APPENDIX E

UXO Preliminary Risk Assessment

PRELIMINARY UNEXPLODED ORDNANCE RISK ASSESSMENT

Cypress Building
Liverpool L7 7EL

Prepared for: TerraConsult Ltd

Project Number: 4968

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CONTENTS

REFERENCES

Publications

Sources of information used in the compilation of this assessment included:

German Air Raids on Britain 1914-18. Morris 1925

Unexploded Ordnance (UXO) – A guide for the Construction Industry. CIRIA C681

Dangerous Energy. Cocroft 2000

The Blitz Then and Now Volumes 1 to 3. Ramsey 1987

Advanced German Weapons WW2. Ford 2000

Dealing with Munitions in Marine Aggregates. UMA 2008

United Nations International Mine Action Standards (IMAS). UN 2010

Military Engineering Volume XII. War Office 1956

German Bomb Fuzes. USN 1945

Fields of Deception & Anti Aircraft Command. Dobinson 1988

Target Reconnaissance Photography. Luftwaffe 1939-44

Internet Information

Additional information was provided through the following credible internet sites, their assistance is credited where appropriate:

Army EOD Incidents

RAF EOD Incidents & Air Situation Reports 1939-45

Luftwaffe Strategy & Tactics

Luftwaffe Bomber Specifications

WO Defence Arrangements 1939-45

News Reports Witness Accounts 1939-45

Latest News Reports

Project Information

Site and project information was provided by TerraConsult Ltd.

TERMS AND DEFINITIONS

Anti Aircraft Ammunition (AAA)

High Explosive shells ranging from 30mm to 155mm used by air defence batteries to attack or deter enemy air attack.

Air Dropped Munition

A bomb or container dropped from an aircraft which is designed to detonate at a pre determined altitude, on impact or using a delay mechanism; after impact.

Air Dropped Sub-Munitions (Bomblet)

Small sub-munitions dispensed from a larger carrier which may be fixed to the aircraft or dropped as a single container munition which was designed to open above the target spreading its contents over a large area. Some designs are extremely dangerous and fitted with anti-handling devices.

Area Clearance

This is the term used for the systematic clearance of explosive ordnance from land, including military property, firing and bombing ranges, airfields and training areas. When the land is a former wartime battle ground, the term used is Battle Area Clearance (BAC)

Blast Zone

This term refers to the area around an explosive detonation where the explosive overpressure (Blast) can cause damage, injury or death.

Explosive Ordnance (EO)

All manufactured or improvised items designed to contain explosive, propellant, pyrotechnic and fissionable material or biological or chemical agents or pre-cursers which when coupled with an initiation or dispersal system are designed to cause damage, injury or death.

Explosive Ordnance Disposal (EOD)

A series of recognised procedures and protocols which are used by specialists in the detection, identification, evaluation, risk assessment, render safe, recovery and disposal of any item of explosive ordnance or improvised explosive device.

Fragmentation Zone

This is the term which refers to the danger area in which a piece of an item of explosive ordnance will travel on detonation. This zone is normally greater than the blast zone.

Geophysical Survey

The use of magnetometers, ground penetrating radar or other geophysical data gathering systems, which is then used for evaluation, risk assessment and to quantify further mitigation requirements.

High Explosive (HE)

High explosives react/detonate at a rate of around 9,000 metres per second, to all intents and purposes, instantaneously.

Incendiary Bomb (IB)

Incendiary bombs ranged from 1kg in size to 500kg the larger sizes were designated as Oil Bombs. Fills range from Thermite mixtures, Phosphorus, Kerosene or other pyrotechnic mixtures.

Intrusive Search

This term refers to the process of introducing a specialist magnetometer by pushing or drilling the sensor in to the ground to a pre determined depth, thus allowing construction activities such as: piling, soil testing and deep intrusive ground works to be conducted safety.

Land Service Ammunition (LSA)

LSA is a term that refers to all items containing explosives, pyrotechnic or noxious compounds which are placed, thrown or projected during land battles.

Oil Bomb (OB)

Large airdropped bomb or modified ordnance container containing flammable material and accelerant, these weapons normally range in weight from 250 – 500kg.

Parachute Mine (PM)

Air-dropped mine designed to detonate at a pre set altitude above the ground. Essentially a large blast bomb with an explosive content of 1600 kg commonly fitted with anti-handling or anti-removal fuzes.

Unexploded Bomb (UXB)

Any air dropped bomb that has failed to function as designed.

Unexploded Ordnance (UXO)

Explosive ordnance that has been primed, fused, armed or otherwise prepared for use or used. It may have been fired, dropped, launched or projected yet remains unexploded either through malfunction or design or for any other cause.

War Office (WO)

This was the United Kingdom Government department responsible for defence of the realm, forerunner of the Ministry of Defence (MoD).

White Phosphorus (WP)

Munitions filled with WP are designed for signalling, screening and incendiary purposes. They achieve their effect by dispersing WP, which burns on contact with the air.

1 INTRODUCTION

1.1 Instruction & Scope

MACC International Ltd was commissioned by TerraConsult Ltd to conduct a Preliminary Unexploded Ordnance (UXO) Risk Assessment for land adjacent to the Cypress Building, Liverpool L7 7EL (See Annex 'A'). The scope of the assessment is to determine the likelihood of an uncontrolled encounter with UXO within the context of ground investigations and subsequent building works.

1.2 Methodology & Purpose

The methodology used in the assessment complies with the United Nations (IMAS) standards, the CIRIA C681 "Unexploded Ordnance (UXO) – A guide for the Construction Industry" and the recognised best practice advocated by the Health and Safety Executive (HSE). The quality and environmental aspects of the assessment comply with UKAS Accredited ISO 9001:2008 and ISO 14001:2004 standards. The purpose of the assessment is that of evaluation and to provide an aid in decision making by our client.

2 DETERMINING THE LIKELIHOOD OF ENCOUNTER

2.1 Aim, Research Restrictions & Indemnity

This assessment has drawn upon archive records which are within the public domain; however these are acknowledged to be incomplete. Consequently, some incidents may have occurred where the records no longer exist or could not be located. The Secretary of State of the United Kingdom and MACC International Ltd does not accept responsibility for the accuracy or completeness of the information contained within the records. Some records regarding the UXO situation on some sites may not yet be within the public domain. Consequently, such information was not available for evaluation by MACC International Ltd.

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2.2 Relevant Publications & Credible Internet Information

Published sources of information used in the compilation of this assessment are listed within the reference section of this assessment including those provided by the client. Additional information was provided through credible internet sites, their assistance is credited where appropriate and details are listed within the reference section of this assessment.

3 FUTURE DEVELOPMENT

Future intentions were not disclosed; however, it is understood that the development will include a new construction adjacent to the existing Cypress building. It has been assumed that geo-environmental investigations will be undertaken prior to subsequent building works.

4 HISTORICAL INFORMATION

4.1 British Archives

Prior to 1942 the United Kingdom did not operate a national recording system for EO/UXO incidents or military use of land. The records compiled during 1939-1942 were conducted under local arrangements and were only as detailed and accurate as the availability of time, personnel and the ease of access to information would allow. In April 1942 the Ministry of Home Security instigated a training programme for all personnel maintaining bomb census records, these standardised national records and greatly improved the accuracy of the information.

4.2 Manned Air Raids & Unmanned Rocket Attack Reports

Liverpool suffered considerable damage and loss of life as a result of enemy bombing raids during WWII. Although a bomb strike within the site footprint was not confirmed, records indicate several strikes in the immediate surrounding area. Bombing incidents occurred c.a.130m to the north of the site at Oxford Street, c.a.150m to the east at Grove Street and c.a.150m to the south east at Vine Street. Given the level of post-war development within the site footprint, this source of UXO contamination is considered credible.

4.3 Other Sources of UXO Contamination

Local fixed and mobile anti-aircraft batteries are known to have been positioned in the area to defend the district against air attacks. It is a matter of record that combat engagements with enemy aircraft did take place during WWII. Consequently, this source of UXO contamination is considered credible.

No records were found to indicate military activity within the site footprint. Consequently, this source of UXO contamination is not considered to be credible.

5 DETERMINING THE NATURE OF RISK

5.1 General

While HE bombs are very unlikely to detonate if left undisturbed it remains inherently dangerous and may function if subjected to suitable stimuli. The most common of these stimuli is shock, friction or heat which may cause the fuze to function or unstable explosive materials (Picrate Acid) to explode. However, in the case of incendiary bombs containing White Phosphorus (WP) exposure of the WP to the air will result in its violent ignition and combustion.

5.2 Bomb Trajectory & Ground Penetration

During WWII the Ministry of Home Security undertook a major assessment on bomb penetration depths using 1,328 actual bomb impact events to provide statistical analysis of penetration potential. As a result they determined the expected behaviour of a range of bomb weights through different geological strata around the Capital. Their findings remain the only empirical gained figures to have been gathered to date for England. A number of factors will influence the behaviour of a bomb on impact with the target and its trajectory through the ground. Relevant factors include: Height and speed of release of the bomb, aerodynamic qualities of the bomb, the angle of flight and impact and the nature of impact surface and sub soil. In determining the potential bomb penetration depths into the ground, historic geotechnical information and typical bomb characteristics were used. The maximum bomb penetration depth is estimated at 10.5 metres from the 1941 ground levels.

5.3 Bombs have been known to strike outside a building footprint and travel below the surface coming to rest within the building footprint. As did the recent 250kg HE bomb found within a cellar in Bethnal Green. The expected offset from impact point is estimated to be 3.0-5.0 metres.

6 ENVIRONMENTAL IMPACT FROM UXO

6.1 Ground Contamination & Health Risk vectors

While it is acknowledged that there is a potential risk of ground contamination arising from explosive fillings which may leach from a damaged bomb casing into the surrounding soil. The amount of explosive material within the most common bombs is not considered sufficient to pose a significant environmental risk. Nevertheless it should be noted that the following components are commonly used in the manufacture of a high explosive bomb and may pose a localised contamination risk to health: metals including; Lead, Zinc, Brass, Copper, Steel, Mercury, Silver Fulminate and Aluminium. Other chemical Compounds including; Trinitrophenol, Trinitrotolulene, Trimethylene Trinitramine, Ammonium, Sodium Nitrate, Nitro-glycerine and White Phosphorus. It is recommended that specialist medical advice be sought to identify specific risks to health posed by these chemical compounds.

7 RISK ASSESSMENT

7.1 Risk Source

Records confirmed that the surrounding area was struck by airdropped munitions. Records are acknowledged to be incomplete and may include omissions and errors; the possibility that items of UXO may have found their way onto the site and remain there to the present day is considered credible.

7.2 Risk Pathway

The risk pathway is considered to be any ground intrusive earth works carried out while undertaking geo-environmental investigations or building work.

7.3 Consequence

The consequences of a UXB detonation on site during construction works are considered to be a factor of the size of the blast and the proximity of assets and individuals to the point of detonation. These will include potential to kill or seriously injure personnel destroy or damage high value site assets, nearby public and private property and infrastructure.

7.4 Risk Rating

Table 1 Risk Level

PRELIMINARY UXO RISK RATING			
Hand Dug Excavations	3 x 1 = 3	1 x 5 = 5	3 x 5 = 15
Limited Mechanical Excavations	3 x 2 = 6	2 x 5 = 10	6 x 10 = 60
Drilling, Sampling, Piling or Bulk Excavations	3 x 3 = 9	3 x 5 = 15	9 x 15 = 135
1= Minimal 5=significant	LOW 0-100	MEDIUM 100-200	HIGH 200+

8 ASSESSMENT FINDINGS

8.1 Risk Levels

The assessment has determined the preliminary UXO risk within the site footprint. When viewed from likelihood versus consequence standpoint; it is considered prudent to recommend a suitable degree of UXO mitigation to permit the work to proceed in the safest "acceptable" manner in compliance with current legislation and best practices.

9 RECOMMENDATIONS FOR RISK MITIGATION

9.1 It is recommended that a detailed UXO Desk Top Study is commissioned to more accurately define the risk level and to complete detailed assessment on the mitigation requirements over the project's lifetime.

9.2 Alternatively, the preliminary risk levels are accepted and the following mitigation measures are carried out as a minimum requirement:

All Risk Levels

- Risk Communication & Safety Planning: Stakeholders should be made aware of the UXO risk levels within the project boundary and the possible impact an encounter may have on the project and third parties.
- Safety Training: In keeping with CDM Regulations concerning all sub-surface hazards, UXO Safety Induction Training should be provided to everyone working or visiting the site. The training should be commensurate with the individual's responsibilities and duties on site. The training should be provided by a competent individual (preferably a trained EOD Engineer) and delivered as a separate module of the Site Safety Induction Course or as a Toolbox Talk.

Additional mitigation requirements for the medium risk activities:

- Drilling, Sampling or Bulk Excavations: These activities should be checked for UXO by an EOD Engineer equipped with specialist magnetometers ahead of the drilling/sampling bits. Where the ground conditions on land will not permit this; Then a UXO safety 'watching brief' should be in place during the work.
- Piling: All positions should be tested using a specialist 'Mag Cone' and be UXO safety certified prior to the commencement of piling.

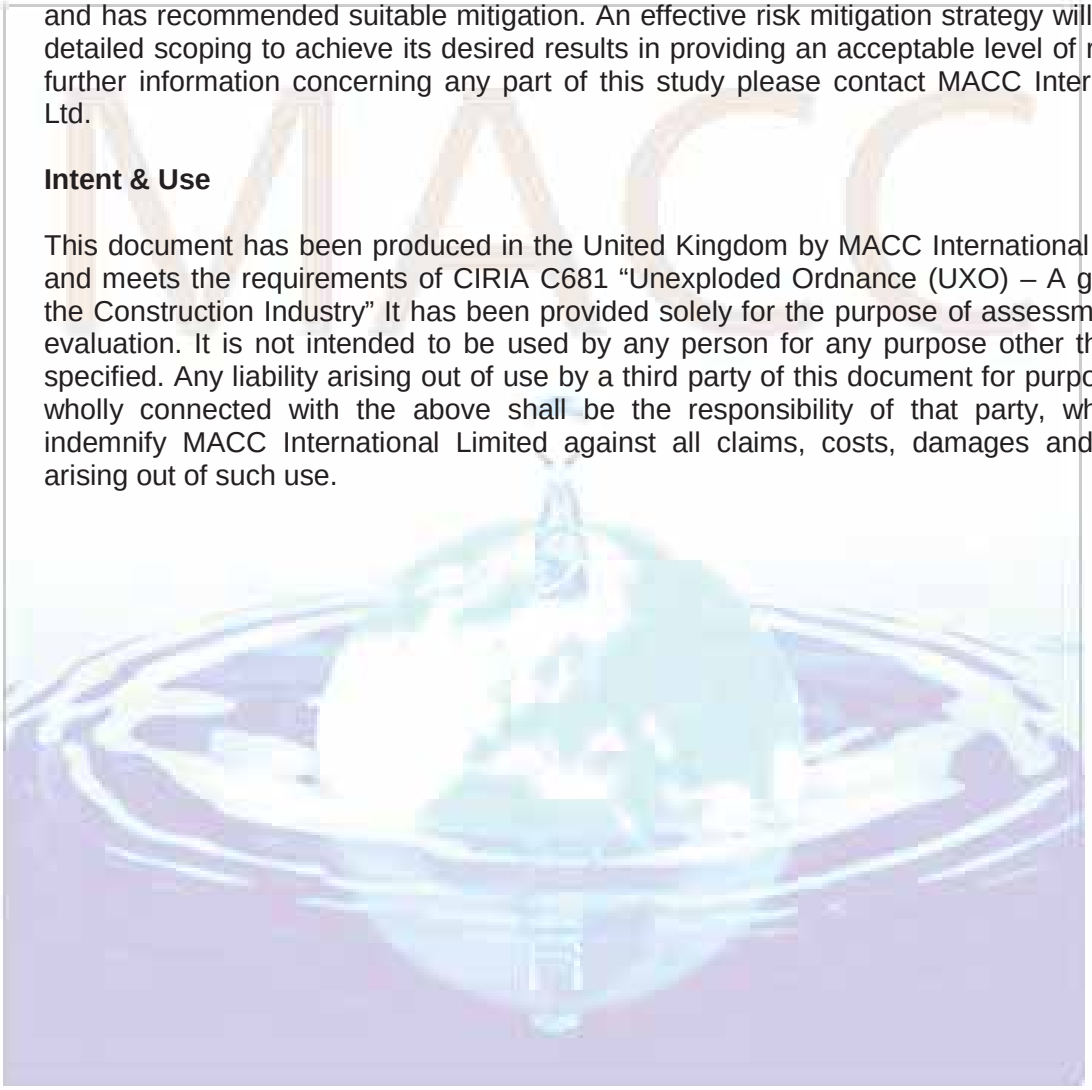
10 POST MITIGATION RISK

10.1 Overview

Prudent execution of the recommended risk mitigation strategy will reduce the risk, however it is emphasised that zero risk is not achievable given the possible variables. The study has confirmed the UXO risk level based on the nature of the work to be undertaken and has recommended suitable mitigation. An effective risk mitigation strategy will require detailed scoping to achieve its desired results in providing an acceptable level of risk. For further information concerning any part of this study please contact MACC International Ltd.

10.2 Intent & Use

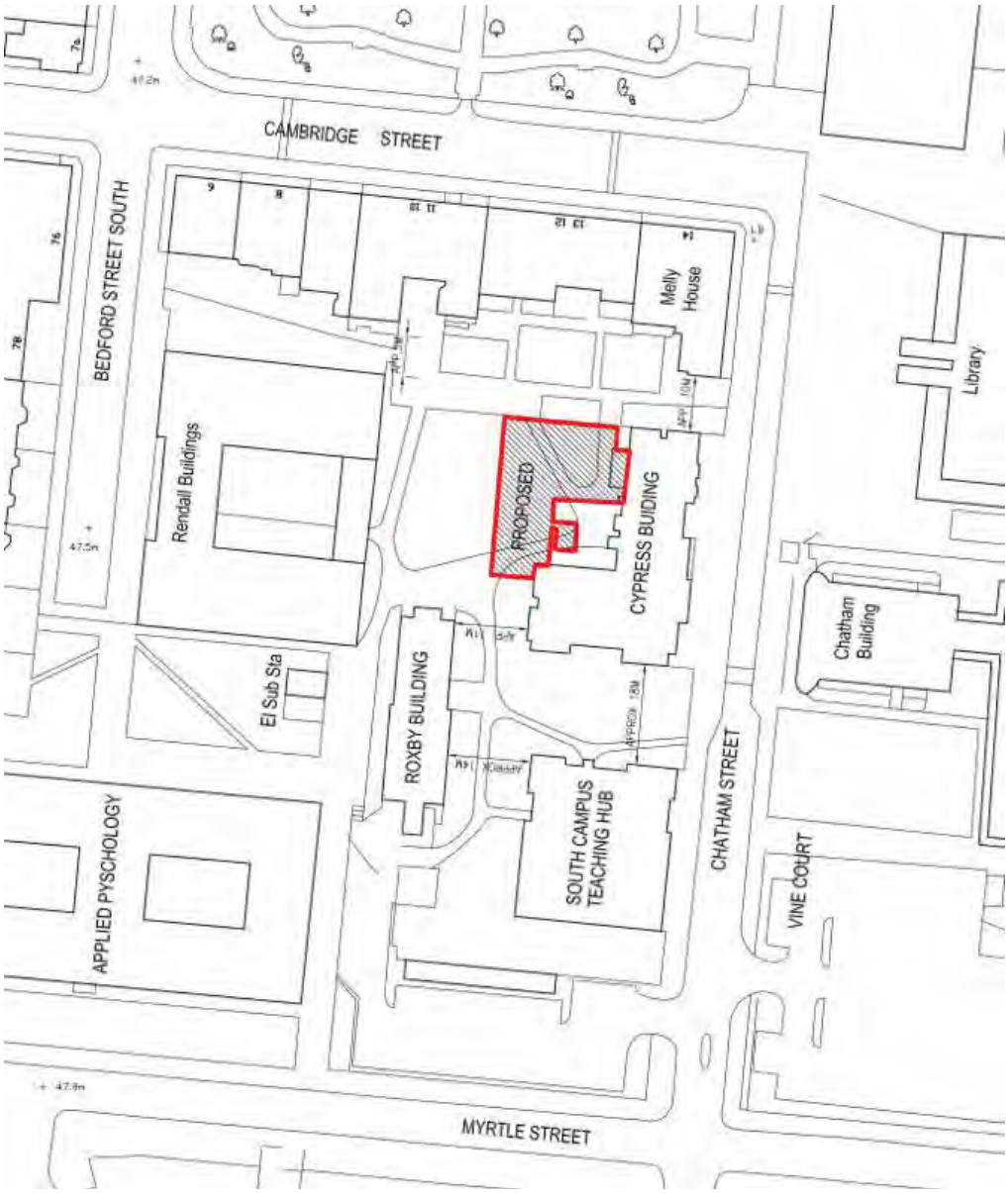
This document has been produced in the United Kingdom by MACC International Limited and meets the requirements of CIRIA C681 “Unexploded Ordnance (UXO) – A guide for the Construction Industry” It has been provided solely for the purpose of assessment and evaluation. It is not intended to be used by any person for any purpose other than that specified. Any liability arising out of use by a third party of this document for purposes not wholly connected with the above shall be the responsibility of that party, who shall indemnify MACC International Limited against all claims, costs, damages and losses arising out of such use.



