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Proposed Residential Development – Site A, Porthcawl

Geo-Environmental & Geotechnical Assessment

Report Reference: ESP.7044d.3123_A.Rev1

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Proposed Residential Development – Site A, Porthcawl

Geo-Environmental & Geotechnical Assessment

Prepared for:
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Report Reference: **ESP.7044d.3123_A_Rev1**

Revision	Status	Date	Written by	Checked by	Approved by
0	Draft	May 2019	D Thomas BSc (Hons) FGS	H Davies MESci CGeol FGS	M Eynon BSc MSc CGeol EurGeol FGS ROGEP Specialist
Report updated following supplementary works and alteration of site boundary					
1	Final	September 2020	D Thomas BSc (Hons) FGS	H Davies MESci CGeol FGS	M Eynon BSc MSc CGeol EurGeol FGS ROGEP Specialist
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Executive Summary – Site A, Porthcawl

Bridgend County Borough Council (hereby referred to as the Council) are in the process of marketing a new development opportunity for a mixed-use scheme involving new commercial, leisure and residential uses in Porthcawl. This summary relates to the investigation of the proposed residential development (Site A) only (see Sections 1.1 and 1.2 for details).

	Potential Hazard	Anticipated Risk	Discussion
Site Setting	*Current Site Status. (Section 2.1)*	-	*The site is presently occupied by open rough grass areas, with compacted gravel surfacing in the east and centre. The gravelled areas are used as a public car park, with barriered access in the north east, with a short tarmacadam access road trending west and south west.*
	Identified Ground Conditions. (Section 5.1)	-	*The site is generally underlain by a thin covering of Made Ground followed by Blown Sand deposits overlying weathered and competent Oxwich Head Limestone bedrock. In the area of the infilled dock slipway and former smithy, deeper Made Ground has been identified.*
	Groundwater Conditions (Section 5.2.1)	-	*The Blown Sands are classed as a Secondary A aquifer, whilst the bedrock Oxwich Head Limestone is classed as Principal Aquifer. Testing indicates the quality of the aquifers has been degraded naturally due to saline intrusion. Previous and recent monitoring data indicates the groundwater beneath the site to generally be present at depths of around 4m to 6.5m below surface level within the Blown Sands and Made Ground within the infilled dock. However, shallower groundwater levels have been identified. Groundwater monitoring suggests tidal influence is limited.*
Geo-Environmental	*Historical Land Use & Potential Contamination Sources (Table 1 & Section 2.8)*	*High*	*Several previous industrial (and potentially contaminative) historical land uses have been identified, including a smithy, dock (infilled), railway land, railway sidings, ground workings, unspecified pit, cuttings, coal tip and its current use as a car park.*
	Chronic Risks to Human Health (Section 5.5 and Section 7.1) ***Risks from Asbestos in shallow soils is presented Below***	*Moderate/ High*	*Assuming a residential end use and excluding the risks from asbestos, the identified levels of soil contamination at the site as part of this initial assessment are considered to pose a risk to future site users and remedial measures are considered likely. Levels are lower outside of the former dock in the general Made Ground and may be acceptable, however considering the past significant industrial history there is a potential for un-identified contamination. Further consideration is required in landscaped areas once determined. Due to the presence of contaminants within the Made Ground soils across the site (including asbestos – see below) potential risks to construction workers are posed. The contractor should comply with the appropriate current Health and Safety at work legislation.*
	Risks to Controlled Waters (Section 7.2)	*Low/ Moderate*	*We consider that the overall risk to controlled waters from the development of the site is likely to be low to moderate. Discussion with NRW will be required to confirm their opinion on the sensitivity of the aquifers considering their natural degradation to confirm the risk. We cannot discount that additional monitoring, testing and assessment may be required. Some risk mitigation is likely to be required if soakaways are used to dispose of surface water run-off.*
	Hazardous Ground Gas (Section 7.3)	*Moderate*	*Completed monitoring indicates the site will require protective measures. Based on the monitoring to date, we consider that the site would be classified as Characteristic Situation CS-2 for a commercial development (CIRIA C665:2007).*
	Asbestos (Section 7.1.1)	*Moderate*	*Chrysotile asbestos has been identified in the infilled dock materials and general Made Ground on-site and in neighbouring areas at quantifiable levels. Once the development proposals are known, we recommend some additional testing for asbestos is undertaken in proposed landscaped areas to confirm the long term risks to human health and generally across the site to confirm risks to construction workers. Specialist advice should be sought and further risk assessment be completed.*
Geotechnical	*Shrinkage or Swelling (Section 8.2.1)*	*Low*	*No shallow fine-grained soils have been encountered within potential influence depths of any proposed planting. The fine grained weathered bedrock at depth will not pose a risk.*
	Ground Dissolution (Section 8.2.2)	*Low/ Moderate*	*The site lies in an area susceptible to limestone solution, however no evidence has been identified by the desk study or during previous or current investigation of solution features on the site. We cannot discount that un-recorded solution features exist beneath the site and further investigation could be considered by the purchaser to reduce the uncertainty of potential risks.*
	Weak/Compressible Ground, requiring non-traditional foundations (Section 8.2.3 and Section 8.3).	*High*	*Compressible soils have been encountered at shallow depth across the site (Made Ground and Blown Sands). Preliminary foundation and floor slab designs have been provided for low and high structural loadings. Once the development location, proposed loadings and settlement tolerances are known, the available information should be reviewed to confirm the potential foundation options.*
	Collapsible Ground (Section 8.2.4)	*Low*	*The unconsolidated/uncompacted Made Ground within the infilled dock and the Blown Sands are potentially susceptible to collapse compression during inundation. This would only likely occur if groundwater levels were to increase during the design life of the proposed development.*
	Running Sand (Section 8.2.5)	*High*	*Where groundwater ingress occurs within the Blown Sand deposits, the potential for running sands is considered high. The design of all excavations or bored foundation solutions (drainage, foundations etc) should consider this hazard.*
	Volumetrically Unstable Slag (Section 8.2.6)	*Moderate*	*The general Made Ground was noted to contain minor constituents of slag. Within the infilled dock and former smithy area, a high proportion of slag was noted. Once the proposed developments are finalised, if any proposed construction (of buildings, roads or hard standings) is positioned in this area, further sampling and analysis of the slag materials should be undertaken to determine the risk.*
	Excavation Stability (8.2.7)	*High*	*Previous and current investigations on and off-site have recorded spalling and collapsing of the pit walls within the Made Ground and the Blow Sand deposits. Support of excavations sides is likely to be necessary.*
	Underground Structures/Services (Section 8.1 and 8.2.3)	*Moderate*	*We understand the masonry associated with the dock slipway and dock remains present. Old foundations associated with the former smithy also cannot be discounted. Cobbles and boulders have been recorded as occasional to frequent in the Made Ground. The development plan will need to consider the presence of the services indicated to be present beneath the site and easements, diversion or protection will require agreement with specific providers.*
	Sulphate Attack on Buried Concrete (Section 7.4.2)	*Moderate*	*Based on current values, the site would be initially classified as Design Sulphate Class DS-3 and Aggressive Chemical Environment for Concrete Class AC-3. This requires confirmation in the infilled dock due to higher levels recorded previously in neighbouring areas.*
	Soakaway Feasibility (Section 8.8)	-	*Investigation works undertaken by ESP for the proposed Food Store (immediately west and north of Site A) indicates that soakaways will likely be feasible in the Blown Sand deposits. Soakaways would not be suitable in the Made Ground soils. If desired, we recommend enquiries are made to Natural Resources Wales to identify whether they would allow such discharge and location specific testing will be required once the design proposals have been finalised.*
Others	*UXO (Section 2.11)*	*Low*	*The preliminary assessment undertaken by a specialist concludes that "a detailed desk study, whilst always prudent, is not considered essential in this instance". No further assessment is considered necessary at this stage.*
	Flooding (Section 2.6.3 & 2.6.4)	*Moderate/ Low*	*The site is not indicated to be at risk of flooding by rivers and the sea. The British Geological Survey (BGS) has a high confidence in there being a potential for below surface clearwater flooding.*
	Invasive Plants (Section 8.1.1)	-	*No evidence of invasive plants was identified during the site works. A specialist survey across the site should be undertaken to confirm this.*
	Further Investigation Required? (Section 9.0)	*Yes*	*Once detailed development design layouts and proposals are known and the site specific regulatory requirements are confirmed, additional investigation and assessment is recommended/required to further assess contamination risks initially assessed or to robustly finalise the geotechnical design advice provided in this report.*

Note: The above is intended to provide a brief summary of the conclusions of the assessment. It does not provide a definitive assessment and must not be referenced as a separate document. Refer to the main body of the report for details.

1 Introduction

ESP completed an assessment report (Ref: ESP.7044d.3123_A) in May 2019, for potential future development of the site for residential purposes. At the time, no formal/finalised designs or proposed development layout plans had been provided and therefore the investigation area was based on the boundary provided to us at the time (see Insert 2).

Following the assessment, the Client issued an indicative 'Site Strategy' drawing to ESP prior to undertaking supplementary works in December 2019 (see Section 1.4). This included an amendment to the site boundary extent which was confirmed in further discussions between March and July 2020. The alteration to the site boundary came about due to finalisation of the site boundary for a separate development site for a proposed Food Store, immediately to the north and west of this assessment area. For reference, an extract of the drawing is shown as Figure 1.

This report supersedes the original ESP report (ESP. 7044d.3123_A), May 2019), for Site A and has been updated so that all information has been assessed relative to the updated site boundary (see Insert 3). Details of this are discussed further in Sections 1.2, 1.4 and 1.5, with relevant updates to the previous report included in the appropriate sections throughout the report.

1.1 Project Background

Bridgend County Borough Council (hereby referred to as the Council) are in the process of marketing a new development opportunity for a mixed-use scheme involving new commercial, leisure and residential uses in Porthcawl. The initial phases include sites to the east of Porthcawl Town Centre (see Insert 1), at the northern section of Salt Lake Car Park (Site A inc. Food Store site) and at the south end of Hillsboro Place Car Park (Site B). The re-development of Site A and B forms part of a first phase of the wider site's regeneration and is set within the adopted masterplan for the area called the Seven Bays Project Supplementary Planning Guidance (SPG) (2007). This report relates to Site A only.

Insert 1 - Site A Location Plan from Ordnance Survey 1:25,000 (OS License No.: AL100015788).

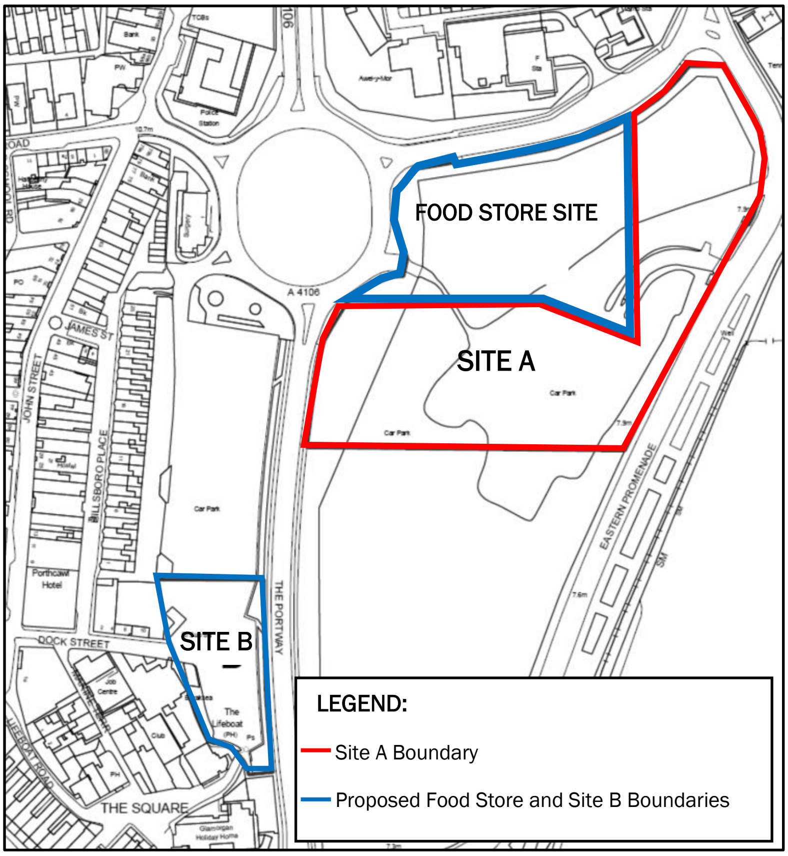
The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by the Client to undertake an integrated geotechnical and geo-environmental investigation and initial assessment to preliminarily identify and evaluate potential ground hazards which could impact on the proposed development in Site A (inc. the Food Store site) and Site B (see Insert 2 below).

The information obtained will help inform the Client's evolving masterplan and form part of the site marketing particulars for these specific areas to enable prospective bidders to understand ground characteristics and enable decisions regarding scheme layout and costings associated with construction and site remediation.

1.2 Study Site and Proposed Development (Site A)

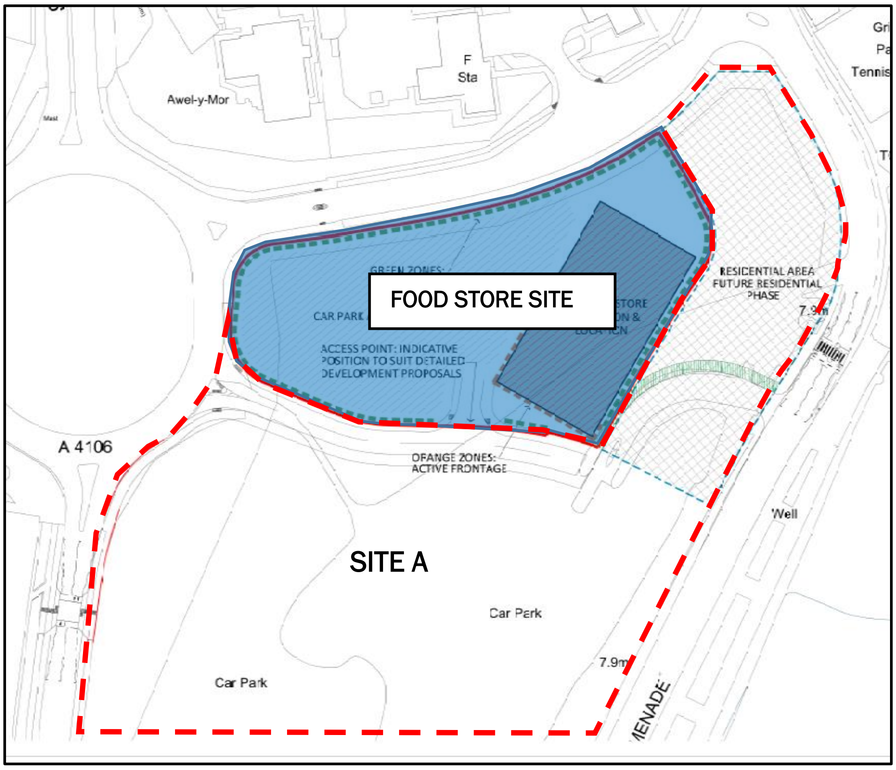
This report relates to the investigation for proposed residential development, hereafter known as Site A (see Insert 3). The report for the proposed Food Store and Site B investigations have been previously issued under separate cover and should be read if detailed context of this area is needed (see Section 1.4 and Section 1.5).

The original extent's of the investigation areas (2018) are indicated in Insert 2.



Insert 2 - Overview of Investigation Areas – As detailed in 2018

The Client issued an indicative 'Site Strategy' drawing to ESP prior to undertaking supplementary works in December 2019 (see Section 1.4). This included an amendment to the site extent which was confirmed in further design discussions between March and July 2020. For reference, an extract of the drawing is shown as Insert 3 below and is presented in full in Figure 1. The Site B boundary remained unchanged.



Insert 3 – Site Strategy Plan – Provided by Council December 2019
NB. Drawing issued following the original investigation and prior to supplementary works

No formal designs or proposed development layout plans have been provided for the residential development at Site A at this time. For the purposes of this report, we have assumed that the proposed residential development will comprise typical two-storey residential dwellings with private gardens, as well as flat type buildings (size unknown) with associated areas of landscaping, estate roads and hardstanding (parking/footpaths etc). We understand that there will be no significant changes to the current ground levels.

Based on the above, we understand that the proposed structure(s) would be classified as Geotechnical Category 2 (BS5930:2015).

1.3 Objective and Scope of Works

All investigation works (including supplementary phases) at Site A, the Food Store site and Site B were undertaken simultaneously.

The objective of the investigation was to obtain information on the geotechnical character and properties of the ground beneath the sites, potential risks posed by contamination and ground gas, and to allow an initial assessment of these ground conditions with particular reference to the potential impact and constraints on the proposed developments. This includes review of extensive existing site information, and targeted additional works in areas where insufficient information was available.

The scope of works for the investigation was mutually developed with the client within an agreed tender budget, and comprised a desk study review of available historical investigation information, historical Ordnance Survey maps, environmental data, geological maps, memoirs and data, and further desk study information, a field reconnaissance visit, the supervision and direction of trial pits, cable percussion boreholes, rotary drill holes, measurement of in-situ CBR values (using DCP equipment),, geotechnical and geo-environmental laboratory testing, assessment of foundation options, risks to human health and controlled waters, and reporting.

The contract was awarded on the basis of a competitive tender quotation, hosted by the Sell 2 Wales portal. The terms of reference for the assessment are as laid down in the Earth Science Partnership tender return package of 17th October 2018 (ref: ESP.7044d.Porthcawl Tender - Method Statement ME 17.10.18 & ESP.7044d.lt1 Investigation BoQ 17.10.18). Instructions to proceed with the supplementary works were received by email in November 2019.

The main investigation for all areas was undertaken in November and December 2018. Supplementary works and continued monitoring (gas and groundwater), were undertaken in late 2019 and early 2020.

1.4 Supplementary Works and Reporting

In line with our recommendations for further investigation detailed in our original report (ESP.7044d.3112_A, May 2019), the Council commissioned additional works to undertake further investigation and assessment across the Food Store site and Site A, to address the additional investigation and assessment works, detailed in the previous recommendations. The additional works for Site A were completed December 2019 and comprised WAC testing and additional testing of the shallow soils for asbestos. Further gas and groundwater monitoring visits were also undertaken in January and February 2020, with on-going assessment undertaken.

Following the updates to the site boundary (Insert 3), ESP proposed that the report for Site A (and the Food Sore Site), should be updated relative to the new boundary changes, to include/omit investigation points (and associated laboratory test results) that now lie within/outside the new boundary. This would also include the additional works completed in December 2019. ESP were formally instructed by email to undertake the updates to the reports at the end of July 2020.

This report updates and supersedes the original report (ESP.7044d.3112_C, February 2019), for Site A.

1.5 Report Format

The reports for the three separate areas (Food Store, Site A and Site B), have been produced individually and the references are as per Table 1 below. A approximate plan of the three areas is shown as Insert 2.

Table 1: Summary of Reports for Porthcawl Investigation

Report Reference	Area of Investigation	Issue Date
ESP.7044d.3123_A	Site A	Original - 29th May 2019
		Revised – September 2020
ESP.7044d.3124_B	Site B	Original - 14th May 2019
		Revised – September 2020
ESP.7044d.3112_C	Proposed Food Store	Original - 1st February 2019
		Revised – August 2020

This report is for the, excluding the food store site. This report is the updated assessment for the Site A area only and supersedes the previously issued report (May, 2019) listed in Table 1 above.

The report includes desk study and field reconnaissance reports (Section 2), details of the investigation undertaken of Eurocode EC7 and BS5930:2015 (Section 4), along with the

Preliminary Risk Assessment stage (Section 3) and Generic Quantitative Risk Assessment (Section 5) of CLR11.

A preliminary evaluation of the resulting risks and any remedial measures potentially required to mitigate identified unacceptable risks from contamination and hazardous ground gas is included in Sections 6 and 7. However, it should be appreciated that this is a preliminary evaluation only and will not generally meet the requirements of the Options Appraisal report of CLR11.

A preliminary risk register, identifying potential geotechnical hazards from the desk study review, is presented as Section 2.9, with a full assessment of the geotechnical conditions including foundation and floor slab options, the feasibility of soakaways, etc. in Section 8 – this complies the relevant elements of the Geotechnical Design Report of BS EN 1997-2 (Eurocode 7) and BS5930:2015. The geotechnical risk register is updated using the findings of the intrusive investigation and assessment in Section 8.2. The report concludes with a summary of any further surveys/ investigations/ assessments recommended (Section 9).

The assessment of the potential for hazardous substances (contamination) or conditions to exist on, at or near the site at levels or in a situation likely to warrant mitigation or consideration appropriate to the proposed end use has been undertaken using the guidance published by CIRIA (2001). This is discussed in more detail in Section 3.2.1 and in Appendix A.

1.6 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site-specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

1.7 Digital Copy of Report

This report is issued as a digital version only.

2 Desk Study and Field Reconnaissance Visit

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps (Appendix B), environmental and geological data reports (Appendix C), exploratory hole records from previous investigations (provided by the Client) at the site and on adjacent land (Appendices D1-D6) and information provided by BCBC Council (Appendix E).

The site boundary in the environmental data report (Appendix C2) and geological data report (Appendix C3) is for Site A and the Foodstore site, with the boundary as it was at the time, in 2018 (see Insert 2). The Food Store site boundary has also been drawn on and any features identified within this area have not been included as part of the 'on site' features.

The site description is based on site visits and inspections throughout the works between November and December 2018 and general views of the site are included as a series of photographs within the Plates section of this report.

2.1 Site Location and Description

The site is located in the north portion of the wider Salt Lake car park to the east of Porthcawl town centre. The National Grid Reference of the approximate centre of the site is (SS) 282021, 176883 and the closest postcode is CF36 5TS (See Insert 1).

The site comprises an irregular shaped parcel of land of around 180m length (north to south) and 165m width (east to west), occupying an area of around 3ha (see Insert 3 and 4).

Insert 4 – Site A Aerial Image (from EnviroInsight report, Appendix C2)

As identified in Insert 4, the site is largely occupied by open rough grass areas, with compacted gravel surfacing in the east and centre. The gravelled areas are used as a public car park during the summer months, with access to the site via barriered access in the north east, with a short access road trending west and south west. The Food Store site is located adjacent to Site A in the north west, as indicated on Insert 3.

It is bounded by:

- To the north: immediately by Eastern Promenade road, followed by buildings associated with Porthcawl Fire Station and residential areas extending more than 1km to the north;
- To the east: Immediately by Eastern Promenade road, followed by Sandy Bay beach, some 25m east. Coney Beach fair is to the north of the beach;
- To the south: immediately by grass/gravel surface land associated with the wider Salt Lake car park which extends approximately 230m further south, followed immediately by a small harbour.
- To the west: immediately by a roundabout off Eastern Promenade and The Portway, followed by largely commercial and residential areas associated with Porthcawl.

A small breeze block hut, likely for car park attendants, is located in the access road to the car park. A number of steel posts are also present across the car parking area, used for mounting the 'Pay and Display' units when they are in use.

A small bund, varying between approximately 0.5m to 1.0m in height, is present along the north and east boundaries. No investigation or soils testing of the bund has been undertaken to date.

We are not aware of a tree survey having been undertaken at this stage, however there are no significant trees at the site. A small area of rough vegetation is located along the east of the site, which will likely be cleared as part of the development works.

The general topography in the area is relatively flat, gradually sloping to the coast to the east/south east. The site itself is generally flat and level.

A topographical survey has been provided by the Client, which indicates a height of around 8.5m to 9m AOD at the site. The Client has also provided a series of service plans (services are also shown on the constraints plan) showing the locations of recorded underground services in the vicinity of the site (see Appendix S).

Following completion of the investigation, a survey was undertaken in March 2019 by Dwr Cymru Welsh Water (DCWW) in order to locate a rising foul sewer which extends across Site B (and trends east and north towards Site A and the food store site). The results of the survey were provided to the Client in March 2019.

Site observations and the available plans indicate the following services to be present at the site:

- Underground rising foul sewer main, trending west to east across the southern area of the site. The main extends from the south, where it passes beneath The Portway, before turning north to the west of Site A. It then turns east and passes beneath the south portion of Site A (see Figure 3);
- Underground surface water drains are identified in the west margins along the boundary, trending north and in the east of the site, approximately 5m inside the west boundary, trending north east and north;
- Street light columns are also indicated along the footpath in the north west and electrical cables associated with these will also be present, although they are not shown.

- Overhead BT cables are shown on the plan (Appendix S) to enter from the east of the site and trend south east. However, on inspection, no overhead cables or telegraph poles are present at the site, indicating that the lines and telegraph poles have been removed in the past (sometime between 2016 and November 2018).
- A number of services are also present within the vicinity of the site, including water mains to the north trending west-east along the north of Eastern Promenade road and surface water sewers trending north some 30m east of the site.

2.2 Site History

2.2.1 Published Historical Maps

The site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps. Extracts from the historical maps are presented in Appendix B and the salient features since the First Edition of the County Series maps are summarised in Table 2 below.

