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Envirocheck® Report:

Datasheet

Order Details:

Order Number:
32285717_1_1

Customer Reference:
112775

National Grid Reference:
546170, 388830

Slice:
A

Site Area (Ha):
48.07

Search Buffer (m):
250

Site Details:

Saltfleetby St Peter
Lincolnshire

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Landmark Information Group

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Document Title	Summary of Ground Conditions along proposed Pipeline Phase 2 Ground Investigation
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1. Introduction

Wingas Storage Ltd UK (WSUK) proposes to utilise the partially depleted gas field at Saltfleetby for use as a gas storage facility. The proposed scheme lies within the Lincolnshire Marshland in the East Lindsey District of Lincolnshire. The scheme will enable WSUK to withdraw gas from the National Transmission System (NTS) for storage when gas demand is low and return it to the NTS at times of high demand. From a civil engineering perspective the scheme comprises 5 areas of proposed development as follows:

- Well Site A - This is an existing gas well facility that will be extended and modified.
- Well Site B - As above.
- Grayfleet Gas Storage Facility (GSF) - A suite of three new compressors and associated plant. The site will be surrounded by a flood protection bund. Large ponds will be constructed adjacent
- Access Road - A new 1.5km road is required to provide access between Well Sites A and B and Grayfleet GSF.
- Gas Pipeline - Approximately 8km of pipeline will connect the NTS at Theddlethorpe to the new facilities at Saltfleetby

Atkins was appointed by Fluor to design and supervise a ground investigation for the entire scheme and provide information on ground and groundwater conditions. The ground investigation was divided into two phases. Phase 1 was carried out in Winter 2010/2011 and focused on the Well Sites A and B, Grayfleet GSF and the access road. Phase 2 was carried out in Spring 2011 and focused on the pipeline route. The phasing was required due to access restrictions.

This report is based on the Phase 2 work along the route of the proposed pipeline. It provides:

- Desk study information
- An assessment of the ground conditions along the length of the pipeline
- A discussion on the geotechnical risk
- A contamination assessment to identify potential constraints on re-use of material as backfill on top of the pipeline construction

A separate Geotechnical Interpretative Report has been produced by Atkins which covers the Phase 1 Ground Investigation.

2. Site Characterisation

2.1. Site Location & Description

For an appreciation of the pipeline route please see the geological long sections contained in Appendix A.

The proposed pipeline is approximately 8km long and connects the National Transmission System at Theddlethorpe with Well Sites A and B and Grayfleet GSF.

The route of the pipeline crosses mainly undeveloped land, primarily used for agricultural purposes.

As part of the pipeline construction a number of small and large drains, ditches and roads require crossing. Two rivers, Great Eau and Long Eau, also require crossing.

2.2. Site History

Historical maps were obtained from Landmark Information Group contained within an Envirocheck Report which is appended to the Phase 1 report. The maps are dated between 1888 and 2010. A short summary is provided below.

- The majority of the proposed pipeline route is shown to cross farmland with the exception of some road and drain/river crossings. Several farms and houses are currently located within 250m of the route ("tanks" are indicated at some farms).
- 1880s maps show the proposed pipeline route runs alongside an old railway line in two locations: at Saltfleetby and between Great Eau and Theddlethorpe All Saints. The 1960s maps show the railway to be dismantled.
- 1975 map shows the North Sea Gas Terminal at the eastern end of the proposed pipeline route at Theddlethorpe.
- 2006 maps indicate development of two gas well sites adjacent to the western end of the proposed pipeline route.

2.3. Geological Setting

The following assessment of the geology has been made from available information resources, including the 1:50,000 scale British Geological Survey (BGS) geological map 'Mablethorpe' (Sheet 104 solid and drift editions).

The drift geology is shown to be Terrington Beds of Holocene age. These are saltmarsh and mud flat deposits resulting from marine transgression. The geological memoir states that the saltmarsh deposits comprise interbedded silty clay and clayey silt with some sand laminae and much organic material.

The Terrington Beds are shown to be underlain by Glacial Till of Pleistocene age deposited during the last ice age. Generally these deposits typically comprise red-brown and clay interbedded with sand or gravel lenses.

The bedrock is shown to be Chalk (Flamborough and Burnham) of Cretaceous age. A BGS research report states that the chalk dips to the northeast by 1 to 2^{o} with the Flamborough Chalk overlying the Burnham Chalk. The Flamborough Chalk is described as white chalk with thin marl beds and negligible flint.

2.4. Previous Ground Investigations

The existing ground investigation information available at the time of writing this report is listed below:

- Ground Investigation for a proposed Gas Pipeline at Theddlethorpe. Site Investigation Services, Report Ref: 45061 dated April 1999.(Ground investigation prior to the construction of a 10 inch gas pipeline that is now laid in the ground).
- Ground Investigation at Rig Sites 'A' and 'B', Saltfleetby, Lincolnshire. Site Investigation Services, Report Ref: 45034 dated July 1999.
- Saltfleetby Gas Storage, nr Louth, Costain Geotechnical Services, Project No 018936/3520 dated August 2005.
- Factual Report on Ground Investigation, UGS Saltfleetby, Soil Mechanics, Report No A0083-10 dated April 2011(Phase 1 GI).

The ground conditions identified in these previous ground investigations has been considered, along with the more recent data, when assessing the ground conditions which are described in Section 4 of this report. The historical chemical testing has not been included within the assessments contained within this report. The assessment in this report is based solely on the 2011 testing data which is expected to be more reliable than the historical data, which was collected in excess of five years ago. A brief summary of the scope of the historical chemical testing is given below.

The April and July 1999 reports did not include any contamination testing. The 2005 report does contain some contamination analysis. However, the investigation covered a wider area than the proposed pipeline route and much of this data cannot be reliably linked to borehole locations (there is some evidence of hydrocarbon contamination within this data, but we cannot identify the location or depths of the samples). The only contamination analysis within the 2005 report that can be reliably connected to the pipeline route, relate to boreholes drilled between Well Site B and Grayfleet GSF.

2.5. Hydrogeology

The Environment Agency's website consulted on 24th August 2010 indicates the superficial deposits (Terrington Beds and Glacial Till) are classified as 'unproductive strata'. These are described as 'drift deposits with low permeability that has negligible significance for water supply or river base flow'.

The underlying 'Chalk Group' bedrock that includes the Flamborough and Burnham Chalk is shown to be a 'principal' aquifer. This is described as 'rock with high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer'.

The chalk is typically at a depth of 20 to 25m beneath ground level (bgl) and is confined by the overlying Glacial Till.

Within 250m of the proposed pipeline route there are 13 active groundwater abstractions listed in the Envirocheck Report (Appendix A). These comprise:

- One abstraction from 'Estuarine/Marine deposits' for 'general farm and domestic use' at Saltfleetby All Saints.
- Twelve abstractions from the Chalk Aquifer for 'general farming and domestic use'. The majority of these are clustered around the western end of the pipeline route.

The site is not located within a groundwater Source Protection Zone.

2.6. Hydrology

An extensive interconnected drainage system is present across this area of Lincolnshire as seen on 10:000 scale Ordnance Survey mapping included in the Envirocheck Report. These vary in size, from narrow un-named field drainage ditches to major drains (such as Grayfleet Drain which is approximately 5m in width at its base). Most of the major drains flow in a north-easterly direction towards the North Sea.

Two rivers (Long Eau and Great Eau) cross the pipeline route before converging 100m to the north east.

The major drains / rivers which cross the pipeline route are as follows (from west to east along the pipeline route):

- Grayfleet Drain.
- Fleet Drain.
- Mar Dike.
- Long Eau.
- Great Eau.
- The Cut (this drain also runs immediately parallel or in close proximity to the proposed pipeline route for ~1.5km).

In addition to these major drains there are numerous minor drains and ditches adjacent to or crossing the proposed pipeline route. These drains ultimately connect into the larger channels listed above.

Within the surrounding area (that is, within 250m of the proposed pipeline route) there are 4 active abstraction licenses listed in the Envirocheck Report (Appendix A). These comprise:

- Three abstractions held by the Alford Drainage Board, where water is "transferred between sources" (Great Eau river and a location near the gas terminals).
- One location where water is extracted from the Great Eau or Long Eau rivers for spray irrigation.

The Envirocheck Report states the 'site is located within an area at risk of flooding from rivers and sea without defences'.

Water quality data was obtained from the Environment Agency on 24 August 2010 for the confluence of the Long Eau & Great Eau rivers. At this location the General River Quality (GRQ) classifications were last recorded in 2009 and were 'A' (very good) for both chemistry and biology. For nutrient classifications, nitrates were noted at the highest classification level (6) and phosphates at a low level (2). Water hardness was reported at the same location at 999mg/l $CaCO_3$.

The Envirocheck Report (Appendix A) reports three recorded pollution incidents to Controlled Waters within 250m of the proposed pipeline route:

- Category 2 (significant incident) is reported to have impacted a 'land locked pond' in May 1993 (located to south of gas terminals). The type of pollutant is not stated.
- Category 3 (minor incident) affecting an 'unknown dyke' that occurred on 12th August 1993 (to the north, beyond Well Site B). The type of pollutant is not stated.
- Category 3 (minor incident) accidental spillage/leakage of chemicals to an unnamed freshwater stream/river on 7th July 1993 (located within gas terminal complex).
-

2.7. Potentially Contaminative Current Land Use

The Theddlethorpe Gas Terminal, located at the eastern end of the proposed pipeline, is recorded in the Envirocheck Report. The records relate to Integrated Pollution Prevention Controls (IPPC), Registered Radioactive Substances and Control of Major Accident Hazard Sites (COMAH).

