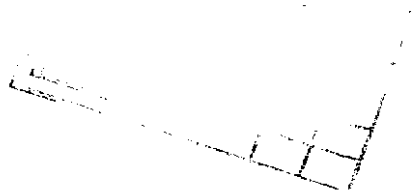
geotechnics





Ground Investigation
at

Loreto College, Manchester

Interpretative Report

for
Loreto College

Engineer : WML Consulting

Project Number : PN071621

December 2007

Issuing office :

North West Office
Geotechnics Limited
The Geotechnical Centre
Unit 1, Borders Industrial Park
River Lane, Saltney
Chester
CH4 8RJ
T: 01244 671 117
F: 01244 671 122
mail@chester.geotechnics.co.uk

Head Office Coventry
Geotechnics Limited
The Geotechnical Centre
203 Torrington Avenue
Tile Hill
Coventry
CV4 9AP
T: 024 7669 4664
F: 024 7669 4642
mail@geotechnics.co.uk

Scottish Office
Geotechnics Limited
The Geotechnical Centre
Block 1, Unit 8
Duckburn Business Park
Dunblane
FK15 0EW
T 01786 823 328
F 01786 823 345
mail@dunblane.geotechnics.co.uk

South West Office
Geotechnics Limited
The Geotechnical Centre
8 Orchard Court
Heron Road, Sowton
Exeter
EX2 7LL
T. 01392 412 446
F 01392 362 159
mail@exeter.geotechnics.co.uk

Geotechnics Limited, Registered in England No. 1757790 at The Geotechnical Centre, 203 Torrington Avenue, Tile Hill, Coventry CV4 9AP

Ground Investigation
at

Interpretative Report

LORETO COLLEGE, MANCHESTER

for
Loreto College

Engineer :
WML Consulting

Project No:
PN071621
December 2007

LIST OF CONTENTS

		Page No
1.0	INTRODUCTION	1
2.0	OBJECT AND SCOPE OF THE INVESTIGATION	1
3.0	PRESENTATION	1
4.0	REVIEW OF PREVIOUS REPORTS	1
	4.1 Desk Study	1
	4.2 Factual Report	2
5.0	INTERPRETATION ARISING FROM INVESTIGATION WORKS	2
	5.1 Ground Conditions Proved	2
	5.2 Soil and Rock Parameters	3
	5.2.1 Soil Parameters	3
	5.2.2 Engineering Parameters	3
	5.3 Gas and Groundwater Conditions	5
	5.3.1 Gas	5
	5.3.2 Groundwater	5
6.0	GEOTECHNICAL EVALUATION	5
	6.1 Proposals	5
	6.2 Foundation Design	6
	6.3 Ground Floor Slabs	6
	6.4 Excavation, Supoprt and other Temporary Works	6
	6.5 Gas Protection Measures	6
7.0	HYDROLOGY AND HYDRO-GEOLOGY	7
	7.1 Hydrology	7
	7.2 Hydro-geology	7
8.0	CHEMICAL CONTAMINATION EVALUATION	7
	8.1 General	7
	8.2 Chemical Attack on Buried Concrete	7
	8.3 Chemical Contamination Risk Assessment	8

CONTENTS AND APPENDICES

APPENDICES

APPENDIX 1	Site Location Plan
APPENDIX 2	Bibliography
APPENDIX 3	Additional Groundwater Chemical Testing
APPENDIX 4	Groundwater Monitoring
APPENDIX 5	Conceptual Model
APPENDIX 6	General Notes and Investigation Techniques

1.0 INTRODUCTION

A geotechnical and geo-environmental investigation was undertaken by Geotechnics Ltd at the site of a proposed new development associated with the existing Loreto College campus, Manchester.

This report has been prepared further to the submission of a Factual Report (Ref PN071621 December 2007 - hereafter referred to as the Factual Report). The investigation was carried out to the instructions of, initially Faber Maunsell, and subsequently WML Consulting, acting on behalf of the Client, Loreto College. AA Projects have acted as the Client's Project Manager during the course of the works.

This report presents an evaluation of the works undertaken and their significance in relation to the proposed works.

2.0 OBJECT AND SCOPE OF THE INVESTIGATION

The object of the investigation was to provide information to assess the geotechnical, geo-environmental, geological and/or hydro-geological ground conditions. All such work is carried out within the limitations posed by trial hole numbers, locations, depths, methods adopted and the scope of approved in situ and laboratory testing. A geotechnical and a geo-environmental interpretation and evaluation of the data obtained were also commissioned, and both are presented herein.

This report is offered as a stand alone document in itself, however the descriptions of the previous works, testing and conclusions is by necessity only of a summary nature. Therefore for a full understanding of the site, the works undertaken, and the findings, this report should be read in conjunction with the Factual Report.

3.0 PRESENTATION

A brief review of the previous works undertaken is given below in Section 4. The subsequent Section 5 describes the information relating to ground conditions, soil and rock parameters, and groundwater which have come about as a consequence of the investigation.

A geotechnical evaluation is made in Section 6.

An evaluation is offered in Sections 7 and 8 in connection with the available groundwater, chemical and contamination data.

Attention is drawn to the General Notes and Investigation Techniques which are included in Appendix 6.

The appendices in this report comprise summary figures and interpretative data rather than the factual data on which are findings are based. The raw information is presented in the Factual Report.

This report draws on a number of published papers, text books and other material; with a list of the documents quoted being given in Appendix 2.

4.0 REVIEW OF PREVIOUS REPORTS

4.1 Desk Study

No formal desk study has been carried out by Geotechnics Ltd. Information contained in the original tender documentation indicated the following:

- The site is underlain by Late Glacial Flood Gravels and Glacial Till (recorded as "Boulder Clay")
- The superficial deposits are in turn underlain by rocks of the Sherwood Sandstone Group.

- A previous investigation (undertaken near the site is recorded to have encountered "*glacial deposits of clay, gravel and sand to depths of between 14.1m and 16.1m where the sandstone bedrock was encountered*".

4.2 Factual Report

The Factual Report recorded the results of the following elements of work:

- Three (3 No.) Cable Percussion boreholes sunk to depths varying between 12.0m and 13.5m below ground level.
- Each of these boreholes were extended by rotary coring to depths of between 22.7m and 25.5m below ground level.
- Three (3 No.) trial pits excavated to depths of up to 4.40m below ground level.
- Monitoring of borehole installations for gas and groundwater was undertaken, and the results recorded in the report.
- A broad range of geotechnical testing was undertaken on samples obtained
- A wide range of chemical / contamination testing was undertaken on samples of soil and groundwater recovered during the investigation works. The testing included tests on solids to assess concentrations of material present, and leachability tests to assess the potential mobility of any contaminants present.
- Additional testing on samples of groundwater obtained during the post investigation monitoring has been carried out. These additional results are included in Appendix 3 of this report.