Table 2: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1880-1884	The site is within Porthcawl Dock with the majority of the south and south east portion is occupied by the main dock, with the slipway and sloping masonry walls identified along the edges. A 'Smithy' is indicated to partially encroach on the site along the north west boundary. Railway lines are indicated to enter the site in the north east and south west, trending west and north east respectively. Outside of the water-filled dock, the site surface is shown to be a mix of rough pasture, shingle and sand.	Porthcawl Dock continues to extend approximately 230m south of the site, followed by the Outer Basin of the dock. A shipbuilding yard is located directly adjacent to the site in the north. A sloping masonry wall is shown adjacent to 'Porth-cawl Sands' beach which is shown 30m south east. The East Pier of the dock is shown some 480m south, adjacent to the harbour entrance. A large number of railway/tramway lines are indicated near to the west site boundary and up to approximately 80m further west. The railway lines trend south/south east from the north towards the dock. Railway land is also identified on the south and eastern edge of the dock, extending to the north east. A tank is indicated at the termination of two railway/tramway lines some 40m east and 4no. further unnamed square structures are also indicated in the area of the tank. A saw mill is shown about 70m south west. A 'Gas Works' is indicated around 170m north east and a well has been identified approximately 150m north. A site of human remains (found A.D. 1846) is shown around 100m north west. Residential areas are shown some 200m north west and 200m south west.
1889-1900	The Smithy is no longer indicated. Additional railway lines are indicated and a coal tip is noted at the termination of the railway lines, on the edge of the dock.	There is no indication of the shipbuilding yard still being present. The number of railway/tramway lines to the west have increased with many extending to coal tips at the edge of the dock. The residential areas to the north, west and south west have expanded. A 'Tumulus' is shown around 100m north west in the position where the site of human remains (found A.D. 1846) was identified above, indicating a mound of earth and stones raised over a grave. 'Porthcawl Water Works' is now shown adjacent to the north boundary of the gas works. The Wells previously identified are no longer indicated.
1919	The railway/tramway lines have been modified with some being dismantled and the coal tip is no longer shown. An area of earthworks likely associated with the coal tip is now indicated.	A tank is indicated approximately 110m to the north west amongst the railway land. The railway/tramway lines on-site extend into the gas works and appear to be connected to a 'Tank' and 'Engine Shed' approximately 160m east. The tramway then extends further east and terminates 820m east of the site in 'Newton Burrows' sand dunes. The coal tips are no longer indicated, and the railway lines no longer terminate at the dock edge. Associated railway lines along the dock and to south west have been dismantled. The residential areas to the north and south have expanded further and are now joined to form one area. The Gas works has expanded with an additional tank indicated. The water works are no longer indicated.
1943 - 1948	The dock is now indicated to have been infilled, with the surface indicated to be shingle/rough ground. The rail/tram lines through the site remain, with further earthworks indicated in the south west. A miniature railway extends south west to north east near/along the east boundary.	The former dock has been infilled, however the 'Outer Basin' remains. The railway land to the west is shown to has expanded and been modified and a tank is now shown directly on the south west boundary, with a railway station now shown some 80m south west. The road at the east boundary is now named Eastern Promenade. Coney Beach Amusement Park is now shown 30m east of the site, with the tank and railway shed previously identified in this area now removed. The residential/ commercial development to the west and north has continued. The gas works are no longer indicated; however, the tanks remain present. The beach is now named Porthcawl Sands.
1965 - 1968	The infilled dock is now shown to be a car park, which occupies a large portion of the site in the south and south west. The car park extends some 230m south. Some earthworks are shown adjacent to the railway lines across the site, which have been modified.	A tank is shown directly adjacent to the west boundary. Some of the railway lines to the west of the site appear to have been removed/decommissioned and 2no. 'water points' are shown 10m west. The surrounding areas have been developed further with residential and commercial buildings. One of the gas tanks has been removed.
1976 - 1980	The railway land (with the exception of the miniature railway) has been removed and the site is indicated to be within a car park. An access road from the east (leading into Salt Lake Car Park) is identified in the east.	The railway land and tanks to the west have been removed and a new road and roundabout are now shown directly adjacent to the west boundary which extends south (The Portway). The car park to the south has expanded beyond the limits of the former dock with an additional car park indicated to the west of the Portway. The existing Fire Station and Police stations are now shown 30m north and 50m north west respectively. The layout of Porthcawl now resembles the present day following further development of the area and the beach has been renamed Sandy Bay. Trecco Bay Holiday Park is now shown approximately 720m east.
1991 - 2014	The miniature railway is no longer present on the 1995 map.	The surrounding area is largely the same as the present-day layout. The gas works is no longer indicated.
2018-2019	An Alun Griffiths Construction (UK) Ltd site compound has been positioned in the west of the site (see Insert 3). No further significant changes identified.	No significant changes identified.

2.3 Previous Investigations and Assessments

The Client has provided a number of previous investigations and assessments undertaken across the wider site. A summary of the previous investigation information provided to ESP at the time of writing this report is detailed below in Table 3 in chronological order. The table also includes several previous investigation records without an accompanying report (extracted from previous reports for ease of reference).

Table 3: Summary of Previous Investigations

Report Title & Description (Reference)	Date	Undertaken By	ESP Reference
Proposed Swimming Pool, Porthcawl (F4222) *Borehole Records only*	Jun, 1979	Norwest Holst Soil Engineering Ltd	NH, 1979
Porthcawl – Proposed Marina Development (S/25037) *Trial Pit Records only*	Apr, 1987	James & Nicholas/Wimpey Laboratories	WL, 1987
Structural Investigation into Condition of Harbour Walls & Breakwater, Porthcawl (DV5107/01) *Borehole Records only*	Mar, 1997	Bridgend County Borough Council	BCBC, 1997
Initial Site Investigation Works at Salt Lake Car Park, Porthcawl. (DSV/TNO/KJC/W99134-36) *Cable tool boreholes, laboratory testing and groundwater monitoring*	Dec, 1999	Johnson Poole & Bloomer	JPB, 1999
Phase 1 Environmental Assessment for Porthcawl Regeneration Area (P8078/G205/B) *Desk Study Assessment*	Dec, 2007	Jubb Consulting Engineers Ltd	JUBB, 2007
Porthcawl Regeneration – Hillsboro Place Car Park (2312.003) *Trial Pit Records only*	May, 2008	Bridgend County Borough Council	BCBC, 2008
Extended Phase 1 Desk Study for Porthcawl Harbourside (CIV10285-2200-101) *Desk Study Assessment & Preliminary Investigation (trial pits undertaken by Integral Geotechnique)*	Jul, 2008	Waterman Civils Consulting Engineering	WC, 2008
Pre-Acquisition environmental Assessment Summary Report – The Portway, Porthcawl (10-3283.03) *Desk Study Assessment*	Sept, 2011	Delta Simmons Environmental Consultants	DS, 2011
Porthcawl Regeneration Site Investigation – Desk Study (G201/DS) *Desk Study Assessment*	Mar, 2013	Quantum Geotechnical	QG, 2013
Porthcawl Regeneration Site Investigation – Phase II Ground Investigation – interpretive Report (G201/IR) *Desk Study Assessment*	Mar, 2013	Quantum Geotechnical	QG, 2013
Porthcawl Sandy Bay PAR Geotechnical Desk Study	Dec, 2016	Ove Arup & Partners Ltd	ARUP, 2016

With regards to Table 3, we have identified the following previous intrusive investigations to have exploratory holes within the Site A area:

- Norwest Holst Soil Engineering Ltd (NH, 1979);
- James & Nicholas/Wimpey Laboratories (WL, 1987);
- Johnson Poole & Bloomer (JPB, 1999);
- Waterman Civils Ltd (WC, 2008);
- Delta Simmons (DS, 2011); and
- Quantum Geotechnical (QG, 2013).

Pertinent information from the above investigations (and investigation outside of the Site A boundary, where relevant) will be referred to in subsequent sections where required and general information on the site has been reviewed from all previous works for this report.

The relevant previous investigations and records are presented in chronological order in Appendices D1 to E6. A plan identifying previous investigation points pertinent to the Site A residential development is presented as Figure 4.

2.4 Archaeological Setting

A full archaeological assessment was not included within the brief. Given that a site of human remains (found A.D. 1846) is shown around 170m north west and given the presence of the historic dock beneath portions of the site, it may be prudent to engage a specialist archaeological consultant to review the historical and archaeological setting and assess the potential impact on the proposed development.

In addition, a previous Desk Study assessment (JUBB, 1997) indicates that flint implements and arrow heads had been identified on a 1:10,560 scale map (1947). ESP have not had site of this map for review.

2.5 Contact with Regulatory Bodies & Local Information Sources

As detailed in Section 2.3, Bridgend County Council (the Client) has provided a series of past investigation reports as part of the commission and the relevant information has been incorporated where relevant.

A preliminary response has indicated that in 2014, Bridgend Council stored several thousand tonnes of mud (reported to be up to 17,000 tonnes), which had been taken from Porthcawl Harbour. This is likely to have needed consent from NRW. It is understood that following complaints from residents that the mud contained contaminated material, NRW undertook investigations. We understand that samples were taken by both NRW and Bridgend Council, however the results or any further information has not been obtained at this time.

Further enquiries are currently being made and any pertinent information will be updated into the section of the report.

2.6 Hydrology

2.6.1 Surface Water Features

The nearest major surface water feature to the site is the seawater within Sandy Bay, with the mean high-water mark approximately 40m east at its closest point. A small harbour is also located approximately 210m south. No rivers are identified within 500m of the site.

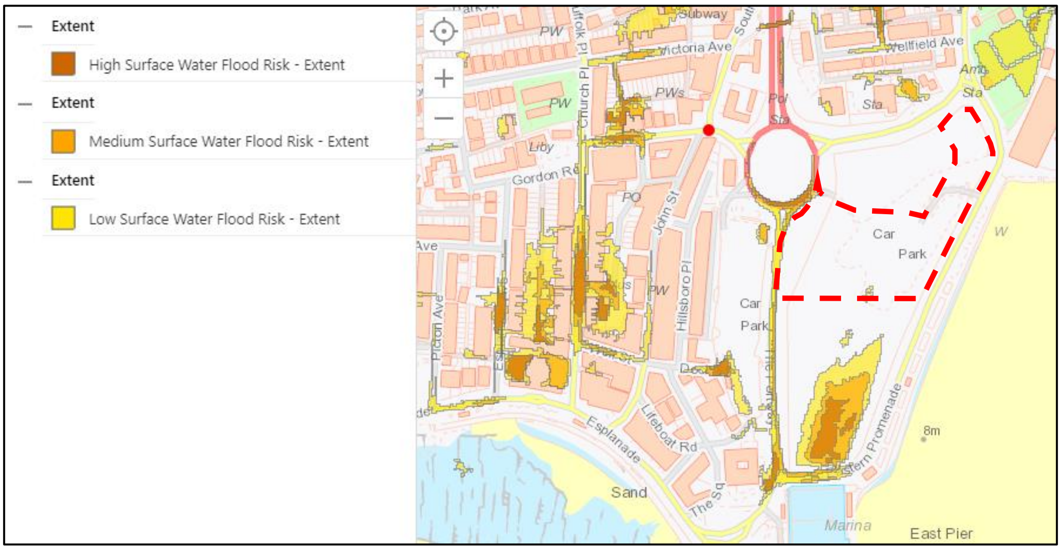
Reference to the Natural Resources Wales website (NRW, 2019) indicates that the water quality with regards to bathing water standards within Sandy Bay, is reported as 'excellent' for 2018. The water quality is also noted to be excellent in Rest Bay (approximately 2.5km north west) and Trecco Bay (approximately 1km east).

2.6.2 Surface Water Abstractions

The environmental data report (Appendix C2) indicates that there are no surface water abstractions within 2km of the site.

2.6.3 Flooding (Rivers, Seas and Surface Water)

From a review of topographical plans and flooding maps presented in the environmental data report the site is not indicated to be at risk of flooding by rivers and the sea. An area some 45m south of the site indicated to be at low risk from flooding (Zone 2 flood area), while the area of Sandy Bay beach 60m to the east is identified to be of high risk of flooding from the sea (Zone 3 flooding). Environment Agency/Natural Resources Wales Zone 2 floodplains estimate the annual probability of flooding as between 1 in 1000 (0.1%) and 1 in 100 (1%) from rivers and between 1 in 1000 (0.1%) and 1 in 200 (0.5%) from the sea. Zone 3 shows the extent of a river flood with a 1 in 100 (1%) or greater chance of occurring in any year or a sea flood with a 1 in 200 (0.5%) or greater chance of occurring in any year.



Insert 5 - Surface Water Flood Risk Map (NRW, 2019)

Very small, isolated areas of surface water flood risk are indicated on-site (see Insert 5), however a low to high risk is indicated on the roundabout/The Portway road adjacent to the west boundary.

2.6.4 Flooding (Groundwater)

The environmental data report (Appendix C) indicates that the British Geological Survey (BGS) has a high confidence in there being a limited potential for below surface clearwater flooding, which suggest that "*given the geological conditions there may be a groundwater flooding hazard to basements and other below surface infrastructure*".

2.7 Geology

2.7.1 Published Geology

The published 1:10,560 scale geological map for the area of the site (Sheet SS87NW) indicates the site to be underlain by Blown Sand overlying bedrock of the Carboniferous Oxwich Head Limestone. A large area of Made Ground is also indicated to the south east, associated with the infilled dock and the reclamation of the sea front, and this is indicated to marginally encroach on the site in the south east corner. Mercia Mudstone Group and Mercia Mudstone Group Marginal Facies bedrock is indicated in areas to the west, which is located unconformably above the Carboniferous Limestone.

Reference to the published 1:50,000 scale geological map for the area of the site (Sheet 262) and the up-to-date mapping available on the website of the British Geological Survey (BGS, 2019) indicates a similar succession. Normal faulting is indicated in the area with the faults generally striking north to south.

2.7.2 Previous Investigations

The previous investigations at the site (see Appendices D1 to E6) have been read and utilised to form a background overview of the geological conditions of the area. The following sections identify specific previous investigation points pertinent to the development of Site A, as summarised in Section 2.3 and the positions are indicated on Figure 4.

2.7.2.1 Norwest Holst Soil Engineering Ltd (NH, 1979)

Borehole records and a plan provided by the Client indicates that the above investigation comprised 6no. boreholes across the north of Salt Lake car park. No report is included with these records. BH2, BH3 and BH4 are positioned within the footprint of Site A (in the north east), with all constructed to a maximum depth of 10m below ground level (BGL). The boreholes on-site are outside of the former dock and slipway.

The ground model identified in the above boreholes comprised Made Ground to a maximum depth of 0.85m, made up of generally ash, clay and hardcore. The Made Ground is underlain by sand to a maximum depth of 10.0m BGL (BH02 only), but generally to around 7.5m depth (likely Blown Sand deposits), followed by clay to a maximum depth of 10m BGL (BH3 and BH4 only). Copies of the site records are presented in Appendix D1.

2.7.2.2 James & Nicholas/Wimpey Laboratories (WL, 1987)

Trial pit records and a plan provided by the Client indicates that the above investigation comprised 45no. trial pits across Salt Lake car park and an area to the south west of the car park. No report is included with these records. Trial pits TP23 to TP26 (inclusive) and TP46 are indicated to be within the site A boundary (see Figure 4). TP23 is indicated to have been constructed on the edge of the former dock, with evidence of the former dock edge tentatively identified. Trial pits TP24 and TP46 are shown to be within the former dock and identified Made Ground materials to a maximum depth of 3.0m, encountered as loose fill of brick rubble, slag, ash and sand. No record is shown within the site records for TP25, TP26 or TP46. Copies of the site records are presented in Appendix D2.

2.7.2.3 Johnson Poole & Bloomer (JPB, 1999)

Borehole records, a plan and a report provided by the Client indicates that the above investigation comprised 11no boreholes, all located within the former infilled dock within Salt Lake Car Park. BH8, BH9 and BH10 are located within the Site A boundary.

The ground model identified from the above boreholes within Site A, comprised Made Ground materials (infilled dock) to a maximum depth of 9.1m, underlain by 'Dock Sediment', identified to a maximum depth of 11.0m. Thin bands of clay, silt and gravel, with some was then identified to a maximum depth of 12.1, where bedrock was encountered. Copies of the site records are presented in Appendix D3.

2.7.2.4 Waterman Civils Ltd (WC, 2008)

An assessment report and associated exploratory hole records provided by the Client identifies the above investigation to have comprised 16no. trial pits across Salt Lake car park. TP103, TP104, TP105 and TP106 are shown to be within the footprint of the Site A development (see Figure 4). TP106 was located within the former slipway/dock.

The general ground model (TP103, TP104 and TP105) comprised Made Ground overlying sand. The Made Ground was generally noted to be between 0.5m and 0.9m BGL and comprised clay, sand and gravel with man-made objects such as ash, clinker, concrete etc. Deeper Made Ground was identified in TP106 (5.0m depth) within the area of the infilled dock, consisting of black sandy gravel with cobbles and boulders. Frequent slag, brick, clinker and ash was encountered throughout these materials. The sand deposits underlying the Made Ground were proven to a maximum depth of 4.2m BGL. Copies of the site records are presented in Appendix D4.

2.7.2.5 Delta Simmons (DS, 2011)

DS undertook a windowless sampling investigation in 2011 as part of their *'Pre-Acquisition environmental Assessment Summary Report – The Portway, Porthcawl'*, for a proposed Tesco supermarket. Ten windowless sample drill holes were constructed across their site, of which, three were located within the south west portion of Site A (WS06 and WS08). Both drill holes were positioned on the edge of the former infilled dock.

In WS06, Made Ground was identified to the base of the drill hole at 4.5m below surface level. The Made Ground comprised sand and gravel with frequent man made materials such as ash, coal, brick, metal and clinker. In WS08, Made Ground was encountered to a depth of 1.3m, comprising sand with manmade objects such as brick, glass and coal. Possible asbestos was noted in WS08 between 0.45m and 1.3m depth within the Made Ground. The Made Ground was underlain by sand, proven to a depth of 4.0m below surface level. Copies of the site records are presented in Appendix D5.

2.7.2.6 Quantum Geotechnical (QG, 2013)

QG undertook a Phase 2 intrusive investigation in 2013 across a wider site area as part of their *'Porthcawl Harbourside Development'* works. The investigation comprised a number of trial pits and rotary drill holes, with four rotary drill holes (RD1 to RD4, inclusive), located within the Site A boundary.

Rotary drill hole positions RD1, RD2 and RD3 were constructed outside of the infilled dock and identified Topsoil overlying sand to a maximum depth of 14.5m below surface level. Soft to firm clay was identified underlying the sand in RD1 and RD2, up to 3.5m in thickness. No clay was encountered in RD3. Limestone and Limestone Conglomerate was then identified underlying the superficial deposits, proven to a maximum depth of 17.5m below surface level. A 0.7m thick band of Mercia Mudstone was noted in RD3, between 15.3m and 16.0m depth.

RD4 appears to have been constructed on the east edge of the former infilled dock and identified a ground model comprising Made Ground to a depth of 9.0m, comprising black ashy sand and gravel with clinker and slag. This was underlain by a layer of clay (9.0m to 10.0m depth), followed by sand deposits to a depth of 15.0m. This was underlain by Limestone and Limestone Conglomerate to 18.0m, with a band of Mercia Mudstone identified between 15.45m and 16.6m depth.

2.7.3 Available BGS Borehole Records/Previous Investigation

Reference to the website of the British Geological Survey (BGS, 2016) indicates that the available records are those of the Norwest Holst Soil Engineering Ltd investigation (NH, 1979), as summarised in Section 2.7.2.1.

2.7.4 Geological Overview

Based on the review of the previous investigation information, we consider that the majority of Site A in the central portion site will be underlain by thick Made Ground associated with the infilled dock. The thicknesses will decrease towards the edges of the former dock and slipway, but will likely be up to 10m thick in the deepest parts. The Made Ground will then be underlain by varying thicknesses (up to approximately 1m) of sand/clay/silt, followed by the Oxwich Head Limestone bedrock, likely weathered in the upper portion.

The north east and south west portions will be underlain by a covering of coarse grained Made Ground (however generally less than 2m thick), followed by Blown Sand deposits to depths of between 7m and 8m followed by a clay above the bedrock (suggested to be of Alluvial nature by QG, 2013). The Oxwich Head Limestone bedrock is anticipated beneath the Blown Sand at a depths of around 10 to 13m BGL, likely being weathered in the upper portion. Locally thicker Made Ground may be present associated with historic industrial features (e.g. the former Smithy).

2.8 Hydrogeology

2.8.1 Aquifer Classification

Reference to the aquifer maps published on the environmental data report (Appendix C2) indicates that the superficial deposits beneath the site (Blown Sands) are classed as a Secondary A aquifer, whilst the bedrock (Oxwich Head Limestone) is classed as Principal Aquifer.

Principal Aquifers generally correspond with the previously classified major aquifers and are described by the Environment Agency as 'rock or drift deposits that have high intergranular and/or fracture permeability'. They may support water supply and/or river base flow on a strategic scale. Principal Aquifers are particularly sensitive to pollution.

Secondary A Aquifers generally correspond with the previously classified minor aquifers, and comprise permeable layers capable of supporting water at a local, rather than strategic, scale and in some cases form an important base flow to rivers. Secondary A Aquifers are sensitive to pollution.

2.8.2 Anticipated Groundwater Bodies

Based on the previous borehole investigation at the site (NH, 1979), water strikes within boreholes constructed in the infilled dock were identified between 5.75m and 6.5m. Standing levels observed ranged between 6.0m and 6.5m BGL.

Previous groundwater monitoring (JPB, 1999) was undertaken within 5no. standpipes installed in boreholes positioned within the infilled dock. These indicate groundwater levels to be generally between 4.2m and 5.6m, although shallower and deeper levels were identified at around 2.8m and 6.8m below surface level respectively.

Previous monitoring undertaken by Quantum Geotechnical (QG, 2013), indicates levels across Salt Lake car park to the east of the site to be between 2.6m and 6.2m BGL.

Based on the above, we consider groundwater is likely within the Wind Blown Sands/infilled dock materials at a depth of around 6.0m below ground level.

2.8.3 Groundwater Movement

Groundwater movement within the Blown Sand will be controlled by intergranular flow whilst, in the bedrock, fracture flow is likely to be dominant.

The JPB investigation (JPB, 1999) looked at variations in groundwater levels over a 12-hour period within the infilled dock only. They concluded that the results of their monitoring indicated fluctuations of the groundwater levels (between 0.06m and 2.33m) within the confines of the infilled dock with changes in tidal levels, however the changes in level were not uniform across the monitored boreholes. The only significant change in water level was observed in the standpipe located closest to the former harbour lock gates in the south end of the former dock, located some 230m south of Site A. The influence of the tide was noted to significantly reduced in the north east of the former dock, as observed within BH10 (on-site).

The ESP monitoring regime for Site A included measurements of the groundwater levels at the site at times of low, high and slack tides.

Based on this, we consider that there is unlikely to be any tidal influence on the groundwater levels outside of the infilled dock beneath Site A. Within the confines of the infilled dock, variations in groundwater levels may occur, with increased fluctuations possible in the southern portion.

The water within Sandy Bay located some 40m to the east of the site and the groundwater within the bedrock beneath the site are likely in hydraulic continuity.

2.8.4 Abstractions and Groundwater Vulnerability

The environmental data report indicates that there are no groundwater abstractions or Source Protection Zones (SPZ's) within 1km of the site. The groundwater vulnerability is shown in the environmental data report to be 'Major Aquifer/High Leaching Potential'.

2.9 Environmental Setting

2.9.1 Summary of Environmental Data

The site exists in a historically industrial, and now an-semi-urban setting. An environmental data report has been provided by the Client from a previous investigation of a wider site area (Appendix C1). ESP have also obtained a site-specific data report for the site and is presented in Appendix C2. The data from both reports has been reviewed and is summarised in Table 4 below and, where salient, discussed in Section 2.9.2.

Table 4: Summary of Environmental Data

Item	On the Site	In the Immediate Vicinity
Environmentally Sensitive Sites[2,3]	None identified.	None recorded within 500m of the site.
Potentially Contaminative Land Use	See Section 2.9.2.1	See Section 2.9.2.1
Historical Tanks, PFS, Garages, Energy Facilities	See Section 2.9.2.2	See Section 2.9.2.2
Potentially Infilled Land	See Section 2.9.2.3	See Section 2.9.2.3
IPPC Authorisations	None identified.	None recorded within 500m of the site.
Discharge Consents	None identified.	1no. 320m south – dock (revoked).
List 1 and 2 Dangerous Substances Sites	None identified.	None recorded within 500m of the site.
Radioactive Substance Sites	None identified.	None recorded within 500m of the site.
Enforcements	None identified.	1no. 180m north west – Dry Cleaners. Current Permit. No enforcement notified.
Pollution Incidents	None identified.	None within 150m of the site. 1no. 280m south – contaminated soil. Minor air impact. 1no. 350m south – oil and fuel (diesel). Minor water impact.
Contaminated Land under Part 2A EPA 1990.	None identified.	None recorded within 500m of the site.
Waste Management Facilities	See Section 2.9.2.4	See Section 2.9.2.4
Current Industrial/Commercial Sites	Site formerly part of Salt Lake car park.	39m north west – Porthcawl Ambulance Station 55m north – Porthcawl Fire Station 210m south west – Electrical Features
Radon	See Section 2.9.2.5	

Notes
1. Environmental data report presented in (Appendix C).
2. Sensitive land uses include Sites of Special Scientific Interest, Nature Reserves, National Parks, Special Areas of Conservation, Special Protection Areas, Ramsar sites, World Heritage sites and Ancient Woodland.
3. Nitrate vulnerable areas relate to the agricultural use of fertilizers and are not considered further in this assessment.

2.9.2 Further Discussion on Salient Environmental Features

2.9.2.1 Potentially Contaminative Land Use

Following a review of the historical mapping (Table 2) and the Environmental Data Report, (Appendix C1 and C2), the following potentially contaminative land uses have been identified on site and within 250m of the site boundary, as summarised in Table 5 below. A plan identifying the location and source of potentially relevant contaminative land uses is presented as Figure 2.

Table 5: Summary of Potentially Contaminative Land Uses

On Site	Within 250m of the Site
Smithy, dock (infilled), railway land, railway sidings, ground workings, unspecified pit, cuttings, coal tip.	Shipbuilding yard, unspecified pit, unspecified tank, railway station, railway land, railway sidings, railway buildings, tanks, fire station, tramways, sawmill, police station, coal tips, engine shed, gas works, gasometer, water works sand pits.

2.9.2.2 Historical/Current Tanks

The historical maps or environmental reports have provided no evidence of any past or recent above ground or underground bulk liquid (e.g. fuels/oils) storage on site. A number of historical tanks have been identified near to the site, as detailed in Table 2, the closest of which was identified in around 1965 adjacent to the west boundary (see Figure 2).

2.9.2.3 Potentially Infilled Land

As identified in Table 2 and shown in Figure 2, a large portion of the site overlies the former Porthcawl Dock, which was filled sometime in the 1960's. Previous investigation works (WL-1987, JPB-1999, WC-2008, DS-2011 and QG-2013), have identified a maximum depth of up to around 10m of fill materials within the infilled dock. Earthworks were also indicated on site associated with the historic railway land.

2.9.2.4 Waste Management Facilities (Historical Registered Landfills)

No current permitted sites are identified within 250m of the site. Both data reports (Appendices C1 and C2), identify a historical landfill 40m north of the site (in the location of where the existing fire station is now located), however it cannot be identified on the historical mapping. The landfill received inert, industrial, commercial and household waste between 1960 and 1974 and is no longer active.

