Otterspool Park, Liverpool

Proposed Skate Park

Desk Study & Ground Investigation Interpretative Report

April 2014

For Liverpool City Council

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EXECUTIVE SUMMARY

Introduction	Mouchel has been commissioned by Liverpool City Council to provide a combined desk study and interpretative ground investigation report in relation to the proposed skate park at Otterspool Park, Liverpool. This report assesses the potential environmental and geotechnical risks and liabilities associated with the proposed development.
Site Setting	The site is located in the Otterspool area approximately 5.7km to the south east of Liverpool city centre and covers approximately 0.7 hectares. The site is currently an area of open parkland within Otterspool Park. The site is generally level with the south and eastern areas sloping down into the central part of the site. Historically, the site has been occupied by a mill, small gasometer and an infilled pond. An infilled dock is present to the east and a former landfill to the south west. The underlying bedrock is a principal aquifer and the Mersey Estuary is present 160m to the south west.
Ground Investigation	A ground investigation was undertaken to assess the site soils, groundwater and ground gas regime to identify any potential risks to future site users of the proposed skate park as well as to controlled waters, structures associated with the skate park i.e. foundations and adjacent site users. Eight windowless sampler holes were drilled with three installed with gas / groundwater monitoring wells as well as four machine excavated trial pits. Laboratory chemical and geotechnical testing was also undertaken as well as post fieldwork gas / groundwater monitoring.
Ground Model	The geology encountered comprised made ground up to depths in excess of 5.45m bgl (limit of the windowless sampler). Natural ground comprising Tidal Flat Deposits and Glacial Till were also encountered along with weathered sandstone bedrock. No gas flow was detected and methane was absent. Carbon dioxide up to 6.9% was recorded.
Human Health Risk Assessment	Site wide contamination comprising lead, benzo(a)pyrene, dibenzo(ah)anthracene and dibenzofuran was present that may pose a risk to human health given a public open space end use. Asbestos was also noted in one location. The proposed Skate Park structures will break the pathway between the identified contamination and the end users; consideration should also be given to capping adjacent areas. The assessment of the gas monitoring results shows that the concentrations of ground gases at the site do not pose a significant risk to site users due to the low concentrations of gas and the absence of flow.
Controlled Waters Risk Assessment	The assessment to consider the risk to the underlying bedrock aquifer and Mersey Estuary from soil leachate at the site indicated elevated concentrations of arsenic, cadmium, chromium, copper, nickel, mercury, zinc and PAHs at locations across the site. However, given the margin of the exceedences, as well as considering factors such as dilution, degradation and migration, it is unlikely that these exceedences pose a significant risk to the underlying bedrock aquifer or the adjacent Mersey Estuary.
Geotechnical Assessment / Preliminary Design	The made ground is unsuitable for the support of structural loads because of its inherent variability and the risk of significant total and differential settlement. All foundations would need to be taken down to competent natural soil below the made ground. Based on our understanding, it is not anticipated that there will be a significant change in site levels in relation to the proposed skate park at this location due to the existing topography. Specific details of the proposed skate park are not yet known. It is recommended that the made ground at the proposed sub base level be improved by applying a heavy proof roller before the sub base is constructed to minimise the risk of differential settlement. Any soft spots would need to be over excavated and replaced with compacted granular fill. Further measures may need to be considered to prevent significant total and differential settlement if significant changes in site levels are proposed. It might be necessary to transfer foundation loads to the underlying clay by trench or piled foundations.

	The design sulphate classification for the foundation soils is DS-4. The Aggressive Chemical Environment for Concrete (ACEC) classification for the site is AC-4, assuming mobile groundwater.
Conclusions / Recommendations	There may be the need to undertake remedial measures at the site due to the potential for risk to human health from soils at the site. This would be dependent on the final design of the skate park. Geotechnical measures are recommended in relation to the construction of the skate park to prevent potential differential settlement and hence cracking to the skate park structures.

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1 Introduction

1.1 Terms of Reference

Mouchel has been commissioned by Liverpool City Council to provide a combined desk study and interpretative ground investigation report in relation to the proposed skate park at Otterspool Park, Liverpool. This report assesses the potential environmental risk and liabilities associated with the proposed development and the continuation of the public open space end use as well as including information pertinent to the geotechnical design.

1.2 Development Proposals/Legislative Context

It is understood that a skate park is to be developed onsite and the site will continue its use as a park (public open space). The construction of the skate park will be subject to planning permission.

The skate park will be constructed mainly above ground using existing slopes. There may be the need to undertake some shallow excavations and to import a small volume of material.

The presence of contaminants which may pose a risk to human health or the environment is a material planning consideration. For planning it should be considered whether the site is suitable for its proposed use, and the responsibility for securing a safe development (including cumulative effects of pollution on health, and the potential sensitivity of the proposed development to adverse effects from pollution) rests with the developer and/or landowner. Planning is concerned with the site's proposed use not its current use, where the amount of contamination is required to be low relative to the level of risk. This is the opposite to Part 2A which considers high levels (significant harm) and the current use of the site.

Section 57 of the Environment Act 1995, adds Part 2A (ss.78A-18YC) to the Environmental Protection Act 1990 and contains the legislative framework for identifying and dealing with contaminated land. Where development is undertaken on land which may be affected by contamination, the National Planning Policy Framework, paragraphs 120 to 122 considers pollution and remediation. This links the contaminated land regime within the development process.

For there to be an environmental liability associated with the site there must be a perceived source (a contaminant), a receptor (humans, living organisms or property) and a pathway between them. The potential presence of all of these aspects would result in a complete contaminant linkage.

1.3 Objectives and Scope

The objective of this study is to assess the potential environmental risks and geotechnical abnormals associated with the development of the skate park at the site and its continued use as a park (public open space).

The scope of work comprises:-

- A site walkover undertaken by a suitably qualified Environmental Scientist,
- Summary of the information obtained from a Groundsure Report,
- A preliminary risk assessment of the potential environmental risk following the methodology of CLR11 and CIRIA C552,
- Design and undertaking of a preliminary intrusive investigation,
- Completion of a generic quantitative risk assessment with regard to risk to human health and the environment,
- Summary of the geotechnical ground conditions and recommendations in order to facilitate the design of the skate park structures,
- Recommendations for further actions / remediation if required.

2 Desk Study Research

2.1 Site Location

The site is located in the Otterspool area approximately 5.7 km to the south east of Liverpool city centre. The site is centred on National Grid Reference (NGR) 337914, 385698 and covers approximately 0.7 hectares.

Figure 1 presents the site location and Figure 2 shows the current site layout.

2.2 Site Setting and Description

A site walkover was undertaken by a qualified Mouchel Geo-Environmental Engineer on 10th December 2013. The site on that day is described below.

The site is currently an area of open parkland within Otterspool Park. The topography of the site is generally level although there are small patches of uneven ground which may be indicative of historic ground workings. The land to the south and east is typically 3 to 4m higher than main site level.

A disused two storey café building is present on land to the north.

No visual or olfactory evidence of contamination was recorded on site.

Three manhole covers were identified on site. One is located in the southern part of the site. The remaining 2 covers are located close to the north western boundary of the site. No other service features were recorded on site.

This site area is unfenced and freely accessible to the public.

2.3 Adjacent Land Use

The table below summaries the adjacent land uses.

Table 1: Summary of Adjacent Land Uses

Direction	Surrounding Land Use
North	Parkland and a disused café
West	Parkland and a Harvester Restaurant
South	Parkland with Otterspool Drive and more parkland beyond
East	Parkland with and an activity/adventure centre for children

2.4 Environmental Designations and Ecology

The Mersey Estuary approximately 160m to the south west of the site is classified as a Site of Special Scientific Interest (SSSI), a Special Protection Area (SPA) and a RAMSAR site.

Dipford Wood and Upton Cleave, 175m and 302m to the north respectively, are ancient woodland.

No invasive weeds such as Japanese Knotweed were noted during the site walkover however, it should be noted that the walkover was not undertaken by a trained ecologist.

2.5 Site History

Historical mapping for the site has been provided as part of the Groundsure Report and is presented in Appendix A.

2.5.1 On Site

The earliest available mapping from 1851 shows Otterspool Mill and a small gasometer present adjacent to the southern boundary of the site.

By 1891, the gasometer was no longer present. The mill buildings remained onsite but were no longer labelled. A pond was located in the central part of the site at this time (labelled as a ‘Tank’ on the 1938 map).

The mill buildings had been demolished by 1927 and the pond had been infilled by 1952. There may also have been some regrading of the site at this time as the southern boundary is shown as sloping ground. The site formed part of a wider area of parkland.

There appear to have been no further significant changes to the site since the early 1950s.

2.5.2 Surrounding Area

The earliest available mapping from 1851 shows the shoreline of the Mersey estuary immediately to the south / south west of the site. Open / park land was present to the north west, north, east and south east with Otterspool House and associated gardens to the north.

In 1927, a disused dock was located to the immediate south east of the site. An arc shaped cutting / embankment was present to the east of the site and appears to link to a railway which was located further to the north east.

Information provided by LCC indicates that between 1929 and 1932, a new river wall was constructed to the west of the site, with the area between the new wall and old shoreline divided into sections by the tipping of groynes. Domestic refuse was used to infill this area.

Tipping was completed in 1949 and Otterspool Drive (road) was added to this land by 1952. The disused dock to the south east had been infilled by this time and a car park was present at this location. Allotment gardens were present 100m to the east.

In 1965, a small area approximately 200m to the west was labelled as a refuse tip. This was no longer present on the 1966-67 mapping.

No further significant changes appear to have been made to the surrounding area since the 1960s.

2.6 Geology

2.6.1 Artificial Ground

The Groundsure Report indicates that made ground is likely to be present across the majority of the site.

There are also ground workings in the form of a disused dock located to the immediate south of the site.

