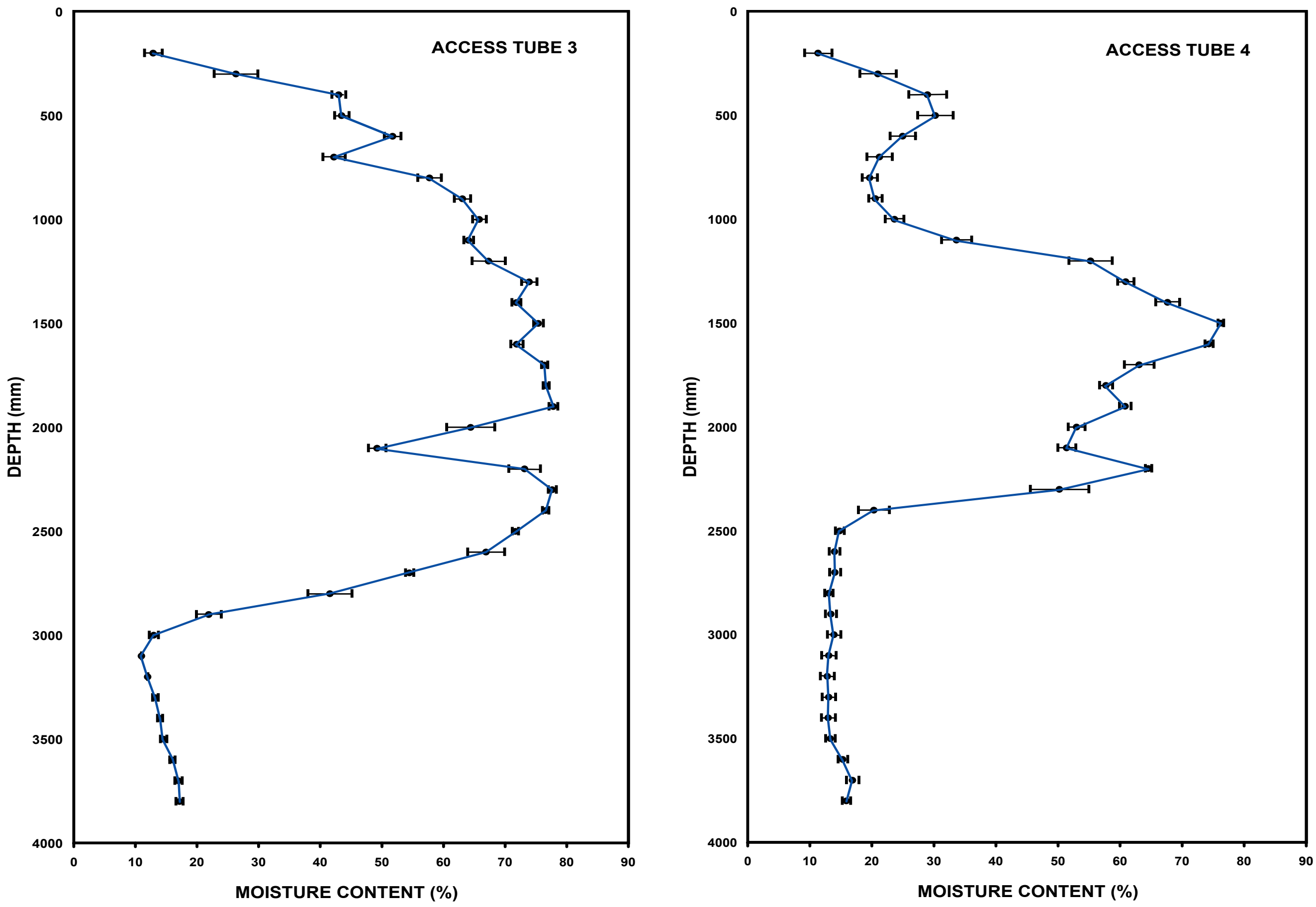


Figure 41b Variation in moisture profiles for Access Tubes 3 & 4 (Schultzgt. 5-7) for the period 1996-2001.

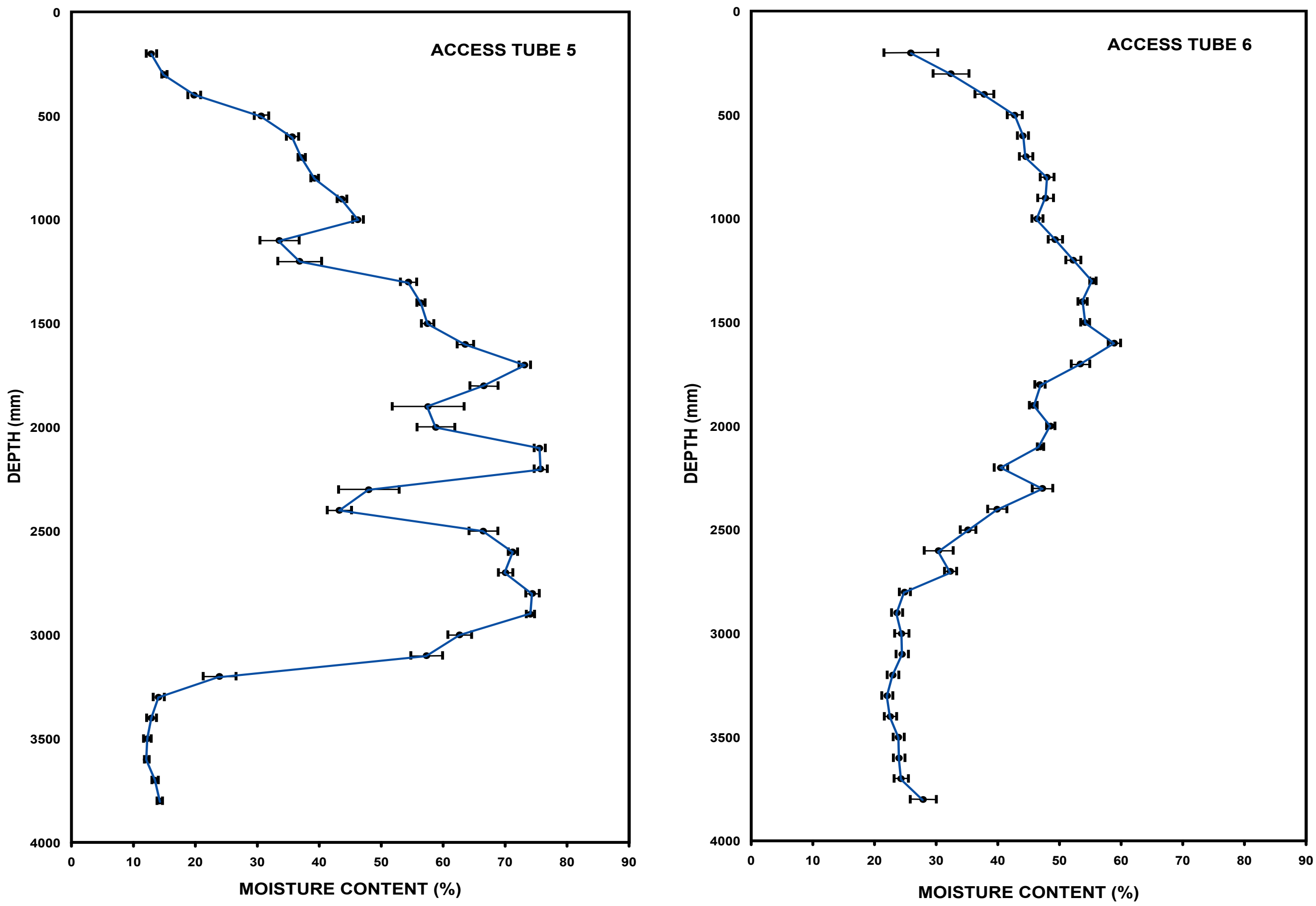


Figure 41c Variation in moisture profiles for Access Tubes 5 & 6 (Schultzgt. 5-7) for the period 1996-2001.

emits only air. Empty samplers arise from a low soil moisture content combined with a coarse sandy soil, a frozen soil, or the lack of full intimate soil contact with the porous ceramic cup at the lower end of the sampler. Table V compares the deposit description with the recovery history for each sampler. Comparison with Table V and laboratory analysis reported in Appendix D provides limited insight into the frequency and volume of collection patterns. Even though many of the deposits into which the samplers have been installed have been characterised as organic cultural layers, a high frequency of included natural sands, gravel and brick debris is recorded. The sampler that is operational but is consistently empty (3B) most likely is not in intimate contact with the surrounding soil, and this is collaborated by the 'made ground' deposit description. The three samplers that have a very low frequency of collection are located in coarse/gravely organic sandy loam pointing to low water retention. The three samplers that have a medium frequency of collection are situated in deposits characterised as organic loam with inclusions of sand. Finally, two of the three high frequency samplers are situated in black loamy peat, while the third is in an organic sandy loam with brick debris.

Soil water analysis

Acidity

Measured acidity over the three years (1998-2001) of water quality monitoring is presented in Appendix F and changes in pH over this period are illustrated in Figure 45. This figure also shows the pH values for soil samples recovered from the boreholes created during installation of the water samplers.

The Schultzgate soil water pH values are the same or lower than the corresponding core soil pH values. The pH values for the soil water samples are mildly acidic to neutral (5.0-6.8), whereas, those for the soil samples exhibit a wider range from mildly acidic to mildly alkaline ((4.9) 5.8-7.7). pH determinations (by soil suspension) made on soil samples recovered from deposit profiles during 1985 excavations at the Library Site (Folkebibliotekstomten) in Trondheim, approximately 210m NE of the Schultzgate project site, ranged from pH 5.6 to 7.5 (Peacock 1985). This range is also wider and slightly higher than the Schultzgate soil water pH values; however, it is the same as the core soil pH values.

The low dissolved oxygen content and 'foul egg' smell associated with soil water samples from sampler 1A are indicative of a strongly reducing environment. This sampler also produces water with a yellow colouration that suggests a more complex chemistry than samples from the other samplers. The yellow colour would suggest either dissolved ionic species or complex organic molecules. The deposits recovered from the boreholes during installation of samplers 1A and 1B were described as "black loamy peat

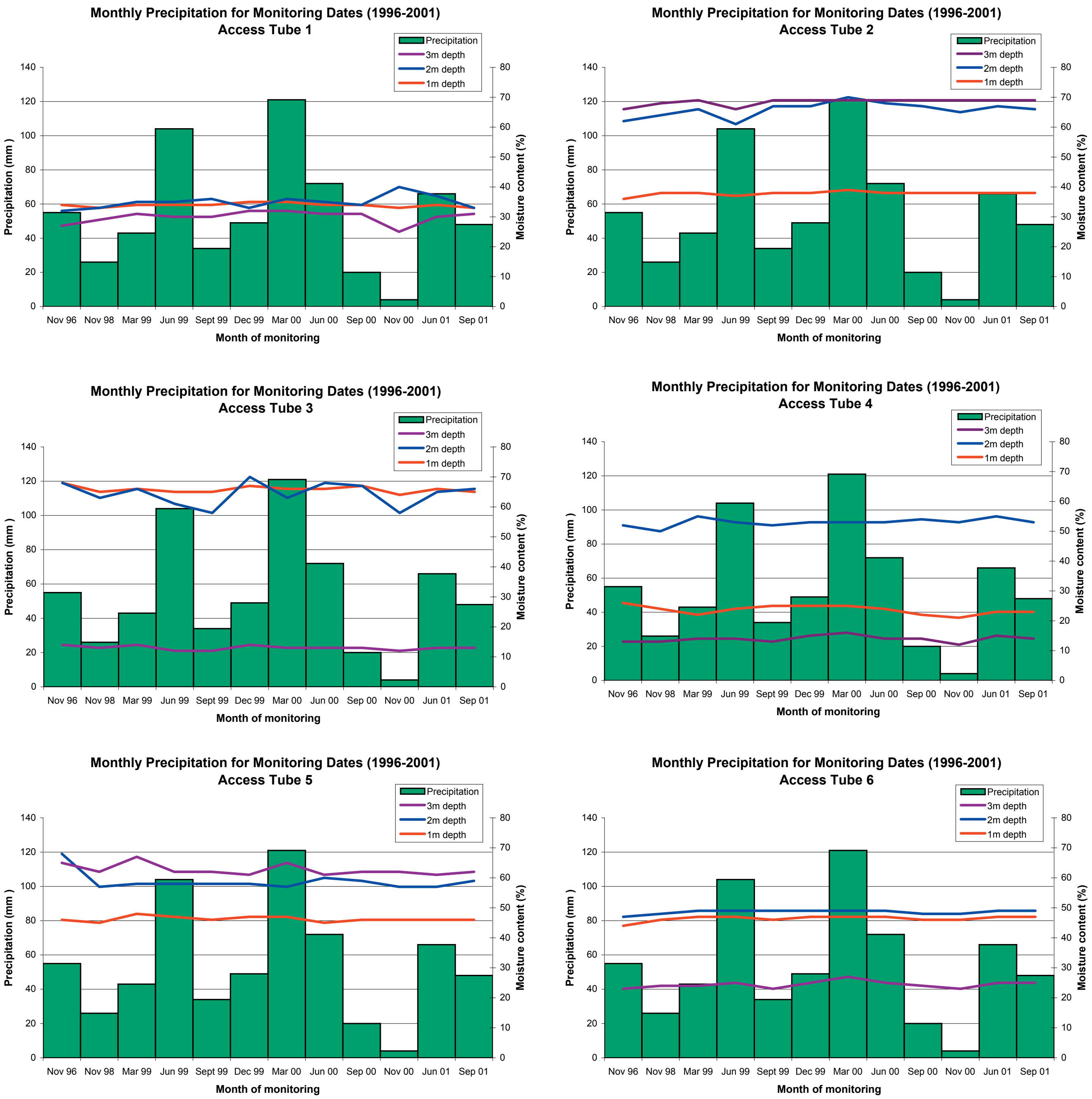


Figure 42 Changes in estimated volumetric moisture content for Access Tubes 1 and 2 (Schultzgt. 3) and Access Tubes 3-6 (Schultzgate 5-7) at 1, 2 and 3 metres below ground level compared with rainfall levels for the monitoring months. (Rainfall data for Værnes from Bjørvæk 1998 and from the Norwegian Meteorological Institute.)

containing wood (foul egg/phenolic smell), leather and bone" (Appendix C). The rotten egg smell of hydrogen sulphide is the classic telltale sign of the activity of sulphate reducing bacteria (Turner-Walker 1998).

Sulphate reducing bacteria (SRB) are anaerobes that use the sulphate ion as an oxidising agent for the metabolism of simple organic compounds, and in turn reduce the sulphate ion to sulphide which then combines with hydrogen ions to produce hydrogen sulphide with its characteristic rotten egg smell. This hydrogen sulphide and free sulphide ions subsequently combine with detrital minerals in the soil to form highly insoluble sulphides, chiefly finely divided pyrites, which are frequently found associated with bone, leather and other artefacts from deep urban deposits. The reduction of sulphides consumes hydrogen ions and thus increases the local alkalinity, i.e., pH. In fact, the pH of sediment recovered during installation of sampler 1A was surprisingly alkaline (pH 7.7) and soil water samples recovered remain markedly more alkaline than others at the site.

The phenolic smell is not one usually associated with buried sediments, although it is occasionally used as a tracer for groundwater pollution arising from industrial activity or landfill sites. The phenolic smell associated with soil samples from Schultzgate are most likely derived from structural timbers

Table V Deposit description at depth of bottom of water suction sampler and sampler recovery history

Suction sampler	*Depth (m) of porous cup*	*Description of deposit (after Appendix C)*	*Recovery (frequency)*			
			Empty	*Small*	*Moderate*	*Full*
1A	2.45	Organic (cultural layer)	2(1*)	1	1	10
1B	1.45	Made ground	NO	-	-	-
2A	2.86	Dark brown/black gravely organic sandy loam	13	2	-	-
2B	1.99	Black loamy peat, brick fragments, inclusions of sandy loam	8	4	1	2
3A	3.09	Organic sandy loam	NO	-	-	-
3B	2.11	Made ground/organic loamy	15	-	-	-
4A	3.00	Greyish coarse sandy	8	3	3	1
4B	1.95	Very woody organic deposit	3(1*)	6	5	-
5A	2.92	Woody organic deposit containing soapstone	9	1	1	4
5B	2.00	Sandy loam organic deposit	9	2	5	-
6A	2.10	Made ground in organic sandy loam	3	2	7	-
6B	2.00	Dark greyish brown sandy loam containing brick fragments	10	3	1	-

* freezing event, NO = not operational

treated with tar in antiquity (Turner-Walker, personal communication 2002). Excavations in the medieval city have produced large volumes of wood that originally formed buildings, walkways or boats. Rags soaked in tar used for treating timbers have also been recovered.

Indications are that the extent to which the water in the in situ archaeological deposits at Schultzgate is influenced by rainwater is limited. Environmental data collected for the Cathedral precinct in 1990-91 reported a mean pH value of 5.5, which is higher than the background pH for the region, 4.9, although these readings ranged widely between 4.2 and 7.3 (Anda and Henriksen 1992).

The sampler values for each access point fluctuate, but in general the variations lie within a modest range for each point. No sampler exhibits a downward (i.e. increase to acidity) or upward (i.e. increase to alkalinity) trend. Caple and Dungworth (1998) report that pH values of dipwell soil water are slightly higher than pH values measured in situ using electrodes installed directly into the archaeological deposit. The water in dipwells is not in intimate contact with the archaeological deposit, and its pH is considered to be less representative of the true in situ pH. The Schultzgate water suction samplers are enclosed and not open to above-surface influences as is the case for dipwells. Experience recovering soil water from the Schultzgate samplers indicates that there is little standing water. In addition, it indicates that the recovered water is predominantly that which has been drawn in from the surrounding soil during the 1-2 day period under vacuum prior to collection. The exception being sampler 1A.

Temperature

No specific provision was taken for monitoring the temperature of the in situ archaeological deposits at Schultzgate. Temperature measurement other than directly in the archaeological deposits is of little relevance. The lack of exposed profiles during project pre-development ruled out such an installation. However, temperature readings were occasionally taken on soil water samples immediately upon recovery. Temperatures at winter sample collection ranged from 4-6°C. On occasion, soil water did freeze; however, this occurred during recovery in winter months as the sample was drawn up through frozen layers or as it travelled across the courtyard at shallow depth. On these occasions, no soil water samples were recovered.

Redox potential

Redox potential readings for the three years (1998-2001) of water quality monitoring are presented in Appendix F, and changes are illustrated in Figure 46. The recorded values range from −242mV to +255mV. The categories of redox potential (Eh) are given in Table VI.

Table VI Categories of redox potential (Eh)

Deposit	*Redox potential (mV)*
Oxidising	+700 to +400
Moderately reducing	+400 to +100
Reducing	+100 to -100
Highly reducing	-100 to -300

Measured values vary both between and within samplers. Sampler 1A has a reducing to highly reducing burial environment; samplers 2B, 4A, 4B, 5A and 5B have moderately reducing to reducing burial environments; while samplers 2A, 6A and 6B have moderately reducing burial environments. Figure 46 illustrates the extent to which sampler 1A has a more reducing environment than the other samplers.

Despite the acknowledged importance of redox potential as a critical indicator of a preserving burial environment for organic materials, it is notoriously difficult to measure. Much of the research that reports difficulties is based upon in situ measurement in the field. The Schultzgate measurements are made on collected soil water which also presents difficulties. Sposito (1990) points out that redox measurements give only a qualitative indication of reduction-oxidation in most soil systems, and that they are useful to classify soils as oxic, suboxic, and anoxic but little beyond that. Despite the problematic nature of measuring this indicator, the Schultzgate data is valuable.

Redox and pH conditions result from coupled biological, geochemical and hydrological processes, and define threshold conditions beyond which materials are unstable. Plotting redox potential (Eh) against acidity (pH) has become common in an attempt to characterise the preservative nature of burial environments. The benchmark Eh-pH diagram (Figure 47) identifies three soil types: normal (oxidised), wet (seasonally saturated) and waterlogged (semi-permanently saturated) (Garrels and Christ 1965 after Bass Becking et.al. 1960). Figure 48 shows the relationship between Eh and pH values for Schultzgate.

If these same values are integrated into the Garrels and Christ diagram, more information can be gleaned into characterising the micro-environments of the pockets from which the water samples are being extracted (Figure 49). The majority of the measurements cluster together in the mildly reducing WET zone. The exception is one group, all of which are from sampler 1A, which lies in the more reducing WATERLOGGED zone. What this suggests is that much of the soil water being recovered is rainwater that has percolated down through the soil profile, and that sampler 1A is situated in a wet, preserving pocket less affected by water input which has its source in oxygenated precipitation.

Dissolved oxygen

The dissolved oxygen (DO_2) levels for the three years (1998-2001) of water quality monitoring at Schultzgate are presented in Appendix F, and the changes are illustrated in Figure 50. The levels

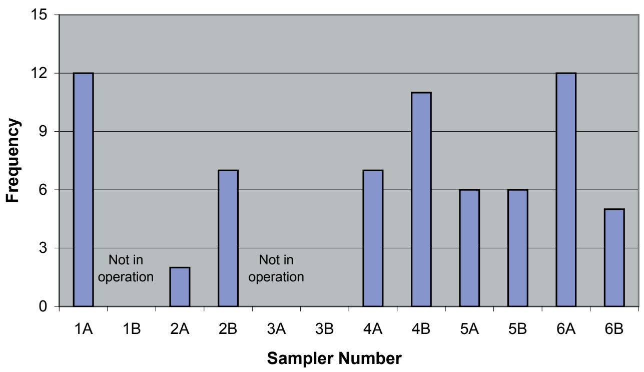


Figure 43 Frequency of soil water recovery for the Schultzgate water samplers for the period 1996-2001.

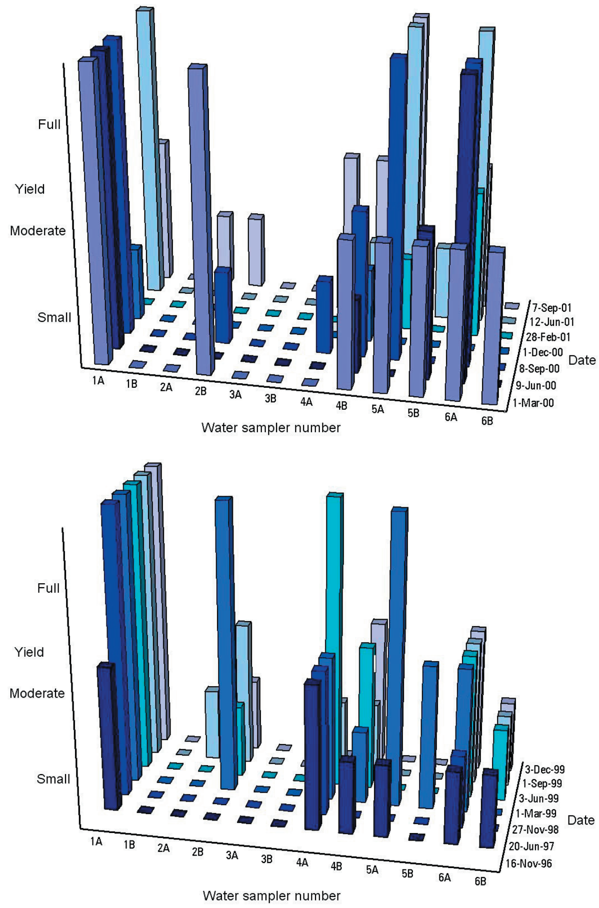


Figure 44 History of soil water recovery for the water samplers for the monitoring period 1996-2001. Samplers 1-3 (Schultzgt.3) and 4-6 (Schultzgt.5-7). Recovery amounts: full (151-250ml), moderate (61-150ml) and small (1-60ml).

ranged from 0.4 to 17.4%. The dissolved oxygen measurements are the most varied of all the parameters evaluated for the Schultzgate soil water samples. Levels do indicate that none of the samplers is directly fed by oxygenated rainwater, but that most have water input that reflects on the distribution, intensity and amount of precipitation and snow cover. Sampler 1A has the lowest and most frequently low DO_2 levels, and samplers 4B and 5A frequently have low DO_2 levels. Consequently, the dissolved oxygen levels are providing information about the extent to which the in situ archaeological deposits are influenced by precipitation.

The current input of oxygenated rainwater into the in situ archaeological deposits at the Schultzgate site will not be substantially altered from pre-construction conditions. Both plots had been a car park with an unpaved surface for over 20 years during which time the in situ archaeological deposits were subjected to oxygenated rainwater.

Electrical conductivity

The measured electrical conductivity levels for the three years (1998-2001) of water quality monitoring at Schultzgate are reported in Appendix F, and the changes are presented in Figure 51. The levels

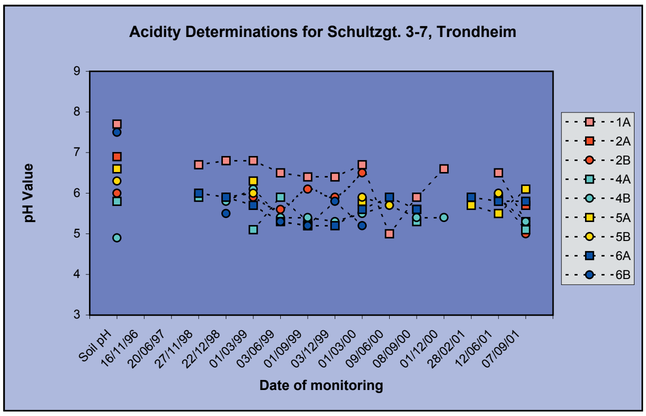


Figure 45 pH determinations for Schultzgate water samples for the period 1998-2001.