The gas terminal is the main current landuse identified within 250m of the proposed pipeline route that could be a major source of contamination. There might also be diesel / heating oil tanks at farms and houses, however these are small point sources and as only a few farms / houses are located within 250m of the pipeline route they are not considered likely to pose a significant contamination source.

A disused railway runs immediately adjacent to the pipeline route. It is understood that the pipeline and associated works will be outside the footprint of the disused railway.

2.8. Landfills

The Envirocheck report identifies two historic and one registered landfill site within 250m of the proposed pipeline route:

- Registered and historic landfills at Lodge Farm, described as 'redundant ditches'. The authorised waste is described as 'soil' (located within 50m of proposed pipeline route).
- Historic landfill at Theddlethorpe Hall Farm which 'included inert waste' (250m to southwest of proposed pipeline route).

2.9. Ecological Receptors

There are no statutory ecological receptors listed in the Envirocheck report within 1km of the sites. Statutory ecological receptors include Sites of Specific Scientific Interest (SSSI), Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and RAMSAR sites (designated under the Convention on Wetlands of International Importance).

3. Ground Investigation

3.1. Scope

The Phase 2 ground investigation was undertaken between April and May 2011 along the route of the proposed pipeline.

The purpose of the ground investigation was to:-

- Investigate the geological profile and groundwater regime
- Determine the geotechnical and chemical characteristics of the soil
- Collect data for geotechnical design analysis
- Collect data for generic contamination risk assessments to inform re-use potential of site won materials

3.2. Fieldwork

The ground investigation was undertaken by Soil Mechanics under the supervision of Atkins. Soil Mechanics are to provide a factual report following the ground investigation but at the time of this report, Soil Mechanics have not issued it to Fluor. The ground investigation comprised the following techniques:

- Cable Percussion boreholes, with Standard Penetration Tests (SPTs) and shear vanes
- Machine excavated Trial Pits
- Geophysical Resistivity Surveys

Photo 1. Cable Percussion Drilling Rig

Photo 2. Trial Pits

4. Ground and Groundwater Conditions

4.1. Overview

The geology of the scheme has been discussed in detail in Atkins' Geotechnical Interpretative Report following the Phase 1 ground investigation (Ref: 5097367/GTG20093413/R006).

A summary of the geology is provided below:

- Terrington Beds
- Glacial Till
- Chalk

The Phase 2 ground investigation confirmed the presence of the above geological sequence along the proposed pipeline route.

As described in the Phase 1 Geotechnical Interpretative Report , the Terrington Beds comprise two units, the Upper Unit and the Lower Unit. The Upper Unit is generally firmer than the underlying Lower Unit and generally comprises silty and often thickly laminated clay. The Lower Unit is generally soft, or very soft silty clay, often dark grey in colour and containing organic material.

An assessment of the ground conditions along the route of the proposed pipeline has been undertaken and a summary is provided in Table 4.1. The table should be read in conjunction with the geological long sections provided as Figures 1 to 16 in Appendix A

The proposed pipeline levels on all the geological sections have been provided to Atkins by Fluor. We have not amended these even at the crossings where the pipeline depth is indicated on the sections to follow the contours of the ground, where in reality it is likely to drop down and under.

4.2. Evidence of Contamination

No visual or olfactory evidence of contamination was encountered during the February – April 2011 ground investigation. The proposed pipeline route passes very close (within 50m of) a recorded landfill (Lodge Farm), but no evidence of buried waste or disturbed ground was encountered at this location.

The only Made Ground encountered along the pipeline route comprised re-worked Glacial Clay. No significant anthropogenic objects (clinker, brick, slag, metal, etc) were encountered in the exploratory holes.

Soil vapour headspace analysis on the environmental soil samples was undertaken onsite using a Photo Ionisation Detector (PID). This instrument is designed to detect the presence and concentrations of volatile organic compounds (VOCs) in the soil vapour. The PID results are provided in the Soil Mechanics logs and summarised in Appendix D. The PID results were generally less than the instrument detection limits, with the exception of 11 samples. Of these, most concentrations were less than 4.5ppm, except a sample from PBH21 (ES6 at 1m) which recorded 128ppm.

The PID readings indicate VOC/SVOC are not present at significant concentrations within the samples analysed, with the exception of the sample from PB21 which was the only sample scheduled for VOC/SVOC (results discussed in Section 5).

<u>Ground Gas</u>

The site investigation did not encounter significant deposits of peat. Only discrete lenses and thin (<2m thick) layers of peat were recorded within the superficial deposits. It was considered unlikely that the peat deposits encountered would be able to generate sufficient quantities of ground gas (methane, hydrogen sulphide, etc) to migrate far off-site. As such no gas monitoring was commissioned.

4.3. Groundwater

Various water strikes were noted within the boreholes during drilling, they are detailed on the following table:

Table 4.2 – Summary of Groundwater strikes during drilling

Borehole	Strata	Depth struck during drilling (m bgl)	Rise recorded after 20 minutes (m bgl)
PBH03	Terrington Beds/Glacial Till Boundary	5.9	5.7
PBH06	Glacial Till	19.6	6.5
PBH07	Glacial Till	19.6	7.8
PBH08	Terrington Beds	6.2	6.0
PBH11	Glacial Till	14.0	12.0
PBH13	Terrington Beds/Glacial Till Boundary	7.5	6.7
PBH14	Terrington Beds	4.3	4.3
PBH15	Glacial Till	18.5	3.0
PBH16	Terrington Beds	1.1	1.1
PBH16	Glacial Till	17.4	5.85
PBH17	Glacial Till	17.5	13.75
PBH22	Terrington Beds	3.0	3.0
PBH25	Terrington Beds	7.2	6.9
PBH26	Terrington Beds	12.0	11.8
PBH27	Glacial Till	13.7	13.2

The groundwater strikes generally represent relatively high permeability zones within the Terrington Beds or Glacial Till. Additional high permeability zones are likely in other areas of the route.

Piezometer standpipes were installed in selected boreholes on completion of drilling in order to assess the groundwater conditions over a longer period.The details of the standpipe installations are shown on the logs in the Soil Mechanics factual report and are summarised in the following table along with the results from the monitoring visits.

The ground levels along the route of the proposed pipeline generally range between 1.478m OD and 2.357mOD. For response zones within the Terrington Beds strata the groundwater levels monitored ranged between 0.853m OD and -4.587m OD (0.96m bgl and 6.81m bgl).

Geological Long Section	Chainage (m)	Topsoil Thickness (m)	Terrington Beds (Upper Unit) Thickness (m)	Terrington Beds (Lower Unit) Thickness (m)	Glacial Till Thickness (m)	Comments
Figure 10	A 3500-4200	0.3 – 0.35	1.65 – 1.9	8.9 – 11.05	Not Proven	The Terrington Beds (Upper Unit) were proven to be between 1.65m and 1.9m thick and comprised soft to firm brown, orange and grey sandy clay. The Terrington Beds (Lower Unit) was proven to be between 8.9m and 11.05m thick and comprised very soft brown and grey silty clay.
Figure 11	A 4200-4900	0.45	1.55 – 2.0	10.85	Not Proven	The Terrington Beds (Upper Unit) were proven to be between 1.55m and 2m in thickness and generally comprised firm to stiff orange brown and grey occasionally sandy clay. The Terrington Beds (Lower Unit) was proven to be 10.85m thick in PBH17 and was described as soft brown and grey clay, occasionally silty, sandy and thinly laminated. The underlying Glacial Till was described as firm to stiff brown slightly sandy slightly gravelly clay. The gravel included chalk and siltstone.
Figure 12	A 4900-5600	0.4 – 0.6	1.5 – 2.6	Not Proven	Not Proven	The Terrington Beds (Upper Unit) were proven o be between 1.5m and 2.6m in thickness and were described as soft and firm brown clay, occasionally silty, sandy or thinly laminated. The thickness of the Terrington Beds (Lower Unit) was not proven. The material was described as very soft and soft grey and dark grey silty or sandy clay. Lenses of slightly fibrous Peat were recorded in BH9 between 7m and 7.9m bgl and brown clayey pseudofibrous Peat was recorded in PBH18 between 5.6m and 5.8m bgl.
Figure 13	A 5600-6300	0.2 – 0.4	1.6 – 2.75	Not Proven	Not Proven	The Terrington Beds (Upper Unit) were proven to be between 1.6m and 2.75m in thickness and were described as firm orange brown and grey clay, occasionally slightly sandy. The thickness of the underlying Terrington Beds (Lower Unit) was not proven. It was described as very soft and soft brown and grey clay.
Figure 14	A 6300-7000	0.2 – 0.45	1.25 – 2.3	Not Proven	Not Proven	The Terrington Beds (Upper Unit) were proven to be between 1.25m and 2.3m thick and described as firm to stiff brown clay. The thickness of the Terrington Beds (Lower Unit) was not proven. The material was described as very soft and soft grey and brown clay, occasionally silty.

