

**ARCHAEOLOGICAL DEPOSIT MONITORING AT 44/45
PARLIAMENT STREET, YORK**

**REPORT TO YORK CITY COUNCIL DETAILING THE
INSTALLATION OF MONITORING POINTS**

FINAL REPORT

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1.0 INTRODUCTION

A project proposal for the establishment of an archaeological monitoring programme was prepared for York City Council by Hunting Land & Environment Ltd. (HLE) in January 1995 [1]. The proposal included a review of the best available monitoring technologies that could be applied to the project site, located in York city centre. Following discussions with all interested parties a detailed project design for the installation of monitoring equipment and establishment of a monitoring programme was prepared by HLE [2]. Access restrictions at the site necessitated a flexible approach to the work, resulting in revisions to the prepared project design.

The work conducted by HLE to collect baseline data, install monitoring points and establish a monitoring programme at the project site is now complete. The findings, together with revisions made to the original project design, are described fully in this report.

2.0 SITE LOCATION

The project site is located within York city centre, primarily on the site of the former Curry's Electrical Store at 44/45 Parliament Street (NGR SE 60445180). This 'L' shaped building has access onto both Pavement and Parliament Street. The geographical location of the site is shown on the enclosed plan, Plan YCC-01/01 .

The site forms part of a shop redevelopment by Marks & Spencer plc, who occupy the adjacent shop premises. HLE successfully established the monitoring programme in June, prior to the commencement of the redevelopment work in September 1995.

3.0 PROJECT BACKGROUND AND OBJECTIVES

In November 1994 an archaeological evaluation excavation was conducted by York Archaeological Trust (YAT) within the building at 44/45 Parliament Street [3]. The work involved hand excavation of a 3.0 by 3.0 metre trench, to a depth of 2.0 metres.

The excavation revealed archaeological deposits dating from the Medieval, Post-Medieval, and Modern period. Finds from the Medieval deposits included; iron objects, bone, antler and horn, textile, leather, pottery and building materials (wood, roof tiles, daub and mortar). Though very variable, the matrix of the deposit was described as; organic rich silty clay with inclusions of ash, charcoal and industrial waste. Much of the organic material within the deposit was thought to be 'manure' or 'cess', being probably faecal in origin.

The damp deposits described, exhibiting an extremely high degree of organic preservation, are viewed as an important archaeological resource for researching the environmental evidence of York's past history. However, the deposits are considered to be fragile because the good state of preservation is due to specific site conditions. This is most probably waterlogging where very low oxygen levels persist (i.e. anoxic/anaerobic conditions). Preservation is also best where such conditions have existed uninterrupted, ideally from the time of burial. Any form of disturbance is therefore of concern as it may cause a shift away from the conditions promoting organic preservation. The 44/45 Parliament Street site provides an opportunity to address some of the concerns regarding the long term survival of an organically rich archaeological resource.

The equipment installed by HLE does not directly monitor the state of organic preservation within the deposits. Instead it is designed to monitor a number of parameters which are considered to be important in understanding the preserving environment surrounding the deposits. These parameters include; water level fluctuations, moisture content changes, and changes in water quality indicators (pH, temperature, conductivity, dissolved oxygen and redox potential).

The equipment selected by HLE is designed to permit repeated monitoring, at the same location, and in a relatively non-destructive manner over a period of at least 5 years. The monitoring programme design has paid close attention to access restrictions, particularly with regard to the eventual re-opening of 44/45 Parliament Street as an extension to the adjacent Marks & Spencer's Store.

4.0 INSTALLATION OF MONITORING EQUIPMENT AND SAMPLE RETRIEVAL

4.1 MONITORING EQUIPMENT SELECTED

The monitoring equipment installed by HLE comprises: two neutron probe access tubes and one dipwell in the pavement of Parliament Street, and five suction samplers and thirteen moisture cells within the 44/45 Parliament Street site. The operating principle of each piece of equipment is documented fully in Appendix 1. Their installation at the project site is described below.

4.2 SITE PREPARATION

The location of the monitoring points was determined by York City Council, following discussion with the other relevant parties. The works necessary to provide access for HLE to install the monitoring equipment was undertaken by staff from YAT. In addition, YAT staff were present in a supervisory role during the installation process. Staff from the Environmental Archaeology Unit (EAU) at the University of York were also consulted during the installation process, and they assisted in the positioning of moisture cells.

Within the building the preparatory work conducted by YAT involved excavating a 10.0 metre long and 1.0 metre wide trench to a depth of 1.4 metres. All depths are reported as metres below the upper surface of the former shop floor, which is referred to as ground level and had been surveyed into Ordnance Datum by YAT. From Parliament Street to the rear of the building the trench ran in approximately a south-west to north-east direction. The trench bisected the original evaluation trench excavated by YAT in November 1994, which was reopened to create a 3.0 by 3.0 metres 'inspection chamber'. Once the monitoring equipment had been installed, backfilling of the trench and forming of the final inspection chamber was undertaken by YAT.

In the pavement of Parliament Street, three access points were created by YAT. For each point, one or two pavements slabs were lifted and the layer of reinforced concrete immediately below broken with a 'jack hammer'. A sufficient area was hand cleared to create a 750 mm deep, and approximately 400 by 400 mm diameter pit. A full search of all buried services had been conducted prior to the lifting of the pavement slabs, and care was exercised at all time during the excavation work.

Following equipment installation a manhole cover was placed over each access point and the pavement then reinstated by YAT. The manhole covers were supplied by HLE according to the specification shown on Plan YCC-01/02.

The monitoring points installed within the pavement area were surveyed into Ordnance Datum by HLE. For this purpose a Ordnance Survey benchmark search had been commissioned prior to the commencement of site work. The benchmark used by HLE is shown below, and full details of the search are given in Appendix 2.

TABLE 1: ORDNANCE SURVEY BENCH MARK DETAILS

National Grid Reference	Description of Mark	Height Above Ground (m)	Altitude (m, AOD.)	Date Verified
SE 6042 5174	Rivet on All Saints Church, north ang.	0.0	15.041	1956

The location of the monitoring points, and YAT excavated trench is shown on Plan YCC-01/03.

4.3 DIPWELL INSTALLATION

On 14th June, the dipwell was installed into a borehole created using a lightweight 'vibro-hammer' corer unit. The operating principle of the corer unit is described fully in Appendix 1, and the depth of installation is shown below in Table 2.

TABLE 2: DIPWELL INSTALLATION

Borehole Number	Monitoring Point Installed	Ground Level, upper surface of pavement slab (m, AOD)	Length of dipwell installed (m)	Top of dipwell (m, AOD)	Base of dipwell (m, AOD)
2	Dipwell	13.49	6.06	13.43	7.37

A profile log, and depths of each sample taken from the borehole, is given in Appendix 3. The samples were analysed for a range of parameters, including moisture loss, organic matter, sulphate and sulphide, total metals, pH, electrical conductivity and redox potential. Results of the analysis are presented in Appendix 4.

On 15th June 1995 water samples recovered from the dipwell were sent for laboratory analysis of; sulphate content, total metals, pH, conductivity and redox potential. A bacteriological examination was also conducted to determine total viable counts of both anaerobic and aerobic bacteria. The results of the water analysis are presented in Appendix 5.

Duplicate water samples were recovered from the dipwell on 27th June, 1995, and a water level within the dipwell was recorded. One set of samples were analysed with a range of portable water quality probes, the parameters determined included pH, electrical conductivity, temperature, dissolved oxygen and redox potential. The second set of samples were sent for laboratory analysis of the same suit of tests performed on the 15th June samples, excluding the bacteriological examination. Both sets of results are presented in Appendix 6 and 7.

4.4 ACCESS TUBE INSTALLATION

The two neutron probe access tubes were successfully installed into hand augured boreholes on 14th and 15th June 1995. The depth of installation of each monitoring point is shown in Table 3. Allowing for the design of the neutron probe, the effective length of both access tubes from which the probe can record soil moisture measurements is 3.80 m.

TABLE 3: ACCESS TUBES INSTALLATION

Borehole Number	Monitoring Point Installed	Ground Level, upper surface of pavement slab (m, AOD)	Length of access tube installed (m)	Top of access tube (m, AOD)	Base of access tube (m, AOD)
1	Access Tube	13.50	3.97	13.40	9.43
3	Access Tube	13.34	3.95	13.22	9.27

Material recovered during creation of each borehole was described in detail, and the findings are reported in Appendix 3. The method of borehole creation using hand auger limited the availability of sample material for laboratory processing. However, because the deposits into which the access tubes were installed appeared to be similar to those described during installation of the dipwell, reference is made to the results of borehole 2 sample analysis, reported in Appendix 4.

On 27th June, the neutron probe was connected to each access tube to record three count rates at 100 mm intervals. A mean of these values was calculated and then a count rate ratio determined by dividing the mean with the water standard mean (R/Rs). The 'Rs' value is a mean count rate when the probe is at 100 per cent moisture level. This value is determined before use of the probe in the field, by attaching it to an access tube installed within a water filled chamber. A 'soil' specific calibration line obtained for the neutron probe system is then applied to the R/Rs ratio to obtain a moisture volume fraction.