Annex A

SITE MAPPING

Site Drawing:



APPENDIX F

Exploratory Hole Records

Borehole Log

TerraConsult

Borehole formation details:

Type:	From:	To:	Start date:	End date:	Crew:	Plant:	Barrel type:	Drill bit:	Logger:	Logged:	Remarks:
IP	0.00	1.20	06-11-17	06-11-17	DP	Hand tools	HWF	PCD	JL	06-11-17	
WLS	0.00	4.70	06-11-17	06-11-17	DP	Commachio GEO 206	HWF	PCD	JL	06-11-17	
RC	4.70	8.30	06-11-17	06-11-17	DP	Commachio GEO 207	HWF	PCD	DD	08-11-17	

Location details:

mE: 335957.57
mN: 389892.03
mAOD: 46.64
Grid: OSGB

Backfill/ Instal'n	Water-strike	Legend	Level	Depth (thick-ness)	Stratum Description	Samples & In Situ Testing: Water	Casing	Depth/Core Run	TCR SCR RQD	If	Results/remarks/ samples
					Firm dark brown sandy CLAY with many roots and rootlets.						
				(0.70)							0.40 ES1
			45.94	0.70	Brown gravelly SAND. Gravel is subangular to subrounded fine to coarse of sandstone and mudstone						
				(0.50)							
			45.44	1.20	Loose light brown slightly gravelly fine to coarse SAND. Gravel is subangular to rounded fine to coarse of sandstone.	Dry		1.20 S			N=6 (1,1/1,1,2,2)
				(1.30)							
						Dry		2.20 S			N=7 (1,1/1,2,2,2)
			44.14	2.50	Dark brown silty slightly gravelly fine to medium SAND.Gravel is rounded fine to coarse of sandstone.						
				(0.60)							
			43.54	3.10	Firm grey sandy slightly gravelly CLAY. Gravel is subangular to rounded fine to coarse of sandstone and mudstone.	Dry		3.20 S			N=11 (1,2/2,3,3,3)
				(1.30)							
						Dry		4.20 S			N=46 (3,4/6,7,13,20)
			42.24	4.40	Highly weathered SANDSTONE recovered as: Orange brown fine SAND						
				(1.05)							
			41.19	5.45	Extremely weak to weak reddish brown fine grained SANDSTONE. Fractures very closely to medium spaced, predominately horizontal (Wilmslow Sandstone Formation)			4.70 - 6.70	85 26 11	20 70 210	
					5.62 - 5.65 m: Very soft pale grey CLAY						
					6.23 - 6.37 m: Reddish brown fine SAND						
					6.58 - 6.66 m: Extremely weak to very weak light grey with orange iron staining MUDSTONE						
				(2.85)							6.85 - 6.95 C
					6.95 - 6.99 m: Extremely weak to very weak light grey with orange iron staining MUDSTONE						
					7.15 - 7.20 m: Firm to stiff light grey and reddish brown extremely closely fissured CLAY			6.70 - 8.30	91 75 9		7.86 - 7.96 C
			38.34	8.30	*8.24 - 8.25 m: Extremely weak to very weak light grey with orange iron staining MUDSTONE* Borehole ends at 8.30 m (Termination reason: Target depth)						
						Water	Casing	Depth/Core Run	TCR SCR RQD	If	Results/remarks

Groundwater entries:

Struck:	Rose to:	Casing:	Sealed:

Diameter & casing:

Dia (mm):	Depth:	Casing:
150	4.70	4.70
118	8.30	8.30

Depth related remarks:

From	to:	Remarks:

Flush details:

Depth:	Type:	Return:	Colour:
4.70 - 8.30	water		

Notes: For explanation of symbols and abbreviations see Key Sheet.
All depths and reduced levels are in meters.

Log issue:

Scale: 1:50

Project: Cypress Building
Project No: 3571
Client: University of Liverpool

Exploratory position reference:

RC01

Borehole Log

TerraConsult

Borehole formation details:

Type:	From:	To:	Start date:	End date:	Crew:	Plant:	Barrel type:	Drill bit:	Logger:	Logged:	Remarks:
IP	0.00	1.20	07-11-17	07-11-17	DP	Hand tools	HWF	PCD	JL	07-11-17	
WLS	0.00	4.50	07-11-17	07-11-17	DP	Commachio GEO 209	HWF	PCD	JL	07-11-17	
RC	4.50	13.50	07-11-17	07-11-17	DP	Commachio GEO 210	HWF	PCD	DD	07-11-17	

Location details:

mE: 335946.50
mN: 389890.75
mAOD: 47.50
Grid: OSGB

Backfill/ Instal'n	Water-strike	Legend	Level	Depth (thick-ness)	Stratum Description	Samples & In Situ Testing: Water	Casing	Depth/Core Run	TCR SCR RQD	If	Results/remarks/ samples
			47.30	0.20	Soft dark brown sandy CLAY with roots and rootlets.						
				(0.40)	Soft dark brown sandy gravelly CLAY. Gravel is angular fine to coarse of brick, concrete and glass						0.40 ES1
			46.90	0.60	Brown silty silghtly gravelly SAND. Gravel is angular to subrounded fine to coarse of sandstone and mudstone						
				(0.50)							
			46.40	1.10	Medium dense brown slightly gravelly SAND. Gravel is subangular to subrounded fine to coarse of sandstone.	Dry		1.20 S			N=11 (1,2/3,2,3,3)
				(2.10)		Dry		2.20 S			N=12 (1,2/3,3,3,3)
			44.30	3.20		Dry		3.20 S			N=13 (1,2/3,3,3,4)
				(0.40)	Firm brown sandy slightly gravelly CLAY. Gravel is subangular to subrounded fine to coarse of sandstone and mudstone.						
			43.90	3.60	Very dense brown gravelly fine to coarse SAND. Gravel is angular to subrounded fine to coarse of sandstone (Possible completely weathered sandstone)						
				(0.70)		Dry		4.10 S			50 (2,3/50 for 295mm)
	SP		43.20	4.30	Highly weathered SANDSTONE recovered as: Light grey fine SAND			4.50 - 6.50	18 0 0		
				(2.20)							
			41.00	6.50	Extremely weak reddish brown fine grained SANDSTONE			6.50 - 7.50	21 0 0		
				(1.27)							
					7.50 - 7.70 m: AZCL						
			39.73	7.77	Extremely weak to very weak light grey fine grained SANDSTONE (Wilmslow Sandstone Formation)						
				(0.46)							
			39.27	8.23	Extremely weak to weak reddish brown fine grained SANDSTONE. Fractures closely spaced, predominately horizontal and 70 - 80 degs (Wilmslow Sandstone Formation)			7.50 - 10.50	93 81 75		8.40 - 8.50 C 8.65 - 8.77 C 9.20 - 9.30 C 9.50 - 9.78 C 9.90 - 10.00 C
						Water	Casing	Depth/Core Run	TCR SCR RQD	If	Results/remarks

Groundwater entries:

Struck:	Rose to:	Casing:	Sealed:

Diameter & casing:

Dia (mm):	Depth:	Casing:
150	4.50	4.50
118	13.50	13.50

Depth related remarks:

From	to:	Remarks:

Flush details:

Depth:	Type:	Return:	Colour:
4.50 - 13.50	water		

AGS

Notes: For explanation of symbols and abbreviations see Key Sheet.
All depths and reduced levels are in meters.

Log issue:

Scale: 1:50

Project: Cypress Building
Project No: 3571
Client: University of Liverpool

Exploratory position reference:

RC02

Borehole Log

TerraConsult

Borehole formation details:

Type:	From:	To:	Start date:	End date:	Crew:	Plant:	Barrel type:	Drill bit:	Logger:	Logged:	Remarks:
IP	0.00	1.20	07-11-17	07-11-17	DP	Hand tools	HWF	PCD	JL	07-11-17	
WLS	0.00	4.50	07-11-17	07-11-17	DP	Commachio GEO 209	HWF	PCD	JL	07-11-17	
RC	4.50	13.50	07-11-17	07-11-17	DP	Commachio GEO 210	HWF	PCD	DD	07-11-17	

Location details:

mE: 335946.50
mN: 389890.75
mAOD: 47.50
Grid: OSGB

Backfill/ Instal'n	Water-strike	Legend	Level	Depth (thick-ness)	Stratum Description	Samples & In Situ Testing: Water	Casing	Depth/Core Run	TCR SCR RQD	If	Results/remarks/ samples
				(5.27)	*10.48 - 10.66 m: Weak light grey MUDSTONE* *10.66 - 11.46 m: NI* *11.60 - 11.64 m: Weak light grey MUDSTONE*			10.50 - 13.50	85 71 32	NI 150 460	10.60 - 10.70 C 11.95 - 12.22 C 13.10 - 13.25 C
			34.00	13.50	Borehole ends at 13.50 m (Termination reason: Target depth)						
						Water	Casing	Depth/Core Run	TCR SCR RQD	If	Results/remarks

Groundwater entries:

Struck: Rose to: Casing: Sealed:

Diameter & casing:

Dia (mm):	Depth:	Casing:
150	4.50	4.50
118	13.50	13.50

Depth related remarks:

From to: Remarks:

Flush details:

Depth: Type: Return: Colour:

AGS

Notes: For explanation of symbols and abbreviations see Key Sheet.
All depths and reduced levels are in meters.

Log issue:

Scale: 1:50

Project: Cypress Building
Project No: 3571
Client: University of Liverpool

Exploratory position reference:

RC02

Borehole Log

TerraConsult

Borehole formation details:

Type:	From:	To:	Start date:	End date:	Crew:	Plant:	Barrel type:	Drill bit:	Logger:	Logged:	Remarks:
IP	0.00	1.20	06-11-17	06-11-17	DP	Hand tools	HWF	PCD	JL	06-11-17	
WLS	0.00	5.00	06-11-17	06-11-17	DP	Commachio GEO 212	HWF	PCD	JL	06-11-17	
RC	5.00	8.60	06-11-17	06-11-17	DP	Commachio GEO 213	HWF	PCD	DD	08-11-17	

Location details:

mE: 335957.38
mN: 389877.97
mAOD: 46.66
Grid: OSGB

Backfill/ Instal'n	Water-strike	Legend	Level	Depth (thick-ness)	Stratum Description	Samples & In Situ Testing: Water	Casing	Depth/Core Run	TCR SCR RQD	If	Results/remarks/ samples
			46.56	0.10	Soft dark brown sandy CLAY with occasional rootlets						
				(0.60)	Soft dark brown sandy gravelly CLAY. Gravel is angular fine to coarse of brick, concrete and glass						0.40 ES1
			45.96	0.70	Light brown silty slightly gravelly SAND. Gravel is angular to subrounded fine to coarse of sandstone and mudstone						
				(0.50)							
			45.46	1.20	Loose dark brown slightly gravelly fine to medium SAND. Gravel is subangular to subrounded fine to coarse of sandstone.	Dry		1.20 S			N=7 (1,1/1,2,2,2)
				(1.90)		Dry		2.20 S			N=6 (1,1/1,1,2,2)
			43.56	3.10	Firm reddish brown sandy slightly gravelly CLAY. Gravel is subangular to rounded fine to coarse of sandstone and mudstone.	Dry		3.20 S			N=7 (1,1/1,2,2,2)
				(1.90)		Dry		4.20 S			N=12 (1,2/3,3,3,3)
	SP		41.66	5.00	Highly weathered SANDSTONE recovered as: Reddish brown fine SAND	Dry		5.00 S			50 (7,10/50 for 220mm)
			41.46	5.20	Extremely weak to weak occasionally mottled black fine grained SANDSTONE. Fractures extremely closley to closely spaced, 0 - 5 degs and 70 - 80 degs (Wilmslow Sandstone Formation) *5.20 - 5.50 m: NI* *5.57 - 5.64 m: Fracture 80 degs*			5.00 - 7.00	62 40 0		5.65 - 5.72 C
				(3.60)	*6.20 - 6.28 m: Fracture 80 degs* *6.25 m: Clay parting with infilled root track* *6.50 - 6.56 m: NI* *6.56 - 6.75 m: Fracture 80 degs* *6.76 - 6.80 m: Recovered as: very soft pale grey CLAY*					NI 80 110	
					8.08 - 8.11 m: Extremely weak pale grey MUDSTONE *8.17 - 8.25 m: Recovered as: very soft pale grey CLAY* *8.25 - 8.30 m: Extremely weak pale grey MUDSTONE*			7.00 - 8.60	86 68 7		7.65 - 7.75 C
			38.06	8.60	Borehole ends at 8.60 m (Termination reason: Target depth)						

Groundwater entries:

Struck:	Rose to:	Casing:	Sealed:

Diameter & casing:

Dia (mm):	Depth:	Casing:
150	5.00	5.00
118	8.60	8.60

Depth related remarks:

From to: Remarks:

Flush details:

Depth:	Type:	Return:	Colour:
5.00 - 8.60	water		

Notes: For explanation of symbols and abbreviations see Key Sheet.
All depths and reduced levels are in meters.

Log issue:

Scale: 1:50

Project: Cypress Building
Project No: 3571
Client: University of Liverpool

Exploratory position reference:

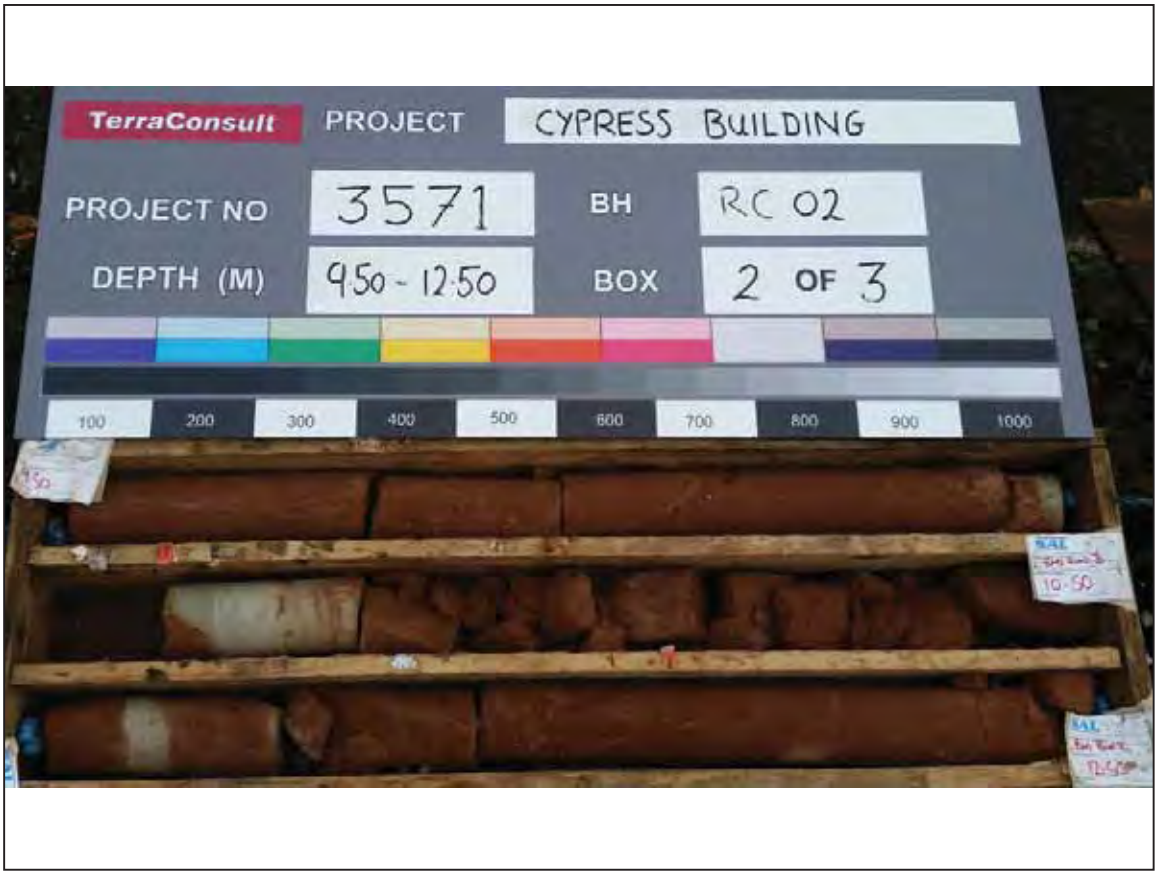
RC03

Core Photos

TerraConsult

RC01 Box 1

RC02 Box 1

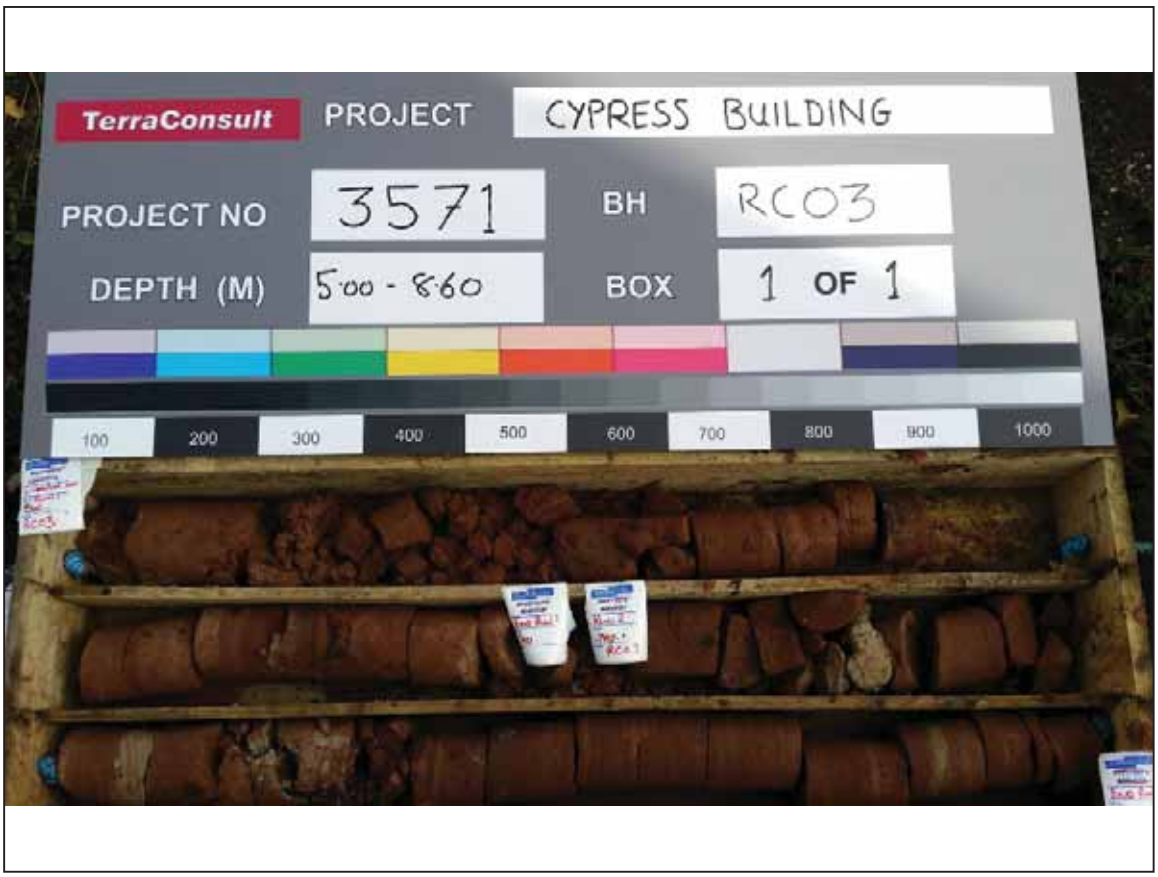


RC02 Box 2

RC02 Box 3

Core Photos

TerraConsult



RC03 Box 1

Trial Pit Log

TerraConsult

Personnel:		Equipment & methods:		Dimensions:	Coordinates & level:	Dates:	
Logged by:	JL	Method:	Hand Excavated Trial Pit	Width:		Start:	06/11/2017
Checked by:				Length:		End:	06/11/2017
		Plant:	Hand Tools	**Orientation:**		Logged:	06/11/2017
		Shoring:		Bearing =	Grid:		