Geological Long Section	Chainage (m)	Topsoil Thickness (m)	Terrington Beds (Upper Unit) Thickness (m)	Terrington Beds (Lower Unit) Thickness (m)	Glacial Till Thickness (m)	Comments
Figure 15	A 700-7700	0.1 – 0.3	0.9 – 1.9	13.3	Not Proven	The Terrington Beds (Upper Unit) was proven to be between 0.9m and 1.9m in thickness and was described as firm to stiff brown and grey occasionally thinly laminated clay. The Terrington Beds (Lower Unit) was proven to be 13.3m thick in PBH23. The material is described as very soft and soft brown and grey clay and sandy silt. PBH23 records an organic odour and peat between 13.4m and 14.5m bgl. PBH24 describes the clay as organic with traces of decaying plant remains between 3.2m and 6m bgl. Pseudofibrous peat was recorded in PBH25 between 5.6m and 6m bgl.
Figure 16	A 7700-8220	0.1 – 0.2	1.0 – 1.9	10.3 – 10.4	10.6	Possible Made Ground interpreted as 'reworked Glacial Till' was recorded in PBH27 between 0.1m and 0.5m bgl. It is described as firm to stiff slightly sandy slightly gravelly clay. The underlying Terrington Beds (Upper Unit) was proven to be between 1.0m and 1.9m thick and was described as brown and grey clay, occasionally thinly laminated and with silt partings. The Terrington Beds (Lower Unit) were proven to be between 10.3m and 10.4m in thickness and comprised very soft and soft brown and grey silty clay and sandy silt. Pseudofibrous peat was recorded in PBH25 between 5.5m and 6.0m bgl, PBH26 between 5.8m and 6.6m bgl and PBH27 between 5.9m and 6.7m bgl. The Glacial Till was proven to be 10.6m thick in PBH27 and was described as firm to stiff locally soft slightly sandy gravelly clay, with the gravel including chalk and flint.

5. Geotechnical Engineering Assessment

5.1 General comments on the pipeline design and construction

The ground in which the pipeline will be constructed predominantly comprises two layers; the Upper and Lower Terrington Beds. The Lower Terrington Beds is a soft/very soft soil and the Upper Terrington Beds forms a relatively firm overlying crust. Generally, it is expected to be advantageous to the pipeline design and construction if the pipeline is founded in the Upper Terrington Beds.

Based on the ground investigation and the groundwater monitoring data it is reasonable to assume a groundwater level at or above ground level for the design of the pipeline. Buoyancy is likely to affect the design of the pipeline and anti flotation measures may be required for the majority of the pipeline.

Soil within the Terrington Beds Upper Unit generally has a high moisture content and compaction tests indicate that in its natural state it might be difficult to compact. This material could potentially be used to backfill around the pipe, and strength parameters have been estimated so that this can be considered further by Fluor in their pipeline analysis. However due the potential difficulties that may arise when compacting this material, Atkins recommend that if the material is to be considered for use as backfill, trials should be carried out ahead of construction to check that the actual in-situ strength, density and other significant parameters that are relied on in the design, will be as good or better than the values used in design. Also compliance testing should be carried out during the works to confirm the suitability of the material along the pipeline length.

If as part of the pipeline design process Fluor decide not to re-use this material in its natural state the following options could be considered.

- Mixing with quick-lime is a possible way to improve this material. This would dry it out and thus allow it to be compacted to a higher density and achieve strength and. The resulting parameters would be higher than the parameters stated in this report, which are for untreated material. The best way to estimate the resulting parameters would be to carry out lime mixing trials on the material. If lime is used then the associated safety and environment issues should be considered when planning the work.
- Imported granular material could be used to bed and surround the pipe.
- Reinforcement of the ground beneath the pipe could be used as a means of controlling downward bearing failure. Anchorage could be used to prevent upward failure.

The Lower-Terrington Beds material is softer than the upper material and would not be suitable for re-use, unless it were treated with lime.

5.2 Design Parameters

Design Parameters requested by the Fluor pipeline engineers are presented on the next few pages.

It is important to ensure that the ground is modelled correctly in pipeline stress software and it is recommended that specialist geotechnical support is used to ensure that this is the case. For example, one particularly important issue is the layering of the soil. If the base of the pipe lies within the upper Terrington Beds, but is just above the base of this unit, it will be appropriate to use the parameters of the Lower Terrington Beds in the "down case".

It is important to recognise that soil is not a uniform material and parameters may vary. Atkins recommend that a sensitivity analysis is undertaken to determine the effect of variations in soil parameters on the pipeline design. It would also be prudent to introduce confirmatory testing into the construction process to ensure that the design assumptions are satisfied, particularly where the parameters are shown to be critical by the sensitivity analysis.

Some details of the methods used to derive these parameters are given below.

The Vertical down case factors have been correlated from the chart provided by Fluor using the Terzaghi local shear curves. The chart is contained in Autopipe design manual.

C as a required parameter has been assumed to be Cu, i.e. undrained shear strength. The Cu values given for each of the pipeline sections have been interpreted from the results of the on site and laboratory testing and moderately conservative parameters have been adopted to account for a degree of local variability. The adhesion factors have been correlated from the Cu values.

Undrained shear strength (Cu) and stiffness (Eu) parameters are provided for the upper layer of the Terrington Units in it its natural state and for where it is re-used as fill material. If this material is re-used as fill to the pipeline its strength and density will be dependent on how well it is compacted. Atkins recommend that if this material is re-used it should be well compacted and then the "well compacted figures" should be used.

During conversations with Fluor's pipeline engineers, there was some suggestion that material may be re-used on site with minimal compaction. This is not recommended by Atkins. However, to allow Flour to consider this further, paramaters for "partially compacted" material have been provided in the table. These parameters are based on the estimation that the material would only retain 50% of its undrained strength due to air voids and softening due to low water entry through the voids. This is a guide only and this approach should be treated with caution.

Young's Modulus has been calculated using the Butler (see references) method of direct correlation with undrained shear strength.

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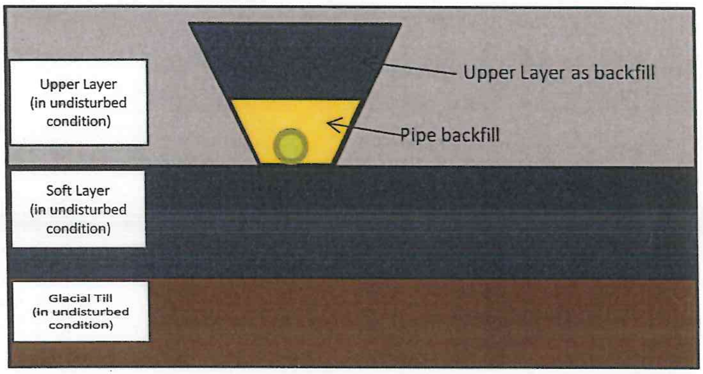
Table 5.1: Pipeline Design Parameters

Soil	Soil Data							Vertical Up case Factor			Vertical Down Case			Transverse Case			
	Bulk Density (Mg/m³)	Buoyant Density (Mg/m³)	K_s (no units)	Soil Internal Angle of Friction (°)	Cohesionless soil/pipe angle of friction a°	Cohesive adhesion factor (a)	Cohesive soil undrained shear strength S_u (KN/m²)	Cohesion of soil (c) of soil above the pipe (KN/m²)	Cohesion Breakout Factor (Fc)	Soil Breakout Factor (Fq)	N_γ	N_c	N_q	Cohesionless depth coefficient Rs	Cohesive Soil Depth Coefficient Rc	Relative Density	Young's Modulus E_u (MPa)
Upper layer as backfill - well compacted	1.75	0.75	0.7	24	N/A	See Table Below	See Table Below	Assumed that undrained shear strength Cu (kN/m²) is required, see below	See Note 3	See Note 3	2.5	9	5	See Note 4	See Note 4	N/A	See Table Below
Upper layer as backfill -partially compacted	1.63	0.65	0.5	20	N/A						1.8	7.5	4			N/A	
Pipe backfill (single sized, lightly compacted)	1.75	0.75	0.7	30	0.3						5	12.5	8			Loose	
Pipe backfill (well graded, well compacted)	2	1.00	0.85	34	0.9						9.5	15	12.5			Dense	
Upper Layer (in undisturbed condition)	1.75	0.75	N/A	24	N/A						2.5	9	5			N/A	
Soft layer (in undisturbed condition)	1.60	0.65	N/A	21	N/A						1.5	7.5	3.5			N/A	
Glacial Till (in undisturbed condition)	2.10	1.10	N/A	30	N/A						5	12.5	8			N/A	

Soil	Cohesive adhesion factor (a)	Cohesive soil undrained shear strength C_u (kN/m²)	Young's Modulus E_u (MPa)
Figure 1			
Upper layer as backfill - well compacted	0.85	40	11.0
Upper layer as backfill -partially compacted	1.00	20	5.5
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.85	40	11.0
Soft layer (in undisturbed condition)	1.00	20	5.0
Glacial Till (in undisturbed condition)	0.70	50	17.5
Figure 2 & 3			
Upper layer as backfill - well compacted	0.90	35	9.6
Upper layer as backfill -partially compacted	1.00	17.5	4.8
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.90	35	9.6
Soft layer (in undisturbed condition)	1.00	20	5.0
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 4			
Upper layer as backfill - well compacted	0.85	40	11.0
Upper layer as backfill -partially compacted	1.00	20	5.5
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.85	40	11.0
Soft layer (in undisturbed condition)	1.00	20	5
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 5			
Upper layer as backfill - well compacted	1.00	35	9.6
Upper layer as backfill -partially compacted	1.00	17.5	4.8
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	1.00	40	11
Soft layer (in undisturbed condition)	1.00	20	5.0
Glacial Till (in undisturbed condition)	N/A	NA	N/A

Indicative sketch of assumed pipeline construction



NOTES

1. The upper layer refers to the Terrington Beds (Upper Unit) and the soft layer refers to the Terrington Beds (Lower Unit).
2. Figures relate to the Geological Long Sections contained in the interpretative report.
3. Cohesion breakout factor, Fc and Soil Breakout Factor, Fq are both functions of the angle of the soil's internal angle of friction, the diameter of the pipe and its depth. These can be determined from the design tables in the AutoPipe Design manual, using the internal angle of shearing, provided in the table. They have not been included in the design table as they will vary according to the pipe depth and if a value were provided it could potentially be seen a soil strength parameter with a "fixed" value.
4. The factors Rc and Rs are both functions of the pipes depth. They have not been included in the design table as they will vary according to the pipe depth and if a value were provided it could potentially be seen a soil strength parameter with a "fixed" value.