2.6.2 Drift Geology

The drift geology map (BGS Sheet 96, 1:50,000) indicates that Tidal Flat Deposits and Glacial Till are present underlying the site.

Tidal Flat Deposits comprise consolidated soft silty clay with layers of sand, gravel and peat.

Glacial Till is unsorted, non-stratified glacial deposits consisting of clay, silt sand and boulders.

2.6.3 Solid Geology

The solid geology map (BGS Sheet 96, 1:50,000) indicates that the site and the surrounding area is underlain by the Chester Pebble Beds Formation. These are cross stratified sandstone which is fine to coarse grained, commonly pebbly with conglomerates and sporadic siltstones.

2.6.4 BGS Borehole Logs

There are no BGS boreholes located onsite or within the immediate surrounding area.

2.7 Hydrogeology

The drift deposits (Tidal Flat Deposits and Glacial Till) are classified as unproductive strata.

The Chester Pebble Beds Formation is classified as a principal aquifer. These are layers of rock or drift deposits that have high intergranular and / or fracture permeability which usually provide a high level of storage and may support water supply / river base flow on a strategic scale.

There are no groundwater source protection zones (SPZs) within 500m of the site.

There are no groundwater abstraction licences located within 500m of the site.

2.8 Hydrology

The Mersey Estuary is located approximately 160m to the south west of the site.

Liverpool City Council has informed Mouchel that a culvert is present running along the western boundary of the site.

There are no surface water abstractions located within 500m of the site.

The site is not located within a flood risk zone.

There are two licensed discharge consents within 500m of the site. Sewer storm overflows are discharged into the Mersey Estuary 442m to the south and approximately 460m to the west.

2.9 Waste Management Facilities and Environmental Permits

There are no Part A(1) / IPPC authorisations or Part B permits within 500m of the site.

There are two former landfills within 500m of the site. Otterspool Phase 1 is located 22m south west of the site and Otterspool Phase 2 is located approximately 440m to the north west. Both accepted industrial, commercial and household wastes.

2.10 Pollution Incidents

There has been one recorded pollution incident within 500m of the site. Firefighting runoff noted approximately 410m to the west was classified as a Category 3 minor impact to water.

2.11 Current Land Use

The Groundsure Report states that there are no potentially contaminative current land uses within 250m of the site.

There are no fuel stations located within 500m of the site.

2.12 Ground Gas and Radon

The Groundsure Report indicates the presence of made ground across the site and there is a former landfill to the south west and an infilled dock to the immediate east. As such, ground gas such as methane and carbon dioxide may be present onsite.

The site is not located within a radon affected area as less than 1% of properties are above the action level.

2.13 Ground Stability

The table below summarises the natural hazards findings presented in the Groundsure Report.

Table 2: Summary of Potential Natural Hazards

Natural Hazard	Hazard Potential
Shrink - Swell Clay	Negligible - Very Low
Landslides	Very Low
Soluble Rocks	Null - Negligible
Compressible Deposits	Very Low
Collapsible Deposits	Negligible - Very Low
Running Sands	Very Low

2.14 Services Information

Services information was obtained prior to the site investigation; water mains and sewer pipes are present underlying the site area.

3 Preliminary Assessment

3.1 Preliminary Ground Model

The site has been formerly occupied by a mill, small gasometer and there is also an infilled pond present. The buildings have been demolished and the site is now used as part of a wider area of parkland. As such, there is the potential for made ground to be present at the site due to the previous uses of the site.

The surrounding area includes an infilled dock to the immediate east and a former landfill site within the land reclaimed from the estuary to the south west.

The site is underlain by drift deposits comprising Tidal Flat Deposits and Glacial Till. These may offer some protection to the underlying principal aquifer (Chester Pebble Beds).

The Mersey estuary is present 160m to the south west of the site at its closest point.

3.2 Potential Contaminant Linkages

The Conceptual Site Model (CSM) has been compiled in accordance with BS10175 and CLR11 and builds on the ground model by the identification of sources, pathways and receptors, illustrating the possible contaminant linkages.

For there to be any environmental liability, there must be a source i.e. something capable of causing pollution or harm, a receptor and a viable pathway between them i.e. a contaminant linkage. If one of these elements is missing, there can be no significant risk. If all are present, then the magnitude of risk is a function of the magnitude of the pollutant, the sensitivity of the receptor and the nature of the migration pathway.

It should be noted that any investigation or development of the site could actually create new pathways which could increase the liabilities associated with the site.

3.2.1 Sources

The previous uses at the site include a mill and gasometer. There is also an infilled pond onsite. The site has mainly been used as a park. There may have been some excavation / regrading at the site. There is an infilled dock and a former landfill site located immediately adjacent to the site. Consequently, there is the potential for contaminated made ground to be present onsite.

The likely contaminants associated with these previous uses include - heavy metals, cyanide, phenols, asbestos, polyaromatic hydrocarbons (PAHs), petroleum hydrocarbons (TPH), acid and alkaline pHs, semi volatile organic compounds (SVOCs) and volatile organic compounds (VOCs).

Furthermore, ground gases such as methane and carbon dioxide may be generated by any fill materials / made ground, particularly if the organic content of this material is high.

Table 3: Source of contamination

Ref	Primary source	Expected distribution	Likely contaminants
S1	Potentially contaminated soil onsite	Made ground is likely to be present across the whole of the site.	Heavy metals, cyanide, phenols, asbestos, PAHs, TPH, SVOCs, VOCs, acid and alkaline pHs.
S2	Potentially contaminated soil offsite	There is an infilled dock to the east and a former landfill to the south west.	

3.2.2 *Receptors*

The most sensitive receptors are considered to be the users of the proposed skate park.

Other receptors include groundwater (principal aquifer), the Mersey estuary and structures associated with the skate park.

Table 4: Receptors

Ref	Receptor	Description
R1	Site Users	The site is to be redeveloped as a skate park.
R2	Groundwater (Principal aquifer)	The bedrock beneath the site is classified as a principal aquifer.
R3	Surface water - Mersey Estuary	The Mersey estuary is located 160m to the south west.

Ref	Receptor	Description
R3	Structures	There may be concrete structures present associated with the skate park such as bowls and ramps.

3.2.3 *Pathways creating contaminant linkages*

The potential pathways for contaminants to reach receptors are highlighted and discussed in the table below.

Table 5: Pathways

Ref	Pathway	Description
P1	Dermal contact with contaminants in soil	Site users may come into contact with contaminants present within the soil onsite via dermal contact.
P2	Ingestion of soil / soil dust	Site users may ingest contaminants present in the soil via hand to mouth transfer and ingestion of soil dust.
P3	Inhalation of soil dust / gas / vapours	Site users may inhale soil dust / gas and vapours.
P4	Leaching and migration	Contaminants present on and adjacent to the site may leach / migrate into the principal aquifer underlying the site.
P5	Vertical and lateral migration of soil gas / vapours	Soil gas / vapours may migrate onto site from the adjacent infilled dock and refuse tip.
P6	Direct contact with contaminants	Structures such as concrete bowls / ramps associated with the skate park may be in direct contact with contaminated soil.

3.3 Risk Evaluation

Each potential contaminant linkage is identified in Table 6 below. Figure 3 provides a visual CSM which outlines the contaminant linkages discussed in the table below.

An evaluation of the risk that each contaminant linkage poses to the site has been undertaken in general accordance with CIRIA guidance document C552, 2001 (as detailed in Appendix B).

The evaluation and the resultant actions identified are based on the available information presented within this report.

Table 6: Risk Evaluation of Potential Contaminant Linkages

1. Hazard Identification		2. Hazard Assessment				3. Risk Estimation		4. Risk Evaluation	5. Managing the Risk
Contaminant Source		Pathway		Receptor		Consequence of risk being realised	Probability of risk being realised	Classification	Action required
S1	Potentially contaminated soil on site	P1	Dermal contact with soil	R1	Site Users	Medium	Low	Moderate / Low	It is possible that harm could arise to these receptors. Investigation is required to clarify the risks and determine the potential liability. Some remedial measures may be required in the long term.
		P2	Ingestion of soil / soil dust			Medium	Low	Moderate / Low	
		P3	Inhalation of soil dust / gas / vapours			Medium	Low	Moderate / Low	
		P4	Leaching and migration	R2	Groundwater - principal aquifer	Medium	Likely	Moderate	
				R3	Surface Water - Mersey Estuary	Medium	Low	Moderate / Low	
		P5	Vertical / lateral migration of soil gas / vapours	R1	Site Users	Medium	Low	Moderate / Low	
		P6	Direct contact with contaminants	R4	Structures associated with the skate park	Mild	Likely	Moderate / Low	

1. Hazard Identification		2. Hazard Assessment				3. Risk Estimation		4. Risk Evaluation	5. Managing the Risk
Contaminant Source		Pathway		Receptor		Consequence of risk being realised	Probability of risk being realised	Classification	Action required
S2	Potentially contaminated soil offsite	P4	Leaching and migration leading to P1 / P2 / P3	R1	Site users	Medium	Low	Moderate / Low	
		P4	Leaching and migration	R2	Groundwater - principal aquifer	Medium	Low	Moderate / Low	
		P5	Vertical / lateral migration of soil gas / vapours	R1	Site Users	Medium	Low	Moderate / Low	

3.4 Potential Waste and Sustainability Considerations

Should any of the material onsite be deemed to pose an unacceptable risk to receptors after a site investigation and assessment of the findings, this material may need to be remediated or if this is not possible, may need to be removed from site. Material may also need to be removed from site as part of the skate park construction. Should any disposal be necessary, consideration will need to be given to testing of the material for disposal to landfill. Any material to be removed from site will need to be assessed to establish the materials acceptability to landfill by comparison to the Waste Acceptance Criteria (WAC) limits.