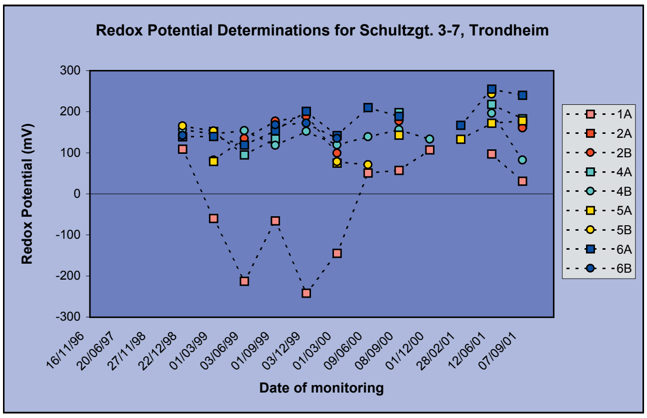


Figure 46 Redox potential determinations for Schultzgate water samples for the period 1998-2001.

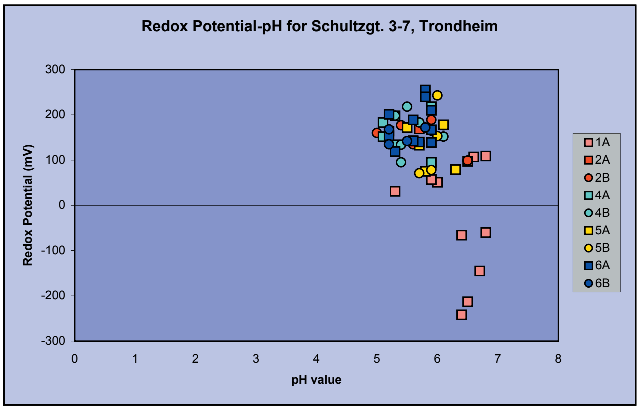


Figure 48 Redox-pH comparison for Schultzgate water samples for the period 1998-2001.

ranged from low (204µS) to high (2020µS), but are moderately stable at each sampler. The exception is the range for sampler 1A which has dropped to a lower level. The levels fall into two distinct groups. Samplers 1A (Schultzgt. 3) and 5A (Schultzgt. 5-7) have consistently high conductivity levels indicating a high concentration of dissolved ionic species. These levels are consistent with those reported for preserving burial environments by other studies (Corfield 1996, Caple et.al. 1997).

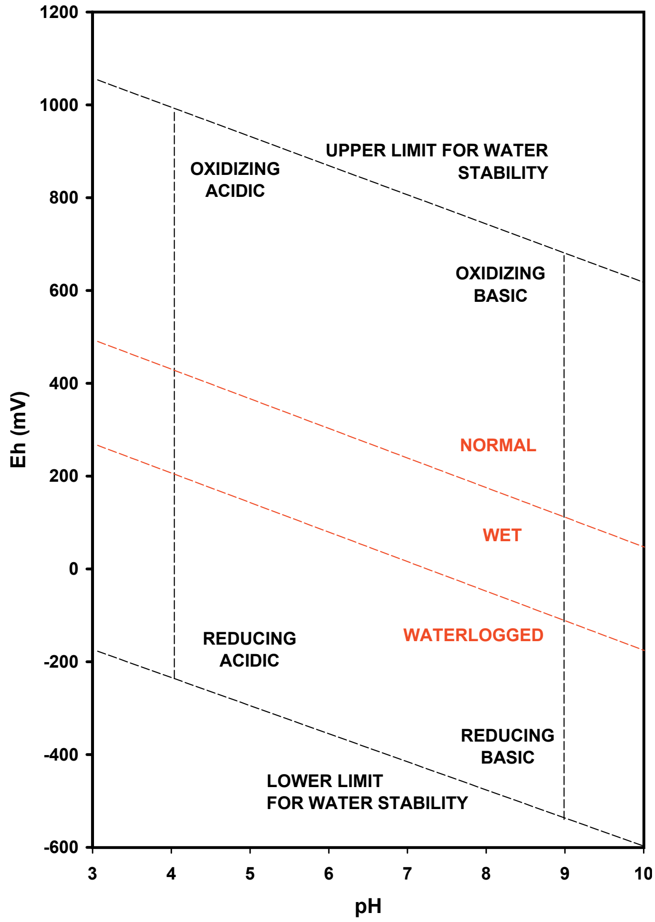


Figure 47 Redox-pH characteristics for soils (Turner-Walker after Garrels and Christ 1965).

The remaining samplers have low conductivity levels indicating a greater loss of dissolved ions from solution (e.g. by precipitation of oxidised species) or that these pockets are fed by rainwater that has permeated through the deposit layers. Measurement of the conductivity of rainwater at 21.1µS compares favourably with conductivity levels of 10.7-42.1µS measured for rainwater in the period 1990-1991 at the Cathedral precinct located approximately 300m south of the Schultzgate project site (Anda and Henriksen 1992).

The electrical conductivity levels of the Schultzgate soil water samples indicate that none of the samplers is directly fed by rainwater, with the possible exception of sampler 6B. Consequently, the electrical conductivity levels are providing information about the extent to which the in situ deposits are influenced by rainwater.

Electrical conductivities of core soil samples recovered during installation were markedly higher (2170-4765µS) (Appendix D), but do reflect chemical differences in the deposits from sandy to loamy peat. In the instances where the analysed soil samples are from the same depth as the corresponding samplers, the soils were sandy loam in character and with electrical conductivities similarly at the lower end of the range.

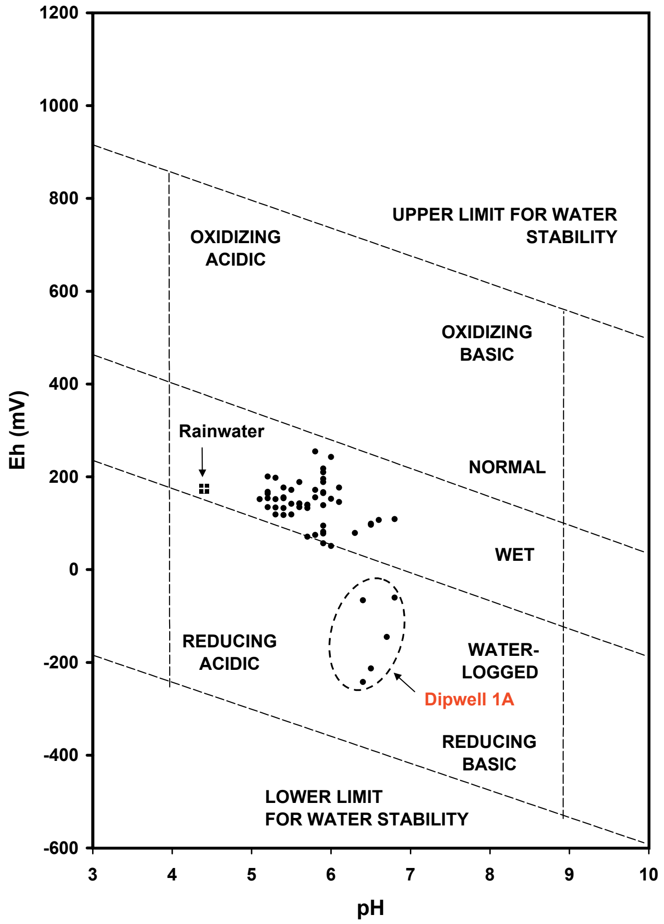


Figure 49 Redox-pH characteristics for Schultzgate water samples for the period 1998-2001 related to soil types. (Turner-Walker after Garrels and Christ 1965).

Comparing the electrical conductivity and acidity (pH) levels also reveals a distinct grouping of the soil chemistry surrounding the samplers (Figure 52). Samplers 1A and 5A form one cluster, with the remaining samplers forming another cluster.

Selected ion species

The measured levels of sulphate, sulphite, nitrate and nitrite in the soil water samples for the three years (1998-2001) of water quality monitoring at Schultzgate are reported in Appendix F. No conclusions have yet been drawn concerning this data. Sulphate levels are not registering because the method employed to analyse soil water samples for sulphate is not sensitive enough. Monitoring studies are not reporting results of soil water analyses for ion species (Corfield 1996), thus providing no comparative data for the Schultzgate measurements. Brunning et al. (2000) analysed for calcium, magnesium, sodium, potassium, nitrate, phosphorus, chloride, and ammonia at the rural Sweet Track site in the UK, and discuss relative changes for the latter three. Attempts have been made to measure for ammonium and sulphide directly in the archaeological deposits using ion selective electrodes; however, these have proved unstable in such application (Caple and Dungworth 1998).

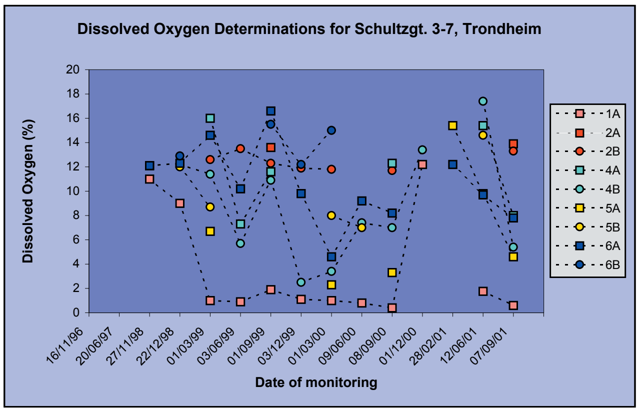


Figure 50 Dissolved oxygen determinations for Schultzgate water samples for the period 1998-2001.

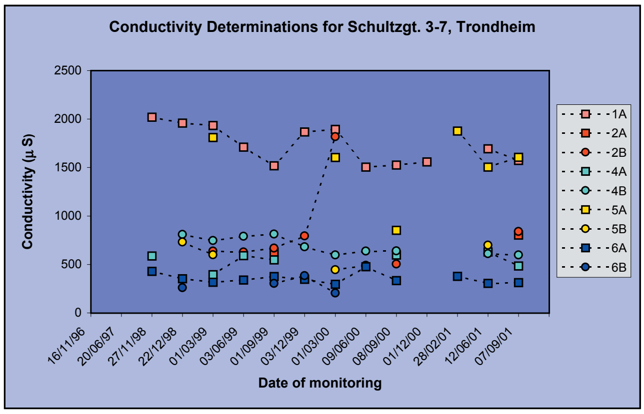


Figure 51 Electrical conductivity determinations for Schultzgate water samples for the period 1998-2001.

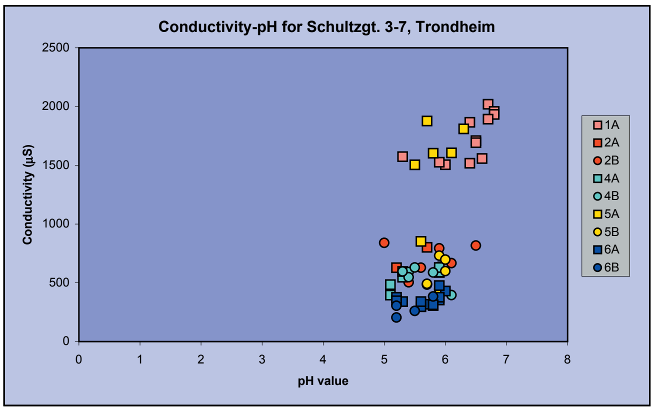


Figure 52 Electrical conductivity-pH comparison for Schultzgate water samples for the period 1998-2001.

Conclusions

The environmental monitoring programme at Schultzgt. 3-7 is the first such programme in Norway developed to monitor in situ archaeological deposits under a redeveloped urban site. It is providing the first systematic evidence on the hydrology and water quality of archaeologically significant buried strata in the protected historic centre of Trondheim.

Similar to many other urban areas in Northwest Europe, Trondheim possesses a wealth of urban occupation deposits containing organic materials preserved in anoxic conditions. Redevelopment of the two plots at Schultzgt. 3-7 was for continued domestic use. The project consisted of two modest, two storey timber-framed buildings of residential flats for, among others, old age pensioners. Earlier watching briefs and smaller archaeological investigations conducted of neighbouring plots revealed several metres of wet cultural strata and many well-preserved organic finds, thus establishing the archaeological sensitivity of the area. However, the costs of a full-scale excavation of the archaeology prior to construction made realisation of the project financially prohibitive. Methods were sought to avoid removing the buried archaeology, and to minimise damage and the effects of redevelopment and construction operations. The viable alternative was an engineering solution of rafted foundations and a developer-funded, long-term post-construction programme of environmental monitoring of the status of the cultural strata beneath the new residential buildings.

The monitoring programme focuses on site hydrology (water quantity) and soil water chemistry (water quality) which are critical factors controlling physico-chemical and biological processes taking place within the in situ archaeological deposits. The programme in itself is not protecting the site from damage. If and when disturbance is discerned, then remedial action will have to be taken to prevent further deterioration.

The desk-based evaluation conducted in the pre-construction stage of the project highlights numerous problems associated with using past site documentation to assess the in situ archaeological deposits. This is especially the case when previous records were not intended for this purpose. The assessment should have more critically analysed the limited stratigraphic and geotechnical details of earlier investigations rather than the archaeological potential of the area. This is particularly important because this information was not later forthcoming in the pre-construction site survey, or in connection with trial pits or trenches. Closer analysis of the details of the desk-based assessment would have alerted to the degree of complexity of the sub-surface stratigraphy. There now needs to be a more rigorous recording of the physical fabric when investigating cultural layers in the city, including if necessary the collection of soil samples for micromorphological characterisation (Courty et al. 1989) with the view of potential laboratory analysis as an adjunct to planning future mitigation strategies.

In the future, in those instances where physical interventions are undertaken in the city, there needs to be more routine, context-specific investigation of the sediment matrix (Nicholson 1998) together with the archaeological and ecological materials found within and the nature of their state of preservation. Watching briefs can also gather information of this nature. Mapping material degradation in relation to artefact micro-environment can promote more objective assessments of archaeological assemblage preservation across the eastern Nidarnes peninsula.

Better and more systematic use must be made of the archive or artefacts and ecofacts recovered from 30 years of archaeological investigations in the city in assessing both the archaeological significance and the potential heterogeneity of a site proposed for redevelopment. The nature of the burial environment is an important factor influencing the deterioration of organic archaeomaterials such as leather and bone, which have been recovered in great quantities across the town. Mapping their different states of preservation should be used to predict the preservation potential of still-buried cultural strata.

The monitoring programme developed for Schultzgt. 3-7 is based on technologies available in 1996. Consultation with the environmental specialists Hunting Technical Services (UK) led to the selection of two monitoring technologies that could provide long-term soil hydrology and water quality information: the neutron probe system to monitor soil hydrology, and water suction samplers to collect and monitor soil water quality. Both systems have proved successfully adaptable to the redevelopment, stratigraphic, geotechnical and climatic conditions of the site.

For practical reasons no access tubes were installed in cultural strata lying directly under the new buildings. Doing so would have required access to ground-floor flats that are peoples' homes. This continues to be the case for the neutron probe system; however, the successful design and operation of remote collection of water samples indicates that with some modification of the system, water suction samplers could be located beneath similar new structures.

The neutron probe system provides soil moisture data down an entire deposit profile and is well-suited to monitoring an urban site such as the Schultzgate project where there has not been pre-construction or construction access to determine the probable locations of water-retaining preserving pockets. Although the technology is now somewhat dated and the portable probe is cumbersome, it is robust, requires minimal maintenance and provides reliable data. By being able to monitor moisture contents of an entire deposit profile as opposed to just the level of the water table or selected profile positions, much more insight into the hydrology of the profile and the site is being gained. And the dramatic difference in moisture profile trends between the two access tubes at Schultzgt. 3, illustrates the necessity of having more than one monitoring point at each plot to ensure that results are representative and not just a 'one off'.

The soil moisture profiles at Schultzgt. 3-7 are clearly not changing, although there has been some slight reduction in the uppermost 10-20cm in some tubes since the building phase was completed. The estimated volumetric moisture contents of the neutron probe access tubes' profiles reflect deposits that are not only above the water table but also, with the possible exception of Access Tube 1 (Schultzgt. 3), not influenced by the water table's capillary fringe. The draining capacity of these deposits is greatly exceeded by water intake in the form of precipitation, providing for moisture-content stable wet layers within the site. Moisture profiles exhibit little direct response to rainfall, and the seasonal patterns of moisture fluctuations are not readily apparent.

The moisture content data shows a moderate to poorly drained but not waterlogged stratigraphy with zones with good water-retentive characteristics. There is downward movement of moisture from the top layers to the deeper water-retentive wet zones, which overlie unsaturated sand and gravel. The lower unsaturated sandy/gravely layers enable the wet zones to retain more water. There is no recharge of the lower dry layers from below (ground water).

Schultzgt. 3-7 is a site that has only pockets, not large areas of anoxic wet burial environments in which there is a known but un-mapped complex of made ground/cultural layer sub-surface stratigraphy, and where there was no access to detailed soil profiles to ensure appropriate placement of suction samplers in deposits that have archaeological organic materials preserved in them. Such a starting point dramatically reduces the potential success rate of the water suction sampler system. This system does not provide for collecting a series of soil water samples down an access tube, but rather one sample at a pre-selected, fixed depth. If no water is recovered at that depth for whatever reason, there is no soil water data for the entire access tube. The total amount of data feeding into the monitoring data base is less than projected, compromising both the comprehensiveness of the programme and the accuracy of site stability assessments made based upon the soil water chemistry data. The project highlights that for such sites where there is no pre-construction access to the in situ archaeological deposits, it is even more imperative that monitoring equipment be installed and activated prior to the start of construction so that the monitoring record has a pre-construction baseline.

Water quality results reflect burial environments with a range of chemistries. Only one of ten functioning water access points is clearly in a pocket with excellent preservation. Several indicate potentially good preservation. Unlike the soil moisture profiles, the soil chemistry reveals that many access points are affected by the dynamics of precipitation input into the Schultzgate system. The soil chemistry results support conclusions of other similar studies of the importance of monitoring pH, redox, conductivity and the dissolved 0_2 as indicators of a preserving burial environment for organic materials. They also support the usefulness of monitoring a range of parameters for collaborating burial environment evidence, for example acidity (pH) and redox potential (Eh), and dissolved oxygen ($D0_2$) and electrical conductivity.

The variability of both the recovery of water samples and their chemistry highlights the necessity of frequent regular monitoring over several years before it is possible to develop a baseline of knowledge about the site. This is in contrast to reported studies that have operated on a much shorter (e.g., one year) time frame. However, much of this work has focused on non-urban, rural sites where the sub-surface stratigraphy is much less complex than that found in an urban context, and where the cultural layers lie close to or below the water table.

The monitoring is ongoing. It is not a one-time process but rather one that involves continued work and vigilance. The initial quarterly site visits were extended from one to several years when it became apparent that initial evaluations could first be made only when there was a multi-year database. Since its start, alterations and refinements have been made to the original monitoring procedure to make it more manageable. The actual techniques used for the monitoring must be evaluated and refined as new needs and analytical techniques develop. Teething problems, mostly climate based, have included: the freezing in place of neutron probe access covers in the winter; flooding of access tubes from rainwater and a burst water pipe in one of the outhouses where a tube was located; and, freezing of water samples in the plastic discharge tubes while pumping samples across the courtyard near-surface ducting.

The project highlights the problem that even when a proposal to preserve in situ archaeological deposits appears sound, it will be years if not decades before the real success of the exercise will be known. Both whether the mitigation strategy is achieving the protection of the in situ deposits, and whether the monitoring programme is adequately mapping the hydrology and soil water quality. Any damage to this site cannot be assessed until the new buildings come down. However, if this site is excavated in the future, the present artefact archive representing 30 years of urban excavations in Trondheim will provide a material preservation baseline with which artefacts recovered from the in situ archaeological deposits at Schultzgate can be compared.

Figure 53 The completed new residences 3-7 on Schultzgate (E.E. Peacock).

A small residential development in a redevelopment-protected historic city centre introduces mitigation concerns of a different nature than those encountered with a large commercial property. Commercially it is arguable as to whether even a monitoring solution is financially viable for a small domestic development. The cost of the 10 year monitoring programme at Schultzgate is approximately 10% the estimated cost of a full-scale archaeological investigation. Still, had it not been for the fact that the developer in this case is one of the largest construction companies in the country with in-house resources to develop alternative building strategies, the site may well not have been redeveloped.

Paradoxically, the choice of timber-framed structures was later criticised for disrupting the continuity of the architecture and history in this part of the city (Christiansen 1997). Though many of the small pockets in the city centre consist of neighbourhoods of narrow alleys lined with wooden residential structures, such is not the case for Schultzgate. This neighbourhood was almost completely destroyed in a fire in 1846 and was rebuilt in accordance with the masony regulations recently passed in 1845. Consequently, the Schultzgate neighbourhood is predominantly, but not entirely, one of brick masonry structures, and the earliest of its kind in the city. Although the new wooden structures would be suitable for other quarters, it was felt that they did not fit in at Schultzgate.

Sammendrag

Peacock, Elizabeth E. (2002). *Miljøovervåking av de in situ arkeologiske kulturlagene på Schultzgt. 3-7, Trondheim, Norge (1996-2001).* Arkeologisk rapport serie 2002-1. Trondheim: Vitenskapsmuseet (NTNU). På engelsk.

Innledning

I forkant av Trondheims Tusenårsjubileum i 1997 ønsket Trondheim kommune i samarbeid med Selmer AS å bygge på eiendommene Schultzgt. 3-7 (fig 7), som er et automatisk fredet kulturminne, men der reguleringsbestemmelsene tillater bygging av boliger. For å unngå en fullstendig arkeologiske undersøkelse av kulturlagene som kunne være både destruktiv, kostbar og tidkrevende, var det ønskelig å bygge oppå kulturlagene. Byggetillatelse ble gitt av Riksantikvaren på betingelse av at bevaringsforholdene av kulturlagene under de nye bygningene blir overvåket i 10-20 år. Miljøovervåk ningsprosjektet i Schultzgate danner grunnlaget for en alternativ forvaltningsløsning for disse tomtene og for de norske middelalderbyene generelt. Det er en forvaltning som unngår fjerning av kulturlagene (dvs. en arkeologisk utgraving), men som framelsker bygningstekniske løsninger som tilfredsstiller ønsket om byfornyelse og samtidig sikrer de uerstattelige arkeologiske og økologiske materialer der de ligger i bygrunnen.

Schultzgate: sted og historie

Boligprosjektet Schultzgate ligger midt i Trondheims sentrum like ved Vår Frue kirke, mellom Vår Frue strete og Erling Skakkes gate (fig 8). Tidligere registreringer og mindre arkeologiske undersøkelser foretatt i årene mellom 1977 og 1992 på de omkringliggende tomter har vist at det finnes tykke (opptil 3m) og fuktige kulturlag i dette området. Disse har også vist at området er intensivt utnyttet i middelalderen. De fleste registreringer har vist et antall bygningsfaser. De fleste av disse ser ut til å være boliger, men i NV del er det funnet indikasjoner på metal-, bein-, lær- og tekstilhåndverk. Schultzgate ble anlagt etter en storbrann i 1846. Små murhus med halv og full kjeller ble reist i dette området etter brannen (fig 10) og revet i 1972 (fig 11). Fram til 1995 ble tomtene brukt som grusbelagt parkeringsplass.

For å få kartlagt den nøyaktige posisjonen av og tilstanden til de skjulte fundamentene til bygningene som var revet tidligere, ble det foretatt maskinell avsjakting av massene i august 1995 under arkeologisk tilsyn av NIKU. Det viste seg å være vanskelig å lokalisere og kartlegge de eksisterende murer og gjenfylte kjellere. Flere av murene hadde rast innover under rivningen av bygningene, og et lag med knuste teglstein og stein dekket mye av området. Det ble ikke foretatt en arkeologiske forundersøkelse før byggestart for å kartlegge kulturlagenes karakter.

Bygningstekniske løsninger

For å bygge direkte på kulturlag krevdes det en bygningsteknisk løsning som ikke forstyrrer kulturlaget, verken ved fjerning, graving, pæling, eller boring, og en løsning som ikke senere fører til uttørring eller sammenpressing. Utbyggingsformen som ble valgt var bygninger i tre med kryprom, to etasjer og loft. Fundamenteringsløsningen ble basert på nedgravde banketter og fjerning av massene i kryprommet. Belastningen ble beregnet til å ikke overstige vektbelastningen fra den tidligere murbebyggelsen.

Overvåkingsparametere og teknologier

Overvåking av kulturlag innebærer en kartlegging og systematisk og regelmessig måling av jordbunnsmiljø (dvs. hydrologi, kjemi, mikrobiologi og subsidens) for å dokumentere påvirkninger utenfra. Det gjøres ved å bruke geo- og jordbrukstekniske undersøkelsesmetoder. Problemet med overvåking av bevaringsforholdene i kulturlag har vært å finne ut hva som skal måles og hvordan det skal gjøres uten å forstyrre det miljøet som skal overvåkes. De gode bevaringsforholdene, særlig for organiske gjenstandsmaterialer og økologiske materialer i de norske middelalderbyene, styres først og fremst av kulturlagets hydrologi og kjemi. Viktige aspekter av kulturlagets hydrologi er: fuktnivå tvers igjennom, tilstedeværelse av grunnvann og forandring i grunnvannsspeilet, og hydrologisk ledningsevne. Kjemiske parametere av betydning er: surhetsgrad (pH), elektrisk ledningsevne, redokspotensial (Eh), og oppløst oksygen (DO_2). Det finnes en rekke metoder som anvendes til miljøovervåking innenfor arkeologiske problemstillinger. Forholdene ved Schultzgate prosjekt utelukket de fleste av disse, særlig lettvinte metoder.