The data report supplied by the Client (appendix C1) also indicates that Salt Lake car park is a landfill and we consider that this is associated with the infilling of the former dock. Previous investigations have identified slag, colliery spoil and other rubble across Salt Lake car park within the former dock footprint. No other details for the Salt Lak car park landfill are listed.

2.9.2.5 Radon

The site is in a Radon Affected Area, as between 5 and 10% of properties are above the Action Level.

2.9.3 On-Site Bulk Materials and Waste Storage

The historical maps have provided no evidence of any past or recent materials/waste storage.

2.10 Preliminary Geotechnical Risk Register

2.10.1 Summary of Potential Geotechnical and Geomorphological Hazards

The potential for various geotechnical and geomorphological hazards at the site (and the wider Site A) is provided in the geological data report (Appendix D). The potential hazards, as reported in this report are listed in Table 6 below, along with any salient further information on the potential hazard identified by ESP in the preparation of this report. Where a potential hazard has been identified, it is discussed further in subsequent sections and presented for reference on Figure 3.

Table 6: Preliminary Geotechnical Risk Register

Ground Stability Hazard	Potential[1]	ESP Comment
Coal Mining	-	Site is not underlain by coal measures bedrock. No further consideration required.
Mining (non-coal)	Identified	See Section 2.10.2.
Shrinking or Swelling Clays	Negligible	See Section 2.10.3.
Landslides	Low	No further information identified to contradict data report.
Ground Dissolution (Soluble Rocks)	Low	See Section 2.10.4
Compressible Ground	Moderate	See Section 2.10.5
Collapsible Ground	Very Low	See Section 2.10.6
Running Sand	High	See Section 2.10.7
Volumetrically Unstable Slag	Not reported.	See Section 2.10.8
Sulphate/Pyritic Ground	Not reported.	See Section 2.10.9
Excavation Instability	Not reported.	See Section 2.10.10
Historic Underground Structures	Not reported.	See Section 2.10.11

Notes
1. Potential as reported in geological data report (Appendix D).
2. Salient hazards discussed in following sections.
3. Position of identified geotechnical hazards presented on Figure 3.
4. An updated Geotechnical Risk Register, following intrusive investigation of salient hazards, is presented as Table 18 in Section 8.2.1.

2.10.2 Mining (Non-Coal)

The Oxwich Head Limestone underlying the site can contain mineral veins, however no evidence of mining has been identified (with the exclusion of the dock excavation) and considering the practicalities of extracting it (bedrock depth of 10m and below groundwater level) the potential is considered very low.

2.10.3 Shrinkable and Swelling Soils

The Wind Blown Sands are coarse grained and therefore are not susceptible to changes in moisture content.

The previous investigations (see Section 2.7.2) identified a horizon of fine-grained soil underlying the Blown Sand deposits from depths of around 7m to 12m bgl and generally in the order of 1m to 2m in thickness. Limited atterberg testing undertaken as part of a previous investigation (QG, 2013) across Salt Lake Car Park, included two samples within Site A (from RD1 and RD3). The test results indicate that the fine-grained soils are of intermediate plasticity and generally low volume change potential (based on the modified plasticity index).

Whilst no trees are currently present, considering the depth of the clays, future planting will unlikely modify their moisture content (in addition they are located below groundwater), therefore we consider that the 'Negligible' potential for shrinkable/swelling soils at the site reported in the geological data report is correct.

2.10.4 Ground Dissolution

The Oxwich Head Carboniferous Limestone bedrock underlying the site is susceptible to chemical weathering, producing natural solution cavities in both the horizontal and vertical direction. Such features can cause uncontrolled subsidence at the surface in the right conditions.

The geological data report (Appendix C3) does not indicate any natural cavities on site, with the closest being 836m to the north (sinkhole and solution pipe).

Previous investigations on-site and in neighbouring areas have not identified any obvious evidence of limestone solution (e.g. significant variations in bedrock depth, cavities etc.)

Therefore, pending further investigation, we consider that the potential for ground dissolution impacting on the development should be advanced from that reported in the geological data report (Very Low) to Low to Moderate.

2.10.5 Compressible Ground

The Made Ground soils anticipated beneath the site (particularly within the infilled dock/slipway) are potentially compressible, particularly where containing organic materials. SPT 'N' values of between 1 (very loose) and 21 (Medium Dense) have been recorded within the dock infill within the Site A boundary. Outside of the Site A boundary, but within the infilled dock, SPT 'N' values of 50 have also been recorded (although this was noted to be a likely obstruction (JPB, 1999). The varying values recorded indicates there is significant variability in its strength and compaction status, both vertically and laterally. Therefore, there is a potential for significant differential settlement at the surface if loaded. The Blown Sand is also potentially compressible/prone to settlement with loose to very dense deposits being identified in the area.

Due to the variability of the strength and performance of the soils, differential settlement is likely between areas spanning the Blown Sand and infilled dock materials.

Therefore, we consider that the potential for compressible ground at the site should be advanced from that reported in the geological data report (Moderate) to High.

2.10.6 Collapsible Ground

The unconsolidated/uncompacted Made Ground within the infilled dock and the Wind Blown Sands are potentially susceptible to collapse compression during inundation, if groundwater levels were to increase.

Previous groundwater monitoring suggests that the groundwater levels are generally consistent across the site and neighbouring areas, and tidal influence is limited in this portion of the sea front. It is unlikely that this will change in the near future, proving that no significant input from the proposed development of the area is proposed (e.g. soakaway drainage).

We consider that the potential for collapsible ground at the site should be advanced from that reported in the geological data report (Very Low) to Low.

2.10.7 Running Sand

Where groundwater is present there is a potential for running sands within excavations within the natural soils (Wind Blown Sands) and we therefore concur with the High potential in the geological report. Groundwater is not generally anticipated above 2m bgl based on available data.

2.10.8 Volumetrically Unstable Slag Materials

The potential for volumetrically unstable slag material to be present on the site is not considered in the environmental data report.

In our experience, on former industrial/railway land sites such as this, there is the potential for slag materials to be present within the Made Ground, and the previous investigations (see Section 2.7.2) have recorded common slag within the infilled slipway and dock as well as less frequent occurrences in the general Made Ground across the site. Fragments of suspected slag materials were also visually observed in the site surface soils.

There are a number of chemically different types of slag found on brownfield sites across the UK. Some forms of slags are volumetrically stable but, depending on their chemistry, some can be extremely unstable when hydrated, which can lead to significant heave at the surface and damage to buildings and hard surfaces.

Given the currently available information, the presence of slag within the shallow Made Ground is expected, and the risk from volumetrically unstable slag is considered Moderate.

2.10.9 Pyritic Ground (include in all reports)

The natural soils underlying the site are not anticipated to contain elevated levels of pyrite, which could oxidise to sulphates.

The Made Ground within the infilled slipway/dock beneath the site in the south east is likely to contain elevated levels of sulphate and potentially pyrite. The previous investigation (JPB, 1999) identified levels of total sulphur within the dock infill material to vary between 0.02% and 0.78%, which gives a calculated total potential sulphate of between 0.06% and 2.34%. Levels of groundwater sulphate were measured from groundwater samples collected from BH2, BH5, BH6, BH7 and BH10, indicating levels of groundwater sulphate within the infilled dock to be between 366mg/L and 2589mg/L.

Groundwater samples collected during the Quantum Geotechnical investigation (QG, 2013) from within the general Made Ground soils indicate levels of groundwater sulphate to range between 16.4mg/L and 72.1mg/L, while samples collected from within the infilled dock indicate levels between 571mg/L and 1,690mg/L.

Based on these elevated levels, a higher class of concrete protection maybe required for foundations in this area. Given the above, we consider that the potential for sulphate/pyrite attack on buried concrete within the infilled dock slipway should be considered High.

No results are available for the general Made Ground soils at the site, however we consider that the risk from elevated levels of sulphate should also be considered to be High at this stage, considering similarities in composition.

2.10.10 Excavation Instability

Previous trial pit investigations on-site and in neighbouring areas have recorded spalling and collapsing of the pit walls within the Made Ground and the Wind Blow Sand.

Support of excavations sides is likely to be necessary for shallow excavations as part of future re-development.

2.10.11 Historic Underground Structures/Obstructions

Review of historical data (see Section 2.2) indicates a large portion of the site is underlain by a former infilled dock and associated slipway/masonry walls. A former smithy was also located adjacent to the slipway. We understand the masonry associated with the dock slipway and dock remain present beneath the site and old foundations associated with the former smithy also cannot be discounted.

Cobbles and boulders have been recorded as occasional to frequent in the dock backfill consisting of slag, metal, rubble etc.

Obstructions/structures will require consideration if a piled design is favoured for the proposed development and where shallow, they may require removal (possibly with large excavators) as part of the site preparation works.

In addition, the design may need to consider the dock wall acting as a ‘hard spot’ and the differential performance between the backfill within the dock/slipway and the natural deposits the either side.

2.11 Unexploded Ordnance

A Preliminary UXO Desk Study assessment of risk has been completed by a specialist Ordnance consultant in accordance with CIRIA guidelines (Stone et al, 2009) and is presented in Appendix F (Zetica, 2019). The preliminary assessment states “a detailed desk study, whilst always prudent, is not considered essential in this instance”.

No further assessment is considered necessary at this stage.

2.12 Radon Hazard

Radon is a colourless, odourless, radioactive gas, which can pose a risk to human health. It originates in the bedrock beneath the site, where uranium and radium rich minerals are naturally present, and can move through fractures in the bedrock, and overlying superficial deposits, to collect in spaces within/beneath structures.

The environmental data report (Appendix C2) indicates that the site is in a Radon Affected Area, as between 5 and 10% of properties are above the Action Level. Given the currently available information, the risk from radon is considered Moderate.

3 Preliminary Geo-Environmental Risk Assessment

3.1 Phase One Conceptual Site Model

3.1.1 Background

The Phase One Conceptual Site Model lists the potential sources of geo-environmental risk, the receptors at risk and the pathways between the two. These are discussed in the following sections.

3.1.2 Potential Contamination Sources

The site history has indicated a number of potentially contaminative historical land uses (see Table 5), including a Smithy, dock (now infilled through landfilling), railway land, railway sidings, ground workings, unspecified pit, coal tip, cuttings and its use as a car park. From the available information, we consider that the following features on site could prove sources of diffuse and point source contamination that could impact on the development, environment or site users. The potential sources are summarised below in Table 7 and presented on Figure 2.

Table 7: Potential Contamination Sources

Contamination Source:	Location	Comments
Infilled Dock Materials (Made Ground - Landfill)	Large portion of the site	Point source of contamination including metals, PAH's hydrocarbons, VOC's, SVOC's and asbestos.
Smithy	Central/West	Point source contamination including metals, PAH's, hydrocarbons and asbestos.
Former Railway Land	Across the site	General diffuse contamination including metals, PAH's hydrocarbons, VOC's, SVOC's and asbestos.
General Made Ground	Across the site	
Fuel leaks from parked cars	South/South East/North east	

NOTES:
1. Potential contamination sources shown on Figure 2.

3.1.3 Potential Contaminants Present

3.1.3.1 Potential Soil Contamination Present

A review of the former investigations which have included Site A (see Section 2.3), indicates limited previous testing across the site.

Testing of the Made Ground within the infilled dock on Site A was undertaken by JPB in 1999. The results indicated elevated levels of metals and total PAH contamination.

Visual evidence of asbestos containing materials has been potentially identified in the JPB, 1999 investigation within the dock backfill.

Within both the general Made Ground and the infilled dock material outside of the Site A boundary, elevated levels of varying contaminants (such as metals and PAH's) have been identified, (above GAC's for residential land use). The JPB investigation identified elevated levels of PAH's within the infilled dock materials (with a maximum total PAH of 2,665mg/kg), however the testing was performed as a screen and no speciation of the PAH compounds was undertaken. Low levels of petroleum hydrocarbon contamination were identified.

Testing off-site, has identified one positive screen for asbestos within the general Made Ground soils in the north east of Salt Lake car park. The sample was later quantified to be <0.001% asbestos (QG, 2013). During the Delta Simmons investigation (DS, 2011), general Made Ground was encountered to a depth of 1.3m below surface level and possible asbestos was noted in WS08 between 0.45m and 1.3m depth.

3.1.3.2 Potential Leachable & Groundwater Contamination Present

Within both the general Made Ground and the infilled dock material inside and outside of the site boundary, elevated levels of leachable metals have been identified in previous investigations (above GAC's for residential land use). Levels of leachable and groundwater PAH's were generally identified to be below the detection limits at that time (current limits are lower), however elevated levels of metals were recorded within the groundwater within the infilled dock.

3.1.3.3 Potential Contaminants

Potential contaminants associated with the above potential sources have also been identified from various guidelines published by DEFRA, the Environment Agency and others. The particular guidance referenced includes the Industry Profile for Railway Land, dockyards and dockland (DoE, 1995).

Based on previous data, guidance and our experience, we consider that the following contaminants could be present on the site:

- heavy metals and semi-metals (arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, zinc); plus other metals as indicated (e.g. barium, boron);
- cyanide, sulphate;
- polyaromatic hydrocarbon (PAH) compounds;
- petroleum hydrocarbons;
- VOC's and SVOC's;
- phenols;
- asbestos.

No evidence has been identified from the desk study to suggest that radioactive substances may be present on the site. The potential presence of radon in discussed in Section 3.1.4.

3.1.4 Potential Sources of Hazardous Ground Gas and Radon

Based on the available information, the following potential sources of hazardous ground gas have been identified on, or in close vicinity of, the site:

On Site

- Infilled dock in south, south east and north east portion of the site (also recorded as landfill) which extends south below Salt Lake car park (see Section 2.9.2.4) - combustible and noxious gases will be generated in any putrescible waste;
- Petroleum hydrocarbons within Made Ground from former railway land and use as car park– un-weathered hydrocarbons can generate hazardous volatile organic vapours and as they degrade, the hydrocarbons can generate combustible and noxious gases;
- General Made Ground – organic and other materials could generate combustible and noxious gases;

Off-Site

- The former Landfill, located 40m to the north - combustible and noxious gases will be generated in any putrescible waste;
- Infilled dock immediately south and partially to the west of the site, extending 230m south/south east - combustible and noxious gases will be generated in any putrescible waste;
- Gas works located 200m north east – contaminated soils – gas works no longer present;
- Petroleum hydrocarbons within Made Ground from former railway land, tanks and car parking in the vicinity of the site– un-weathered hydrocarbons can generate hazardous volatile organic vapours and as they degrade, the hydrocarbons can generate combustible and noxious gases.

Previous monitoring across Salt Lake car park (including four positions within the Site A boundary) indicated generally low levels of hazardous ground gases (QG,2013). The maximum recorded concentration of carbon dioxide was 2.1% and the maximum recorded concentration of methane was 0.1%).

Based on the guidelines presented by O'Riordan and Milloy (1995) and revised by Wilson et al (2009), the above potential gas sources would generally be classified as of low to moderate, however the Landfill 40m to the north would be classified as of moderate to very high gas generation potential considering its age. Further detail on the materials deposited may allow reduction in the source potential.

As discussed in Section 2.11, the risk from radon is moderate and basic radon protection measures are required for development (see Section 7.3.2).

3.1.5 Potential Receptors

As discussed in Section 1.1, the proposed site development will comprise the construction of typical two-storey residential dwellings with private gardens, as well as flats type buildings with associated areas of landscaping, estate roads and hardstanding (parking/footpaths etc).

The nearest major surface water feature to the site is the seawater within Sandy Bay, with the mean high water mark approximately 40m west at its closest point. A small harbour is also located approximately 230m south. No rivers are identified within 500m of the site.

The superficial deposits beneath the site (Blown Sands) are classed as a Secondary A aquifer, whilst the bedrock (Oxwich Head Limestone) is classed as Principal Aquifer (although it is not within a source protection zone). However, as discussed in Section 2.8.5, the quality of the groundwater bodies beneath the site have been naturally degraded by the intrusion of saline waters and therefore they are unlikely to be as sensitive as their designation suggests. This is likely the reason that no groundwater abstractions or SPZ's are noted within 1km of the site and the groundwater beneath the site is not suitable for use as drinking water. Degradation through contamination associated with the former dock has also been noted.

Given the above, we consider that the most vulnerable receptors with regards to any contamination or hazardous ground gas present are likely to be as follows.

- Future residents, the critical receptors being young children playing in private garden areas.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The water quality in Sandy Bay and the harbour to the south.
- The groundwater within the Oxwich Head Limestone bedrock (Principal Aquifer).
- The groundwater within the Blown Sands strata (Secondary A aquifer).

3.1.6 Potential Migration Pathways

Based on the Conceptual Site Model discussed in the previous sections, the following are considered the most likely migration pathways with regard to any contamination or hazardous ground gas present beneath the site.

Site Users:

- Ingestion of soils and inhalation of dust in gardens and landscaping areas.
- Ingestion of edible plants and dust associated with such plants.
- Dermal contact with contaminated soils.
- Exposure to asbestos containing materials within the shallow soils.
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential risk from toxic ground gas/vapours from on-site sources.
- Potential exposure to flammable or toxic ground gas/vapours originating from off-site sources – the near surface coarse Made Ground and Blown Sands are likely to allow free migration of any gas/vapours present.
- Chronic (long term) exposure to unacceptable levels of radon.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the shallow soils.
- Ingestion of soils and inhalation of dust across site.
- Dermal contact with contaminated soils.
- Potential explosive risk from flammable or toxic ground gas/vapours from on-site sources.
- Potential explosive risk from flammable or toxic ground gas/vapours from off-site sources.

Groundwater:

- Leaching of mobile contaminants into the water-bearing strata within the Blown Sand and bedrock. The conceptual ground model indicates continuity between the superficial and bedrock aquifers is likely due to the dock.

Sandy Bay:

- Leaching of mobile contaminants to the groundwater beneath the site, and then on to the nearby Sandy Bay and the harbour to the south. Previous investigation information indicates they are in hydraulic continuity.
- Surface run-off of contaminated leachate to adjacent drainage and in to any outfalls to Sandy Bay.

Buildings:

- Sulphate attack on buried concrete (foundations, drainage etc.).
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential explosive risk from flammable ground gas/vapours from off-site sources.

Although the majority of the site is likely to be hard-surfaced, any soakaways constructed for the development have the potential to leach contaminants from the infiltration strata, which could then impact on the groundwater beneath the site.

3.2 Preliminary Risk Evaluation & Plausible Pollutant Linkages

The land use history of the site and surrounding area, as established from the desk study and walkover, has identified a number of potential contamination linkages due to ground conditions or former operations either on, adjacent to, or in the vicinity of the site. Note that these potential linkages will need to be later assessed and re-established using actual site data obtained from an exploratory investigation.

3.2.1 Introduction to Risk Evaluation Methodology

The methodology set out in CIRIA C552 *Contaminated Land Risk Assessment – A Guide to Good Practice* (Rudland et al, 2001), has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

Whilst at a later stage, this methodology may be informed by quantitative data (such as laboratory test results) the assessment is a qualitative method of interpreting findings to date and evaluating risk. The methodology requires the classification of:

- The magnitude of the potential consequence (severity) of risk occurring (Table A1 in Appendix A):
- The magnitude of the probability (likelihood) of risk occurring (Table A2 in Appendix A).

The classifications defined above are then compared to indicate the risk presented by each pollutant linkage, allowing evaluation of a risk category (Tables A3 and A4 in Appendix A). These tables have been revised slightly from those presented in CIRIA C552, to allow for the circumstances where no plausible linkage has been identified and, therefore, no risk would exist.

The methodology described above has been used to establish Plausible Pollutant Linkages (PPL) based on the Conceptual Site Model generated for the site and proposed development, and to evaluate the risks posed by those linkages, using information known about the site, at this desk study stage. This is presented as Table 8 in Section 3.2.2 below.

3.2.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

Table 8: Preliminary Risk Evaluation & Plausible Pollutant Linkages (PPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants within infilled dock materials	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Likely[2]	Moderate Risk	Sampling of infilled dock materials to confirm levels of total contamination present.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	High Likelihood[2]	Moderate/Low Risk	
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Severe - site lies on Principal & Secondary A Aquifer	Likely[2]	High Risk	Sampling of infilled dock materials to confirm levels of leachable contamination and sampling of the groundwater to confirm levels of contamination present.
	Leaching of soil contaminants	Impact on Sandy Bay/Harbour	Medium - site lies 40m from Sandy Bay (in continuity with groundwater)	Likely[2]	Moderate Risk	
Potential contaminants in shallow soils (General Made Ground)	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Likely[3]	Moderate Risk	Sampling of near-surface soils to confirm levels of total contamination present.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	High Likelihood[3]	Moderate/Low Risk	
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Severe - site lies on Principal & Secondary A Aquifer	Likely[3]	High Risk	Sampling of near-surface soils to confirm levels of leachable contamination and sampling of the groundwater to confirm levels of contamination present.
	Leaching of soil contaminants	Impact on Sandy Bay/Harbour	Medium - site lies 40m from Sandy Bay (in continuity with groundwater)	Likely[3]	Moderate Risk	
Asbestos within infilled dock materials	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Likely[4]	Moderate Risk	Sampling infilled dock materials for asbestos.
Asbestos in general shallow soils	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Likely[4]	Moderate Risk	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood[5]	Moderate Risk	Sampling of soils and groundwater to further confirm levels of sulphate, pH.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	High likelihood[6]	Very High Risk	Install and monitor gas wells.
	Damage through explosion.	Building/Property	Severe – acute risk.		Very High Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		Very High Risk	
Radon gas	Migration into Buildings	Site Users (employees)	Medium – potential for chronic levels	Likely[7]	Moderate Risk	See Section 5.12

Notes:
1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Deep Made Ground will be present within the area of the former dock which occupies large areas of the site in the south/south east and east, comprising landfilled industrial waste e.g. slag, rubble, coal ash etc. Previous laboratory testing has identified elevated levels of metals and PAH’s within soil and leachate testing.
3. Shallower Made Ground is likely to be present across the majority of the site, associated with the railway land, shipbuilding yard and Smithy etc. There is a potential for localised deeper Made Ground. Limited test data is currently available on site for the general Made Ground, which indicates generally low levels of contamination.
4. Previous investigations have identified asbestos within the infilled dock materials as well as the general Made Ground across Salt Lake car park. (Section 3.1.3.1).
5. Previous works have identified elevated levels of sulphate within the soils and groundwater within the infilled dock. The Made Ground anticipated across the site may also contain elevated levels of sulphate (Section 2.10.8).
6. A number of potential sources of on-site and off-site hazardous ground gas/vapours have been identified (Section 3.1.4).
7. Radon risk identified in environmental data report. Basic protection measures will be required for the development. (Section 5.12).
8. The above risk evaluation is updated following the intrusive investigation and testing in Table 20, Section 6.2.

4 Exploratory Investigation

4.1 Investigation Points (ESP, 2018 & 2019)

Whilst all areas where investigated simultaneously, only the investigation undertaken and strategy employed on Site A (excluding the Food Store site) is described in the following section. For further information on the neighbouring sites, refer to the reports referenced in Table 1.

4.1.1 Introduction

The initial intrusive investigation was undertaken between 7th November 2018 and 7th December 2018 in accordance with BS5930:2015 and BS10175:2013 and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Section 2). It comprised trial pitting, cable percussion boreholes, rotary open hole drilling, rotary coring, measurement of the correlated in-situ CBR value using DCP equipment, gas and groundwater monitoring and sampling of groundwater.

Supplementary works were undertaken on 7th and 8th November 2019 following recommendations made in the original 2018 assessment, which consisted of shallow trial pitting. The works were undertaken in accordance with BS5930:2015 and BS10175:2013 and were designed to collect samples for laboratory testing for asbestos and Waste Acceptance Criteria (WAC) testing. This would allow further assessment of asbestos risks and waste management requirements.

The exploratory holes in all phases were supervised and logged by an engineering geologist in general accordance with BS5930:2015, BS EN ISO14688-1: 2018 and BS EN ISO 14689: 2018, along with published weathering schemes.

Descriptions and depths of the strata encountered are presented on the cable percussion borehole records (Appendix G), trial pit records (Appendix H1 and H2) and the rotary drill hole records (Appendix I). The results of the in-situ testing and monitoring are presented in Appendices J to L. The investigation point positions are shown on Figures 5 (2018) and 6 (2019).

The ground levels and coordinates of the investigation points were surveyed by Davies Surveys on completion and are shown on the various hole records.

4.1.2 Investigation Strategy

Given the updates to the proposed layout and changes to the boundaries following our initial assessment in 2018, some of the targeted investigation, sampling and testing may not be now be relevant due to the design layout changes. These aspects are addressed further in the subsequent sections.

4.1.2.1 2018 Investigation Strategy

The 2018 investigation strategy was generally designed in accordance with BS10175:2013, taking into account the previous investigation information and the potential for geotechnical hazards to be present. When considering the previous and current investigation points a general spacing of around 10 - 25m was achieved, which is in accordance with the spacing for a 'detailed investigation'.

The desk study identified a number of potential contaminant sources/geotechnical hazards at the site (see Figure 2 and 3 respectively) including:

- Infilled Dock Materials (Made Ground) – South/South East/East.
- Dock Masonry Walls – Central East.
- Smithy – Central East.
- Coal Tip – South West
- Former Railway Land – Across Site.
- General Made Ground – Across Site.
- Fuel leaks from parked cars – South/South East.

4.1.2.2 2019 Investigation Strategy

Following completion of the 2018 assessment, further works were undertaken to target specific hazards and areas that required further understanding. The works comprised shallow trial pitting to collect samples for asbestos testing on a 25m grid spacing across the site and WAC testing. These are discussed further in the subsequent sections of this report.

4.1.2.3 Investigation Point Locations

The investigation points were selected to maximise the information obtained on the hazards detailed in Sections 4.1.2.1 and 4.1.2.2, as well as obtaining a general overview of the general ground conditions present. In this regard, several the investigation points were targeted at the above sources, as summarised in Table 9 below.