5.0 INTERPRETATION ARISING FROM INVESTIGATION WORKS

5.1 Ground Conditions Proved

The investigation confirmed the basic stratigraphy as outlined in the following basic geology:

Made Ground (MGr) was identified in each of the six exploratory holes. Its base was shown to lie at a minimum of 0.53m below ground level, extending to in excess of 2.40m in TP101. The MGr was deepest toward the south-western corner of the site and was shallowest at the north-western corner. Over the general area it is expected that the base of the MGr will be encountered between 1.50m and 2.00m below ground level, with localised variations. The maximum anticipated depth is of the order of 2.75m.

The uppermost natural stratum beneath the site comprises presumed alluvial clay (ALV) strata encountered only in TP102 and BH101 (i.e. over the western part of the site). Its absence in TP101 is explained by the local over-deepening of the MGr at this location. The base of the alluvium was encountered at depths of between 1.65m and 1.80m below ground level.

The MGr and alluvium are underlain by sand and gravel strata believed to be of fluvio-glacial origin (GSG). The base of the GSG was proven in the three boreholes, and in TP103, and was encountered between 4.00m and 5.30m below ground level.

Glacial Till (GLT), recorded as "Boulder Clay" on the Geological Map, was present beneath the sand and gravel. The base of the GLT was proven in each of the three boreholes and was shown to lie at depths of between 9.50m and 12.20m below ground level, with Sherwood Sandstone below.

Stratigraphic Column



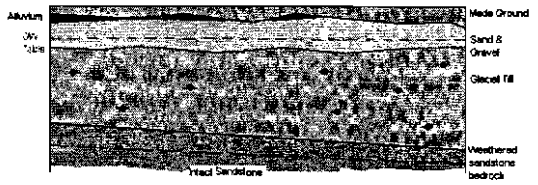
Made Ground:

Alluvium (Holocene)
Glacial Outwash Sands (Late Pleistocene

Glacial Till (Pleistocene)

Sherwood Sandstone (Permo-Triassic)

The stratigraphic column above illustrates the geological relationships between the various strata encountered, although this is made more meaningful when viewed as a "typical" section through the site as shown below.



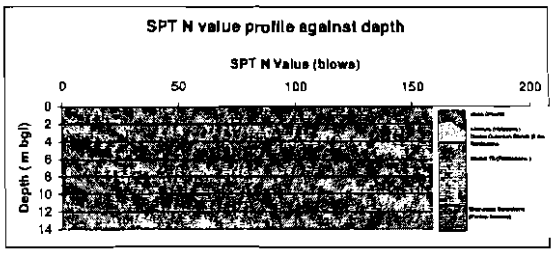
5.2 Soil and Rock Parameters

5.2.1 Soil Parameters

The graph below shows the relationship between SPT blow count and depth below ground level, and allows comparison with the typical geological profile shown to the right. SPT N values in excess of 50 have been calculated as extrapolated SPT N values from the relationship:

$$N_{(extrap)} = (N/pen) \times 300$$

Where N = recorded blow count, and
pen = recorded penetration (mm)



The significant geological breaks can be identified in the profile with the sand and gravel/glacial till interface at about 4m apparent, as is the presence of the bedrock horizon at 10m or so below ground level.

5.2.2 Engineering Parameters

Made Ground
As is frequently the case with MGr, this stratum was notable for its variability. Particle size distribution tests yielded results ranging from a slightly gravelly sandy clay to a slightly silty sandy gravel with cobbles. The MGr therefore comprises both cohesive and granular substrata.

In earthworks testing, (4.5kg rammer compaction test) the cohesive material yielded (1 test only) an Optimum Moisture Content of 16% with a maximum dry density of 1.78Mg/m^3. The granular material gave results of 10% and 11% (2 tests) and maximum dry densities of 2.00Mg/m^3 and 1.85Mg/m^3.

SPT blow counts (2 tests) of 7 and 23 blows were recorded; with the lower value considered representative of the typical matrix material and the higher value being influenced by the presence of coarse gravel and cobbles.

Engineering descriptions confirmed the presence of the following materials within the Made Ground:

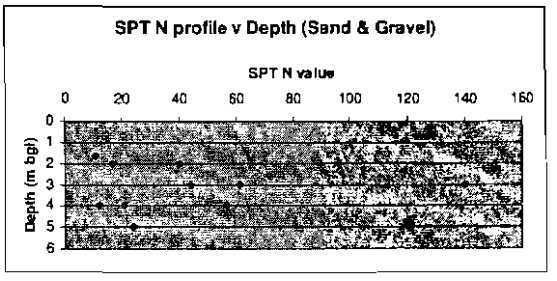
Brick, clinker, ash, glass, concrete, wood, metal, plastic and ceramics

Alluvium
The testing undertaken on alluvial clays was limited to one multistage triaxial test and two plasticity indices with moisture content determination. The clay was seen to be brown mottled orange, of intermediate plasticity with a recorded shear strength of 36kN/m^2.

Sand and Gravel
Particle size distribution tests carried out on samples of the glacial sand and gravel show that it varies from (at its finest) a slightly silty gravelly predominantly fine to medium grained sand (e.g. BH102 at 2.00m depth) to a slightly silty sandy gravel with cobbles (TP102 at 4.00m depth).

The SPT plot below shows the variation in blow count against depth. It is considered likely that the lower blow counts recorded in the range 15 to 25 represent the response associated with the finer materials, whilst the higher N values reflect the presence of coarse gravel and cobbles.

For design purposes it is recommended that blow counts of 15 to 20 are deemed representative of the materials; indicative of a medium dense relative density, and associated with angle of friction (φ) of between 31^0 and 33^0.



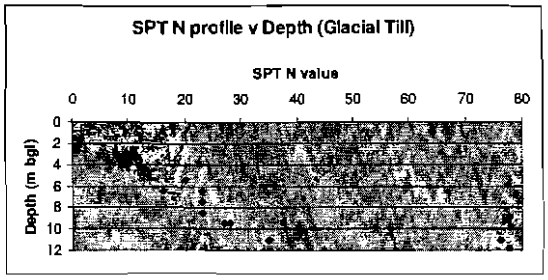
Glacial Till
Atterburg Limit tests (6 No) yielded plasticity data typical of initially intermediate plasticity clay (up to 6.45m depth) becoming of low plasticity at greater

depth.
The following graph indicates the variation in SPT N Value with depth for the GLT. The SPT N value is frequently taken as indicative of clay shear strength as per the equation:

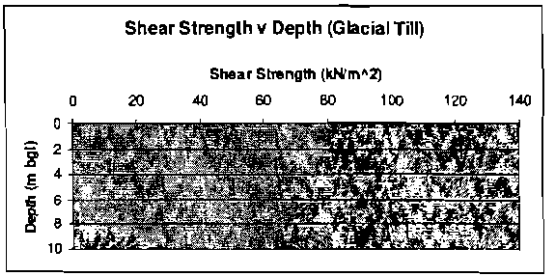
$$Cu\ (kN/m^2) = f_1 N$$

where f_1 is generally taken to lie between 5 and 6.