Kulturlagene i Schultzgate lå ikke åpne. De hadde ikke vært undersøkt arkeologisk tidligere, og ble ikke tilgjengelige via grøfting eller sjakting under byggeprosessen. Dette betydde at jordbunnen ikke ble tilgjengelig for noen form for analyse eller direkte måling, slik at jordprøver ikke kunne tas ut, og det utelukket videre målemetoder basert på jordprøver. I tillegg ligger kulturlagene godt over grunnvannsspeilet slik at overvåking av speilets nivå og henting av grunnvann til kjemisk analyse ikke gir mening. Den eneste tilgangen til kulturlagene ble gjennom rør som settes ned under byggeprosessen.

Miljøovervåkningsprosjektet ble til slutt utformet slik at det ble installert rør i underliggende kulturlag på eiendommene Schultzgt. 3-7 slik at det vil være mulig å måle eventuelle endringer i fuktnivået og hydrologiske ledningsevne og trekke ut jordbunnsvann til analyse av forskjellige parametre. Det ble ikke prosjektert for mulig trykk eller setning, fordi den økte belastningen på kulturlaget fra nybyggene ble beregnet til å ikke overstige vektbelastningen fra den tidligere murbebyggelsen.

Installasjon

Installasjon av målerør og stakerør foregikk 12-14. november 1996 etter byggestart i oktober. Selmer AS holdt de bestemte installasjonsområdene frostfrie og ga adgang til områdene før, under og etter installasjon.

Seks stakerør av aluminium med lukket spiss ble installert for fuktinnholdsbestemmelse ved bruk av neutronprobe (fig 24). Punkt 1 og 2 ligger på Schultzgt. 3 (fig 27) og punkt 3-6 ligger på Schultzgt. 5-7 (fig 28). Punkt 1 og 4 befinner seg utendørs på gårdsplassene, mens 2, 3, 5 og 6 er innendørs i bakgårdene i boder med betonggulv. Hvert rør ble senket ned til en maksimal dybde av 4,48m som gir ca. 3,98m til adgang for neutronprobe. Jordmassen som ble gravd ut under boring ble analysert for jordbunnsart og kjemisk sammensetning (Appendix C og D).

Tolv stakerør av plast med en keramisk porøs kappe festet på rørtuppen ble installert for innsamling av jordbunnsvann til kjemiske analyse (fig 26). Seks punkter ble installert i både Schultzgt. 3 og Schultzgt. 5-7 (fig 27 og 28). Rørene ble senket ned til forskjellige dybde, fra 1,45 til 3,09 m. Jordmassen som ble gravd ut under boring ble analysert for jordbunnsart og kjemisk sammensetning (Appendix C og D).

Overvåkingsprogram

Kulturlagene på Schultzgate har blitt overvåket fire ganger om året (mellom november 1998 og september 2001): i overgangene august-september, november-desember, februar-mars og mai-juni. Tolv serier med fuktmålinger har blitt tatt med neutronprobe: like etter installasjon i november 1996 og fra november 1998. Tretten serier med vannprøver har blitt tatt og analysert. Forsøkene like etter installasjon resulterte ikke i vannprøver på grunn av kulden, og forsøkene i juni 1997 samlet en ikke inn vannprøver til analyse.

Leverandøren av neutronprober gikk konkurs like etter installasjonen i Schultzgate. Et brukt eksemplar ble skaffet til prosjektet gjennom Institute of Hydrology (UK), men dette tok over et år. I tillegg visste det seg at analyse av vannprøvene på et lokal laboratorium ikke lot seg gjennomføre med mindre enn 3 måneders ventetid. Dette var uakseptabelt med hensyn til noen av parametrene som skulle kontrolleres, særlig analyse av redokspotensial (Eh) og oppløst oksygen (DO_2). Disse må analyseres så snart som mulig etter at prøvene er tatt opp. Til slutt ble et sett av analyseprosedyrer utviklet ved Vitenskapsmuseets Konserveringslaboratorium, slik at målingene gjennomføres på huset like etter innsamling.

Resultater

Kulturlagenes hydrologi kartlegges med en profil gjennom kulturlagene ved bruk av de seks aluminiumsrørene og en neutronprobe. Feltmålingene blir konvertert til kalkulert volumetrisk fuktinnhold basert på jordbunnstype (Appendix E). Bortsatt fra de øverste ca. 30cm (som er forstyret av klimatiske forhold) er fuktinnhold mellom 1996 og 2001 stabile og ikke direkte styrt av nedbørsmengde.

Kulturlagenes kjemi har visste seg å være vanskelig å tolke (Appendix F). Mye av det skyldes at vannprøvene er hentet opp fra lag med et bredt spektrum av kjemiske forhold inkludert mindre bevarende miljøer. Verdiene av de forskjellige parametrene som måles varierer noe, men ser ut til å være stabile innenfor en vis ramme. For de ti fungerende målepunkter viser ingen parametrene en synkende eller stigende tendens.

Målte pH-verdier ligger mellom 5,0 og 6,8 (fig 45) som er godt innenfor pH-området som ble målt for jordprøvene fra både Schultzgate (Appendix D) og Folkebibliotekstomten (Peacock 1985). Redoksmålingene (Eh) varierer fra –242 til +255mV, dvs. fra noe reduserende til meget reduserende miljøer (fig 46). Sammenheng mellom redoks og pH (fig 47) kan brukes for å få et inntrykk av kulturlagets bevarende karakter. Data fra Schultzgate viser to atskilte grupper, en med noe reduserende våte kulturlag og en med klart reduserende, vanntrukne kulturlag (fig 49).

Oppløst oksygen (DO_2) i vannprøvene har variert mellom 0,4 and 17,4%, hvor luften inneholder 20,9% (fig 50). De målte verdiene svinger mye, men viser i hvilken grad mikromiljøet rundt hvert målepunkt er styrt av nedbørsmengde og -kjemi. Elektriske ledningsevne i vannprøvene ligger mellom 204 og 2020µS, og er forholdsvis stabile for hver målepunkt (fig 51). Trenden som kom frem ved pH-redokssammenligningen er til stede i verdiene for elektriske ledningsevne, særlig når de legges sammen med pH-verdiene (fig 52). Igjen viser dataene to atskilte grupper, der den ene har de høye ledningsevneverdiene som er karakteristisk for gode bevaringsforhold for organiske materialer.

Fortolking

Hydrologien for kulturlagene på Schultzgate er tilfredsstillende kartlagt og stabil. Vannmålingene har vist seg å være meget kompliserte å tolke. Analyse av flere kjemiske parametere er av betydelig hjelp i dette tolkningsarbeidet. Tomtene på Schultzgate er meget heterogene og omgjort. Dette visste det seg allerede ved overflatundersøkelsen i 1995. Mangel på tilgang til profiler for kulturlagene før eller under byggeperioden resulterte i en 'blind' vurdering når det gjelder plasseringen av både målerør og stakerør. Et resultat er at noen vannprøver er hentet opp fra lommer i kulturlag som er og har vært av mindre bevarende karakter. Med grunnlag i de kjemiske målingene så langt ser forholdene i kulturlagene ut til ikke å ha vært påvirket av fornyelsen av tomtene.

Overvåkingssystemets velegnethet

Miljøovervåkningsprosjektet i Schultzgt. 3-7 er det første av sitt slag både i Norge og i et liknende nordlig klima. I tillegg sto det overfor tekniske problemer som lignende overvåkingsprosjekter i utlandet ikke ble utsatt for. Som konsekvens har prosjektet blitt utsatt for et bredt utvalg av tekniske, oppstarts- og tolkningsproblemer. Det fleste er nå overstått. Målerørene er forholdsvis robuste og har lang levetid. Neutronprobeteknologien er noe foreldet, men den er meget enkel i bruk og leverer lett forståelige og brukbare data. Ulempen er en krevende installasjonsprosedyre. Uttak av vannprøver er noe krevende, men gjennomførbar. Analyseprosedyrene som er utviklet fungerer og passer til prosjektets behov og nøyaktighetsnivå, men noen av analysemetodene kan videreutvikles. Tolkning av målingsresultatene har vært krevende på grunn av kulturlagenes sammensetning og manglende forhåndskartlegging. En arkeologiske forundersøkelse før bygging ville gitt verdifull informasjon til å lette tolkingen, men samtidig gjort en inngrep i kulturlagene som skulle bevares. Det er først etter flere års grunnlag at det har vært mulig å danne et bilde over de underjordiske forholdene i Schultzgate.

Konklusjoner

I prosjektet Miljøovervåking av kulturlagene i Schultzgt. 3-7 har det vært lagt vekt på å kartlegge forholdene inne i de skjulte kulturlagene under nybyggene i Schultzgt. 3 og Schultzgt. 5-7. Det har også blitt lagt vekt på ulike hydrologiske og kjemiske parametre som påvirker bevaring/nedbrytning av organiske arkeologiske og økologiske materialer, og tekniske løsninger for vurdering av disse.

Resultatene av målinger og analyser understreker hvor viktig det er at overvåking gjøres over flere år for å danne et representativt bilde av forholdene. Av den grunn er det viktig at overvåkingen for å kartlegge jordbunns hydrologiske og kjemiske karakter i uberørt stand er satt i gang før noen form for inngrep stettes i gang i prosjektområdet. Denne komparative 'baseline' brukes videre til vurderingen av alle måleresultater. I tillegg viser det at 'desk-based assessment' må legge mer vekt på kartleggingen av kulturlagets heterogene karakter, og at det må aktivisere det arkeologiske gjenstandsmaterialet fra byen i kartleggingen av bevaringspotensialet av kulturlaget.

Så langt ser det ut til at nybyggene på Schultzgate ikke har forandret på parametrene som overvåkes. Dette indikerer at den byggetekniske løsningen på Schultzgt. 3-7 er vellykket så langt (fig 53). Overvåkingsprosjektets design er godt egnet som utgangspunkt for andre lignende prosjekter i middelalderbyene hvor kulturlagene ligger over og ikke i kontakt med grunnvannspeilet. Erfaringer så langt danner et godt grunnlag og kunnskap for etablering av andre miljøovervåkningsprosjekter i Trondheim.

Miljøovervåkingsprosjektet i Schultzgate ble utformet for å løse en konkret, forholdsvis liten byggesak i en provinsby der det var ønskelig å ikke grave ut men bevare de underliggende kulturlagene der de ligger. I forbindelse med prosjekteringen ble råd og kompetanse hentet inn fra andre miljøer, særlig i utlandet. Den teknologiske løsningen som ble utviklet for Schultzgt. 3-7 har utgangspunkt i lignende forvaltningssaker i utlandet. I tillegg den økende database av analyseresultater, sammenlignes det med lignende miljøovervåkingsresultater ut over Norges grenser. Det forvaltningsdilemmaet som en sliter med overfor Schultzgate er noe de fleste byene i Nord-Europa sliter med for tiden. For å gi noe tilbake til disse miljøer som har bidratt med ekspertise og interesse, og for å dele resultater og erfaringer fra Schultzgateprosjektet med det større byforvalningsmiljøet i Europa, har Institutt for arkeologi og kulturhistorie ved Vitenskapsmuseet, Norges teknisk-naturvitenskapelige universitet (NTNU), valgt å publisere denne prosjektrapporten på engelsk.

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Appendix A

Desk-based assessment

(Reed 1995)

Historical evidence
Three of the roads in the area are probably of medieval origin:

Munkhaugveita, which divides the two blocks from one another, is first mentioned in 1617 when it is referred to as *the street running out to the smithies*. The origins of the name is uncertain but the *haug* part of the name is probably from the Old Danish word for garden, whilst the *munk* part is almost certain the word form monk. it is thought therefore that the area may have been used by monks as gardens.

St. Jørgensveita, which runs to the east of the site, gets its name from St. Jørgens almshouse which was established in 1607, there is little doubt, however, that the street is much older. The earliest name which is recorded for this street is *det gamle Kirkestrete*, the old church street, St. Jørgensveita leads up to the cathedral.

Vår Frue Strete, which forms the northern boundary of the area, is undoubtedly medieval and has had the same names as far back in time as it can be followed (the beginning of the 17th century). The name has probably arisen because of the proximity to Vår Frue (Our Ladies) church on the north side of the road.

The fourth road ***Schultz gate***, which lays to the west of the properties was laid out after a fire in 1846 and received its name from Pastor Schultz who had owned St. Jørgensveita 6 in 1830.

In the 17th century the properties Schultz gate 5 and 7 formed parts of 2 larger properties fronting onto St. Jørgensveita. The extant documentary evidence gives no indication of the lay-out of these properties. The archaeological evidence, however, showed that the southernmost of these properties had a cellared house on the corner of St. Jørgensveita and Munkhaugveita, under the present St. Jørgensveita 6a. In 1653 Schultz gate 3 formed part of a large property covering the north-east corner of Munkhaugveita and St. Jørgensveita.

After the catastrophic town fire of 1681 there appears to have been little change in the pattern of properties here as this area was not re-regulated.

The properties fronting onto Munkhaugveita between St. Jørgensveita and Munkegate burnt in a fire in 1827. These were rebuilt only to burn again in a fire in 1846 which destroyed the area between Erling Skakkes gate to the south, Vår Frue gate to the north, St. Jørgensveita to the east and Munkegate to the west. These properties had up to this point in time on the whole followed the pattern reflected in the 17th century documents. With the laying out of Schultz gate, however, this pattern changed. The properties now fronted onto this newly established street. The buildings erected after this fire were built of brick, this had become compulsory after a fire in the northern part of the town in 1841.

Archaeological evidence
It is known that at least one of the 17th century properties had a cellar and the other two may well have had. As with the recorded cellar these were probably along the frontage to St. Jørgensveita.

During the 18th century and possibly into the 19th century the properties almost certainly had large rubbish pits in there yards. Evidence from other excavations shows that these are normally placed to the rear of the property near the boundary with the neighbouring property.

All of the houses erected in 1846 appear to have been cellared with the cellars on the street frontage, some of these were only half-cellars, in particular that under Schultz gate 7. The foundations were solidly built of roughly hewn greystone blocks. At the back of the properties, along the boundaries of the adjacent properties, were yards surrounded by various outhouses. Sometime during the beginning of this century services, water and sewer pipes, were laid into the properties which undoubtedly had manholes in the backyards. These services normally pass through gateways and into the yards.

Preliminary examination of site

In June 1995 Riksantikvaren gave Selmer A/S permission to remove the modern overburden in order to pinpoint the exact position and quality of the foundation of the demolished buildings. The deposits were removed mechanically in August 1995 under archaeological supervision. This work showed that the overburden varied in thickness from a few centimetres in the south to ca. 0.60m in the north. With the exception of Schultz gate 3 and 5 the removed material consisted of gravel laid over demolition rubble. On the rest of the site there was a thin layer of demolition debris covered by a very compact layer of *subus*. The walls were very difficult to plan exactly, particularly those belonging to the cellars. Here a number of walls had collapsed into the cellar during demolition, it was not therefore possible to find these without digging down deeper than the surrounding area. Otherwise some of the stones from the other walls had been disturbed during demolition, and some even during the present machine clearance. On Schultz gate 3 the main problem was that the brick built walls had been demolished and the whole area was covered with a quite thick layer of broken bricks. It was therefore almost impossible to find out what was a wall and what was not.

On Schultz gate 3 and 5A it was not possible to precisely locate the backfilled cellars. On 5A it was quite apparent from the backfill where the cellar was located but it was not possible to locate the walls. On Schultz gate 5B an almost quadratic cellar was recorded on the street frontage, the existence of this had not previously been recorded. The known cellar on Schultz gate 7 was somewhat large than previously recorded.

Previous archaeological records in the area

<u>TA73</u> In connection with the reparing of a waterpipe a hole was dug in Vår Frue strete by the corner of Schultz gate in1947. At a depth of about 2,25m well preserved split logs were found. These lay closely packed at right-angles to the direction of the present road. Over this were two layers of timber paving with planks laid in the same direction as the present road. Natural subsoil was not recorded here.

<u>TA 1984/3</u> In connection with repairs to a waterpipe a hole was dug on the corner of Schultz gate and Vår Frue strete in 1984. The mechanical excavation was done and the hole refilled before any recording could be done. According to verbal evidence from the machine driver the interface between occupation deposits and the natural subsoil lay at ca. 2m below the present road surface.

<u>TA99</u> In 1935 a trench for the insertion of a gas main was dug along Munkhaugveita. In the eastern part by the junction with Schultz gate the trench was dug down to a depth of 1,25m and cut through numerous layers of earth and sand. The recorded layers rose by ca. 0,5m further to the east. At various height in the section traces of timbers were recorded. No information about the subsoil is given.

<u>TA 132</u> In connection with the construction of the petrol station on Munkhaugveita 3 holes were dug in the courtyard. The deposits were recorded as a uniform black earth down to a depth of ca. 3m when the excavating was halted. The natural subsoil was not encountered.

<u>TA 1992/9</u> In 1992 a hole was dug in the forecourt of the petrol station for the insertion of a new petrol tank. The upper 1,5m of deposits had been destroyed by a cellar, but under this was approximately 2m of organic rich deposits. Into the natural subsoil, which here consisted of .. and lay at ca. 8.80masl, was dug a ca. 3m diameter and ca. 0.4m deep pit. The backfill of this pit included wood chips, moss and branches from pine trees, the pine needles were still green. Material from the pit was C14 date to ...

TA 1985/12 In connection with plans for the redevelopment of the area to the north-west of the junction between Schultz gate and Munkhaugveita trial excavations to evaluate the site were undertaken in 1985. The evaluation consisted of four trenches and two boreholes.

In trench A 9 phase of wooden constructions were found, the wood was very well preserved. The phases were dated to the period from the late 11th or early 12th century to the 14th century. The present day surface here lay at ca. 12.50masl and the natural sand lay between 10.10masl and 10.40masl.

Trench B was excavated in the forecourt of the petrol station and lay close to a modern cellar. No archaeological deposits were recorded her. (See TA 1992/9).

In trench C the well preserved remains of 7 phases of wooden buildings were found. These were dated to the period from the late 11th century to the 13th century. The present day surface here lay at ca. 12.34masl and the natural sand lay between 9.34masl in the south and 10.00masl in the north.

In trench D, which was heavily disturbed by intrusions, only to phases of wooden buildings were documented. The present day surface lay at ca. 12.10masl and the natural sand lay between 10.10masl and 10.40masl.

The two boreholes were drilled from at surface level of ca. 12.65masl and showed that the interface between the archaeological deposits and the natural subsoil lay at ca. 9.50masl.

TA 1977/5 In connection with the rehabilitation of the two properties St. Jørgensveita 6A and 6B an excavation took place along the lines of the foundations for the new extension. A number of medieval wooden structures were found, but because of the limited extent of the excavation it was not possible to gain information about their size and shape.

It was clear from the onset that the upper layers were badly disturbed by a number of modern constructions. These included manholes, settling tanks and the foundations of the demolished outhouses.

Of post-medieval structures the clearest is K13 which is the sloping staircase into a cellar which lay between areas B and C outside the excavated area. The split logs forming the W wall were visible in the E section of area A. The stairs were heavily burnt and the finds suggest that the building has been destroyed in the fire of 1681.

The medieval deposits

In the SW part of the trench were the remains of a number of different construction which because of later intrusions had no physical connections with the rest of the area (*Komplex 5*).

These constructions were in the form of 5 different layers of wooden paving which it was possible to divide into distinct phases based on the direction of the planks. All the phases of timber slope downwards towards the E, this is probably caused by subsidence and decay arising after the excavation of the post-medieval cellar K13. The earliest phase consisted of NS planks while phase 2 consisted of EW planks. Phase 3 which lay at ca. 11.25masl also contained EW planks while phase 4 had NS planking. The final phase recorded lay at ca. 11.50masl and consisted of poorly preserved planks of indeterminate direction.

Below the levels of planking were two intercutting pits dug into the natural sand, the bases of which lay at ca. 9.95masl. The function of these pits is unclear, but they may be refuse pits.

No dateable finds were made in this area, but all features are presumed to be of medieval date.

> *Layer 31 consisted of demolition debris. This overlay a poorly preserved planked surface. Under the planking was a compact brown clayey earth layer (32). Under 32 was a layer consisting of sand, clay and stone chips (50)* which overlay another plank surface. This *in turn overlay a patch of light sand (64). Sealed by these layers was a planked surface made up of N-S planks. Directly below this was another plank surface consisting of E-W planks on N-S joists. Below these there was another layer of E-W planks which lay directly on a compact greasy earth layer with wood chips (47/109). Below this was another planked surface which in turn overlay another earth layer with wood chips (87).* The latter overlay a lens of charcoal (96) followed by a dark brown greasy earth layer (97). This in turn overlay a layer of sand (88) which overlay a sandy brown soil with some decayed bone (48/110).
>
> *Overlaying and partly cut into the natural subsoil was a thick layer of wood chips with inclusions of sand and charcoal (98).*

At the E end of area B lay various layer of planking (*Komplex 1*) in either N-S direction or E-W, the highest surviving timbers lay at ca. 12.20masl. Because of modern disturbances it was not possible to find a relationship between this and features on the rest of the site.

Based on the few finds this complex dates from the 13th and 14th centuries.

To the S of the junction between trenches A and B was a series of intrusion of various dates (*Komplex 3*). The earliest of these was difficult to relate to the surrounding features but appears to have cut *komplex 4*, while a number of layers covering *komplex 4* seem to have sunk into then.

> *It was difficult to document the exact extent and content of this feature. In and under the clay layer (60) were a number of planks and logs. Similarly disassociated timbers were found in the wood chip layer, 67, and the clay and sand layers 70 and 85. The deposits in this area were unstable and extremely wet, so much so that it was almost impossible to get a clear picture of the internal relationships between the layers and the timbers.*

Due to safety reasons this feature was not excavated below ca. 9.95masl, but at this level some timbers were found. Whether these represent a timber frame within the feature could not be ascertained.

It is difficult to dated this feature which obviously post-dates *komplex 2*. Finds from the layers sealing it suggest that it is from the late 13th century.

In the central part of trench A at its junction with trench B was a relatively large area of undisturbed medieval deposits (*Komplex 2*).

> *Here there was a greasy brown earth layer which in part overlay an unburnt plank construction (34) and in part a layer of fire debris (33).The planks were limited in extent, consisting of two parallel E-W planks with a N-S plank beneath.....Under 33 was a thick light sandy clay layer (30)...containing several E-W planks.*
>
> *Under 30 was a layer of wood chips (35) which covered most of the central area....Below 35 and a light blue-grey clay layer (60) was a layer of earth mixed with sand, clay and wood chips (59).*

> *Below 59 was a layer of light coloured sand (55) followed by a light coloured clay layer (56).....Below these layers at ca. 11.65masl was a layer of wood chips (65) which overlay a layer of greyish black sand (72). In connection with 72 were a number of more or less randomly spread planks and logs Below this was a hard packed layer containing wood chips and twigs (74)....under this the wooden building (90) began to appear.*

This construction consisted of a plank surface with broad planks, up to 0.35m, laid in a N-S direction, these lay at ca.11.20masl. The planks lay on top of E-W running joists. An E-W log at ca. 13.20m formed the N boundary of this construction which was cut by complex 3 to the S and continued out of the excavated area to the W and E. The maximum preserved size of the shows that the building was at least 4.75x4.60m.

> Under the planks (90) was *a compact green-brown layer containing wood chips and moss (75)...under this were several round logs in a layer of wood chips (93). Below this were the remains of a burnt plank floor.*
>
> *Below this at ca. 11.10masl was a ca. 0.2m thick compact layer of dark grey sandy clay with some bones, stones and wood chips (103). Below this was a layer of orange sand (104) followed by a layer of dirty sand mixed with organic material and some charcoal (105). This was followed by a layer of charcoal (106) and a layer of burnt sand (107). The latter directly overlay the natural sand.*

Pottery found in the layers sealing the plank floor (90) was mainly of thirteenth century date. On the floor were found three decorated planks from a chest, the decoration suggests that these were of a 12th century dated. It is therefore possible that this floor should be dated to the 12th or early 13th century.