6. Contamination Assessment

6.1. Introduction

A contamination assessment has been undertaken to aid compliant re-use of materials excavated as part of the works programme. The assessment includes screening of results in a generic quantitative risk assessment (GQRA) for human health and controlled waters receptors. This has allowed assessment of the potential for reuse of material excavated during the development.

A gas assessment has not been undertaken as no significant sources of gas were identified (see section 5.2).

6.2. Conceptual Site Model

A Conceptual Site Model (CSM) describes the relationship between potential sources of contamination (resulting from both on and off-site historical and recent activities) and receptors to that potential contamination.

As part of the CSM development, three elements, the source of contamination and associated contaminants, receptors to that contamination and the pathways between the two are identified and assessed.

Where a pathway between a source and a receptor is identified in the CSM a potential pollutant linkage (PPL) could be present and this can be taken forward for further assessment, whereas if any of the three elements (source, receptor or pathway) are absent then a PPL is not present and the risk can be discounted. The CSM therefore informs the selection of generic assessment criteria used for screening the laboratory results.

A CSM has been developed for the proposed pipeline route based on the desk study information and observations made during the site investigation (presented in Appendix C). The CSM has identified the following PPLs, which have been taken forward for consideration within the re-use of site won materials assessment:

- Risks to human health (farm workers and walkers) from potentially contaminated soils via dermal contact, ingestion and inhalation of dusts and outdoor inhalation of vapours.
- Risks to property in the form of crops (and thereby human health) from potentially contaminated soils via contact with dust and by root uptake.
- Risks to surface waters (drains, rivers, ponds) from potentially contaminated soils via surface run-off and shallow migration through superficial deposits and preferential pathways such as service corridors and field drains.
- Risks to a shallow groundwater abstraction from shallow migration through superficial deposits and preferential pathways such as service corridors and field drains.

The below GQRA assesses long term chronic risks to end-users and not the short term / acute risks potentially posed to construction/maintenance workers. Risks to construction / maintenance workers should be covered by health and safety / CDM regulations and remain the responsibility of the Contractor. The potential risks posed to workers during excavation works from contaminants recorded within the soils and ground gas originating from peat (methane, hydrogen sulphide, etc) must be considered within future health and safety assessments.

6.3. Re-use Assessment

Human Health and Arable Crops GQRA

A GQRA entails the comparison of soil sampling results against generic assessment criteria (GAC). The site is to be developed as a pipeline with the proposed route excavated then reinstated with site won material once the pipe is in place. No above-ground structures are anticipated and in most areas the existing land use (predominantly agricultural) will continue above the new pipeline.

The human health GAC selected for this assessment are Soil Guideline Values (SGVs) published by the Environment Agency, and Atkins'-derived Soil Screening Values (SSVs) for "Allotments" land use. This has been selected as allotment land use is considered roughly analogous to the land use for the pipeline route (crops for human consumption), which include consideration of exposure routes of plant uptake and human health via dermal contact, dust and inhalation. The allotment values are likely to be conservative for the actual end use as the human interaction on site will be much lower than on an allotment, and arable crops do not uptake and accumulate contaminants as readily as the root vegetables, etc, considered in the allotment GACs.

The Atkins'-derived SSVs have been developed based on the current (2009) guidance issued by the Environment Agency. This specifically includes Science Report 2 (Ref. SC050021/SR2), Science Report 3 (Ref. SC050021SR3) and the CLEA v1.06 model.

The average (geomean) value for soil organic matter (SOM) for the 31 samples analysed is 1.97, however Allotment SSVs are only available for 6% SOM so these have been used.

As the crops (mostly arable) are likely to be for human consumption and GAC do not exist for the protection of crops, the SGV/SSV for allotments are considered to a reasonable GAC.

Samples from all depths have been screened together as there is potential for material to be excavated and placed at shallower depth than the material may currently lie, where pathways to human health could exist. Samples have been grouped for screening according to the historical/current landuse types present on or in close proximity to the pipeline route (i.e. potential sources of contamination). These are former railway / existing pipeline, gas terminal and farmland.

Chemical analysis results of soil samples have been compared against the GAC. This screening is presented as Table E1 in Appendix E.

The findings of the GQRA show all sample concentrations are either below the GAC or method detection limits. The only notable exceptions being five VOCs (all benzene derivatives) from sample PBH21 (farmland), which do not have GAC, but recorded concentrations of up to 4µg/kg. However, considering the low concentrations it is unlikely these few VOC would pose an unacceptable risk to human health (the GAC for benzene is 70µg/kg). No asbestos was identified.

Therefore, the re-use of site won materials is not considered to present an unacceptable risk to human health (or the crops), based on the existing land use continuing following establishment of the new pipeline. As the GAC for the pipeline route relate to a more sensitive landuse than that used in Phase 1, the pipeline materials could also be re-used in the Phase 1 site areas.

Controlled Waters GQRA

Surface waters

As identified in the CSM, risks are presented to surface waters by runoff and from shallow groundwater being in continuity with the numerous drains/rivers crossed by or adjacent to the proposed pipeline route.

The Phase 2 soil-leachate and Phase 1 groundwater test results have been screened against suitable GAC which comprise freshwater EQS published under the EU Water Framework Directive (WFD). Where these are not available for a determinand, United Kingdom EQS have been used. Further, in the absence of an appropriate UK EQS, GAC have been taken from the UK Drinking Water Standards (DWS). The hardness results from samples collected from five major watercourses crossed by the pipeline route were used to select appropriate GAC.

The soil-leachate and groundwater screening results are presented as Table E2 and Table E3, respectively, in Appendix E.

Exceedences of GAC have been identified in soil-leachate samples from many locations along the proposed pipeline route and these are summarised in Table 5.1.

GAC exceedences have been identified in soil-leachate samples collected from all strata types along the entire route, regardless of historical/current landuse types. However, in the groundwater samples analysed (as part of Phase 1) only sulphate exceeds the GAC in one sample collected from AWS01 in Well Site A. The results are summarised in Table 5.1.

Shallow Groundwater Abstraction

A further potential risk to an abstraction well which abstracts water from superficial deposits was assessed. Leachate results from selected locations in close proximity to the abstraction location have been screened against DWS criteria. The soil leachate screening for the shallow groundwater receptor is presented as Table E4 in Appendix E.

No exceedences were encountered in the two samples screened. Therefore, it is considered that potential risks posed to the shallow groundwater abstraction from re-using materials along the pipeline are low.

Table 5.1 – Surface Water Receptors Screen

Historical / Current Landuse on / near site	Material Type	Receptor / Contaminants & number of GAC failures		
		Human Health	Surface Water – Soil-leachate Samples	Surface Water - Groundwater Samples
Farm land	Clay (4 samples)	None	Sulphate(1) Lead(1) Zinc (2) Total Cyanide (1) Anthracene (1) Fluoranthene (1) Benzo[b]fluoranthene + Benzo[k]fluoranthene (1) Benzo[g,h,i]perylene + Indeno[1,2,3-cd]pyrene (1)	Total Sulphate (1) *Note:* *groundwater samples were only collected in Phase 1 and thus are clustered at the western end of the pipeline route. No groundwater data exists for the majority of the route. Additionally, cyanide was not included in the groundwater analysis (as it did not exceed the leachate GAC in Phase 1).*
Existing pipeline / Railway	Topsoil (2 samples)	None	Zinc (2) Total Cyanide (1) Free Cyanide (1) Anthracene (1)	
	Clay (8 samples)	None	Lead(1) Zinc (4) Total Cyanide (1) Fluoranthene (2) Benzo[b]fluoranthene + Benzo[k]fluoranthene (1) Benzo[g,h,i]perylene + Indeno[1,2,3-cd]pyrene (1)	
Gas Terminal Area	Topsoil (1 sample)	None	Total Cyanide (1) Free Cyanide (1)	
	Clay (2 samples)	None	Zinc (2) Fluoranthene (1) Benzo[b]fluoranthene + Benzo[k]fluoranthene (1)	

6.4. Summary of re-use assessment

The information provided in this section is written from an environmental perspective. Re-use is also dependant on engineering properties of the materials.