On this basis the shear strength of the GLT would appear to increase from about 75kN/m^2 at 6m depth to a maximum of 150kN/m^2 at 10m depth.

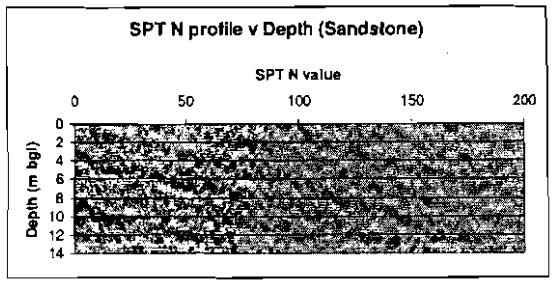


In addition to this empirical relationship there is direct evidence of the shear strength of the GLT between 5m and 8m depth. With one notable exception (BH103 at 5.00m depth) the shear strengths are in the range 91kN/m^2 to 131kN/m^2 (i.e. generally consistent with the values derived from the SPT data).



Weathered Bedrock

The uppermost bedrock materials were shown to be weathered to the condition of a soil, and were penetrated by the cable tool drilling techniques. SPT tests were carried out at intervals in this uppermost "rock" material with the results plotted against depth below ground level shown below:



As can be seen there is a general trend of increased N value with depth below ground level for the results in the weathered sandstone.

Turner and Grose have published a relationship between SPT N value and unconfined compressive strength, as follows:

$$UCS\ (kPa) = 0.6154N^{1.67}$$

(The original paper was for mudstones only, but Geotechnics Ltd has used this formula successfully to predict strengths of Permo-Triassic Sandstone).

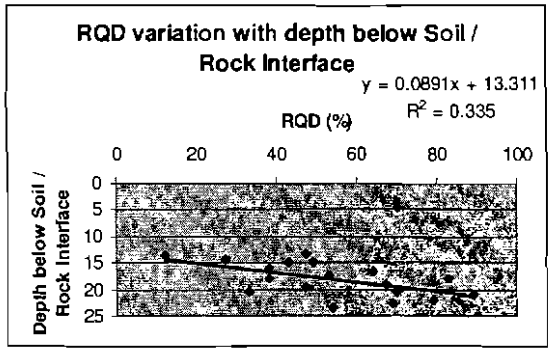
Based on this formula, an unconfined compressive strength (UCS) can be estimated from the extrapolated N values, giving rise to an estimated UCS at the base of the completely weathered horizon (i.e. at an N value of 150) of 0.9MPa.

Between the soil/rock interface and the weathered/intact rock interface the material is transitional, comprising a very weak rock. The cable percussion drilling rig was able to penetrate between 0.85m and 3.43m into the upper weathered horizon.

Intact Bedrock

Engineering descriptions of the recovered core strata indicate a generally weak or moderately weak strength, in places becoming moderately strong.

The plot below indicates the variation of Rock Quality Designation (RQD) with depth below the soil/rock interface, as measured in the rock core recovered.



The data illustrates a generalised increase in RQD, a generally recognised measure of rock mass competency, with depth below the soil/rock interface.

The rock core recovered has been assessed using the Geomechanics Jointed Rock Mass Classification System, as indicated below:

Parameter	Rock Mass Criteria
UCS = 1-3MPa	0
Drill Core Quality (RQD) = 25-50%	8
Spacing of joints = 50mm to 300mm	10
Condition of joints = Slightly rough surfaces	12
Groundwater – "Moist" only	7
Total by summation	**37**

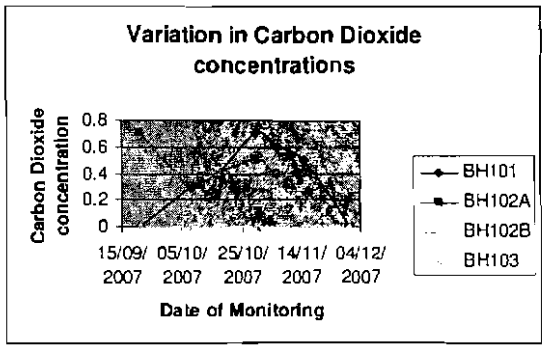
A rock mass rating of 37 is classified as being a "poor" rock mass.

The core recovered is selective, and this rock mass rating is representative of the better rock material present; the poorer material was not recovered by the drilling process.

5.3 Gas and Groundwater Conditions

5.4.1 Gas

The graph below summarises the results of the monitoring to date with respect to carbon dioxide concentrations. Over the monitoring period barometric pressure has varied from 992mb to 1027mb.



As can be seen the peak concentration in two of the four instruments is 0.7%. Based on the available information a design value of 1.0% is considered appropriate.

No methane/explosive gases were recorded.

The recorded flow rates varied from being negligible to a minimum negative flow of -0.6litres/hour. This minimum was, somewhat surprisingly, associated with the minimum barometric pressure recorded.

5.4.2 Groundwater

The groundwater monitoring instruments are designed to monitor the following strata:

BH101 – Regional water table in underlying sandstone bedrock strata
BH102 - Double instrument – 50mm standpipe monitoring shallow perched water table in Made Ground and deep piezometer measuring regional water table in uppermost bedrock strata
BH103 – Measuring shallow perched water table in sand and gravel.

The monitoring to date indicates the following with respect to the groundwater conditions prevalent:

BH101 – Indicates that the regional water table is confined, with the potentiometric surface located at about 5.50m to 6.00m below ground level.
BH102 – Indicates that the perched water table in the superficial materials lies deeper than 1.50m, and that the regional water table is confined, with the potentiometric surface located at about 6.00m to 6.20m below ground level.

Between them these two boreholes would suggest that a gradient exists on the potentiometric surface with a component of groundwater movement apparent in the direction of BH102 from BH101 (i.e. toward the southeast).

BH103 – indicates that the shallow perched water table in the sand and gravel lies at a depth of between 3.50m and 4.00m below ground level.

6.0 GEOTECHNICAL EVALUATION

6.1 Proposals

Preliminary information supplied by Faber Maunsell (FMa) indicates that the development scheme is to comprise the construction of a new college building, the remodelling of some existing buildings and associated hardstanding and landscaping work.

FMa have further indicated that substantial column loads (of the order of 4000kN) are anticipated. However, at this stage no detailed proposed site layout drawing has been made available.

6.2 Foundation Design

Neither the MGr nor the intermittent ALV strata are considered suitable for bearing purposes as a consequence of their weak and/or inconsistent material properties. The MGr stratum is unreliable and likely to give rise to excessive differential settlements, while the alluvial strata are too weak, with associated bearing capacity and total settlement.

The underlying sand and gravel stratum, encountered at depths of typically between 2m and 3m below ground level, is considered to be a suitable bearing stratum for light to moderate loads. It is recommended that foundations on this sand and gravel should be designed based on an Allowable Bearing Capacity of 100kN/m^2.