The operation of the neutron probe on Access Tube 1 is shown in Figure 4.

Though it was not possible to produce a site specific calibration line, the archaeological deposits had many of the characteristics of a peaty organic soil. Therefore using a calibration line determined for clay/peat soils, it was possible to obtain the moisture volume fraction, calculated as follows:

$$\text{Moisture Volume Fraction} = 0.958 \times R/Rs - 0.012$$

(Institute of Hydrology, 1979 [4])

The neutron probe data collected on 27th June 1995 and calculated moisture volume fractions are presented in Appendix 8. It should, however, be noted that the use of a standard calibration line rather than a site specific line necessitates that the reported moisture volume fractions be regarded as estimated and not absolute values.

The techniques available to produce a site specific calibration line include; a drum, field and theoretical calibration. Unfortunately the drum calibration conducted in the laboratory and the field calibration techniques would have both required substantial quantities of the archaeological deposit, which it was not possible to obtain without causing unnecessary disturbance to the site. The theoretical calibration technique relies on the detailed chemical analysis and bulk density determination of the deposit, and on a number of mathematical approximations. Again it was not possible to obtain sufficient undisturbed material to perform bulk density calculations, and mathematical approximations applicable to the archaeological deposits are not as yet available.

4.5 SUCTION SAMPLER INSTALLATION

The five suction samplers were each installed into boreholes created by the 'vibro-hammer' corer unit. Boreholes 4, 5, 6 and 7 were located within the base of the trench excavated by YAT, and borehole 8 was within the excavated inspection chamber. The material recovered from each borehole was initially described and representative samples then collected for laboratory analysis. The profile logs and points of sample collection are shown in Appendix 3, and the results of the laboratory analysis are shown in Appendix 4. An incomplete profile log was recorded for borehole 5, because the continuous cores obtained were not available for examination at the time of borehole creation. Instead, the cores were placed in plastic sleeves and made available to the EAU for their own studies.

The depth of installation for each suction sampler is shown below in Table 4.

TABLE 4: DEPTH OF SUCTION SAMPLER INSTALLATION

Borehole Number (sampler number)	Ground Level, upper surface of former shop floor (m, AOD)	Depth from ground level to base of sampler (m)	Base of sampler (m, AOD)
4	14.30	5.91	8.39
5	14.30	5.20	9.10
6	14.30	5.00	9.30
7	14.30	5.84	8.46
8	14.30	6.28	8.02

The suction samplers were installed on 13th and 14th June, 1995. Duplicate water samples were then successfully recovered during a monitoring visit conducted by HLE on 27th June, 1995. One set of samples were analysed using portable water quality probe, and the others were sent for laboratory analysis; the findings are reported in Appendix 6 and 7.

4.6 MOISTURE CELL INSTALLATION

Thirteen moisture cells were inserted into the four exposed profiles of the inspection chamber on 19 June, 1995. The varied nature of the deposits necessitated supervision by the EAU to ensure that the cells were inserted into material of archaeological interest. The deposits identified and into which cells were inserted included; organic rich material (possibly cess), silty clay material (pit fills) and ashy layers. At each point a slit was made and the cell pushed to a depth of approximately 100 mm into the deposit. Care was taken to ensure that intimate contact between the cells and deposit was achieved at all times.

Yellow tags marking the position of cell insertion within the South Facing profile of the inspection chamber are shown in Figure 5. The figure also shows a redundant concrete floor directly above the deposit and, above that, a more modern concrete slab of the former shop floor.

At the points of insertion, two samples were taken for laboratory analysis. A disturbed sample was taken to provide sufficient material for laboratory determination of pH, electrical conductivity, and percentage organic matter. Then a density ring was used to obtain an undisturbed core sample from which values for field moisture content (gravimetric and volumetric) and dry bulk density could be calculated. A gravimetric moisture content is determined when a known weight of a sample is dried in an oven at a temperature of 100-110 °C, then weighed again and the moisture loss by heating calculated. A moisture content expressed as a volume percentage is the volume of soil water as a percentage of the volume of the soil sample.

The positioning of the cells and the results of the laboratory analysis are given in Appendix 9 and 10 respectively.

Once inserted the cells were connected to one of three dataloggers which had been configured to log the resistance of all thirteen cells, and temperature from eight of the cells. The temperature of each cell, logged as a value in degrees centigrade, reflects the temperature of the surrounding deposit. Logged as a value in ohms, the varying resistance of each cell is used as an indicator of moisture change. Resistance values of each cell before and after installation are shown in Appendix 11. No cell temperature data has as yet been collected.

The datalogger to which the cells are attached, and the lap-top used to download the monitoring data, is shown in Figure 6.

The conversion of a cell's resistance into a field moisture content, requires reference to a calibration curve. The varied nature of the deposits, however, prevented a reliable calibration being performed and so moisture change over time and spatially down the profile is reported, rather than absolute values. This is discussed further in the section 5.2 of the report.

5.0 DISCUSSION

5.1 SITE CONDITIONS

The archaeological deposits into which the monitoring equipment has been installed does not fit into standard soil classification schemes, other than in the general category of 'made-ground'. Made ground is not strictly soil because it is ground filled by human activity, rather than formed as a result of geomorphological processes. The monitoring technologies used in this project have been developed over many years for use in a wide variety of soil types, including those modified, but not totally formed, by human activity. The application of the monitoring technologies to made ground is relatively new and unsurprisingly there is a lack of published data to refer to, particularly with regard to calibration of the equipment.

The archaeological deposits have, however, been regarded as soil material, in so far as to subject them to a number of standard soil tests. The results of the analysis are important to; characterise the deposits for descriptive purposes, assess if they will act in an aggressive manner to the buried equipment and to determine the reliability of monitoring data retrieved.

Material recovered from borehole 2 indicates that natural ground occurs at approximately 6.5 m. AOD. Described as a slightly calcareous dark greyish brown silty material, with an alkaline pH (8.2) and relatively low organic matter content (7.3%), it is possible that this is buried/relict soil.

Three of the cores from borehole 2 are shown in Figure 7. The left-hand core, from between 11.69 and 10.94 m AOD (1.80 to 2.55 m bgl), shows a dark grey or black loamy 'peaty' deposit in which there are a few fragments of builders debris and abundant wood remains. The middle core, from between 9.24 and 8.49 m AOD (4.25 to 5.00 m bgl) contains a black loamy 'peaty' material with abundant wood remains. The right-hand core, from between 7.99 and 7.24 m AOD (5.50 to 6.25 m bgl), contains a very dark grey/black organic silty/clay and a few limestone or masonry stones. In the figure, the builders debris and stone shows up as the white areas, and the wood as the yellow areas. All depths are approximations.

Natural ground was not encountered in any of the other boreholes possibly because they were shallower, terminating at between 9.43 and 7.35 m AOD. Those boreholes that passed to at least 8.5 m AOD did reveal a stiff non calcareous very dark greyish brown clay. However the presence of charcoal flecks within this material indicates that though a 'soil', it had been modified by human activity.

The deposits overlying the dark greyish brown material are variable and represent the occupational layers of York city centre. The matrix of the deposits generally had the following characteristics; dark brown or black colour, low bulk density (less than 1.1 g/cm) and high organic matter content (greater than 12 %). Contained within this matrix were quantities of domestic and industrial waste, and builders debris.

Characterisation of the site has been attempted by reference to a proposed urban soil classification scheme. Assuming that the natural described from borehole 2 is a buried soil, the York deposits conform to a 'compost-deepened' soil [5]. This term applies to all deepened soils with a surface horizon more than 400 mm thick, resulting from the addition of earth-containing manures or waste materials from former human occupation (middens). In addition, because of the generally high organic matter content the deposits can more correctly be referred to as a compost-deepened organic soil. This soil description will be assumed when interpreting the monitoring data.

An assessment of the deposits potential aggressiveness to the installed monitoring equipment is made from electrical conductivity (EC) measurements, as these are indicators of the total quantities of soluble salts in a sample. Compared to a classification scheme used for agricultural soils, the EC values of the deposits indicate saline conditions of varying severity. The interpretation used is that an EC values of between 4 and 8 ms/cm are typical of slightly saline conditions, then between 8 and 15 ms/cm are moderately saline, and above 15 ms/cm is strongly saline [6]. An EC value below 4 ms/cm is indicative of a non-saline soil. The deposits have EC values of between 2.43 and 17.78 ms/cm.

It is important that a classification of deposits also make reference to EC measurements of groundwater (or soil water) samples. This is because the deposit analysis reveals a total potential reservoir of salts but does not reflect in their solubility. Though all naturally occurring water contains some amount of dissolved salts, the five water samples analysed had relatively high EC values of between 5.11 and 5.95 ms/cm. This indicates that a proportion of the salts present are in a soluble form. In conclusion, the deposit's salt content has the potential to act in an aggressive manner to buried metal objects, and will also influence the moisture cell data.