From a contamination perspective the topsoil and clay along the pipeline route have been assessed and are considered appropriate for re-use anywhere along the pipeline, Well Sites A and B, Grayfleet GSF and access road site areas in respect to human health, arable crops and the shallow groundwater abstraction receptors.

However, there are numerous exceedences of the surface waters GAC in the soil-leachate screen, which suggest that various metals, cyanide and PAHs could be leached from the natural soils at concentrations that could pose an unacceptable risk to surface waters.

Generic risk assessment (GAC screen) just assesses the initial leaching of contaminants from the soil into pore water, it does not allow for the downward migration of the pore water, eventual dilution in the shallow groundwater contained in the superficial deposits and attenuation along the groundwater flow path to the surface waters. Likewise it does not allow for dilution of the initial leachate within surface water run-off.

Groundwater sampling was not included within the Phase 2 scope of works, however, some groundwater sampling was carried out in Phase 1 (which coincides with the western end of the pipeline route). Almost the same contaminants failed the leachate GAC screen in Phase 1 as in Phase 2, with the exception of cyanide which is recorded above the GAC in several samples along the pipeline route. The ground conditions along the pipeline route are very similar to those in Phase 1 (except for considerably less Made Ground being present along the pipeline route).

As the contaminants and ground conditions are similar in Phase 1 and Phase 2 site areas, it is reasonable to consider the groundwater results of Phase 1 in the Phase 2 assessment to allow a rudimentary assessment of the main pollutant migration pathway (groundwater flow).

Of the contaminants tested in the groundwater samples only one sulphate exceeded the GAC in one sample (AWS01). As the majority of the contaminants in the Phase 1 groundwater samples are recorded below the GAC it is considered unlikely that re-using the natural soils excavated from the pipeline route would pose an unacceptable risk to controlled waters. However, as the groundwater samples are limited to the western end and due to the dispersed GAC exceedence by cyanide in the leachate results, there is a risk that regulatory scrutiny of this assessment would require additional assessment to confirm the absence of risk and to allow re-use of the material. Additional assessment could include sampling of groundwater and analysis of in-situ equilibrated cyanide concentrations/ comparison against GAC, and/or detailed quantitative risk assessment (DQRA) to model the site-specific pathway scenarios that the generic screening does not allow for, thereby deriving less conservative screening criteria. To preclude the need for such further assessment, it would be advisable to obtain regulatory opinion. Should this not be forthcoming, Atkins does not envisage that the additional assessments would present an obstacle to the proposed works, as we envisage that groundwater sampling or DQRA for cyanide would eliminate the theoretical risk identified during this generic screening exercise.

If the Client intends to re-use materials excavated from the pipe trenches as backfill on top of the new pipe and wishes to follow the CL:AIRE code of practice then the Client will need to demonstrate (within his Material Management Plan) that suitable risk assessments have been completed and that re-using the materials does not pose an unacceptable risk to surface waters.

From a contamination perspective Atkins considers it is likely materials will be suitable for re-use, because re-use of soils excavated from the pipeline route as backfill either on top of the new pipe or within the Well Sites A&B / Grayfleet GSF are considered unlikely to pose an unacceptable risk to human health, arable crops or controlled waters. However, so far as concerns the potential risk to surface waters, the above conclusion is based on limited groundwater data (from the western end of the pipeline). Further confidence in the anticipated conclusion that risks to controlled waters are absent would be gained by completing the following tasks, which could also be included in a Materials Management Plan:

- Collection of additional groundwater samples from along the entire pipeline route (monitoring wells are already in place)
- Analysis for those contaminants that exceed the Phase 2 leachate GAC.
- Revise the GQRA presented herein with the findings of the additional testing/assessment

Materials that have to be disposed off-site to a waste treatment/disposal facility will require analysis by the construction contractor. Samples will need to be collected from the excavated materials stockpiles for testing (using suites based on those used in this report) to allow waste characterisation. Also Waste Acceptance Criteria (WAC) tests might be required to further define the waste class (e.g. could the material be classed as inert).

7. References

Environment Agency (2009) Human Health Toxicological Assessment of Contaminants in Soil, Science Report, Final SC050021/SR2

Environment Agency (2009) Updated Technical Background to the CLEA Model, Science Report, SC050021/SR3

Soil Mechanics Factual Report on Ground Investigation (Report No A0083-10) dated April 2011

Soil Mechanics, Principles and Practice, G E Barnes (2000)

Foundation Design and Construction, M J Tomlinson (2001)

BS8002:1994 Code of practice for Earth retaining structures (1995)

Envirocheck Report, Landmark Information Group (Order No 32285717_1_1) dated 25th August 2010

British Geological Survey (BGS) Map Sheet 104 'Mablethorpe' (Solid and Drift Edition)

The Standard Penetration Test – Its Application and Interpretation, M A Stroud

BRE Special Digest 1:2005, 3rd Edition, Concrete in aggressive ground

Ground Investigation for a proposed Gas Pipeline at Theddlethorpe, Report Ref: 45061, April 1999

Ground Investigation at Rig Sites 'A' and 'B', Saltfleetby, Lincolnshire, Report Ref: 45034, July 1999

Costain Geotechnical Services, Saltfleetby Gas Storage Project, Nr Louth, Ground Investigation Interpretative Report, Contract No: 018936/3520 Rev A

BGS Research Report RR/06/03, The Chalk aquifer system of Lincolnshire, E J Whitehead and A R Lawrence (2006)

BUTLER, F.G. (1975) Heavily over consolidated clays. Conference on settlement of structures, Cambridge, Review Paper. Session III. London; Pentech Press.

Soil Mechanics, UGS Saltfleetby Factual report on Ground Investigation No: A0083-10

Appendices

Appendix A. Pipeline Route Geological Long Sections

Appendix B. Not Used

Appendix C. Conceptual Site Model

Appendix D. PID Results

Appendix E. Contaminant Screening Tables

6. Contamination Assessment

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6.3. Re-use Assessment

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The human health GAC selected for this assessment are Soil Guideline Values (SGVs) published by the Environment Agency, and Atkins'-derived Soil Screening Values (SSVs) for "Allotments" land use. This has been selected as allotment land use is considered roughly analogous to the land use for the pipeline route (crops for human consumption), which include consideration of exposure routes of plant uptake and human health via dermal contact, dust and inhalation. The allotment values are likely to be conservative for the actual end use as the human interaction on site will be much lower than on an allotment, and arable crops do not uptake and accumulate contaminants as readily as the root vegetables, etc, considered in the allotment GACs.

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The average (geomean) value for soil organic matter (SOM) for the 31 samples analysed is 1.97, however Allotment SSVs are only available for 6% SOM so these have been used.

As the crops (mostly arable) are likely to be for human consumption and GAC do not exist for the protection of crops, the SGV/SSV for allotments are considered to a reasonable GAC.

Samples from all depths have been screened together as there is potential for material to be excavated and placed at shallower depth than the material may currently lie, where pathways to human health could exist. Samples have been grouped for screening according to the historical/current landuse types present on or in close proximity to the pipeline route (i.e. potential sources of contamination). These are former railway / existing pipeline, gas terminal and farmland.

Chemical analysis results of soil samples have been compared against the GAC. This screening is presented as Table E1 in Appendix E.

The findings of the GQRA show all sample concentrations are either below the GAC or method detection limits. The only notable exceptions being five VOCs (all benzene derivatives) from sample PBH21 (farmland), which do not have GAC, but recorded concentrations of up to 4μg/kg. However, considering the low concentrations it is unlikely these few VOC would pose an unacceptable risk to human health (the GAC for benzene is 70μg/kg). No asbestos was identified.

Therefore, the re-use of site won materials is not considered to present an unacceptable risk to human health (or the crops), based on the existing land use continuing following establishment of the new pipeline. As the GAC for the pipeline route relate to a more sensitive landuse than that used in Phase 1, the pipeline materials could also be re-used in the Phase 1 site areas.

Controlled Waters GQRA

Surface waters

As identified in the CSM, risks are presented to surface waters by runoff and from shallow groundwater being in continuity with the numerous drains/rivers crossed by or adjacent to the proposed pipeline route.

The Phase 2 soil-leachate and Phase 1 groundwater test results have been screened against suitable GAC which comprise freshwater EQS published under the EU Water Framework Directive (WFD). Where these are not available for a determinand, United Kingdom EQS have been used. Further, in the absence of an appropriate UK EQS, GAC have been taken from the UK Drinking Water Standards (DWS). The hardness results from samples collected from five major watercourses crossed by the pipeline route were used to select appropriate GAC.

The soil-leachate and groundwater screening results are presented as Table E2 and Table E3, respectively, in Appendix E.

Exceedences of GAC have been identified in soil-leachate samples from many locations along the proposed pipeline route and these are summarised in Table 5.1.

GAC exceedences have been identified in soil-leachate samples collected from all strata types along the entire route, regardless of historical/current landuse types. However, in the groundwater samples analysed (as part of Phase 1) only sulphate exceeds the GAC in one sample collected from AWS01 in Well Site A. The results are summarised in Table 5.1.