For the anticipated order of column loading this will require footings in excess of 6m square. This is likely to be outside the range of normal economic viability.

Consequently it is anticipated that piled solutions will be appropriate. Given the relatively shallow depth to the bedrock it is recommended that end-bearing piles be utilised, founded at depths of the order of 13m to 25m below ground level, socketed into the Sherwood Sandstone bedrock.

It is anticipated that suitable foundations could be constructed using either traditional cable tool bored piles or continuous flight auger piles (with appropriate capacity to achieve penetration into the upper weathered sandstone bedrock material).

It is strongly recommended that piling contractors are involved in preliminary design of the piles. It is anticipated that concrete bored piles, nominally socketed in to rock, of the order of 350mm diameter will offer an allowable Working Load of approximately 1900kN. This implies that in order to achieve the required working loads pile groups of three piles per column are likely to be required.

Alternatively specialist piling contractors may be prepared to offer a more closely designed pile arrangement, utilising less conservative input parameters, based on their intimate knowledge of their particular pile systems.

In addition, following on from comments made below (Section 8), in respect of chemical contamination the Piling Contractors will need to ensure that pile construction methods do not create new potential pathways between (potentially contaminant bearing) Made Ground and bedrock.

6.3 Ground Floor Slabs

Given the presence of variable depths of inconsistent Made Ground and impersistent soft alluvial clays it is recommended that suspended floor slabs be utilised, bearing on the main structural footings.

6.4 Excavation, Support and other Temporary Works

Excavation for service and foundation trenches will for the most part be considered as "easy digging" well within the capability of standard backhoe excavators. However due allowance should be made for the potential presence of large obstructions (concrete and brickwork in particular) within the Made Ground, which may require breaking out or grubbing up.

Open excavations for footings or service trenches, particularly those requiring man-entry, will require either appropriate support or use of safe batter angles to ensure stability. For batters constructed in Made Ground and Glacial Sand and Gravel "in the dry" batter angles of 1 vertical to 3 horizontal are considered appropriate. However, beneath the water table this will be considerably reduced and it is anticipated that the deepest service trenches may well encounter the perched water table recorded at 3.50m depth.

Given the relatively high permeability of the sand and gravel stratum it is unlikely that simple sump pumping will be sufficient to deal with the potential inflows. There will therefore be a considerable advantage gained if excavation below the required formation level can be avoided.

6.5 Gas Protection Measures

Based on a peak gas concentration (carbon dioxide) of 1% by volume and assuming a nominal flow of gas (1.0 litres/hour), a Gas Screening Value of 0.01 X 1 = 0.01 litres/hour can be established. The GSV is substantially less than the limit (0.07 litres/hour) of Characteristic Situation 1.

On the basis of the available information it is likely

that no particular design precautions will be necessary with respect to methane or carbon dioxide.

7.0 HYDROLOGY AND HYDRO-GEOLOGY

7.1 Hydrology

The site does not lie in an area recorded by the Environment Agency as being at risk from flooding, however areas within about 600m of the site to the northeast and east are deemed at risk from extreme flood events.

7.2 Hydro-geology

The site lies on an outcrop of Permo-Triassic Sandstone, known to be a Major Aquifer (Highly Permeable). The overlying soil strata are classed as being of high leaching potential, on a worst case assumption, as a consequence of their urban setting.

The porosity of the Sherwood Sandstone Group strata is typically of the order of 20% to 30%. Transmissivity values are highly variable, reflecting the importance of water flow along discontinuities such as faults, fissures and bedding within the rock mass.

The potentiometric surface on the groundwater present in the underlying Sherwood Sandstone is indicated by the Hydro-geological Map of Clwyd and the Cheshire Basin to lie at an elevation of less than 20m above Ordnance Datum.

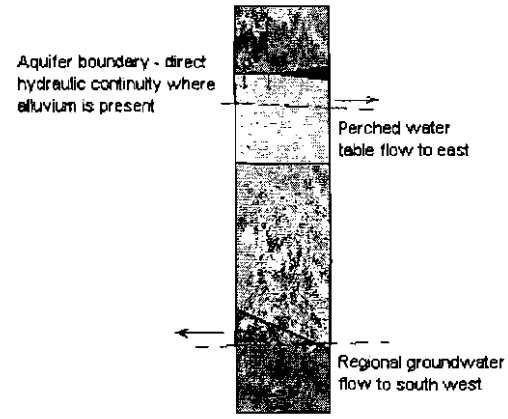
With local ground levels believed to be of the order of 32m OD it follows that the regional groundwater table is expected to lie at about 12m below local ground level, ie roughly coincident with the top of bedrock. On this basis the sandstone aquifer is not considered likely to be confined by the overlying GLT. This is contrary to the observations made during the post fieldwork monitoring which would suggest that this aquifer is confined, and showing an elevated head of about 5m to 6m above the soil/rock interface.

Based on the contours on the published hydro-geological map it is anticipated that the general regional groundwater flow direction will be from northeast to southwest. This will however be substantially influenced by local effects, in particular where abstraction boreholes and the like are present.

In addition to the regional groundwater table it is probable that a local perched water table is present within the MGr and the underlying GSG. This boundary is anticipated to vary from an essentially impermeable boundary where the impersistent clay is present, to a boundary with direct hydraulic continuity across it, where the alluvium is absent.

Within this upper perched groundwater body flow directions are likely to be from west to east toward the low ground associated with the elevated flood risk.

The following figure illustrates the hydro-geological setting of the site and immediately surrounding area.



8.0 CHEMICAL CONTAMINATION EVALUATION

8.1 General

It should be noted that the original project specification, and in particular the scope of the chemical contamination testing, was defined by the original Bill of Quantities prepared by Faber Maunsell. The interpretation that follows is necessarily limited therefore to conclusions that can be derived from the particular scheduled tests.

8.2 Chemical Attack on Buried Concrete

The site does not lie in an area where potentially pyritic bedrock is anticipated, and the presence of significant quantities of Made Ground and the city centre setting implies that the site can be described as brownfield.

The characteristic value for the soils sulphate content is 0.633 g/l. The site therefore falls within the DS-2 classification of BRE Special Digest SD1. The pH is in excess of 5.5 and hence an ACEC class of AC-1s is considered to be appropriate.

8.3 Chemical Contamination Risk Assessment

Human Health Risk Assessment

Current UK guidance with respect to the assessment of potentially contaminated land is risk based, and utilises the Source-Pathway-Receptor methodology, with a fitness-for-purpose criterion.

The first element of this assessment is the establishment of the presence of any sources of potential contamination. The first step in this process is the informal qualitative assessment based on the available Desk Study information. In this instance FMa have identified the following potential sources as being present:

Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Vanadium, Zinc, Arsenic, Boron, Sulphur, Nitrate, Sulphate, Sulphur, PAHs, Aromatic Hydrocarbons, Chlorinated Hydrocarbons, Phenols, Asbestos and PCBs.