Samples can be tested using WAC testing in accordance with testing method BS EN 12457-3 in order to assess the materials acceptability to landfill.

3.5 Safety, Health and Environment Considerations

Site personnel involved with any investigation work should be appropriately qualified with experience of working on potentially contaminated sites. Appropriate personal protective equipment (PPE) should be worn by person working in close proximity to fill materials and a reasonable standard of hygiene maintained.

To eliminate any risk from hand to mouth transfer of potentially harmful material, smoking, eating and drinking should be prohibited within the working area and prior to washing hands.

3.6 Geotechnical Considerations

The probable geology described in Section 2.6 indicates that the sandstone bedrock (Chester Pebble Beds Formation) is overlain by Glacial Till and Tidal Flat Deposits. Made ground is present on site (as the site has been formerly occupied by a mill, gasometer and a pond) although its depth is currently unknown. Settlement of the existing made ground may be induced if loading at the existing ground surface is increased due to placement of fill or concrete structures, resulting in cracking of cast-in-situ concrete elements.

It is recommended that any structures associated with the Skate Park are founded on competent strata comprising engineered fill, Glacial Till or bedrock. Beneath proposed structures, any existing made ground or loose/ soft natural deposits (Tidal Flat Deposits) may require excavation and recompaction (if suitable) or replacement with imported engineering fill. Other geotechnical solutions may be appropriate where made ground extends to significant depths.

4 Ground Investigation

4.1 Design Rationale and Scope

The rationale for the investigation was to assess the site soils, groundwater and ground gas regime to identify any potential risks to future site users of the proposed skate park as well as to controlled waters and structures associated with the skate park. This investigation will also provide information relating to the geotechnical conditions at the site which will assist in determining the foundation design for the skate park structures.

The scope of the investigation was as detailed below:

- Eight windowless sampler holes to a nominal depth of 5m with standard penetration tests (SPTs),
- Four machine excavated trial pits to a nominal depth of 4.5m,
- Three gas / groundwater monitoring installations,
- Chemical and geotechnical laboratory analysis.

4.2 Fieldwork

The intrusive investigation was undertaken by Ian Farmer Associates and monitored by Mouchel. Ian Farmer Associates carried out the drilling of the exploratory holes as well as the logging and soil sampling. Subsequent gas / groundwater monitoring and groundwater sampling of the monitoring installations was carried out by Mouchel.

The investigation was carried out in general accordance with the following standards:

- BS5930:1999 Code of practice for site investigations, as modified by BS14688 for soil and rock descriptions;
- BS10175:2011 Code of Practice for the Investigation of Potentially Contaminated Sites.
- BS EN 1997-2:2007 Eurocode 7: Geotechnical design – Ground investigation and testing,

- BS EN ISO 22475-1:2006: Geotechnical investigation and testing. Sampling methods and groundwater measurements. Technical principles for execution.

- Secondary Model Procedure for the Development of Appropriate Soil Sampling Strategies for Land Contamination, 2001 (Environment Agency).

The table below summarises the exploratory holes undertaken at the Otterspool Park site.

Table 7: Summary of Site Activities

Activity	Date Undertaken	Exploratory Hole Reference	Maximum Depth
Windowless sampler holes with 3 no. gas / groundwater installations	17th - 18th February 2012	WS01 - WS08, WS02A	5.45m
Machine excavated trial pits	18th February 2014	TP01 - TP04	4.5m

WS02 was redrilled as WS02A due to an obstruction in the original windowless sampler hole.

The location of the exploratory holes is shown on the figure provided within the Ground Investigation Factual Report which is presented in Appendix C. The exploratory hole logs are presented in this Factual Report.

Three of the windowless sampler holes were installed with gas / groundwater monitoring standpipe with details of these installations summarised in the table below.

Table 8: Gas / Groundwater Monitoring Installation Details

Exploratory Hole Reference	Type of Installation	Depth of Response Zone (m bgl)	Response Zone Stratum
WS01	50mm standpipe	1.00 - 5.45	Made ground
WS06	50mm standpipe	0.80 - 4.80	Made ground
WS08	50mm standpipe	1.00 - 3.00	Made ground

Gas monitoring and groundwater monitoring was undertaken on a three occasions in the month following the completion of the site investigation. Groundwater sampling was carried out during the first monitoring visit.

Details of monitoring programme carried out at the Otterspool Park site are given in the table below.

Table 9: Gas and Leachate / Groundwater Monitoring Programme

Exploratory Hole Reference	Monitoring Visit 1 04/03/2014	Monitoring Visit 2 16/03/2014	Monitoring Visit 3 21/03/2014
WS01	Gas / groundwater monitoring, no recharge following purging - no water sample	Gas / groundwater monitoring	Gas / groundwater monitoring
WS06	Gas / groundwater monitoring, dry - no water sample	Gas / groundwater monitoring	Gas / groundwater monitoring
WS08	Gas / groundwater monitoring, dry - no water sample	Gas / groundwater monitoring	Gas / groundwater monitoring

Groundwater sampling was planned during the first monitoring visit but the monitoring installations were either dry or did not recharge after purging. Therefore, no groundwater samples were obtained from the site.

Results of the gas / groundwater monitoring can be found in Appendix D.

4.3 Chemical Laboratory Testing

Soil samples were obtained made ground during the drilling of the windowless sampler holes and excavation of the trial pits.

All soil samples were stored in airtight containers appropriately labelled and transported in cool boxes with ice packs maintained at 4°C, under completed chain of custody documentation. SAL Ltd is appropriately accredited for the analysis required and is an approved supplier under the Mouchel Quality Management System.

The testing suite was based on the types of contaminants expected to be associated with an area of land previously occupied by a mill, gasometer and infilled pond with an infilled dock and landfill located adjacent to the site.

4.3.1 Soils

The table below outlines the soil analysis undertaken on samples taken from the proposed skate park site at Otterspool Park.

Table 10: Summary of Soil Analysis

Suite Reference	Analysis	No. of Samples Scheduled
Soil Suite	Metals - arsenic, cadmium, chromium, hexavalent chromium, copper, nickel, mercury, lead, selenium, zinc	12
	pH	12
	Asbestos	12
	Total cyanide	12
	Soil organic matter	12
	Total phenols	12
	Speciated 16 PAHs	12
	Total petroleum hydrocarbons (TPHCWG)	12
	PCB 7 congeners	12
	PCB WHO 12	12
	Semi volatile organic compounds (SVOCs)	12
	Volatile organic compounds (VOCs)	12

The results of the soil chemical analysis are presented in Appendix E.

4.3.2 Leachate

The table below outlines the soil leachate analysis undertaken on selected soil samples taken from the proposed skate park site at Otterspool Park.

Table 11: Summary of Leachate Analysis

Suite Reference	Analysis Suite	No. of Samples Scheduled
Leachate Suite	Metals - arsenic, cadmium, chromium, hexavalent chromium, copper, nickel, mercury, lead, selenium, zinc	8
	pH	8
	Total cyanide	8
	Total phenols	8
	Speciated 16 PAHs	8
	Total petroleum hydrocarbons (TPHCWG)	8

The results of the soil leachate chemical analysis are presented in Appendix E.

4.4 Geotechnical Laboratory Testing

A summary of the geotechnical tests scheduled on soil samples taken from the proposed skate park site at Otterspool Park is given in the table below.

Table 12: Summary of Geotechnical Laboratory Testing

Geotechnical Test	Test Method	No. samples scheduled
Classification/Compaction		
Moisture Content	BS1377: Part 2: 1990; Clause 3	8
Liquid / plastic limits	BS1377: Part 2: 1990	8
Particle Size Distribution	BS1377: Part 2: 1990; Clause 9	6
Determination of dry density/moisture content relationship (2.5kg hammer)	BS1377: Part 4: 1990	4
Chemical (tests on soils and groundwater)		
BRE SD1 Suite – acid soluble / water soluble sulphate, pH, Total	TRL Report 447	8

Geotechnical Test	Test Method	No. samples scheduled
Sulphur		

The results of the geotechnical laboratory analysis are presented in Appendix C.

5 Ground Model

5.1 Topography and Geomorphology

The topography of the site is generally level although there are small patches of uneven ground which may be indicative of historic ground workings. The land to the south and east is typically 3 to 4m higher than main site level.

5.2 Geology

The geology recorded during the investigation was consistent with the expected geology noted during the desk study phase of the investigation.

A brief description of the encountered geology is presented in the sections below. Exploratory hole logs are presented in Appendix C.

5.2.1 Made Ground

Made ground was encountered at each of the exploratory hole locations across the site. The thickness varied between 4m and in excess of 5.45m, with the thickest located in WS01, WS02A and WS03 in the northern part of the site. The base of the made ground was not proven in these holes. The base of the made ground was proven in WS04, WS05, WS06, WS07 and WS08.

The upper made ground varies across the site with a clayey sand present in northern and southern part of the site, namely in WS01, WS02A, TP01 and TP03. A sandy, gravelly clay with slate, brick, tile, glass, ash, clinker, concrete and sandstone was present in the more central areas of the site i.e. WS02, WS03, WS04, WS05, WS08 and TP02.

The most widespread and thickest made ground which occurred underlying the upper made ground comprised a silty sand and gravel with brick, concrete, ash, clinker, slate, tile, glass and slag with occasional wood fragments, pottery and metal fragments. This type of made ground was encountered in all the exploratory hole across the site.

The only olfactory evidence of contamination noted during the investigation was a hydrocarbon odour in TP01 at 2.6m bgl within the silty sand and gravel made ground.

5.2.2 Natural Ground

Superficial deposits comprising a clayey, silty sand was encountered in WS04 and WS06 at depths of 5m bgl and 4.8m bgl respectively. This material represents the Tidal Flat Deposits and its location on site correlates with the geological mapping.