Shallow Groundwater Abstraction

A further potential risk to an abstraction well which abstracts water from superficial deposits was assessed. Leachate results from selected locations in close proximity to the abstraction location have been screened against DWS criteria. The soil leachate screening for the shallow groundwater receptor is presented as Table E4 in Appendix E.

No exceedences were encountered in the two samples screened. Therefore, it is considered that potential risks posed to the shallow groundwater abstraction from re-using materials along the pipeline are low.

Table 4.1 – Summary of Ground Conditions along the route of the Proposed Pipeline

Geological Long Section	Chainage (m)	Topsoil Thickness (m)	Terrington Beds (Upper Unit) Thickness (m)	Terrington Beds (Lower Unit) Thickness (m)	Glacial Till Thickness (m)	Comments
Figure 1	B 0-700	0.2	1.0 – 2.75	0.7 – 2.45	21.5	The Terrington Beds were absent from exploratory holes ABH02 and BHAM4. In exploratory holes AWS01 and AWS02 only the Upper Unit of the Terrington Beds were present, the Lower Unit appeared to be absent. The Terrington Beds (Upper Unit) was proven to be between 1.0m and 2.75m in thickness and comprised soft to firm often thickly laminated slightly sandy or sandy silty clay. The Terrington Beds (Lower Unit) where present was proven to be between 0.7m and 2.45m in thickness and generally comprised soft brown and grey silty clay, with occasional peat inclusions and silt lenses. The Glacial Till was proven to be 21.5m thick in ABH02. Generally it was described as firm to stiff slightly gravelly or gravelly slightly sandy or silty clay. The gravel was described as being angular to subrounded fine to coarse chalk, flint, sandstone, mudstone and siliceous rock.
Figures 2 & 3	B 700-1560	0.2	1.6 – 3.0	1.4 – 3.3	Not Proven	The Terrington Beds (Upper Unit) was proven to be between 1.6m and 3.0m in thickness and generally comprised soft to firm and firm locally stiff orange brown and grey brown clay, often thickly laminated and with occasional silt partings. The underlying Lower Unit was proven to be between 1.4m and 3.3m in thickness and was generally described as very soft and soft brown and grey brown clay. It should be noted that a layer of peat 1.2m in thickness was encountered in exploratory hole PBH03 between 4.5m and 5.7m bgl. It is described as black plastic fibrous clayey peat. The thickness of the underlying Glacial Till was not proven. It is generally described as stiff grey brown slightly gravelly slightly sandy clay and gravelly clay. The gravel is described as being subangular to subrounded fine to coarse chalk and occasional siltstone and flint.
Figure 4	C 0-520	0.2 – 0.4	0.8 – 1.9	3.3 – 4.2	17	The Terrington Beds (Upper Unit) was proven to be between 0.8m and 1.9m thick and generally comprised firm and firm to stiff brown, orange brown and grey clay occasionally thickly laminated and with occasional silt partings. The underlying Lower Unit was proven to be between 3.3m and 4.0m in thickness and is typically described as very soft and soft dark grey, brown and grey clay, occasionally silty and containing organic matter and silt partings. It should be noted that a peat layer 0.5m in thickness was encountered in PBH04 comprising black plastic clayey pseudo-fibrous peat. The thickness of Glacial Till was proven in exploratory hole GSFBH02 during the Phase 1 ground investigation. It was proven to be 17m thick and typically comprised soft to very stiff grey and brown slightly sandy slightly gravelly clay. The gravel comprised subangular to subrounded fine to medium chalk and occasional flint and siltstone.

Geological Long Section	Chainage (m)	Topsoil Thickness (m)	Terrington Beds (Upper Unit) Thickness (m)	Terrington Beds (Lower Unit) Thickness (m)	Glacial Till Thickness (m)	Comments
Figure 5	A 0-700	0.2 – 0.8	0.8 – 2.3	3.9 – 6.5	16.7 – 17.6	The Terrington Beds (Upper Unit) was proven to be between 0.8m and 2.3m in thickness and typically comprised firm locally stiff thickly laminated orange brown and grey clay with occasional silt partings. The underlying Lower Unit was proven to be between 3.9m and 6.5m in thickness and generally comprised very soft and soft dark grey clay with occasional slit lenses. Occasional shell fragments were encountered in PWS12. Pockets of fibrous black peat were recorded in GSFWS04. Black clayey pseudofibrous peat was encountered in PBH4 between 4.4m and 4.9m bgl and in PBH7 between 5.1m and 5.5m bgl and 7.9m to 8.2m bgl. The thickness of Glacial Till was proven to be between 16.7m and 17.6m in three exploratory holes and comprised firm to stiff brown and grey brown slightly gravelly clay. The gravel consisted of chalk, flint and siltstone. Occasional bands of sand were also noted.
Figure 6	A 700-1400	0.15 – 0.2	1.65 – 2.0	Not Proven	Not Proven	The Terrington Beds (Upper Unit) was proven to be between 0.65m and 2.0m in thickness and was described as firm orange brown and grey clay. The Terrington Beds (Lower Unit) thickness was not proven. The material was described as very soft and soft brown and grey occasionally black clay.
Figure 7	A 1400-2100	0.2 – 0.35	1.65 – 1.9	6.4	Not Proven	The Terrington Beds (Upper Unit) was proven to be between 1.65m and 1.9m in thickness and typically comprised firm orange brown and grey clay. The Terrington Beds (Lower Unit) was proven to be 6.4m thick in PBH10 and was described as very soft brown and grey occasionally black clay and silty clay. The thickness of the underlying Glacial Till was not proven; it was described as firm brown slightly sandy slightly gravelly clay, with the gravel including chalk and occasional siltstone and flint.
Figure 8	A 2100-2800	0.3 – 1.0	1.9 – 2.2	4.95 – 6.3	Not Proven	The thickness of the Terrington Beds (Upper Unit) was proven to be between 1.9m and 2.2m and comprised soft to firm locally stiff thinly laminated clay, occasionally silty or sandy. The Terrington Beds (Lower Unit) was proven to be between 4.95m and 6.3m in thickness and comprised very soft and soft brown and grey clay, often silty and organic. A peat layer was recorded in BH6 between 5.5m and 6.0m bgl.
Figure 9	A 2800-3500	0.3	0.9 – 2.3	Not Proven	Not Proven	The Terrington Beds (Upper Unit) were proven to be between 0.9m and 2.3m thick and comprised firm and stiff brown clay and sandy clay. The thickness of the Lower Unit was not proven. The material is generally described as very soft brown and grey clayey silt and silty clay.

Table 5.1 – Surface Water Receptors Screen

Historical / Current Landuse on / near site	Material Type	Receptor / Contaminants & number of GAC failures		
		Human Health	**Surface Water – Soil-leachate Samples**	**Surface Water - Groundwater Samples**
Farm land	Clay (4 samples)	None	Sulphate(1) Lead(1) Zinc (2) Total Cyanide (1) Anthracene (1) Fluoranthene (1) Benzo[b]fluoranthene + Benzo[k]fluoranthene (1) Benzo[g,h,i]perylene + Indeno[1,2,3-cd]pyrene (1)	Total Sulphate (1) *Note: groundwater samples were only collected in Phase 1 and thus are clustered at the western end of the pipeline route. No groundwater data exists for the majority of the route. Additionally, cyanide was not included in the groundwater analysis (as it did not exceed the leachate GAC in Phase 1).*
Existing pipeline / Railway	Topsoil (2 samples)	None	Zinc (2) Total Cyanide (1) Free Cyanide (1) Anthracene (1)	
	Clay (8 samples)	None	Lead(1) Zinc (4) Total Cyanide (1) Fluoranthene (2) Benzo[b]fluoranthene + Benzo[k]fluoranthene (1) Benzo[g,h,i]perylene + Indeno[1,2,3-cd]pyrene (1)	
Gas Terminal Area	Topsoil (1 sample)	None	Total Cyanide (1) Free Cyanide (1)	
	Clay (2 samples)	None	Zinc (2) Fluoranthene (1) Benzo[b]fluoranthene + Benzo[k]fluoranthene (1)	

6.4. Summary of re-use assessment

The information provided in this section is written from an environmental perspective. Re-use is also dependant on engineering properties of the materials.

From a contamination perspective the topsoil and clay along the pipeline route have been assessed and are considered appropriate for re-use anywhere along the pipeline, Well Sites A and B, Grayfleet GSF and access road site areas in respect to human health, arable crops and the shallow groundwater abstraction receptors.

However, there are numerous exceedences of the surface waters GAC in the soil-leachate screen, which suggest that various metals, cyanide and PAHs could be leached from the natural soils at concentrations that could pose an unacceptable risk to surface waters.

Generic risk assessment (GAC screen) just assesses the initial leaching of contaminants from the soil into pore water, it does not allow for the downward migration of the pore water, eventual dilution in the shallow groundwater contained in the superficial deposits and attenuation along the groundwater flow path to the surface waters. Likewise it does not allow for dilution of the initial leachate within surface water run-off.

Groundwater sampling was not included within the Phase 2 scope of works, however, some groundwater sampling was carried out in Phase 1 (which coincides with the western end of the pipeline route). Almost the same contaminants failed the leachate GAC screen in Phase 1 as in Phase 2, with the exception of cyanide which is recorded above the GAC in several samples along the pipeline route. The ground conditions along the pipeline route are very similar to those in Phase 1 (except for considerably less Made Ground being present along the pipeline route).