A number of these contaminants have been subject of published DEFRA Soil Guideline Values. This relates the expected land use to potential exposure pathways and human health risk. Four land use categories have been established:

- Residential with domestic gardens
- Residential without plant uptake
- Allotments
- Industrial / Commercial

For the purposes of this report it is assumed that the college development scheme is broadly equivalent to Residential without plant uptake land use. This is considered a very conservative assumption provided landscaping proposals do not include planting of significant quantities of edible fruit, berry and nut bearing plants etc .

SGVs have been published for the following contaminants:

Arsenic, Cadmium, Chromium, Mercury, Nickel, Selenium, Lead, Phenol, Toluene, Ethyl Benzene.

The following table shows the comparison between the relevant SGV and the 95th percentile concentration.

Contaminant	95th Percentile Concentration (mg/kg)	DEFRA SGV(1) (mg/kg)
Arsenic(5)	10.05	20
Cadmium	0.66	8(2)
Chromium	19.34	200
Mercury(5)	0.91	15
Nickel	24.81	75
Selenium	<3.00	260
Lead	77.38	450(3)
Phenol	<0.15	21,900(4)
Toluene	<10	3000(4)
Ethyl Benzene	<10	16000(4)

(1) Residential without plant uptake land use assumed
(2) pH of 8 is deemed representative
(3) Based on the geometric mean
(4) Soil Organic Matter 1% is deemed representative
(5) Statistically the peak value is shown to be an outlier

None of the results exceed the SGV and would not therefore be considered to represent a source with respect to human health risk assessment.

However, it should be noted that in two cases (Arsenic and Mercury) statistical analysis indicates that the peak concentrations encountered are outliers with respect to a normal distribution. Reviewing the data indicates that these peaks relate to the same soil sample (BH103 at 0.50m depth).

Further review confirms that this sample also contains the peak concentrations associated with the following contaminants:

Chromium, Lead, Nickel, Zinc, Soil Organic Matter

Consequently it appears that this location represents a contamination "hotspot", and the material present at this location should be excavated with care and inspected to determine its likely mode of origin.

Further testing will need to be undertaken to determine its suitability for placing beneath concrete or tarmac hard cover (i.e. being retained on site) or alternatively being taken from site to an appropriate landfill for tipping.

For those contaminants for which SGVs are not yet available comparison is made with other

authoritative limiting criteria, as set out in the following hierarchy:

Geotechnics Soil Screening Values (SSVs) – calculated using the CLEA methodology (assumed sandy soil, 1% SOM, pH = 7)

LQM CIEH Generic Assessment Criteria (GACs) (assumed sandy soil, 1% SOM, pH = 7)

The following table summarises the result of this exercise:

Contaminant	Peak Concentation (mg/kg – unless stated otherwise)	Limiting Criteria (1)(2) SSV / GAC (mg/kg – unless stated otherwise)
Benzene	<0.01	0.038(1)
Xylene	<0.01	3(1)
Copper	110	2080(2)
Zinc	390	8250(2)
Vanadium	79	150(2)
Benzo-a-pyrene	8.8	1.3(2)
Dibenzo-ah-anthracene	1.2	1.3(2)
Fluorene	10	2770(2)
Napthalene	1.8	6.94(2)

(1) Geotechnics Soil Screening Value
(2) LQM Generic Assessment Criteria

The only data where the peak concentration exceeds the relevant limiting criterion is Benzo-a-pyrene, which is known to be a fairly ubiquitous contaminant associated with burning of organic materials.

The data for Benzo-a-pyrene has been revisited and the following conclusions can be drawn:

The following locations fail the test against the SSV:

TP101 - 0.30m, TP101 - 0.50m, TP101 - 1.20m, TP101 - 2.20m, TP102 - 0.50m, BH101 - 0.80m, BH102 - 1.20m.

All of these points (except BH101 at 0.80m depth) represent Made Ground material which is known to incorporate ash. BH101 at 0.80m is the uppermost soil stratum immediately beneath the Made Ground. The presence of Benzo-a-pyrene probably indicates a degree of intermixing of natural and filled materials at the soil interface.

Taking the 95th percentile concentration as being the relevant design value yields a figure for comparison against the SSV of 3.6mg/kg and confirms that the data is consistent with a normally distributed data set (i.e. the peak value does not constitute an outlier).

By comparing the ratios of the following PAHs; Chrysene, Fluoranthene, Benzo-a-Anthracene and Pyrene, an estimate of the mode of origin of the PAHs present can be obtained. This would suggest that in this case the origin is coal and coal combustion products, although some of the data is also consistent with petroleum combustion products.

Recently published guidance from DEFRA (CLAN 6/06, Assessing Risks from Land Contamination – A Proportionate Approach) acknowledged Benzo-a-pyrene as a particular case as detailed below:

> *"Proposal 14 – Consider substance specific adjustment to take into account widespread use.*
>
> *This aims to deal with particular contaminants – for example benzo-a-pyrene or lead – which could be ubiquitous because they can arise from general activities such as bonfires etc, or deposition from traffic. The aim would be to establish the extent and an appropriate mechanism for identifying the unacceptable risk from these substances."*

Given the urban setting and the presence of urban Made Ground the presence of Benzo-a-pyrene in significant quantities is almost unavoidable. The key to dealing with this substance therefore is to acknowledge its potential presence as a source, but to deal with it under the Source – Pathway – Receptor Model.

Other contaminants which are shown to be present only in negligible concentrations (less than the relevant Limit of Detection) are Cyanide, Asbestos, Volatile and Semi-volatile Organic Compounds, PCBs and MTBE.

Further testing has been undertaken to assess the potential mobility of the contaminants by undertaking leaching of the soil material. Testing is then undertaken on the derived eluate material to determine concentrations in water.

The results of this testing can then be compared with appropriate limiting criteria such as Water Supply (Water Quality) Regulations (DWR) or Environmental Quality Standards (EQS).

The following table shows the results of this comparison with respect to the Water Supply Regulations:

Contaminant	Peak Concentration (µg/l)[1]	Mean Concentration (µg/l)	Limiting Criteria (DWR)
Dissolved Arsenic	12	6.5	10
Dissolved Boron	41	26.5	1000
Dissolved Cadmium	<0.4	<0.4	5
Dissolved Chromium	6	3	50
Dissolved Lead	1	<1	25
Dissolved Copper	43	15	2000
Dissolved Nickel	4	2	20
Dissolved Selenium	4	2	10
Dissolved Mercury	<0.05	<0.05	1
Nitrate as NO_3	3100	1466	50000
Total Cyanide	<50	<50	50
pH	10.38 pH units	8.84 pH units	>6.5, <10 pH units

(1) Unless shown otherwise

It is apparent that only two contaminants are of concern even with respect to the stringent standards associated with consumer's tap water. In the case of Arsenic, only one result out of six exceeds the limit by 20%.