Backfill/ Instal'n	Water-strike	Legend	Level & Depth (Thickness)	Stratum Description	Samples & In Situ Testing		
					Depth	Type & No	Results
			0.15	Dark brown sandy CLAY with rootlets MADE GROUND			
			(0.75)	Dark brown sandy slightly gravelly CLAY. Gravel is fine to coarse, angular sub-rounded, predominantly brick, occasional concrete, ash, textiles, plastic. MADE GROUND	0.60	ES1	
			0.90	Trial pit ends at 0.90m (Brick obstructions)			
					Depth	Type & No	Results

Groundwater entries:

Depth:	Rose to:	Remarks:

Depth related remarks:

From	to:	Remarks:
0.90	0.90	Possible Brick footings

General remarks:
Weather:
Stability:
Remarks:

AGS

Notes: For explanation of symbols and abbreviations see Key Sheet.
All depths and reduced levels are in metres.

Log issue:
Scale: 1:25

Project: Cypress Building
Project No: 3571
Client: University of Liverpool

Exploratory position reference:

HD01

Sheet 1 of 1

Trial Pit Log

TerraConsult

Personnel:	Equipment & methods:	Dimensions:	Coordinates & level:	Dates:
Logged by: JL	Method: Hand Excavated Trial Pit	Width:		Start: 06/11/2017
Checked by:		Length:		End: 06/11/2017
	Plant: Hand Tools	**Orientation:**		Logged: 06/11/2017
	Shoring:	Bearing =	Grid:	

Backfill/ Instal'n	Water-strike	Legend	Level & Depth (Thickness)	Stratum Description	Samples & In Situ Testing		
					Depth	Type & No	Results
			0.15	Dark brown sandy CLAY with rootlets. MADE GROUND			
			(0.45)	Dark brown sandy slightly gravelly CLAY. Gravel is fine to coarse, angular sub-rounded, predominantly brick with concrete and ash. MADE GROUND	0.50	ES1	
			0.60	Brown silty slightly gravelly fine to coarse SAND.	0.90	ES2	
			(0.60)				
			1.20	Trial pit ends at 1.20m (Target Depth)			
					Depth	Type & No	Results

Groundwater entries:
Depth: Rose to: Remarks:

Depth related remarks:
From to: Remarks:

General remarks:
Weather:
Stability:
Remarks:

AGS

Notes: For explanation of symbols and abbreviations see Key Sheet.
All depths and reduced levels are in metres.

Log issue:
Scale: 1:25

Project: Cypress Building
Project No: 3571
Client: University of Liverpool

Exploratory position reference:
HD02

Trial Pit Photos

TerraConsult

HD01 1

HD01 4

Trial Pit Photos

TerraConsult

HD02 3

HD02 4

SPT Hammer Energy Test Report

in accordance with BSEN ISO 22476-3:2005

ARCHWAY ENGINEERING
AINLEYS INDUSTRIAL ESTATE
ELLAND
WEST YORKSHIRE
HX59JP

SPT Hammer Ref:	AR824
Test Date:	07/12/2016
Report Date:	07/12/2016
File Name:	AR824.spt
Test Operator:	SH

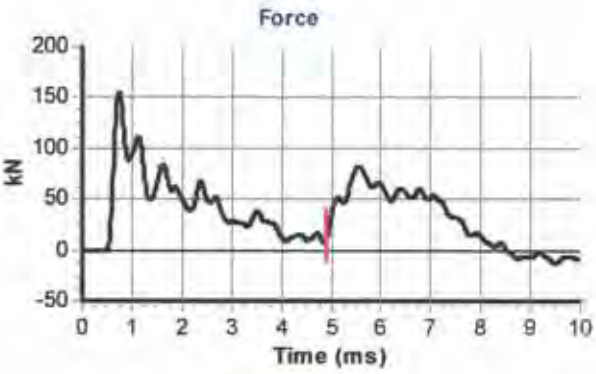
Instrumented Rod Data

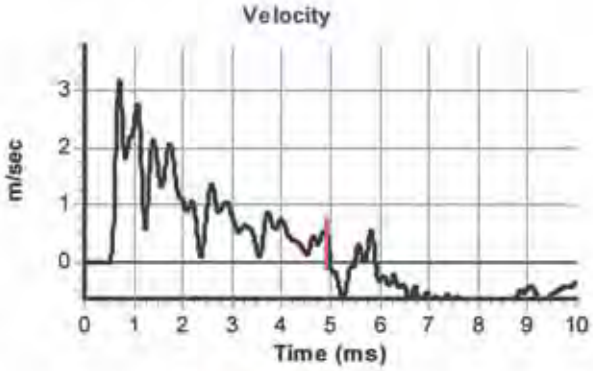
Diameter d_r (mm):	54
Wall Thickness t_r (mm):	6.1
Assumed Modulus E_a (GPa):	208
Accelerometer No.1:	7080
Accelerometer No.2:	7079

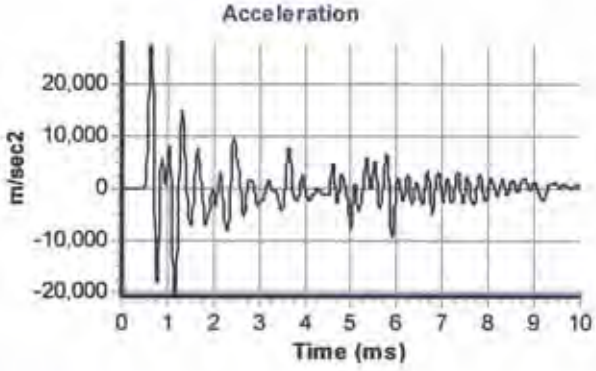
SPT Hammer Information

Hammer Mass m (kg):	63.5
Falling Height h (mm):	760
SPT String Length L (m):	10.0

Comments / Location
CALIBRATION







Calculations

Area of Rod A (mm2):	918
Theoretical Energy E_{theor} (J):	473
Measured Energy E_{meas} (J):	303

Energy Ratio E_r (%): 64

Signed: M.GARDNER
Title: FITTER

The recommended calibration interval is 12 months

Exploratory Hole Key Sheet

TerraConsult

SAMPLES:

Undisturbed:	
U	Driven tube sample
UT	Thin wall driven tube sample
TW	Pushed thin wall tube sample
P	Pushed piston sample
L	Liner sample (from windowless or similar sampler), full recovery unless otherwise stated
CBR	CBR mould sample
BLK	Block sample
C	Core sample (from rotary core) taken for laboratory testing
Disturbed:	
D	Small sample
B	Bulk sample
AMAL	Amalgamated sample
Environmental:	
ES	Environmental soil sample
EW	Environmental water sample
Comments:	Sample reference numbers are assigned to every sample taken. A sample reference of 'NR' indicates that an attempt was made to take a tube sample; however, there was no recovery. Sample recovery is given as a percentage.

TESTS:

SPT S or SPT C	Standard Penetration Test, open shoe (S) or solid cone (C)
	The Standard Penetration Test is defined in BS EN ISO 22476-3 (2005). The incremental blow counts are given in the Field Records column; each increment is 75mm unless stated otherwise and any penetration under self weight in mm (SW) is noted. Where the full 300mm test drive is achieved the total number of blows for the test drive is presented as N = ** in the Test column. Where the test drive blows reach 50 (either in total or for a single increment) the total blow count beyond the seating drive is given (without the N = prefix).
ICBR	In situ CBR
IV	In situ vane shear strength, peak (p) and remoulded (r), kPa
HV	Hand vane shear strength, peak (p) and remoulded (r), kPa
PP	Pocket penetrometer test, converted to shear strength, kPa
KFH, KRH, KPI	Variable head permeability tests (KFH = falling head test, KRH = rising head test, KPI = packer test), permeability value
PID/FID	Photo-ionisation detector/Flame-ionisation detector
	Test results provided in Field Records column

DRILLING RECORDS:

The mechanical indices (TCR/SCR/RQD & If) are defined in BS 5930: 2015 and BS EN ISO 22575-1 (2006)

TCR	Total Core Recovery, %
SCR	Solid Core Recovery, %
RQD	Rock Quality Designation, %
If	Fracture spacing, mm. Minimum, typical and maximum spacings are presented.
NI	Non intact is used where the core is fragmented.
CRF	Core recovered (length in m) in the following run
AZCL	Assessed zone of core loss
NR	Not recovered

GROUNDWATER:

▼ Groundwater strike

▽ Groundwater level after standing period

DEPTH REMARKS:

EoS	End of Shift
SoS	Start of Shift
EoBH	End of Borehole

INSTRUMENTATION:

Details of installations are given on the Record. Legend column shows installed instrument depths including slotted pipe section or tip depth, response zone filter material type and layers of backfill. The type of instrument installed is indicated by a code adjacent to the Legend column at the base of the instrument.

SP	Standpipe
SPIE	Standpipe piezometer
PPIE	Pneumatic piezometer
EPIE	Electronic piezometer
HPIE	Hydraulic piezometer
GMP	Gas monitoring standpipe
(xx)	Internal diameter
ICE	Biaxial inclinometer
ICM	Inclinometer tubing for use with probe
SLIP	Slip indicator
ESET	Electronic settlement cell/gauge
ETM	Magnetic extensometer settlement point
ETR	Rod extensometer

EXPLORATORY HOLE TYPE:

CP	Cable percussion
DP	Dynamic probe
DCP	Dynamic cone penetrometer
HA	Hand auger
IP	Inspection pit
OP	Observation pit/trench
PC	Pavement core
RC	Rotary core
RO	Rotary open hole
SH	Shaft
SNC	Sonic (resonance)
TP	Trial pit/trench
TRAV	Traverse
WLS	Windowless (dynamic) sample
WS	Window (dynamic) sample

AGS

Project: **Cypress Building**

Project No: **3571**

Client: **University of Liverpool**

Reference

KEY SHEET

APPENDIX G

Gas and Groundwater Monitoring

No: 3571

GROUNDWATER AND GROUND GAS MONITORING

TerraConsult

Site: Cypress Building, Liverpool

Location	Date	Monitored by	Well Details		Groundwater		Gas											Weather	
			Standpipe diameter (mm)	Depth to Base (m bgl)	Water Depth (m bgl)	Water Sample Taken?	Atmospheric Pressure (mbar)	Atmospheric Pressure Comment	Relative Pressure (mb)	Flow (l/h)	CH_4 (% v/v)	GSV CH_4 (l/hr)	CO_2 (% v/v)	GSV CO_2 (l/hr)	O_2 (% v/v)	CO (ppm)	H2S (ppm)	VOC (ppm)	Conditions	Ambient Temp ^oC
RC02	14/11/17	GB	51	5.10	damp at base	N	1015	Steady	0.01	0.1	0.1	0.0001	2.1	0.0021	18.3	1	1	0.1	Overcast	12
	21/11/17	MG	51	5.10	5.02	N	998	Steady	0.01	0.1	0.1	0.0001	6.5	0.0065	14.2	1	1	0.1	Overcast	12
														0.0000						
RC03	14/11/17	GB	51	5.06	damp at base	N	1015	Steady	0.01	0.1	0.1	0.0001	3.5	0.0035	17.0	1	1	0.1	Overcast	12
	21/11/17	MG	51	5.06	damp at base	N	998	Steady	0.01	0.1	0.1	0.0001	4.5	0.0045	15.5	1	1	0.1	Overcast	12

Denotes result less than the detection limit indicated.

NOTES:
NM = Not Measured.
(x) = Peak value recorded.
[grey] = Below detection limit.

$$GSV\ (l/HR) = \frac{[\text{gas concentration } (\%v/v)] \times [\text{gas well flow rate } (l/hr)}{100}$$

Instrumentation Specifications

Gas Monitoring – Permanent Gases

Gas monitoring for permanent gases (e.g. methane, carbon dioxide, oxygen etc) at TerraConsult is carried out using a GasData GFM 400 series gas analyser with flow meter which measures borehole flow rates, bulk gas concentrations (methane, carbon dioxide and oxygen), barometric and differential pressure.

The specification range of the GFM 400 series is as follows:

Feature	Method/Type	Range	Resolution
Methane	Infrared	0 - 100%v/v	0.1%
Lower Detection Limit (LEL)	Infrared	0 - 100%v/v	0.1%
Carbon Dioxide	Infrared	0 - 100%v/v	0.1%
Oxygen	Electrochemical	0 - 25%v/v	0.1%
Hydrogen Sulphide	Electrochemical	0 - 5,000ppm	1ppm
Carbon monoxide	Electrochemical	0 – 2,000ppm	1ppm
Atmospheric Pressure	Absolute Pressure Sensor	800 – 1,200mb	1mb
Differential Pressure	Thermal Dissipation	±1,250Pa	0.1Pa
Temperature	Bi-metal	-10ºC to +100ºC	1ºC
Flow	Thermal Dissipation	-60 – 100 l/hr	0.1 l/hr

Volatile Organic Compounds

TerraConsult uses a PhoCheck Tiger Photo Ionisation Detector (PID) to detect a large range of Volatile Organic Compounds (VOCs) which are potentially dangerous from both a poisoning and/or an explosive perspective.

The sensor specification is as follows:

Feature	Method/Type	Range	Resolution
Total VOCs	PID	1ppb – 10,000ppm & 1ppb to 20,000ppm for specific gases	+/- 5% displayed reading +/- one digit

Calibration

Measuring equipment owned by TerraConsult is maintained in good condition and regularly inspected to ensure that it is capable of accurate and effective operation and is calibrated in line with the manufacturer's recommendations. When equipment is hired for use, the hirer will be required to provide a calibration certificate with the equipment.

In accordance with TerraConsult's ISO 9001:2008 accreditation, the process of calibrating and maintenance of TerraConsult's own measuring equipment is carried out in accordance with our quality system procedures and a register of all measuring equipment is maintained and calibration certificates collated and stored accordingly.

Prior to the use of any measuring equipment, the user will undertake suitable checks to ensure that it is fit for use and within the calibration tolerances specified.

Should a copy of the relevant calibration certificate be required, please contact TerraConsult directly to request a copy.
.

APPENDIX H

Laboratory Chemical Test Results

Jimmy Thornburn
TerraConsult Ltd
Bold Business Centre
Bold Lane
Sutton
St Helens
Merseyside
WA9 4TX

QTS Environmental Ltd
Unit 1
Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Kent
ME17 2JN
t: 01622 850410
russell.jarvis@qtsenvironmental.com

QTS Environmental Report No: 17-66927

Site Reference:	Cypress Building
Project / Job Ref:	3571
Order No:	PO-002069
Sample Receipt Date:	10/11/2017
Sample Scheduled Date:	10/11/2017
Report Issue Number:	1
Reporting Date:	16/11/2017

Authorised by:

Russell Jarvis
Associate Director of Client Services

Authorised by:

Dave Ashworth
Deputy Quality Manager

QTSE is the trading name of DETS Ltd, company registration number 03705645

QTS Environmental Ltd
Unit 1, Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Maidstone
Kent ME17 2JN
Tel : 01622 850410

Soil Analysis Certificate						
QTS Environmental Report No: 17-66927	Date Sampled	06/11/17	06/11/17	06/11/17	06/11/17	06/11/17
TerraConsult Ltd	Time Sampled	None Supplied	None Supplied	None Supplied	None Supplied	None Supplied
Site Reference: Cypress Building	TP / BH No	HD1	HD2	RC01	RC02	RC03
Project / Job Ref: 3571	Additional Refs	None Supplied	None Supplied	None Supplied	None Supplied	None Supplied
Order No: PO-002069	Depth (m)	0.60	0.40	0.40	0.40	0.40
Reporting Date: 16/11/2017	QTSE Sample No	301224	301225	301226	301227	301228

Determinand	Unit	RL	Accreditation					
Asbestos Screen (S)	N/a	N/a	ISO17025	Not Detected	Not Detected	Not Detected	Not Detected	
pH	pH Units	N/a	MCERTS	7.9	7.9	7.5	7.4	7.6
Total Cyanide	mg/kg	< 2	NONE	< 2	< 2	< 2	< 2	< 2
Total Sulphate as SO_4	mg/kg	< 200	NONE	293			276	
Total Sulphate as SO_4	%	< 0.02	NONE	0.03			0.03	
W/S Sulphate as SO_4 (2:1)	mg/l	< 10	MCERTS	26	24	19	11	11
W/S Sulphate as SO_4 (2:1)	g/l	< 0.01	MCERTS	0.03	0.02	0.02	0.01	0.01
Organic Matter	%	< 0.1	MCERTS	2.6			4.1	
Total Organic Carbon (TOC)	%	< 0.1	MCERTS	1.5	1.9	1.6	2.4	2.3
W/S Chloride (2:1)	mg/kg	< 1	MCERTS	21			23	
W/S Chloride (2:1)	mg/l	< 0.5	MCERTS	10.3			11.5	
Arsenic (As)	mg/kg	< 2	MCERTS	9	15	19	7	9
Cadmium (Cd)	mg/kg	< 0.2	MCERTS	< 0.2	< 0.2	< 0.2	0.3	< 0.2
Chromium (Cr)	mg/kg	< 2	MCERTS	11	11	14	14	5
Copper (Cu)	mg/kg	< 4	MCERTS	56	54	61	32	21
Lead (Pb)	mg/kg	< 3	MCERTS	178	269	195	72	44
Mercury (Hg)	mg/kg	< 1	NONE	< 1	< 1	< 1	< 1	< 1
Nickel (Ni)	mg/kg	< 3	MCERTS	10	10	21	11	7
Selenium (Se)	mg/kg	< 3	NONE	< 3	< 3	< 3	< 3	< 3
Zinc (Zn)	mg/kg	< 3	MCERTS	90	142	121	69	16
Total Phenols (monohydric)	mg/kg	< 2	NONE	< 2	< 2	< 2	< 2	< 2
DRO (C10 - C24)	mg/kg	< 6	MCERTS	59			18	
Oil (C25 - C40)	mg/kg	< 6	MCERTS	64			31	
Mineral Oil (C10 - C40)	mg/kg	< 10	MCERTS	< 10			< 10	