A silty, sandy, gravelly clay was encountered in WS05 and WS08 at depths of 4.1m bgl and 4m bgl respectively. This material represents the Glacial Till and its location on site correlates with the geological mapping.

Bedrock comprising a weak sandstone was encountered in only one exploratory, WS07, at a depth of 5m bgl. In this location, the bedrock was directly overlain by made ground.

5.3 Groundwater

Groundwater was only encountered in one exploratory hole, WS03, during the site works. This was a strike within the made ground at 5m bgl.

During the monitoring of the groundwater installations, WS06 and WS08 were dry throughout the monitoring period. WS01 contained 0.16m of groundwater during the first visit. This was purged in order to obtain a groundwater sample but insufficient recharge occurred. Subsequent monitoring visits recorded either very little (0.02m) or no groundwater.

5.4 Chemical Distribution

The concentrations of metals and hydrocarbons vary throughout the made ground across the site. No specific area appears to contain the highest concentrations.

5.5 Ground Gas

The gas monitoring results show that carbon dioxide was recorded between 0.1% and 6.9%. No methane, carbon monoxide or hydrogen sulphide were noted during the monitoring period. Flow was also absent.

6 Human Health Risk Assessment

6.1 Soils

6.1.1 Methodology

Based on the Preliminary Risk Assessment and Ground Model for this site, a Generic Quantitative Risk Assessment for human health has been undertaken in accordance with CLR and SR (SC050021 series) (DEFRA) guidance and comprises the following:

- selection of appropriate generic screening values for human health assessment;
- creation of relevant datasets from which to undertake the assessment;
- assessment of contamination distribution and comparison of site data to screening values using the approach outlined in the CL:AIRE / CIEH guidance;
- assessment of risks to receptors;
- determination of requirements for further investigation or remediation.

Selection of Soil Screening Values

It is understood that the Otterspool Park site that has been investigated is to be redeveloped as a skate park within the wider area of public open space. As such, the chemical data has been screened against a generic public open space scenario.

The Environment Agency (EA) has not produced any Soil Guideline Values (SGVs) for this land use. Mouchel have developed the public open space scenario based upon the generic allotments scenario with the plant uptake pathways disabled. This scenario considers a 0-6 year old female who visits site regularly but is not living above any contaminant plume that may be present. The model does not include the consumption of site grown vegetables. Time is spent outdoors only, with exposure varying during child development. However, cadmium, which was released by the EA as a SGV in July 2009, is based on a lifetime exposure as cadmium builds up over time in the kidneys. As such, cadmium has been assessed for a public open space land use for a 75 year period (lifetime exposure).

The SOM concentrations averaged 16.2% across the site. As such, all the data has been compared against a public open space scenario at 6% SOM which reflects a more site specific screening value.

A detailed description of the derivation of GAC's has been included in Appendix F.

Creation of Relevant Datasets

It is not known if site levels will change during the works. Therefore all the soil samples from the made ground encountered have been assessed as one population.

6.1.2 Assessment

The human health risk assessment has been carried out in accordance with the CL:AIRE / CIEH guidance.

The purpose of the assessment is to determine whether there is sufficient evidence that the true mean of the population falls below the critical concentration (screening value) i.e. that the site is uncontaminated and suitable for the intended end use.

Statistics are used to assist in answering the key question raised above and to help decide whether to support a particular hypothesis. The Null Hypothesis is the starting point because it is believed to be true but needs to be proved.

In terms of planning, the hypotheses are as follows:

- Null hypothesis (H_0) - the true mean concentration is equal to, or greater than, the critical concentration;
- Alternative hypothesis (H_1) - the true mean concentration is less than the critical concentration.

The null hypothesis needs to be rejected in order to confirm that the land is uncontaminated and suitable for the proposed end use under the planning regime.

Identification of Contaminants of Concern

Potential contaminants of concern (CoC) have been identified where any exceedences of the critical concentrations have been noted.

A screening table displaying the outcome of this initial screening has been produced and is displayed in Appendix G and a summary of this is included in the table below.

Table 13: Identification of Contaminants of Concern

Determinand	Critical Concentration	Range of concentrations	Number of exceedences
Lead	1400	66 - 4100	3/12
Benzo(a)anthracene	29	<0.1 - 35	2/12
Chrysene	41	<0.1 - 44	1/12
Benzo(a)pyrene	4.6	<0.1 - 57	5/12
Dibenzo(ah)anthracene	4.3	<0.1 - 7.3	2/12
Dibenzofuran	3.4	<0.1 - 8	2/12

All concentrations in mg/kg.

* - some detection limits for samples tested were also in excess of the critical concentration.

The following CoC have been identified during this initial screening:

- Lead
- Benzo(a)anthracene
- Chrysene
- Benzo(a)pyrene
- Dibenzo(ah)anthracene
- Dibenzofuran

In addition, chrysotile asbestos was detected in TP04 at 3m bgl.

All the other determinands recorded concentrations that were lower than the critical concentration so have been discounted from any further assessment as there is not considered to be a risk from these contaminants.

Statistical Analysis

As detailed above, exceedences were recorded for lead, benzo(a)anthracene, chrysene, benzo(a)pyrene, dibenzo(ah)anthracene and dibenzofuran. As such, these CoC were taken forward for further assessment including the use of statistical assessment as detailed with the CL:AIRE / CIEH guidance.

The following steps were undertaken:

- With regard to non-detects, where the proportion of these within the dataset was less than 15%, the non detect value was replaced with the value of the method detection limit. Where the proportion was greater than 15%, the non detect value was replaced with a value representative of half that of the method detection limit as per the guidance.

- Outliers - Grubb's Test was performed to determine if any of the concentrations represented statistical outliers. The dataset has been visually checked and any apparently anomalous readings have been investigated i.e. by checking the field logs and checking the laboratory results for any data entry issues. Unless it could be determined that the outlier was the result of a reporting error or represented part of a separate dataset, the value remained within the dataset for assessment.

Non detects and outliers were dealt with as above and the sample mean was calculated and compared against the critical concentration.

Where the sample mean was greater than the critical concentration, the assessment was stopped as the null hypothesis cannot be rejected i.e. the true mean must be greater than the critical concentration, therefore there is considered to be a risk to human health from this CoC and further action is required to deal with this contaminant.

Where the sample mean was lower than the critical concentration, further statistical analysis was carried out for that CoC.

The table below summarises the outcome of the sample mean comparison with the critical concentration.

Table 14: Sample Mean Concentration

CoC	Sample Mean	Critical Concentration	Outcome
Lead	1337.17	1400	May be possible to reject null hypothesis - true mean may be less than critical concentration
Benzo(a)anthracene	7.89	29	May be possible to reject null hypothesis - true mean may be less than critical concentration
Chrysene	9.32	41	May be possible to reject null hypothesis - true mean may be less than critical concentration
Benzo(a)pyrene	10.83	4.6	Cannot reject the null hypothesis
Dibenzo(ah)anthracene	1.63	4.3	May be possible to reject null hypothesis - true mean may be less than critical concentration
Dibenzofuran	1.11	3.4	May be possible to reject null hypothesis - true mean may be less than critical concentration

All concentrations in mg/kg.

The assessment for benzo(a)pyrene indicates that the sample mean is greater than the critical concentration and therefore, it is not possible to reject the null hypothesis. As such, no further statistical analysis is required for benzo(a)pyrene.

For lead, benzo(a)anthracene, chrysene, dibenzo(ah)anthracene and dibenzofuran, it may be possible to reject the null hypothesis and determine that the site is suitable for its proposed end use for these determinands. Further statistical analysis including the calculation of the 95% upper confidence level (UCL) of the mean is required.

As part of the further statistical analysis, the following steps were undertaken:

- Normality - The normality of the population was established using probability plots as well as the Shapiro Wilk Test.

- Calculation of the 95% UCL of the mean - where there was no significant departure from normality, the one sample t-test was used and where there was a significant departure from normality, the one sided Chebychev Theorem was used.

The table below summarises the outcome of the 95% UCL assessment for CoC.

Table 15: Summary of 95%UCL assessment for CoC

Determinand	Critical Concentration	95%UCL	Outcome
Lead	**1400**	**1931**	**No outliers, normally distributed - one sample t-test used. Cannot reject the null hypothesis.**
Benzo(a)anthracene	29	24	No outliers, not normally distributed - one sided Chebychev Theorem used. Reject the null hypothesis with high level of confidence (p_1 = 0.97)
Chrysene	41	29	No outliers, not normally distributed - one sided Chebychev Theorem used. Reject the null hypothesis with high level of confidence (p_1 = 0.98)
Dibenzo(ah)anthracene	**4.3**	**4.88**	**No outliers, not normally distributed - one sided Chebychev Theorem used. Cannot reject the null hypothesis.**
Dibenzofuran	**3.4**	**4.1**	**No outliers, not normally distributed - one sided Chebychev Theorem used. Cannot reject the null hypothesis.**

All concentration in mg/kg.

6.1.3 Discussion

The outcome of the statistical analysis has indicated that there is a site wide contamination issue due to lead, benzo(a)pyrene, dibenzo(ah)anthracene and dibenzofuran.

Chrysotile asbestos was also noted in one isolated location.

6.1.4 Conclusions

There is a potential risk to human health at the site from lead, benzo(a)pyrene, dibenzo(ah)anthracene, dibenzofuran and asbestos which will need to be addressed.

The proposed Skate Park structures will break the pathway between the identified contamination and the end users; consideration should also be given to capping adjacent areas.

6.2 Ground Gas

6.2.1 Methodology

A ground gas risk assessment will be completed in general accordance with the CIRIA document C665:2007, “Assessing Risks Posed by Hazardous Ground Gases to Buildings”. Reference has also been made to the British Standard BS8485:2007, “Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments” and the Health and Safety Executive document EH40/2005 “Workplace Exposure Limits”.