The area at the N end of the trench was difficult to interpret due to a number of modern intrusions and the fragmentary nature of many of the remains. Based on the site notes the sequence can be reconstructed as follows:

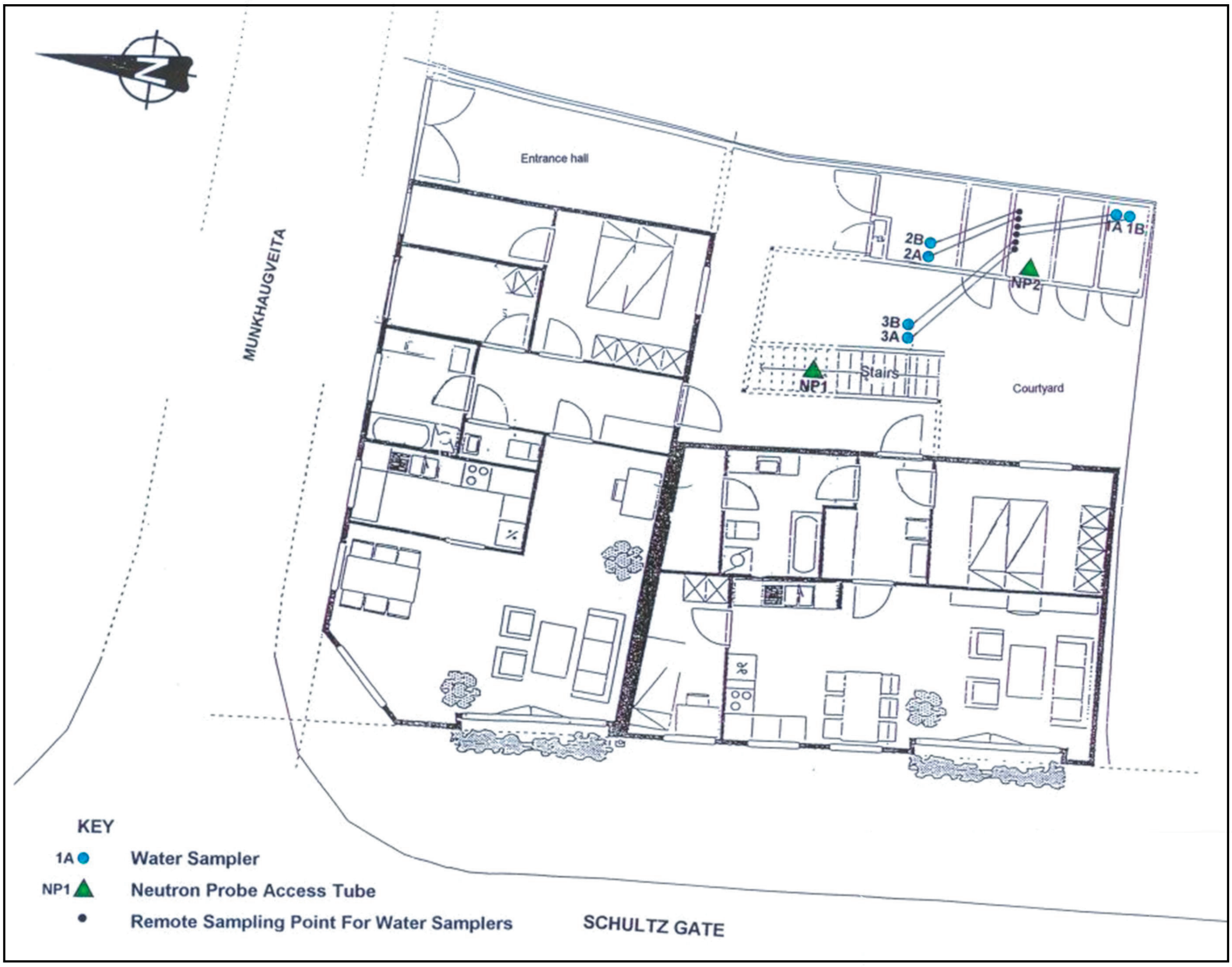
> Below the modern constructions and intrusions was a decomposed brown organic layer (25) which overlay a layer of grey clay mixed with some bone and wood chips (52). Below this was a dark brown earth layer with some wood chips (54) followed by a compact layer of smelly wood chips (58). Under this at ca. 11.25masl was a sandy dark grey layer with some wood chips and the fragmentary remains of planks (76). This was followed by a layer of wood chips mixed with twigs (78) which overlay a compact layer of wood chips (82). Below 82 was a layer of clayey sand (91) which was followed by a thick layer of wood chips (92). Next as grey clayey earth with some charcoal and stones (94) followed a layer of grey sand (99). Below these two layers was a sandy wood chip layer (101) and a light grey clayey layer with wood chips (102). These overlay a mixed layer of dark sand with organic remains, some charcoal and ash (105). This came down to a layer of charcoal (106) at ca. 10.85masl. There was no further excavation below this point.

After the archaeological excavation was finished the trench was extended mechanically to the SW corner of Vår Frue Strete 1 and 1m wide E-W trench was dug parallel to the S wall of this property. The trench was bottomed at ca. 10.40masl without the natural subsoil being encountered. A number of wooden post were visible in the S section of the E-W trench suggesting that there has been a property boundary at this point. This would appear to fit well with the documentary sources and the present property divisions. The stratigraphy here was much the same as the adjacent area.

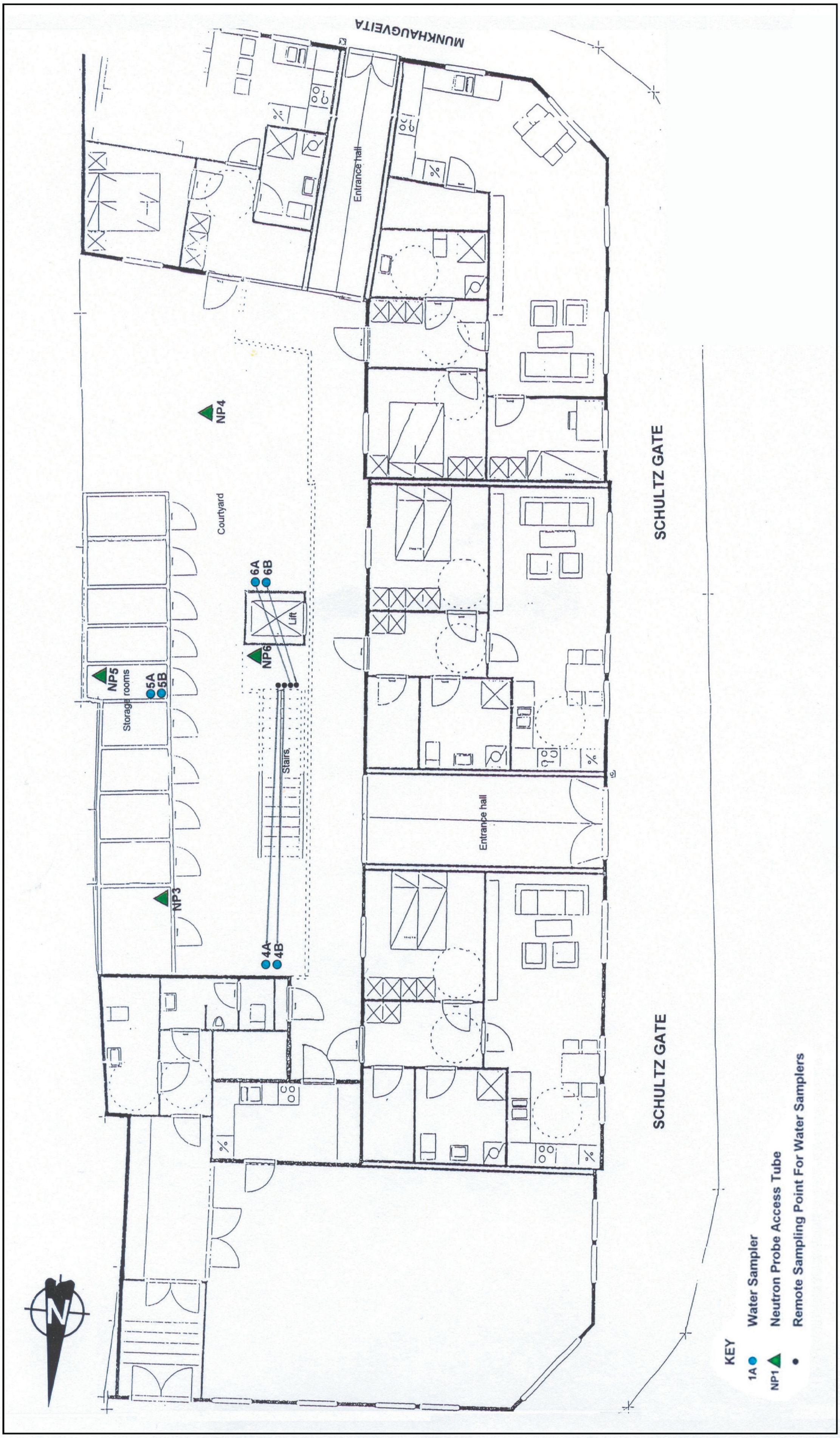
Appendix B

Building plans for Schultzgt. 3 and Schultzgt. 5-7

Architect's Drawings: Schultzgt. 3



Architect's Drawings: Schultzgt. 5-7



Appendix C

Borehole logs for neutron probe access tubes and water suction samplers

(After Hunting 1997)

NEUTRON PROBE ACCESS TUBE 1: BOREHOLE LOG 12/11/96

Description	Depth (m)	Thickness (m)	Sample Ref.	Sample Depth (m)
MADE GROUND (hard-core)	0.96	0.96		
SOIL/MADE GROUND Looser sandy loam containing brick	1.11	0.16		
SOIL/MADE GROUND Looser sandy loam containing brick	1.33	0.22		
SOIL Looser sandy loam with unidentified hard fragments	1.65	0.32	NP1/12	0.87-1.80
SOIL Sandy loam becoming greasy & wet	1.95	0.30	NP1/13	1.80-1.95
SOIL Wet & sticky sandy loam, dark organic matter present	2.15	0.20		
SOIL Sandy soil with increasing sand content	2.55	0.40		
SOIL Sandy soil with unidentified hard fragments	2.95	0.40	NP1/14	2.10-2.95
SOIL Sandy clay, possibly wetter/sticky	3.10	0.15		
SAND Coarse wet sand	3.40	0.30	NP1/15	2.95-3.40
SOIL Dark organic rich clay soil (greasy & wet with wood)	3.85	0.45	NP1/16	3.40-4.00
SOIL Dark organic rich clay soil	4.00	0.15		
END OF BOREHOLE	4.00			

NEUTRON PROBE ACCESS TUBE 2: BOREHOLE LOG 12/11/96

Description	Depth (m)	Thickness (m)	Sample Ref.	Sample Depth (m)
MADE GROUND (hard-core)	1.05	1.05		
SOIL/MADE GROUND Dark sandy clay	1.33	0.28	NP2/17	1.05-1.48
SOIL Dark sandy/clay/loam & increasing organic matter	1.48	0.15		
SOIL Moist/sticky sandy/clay/loam & increasing organic matter	1.65	0.17	NP2/18	1.48-1.78
SOIL Drier dark sandy/clay/loam with high organic matter/wood	1.85	0.20	NP2/19	1.80-1.95
WOOD Woody material in loam soil (phenolic pine smell)	1.95	0.10		
SOIL Organic sandy clay	2.15	0.20		
SOIL Very wet loam, highly organic (free water in profile)	2.25	0.10		
SOIL Very wet clayey soil with visible wood frags and sulphurous smell	2.55	0.30	NP2/20	2.15-2.55
WOOD Probable wood obstruction in borehole	2.70	0.15		
SOIL Moist clayey soil, highly organic with visible wood frags	3.10	0.40	NP2/21	2.65-3.10
SOIL Wet organic sandy clay loam	3.20	0.15		
SOIL Sandy loam with less organic matter	3.35	0.15	NP2/22	3.10-3.50
GRAVEL Coarse sandy gravel	3.65	0.30		
SAND Moist coarse sand	3.98	0.35		
END OF BOREHOLE	4.00			

NEUTRON PROBE ACCESS TUBE 3: BOREHOLE LOG 13/11/96

Description	Depth (m)	Thickness (m)	Sample Ref.	Sample Depth (m)
MADE GROUND (hard-core)	0.40	0.40		
SOIL/MADE GROUND Highly organic loam containing brick frags	0.55	0.15		
SOIL Highly organic loam containing wood frags	0.70	0.15		
SOIL Moist highly organic sandy loam containing wood frags	1.00	0.30	NP3/23	0.40-1.15
SOIL Moist? sticky highly organic loamy soil	1.15	0.15		
SOIL Moist highly organic loam containing larger wood frags	1.50	0.35		
SOIL Moist highly organic loam, many wood frags, sulphurous smell	1.95	0.45	NP3/24	1.15-1.95
SOIL Moist highly organic loam with sand lenses, sulphurous smell	2.30	0.35	NP3/25	1.95-2.25
SOIL Slightly moist sandy/clay/loam, high organic content	2.55	0.25		
SOIL Sandy/loam, high organic content, strong sulphurous smell	2.85	0.30	NP3/26	2.55-2.85
SAND Coarse sand	3.45	0.60	NP3/27	2.85-3.15
GRAVEL Coarse sandy gravel	3.95	0.50		
END OF BOREHOLE	4.00			

NEUTRON PROBE ACCESS TUBE 4: BOREHOLE LOG 14/11/96

Description	Depth (m)	Thickness (m)	Sample Ref.	Sample Depth (m)
MADE GROUND (hard-core)	1.15	1.15		
SOIL Very moist highly organic loam containing abundant wood frags	1.30	0.15		
SOIL Moist organic sandy loam containing wood frags	1.45	0.15		
SOIL Moist organic loamy soil	1.60	0.15		
SOIL Organic sandy loam with probable grit/fine gravel	1.75	0.25		
SOIL Wet highlyorganic loamy soil with sand lenses	2.10	0.35		
SOIL Moist highly organic loamy soil	2.30	0.20		
SAND Coarse sand containing some organic matter	2.55	0.25		
SAND Coarse wet sand	2.85	0.30		
GRAVEL Wet sandy gravel	3.05	0.20		
SAND Coarse wet sand	3.30	0.25		
GRAVEL Probable sandy gravel	3.95	0.65		
END OF BOREHOLE	4.00			

NEUTRON PROBE ACCESS TUBE 5: BOREHOLE LOG 14/11/96

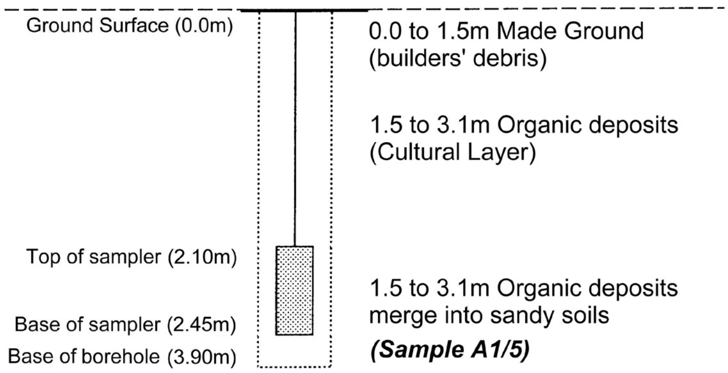
Description	Depth (m)	Thickness (m)	Sample Ref.	Sample Depth (m)
MADE GROUND (hard-core)	0.45	0.45		
SOIL/MADE GROUND Organic loam with brick fragments	0.60	0.15		
SOIL Organic loam with brick fragments	0.90	0.30		
SOIL Moist organic loamy soil, less frequent brick	1.05	0.15		
SOIL Moist/wet organic loamy soil, abundant wood fragments	1.20	0.15		
SOIL Wet sticky organic loamy soil	1.50	0.35		
SOIL Wet sticky organic loamy soil, frequent brick fragments	1.65	0.20		
SOIL Moist highly organic loamy soil, abundant wood fragments	1.80	0.25		
SOIL Wet organic loamy soil, abundant wood fragments	2.15	0.35		
SOIL Moist highly organic loamy soil, abundant wood fragments	2.30	0.15		
SOIL Organic loamy sand, less organic matter	2.45	0.15		
SOIL Organic loam/loamy clay, abundant wood fragments	2.60	0.15		
SOIL Moist organic loam, large wood fragments & sulphurous smell	3.10	0.50		
SAND Coarse sand	3.35	0.25		
GRAVEL Coarse sandy gravel	3.70	0.35		
GRAVEL Coarse sandy gravel & few soapstone frags	3.85	0.15		
GRAVEL Coarse sandy gravel	4.05	0.20		
END OF BOREHOLE	4.05			

NEUTRON PROBE ACCESS TUBE 6: BOREHOLE LOG 14/11/96

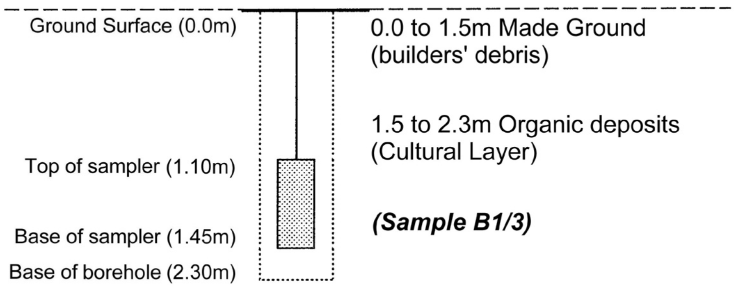
Description	Depth (m)	Thickness (m)	Sample Ref.	Sample Depth (m)
MADE GROUND (hard-core)	0.60	0.60		
SOIL/MADE GROUND Organic loam	0.75	0.15		
SOIL Organic loam with few brick fragments & sand inclusions	0.90	0.15		
SOIL Moist organic loam, few brick fragments & sand inclusions	1.20	0.30	NP6/28	0.60-1.35
SOIL Wet organic loamy soil	1.35	0.15		
SOIL Moist organic sandy clay/loam	1.50	0.15	NP6/29	1.35-1.50
SOIL Organic loamy soil, increasing quantity of wood frags	1.75	0.25		
SOIL Organic loamy soil with clay inclusions & wood fragments	1.90	0.15		
SOIL Stoney organic clay loam	2.05	0.15	NP6/30	1.75-2.20
SOIL Wet organic sandy loam/clay loam, fine gravel present	2.20	0.15		
SOIL Moist organic sandy loam,wood fragments	2.35	0.15	NP6/31	2.20-2.65
SOIL Wet sandy loam/loamy sand, less organic matter	2.70	0.35		
GRAVEL Coarse sandy gravel (fine grit)	3.15	0.55	NP6/32	2.65-2.85
SAND Coarse sand	3.65	0.50		
GRAVEL Coarse sandy gravel	4.00	0.35		
END OF BOREHOLE	4.05			

BOREHOLE LOGS: (BOREHOLES FORMED UNDER INSTALLATION OF SUCTION SAMPLERS 1 & 2)

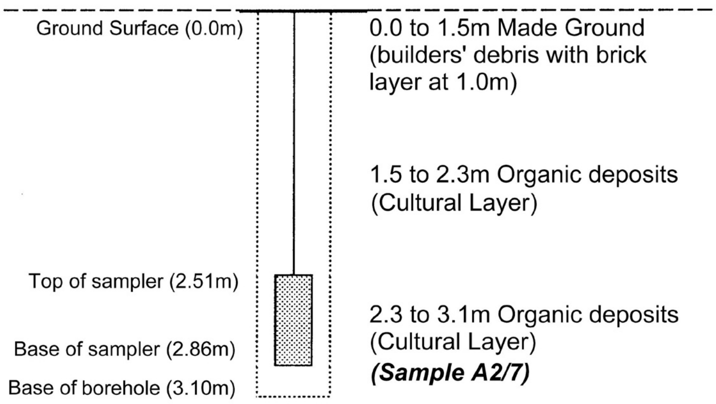
Borehole1A (Suction Sampler 1A)



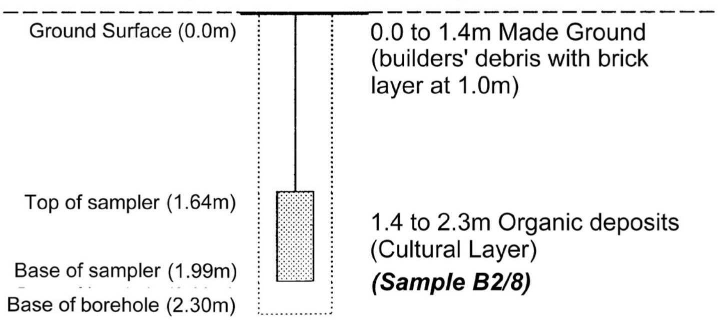
Borehole1B (Suction Sampler 1B)



Borehole 2A (Suction Sampler 2A)

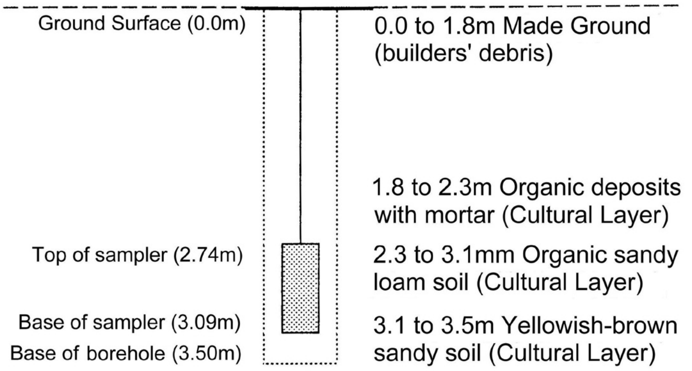


Borehole 2B (Suction Sampler 2B)

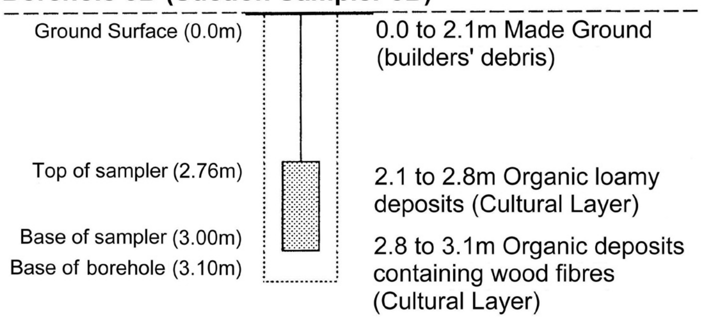


BOREHOLE LOGS: (BOREHOLES FORMED UNDER INSTALLATION OF SUCTION SAMPLERS 3 & 4)

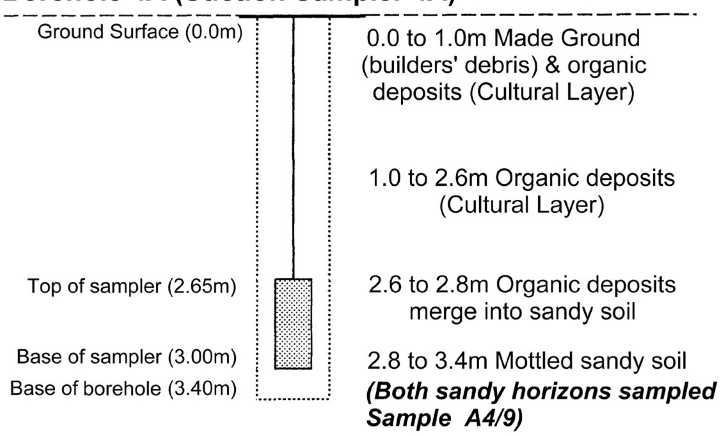
Borehole 3A (Suction Sampler 3A)



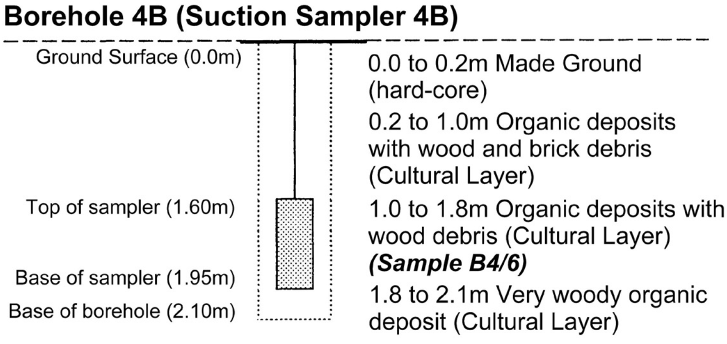
Borehole 3B (Suction Sampler 3B)



Borehole 4A (Suction Sampler 4A)

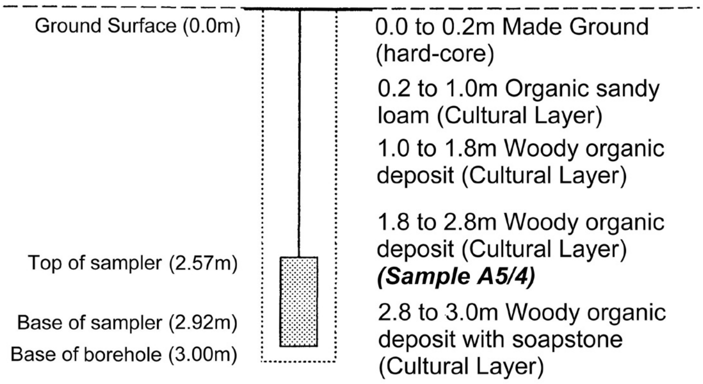


Borehole 4B (Suction Sampler 4B)

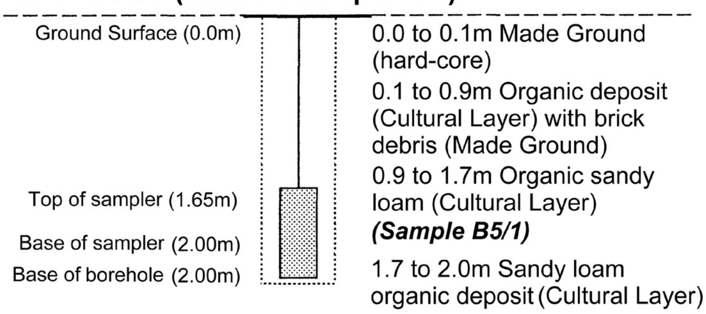


BOREHOLE LOGS: (BOREHOLES FORMED UNDER INSTALLATION OF SUCTION SAMPLERS 5 & 6)