Analytical results are expressed on a dry weight basis where samples are assisted-dried at less than 30°C
Subcontracted analysis (S)

QTS Environmental Ltd
Unit 1, Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Maidstone
Kent ME17 2JN
Tel : 01622 850410

Soil Analysis Certificate - Speciated PAHs						
QTS Environmental Report No: 17-66927	Date Sampled	06/11/17	06/11/17	06/11/17	06/11/17	06/11/17
TerraConsult Ltd	Time Sampled	None Supplied	None Supplied	None Supplied	None Supplied	None Supplied
Site Reference: Cypress Building	TP / BH No	HD1	HD2	RC01	RC02	RC03
Project / Job Ref: 3571	Additional Refs	None Supplied	None Supplied	None Supplied	None Supplied	None Supplied
Order No: PO-002069	Depth (m)	0.60	0.40	0.40	0.40	0.40
Reporting Date: 16/11/2017	QTSE Sample No	301224	301225	301226	301227	301228

Determinand	Unit	RL	Accreditation					
Naphthalene	mg/kg	< 0.1	MCERTS	0.38	0.26	0.19	< 0.1	< 0.1
Acenaphthylene	mg/kg	< 0.1	MCERTS	< 0.1	0.13	< 0.1	< 0.1	< 0.1
Acenaphthene	mg/kg	< 0.1	MCERTS	0.40	0.86	< 0.1	< 0.1	< 0.1
Fluorene	mg/kg	< 0.1	MCERTS	0.29	0.61	< 0.1	< 0.1	< 0.1
Phenanthrene	mg/kg	< 0.1	MCERTS	3.13	5.86	0.99	0.31	< 0.1
Anthracene	mg/kg	< 0.1	MCERTS	0.60	1.24	0.16	< 0.1	< 0.1
Fluoranthene	mg/kg	< 0.1	MCERTS	4.33	6.80	1.32	0.35	0.14
Pyrene	mg/kg	< 0.1	MCERTS	4.15	6.30	1.28	0.34	0.13
Benzo(a)anthracene	mg/kg	< 0.1	MCERTS	1.99	2.75	0.67	0.18	< 0.1
Chrysene	mg/kg	< 0.1	MCERTS	2.07	3.51	0.74	0.20	< 0.1
Benzo(b)fluoranthene	mg/kg	< 0.1	MCERTS	2.29	3.56	0.81	0.25	< 0.1
Benzo(k)fluoranthene	mg/kg	< 0.1	MCERTS	0.99	1.30	0.33	< 0.1	< 0.1
Benzo(a)pyrene	mg/kg	< 0.1	MCERTS	2.02	2.81	0.52	0.16	< 0.1
Indeno(1,2,3-cd)pyrene	mg/kg	< 0.1	MCERTS	1.19	1.75	0.33	< 0.1	< 0.1
Dibenz(a,h)anthracene	mg/kg	< 0.1	MCERTS	0.16	0.22	< 0.1	< 0.1	< 0.1
Benzo(ghi)perylene	mg/kg	< 0.1	MCERTS	1.11	1.61	0.31	0.12	< 0.1
Coronene	mg/kg	< 0.1	NONE	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Total Oily Waste PAHs	mg/kg	< 1	MCERTS	10.7	15.9	3.4	< 1	< 1
Total Dutch 10 PAHs	mg/kg	< 1	MCERTS	17.8	27.9	5.6	1.3	< 1
Total EPA-16 PAHs	mg/kg	< 1.6	MCERTS	25.1	39.6	7.7	1.9	< 1.6
Total WAC-17 PAHs	mg/kg	< 1.7	NONE	25.1	39.6	7.7	1.9	< 1.7

Analytical results are expressed on a dry weight basis where samples are assisted-dried at less than 30^{o}C

QTS Environmental Ltd
Unit 1, Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Maidstone
Kent ME17 2JN
Tel : 01622 850410

Soil Analysis Certificate - TPH CWG Banded						
QTS Environmental Report No: 17-66927	Date Sampled	06/11/17	06/11/17			
TerraConsult Ltd	Time Sampled	None Supplied	None Supplied			
Site Reference: Cypress Building	TP / BH No	HD1	RC02			
Project / Job Ref: 3571	Additional Refs	None Supplied	None Supplied			
Order No: PO-002069	Depth (m)	0.60	0.40			
Reporting Date: 16/11/2017	QTSE Sample No	301224	301227			

Determinand	Unit	RL	Accreditation					
Aliphatic >C5 - C6	mg/kg	< 0.01	NONE	< 0.01	< 0.01			
Aliphatic >C6 - C8	mg/kg	< 0.05	NONE	< 0.05	< 0.05			
Aliphatic >C8 - C10	mg/kg	< 2	MCERTS	< 2	< 2			
Aliphatic >C10 - C12	mg/kg	< 2	MCERTS	< 2	< 2			
Aliphatic >C12 - C16	mg/kg	< 3	MCERTS	< 3	< 3			
Aliphatic >C16 - C21	mg/kg	< 3	MCERTS	< 3	< 3			
Aliphatic >C21 - C34	mg/kg	< 10	MCERTS	< 10	< 10			
Aliphatic (C5 - C34)	mg/kg	< 21	NONE	< 21	< 21			
Aromatic >C5 - C7	mg/kg	< 0.01	NONE	< 0.01	< 0.01			
Aromatic >C7 - C8	mg/kg	< 0.05	NONE	< 0.05	< 0.05			
Aromatic >C8 - C10	mg/kg	< 2	MCERTS	< 2	< 2			
Aromatic >C10 - C12	mg/kg	< 2	MCERTS	< 2	< 2			
Aromatic >C12 - C16	mg/kg	< 2	MCERTS	2	< 2			
Aromatic >C16 - C21	mg/kg	< 3	MCERTS	17	< 3			
Aromatic >C21 - C35	mg/kg	< 10	MCERTS	38	< 10			
Aromatic (C5 - C35)	mg/kg	< 21	NONE	57	< 21			
Total >C5 - C35	mg/kg	< 42	NONE	57	< 42			

Analytical results are expressed on a dry weight basis where samples are assisted-dried at less than 30°C

QTS Environmental Ltd
Unit 1, Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Maidstone
Kent ME17 2JN
Tel : 01622 850410

Soil Analysis Certificate - BTEX / MTBE						
QTS Environmental Report No: 17-66927	Date Sampled	06/11/17	06/11/17			
TerraConsult Ltd	Time Sampled	None Supplied	None Supplied			
Site Reference: Cypress Building	TP / BH No	HD1	RC02			
Project / Job Ref: 3571	Additional Refs	None Supplied	None Supplied			
Order No: PO-002069	Depth (m)	0.60	0.40			
Reporting Date: 16/11/2017	QTSE Sample No	301224	301227			

Determinand	Unit	RL	Accreditation					
Benzene	ug/kg	< 2	MCERTS	< 2	< 2			
Toluene	ug/kg	< 5	MCERTS	< 5	< 5			
Ethylbenzene	ug/kg	< 2	MCERTS	< 2	< 2			
p & m-xylene	ug/kg	< 2	MCERTS	7	< 2			
o-xylene	ug/kg	< 2	MCERTS	4	< 2			
MTBE	ug/kg	< 5	MCERTS	< 5	< 5			

Analytical results are expressed on a dry weight basis where samples are assisted-dried at less than 30^{O}C

QTS Environmental Ltd
Unit 1, Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Maidstone
Kent ME17 2JN
Tel : 01622 850410

Waste Acceptance Criteria Analytical Certificate - BS EN 12457/2

QTS Environmental Report No: 17-66927		**Date Sampled**	06/11/17				**Landfill Waste Acceptance Criteria Limits**		
TerraConsult Ltd		**Time Sampled**	None Supplied				**Inert Waste Landfill**	**Stable Non-reactive HAZARDOUS waste in non-hazardous Landfill**	**Hazardous Waste Landfill**
Site Reference: Cypress Building		**TP / BH No**	HD1						
Project / Job Ref: 3571		**Additional Refs**	None Supplied						
Order No: PO-002069		**Depth (m)**	0.60						
Reporting Date: 16/11/2017		**QTSE Sample No**	301224						
Determinand	**Unit**	**MDL**							
TOC[MU]	%	< 0.1	1.5				3%	5%	6%
Loss on Ignition	%	< 0.01	3.10				--	--	10%
BTEX[MU]	mg/kg	< 0.05	< 0.05				6	--	--
Sum of PCBs	mg/kg	< 0.1	< 0.1				1	--	--
Mineral Oil[MU]	mg/kg	< 10	< 10				500	--	--
Total PAH[MU]	mg/kg	< 1.7	25.1				100	--	--
pH[MU]	pH Units	N/a	7.9				--	>6	--
Acid Neutralisation Capacity	mol/kg (+/-)	< 1	< 1				--	To be evaluated	To be evaluated
Eluate Analysis			**10:1 mg/l**			**Cumulative 10:1 mg/kg**	**Limit values for compliance leaching test using BS EN 12457-3 at L/S 10 l/kg (mg/kg)**		
Arsenic[U]			< 0.01			< 0.1	0.5	2	25
Barium[U]			< 0.02			< 0.2	20	100	300
Cadmium[U]			< 0.0005			< 0.005	0.04	1	5
Chromium[U]			< 0.005			< 0.05	0.5	10	70
Copper[U]			< 0.01			< 0.1	2	50	100
Mercury[U]			< 0.0005			< 0.01	0.01	0.2	2
Molybdenum[U]			0.003			0.03	0.5	10	30
Nickel[U]			< 0.007			< 0.07	0.4	10	40
Lead[U]			0.010			0.10	0.5	10	50
Antimony[U]			< 0.005			< 0.05	0.06	0.7	5
Selenium[U]			< 0.005			< 0.05	0.1	0.5	7
Zinc[U]			< 0.005			< 0.05	4	50	200
Chloride[U]			3			26	800	15000	25000
Fluoride[U]			1.5			15	**10**	150	500
Sulphate[U]			3			31	1000	20000	50000
TDS			72			720	4000	60000	100000
Phenol Index			< 0.01			< 0.1	1	-	-
DOC			7.9			78.9	500	800	1000
Leach Test Information									
Sample Mass (kg)			0.10						
Dry Matter (%)			86.5						
Moisture (%)			15.6						
Stage 1									
Volume Eluate L10 (litres)			0.89						

Results are expressed on a dry weight basis, after correction for moisture content where applicable
Stated limits are for guidance only and QTS Environmental cannot be held responsible for any discrepencies with current legislation
M Denotes MCERTS accredited test
U Denotes ISO17025 accredited test

QTS Environmental Ltd
Unit 1, Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Maidstone
Kent ME17 2JN
Tel : 01622 850410

Soil Analysis Certificate - Sample Descriptions	
QTS Environmental Report No: 17-66927	
TerraConsult Ltd	
Site Reference: Cypress Building	
Project / Job Ref: 3571	
Order No: PO-002069	
Reporting Date: 16/11/2017	

QTSE Sample No	TP / BH No	Additional Refs	Depth (m)	Moisture Content (%)	Sample Matrix Description
301224	HD1	None Supplied	0.60	13.5	Black sandy clay with coal
301225	HD2	None Supplied	0.40	14.6	Black sandy clay with coal
301226	RC01	None Supplied	0.40	16.1	Black sandy clay with brick and coal
301227	RC02	None Supplied	0.40	16.9	Black sandy clay with vegetation and coal
301228	RC03	None Supplied	0.40	17.1	Black sandy clay with coal

Moisture content is part of procedure E003 & is not an accredited test

Insufficient Sample I/S

Unsuitable Sample U/S

QTS Environmental Ltd
Unit 1, Rose Lane Industrial Estate
Rose Lane
Lenham Heath
Maidstone
Kent ME17 2JN
Tel : 01622 850410

4480

Soil Analysis Certificate - Methodology & Miscellaneous Information

QTS Environmental Report No: 17-66927

TerraConsult Ltd

Site Reference: Cypress Building

Project / Job Ref: 3571

Order No: PO-002069

Reporting Date: 16/11/2017

Matrix	Analysed On	Determinand	Brief Method Description	Method No
Soil	D	Boron - Water Soluble	Determination of water soluble boron in soil by 2:1 hot water extract followed by ICP-OES	E012
Soil	AR	BTEX	Determination of BTEX by headspace GC-MS	E001
Soil	D	Cations	Determination of cations in soil by aqua-regia digestion followed by ICP-OES	E002
Soil	D	Chloride - Water Soluble (2:1)	Determination of chloride by extraction with water & analysed by ion chromatography	E009
Soil	AR	Chromium - Hexavalent	Determination of hexavalent chromium in soil by extraction in water then by acidification, addition of 1,5 diphenylcarbazide followed by colorimetry	E016
Soil	AR	Cyanide - Complex	Determination of complex cyanide by distillation followed by colorimetry	E015
Soil	AR	Cyanide - Free	Determination of free cyanide by distillation followed by colorimetry	E015
Soil	AR	Cyanide - Total	Determination of total cyanide by distillation followed by colorimetry	E015
Soil	D	Cyclohexane Extractable Matter (CEM)	Gravimetrically determined through extraction with cyclohexane	E011
Soil	AR	Diesel Range Organics (C10 - C24)	Determination of hexane/acetone extractable hydrocarbons by GC-FID	E004
Soil	AR	Electrical Conductivity	Determination of electrical conductivity by addition of saturated calcium sulphate followed by electrometric measurement	E022
Soil	AR	Electrical Conductivity	Determination of electrical conductivity by addition of water followed by electrometric measurement	E023
Soil	D	Elemental Sulphur	Determination of elemental sulphur by solvent extraction followed by GC-MS	E020
Soil	AR	EPH (C10 – C40)	Determination of acetone/hexane extractable hydrocarbons by GC-FID	E004
Soil	AR	EPH Product ID	Determination of acetone/hexane extractable hydrocarbons by GC-FID	E004
Soil	AR	EPH TEXAS (C6-C8, C8-C10, C10-C12, C12-C16, C16-C21, C21-C40)	Determination of acetone/hexane extractable hydrocarbons by GC-FID for C8 to C40. C6 to C8 by headspace GC-MS	E004
Soil	D	Fluoride - Water Soluble	Determination of Fluoride by extraction with water & analysed by ion chromatography	E009
Soil	D	FOC (Fraction Organic Carbon)	Determination of fraction of organic carbon by oxidising with potassium dichromate followed by titration with iron (II) sulphate	E010
Soil	D	Loss on Ignition @ 450oC	Determination of loss on ignition in soil by gravimetrically with the sample being ignited in a muffle furnace	E019
Soil	D	Magnesium - Water Soluble	Determination of water soluble magnesium by extraction with water followed by ICP-OES	E025
Soil	D	Metals	Determination of metals by aqua-regia digestion followed by ICP-OES	E002
Soil	AR	Mineral Oil (C10 - C40)	Determination of hexane/acetone extractable hydrocarbons by GC-FID fractionating with SPE cartridge	E004
Soil	AR	Moisture Content	Moisture content; determined gravimetrically	E003
Soil	D	Nitrate - Water Soluble (2:1)	Determination of nitrate by extraction with water & analysed by ion chromatography	E009
Soil	D	Organic Matter	Determination of organic matter by oxidising with potassium dichromate followed by titration with iron (II) sulphate	E010
Soil	AR	PAH - Speciated (EPA 16)	Determination of PAH compounds by extraction in acetone and hexane followed by GC-MS with the use of surrogate and internal standards	E005
Soil	AR	PCB - 7 Congeners	Determination of PCB by extraction with acetone and hexane followed by GC-MS	E008
Soil	D	Petroleum Ether Extract (PEE)	Gravimetrically determined through extraction with petroleum ether	E011
Soil	AR	pH	Determination of pH by addition of water followed by electrometric measurement	E007
Soil	AR	Phenols - Total (monohydric)	Determination of phenols by distillation followed by colorimetry	E021
Soil	D	Phosphate - Water Soluble (2:1)	Determination of phosphate by extraction with water & analysed by ion chromatography	E009
Soil	D	Sulphate (as SO4) - Total	Determination of total sulphate by extraction with 10% HCl followed by ICP-OES	E013
Soil	D	Sulphate (as SO4) - Water Soluble (2:1)	Determination of sulphate by extraction with water & analysed by ion chromatography	E009
Soil	D	Sulphate (as SO4) - Water Soluble (2:1)	Determination of water soluble sulphate by extraction with water followed by ICP-OES	E014
Soil	AR	Sulphide	Determination of sulphide by distillation followed by colorimetry	E018
Soil	D	Sulphur - Total	Determination of total sulphur by extraction with aqua-regia followed by ICP-OES	E024
Soil	AR	SVOC	Determination of semi-volatile organic compounds by extraction in acetone and hexane followed by GC-MS	E006
Soil	AR	Thiocyanate (as SCN)	Determination of thiocyanate by extraction in caustic soda followed by acidification followed by addition of ferric nitrate followed by colorimetry	E017
Soil	D	Toluene Extractable Matter (TEM)	Gravimetrically determined through extraction with toluene	E011
Soil	D	Total Organic Carbon (TOC)	Determination of organic matter by oxidising with potassium dichromate followed by titration with iron (II) sulphate	E010
Soil	AR	TPH CWG (ali: C5- C6, C6-C8, C8-C10, C10-C12, C12-C16, C16-C21, C21-C34, aro: C5-C7, C7-C8, C8-C10, C10-C12, C12-C16, C16-C21, C21-C35)	Determination of hexane/acetone extractable hydrocarbons by GC-FID fractionating with SPE cartridge for C8 to C35. C5 to C8 by headspace GC-MS	E004
Soil	AR	TPH LQM (ali: C5-C6, C6-C8, C8-C10, C10 C12, C12-C16, C16-C35, C35-C44, aro: C5-C7, C7-C8, C8-C10, C10-C12, C12-C16, C16-C21, C21-C35, C35-C44)	Determination of hexane/acetone extractable hydrocarbons by GC-FID fractionating with SPE cartridge for C8 to C44. C5 to C8 by headspace GC-MS	E004
Soil	AR	VOCs	Determination of volatile organic compounds by headspace GC-MS	E001
Soil	AR	VPH (C6-C8 & C8-C10)	Determination of hydrocarbons C6-C8 by headspace GC-MS & C8-C10 by GC-FID	E001

D Dried
AR As Received

APPENDIX I

Laboratory Geotechnical Test Results

Laboratory Report

GEO Site & Testing Services Ltd

Contract Number: 37245

Client's Reference: **3571**

Report Date: **13-11-2017**

Client **Terra Consult Limited**
Unit 34,
Bold Business Centre,
Bold Lane,
Sutton,
St. Helens,
WA9 4TX