Analysed samples from upper sections of the archaeological deposit report higher EC values than from the base of the sampled profile. For example, the EC of samples from the top and bottom of borehole 4 were 4.99 and 2.59 ms/cm respectively. The top sample was taken from the deposit at approximately 1.85 metres below ground level. Samples recovered during installation of the moisture cells were also analysed for EC and again it appeared to decrease with depth. For example, the EC of samples from 0.98, 1.20 and 1.80 metres down the south facing face of the deposit were 13.94, 13.32 and 9.08 ms/cm respectively.

This characteristic of decreasing EC with depth was most evident in deposits sampled from within the building, rather than those below the pavement slab at borehole 2 location. A redundant concrete floor lay directly over the deposits, and it is possible that soluble salts from the concrete may have migrated down into the deposits where they then precipitated out. Possible visible evidence to this were accumulations of a white powdery substance in the deposit. This has not as yet been formally identified but could possibly be Calcium humate, which is a fulvic acid salt formed by reactions between organic acids (formed by the decay of organic matter) and concrete.

In addition to EC measurements, a determination of individual salts is used to assess corrosion risks, in particular sulphate attack. The most abundant salts are generally calcium sulphate, magnesium sulphate and sodium sulphate. The latter two salts are more soluble than calcium sulphate, which possibly explains why calcium levels within the deposits were higher than magnesium and sodium levels, and the reverse was true for the water samples; see table below:

TABLE 5: SAMPLE ANALYSIS FROM BOREHOLE 2

Parameter	Deposit sample from near base of borehole 2	Water sample from base of borehole 2
Calcium	31000 mg/kg	108 mg/l
Magnesium	5260 mg/kg	380 mg/l
Sodium	884 mg/kg	276 mg/l

Sulphate attack is normally associated with the deterioration of building materials, particularly concrete and cast iron piping. The monitoring equipment most likely to be affected by high sulphate concentrations are the moisture cells and suction samplers (because of their reliance on a porous ceramic cup).

Sulphates are a natural constituent of uncontaminated soils, and typical values range from 0 to 2000 mg/kg [7]. The archaeological deposits contained sulphate levels of between 776 and 8250 mg/kg, with the highest values recorded from the three near surface samples. Based on Building Research Guidelines (BRE), the reported sulphate levels in both deposit and water samples were in Class 1, except for the near surface samples that had levels in Class 2 [8]. The BRE guidelines recognise five soil classes; soils within Class 1 are considered non-aggressive, and within Class 2 they impose a slight risk of sulphate attack on concrete. Therefore the deposits do not pose a significant hazard to the water sampler's ceramic cup. Within the surface of the deposit, there is however, some risk of metal corrosion if the level of soluble sulphate rises above 1000 mg/kg. Also noted is that the surface deposits had lower pH's than in samples from the base of the profile, indicating more acid and so more aggressive conditions.

Also determined, were the deposit's sulphide content which, except for one sample, were at or below 30 mg/kg. Because the deposits contain appreciable concentrations of sulphate from which sulphides are formed (by sulphate reducing bacteria), and a natural soil typically has a sulphide content of between 0 and 10 mg/kg, the values for the York site are considered low. It is possible that an under-estimation has occurred due to the unavoidable exposure of deposits to the atmosphere during sampling collection, and the time taken for laboratory analysis of the samples. On exposure to oxygen, sulphides can form hydrogen sulphide gas which has a characteristic 'rotten-egg' odour, and this was detected during construction of all eight boreholes. Because hydrogen sulphide is highly toxic all the site work was undertaken in well a ventilated environment.

The sulphate reducing bacteria (e.g. *Desulfovibrio*) are one of many that exist in a soil environment. A bacteriological examination of two water samples from the dipwell show that active aerobic and anaerobic bacterial populations are present at the project site. Though a careful sampling procedure was followed, it is probable that the aerobic count is higher than actual due to unavoidable contamination of the sample. The examination therefore indicates that conditions are anaerobic (waterlogged and low oxygen levels) because of the relatively small difference between the aerobic and anaerobic counts. Had aerobic conditions been present, the high organic matter content of the deposits would have supported larger populations of aerobic bacteria and, due to competition, a lower anaerobic bacterial population.

Finally the results of a metal determination from four of the borehole samples were compared to a set of guidelines for the classification of contaminated soils [9]. For each parameter analysed the level in the deposit was close to, or within, that typically found in an uncontaminated soil. The only exception were high values recorded for magnesium. A similar determination conducted on the water samples also reports low metal contents, with no demonstrable pollution indicators. The site appears to contain no metal pollutants that would pose a hazard to the installed monitoring equipment.

5.2 MONITORING DATA

5.2.1 Measurements Taken

The monitoring programme established by HLE is concerned with the process of obtaining and then comparing two independent measurements over a period of time on a number of successive occasions. The measurements (or data sets) to be compared are; dipwell water level, dipwell water quality, deposit water quality, and the moisture content of the deposits. Water quality is a general term for the reporting of five separate parameters; temperature, electrical conductivity, pH, dissolved oxygen and redox potential.

The following discussion concerns monitoring data obtained during the installation of the monitoring equipment, carried out between 14th and 19th June 1995. Reference is also made to data obtained during the first site visit of the monitoring programme, conducted on 27th June 1995.

5.2.2 Dipwell water level

Immediately after its installation on 14th June a water column was detected within the dipwell. To allow equilibrium between the water level within dipwell and surrounding deposits to be established the first measurement was not taken until 27th June.

The reported water level was 9.88 metres above Ordnance Datum level.

5.2.3 Quality of water samples from dipwell

The water sample collected on 27th June had a temperature approximately 2 °C lower than that of the ambient surroundings. The air temperature of 17.5 °C reflected the relatively warm June weather. Because of the deposit's buffering effect, it is expected that seasonal fluctuations in dipwell water temperature will be less than that recorded for air temperature. Dipwell water temperature may also be influenced by rates of bacterial activity since they can generate heat during the process of organic decomposition. An examination conducted on two dipwell samples confirmed the presence of a bacterial population, though their role in organic decomposition has not been established. The optimum temperature for decomposition in a soil environment is between 25 and 30 °C, and little decomposition takes place below 10 °C [10].

The dipwell water sample had a low dissolved oxygen content of approximately 0.8 mg/l. This is an approximate value because reliable measurements at such low levels are problematic with portable dissolved oxygen probes. In comparison, river systems require a minimum concentration of dissolved oxygen to maintain a good fish population of 5.0 mg/l [11].

The redox potential of the sample sent for laboratory analysis and for duplicate sample analysed using a portable probe were similar; +220 and +231 mV respectively. Anaerobic deposits with a reducing environment have redox potential values of between +200 and -400 mV, as opposed to well drained deposits with values of between +300 and +800 mV [12]. The evidence from the York site is that the deposits are anaerobic and so these slightly high values maybe a reflection of the disturbance caused during dipwell installation. Therefore, with time, it is expected that the redox values will fall.

The pH and EC values of the duplicate samples, determined by on-site testing and laboratory analysis were both similar; 6.9 and 7.0 for pH and, 4.6 ms/cm and 5.9 ms/cm for EC.

5.2.4 Quality of water samples from suction samplers

Samples of sufficient size for on-site analysis of the water quality parameters were obtained from four of the five suction samplers. In addition, duplicate samples from three of the suction samplers were obtained and sent for laboratory processing.

Sample temperatures were approximately 1 °C higher than the dipwell sample. The on-site and laboratory analysis indicates slightly higher pH values in the suction samplers than the dipwell sample. The water sample pH's, were in all cases, lower than those recorded from borehole core samples taken at the level in which the samplers are installed; approximately 7.3 compared to 8.2. EC values were again high, ranging between 4.0 and 5.8 ms/cm.

The dissolved oxygen level and redox potential value from all four samples was relatively high, when compared to the dipwell sample and considering the nature of the deposits. A gap of 14 to 15 days had been allowed between suction sampler installation and sample collection, but it is possible that this was insufficient time to allow for the effects of site disturbance caused during installation. In particular, a soil slurry was used in the backfill of the boreholes and it is therefore likely that this first water sample is not truly representative of the 'natural' site conditions. The water quality of future samples should more accurately reflect the anaerobic conditions that are believed to exist within the deposits.

A second consideration is; any interpretation of the data should be made with an understanding of the sampling strategy used with suction samplers. The physical act of applying a vacuum and then pressure to recover water samples may affect a number of the monitored parameters, for example, increasing the dissolved oxygen content. The effect of distance travelled by the sample from suction sampler to sample bottle may influence the monitored parameters, for example, temperature. Residues left in the discharge tube are a potential source of contamination, though this potential error is lessened because the initial sample recovered is discarded so as to flush the discharge tube.