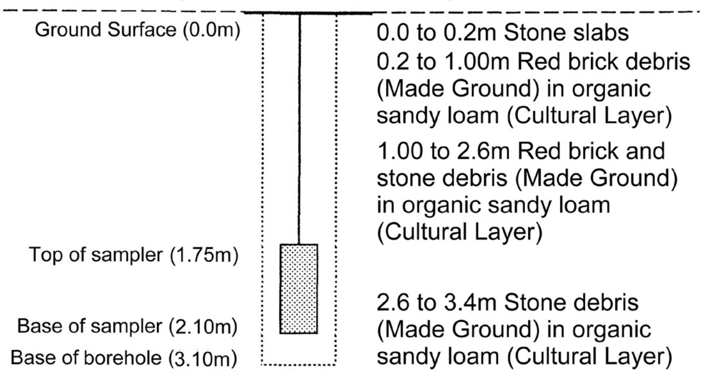
Borehole 5A (Suction Sampler 5A)



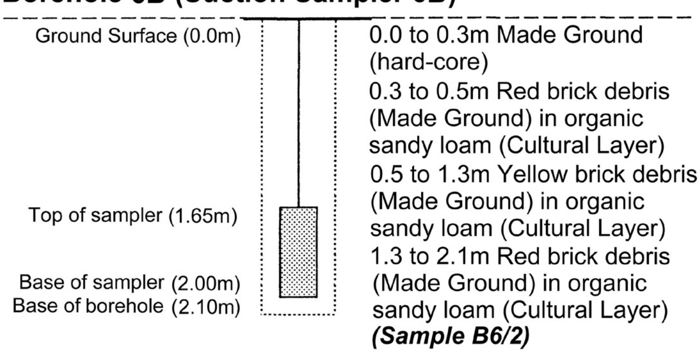
Borehole 5B (Suction Sampler 5B)



Borehole 6A (Suction Sampler 6A)



Borehole 6B (Suction Sampler 6B)



Appendix D

Soil analysis of neutron probe access tube cores and water suction sampler cores

(After Hunting 1997)

Soil Texture and Chemical Analysis[1] for Neutron Probe Access Tubes' Core Samples[1]

Access Tube	*Sample*	*Sample depth (m)*	*Brief Description*	*Receipt moisture content (%)*	*Organic matter (%)*	
					LOI	*wet oxidation*
1	NP1/12	0.87-1.80	Brown sandy loam	14	4	7
1	NP1/13	1.80-1.95	Very dark brown/black sandy loam	19	4	4
1	NP1/14	2.10-2.95	Olive grey coarse sandy loam/loamy sand	11	<1	<1
1	NP1/15	2.95-3.40	Dark olive grey coarse sand	12	1	3
1	NP1/16	3.40-4.00	Black variable stony and organic clay	32	10	11
2	NP2/17	1.05-1.48	Black organic loam	33	13	21
2	NP2/18	1.48-1.78	Black organic loam	44	31	23
2	NP2/19	1.80-1.95	Light brown loam, abundant wood fragments	36	21	11
2	NP2/20	2.15-2.55	Dark brown gritty sandy loam	43	14	13
2	NP2/21	2.65-3.10	Very dark brown organic sandy loam	42	18	10
2	NP2/22	3.10-3.50	Olive loamy gravely sand	14	3	5
3	NP3/23	0.40-1.15	Dark brown organic loam	38	18	8
3	NP3/24	1.15-1.95	Dark brown organic loam	60	39	42
3	NP3/25	1.95-2.25	Black sandy loam	44	23	15
3	NP3/26	2.55-2.85	Dark brown sandy loam	25	11	13
3	NP3/27	2.85-3.15	Yellowish brown coarse sand	5	1	1
6	NP6/28	0.60-1.35	Dark brown gritty/gravelly organic sandy loam	22	8	6
6	NP3/29	1.35-1.50	Dark brown organic sandy clay loam	30	9	8
6	NP3/30	1.75-2.20	Dark brown stony sand clay loam	27	6	6
6	NP3/31	2.20-2.65	Brown gravelly sandy loam	17	4	7
6	NP3/32	2.65-2.85	Greyish brown gritty/coarse sandy loam	12	2	3

1 Analysis conducted by Mountainheath Laboratories, Stevenage, Hertfordshire. (Reported in Hunting 1997)

Soil Texture and Chemical Analysis for Water Samplers' Core Samples[1]

Borehole	*Sample*	*Sample depth (m)*	*Description*	*Receipt moisture content (%)*	*Organic matter (%)*		*pH*	*Conductivity (µs/cm)*	*Sulphate (mg/kg)*	*Sulphide (mg/kg)*
					LOI	*wet oxid'n*				
1A	A1/5	3.1-3.9	Greyish brown/greyish yellow, coarse slightly gravely sand	11	2	1	7.7	2400	45	1.6
1B	B1/3	1.5-2.3	Black loamy peat containing wood (foul egg/phenolic smell), leather & bone	54	33	47	7.2	4765	1080	4.0
2A	A2/7	2.3-3.1	Dark brown/black gravely organic sandy loam	25	6	7	6.9	2170	85	<1
2B	B2/8	1.4-2.3	Black loamy peat, few brick fragments, inclusions of sandy loam	30	7	10	6.0	2170	99	<1
4A	A4/9	2.6-3.4	Greyish coarse sand	7	1	3	5.8	2270	116	<1
4B	B4/6	1.0-1.8	Black loamy peat containing abundant wood fragments	53	33	47	4.9	3030	2330	<1
5A	A5/4	1.8-2.8	Black loamy peat containing abundant wood fragments	36	17	16	6.6	3510	650	<1
5B	B5/1	0.9-1.7	Dark brown/black gravely organic sandy loam	32	9	7	6.3	3680	45	<1
6B	B6/2	1.3-2.1	Dark greyish brown sandy loam containing red brick debris	19	4	5	7.5	2230	87	<1

1 Analysis conducted by Mountainheath Laboratories, Stevenage, Hertfordshire. (Reported in Hunting 1997)

Appendix E

Soil hydrology: estimated volumetric moisture content by neutron probe

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 5-6 September 2001

Water Standard Mean (Rs) for above site visit is: ***808 cps***

	Access Tube 1			Access Tube 2			Access Tube 3			Access Tube 4			Access Tube 5			Access Tube 6		
Depth (mm)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)
200	*	808	*	*	808	*	127	808	12%	114	808	9%	138	808	13%	245	808	25%
300	165	808	16%	281	808	29%	251	808	25%	209	808	21%	153	808	15%	312	808	32%
400	169	808	17%	299	808	30%	419	808	43%	283	808	29%	201	808	20%	361	808	37%
500	137	808	13%	211	808	21%	419	808	43%	302	808	31%	306	808	31%	415	808	43%
600	171	808	17%	251	808	25%	501	808	52%	245	808	25%	345	808	35%	425	808	44%
700	209	808	21%	283	808	29%	389	808	40%	209	808	21%	364	808	37%	430	808	45%
800	252	808	25%	306	808	31%	541	808	56%	190	808	19%	384	808	40%	462	808	48%
900	308	808	31%	344	808	35%	605	808	63%	198	808	20%	421	808	44%	465	808	48%
1000	326	808	33%	368	808	38%	621	808	65%	228	808	23%	444	808	46%	455	808	47%
1100	299	808	30%	411	808	43%	635	808	64%	317	808	32%	306	808	31%	479	808	50%
1200	289	808	29%	523	808	55%	705	808	67%	519	808	54%	351	808	36%	501	808	52%
1300	307	808	31%	601	808	63%	684	808	74%	584	808	61%	521	808	54%	524	808	55%
1400	329	808	34%	589	808	62%	714	808	72%	643	808	67%	540	808	56%	517	808	54%
1500	322	808	33%	632	808	66%	677	808	75%	724	808	76%	543	808	57%	518	808	54%
1600	326	808	33%	631	808	66%	724	808	71%	705	808	74%	615	808	64%	565	808	59%
1700	335	808	34%	605	808	63%	724	808	76%	614	808	64%	688	808	72%	502	808	52%
1800	355	808	36%	648	808	68%	737	808	76%	556	808	58%	620	808	65%	454	808	47%
1900	419	808	43%	639	808	67%	632	808	77%	587	808	61%	516	808	54%	446	808	46%
2000	327	808	33%	627	808	66%	468	808	66%	510	808	53%	562	808	59%	473	808	49%
2100	298	808	30%	564	808	59%	688	808	49%	496	808	52%	731	808	77%	457	808	47%
2200	227	808	23%	505	808	53%	742	808	72%	616	808	64%	716	808	75%	389	808	40%
2300	199	808	20%	544	808	57%	731	808	78%	497	808	52%	432	808	45%	466	808	48%
2400	192	808	19%	586	808	61%	682	808	77%	208	808	21%	424	808	44%	385	808	40%
2500	189	808	19%	571	808	60%	647	808	72%	158	808	15%	640	808	67%	341	808	35%
2600	195	808	19%	540	808	56%	518	808	68%	151	808	15%	675	808	71%	297	808	30%
2700	184	808	18%	727	808	76%	414	808	54%	152	808	15%	675	808	71%	320	808	33%
2800	159	808	15%	680	808	71%	414	808	43%	140	808	13%	693	808	73%	250	808	25%
2900	201	808	20%	641	808	67%	226	808	23%	142	808	14%	704	808	74%	234	808	24%
3000	305	808	31%	655	808	69%	137	808	13%	146	808	14%	597	808	62%	246	808	25%
3100	240	808	24%	494	808	51%	117	808	11%	141	808	14%	543	808	57%	244	808	25%
3200	190	808	19%	414	808	43%	126	808	12%	138	808	13%	239	808	24%	235	808	24%
3300	225	808	23%	261	808	26%	137	808	13%	136	808	13%	150	808	14%	225	808	23%
3400	327	808	33%	210	808	21%	142	808	14%	138	808	13%	143	808	14%	229	808	23%
3500	486	808	51%	204	808	20%	151	808	15%	136	808	13%	135	808	13%	243	808	24%
3600	509	808	53%	182	808	18%	166	808	16%	157	808	15%	133	808	13%	245	808	25%
3700	530	808	55%	170	808	17%	176	808	17%	173	808	17%	144	808	14%	246	808	25%
3800	605	808	63%	175	808	17%	175	808	17%	169	808	17%	149	808	14%	284	808	29%
3900	585	808	61%	154	808	15%	*	808	*	*	808	*	*	808	*	*	808	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 11 June 2001

Water Standard Mean (Rs) for above site visit is: ***808 cps***

	Access Tube 1			**Access Tube 2**			**Access Tube 3**			**Access Tube 4**			**Access Tube 5**			**Access Tube 6**		
Depth (mm)	**R (cps)**	**Rs (cps)**	**Mc (%)**	**R (cps)**	**Rs (cps**	**Mc (%)**	**R (cps)**	**Rs (cps)**	**Mc (%)**	**R (cps)**	**Rs (cps)**	**Mc (%)**	**R (cps)**	**Rs (cps)**	**Mc (%)**	**R (cps)**	**Rs (cps)**	**Mc (%)**
200	*	808	*	*	808	*	123	808	12%	99	808	9%	131	808	12%	252	808	25%
300	175	808	17%	305	808	31%	239	808	24%	198	808	20%	153	808	15%	309	808	32%
400	187	808	18%	313	808	32%	421	808	44%	273	808	28%	195	808	19%	361	808	37%
500	164	808	16%	230	808	23%	417	808	43%	315	808	32%	283	808	29%	413	808	43%
600	157	808	15%	268	808	27%	505	808	53%	267	808	27%	343	808	35%	433	808	45%
700	231	808	23%	291	808	30%	403	808	42%	225	808	23%	358	808	37%	431	808	45%
800	238	808	24%	308	808	31%	550	808	57%	203	808	20%	379	808	39%	466	808	48%
900	294	808	30%	339	808	35%	598	808	63%	209	808	21%	415	808	43%	466	808	48%
1000	331	808	34%	370	808	38%	627	808	66%	226	808	23%	445	808	46%	453	808	47%
1100	320	808	33%	396	808	41%	611	808	64%	307	808	31%	336	808	34%	482	808	50%
1200	303	808	31%	523	808	55%	626	808	66%	501	808	52%	324	808	33%	504	808	52%
1300	303	808	31%	602	808	63%	704	808	74%	600	808	63%	501	808	52%	530	808	55%
1400	332	808	34%	593	808	62%	676	808	71%	630	808	66%	535	808	56%	510	808	53%
1500	327	808	33%	622	808	65%	712	808	75%	726	808	76%	543	808	57%	523	808	55%
1600	319	808	33%	638	808	67%	683	808	72%	717	808	75%	593	808	62%	558	808	58%
1700	343	808	35%	598	808	63%	726	808	76%	628	808	66%	687	808	72%	510	808	53%
1800	340	808	35%	658	808	69%	730	808	77%	558	808	58%	615	808	64%	460	808	48%
1900	421	808	44%	627	808	66%	734	808	77%	590	808	62%	530	808	55%	445	808	46%
2000	360	808	37%	636	808	67%	620	808	65%	524	808	55%	548	808	57%	473	808	49%
2100	309	808	32%	564	808	59%	461	808	48%	486	808	51%	715	808	75%	457	808	47%
2200	245	808	25%	522	808	54%	694	808	73%	618	808	65%	716	808	75%	402	808	42%
2300	210	808	21%	526	808	55%	737	808	77%	532	808	55%	451	808	47%	465	808	48%
2400	194	808	19%	590	808	62%	727	808	76%	226	808	23%	410	808	42%	398	808	41%
2500	200	808	20%	569	808	59%	685	808	72%	159	808	15%	636	808	67%	354	808	36%
2600	195	808	19%	532	808	55%	638	808	67%	153	808	15%	679	808	71%	314	808	32%
2700	194	808	19%	713	808	75%	521	808	54%	154	808	15%	668	808	70%	325	808	33%
2800	166	808	16%	685	808	72%	396	808	41%	146	808	14%	693	808	73%	255	808	26%
2900	179	808	18%	644	808	68%	213	808	21%	145	808	14%	702	808	74%	243	808	24%
3000	296	808	30%	659	808	69%	138	808	13%	153	808	15%	585	808	61%	248	808	25%
3100	256	808	26%	517	808	54%	116	808	11%	145	808	14%	535	808	56%	249	808	25%
3200	199	808	20%	419	808	43%	126	808	12%	144	808	14%	218	808	22%	236	808	24%
3300	205	808	20%	275	808	28%	136	808	13%	144	808	14%	143	808	14%	228	808	23%
3400	300	808	31%	210	808	21%	143	808	14%	143	808	14%	133	808	13%	231	808	23%
3500	451	808	47%	204	808	20%	152	808	15%	144	808	14%	128	808	12%	245	808	25%
3600	521	808	54%	184	808	18%	167	808	16%	156	808	15%	128	808	12%	249	808	25%
3700	511	808	53%	170	808	17%	178	808	17%	180	808	18%	142	808	14%	247	808	25%
3800	601	808	63%	176	808	17%	178	808	17%	168	808	16%	151	808	15%	298	808	30%
3900	598	808	63%	155	808	15%	*	808	*	*	808	*	*	808	*	*	808	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

for site visit of 29-30 November 2000

Water Standard Mean (Rs) for above site visit is: ***808 cps***

	Access Tube 1			***Access Tube 2***			***Access Tube 3***			***Access Tube 4***			***Access Tube 5***			***Access Tube 6***		
Depth (mm)	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***
200	*	808	*	*	808	*	116	808	11%	99	808	9%	136	808	13%	259	808	26%
300	144	808	14%	290	808	30%	223	808	22%	192	808	19%	150	808	14%	320	808	33%
400	149	808	14%	279	808	28%	408	808	42%	259	808	26%	196	808	19%	368	808	38%
500	140	808	13%	195	808	19%	403	808	42%	286	808	29%	299	808	30%	418	808	43%
600	126	808	12%	236	808	24%	482	808	50%	234	808	24%	333	808	34%	428	808	44%
700	202	808	20%	279	808	28%	426	808	44%	195	808	19%	351	808	36%	430	808	45%
800	217	808	22%	303	808	31%	562	808	59%	181	808	18%	373	808	38%	460	808	48%
900	272	808	28%	336	808	34%	619	808	65%	193	808	19%	418	808	43%	459	808	48%
1000	323	808	33%	366	808	38%	614	808	64%	215	808	21%	448	808	46%	447	808	46%
1100	308	808	31%	398	808	41%	599	808	63%	313	808	32%	316	808	32%	476	808	49%
1200	284	808	29%	521	808	54%	684	808	72%	509	808	53%	335	808	34%	503	808	52%
1300	290	808	30%	600	808	63%	681	808	71%	577	808	60%	510	808	53%	528	808	55%
1400	314	808	32%	590	808	62%	696	808	73%	631	808	66%	532	808	55%	517	808	54%
1500	317	808	32%	633	808	66%	706	808	74%	726	808	76%	543	808	57%	511	808	53%
1600	311	808	32%	643	808	67%	702	808	74%	705	808	74%	599	808	63%	564	808	59%
1700	331	808	34%	598	808	63%	732	808	77%	605	808	63%	684	808	72%	500	808	52%
1800	318	808	33%	646	808	68%	725	808	76%	541	808	56%	611	808	64%	445	808	46%
1900	388	808	40%	637	808	67%	733	808	77%	579	808	61%	534	808	56%	436	808	45%
2000	389	808	40%	625	808	65%	556	808	58%	510	808	53%	547	808	57%	466	808	48%
2100	299	808	30%	563	808	59%	493	808	51%	477	808	50%	723	808	76%	451	808	47%
2200	256	808	26%	513	808	53%	728	808	77%	611	808	64%	710	808	75%	378	808	39%
2300	208	808	21%	538	808	56%	729	808	77%	489	808	51%	428	808	44%	454	808	47%
2400	180	808	18%	579	808	61%	722	808	76%	204	808	20%	423	808	44%	373	808	38%
2500	184	808	18%	567	808	59%	678	808	71%	144	808	14%	636	808	67%	333	808	34%
2600	175	808	17%	539	808	56%	590	808	62%	136	808	13%	671	808	70%	281	808	29%
2700	184	808	18%	728	808	77%	506	808	53%	139	808	13%	669	808	70%	305	808	31%
2800	158	808	15%	680	808	71%	352	808	36%	127	808	12%	694	808	73%	239	808	24%
2900	152	808	15%	642	808	67%	193	808	19%	127	808	12%	696	808	73%	227	808	23%
3000	245	808	25%	654	808	69%	126	808	12%	130	808	12%	590	808	62%	232	808	23%
3100	267	808	27%	500	808	52%	113	808	11%	122	808	11%	539	808	56%	234	808	24%
3200	205	808	20%	410	808	42%	124	808	12%	119	808	11%	227	808	23%	217	808	22%
3300	179	808	18%	262	808	27%	133	808	13%	118	808	11%	139	808	13%	207	808	21%
3400	243	808	24%	208	808	21%	135	808	13%	121	808	11%	130	808	12%	212	808	21%
3500	382	808	39%	204	808	20%	143	808	14%	125	808	12%	122	808	11%	227	808	23%
3600	517	808	54%	179	808	18%	157	808	15%	142	808	14%	123	808	12%	228	808	23%
3700	505	808	53%	168	808	16%	164	808	16%	157	808	15%	135	808	13%	227	808	23%
3800	541	808	56%	168	808	16%	165	808	16%	154	808	15%	141	808	14%	266	808	27%
3900	586	808	61%	143	808	14%	*	808	*	*	808	*	*	808	*	*	808	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe

for site visit of 9 September 2000

Water Standard Mean (Rs) for above site visit is: ***808 cps***

	Access Tube 1			Access Tube 2			Access Tube 3			Access Tube 4			Access Tube 5			Access Tube 6		
Depth (mm)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)
200	*	808	*	*	808	*	120	808	11%	101	808	9%	142	808	14%	226	808	23%
300	174	808	17%	259	808	26%	225	808	23%	197	808	20%	159	808	15%	301	808	31%
400	184	808	18%	302	808	31%	401	808	41%	277	808	28%	209	808	21%	357	808	37%
500	151	808	15%	216	808	22%	412	808	43%	314	808	32%	309	808	32%	409	808	42%
600	164	808	16%	247	808	25%	488	808	51%	257	808	26%	348	808	36%	422	808	44%
700	208	808	21%	285	808	29%	394	808	41%	213	808	21%	357	808	37%	423	808	44%
800	246	808	25%	304	808	31%	572	808	60%	194	808	19%	388	808	40%	461	808	48%
900	296	808	30%	331	808	34%	591	808	62%	196	808	19%	424	808	44%	466	808	48%
1000	329	808	34%	371	808	38%	642	808	67%	221	808	22%	445	808	46%	446	808	46%
1100	303	808	31%	388	808	40%	620	808	65%	312	808	32%	305	808	31%	474	808	49%
1200	291	808	30%	515	808	54%	617	808	65%	504	808	52%	355	808	36%	500	808	52%
1300	301	808	31%	594	808	62%	715	808	75%	593	808	62%	527	808	55%	528	808	55%
1400	327	808	33%	592	808	62%	677	808	71%	627	808	66%	541	808	56%	509	808	53%
1500	323	808	33%	625	808	65%	712	808	75%	726	808	76%	545	808	57%	518	808	54%
1600	318	808	33%	643	808	67%	674	808	71%	711	808	75%	614	808	64%	551	808	58%
1700	341	808	35%	590	808	62%	723	808	76%	622	808	65%	693	808	73%	534	808	56%
1800	356	808	37%	658	808	69%	734	808	77%	552	808	58%	629	808	66%	449	808	47%
1900	422	808	44%	630	808	66%	746	808	78%	587	808	61%	529	808	55%	441	808	46%
2000	333	808	34%	641	808	67%	641	808	67%	522	808	54%	564	808	59%	466	808	48%
2100	302	808	31%	560	808	58%	465	808	48%	483	808	50%	725	808	76%	450	808	47%
2200	239	808	24%	527	808	55%	679	808	71%	613	808	64%	713	808	75%	390	808	40%
2300	200	808	20%	516	808	54%	737	808	77%	526	808	55%	443	808	46%	436	808	45%
2400	192	808	19%	593	808	62%	730	808	77%	224	808	22%	426	808	44%	408	808	42%
2500	195	808	19%	562	808	59%	681	808	71%	159	808	15%	644	808	68%	343	808	35%
2600	197	808	20%	522	808	54%	658	808	69%	148	808	14%	673	808	71%	294	808	30%
2700	189	808	19%	690	808	72%	528	808	55%	152	808	15%	674	808	71%	325	808	33%
2800	162	808	16%	689	808	72%	430	808	45%	138	808	13%	710	808	75%	246	808	25%
2900	195	808	19%	646	808	68%	235	808	24%	141	808	14%	704	808	74%	236	808	24%
3000	306	808	31%	662	808	69%	140	808	13%	145	808	14%	594	808	62%	237	808	24%
3100	245	808	25%	521	808	54%	117	808	11%	137	808	13%	548	808	57%	245	808	25%
3200	187	808	18%	418	808	43%	124	808	12%	136	808	13%	229	808	23%	227	808	23%
3300	218	808	22%	272	808	28%	138	808	13%	137	808	13%	149	808	14%	222	808	22%
3400	372	808	38%	214	808	21%	141	808	14%	135	808	13%	133	808	13%	223	808	22%
3500	474	808	49%	207	808	21%	148	808	14%	140	808	13%	127	808	12%	234	808	24%
3600	515	808	54%	186	808	18%	165	808	16%	152	808	15%	125	808	12%	239	808	24%
3700	513	808	53%	172	808	17%	174	808	17%	175	808	17%	138	808	13%	237	808	24%
3800	572	808	60%	170	808	17%	178	808	17%	165	808	16%	146	808	14%	284	808	29%
3900	596	808	62%	151	808	15%	*	808	*	*	808	*	*	808	*	*	808	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

for site visit of 23 and 26 June 2000

Water Standard Mean (Rs) for above site visit is: ***808 cps***

	Access Tube 1			***Access Tube 2***			***Access Tube 3***			***Access Tube 4***			***Access Tube 5***			***Access Tube 6***		
Depth (mm)	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***
200	*	808	*	*	808	*	125	808	12%	130	808	12%	142	808	14%	276	808	28%
300	187	808	18%	125	808	12%	260	808	26%	224	808	22%	159	808	15%	325	808	33%
400	192	808	19%	155	808	15%	419	808	43%	300	808	31%	221	808	22%	379	808	39%
500	153	808	15%	179	808	18%	418	808	43%	308	808	31%	321	808	33%	422	808	44%
600	164	808	16%	248	808	25%	492	808	51%	252	808	25%	348	808	36%	429	808	44%
700	210	808	21%	282	808	29%	396	808	41%	214	808	21%	362	808	37%	440	808	46%
800	240	808	24%	306	808	31%	547	808	57%	197	808	20%	392	808	40%	470	808	49%
900	301	808	31%	339	808	35%	600	808	63%	205	808	20%	431	808	45%	467	808	49%
1000	328	808	34%	370	808	38%	626	808	66%	241	808	24%	437	808	45%	455	808	47%
1100	302	808	31%	387	808	40%	610	808	64%	335	808	34%	304	808	31%	484	808	50%
1200	296	808	30%	517	808	54%	637	808	67%	555	808	58%	377	808	39%	511	808	53%
1300	298	808	30%	601	808	63%	705	808	74%	578	808	60%	528	808	55%	523	808	55%
1400	326	808	33%	591	808	62%	680	808	71%	660	808	69%	543	808	57%	519	808	54%
1500	327	808	33%	622	808	65%	720	808	76%	730	808	77%	544	808	57%	521	808	54%
1600	319	808	33%	645	808	68%	677	808	71%	707	808	74%	622	808	65%	571	808	60%
1700	342	808	35%	588	808	61%	727	808	76%	596	808	62%	692	808	73%	500	808	52%
1800	347	808	36%	660	808	69%	733	808	77%	558	808	58%	625	808	65%	459	808	48%
1900	425	808	44%	615	808	64%	746	808	78%	585	808	61%	511	808	53%	446	808	46%
2000	338	808	35%	646	808	68%	646	808	68%	509	808	53%	572	808	60%	474	808	49%
2100	311	808	32%	561	808	59%	461	808	48%	499	808	52%	728	808	77%	454	808	47%
2200	236	808	24%	538	808	56%	690	808	72%	624	808	65%	715	808	75%	395	808	41%
2300	200	808	20%	503	808	52%	741	808	78%	482	808	50%	423	808	44%	469	808	49%
2400	191	808	19%	606	808	63%	730	808	77%	202	808	20%	455	808	47%	388	808	40%
2500	196	808	19%	557	808	58%	681	808	71%	156	808	15%	663	808	70%	354	808	36%
2600	194	808	19%	522	808	54%	655	808	69%	147	808	14%	676	808	71%	307	808	31%
2700	192	808	19%	705	808	74%	524	808	55%	148	808	14%	679	808	71%	320	808	33%
2800	160	808	16%	703	808	74%	409	808	42%	136	808	13%	707	808	74%	248	808	25%
2900	176	808	17%	648	808	68%	233	808	23%	140	808	13%	702	808	74%	241	808	24%
3000	306	808	31%	655	808	69%	139	808	13%	144	808	14%	584	808	61%	247	808	25%
3100	245	808	25%	541	808	56%	118	808	11%	135	808	13%	511	808	53%	247	808	25%
3200	191	808	19%	423	808	44%	127	808	12%	132	808	13%	217	808	22%	232	808	23%
3300	210	808	21%	289	808	29%	140	808	13%	134	808	13%	148	808	14%	224	808	22%
3400	306	808	31%	215	808	21%	143	808	14%	135	808	13%	147	808	14%	230	808	23%
3500	467	808	49%	206	808	21%	149	808	14%	139	808	13%	135	808	13%	242	808	24%
3600	515	808	54%	187	808	18%	163	808	16%	152	808	15%	133	808	13%	243	808	24%
3700	514	808	54%	170	808	17%	172	808	17%	172	808	17%	142	808	14%	239	808	24%
3800	568	808	59%	175	808	17%	179	808	18%	163	808	16%	152	808	15%	283	808	29%
3900	604	808	62%	152	808	15%	*	808	*	*	808	*	*	808	*	*	808	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 20-21 March 2000