Contract Title: **Cypress Building**

For the attention of: **Jimmy Thorburn**

Date Received: **10-11-2017**

Date Commenced: **10-11-2017**

Date Completed: **13-11-2017**

Test Description	Qty
Moisture Content 1377 : 1990 Part 2 : 3.2 - * UKAS	2
4 Point Liquid & Plastic Limit (LL/PL) 1377 : 1990 Part 2 : 4.3 & 5.3 - * UKAS	2
Disposal of Samples on Project	1

Notes: **Observations and Interpretations are outside the UKAS Accreditation**
*** - denotes test included in laboratory scope of accreditation**
 # - denotes test carried out by approved contractor
@ - denotes non accredited tests

Approved Signatories:
Alex Wynn (Associate Director) - Ben Sharp (Contracts Manager) - Emma Sharp (Office Manager)
Paul Evans (Quality/Technical Manager) - Richard John (Advanced Testing Manager) - Sean Penn (Administrative Assistant)
Vaughan Edwards (Managing Director) - Wayne Honey (Administrative/Quality Assistant)

GEO Site & Testing Services Ltd
Unit 3-4, Heol Aur, Dafen Ind Estate, Dafen, Llanelli, Carmarthenshire SA14 8QN
Tel: 01554 784040 Fax: 01554 784041 info@gstl.co.uk gstl.co.uk

GSTL	LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX (BS 1377 : Part 2 : 1990 Method 5) DESCRIPTIONS	
Contract Number	**37245**	
Site Name	**Cypress Building**	

Hole Reference	Sample Number	Sample Type	Depth (m)			Descriptions
BHRC01		D	3.80	-		Brown silty CLAY
BHRC02		D	3.20	-		Brown slightly fine to coarse gravelly slightly sandy silty CLAY
				-		
				-		
				-		
				-		
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Operators	Checked	12/11/2017	Sean Penn	
RO/MH	Approved	13/11/2017	Ben Sharp	

UKAS TESTING 2788

GSTL	LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX (BS 1377 : Part 2 : 1990 Method 5)	
Contract Number	**37245**	
Site Name	**Cypress Building**	

Hole Reference	Sample Number	Sample Type	Depth (m)			Moisture Content %	Liquid Limit %	Plastic Limit %	Plasticity index %	Passing .425mm %	Remarks
BHRC01		D	3.80	-		22	42	24	18	100	CI Intermediate Plasticity
BHRC02		D	3.20	-		14	28	16	12	95	CL Low Plasticity
				-							
				-							
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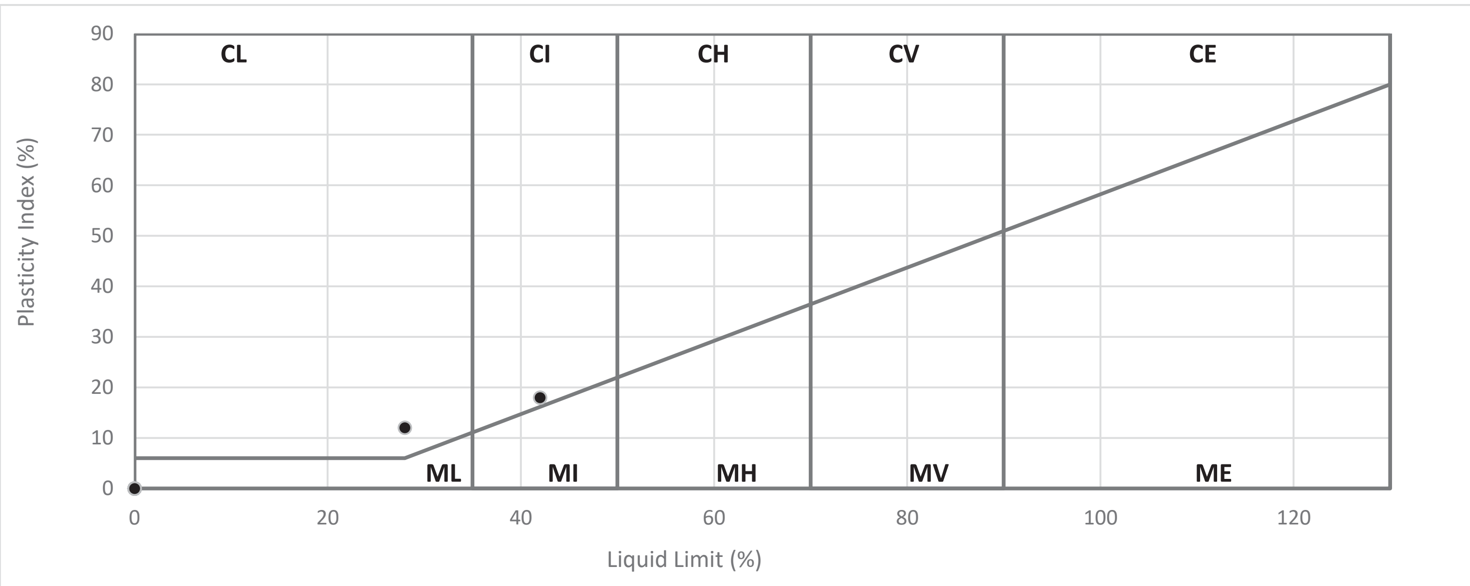
Symbols: NP : Non Plastic # : Liquid Limit and Plastic Limit Wet Sieved

PLASTICITY CHART FOR CASAGRANDE CLASSIFICATION
BS 5930:1999+A2:2010



Operators	Checked	12/11/2017	Sean Penn	
DB	Approved	13/11/2017	Ben Sharp	

Laboratory Report

GEO Site & Testing Services Ltd

Contract Number: 37231

Client's Reference: **3571**

Report Date: **14-11-2017**

Client **Terra Consult Limited**
Unit 34,
Bold Business Centre,
Bold Lane,
Sutton,
St. Helens,
WA9 4TX

Contract Title: **Cypress Building**

For the attention of: **Jimmy Thorburn**

Date Received: **09-11-2017**

Date Commenced: **09-11-2017**

Date Completed: **14-11-2017**

Test Description	Qty
Uniaxial Compressive Strength of Rock incl sample prep 54-165mm diameter cores ISRM Part 1 Methods For Rock Characterisation 1974-2006 - @ Non Accredited Test	2
Determination of Point Load Value Axial or Diametrical including WC ISRM Suggested Method for Point Load Strength 1974-2006 - * UKAS	13
Disposal of Samples on Project	1

Notes: **Observations and Interpretations are outside the UKAS Accreditation**
*** - denotes test included in laboratory scope of accreditation**
 # - denotes test carried out by approved contractor
@ - denotes non accredited tests

Approved Signatories:
Alex Wynn (Associate Director) - Ben Sharp (Contracts Manager) - Emma Sharp (Office Manager)
Paul Evans (Quality/Technical Manager) - Richard John (Advanced Testing Manager) - Sean Penn (Administrative Assistant)
Vaughan Edwards (Managing Director) - Wayne Honey (Administrative/Quality Assistant)

GEO Site & Testing Services Ltd
Unit 3-4, Heol Aur, Dafen Ind Estate, Dafen, Llanelli, Carmarthenshire SA14 8QN
Tel: 01554 784040 Fax: 01554 784041 info@gstl.co.uk gstl.co.uk

GSTL	Determination of Unconfined Compressive Strength ISRM Suggested Methods Vol 16, No. 2, pp. 135-140 1979	
Contract Number	37231	
Site Name	Cypress Building	
Sample Preperation	Sawing and Grinding	
Date Tested	14-11-17	

Hole Reference	Depth (m)			Diameter	Length	Initial Mass	Moisture Content	Bulk Density	Dry Density	Load Failure	Maximum Strength	Type of Failure
BHRC02	9.50		9.76	75	196	1808.6	9.20	2.09	1.91	50.6	11.5	Axial Splitting
BHRC02	11.95		12.22	73	141	1284.6	8.70	2.18	2.00	30.8	7.4	Axial Splitting

Key	Reported As
Diameter	mm
Length	mm
Initial Mass	g
Moisture Content	%
Bulk Density	Mg/m^3
Dry Density	Mg/m^3
Load Failure	kN
Maximum Strength	mpa

Operators	Checked	13-11-17	Ben Sharp	
JD	Approved	14-11-17	Paul Evans	

GSTL	Point Load Test Int. J. Rock Mech. Sci. & Geomech. Abstr. Vol. 22, No. 2, pp. 51 - 60, 1985.	
Contract Number	37231	
Site Name	Cypress Building	
Sample Type	Core	
Date Tested	14-11-17	

Hole Reference	Depth (m)			Test Type		Width	Platen Seperation	Failure Load	Equivalent Diameter	Point Load	Size Factor	Point Load Index	Moisture Content	Description	Angle Between Plane of Anisotropy & Core Axis	Type of Anisotropy (Bedding or Cleavage)
				d / a / b / i	l //											
BHRC01	6.85	-	9.95	d			73	0.50		0.09	1.19	0.11	13.1	SANDSTONE		
	7.86	-	7.96	d			72	0.49		0.09	1.18	0.11	9.4	SANDSTONE		
BHRC02	8.40	-	8.50	d			73	1.61		0.30	1.19	0.36	9.1	SANDSTONE		
	8.65	-	8.72	d			73	0.54		0.10	1.19	0.12	10.5	SANDSTONE		
		-		d			78	0.73		0.12	1.22	0.15	10.1	SANDSTONE		
		-		a		74	57	0.87	73.28	0.16	1.19	0.19	11.0	SANDSTONE		
		-		a		73	57	1.06	72.79	0.20	1.18	0.24	10.3	SANDSTONE		
	9.20	-	9.30	d			73	0.88		0.16	1.19	0.20	9.1	SANDSTONE		
	9.90	-	10.00	d			73	1.38		0.26	1.19	0.31	9.8	SANDSTONE		
	10.00	-	10.70	d			73	0.66		0.12	1.19	0.15	9.3	SANDSTONE		
	13.10	-	13.25	d			57	2.00		0.62	1.06	0.65	9.7	SANDSTONE		
BHRC03	5.65	-	5.72	d			72	0.25		0.05	1.18	0.06	10.9	SANDSTONE		
	7.65	-	7.75	d			73	1.05		0.20	1.19	0.23	9.2	SANDSTONE		
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Key	Reported As
Width	(W) mm
Platen Separation	(D) mm
Failure Load	(P) kN
Equivalent Diameter	(De) mm
Point Load	(Is) MPa
Size Factor	(F)
Point Load Index	(Is(50)) MPa
Moisture Content	%
Description	SC

Operators	Checked	13-11-17	Ben Sharp	
JD	Approved	14-11-17	Paul Evans	

APPENDIX J

Summary of Chemical Test Results of Soil Samples

TerraConsult

Site: Cypress Building

CHEMICAL STATISTICAL ANALYSIS - based on CLEA v1.06 (Sandy Loam 1% SOM)

Job No: 3571

Analyte	Limit of Detection	Statistical Analysis										SGV / GAC Statistical Results			SGV / GAC Criteria Source		pC4SL Screening Criteria		pC4SL Screening Criteria		pC4SL Screening Criteria		pC4SL Criteria Source		LQM/CIEH S4UL Screening Criteria		LQM/CIEH S4UL Screening Criteria		LQM/CIEH S4UL Criteria Source	
		TerraConsult	TerraConsult	TerraConsult	TerraConsult	TerraConsult																								
		Black sandy clay with coal	Black sandy clay with coal	Black sandy clay with brick and coal	Black sandy clay with vegetation and coal	Black sandy clay with coal	n	Standard Deviation	Minimum	Average	Maximum	Maximum	Commercial & Industrial Tier 1 Screening Threshold	Pass/ Fail	Source of Screening Criteria	Source of Toxicological Data	Commercial	Pass / Fail	POS(resi)	Pass / Fail	POS(park)	Pass / Fail	Source of Screening Criteria	Source of Toxicological Data	Commercial	Pass / Fail	POS(resi)	Pass / Fail	Source of Screening Criteria	Source of Toxicological Data
		06/11/17	06/11/17	06/11/17	06/11/17	06/11/17																								
		HD1	HD2	RC01	RC02	RC03																								
		0.60	0.40	0.40	0.40	0.40																								
Stone Content	<0.1 %							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asbestos Screen	Positive / Negative	Negative	Negative	Negative	Negative	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metals																														
Arsenic (total)	<2 mg/kg	9.0	15.0	19.0	7.0	9.0	5	5.02	7	12	19	19.00	635	Pass	SC050021*	SC050021	640	Pass	79	Pass	170	Pass	CLEA v1.06	Defra 2014	640	Pass	79	Pass	CLEA v1.06	LQM/CIEH 2014
Cadmium (total)	<0.2 mg/kg	0.2	0.2	0.2	0.3	0.2	5	0.04	0	0	0	0.30	230	Pass	SC050021*	SC050021	420	Pass	220	Pass	560	Pass	CLEA v1.06	Defra 2014	190	Pass	120	Pass	CLEA v1.06	LQM/CIEH 2014
Chromium (total) (III for S4ULs)	<2 mg/kg	11	11	14	14	5	5	3.67	5	11	14	14.00	30400	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	8600	Pass	1500	Pass	CLEA v1.06	LQM/CIEH 2014
Copper (total)	<4 mg/kg	56	54	61	32	21	5	17.34	21	45	61	61.00	71700	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	68000	Pass	12000	Pass	CLEA v1.06	LQM/CIEH 2014
Lead (total)	<3 mg/kg	178.0	269.0	195.0	72.0	44.0	5	92.57	44	152	269	269.00	N/A	-	-	-	6000	Pass	760	Pass	1400	Pass	CLEA v1.06	Defra 2014	-	-	-	-	-	-
Mercury (total inorganic)	<1 mg/kg	1	1	1	1	1	5	0.00	1	1	1	1.00	3640	Pass	SC050021*	SC050021	-	-	-	-	-	-	-	-	1100	Pass	120	Pass	CLEA v1.06	LQM/CIEH 2014
Nickel (total)	<3 mg/kg	10.0	10.0	21.0	11.0	7.0	5	5.36	7	12	21	21.00	840	Pass	CLEA v1.071	EFSA	-	-	-	-	-	-	-	-	980	Pass	230	Pass	CLEA v1.06	LQM/CIEH 2014
Selenium (total)	<3 mg/kg	3	3	3	3	3	5	0.00	3	3	3	3.00	13000	Pass	SC050021*	SC050021	-	-	-	-	-	-	-	-	120000	Pass	1100	Pass	CLEA v1.06	LQM/CIEH 2014
Zinc (total)	<3 mg/kg	90	142	121	69	16	5	48.87	16	88	142	142.00	662000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	730000	Pass	81000	Pass	CLEA v1.06	LQM/CIEH 2014
Inorganic																														
pH Value	pH Units	7.9	7.9	7.5	7.4	7.6	5	0.23	7.4	8	7.9	7.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyanide (total)	<2 mg/kg	2.0	2.0	2.0	2.0	2.0	5	0.00	2	2	2.0	2.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride (2:1)	<0.5 mg/l	10.3			11.5		2	0.85	10.3	11	11.5																			
Sulphate (2:1)	<0.01 g/l	0.03	0.02	0.02	0.01	0.01	5	0.01	0.01	0	0	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulphate (total)	<200 mg/kg	293			276		2	12.02	276.00	285	293	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Organic																														
Soil Organic Matter	<0.1 %	2.6			4.1		2	1.06	2.6	3	4.10	4.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	<0.1 %	1.5	1.9	1.6	2.4	2.3	5	0.40	1.5	2	2.40	2.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cresol	0.1 mg/kg						0	#DIV/0!	0	#DIV/0!	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenol (Total Monohydric)	<2 mg/kg	2.0	2.0	2.0	2.0	2.0	5	0.00	2	2	2.0	2.00	24200	Pass	CLEA v1.06	SC050021	-	-	-	-	-	-	-	-	760	Pass	760	Pass	CLEA v1.06	LQM/CIEH 2014
PAH																														
Naphthalene	<0.1 mg/kg	0.4	0.3	0.2	0.1	0.1	5	0.11	0.1	0	0.4	0.38	200	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	190	Pass	4900	Pass	CLEA v1.06	LQM/CIEH 2014
Acenaphthylene	<0.1 mg/kg	0.1	0.1	0.1	0.1	0.1	5	0.00	0.1	0	0.1	0.13	84000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	83000	Pass	15000	Pass	CLEA v1.06	LQM/CIEH 2014
Acenaphthene	<0.1 mg/kg	0.4	0.9	0.1	0.1	0.1	5	0.32	0.1	0	0.9	0.86	8500	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	84000	Pass	15000	Pass	CLEA v1.06	LQM/CIEH 2014
Fluorene	<0.1 mg/kg	0.3	0.6	0.1	0.1	0.1	5	0.21	0.1	0	0.6	0.61	64000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	63000	Pass	9900	Pass	CLEA v1.06	LQM/CIEH 2014
Phenanthrene	<0.1 mg/kg	3.1	5.9	1.0	0.3	0.1	5	2.42	0.1	2	5.9	5.86	22000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	22000	Pass	3100	Pass	CLEA v1.06	LQM/CIEH 2014
Anthracene	<0.1 mg/kg	0.6	1.2	0.2	0.1	0.1	5	0.48	0.1	0	1.2	1.24	530000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	520000	Pass	74000	Pass	CLEA v1.06	LQM/CIEH 2014
Fluoranthene	<0.1 mg/kg	4.3	6.8	1.3	0.4	0.1	5	2.89	0.1	3	6.8	6.80	23000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	23000	Pass	3100	Pass	CLEA v1.06	LQM/CIEH 2014
Pyrene	<0.1 mg/kg	4.2	6.3	1.3	0.3	0.1	5	2.69	0.1	2	6.3	6.30	54400	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	54000	Pass	7400	Pass	CLEA v1.06	LQM/CIEH 2014
Benz(a)anthracene	<0.1 mg/kg	2.0	2.8	0.7	0.2	0.1	5	1.17	0.1	1	2.8	2.75	92	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	170	Pass	29	Pass	CLEA v1.06	LQM/CIEH 2014
Chrysene	<0.1 mg/kg	2.1	3.5	0.7	0.2	0.1	5	1.45	0.1	1	3.5	3.51	138	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	350	Pass	57	Pass	CLEA v1.06	LQM/CIEH 2014
Benzo(b)fluoranthene	<0.1 mg/kg	2.3	3.6	0.8	0.3	0.1	5	1.48	0.1	1	3.6	3.56	100	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	44	Pass	7.1	Pass	CLEA v1.06	LQM/CIEH 2014
Benzo(k)fluoranthene	<0.1 mg/kg	1.0	1.3	0.3	0.1	0.1	5	0.54	0.1	1	1.3	1.30	140	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	1200	Pass	190	Pass	CLEA v1.06	LQM/CIEH 2014
Benzo(a)pyrene	<0.1 mg/kg	2.0	2.8	0.5	0.2	0.1	5	1.22	0.1	1	2.8	2.81	14	Pass	CLEA v1.06	LQM 2009	77	Pass	10	Pass	21	Pass	CLEA v1.06	Defra 2014	35	Pass	5.7	Pass	CLEA v1.06	LQM/CIEH 2014
Indeno(123cd)pyrene	<0.1 mg/kg	1.2	1.8	0.3	0.1	0.1	5	0.73	0.1	1	1.8	1.75	60	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	500	Pass	82	Pass	CLEA v1.06	LQM/CIEH 2014
Dibenzo(ah)anthracene	<0.1 mg/kg	0.2	0.2	0.1	0.1	0.1	5	0.04	0.1	0	0.2	0.22	13	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	3.5	Pass	0.57	Pass	CLEA v1.06	LQM/CIEH 2014
Benzo(ghi)perylene	<0.1 mg/kg	1.1	1.6	0.3	0.1	0.1	5	0.67	0.1	1	1.6	1.61	650	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	3900	Pass	640	Pass	CLEA v1.06	LQM/CIEH 2014
Coronene	<0.1 mg/kg	0.1	0.1	0.1	0.1	0.1	5	0.00	0.1	0	0.1	0.13	1900	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Oily Waste PAHs	<1 mg/kg	10.7	15.9	3.4	1.0	1.0	5	6.63	1.0	6	15.9	15.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Dutch 10 PAHs	<1 mg/kg	17.8	27.9	5.6	1.3	1.0	5	11.78	1.0	11	27.9	27.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total EPA-16 PAHs	<1.6 mg/kg	25.1	39.6	7.7	1.9	1.6	5	16.67	1.6	15	39.6	39.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total WAC-17 PAHs	<1.7 mg/kg	25.1	39.6	7.7	1.9	1.7	5	16.65	1.7	15	39.6	39.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BTEX Benzene	<0.002 mg/kg	0.002			0.002		2	0.00	0.002	0	0.002	0.00	43.6	Pass	CLEA v1.06	SC050021	100	Pass	140	Pass	110	Pass	CLEA v1.06	Defra 2014	27	Pass	72	Pass	CLEA v1.06	LQM/CIEH 2014
Toluene	<0.005 mg/kg	0.005			0.005		2	0.00	0.005	0	0.005	0.01	86200	Pass	CLEA v1.06	SC050021	-	-	-	-	-	-	-	-	56000	Pass	56000	Pass	CLEA v1.06	LQM/CIEH 2014
Ethyl Benzene	<0.002 mg/kg	0.002			0.002		2	0.00	0.002	0	0.002	0.00	25000	Pass	CLEA v1.06	SC050021	-	-	-	-	-	-	-	-	5700	Pass	24000	Pass	CLEA v1.06	LQM/CIEH 2014
Xylene (o)	<0.002 mg/kg	0.004			0.002		2	0.00	0.002	0	0.004	0.00	10,700	Pass	CLEA v1.06	SC050021	-	-	-	-	-	-	-	-	6600	Pass	41000	Pass	CLEA v1.06	LQM/CIEH 2014
Xylene (m)	<0.002 mg/kg	0.004			0.002		2	0.00	0.002	0	0.004	0.00	9,990	Pass	CLEA v1.06	SC050021	-	-	-	-	-	-	-	-	6200	Pass	41000	Pass	CLEA v1.06	LQM/CIEH 2014
Xylene (p)	<0.002 mg/kg	0.004			0.002		2	0.00	0.002	0	0.004	0.00	9,630	Pass	CLEA v1.06	SC050021	-	-	-	-	-	-	-	-	5900	Pass	41000	Pass	CLEA v1.06	LQM/CIEH 2014
MTBE	<0.005 mg/kg	0.005			0.005		2	0.00	0.005	0	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum Hydrocarbons																														
DRO (C_{10} - C_{28})	<6 mg/kg	59			18		2	28.99	18	39	59	59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil (C_{25} - C_{40})	<6 mg/kg	64			31		2	23.33	31	48	64	64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mineral Oil (C_{10} - C_{40})	<10 mg/kg	10			10		2	0.00	10	10	10	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TPH (C_6 - C_{40})	<10 mg/kg						0	#DIV/0!	0	#DIV/0!	0.0	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aliphatic >C_5 - C_6	<0.01 mg/kg	0.01			0.01		2	0.00	0.01	0	0.0	0.01	3400	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	3200	Pass	570000	Pass	CLEA v1.06	LQM/CIEH 2014
Aliphatic >C_6 - C_8	<0.05 mg/kg	0.05			0.05		2	0.00	0.05	0	0.1	0.05	8300	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	7800	Pass	600000	Pass	CLEA v1.06	LQM/CIEH 2014
Aliphatic >C_8 - C_{10}	<2 mg/kg	2			2		2	0.00	2	2	2.0	2.00	2100	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	2000	Pass	13000	Pass	CLEA v1.06	LQM/CIEH 2014
Aliphatic >C_{10} - C_{12}	<2 mg/kg	2			2		2	0.00	2	2	2.0	2.00	10000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	9700	Pass	13000	Pass	CLEA v1.06	LQM/CIEH 2014
Aliphatic >C_{12} - C_{16}	<3 mg/kg	3			3		2	0.00	3	3	3.0	3.00	61000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	59000	Pass	13000	Pass	CLEA v1.06	LQM/CIEH 2014
Aliphatic >C_{16} - C_{21}	<3 mg/kg	3			3		2	0.00	3	3	3.0	3.00	1600000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	160000	Pass	250000	Pass	CLEA v1.06	LQM/CIEH 2014
Aliphatic >C_{21} - C_{35}	<10 mg/kg	10			10		2	0.00	10	10	10.0	10.00	1600000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	160000	Pass	250000	Pass	CLEA v1.06	LQM/CIEH 2014
Total Aliphatic >C_5 - C_{35}	<21 mg/kg	21			21		2	0.00	21	21	21.0	21.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aromatic C_5 - C_7	<0.01 mg/kg	0.01			0.01		2	0.00	0	0	0.01	0.01	28000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	26000	Pass	56000	Pass	CLEA v1.06	LQM/CIEH 2014
Aromatic C_7 - C_8	<0.05 mg/kg	0.05			0.05		2	0.00	0	0	0.05	0.05	59000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	56000	Pass	56000	Pass	CLEA v1.06	LQM/CIEH 2014
Aromatic >C_8 - C_{10}	<2 mg/kg	2.00			2		2	0.00	2	2	2.0	2.00	3700	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	3500	Pass	5000	Pass	CLEA v1.06	LQM/CIEH 2014
Aromatic >C_{10} - C_{12}	<2 mg/kg	2.00			2		2	0.00	2	2	2.0	2.00	17000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	16000	Pass	5000	Pass	CLEA v1.06	LQM/CIEH 2014
Aromatic >C_{12} - C_{16}	<2 mg/kg	2.00			2		2	0.00	2	2	2.0	2.00	36000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	36000	Pass	5100	Pass	CLEA v1.06	LQM/CIEH 2014
Aromatic >C_{16} - C_{21}	<3 mg/kg	17			3		2	9.90	3	10	17.0	17.00	28000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	28000	Pass	3800	Pass	CLEA v1.06	LQM/CIEH 2014
Aromatic >C_{21} - C_{35}	<10 mg/kg	38			10		2	19.80	10	24	38.0	38.00	28000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	28000	Pass	3800	Pass	CLEA v1.06	LQM/CIEH 2014
Aromatic >C_{35} - C_{44}	<10 mg/kg						0	#DIV/0!	0	#DIV/0!	0.0	0.00	28000	Pass	CLEA v1.06	LQM 2009	-	-	-	-	-	-	-	-	28000	Pass	3800	Pass	CLEA v1.06	LQM/CIEH 2014
Total Aromatic >C_5 - C_{35}	<21 mg/kg	57			21		2	25.46	21	39	57.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Below Detection Limits.
Exceeded GAC/SGV
Exceeded pC4SL / S4ULs
Assessment criteria for pH, Sulphide and Sulphate are not based on human health. Sulphate criteria assumes DS-1 ACEC classification for concrete.