The sampling of water by means of porous cups may lead to chemical changes in the sample caused by the sampler or sampling strategy. In particular, a change in solute concentration during sampling (measured by the samples EC) may occur, due to filtering by the ceramic cup. This is of concern in organic rich deposits because ceramic cups may cause filtering of large humic molecules and particles. However, when EC data from the suction samplers is compared with that obtained from the dipwell and deposit samples, the values are within the expected range.

The worst case scenario is that the chemical or microbial environment in the cup or at the surface may change over time, causing the sample to be merely a product of the 'artificial' environment around the sampler rather than the 'soil' solution itself. Experiments conducted into evaluating the use of suction samplers have indicated that this is not a significant problem, however reference was made to filtering by the ceramic cup in organic soils [13].

Despite these criticisms, the samplers are still considered to be the best option for providing samples from unsaturated conditions, where the option of direct sample retrieval is not available. Possible sources of error in the suction sampler operating procedure will be evaluated during the course of the monitoring programme.

Since sampling actually decreases the water content of the deposits, it is not intended to collect samples from every suction sampler during each monitoring visit. The unused suction samplers are still important as reserve units should the monitored ones fail. This is part of the project design because, once installed, there is no direct access to a sampler for maintenance, and the opportunity for installing additional suction samplers is not considered likely.

5.2.5 Monitoring data from moisture cells

Before installation, the operation of each moisture cell was tested by recording a cell resistance in air (0 % moisture content) and then in a water bath (100 % moisture content). All the cells operated satisfactorily, recording a rapid fall in resistance from 2540000 ohms in air, to values below 1000 ohms in water. The cells were then dried and prepared for use.

At the point of cell insertion, moisture contents of the deposits were determined from samples collected on 19th June. With reported gravimetric moisture contents as high as 129.61%, the results confirm that the deposits are in a very wet, to saturated state. Immediately after sample collection all the moisture cells were inserted. A single resistance value was then recorded one day later and again nine days later. The data reports a fall in resistance within all thirteen cells, which is a reflection of the cells responding to the wet deposits surrounding them. It is unclear how much time is required for each cell to reach equilibrium with their surroundings, and therefore further falls in resistance may be experienced.

Though only two data sets are available, the resistance values presented in Appendix 11 indicate that, in each of the four archaeological faces, the lowest cell resistances are from those at the base of the profile. Volumetric moisture contents of the deposits were determined in an attempt to understand the relationship between soil moisture content and soil cell resistance. Unfortunately, the variable nature of the deposits and the presence of man-made debris, particularly tile and brick, reduced the accuracy of the laboratory derived data. This is considered a major reason why there is no apparent relationship between samples having high volumetric moisture contents and the associated cells having a low resistance. Therefore, rather than reporting estimated values for volumetric moisture content of the deposits, the monitoring data will indicate relative changes in moisture content with time and spatially down the profile.

However two additional reasons for the difficulty in data interpretation are; cell uniformity and the effect dissolved salts can have on the resistance of a cell. Preliminary studies conducted in the United States have shown very little difference between the moisture-resistance relations of duplicate cells, chosen at random, when placed in the same soil [14]. The studies were conducted on a small sample, but the findings are at least encouraging with regard to cell uniformity.

Secondly, the reciprocal of electrical resistance described by Ohm's law and expressed as 'R' is electrical conductivity (EC), expressed as '1/R'. Therefore EC is a measure of the ease with which a substance like soil will conduct an electrical current. The EC of a soil depends on both the water content and the amount of salts dissolved in the that water. Because soil has an inherently high resistance, and thus a low conductance, moisture cells as a means of monitoring soil moisture content changes are generally applicable. Unfortunately, analysis of samples from the York project site has shown that the deposits are both wet and saline. Though this is likely to affect resistance of the cells, it is hoped that appreciable changes in deposit moisture content will still be observed. Reference to the EC values of water obtained from the suction samplers will be important as an indicator of any significant changes in the concentration of soluble salts within the soil water.

Notwithstanding this potential interference and given site access restraints, the moisture cells are still regarded as the most appropriate piece of equipment for the estimation of moisture change over time.

5.2.6 Monitoring data from neutron probe system

Values for the volumetric moisture content at selected depths down two separate profiles are available for the York project site. Data is only available from the site visit of 27th June, 1995, and so a review of changing values with time is not yet possible.

Spatially down both profiles the data reports a lower moisture content at the surface of the deposits. Surface measurements of moisture content by the neutron probe are problematic because neutrons introduced into the deposit at these shallow depths can escape into the atmosphere. Calculated moisture contents near to the ground surface may therefore be underestimated. Excluding data from the surface 200 mm of the deposits, both monitored profiles had high to very high moisture contents, ranging between 64% and 90% (the depths quoted are as metres measured below ground level).

Reviewing the values individually, a relatively low moisture content of 64% is reported within access tube 1 (borehole 1) at 1.6 metres. Above 1.6 metres the values are generally above 70%. Between 1.7 and 2.3 m the moisture content value increased to over 80%, after which it fell to below 80%. An increase to 81% is then reported between 2.9 and 3.0 metres, after that the value falls again to below 80% and stays relatively constant to the final reading at 3.8 metres.

An interpretation of this data is attempted by reference to the profile description at borehole 1, reported in Appendix 2. The material recovered noted that at 1.6 metres a concentration of building debris (mainly mortar) was found, which possibly explains the low moisture content. Above and immediately below this level the deposits were variable, containing organic matter and building debris. The deposits below 1.6 metres were however wetter (moister) than the surface deposits, and this is reflected in the moisture content values. The fall in moisture content between 2.4 and 2.7 metres, then a rise at 3.0 metres, and finally a fall to levels below 80% at the base of the profile can possibly be attributed to variations in the deposits. At between 2.3 and 2.8 metres the deposit was very moist, immediately below there was a wetter horizon that quickly passed to a moderately moist horizon which continued to the base of the logged profile.

Compared to access tube 1, a narrower range of calculated moisture contents are reported for the profile around access tube 3 (borehole 3); between 66% and 84%. The high values at around 2.2 metres relates well to the profile description, which noted wetter deposits at this level. Also in agreement with the profile description is the low value of 71% at 2.6 metres, where a hard unidentified object (possibly bone or mortar) was encountered in the profile. Below 2.6 metres the calculated moisture content increases to around 80%.

This simplistic interpretation of the neutron probe data indicates that both horizon (layer) and moisture content differences down the archaeological deposits can be identified.

To evaluate the validity of data obtained from the neutron probe, the operating principle of the neutron probe and the reliance on a standard calibration line must be taken into consideration. Hydrogen, which exerts the principle effect on the count rate recorded by the neutron probe occurs primarily in the free water of the deposit. However hydrogen also occurs as bound water and in organic matter, and in this from it can cause an overestimation of the moisture content.

Experiments show that bound water in the mineral fraction of a soil does not affect the neutron probe calibration greatly as the amount is relatively constant during wetting and drying, and because of a fortuitous correlation between bound water content and the concentration of neutron absorbing elements, especially in clay. Because the hydrogen content of humus is approximately 5% of its weight and in water it is 11%, the amount of hydrogen in organic matter may form a large part of the total hydrogen in a soil. It is, however, reported that a 96% increase in organic matter increased the count rate by only 25%. Also readings from a highly organic topsoil containing 75% moisture were still on the calibration line applied to the count rates [15].

Whilst the presence of hydrogen in other forms can over estimate the moisture content, a concentration of neutron-absorbing elements decreases the count rate causing an under estimation of the moisture content. The element of possible significance to the project site is magnesium, because in the four deposit samples analysed it was found to be above the level normally seen in a natural uncontaminated soil. This element is known to decrease count rates, but it's effect on the reported data from the two access tubes is not known [15].

Moisture content is known to increase with increasing bulk density owing to the impedence of neutron transport. Because the effect is less than that of neutron-absorbing elements and the archaeological deposits generally have low bulk densities, this is not considered a major influencing factor on the count rate. The thin and denser clay layers that do occur in the deposits are felt to be too small to have a noticeable effect on the count rates, though ideally the profile should have a uniform bulk density.

An increase in temperature, decreases neutron density in the vicinity of the probe's source. This effect is more significant at higher moisture contents. An effect on the count rate has been noted at sites where a temperature range of 35 °C is experienced. Though unlikely to occur in York, attention will be given to temperature data from the moisture cells and dipwell water sample.

In summary, it is considered that a degree of over-estimation in the values has occurred. This is because of the reported effect of hydrogen in organic matter, and the moisture contents from the two monitored profiles are in places exceptionally high. The application of the clay/peat calibration line to the data is thought to be acceptable provided that the calculated values are interpreted as moisture change, rather than as absolute values. Further evaluation of the data's validity will be conducted once a number of data sets have been collected over the coming months.

Relating the moisture content data to differing layers in the archaeological deposits requires good vertical resolution by the neutron probe. The inaccuracy of readings is increased as the number of layers within the profile increase, such that with poor resolution the 'wet' and 'dry' layers on either side of an interface are under-estimated and over-estimated respectively. With the exception of the isolated objects discussed earlier (bone and mortar), the data interpretation assumes the archaeological deposits to be fairly uniform, i.e. wet, highly organic and with low bulk densities.