Water Standard Mean (Rs) for above site visit is: ***808 cps***

	Access Tube 1			Access Tube 2			Access Tube 3			Access Tube 4			Access Tube 5			Access Tube 6		
Depth (mm)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)
200	*	808	*	*	808	*	147	808	14%	135	808	13%	135	808	13%	376	808	38%
300	215	808	21%	143	808	14%	301	808	31%	227	808	23%	157	808	15%	393	808	41%
400	216	808	22%	176	808	17%	433	808	45%	307	808	31%	196	808	19%	402	808	42%
500	178	808	17%	210	808	21%	434	808	45%	308	808	31%	307	808	31%	431	808	45%
600	183	808	18%	286	808	29%	525	808	55%	256	808	26%	347	808	36%	439	808	46%
700	244	808	25%	311	808	32%	430	808	45%	228	808	23%	360	808	37%	445	808	46%
800	250	808	25%	321	808	33%	577	808	60%	208	808	21%	380	808	39%	478	808	50%
900	306	808	31%	340	808	35%	620	808	65%	220	808	22%	424	808	44%	471	808	49%
1000	340	808	35%	380	808	39%	630	808	66%	247	808	25%	449	808	47%	457	808	47%
1100	327	808	33%	383	808	39%	616	808	64%	344	808	35%	334	808	34%	484	808	50%
1200	311	808	32%	506	808	53%	652	808	68%	550	808	57%	352	808	36%	504	808	52%
1300	312	808	32%	585	808	61%	706	808	74%	590	808	62%	520	808	54%	538	808	56%
1400	342	808	35%	599	808	63%	683	808	72%	658	808	69%	543	808	57%	524	808	55%
1500	334	808	34%	601	808	63%	719	808	76%	728	808	77%	560	808	58%	527	808	55%
1600	332	808	34%	665	808	70%	690	808	72%	710	808	75%	606	808	63%	570	808	60%
1700	351	808	36%	593	808	62%	731	808	77%	606	808	63%	704	808	74%	506	808	53%
1800	358	808	37%	662	808	69%	728	808	77%	569	808	59%	648	808	68%	459	808	48%
1900	436	808	45%	595	808	62%	748	808	79%	593	808	62%	566	808	59%	452	808	47%
2000	355	808	36%	669	808	70%	604	808	63%	513	808	53%	543	808	57%	471	808	49%
2100	314	808	32%	571	808	60%	473	808	49%	497	808	52%	714	808	75%	458	808	48%
2200	251	808	25%	568	808	59%	716	808	75%	624	808	65%	733	808	77%	417	808	43%
2300	216	808	22%	486	808	51%	742	808	78%	479	808	50%	502	808	52%	480	808	50%
2400	204	808	20%	621	808	65%	724	808	76%	206	808	21%	401	808	41%	397	808	41%
2500	211	808	21%	557	808	58%	679	808	71%	160	808	16%	616	808	64%	373	808	38%
2600	210	808	21%	515	808	54%	627	808	66%	158	808	15%	689	808	72%	361	808	37%
2700	206	808	21%	688	808	72%	524	808	55%	158	808	15%	661	808	69%	335	808	34%
2800	178	808	17%	721	808	76%	390	808	40%	145	808	14%	712	808	75%	270	808	27%
2900	193	808	19%	648	808	68%	214	808	21%	153	808	15%	717	808	75%	254	808	26%
3000	317	808	32%	655	808	69%	135	808	13%	161	808	16%	623	808	65%	264	808	27%
3100	258	808	26%	563	808	59%	119	808	11%	156	808	15%	578	808	60%	263	808	27%
3200	204	808	20%	432	808	45%	131	808	12%	153	808	15%	264	808	27%	248	808	25%
3300	223	808	22%	303	808	31%	141	808	14%	154	808	15%	154	808	15%	242	808	24%
3400	321	808	33%	221	808	22%	151	808	15%	151	808	15%	139	808	13%	247	808	25%
3500	476	808	49%	204	808	20%	155	808	15%	156	808	15%	135	808	13%	258	808	26%
3600	517	808	54%	192	808	19%	173	808	17%	171	808	17%	128	808	12%	259	808	26%
3700	513	808	53%	171	808	17%	186	808	18%	189	808	19%	147	808	14%	263	808	27%
3800	574	808	60%	179	808	18%	181	808	18%	178	808	17%	153	808	15%	301	808	31%
3900	596	808	62%	159	808	15%	*	808	*	*	808	*	*	808	*	*	808	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

for site visit of 2-3 December 1999

Water Standard Mean (Rs) for above site visit is: ***808 cps***

	Access Tube 1			***Access Tube 2***			***Access Tube 3***			***Access Tube 4***			***Access Tube 5***			***Access Tube 6***		
Depth (mm)	***R (cps)***	***Rs (cps)***	***mc (%)***	***R (cps)***	***Rs (cps***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***
200	*	808	*	*	808	*	125	808	12%	146	808	14%	138	808	12%	247	808	25%
300	209	808	21%	146	808	14%	227	808	23%	234	808	24%	153	808	15%	310	808	32%
400	204	808	20%	178	808	17%	408	808	42%	311	808	32%	195	808	19%	369	808	38%
500	159	808	15%	209	808	21%	414	808	43%	303	808	31%	297	808	30%	415	808	43%
600	211	808	21%	276	808	28%	503	808	52%	254	808	26%	347	808	36%	428	808	44%
700	231	808	23%	294	808	30%	422	808	44%	224	808	22%	367	808	38%	428	808	44%
800	264	808	27%	314	808	32%	553	808	58%	212	808	21%	384	808	40%	463	808	48%
900	317	808	32%	345	808	35%	601	808	63%	215	808	21%	428	808	44%	465	808	48%
1000	343	808	35%	371	808	38%	643	808	67%	247	808	25%	450	808	47%	457	808	47%
1100	311	808	32%	402	808	42%	618	808	65%	355	808	36%	312	808	32%	483	808	50%
1200	312	808	32%	522	808	54%	614	808	64%	566	808	59%	354	808	36%	509	808	53%
1300	318	808	33%	604	808	63%	710	808	75%	588	808	61%	520	808	54%	525	808	55%
1400	337	808	35%	587	808	61%	681	808	71%	661	808	69%	543	808	57%	520	808	54%
1500	327	808	33%	632	808	66%	718	808	75%	730	808	77%	545	808	57%	520	808	54%
1600	331	808	34%	639	808	67%	679	808	71%	716	808	75%	603	808	63%	571	808	60%
1700	341	808	35%	591	808	62%	725	808	76%	599	808	63%	698	808	73%	506	808	53%
1800	366	808	38%	656	808	69%	735	808	77%	565	808	59%	628	808	66%	453	808	47%
1900	426	808	44%	629	808	66%	742	808	78%	594	808	62%	530	808	55%	443	808	46%
2000	327	808	33%	640	808	67%	670	808	70%	510	808	53%	553	808	58%	470	808	49%
2100	298	808	30%	564	808	59%	473	808	49%	509	808	53%	720	808	76%	451	808	47%
2200	238	808	24%	522	808	54%	670	808	70%	621	808	65%	718	808	75%	391	808	40%
2300	207	808	21%	516	808	54%	741	808	78%	463	808	48%	441	808	46%	465	808	48%
2400	201	808	20%	596	808	62%	732	808	77%	193	808	19%	431	808	45%	371	808	38%
2500	197	808	20%	564	808	59%	687	808	72%	160	808	16%	638	808	67%	344	808	35%
2600	199	808	20%	520	808	54%	674	808	71%	159	808	15%	681	808	71%	298	808	30%
2700	190	808	19%	711	808	75%	531	808	55%	155	808	15%	677	808	71%	314	808	32%
2800	166	808	16%	695	808	73%	443	808	46%	143	808	14%	706	808	74%	249	808	25%
2900	206	808	21%	648	808	68%	237	808	24%	149	808	14%	706	808	74%	232	808	23%
3000	310	808	32%	660	808	69%	145	808	14%	154	808	15%	585	808	61%	246	808	25%
3100	245	808	25%	519	808	54%	120	808	11%	146	808	14%	533	808	56%	242	808	24%
3200	189	808	19%	424	808	44%	126	808	12%	147	808	14%	209	808	21%	228	808	23%
3300	228	808	23%	280	808	28%	142	808	14%	144	808	14%	145	808	14%	224	808	22%
3400	332	808	34%	215	808	21%	146	808	14%	144	808	14%	131	808	12%	231	808	23%
3500	485	808	50%	207	808	21%	153	808	15%	147	808	14%	128	808	12%	237	808	24%
3600	515	808	54%	185	808	18%	165	808	16%	162	808	16%	126	808	12%	243	808	24%
3700	514	808	54%	171	808	17%	176	808	17%	177	808	17%	143	808	14%	245	808	25%
3800	577	808	60%	176	808	17%	178	808	17%	165	808	16%	147	808	14%	278	808	28%
3900	572	808	60%	156	808	15%	*	808	*	*	808	*	*	808	*	*	808	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 3 September 1999

Water Standard Mean (Rs) for above site visit is: ***809 cps***

	Access Tube 1			Access Tube 2			Access Tube 3			Access Tube 4			Access Tube 5			Access Tube 6		
Depth (mm)	R (cps)	Rs (cps)	mc (%)	R (cps)	Rs (cps	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)
200	*	809	*	*	809	*	153	809	15%	144	809	14%	142	809	14%	239	809	24%
300	176	809	17%	126	809	12%	325	809	33%	230	809	23%	155	809	15%	305	809	31%
400	184	809	18%	154	809	15%	423	809	44%	305	809	31%	203	809	20%	357	809	37%
500	146	809	14%	179	809	18%	442	809	46%	291	809	30%	304	809	31%	410	809	42%
600	163	809	16%	248	809	25%	480	809	50%	230	809	23%	344	809	35%	428	809	44%
700	210	809	21%	282	809	29%	431	809	45%	202	809	20%	360	809	37%	430	809	44%
800	244	809	25%	303	809	31%	574	809	60%	195	809	19%	380	809	39%	462	809	48%
900	299	809	30%	337	809	35%	621	809	65%	206	809	20%	424	809	44%	462	809	48%
1000	331	809	34%	370	809	38%	620	809	65%	244	809	25%	446	809	46%	447	809	46%
1100	299	809	30%	389	809	40%	603	809	63%	360	809	37%	316	809	32%	475	809	49%
1200	292	809	30%	515	809	54%	675	809	71%	566	809	59%	357	809	37%	507	809	53%
1300	304	809	31%	601	809	63%	689	809	72%	580	809	61%	533	809	56%	533	809	56%
1400	333	809	34%	590	809	62%	691	809	72%	671	809	70%	546	809	57%	510	809	53%
1500	321	809	33%	621	809	65%	715	809	75%	726	809	76%	543	809	57%	514	809	53%
1600	315	809	32%	641	809	67%	695	809	73%	703	809	74%	627	809	66%	557	809	58%
1700	338	809	35%	591	809	62%	723	809	76%	595	809	62%	703	809	74%	521	809	54%
1800	344	809	35%	658	809	69%	727	809	76%	552	809	58%	640	809	67%	448	809	46%
1900	422	809	44%	624	809	65%	737	809	77%	575	809	60%	527	809	55%	440	809	46%
2000	349	809	36%	637	809	67%	560	809	58%	501	809	52%	553	809	58%	472	809	49%
2100	307	809	31%	565	809	59%	501	809	52%	504	809	52%	726	809	76%	451	809	47%
2200	237	809	24%	520	809	54%	733	809	77%	619	809	65%	722	809	76%	392	809	40%
2300	205	809	20%	513	809	53%	740	809	78%	438	809	45%	441	809	46%	447	809	46%
2400	188	809	19%	596	809	62%	730	809	77%	181	809	18%	420	809	43%	397	809	41%
2500	188	809	19%	571	809	60%	687	809	72%	143	809	14%	646	809	68%	342	809	35%
2600	188	809	19%	521	809	54%	589	809	62%	139	809	13%	680	809	71%	298	809	30%
2700	181	809	18%	726	809	76%	517	809	54%	140	809	13%	671	809	70%	317	809	32%
2800	156	809	15%	690	809	72%	356	809	37%	132	809	13%	702	809	74%	246	809	25%
2900	183	809	18%	650	809	68%	191	809	19%	136	809	13%	709	809	74%	234	809	23%
3000	297	809	30%	658	809	69%	129	809	12%	134	809	13%	598	809	62%	233	809	23%
3100	246	809	25%	511	809	53%	117	809	11%	127	809	12%	552	809	58%	243	809	24%
3200	187	809	18%	423	809	44%	129	809	12%	125	809	12%	237	809	24%	229	809	23%
3300	212	809	21%	277	809	28%	137	809	13%	128	809	12%	144	809	14%	222	809	22%
3400	315	809	32%	214	809	21%	143	809	14%	131	809	12%	132	809	13%	221	809	22%
3500	470	809	49%	206	809	20%	145	809	14%	135	809	13%	126	809	12%	229	809	23%
3600	517	809	54%	183	809	18%	161	809	16%	154	809	15%	124	809	12%	234	809	23%
3700	511	809	53%	168	809	16%	172	809	17%	166	809	16%	140	809	13%	233	809	23%
3800	567	809	59%	177	809	17%	171	809	17%	156	809	15%	143	809	14%	262	809	26%
3900	571	809	59%	145	809	14%	*	809	*	*	809	*	*	809	*	*	809	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

for site visit of 4 June 1999

Water Standard Mean (Rs) for above site visit is: ***811 cps***

	Access Tube 1			***Access Tube 2***			***Access Tube 3***			***Access Tube 4***			***Access Tube 5***			***Access Tube 6***		
Depth (mm)	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***
200	*	811	*	122	811	12%	146	811	14%	133	811	12%	136	811	12%	258	811	25%
300	186	811	18%	149	811	14%	305	811	31%	224	811	22%	155	811	15%	317	811	32%
400	191	811	19%	176	811	17%	420	811	43%	300	811	30%	194	811	19%	371	811	38%
500	149	811	14%	237	811	24%	437	811	45%	294	811	30%	292	811	30%	417	811	43%
600	171	811	17%	286	811	29%	499	811	52%	248	811	25%	345	811	35%	429	811	44%
700	211	811	21%	300	811	30%	411	811	42%	216	811	21%	362	811	37%	439	811	45%
800	243	811	24%	317	811	32%	567	811	59%	204	811	20%	381	811	39%	466	811	48%
900	301	811	31%	375	811	38%	594	811	62%	212	811	21%	420	811	43%	464	811	48%
1000	330	811	34%	363	811	37%	621	811	65%	242	811	24%	457	811	47%	454	811	47%
1100	300	811	30%	484	811	50%	602	811	63%	344	811	35%	330	811	34%	483	811	50%
1200	294	811	30%	565	811	59%	676	811	71%	554	811	58%	348	811	36%	517	811	54%
1300	304	811	31%	615	811	64%	704	811	74%	583	811	61%	516	811	54%	535	811	56%
1400	330	811	34%	595	811	62%	697	811	73%	663	811	69%	539	811	56%	522	811	54%
1500	323	811	33%	672	811	70%	718	811	75%	729	811	76%	547	811	57%	519	811	54%
1600	325	811	33%	595	811	62%	701	811	73%	708	811	74%	610	811	64%	567	811	59%
1700	344	811	35%	655	811	68%	733	811	77%	589	811	61%	701	811	73%	515	811	53%
1800	347	811	35%	592	811	62%	727	811	76%	564	811	59%	633	811	66%	449	811	46%
1900	426	811	44%	668	811	70%	748	811	78%	584	811	61%	546	811	57%	445	811	46%
2000	343	811	35%	584	811	61%	581	811	61%	509	811	53%	554	811	58%	472	811	49%
2100	306	811	31%	575	811	60%	496	811	51%	517	811	54%	719	811	75%	457	811	47%
2200	239	811	24%	462	811	48%	721	811	75%	619	811	65%	723	811	76%	394	811	41%
2300	198	811	20%	621	811	65%	751	811	79%	442	811	46%	446	811	46%	465	811	48%
2400	191	811	19%	559	811	58%	727	811	76%	189	811	19%	422	811	44%	379	811	39%
2500	190	811	19%	536	811	56%	686	811	72%	155	811	15%	642	811	67%	350	811	36%
2600	191	811	19%	648	811	68%	612	811	64%	150	811	14%	682	811	71%	299	811	30%
2700	187	811	18%	738	811	77%	517	811	54%	150	811	14%	675	811	71%	315	811	32%
2800	157	811	15%	648	811	68%	363	811	37%	137	811	13%	715	811	75%	244	811	24%
2900	185	811	18%	641	811	67%	202	811	20%	146	811	14%	702	811	73%	238	811	24%
3000	299	811	30%	635	811	66%	129	811	12%	146	811	14%	591	811	62%	246	811	25%
3100	244	811	24%	447	811	46%	116	811	11%	142	811	14%	526	811	55%	243	811	24%
3200	185	811	18%	363	811	37%	129	811	12%	141	811	13%	217	811	22%	226	811	23%
3300	215	811	21%	229	811	23%	142	811	14%	143	811	14%	139	811	13%	225	811	22%
3400	305	811	31%	210	811	21%	149	811	14%	142	811	14%	131	811	12%	231	811	23%
3500	469	811	49%	195	811	19%	152	811	15%	143	811	14%	126	811	12%	241	811	24%
3600	516	811	54%	172	811	17%	168	811	16%	164	811	16%	124	811	12%	240	811	24%
3700	510	811	53%	175	811	17%	179	811	18%	173	811	17%	137	811	13%	245	811	25%
3800	579	811	60%	163	811	16%	178	811	17%	160	811	16%	149	811	14%	291	811	30%
3900	576	811	60%	139	811	13%	*	811	*	*	811	*	*	811	*	*	811	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 3 March 1999

Water Standard Mean (Rs) for above site visit is: ***806 cps***

	Access Tube 1			***Access Tube 2***			***Access Tube 3***			***Access Tube 4***			***Access Tube 5***			***Access Tube 6***		
Depth (mm)	***R (cps)***	***Rs (cps)***	***mc (%)***	***R (cps)***	***Rs (cps***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***	***R (cps)***	***Rs (cps)***	***Mc (%)***
200	*	806	*	*	806	*	144	806	14%	106	806	10%	132	806	12%	247	806	25%
300	180	806	18%	126	806	12%	249	806	25%	219	806	22%	152	806	15%	306	806	31%
400	180	806	18%	153	806	15%	413	806	43%	293	806	30%	192	806	19%	362	806	37%
500	143	806	14%	179	806	18%	416	806	43%	337	806	35%	285	806	29%	405	806	42%
600	163	806	16%	250	806	25%	496	806	52%	282	806	29%	348	806	36%	420	806	44%
700	208	806	21%	284	806	29%	397	806	41%	252	806	26%	364	806	38%	427	806	44%
800	240	806	24%	309	806	32%	537	806	56%	219	806	22%	381	806	39%	461	806	48%
900	299	806	31%	341	806	35%	594	806	62%	216	806	22%	421	806	44%	459	806	48%
1000	328	806	34%	372	806	38%	633	806	66%	222	806	22%	457	806	48%	448	806	47%
1100	299	806	31%	403	806	42%	621	806	65%	288	806	29%	356	806	37%	472	806	49%
1200	291	806	30%	519	806	54%	633	806	66%	462	806	48%	336	806	35%	500	806	52%
1300	298	806	30%	603	806	63%	714	806	75%	587	806	62%	515	806	54%	531	806	56%
1400	330	806	34%	592	806	62%	681	806	72%	607	806	64%	540	806	56%	511	806	53%
1500	321	806	33%	643	806	68%	725	806	76%	719	806	76%	568	806	59%	525	806	55%
1600	318	806	33%	630	806	66%	686	806	72%	715	806	75%	594	806	62%	564	806	59%
1700	337	806	35%	607	806	64%	731	806	77%	644	806	68%	710	806	75%	523	806	55%
1800	339	806	35%	654	806	69%	735	806	77%	559	806	59%	658	806	69%	447	806	46%
1900	423	806	44%	642	806	67%	741	806	78%	569	806	60%	603	806	63%	433	806	45%
2000	344	806	35%	630	806	66%	626	806	66%	525	806	55%	552	806	58%	473	806	49%
2100	307	806	31%	558	806	58%	465	806	48%	482	806	50%	710	806	75%	456	806	47%
2200	234	806	24%	504	806	53%	691	806	73%	607	806	64%	744	806	78%	386	806	40%
2300	201	806	20%	550	806	58%	744	806	78%	570	806	60%	548	806	57%	452	806	47%
2400	188	806	19%	579	806	61%	730	806	77%	259	806	26%	392	806	41%	392	806	41%
2500	194	806	19%	568	806	59%	687	806	72%	152	806	15%	600	806	63%	337	806	35%
2600	191	806	19%	540	806	56%	653	806	69%	143	806	14%	690	806	73%	295	806	30%
2700	186	806	18%	731	806	77%	524	806	55%	146	806	14%	649	806	68%	319	806	33%
2800	156	806	15%	672	806	71%	431	806	45%	139	806	13%	721	806	76%	246	806	25%
2900	179	806	18%	648	806	68%	232	806	23%	130	806	12%	714	806	75%	232	806	23%
3000	306	806	31%	657	806	69%	144	806	14%	141	806	14%	634	806	67%	237	806	24%
3100	245	806	25%	482	806	50%	118	806	11%	133	806	13%	589	806	62%	241	806	24%
3200	192	806	19%	405	806	42%	125	806	12%	130	806	12%	278	806	28%	223	806	22%
3300	215	806	22%	254	806	26%	139	806	13%	132	806	13%	153	806	15%	218	806	22%
3400	310	806	32%	211	806	21%	145	806	14%	135	806	13%	136	806	13%	219	806	22%
3500	465	806	48%	205	806	20%	152	806	15%	136	806	13%	131	806	12%	234	806	24%
3600	516	806	54%	178	806	18%	167	806	16%	150	806	15%	127	806	12%	237	806	24%
3700	515	806	54%	172	806	17%	175	806	17%	174	806	17%	144	806	14%	236	806	24%
3800	571	806	60%	173	806	17%	178	806	18%	168	806	16%	147	806	14%	261	806	26%
3900	566	806	59%	145	806	14%	*	806	*	*	806	*	*	806	*	*	806	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 27 November 1998