Notes

1. Generic Qualitative Assessment Criteria have been used where appropriate based on the current CLEA 1.06 Model (default values, sandy loam 1%SOM). Where no CLEA generic guideline value has been calculated no assessment has been made. The results presented show maximum and mean concentrations. This is to provide a reasonable prediction of the range of data rather than to provide any detailed statistical appraisal.
2. Results lower than detection limit are shaded in grey.
3. When the test result is recorded as being less than the detection limit, the result used for the analysis is the detection limit.
4. Cyanide (total)*, in the absence of a GQAC based on current CLEA 1.06 Model, the Atrisk Soil Value for Cyanide (free) has been used.
5. For metals, where an SGV has been published, this value has been used. Note that the published SGVs do not include the residential without plant uptake scenario. CLEA v1.06 has therefore been used to derive GACs for this scenario. For organics, CLEA v1.06 has been used (as the SGV assumes 6% SOM)
6. pC4SL based on adjusted toxicology and expsoure assumptions
7. pC4SL for benzene assumes 6% SOM

APPENDIX K

Current Guidance for Ground Gas Risk Assessment

Current Guidance for Ground Gas Risk Assessment

Origin of Ground and Landfill Gases

When carrying out a ground gas risk assessment for permanent ground gases (e.g. methane and carbon dioxide), the origin or source of the gases is important as potential risks will vary depending on the source. This Appendix relates to the risk of the two main ground gases of concern: methane and carbon dioxide, and does not apply to other ground gases (e.g. radon or vapours from hydrocarbon spills). Methane and carbon dioxide are major constituents of landfill gas but can also occur from a variety of anthropogenic and natural sources, as summarised in Table G1 below:

Table G1. Potential Sources of Ground Gases

Gas	Source	Comments
Landfill Gas	Anaerobic decomposition of degradable waste within landfill sites. Typically 60% methane and 40% carbon dioxide during methanogenic phase.	Composition varies over time, particularly in early stages. Contains a range of minor constituents (particularly carbon monoxide and hydrogen sulphide).
Landfill Associated Gases	- Anaerobic degradation of leachate external to the site; - Degassing of dissolved gases in groundwater; - Evolution of gases following interaction between leachate and groundwater	Can result in secondary (external) production of methane or carbon dioxide.
Made Ground	Anaerobic degradation of organic components	Very variable depending on source
Sewer Gas, Cess Pits	Anaerobic degradation of organic components of sewage producing methane and carbon dioxide.	Often characterised by hydrogen sulphide odour.
Mains Gas	Leakage from underground pipework or storage tanks. Mainly methane but often contains higher alkanes.	An odouriser is added to permit detection of leaks. Typically 90% CH_4, but 1 to 27% C_2-C_4 alkanes, May also contain other trace gases e.g. CO, helium and CO_2 (from degradation of CH_4 in the ground).
Other Anthropogenic Sources	- Degradation of leaked or spilled hydrocarbons or other industrial chemicals; - Anaerobic degradation of organic contaminants in groundwaters (e.g. silage liquor); - Reactions between monitoring well construction components and environment; - Burial grounds/cemeteries.	Hydrocarbon spillages often have an 'oily' odour. Fuel spillages common – Petrol or Diesel and can contain a wide range of VOC's. Can degrade to produce methane / carbon dioxide.
Alluvium / Marsh / Peat Gas	Anaerobic microbial degradation of organic material (usually waterlogged vegetation / peat). Often associated with the presence of alluvial deposits or dredgings.	
Geogenic Gas	Natural seepages of carbon dioxide and hydrocarbon gases derived from geologic sources such as coal seams and deep oil / gas source formations. Can be present in solution in groundwaters.	Methane most common but can contain carbon dioxide and higher alkanes.
Mine Gases	Various types. Most common is "fire damp" with high methane, produced by the desorption of gas trapped in coal. "Black damp" (Stythe gas) with high carbon dioxide and denser than air. "White damp" is high in carbon monoxide.	Methane most common. Can contain higher alkanes, carbon dioxide and carbon monoxide. Often low in oxygen.
Natural Shallow Ground Gas	Various types - high carbon dioxide formed by subsurface aerobic activity leading to depleted oxygen and elevated carbon dioxide; - chemical degradation of rocks (e.g. carbonates) producing carbon dioxide; - carbon dioxide production in root zone of soils by plants.	Gases can be emitted from ground under falling barometric pressure conditions.

This Appendix concentrates on the assessment of risk from methane and carbon dioxide. This Appendix does not provide guidance for the assessment of risk when other gases are present due to 'Other Sources' from the above table (particularly organic compounds such as BTEX and VOC's or for the risk from radon or hydrogen sulphide).

To determine the origin of the gas a range of factors must be considered together, including;

1. Proximity of likely sources;
2. Ground conditions (geology, hydrogeology, anthropogenic pathways etc);
3. Properties of gases present including:
   - Chemical composition;
   - Physical properties;
   - Ratios of components e.g. methane : carbon dioxide.
4. Timeframe of activities such as infilling periods, capping works, installation of gas control systems etc.

Identification of the originating source may be problematic given that there may be more than one source present and trace gas analysis may be required. Identification of the sources of the gases encountered during monitoring is usually carried out through a process of eliminating the most unlikely potential sources (given the site setting) and selecting those which are the more likely candidates.

Hazards Associated with Presence of Ground Gases

Methane gas is combustible and potentially explosive. When the concentration of methane in air is between the limits of 5.0%v/v and 15.0%v/v an explosive mixture is formed. The Lower Explosive Limit (LEL) of methane is 5.0%v/v, which is equivalent to 100% LEL. The 15.0%v/v limit is known as the Upper Explosive Limit (UEL), but concentrations above this level cannot be assumed to represent safe concentrations. Further, the LEL and UEL will vary (up and down) depending upon the proportion of other gases (including oxygen). However, the fact that methane is a colourless, odourless gas means that there is no simple indicator of the presence of the gas until such a time as explosive limits are reached and an incident occurs. Methane is lighter than air and has a low toxicity. However, at high concentrations it can result in asphyxiation due to oxygen displacement.

Carbon dioxide is a colourless, odourless gas, which, although non-flammable, is both toxic and an asphyxiant. As carbon dioxide is denser than air, it will collect in low points and depressions. The UK Health & Safety Executive (HSE) has published information relating to concentrations of carbon dioxide that humans may be exposed to, which uses concentrations contained in the Control of Substances Hazardous to Health Regulations 2002 (as amended). These are the Long Term Occupational Exposure Limit (LTOEL, 8 hour period) and the Short Term Occupational Exposure Limit (STOEL, 15 minute period), which are 0.5% and 1.5% carbon dioxide, respectively.

Parameters Influencing the Rate of Ground Gas Production

Figure G2 is taken from EA guidance document LFTGN 03 illustrates typical ground gas generation curves from biodegradable materials:

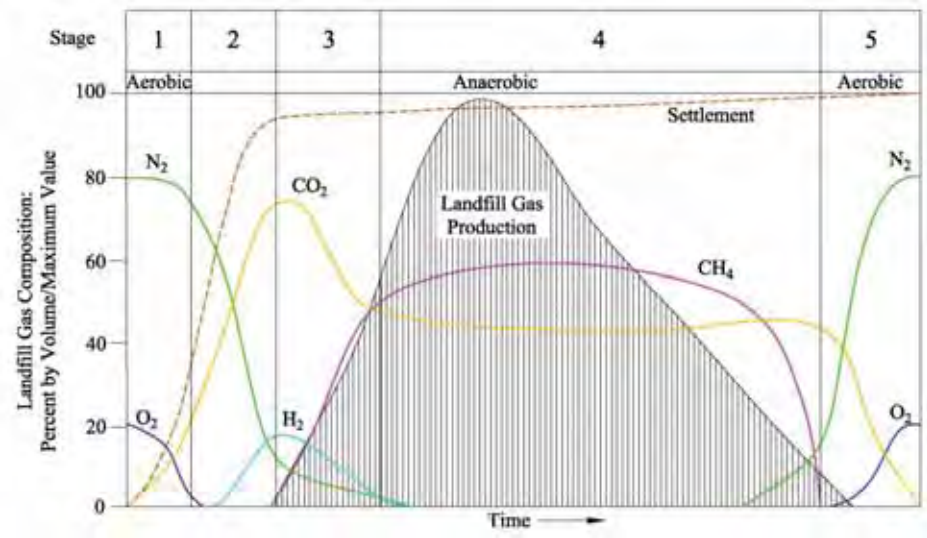


Figure G2. Idealised Representation of Landfill Gas Generation.

The production of methane and carbon dioxide at a landfill site may be expected to be considerable and ongoing. Concentrations of methane will eventually decrease, followed by concentrations of carbon dioxide, but the duration and rate of gas production can vary markedly between sites. Five distinct phases of gas production occur during the process which are, in order of event (as marked on Figure G2), as follows:

1. An aerobic phase involving oxygen depletion and temperature increase through aerobic respiration;
2. The establishment of anaerobic conditions and the evolution of carbon dioxide and hydrogen through acidogenic activity;
3. Commencement of methanogenic activity; the establishment of populations of methanogenic bacteria;
4. A phase of stable methanogenic activity, which may go on for many tens of years;
5. A phase of decreasing methanogenic activity, representing depletion of the organic material and a return to aerobic conditions.

The time scale for the return to the normal ground gas concentrations will be highly variable, depending upon the types and quantities of materials present. In addition, the optimum parameters influencing the rate of decomposition and ground gas production within the ground at a site are as follows:

- High water content with adequate rainfall and water infiltration to provide moisture content between approximately 20 to 26%;
- Conditions that either are or are very close to anaerobic;
- High proportion of biodegradable materials;
- A pH between 6.5 and 8.5, ideally verging slightly on the acidic between pH 6 to 7;
- Temperature between 25°C and 55°C;
- The ratio of the biochemical and chemical oxygen demands (BOD:COD);
- High permeability;
- Small particle size, as finer subsurface materials possess a greater surface area to provide a growing ‘face’ for the micro-organisms but high fines levels reduces permeability and reduces decomposition rate.

For this reason, it is vital that sources of methane and carbon dioxide are identified prior to the commencement of any work on a construction site, and that the ground gas regime is characterised at the worst temporal conditions a site may experience. From this, a risk assessment is carried out to identify the risk at the site from ground gases so that suitable protection measures can be designed and incorporated into a development to prevent a dangerous build-up of gas occurring.

Factors Influencing the Migration and Behaviour of Ground Gases

There are many factors that influence the migration of ground gases which can affect the risk from a gassing source:

- driving force – pressure differential along a pathway, diffusion and dissolved in solution;
- meteorological conditions – short term and seasonal conditions including atmospheric pressure changes (e.g. rapidly falling pressure causes gas to expand increasing emission rates), rainfall, frozen ground and thawing, temperature;
- geological and groundwater conditions – these can have the over-riding influence on the direction/pathways and quantity of migrating gas;
- anthropogenic influences – man-made pathways include mine shafts, service runs/drains, foundation piles, underground voids/pits/basements, foundation/building design/construction

Guidance Documents

Currently in the UK, there are no statutory threshold limits for hazardous gases in the ground as site specific variables mean that standard threshold values cannot be applied. The published guidance relating to development of sites where methane and carbon dioxide are present has been produced in response to building projects on or close to landfill sites, as both gases are principal constituents of landfill gas. Much of the historic guidance that has been produced on gas risk assessment focused on landfill sites and as a result there has previously been a lack of clarity when relating the process to gas conditions on non-landfill sites.

Statutory guidance regarding methane in the ground has previously taken a limiting concentration of 1.0 % by volume methane (equal to 20% of the lower explosive limit of methane in air) above which necessary actions will be appropriate. For carbon dioxide the limiting recommended trigger was 1.5 % by volume (the Long Term Exposure Limit for carbon dioxide). Above these concentrations the Building Regulations Approved Document C (1992) stated that consideration should be given to whether actions may be appropriate, whilst more specific solutions would be likely to be necessary at concentrations greater than 5% by volume of carbon dioxide (Building Regulations Approved Document C, 1992). However, the latest fully revised version of Approved Document C (DoE, 2004) no longer endorses this approach and instead requires the use of a risk-based approach in interpreting the findings of a gas monitoring survey. Further, the latest EA documentation on landfill gas (LFTGN 03, 2004) continues to sanction the use of a risk-based approach through a structured approach to the assessment of ground gases and links with the risk assessment process outlined within CLR 11 for soil contaminants.