Although there are some complications associated with the use of the neutron probe, it is still considered the most appropriate method of collecting moisture data at the same point down a profile, on a long term and non-destructive basis. This is because, provided all other influencing factors stay constant, any change in readings over time may be attributed to moisture content changes in the deposit.

It is possible that a change may occur in the amount of hydrogen present, that is not associated with soil water. Release of hydrogen bound up in the organic matter present will occur during the process of organic decomposition. Though decomposition at the project site is thought to be inhibited by the anaerobic conditions, some decay may be occurring. For example, the release of gaseous hydrogen sulphide was observed during installation of the monitoring equipment. Any effects associated with these processes will be evaluated during the course of the monitoring programme

6.0 SUMMARY

The project at 44/45 Parliament Street, York, represents an innovative approach to the *in-situ* monitoring of an organic rich archaeological resource. Though not without problems, the monitoring equipment selected is considered to be the most appropriate with regard to parameters being monitored and the conditions encountered at the project site.

The two site conditions that have most strongly influenced the choice and operation of the equipment are; site access and the physical/chemical characteristic of the deposits themselves. The influence of these characteristics has still to be fully assessed and will be further investigated during the course of the established monitoring programme.

The sampling strategy used with each piece of monitoring equipment will be reviewed during the course of the project, to ensure that possible sources of error in the interpretation of the monitoring data does not result from the equipment chosen.

7.0 REFERENCES

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APPENDIX 1

1.0 MONITORING EQUIPMENT DESIGN SPECIFICATIONS

1.1 DIPWELL DESIGN

If present, a water level at a site can be monitored using a dipwell (standpipe). This is constructed from small diameter rigid open plastic tube, with a lower section of slotted pipe.

The dipwell is installed into a vertical borehole, created either by hand auger or mechanical corer. At the York project site, a lightweight 'vibro-hammer' corer unit was used, handled by two trained operators and powered by a diesel generator. The corer can be operated in areas with limited access, and is a relatively quick method for borehole construction. The system uses a percussion hammer to drive a 2 metre long 'window sampler' into the ground, into which the soil material passes. On reaching the required depth, the sampler is jacked out and the soil core it contains then described. In suitable conditions, a virtually continuous core is made available from which disturbed samples can be extracted for subsequent laboratory analysis.

Where retrieval of uncontaminated and continuous cores are important, the sampler can be replaced with a 'window-less sampler' that contains a plastic sleeve. The sampler is driven in and then jacked out as before, except that the core contained within the plastic sleeve can be removed intact for later study. Though this system has the disadvantage that a core is not immediately accessible for descriptive purposes, they are more representative of the undisturbed profile.

The borehole constructed is unlined, and therefore dipwell installation should be undertaken immediately to reduce the likelihood of borehole collapse. Depths of up to 10 metres can be achieved, especially where fine grained fills and alluvium have sufficient cohesion to keep the holes open.

Once installed, the void around the dipwell is backfilled with excavated spoil, replaced in the same order as it was excavated. At ground level a bentonite clay seal is created around the dipwell in order to limit surface water draining down the sides of the monitoring point. Finally, the clearly labelled dipwell is sealed with a removable plastic cap.

A water level is recorded by lowering the tip of a portable dip-meter down the dipwell, a light and audible signal indicates water contact. The level is measured off the graduated cable on the meter. The dipwell also provides a sampling point for the recovery of water samples that can then be analysed for water quality. Water samples are recovered using a bailer technique.

1.2 SOIL MOISTURE MEASUREMENTS: ELECTRICAL MOISTURE CELLS

The principle of the electrical resistance cells is based on a change in electrical resistance of a porous material due to variations in moisture content. The cells selected for the York project site comprise two plates separated by a processed glassfibre binding which provides the electrical coupling. The cells are approximately 25 by 38 by 3 mm in size, and use in their construction, stainless steel corrosion resistance plates. A small thermistor included within the body of the cell enables changes in soil temperature to be monitored. The resistance of the thermistor in the cell is accurate to 1%, cell uniformity with regard to moisture-resistance relations are not however guaranteed. Each cell is connected to a three wire conductor cable that is approximately 9.5 metres long. The resistance of such a cable probably exceeds 1 megohm, however no significant corrections need to be made at measured cell resistance's of less than 50 000 ohms [14].

Each cell has to be inserted carefully into the material which it is to monitor to ensure intimate contact between it and the surrounding material. The characteristics of the material to be monitored should be determined to assess the reliability of monitoring data recovered. For example; soils with a shrink-swell capacity cause contact problems between the cell and soil, and a saline environment may cause data interpretation problems. Aggressive soil conditions can lead to cell deterioration and loss of data.

The resistance (in ohms) and temperature (in degree's centigrade) of the cells can be obtained manually by connecting each cell in turn to a portable meter device. Alternatively each cell is connected to a datalogger, programmed to automatically record readings on a fixed time frequency.

Left permanently at the project site the dataloggers are small, rugged and have a internal ten year life span lithium battery. They have an internal temperature sensor which monitors surrounding air temperature, plus the seven channels to monitor either resistance or temperature from the cells. Set to record at 30 minute intervals, the memory capacity of the datalogger permits 80 days of continuous monitoring. To retrieve and view the data, each datalogger has to be connected to a personnel computer and the appropriate software run.

Figure 1.0 shows the design of electrical resistance cells installed at the York project site.

1.3 SOIL MOISTURE MEASUREMENTS: NEUTRON PROBE SYSTEM

Changes in moisture content of a soil, over time and down a profile, can be determined using a neutron probe system [4]. The system requires permanently installed 40 mm internal diameter aluminium alloy access tubes. The tubes are sealed at their lower end with a aluminium nose cone, and at the other end with a removable neoprene bung. Soil moisture measurements are taken from each tube in turn using a portable neutron probe.

The probe consists of a radioactive source combined with a Boron trifluoride detector. The probe is connected to an access tube, and the source then lowered to the depth from which measurements are to be taken. The source emits fast neutrons into the surrounding soil, which on collision with hydrogen atoms, are scattered and slowed down to thermal velocities. The 'cloud' of slow neutrons can then be sensed by the detector, allowing a mean count rate (in counts per second) to be recorded electronically by the probe's ratescaler over either a 16 or 64 second period. A graduated depth counter on the probe enables measurements to be taken accurately at 100 mm intervals down the length of the access tube. This is except for approximately the final 100 mm of the tube, which is inaccessible to the source.

The count rate from each recording depth is linearly related to the volumetric moisture content of the soil by use of a calibration curve. The wetter the soil, the greater chance of collisions near the probe's detector between neutrons and the nuclei of hydrogen in the soil, which is mainly in the form of water. However, every element present in the soil matrix has scattering and absorbing properties for neutrons which, although individually much less than that of hydrogen, together influence the count rate to an extent. Every soil therefore has in theory at least, a unique calibration curve.

The access tubes are installed into a borehole created by hand using a system of steel guide tubes. The 1 metre sections of guide tubes are driven into the ground using a weighted rammer. As soil material passes into the guide tube it is removed with a screw auger and immediately described to produce a profile log. Once the desired depth has been reached, the guide tubes are jacked out and the access tube then carefully inserted into the borehole to the full depth. The borehole created should be 100 mm deeper than the selected length of access tube to allow for the tube's nose cone.

For accuracy of monitoring it is important that a tight fit is achieved between the 'soil' and access tube. This is to avoid air gaps or water draining down the side of the tube.

The neutron probe, as operated in the field, is shown in Figure 2.0

1.4 SUCTION SAMPLER DESIGN

When ground water is not present from which to collect samples for water quality monitoring 'pressure-vacuum soil water samplers' (suction sampler) can be used. The suction sampler consists of a plastic body that has at the lower end a round bottom porous ceramic cup. At the other end there is a silicone plug through which two polyethylene plastic tubes are inserted, the plug is sealed into the suction sampler body using a threaded clamp ring.

The suction samplers are installed down an unlined borehole to the depth from which water samples are to be collected. The boreholes are constructed in the same manner as those used for the installation of the dipwell. Before installation of the suction samplers, a slurry is made from some of the excavated spoil. This is poured to the base of the borehole to insure a good contact with the porous cup of the suction sampler as it is lowered into the archaeological deposit. The remaining void of the borehole is backfilled with excavated spoil, screened to remove large objects and replaced in the same order in which it was removed.

The two tubes that pass into the suction sampler body are the 'pressure-vacuum' tube and the 'discharge' tube. The first tube is inserted through the plug so that it extends into the sampler body by approximately 30 mm. The discharge tube is passed through the plug to almost reach the base of the sampler. The exposed lengths of tube that pass up the borehole are protected from damage by running them through a thick walled flexible plastic pipe (19 mm internal diameter, 25 mm external diameter).