Table 9: Placement Rationale for ESP Investigation Points

Point ID	Location	Placement Rationale
TP01, TP06, TP19, TP21, TP22, TP23, TP24, TP25, BH06, BH07/RC07, BH12	South/South East and East	To investigate the extent and composition of Made Ground within the infilled dock and slipway area and area of former Smithy. Obtain groundwater samples and monitor potential ground gasses from within the dock.
RC07, RC08	South and West	To obtain core samples to gain information on the bedrock type and its condition beneath the proposed development.
TP28, TP29, BH08/RC08	West	To investigate closest available position to area where historical tank was identified adjacent to the site boundary.
TP01, TP05, TP10, TP11, TP12, TP13, TP26, TP27, BH04, BH08	Across Site A	To investigate general ground model across the site including areas of former railway land, dock land and car parking to confirm the extent and contamination status of any Made Ground. Obtain groundwater samples and monitor ground gasses within the area.
DCP01, DCP02, DCP03, DCP04, DCP05, DCP9, DCP11, DCP12	Along proposed access road.	To obtain preliminary design values for the proposed road.
DCP6, DCP7, DCP8, DCP10, DCP16, DCP17, DCP18, DCP19, DCP21	East	To determine general CBR values within the Site A footprint for pavement design.
AS3-AS6, AS18-AS20 and AS23-AS41	Across Site A	To collect samples on an approximate 25m grid across the site to allow further laboratory testing (asbestos and WAC).

Key to Investigation Points:
TP: Trial pits.
BH: Cable percussion boreholes.
RC: Rotary Cored (and open hole) drill hole.
DCP: Dynamic cone penetrometer
AS: Supplementary Trial Pit to obtain additional samples for asbestos and WAC testing

4.2 Trial Pits

4.2.1 ESP, November 2018 & April 2019

8no. trial pits (TP01, TP05, TP06, TP10 – TP13 and TP19) were excavated across the site on 7th and 8th November 2018 using a wheeled, back-acting hydraulic excavator. Following the survey undertaken by DCWW to locate the rising sewer main in the south, 9no. further trial pits were undertaken in the south of the site (TP21 to TP29) on 2nd April 2019. The trial pits were excavated to a maximum depth of 3.9m. The trial pit records are presented as Appendix H1.

Disturbed samples were collected from the trial pits for laboratory testing. No man entry into the pits was undertaken. On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket. Where the gravel car park surface was present, this was reinstated at the surface of the trial pits. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

No man entry into the pits was undertaken. On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket. Where the gravel car park surface was present, this was reinstated at the surface of the trial pits. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

4.2.2 ESP, December 2019

26no. shallow trial pits (AS3-AS6, AS16, AS18-AS20 and AS23-AS41) were excavated across the site on 10th and 11th December 2019 using a wheeled, back-acting hydraulic excavator. The outstanding positions not noted above were located within the adjacent Food Store. The trial pits were excavated to a maximum depth of 3.6m within the area of the infilled dock and to a maximum of 1.6m outside of the infilled dock area. Deeper trial pits were constructed within the infilled dock area to gain an understanding of the vertical extent of contaminants (asbestos). The trial pit records are presented as Appendix H2.

Samples from the Made Ground and Infilled Dock materials were collected, in order that supplementary laboratory testing for asbestos screening/quantification (see Section 5.5.4) and Waste Acceptance Criteria (WAC) testing (see Sections 4.10.4 and 7.6.4), could be undertaken.

No man entry into the pits was undertaken. On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket. Where the gravel car park surface was present, this was reinstated at the surface of the trial pits. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

4.3 Cable Percussion Boreholes

5no. 150/200mm diameter cable percussion boreholes (BH04, BH06, BH07, BH08 and BH12) were constructed to a maximum depth of 14.2m between 20th November and 7th December 2018. The borehole records are presented as Appendix G1. At the commencement of each borehole, a service inspection pit was excavated by hand to a depth of 1.2m.

100mm diameter thick wall (OS-TK/W) open tube samples were collected from the fine-grained soils within the boreholes, where suitable, with a disturbed sample recovered from the open tube cutting shoe. Further small and large plastic tub and bag disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes.

Standard Penetration Tests (SPT) were carried out using a split spoon and solid cone in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the coarse-grained soils encountered in the borehole and to provide an correlated assessment of the likely undrained shear strength of fine-grained soils using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field.

Depending on the nature of the test undertaken and the soils subjected to testing, field SPT N-values may require correction before using in design. In accordance with BS EN ISO 22476-3 (2005), SPT N-values in sandy soils need to be corrected for a number of aspects such as overburden pressure, rod length and rod energy ratio in sands.

Caution must be applied when using in-situ data collected using a solid cone. Much of the existing correlations using N-values obtained from Standard Penetration Tests rely on the energy imposed on a split-spoon sampler (SPT) and not a solid cone (SPT-C). The solid cone has a greater surface area and, therefore, imparts a lower energy per blow than the split-spoon sampler, and can result in an over-estimation of the true SPT N-value. Based on the relationship of energy inputs at the point of penetration (Thorburn 1986), it can be inferred that the equivalent SPT N-value for a test using a cone (SPT-C) is equal to:

$$\text{SPT N-value} = \frac{\text{SPT-C}}{1.869}$$

The corrected SPT N-values (allowing for the use of a solid cone and the presence of sandy soils) are presented as Appendix G2.

Chiselling at the base of the boreholes was undertaken in order to prove the presence of the Oxwich Head Limestone bedrock.

On completion, monitoring instrumentation was installed in the boreholes as detailed in Section 4.6.1. Below the instrumentation, the borehole was backfilled with bentonite where required.

4.4 Rotary Cored Drillholes

2no. 150mm diameter rotary percussive drill hole (RC07 and RC08), were constructed to a maximum depth of 21m between 3rd and 5th December 2018. The drill holes were constructed to collect core samples of the bedrock beneath the site.

Initially, the ODEX 115 system of simultaneous open hole drilling and casing was used in the superficial deposits. Compressed air was used as a flushing medium to keep the drill bits cool and return arisings to the surface. Once the drill hole had been progressed to the bedrock, the method was switched to coring to obtain samples of the bedrock as described below.

Cores of nominal 100mm diameter were recovered in plastic liners using a triple tube barrel system, over runs of nominal 1.5m length. Compressed air and water was used as a flushing medium to keep the drill bits cool and aid the coring process. The percentage recovery of the samples was good and therefore a reduction in the length of core run (to improve recovery), was not required. The recovered cores were sealed in the plastic liners and placed in solid core boxes to prevent disturbance and swelling before logging. The plastic liners were only cut immediately prior to logging and sampling. In addition to the nature of the rock material, the identified fractures within the rock mass were also logged in accordance with BS5930:2015. The Rock Quality Designation (RQD) recorded was for rock core 100mm or greater in length. The fracture state of the recovered cores is presented on the drill hole records, which are presented in Appendix I.

On completion, instrumentation was installed in boreholes as detailed in Section 4.6.1. Below the instrumentation, the borehole was backfilled with bentonite and arisings.

4.5 Dynamic Cone Penetrometer Testing (DCP)

CBR testing using the TRL approved dynamic cone penetrometer (DCP) was undertaken across the site (Food Store & Site A) based on the original layout proposals on 26th November 2018. The testing was undertaken along the length of the then proposed road to the south of the proposed food store (now relocated) and in general areas across the site. Following the updates to the boundary, 14no. positions (DCP01 to DCP08, DCP10 to DCP13 and DCP17 to DCP18) are identified to be within Site A. The test results are presented in Appendix J.

The DCP testing was undertaken from the existing ground surface with no service pit excavated. Appropriate precautions were taken during the testing to ensure the safety of ESP operatives.

The DCP test involves the fall of a fixed weight over a fixed height to force a 20mm diameter, 60° cone into the near surface soils. The depth of penetration for varying numbers of blows is recorded and is then converted to a CBR value using well established empirical correlations (Highways Agency, 2008). In general, the tests were undertaken between the existing ground surface and 0.9m below ground level, thus providing a profile of correlated CBR values within the near-surface soils. No water was added to the soils prior to testing, so they were in their natural condition. The correlated CBR values are also shown on the test result sheets in Appendix J.

4.6 Instrumentation

4.6.1 Gas Well Installations

Single or dual 50mm diameter monitoring wells were installed in selected boreholes in accordance with BS8576:2013 in order to allow monitoring of hazardous ground gases. The wells, comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seals above and below the response zone, and a lockable vandal proof cover, were installed as detailed on the borehole records and summarised in Table 10 below.

Table 10: *Gas Well Installations*

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum
BH04	19/11/2018	0.5 – 6.7m	Blown Sand
BH06	23/11/2018	1.0 – 8.75m	Infilled Dock/Blown Sand
RC07(s) 2	04/12/2018	1.0 – 8.75m	Infilled Dock
RC07(d) 2		15.0 – 18.0m	OHL
RC08	30/11/2018	1.0 – 10.0m	Made Ground/OHL
BH12	07/12/2018	1.0 – 9.0m	Infilled Dock

Notes
1. Details of each monitoring well are presented on the individual borehole records (Appendices G and I).
2. RC07 installed with a dual monitoring well comprising a shallow (s) and deeper (d) well as detailed above.
3. OHL = Oxwich Head Limestone bedrock.

4.6.1 Gas Monitoring

Monitoring of the installed gas wells has been undertaken on a ‘spot’ monitoring basis (periodic visits to monitor gas levels at the time of the visit). CIRIA C665 (Wilson et al, 2007) provides guidance on the number and frequency of monitoring visits required for installed gas wells. These depend on the gas generation potential of the source and the sensitivity of the development to gas risk and are designed as a typical minimum only.

As discussed in Section 3.1.4, the most significant sources in the vicinity of the site in terms of gas risk are the infilled dock and the former recorded landfill located 40m north, classified as being of moderate to very high gas generation potential. In addition, a number of on-site sources (infilled dock, railway land and Made Ground) are also present and represent a low to moderate risk. The proposed residential development is classified as of high sensitivity in terms of gas risk. Therefore, based on the guidelines in CIRIA C665, a minimum of twelve monitoring visits are required over a six month period would likely be required.

Our original report (ESP.7044d.3123_A, May 2019), provided an assessment of the potential risks posed by hazardous ground gas based on 6no. visits. Additional monitoring visits have now been undertaken and overall, the results equate to 12no. fortnightly visits. To assess potential tidal effects on the ground gas regime, monitoring was undertaking during both rising and falling tides (this is noted on the results).

The results of the gas and groundwater monitoring undertaken to date are presented in Appendix K and a summary table of all previous and recent groundwater monitoring is presented in Appendix L.

During each visit, Gas Data LMSxi G3.18e portable monitoring equipment was used to measures levels of the following ground gases within the airspace in the wells and the flow rates from the wells:

- Methane - total and percentage of Lower Explosive limit (LEL);
- Carbon dioxide.
- Oxygen; and
- Hydrogen sulphide.

The percentage of nitrogen is also calculated by difference. The equipment uses infra-red methane (CH4) and carbon dioxide (CO2) detectors, coupled with pressure (barometric and well), temperature and flow sensors. A photo-ionisation detector (PID) was used during the monitoring to measure the levels of volatile organic compounds present in the well.

Following measurement of gas levels and flow rates, the well cap was removed, and groundwater levels were measured using a dip-meter from the site surface. During each visit, an interface probe was used to measure the presence of any phase-separated hydrocarbons in the groundwater.

Monitoring was also undertaken during different tidal conditions (e.g. rising, falling etc.) to assess the potential for any variation due to the piston effect.

4.7 Sampling Strategy

4.7.1 Soil Sampling – ESP, November 2018

Soil samples were collected from the exploratory holes as discussed in the previous sections. The sampling procedures were selected on the basis of the suitability for the laboratory testing proposed (see Sections 4.17 and 4.18).

Sampling for soil contaminants was undertaken on a targeted strategy, focused on the contaminant sources identified in Section 3.1.2. Further soil samples were also taken randomly from non-targeted areas to provide a general indication of the variability in concentrations of possible diffuse source contamination across the site as a whole.

No testing of the stockpiled Topsoil (bunded along the north and east boundaries) on-site has been undertaken to date. If planned to be used as part of future development proposals, testing of its suitability in accordance with the proposed development should be undertaken.

Environmental samples (denoted as ES on the exploratory holes records) were collected for possible geo-environmental laboratory testing and generally comprised a plastic tub, an amber glass jar and an amber glass vial. The sample containers provided clean by the testing laboratory appropriate for the proposed testing to be scheduled. Immediately after collection the samples were placed in sealed cool boxes with ice packs where they remained during storage and transport to the laboratory.

Samples for logging and geotechnical laboratory testing purposes were collected at regular intervals within the exploratory holes.

4.7.2 Soil Sampling – ESP, December 2019

Samples for asbestos screening were collected during the additional site works in December 2019 from all trial pits across Site A site detailed in Section 4.2.2. Sampling for asbestos was undertaken on a targeted strategy, focused on the Made Ground and/or infilled dock materials. Samples were collected on a 25m grid spacing in order that a more detailed assessment of the potential risks from asbestos could be undertaken.

Samples for Waste Acceptance Criteria (WAC) testing were also collected from locations AS4, AS18, AS29, AS30, AS34, AS38, AS40 and AS41. This is discussed further in Section 4.10.4.

4.7.3 Soil Sample Quality

Samples of soil recovered from investigations are classified as Classes 1 to 5 in terms of quality and depend on the investigation and sampling method, the particle size of the strata sampled, and the presence of groundwater. Class 1 and 2 samples are those in which there has been no or only slight disturbance of the soil structure, with moisture contents and void ratios being similar to the in-situ soil. Class 3 and 4 samples contain all the constituents of the in-situ soil in their original proportions, and the soil has retained its original moisture content, but the structure of the soil has been disturbed. In Class 5 samples, the soil structure and original layering cannot be identified and the water content may have changed from that in-situ. The category and class of samples are discussed further in BS EN ISO 22476:2006, EN 1997-2:2007 and BS5930:2015.

In general terms, disturbed samples recovered from trial pits (bulk bags and small tubs) are classed as Class 3 (if dry), Class 4 (fine soil below the water table), or Class 5 (coarse soils from beneath the water table).

During cable percussion drilling, samples of fine-grained soils collected using thin wall, open tube samplers (OS-T/W) are generally Class 1 samples, whist samples collected using thick wall, open tube samplers (OS-TK/W) are classed as Class 2 or 3, provided they are sealed and waxed on collection.

The split spoon sample from a Standard Penetration Test (SPT) is usually considered a Class 5 sample however, it can be deemed Class 4 in homogeneous fine-grained soils. Disturbed sampling (bulk bags and small tubs) from boreholes is considered Class 3 (if dry), Class 4 (fine soil below the water table) or Class 5 (coarse soils from beneath the water table).

Provided recovery is good, rock cores collected using rotary techniques are classified as Class 2 samples, provided that the plastic liners are sealed and only opened immediately prior to logging. The arisings recovered during open-holes drilling are considered Class 5 samples.

The quality class of each sample collected as part of the investigation is shown on the exploratory hole records.

4.7.4 Groundwater Sampling

Prior to sampling and to attempt to collect the most representative water samples the wells were developed by purging, with the removal of three well volumes before sampling during the first monitoring visit.

In order to establish the groundwater quality beneath the site, samples of groundwater were collected from the installed wells on 19th December 2018 and 14th January 2019 in general accordance with BS ISO 5667-11 (2009) using a low flow pump. The use of the low flow pump during water sampling eliminates the need to purge the wells prior to sampling.

All groundwater samples taken for possible laboratory chemical analysis were collected in suitable clean containers provided by the testing laboratory for (e.g. clean polyethylene jars/bottles with fitted lids for routine soil testing, clear or amber glass bottles with screw on air-tight caps for organic contaminants, glass vials for volatile contaminants, etc.). Immediately after collection the samples were placed in sealed cool boxes with an ice pack where they remained during storage and transport to the laboratory.

4.8 Evidence of Site Hazards Found During Site Works

With regard to potential hazards identified in the desk study and Preliminary Risk Assessment, the following observations were made.

4.8.1 Site Stability

During the trial pit investigation, spalling of the pit walls was observed across the site within the Made Ground and Blown Sand deposits, generally identified to be minor, becoming more significant with depth.

Significant spalling was identified in TP21 and 23 throughout the excavationwithin the Made Ground in the area of the infilled dock. Trial pits undertaken outside of the Site A boundary during the Food Store investigation, also identified significant spalling of the infilled dock materials.

Instability within the Blown Sand deposits was also noted in throughout the investigation below a depth of approximately 1.5m below surface level, resulting in the infilling of the pit walls and termination of the trial pits (as detailed on the trial pit records, Appendix H1).

No obvious evidence of the dock masonry wall or foundations associated with the former smithy were encountered during the investigation.

No evidence of limestone solution was identified during the investigation.

4.8.2 Site Evidence of Contamination

Made Ground was encountered across the site, with deeper Made Ground identified in the area of the infilled dock. Due to the significant variation in depth and composition, we consider that the ‘general Made Ground’ and ‘infilled dock Made Ground’ should be assessed as two different horizons.

The general Made Ground was relatively shallow and comprised re-worked soils with man-made objects, while the dock infill materials were generally a mix of slag and rubble. The details of the strata encountered are presented in Section 5.1.

No significant direct visual or olfactory evidence of contamination was noted during the works and the PID readings did not identify any volatile gases during the investigation.

4.9 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples from the suitable quality classes recovered from the exploratory holes in order to obtain information on the geotechnical properties on the soils beneath the site.

The following tests were undertaken by a UKAS accredited laboratory on samples selected by ESP in accordance with the methodologies presented in BS1377:1990. The results are presented in Appendix M.

- Particle size analysis;
- Quick undrained triaxial (undrained shear strength);
- Point Load Value of rock; and
- Uniaxial Compressive Strength (UCS) of rock.

Selected samples were also analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005). Due to the potential presence of pyrite in the soils (see Section 2.9.13), these samples were also analysed to determine the levels of total sulphur, acid soluble sulphate in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005).

Samples of groundwater recovered from the exploratory holes/installed wells were also analysed for the levels of sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005).

The results of the sulphate testing are included with the geo-environmental test results in Appendix N3 (soils) and P3 (groundwater)

4.10 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil, leachate generated from shallow soils and groundwater.

The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment (see Section 4.1.1).

4.10.1 Soil Samples

4.10.1.1 2018 Investigation

To allow an assessment of the potential chronic risks posed to human health, a total of 19no. samples (11no. from within the infilled dock, 6no. general Made Ground and 2no. natural Blown Sand) have been analysed for the contaminants identified in Section 3.1.2, plus other determinands typically present on brownfield sites in the UK. The geo-environmental soil test results from 2018 and 2019 are presented in Appendix N3.

The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;

- Total cyanide, asbestos qualitative screen (presence or absence);
- Soil organic content, pH value;
- Petroleum hydrocarbons (CWG ali/aro carbon banded C_5 to C_{35});
- Semi-volatile organic compounds (SVOCs);
- Volatile organic compounds (including chlorinated solvents); and
- Asbestos quantification analysis.

4.10.1.2 2019 Investigation – Asbestos Only

To allow an assessment of the potential chronic risks posed to human health, a total of 35no. samples (19no. from within the infilled dock, 12no. general Made Ground, 3no Topsoil and 2no. natural Blown Sand) have been analysed for asbestos only, to further assess the potential risks from asbestos to the site developers and end-users (residents).

Where a positive identification of asbestos was noted, further quantitative analysis was undertaken to determine the levels of asbestos within the sample (by percentage weight). The asbestos results from 2019 are presented in Appendix N3.

4.10.2 Leachate Samples (2018 Only)

In order to allow an assessment of the potential pollution risks to controlled waters, samples of leachate have been generated from 4no. samples of general Made Ground soil and 7no. samples of dock infill Made Ground recovered from the exploratory holes. The leachate preparation was carried out in accordance with the guidance given in BS EN 12475 at 10:1 elluate ratio. The results of the leachate tests are presented in Appendix O2.

The resulting leachate was analysed for the following determinants:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Cyanide, soluble sulphate, pH value;
- Petroleum hydrocarbons (CWG ali/aro carbon banded C_5 to C_{35});
- Volatile organic compounds (including chlorinated solvents); and
- Semi-volatile organic compounds (SVOCs).

4.10.3 Groundwater Samples (2018 Only)

In order to allow an assessment of the potential pollution risks to controlled waters, samples of groundwater recovered from selected wells have been analysed for the following determinands:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Cyanide, soluble sulphate, pH value;
- Petroleum hydrocarbons (CWG ali/aro carbon banded C_5 to C_{35});
- Volatile organic compounds (including chlorinated solvents); and
- Semi-volatile organic compounds (SVOCs).

Samples of groundwater collected during two visits on 19th December 2018 and 14th January 2019 have been analysed and the results are presented in Appendix P3. Testing of SVOCs and VOCs was only undertaken on the second visit.

4.10.4 WAC Testing (2019)

In order to assess the disposal options for the site arisings in term of landfill, the soils have been classified in terms of hazardous/inert waste by analysing leachate generated from a total of 9no. samples of soils that are likely to require excavation and removal from the site, in accordance with the Landfill Directive (2004) – Waste Acceptance Criteria (WAC) testing. The samples comprise 5no. infilled dock materials, 3no. general Made Ground and 1no. Blown Sand sample.

Two separate strengths of leachate generated from the soils (at 2:1 and 8:1 concentrations) are analysed and analysed for the following determinands:

- Total organic carbon, loss on ignition, pH, acid neutralisation capacity, total dissolved solids, dissolved organic carbon.
- BTEX, PCBs (7 congeners), mineral oil (C_{10}-C_{40}), PAHs, phenol index.
- Arsenic, barium, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, antimony, selenium, zinc.
- Chloride, fluoride, sulphate (as SO_4).

The results of the WAC testing are presented in Appendix R.

5 Development of the Revised Conceptual Model

5.1 Geology

Outside of the infilled dock area, the exploratory holes have identified the site to be generally underlain by a thin covering of Made Ground followed by Blown Sand deposits overlying weathered and competent Oxwich Head Limestone bedrock. Within the area of the infilled dock (see Figure 5), deeper Made Ground has been identified. The extent of the infill materials was in accordance with the anticipated dock footprint shown on Figures 2 and 3.

Previous investigations identified a layer of clay beneath the Blown Sand and above the bedrock. This fine grained soil was encountered during the recent ESP investigation and while the previous investigation indicated the soil to be a superficial deposit, we consider this to be the upper most portion of the weathered bedrock (detailed below).

These strata are discussed in more detail in the following sections and the geological succession identified is presented on a Conceptual Ground Model in Figure 6.

Made Ground (General): encountered to a maximum depth of 1.4m generally as dark brown, occasionally light brown, with patches of black, sandy to very sandy, silty sandstone gravel. The Made Ground also contained a number of man-made objects such as glass and brick and occasional, probable fine-medium gravel sized slag fragments.

Deeper Made Ground, outside of the infilled dock area was encountered in BH08 in the west portion of the site. The Made Ground was observed to a depth of 7.5m below ground level, comprising coarse grained soils of light brown sand to a depth of 3m, underlain by light brown gravel and cobbles to a depth of 7.5m. The Made Ground was identified to be likely re-worked soils and given the position of BH08, we consider that this is likely in the area of earthworks identified in Table 2, in the area of the former coal tip and railway land.

Field SPT N-values from the ESP investigation within the Made Ground (re-worked soils in BH08 only) varied between 15 and 48, with an average of 30. This indicates a generally medium dense state. The SPT results within the reworked sands between 0.3m and 3.0m depth during the ESP investigation have been corrected in accordance with BS EN ISO 22476-3 (2005), as presented in Appendix G2. Corrected N-values are shown to be 25 and 24 at 1.2m and 2.0m respectively, indicating a medium dense state.

Previous investigation information has identified localised Made Ground up to approximately 3.0m bgl outside of the dock, however the base of the Made Ground was not proven due to spalling. Therefore, deeper Made Ground could be present at the site, as identified in BH08.

Made Ground (Dock Infill): encountered in TP01, TP06, TP19 to TP26 (inclusive), BH06, BH07 and BH12 (see Figure 5), underlying the car park surface. This strata was observed to a maximum depth of 11.25m below ground level (BH12) as a black and dark grey, occasionally brownish black, very sandy angular gravel and cobbles. The gravel and cobbles largely comprised whole and crushed bricks, concrete and slag with occasional metal, timber and glass. Occasional lenses of fine soils were also identified intermittently throughout the strata. This is consistent with that encountered previously within the dock.

No obvious evidence of fine grained dock sediment was noted in the current investigation at the base of the infilled dock, however it was consistently recorded as part of the JPB, 1999 investigation.

Field SPT N-values from the ESP investigation within the coarse infilled dock Made Ground varied generally between 4 and 15, with an average of 9. This indicates a generally loose state in terms of density, with some higher density bands present. This is comparable to that recorded previously.

Laboratory particle size analyses within infilled dock materials he laboratory tests have indicated the infilled dock materials to be predominantly fine to coarse gravel with cobbles and sand, with minor fractions of silt/clay, as observed during the field works.

Previous investigation information has identified similar ground conditions within the infilled dock.

Blown Sand Deposits: encountered beneath the Made Ground generally from depths of between 0.2 and 1.4m below surface level, to a maximum depth of 10.5m.

A band of very dense brown very sandy rounded sandstone gravel and cobbles was encountered in BH07 between 11.2 and 13.1m depth. This was identified as a probable band of Marine Beach deposits within the Blown Sand. An organic clay layer (potential Relict Topsoil) was also recorded in BH05 between 6.0m and 6.4m.

Particle size analyses within the laboratory tests have indicated the Blown Sands to comprise between 24% and 68% sand, predominantly medium/coarse, with fractions of gravels and cobbles. Between 1% and 19% fine grained soils (silt and clay) were also identified in the particle size analyses.

Field SPT N-values from the ESP investigation within the Blown Sands varied between 4 and 23, with an average of 16. This indicates a generally medium dense state. The SPT results within the Blown Sand during the ESP investigation and the previous NH, 1979 investigation have been corrected in accordance with BS EN ISO 22476-3 (2005), as presented in Appendix G2. Values generally improve with depth, and the sands are generally in a medium dense state.

Grade E/D Oxwich Head Limestone Bedrock: identified in boreholes BH04, BH06 and BH07 only, from depths of between 6.7m and 13.3m depth as a grey, sandy, gravelly clay. In BH04, the clay was identified to be a light brownish red colour. Six field SPT-N values were obtained solely within this strata, identifying N-values of between 4 and 14, with an average of 8. This indicates the weathered fine grained soils generally be of soft to firm consistency. One unconsolidated undrained shear strength tests have been undertaken on a sample of the weathered clay from BH06 (11.0m depth). The testing had a confining pressure of 220kN, with the results indicating the strength of the soil to be low in accordance with BS5930 definition.