With the above in mind, recent guidance has been produced in 2006 and 2007 with the aim of providing up to date advice in relation to residential and commercial development. The guidance does not address issues associated with gas derived from landfills, for this refer to *"Guidance on the Management of Landfill Gas"* (Environment Agency 2004) for an overview.

Recent guidance relevant to gas assessments for residential and commercial development includes;

- **Wilson *et al.* (CIRIA C665, December 2007) *"Assessing Risks Posed by Hazardous Ground Gases for Buildings."***

  This document provides up to date advice on all aspects of ground gas risk assessment such as investigation, monitoring programmes, data collection and interpretation. The guidance presents separate methodologies for the characterisation of:

  - **All development types except low rise housing with gardens and for Low Rise Buildings without a 150mm void** (Situation A) (Table 8.5 CIRIA C665)

  and;

  - **Low rise housing with gardens with a 150mm ventilated sub-floor void** (Situation B) (Table 8.7 CIRIA C665)
    (See below for further explanation of the methods of characterisation)

- **Boyle and Witherington (NHBC / RSK Group, Report 10627-R01(04) January 2007) *"Guidance on the Evaluation of Development Proposals on Sites where Methane and Carbon Dioxide are Present."***
  This document presents the "Traffic Lights System" detailed below and is relevant only for low rise properties (e.g. bungalows and town houses) that have a ventilated sub-floor void (i.e. Situation B as described in CIRIA C665).

- **Wilson and Card (CIEH, expected 2011) *"Ground Gas Handbook for Designers and Regulators"***
  This document is expected to provide practical guidance on ground gas assessments and the design and evaluation of protection measures.

- **British Standard (BS 8485, June 2015) *"Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings"***
  This document provides an overview of gas characterisation and assessment. The Standard is intended to be used by designers of gas protection measures and regulators involved in the assessment of design solutions. The Standard provides a framework in line with CLR11 allowing designers to judge the adequacy of ground gas and related site investigation data. The document provides an approach to determine appropriate ground gas parameters that can be used to identify a range of possible construction solutions mitigating against the presence of ground gas on a development site.

Each of these documents continues to highlight the importance of, and give further guidance towards, carrying out a tiered risk-based decision-making process in accord with government policy on dealing with contamination from historic or natural sources and highlight the importance of the Conceptual Model in site characterisation. These documents also stress the importance that the assessor should be confident that the ground gas monitoring results are representative of the likely worse case ground gas regime on a site and that the data collected from the site is sufficient. With this in mind, CIRIA C665 sets out ideal monitoring periods as below.

Idealised Frequency and Period of Monitoring (after Table 5.5a and 5.5b, CIRIA C665)						
		Generation Potential of Source				
		Very Low	Low	Moderate	High	Very High
Sensitivity of Development	Low (Commercial)	4/1	6/2	6/3	12/6	12/12
	Moderate (Flats)	6/2	6/3	9/6	12/12	24/24
	High (Residential with Gardens)	6/3	9/6	12/6	24/12	24/24

Notes

1. First number is the number of readings and the second is the minimum period in months (e.g. 6/2 – six sets of readings over two months).

2. At least two sets of readings must be at low (preferably under 1,000 mb) and falling pressure.

3. High sensitivity end use on high or very high hazard site will not normally be acceptable unless the source is treated to reduce gassing potential.

Before the latest guidance, good practice for site characterisation had been based upon the method proposed by Wilson and Card (1999). CIRIA C665 (2007) effectively supersedes Wilson and Card (1999) and includes a modified version of the Wilson and Card method (Tables 8.5, 8.6 and Box 8.1). Gas concentrations and flow rates for either methane and/or carbon dioxide measured at a site to 'Characteristic Situations.' Appropriate protection measures are selected from Table 8.6 (if using modified Wilson & Card method) and from Box 8.4 from CIRIA C665 (if using the NHBC traffic lights method). Throughout the risk assessment process, strong regard must be given to the nature of the gassing source, the flow rates and the estimated surface emissions. Note that certain protection measures are stated in CIRIA Report 149 that are now considered wholly inappropriate to certain developments and consequently should not be used without modification. Throughout the process, it is important to remember that these tables are not intended to be used as a definitive design tool and have been prepared to show the typical scope of measures for gas control.

Both the NHBC (2007) and CIRIA (2007) guidance documents and BS 8485 (2015) propose that both ground gas concentrations and flow rates are used to calculate the limiting gas well gas volume flow rates for methane and carbon dioxide, based on the ground gas conditions monitored for during the worse-case temporal conditions. This limiting gas well volume flow rate is termed the Gas Screening Value (GSV, note that this was termed borehole gas volume flow), and is calculated as follows:

$$\textbf{GSV}\ (\text{l/hr}) = \frac{[\text{gas well gas concentration (\%v/v)}]\ \textbf{x}\ [\text{gas well flow rate (l/hr)}]}{100}$$

These GSVs are then compared to generic 'Traffic Lights' contained within the NHBC guidance, which present typical maximum gas concentrations and limiting GSV's, for 'Situation B Development' (Low rise housing with gardens).

Table 8.7 NHBC Traffic light system for 150 mm void				
Traffic Light	**Methane [1]**		**Carbon Dioxide [2]**	
	Typical max concentration [3] (% by volume)	**Gas Screening Value [2,4] (litres/hour)**	**Typical max concentration [3] (% by volume)**	**Gas Screening Value [2,4] (litres/hour)**
Green	**1**	**0.13**	**5**	**0.78**
Amber 1	**5**	**0.63**	**10**	**1.6**
Amber 2	**20**	**1.60**	**30**	**3.10**
Red				

Notes:
1. The worst-case ground gas regime identified on the site, either methane or carbon dioxide, at the worst-case temporal conditions that the site may be expected to encounter will be the decider as to what Traffic Light is allocated;
2. Borehole Gas Volume Flow Rate, in litres per hour as defined in Wilson and Card (1999), is the borehole flow rate multiplied by the concentration in the air stream of the particular gas being considered;
3. The Typical Maximum Concentrations can be exceeded in certain circumstances should the Conceptual Site Model indicate it is safe to do so;
4. The Gas Screening Value thresholds should not generally be exceeded without the completion of a detailed ground gas risk assessment taking into account site-specific conditions.

Box 8.4 of CIRIA C665 Gas protection measures for low-rise housing development based upon allocated NHBC Traffic light (Boyle and Witherington, 2007)	
Traffic Light Classification	**Protection Measures Required**
Green	Negligible gas regime identified and gas protection measures are not considered necessary.
Amber 1	Low to intermediate gas regime identified, which requires low-level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into buildings. Gas protection measures should be as prescribed in BRE Report 414. Ventilation of the sub-floor void should facilitate a minimum of one complete volume change per 24 hours.
Amber 2	Intermediate to high gas regime identified, which requires high-level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to prevent the ingress of gas into buildings. Gas protection measures should be as prescribed in BRE Report 414. Membranes should always be fitted by a specialist Contractor. As with Amber 1, ventilation of the sub-floor void should facilitate a minimum of one complete volume change per 24 hours. Certification that these passive protection measures have been installed correctly should be provided.
Red	High gas regime identified. It is considered that standard residential housing would not normally be acceptable without a further Gas Risk Assessment and/or possible remedial mitigation measures to reduce and/or remove the source of gas.

For a 'Situation A Development' (All development except low rise housing with gardens), the GSV value is used to derive the appropriate Characteristic Situation from Table 8.5 of CIRIA C665 (below):

Table 8.5 from CIRIA C665 Modified Wilson and Card Classification

Characteristic Situation (CIRIA R149)	Comparable Partners in Technology gas Regime (see Box 8.2)	Risk Classification	Gas Screening Value (CH_4 or CO_2) (l/hr)[1]	Additional Factors	Typical Source of Generation
1	A	Very low risk	<0.07	Typically methane ≤ 1% and/or carbon dioxide ≤ 5%. Otherwise consider increase to Situation 2	Natural soils with low organic content "Typical" made ground
2	B	Low risk	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3	Natural soil, high peat/organic content. "Typical" made ground
3	C	Moderate risk	<3.5		Old landfill, inert waste, mine working flooded
4	D	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures.	Mine working susceptible to flooding, completed landfill (WMP 26B criteria)
5	E	High risk	<70		Mine working unflooded inactive with shallow workings near surface
6	F	Very high risk	>70		Recent landfill site

It was intended in CIRIA C665 that the characteristic situation allocated to the development from the table above would then be used in Table 8.6 of CIRIA C665 in order to determine the level of gas protection the development requires. However, BS8485:2015 superseded this document and a different set of mitigation standards were put forward.

The recommended minimum gas protection score (points) be selected based on the building type (Table 3 which defines four building types) and the ground gas Characteristic Situation as detailed in Table 4 of BS8485:2015 (see below).

The first step in the decision making process is to obtain the level of gas protection necessary in the range 0 to 7.5 from Table 4. Then a combination of structural barriers (Table 5) ventilation protection measures (Table 6) and/or gas resistant membranes (Table 8)should be chosen to meet that requirement. The level of gas protection necessary should take into account the characteristic gas situation and a number of other factors. The whole decision making process should be made transparent, where all parties can see the approach being taken, can understand the various steps and decisions made and be confident that a risk-assessed solution has been designed and installed commensurate with the construction and site constraints.

Where the gas Characteristic Situation is 4 or more (and for NHBC Red situations according to CIRIA C665), the site requires a comprehensive risk assessment to confirm the scope of protection measures. These are higher risk sites and reliance on Table 4 alone is not sufficient.

BS8485:2015 Table 3 Building Types				
	Type A	**Type B**	**Type C**	**Type D**
Ownership	Private	Private or commercial/ public, possible multiple	Commercial / public	Commercial / industrial
Control (change of use, structural alterations, ventilation	None	Some but not all	Full	Full
Room sizes	Small	Small / medium	Small to large	Large industrial / retail park style

BS8485:2015 Table 4 Gas Protection Score by CS and Type of Building				
CS	**Required Gas Protection**			
	High risk	**Medium risk**		**Low risk**
	Type A	**Type B**	**Type C**	**Type D**
1	0	0	0	0
2	3.5	3.5	2.5	1.5
3	4.5	4	3	2.5
4	6 (A)	5.5(A)	4.5	3.5
5	(B)	6.5(A)	5.5	4.5
6	(B)		7.5	6.5

a) Residential building should not be built on CS4 or higher sites unless the type of construction or site circumstances allow additional levels of protection to be incorporated, e.g. high-performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system, e.g. in institutional and/or fully serviced contractual situations.

b) The gas hazard is too high for this empirical method to be used to define the gas protection measures

NOTE 3 The NHBC has published guidance for use on residential developments, which utilise an alternative classification ("traffic light") system. This guidance typically applies to Type A buildings utilising beam and block floor constructions with clear void ventilation. The design choice variables are limited to decisions relating to the membrane specification and verification recommendations (see Table 7). Designers utilising this system would therefore need to refer to NHBC to assess compliance for specific recommendations [see 8485:2015 for further on this note]

NOTE4 The method of selecting the combination of these types of protection is given in section 7.2 of BS8485:2015. Once type of measures has been decided, the detailed design and specification of the measures should be undertaken (section 7.3)

Section 7.2 defines the order of selecting protective measures. The first choice is provided by structural barriers as defined in Table 5.

BS8485:2015 Table 5 Gas protection scores for structural barriers		
PROTECTION ELEMENT/SYSTEM	**SCORE**	**COMMENTS**
Floor and substructure design		
Floor slabs		<u>General</u> – *score conditional that breaches of slab are sealed*
Block and beam floor slab	0	
Cast in situ ground-bearing floor slab (with only nominal mesh reinforcement)	0.5	
Cast in situ monolithic reinforced ground-bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations (with only nominal mesh reinforcement)	1 or 1.5	*To achieve 1.5, raft or suspended slab to be well reinforced to prevent cracking and minimal penetrations*
Basement floor and walls to BS 8102:2009, Grade 2 waterproofing	2	
Basement floor and walls to BS 8102:2009, Grade 3 waterproofing	2.5	*Conditional that waterproofing is not based on geosynthetic clay liner*

Ventilation methods are detailed in Table 6, and points can only be gained from using one of the five types

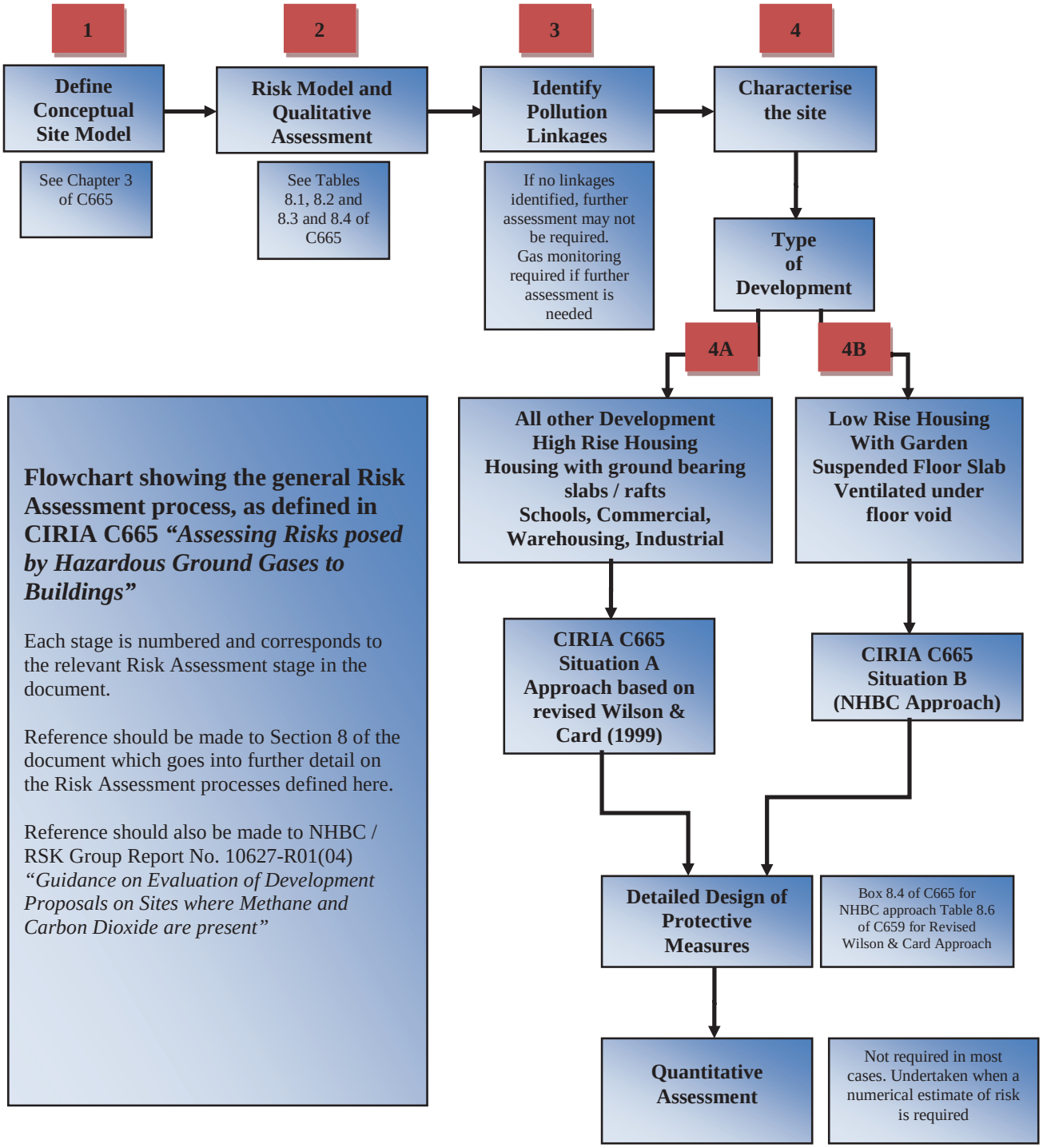
BS8485:2015 Table 6 Gas Protection Scores for Ventilation Protection Measures		
PROTECTION ELEMENT/SYSTEM	**SCORE**	**COMMENTS**
a) Pressure relief pathway (usually formed by low fines gravel or with a thin geocomposite blanket with strips terminating in a gravel trench external to the building	0.5	*Whenever possible, a pressure pathway relief pathway (as a minimum) should be installed in all gas protection measures systems.* *If a layer has a low permeability and/or is not terminating in a venting trench (or similar), then the score is zero.*
b) Passive sub floor dispersal layer		*Performance criteria shown in Fig B.6 and B.7 of BS 8484:2015.[See Annex B]*
Very good performance	2.5	
Good performance	1.5	
Media used to provide the dispersal layer are: • Clear void • Polystyrene void forming blanket • Geocomposite void former blanket • No-fines gravel layer with gas drains • No-fines gravel layer		
c) Active dispersal layer, usually comprising fans with active abstraction (suction) from a subfloor dilution layer, with roof level vents. The dilution layer may comprise a clear void or be formed of geocomposite or polystyrene void formers	1.5 to 2.5	*This system relies on continued serviceability of the pumps, therefore alarm and response systems should be in place. [See Annex B].*
d) Active positive pressurisation by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket	1.5 to 2.5	*This system relies on continued operation of the pumps, therefore alarm and response systems should be in place. [See Annex B].*
e) Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or under croft)	4	*Assumes car park is vented , designed to Building Regulations 2000, Approved Document F.*

Membrane methods are detailed in Table 7.

BS8485:2015 Table 7 Gas protection score for gas resistant membrane		
PROTECTION ELEMENT/SYSTEM	**SCORE**	**COMMENTS**
Gas resistant membrane meeting all of the following criteria: • Sufficiently impervious to gases with a methane gas transmission rate <40.0 ml/day/m^2/atm (average) for sheet and joints (tested in accordance with BS ISO 15105-1 manometric method) • Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • Sufficiently strong to withstand in-service stresses (eg settlement if placed below a floor slab); • Sufficiently strong to withstand the installation process and following trades until covered (eg penetration from steel fibres in fibre reinforced concrete, dropping tools etc); • capable, after installation, of providing a complete barrier to the entry of the relevant gas; and • verified in accordance with CIRIA C735	2	*The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation, and the integrity of joints.* *If a membrane is installed that does not meet the criteria, then the score is zero.*

For a site which is impacted by migratory gases from an off-source, the development may be protected by imposing pathway intervention methods, which if successfully validated, could also remove the need for further analysis. It is essential that the gas regime in these circumstances has been fully characterised and that the only source impacting the site is located off site and that the pathway is clearly defined and its interception equally proven before construction commences. Pathway intervention methods may include vertical membrane installations, venting trenches, rows of stone columns, activated trenches and various proprietary systems. These systems are particularly relevant to domestic housing where there is limited scope for foundation type solutions.

Following the choice of protection measures, detailed design should be entered into [section 8 of BS 8485:2015].



APPENDIX L

Summary of Guidance for Classification of Soil as a Waste Material

Guidance for Classification of Soil for Off Site Disposal at a Landfill Site

Many site developments create a portion of excess soils and Made Ground which if not re-usable, are required to be disposed off-site at a suitably licensed landfill site. The regulations and associated guidance published by the Environment Agency is relatively complex and lengthy. This guidance provides a summary of the following documents which should be referred to when assessing soil (and common constituents found within Made Ground on remediation sites) for off-site disposal:

- Guidance for Waste destined for disposal in landfills: Interpretation of the Waste Acceptance Requirements of the Landfill (England and Wales) Regulations 2002 (as amended) (EA, 2004);
- Guidance on Sampling and Testing of Wastes to Meet Landfill Waste Acceptance Procedures (EA, April 2005);
- WM3 - Hazardous Waste: Interpretation of the Definition and Classification of Hazardous Wastes (EA, May 2015);
- European Regulation No 1272/2008 on Classification, Labelling and Packaging of substances 2015 (CLP 2015);
- Guidance on Waste Destined for Disposal in Landfill (EA, June 2006);
- Treatment of Non-hazardous wastes for Landfill (EA, February 2007).