As the contaminants and ground conditions are similar in Phase 1 and Phase 2 site areas, it is reasonable to consider the groundwater results of Phase 1 in the Phase 2 assessment to allow a rudimentary assessment of the main pollutant migration pathway (groundwater flow).

Of the contaminants tested in the groundwater samples only one sulphate exceeded the GAC in one sample (AWS01). As the majority of the contaminants in the Phase 1 groundwater samples are recorded below the GAC it is considered unlikely that re-using the natural soils excavated from the pipeline route would pose an unacceptable risk to controlled waters. However, as the groundwater samples are limited to the western end and due to the dispersed GAC exceedence by cyanide in the leachate results, there is a risk that regulatory scrutiny of this assessment would require additional assessment to confirm the absence of risk and to allow re-use of the material. Additional assessment could include sampling of groundwater and analysis of in-situ equilibrated cyanide concentrations/ comparison against GAC, and/or detailed quantitative risk assessment (DQRA) to model the site-specific pathway scenarios that the generic screening does not allow for, thereby deriving less conservative screening criteria. To preclude the need for such further assessment, it would be advisable to obtain regulatory opinion. Should this not be forthcoming, Atkins does not envisage that the additional assessments would present an obstacle to the proposed works, as we envisage that groundwater sampling or DQRA for cyanide would eliminate the theoretical risk identified during this generic screening exercise.

If the Client intends to re-use materials excavated from the pipe trenches as backfill on top of the new pipe and wishes to follow the CL:AIRE code of practice then the Client will need to demonstrate (within his Material Management Plan) that suitable risk assessments have been completed and that re-using the materials does not pose an unacceptable risk to surface waters.

From a contamination perspective Atkins considers it is likely materials will be suitable for re-use, because re-use of soils excavated from the pipeline route as backfill either on top of the new pipe or within the Well Sites A&B / Grayfleet GSF are considered unlikely to pose an unacceptable risk to human health, arable crops or controlled waters. However, so far as concerns the potential risk to surface waters, the above conclusion is based on limited groundwater data (from the western end of the pipeline). Further confidence in the anticipated conclusion that risks to controlled waters are absent would be gained by completing the following tasks, which could also be included in a Materials Management Plan:

- Collection of additional groundwater samples from along the entire pipeline route (monitoring wells are already in place)
- Analysis for those contaminants that exceed the Phase 2 leachate GAC.
- Revise the GQRA presented herein with the findings of the additional testing/assessment

Materials that have to be disposed off-site to a waste treatment/disposal facility will require analysis by the construction contractor. Samples will need to be collected from the excavated materials stockpiles for testing (using suites based on those used in this report) to allow waste characterisation. Also Waste Acceptance Criteria (WAC) tests might be required to further define the waste class (e.g. could the material be classed as inert).

Exploratory Hole ID	Sample reference	Sample depth (m bgl)	PID result (PPM)	Sample Description
PBH3	ES2	0.4	0.0	Brown CLAY
PBH3	ES4	1.1	0.0	Brown CLAY
PBH4	ES3	0.4	0.0	Brown CLAY. Rare rootlets.
PBH4	ES5	1	0.0	Brown CLAY
PBH4	ES8	1.9	0.0	Brown CLAY
PBH5	ES3	0.4	0.0	Dark brown CLAY. Rare rootlets.
PBH5	ES5	1	0.0	Brown CLAY
PBH5	ES8	1.9	0.0	Brown CLAY
PBH6	ES2	0.4	0.0	Brown CLAY
PBH6	ES4	1	0.0	Brown CLAY
PBH6	ES7	1.9	0.0	Brown CLAY
PBH7	ES2	0.4	0.5	Brown CLAY. Rare rootlets.
PBH7	ES5	1	1.0	Brown mottled orange brown and grey CLAY
PBH7	ES8	1.9	0.0	Brown mottled orange brown and grey CLAY
PBH8	ES3	0.3	0.0	Dark brown slightly sandy silty CLAY.
PBH8	ES4	0.6	0.0	Dark brown slightly sandy silty CLAY.
PBH8	ES6	1	0.0	Dark brown slightly sandy silty CLAY.
PBH8	ES10	2.2	0.0	Dark brown mottled grey slightly sandy silty CLAY
PBH9	ES3	0.3	0.0	Brown mottled orange brown and grey CLAY
PBH9	ES4	0.6	0.0	Brown mottled orange brown and grey CLAY
PBH10	ES1	0.5	0.0	Brown CLAY
PBH10	ES3	1	0.0	Brown CLAY
PBH10	ES6	1.5	0.0	Brown CLAY
PBH10	ES7	2	0.0	Brown CLAY (TERRINGTON BEDS)
PBH11	ES3	0.3	0.0	Brown thinly laminated slightly gravelly CLAY
PBH11	ES4	0.6	0.0	Brown thinly laminated slightly gravelly CLAY
PBH11	ES6	1	0.0	Brown thinly laminated slightly gravelly CLAY
PBH11	ES7	1.5	0.0	Brown thinly laminated slightly gravelly CLAY
PBH13	ES1	0.5	0.0	Dark grey brown slightly sandy silty CLAY
PBH13	ES3	1	0.0	Dark grey brown slightly sandy silty CLAY
PBH13	ES7	2	0.0	Dark grey brown slightly sandy silty CLAY
PBH15	ES2	0.3	0.0	Brown slightly sandy thinly laminated CLAY
PBH15	ES3	0.5	0.0	Brown sandy CLAY
PBH15	ES5	1	0.0	Brown sandy CLAY
PBH16	ES3	1	NR	Brown mottled grey and orange brown sandy CLAY
PBH16	ES6	1.5	NR	Brown mottled grey and orange brown sandy CLAY
PBH16	ES7	2	NR	Brown silty CLAY
PBH17	ES1	0.5	1.4	Brown mottled orangish brown and grey CLAY
PBH17	ES3	1	1.4	Brown mottled orangish brown and grey CLAY
PBH17	ES6	1.5	0.8	Brown mottled orangish brown and grey CLAY
PBH17	ES7	2	1.6	Brown CLAY
PBH18	ES3	0.4	0.0	Dark brown CLAY. Rare rootlets.
PBH18	ES5	1	0.0	Brown CLAY. Rare rootlets.
PBH18	ES8	1.9	0.0	Brown and grey clay

Exploratory Hole ID	Sample reference	Sample depth (m bgl)	PID result (PPM)	Sample Description
PBH19	ES1	0.5	0.0	Brown mottled orangish brown and grey CLAY
PBH19	ES3	1	0.0	Brown mottled orangish brown and grey CLAY
PBH19	ES6	1.5	0.0	Brown mottled orangish brown and grey CLAY
PBH20	ES1	0.5	0.0	Brown slightly gravelly CLAY with rare rootlets
PBH20	ES3	1	0.0	Brown slightly gravelly CLAY with rare rootlets
PBH20	ES6	1.5	0.0	Brown mottled orangish brown slightly sandy CLAY
PBH20	ES7	2	0.0	Brown mottled orangish brown slightly sandy CLAY, rare decaying plant remains
PBH21	ES2	0.2	2.6	Brown slightly gravelly CLAY with occasional rootlets (TOPSOIL)
PBH21	ES4	0.5	4.5	Brown CLAY
PBH21	ES6	1	128.0	Brown CLAY
PBH22	ES1	0.5	0.0	Brown mottled orangish brown and grey CLAY with rare rootlets.
PBH22	ES3	1	0.0	Brown mottled orangish brown and grey CLAY with rare rootlets.
PBH22	ES6	1.5	0.0	Brown CLAY
PBH23	ES1	0.3	0.0	Brown CLAY, occasional rootlets (TOPSOIL)
PBH23	ES2	0.75	0.0	Brown mottled orangish brown CLAY
PBH23	ES5	1.3	0.0	Brown CLAY
PBH23	ES8	2	0.0	Brown CLAY
PBH24	ES1	0.3	0.0	Brown CLAY with frequent rootlets
PBH24	ES2	0.75	0.0	Brown mottled grey CLAY with rootlets
PBH24	ES3	1.25	0.0	Brown mottled grey CLAY with rootlets
PBH24	ES9	1.75	0.0	Brown, locally grey, organic CLAY (TERRINGTON BEDS)
PBH25	ES2	0.4	0.0	Thinly laminated brown mottled grey CLAY
PBH25	ES4	1	0.0	Thinly laminated brown mottled grey CLAY
PBH25	ES7	1.9	0.0	Thinly laminated brown mottled grey CLAY
PBH26	ES2	0.4	0.5	Brown thinly laminated occasionally mottled grey CLAY
PBH26	ES5	1.1	0.0	Brown mottled grey CLAY with occasional silt partings
PBH26	ES8	1.9	0.2	Brown CLAY