The assessment will comprise the following:

- Review of results;
- Calculation of Gas Screening Values for methane (CH_4) and carbon dioxide (CO_2);
- Assessment of O_2, CO and H_2S concentrations using EH40/2005;
- Assessment of risks from ground gas; and
- Recommendations for gas protection measures if necessary.

6.2.2 Review of Field Data

Methane, carbon dioxide, oxygen, hydrogen sulphide, carbon monoxide and flow rates were monitored on three occasions over the month following the completion of the site works.

Atmospheric pressure ranged from 1008mb to 1029mb across the monitoring period with both rising and falling pressure trends in the days preceding the visits.

The table below summarises the range of concentrations detected during the monitoring visits. The full monitoring records are presented in Appendix D.

Table 16: Summary of Ground Gas Monitoring Data

Hole Ref	Methane %	Carbon Dioxide %	Oxygen %	Carbon Monoxide ppm	Hydrogen Sulphide ppm	Flow rate l/hr
WS01	All 0	6.4 - 6.9	11.5 -14.2	All 0	All 0	All 0
WS06	All 0	2.6 - 5.9	15 - 19.2	All 0	All 0	All 0
WS08	All 0	0.1 - 1.8	19.3 - 20.9	All 0	All 0	All 0

6.2.3 *Calculation of Gas Screening Values*

The gas monitoring data obtained during the monitoring visits has been used to give a semi-quantitative estimate of risk for the site. The characterisation process employs the maximum gas concentrations and flow rates to generate Gas Screening Values (GSVs). As the proposed development is a skate park Situation A of CIRIA C665 has been assumed. The Modified Wilson and Card Classification as described in Table 8.5 of CIRIA C665 has been used.

The GSV for the site has been calculated as 0l/hr using the data from the monitoring rounds. This indicates that the site is considered to pose a very low risk and falls within Characteristic Situation 1

6.2.4 *Assessment of Oxygen (O_2), Carbon Monoxide (CO) and Hydrogen Sulphide (H_2S)*

EH40/2005 Workplace Exposure Limits (HSE 2005) has been used to assess the risk to human health from carbon monoxide (CO), hydrogen sulphide (H_2S) and oxygen (O_2). The exposure limits relate to conditions in a workplace and therefore are not directly applicable to soil gas concentrations. However they can be used to identify which gases do not present a risk and which may require further assessment. For the assessment of O_2 concentrations, EH40/2005 makes reference to the Mines and Quarries Act (1954) which states a minimum of 19%v/v. 20.8%v/v is the normal concentration of O_2 in air.

EH40/2005 presents long-term exposure limits (8-hour TWA reference period) and short-term exposure limit (15 minute reference period) for the workplace for both carbon monoxide and hydrogen sulphide.

A summary of the gas concentrations recorded during the three rounds of monitoring and the assessment criteria are presented in table below.

Table 17: Summary O_2, CO and H_2S Results and Assessment Criteria

Parameter	Minimum Recorded Value	Maximum Recorded Value	8-hour TWA Exposure Limit	15-minute exposure limit	Minimum Concentration (Mines and Quarries Act)
Oxygen	11.5	20.9	n/a	n/a	19%
Carbon Monoxide	All 0		30ppm	200ppm	n/a
Hydrogen Sulphide	All 0		5ppm	10ppm	n/a

6.2.5 *Discussion*

The GSV calculated for the site indicates that the site is considered to pose a very low risk from ground gas.

Oxygen levels were recorded as being below the minimum concentration of 19% in WS01 on all three monitoring visits and WS06 on two out of the three visits. However, the proposed development does not include any structures that the ground gas could migrate into. Therefore, these reduced oxygen concentrations are not considered to pose a risk.

6.2.6 *Conclusions*

The assessment of the gas monitoring results shows that the concentrations of ground gas at the site do not pose a significant risk to future site users or nearby property due to the low concentrations and absence of flow.

No gas protection measures are required for sites that are classified as Characteristic Situation 1.

7 Controlled Waters Risk Assessment

7.1 Methodology

Based on the Preliminary Risk Assessment and Ground Model for this site, a Level 1 Screening Assessment has been undertaken in general accordance with Environment Agency guidance Environment Agency Remedial Targets Methodology, Hydrogeological Risk Assessment for Land Contamination, 2006.

The methodology comprises:

- identification of potential contaminant linkages;
- selection of appropriate generic screening values for controlled waters;
- screening measured concentrations of leachate and groundwater against the generic screening values;
- assessment of contaminant distribution and risk to receptors;
- identification of contaminants of concern and relevant contaminant linkages;
- identification of potential contaminants and contaminant linkages which are no longer of concern.

7.1.1 Identification of Potential Contaminant Linkages

The bedrock underlying the site is classified as a principal aquifer. The geological mapping shows that this is overlain across the majority of the site by Glacial Till with a strip of Tidal Flat Deposits in the eastern part of the site. However, the ground investigation has shown that the Glacial Till is intermittent and that in one hole the made ground lies directly onto the bedrock. The Tidal Flat Deposits were logged as being predominantly granular in nature. Therefore, there is a potential contaminant linkage between the contaminants present in the soil onsite and the underlying aquifer.

The River Mersey is located 160m to the south east and there is considered to be a potential contaminant linkage between the soils onsite and the River via the superficial deposits.

7.1.2 Selection of Generic Screening Values

The controlled waters receptors in this case are groundwater within the underlying principal aquifer as well as water within the River Mersey. Therefore, UK Drinking Water Standards (DWS) have been used to assess the potential risk to the underlying aquifer and Environment Agency Environmental Quality Standards (EQS) for coastal / marine / estuaries for the potential risk to the Mersey Estuary.

7.1.3 Screening - Soil Leachate

A summary of the exceedences of the DWS values for the soil leachate samples is included in the table below. A full table showing the screened results can be found in Appendix H.

Table 18: DWS Screening - Leachate

Determinand	Screening Value (ug/l)	Range of Values (ug/l)	Number of Exceedences	Location of Exceedences
Arsenic	10	0.5 - 11	1/8	TP01 4m
Nickel	20	<1 - 97	3/8	TP02 3m TP01 4m WS07 0.8m
Benzo(a)pyrene	0.01	<0.02 - 2	5/8	WS03 0.6m TP03 1.9m WS08 0.5m WS04 0.5m TP01 4m
Total PAH	0.1	<0.04 - 5.7	4/8	WS03 0.6m TP03 1.9m WS08 0.5m WS04 0.5m

A summary of the exceedences of the EQS values for the soil leachate samples is included in the table below. A full table showing the screened results can be found in Appendix H.

Table 19: EQS Screening - Leachate

Determinand	Screening Value (ug/l)	Range of Values (ug/l)	Number of Exceedences	Location of Exceedences
Cadmium	0.2	<0.02 - 0.58	2/8	TP02 3m WS07 0.8m
Chromium VI	0.6	<3 - 3	1/8	TP03 1.9m
Copper	5	<0.5 - 10	3/8	WS03 0.6m TP03 1.9m WS04 0.5m
Nickel	20	<1 - 97	3/8	TP02 3m TP01 4m WS07 0.8m
Zinc	40	4 - 560	2/8	TP02 3m WS07 0.8m
Mercury	0.05	<0.05 - 0.16	1/8	WS07 0.8m
Anthracene	0.1	<0.02 - 0.19	2/8	WS04 0.5m TP01 4m
Benzo(a)pyrene	0.05	<0.01 - 2	2/8	TP03 1.9m WS04 0.5m
Benzo(b+k)fluoranthene	0.03	<0.02 - 3.1	5/8	WS03 0.6m TP03 1.9m WS08 0.5m

Determinand	Screening Value (ug/l)	Range of Values (ug/l)	Number of Exceedences	Location of Exceedences
				WS04 0.5m TP01 4m
Benzo(ghi)perylene / indeno(123cd)pyrene	0.002	<0.02 - 2.6	5/8	WS03 0.6m TP03 1.9m WS08 0.5m WS04 0.5m TP01 4m
Fluoranthene	0.1	<0.01 - 1.9	2/8	WS04 0.5m TP01 4m

7.1.4 Contaminant Distributions and Risk to Receptors

There are elevated concentrations of arsenic, cadmium, chromium, copper, nickel, mercury, zinc and PAHs at isolated locations across the site. However, given the margin of exceedences and once factors such as dilution, degradation and migration are taken into account, it is unlikely that these exceedences will pose a significant risk to the underlying bedrock or the adjacent Mersey Estuary.

7.1.5 Identification of Contaminants of Concern and Relevant Contaminant Linkages

There are not considered to be any Contaminants of Concern with regard to controlled waters that require taking forward to detailed quantitative risk assessment. No significant contaminant linkages are considered to exist at the site that pose a risk to controlled waters.

8 Geotechnical Assessment

This geotechnical assessment is carried out in accordance with BS EN1997 Part 1, based on the Factual Report provided by Ian Farmer Associates. The geotechnical 'characteristic' parameters (defined in EC7 as moderately conservative) are derived from:

- The results of geotechnical laboratory testing,
- Standard Penetration Test 'N' values and the published correlations for undrained shear strength (c_u) and
- Published reference data where no field or laboratory data was available.

8.1 Made Ground

Made ground was encountered in all the exploratory holes at the existing ground level to depth of >5.45mbgl in WS01, WS02A and WS03. The base of the made ground was only proven in WS04, WS05, WS06, WS07 and WS08.

The made ground was generally variable comprising slightly silty to silty very sandy gravel, slightly silty very gravelly sand and slightly sandy to sandy slightly gravelly clay. The gravel and cobble content consisted of angular to subangular fragments of brick, concrete, glass, slate, ash, clinker and sandstone.