It is important to distinguish between the waste classification system and the designation of materials as "suitable for use" on site. A material may be retained on site for an appropriate end use if that end-use is clearly designated and that a site-specific risk assessment ensures that it does not pose a risk to human health or controlled waters. However, if this material is excavated and sent for disposal, the material is then subject to waste management regulations and the two systems cannot be directly correlated. It is therefore important to note that classifying a material as hazardous (should it be excavated and become a waste) does not necessarily indicate that it might not be suitable to be kept on site for re-use. Separate guidance in the form of a Code of Practice (CL:AIRE Version 2, 2011) has been developed jointly between the development industry and the Environment Agency to provide best practice when assessing whether materials are wastes or not, and for determining when waste can cease to be waste for a particular use.

In accordance with the current waste regulations (or Landfill Directive, as they are more commonly known), from 30th October 2007 all waste materials produced from construction sites have to be pre-treated prior to disposal. Pre-treatment includes waste minimisation, recovery (e.g. separation of demolition waste to be used as hardcore) and separation of materials into different waste categories (e.g. separate inert waste from hazardous waste etc). Mixing of different waste types shall be avoided and intentional mixing of inert materials with hazardous waste to 'dilute it' and hence change its waste classification, is illegal.

The current waste regulations (based on the EU landfill directive) introduced a two tier classification system for waste materials, defining them as either being hazardous or non-hazardous. Landfills are licensed to take wastes based on a three tier classification system with the non- hazardous waste divided into two sub-categories:

- Non-Hazardous - inert;
- Non-Hazardous - non-hazardous;
- Hazardous.

Waste materials are categorised with a six figure numeric code in the European Waste Catalogue. Commonly found construction and demolition wastes including excavated soil from contaminated sites and Made Ground with their waste codes are summarised below (this is not a comprehensive list):

Waste Code	**What is it?**	**Likely Waste Category–**		
		Inert Waste	**Non-Hazardous**	**Hazardous Waste**
17 01 01 Concrete	Concrete, possibly with reinforcement (from Construction & Demolition)	✓		
17 01 02 Bricks		✓		
17 01 06* Mixtures of concrete, bricks, tiles & ceramics containing dangerous substances	These are not normally considered hazardous but if they are contaminated (e.g. by asbestos) then could be hazardous – see comment above			✓
17 01 07 Mixtures of concrete, bricks, tiles & ceramics other than those in 17 01 06	This is mixed inerts c.f. 17 09 04	✓		
17 05 03* soils and stones containing dangerous substances				✓
17 05 04 soils and stones other than those mentioned in 17 05 03	Soil and stones only (excluding top soil, peat, soil and stones from contaminated sites)	✓		
17 06 05* Construction materials containing asbestos	e.g. corrugated asbestos sheeting			✓
17 08 02 Gypsum-based construction materials other than those mentioned in 17 08 01	Plaster & plasterboard (although specific disposal requirements are required for high sulphate waste – see EA guidance 'Understanding the Landfill Directive' version 1.0 March 2010.		✓	
17 09 01* Construction & demolition wastes containing mercury				✓
17 09 02* Construction & demolition wastes containing PCBs	Waste with more than 50 mg/kg of PCB's are hazardous			✓
17 09 03* Other mixed construction & demolition wastes containing dangerous substances	Broad range of potentially (see notes below – if asterix the waste is hazardous) hazardous wastes			✓
17 09 04 Mixed construction & demolition wastes other than those mentioned in 17 09 01, 17 09 02 & 17 09 03	Mixed inerts with soil, tarmac, cables, vegetation, plaster, etc. (this waste can only be considered inert if it passes the waste acceptance criteria identified in the regulations).	✓	✓	

Note: all wastes with an asterix code are hazardous regardless of whether they are mirror or absolute entries in the EWC list the decision to with regard to composition must come before applying the code for mirror entries.

Some materials are classified as Inert Waste based in its origin (e.g. 17 01 01 Concrete, or glass) without any requirement for laboratory chemical analysis.

However, most soils will require laboratory testing to confirm whether they are classified as Hazardous Waste. The protocol for assessing these materials and the appropriate threshold values is complicated and are set out in the Environment Agency's "Technical Guidance *WM3* Hazardous Waste – Interpretation of the Definition and Classification of Hazardous Waste" (2015). If the test results for the waste indicates that it is not hazardous then further analysis of the waste is required to determine whether it is Inert Waste. If the waste does not meet the criteria for either Hazardous or Inert, then it is by default classified as Non-hazardous Waste.

As an alternative location to landfills for off-site disposal of inert and non-hazardous waste, there are a number of sites which have Waste Permit Exemptions that can accept certain categories of inert and non-hazardous wastes. Additionally some quarries can accept certain types of wastes to be used for quarry restoration material. For both alternatives to disposal at landfill sites the material still requires chemical testing as these sites have site specific acceptance criteria for wastes. It should also be noted that these types of site do not incur landfill tax which in the 2017/18 tax year is £2.70 for inactive waste (inert and some types of non-hazardous waste) and £86.10/Tonne for active waste (some types of non-hazardous waste and hazardous waste. Note that the Inland Revenue uses a different classification scheme for waste for tax purposes to the European Waste Classification scheme.

Waste Categorisation

The process of determining the category of wastes is a three stage process:

- Stage 1 – is the waste either Hazardous or Inert by definition without the requirement for chemical analysis (if it is then Stages 2 and 3 are not required);
- Stage 2 - Waste characterisation;
- Stage 3 - WAC classification.

Waste characterisation determines if a waste is hazardous or not. Excavated soil is characterised using a system based on the contaminants present and their hazardous properties. The system uses total concentrations of the contaminants. Thresholds (as a percentage of the waste) have been set for the various hazardous properties.

Fourteen hazardous properties together with other scenarios where material could cause a hazard have been defined:

- Hazardous properties: explosive, oxidising, highly flammable/flammable, irritant, harmful, toxic, carcinogenic, corrosive, infectious, toxic for reproduction, mutagenic and ecotoxic;
- Substances which can release toxic/very toxic gases in contact with water, acid or air;
- Substances which, after disposal, can yield another substance, e.g. a leachate, which possesses any of the above hazardous properties.

Some of the hazardous properties are sub-divided e.g. there are three categories of carcinogenic, mutagenic and toxic for reproduction substances. The hazardous properties were originally defined in the European Hazardous Waste Directive 91/689/EC. Should a waste contain a contaminant with one or more of the listed hazardous properties at a concentration equal to or above the threshold value for the particular

property, then the waste is hazardous. The hazardous properties of a wide range of chemicals are sourced from CLP 2015.

There are many reasons why waste soil is classified as being hazardous but the majority of reasons can be divided into the following four groups:

- Hydrocarbons – this is probably the most common reason for the hazardous classification of soils. For most soils hydrocarbon analysis will be required for both Polycyclic Aromatic Hydrocarbons (PAH) and speciated Petroleum Hydrocarbons (PHCs) but depending on the site's history other groups of organic contaminants may also be is included in any analysis suite for soil samples;
- Metals – Particularly sites from former metal processing or mining sites and also some types of ash have metal concentrations that are sufficiently high to characterise materials requiring disposal as hazardous waste.
- Asbestos;
- Anions – e.g. sulphate in plasterboard (there are special disposal requirements for high sulphate waste and specific WAC requirements); it is possible that sulphate salts of metals and semi-metals could make the waste hazardous – the sulphate concentration could possibly be significant under H12, H13 and H14.

The characterisation of wastes with significant metal concentrations involves some processing of the analysis data. The chemical analysis results for inorganic substances are generally reported as total concentrations e.g. total lead, total arsenic, total sulphate etc. However, CLP 2015 deals with the hazardous properties of actual compounds e.g. lead sulphate, arsenic pentoxide, nickel carbonate. Therefore, the total metal results have to be converted into assessed chemical analysis results for the compound most likely to be present in the soil samples. For example, if the sample contains high total lead concentrations and high sulphate concentrations, then the lead is likely to be present in the soil as lead sulphate. The most likely compounds can often be determined from a desk study or previous site uses. If the site has been derelict for a number of years, consideration should be given as to whether water soluble compounds should or should not be chosen, as rainfall could have removed them from the soil (this does not apply if the soil has been taken from below under a concrete slab etc). Chemical knowledge and common sense needs to be used in choosing a suitable compound.

If no data is available, then a worst case scenario has to be assumed and the most hazardous compound likely to be present has to be chosen. For example, metal chromates (lead chromate, nickel chromate) are often the most hazardous compounds formed by many metals, but if the chromium concentrations in the soil are low, chromates are unlikely to be present. It should also be noted that for many of the hazard categories, the cumulative hazard from different compounds is added (e.g. add the concentrations of the copper, lead and zinc compounds together to assess the Hazard Category H14 Ecotoxicity).

If the results of the above assessment determine that the waste is hazardous, it must then be analysed for the Waste Acceptance Criteria (WAC) analysis contained within appropriate Environmental Permitting Regulations (this comprises mainly leachate but also analysis for TOC and Loss on ignition). WAC limit values have been set for the listed determinands. If any of the determinands exceed their limit value, the waste must be pre-treated to reduce concentrations to below the limit values before the waste may be disposed of at a landfill site licensed to take hazardous waste.

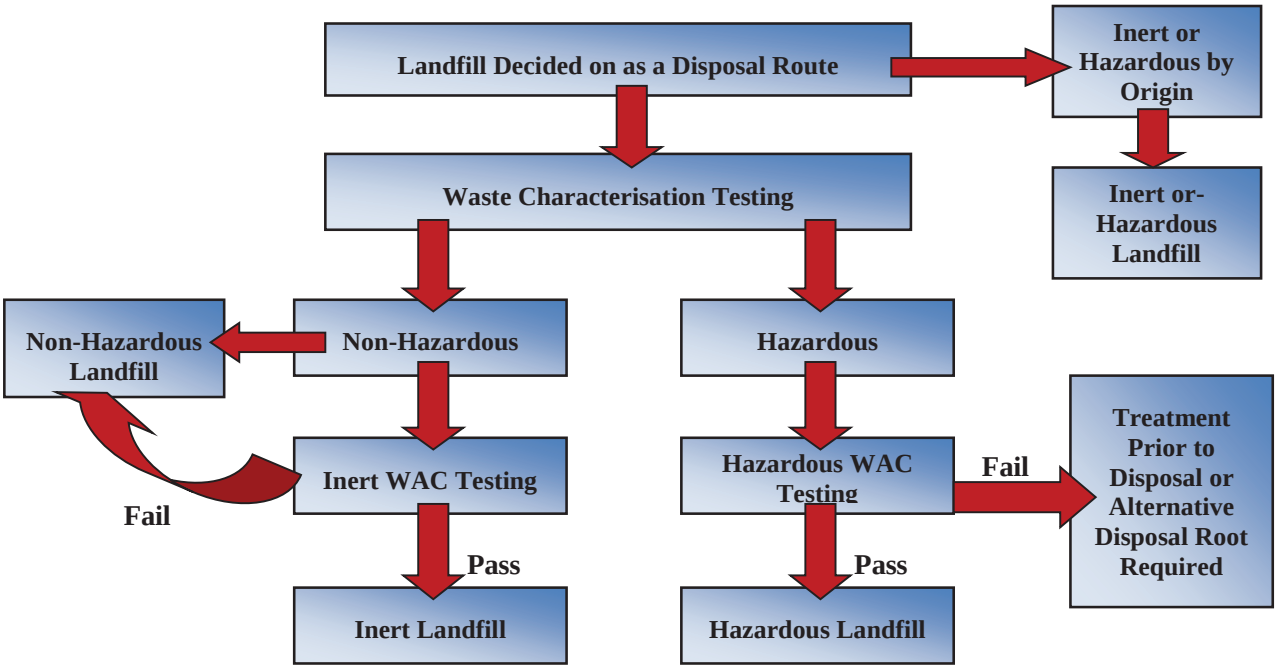
For waste classified as not being hazardous, then there are two options available. Currently, waste correctly characterised as not being hazardous may be disposed of without WAC testing to a non-hazardous landfill. Alternatively WAC testing for Inert Waste can be carried out (this is similar to the list for hazardous waste

with the addition of PAH's, BTEX and Mineral Oil). If the results pass the Inert WAC criteria it can be disposed of at an Inert Waste Landfill. If any of the WAC test results exceed the Inert WAC criteria the waste has to be disposed at a non- hazardous landfill. There are WAC limits for non-hazardous waste set for pH and TOC. If these two criteria are not met then the waste must be pre-treated to so that it meets the criteria before it can be disposed.

If materials fail the WAC criteria they can be pre-treated on site or taken to a soil treatment centre for pre-treatment (such as at the facility run by Biffa at Risley near Warrington). Here the soil's hazardous properties may be reduced (e.g. by bioremediation of hydrocarbons).

It should be noted that in order to dispose of Hazardous Waste, the site must register as a producer of Hazardous Waste with the Environment Agency. When disposing of waste materials to landfill sites the appropriate Duty of Care Waste Transfer procedures must be followed.

Landfilled Waste Decision Tree



Landfill Tax

It should be noted that HM Revenue and Customs (HMRC) classify wastes for tax purposes using a different scheme to the three fold landfill EU Landfill Directive scheme (i.e. the hazardous, non-hazardous and inert). HMRC have a two-fold system for landfill tax. The Standard Landfill Tax is currently £86.10/T and applies to all wastes unless they qualify for the reduced rate of landfill tax of £2.70/T. The wastes that qualify for the reduced rate of Landfill Tax are set out in The Landfill Tax (Qualifying Material) Order 2011 with supplementary information on the interpretation of these regulations in HMRS "Notice LFT1 – A General Guide to Landfill Tax" (May 2012) and HMRC Briefing Notes 15/12 and 18/12.

APPENDIX M

Unforeseen Ground Contamination

Unforeseen Ground Contamination

There is the potential for areas of previously unexpected contamination to be present, as is the case with any "brownfield" site. Any significant quantities of asbestos, significant ashy soils, unusual, brightly coloured or significantly oily or odorous material should be considered in this category. If unexpected contamination is found the following procedures should be adhered to:

1. All site works at the position of the suspected contamination will cease.
2. A suitably trained geo-environmental specialist should assess the visual and olfactory observations of the condition of the ground and the extent of contamination and the Client and the Local Authority should be informed of the discovery. Should the contamination be likely to affect controlled waters the Environment Agency shall also be informed.
3. The suspected contaminated material will be investigated and tested appropriately in accordance with the assessed risks. The investigation works will be carried out in the presence of a suitably qualified geo-environmental engineer. The investigation works shall commence to recover samples for testing and, using visual and olfactory observations of the condition of the ground, delineate the area over which contaminated materials are present.
4. The unexpected contaminated material will either be left in situ or be stockpiled whilst testing is carried out and suitable assessments completed to determine whether the material can be re-used on site or requires to be disposed as appropriate.
5. Where the material is left in situ awaiting results it will be reburied or covered with plastic sheeting.
6. Where the potentially contaminated material is to be temporarily stockpiled it will either be placed either on a prepared surface of Glacial Till, or on 2000 gauge Visqueen sheeting (or other impermeable surface) and covered to prevent dust and odour emissions.
7. Any areas where unexpected visual or olfactory ground contamination will be surveyed, a photographic record kept and testing results incorporated into the Verification Report.
8. A photographic recorded will be made of relevant observations.
9. The testing suite will be determined by the independent geo-environmental specialist on the basis of visual and olfactory observations.
10. Test results will be compared against current assessment criteria suitable for the future use of the area of the site affected.
11. The results of the investigation and testing of any suspect unexpected contamination will be used to determine the relevant actions. After consultation with the Local Authority and if necessary the Environment Agency, materials should either be:
    - re-used in areas where test results indicate that it meets compliance targets so it can be reused without treatment; or
    - treatment of material on site to meet compliance targets so it can be reused; or
    - removal from site to a treatment centre or to a suitably licensed landfill or permitted treatment facility.
12. Verification Report will be produced for the work.

Asbestos

Asbestos cement products and asbestos fibres have not been encountered in the soils at the site, but based on the age of the Made Ground material containing asbestos could be expected to be encountered. If non-notifiable asbestos (e.g. chrysotile asbestos cement board) is encountered in excavations then it will be dealt with in accordance with the Control of Asbestos Regulations 2012 (CAR 2012) and the HSE's ACoP for asbestos (2013). Finding non-notifiable asbestos is a very common occurrence on brownfield sites and is a relatively low risk activity and can be dealt with as a matter of routine. Therefore it is not proposed that the Council will be notified but an appropriate record will be kept of confirmatory testing and disposal. This will be included in remediation verification reports.

If suspect notifiable asbestos is encountered then the Council and the HSE will be notified. An appropriate action plan will be agreed with the Council and the HSE in accordance with CAR 2012. The action plan will include the preparation of the Risk Assessment and Plan of Work in accordance with CAR and other statutory requirements including:

- Site mobilisation;
- Excavation methodology;
- Handling, movement and storage on site of excavation arisings;
- Any processing of excavation arisings containing ACMs;
- Movement and placement of arisings to final destination;
- Placing of cover system over soils with and ACMs remaining on site;
- Off-site disposal of ACMs;
- Licences;
- PPE & RPE;
- Dust and fibre monitoring.

Potential mitigation measures that would be required include:

- Site investigation and risk assessment;
- Removal or treatment of asbestos hotspots;
- Use of PPE and RPE by construction workers; and
- Compliance monitoring.

Unexpected Tanks

No buried underground fuel storage tanks have been encountered during the site investigation works; however, there remains a low risk that tanks are present on site. Should an underground tank be encountered, operations should cease in the area. Additionally there may be pipework associated with these tanks which could have oily residues. The following procedures are to be adhered to if tanks and pipework are identified:

1. All site works at the position of the tanks/pipework should stop.

2. A description of the tank should be made by the geo-environmental engineer including; condition and surround, along with visual and olfactory observations should any contents in the tank be apparent. A photographic recorded will also be made of relevant observations.
3. The tank's position and depth should be determined and marked on a plan of the site.
4. The independent geo-environmental engineer will inform Client and the Local Authority.
5. During the presence of the independent geo-environmental engineer, investigation works should be undertaken to obtain samples of any liquid or sludge contents and to establish dimensions of the tank.
6. Testing will be determined on the basis of visual and olfactory observations by independent geo-environmental engineer.
7. Test results will be compared against current assessment criteria and proposals for disposal of any contents determined in agreement with the appropriate Regulatory Parties.
8. Emptying the tank and disposal of contents to a suitable licenced disposal facility.
9. Degassing and removal of the tank by a suitably qualified contractor will be required, and a Naked Flame Certificate should be provided.
10. Once the tank has been emptied in accordance with the above proposals, it is to be removed for disposal to a licensed waste management facility. Copies of the relevant waste consignment notes are to be kept and included in the Verification Report.
11. Excavation and remediation of any contaminated soils around the tank will be carried out.
12. Samples of the base and sides of the resultant hole will be sampled and supervised by the independent geo-environmental engineer to confirm whether risks to human health or controlled waters.

All of the above information will be incorporated into the Verification Report and submitted to the regulatory parties, the Local Authority and the Environment Agency where groundwater may potentially have been impacted.