In the case of PAHs both the peak, and the mean concentrations exceed the limit for drinking water, but this is clearly set well above standards appropriate for rare / occasional physical contact with construction workers and / or residents. Again the elevated levels of PAH are consistent with the occurrence of previously identified Benzo-a-pyrene in ash bearing fill. Trace amounts of 13 out of the remaining 15 remaining USEPA PAHs were identified, albeit at very small concentrations (measured in ng/l).

The following organic contaminants were not present in the eluate at detectable concentrations:

PCBs, BTEX, Aromatic or Aliphatic hydrocarbons, MTBE, Benzo-k-fluoranthene, Dibenzo-ah-anthracene, SVOCs (other than a trace in one sample of Pentachlorophenol, VOCs.

Environmental Contamination – Groundwaters

A similar comparison can be undertaken with the Environmental Quality Standards to assess the suitability of the soils with respect to the presence of the local aquifer. The presence of a thick sequence of Glacial Till between the Made Ground and the underlying bedrock implies that the groundwater in the underlying deep aquifer is isolated from the Made Ground.

Nevertheless the leachate results can offer an indication as to the mobility of the contaminants and their acceptability for "release" of the eluate into the environment.

Contaminant	Peak Concentration (µg/l)[2]	Mean Concentration (µg/l)	Limiting Criteria (EQS)
Dissolved Arsenic	12	6.5	50
Dissolved Boron	41	26.5	2000
Dissolved Cadmium	<0.4	<0.4	2.5
Dissolved Chromium	6	3	5[1]
Dissolved Lead	1	<1	4
Dissolved Copper	43	15	5[1]
Dissolved Nickel	4	2	50
Dissolved Vanadium	33	13	20
Dissolved Mercury	<0.05	<0.05	1
pH	10.38 pH units	8.84 pH units	9 pH units

(1)Based on worst case assumption with respect to hardness
(2) Unless shown otherwise

It is evident from this information that eluate derived from the Made Ground should be considered to be of concern with respect to its release into the environment. Concerns are apparent with respect to the potential mobility of Chromium, Copper and Vanadium.

In this regard more realistic assessment can be made by comparing the results of testing on samples of the actual groundwater (results included in Appendix 3) as shown in the following table:

Contaminant	Peak Concentration (µg/l)[2]	Mean Concentration (µg/l)	Limiting Criteria (EQS)
Dissolved Arsenic	<1	<1	50
Dissolved Boron	160	93	2000
Dissolved Cadmium	0.6	<0.46	2.5
Dissolved Chromium	9	5.7	5[1]
Dissolved Lead	22	13	4
Dissolved Copper	4	3.7	5[1]
Dissolved Nickel	10	8	50
Dissolved Vanadium	2	<1.3	20
Dissolved Mercury	<0.01	<0.01	1
pH	8.51 pH units	8.17 pH units	9 pH units

(1)Based on worst case assumption with respect to hardness
(2) Unless shown otherwise

Concentrations of Chromium and Lead exceed the relevant Environmental Quality Standards. It will therefore be necessary to ensure that the development does not cause contamination of the underlying aquifer, and pile design and construction methods will need to take this into account.

Written By: .....
Keith Nicholls, BSc, MSc, CEng, FIM³, MIQ, MICE
Principal Engineer

Checked By: .....
John Knowles, BSc (Hons), MSc, FGS
Principal Engineer
for GEOTECHNICS LIMITED - North West Office

APPENDIX 1
Site Location Plan

SITE LOCATION PLAN



© Crown Copyright Reserved, OS License Number: 100020449

Project Number : PN071621

Ground Investigation
at
Loreto College, Manchester
for
Loreto College

geotechnics

APPENDIX 2
Bibliography

List of References referred to in the Text

"Ground Investigation at Loreto College, Manchester". **Geotechnics Ltd**, Job No PN071621, Factual Report, December 2007.

"Rock Mass Classifications in Rock Engineering". **Bieniawski, ZT**, Proc Symp Exploration for Rock Engineering, Jo'burg, November 1976.

"Hydrogeological Map of Clwyd and the Cheshire Basin". **British Geological Survey**, 1:100000 Scale, 1989.

"Concrete in Aggressive Ground". **Building Research Establishment,** BRE Special Digest 1 , 2005.

"Assessing Risks from Land Contamination – a proportionate approach" **DEFRA,** CLAN 6/06, 2006.

APPENDIX 3
Additional Groundwater Chemical Testing

Validated ☑
Preliminary ☐

ALcontrol Geochem Analytical Services
Table Of Results

* ISO 17025 accredited
M MCERTS accredited
• Subcontracted test
» Shown on prev. report

Job Number: 07/14272/02/01 **Matrix:** LIQUID
Client: Geotechnics Ltd **Location:** LORETO COLLEGE
Client Ref. No.: PN071621 **Client Contact:** Emma Sykes

Sample Identity	BH1 PIESO	BH2 PIESO	BH3							Method Code	LoD/Units
Depth (m)	-	-	-								
Sample Type	LIQUID	LIQUID	LIQUID								
Sampled Date	30.11.07	30.11.07	30.11.07								
Sample Received Date	03.12.07	03.12.07	03.12.07								
Batch	5	5	5								
Sample Number(s)	82-83	84-85	86-87								
Arsenic Dissolved (ICP-MS)	<1	<1	<1							TM152[#]	<1 ug/l
Boron Dissolved (ICP-MS)	<10	110	160							TM152[#]	<10 ug/l
Cadmium Dissolved (ICP-MS)	<0.4	0.6	<0.4							TM152[#]	<0.4 ug/l
Chromium Dissolved (ICP-MS)	2	9	6							TM152[#]	<1 ug/l
Copper Dissolved (ICP-MS)	3	4	4							TM152[#]	<1 ug/l
Lead Dissolved (ICP-MS)	22	15	1							TM152[#]	<1 ug/l
Nickel Dissolved (ICP-MS)	8	6	10							TM152[#]	<1 ug/l
Selenium Dissolved (ICP-MS)	<1	<1	3							TM152[#]	<1 ug/l
Vanadium Dissolved (ICP-MS)	<1	<1	2							TM152[#]	<1 ug/l
Zinc Dissolved (ICP-MS)	80	61	7							TM152[#]	<3 ug/l
Mercury Dissolved (CVAF)	<0.01	<0.01	<0.01							TM183[#]	<0.01 ug/l
Conductivity (at 25 deg.C)	0.58	0.83	1.8							TM120[#]	<0.014 mS/cm
Nitrate as NO3	1.2	1.8	26							TM102[#]	<0.3 mg/l
Sulphate (soluble)	35	110	650							TM098[#]	<3 mg/l
Sulphide	<0.5	<0.5	<0.5							TM101	<0.5 mg/l
Total Organic Carbon	6	4	5							TM090[#]	<1 mg/l
Phenols Monohydric	<0.01	<0.01	<0.01							TM062[#]	<0.01 mg/l
Total Cyanide	<0.05	<0.05	<0.05							TM153[#]	<0.05 mg/l
pH Value	8.51	8.16	7.85							TM133[#]	<1.00 pH Units
EPH (DRO) (C10-C40) Aqueous	<10	150	<10							TM172[#]	<10 ug/l
GRO (C4-C10)	<10	<10	<10							TM089[#]	<10 ug/l
GRO (C10-C12)	<10	<10	<10							TM089[#]	<10 ug/l
Benzene	<10	<10	<10							TM089[#]	<10 ug/l
Toluene	<10	<10	<10							TM089[#]	<10 ug/l
Ethyl benzene	<10	<10	<10							TM089[#]	<10 ug/l
m & p Xylene	<10	<10	<10							TM089[#]	<10 ug/l
o Xylene	<10	<10	<10							TM089[#]	<10 ug/l
Sum m&p and o Xylene	<10	<10	<10							TM089[#]	<10 ug/l
Sum of BTEX	<10	<10	<10							TM089[#]	<10 ug/l
MTBE	<10	<10	<10							TM089[#]	<10 ug/l