Water Standard Mean (Rs) for above site visit is: ***807 cps***

	Access Tube 1			Access Tube 2			Access Tube 3			Access Tube 4			Access Tube 5			Access Tube 6		
Depth (mm)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)	R (cps)	Rs (cps)	Mc (%)
200	*	807	*	*	807	*	140	807	13%	148	807	14%	*	807	*	*	807	*
300	*	807	*	*	807	*	266	807	27%	233	807	23%	154	807	15%	311	807	32%
400	184	807	18%	154	807	15%	422	807	44%	301	807	31%	203	807	20%	366	807	38%
500	130	807	12%	185	807	18%	413	807	43%	279	807	28%	305	807	31%	415	807	43%
600	196	807	19%	261	807	26%	496	807	52%	224	807	22%	347	807	36%	426	807	44%
700	216	807	22%	287	807	29%	390	807	40%	195	807	19%	360	807	37%	430	807	45%
800	263	807	27%	313	807	32%	549	807	57%	187	807	18%	379	807	39%	462	807	48%
900	315	807	32%	351	807	36%	598	807	63%	201	807	20%	421	807	44%	451	807	47%
1000	322	807	33%	366	807	38%	621	807	65%	242	807	24%	438	807	45%	447	807	46%
1100	296	807	30%	415	807	43%	611	807	64%	352	807	36%	318	807	33%	483	807	50%
1200	291	807	30%	529	807	55%	640	807	67%	555	807	58%	359	807	37%	504	807	53%
1300	312	807	32%	605	807	63%	703	807	74%	575	807	60%	525	807	55%	530	807	55%
1400	327	807	34%	588	807	62%	687	807	72%	662	807	70%	547	807	57%	529	807	55%
1500	317	807	32%	652	807	68%	726	807	76%	725	807	76%	545	807	57%	522	807	54%
1600	330	807	34%	621	807	65%	685	807	72%	701	807	74%	619	807	65%	573	807	60%
1700	324	807	33%	617	807	65%	731	807	77%	577	807	60%	695	807	73%	499	807	52%
1800	371	807	38%	636	807	67%	730	807	77%	550	807	57%	636	807	67%	445	807	46%
1900	416	807	43%	649	807	68%	744	807	78%	574	807	60%	527	807	55%	432	807	45%
2000	320	807	33%	613	807	64%	604	807	63%	479	807	50%	548	807	57%	462	807	48%
2100	271	807	28%	570	807	60%	460	807	48%	502	807	52%	708	807	74%	447	807	46%
2200	214	807	21%	483	807	50%	704	807	74%	620	807	65%	714	807	75%	383	807	40%
2300	191	807	19%	578	807	60%	735	807	77%	427	807	44%	431	807	45%	455	807	47%
2400	190	807	19%	573	807	60%	729	807	77%	177	807	17%	426	807	44%	361	807	37%
2500	182	807	18%	559	807	58%	683	807	72%	145	807	14%	645	807	68%	330	807	34%
2600	189	807	19%	587	807	61%	631	807	66%	139	807	13%	674	807	71%	280	807	28%
2700	167	807	16%	736	807	77%	527	807	55%	140	807	13%	673	807	71%	300	807	31%
2800	152	807	15%	664	807	70%	397	807	41%	130	807	12%	709	807	75%	234	807	24%
2900	223	807	22%	643	807	67%	211	807	21%	137	807	13%	706	807	74%	228	807	23%
3000	286	807	29%	649	807	68%	135	807	13%	135	807	13%	588	807	62%	236	807	24%
3100	223	807	22%	463	807	48%	114	807	11%	128	807	12%	543	807	57%	232	807	23%
3200	178	807	18%	399	807	41%	125	807	12%	128	807	12%	216	807	22%	217	807	22%
3300	234	807	24%	250	807	25%	136	807	13%	132	807	13%	140	807	13%	213	807	21%
3400	354	807	36%	211	807	21%	145	807	14%	131	807	12%	131	807	12%	219	807	22%
3500	514	807	54%	204	807	20%	147	807	14%	134	807	13%	124	807	12%	232	807	23%
3600	510	807	53%	176	807	17%	160	807	16%	158	807	15%	124	807	12%	227	807	23%
3700	567	807	59%	173	807	17%	171	807	17%	164	807	16%	139	807	13%	237	807	24%
3800	609	807	64%	175	807	17%	171	807	17%	157	807	15%	143	807	14%	253	807	26%
3900	*	807	*	147	807	14%	*	807	*	*	807	*	*	807	*	*	807	*

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 16 November 1996[1]

Water Standard Mean (Rs) for above site visit is: ***895 cps***

	Access Tube 1						*Access Tube 2*						*Access Tube 3*					
Depth (mm)	*R1 (cps)*	*R2 (cps)*	*R3 (cps)*	*Mean (cps)*	*Rs (cps)*	*Mc (%)*	*R1 (cps)*	*R2 (cps)*	*R3 (cps)*	*Mean (cps)*	*Rs (cps)*	*Mc (%)*	*R1 (cps)*	*R2 (cps)*	*R3 (cps)*	*Mean (cps)*	*Rs (cps)*	*Mc (%)*
200	292	283	290	288	895	26%	163	164	165	164	895	14%	168	165	170	168	895	15%
300	288	297	292	292	895	27%	180	184	183	182	895	16%	282	283	278	281	895	26%
400	236	230	237	234	895	21%	184	187	186	186	895	16%	456	448	452	452	895	42%
500	206	207	202	205	895	18%	194	197	196	196	895	17%	452	455	459	455	895	43%
600	293	289	292	291	895	27%	247	247	247	247	895	22%	544	549	549	547	895	51%
700	268	271	273	271	895	25%	295	297	298	297	895	27%	456	454	455	455	895	42%
800	306	316	304	309	895	28%	336	334	337	336	895	31%	577	580	579	579	895	54%
900	348	349	355	351	895	32%	376	377	377	377	895	35%	646	645	646	646	895	61%
1000	361	364	369	365	895	34%	396	389	384	390	895	36%	719	710	719	716	895	68%
1100	355	356	346	352	895	33%	493	499	491	494	895	46%	681	688	698	689	895	65%
1200	345	348	356	350	895	32%	596	605	607	603	895	57%	680	682	685	682	895	64%
1300	363	371	377	370	895	34%	671	675	673	673	895	64%	794	792	800	795	895	75%
1400	379	368	375	374	895	35%	645	646	646	646	895	61%	761	755	751	756	895	72%
1500	354	362	362	359	895	33%	729	727	732	729	895	69%	811	811	812	811	895	77%
1600	382	389	384	385	895	36%	673	672	674	673	895	64%	744	746	756	749	895	71%
1700	372	378	374	375	895	35%	721	704	714	713	895	67%	800	801	805	802	895	76%
1800	434	427	433	431	895	40%	680	674	672	675	895	64%	812	820	804	812	895	77%
1900	427	430	424	427	895	40%	737	741	741	740	895	70%	829	825	837	830	895	79%
2000	342	346	344	344	895	32%	659	658	650	656	895	62%	719	714	726	720	895	68%
2100	295	287	288	290	895	26%	643	631	637	637	895	60%	530	529	531	530	895	50%
2200	240	247	241	243	895	22%	524	524	519	522	895	49%	733	724	733	730	895	69%
2300	224	216	226	222	895	20%	679	681	686	682	895	64%	812	823	806	814	895	77%
2400	230	224	227	227	895	20%	630	623	620	624	895	59%	796	805	806	802	895	76%
2500	218	216	222	219	895	20%	591	590	588	590	895	56%	765	761	760	762	895	72%
2600	226	227	229	227	895	20%	717	706	707	710	895	67%	744	737	739	740	895	70%
2700	194	197	188	189	895	17%	801	804	806	804	895	76%	580	581	583	581	895	55%
2800	183	183	184	183	895	16%	709	703	713	708	895	67%	488	489	492	490	895	46%
2900	295	306	301	301	895	28%	717	707	711	712	895	67%	270	273	266	270	895	25%
3000	290	292	300	294	895	27%	702	691	690	694	895	66%	160	161	158	160	895	14%
3100	241	235	237	238	895	21%	489	493	481	488	895	46%	132	124	129	128	895	11%
3200	216	217	221	218	895	20%	385	393	381	386	895	36%	140	134	137	137	895	12%
3300	299	303	294	299	895	27%	247	245	252	248	895	22%	153	150	150	151	895	13%
3400	454	445	456	452	895	42%	230	233	234	232	895	21%	160	158	155	158	895	14%
3500	582	578	590	583	895	55%	228	232	225	228	895	21%	172	169	167	169	895	15%
3600	564	565	566	565	895	53%	192	190	187	190	895	17%	177	184	178	180	895	16%
3700	624	617	608	616	895	58%	197	186	190	191	895	17%	187	182	183	184	895	16%
3800	642	636	636	638	895	60%	186	198	185	186	895	16%	183	190	191	188	895	17%
3900	624	611	628	621	895	59%	160	154	156	157	895	14%	190	187	195	191	895	17%

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second, and R1, R2 and R3 are replicate readings. [1]After Hunting 1997.

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Measurements by Neutron Probe
for site visit of 16 November 1996[1] (cont.)

Water Standard Mean (Rs) for above site visit is: ***895 cps***

	Access Tube 1						***Access Tube 2***						***Access Tube 3***					
Depth (mm)	***R1 (cps)***	***R2 (cps)***	***R3 (cps)***	***Mean (cps)***	***Rs (cps)***	***Mc (%)***	***R1 (cps)***	***R2 (cps)***	***R3 (cps)***	***Mean (cps)***	***Rs (cps)***	***Mc (%)***	***R1 (cps)***	***R2 (cps)***	***R3 (cps)***	***Mean (cps)***	***Rs (cps)***	***Mc (%)***
200	*	*	*	*	895	*	146	146	146	146	895	13%	233	236	241	237	895	21%
300	160	151	155	155	895	13%	178	177	184	180	895	16%	316	318	317	317	895	29%
400	227	239	233	233	895	21%	232	229	231	231	895	21%	392	392	381	388	895	36%
500	254	251	260	255	895	23%	335	335	338	336	895	31%	428	434	434	432	895	40%
600	241	244	233	239	895	22%	404	407	405	405	895	38%	450	450	451	450	895	42%
700	216	216	218	217	895	19%	408	418	412	413	895	38%	452	455	458	455	895	42%
800	211	208	208	209	895	19%	422	416	429	422	895	39%	478	477	480	478	895	45%
900	234	246	237	239	895	22%	462	445	454	454	895	42%	474	468	474	472	895	44%
1000	280	278	283	280	895	26%	482	491	492	488	895	46%	475	473	467	472	895	44%
1100	379	369	379	376	895	35%	448	462	443	451	895	42%	493	486	493	491	895	46%
1200	587	582	573	581	895	55%	508	504	493	502	895	47%	515	528	534	526	895	49%
1300	610	613	626	616	895	58%	605	590	609	601	895	57%	590	602	596	596	895	56%
1400	710	699	717	709	895	67%	608	605	605	606	895	57%	566	563	564	564	895	53%
1500	802	794	804	800	895	76%	629	639	630	633	895	60%	591	588	575	585	895	55%
1600	778	769	776	774	895	73%	658	649	655	654	895	62%	602	607	603	604	895	57%
1700	640	636	636	637	895	60%	779	775	778	777	895	74%	595	600	602	599	895	56%
1800	602	598	619	606	895	57%	764	769	760	764	895	72%	493	503	499	498	895	47%
1900	622	629	623	625	895	59%	776	782	782	780	895	74%	480	481	482	481	895	45%
2000	543	548	554	548	895	52%	720	724	721	722	895	68%	503	504	506	504	895	47%
2100	529	517	528	525	895	49%	795	794	780	790	895	75%	489	495	495	493	895	46%
2200	667	675	675	672	895	64%	807	806	806	806	895	77%	423	428	426	426	895	40%
2300	496	496	513	502	895	47%	615	608	623	615	895	58%	463	468	470	467	895	44%
2400	200	201	203	201	895	18%	436	434	431	434	895	40%	442	436	439	439	895	41%
2500	162	161	157	160	895	14%	650	653	658	654	895	62%	351	355	357	354	895	33%
2600	155	154	150	153	895	13%	766	773	752	764	895	72%	309	307	314	310	895	28%
2700	152	151	155	153	895	13%	718	716	730	721	895	68%	337	334	336	336	895	31%
2800	144	150	148	147	895	13%	805	798	791	798	895	76%	262	270	267	266	895	24%
2900	147	151	150	149	895	13%	803	797	780	793	895	75%	256	252	250	253	895	23%
3000	149	148	146	148	895	13%	680	690	679	683	895	65%	260	253	259	257	895	23%
3100	144	140	142	142	895	12%	652	648	641	647	895	61%	266	251	270	262	895	24%
3200	143	147	141	144	895	12%	314	315	314	314	895	29%	242	249	244	245	895	22%
3300	138	142	140	140	895	12%	180	179	175	178	895	16%	235	233	238	235	895	21%
3400	144	148	143	145	895	12%	159	161	161	160	895	14%	234	238	244	239	895	22%
3500	157	153	151	154	895	13%	149	154	153	152	895	13%	248	255	245	249	895	23%
3600	186	175	176	179	895	16%	137	142	148	142	895	12%	250	252	248	250	895	23%
3700	189	193	190	191	895	17%	156	159	152	156	895	13%	252	251	251	251	895	23%
3800	176	176	178	177	895	16%	168	162	163	164	895	14%	265	271	265	267	895	24%
3900	*	*	*	*	895	*	165	162	165	164	895	14%	271	269	271	270	895	25%

KEY Rs = Water Standard Count Rate, Mc = volumetric moisture content, cps = counts per second, and R1, R2 and R3 are replicate readings. [1]After Hunting 1997.

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

Estimated volumetric moisture content for Access Tube 1

Deposit desc[1]	Depth (mm)	Nov 1996[1]	Nov 1998	Mar 1999	Jun 1999	Sep 1999	Dec 1999	Mar 2000	Jun 2000	Sep 2000	Nov 2000	Jun 2001	Sep 2001
Variable made ground	200	26%	*	*	*	*	*	*	*	*	*	*	*
	300	27%	*	18%	18%	17%	21%	21%	18%	17%	14%	17%	16%
	400	21%	18%	18%	19%	18%	20%	22%	19%	18%	14%	18%	17%
	500	18%	12%	14%	14%	14%	15%	17%	15%	15%	13%	16%	13%
	600	27%	19%	16%	17%	16%	21%	18%	16%	16%	12%	15%	17%
	700	25%	22%	21%	21%	21%	23%	25%	21%	21%	20%	23%	21%
	800	28%	27%	24%	24%	25%	27%	25%	24%	25%	22%	24%	25%
	900	32%	32%	31%	31%	30%	32%	31%	31%	30%	28%	30%	31%
	1000	34%	33%	34%	34%	34%	35%	35%	34%	34%	33%	34%	33%
	1100	33%	30%	31%	30%	30%	32%	33%	31%	31%	31%	33%	30%
	1200	32%	30%	30%	30%	30%	32%	32%	30%	30%	29%	31%	29%
	1300	34%	32%	30%	31%	31%	33%	32%	30%	31%	30%	31%	31%
Organic sandy loam	1400	35%	34%	34%	34%	34%	35%	35%	33%	33%	32%	34%	34%
	1500	33%	32%	33%	33%	33%	33%	34%	33%	33%	32%	33%	33%
	1600	36%	34%	33%	33%	32%	34%	34%	33%	33%	32%	33%	33%
	1700	35%	33%	35%	35%	35%	35%	36%	35%	35%	34%	35%	34%
	1800	40%	38%	35%	35%	35%	38%	37%	36%	37%	33%	35%	36%
	1900	40%	43%	44%	44%	44%	44%	45%	44%	44%	40%	44%	43%
	2000	32%	33%	35%	35%	36%	33%	36%	35%	34%	40%	37%	33%
	2100	26%	28%	31%	31%	31%	30%	32%	32%	31%	30%	32%	30%
Variable sandy loam and sandy clay loam	2200	22%	21%	24%	24%	24%	24%	25%	24%	24%	26%	25%	23%
	2300	20%	19%	20%	20%	20%	21%	22%	20%	20%	21%	21%	20%
	2400	20%	19%	19%	19%	19%	20%	20%	19%	19%	18%	19%	19%
	2500	20%	18%	19%	19%	19%	20%	21%	19%	19%	18%	20%	19%
	2600	20%	19%	19%	19%	19%	20%	21%	19%	20%	17%	19%	19%
	2700	17%	16%	18%	18%	18%	19%	21%	19%	19%	18%	19%	18%
	2800	16%	15%	15%	15%	15%	16%	17%	16%	16%	15%	16%	15%
	2900	28%	22%	18%	18%	18%	21%	19%	17%	19%	15%	18%	20%
	3000	27%	29%	31%	30%	30%	32%	32%	31%	31%	25%	30%	31%
Coarse sand	3100	21%	22%	25%	24%	25%	25%	26%	25%	25%	27%	26%	24%
	3200	20%	18%	19%	18%	18%	19%	20%	19%	18%	20%	20%	19%
	3300	27%	24%	22%	21%	21%	23%	22%	21%	22%	18%	20%	23%
	3400	42%	36%	32%	31%	32%	34%	33%	31%	38%	24%	31%	33%
Organic clay, wood	3500	55%	54%	48%	49%	49%	50%	49%	49%	49%	39%	47%	51%
	3600	53%	53%	54%	54%	54%	54%	54%	54%	54%	54%	54%	53%
	3700	58%	59%	54%	53%	53%	54%	53%	54%	53%	53%	53%	55%
	3800	60%	64%	60%	60%	59%	60%	60%	59%	60%	56%	63%	63%
	3900	59%	*	59%	60%	59%	60%	62%	62%	62%	61%	63%	61%

[1]After Hunting 1997

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

Estimated volumetric moisture content for Access Tube 2

Deposit desc[1]	*Depth (mm)*	*Nov 1996*[1]	*Nov 1998*	*Mar 1999*	*Jun 1999*	*Sep 1999*	*Dec 1999*	*Mar 2000*	*Jun 2000*	*Sep 2000*	*Nov 2000*	*Jun 2001*	*Sep 2001*
Made ground (cored by rotary auger)	200	14%	*	*	12%	*	*	*	*	*	*	*	*
	300	16%	*	12%	14%	12%	14%	14%	12%	26%	30%	31%	29%
	400	16%	15%	15%	17%	15%	17%	17%	15%	31%	28%	32%	30%
	500	17%	18%	18%	24%	18%	21%	21%	18%	22%	19%	23%	21%
	600	22%	26%	25%	29%	25%	28%	29%	25%	25%	24%	27%	25%
	700	27%	29%	29%	30%	29%	30%	32%	29%	29%	28%	30%	29%
	800	31%	32%	32%	32%	31%	32%	33%	31%	31%	31%	31%	31%
	900	35%	36%	35%	38%	35%	35%	35%	35%	34%	34%	35%	35%
	1000	36%	38%	38%	37%	38%	38%	39%	38%	38%	38%	38%	38%
Organic sandy clay loam	1100	46%	43%	42%	50%	40%	42%	39%	40%	40%	41%	41%	43%
	1200	57%	55%	54%	59%	54%	54%	53%	54%	54%	54%	55%	55%
	1300	64%	63%	63%	64%	63%	63%	61%	63%	62%	63%	63%	63%
	1400	61%	62%	62%	62%	62%	61%	63%	62%	62%	62%	62%	62%
	1500	69%	68%	68%	70%	65%	66%	63%	65%	65%	66%	65%	66%
	1600	64%	65%	66%	62%	67%	67%	70%	68%	67%	67%	67%	66%
	1700	67%	65%	64%	68%	62%	62%	62%	61%	62%	63%	63%	63%
	1800	64%	67%	69%	62%	69%	69%	69%	69%	69%	68%	69%	68%
Woody loam	1900	70%	68%	67%	70%	65%	66%	62%	64%	66%	67%	66%	67%
Variable organic sandy clay loam and wood	2000	62%	64%	66%	61%	67%	67%	70%	68%	67%	65%	67%	66%
	2100	60%	60%	58%	60%	59%	59%	60%	59%	58%	59%	59%	59%
	2200	49%	50%	53%	48%	54%	54%	59%	56%	55%	53%	54%	53%
	2300	64%	60%	58%	65%	53%	54%	51%	52%	54%	56%	55%	57%
	2400	59%	60%	61%	58%	62%	62%	65%	63%	62%	61%	62%	61%
	2500	56%	58%	59%	56%	60%	59%	58%	58%	59%	59%	59%	60%
	2600	67%	61%	56%	68%	54%	54%	54%	54%	54%	56%	55%	56%
	2700	76%	77%	77%	77%	76%	75%	72%	74%	72%	77%	75%	76%
	2800	67%	70%	71%	68%	72%	73%	76%	74%	72%	71%	72%	71%
	2900	67%	67%	68%	67%	68%	68%	68%	68%	68%	67%	68%	67%
	3000	66%	68%	69%	66%	69%	69%	69%	69%	69%	69%	69%	69%
Sandy clay loam	3100	46%	48%	50%	46%	53%	54%	59%	56%	54%	52%	54%	51%
	3200	36%	41%	42%	37%	44%	44%	45%	44%	43%	42%	43%	43%
Sandy loam, gravelly sand	3300	22%	25%	26%	23%	28%	28%	31%	29%	28%	27%	28%	26%
	3400	21%	21%	21%	21%	21%	21%	22%	21%	21%	21%	21%	21%
	3500	21%	20%	20%	19%	20%	21%	20%	21%	21%	20%	20%	20%
	3600	17%	17%	18%	17%	18%	18%	19%	18%	18%	18%	18%	18%
	3700	17%	17%	17%	17%	16%	17%	17%	17%	17%	16%	17%	17%
	3800	16%	17%	17%	16%	17%	17%	18%	17%	17%	16%	17%	17%
	3900	14%	14%	14%	*	14%	15%	15%	15%	15%	14%	15%	15%

[1]After Hunting 1997

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

Estimated volumetric moisture content for Access Tube 3

Deposit desc[1]	*Depth (mm)*	*Nov 1996*[1]	*Nov 1998*	*Mar 1999*	*Jun 1999*	*Sep 1999*	*Dec 1999*	*Mar 2000*	*Jun 2000*	*Sep 2000*	*Nov 2000*	*Jun 2001*	*Sep 2001*
Made ground	200	15%	13%	14%	14%	15%	12%	14%	12%	11%	11%	12%	12%
Made ground	300	26%	27%	25%	31%	33%	23%	31%	26%	23%	22%	24%	25%
	400	42%	44%	43%	43%	44%	42%	45%	43%	41%	42%	44%	43%
Organic loam, wood	500	43%	43%	43%	45%	46%	43%	45%	43%	43%	42%	43%	43%
	600	51%	52%	52%	52%	50%	52%	55%	51%	51%	50%	53%	52%
	700	42%	40%	41%	42%	45%	44%	45%	41%	41%	44%	42%	40%
	800	54%	57%	56%	59%	60%	58%	60%	57%	60%	59%	57%	56%
	900	61%	63%	62%	62%	65%	63%	65%	63%	62%	65%	63%	63%
	1000	68%	65%	66%	65%	65%	67%	66%	66%	67%	64%	66%	65%
	1100	65%	64%	65%	63%	63%	65%	64%	64%	65%	63%	64%	64%
	1200	64%	67%	66%	71%	71%	64%	68%	66%	65%	72%	66%	67%
	1300	75%	74%	75%	74%	72%	75%	74%	74%	75%	71%	74%	74%
	1400	72%	72%	72%	73%	72%	71%	72%	71%	71%	73%	71%	72%
	1500	77%	76%	76%	75%	75%	75%	76%	76%	75%	74%	75%	75%
	1600	71%	72%	72%	73%	73%	71%	72%	71%	71%	74%	72%	71%
	1700	76%	77%	77%	77%	76%	76%	77%	76%	76%	77%	76%	76%
	1800	77%	77%	77%	76%	76%	77%	77%	77%	77%	76%	77%	76%
	1900	79%	78%	78%	78%	77%	78%	79%	78%	78%	77%	77%	77%
Organic sandy loam and sandy lenses	2000	68%	63%	66%	61%	58%	70%	63%	68%	67%	58%	65%	66%
	2100	50%	48%	48%	51%	52%	49%	49%	48%	48%	51%	48%	49%
	2200	69%	74%	73%	75%	77%	70%	75%	72%	71%	77%	73%	72%
Organic sandy clay loam	2300	77%	77%	78%	79%	78%	78%	78%	78%	77%	77%	77%	78%
	2400	76%	77%	77%	76%	77%	77%	76%	77%	77%	76%	76%	77%
	2500	72%	72%	72%	72%	72%	72%	71%	71%	71%	71%	72%	72%
	2600	70%	66%	69%	64%	62%	71%	66%	69%	69%	62%	67%	68%
Organic sandy loam	2700	55%	55%	55%	54%	54%	55%	55%	55%	55%	53%	54%	54%
	2800	46%	41%	45%	37%	37%	46%	40%	42%	45%	36%	41%	43%
	2900	25%	21%	23%	20%	19%	24%	21%	23%	24%	19%	21%	23%
	3000	14%	13%	14%	12%	12%	14%	13%	13%	13%	12%	13%	13%
	3100	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
Sandy gravel	3200	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%
	3300	13%	13%	13%	14%	13%	14%	14%	13%	13%	13%	13%	13%
	3400	14%	14%	14%	14%	14%	14%	15%	14%	14%	13%	14%	14%
	3500	15%	14%	15%	15%	14%	15%	15%	14%	14%	14%	15%	15%
	3600	16%	16%	16%	16%	16%	16%	17%	16%	16%	15%	16%	16%
	3700	16%	17%	17%	18%	17%	17%	18%	17%	17%	16%	17%	17%
	3800	17%	17%	18%	17%	17%	17%	18%	18%	17%	16%	17%	17%
	3900	17%	*	*	*	*	*	*	*	*	*	*	*