On leaving the borehole, the tubes from each suction sampler are lain along a trench to a single collection point at ground level. To prevent damage to the pipes when the trench is backfilled the pipes are again laid in protective ducting. Finally, to prevent debris entering the tubes, the ends are sealed with a stainless steel pinch clamp. The suction samplers are now left in place for the duration of the monitoring programme.

The installation of a suction sampler is shown in simplified form on Figure 3.0.

A water sample is collected by first closing the pinch clamp on the discharge tube, then connecting the pressure-vacuum tube to the vacuum port on a portable hand pump. The pump is stroked until a vacuum of approximately 60 centibars is created within the sampler body. The pinch clamp on the pressure-vacuum tube is then closed securely to seal the sampler under vacuum. The hand pump can then be removed for other uses.

The suction sampler is allowed to sit for a period of time under vacuum which causes water to move from the deposit, through the porous cup and into the sampler. To recover a water sample, the pressure-vacuum tube is connected to the hand pump's pressure port and the discharge tube is placed in a sample bottle. The pinch clamps on both tubes are opened and a few strokes of the hand pump are then used to develop enough pressure within the suction sampler to force water into the sample bottle. The water first obtained is discarded since it may contain residues from the previous sampling operation. Sampling continues until all water within the suction sampler has been collected.

APPENDIX 2

ORDNANCE SURVEY BENCH MARK LIST

National Grid Reference	Description of Mark	Height Above Ground (m)	Altitude (m, AOD)	Date Verified
SE 6042 5174	Rivet on All Saints Church, north ang.	0.0	15.041	1956
SE 6032 5168	No.1 Nessgate east side road junction, north-west face, west ang.	0.3	14.61	1960
SE 6043 5159	Building south-west side road, north-east face, east ang.	0.4	13.50	1960
SE 6040 5201	NBM shop No.68 Low Petergate, south-west face, west ang.	0.5	16.90	1960
SE 6066 5184	NBM No.10 The Stonebow, north-west face, north ang.	0.8	10.84	1960
SE 6019 5185	NBM Westminster Bank east side road, south-east face, south ang.	0.4	13.97	1960
SE 6026 5160	No.14 King Street, north face, north-west ang.	0.5	8.63	1960

APPENDIX 3

BOREHOLE LOGS

Project Name: Archaeological Deposit Monitoring, York
Borehole Number: 1
Borehole Location: Pavement area of Parliament Street
Ground Level: 13.50m AOD (upper surface of pavement slab)
Equipment Used: Hand auger
Logged By: Robert Clarke
Date: 14 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
0.65	Access pit excavated below surface of pavement slab.			
0.97	Slightly/moderately moist, slightly sticky black loamy peat material.			
1.35	Slightly/moderately moist, slightly sticky black loamy peaty material with common builder debris (brick fragments and mortar).			
1.40	Slightly/moderately moist, slightly sticky black loamy peat material as above, with common fragments of wood.			
1.55	Concentration of hard mortar debris.			
1.80	Very moist, moderately sticky black loamy peat material. Inclusions of leather and wood fragments.			
2.25	Becoming wet, very sticky black loamy peat. Inclusions of builders debris (brick, limestone or mortar) and wood fragments. Strong foul egg smell.			
2.30	As above, but less moisture and denser horizon.			
2.80	Wet, very sticky black peaty loam. Wood material abundant. Strong foul egg smell.			
2.95	Very moist and moderately sticky black loamy peat. Inclusion of woody material and limestone or mortar. At 3.00 very wet material encountered. Strong foul egg smell.			
3.15	Very moist, moderately sticky black loamy peat, with inclusions of dark brown material (organic matter?). Abundant wood fragments. Strong foul egg smell.			
3.45	Slightly/moderately moist, slightly sticky black loamy peat. Abundant wood fragments. Strong foul egg smell.			
3.60	Slightly/moderately moist, slightly sticky black loamy peat with inclusions of dark brown material (organic matter?). Limestone/mortar fragments and wood common. strong foul egg smell.			
4.05	Slightly/moderately moist, slightly sticky black loamy peat. Abundant wood fragments, builders debris (brick, mortar) and shell fragments. Strong foul egg smell.			
	END OF HOLE			

APPENDIX 3 (CONTINUED)

Project Name: Archaeological Deposit Monitoring, York
Borehole Number: 2
Borehole Location: Pavement area of Parliament Street
Ground Level: 13.49m AOD (upper surface of pavement slab)
Equipment Used: Corer unit with window sampler
Logged By: Matthew Davis
Date: 14 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
0.60	Access pit excavated below surface of pavement slab.			
1.55	Slightly/moderately moist, slightly sticky black loamy 'peaty' material. Calcareous.	BH2 C1	Soil	0.80-1.10
2.80	Slightly/moderately moist, slightly sticky very dark grey/black loamy 'peaty' material. Few fragments of builder debris, ash and abundant wood remains. Slight calcareous.			
5.25	Very moist, moderately sticky black loamy 'peaty' material. Abundant wood remains. Calcareous.	BH2 C2	Soil	2.80-3.10
6.50	Very moist, moderately sticky very dark grey/black organic silty/clay, few stones (limestone/masonry?). At 5.85m single piece of red brick/tile, possibly Roman. Calcareous.	BH2 C5	Soil	5.25-5.77
7.00	Wet, very sticky very dark greyish brown organic silt, few stones (limestone/masonry?). Very slight calcareous. Water encountered	BH2 C6	Soil	6.50-7.00
	END OF HOLE			

APPENDIX 3 (CONTINUED)

Project Name: Archaeological Deposit Monitoring, York
Borehole Number: 3
Borehole Location: Pavement area of Parliament Street
Ground Level: 13.34m AOD (upper surface of pavement slab)
Equipment Used: Hand auger
Logged By: Robert Clarke
Date: 15 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
0.58	Access pit excavated below surface of pavement slab.			
0.73	Slightly moist, slightly sticky black loamy 'peaty' material, with few fragments of builders debris (brick, mortar)			
1.25	Slightly moist, slightly sticky black loamy 'peaty' material with common builder debris (brick fragments and mortar), and a few wood fragments.			
1.40	As above, but wood fragments abundant and leather common			
1.70	Moderately moist, moderately sticky black loamy 'peaty' material. Inclusions of builders debris and abundant wood fragments.			
1.85	As above, faint foul egg smell.			
2.00	Very moist, moderately sticky black loamy 'peaty' material. Extremely abundant wood pieces and fragments. Slight foul egg smell.			
2.25	Becoming wet, very sticky black loamy 'peaty' material. Common wood fragments. Strong foul egg smell.			
2.45	Wet, very sticky black loamy 'peaty' material. Abundant wood remains. Very strong foul egg smell.			
2.60	As above, also few bone fragments.			
2.90	As above, also common mortar fragments			
3.35	Slightly/moderately moist, moderately sticky black loamy 'peaty' material. Abundant wood remains, few bone fragments.			
4.10	Very moist, very sticky black loamy 'peaty' material. Common to abundant wood remains, few bone fragments.			
	END OF HOLE			

APPENDIX 3 (CONTINUED)

Project Name: Archaeological Deposit Monitoring, York
Borehole Number: 4
Borehole Location: Within building, in base of trench excavated by YAT
Ground Level: 14.30m AOD (upper surface of former shop floor)†
Equipment Used: Corer unit with window sampler
Logged By: Matthew Davis
Date: 13 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
1.10	Trench excavated by YAT.			
2.10	Slightly moist, slightly sticky dark brown organic silty clay. Abundant wood remains giving a 'compost' soil texture. Slight calcareous.	BH4 C1	Soil	1.60-2.10
2.60	Slightly moist, slightly sticky, very dark grey/black loamy 'peaty' material. Few to common bone fragments and wood remains. Non-calcareous.	BH4 C2	Soil	2.10-2.60
4.10	Slightly moist, slightly sticky, very dark grey/black loamy 'peaty' material. Common bone fragments and wood remains. Very calcareous.	BH4 C3	Soil	3.10-4.10
5.60	Slightly moist, slightly sticky, very dark grey/black loamy 'peaty' material. Slight calcareous. Foul egg smell.	BH4 C4 BH4 C5A	Soil Soil	4.10-5.10 5.10-5.60
6.10	Slightly moist, stiff, very dark greyish brown clay (still made ground, as charcoal flecks present). Non-calcareous.	BH4 C5B	Soil	5.60-6.10
	END OF HOLE			

APPENDIX 3 (CONTINUED)

Project Name: Archaeological Deposit Monitoring, York
Borehole Number: 5
Borehole Location: Within building, in base of trench excavated by YAT
Ground Level: 14.30m AOD (upper surface of former shop floor)†
Equipment Used: Corer unit with window-less sampler
Logged By: Matthew Davis
Date: 14 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
0.95	Trench excavated by YAT.			
1.95	Horizon unavailable for describing	EAU/1	Undisturbed soil core in plastic sleeve	
2.95	Horizon unavailable for describing	EAU/2	Undisturbed soil core in plastic sleeve	
3.95	Horizon unavailable for describing	EAU/3	Undisturbed soil core in plastic sleeve	
4.95	Horizon unavailable for describing	EAU/4	Undisturbed soil core in plastic sleeve	
5.50	Slightly moist, stiff, very dark greyish brown clay (still made ground, as charcoal flecks present). Non-calcareous.			
	END OF HOLE			