Date 17.12.2007

Validated ☑
Preliminary ☐

ALcontrol Geochem Analytical Services
Table Of Results

' ISO 17025 accredited
M MCERTS accredited
* Subcontracted test
» Shown on prev. report

Job Number: 07/14272/02/01 **Matrix:** LIQUID
Client: Geotechnics Ltd **Location:** LORETO COLLEGE
Client Ref. No.: PN071621 **Client Contact:** Emma Sykes

Sample Identity	BH1 PIESO	BH2 PIESO	BH3						Method Code	LoD/Units
Depth (m)	-	-	-							
Sample Type	LIQUID	LIQUID	LIQUID							
Sampled Date	30.11.07	30.11.07	30.11.07							
Sample Received Date	03.12.07	03.12.07	03.12.07							
Batch	5	5	5							
Sample Number(s)	82-83	84-85	86-87							
PAH by GCMS										
Naphthalene Aqueous	<26	<26	<26						TM074	<26 ng/l
Acenaphthylene Aqueous	<11	<11	<11						TM074	<11 ng/l
Acenaphthene Aqueous	<15	<15	23						TM074	<15 ng/l
Fluorene Aqueous	<14	<14	16						TM074	<14 ng/l
Phenanthrene Aqueous	<22	<22	140						TM074	<22 ng/l
Anthracene Aqueous	<15	<15	41						TM074	<15 ng/l
Fluoranthene Aqueous	48	18	290						TM074	<17 ng/l
Pyrene Aqueous	43	22	340						TM074	<15 ng/l
Benz(a)anthracene Aqueous	<17	<17	130						TM074	<17 ng/l
Chrysene Aqueous	<13	<13	140						TM074	<13 ng/l
Benzo(b)fluoranthene Aqueous	<23	<23	230						TM074	<23 ng/l
Benzo(k)fluoranthene Aqueous	<27	<27	86						TM074	<27 ng/l
Benzo(a)pyrene Aqueous	<9	<9	180						TM074	<9 ng/l
Indeno(123cd)pyrene Aqueous	<14	<14	94						TM074	<14 ng/l
Dibenzo(ah)anthracene Aqueous	<16	<16	27						TM074	<16 ng/l
Benzo(ghi)perylene Aqueous	<16	<16	140						TM074	<16 ng/l
PAH 16 Total Aqueous	91	40	1900						TM074	<27 ng/l

Date 17.12.2007

Validated ☑
Preliminary ☐

ALcontrol Geochem Analytical Services
Table Of Results

' ISO 17025 accredited
M MCERTS accredited
* Subcontracted test
» Shown on prev. report

Job Number: 07/14272/02/01 **Matrix:** LIQUID
Client: Geotechnics Ltd **Location:** LORETO COLLEGE
Client Ref. No.: PN071621 **Client Contact:** Emma Sykes

Sample Identity	BH1 PIESO	BH2 PIESO	BH3							Method Code	LoD/Units
Depth (m)	-	-	-								
Sample Type	LIQUID	LIQUID	LIQUID								
Sampled Date	30.11.07	30.11.07	30.11.07								
Sample Received Date	03.12.07	03.12.07	03.12.07								
Batch	5	5	5								
Sample Number(s)	82-83	84-85	86-87								
PCB 7 Congeners											
PCB congener 28	<10	<10	<10							TM070	<10 ng/l
PCB congener 52	<10	<10	<10							TM070	<10 ng/l
PCB congener 101	<10	<10	<10							TM070	<10 ng/l
PCB congener 118	<10	<10	<10							TM070	<10 ng/l
PCB congener 153	<10	<10	<10							TM070	<10 ng/l
PCB congener 138	<10	<10	<10							TM070	<10 ng/l
PCB congener 180	<10	<10	<10							TM070	<10 ng/l
Total of 7 Congener PCBs	<10	<10	<10							TM070	<10 ng/l

Date 17.12.2007

Validated ☑
Preliminary ☐

ALcontrol Geochem Analytical Services
Table Of Results

' ISO 17025 accredited
M MCERTS accredited
* Subcontracted test
» Shown on prev. report

Job Number: 07/14272/02/01 **Matrix:** LIQUID
Client: Geotechnics Ltd **Location:** LORET0 COLLEGE
Client Ref. No.: PN071621 **Client Contact:** Emma Sykes

Sample Identity	BH1 PIESO	BH2 PIESO	BH3							Method Code	LoD/Units
Depth (m)	-	-	-								
Sample Type	LIQUID	LIQUID	LIQUID								
Sampled Date	30.11.07	30.11.07	30.11.07								
Sample Received Date	03.12.07	03.12.07	03.12.07								
Batch	5	5	5								
Sample Number(s)	82-83	84-85	86-87								
SVOC by GCMS											
Phenols											
2-Chlorophenol	<1	<1	<1							TM176	<1 ug/l
2-Methylphenol	<1	<1	<1							TM176	<1 ug/l
2-Nitrophenol	<1	<1	<1							TM176	<1 ug/l
2,4-Dichlorophenol	<1	<1	<1							TM176	<1 ug/l
2,4-Dimethylphenol	<1	<1	<1							TM176	<1 ug/l
2,4,5-Trichlorophenol	<1	<1	<1							TM176	<1 ug/l
2,4,6-Trichlorophenol	<1	<1	<1							TM176	<1 ug/l
4-Chloro-3-methylphenol	<1	<1	<1							TM176	<1 ug/l
4-Methylphenol	<1	<1	<1							TM176	<1 ug/l
4-Nitrophenol	<1	<1	<1							TM176	<1 ug/l
Pentachlorophenol	<1	<1	<1							TM176	<1 ug/l
Phenol	<1	<1	<1							TM176	<1 ug/l
PAHs											
2-Chloronaphthalene	<1	<1	<1							TM176	<1 ug/l
2-Methylnaphthalene	<1	<1	<1							TM176	<1 ug/l
Phthalates											
Bis(2-ethylhexyl) phthalate	3	<2	2							TM176	<2 ug/l
Butylbenzyl phthalate	<1	<1	<1							TM176	<1 ug/l
Di-n-butyl phthalate	<1	<1	<1							TM176	<1 ug/l
Di-n-Octyl phthalate	<5	<5	<5							TM176	<5 ug/l
Diethyl phthalate	<1	<1	<1							TM176	<1 ug/l
Dimethyl phthalate	<1	<1	<1							TM176	<1 ug/l
Other Semi-volatiles											
1,2-Dichlorobenzene	<1	<1	<1							TM176	<1 ug/l
1,2,4-Trichlorobenzene	<1	<1	<1							TM176	<1 ug/l
1,3-Dichlorobenzene	<1	<1	<1							TM176	<1 ug/l