A band of light brownish red sandy clay was also observed in BH06 between 13.3 and 13.8m depth overlying the competent bedrock. This band of clay was identified in the field to be of firm consistency.

These clay layers are indicated to be consistent with the fine grained layers encountered previously on-site.

Grade C Oxwich Head Limestone Bedrock: Identified in all of the boreholes (BH06, BH07 and BH12) between 11.25m and 13.8m below surface level as a light grey and occasionally reddish brown limestone, recovered as angular gravel and cobbles within the cable percussion boreholes following chiselling of the rock. SPT N-Values in the bedrock were all in excess of 50.

Grade B Oxwich Head Limestone Bedrock: encountered in the cored drill holes RC07 and RC08 only from a depth of between 8.2m (RC08) and 13.5m (RC07) below surface level as a light grey and occasionally dark grey thinly to medium bedded calcitic limestone. Fractures within the bedrock were generally very closely to closely spaced with localised weathering and fine-medium gravel infilling. A band of light reddish brown, occasionally greenish grey, mudstone was identified in RC07 between 18.25m and 19.5m depth and in RC08 between 11.25m and 11.55m depth. This is identified to be Mercia Mudstone Group bedrock.

The limestone was estimated to be weak (locally) to medium strong in terms of strength. Laboratory strength testing on recovered rock core samples on-site indicates the strength be medium strong. The Mercia Mudstone was observed to be weak to medium strong.

5.2 Hydrogeology

5.2.1 Groundwater Bodies

5.2.1.1 Recent Groundwater Findings (ESP, 2018 & 2019)

Table 11: *Summary of Recent Groundwater Information*

Investigation	BH ID	Stratum	Comment
ESP, 2018/2019	BH04	Blown Sand	Water strike at 7.2m, rose to 5.8m after 20 minutes. Standing water levels recorded at 5.8m depth. Monitored levels recorded between 4.45m and 4.88m depth.
	BH06	Made Ground (infilled dock) & Blown Sand	Water strike in Blown Sand at 6.4m depth, rising to 4.3m after 20 minutes. Water strike in Oxwich Head Limestone at 13.8m depth, rising to 10.5m after 20 minutes. Standing levels between 4.3m and 6.2m depth recorded. Monitored levels recorded between 4.45m and 5.12m depth.
	BH07 (general)	Made Ground (infilled dock) & Blown Sand	Water strike at 5.25m within infilled dock materials, rising to 5.0m after 20 minutes. Standing levels between 5.0m and 6.25m depth recorded.
	BH07(s)	Made Ground (Infilled Dock)	Monitored levels recorded between 5.32 and 5.7m depth.
	BH07(d)	Oxwich Head Limestone	Monitored levels recorded between 4.73m and 5.37m depth.
	BH08	Made Grond/Oxwich Head Limestone	No water strikes recorded during cable percussion or rotary drilling. Standing water level recorded at 6.5m depth during cable percussion drilling. Monitored levels recorded between 6.97m and 7.19m depth.
	BH12	Made Ground (Infilled Dock)	Water strike recorded at 5.6m depth, rising to 5.2m after 20 minutes. Standing water levels recorded at 5.2m depth. Monitored levels recorded between 4.70m and 5.51m depth.

Previous investigation works (DS, 2011), indicated the windowless sample boreholes (WS06 and WS08), were dry to 4.5m and 4m respectively.

QG, 2013 monitored levels from boreholes RD1 to RD4 within standpipes installed within the Blow Sand deposits indicated monitored groundwater levels recorded between 2.67m and 4.22m depth.

The above readings are in accordance with that recorded previously and therefore we consider that the main groundwater body beneath the site is within the Blown Sand deposits at a depth of between approximately 4m to 6.5m below surface level. A deeper water body also likely exists within the Oxwich Head Limestone bedrock.

5.2.2 Tidal Influence

Investigations undertaken by JPB in 1999 indicated that limited tidal influence was identified in the north portion of the dock.

QG, 2013 monitored the groundwater levels in RD1 to RD4 (within Site A) over a 12 hour cycle of a spring tide. The boreholes are located on the east boundary nearest to Sandy Bay. The range of levels recorded are shown below:

- RD1 – 3.85m to 3.96m
- RD2 – 3.66m to 3.69m
- RD3 – 3.36m to 3.38m
- RD4 – 2.39m to 2.52m

Slight variations in levels were recorded, with the maximum difference being observed in RD4 (0.13m over 12 hours of monitoring).

The ESP monitoring regime to date has included measurements of the groundwater levels at the site at times of low, high and slack tides. No significant differences in the groundwater levels have been identified at varying tide levels and we do not consider that the tidal influence of Sandy Bay will significantly affect the groundwater levels at the site.

5.2.3 Hydraulic Gradient

Based on the site setting and available information, we consider that the hydraulic gradient beneath the site is likely to be slightly towards Sandy Bay to the south and south east and the groundwater within the bedrock beneath the site is likely in hydraulic continuity with the waters in Sandy Bay.

5.3 Site Instability

5.3.1 Global Site Stability

No evidence was identified of potential landslides or unstable ground in the Preliminary Geotechnical Risk Register (Table 6) and we identified no evidence of any global instability issues on the site.

5.3.2 Excavation Stability

During the trial pit investigation, spalling of the pit walls was observed across the site within the Made Ground and Blown Sand deposits, becoming more significant with depth.

5.4 Limestone Solution

No evidence of limestone solution was identified in the investigation.

5.5 Chronic Risks to Human Health – Generic Assessment of Risks

5.5.1 Assessment Methodology

The long term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

5.5.2 Assessment Criteria

In 2014, DEFRA published the Category 4 Screening Levels (C4SL) for use in Part 2A determinations. The C4SL are designed to be more pragmatic, but still strongly precautionary, assessment criteria compared to the previous assessment criteria (SGV – see below) used to assess chronic human health risks. They are designed for use in deciding whether land is suitable for use and definitely not contaminated, and DEFRA and the Welsh Government have recommended that they be used in assessing human health risks during the planning regime (i.e. as part of standard development investigations). However, the C4SL have been calculated for a limited number of contaminants at this stage, and range of land uses including residential, commercial and public open space, but are based on a 'low level' of risk rather than the 'minimal level' of risk adopted by the Environment Agency in preparing their Soil Guideline Values (SGV). At the time of writing, the use of the C4SL in planning has not yet been accepted by many parties, including some regulators. The C4SL have also only been published for a limited number of contaminants. The C4SL have not been generally adopted in this assessment.

In this assessment, where available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) in the first instance. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments - not public open space). Where no SGV is available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) have been adopted (Nathanail et al, 2015). These assessment criteria adopt updated toxicological data and exposure models, but the same 'minimal level' of risk as the SGV (i.e. unlike the C4SL). The S4ULs have been published for a large number of contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e. including public open space scenarios.

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL:AIRE and the Environmental Industries Commission (CL:AIRE/EIC, 2010) have been adopted. These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e. not public open space).

At the time of writing there is no published SGV, S4UL or CL:AIRE/EIC assessment criteria for lead. For the purposes of this assessment, and in the absence of any other current authoritative guidance, the Category 4 Screening Level (C4SL) value published by DEFRA has been adopted.

Details of the source of the GAC adopted for each contaminant are presented on the assessment table below.

No proposed development plan has been provided to date. However, we understand the proposed development will comprise a variety of residential type buildings. We understand that residential properties with private gardens are proposed in some areas and therefore, the GAC appropriate for the residential land use with plant uptake have been adopted in this assessment. In addition, we understand that flat type buildings and external landscaping areas are proposed. Within these areas, no growing of edible plants is anticipated, therefore, the GAC appropriate for public open space around residential properties have been adopted in this assessment.

The GAC for most organic compounds are dependent on the organic content of the soil Analysis has shown that the soil organic content in the soils analysed from the dock infill materials ranged from 6.1% to 15% and for the general Made Ground the soil organic content ranged from 1.7% to 9%. Therefore, for the purposes of this assessment, the GAC for a soil organic content of 1% has been adopted for both sets of data. This again is considered a conservative approach for the majority of the soils at the site.

5.5.3 Generic Quantitative Risk Assessment - Background

The samples analysed for soil contaminants comprised historical data from previous investigations as well as the most recent testing undertaken by ESP (ESP, 2018). The samples considered in this assessment are detailed below:

- 8no. samples dock infill materials (JPB, 1999);
- 2no. samples dock infill materials (DS, 2011);
- 12no. samples dock infill materials (ESP, 2018);
- 5no. samples of the general Made Ground soils (ESP, 2018); and
- 2no. samples natural Blown Sand soils (ESP, 2018).

The JPB samples were analysed for metals and total PAH only. The DS samples were tested for metals, with PAH and BTEX tested in one of the samples only. The appropriate results have been included in the below analysis where required. At this stage, we have combined the general Made Ground soils and the natural Blown Sand soils to consider together. The dock infill materials will be assessed separately, as detailed in the tables below. If any exceedances are identified, a statistical analysis based on particular averaging areas may be undertaken to further assess the risks. The risks from asbestos are considered further in Section 7.1.1.

The results of the Generic Quantitative Risk Assessment (GQRA) are presented in Tables 12 to 14.

5.5.4 GQRA – Residential Properties with Plant Uptake – Dock Infill and General Made Ground/Blown Sands

In the first instance, all the results were comparted against the most stringent residential with plant uptake guideline values.

Table 12: Summary Soil Results – GAC's for Residential Properties with Plant Uptake – Dock Infill & General Made Ground/Blown Sand Deposits

Determinand	Range Recorded		GAC	Source of GAC	Exceedances
	Made Ground – Dock Infill (MG-DI)	General Made Ground & Blown Sand (MG/BS)			
	JPB, 1999. DS, 2011. ESP, 2018.	ESP, 2018.			
Metals and Semi-metals					
Arsenic	10 - **84**mg/kg	5.7 - 24mg/kg	32mg/kg	SGV[2]	**13 of 22 (MG-DI). 1 of 7 (MG/BS)**
Barium	240 – **1,900**mg/kg	45 - 410mg/kg	1,300mg/kg	CL:AIRE[4]	**3 of 12 (MG-DI).** None of 7 (MG/BS)
Beryllium	0.7 – **3.3**mg/kg	0.2 – 0.7mg/kg	1.7mg/kg	S4UL[3]	**3 of 12 (MG-DI).** None of 7 (MG/BS)
Boron	0.3 – 10mg/kg	<0.2 – 0.8mg/kg	290mg/kg	S4UL[3]	None of 22 (MG-DI). None of 7 (MG/BS)
Cadmium	0.3 - **69**mg/kg	0.2 – 0.6mg/kg	10mg/kg	SGV[2]	**2 of 22 (MG-DI).** None of 7 (MG/BS)
Chromium (total)[6]	6 - 600mg/kg	6.4 - 314mg/kg	910mg/kg	S4UL[3]	None of 22 (MG-DI). None of 7 (MG/BS)
Chromium (hexavalent)	<1.0mg/kg	<1.0mg/kg	6.0mg/kg	S4UL[3]	None of 22 (MG-DI). None of 7 (MG/BS)
Copper	41 – **5,000**mg/kg	13 – 70mg/kg	2,400mg/kg	S4UL[3]	**3 of 22 (MG-DI).** None of 7 (MG/BS)
Lead	50 – **4,400**mg/kg	36 - 190mg/kg	200mg/kg	C4SL[5]	**16 of 22 (MG-DI).** None of 7 (MG/BS)
Mercury[7]	0.06 – 0.79mg/kg	<0.05 – 0.1mg/kg	170mg/kg	S4UL[3]	None of 22 (MG-DI). None of 7 (MG/BS)
Nickel	20 - **300**mg/kg	8 - 16mg/kg	130mg/kg	S4UL[3]	**1 of 20 (MG-DI).** None of 7 (MG/BS)
Selenium	<0.5 - 6mg/kg	<0.5 – 0.8mg/kg	350mg/kg	SGV[2]	None of 22 (MG-DI). None of 7 (MG/BS)
Vanadium	29 - 190mg/kg	12 - 23mg/kg	410mg/kg	S4UL[3]	None of 12 (MG-DI). None of 7 (MG/BS)
Zinc	118 – **8,925**mg/kg	47 - 300mg/kg	3,700mg/kg	S4UL[3]	**2 of 22 (MG-DI).** None of 7 (MG/BS)
Polyaromatic Hydrocarbons (PAH)					
Acenaphthene	<0.03 – 1.3mg/kg	<0.03 – 0.04mg/kg	210mg/kg	S4UL[3,8]	None of 13 (MG-DI). None of 7 (MG/BS)
Acenaphthylene	<0.03 – 0.61mg/kg	<0.03 – 0.18mg/kg	170mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Anthracene	<0.03 – 1.2mg/kg	<0.03 – 0.29mg/kg	2,400mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Benzo(a)anthracene	0.06 – 6.4mg/kg	<0.03 – 0.3mg/kg	7.2mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Benzo(a)pyrene	0.04 – **21**mg/kg	<0.03 – 0.65mg/kg	2.2mg/kg		**1 of 13 (MG-DI)**.. None of 7 (MG/BS)
Benzo(b)fluoranthene	0.07 – **9.1**mg/kg	<0.03 – 0.19mg/kg	2.6mg/kg		**1 of 13 (MG-DI)**.. None of 7 (MG/BS)
Benzo(ghi)perylene	0.05 – 28mg/kg	<0.03 – 0.38mg/kg	320mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Benzo(k)fluoranthene	<0.03 – 9.7mg/kg	<0.03 – 0.48mg/kg	77mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Chrysene	0.08 – 7.2g/kg	<0.03 – 0.09mg/kg	15mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Dibenzo(a,h)anthracene	<0.03 – **2.6**mg/kg	<0.03 – 0.**67**mg/kg	0.24mg/kg		**1 of 13 (MG-DI).. 1 of 7 (MG/BS)**
Fluoranthene	0.15 –6mg/kg	<0.03 – 0.15mg/kg	280mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Fluorene	<0.03 – 0.52mg/kg	<0.03 – 0.19mg/kg	170mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Indeno(123-cd)pyrene	<0.03 – 17mg/kg	<0.03 – 0.04mg/kg	27mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Naphthalene	<0.03 – 1.4mg/kg	<0.03 – 0.26mg/kg	2.3mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Phenanthrene	0.1 – 6.2mg/kg	<0.03 – 0.53mg/kg	95mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Pyrene	0.13 – 12mg/kg	<0.03 – 4mg/kg	620mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
BTEX Compounds					
Benzene	<0.01 – **7.9**mg/kg	<0.01mg/kg	0.087mg/kg	S4UL[3,8]	**1 of 13** (MG-DI). None of 7 (MG/BS)
Toluene	<0.01 - 19mg/kg	<0.01mg/kg	130mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Ethyl benzene	<0.01 – 3.2mg/kg	<0.01mg/kg	47mg/kg		None of 13(MG-DI). None of 7 (MG/BS)
Xylene[9]	<0.01 - 17mg/kg	<0.01mg/kg	56mg/kg		None of 13 (MG-DI). None of 7 (MG/BS)
Aliphatic Petroleum Hydrocarbons (Equivalent Carbon Number)					
Ali EC 5-6	<0.01mg/kg	<0.01 – 2.5mg/kg	42mg/kg	S4UL[3,8]	None of 12(MG-DI). None of 7 (MG/BS)
Ali EC 6-8	<0.01mg/kg	<0.01mg/kg	100mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Ali EC 8-10	<0.01mg/kg	<0.01mg/kg	27mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Ali EC 10-12	<1.5mg/kg	<1.5mg/kg	130mg/kg*		None of 12(MG-DI). None of 7 (MG/BS)
Ali EC 12-16	<1.2mg/kg	<1.2mg/kg	1,100mg/kg*		None of 12(MG-DI). None of 7 (MG/BS)
Ali EC 16-35	<1.5 - 360mg/kg	<1.5mg/kg	65,000mg/kg*		None of 12(MG-DI). None of 7 (MG/BS)
Aromatic Petroleum Hydrocarbons (Equivalent Carbon Number)					
Aro EC 5-7	<0.01mg/kg	<0.01mg/kg	70mg/kg	S4UL[3,8]	None of 12(MG-DI). None of 7 (MG/BS)
Aro EC 7-8	<0.01mg/kg	<0.01mg/kg	130mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Aro EC 8-10	<0.01mg/kg	<0.01mg/kg	34mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Aro EC 10-12	<0.9mg/kg	<0.9mg/kg	74mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Aro EC 12-16	<0.5mg/kg	<0.5mg/kg	140mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Aro EC 16-21	<0.6 – 6.1mg/kg	<0.6mg/kg	260mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Aro EC 21-35	<1.4 - 81mg/kg	<1.4mg/kg	1,100mg/kg		None of 12(MG-DI). None of 7 (MG/BS)
Other Organic Compounds					
Phenol	<0.3mg/kg	<0.3 – 0.4mg/kg	280mg/kg	S4UL[3,8]	None of 18 (MG-DI). None of 7 (MG/BS)

Notes
1. Assessment for commercial land use.
2. CLR SGV: Soil Guideline Value published by Environment Agency.
3. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.
4. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
5. C4SL: Category 4 Screening Level. No current SGV, S4UL or CLAIRE/EIC assessment criteria for lead. Category 4 Screening Level adopted in assessment.
6. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
7. S4UL for inorganic mercury adopted.
8. GAC for organic compounds based on 1% soil organic content.
9. GAC for xylene based on p-xylene (lowest S4UL).
10. Exceedances highlighted in red and bold.
11. Laboratory results presented in Appendix P1 (JPB, 1999) and Appendix P2 (ESP, 2018).

Infilled Dock Materials

The test results from the infilled dock materials from the previous JPB investigation (JPB, 1999), indicated elevated levels of arsenic, cadmium, and zinc.

The previous DS test results from the infilled dock (DS, 2011) for metals were all below the respective GAC's for residential development, with the exception of lead, where both samples tested were identified to be above the GAC. Three elevated levels of PAH and one elevated level of benzene were also identified from the one sample tested (WS06).

The test results from the infilled dock materials from the ESP investigation (ESP, 2018) indicated elevated metal contamination in several samples. The elevated results show Arsenic, Barium, Beryllium, Copper, Lead and Nickel are all present at unacceptable levels, when compared to the guidelines for residential developments with plant uptake. No elevated levels of PAH, TPH or BTEX were identified from the ESP testing of the infilled dock materials.

The two elevated levels of cadmium and zinc identified in Table 12 are from the previous JPB investigation. No elevated levels of cadmium or zinc were identified in the Delta Simmons or ESP investigations.

All VOC and SVOC test results ranged between <0.1 and 1.5mg/kg. The levels of VOC's and SVOC's are not considered to pose a significant risk to human health.

All VOC and SVOC test results were below laboratory detection limits, with the exception of one level of 2-Methylnaphthalene, which was recorded at 0.1mh/kg from TP12, 0.5m within the general Made Ground. This is not considered to be of risk to human health.

General Made Ground/Blown Sand Deposits

From Table 12, the test results from the general Made Ground and Blown Sand soils show all of the determinands are well below their respective GAC's, with the exception of 1no. marginally elevated level of Dibenzo(a,h)anthracene from TP12 (0.5m).

Given the low levels identified in Table 12, we do not consider that the results need comparison to the GAC for flat type buildings. When design proposals and the site layout have been finalised, assessment of the potential risks from contamination in garden areas should be reviewed.

5.5.5 GQRA –Flat Type buildings – Dock Infill Only

Given the elevated levels of contamination within the infilled dock materials, and the uncertainty with regards to development layout at this stage, we have assessed the results against the guideline values for flat type buildings and for public open space also (presented in Tables 13 and 14 below).

As all values of PAH and TPH were below the most stringent residential guideline values they have not been compared to the GACs for flat type building or public open space.

Table 13: Soil Results for Infilled Dock Materials compared against GAC's for Flat Type Buildings

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	10 - **84**mg/kg	79mg/kg	S4UL[2]	**1 of 22**
Barium	240 – **1,900**mg/kg	1,300mg/kg	CL:AIRE[4]	**3 of 12**
Beryllium	0.7 – **3.3**mg/kg	2.2mg/kg	S4UL[2]	**2 of 12**
Boron	0.3 – 10mg/kg	21,000mg/kg	S4UL[2]	None of 22
Cadmium	0.3 - 69mg/kg	120mg/kg	S4UL[2]	None of 22
Chromium (total)[5]	6 - 600mg/kg	1,500mg/kg	S4UL[2]	None of 22
Chromium (hexavalent)	<1.0mg/kg	7.7mg/kg	S4UL[2]	None of 22
Copper	41 - 5000mg/kg	12,000mg/kg	S4UL[2]	None of 22
Lead	50 – **4,400**mg/kg	630mg/kg	C4SL[5]	**7 of 22**
Mercury[6]	0.06 – 0.79mg/kg	120mg/kg	S4UL[2]	None of 22
Nickel	20 - **300**mg/kg	230mg/kg	S4UL[2]	**1 of 22**
Selenium	<0.5 - 6mg/kg	1,100mg/kg	S4UL[2]	None of 22
Vanadium	29 - 190mg/kg	2,000mg/kg	S4UL[2]	None of 22
Zinc	118 - 8925mg/kg	81,000mg/kg	S4UL[2]	None of 22
BTEX Compounds				
Benzene	<0.01 – 7.9mg/kg	72mg/kg	S4UL[2,7]	None of 13
Toluene	<0.01 - 19mg/kg	56,000mg/kg		None of 13
Ethyl benzene	<0.01 – 3.2mg/kg	24,000mg/kg		None of 13
Xylene[8]	<0.01 - 17mg/kg	41,000mg/kg		None of 13

Notes
1. Assessment for flat type buildings.
2. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved. No SGV published for this land use.
3. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
4. C4SL: Category 4 Screening Level. No current SGV, S4UL or CLAIRE/EIC assessment criteria for lead. Category 4 Screening Level adopted in assessment.
5. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
6. GAC for inorganic mercury adopted.
7. GAC for organic compounds based on 1% soil organic content.
8. GAC for xylene based on p-xylene (lowest S4UL).
9. ESP - Generic Assessment Criteria generated by ESP using CLEA software.
10. Exceedances highlighted in red and bold.
11. Laboratory results presented in Appendix N3.

Table 14: Soil Results for Infilled Dock materials compared against GAC's for Public Open Space

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	10 - 84mg/kg	170mg/kg	S4UL[2]	None of 22
Beryllium	0.7 – 3.3mg/kg	63mg/kg	S4UL[2]	None of 12
Cadmium	0.3 - 69mg/kg	555mg/kg	S4UL[2]	None of 22
Chromium (total)[5]	6 - 600mg/kg	33,000mg/kg	S4UL[2]	None of 22
Chromium (hexavalent)	<1.0mg/kg	220mg/kg	S4UL[2]	None of 22
Copper	41 - 5000mg/kg	44,000mg/kg	S4UL[2]	None of 22
Lead	50 – **4,400**mg/kg	1,300mg/kg	C4SL[5]	**5 of 22**
Mercury[6]	0.06 – 0.79mg/kg	240mg/kg	S4UL[2]	None of 20
Nickel	20 - 300mg/kg	800mg/kg	S4UL[2]	None of 20
Selenium	<0.5 - 6mg/kg	1,800mg/kg	S4UL[2]	None of 20
Zinc	118 - 8925mg/kg	170,000mg/kg	S4UL[2]	None of 20
BTEX Compounds				
Benzene	<0.01 – 7.9mg/kg	90mg/kg	S4UL[2,7]	None of 13
Toluene	<0.01 - 19mg/kg	87,000mg/kg*		None of 13
Ethyl benzene	<0.01 – 3.2mg/kg	17,000mg/kg*		None of 13
Xylene[8]	<0.01 - 17mg/kg	17,000mg/kg*		None of 13

Notes
1. Assessment for public open space (landscaping around residential units, without growth of home-grown produce.
2. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved. No SGV published for this land use.
3. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
4. C4SL: Category 4 Screening Level. No current SGV, S4UL or CLAIRE/EIC assessment criteria for lead. Category 4 Screening Level adopted in assessment.
5. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
6. GAC for inorganic mercury adopted.
7. GAC for organic compounds based on 1% soil organic content.
8. GAC for xylene based on p-xylene (lowest S4UL).
9. ESP - Generic Assessment Criteria generated by ESP using CLEA software.
10. Exceedances highlighted in red and bold.
11. Laboratory results presented in Appendix N3.

As Shown in Tables 13 and 14, the levels of some metals remain above the GAC's for flats and public open space, albeit significantly reduced when comparing the results to the GAC's for residential land use with plant uptake.

No design proposals or layout plans are available at this time and therefore no further assessment can be undertaken at this stage. Once design proposals and the site layout has been finalised, further assessment of the risks on a zoned or plot-by-plot basis should be undertaken to determine the risks to the site end users, dependant on the final land use (private house or flat).

5.5.6 Asbestos

5.5.6.1 November 2018

A qualitative analysis has identified chrysotile asbestos present as bundles of fibres in the infilled dock materials in five samples, as detailed below:

- TP06 (2.5m) – Dock Infill Materials – Bundle of Chrysotile fibres.
- TP21 (0.6m) – Dock Infill Materials – Small Bundle of Chrysotile fibres.
- TP23 (0.6m) – Dock Infill Materials – Small Bundle of Chrysotile fibres.
- TP23 (1.8m) – Dock Infill Materials – Small Bundle of Chrysotile fibres.
- TP26 (0.5m) – Dock Infill Materials – Bundle of Chrysotile fibres.

Further quantitative testing has been undertaken and identified that the levels of this asbestos is as follows:

- TP06 (2.5m) – Chrysotile bundles in sample = 0.003%
- TP21 (0.6m) – Chrysotile bundles in sample = <0.001%
- TP23 (0.6m) – Chrysotile bundles in sample = 0.005%
- TP23 (1.8m) – Chrysotile bundles in sample = 0.001%
- TP26 (0.5m) – Chrysotile bundles in sample = 0.009%

No asbestos was identified in the remainder of the samples tested.