APPENDIX 3 (CONTINUED)

Project Name: Archaeological Deposit Monitoring, York
Borehole Number: 6
Borehole Location: Within building, in base of trench excavated by YAT
Ground Level: 14.30m AOD (upper surface of former shop floor)†
Equipment Used: Corer unit with window sampler
Logged By: Matthew Davis
Date: 14 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
1.00	Trench excavated by YAT.			
2.00	Slightly moist, slightly sticky dark brown organic silty clay, with ash lenses. Abundant wood remains giving a 'compost' texture. Slight calcareous.			
2.17	Slightly moist, slightly sticky, very dark greyish brown organic clay material. Slight calcareous.			
2.63	Slightly moist, slightly sticky, black loamy 'peaty' material, with burnt hazelnuts. Calcareous.			
3.50	Dark reddish grey gritty ash horizon.			
4.50	Slightly moist, slightly sticky, very dark grey/black loamy 'peaty' material. Common bone fragments and wood remains. Calcareous.			
4.65	Slightly moist, slightly sticky, very dark greyish brown organic clay, few stones present (limestone/masonry?). Calcareous.			
5.40	Wet, very sticky black loamy peat material. Charcoal, ash and wood remains present. Slight calcareous.	BH6 C5	Soil	5.00-5.40
5.80	Slightly moist, stiff, very dark greyish brown clay (still made ground, as charcoal flecks present). Non-calcareous.			
	END OF HOLE			

APPENDIX 3 (CONTINUED)

Project Name: Archaeological Deposit Monitoring, York
Borehole Number: 7
Borehole Location: Within building, in base of trench excavated by YAT
Ground Level: 14.30m AOD (upper surface of former shop floor)†
Equipment Used: Corer unit with window sampler
Logged By: Matthew Davis
Date: 13 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
1.40	Trench excavated by YAT.			
2.40	Slightly moist, slightly sticky dark brown organic silty clay. Abundant wood remains giving a 'compost' soil texture. Slight calcareous.	BH7 C1	Soil	1.80-2.40
2.90	Slightly moist, slightly sticky, very dark grey/black loamy 'peaty' material, with ash inclusions. Common wood remains. Calcareous.	BH7 C2	Soil	2.40-2.90
3.10	Dark reddish grey gritty ash horizon.			
4.40	Slightly moist, slightly sticky very dark grey/black loamy 'peaty' material. Abundant wood remains. Calcareous.	BH7 C3	Soil	3.40-4.40
4.90	Slightly moist, slightly sticky variable material; black loamy peat and dark brown organic clay. Calcareous.			
5.40	Wet, very sticky black loamy 'peaty' material. Non-calcareous. Foul egg smell.	BH7 C4	Soil	4.90-5.40
6.40	Slightly moist, stiff, very dark greyish brown clay (still made ground, as charcoal flecks present). Non-calcareous.			
	END OF HOLE			

APPENDIX 3 (CONTINUED)

Borehole Number: 8
Borehole Location: Within building, base of YAT excavated inspection chamber
Ground Level: 14.30m AOD (upper surface of former shop floor)†
Equipment Used: Corer unit with window sampler
Logged By: Matthew Davis
Date: 14 June 1995

DEPTH (m)*	HORIZON DESCRIPTION ‡	SAMPLE		
		Ref.	Type	Depth (m)
1.95	Inspection chamber excavated by YAT.			
2.15	Slightly moist, slightly sticky dark brown organic silty clay. Abundant wood remains giving a 'compost' soil texture. Calcareous.			
3.14	Slightly moist, slightly sticky, very dark grey/black loamy 'peaty' material, with charcoal inclusions. Common wood remains. Calcareous.			
3.17	Slightly moist, stiff dark brown organic clay.			
4.75	Slightly moist, slightly sticky very dark grey/black loamy 'peaty' material. Common wood remains. Calcareous.			
4.95	Slightly moist, stiff dark brown organic clay.			
6.85	Slightly moist, slightly sticky very dark grey/black loamy 'peaty' material, with clay lens. Few bone fragments and stones (limestone/masonry?), common wood remains. Slightly calcareous.			
6.95	Slightly moist, dense very dark greyish brown clay (still made ground, as charcoal flecks present). Non-calcareous.			
	END OF HOLE			

‡ Descriptions based on the Soil Survey guidelines [16]

* All depths reported as metres below ground level

† 14.30 m AOD is a mean value, calculated from twelve spot levels taken on the shop floor by YAT in June, 1995.

APPENDIX 4

ANALYSIS OF BOREHOLE CORES

Analysis conducted by: TES Bretby
 Sample received: June 20, 1995

Sample id	BH2/C1	BH2/C2	BH2/C5	BH2C6	BH7/C1	BH7/C2	BH7/C3	BH7C4
Parameter								
Aluminium			6100	3240				
Arsenic			14	11				
Cadmium			<1	<1				
Chromium (total)			4	<2				
Cobalt			7	4				
Copper			160	56				
Iron			19800	13600				
Lead			369	217				
Manganese			619	576				
Mercury			<2	<2				
Moisture content %*	4.4	5.0	4.9	2.1	5.4	3.3	3.4	2.1
Molybdenum			4	<2				
Nickel			11	3				
SO ₄ (acid sol)	4380	1910	2160	1930	8250	2070	2100	900
SO ₄ (H ₂ O sol) mg/l*	1550	311	514	886	1990	448	780	212
Sulphide	123	23	19	16	<10	31	<10	<10
Vanadium			24	13				
Zinc			303	88				
Barium			250	177				
Calcium			31000	121000				
EC us/cm	2950	2640	2490	2690	3340	2430	2430	2550
Magnesium			5260	39500				
Organic matter %*	4.8	16.7	22.6	7.3	16.0	16.3	13.8	2.6
pH units	7.7	7.8	8.0	8.2	7.0	7.9	7.8	8.0
Sodium			884	524				
Strontium			93	132				

Results expressed as mg/kg Air Dried unless stated.

*Water soluble Sulphate on 2:1 water:soil extract. Moisture content determined from air dried sample. Organic matter determined using the 'dichromate digest' method

APPENDIX 4 (CONTINUED)

Analysis conducted by: TES Bretby
 Sample received: June 20, 1995

Sample id	BH4/C1	BH4/C2	BH4/C3	BH4/C4	BH4/C5B	BH4/C5A	BH6/C5
Parameter							
Aluminium					13500	10600	
Arsenic					10	9	
Cadmium					<1	<1	
Chromium (total)					21	11	
Cobalt					15	8	
Copper					47	108	
Iron					39400	22100	
Lead					59	249	
Manganese					383	563	
Mercury					<2	<2	
Moisture content %*	5.1	3.9	2.7	3.1	2	2.4	2.2
Molybdenum					<2	<2	
Nickel					28	9	
SO ₄ (acid sol)	7160	3250	1330	1630	947	776	938
SO ₄ (H ₂ O sol) mg/l*	1680	980	424	387	223	121	193
Sulphide	<10	<10	<10	18	<10	<10	<10
Vanadium					46	28	
Zinc					133	128	
Barium					204	206	
Calcium					14100	19600	
EC us/cm	4990	3410	2470	2480	2590	2610	2560
Magnesium					5460	4580	
Organic matter %*	12.8	15.6	10.0	12.2	3.4	5.5	15.0
pH units	6.4	6.9	8.2	7.9	8.4	8.3	
Sodium					556	316	
Strontium					38	57	

Results expressed as mg/kg Air Dried unless stated.