[1]After Hunting 1997

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

Estimated volumetric moisture content for Access Tube 4

Deposit desc[1]	*Depth (mm)*	*Nov 1996*[1]	*Nov 1998*	*Mar 1999*	*Jun 1999*	*Sep 1999*	*Dec 1999*	*Mar 2000*	*Jun 2000*	*Sep 2000*	*Nov 2000*	*Jun 2001*	*Sep 2001*
Made ground (cored by rotary auger)	200	*	14%	10%	12%	14%	14%	13%	12%	9%	9%	9%	11%
	300	13%	23%	22%	22%	23%	24%	23%	22%	20%	19%	20%	21%
	400	21%	31%	30%	30%	31%	32%	31%	31%	28%	26%	28%	29%
	500	23%	28%	35%	30%	30%	31%	31%	31%	32%	29%	32%	31%
	600	22%	22%	29%	25%	23%	26%	26%	25%	26%	24%	27%	25%
	700	19%	19%	26%	21%	20%	22%	23%	21%	21%	19%	23%	21%
	800	19%	18%	22%	20%	19%	21%	21%	20%	19%	18%	20%	19%
	900	22%	20%	22%	21%	20%	21%	22%	20%	19%	19%	21%	20%
	1000	26%	24%	22%	24%	25%	25%	25%	24%	22%	21%	23%	23%
Made ground	1100	35%	36%	29%	35%	37%	36%	35%	34%	32%	32%	31%	32%
Organic loamy	1200	55%	58%	48%	58%	59%	59%	57%	58%	52%	53%	52%	54%
	1300	58%	60%	62%	61%	61%	61%	62%	60%	62%	60%	63%	61%
	1400	67%	70%	64%	69%	70%	69%	69%	69%	66%	66%	66%	67%
	1500	76%	76%	76%	76%	76%	77%	77%	77%	76%	76%	76%	76%
	1600	73%	74%	75%	74%	74%	75%	75%	74%	75%	74%	75%	74%
	1700	60%	60%	68%	61%	62%	63%	63%	62%	65%	63%	66%	64%
	1800	57%	57%	59%	59%	58%	59%	59%	58%	58%	56%	58%	58%
	1900	59%	60%	60%	61%	60%	62%	62%	61%	61%	61%	62%	61%
	2000	52%	50%	55%	53%	52%	53%	53%	53%	54%	53%	55%	53%
	2100	49%	52%	50%	54%	52%	53%	52%	52%	50%	50%	51%	52%
	2200	64%	65%	64%	65%	65%	65%	65%	65%	64%	64%	65%	64%
	2300	47%	44%	60%	46%	45%	48%	50%	50%	55%	51%	55%	52%
	2400	18%	17%	26%	19%	18%	19%	21%	20%	22%	20%	23%	21%
Course sand sandy gravel	2500	14%	14%	15%	15%	14%	16%	16%	15%	15%	14%	15%	15%
	2600	13%	13%	14%	14%	13%	15%	15%	14%	14%	13%	15%	15%
	2700	13%	13%	14%	14%	13%	15%	15%	14%	15%	13%	15%	15%
	2800	13%	12%	13%	13%	13%	14%	14%	13%	13%	12%	14%	13%
	2900	13%	13%	12%	14%	13%	14%	15%	13%	14%	12%	14%	14%
	3000	13%	13%	14%	14%	13%	15%	16%	14%	14%	12%	15%	14%
	3100	12%	12%	13%	14%	12%	14%	15%	13%	13%	11%	14%	14%
	3200	12%	12%	12%	13%	12%	14%	15%	13%	13%	11%	14%	13%
	3300	12%	13%	13%	14%	12%	14%	15%	13%	13%	11%	14%	13%
	3400	12%	12%	13%	14%	12%	14%	15%	13%	13%	11%	14%	13%
	3500	13%	13%	13%	14%	13%	14%	15%	13%	13%	12%	14%	13%
	3600	16%	15%	15%	16%	15%	16%	17%	15%	15%	14%	15%	15%
	3700	17%	16%	17%	17%	16%	17%	19%	17%	17%	15%	18%	17%
	3800	16%	15%	16%	16%	15%	16%	17%	16%	16%	15%	16%	17%
	3900	*	*	*	*	*	*	*	*	*	*	*	*

[1]After Hunting 1997

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

Estimated volumetric moisture content for Access Tube 5

Deposit desc[1]	***Depth (mm)***	***Nov 1996***[1]	***Nov 1998***	***Mar 1999***	***Jun 1999***	***Sep 1999***	***Dec 1999***	***Mar 2000***	***Jun 2000***	***Sep 2000***	***Nov 2000***	***Jun 2001***	***Sep 2001***
Made ground (cored by rotary auger	200	13%	*	12%	12%	14%	12%	13%	14%	14%	13%	12%	13%
	300	16%	15%	15%	15%	15%	15%	15%	15%	15%	14%	15%	15%
	400	21%	20%	19%	19%	20%	19%	19%	22%	21%	19%	19%	20%
Made ground	500	31%	31%	29%	30%	31%	30%	31%	33%	32%	30%	29%	31%
	600	38%	36%	36%	35%	35%	36%	36%	36%	36%	34%	35%	35%
Organic loamy, some wood and brick	700	38%	37%	38%	37%	37%	38%	37%	37%	37%	36%	37%	37%
	800	39%	39%	39%	39%	39%	40%	39%	40%	40%	38%	39%	40%
	900	42%	44%	44%	43%	44%	44%	44%	45%	44%	43%	43%	44%
	1000	46%	45%	48%	47%	46%	47%	47%	45%	46%	46%	46%	46%
	1100	42%	33%	37%	34%	32%	32%	34%	31%	31%	32%	34%	31%
	1200	47%	37%	35%	36%	37%	36%	36%	39%	36%	34%	33%	36%
	1300	57%	55%	54%	54%	56%	54%	54%	55%	55%	53%	52%	54%
	1400	57%	57%	56%	56%	57%	57%	57%	57%	56%	55%	56%	56%
	1500	60%	57%	59%	57%	57%	57%	58%	57%	57%	57%	57%	57%
	1600	62%	65%	62%	64%	66%	63%	63%	65%	64%	63%	62%	64%
Organic loamy, and wood	1700	74%	73%	75%	73%	74%	73%	74%	73%	73%	72%	72%	72%
	1800	72%	67%	69%	66%	67%	66%	68%	65%	66%	64%	64%	65%
	1900	74%	55%	63%	57%	55%	55%	59%	53%	55%	56%	55%	54%
	2000	68%	57%	58%	58%	58%	58%	57%	60%	59%	57%	57%	59%
	2100	75%	74%	75%	75%	76%	76%	75%	77%	76%	76%	75%	77%
	2200	77%	75%	78%	76%	76%	75%	77%	75%	75%	75%	75%	75%
Organic loamy, sand	2300	58%	45%	57%	46%	46%	46%	52%	44%	46%	44%	47%	45%
	2400	40%	44%	41%	44%	43%	45%	41%	47%	44%	44%	42%	44%
Organic loamy. clay loam and wood	2500	62%	68%	63%	67%	68%	67%	64%	70%	68%	67%	67%	67%
	2600	72%	71%	73%	71%	71%	71%	72%	71%	71%	70%	71%	71%
	2700	68%	71%	68%	71%	70%	71%	69%	71%	71%	70%	70%	71%
	2800	76%	75%	76%	75%	74%	74%	75%	74%	75%	73%	73%	73%
	2900	75%	74%	75%	73%	74%	74%	75%	74%	74%	73%	74%	74%
	3000	65%	62%	67%	62%	62%	61%	65%	61%	62%	62%	61%	62%
	3100	61%	57%	62%	55%	58%	56%	60%	53%	57%	56%	56%	57%
Sandy gravel	3200	29%	22%	28%	22%	24%	21%	27%	22%	23%	23%	22%	24%
	3300	16%	13%	15%	13%	14%	14%	15%	14%	14%	13%	14%	14%
	3400	14%	12%	13%	12%	13%	12%	13%	14%	13%	12%	13%	14%
	3500	13%	12%	12%	12%	12%	12%	13%	13%	12%	11%	12%	13%
	3600	12%	12%	12%	12%	12%	12%	12%	13%	12%	12%	12%	13%
	3700	13%	13%	14%	13%	13%	14%	14%	14%	13%	13%	14%	14%
	3800	14%	14%	14%	14%	14%	14%	15%	15%	14%	14%	15%	14%
	3900	14%	*	*	*	*	*	*	*	*	*	*	*

[1]After Hunting 1997

Monitoring the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Measurements by Neutron Probe

Estimated volumetric moisture content for Access Tube 6

Deposit desc[1]	*Depth (mm)*	*Nov 1996*[1]	*Nov 1998*	*Mar 1999*	*Jun 1999*	*Sep 1999*	*Dec 1999*	*Mar 2000*	*Jun 2000*	*Sep 2000*	*Nov 2000*	*Jun 2001*	*Sep 2001*
Made ground (cored by rotary auger)	200	21%	*	25%	25%	24%	25%	38%	28%	23%	26%	25%	25%
	300	29%	32%	31%	32%	31%	32%	41%	33%	31%	33%	32%	32%
	400	36%	38%	37%	38%	37%	38%	42%	39%	37%	38%	37%	37%
	500	40%	43%	42%	43%	42%	43%	45%	44%	42%	43%	43%	43%
	600	42%	44%	44%	44%	44%	44%	46%	44%	44%	44%	45%	44%
	700	42%	45%	44%	45%	44%	44%	46%	46%	44%	45%	45%	45%
Variable organic loam with sandy clay loam and sandy loam textures	800	45%	48%	48%	48%	48%	48%	50%	49%	48%	48%	48%	48%
	900	44%	47%	48%	48%	48%	48%	49%	49%	48%	48%	48%	48%
	1000	44%	46%	47%	47%	46%	47%	47%	47%	46%	46%	47%	47%
	1100	46%	50%	49%	50%	49%	50%	50%	50%	49%	49%	50%	50%
	1200	49%	53%	52%	54%	53%	53%	52%	53%	52%	52%	52%	52%
	1300	56%	55%	56%	56%	56%	55%	56%	55%	55%	55%	55%	55%
	1400	53%	55%	53%	54%	53%	54%	55%	54%	53%	54%	53%	54%
	1500	55%	54%	55%	54%	53%	54%	55%	54%	54%	53%	55%	54%
	1600	57%	60%	59%	59%	58%	60%	60%	60%	58%	59%	58%	59%
	1700	56%	52%	55%	53%	54%	53%	53%	52%	56%	52%	53%	52%
	1800	47%	46%	46%	46%	46%	47%	48%	48%	47%	46%	48%	47%
	1900	45%	45%	45%	46%	46%	46%	47%	46%	46%	45%	46%	46%
	2000	47%	48%	49%	49%	49%	49%	49%	49%	48%	48%	49%	49%
	2100	46%	46%	47%	47%	47%	47%	48%	47%	47%	47%	47%	47%
	2200	40%	40%	40%	41%	40%	40%	43%	41%	40%	39%	42%	40%
	2300	44%	47%	47%	48%	46%	48%	50%	49%	45%	47%	48%	48%
	2400	41%	37%	41%	39%	41%	38%	41%	40%	42%	38%	41%	40%
Sandy loam	2500	33%	34%	35%	36%	35%	35%	38%	36%	35%	34%	36%	35%
	2600	28%	28%	30%	30%	30%	30%	37%	31%	30%	29%	32%	30%
	2700	31%	31%	33%	32%	32%	32%	34%	33%	33%	31%	33%	33%
Coarse sand, sandy gravel	2800	24%	24%	25%	24%	25%	25%	27%	25%	25%	24%	26%	25%
	2900	23%	23%	23%	24%	23%	23%	26%	24%	24%	23%	24%	24%
	3000	23%	24%	24%	25%	23%	25%	27%	25%	24%	23%	25%	25%
	3100	24%	23%	24%	24%	24%	24%	27%	25%	25%	24%	25%	25%
	3200	22%	22%	22%	23%	23%	23%	25%	23%	23%	22%	24%	24%
	3300	21%	21%	22%	22%	22%	22%	24%	22%	22%	21%	23%	23%
	3400	22%	22%	22%	23%	22%	23%	25%	23%	22%	21%	23%	23%
	3500	23%	23%	24%	24%	23%	24%	26%	24%	24%	23%	25%	24%
	3600	23%	23%	24%	24%	23%	24%	26%	24%	24%	23%	25%	25%
	3700	23%	24%	24%	25%	23%	25%	27%	24%	24%	23%	25%	25%
	3800	24%	26%	26%	30%	26%	28%	31%	29%	29%	27%	30%	29%
	3900	25%	*	*	*	*	*	*	*	*	*	*	*

[1]After Hunting 1997

Appendix F

Water quality: soil water chemistry for water samples

Monitoring of the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Chemistry

Site Visit	*Operation (ml)*	*Colour*	*Soil pH*[1]	*pH*	*Suphate (SO_4^{-2}) mg/l*	*Sulphite (SO_2^{-2}) mg/l*	*Nitrate (NO_3^-) mg/l*	*Nitrite (NO_2^-) mg/l*	*Redox mV*	*Dissolved O²* %	*Conductivity μ S*
Suction sampler 1A *(2.45m)*											
16/11/96	Empty	*	7.7								
20/06/97	Empty	*	7.7								
27/11/98	Full	*	7.7	6.7	<200	12	<5	<0.5	*	11.0	2020
22/12/98	Full	*	7.7	6.8	<200	16	<5	<0.5	109	9.0	1958
01/03/99	Full (230)	yellow	7.7	6.8	<200	14	<5	<0.5	-60	1.0	1933
03/06/99	Full (230)	yellow	7.7	6.5	<200	11	<5	<0.5	-213	0.9	1710
01/09/99	Full (240)	yellow	7.7	6.4	<200	15	<5	<0.5	-66	1.9	1518
03/12/99	Full (200)	yellow	7.7	6.4	<200	<10	<5	<0.5	-242	1.1	1866
01/03/00	Full (200)	yellow	7.7	6.7	<200	11	5	0.5	-145	1.0	893
09/06/00	Full (200)	yellow	7.7	6.0	<200	<10	3	<0.5	51	0.8	1505
08/09/00	Full (170)	yellow	7.7	5.9	<200	19	3	0.6	57	0.4	1526
01/12/00	Small (45)	yellow	7.7	6.6	<200	24	4	0.7	107	12.2	1558
28/02/01	Frozen		7.7								
12/06/01	Full (215)	yellow	7.7	6.5	<200	21	4	<0.5	97	1.6	1693
07/09/01	Moderate (150)	yellow	7.7	5.3	<200	21	3	<0.5	31	0.6	1574
Suction sampler 1B *(1.45m)*											
	Not in operation		7.2								
Rainwater											
(01.12.00)		w.white		4.4	<200	25	5	<0.5	175	17.6	21.1

KEY * = No data [1] = Laboratory analysis on soil samples recovered during borehole construction in November 1996

Monitoring of the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Chemistry

Site Visit	*Operation (ml)*	*Colour*	*Soil pH*[1]	*pH*	*Suphate (SO_4^{-2}) mg/l*	*Sulphite (SO_2^{-2}) mg/l*	*Nitrate (NO_3^-) mg/l*	*Nitrite (NO_2^-) mg/l*	*Redox mV*	*Dissolved O^2 %*	*Conductivity µ S*
Suction sampler 2A *(2.86m)*											
16/11/96	Empty		6.9								
20/06/97	Empty		6.9								
27/11/98	Empty		6.9								
22/12/98	Empty		6.9								
01/03/99	Empty		6.9								
03/06/99	Empty		6.9								
01/09/99	Small (30)	lt.yellow	6.9	5.2	<200	12	46	0.5	164	13.6	628
03/12/99	Empty		6.9								
01/03/00	Empty		6.9								
09/06/00	Empty		6.9								
08/09/00	Empty		6.9								
01/12/00	Empty		6.9								
28/02/01	Empty		6.9								
12/06/01	Empty		6.9								
07/09/01	Small (30)	lt.yellow	6.9	5.7	<200	24	>90	0.9	169	13.9	802
Suction sampler 2B *(1.99m)*											
16/11/96	Empty		6.0								
20/06/97	Empty		6.0								
27/11/98	Empty		6.0								
22/12/98	Empty		6.0								
01/03/99	Full (180)	lt.yellow	6.0	5.9	<200	10	44	<0.5	82	12.6	636
03/06/99	Small (50)	lt.yellow	6.0	5.6	<200	10	41	0.5	135	13.5	628
01/09/99	Moderate (70)	lt.yellow	6.0	6.1	<200	16	50	0.6	177	12.3	667
03/12/99	Small (35)	lt.yellow	6.0	5.9	<200	12	70	<0.5	189	11.9	793
01/03/00	Full (180)	yellow	6.0	6.5	<200	<10	7	<0.5	99	11.8	1817
09/06/00	Empty		6.0								
08/09/00	Small (50)	w.white	6.0	5.4	<200	27	56	1.2	177	11.7	504
01/12/00	Empty		6.0								
28/02/01	Empty		6.0								
12/06/01	Empty		6.0								
07/09/01	Small (20)	lt.yellow	6.0	5.0	<200	21	>90	1.3	160	13.3	840
Suction sampler 3A *(3.09m)*											
	Not in operation										
Suction sampler 3B *(2.11m*											
	No sample ever recovered										

Monitoring of the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Chemistry

Site Visit	*Operation (ml)*	*Colour*	*Soil pH*[1]	*pH*	*Suphate (SO_4^{-2})*	*Sulphite (SO_2^{-2})*	*Nitrate (NO_3^-)*	*Nitrite (NO_2^-)*	*Redox*	*Dissolved O*[2]	*Conductivity*
					mg/l	***mg/l***	***mg/l***	***mg/l***	***mV***	***%***	***µ S***
Suction sampler 4A *(3.00m)*											
16/11/96	Empty		5.8								
20/06/97	Empty		5.8								
27/11/98	Moderate	*	5.8	5.9	<200	12	14	<0.5	*	12.1	587
22/12/98	Empty		5.8								
01/03/99	Moderate (70)	lt.yellow	5.8	5.1	<200	11	36	<0.5	152	16.0	395
03/06/99	Full (170)	lt.yellow	5.8	5.9	<200	11	16	0.5	95	7.3	591
01/09/99	Small (50)	lt.yellow	5.8	5.3	<200	<10	11	0.5	134	11.6	547
03/12/99	Empty		5.8								
01/03/00	Empty		5.8								
09/06/00	Empty		5.8								
08/09/00	Small (20)	lt.yellow	5.8	5.3	<200	27	12	0.5	198	12.3	596
01/12/00	Empty		5.8								
28/02/01	Empty		5.8								
12/06/01	Small (15)	w.white	5.8	5.9	<200	26	43	0.7	218	15.4	630
07/09/01	Moderate (100)	lt.yellow	5.8	5.1	<200	24	9	0.6	183	8.0	484
Suction sampler 4B *(1.95m)*											
16/11/96	Empty		4.9								
20/06/97	Empty		4.9								
27/11/98	Empty		4.9								
22/12/98	Small	*	4.9	5.8	<200	11	<5	<0.5	156	12.2	809
01/03/99	Small (45)	lt.yellow	4.9	6.1	<200	13	<5	<0.5	146	11.4	745
03/06/99	Moderate (100)	lt.yellow	4.9	5.4	<200	11	<5	0.6	154	5.7	790
01/09/99	Small (60)	lt.yellow	4.9	5.4	<200	13	<5	0.8	118	10.9	813
03/12/99	Moderate (150)	lt.yellow	4.9	5.3	<200	14	<5	<0.5	152	2.5	680
01/03/00	Moderate (70)	w.white	4.9	5.5	<200	<10	3	<0.5	119	3.4	597
09/06/00	Small (60)	lt.yellow	4.9	5.7	<200	<10	4	0.7	139	7.4	637
08/09/00	Moderate (125)	lt.yellow	4.9	5.4	<200	27	4	0.6	156	7.0	639
01/12/00	Small (10)	w.white	4.9	5.4	<200	25	5	<0.5	133	13.4	insufficient
28/01/00	Frozen		4.9								
12/06/01	Small (10)	w.white	4.9	5.9	<200	23	15	0.5	196	17.4	610
07/09/01	Moderate (120)	lt.yellow	4.9	5.3	<200	28	3	0.5	82	5.4	597

Monitoring of the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway
Soil Water Chemistry

Site Visit	*Operation (ml)*	*Colour*	*Soil pH[1]*	*pH*	*Suphate (SO_4^{-2})*	*Sulphite (SO_2^{-2})*	*Nitrate (NO_3^-)*	*Nitrite (NO_2^-)*	*Redox*	*Dissolved O²*	*Conductivity*
					mg/l	*mg/l*	*mg/l*	*mg/l*	*mV*	*%*	*μ S*
Suction sampler 5A *(2.92m)*											
16/11/96	Empty		6.6								
20/06/97	Empty		6.6								
27/11/98	Empty		6.6								
22/12/98	Empty		6.6								
01/03/99	Full (180)	yellow	6.6	6.3	<200	10	<5	<0.5	79	6.7	1810
03/06/99	Empty		6.6								
01/09/99	Empty		6.6								
03/12/99	Empty		6.6								
01/03/00	Moderate (140)	lt.yellow	6.6	5.8	<200	<10	5	0.9	75	2.3	1603
09/06/00	Empty		6.6								
08/09/00	Full (170)	w.white	6.6	5.6	<200	27	4	<0.5	143	3.3	852
01/12/00	Empty		6.6								
28/02/01	Small (10)	yellow	6.6	5.7	<200	28	6	0.6	133	15.4	1877
12/06/01	Full (170)	lt.yellow	6.6	5.5	<200	23	5	<0.5	172	9.8	1504
07/09/01	Full (170)	lt.yellow	6.6	6.1	<200	23	7	1.3	178	4.6	1606
Suction sampler 5B *(2.00m)*											
16/11/96	Empty		6.3								
20/06/97	Empty		6.3								
27/11/98	Empty		6.3								
22/12/98	Moderate	*	6.3	5.9	<200	11	16	<0.5	165	12.0	731
01/03/99	Moderate (150)	lt.yellow	6.3	6.0	<200	14	8	0.9	153	8.7	599
03/06/99	Empty		6.3								
01/09/99	Empty		6.3								
03/12/99	Empty		6.3								
01/03/00	Moderate (150)	w.white	6.3	5.9	<200	11	5	0.5	78	8.0	444
09/06/00	Moderate (150)	w.white	6.3	5.7	<200	<10	12	0.6	71	7.0	491
08/09/00	Empty		6.3								
01/12/00	Empty		6.3								
28/02/01	Empty		6.3								
12/06/01	Small (25)	w.white	6.3	6.0	<200	20	6	0.6	243	14.6	697
07/09/01	Small (1)	w.white	6.3				insufficient sample size for analysis				

Monitoring of the In Situ Archaeological Deposits at Schultzgt. 3-7, Trondheim, Norway

Soil Water Chemistry

Site Visit	*Operation (ml)*	*Colour*	*Soil pH*[1]	*pH*	*Suphate (SO_4^{-2}) mg/l*	*Sulphite (SO_2^{-2}) mg/l*	*Nitrate (NO_3^-) mg/l*	*Nitrite (NO_2^-) mg/l*	*Redox mV*	*Dissolved O^2 %*	*Conductivity µ S*
Suction sampler 6A *(2.10m)*											
16/11/96	Empty										
20/06/97	Empty										
27/11/98	Small	*		6.0	<200	13	<5	<0.5	*	12.1	430
22/12/98	Small	*		5.9	<200	14	<5	<0.5	139	12.3	353
01/03/99	Moderate (80)	lt.yellow		5.7	<200	13	<5	0.6	140	14.6	317
03/06/99	Moderate (140)	lt.yellow		5.3	<200	11	<5	<0.5	119	10.2	340
01/09/99	Moderate (140)	lt.yellow		5.2	<200	<10	<5	0.6	154	16.6	376
03/12/99	Moderate (80)	lt.yellow		5.2	<200	10	<5	<0.5	201	9.8	347
01/03/00	Moderate (100)	lt.yellow		5.6	<200	<10	3	<0.5	142	4.6	296
09/06/00	Full (160)	w.white		5.9	<200	<10	6	0.6	210	9.2	476
08/09/00	Full (155)	w.white		5.6	<200	20	4	<0.5	189	8.2	334
01/12/00	Empty										
28/02/01	Moderate (70)	w.white		5.9	<200	24	8	0.8	167	12.2	377
12/06/01	Full (215)	w.white		5.8	<200	21	5	<0.5	255	9.7	306
07/09/01	Moderate (150)	w.white		5.8	<200	24	3	0.6	240	7.8	313
Suction sampler 6B *(2.00m)*											
16/11/96	Empty		7.5								
20/06/97	Empty		7.5								
27/11/98	Empty		7.5								
22/12/98	Full	*	7.5	5.5	<200	10	7	<0.5	142	12.9	260
01/03/99	Empty		7.5								
03/06/99	Small (15)	lt.yellow	7.5	5.3	<200	10	6	<0.5	insufficient sample size for analysis		
01/09/99	Small (60)	lt.yellow	7.5	5.2	<200	<10	8	0.7	168	15.5	304
03/12/99	Small (45)	w.white	7.5	5.8	<200	10	<5	0.5	172	12.2	383
01/03/00	Moderate (80)	w.white	7.5	5.2	<200	10	3	<0.5	135	15.0	204
09/06/00	Empty		7.5								
08/09/00	Empty		7.5								
01/12/00	Empty		7.5								
28/02/01	Empty		7.5								
12/06/01	Empty		7.5								
07/09/01	Empty		7.5								