Testing off-site, has identified one positive screen for asbestos within the general Made Ground soils in the north east of Salt Lake car park. The sample was later quantified to be <0.001% asbestos (QG, 2013). During the Delta Simmons investigation (DS, 2011), general Made Ground was encountered to a depth of 1.3m below surface level and possible asbestos was noted in WS08 between 0.45m and 1.3m depth.

This is discussed further in Section 7.1.1.

5.5.6.2 December 2019

A qualitative analysis of 37no. samples has identified chrysotile asbestos present as bundles of fibres and crocidolite bundles fibres in five samples, as detailed below:

- AS20 (0.1m) – General Made Ground – Small Bundle of Chrysotile fibres.
- AS29 (1.0m) – Dock Infill Materials – Bundles of Chrysotile fibres.
- AS30 (2.2m) – Dock Infill Materials – Bundle of Chrysotile fibres.
- AS33 (1.5m) – Dock Infill Materials – Bundle of Chrysotile fibres.
- AS34 (3.3m) – Dock Infill Materials – Bundle of Chrysotile fibres.

Further quantitative testing has been undertaken and identified that the levels of this asbestos is as follows:

- AS20 (0.1m) – Chrysotile bundles in sample = 0.002%
- AS29 (1.0m) – Chrysotile bundles in sample = 0.040%
- AS30 (2.2m) – Chrysotile bundles in sample = 0.095%
- AS33 (1.5m) – Chrysotile bundles in sample = 0.007%
- AS34 (3.3m) – Chrysotile bundles in sample = 0.002%

No asbestos was identified in the remainder of the samples tested.

The results are presented in Appendix P2. And the risks from asbestos are discussed further in Section 7.1.1.

5.6 Risk to Controlled Waters - Level One/Two Assessment

5.6.1 Methodology

The potential impact of contamination originating at the site on controlled waters in the area of the site (i.e. groundwater and surface water) has been initially evaluated in line with the Environment Agency guidance (Carey et al, 2006).

Levels of leachable contamination within the soil samples and contamination within the groundwater beneath the site have been analysed, which represents a 'Level Two' risk assessment (Carey et al, 2006).

5.6.2 Assessment Criteria

As for the assessment of human health risks above, the results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area.

The Preliminary Risk Assessment (Section 3) has identified that the following controlled water receptors are potentially at risk from contamination originating at the site:

- The groundwater within the Carboniferous Limestone bedrock which is classified as a Principal Aquifer. The site is not within a source protection zone (SPZ).
- The groundwater within the Blown Sand deposits, classified as a Secondary A aquifer, where the groundwater could be abstracted for potable use in the future.
- The water within Sandy Bay located some 40m to the south east of the site. The groundwater within the shallow soils beneath the site are likely in hydraulic continuity with the water in Sandy Bay.

Given the available information, we consider that the most vulnerable receptor with regards to leachable and mobile contamination would be the water within Sandy Bay which is in hydraulic continuity with the shallow groundwater in the Blown Sands and the deeper bedrock beneath the site.

In order to assess the potential impact on the waters in Sandy Bay and beneath the site, the levels of contaminants have been compared to the Environmental Quality Standards (EQS) for salt water. For the purposes of this assessment, the Annual Average (AA) EQS have been adopted which represent the acceptable levels of a contaminant over an annual period. No annual average EQS has been published for mercury compounds, so the Maximum Allowable Concentration (MAC) EQS has been adopted for this metal.

There are currently no EU or UK guidelines for ethylbenzene and the World Health Organisation criteria (WHO, 2011) has been adopted for this compound. Similarly, there are no published assessment criteria for the higher chain petroleum hydrocarbons within controlled waters. The Environment Agency have previously stipulated an assessment criteria of 10µg/l for all bands of petroleum hydrocarbons, and this has been used tentatively as the assessment criteria. However, it should be appreciated that this only represents a preliminary, broad-brush appraisal of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk.

Despite being Secondary A and Principal Aquifers, the groundwater is not considered a potable resource due to natural saline intrusion degrading its quality. However, to generally assess their quality, the results of the testing have also been compared to the Threshold Values (TV) published in the Water Framework Directive (WFD, 2015). It is appreciated that these threshold values are designed to be protective of the general groundwater body and not for use on a site specific basis, however, in the absence of other published guidelines, we consider that they may be adopted to provide an indication of the groundwater quality beneath the site.

The actual assessment criteria adopted are shown in the following table(s), and further details on them can be found in the respective published documents.

Contaminants within controlled waters have been classed as Priority or non-Priority Substances by the European Union. Priority Substances are those toxic substances whose emissions are to be reduced progressively over time. Whilst the Non-Priority Substances comprise the remaining contaminants analysed in this assessment. The classification of each substance analysed is presented in Table 4 in the following sections.

5.6.3 Assessment of Leachate & Groundwater Test Results

The leachate assessment considers contaminant levels based on 7no. leachates from the infilled dock materials and 4no. leachates of the general Made Ground from the ESP investigation (ESP, 2018).

The groundwater assessment considers contaminant levels based on and 8no. samples of the groundwater from the infilled dock materials (two sampling rounds from four installed wells) and 6no. samples from the groundwater within the Blown Sand deposits (two sampling rounds from three installed wells from the ESP investigation (ESP, 2018). 4no. sample results have also been included from QG, 2013, for the analysis of groundwater samples within the Blown Sand deposits.

JPB groundwater results (JPB, 1999) for boreholes B8, B9 and B10 are within the infilled dock materials within Site A. Quantum Geotechnical groundwater results (QG, 2013) for boreholes RD1, RD2, RD3 and RD4 are within the Blown Sand Deposits in the north east and east of the site.

No details of the sample quality from the previous works (JPB, 1999) have been presented in their report and the limits of detection for the laboratory are significantly higher (less accurate), than those used during the recent ESP investigation. Therefore, the results have not been included in the below analysis and should be used as an indicative assessment only and the more recent ESP laboratory test results should be considered a more accurate assessment of the soils/groundwater beneath Site A.

The results of the leachate and groundwater testing and their comparison to the relevant assessment criteria is presented in Table 15 and 16 below, based on the surface water in Sandy Bay as the most vulnerable receptor.

Table 15: Summary of Geo-environmental Results – Leachates

Compound	Range Recorded		TV (WFD 2015)	2015 EQS Value (WFD) *Saltwater*	Exceedances
	Made Ground – Dock Infill (MG-DI)	General Made Ground (MG)			
	ESP, 2018	ESP, 2018			
Metals					
Arsenic[1]	0.27 – 2.7 µg /l	0.36 - 2µg/l	7.5µg/l	25ug/l[1]	None
Boron[2]	<100 - 600µg/l	<100 - 530µg/l	750µg/l	1000ug/l[1]	None
Cadmium[1,6,]	<0.03µg/l	<0.03µg/l	3.75µg/l	0.2 ug/l[1]	None
Chromium VI[2]	<0.25 – 1.1µg/l	<0.25µg/l	37.5µg/l	0.6 ug/l[1]	1 of 7 (MG-DI) - EQS
Copper[2,3]	0.5 – 4.8µg/l	0.7 – 1.3µg/l	1,500µg/l	3.76 ug/l [1,10]	1 of 7 (MG-DI) - EQS
Iron[2]	6.2 - 100µg/l	67 - 210µg/l	1,000µg/l	1000 ug/l[1]	None
Lead[1]	0.24 – 5.0µg/l	0.52 – 1.2µg/l	7.5µg/l	1.3 ug/l[1]	2 of 7 (MG-DI) - EQS
Mercury[1,5]	<0.01µg/l	<0.01µg/l	0.75µg/l	0.07 ug/l[2]	None
Nickel[1]	<0.5µg/l	<0.5µg/l	15µg/l	8.6 ug/l[1]	None
Zinc[2,4]	<1.3 - 12µg/l	<1.3 – 2.1µg/l	-	7.9 ug/l[1]	2 of 7 (MG-DI) - EQS
PAH compounds					
Anthracene[1]	<0.01 – 0.02µg/l	<0.01 – 0.05µg/l	-	0.1µg/l	None
Benzo[a]pyrene[1]	<0.01 – 0.73µg/l	<0.01 – 0.18µg/l	0.075µg/l	0.00017µg/l	6 of 7 (MG-DI) – TV 6 of 7 (MG-DI) – EQS 1 of 4 (MG) - EQS
Fluoranthene[1]	0.02 – 0.92µg/l	0.02 – 0.13µg/l	0.075µg/l	0.0063µg/l	4 of 7 (MG-DI) – TV 7 of 7 (MG-DI) – EQS 1 of 4 (MG) – TV 4 of 4 (MG) – EQS
Naphthalene[1]	<0.05 - 0.26µg/l	<0.05 - 0.07µg/l	0.075µg/l	2.0µg/l	1 of 7 (MG-DI) – TV
Petroleum Hydrocarbon Compounds					
Benzene[1]	<1.0µg/l	<1.0µg/l	5.16µg/l	8µg/l	None
Toluene[2]	<1.0µg/l	<1.0µg/l	38.2µg/l	8µg/l	None
Ethylbenzene[2, 6]	<1.0µg/l	<1.0µg/l	300µg/l	300ug/l[5]	None
Xylene[2]	<1.0µg/l	<1.0µg/l	15.5µg/l	30ug/l[1]	None
Other Contaminants					
Cyanide[2]	<40µg/l	<40µg/l	10µg/l	1.0µg/l	None
Phenol[2]	<1.5µg/l	<1.5µg/l	74µg/l	7.7µg/l	None

Key to Table 15:
TV – Threshold Value, for general quality of groundwater body (from Schedule 5, Table 1, WFD, Directions 2015). TV for drinking water used where general quality TV was available.
EQS – Environmental Quality Standard (saltwater/other surface waters) - Annual Average (AA, from Part 2, Table 1 and Part 3, Table 1, WFD Directions, 2015).

Notes:
1. Priority substance. EQS taken from Part 3, Table 1, WFD Directions (2015).
2. Non-priority substance (i.e. not listed in Part 3, WFD Directions (2015).
3. Most stringent value. No monitoring for dissolved oxygen undertaken, however if detailed assessment is required, dissolved oxygen measurements should be taken to determine EQS value.
4. No EQS-AA for mercury. Value adopted is maximum allowable concentration (MAC).
5. World Health Organisation, Guidelines for Drinking Water. Fourth Edition. (WHO, 2011)
6. *Cadmium = lowest published EQS.
7. Test results presented in Appendix Q1.
8. Caution should be applied when considering the results of JPB, 1999 – LOD's for some compounds differ between JPB investigation and ESP investigation.

Table 16: Summary of Geo-environmental Results – Groundwater

Compound	Range Recorded		TV (WFD 2015)	2015 EQS Value (WFD) *Saltwater*	Exceedances
	Made Ground – Dock Infill (MG-DI)	Blown Sand Deposits (BS)			
	ESP, 2018	QG, 2013 & ESP, 2018			
Metals					
Arsenic[1]	1.1 – 3.5µg/l	0.7 – 10µg/l	7.5µg/l	25ug/l[1]	1 of 10 (BS) – TV
Boron[2]	570 – 3,600µg/l	36 – 2,100µg/l	750 µg/l	1000ug/l[1]	6 of 8 (MG-DI) – TV & EQS 2 of 10 (BS) - EQS
Cadmium[1,6,]	0.05 – 0.71µg/l	<0.03 – 0.14µg/l	3.75µg/l	0.2 ug/l[1]	4 of 8 (MG-DI)– EQS
Chromium VI[2]	<0.25 – 1.1µg/l	<0.25 – 1.8µg/l	37.5 µg/l	0.6 ug/l[1]	3 of 8 (MG-DI)– EQS 4 of 10 (BS) - EQS
Copper[2,3]	<0.4 – 2.5µg/l	<0.4 – 2.2µg/l	1,500µg/l	3.76 ug/l [1,10]	None
Iron[2]	16 - 170µg/l	14 - 95µg/l	1,000µg/l	1000 ug/l[1]	None
Lead[1]	0.16 – 3.3µg/l	0.44 – 6.8µg/l	7.5µg/l	1.3 ug/l[1]	2 of 8 (MG-DI)– EQS 2 of 10 (BS) - EQS
Mercury[1,5]	<0.01µg/l	<0.01 – 0.01µg/l	0.75µg/l	0.07 ug/l[2]	None
Nickel[1]	1.4 – 4.4µg/l	<0.5 – 3.2µg/l	15µg/l	8.6 ug/l[1]	None
Zinc[2,4]	7.6 - 78µg/l	23 - 76µg/l	-	7.9 ug/l[1]	7 of 8 (MG-DI)– EQS 4 of 10 (BS) - EQS
PAH compounds					
Anthracene[1]	<0.01µg/l	<0.01 – 0.01µg/l	-	0.1µg/l	None
Benzo[a]pyrene[1]	<0.01 – 0.02µg/l	<0.01µg	0.075µg/l	0.00017µg/l	1 of 8 (MG-DI)– EQS
Fluoranthene[1]	<0.01 – 0.04µg	<0.01µg	0.075µg/l	0.0063µg/l	3 of 8 (MG-DI)– EQS
Naphthalene[1]	<0.05 – 0.07µg/l	<0.05 – 0.08µg/l	0.075µg/l	2.0µg/l	2 of 8 (BS) – TV
Other Contaminants					
Cyanide[2]	<40µg/l	<40µg/l	10µg/l	1.0µg/l	None of 2
Phenol[2]	<1.5µg/l	<1.5µg/l	74µg/l	7.7µg/l	None of 2

Key to Table 12:
TV – Threshold Value, for general quality of groundwater body (from Schedule 5, Table 1, WFD, Directions 2015). TV for drinking water used where general quality TV was available.
EQS – Environmental Quality Standard (saltwater/other surface waters) - Annual Average (AA, from Part 2, Table 1 and Part 3, Table 1, WFD Directions, 2015).

Notes:
1. Priority substance. EQS taken from Part 3, Table 1, WFD Directions (2015).
2. Non-priority substance (i.e. not listed in Part 3, WFD Directions (2015).
3. Most stringent value. No monitoring for dissolved oxygen undertaken, however if detailed assessment is required, dissolved oxygen measurements should be taken to determine EQS value.
4. No EQS-AA for mercury. Value adopted is maximum allowable concentration (MAC).
5. World Health Organisation, Guidelines for Drinking Water. Fourth Edition. (WHO, 2011)
6. *Cadmium = lowest published EQS.
7. Test results presented in Appendix R1.
8. Caution should be applied when considering the results of JPB, 1999 – LOD's for some compounds differ between JPB investigation and ESP investigation.

5.6.4 Discussion of Results

5.6.4.1 Infilled Dock Materials - Leachates

Limited leachate testing from previous investigation indicates generally low levels of metal contamination (JPB, 1999).

Elevated levels of leachable metals against the EQS assessment criteria have been identified from two samples tested in the area of the infilled dock during the recent ESP investigation, in the south of the site (TP21, 0.6m and TP26, 0,5m).

Elevated levels of leachable PAH compounds against the TV and EQS assessment criteria have been identified in six samples tested in the area of the infilled dock during the recent ESP investigation, in the south of the site.

These criteria are considered to be extremely stringent and the levels identified do not necessarily pose a high risk to the groundwater beneath the site. See Section 7.2 for further discussion.

All of the volatile and semi-volatile organic compounds tested for during the ESP investigation were below laboratory detection limits. No testing for VOC's and SVOC's was undertaken during the previous investigations (JPB, 1999 and QG, 2013).

5.6.4.2 General Made Ground - Leachates

From the results of the ESP investigation, all levels of leachable metals were below the guideline values (or below laboratory detections limits).

Four elevated levels of leachable PAH compounds against the TV and EQS assessment criteria have been identified from samples tested from the general Made Ground during the recent ESP investigation (TP05-0.5m, TP12-0.5m, TP27-0.3m and TP28-0.2m). No elevated levels of PAH from leachates were identified during previous investigations (JPB, 1999 and QG,2013).

The assessment criteria are considered to be extremely stringent and the levels identified do not necessarily pose a high risk to the groundwater beneath the site. See Section 7.2 for further discussion.

All of the volatile and semi-volatile organic compounds tested for during the ESP investigation were below laboratory detection limits.

5.6.4.3 Infilled Dock Materials - Groundwater

As shown in Table 16 above, elevated levels of metals were identified from tests undertaken on water samples obtained from wells within the infilled dock materials recent ESP investigation (ESP, 2018). This is consistent with previous testing by JPB, 1999 and QG, 2013. Elevated levels of sulphate and chloride are noted, indicating saline intrusion from the seawater to the east.

Marginally elevated levels of PAH compounds were identified on samples from within the area of the infilled dock.

Speciated PAH testing was not undertaken on groundwater samples during the previous JPB investigation, however six PAH screen tests were undertaken on recovered groundwater samples from within the infilled dock. All of the tests identified the PAH's to be below the laboratory detection limits (<1mg/L). These results should be viewed with caution, given the far more stringent assessment criteria values used today.

Speciated PAH testing undertaken by QG, 2013 indicates all levels to be below laboratory detection limits.

All of the TPH compounds tested for during the ESP investigation were below laboratory detection limits, with the exception of one sample from BH07(d), where marginally elevated levels have been identified. No testing for VOC's and SVOC's was undertaken on wells within the infilled dock during the previous investigation (JPB, 1999 and QG, 2013)).

5.6.4.4 Blown Sand Deposits - Groundwater

The QG investigation identified one elevated level of arsenic, with two elevated levels of boron, and chromium also identified against the TV assessment criteria. All of the PAH levels were below laboratory detection limits.

Elevated levels of chromium VI and lead (BH08) have been identified from groundwater samples tested from one well installed within the Blown Sand deposits. One marginally elevated levels of PAH (BH04) was identified from groundwater samples tested from one well installed within the Blown Sand deposits. No elevated levels of PAH contamination in the groundwater within the Blown Sands was identified during previous investigations (QG,2013).

All of the TPH, VOC's and SVOC's compounds tested for during the ESP investigation were below laboratory detection limits, No testing for VOC's and SVOC's was undertaken during the previous investigation (JPB, 1999). All VOC tested for during the QG, 2013 investigation indicates all levels to be below laboratory detection limits.

5.7 New Planting

Soil contamination can have a deleterious impact on the health of new plants. Such 'phytotoxic' effects can include inhibited growth, nutrient deficiencies and discolouration of vegetation. However, the potential impact on planting is difficult to quantify partly due to differing abilities of various plants to tolerate different soil conditions.

Contaminants are taken up by plants in a number of ways, the principal mechanism being via root uptake, but also including adsorption to roots. The impact on contaminants on plant growth depends on a number of factors, including the plant species, the soil type, the soil pH, the availability of the contaminant, and the impact of other external stresses on the plant such as drought.

The British Standard for the provision of Topsoil (BS3882:2007) provides guidance on acceptable levels of copper, nickel and zinc within a growing medium, which vary with soil pH value. ICRCL 70/90 (1990) discussing the restoration of metalliferous mining sites also provides 'threshold trigger levels' for a number of metals and fluoride, below which there should be no impact on plant growth. Finally MAFF (1998) provides assessment criteria for the assessment of the impact of a number of metals on the growth of plants. For the purposes of this assessment, we have adopted the BS3882 guidance values in the first instance, followed by the MAFF published guidelines, and finally the ICRCL 'trigger values'.

This assessment summarises the Made Ground soils outside of the infilled dock only. The assessment along with the assessment criteria adopted are presented in Table17 below:

Table 17: Summary of Assessment Criteria for Planting

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	5.7 - 48mg/kg	250mg/kg	MAFF[1]	None
Cadmium	0.2 – 0.6mg/kg	3mg/kg	ICRCL[2]	None
Chromium (total)[6]	6.4 - 35mg/kg	400mg/kg	MAFF[1]	None
Copper	13 – 70mg/kg	200mg/kg	BS3882[3]	None
Lead	36 - 190mg/kg	300mg/kg	MAFF[1]	None
Mercury	<0.05 – 0.1mg/kg	1mg/kg	MAFF[1]	None
Nickel	8 - 16mg/kg	110mg/kg	BS3882[3]	None
Zinc	47 - 300mg/kg	300mg/kg	BS3882[3]	None

Notes
1. MAFF: Ministry of Agriculture, Fisheries and Food guideline for maximum permissible concentrations in agricultural soils.
2. ICRCL: ICRCL 70/90.
3. BS3882:2007 – values dependent on soil pH values.
4. Laboratory test results presented in Appendix N3.

The testing has indicated levels of zinc to potentially be present at concentrations which could be potentially phytotoxic to new planting. This should be considered in designing the planting regime for the development.

5.8 Ground Gas

5.8.1 Degradation of Organic Materials

The likelihood and severity of a gassing event is considered as part of the risk assessment process in accordance with C665 (Wilson et al, 2007). The Preliminary Risk Assessment (Section 3.1.3) has identified numerous potential sources of hazardous ground gas within the site boundaries or in close proximity, which could impact on the proposed development.

Gas wells have been installed and 12no. fortnightly visits have been completed to date. The monitoring has been undertaken at varying tidal states and varying atmospheric pressures in an attempt to capture a range of varied conditions, as well as the worst-case scenario (i.e. rising tide, falling pressure).

Further gas monitoring has now been completed based on the guidelines in CIRIA C665 and recommendations in our previous report (ESP, 2018).

The monitoring results to date are presented in Appendix K and are summarised in Table 18 below:

Table 18: Summary of Gas Monitoring Data (Visits 1 to 6)

Well	Response Zone Depth[1] (m)	No visits	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Gas Flow (L/hr)	Water depth (m)	Atmospheric pressure
BH04	0.5-6.7	12	Nd – 5.8	Nd – 5.0	15.8 - 21.5	-0.5 – 1.4	4.45 – 4.88	989 – 1,028
BH06	1.0-8.75	12	Nd – 0.7	Nd – 6.8	13.1 - 21.5	-1.4 – 2.1	4.45 – 5.12	
BH07(s)	1.0-8.75	12	Nd – 0.7	Nd – 5.2	14 - 21.8	-3 – 1.2	5.32 – 5.7	
BH07(d)	15-18	12	Nd – 0.6	Nd – 2.2	17.5 - 21.6	-0.7 – 1.2	4.73 – 5.37	
BH08	1.0-10	12	Nd – 0.7	Nd – 2.7	20.2 - 21.9	-0.9 – 2.2	6.97 – 7.19	
BH12	1.0-9.0	12	Nd – 1.1	Nd – 10.2	7.7 – 21.5	-1.8 – 0.2	4.70 – 5.51	

Notes:
1. Nd – none detected with instrument (<0.2% for methane, <0.1% for carbon dioxide).
2. (s) – shallow well. (d) – deep well.

The monitoring to date has indicated levels of methane between below the detection limit and 5.8% and carbon dioxide levels between below detection and 10.2%. Oxygen was depleted where the levels of methane and carbon dioxide were elevated. Maximum gas flow rates of 2.2l/hr were recorded. Levels of volatile organic compounds were recorded as below detection.

The monitoring is in general accordance with that recorded previously, albeit higher levels of carbon dioxide have been recorded.

The results of monitoring undertaken to date (six visits) have been used to calculate initial Gas Screening Values (GSV) for the site using the methodology published in CIRIA C665 (Wilson et al, 2007). The initial calculated GSVs for the site are presented in Table 19:

Table 19: Gas Screening Values (based on ten visits)

	Maximum Recorded Level (%)	Maximum Gas Flow Rate (L/hr)	GSV (L/hr)
Methane	5.8	2.2	0.1276
Carbon dioxide	10.2	2.2	0.2244

Notes:
1. GSV calculated using method derived in CIRIA 665 (2007).

On the basis of the initial GSVs, we consider that the site would be classified as Characteristic Situation CS-2 as a minimum for a residential development (CIRIA C665:2007).

5.8.2 Radon

As discussed in Section 2.11, the risk from radon is moderate and basic radon protection measures are required for development (see Section 7.3.2).

5.9 Sulphate Attack

The assessment of the concrete protection against sulphate attack has been undertaken in accordance with BRE SD1 (2005).

5.9.1 Classification of Site:

Due to the presence of Made Ground on the site, we consider that it should be measured as ‘brownfield’ in terms of concrete classification.

5.9.2 Groundwater Setting:

Groundwater was encountered in the exploratory holes at a minimum depth of 3.95m. The monitoring to date has identified the groundwater levels at the site to be in the region of 4m to 7.0m below surface level, which will likely be in contact with any deep foundations (see Section 8.3. Therefore, groundwater has been considered as mobile in this assessment.

5.9.3 Sulphate Levels:

Sulphate results from all previous investigations within the Site A boundary (where applicable) and the recent ESP investigation have been considered in the below assessment.

In order to assess the site accurately, the infilled dock materials have been assessed separately from the general shallow Made Ground and Blown Sands across the majority of the site.

5.9.3.1 Infilled Dock Materials

The previous JPB report (JPB, 1999), indicates a number of sulphate tests undertaken on the infilled dock materials (soils analysis), however there is no indication of whether the result are an analysis of the levels of sulphate as SO_3 or SO_4. Therefore, we have reviewed the results as an indicative assessment.

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the infilled dock materials to be between 10mg/l and 180mg/L (based on five results from ESP, 2018 investigation). As levels of water soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. The levels of acid soluble sulphate were recorded to be between 0.05% and 0.28% and the levels of total sulphur were recorded between 0.02% and 0.18%. The calculated level of total potential sulphate is between 0.06% and 0.60% and the oxidizable sulphides are between 0.01% and 0.48%. As the level of oxidizable sulphides exceeds 0.3% in some samples, pyrite is likely to be present.

pH values within the infilled dock materials were recorded as between 7.5 and 10.8. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g. hydrochloric and nitric acids).

Analysis of samples of groundwater collected from the infilled dock materials stratum has indicated levels of dissolved sulphate (as SO_4) to be between 240mg/L and 1,200mg/l. The pH values ranged between 7.1 and 7.6, indicating near neutral to slightly alkaline water to be present.

5.9.3.2 General Made Ground & Blown Sands

Given that any shallow foundations will likely come into contact with both the general Made Ground and Blown Sand deposits identified across the site, the assessment of the potential risk to buried concrete has used results from both strata.

No soil sulphate analyses have been carried out from the investigation points within the Site A boundary during the previous Quantum Geotechnical investigation (QG, 2013), however, analysis of water samples from RD1, RD2, RD3 and RD4 within the Blown Sand deposits have been used in the below assessment.