Date 17.12.2007

Validated ☑
Preliminary ☐

ALcontrol Geochem Analytical Services
Table Of Results

' ISO 17025 accredited
M MCERTS accredited
* Subcontracted test
» Shown on prev. report

Job Number: 07/14272/02/01 **Matrix:** LIQUID
Client: Geotechnics Ltd **Location:** LORETO COLLEGE
Client Ref. No.: PN071621 **Client Contact:** Emma Sykes

Sample Identity	BH1 PIESO	BH2 PIESO	BH3							Method Code	LoD/Units
Depth (m)	-	-	-								
Sample Type	LIQUID	LIQUID	LIQUID								
Sampled Date	30.11.07	30.11.07	30.11.07								
Sample Received Date	03.12.07	03.12.07	03.12.07								
Batch	5	5	5								
Sample Number(s)	82-83	84-85	86-87								
Other Semi-volatiles (cont)											
1,4-Dichlorobenzene	<1	<1	<1							TM176	<1 ug/l
2-Nitroaniline	<1	<1	<1							TM176	<1 ug/l
2,4-Dinitrotoluene	<1	<1	<1							TM176	<1 ug/l
2,6-Dinitrotoluene	<1	<1	<1							TM176	<1 ug/l
3-Nitroaniline	<1	<1	<1							TM176	<1 ug/l
4-Bromophenylphenylether	<1	<1	<1							TM176	<1 ug/l
4-Chloroaniline	<1	<1	<1							TM176	<1 ug/l
4-Chlorophenylphenylether	<1	<1	<1							TM176	<1 ug/l
4-Nitroaniline	<1	<1	<1							TM176	<1 ug/l
Azobenzene	<1	<1	<1							TM176	<1 ug/l
Bis(2-chloroethoxy)methane	<1	<1	<1							TM176	<1 ug/l
Bis(2-chloroethyl)ether	<1	<1	<1							TM176	<1 ug/l
Carbazole	<1	<1	<1							TM176	<1 ug/l
Dibenzofuran	<1	<1	<1							TM176	<1 ug/l
Hexachlorobenzene	<1	<1	<1							TM176	<1 ug/l
Hexachlorobutadiene	<1	<1	<1							TM176	<1 ug/l
Hexachlorocyclopentadiene	<1	<1	<1							TM176	<1 ug/l
Hexachloroethane	<1	<1	<1							TM176	<1 ug/l
Isophorone	<1	<1	<1							TM176	<1 ug/l
N-nitrosodi-n-propylamine	<1	<1	<1							TM176	<1 ug/l
Nitrobenzene	<1	<1	<1							TM176	<1 ug/l

Date 17.12.2007

Validated ☑
Preliminary ☐

ALcontrol Geochem Analytical Services
Table Of Results

' ISO 17025 accredited
M MCERTS accredited
* Subcontracted test
» Shown on prev. report

Job Number: 07/14272/02/01 **Matrix:** LIQUID
Client: Geotechnics Ltd **Location:** LORETO COLLEGE
Client Ref. No.: PN071621 **Client Contact:** Emma Sykes

Sample Identity	BH1 PIESO	BH2 PIESO	BH3							Method Code	LoD/Units
Depth (m)	-	-	-								
Sample Type	LIQUID	LIQUID	LIQUID								
Sampled Date	30.11.07	30.11.07	30.11.07								
Sample Received Date	03.12.07	03.12.07	03.12.07								
Batch	5	5	5								
Sample Number(s)	82-83	84-85	86-87								
Volatile Organic Compounds											
Dichlorodifluoromethane	<1	<1	<1							TM116'	<1 ug/l
Chloromethane	<1	<1	<1							TM116'	<1 ug/l
Vinyl Chloride	<1	<1	<1							TM116'	<1 ug/l
Bromomethane	<1	<1	<1							TM116'	<1 ug/l
Chloroethane	<1	<1	<1							TM116'	<1 ug/l
Trichlorofluoromethane	<1	<1	<1							TM116'	<1 ug/l
trans-1-2-Dichloroethene	<1	<1	<1							TM116'	<1 ug/l
Dichloromethane	<1	<1	<1							TM116'	<1 ug/l
Carbon Disulphide	<1	<1	<1							TM116'	<1 ug/l
1,1-Dichloroethene	<1	<1	<1							TM116'	<1 ug/l
1,1-Dichloroethane	<1	<1	<1							TM116'	<1 ug/l
Methyl Tertiary Butyl Ether	<1	<1	<1							TM116'	<1 ug/l
cis-1-2-Dichloroethene	<1	<1	<1							TM116'	<1 ug/l
Bromochloromethane	<1	<1	<1							TM116'	<1 ug/l
Chloroform	<1	<1	<1							TM116'	<1 ug/l
2,2-Dichloropropane	<1	<1	<1							TM116'	<1 ug/l
1,2-Dichloroethane	<1	<1	<1							TM116'	<1 ug/l
1,1,1-Trichloroethane	<1	<1	<1							TM116'	<1 ug/l
1,1-Dichloropropene	<1	<1	<1							TM116'	<1 ug/l
Benzene	<1	<1	<1							TM116'	<1 ug/l
Carbontetrachloride	<1	<1	<1							TM116'	<1 ug/l
Dibromomethane	<1	<1	<1							TM116'	<1 ug/l
1,2-Dichloropropene	<1	<1	<1							TM116'	<1 ug/l
Bromodichloromethane	<1	<1	<1							TM116'	<1 ug/l
Trichloroethene	<1	<1	<1							TM116'	<1 ug/l
cis-1-3-Dichloropropene	<1	<1	<1							TM116'	<1 ug/l
trans-1-3-Dichloropropene	<1	<1	<1							TM116'	<1 ug/l
1,1,2-Trichloroethane	<1	<1	<1							TM116'	<1 ug/l
Toluene	<1	<1	<1							TM116'	<1 ug/l
1,3-Dichloropropane	<1	<1	<1							TM116'	<1 ug/l

Date 17.12.2007