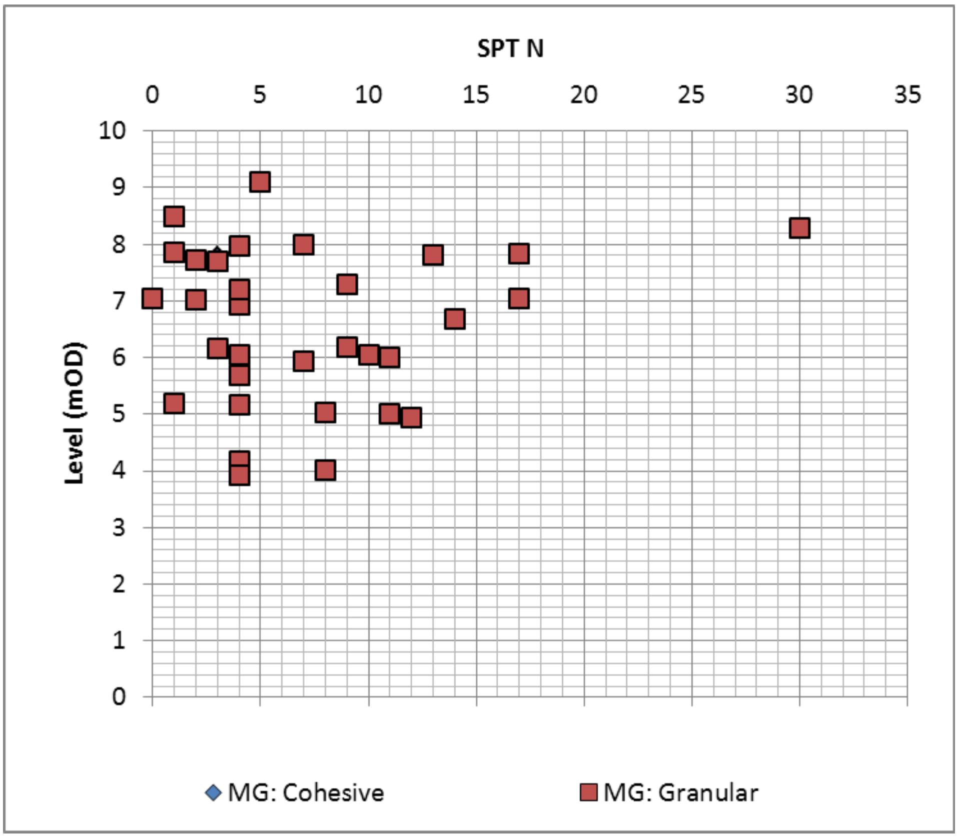
Three moisture content tests undertaken on samples from the granular made ground recorded moisture content of 33 to 42%.

Four Atterberg Limit Tests undertaken on samples of fine soils from the made ground recorded, liquid limit of 30 to 31%, plastic limit of 14 to 20% and plasticity index of 11 to 16% indicating clay of low plasticity.

Four PSD tests undertaken on samples from the made ground indicated a Uniformity Coefficient, $U_{c,}$ of greater than 6 indicating that the material is well graded.

Four compaction tests undertaken on samples from the made ground indicated optimum moisture content of 10 to 31% and maximum dry density of 1.21 to 1.85Mg/m^3.

Thirty three SPT tests were carried out within the granular made ground. The SPT 'N' values ranged between 0 and 33. The results indicate the granular made ground is loose to dense. One SPT test carried out within the cohesive made ground recorded SPT 'N' value of 3. The 'N' values for both the granular and cohesive made ground are plotted with level in the diagram below. The high figures are suspected to be due to obstructions within the made ground.



8.1.1 *Granular Made Ground*

Based on material grading and grain shape, PD6694 suggests a critical state friction angle, $\Phi'_{crit\ of}$ 34°. However, due to the variable density, for design purposes a characteristic value Φ' of 31° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffness is derived using the following correlation between SPT N value and vertical Young's Modulus, E' for gravelly sand presented by Bowles (1988) as follows:

$E' = 600(N+6)$ (kPa)

Using a characteristic SPT N value of 8, a vertical drained Young's modulus, E'_v of 6MPa is indicated.

Where required, a bulk unit weight of 18kN/m^3 above the water table and 21kN/m^3 below has been adopted.

8.1.2 *Cohesive Made Ground*

Based on relationships between SPT N value and undrained shear strength developed by Stroud (1975), adopting the highest plasticity index value of 16% and applying an f_1 value of 5.0, the SPT result indicate an equivalent undrained shear strength, c_u of 20kPa.

Based on the highest plasticity index, PD6694 suggests a critical state friction angle, $\Phi'_{crit\ of}$ 29°. For design purposes a characteristic value Φ' of 28° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffnesses are derived using the correlation between undrained shear strength and plasticity index by Stroud (1974). Using a characteristic undrained shear strength of 20kPa and the highest plasticity index of 16%, a vertical undrained Young's modulus, E_{uv} and drained Young's modulus, E'_v of 6.5MPa and 4.5MPa have been indicated respectively. The coefficient of volume compressibility, m_v is estimated to be 0.2m^2/MN.

Where required, a bulk unit weight of 17kN/m^3 above the water table and 17kN/m^3 below has been adopted.

8.2 Clay

Clay was encountered in WS05 and WS08 beneath the made ground. The base of the clay was not proven in these exploratory holes.

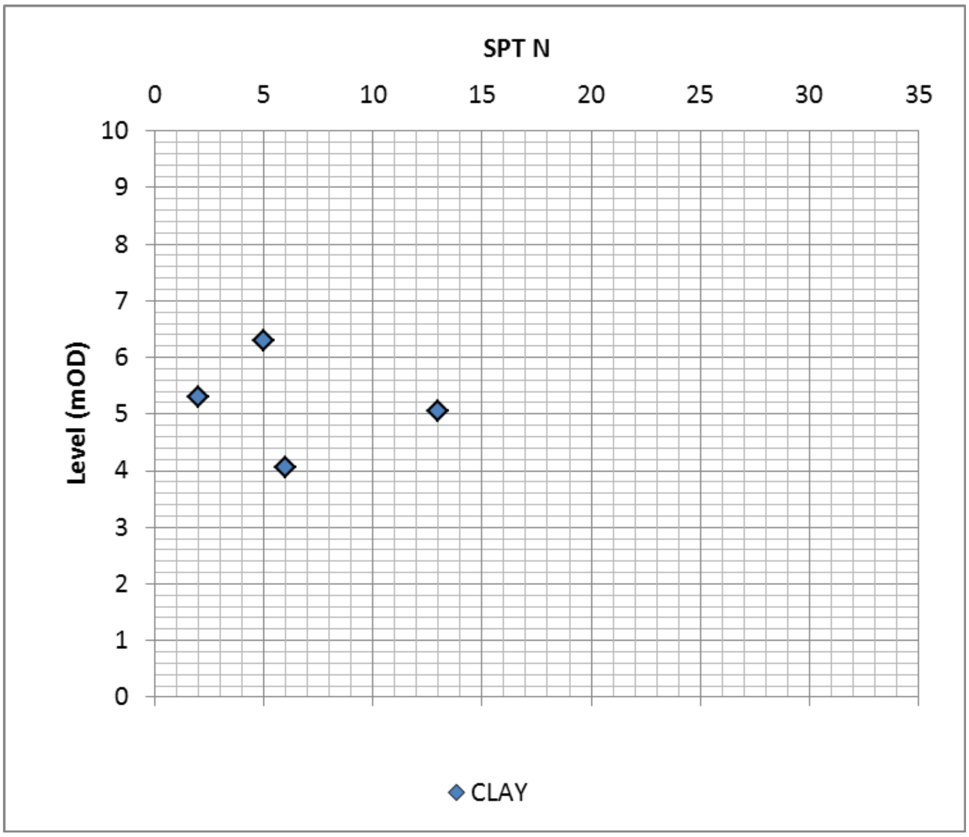
The clay was generally described as firm orange brown slightly silty slightly sandy to sandy slightly gravelly clay. The clay was interpreted as Glacial Till.

One PSD test undertaken on a sample from the clay indicated a Uniformity Coefficient, $U_{c,}$ of greater than 6 indicating that the material is well graded.

One moisture content test undertaken on a sample from the clay recorded moisture content of 17%.

Four Atterberg Limit Tests undertaken on samples from the clay recorded moisture content of 14 to 20%, liquid limit of 25 to 32%, plastic limit of 14 to 20% and plasticity index of 11 to 12% indicating clay of low plasticity.

Four SPT tests were carried out within the clay. The SPT 'N' values ranged between 2 and 13. The 'N' values for the clay are plotted with level in the diagram below.



Based on relationships between SPT N value and undrained shear strength developed by Stroud (1975), adopting the highest plasticity index value of 12% and applying an f_1 value of 5.0, the SPT results indicate equivalent undrained shear strength, c_u of 10 to 65kPa indicating very soft to firm consistency.

Based on the highest plasticity index, PD6694 suggests a critical state friction angle, Φ'_{crit} of 30°. For design purposes a characteristic value Φ' of 28° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffnesses are derived using the correlation between undrained shear strength and plasticity index by Stroud (1974). Using a characteristic undrained shear strength of 40kPa based on field description of firm and the highest plasticity index of 12%, a vertical undrained Young's modulus, E_{uv} and drained Young's modulus, E'_v of 12.5MPa and 10.0MPa have been indicated respectively. The coefficient of volume compressibility, m_v is estimated to be $0.1m^2/MN$.

Where required, a bulk unit weight of 18kN/m^3 above the water table and 18kN/m^3 below has been adopted.