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the shallow Made Ground and Blown Sand deposits to be between 10mg/L and 24mg/l. As levels of water soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. Levels of acid soluble sulphate varied between 0.04% and 0.05% and total sulphur between 0.02 and 0.03% From these results, the calculated levels of total potential sulphate are between 0.02 and 0.9%, and oxidizable sulphides are between 0.02 and 0.04%. As the levels of oxidizable sulphide are well below 0.3%, pyrite is unlikely to be present.

pH values in the shallow Made Ground and Blown Sand deposits varied between 8.3 and 9.5, indicating near neutral /slightly alkaline soil conditions to exist. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g. hydrochloric and nitric acids).

Analysis of samples of groundwater collected from the Blown Sand deposits stratum (QG, 2013 and ESP, 2018) has indicated levels of dissolved sulphate (as SO_4) of between 16 and 1,690mg/l. pH values varied between 8.3 and 8.5, indicating slightly alkaline water to be present.

5.9.4 Foundation Concrete Design

5.9.4.1 Infilled Dock Materials

Using the above ESP results, we consider that the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	180mg/l;
Groundwater sulphate:	1,200mg/l;
Total potential sulphate:	0.6%
pH value:	7.1

It should be noted that higher values, were recorded as part of the JPB investigation and this is discussed within Section 7.4.2.

5.9.4.2 General Made Ground & Blown Sand Deposits

Using the above results, we consider that the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	24mg/l;
Groundwater sulphate:	1,690mg/l;
Total potential sulphate:	0.9%
pH value:	8.3

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

The site history has indicated several potentially contaminative historical land uses (see Table 5), including a smithy, dock (now infilled), railway land, railway sidings, ground workings, unspecified pit, cuttings, coal tip and its use as a car park (although the majority of the site was not used for parking).

In the area of the infilled dock, deep Made Ground has been identified by previous and current investigations to a depth of around 11m below ground level. No obvious significant visual or olfactory evidence of significant contamination was identified across the site.

Outside of the infilled dock, investigation information (historic and current) has identified a general ground model comprising a thinner covering of Made Ground followed by Blown Sand deposits overlying Oxwich Head Limestone bedrock.

The test results from the infilled dock materials from the previous investigations and the recent ESP investigation (ESP, 2018) indicate elevated metal contamination in several samples. The elevated results show arsenic, barium, beryllium, cadmium, copper, lead, nickel, zinc are all present at unacceptable levels, when compared to the guidelines for residential developments with plant uptake. No elevated levels of PAH, TPH or BTEX were identified from the ESP testing of the infilled dock materials, however some elevated PAHs and an isolated level of benzene have been recorded previously.

Test results from the general Made Ground and Blown Sand soils show all of the determinands are well below their respective GAC's, with the exception of 1no. marginally elevated level of Dibenzo(a,h)anthracene from TP12 (0.5m). We cannot however discount that elevated levels exist across the site considering the significant industrial history.

A qualitative analysis (2018 and 2019) has identified chrysotile asbestos present as bundles of fibres in 9no. Samples of the infilled dock materials and 1no. sample of the general Made Ground soils. Further quantitative testing has been undertaken and identified that the levels of this asbestos varies between less than 0.001% and 0.095%.

No asbestos was identified in the remainder of the samples tested.

Off site testing across the Food Store area at the same time as the testing/sampling undertaken for Site A has identified that of 15no. samples screened for asbestos, 3no. were positive (with chrysotile and crocidolite asbestos identified). Quantitative testing identified that the levels of asbestos ranged between <0.001% and 0.170%.

Historical testing off-site, has identified one positive screen for asbestos within the general Made Ground soils in the north east of Salt Lake car park. The sample was later quantified to be <0.001% asbestos (QG, 2013). During the Delta Simmons investigation (DS, 2011), general Made Ground was encountered to a depth of 1.3m below surface level and possible asbestos was noted in WS08 between 0.45m and 1.3m depth.

The risks from asbestos are discussed further in Section 7.1.1.

Leachate testing has identified marginally elevated levels of metals and PAH's within the infilled dock materials and general Made Ground. Groundwater testing has also identified elevated levels of metals and PAH's within the area of the infilled dock, as well as marginal elevations of metals and PAH's recorded within samples recovered from the Blown Sand strata. The criteria used are considered to be extremely stringent and the levels identified do not necessarily pose a high risk to the groundwater beneath the site. All of the volatile and semi-volatile organic compounds tested for during the ESP investigation were below laboratory detection limits. See Section 7.2 for further discussion.

As discussed in Section 5.2.1, we do not consider that there is a separate, perched, water body within the infilled dock. Based on the findings to date and recent monitoring of the groundwater across the site, we consider that the groundwater within and outside of the infilled dock is in hydraulic continuity with the main groundwater body identified within the Blown Sands.

6.2 Revised Risk Evaluation & Relevant Pollutant Linkages

As discussed in detail within Section 3.2.1, the methodology set out in CIRIA C552 (2001) has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

The risks evaluated at the desk study stage of this report (Table 6, Section 3.2.2) have been updated and revised in Table 20 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 20: Revised Risk Evaluation & Relevant Pollutant Linkages (RPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants within infilled dock materials	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	High Likelihood[2]	High Risk	See Section 7.1.2.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	High Likelihood[2]	Moderate/Low Risk	See Section 7.1.4.
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Severe - site lies on Principal & Secondary A Aquifer	Low Likelihood[2]	Moderate Risk	See Section 7.2
	Leaching of soil contaminants	Impact on Sandy Bay/Harbour	Medium - site lies 40m from Sandy Bay (in continuity with groundwater)	Low Likelihood[2]	Moderate/Low Risk	
Potential contaminants in shallow soils (General Made Ground)	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Low Likelihood[3]	Moderate/Low Risk	See Section 7.1.2.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Likely[3,4]	Low Risk	See Section 7.1.4.
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Severe – site lies on Principal & Secondary A Aquifer	Low Likelihood[3]	Moderate Risk	See Section 7.2
	Leaching of soil contaminants	Impact on Sandy Bay/Harbour	Medium – site lies 40m from Sandy Bay (in continuity with groundwater)	Low Likelihood[3]	Moderate/Low Risk	
Asbestos within infilled dock materials)	Inhalation of fibres	Construction/ Maintenance Workers & Site Users (residents)	Medium – potential for chronic levels	High Likelihood[5]	High Risk	See Section 7.1.1.
Asbestos in shallow soils	Inhalation of fibres		Medium – potential for chronic levels	High Likelihood[5]		
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High Likelihood[6]	Moderate Risk	See Section 7.4.2.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Likely[7]	High Risk	See Section 7.3.
	Damage through explosion.	Building/Property	Severe – acute risk.		High Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		High Risk	
Radon gas	Migration into Buildings	Site Users (shoppers)	Medium – potential for chronic levels	Likely[8]	Moderate Risk	See Section 5.12

Notes:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Testing of the infilled dock materials has identified elevated levels of metals and PAH's with regards to the GAC's for residential land use, which pose a risk to the site end users. When compared to the GAC's for flat type buildings and public open space, marginal elevations are still identified, albeit at a reduced number. Considering the proposed development, we assume that some areas of the site surface will be occupied by hardstanding and therefore exposure risks to end users will mitigated where this occurs. See Section 7.1.2.
3. Laboratory chemical testing of the general Made Ground soils from across the site has identified generally low levels of soil contaminants with regards to the GAC's for residential land use. However, the presence of local elevated levels cannot be discounted.
4. Due to the presence of contaminants within the Made Ground soils across the site (including asbestos – see Section 7.1.1), in accordance with best practice, we recommend prevention of exposure to the soils to mitigate any potential health risks. See Section 7.1.4.
5. Qualitative analysis has identified chrysotile and amphibole asbestos present as bundles of fibres in the infilled dock materials and general Made Ground. Further quantitative testing has been undertaken and identified that the levels of this asbestos varies between less than 0.001% and 0.095%. See Section 7.1.1.
6. Elevated levels of sulphates recorded therefore increased concrete classification likely to be required. See Section 7.4.2.
7. Monitoring to date has indicated levels of methane between below the detection limit and 5.8%, and carbon dioxide levels between below detection and 10.2%. Gas protection in line with CS2 measures will be required. See Section 7.3.
8. The risk from radon is moderate and basic radon protection measures are required for development. See Section 5.12.

7 Remedial Strategy for Contamination Risks

The objective of the investigation was to obtain sufficient information to allow an initial assessment of the ground conditions and potential geo-environmental risks and constraints on the proposed residential development. Once detailed development proposals are known and regulatory/planning conditions have been prescribed, some additional investigation and assessment will be required to further assess the risks initially assessed in the following section.

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date, and do not form the full Options Appraisal stage of CLR11. If at any stage of the construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all of the following should be reviewed and the advice of a geo-environmental specialist sought immediately.

7.1 Risks to Health

7.1.1 Asbestos

As indicated in Section 5.5.4, a qualitative analysis has identified chrysotile asbestos present as bundles of fibres in 9no. samples of the infilled dock materials and 2no. samples of the general Made Ground. Further quantitative testing has been undertaken and identified that the levels of this asbestos varies between less than 0.001% and 0.095%.

Off site testing across the Food Store area at the same time as the testing/sampling undertaken for the Food Store site has identified that of 15no. samples screened for asbestos, 3no. were positive (with chrysotile and crocidolite asbestos identified). Quantitative testing identified that the levels of asbestos ranged between <0.001% and 0.170%.

Historical testing off-site, has identified one positive screen for asbestos within the general Made Ground soils in the north east of Salt Lake car park. The sample was later quantified to be <0.001% asbestos (QG, 2013). During the Delta Simmons investigation (DS, 2011), general Made Ground was encountered to a depth of 1.3m below surface level and possible asbestos was noted in WS08 between 0.45m and 1.3m depth.

There is no clear UK guidance on what would constitute an acceptable concentration of asbestos in soil. Working with asbestos (even within soils) is governed by the Control of Asbestos Regulations (2012). This requires that the excavation and removal of the asbestos contaminated soils musty be undertaken by a licensed contractor. One mitigating option could be to remove all asbestos contaminated soils from site prior to development, however given there is a covering of Made Ground across the whole site and widespread asbestos has not been identified, this would unlikely be suitable or practical.

To provide an initial analysis of the potential risk from asbestos, we have undertaken a preliminary risk assessment in line with the Joint Industry Working Group (JIWG) 'Decision Support Tools for the Qualitative Risk Ranking of Work Activities and Receptors Involved in or Exposed to Asbestos in Soil or Construction & Demolition Materials'. This tool is designed to provide a consistent decision-making format to further assess the potential risk from asbestos. Based on the currently available information, a high risk is anticipated for the site end users and the groundworkers during construction is likely to be at a medium level.

Considering the proposed residential development, some of the site surface will be occupied by hardstanding (roads, paths, driveways etc) and therefore exposure risks to end users will be mitigated in these areas. Once the development proposals are known, we recommend some additional testing for asbestos is undertaken in proposed gardens and landscaped areas to confirm the risk where there is an exposure potential. If asbestos contamination is recorded within garden areas, remedial action consisting of source removal or a capping layer will likely be required.

For construction workers suitable mitigation measures and PPE will likely be required as a precautionary measure in accordance with current health and safety requirements.

We recommend that an asbestos specialist should be employed to undertake further assessment of the risk posed by asbestos present in the soils to construction and maintenance workers and the general public prior to any development. Input may also be required for human health risks dependent on the results of the additional testing in landscaped areas.

The following sections presume that any risks from asbestos materials at the site are mitigated.

7.1.2 Site End Users

In order to initially assess the risks across the site, the infilled dock materials have been assessed separately from the general shallow Made Ground and Blown Sands across the majority of the site (see Figure 2).

7.1.2.1 Development in areas of Infilled Dock

Levels of metals been identified above the generic assessment criteria and, therefore, are present at unacceptable levels with respect to the users of the proposed residential development (private gardens of public open space). Elevated PAH levels are also present, albeit below their respective GAC's. Appropriate measures would need to be taken prior to development to break the pollutant linkage and mitigate these risks in areas of soft surfacing (e.g. gardens, public landscaping etc.). In areas of hard surfacing (e.g. beneath structures, driveways, roads and other hard standings), the hard surface would break the pollutant linkage and no further risk mitigation would be required in terms of risks to human health.

Provided that finished site levels allow, one option of mitigating risks posed by non-volatile contaminants could be to isolate the contaminated soils beneath a surface cover layer of clean, inert soils, however, It may be necessary to remove some of the contaminated soils in order to provide sufficient space to allow a minimum 600mm thickness of clean cover to be constructed.

The thickness and make up of this layer would need to be agreed with the regulators.

In accordance with CLR11, the preferred risk mitigation strategy should be detailed within a remediation strategy and implementation plan and supervised and validated by a geo-environmental specialist. On completion, a validation report should be prepared to demonstrate to regulators and insurance providers that the risk has been successfully mitigated.

Once the final layout and design proposals have been completed, we recommend that additional testing and assessment is undertaken in areas of private gardens and landscaping in order to further assess the potential risks to the site end users.

7.1.2.2 Development outside of the Infilled Dock

Laboratory chemical testing of the Made Ground soils and Blown Sand deposits from across the site has identified generally low levels of soil contaminants with regards to the GAC's for a residential end use. As part of the proposed residential development, we assume that parts of the site surface will be occupied by hardstanding (roads, paths, driveways etc) and therefore exposure risks to end users will be mitigated in these areas.

Where development occurs outside of the areas of the infilled dock, the identified levels of soil contamination at the site as part of this initial assessment are considered to pose a low risk to future residential site users. However, considering the past significant industrial history there is a potential for un-identified contamination across the site.

Even if the shallow Made Ground is suitable, it is possible that the soils present would not be aesthetically suitable and therefore would require removal and replacement or alternatively suitable soil placed above.

Once the development proposal are known, we recommend additional testing is undertaken in proposed landscaped areas to confirm the low risk initially identified.

7.1.3 New Service Connections

The current water industry guidance for the suitability of pipe materials on potentially contaminated sites (Blackmore et al, 2010) has onerous requirements and it is likely/possible, based on this guidance, that the levels of contaminants on site may prevent the use of plastic pipework. We recommend that enquiries are made to the local water authority to confirm their requirements for underground service materials for this development.

7.1.4 Risk to Construction and Maintenance Workers

Short term (acute) risks to construction and maintenance workers are generally poorly understood within the industry, certainly when compared to the volume of research undertaken on long term risks.

Due to the presence of contaminants within the infilled dock materials and the general Made Ground soils across the site (including asbestos – see Section 7.1.1), in accordance with best practice, we recommend prevention of exposure to the soils to mitigate any potential health risks. This will comprise, as a minimum, the use of overalls, boots, gloves etc. to prevent dermal exposure and washing facilities to prevent ingestion (i.e. at lunch-times). These controls must be strictly implemented at this site and should be reviewed throughout the works during excavations and earthworks etc. (see Section 7.1.5). The recommendations contained within the Health and Safety Executive Document: *Protection of Workers and the General Public During the Development of Contaminated Land* (HSE, 1991) should be implemented.

The above precautions would be required for both construction workers during development and maintenance workers following development. A copy of this report and these recommendations should be included in the Health and Safety File for the development and provided to all future ground workers, including utility companies so that they may undertake their own assessment of risks to their operatives.

7.1.5 General Public/Neighbouring Properties

The site lies adjacent to a Sandy Bay beach and the Eastern Promenade, which is often very busy, especially during the summer months. Visitors to the beach and the surrounding areas (especially children) would be particularly sensitive to any dust created during development. We recommend strict dust control measures during development, and particular care would be required when excavating any Made Ground soils (where localised asbestos has been identified – see Section 7.1.1).

7.2 Risks to Controlled Waters

The superficial deposits beneath the site (Blown Sands) are classed as a Secondary A aquifer and the bedrock (Oxwich Head Limestone) is classed as Principal Aquifer and we consider they are in hydraulic continuity. The water bodies are also in hydraulic continuity with Sandy Bay and the quality of the aquifers has been naturally degraded by the intrusion of saline waters and therefore they are unlikely to be as sensitive as their designation suggests. Previous testing has identified elevated levels of chloride, sulphate and boron which are indicators of saline intrusion, and this is likely the reason that no groundwater abstractions or SPZ's are noted within 1km of the site as the groundwater is not suitable as a potable supply.

Historical industry (Smithy, shipbuilding yard, railway land, unspecified pit, cuttings etc) and the construction, operation and subsequent infilling of the former dock will have also degraded the overall quality of the soils and groundwater beneath site over time.

No significant or olfactory evidence of contamination was identified during the investigation. Elevated total soil concentrations of metals (not with respect to human health GACs) have been recorded, with low levels of PAHs and generally non-detectable levels of TPH, SVOC and VOC contamination. Leachate testing has recorded leachable levels of metals and PAHs above the stringent current guidelines, with all others below the surface water and groundwater acceptance criteria.

Current contamination levels of the groundwater are identified to be generally consistent within the dock and outside of it based on the information to date. Levels of some metals and PAH contamination are marginally elevated against the stringent assessment criteria and all of the TPH, volatile and semi-volatile organic compounds tested for during the ESP investigation were generally low.

Compared to some of the levels recorded during the JPB, 1999 investigation contamination levels with the dock appear to have reduced, which may indicate some natural attenuation has occurred.

Given the results of this Level 2 assessment, we consider that the overall risk to controlled waters from the development of the site is likely to be low to moderate. Discussion with NRW will be required to confirm their opinion on the sensitivity of the aquifers to confirm the risk. If considered lower than classified due to saline intrusion, it is possible that limited further testing and assessment may be required.

We cannot discount that as part of future planning submissions, additional testing and assessment may be requested in accordance with specific local authority and NRW requirements which are currently unknown. This could include a Level 3 controlled waters risk assessment.

Some risk mitigation is likely to be required if soakaways are used to dispose of surface water run-off.

If a piled foundation is the chosen option for the proposed development a standalone risk assessment may be requested by the regulatory authorities to demonstrate that the foundation construction will not create additional contamination pathways that could detriment underlying aquifers. Considering the conceptual model (see Figure 6), we consider that the shallow and deep aquifers are in hydraulic continuity generally across the site and within the infilled dock area, therefore there the risk of additional contaminant loading as a result of piling is likely to be low.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

As discussed in Section 5.8.1, the gas wells have been installed and monitored for hazardous gases on 12no. occasions, which completes the gas monitoring for the site. The monitoring has attempted to capture worst case conditions and has been undertaken at varying tidal states and varying atmospheric pressures in an attempt to capture a range of varied conditions, as well as the worst case scenario (i.e. rising tide, falling pressure).

Based on the monitoring undertaken to date, the site would be initially classified as a minimum of Characteristic Situation CS-2 for a residential development (CIRIA C665:2007).

Further advice can be provided by this office once the design of the buildings has been finalised.

7.3.2 Risk to the Development – Radon

The risk from radon is moderate and basic radon protection measures are required for development.

7.3.3 Risk to Construction and Maintenance Workers

Carbon dioxide is a particular risk in Made Ground materials as it is commonly present and as it is heavier than air, it can displace it at the base of excavations, which can then lead to workers being at risk from asphyxiation.

If during construction any organic materials are encountered, they should be excavated and replaced.

The presence of elevated levels of methane, carbon dioxide and depleted oxygen in the Made Ground could pose a risk to construction workers, and lead to asphyxiation in confined spaces. All excavations should be treated as confined spaces and suitable precautions taken prior to man entry.

7.4 Risks to Property

7.4.1 Spontaneous Combustion

No evidence of combustible materials has been identified in the shallow soils. Therefore, the risk from spontaneous combustion is considered to be low.

7.4.2 Sulphate Attack on Buried Concrete

Given the proposed development, there is a potential for shallow (for lightly loaded, minor structures) and deeper piled foundations (see Section 8.3). For an accurate analysis of the two potential foundation solutions, we have considered the general Made Ground/Blown Sand deposits, separately to the infilled dock materials.

7.4.2.1 Infilled Dock Materials

The following characteristic values are applicable for these shallow soils at the site (all as SO_4):

Water soluble sulphate:	180mg/l;
Groundwater sulphate:	1,200mg/l;
Total potential sulphate:	0.6%
pH value:	7.1

Based on these characteristic values, we consider areas within the infilled dock would be classified as Design Sulphate Class DS-3 and Aggressive Chemical Environment for Concrete Class AC-3, allowing for mobile groundwater. The above characteristic values are on the threshold of the DS2 and DS3 (AC2/AC3) classification. If a reduction in classification is required, further testing of groundwater samples should be undertaken to obtain a larger data set to undertake further assessment.

7.4.2.2 General Made Ground & Blown Sand Deposits

The following characteristic values are applicable for these shallow soils at the site (all as SO_4):

Water soluble sulphate:	24mg/l;
Groundwater sulphate:	1,690mg/l;
Total potential sulphate:	0.9%
pH value:	8.3

Based on these characteristic values, we consider areas within the infilled dock would be classified as Design Sulphate Class DS-3 and Aggressive Chemical Environment for Concrete Class AC-3, allowing for mobile groundwater. The above characteristic values are on the threshold of the DS2 and DS3 (AC2/AC3) classification. If a reduction in classification is required, further testing of groundwater samples should be undertaken to obtain a larger data set to undertake further assessment.

7.5 Risks to New Planting

As discussed in Section 5.11, analysis of the general shallow Made Ground has indicated the levels of zinc to be above the respective assessment criteria. Therefore, phytotoxic impact on future planting could occur in these areas.

The soils within the infilled dock are not considered to be suitable for planting.

A landscaping specialist should be consulted with regards to future planting across the site.

7.6 Re-Use of Materials/Disposal of Excess Arisings

7.6.1 General Comments on Re-use/Disposal

All soils or other materials excavated from any site are generally classified as waste under the Waste Framework Directive (European Union, 2008) and their re-use is controlled by this legislation.

If the soils are to be re-used on site (e.g. within the red-line planning boundary), provided that they are 'uncontaminated' or other naturally occurring deposits and they are certain to be used for the purposes of construction in their natural state on the site from which they are excavated, they may be excluded from waste regulation (Duckworth, 2011). A Materials Management Plan (MMP) may be required – further guidance can be provided by this office once proposals have been finalised. However, if they are man-made or contaminated materials, their use on the site may be limited.

If the soils are to be removed from site, they are automatically classified as waste, and they may only be:

- Disposed at a licensed landfill;
- Disposed at a licensed, permitted soil treatment centre; or
- Removed to a Receiver Site for beneficial re-use.

In Scenarios 1 and 2, the materials must be transferred by a licensed waste carrier and the waste producer (the developer) must ensure that the destination landfill or treatment centre is a legitimate operation (e.g. by requesting a copy of the Environmental Permit before releasing the soils).

Prior to removal from site, the excavated arisings would need to be classified as either 'hazardous' or 'non-hazardous' waste based on the hazard that they pose– a WM3 assessment (note that this is a different assessment to the risk assessments reported on in earlier sections of this report). This can commonly be undertaken on the results of soils testing undertaken during the investigation, although further sampling and testing may be required. A preliminary WM3 assessment is presented in the following section (Section 7.6.2).

Only once the soils have been classified under the WM3 assessment, would Waste Acceptability Criteria (WAC) testing then be required to determine the type of landfill in which the arisings could be disposed in Scenario 1. Further testing and assessment may also be required by the soil treatment centre in Scenario 2.

In Scenario 3, management of soils could be undertaken via an Environmental Permit or Exemption. However, these can take time and are costly to arrange. Therefore, in certain circumstances, it is permissible to use the protocols laid down in the CL:AIRE Definition of Waste, Development Industry Code of Practice (DoWCoP, Duckworth, 2011) to classify the arisings and put a management plan in place to control the use. This involves approval of the proposals by a Qualified Person and is generally more efficient (in terms of time and cost) to implement.

For information, a material re-use flowchart in included as Appendix R of this report. Further guidance on the legislative requirements of the re-use/disposal of materials generated by the development can be provided by this office once the development proposals have been finalised.

7.6.2 WM3 Assessment

An initial WM3 assessment has been undertaken on samples of shallow Made Ground soils across the site and is presented in Appendix S. To determine the hazardous nature of waste soils, the current legislation requires that they are classified under the European Waste Catalogue 2000/532/EC (EWC), part of the Waste Framework Directive 2008/98/EC (WFD). The EWC contains 846, six-digit waste codes arranged in twenty chapters, where each chapter is based on a generic industry or process that generated the waste or upon the type of waste. The EWC is based on a hazard assessment, rather than an assessment of risk, i.e. a different approach to when evaluating the impact on human health or controlled waters.

The EWC differentiates between hazardous and non-hazardous by identifying hazardous waste entries with an asterisk.

Soils excavated from development sites would normally be classified as one of two 'mirror' entries:

- 17-05-03*: soil and stones containing dangerous substances - hazardous waste (note the asterisk).
- 17-05-04: soils and stones other than those mentioned in 17 05 03 - non-hazardous waste.

The class into which soils fall depends on the levels of contaminants, and the likely form of the compound present. The available test data has been assessed for both the general Made Ground and the infilled dock materials and the output from the WM3 model is summarised in Table 21 below and presented in full in Enclosure Q.

Table 21: Summary of WM3 Assessment

Soils	Waste Classification	EWC Code
General Made Ground	Non-Hazardous Waste	17 05 04
Infilled Dock Materials	Hazardous Waste	17 05 03*

No geo-environmental testing has been undertaken on the shallow natural Blown Sands, however these are likely to be classed as 'non-hazardous' waste. Further testing may be warranted once arisings have been generated to confirm their classification and refine disposal options/costs.

7.6.3 Waste Classification

On the basis of the results of the WM3 assessment, the shallow general Made Ground soils which are likely to be generated as waste arisings by the development may be initially considered 'non-hazardous'. The infilled dock materials are initially considered 'hazardous'. These classifications are initial only, and should be confirmed with waste receivers/hauliers. Further testing may be warranted once arisings have been generated to confirm their classification.

As on any development site, the potential for localised significant contamination cannot be discounted and if any are found during ground works, these would need further classification in terms of waste prior to disposal.

WAC testing may also be requested from disposal destinations to confirm that the waste can be accepted in accordance with their specific permitting/licencing.

7.6.4 Landfill Disposal

9no. no samples of the Made Ground shallow soils have been analysed for Waste Assessment Criteria (WAC) and the results are presented in Appendix R. The samples comprise 5no. infilled dock materials, 3no. general Made Ground and 1no. Blown Sand sample.