*Water soluble Sulphate on 2:1 water:soil extract. Moisture content determined from air dried sample. Organic matter determined using the 'dichromate digest' method

APPENDIX 4 (CONTINUED)

The TES Bretby supplied data for moisture content of each sample was determined from an air dried sample. Using additional data supplied by TES Bretby, the gravimetric moisture content of each sample has been estimated as follows:

TES id.	HLE id.	Weight of sample as received (g)	Moisture loss on air drying (%)	Weight of air dry sample (g)	Moisture loss on oven drying (%)	Total moisture content of sample (%)
8646	BH2 C1	786	54.7	356.1	4.4	56.7
8641	BH2 C2	620	53.5	288.3	5.0	55.8
8651	BH2 C5	642	54.8	290.2	4.9	57.0
8650	BH2 C6	950	25.7	705.9	2.1	27.3
8640	BH4 C1	562	49.8	282.1	5.1	52.4
8645	BH4 C2	675	44.7	373.3	3.9	46.9
8644	BH4 C3	558	55.6	247.8	2.7	56.8
8638	BH4 C4	921	41.2	541.6	3.1	43.0
8649	BH4 C5B	994	24.1	754.5	2.0	25.6
8652	BH4 C5A	1056	27.6	764.5	2.4	29.3
8643	BH6 C5	912	30.4	634.8	2.2	31.9
8642	BH7 C1	645	53.8	298.0	5.4	56.3
8639	BH7 C2	536	49.4	271.2	3.3	51.1
8648	BH7 C3	658	44.2	367.2	3.4	46.1
8647	BH7 C4	871	28.6	621.9	2.1	30.1

* air dry sample then dried in oven

APPENDIX 5

LABORATORY ANALYSIS OF WATER SAMPLES

FROM 15TH JUNE, 1995

Analysis conducted by:
Sample received:

TES Bretby
June 15, 1995

Sample id	BH2/SAMPLE 1
Parameter	
pH	7.1
EC (us/cm @ 25°C)	5950
Redox Potential (mV)	+161
Total Sulphur (as SO ₄)	152
Calcium (as Ca)	108
Magnesium (as Mg)	380
Barium (as Ba)	0.02
Strontium (as Sr)	0.28
Sodium (as Na)	276
Potassium (as K)	259
Nickel (as Ni)	0.05
Chromium (as Cr)	0.12
Cadmium (as Cd)	<0.01
Copper (as Cu)	0.01
Lead (as Pb)	<0.03
Zinc (as Zn)	<0.01
Manganese (Mn)	0.10
Iron (Fe)	0.06
Aluminium (as Al)	<0.01
Arsenic (as As)	<0.04

All results expressed as mg/l, except where stated.
Analysis carried out on a filtered sample

APPENDIX 5 (CONTINUED)
BACTERIOLOGICAL EXAMINATION

Sample id	BH2/SAMPLE 2	BH2/SAMPLE 3
Parameter		
Total Viable Bacteria Count (Aerobic) @ 35°C	320 000	260 000
Total Viable Bacteria Count (Aerobic) @ 25°C	650 000	500 000
Total Viable Bacteria Count (Anaerobic) @ 35°C	160 000	220 000
Total Viable Bacteria Count (Anaerobic) @ 25°C	300 000	120 000

All results expressed as cfu/ml

APPENDIX 7

LABORATORY ANALYSIS OF WATER SAMPLES FROM

SITE VISIT OF 27TH JUNE, 1995

Analysis conducted by: TES Bretby
 Sample received: June 27, 1995

Sample id	BH2/SAMPLE 4	WS4/SAMPLE 5	WS7/SAMPLE 6	WS8/SAMPLE 9
Parameter				
pH	7.0	7.4	7.4	7.2
EC (us/cm @ 25°C)	5910	5110	5150	5490
Redox Potential (mV)	+231	+186	+175	+164
Total Sulphur (as SO ₄)	70	89	208	49
Calcium (as Ca)	92	90	73	152
Magnesium (as Mg)	414	170	231	188
Barium (as Ba)	<0.01	0.03	0.02	0.03
Strontium (as Sr)	<0.03	0.39	0.38	0.54
Sodium (as Na)	254	196	210	230
Potassium (as K)	181	447	421	527
Nickel (as Ni)	0.06	0.03	0.04	0.03
Chromium (as Cr)	0.09	0.03	0.05	0.06
Cadmium (as Cd)	<0.01	<0.01	<0.01	<0.01
Copper (as Cu)	<0.01	0.01	0.01	<0.01
Lead (as Pb)	0.05	<0.03	<0.03	<0.03
Zinc (as Zn)	<0.01	<0.01	<0.01	<0.01
Manganese (Mn)	0.08	0.03	<0.01	0.44
Iron (Fe)	<0.01	0.02	0.02	0.09
Aluminium (as Al)	<0.01	<0.01	<0.01	<0.01
Arsenic (as As)	<0.04	<0.04	<0.04	<0.04

All results expressed as mg/l, except where stated.
 Analysis carried out on a filtered sample

APPENDIX 9

MOISTURE CELL INSTALLATION: POINT OF INSERTION

Cell Number	Site Identification (Logger 'L' & Cell 'C')	Parameter monitored by Cell	Exposed face within inspection chamber	Approximate cell position, metres from ground level*	Depth of insertion into deposit (mm)
1	L1/C1	Resistance & Temperature	North facing	1.12	50
2	L1/C2	Resistance & Temperature	North facing	1.78	85
3	L1/C4	Resistance	West facing	1.25	85
4	L1/C3	Resistance & Temperature	West facing	1.81	85
5	L2/C5	Resistance & Temperature	East facing	0.95	100
6	L2/C8	Resistance	East facing	1.10	100
7	L2/C7	Resistance & Temperature	East facing	1.35	114
8	L2/C6	Resistance & Temperature	East facing	1.68	100
9	L3/C9	Resistance & Temperature	South facing	0.99	160
10	L3/C11	Resistance	South facing	1.22	115
11	L3/C12	Resistance	South facing	1.46	110
12	L3/C13	Resistance	South facing	1.64	110
13	L3/C10	Resistance & Temperature	South facing	1.80	112

* Ground level taken as the upper surface of former shop floor (14.30m AOD)

APPENDIX 10

MOISTURE CELL INSTALLATION: RESULTS OF SAMPLE ANALYSIS

DESCRIPTION OF SAMPLE, RECOVERED AT POINT OF MOISTURE CELL INSERTION

Sample/ Cell Number	Sample depth from ground level (m)*	Sample description
1	1.10	Very dark greyish brown non calcareous material, containing builder debris, bone and cess (pit fill?)
2	1.77	Very dark grey calcareous highly organic material, containing charcoal (pit fill?)
3	1.15	Dark brown non calcareous material, containing builders debris, bone, charcoal and cess
4	1.85	Very dark grey calcareous material, containing builders debris, bone, charcoal and cess
5	0.90	Mottled dark greyish brown non calcareous material, containing builders debris (roof tile) and cess
6	1.10	Mottled very dark grey non calcareous material, containing builders debris, wood and cess (pit fill?)
7	1.30	Very dark greyish brown non calcareous material, inclusions of lighter material present, contains builders debris and wood (pit fill?)
8	1.60	Very dark grey calcareous highly organic material
9	0.98	Very dark greyish organic brown non calcareous material, containing builders debris, bone and cess (pit fill?)
10	1.20	Very dark grey calcareous organic material, containing builders debris, bone and charcoal
11	1.46	Dark brown calcareous organic material, containing pot fragments, builders debris, bone and cess
12	1.64	Very dark grey calcareous highly organic material, containing builders debris
13	1.80	Black slightly calcareous highly organic material, containing builders debris, ash and charcoal

APPENDIX 10 (CONTINUED)

RESULTS OF SAMPLE ANALYSIS

Analysis conducted by: Silsoe College (Cranfield University)
 Samples Received: June 22, 1995

Sample/ Cell Number	Sample depth from ground level (m)*	Gravimetric moisture content (%)	Volumetric moisture content (%)	Dry Bulk Density (g/cm)	pH	Electrical conductivity (ms/cm)	Organic matter‡ (%)
1	1.10	60.35	51.90	0.86	6.98	16.42	12.47
2	1.77	84.07	49.60	0.59	6.03	11.80	25.91
3	1.15	53.27	47.41	0.89	6.93	11.81	15.71
4	1.85	72.68	54.51	0.75	6.98	8.23	17.39
5	0.90	78.55	51.06	0.65	5.30	17.78	15.15
6	1.10	69.87	57.29	0.82	5.46	15.60	16.43
7	1.30	89.99	60.29	0.67	5.39	15.93	16.22
8	1.60	86.65	53.72	0.62	5.92	9.89	28.70
9	0.98	82.99	43.98	0.53	5.62	13.94	19.54
10	1.20	78.08	53.88	0.69	5.92	13.32	21.58
11	1.46	58.46	44.43	0.76	6.34	12.52	19.83
12	1.64	75.03	63.78	0.85	6.47	9.55	24.69
13	1.80	129.61	62.21	0.48	6.61	9.08	33.95

* Ground level taken as the upper surface of former shop floor (14.30m AOD)

‡ Organic matter content determination using 'loss on ignition' method.

APPENDIX 11

RESISTANCE OF MOISTURE CELLS BEFORE AND AFTER INSTALLATION

Cell Number (and Logger/Cell id.)	Resistance of Cell held in air before installation (ohms)	Cell Resistance after installation, 20/06/1995 (ohms)	Cell Resistance after installation, 27/06/95 (ohms)
1 (L1C1)	2540000	4655	3710
2 (L1C2)	2540000	670	581
3 (L1C4)	2540000	2750	2085
4 (L1C3)	2540000	1806	1591
5 (L2C5)	2540000	1384	1135
6 (L2C8)	2540000	2439	2028
7 (L2C7)	2540000	2687	2085
8 (L2C6)	2540000	944	670
9 (L3C9)	2540000	1233	944
10 (L3C11)	2540000	2879	1860
11 (L3C12)	2540000	2260	1283
12 (L3C13)	2540000	2687	1538
13 (L3C10)	2540000	1538	537

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