8.3 Sand

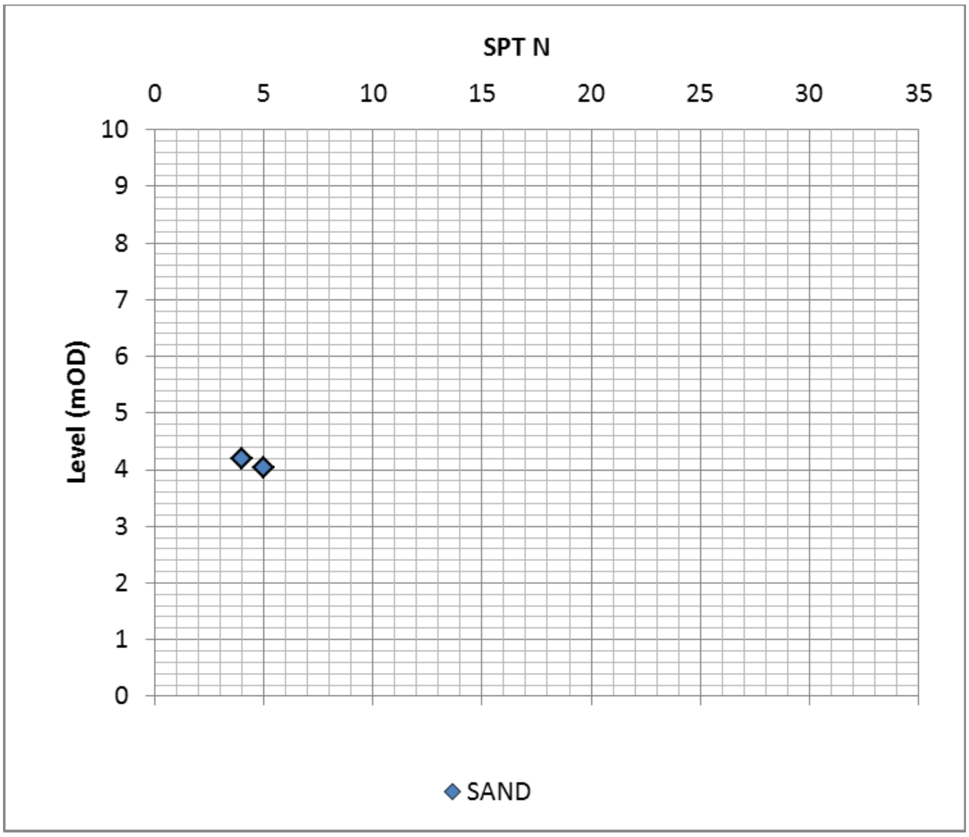
Sand was encountered in WS04 and WS06 beneath the made ground. The base of the sand was not proven in these exploratory holes.

The sand was generally described as clayey slightly silty fine to coarse sand. The sand was interpreted as Tidal Flat Deposits.

One PSD test undertaken on a sample from the sand indicated a Uniformity Coefficient, $U_{c,}$ of greater than 6 indicating that the material is well graded.

Two moisture content tests undertaken on samples from the sand recorded moisture content of 24 and 50%.

Two SPT tests were carried out within the sand. SPT ‘N’ values of 4 and 5 were recorded. The results indicate the sand is loose. The ‘N’ values for sand are plotted with level in the diagram below.



Based on material grading and grain shape, PD6694 suggests a critical state friction angle, $\Phi'_{crit\ of}$ 32°. For design purposes a characteristic value Φ' of 32° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffness is derived using the following correlation between SPT N value and vertical Young's Modulus, E' for gravelly sand presented by Bowles (1988) as follows:

$E' = 600(N+6)$ (kPa)

Using a characteristic SPT N value of 8, a vertical drained Young's modulus, E'_v of 6MPa is indicated.

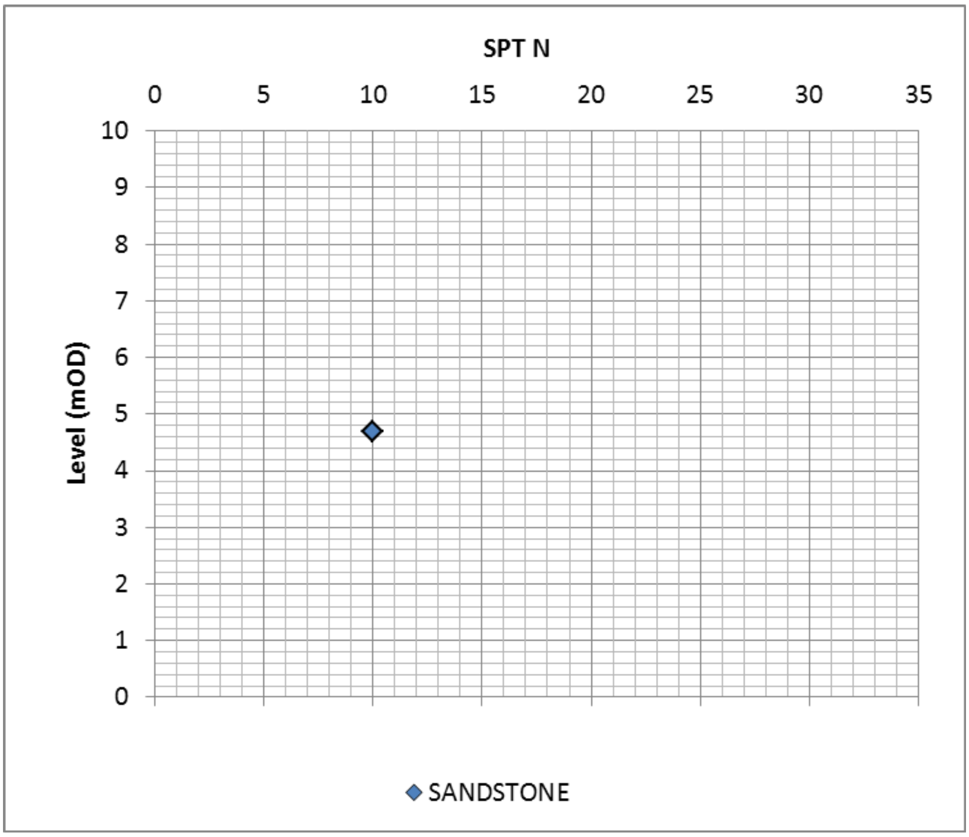
Where required, a bulk unit weight of 17kN/m^3 above the water table and 20kN/m^3 below has been adopted.

8.4 Sandstone

Sandstone was encountered in WS07. The base of the sandstone was not proven in this exploratory hole.

The sandstone was generally described as very weak red brown fine to coarse grained weathered sandstone. The sandstone was interpreted as weathered sandstone.

One SPT test was carried out within the sandstone. SPT 'N' values of 10 was recorded. The result indicate the weathered sandstone is medium dense. The 'N' value for sandstone is plotted with level in the diagram below.



Based on an assumed material grading and grain shape, PD6694 suggests a critical state friction angle, $\Phi'_{crit\ of}$ 32°. For design purposes a characteristic value Φ' of 32° will be adopted. Effective cohesion, c' will be taken as 0kPa.

Soil stiffness is derived using the following correlation between SPT N value and vertical Young's Modulus, E' for gravelly sand presented by Bowles (1988) as follows:

E' = 600(N+6) (kPa)

Using a characteristic SPT N value of 10, a vertical drained Young's modulus, E'_v of 9.5MPa is indicated. The stiffness of the sandstone is however expected to increase rapidly with depth.

Where required, a bulk unit weight of 18kN/m^3 above the water table and 21kN/m^3 below has been adopted.

8.5 Groundwater Levels

Groundwater strike was observed in the WS03 at 5.0m bgl. 50mm slotted standpipes were installed in WS01, WS06 and WS08. The results of the groundwater monitoring are presented in the table below.

Table 20: Groundwater Monitoring Data

Location	Water Level (m bgl)			Strata type
	04/03/2014	16/03/2014	21/03/2014	
WS01	4.89	5.04	Dry	Made Ground
WS06	Dry	Dry	Dry	Made Ground
WS08	Dry	Dry	Dry	Made Ground

8.6 Geotechnical Characteristic Soil Parameters

Geotechnical 'characteristic' parameters used for the foundation design have been derived from the borehole logs, in-situ test results, laboratory test results, published correlations and reference data. A summary of the recommended characteristic soil parameters are shown in the table below.

Table 21: Summary of Characteristic Design Parameters

Properties	GRANULAR MADE GROUND	COHESIVE MADE GROUND	CLAY	SAND	SANDSTONE
Bulk unit weight, γ_b (kN/m^3)	18	17	18	17	18
Saturated unit weight, γ_{sat} (kN/m^3)	21	17	18	20	21
Undrained Shear Strength c_u (kN/m^2)	-	20	40	-	-
Effective Cohesion c'	0	0	0	0	0

Properties	GRANULAR MADE GROUND	COHESIVE MADE GROUND	CLAY	SAND	SANDSTONE
(kN/m^3)					
Peak friction angle, Φ'_{peak} (degrees)	31	28	28	32	32
Critical state friction angle, Φ'_{crit} (degrees)	31	28	28	32	32
Vertical Undrained Young's Modulus, E_{uv} (MPa)	-	6.5	12.5	-	-
Vertical Drained Young's Modulus, E'_v (MPa)	8.0	4.5	10.0	6.0	9.5
Coefficient of Volume Compressibility m_v (m^2/MN)	-	0.2	0.1	-	-

9 Land Contamination Risks and Remediation Requirements

9.1 Revised Conceptual Model

Based on the findings of the human health and the controlled waters risk assessments, the conceptual model can be revised as described in the sections below and significant contaminant linkages identified if present.

9.2 Discounted Contaminant Linkages

There is no longer considered to be significant contaminant linkages between the contaminants onsite and controlled waters, as well as between soil gas and future site users and property / structures.

9.3 Remaining Potential Contaminant Linkages

There is the potential for risk to human health to occur from contaminants at the site given the public open space end use from lead, benzo(a)pyrene, dibenzo(ah)anthracene and dibenzofuran. Chrysotile asbestos was also present onsite.