We recommend that the chosen receiver site is provided with the full set of laboratory results from the previous and current investigations (including the WAC testing) and our WM3 assessment for them to select the classification of the soils.

A summary of the results for each strata is presented below.

Infilled Dock Materials

The results of 5no. WAC tests indicate that the infilled dock materials would generally satisfy the criteria for ‘inert’ disposal, however the pH levels in all samples exceed the limit for ‘stable non-reactive’. The sulphate levels identified in AS34, 3.3m and AS41, 3.5m also categorise them as stable non-reactive in terms of landfill disposal.

The levels of Total Organic Carbon in all samples (except AS34, 3.3m), would indicate they are hazardous in terms of landfill disposal.

General Made Ground

The results of 3no. WAC tests indicate that the general Made Ground materials would generally satisfy the criteria for ‘inert’ disposal, however the pH levels in all samples exceed the limit for ‘stable non-reactive’ (in terms of landfill disposal).

The levels of Total Organic Carbon in AS4 (0.2m) and all samples (except AS34, 3.3m), would classify the samples as them as stable non-reactive.

Off-site testing undertaken for the Food Store site investigation, indicated that the general Made Ground soils would be classified as stable non-reactive, in terms of landfill disposal, due to elevated levels of Total Organic Carbon.

Blown Sand Deposits

The results of 1no. WAC test indicates that the Blown Sand deposits would generally satisfy the criteria for ‘inert’ disposal, however the pH level exceed the limit for ‘stable non-reactive’ (in terms of landfill disposal).

7.6.5 Imported Materials

Any soils or materials to be imported to site (including Topsoil) should be certified clean and inert, and suitable for use. An appropriate number of samples (depending on the volume of soils imported) should be analysed for an appropriate suite of contaminants, and verification certificates should be provided. Further guidance can be provided by this office if required.

8 Geotechnical Comments

The objective of the investigation was to obtain sufficient information on the geotechnical character and properties of the ground beneath the site to allow an initial assessment of the ground conditions with particular reference to the potential impact and constraints on the proposed developments.

The development layout and design has yet to be finalised and therefore once known some addition work to inform detailed design cannot be discounted.

8.1 Site Preparation and Earthworks

8.1.1 Unexploded Ordnance

As discussed in Section 2.11, a specialist preliminary assessment has concluded that '*a detailed desk study, whilst always prudent, is not considered essential in this instance'.*

*A*lthough no special precautions are considered necessary, a careful watch should be maintained during all excavation and any suspected ordnance identified should be investigated further by specialists. Ordnance awareness is recommended during site inductions.

8.1.2 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed or Himalayan Balsam was identified on the site during the site works. Notwithstanding this, the works were undertaken during the winter months and invasive species may not have been visible. A survey across the site should be undertaken during the summer months to check for any invasive species.

8.1.3 Existing Foundations and Services

As detailed in Section 2.2, a large portion of the site (see Figure 5) is within the area of the former dock, dock slipway sloping masonry wall and partially by the former Smithy. The Smithy was likely demolished sometime in the early 1900's, while the infilling of the dock is identified to have occurred sometime in the 1940's.

It is likely that some underground structures and/or obstructions associated with the above may remain, especially in the area of the infilled dock. No significant obstructions were identified during the current investigation; however, rubble was noted in the south east corner and cobbles and boulders were identified across the site previously. These sub-structures and any others identified during development should be grubbed up within the zone of influence of the development as part of the site preparation works.

Site observations and the Constraints Plan presented in Appendix S indicate the following:

- Underground rising foul sewer main, trending west to east across the southern area of the site. The main extends from the south, where it passes beneath The Portway, before turning north to the west of Site A. It then turns east and passes beneath the south portion of Site A (see Figure 3);
- Underground surface water drains are identified in the west margins along the boundary, trending north and in the east of the site, approximately 5m inside the west boundary, trending north east and north;

- Street light columns are also indicated along the footpath in the north west and electrical cables associated with these will also be present, although they are not shown.
- Overhead BT cables are shown on the plan (Appendix S) to enter from the east of the site and trend south east. However, on inspection, no overhead cables or telegraph poles are present at the site, indicating that the lines and telegraph poles have been removed in the past (sometime between 2016 and November 2018).
- A number of services are also present within the vicinity of the site, including water mains to the north trending west-east along the north of Eastern Promenade road and surface water sewers trending north some 30m east of the site.

The development plan may need to consider the presence of these services and easements, diversion or protection will require agreement with specific providers.

8.1.4 New Services

For new services, flexible pipework and connections should be provided as a safeguard against potential settlements. Consideration could be given to increasing the gradients on sewage connections to mitigate against possible settlements.

8.1.5 Earthworks

We have not been advised that the development requires any significant earthworks. The site is relatively flat and, therefore, no such earthworks are anticipated. If any significant changes in ground level are proposed, further geotechnical advice should be sought from this office.

A review of the risks to construction workers with regards to contamination (including the potential for asbestos in the soils) should be undertaken for any earthworks (see Section 7.1.4).

In line with the published Manual of Contract Documents For Highway Works, Volume 1 Specification For Highway Works Series 600 Earthworks document, preliminary testing of the general Made Ground soils indicate that the Made Ground would be classified (in terms of material re-use) as either general granular (Class 1) or cohesive fill (Class 2). As the material is Made Ground and highly variable, further testing of the soil mass would be required if detailed categorising of the soils is required.

Testing of the Blown Sand indicate it would be generally be classed as General Granular Fill.

It should be noted that this is an initial assessment only and further sampling will be required to formally assess material reuse.

8.2 Geotechnical Risk Register

8.2.1 Updated Geotechnical Risk Register

The desk study (Section 2) identified the following potential geotechnical hazards at the site:

- Shrinkable and Swelling Soils;
- Ground Dissolution;
- Compressible Ground;
- Collapsible Ground;
- Running Sand;
- Volumetrically Unstable Slag Materials;

- Pyritic Ground (include in all reports);
- Excavation Instability;
- Historic Underground Structures/Obstructions;

This has been updated in Table 22 with additional information on these and other potential geotechnical/construction risks identified by the intrusive investigation.

Table 22: *Updated Geotechnical Risk Register*

Hazard	Risk	Comments
Shrinking or Swelling Clays	Negligible	See Section 8.2.1
Ground Dissolution (Soluble Rocks)	Low	See Section 8.2.2
Compressible Ground/ Settlement of Foundations	Moderate	See Section 8.2.3
Collapsible Ground	Very Low	See Section 8.2.4
Running Sand	High	See Section 8.2.5
Volumetrically Unstable Slag	Not reported.	See Section 8.2.6
Sulphate Attack	High	See Section 7.4.2
Excavation Instability	Not reported.	See Section 8.2.7
Historic Underground Structures	Not reported.	See Section 8.2.8

Notes
1. This table updates Table 3 in Section 2.9.1using the results of the intrusive investigation.
2. Further discussion is presented in the following sections.

8.2.2 Shrinking or Swelling Clays

No shallow fine-grained soils have been encountered. Fine grained weathered bedrock at depth will not be affected by proposed planting. The Wind Blown Sands are coarse grained and therefore are not susceptible to changes in moisture content.

8.2.3 Ground Dissolution (Limestone Solution)

As discussed in Section 2.10.4, the site lies in an area susceptible to limestone solution, however no evidence has been identified by the desk study or during previous or current investigation of solution features on the site.

The bedrock is located at depths of greater than 10m bgl, therefore any evidence of any features will unlikely be encountered during any shallow excavations as part of the re-development.

We cannot discount that solution features exist beneath the site, particularly due to its coastal location. These may affect piled foundations due to variations in rockhead depth or the possible presence of natural cavities . Further investigation which may include geophysical surveying may be considered by the purchaser to reduce the uncertainty of potential risks from un-recorded solution features beneath the site.

If any anomalous conditions are encountered, they should be subject to further investigation by an experienced geological engineer.

8.2.4 Compressible Ground

The Made Ground across the site and within the infilled dock comprises a generally coarse-grained stratum of sand, gravel and cobbles. The shallow general Made Ground was visually estimated to be loose and occasionally medium dense, with corrected SPT N-values within the deeper Made Ground (re-worked soils) indicating a general medium dense state.

Field SPT N-values within the coarse infilled dock Made Ground varied generally between 4 and 19, with an average of 8. This indicates a generally loose state in terms of density, with some higher density bands present.

The Blown Sand comprises a generally coarse-grained stratum of sand. Corrected N-values are shown to be generally between 4 and 50+, with an average of 28. Values generally improve with depth, and the sands are generally in a medium dense state.

Due to the areas of the site underlain by the infilled dock, slipway, masonry walls and smithy, it may span areas of shallow Made Ground and areas underlain by these features, which vary vertically and laterally in depth and strength. As a result differential settlement is likely and a deeper piled solution is likely to be the favoured foundation option to avoid potential structural effects. The competent Oxwich Head Limestone bedrock is likely to be of low compressibility and therefore the likely founding strata for a piled foundation solution.

If a building is located outside of the infilled dock slipway, founding in the medium dense Blown Sands may be feasible dependent on proposed loadings, settlement tolerances and construction practicalities. However, further detailed assessment would be required in foundation locations to provide sufficient confidence to enable this. Considering the coarse grained nature of the shallow soils, their compression and subsequent settlement of structures or earthworks at the surface, is likely to occur relatively quickly and probably within the construction period for any shallow foundations.

Consideration of compressible ground with regards to foundation design is presented in Section 8.3.

8.2.5 Collapsible Ground

The unconsolidated/uncompacted Made Ground within the infilled dock and the Wind Blown Sands are potentially susceptible to collapse compression during inundation, if groundwater levels were to increase. Groundwater monitoring suggests that the groundwater levels are generally consistent across the site and neighbouring areas, and tidal influence is limited in this portion of the sea front. Therefore, we consider the potential risk for collapsible ground at the site is low.

8.2.6 Running Sand

Previous and recent monitoring data indicates the groundwater beneath the site to generally be present at depths of around 4m to 6m below surface level. However, shallower groundwater levels have been identified and a careful watch should be undertaken throughout the works for any water ingress. Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 2m depth. For shallow excavations above this level, the potential risk for running sands is considered lower proving that management of surface water run-off is designed appropriately.

Where groundwater ingress is present within the Blown Sand deposits, the potential for running sands is considered high. The design of all excavations or bored foundation solutions (drainage, foundations etc) should consider this hazard. Tidal influence on groundwater levels is not considered to be significant.

8.2.7 Volumetrically Unstable Slag

The general Made Ground was noted to contain minor constituents of slag gravels across the site, however the overall content is not considered to be of significant risk. If any areas of high quantities of slag gravels are identified during the works, they should be removed and replaced with clean inert fill.

Within the infilled dock and former smithy area, a high proportion of the recovered gravels and cobbles were noted to be slag. Some forms of slags are volumetrically stable but, depending on their chemistry, some can be extremely unstable when hydrated, which can lead to significant heave at the surface and damage to buildings and hard surfaces.

Once the proposed developments are finalised, if any proposed construction (of buildings, roads or hard standings) is positioned in this area, further sampling and analysis of the slag materials should be undertaken to determine the risk to the proposed development.

8.2.8 Excavation Stability

Previous and current trial pit investigations on-site and in neighbouring areas have recorded spalling and collapsing of the pit walls within the Made Ground and the Blow Sand deposits.

Support of excavations sides is likely to be necessary for shallow excavations as part of future re-development.

8.2.9 Historic Underground Structures/Obstructions

We understand the masonry associated with the dock slipway and dock remain present beneath the site and old foundations associated with the former smithy also cannot be discounted. Cobbles and boulders have been recorded as occasional to frequent in the dock backfill consisting of slag, metal, rubble etc.

Obstructions/structures will require consideration if a piled design is favoured for the proposed development and where shallow, they may require removal (possibly with large excavators) as part of the site preparation works.

In addition, the design may need to consider the dock wall acting as a ‘hard zone’ and the differential performance between the backfill within the dock/slipway and the natural deposits the either side.

8.3 Foundation Design and Construction

The choice of optimum foundations for the main new structures will depend on the nature of each structure, its foundation loads, and its tolerance to ground movements, with particular reference to the potentially compressible general Made Ground, infilled dock materials and Blown Sand deposits beneath the site and layout. The following should be reviewed once these aspects of the future development have been finalised and the further investigation has been completed.

At this time, we understand that the development will likely comprise typical two-storey residential dwellings with private gardens, as well as flat type buildings (size unknown) and the following recommendations are based on this.

Once the design of the structures are known, the foundation options will need to be reviewed by a geotechnical engineer.

8.3.1 Low Structural Loadings/Shallow Foundations

For properties located outside of the infilled dock, founding in the medium dense Blown Sands above the water table may be feasible dependent on proposed loadings, settlement tolerances and construction practicalities. Shallow spread or raft foundations with some excavation and replacement may be viable. Excavation and replacement and a raft foundation may also be possible in the infilled dock. However, further detailed assessment would be required in foundation locations to determine feasibility.

The shallow coarse grained Blown Sand Deposits or dock infill at the site may be suitable for shallow treatment such as vibratory ground treatment improvements, however it should be noted that such treatment may not achieve the required bearing capacity for higher loaded buildings (e.g. if multi-storey flats are proposed). We understand dynamic compaction has also been utilised on sites where similar ground conditions exist (i.e. thick Blown Sands), however due to the sites proximity to neighbouring developments and associated constraints, detailed consideration of potential effects would be required. Consideration of potential vibration effects on saturated sands on-site and off-site would be required (i.e. liquefaction) as part of any ground treatment.

If shallow foundations are desired and potentially ground improvement works are necessary, further assessment and careful design will be required, including consideration of the potential impact on adjacent structures and services.

8.3.2 High Structural Loadings/Deeper Foundations

The presence of potentially compressible soils at shallow depth possessing variable strength and locally low bearing and high compressibility properties (see Section 8.2.3) and possible high loads for the proposed development could lead to significant and unacceptable settlements for significant structures constructed on shallow footings of any form. Therefore, we consider that piled foundations are likely to be required for these buildings.

We consider that the piled foundations should be taken down to the competent Oxwich Head Limestone bedrock at minimum depths of approximately 10m below ground level. The following criteria should be considered for pile design:

- The magnitude and resulting effect of different structural loadings, including any machine vibration effects (e.g. liquefaction within deeper saturated sands);
- Possible impacts on neighbouring structures and underground service;
- Pile/soil/structure interaction effects;
- The potential presence of obstructions which includes former dock masonry and large boulders within the Made Ground and the potential for buckling;

The final safe working load on the pile will be dependent on the pile type, diameter and length of the piles, the penetration into the bearing stratum, and the settlement tolerances required.

Based on the available information, and given the site constraints, it is likely that the most appropriate system is likely to be a driven, displacement pile system, which may prove most efficient for the particular ground conditions, particularly as the quantity of arisings will be limited. The use of driven piles should only be considered if vibrations and environmental constraints can be maintained within acceptable limits, with regard to the proximity of existing buildings and services.

Alternatively, a non-displacement vibration-less technique such as bored piles or continuous flight auger piles, however, this technique will generate arisings at the surface which will need to be re-used or disposed of under a materials management plan. Running sands within the Blown Sand deposits when groundwater is encountered may also create difficulties with this technique.

Discussions should be held with specialist piling contractors to obtain specific piling proposals based on their particular proprietary system and to evaluate costs. The piling contractor should be asked to provide a performance specification and in particular the magnitude of total and differential settlements which could be guaranteed. Test loading will be required on a proportion of the piles to confirm that they are adequate to carry the design working loads, and the contractor should monitor closely the pile installations to satisfy himself that the ground conditions encountered are as good as, or better than, those assumed in his design. Care should be taken to ensure that piles are not stopped short on obstructions and that all are taken down into the coarse-grained glacial soils.

If required, further guidance on design criteria can be given by this office when structural loadings, design, layout and cost implications have been finalised.

8.4 Floor Slab Foundations

Due to over 600mm of Made Ground in some areas across the site we consider that ground bearing floor slabs would not be feasible without treatment of the ground prior to construction, for example through excavation and replacement. Alternatively, suspended floor slabs could be used or incorporated into a piled foundation design if this is the preferred option.

Shrinkage and swelling will not require consideration due to the coarse grained nature of the Wind Blown Sands.

The floor slab design may need to consider the gas risk posed and the protection measures required in accordance with BS8485:2019.

Further advice can be provided by this office once the floor slab designs have been finalised and sufficient gas monitoring has been undertaken.

8.5 Retaining Wall Design

We are not aware of any retaining structures being required in the development.

8.6 Pavement Design

We understand that vehicle access roads and areas of hardstanding are proposed at the site.

8.6.1 Design CBR Value

An assessment of the likely CBR values in areas of grade (no change in ground level) has been undertaken using a dynamic cone penetrometer (DCP). Testing was undertaken at 16no. positions (DCP01 to DCP8, DCP10 and DCP16 to DCP19). The results of the DCP testing are converted to CBR values using correlations published by the Highways Agency (2008).

The DCP results and the correlated CBR values are presented in Appendix J. From the DCP testing, we consider that the following CBR values are appropriate for the soils beneath the site surface (excluding the surface Topsoil/Car Park surface).

Table 23: *Summary of Corrected CBR Values from DCP Testing (beneath the surface Topsoil)*

DCP Ref.	Location	Depth range	CBR Value	Probable Soils
DCP1	South East	0.2 – 0.5m 0.5 – 0.8m	5 - 10% 3 - 4%	Coarse Made Ground (dock infill)
DCP2-DCP4	South	0.2 – 0.8%	5 - 10%	Coarse Made Ground (dock infill)
DCP5	South West	0.2 – 0.6m 0.6 - 0.9m	>10% 2 – 4%	Made Ground & Blown Sand
DCP6	South West	0.2 – 0.9m	>10%	Made Ground & Blown Sand
DCP7 & DCP8	Central South	0.2 – 0.9m	>10%	Coarse Made Ground (dock infill)
DCP10	East	0.2 – 0.4m 0.4 – 0.7m 0.7 – 0.9m	3 - 5% 2.5 - 4% 5-10%	Made Ground & Blown Sand
DCP11 – DCP13	North/North West	0.2 – 0.9m	>10%	Made Ground & Blown Sand
DCP17 & DCP18	North East	0.2 – 0.4m 0.4 – 0.9m	5 - 10% >10%	Made Ground & Blown Sand

Notes
1. Some thin slightly lower strength bands present.
2. Soils with CBR values less than 2.5% (highlighted in red) are not suitable for road pavements without treatment.
3. Correlation based on Highways Agency (2008) methodology.

Based on the above testing, we consider that a Design CBR value of 3 to 5% would likely be suitable for preliminary design purposes for the shallow Wind Blown Sand and Made Ground. However, locally lower values may be achievable in the Made Ground (less than 2.5%).

Considering their coarse-grained nature, improvement works could be undertaken on the Wind Blown Sand and Made Ground to improve design values.

The near-surface soils comprise coarse-grained materials and we would not expect the Design CBR value to vary to any significant degree seasonally or in the long term.

The final sub-grade should be inspected by a qualified engineer, and any soft or loose material removed and replaced as necessary, to ensure that the Design CBR value is achieved. It is further recommended that the sub-grade be proof rolled with a suitable roller prior to the placement of the sub-base materials. To improve the sub-base performance, the use of a suitable geo-grid may be considered.

We consider that it would be prudent to re-measure the CBR values of the sub-grade on exposure to confirm that they are equal to or better than the values measured in this investigation (as recommended by the Highways Agency [HA, 2009a]). If the CBR values in the sub-grade are found to be lower than the Design CBR, the subgrade must be improved to achieve the Design CBR or the road pavement foundation redesigned.

8.6.2 Susceptibility to Frost Action

The near surface coarse grained soils are considered to be non-frost susceptible.

8.7 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators. Old structures/obstructions may require higher capacity machines for their removal (e.g. around the former smithy, former masonry wall and infilled dock etc).

Support of excavations sides is likely to be necessary for shallow excavations as part of future re-development and careful temporary works design will be needed which should include management of surface water run-off.

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 2m depth, however due to seasonal variations and localised perched water bodies, it cannot be totally discounted. Where water ingress occurs, it is likely that pumping from screened sumps within shallow excavations will be adequate.

8.8 Soakaway Drainage

No soakaway infiltration testing has been undertaken at the site however, based on the findings of the investigation (and soakaway testing undertaken for the adjacent Food Store site), some preliminary comments can be made.

ESP undertook a soakaway assessment in December 2019 for the proposed Food Store site, located directly adjacent to Site A to the north and west (see Figure 1). The testing indicated that the infiltration capacity of the Blown Sands was identified to be good and 2no. tests were completed, in line with the published guidance (BRE365, 2016).

The Wind Blown Sands beneath Site A are predominantly coarse-grained in composition and are likely to have similar infiltration characteristics as those observed within the Wind Blown Sand deposits within the Food Store investigation. Soakaway infiltration testing in accordance with BRE 365 should be undertaken at the proposed positions and depths of soakaways to confirm the likely infiltration rates. It should be noted that due to the stability of the Blown Sand deposits, clean aggregate will be required to fill the pits for soakaway testing, to maintain stability during the assessment.

Soakaways would not be suitable in the Made Ground soils or infilled dock materials without detailed risk assessment to demonstrate they would not pose a contamination risk to the identified controlled waters.

The infiltration stratum at the site would be the Blown Sand deposits, which is in hydraulic continuity with the underlying Oxwich Head Limestone bedrock, which is classed as a Principal aquifer and the groundwater within is vulnerable to pollution. The Environment Agency has a general policy that no direct discharge of surface run-off would be accepted in vulnerable groundwater aquifers, however as indicated in this report saline intrusion has degraded its quality.

We recommend that enquiries are made to Natural Resources Wales (who have taken over the role of the Environment Agency) to identify whether they would allow such discharge at the site, if soakaways are required. As a minimum, risk mitigation measures such as oil interceptors are likely to be required.

Soakaways should be positioned a minimum of 5m from all foundations. Consideration of the dissolution risks associated with the underlying limestone bedrock would also be required. Any additional works undertaken to determine the potential risk from solution features would likely inform this.

9 Recommendations

The objective of the investigation was to obtain information on the character and properties of the ground beneath the site, to allow an initial assessment of potential geotechnical and geo-environmental risks and constraints, to enable prospective bidders to make decisions regarding scheme layout and costings associated with construction and site remediation.

Using previous investigation information and current findings we consider this has largely been achieved for Site A. However, certain aspects require more clarity.

Once detailed development design layouts and proposals are known and the site specific regulatory requirements (local authority and NRW) are confirmed as part of the associated planning conditions, some additional investigation, monitoring and assessment is recommended/may be required to further assess contamination risks initially assessed or to robustly finalise the geotechnical design advice provided in this report.

We recommend further work should include the following geo-environmental and geotechnical investigation:

Geo-Environmental

1. Once the development proposal are known, we recommend some additional testing for asbestos is undertaken in proposed landscaped areas to confirm the risk where there is an exposure potential to long term end users. Additional testing could also be undertaken to further assess risks to construction workers.
2. We recommend that an asbestos specialist should be employed to undertake further assessment of the risk posed by asbestos present in the soils to construction and maintenance workers and the general public prior to any development. Input may also be required for human health risks dependent on the results of the additional testing in landscaped areas.
3. Considering the past significant industrial history and the sensitive residential end use, there is a likely requirement for remedial action in landscaped areas, particularly within the infilled dock. Once the development proposal are known, we recommend additional contamination testing and assessment is undertaken in proposed landscaped areas to confirm the risk to human health.
4. In accordance with CLR11, the risk mitigation strategy should be detailed within a remediation strategy and implementation plan and supervised and validated by a geo-environmental specialist. On completion, a validation report should be prepared to demonstrate to regulators and insurance providers that the risk has been successfully mitigated.
5. We consider that the overall risk to controlled waters from the development of the site is likely to be low to moderate. Discussion with NRW will be required to confirm their opinion on the sensitivity of the aquifers to confirm the risk. We cannot discount that additional testing and assessment may be requested in accordance with specific local authority and NRW requirements which are currently unknown.
6. Ground gas protection measures in accordance with a CS-2 classification is required. Radon protection measures are also necessary. If during construction any organic materials are encountered, they should be excavated and replaced.
7. Previous testing may indicate that the sulphate risk from the Made Ground within the infilled dock is greater than that measured during the current ESP investigation (DS-3), however there is some uncertainty with regards to this classification. Further testing would be required to confirm the required design class in the infilled dock.
8. A landscaping specialist should be consulted with regards to future planting across the site.

Geotechnical

1. Once the development location, proposed loadings and settlement tolerances are known, the available information should be reviewed to confirm the potential foundation options that have been initially presented within this report. If a shallow design is desirable, further detailed assessment would be required to determine feasibility.
2. We understand the masonry associated with the dock slipway and dock remain present beneath the site and old foundations associated with the former smithy also cannot be discounted. Cobbles and boulders have been recorded as occasional to frequent in the dock backfill consisting of slag, metal, rubble etc. Obstructions/structures will require consideration if a piled design is favoured for the proposed development and where shallow, they may require removal (possibly with large excavators) as part of the site preparation works.
3. The development plan will need to consider the presence of the services indicated to be present beneath the site and easements, diversion or protection will require agreement with specific providers.
4. Within the infilled dock and former smithy area, a high proportion of the recovered gravels and cobbles were noted to be slag. Once the proposed developments are finalised, if any proposed construction (of buildings, roads or hard standings) are to be positioned in this area, further sampling and analysis of the slag materials should be undertaken to zone their extent, determine their expansion potential and potential risks to the proposed development.
5. Support of excavations sides is likely to be necessary for shallow excavations as part of future re-development and careful temporary works design will be needed which should include management of surface water run-off.
6. We cannot discount that solution features exist beneath the site. These may affect piled foundations due to variations in rockhead depth or the possible presence of natural cavities . Further investigation which may include geophysical surveying could be considered by the purchaser to reduce the uncertainty of potential risks from un-recorded solution features beneath the site.
7. If soakaway drainage is desired, we recommend that enquiries are made to Natural Resources Wales to identify whether they would allow such discharge at the site considering the designation of the underlying aquifers. Based on testing undertaken for the adjacent proposed Food Store site, the Wind Blown Sand will likely be a suitable infiltration stratum, however soakaway infiltration testing in accordance with BRE 365 should be undertaken at the proposed positions and depths of soakaways to confirm the likely infiltration rates.

Proposals for the above can be provided by ESP once development proposals have been formalised.

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