PID Results Summary

Exploratory Hole ID	Sample reference	Sample depth (m bgl)	PID result (PPM)	Sample Description
PTP01	ES1	0.5	0.0	Brown slightly gravelly clay.
PTP01	ES4	1	0.0	Brown slightly gravelly clay.
PTP01	ES6	1.5	0.0	Brown slightly gravelly clay.
PTP03	ES1	0.5	0.0	Brown mottled grey and orangish brown CLAY.
PTP03	ES4	1	0.0	Brown mottled grey and orangish brown CLAY.
PTP03	ES6	1.5	0.0	Brown mottled grey and orangish brown CLAY.
PTP04	ES1	0.5	0.0	Brown mottled orangish brown and grey CLAY.
PTP04	ES4	0.8	0.0	Brown mottled grey and orangish brown CLAY.
PTP04	ES8	1.5	0.0	Brown mottled grey and orangish brown CLAY.
PTP06	ES1	0.5	0.0	Brown mottled orangish brown and grey CLAY.
PTP06	ES4	1	0.0	Brown mottled orangish brown and grey CLAY.
PTP06	ES6	1.5	0.0	Brown mottled orangish brown and grey CLAY.
PTP08	ES1	0.5	0.0	Brown mottled orangish brown and grey CLAY.
PTP08	ES5	1	0.0	Brown mottled orangish brown and grey CLAY.
PTP08	ES7	1.5	0.0	Brown mottled orangish brown and grey CLAY.
PTP09	ES1	0.5	0.0	Brown CLAY.
PTP09	ES4	1	0.0	Brown CLAY.
PTP09	ES6	1.5	0.0	Brown CLAY.
PTP10C	ES1	0.1	0.0	Brown mottled grey CLAY.
PTP10C	ES3	0.8	0.0	Brown mottled grey CLAY.
PTP10C	ES5	1.8	0.0	Brown mottled grey CLAY.
PTP11A	ES1	0.1	0.0	Brown CLAY. Occasional Rootlets (Topsoil).
PTP11A	ES4	0.9	0.0	Brown CLAY.
PTP11A	ES8	1.7	0.0	Light brown mottled orangish brown sandy CLAY.
PTP11B	ES1	0.5	0.0	Brown mottled orangish brown and grey CLAY. Rare organic material.
PTP11B	ES4	1	0.0	Brown mottled orangish brown and grey CLAY. Rare organic material.
PTP11B	ES6	1.5	0.0	Light brown mottled orangish brown and grey CLAY.
PTP12A	ES1	0.5	0.0	Orangish brown sandy CLAY
PTP12A	ES4	1	0.0	Orangish brown sandy CLAY
PTP12A	ES6	1.5	0.0	Orangish brown sandy CLAY
PTP13A	ES1	0.5	0.0	Brown CLAY. Occasional Rootlets (Topsoil)
PTP13A	ES4	1	0.0	Light brown sandy CLAY
PTP13A	ES6	1.5	0.0	Light brown sandy CLAY
PTP15B	ES1	0.1	0.0	Brown CLAY. Occasional Rootlets (Topsoil)
PTP15B	ES3	0.7	0.0	Brown mottled grey CLAY
PTP15B	ES5	1.7	0.0	Brown mottled orangish brown and grey CLAY

Table 4.3 – Water Level Details from Piezometer Standpipe Monitoring

Borehole	Response Zone (m AOD)	Response Zone Strata	Water Depth April/May 2011 (m BGL)	Water Level April/May 2011 (m AOD)
PBH03	1.308 to -3.892	Terrington Beds	1.97	0.138
PBH04	1.054 to -8.196	Terrington Beds/Glacial Till	1.53	0.324
PBH05	1.107 to -3.593	Terrington Beds/Glacial Till	1.50	0.407
PBH06	1.569 to -14.231	Terrington Beds/Glacial Till	0.32	1.549
PBH07	-11.056 to -17.656	Glacial Till	1.1	0.844
PBH08	-1.687 to -5.187	Terrington Beds	0.96	0.853
PBH09	1.102 to -8.098	Terrington Beds	5.54	-3.638
PBH10	1.393 to -7.807	Terrington Beds/Glacial Till	3.57	-1.377
PBH11	1.351 to -12.349	Terrington Beds/Glacial Till	2.02	0.131
PBH13	-2.746 to -5.746	Terrington Beds	1.03	0.724
PBH14	1.268 to -7.932	Terrington Beds	1.41	0.658
PBH15	-8.464 to -14.964	Terrington Beds/Glacial Till	0.70	1.536
PBH16	-13.547 to -18.047	Glacial Till	0.30	1.653
PBH17	-11.178 to -18.178	Glacial Till	1.35	0.472
PBH18	0.946 to -8.454	Terrington Beds	3.41	-1.664
PBH19	1.423 to -7.777	Terrington Beds	6.81	-4.587
PBH20	1.264 to -7.936	Terrington Beds	1.81	0.254
PBH21	1.557 to -7.643	Terrington Beds	2.06	0.297
PBH22	0.873 to -8.327	Terrington Beds	1.51	0.163
PBH23	1.037 to -13.163	Terrington Beds	1.35	0.487
PBH24	0.874 to -8.326	Terrington Beds	1.20	0.474
PBH25	1.08 to -8.12	Terrington Beds	1.31	0.57
PBH26	0.578 to -11.872	Terrington Beds/Glacial Till	1.32	0.158

Figure 6			
Upper layer as backfill - well compacted	0.85	40	11.0
Upper layer as backfill -partially compacted	1.00	20	5.5
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.85	40	11.0
Soft layer (in undisturbed condition)	1.00	15	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 7			
Upper layer as backfill - well compacted	0.85	40	11.0
Upper layer as backfill -partially compacted	1.00	20	5.5
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.85	40	11.0
Soft layer (in undisturbed condition)	1.00	15	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 8			
Upper layer as backfill - well compacted	1.00	25	6.8
Upper layer as backfill -partially compacted	1.00	12.5	3.4
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	1.00	30	5.5
Soft layer (in undisturbed condition)	1.00	20	5.0
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 9			
Upper layer as backfill - well compacted	0.95	25	6.9
Upper layer as backfill -partially compacted	1.00	12.5	3.4
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.95	25	6.9
Soft layer (in undisturbed condition)	1.00	15	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 10			
Upper layer as backfill - well compacted	0.90	30	8.3
Upper layer as backfill -partially compacted	1.00	15	4.1
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.90	40	8.3
Soft layer (in undisturbed condition)	1.00	20	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 11			
Upper layer as backfill - well compacted	0.85	45	12.4
Upper layer as backfill -partially compacted	[illegible]	22.5	6.2
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.85	45	12.4
Soft layer (in undisturbed condition)	1.00	20	6.3
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 12			
Upper layer as backfill - well compacted	0.90	30	8.3
Upper layer as backfill -partially compacted	1.00	15	4.1
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.90	30	8.3
Soft layer (in undisturbed condition)	1.00	25	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 13			
Upper layer as backfill - well compacted	0.90	35	8.3
Upper layer as backfill -partially compacted	1.00	17.5	4.1
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.90	30	8.3
Soft layer (in undisturbed condition)	1.00	15	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 14			
Upper layer as backfill - well compacted	0.90	35	8.3
Upper layer as backfill -partially compacted	1.00	17.5	4.1
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.90	40	8.3
Soft layer (in undisturbed condition)	1.00	20	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A

Figure 15			
Upper layer as backfill - well compacted	0.60	40	17.9
Upper layer as backfill -partially compacted	0.90	20	8.9
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.60	65	17.9
Soft layer (in undisturbed condition)	1.00	15	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A
Figure 16			
Upper layer as backfill - well compacted	0.90	35	8.3
Upper layer as backfill -partially compacted	1.00	17.5	4.1
Pipe backfill (single sized, lightly compacted)	N/A	N/A	N/A
Pipe backfill (well graded, well compacted)	N/A	N/A	N/A
Upper Layer (in undisturbed condition)	0.90	40	8.3
Soft layer (in undisturbed condition)	1.00	15	3.8
Glacial Till (in undisturbed condition)	N/A	NA	N/A

7. References

Environment Agency (2009) Human Health Toxicological Assessment of Contaminants in Soil, Science Report, Final SC050021/SR2

Environment Agency (2009) Updated Technical Background to the CLEA Model, Science Report, SC050021/SR3

Soil Mechanics Factual Report on Ground Investigation (Report No A0083-10) dated April 2011

Soil Mechanics, Principles and Practice, G E Barnes (2000)

Foundation Design and Construction, M J Tomlinson (2001)

BS8002:1994 Code of practice for Earth retaining structures (1995)

Envirocheck Report, Landmark Information Group (Order No 32285717_1_1) dated 25th August 2010

British Geological Survey (BGS) Map Sheet 104 'Mablethorpe' (Solid and Drift Edition)

The Standard Penetration Test – Its Application and Interpretation, M A Stroud

BRE Special Digest 1:2005, 3rd Edition, Concrete in aggressive ground

Ground Investigation for a proposed Gas Pipeline at Theddlethorpe, Report Ref: 45061, April 1999

Ground Investigation at Rig Sites 'A' and 'B', Saltfleetby, Lincolnshire, Report Ref: 45034, July 1999

Costain Geotechnical Services, Saltfleetby Gas Storage Project, Nr Louth, Ground Investigation Interpretative Report, Contract No: 018936/3520 Rev A

BGS Research Report RR/06/03, The Chalk aquifer system of Lincolnshire, E J Whitehead and A R Lawrence (2006)

BUTLER, F.G. (1975) Heavily over consolidated clays. Conference on settlement of structures, Cambridge, Review Paper. Session III. London; Pentech Press.

Soil Mechanics, UGS Saltfleetby Factual report on Ground Investigation No: A0083-10