9.4 Additional Works Required to Assess Outstanding Contaminant Linkages

The risk to human health will need to be dealt with when designing the proposed skate park. The made ground at the site is considered to pose a risk to human health. This risk may be negated if the proposed skate park involves the site being entirely covered in hardstanding i.e. breaking the contaminant linkage. Alternatively, if the made ground is not considered to be geotechnically suitable, excavation, removal and replacement with clean, engineered fill may be an option which would also remove the contaminant source and therefore, break the contaminant linkage.

9.5 Remediation Requirements

9.5.1 Human Health – Soils

There is a potential risk to human health from the soil at the site. Depending on the design of the skate park, the contaminant linkage could be broken by either ensuring that the whole site is covered in hardstanding and / or removing and replacing the made ground with clean, engineered fill.

9.5.2 Human Health – Ground Gas

There are no remedial requirements identified by these assessments with regard to the risk to human health from ground gas at the site.

9.5.3 Controlled Waters

There are no remedial requirements identified by these assessments with regard to the risk to controlled waters from soils at the site.

10 Geotechnical Design

10.1 Foundation Analysis and Recommendations

Ground conditions across the site generally comprised topsoil and made ground overlying sands and clays. Existing ground investigation data indicates that the thickness of the made ground varies from 4.0m to depths of greater than 5.45m.

The made ground appears to be composed of heavily degraded landfill material. It is also very variable in its relative density, but generally low densities and low stiffnesses were recorded. Therefore it is considered unsuitable for the support of structural loads because of its inherent variability and the risk of significant total and differential settlement. All foundations would need to be taken down to competent natural soils below the made ground.

If the skate surface is formed and cast directly on to the made ground, whether at existing level, in excavated hollows or in placed (and compacted) mounds, then the ground can be expected to settle in a variable and unpredictable manner. The magnitude of the settlement can be reduced by heavy proof rolling of excavated surfaces and full compaction of any placed fills, but medium to long term settlement can still be expected. This could lead to cracking of the skate park surface. It is therefore recommended that the designer allow for a stone blanket layer of at least 150mm beneath the surface and that a geogrid or mesh reinforcement is incorporated into the surface construction to aid dispersal of loads and the effects of differential settlement.

It is assumed that the higher sections of the skate structure, along with any ramps and rails will be formed by mass concrete or steel and would induce additional load on the founding material. For preliminary design, it is assumed that these sections will be founded on trench footings, which should be founded within the clay at a depth 4.0m below ground. Assuming a concentrically loaded foundation and a trench footing width of 1.5m, a safe bearing capacity of 70kN/m^2 is indicated when assessed to BS8004, though that would have to be verified during detail design. Anticipated settlement of the proposed trench footing will be in the order of 25mm. It is recognised that a depth of 4.0m to a reliable bearing stratum would require significant excavation and may require shoring or other support in the temporary works and may not be feasible.

It may be feasible to consider excavating and replacing the founding material with imported fill or site won material. Site won material could be classed as a Class 1 General Fill but would need to be selected, screened, crushed and recompacted in accordance to the acceptability and compaction criteria indicated within Series 600 of the Specification of Highway Works. Safe bearing pressure and the settlement performance would depend on the depth of the improvement and will need to be evaluated at detailed design.

Vibro-stone columns could be considered as a ground improvement technique within these ground conditions. The safe bearing pressure and settlement performance would depend on the depth and spacing of the stone columns and advice should be sought through a specialist contractor at detailed design.

Alternately, piles may be adopted to rely on end bearing on the unweathered sandstone. Due to the variability of the made ground, any skin friction contribution from the made ground will be ignored.

If the decision is made to found any ramps, rails or other structures within the made ground, then the foundation should be designed to account for a very low allowable bearing capacity of 20KN/m2 and should be tolerant of considerable differential settlements which may be of the order of 50-100mm over a period of time.

Checks will be required at detail design to determine the potential of differential settlement between the higher and lower sections of the skate structure. This will be required to determine the need for structural reinforcement to prevent cracking between the upper and lower sections of the skate structure due to differential settlement.

Any soft spots encountered would need to be over excavated and replaced with compacted granular fill.

Once the general arrangements of the proposal have been established, slope stability checks might be required to ensure that the proposal does not destabilise the existing slope. The loadings of the proposed skate structure should be determined and the risk of differential settlement evaluated accordingly. The bearing resistance should be assessed in detail when the structural design and applied foundation loads have been completed.

10.2 Concrete Classification

Chemical testing in accordance with BRE Special Digest 1 was carried out on a total of 8 soil samples recovered from the exploratory holes. The range of results is presented in the table below.

Table 22: Results of BRE Special Digest 1 Chemical Testing

Chemical Test	Range of Results	
	Lowest	Highest
Total SO_4 (%)	<0.01%	0.10%
SO_4 in 2:1 Water:Soil (g/l)	<0.1g/l	5.3g/l
pH	7.0	8.0
Total Sulphur (%)	0.01%	0.59%

The aggressiveness of the chemical environment with respect to new buried concrete has been assessed in accordance with BRE Special Digest 1 – Concrete in aggressive ground, 2005. Characteristic values of 3800mg/l for soluble sulphate and 7.0 for pH have been determined.

The design sulphate classification for the foundation soils is DS-4. The Aggressive Chemical Environment for Concrete (ACEC) classification for the site, assuming mobile groundwater is AC-4.

10.3 Groundwater

Three groundwater monitoring visits indicate that the groundwater is at 4.89 to 5.04m bgl in WS01 and is dry in WS06 and WS08. Detailed design should be carried out to take account of the seasonal variation of the groundwater level based on groundwater monitoring results.

10.4 Geotechnical Risk and Uncertainty

The ground is never without uncertainty and risk and therefore in detailed design, the following should be considered:

- Granular and cohesive made ground was encountered in the ground investigation. Due to this variability the characteristic soil properties will be subjected to considerable uncertainty. The detailed design should take account of this uncertainty.

- Depth of un-weathered sandstone is not determined from existing GI. SPT undertaken at 5m bgl indicates SPT N value of 10 which indicates that the material is medium dense. This is interpreted as possible weathered sandstone.

- Slope stability checks to determine the risk of slope instability due the proposed skate structure

- Detail settlement checks to determine the risk of differential settlement between different sections of the skate structure.

11 Conclusions

11.1 Ground Model

The topography of the site is generally level although there are small patches of uneven ground which may be indicative of historic ground workings. The land to the south and east is typically 3 to 4m higher than main site level.

Made ground was encountered at each of the exploratory hole locations across the site. The thickness varied between 4m and in excess of 5.45m with the thickest located in WS01, WS02A and WS03 in the northern part of the site.

Superficial deposits comprising a clayey, silty sand (Tidal Flat Deposits) was encountered in WS04 and WS06 at depths of 5m bgl and 4.8m bgl respectively. A silty, sandy, gravelly clay (Glacial Till) was encountered in WS05 and WS08 at depths of 4.1m bgl and 4m bgl respectively. Bedrock comprising a weak sandstone was encountered in only one exploratory, WS07, at a depth of 5m bgl.

The gas monitoring results show that carbon dioxide was recorded between 0.1% and 6.9%. No methane, carbon monoxide or hydrogen sulphide were noted during the monitoring period. Flow was also absent.

11.2 Human Health Assessment

The outcome of the statistical analysis has indicated that there is a site wide contamination issue due to lead, benzo(a)pyrene, dibenzo(ah)anthracene and dibenzofuran. Asbestos was noted in one location.

The proposed Skate Park structures will break the pathway between the identified contamination and the end users; consideration should also be given to capping adjacent areas.

The assessment of the gas monitoring results shows that the concentrations of ground gas at the site do not pose a significant risk to future site users or nearby property due to the low concentrations and absence of flow.

11.3 Controlled Waters Assessment

There are elevated concentrations of arsenic, cadmium, chromium, copper, nickel, mercury, zinc and PAHs at isolated locations across the site. However, given the margin of exceedences and once factors such as dilution, degradation and migration are taken into account, it is unlikely that these exceedences will pose a significant risk to the underlying bedrock or the adjacent Mersey Estuary.

11.4 Geotechnical Assessment

The preliminary GI has indicated that the site is underlain by 4-4.5m of landfill material, a thin layer of soft to firm clay and then sandstone at depth.

The nature of the superficial materials is that they are of low strength and high variability. Settlement and cracking of the skate surface could be expected unless these deposits are thoroughly compacted.

Based on our understanding, it is not anticipated that there will be a significant change in site levels in relation to the proposed Skate Park at this location due to the existing topography. Further measures may need to be considered to prevent significant total and differential settlement if changes in site levels are proposed. It might be necessary to transfer foundation loads to the underlying clay by trench or piled foundations. If ramps, rails and other structures are founded within the made ground, they should be designed for very low bearing pressures and be tolerant of high levels of differential settlement.

12 Recommendations

12.1 Further Intrusive Investigations

No further intrusive investigations are proposed, based on our understanding of the proposed skate park.

12.2 Detailed Quantitative Risk Assessment Requirements

No detailed quantitative risk assessment is required based on our current understanding of the proposed skate park.

12.3 Remedial Requirements

Remedial measures with regard to the potential risk to human health may be required depending on the final design of the skate park.

12.4 Geotechnical Requirements

The ground conditions are poor and geotechnical measures are recommended in relation to the construction of the skate park to prevent potential differential settlement and hence cracking to the skate park structures and the skate surface.

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Appendix A Groundsure Report

Appendix B Risk Evaluation

Appendix C Ground Investigation Factual Report

Appendix D Gas / Groundwater Monitoring

Appendix E Chemical Analysis Results

Appendix F GAC Methodology

Appendix G Human Health Risk Assessment

Appendix H Controlled Waters Risk Assessment