Quantum Geotechnical

PEMBROKE DOCK PORT – PHASE I GROUND INVESTIGATION

INTERPRETATIVE REPORT

Report No. G624/IR

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April 2015

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0. FOREWORD

The following Conditions and Notes on Site Investigation Procedures should be read in conjunction with this report.

0.1. General

Recommendations made and opinions expressed in the report are based on the strata observed in the excavations, together with the results of site and laboratory tests. No responsibility can be held for conditions which have not been revealed by the Exploratory Holes or which occur between Exploratory Holes. Whilst the report may suggest the likely configuration of strata, both between Exploratory Holes and below the maximum depth of investigation, this is only indicative and liability cannot be accepted for its accuracy.

Unless specifically stated, no account has been taken of possible subsidence due to mineral extraction below or close to the site.

0.2. Investigation Procedures

Rotary open-hole and coring, and trial pitting techniques for ground investigation have been employed within the project. All Exploratory Hole operations, sampling and logging of soils, rocks and in-situ testing complies with the recommendations of the British Code of Practice BS 5930 (1999), 'Site Investigations' as superseded in part by BS EN ISO 14688-1 (2002) and 14688-2 (2004), British Code of Practice BS 10175 (2001) 'Investigation of Potentially Contaminated Sites' and BS 1377: 1990, 'Methods of Test for Soils for Engineering Purposes'.

0.3. Routine Sampling

Representative bulk, disturbed and environmental samples of the different strata are taken following completion of logging. These samples are sealed and labelled in clear plastic bags and 2kg plastic tubs. Soil samples obtained for environmental testing are sampled and sealed in borosilicate amber jars or in specialist vessels where required. All samples are returned from site to QGL's laboratory for controlled storage within 24 hours of sampling to await test scheduling/requirements.

0.4. In-Situ Testing

In-situ testing comprised:

- Standard (/Cone) Penetration Tests in Boreholes

0.5. Groundwater

Where possible, the depth of entry of any influx of groundwater is recorded during the course of excavation or boring operations. The rate of inflow into the excavation or borehole is monitored during the course of the excavation or during boring procedures. Upon encountering any water strikes, work is temporarily halted and the water levels monitored for a standard twenty minute period recording the change in water level at the end of the twenty minutes.

Groundwater conditions observed in the excavations are those appertaining to the period of investigation. It should be noted, however, that groundwater levels are subject to diurnal, seasonal and climatic variations and can also be affected by drainage conditions or other causes.

0.6. Retention of Samples

After satisfactory completion of all the scheduled laboratory tests on any sample, the remaining material is discarded. Further to notifying the Engineer/ Client with one week's notice all soil and/or rock samples will be discarded 28 days after submission of the approved final report.

1. INTRODUCTION

1.1. General

Upon the instructions of the Client, Milford Haven Port Authority, Quantum Geotechnical Limited (QGL) was commissioned to undertake a Phase II Ground Investigation on a brownfield parcel of land located at the eastern end of the Port of Pembroke Dock. The works are to investigate and assess the ground conditions in preparation for infrastructure and buildings relating to the potential construction of a tidal lagoon power generation scheme.

In this interpretative report, a factual account of the fieldwork, the strata encountered including contamination and groundwater observations are detailed. Guidance and recommendations on allowable bearing capacities, foundation types, and general site ground stability and drainage are given in the interpretative report. An assessment of contamination issues is also made.

1.2. Purpose of Ground Investigation

The objective of the ground investigation is to identify the underlying ground conditions and provide geotechnical and geo-environmental recommendations for the currently anticipated site end use.

1.3. Scope of Work

The general scope of work undertaken in the preparation of this assessment was as follows:

- Conduct an intrusive ground investigation as specified by the Client to ascertain further geotechnical and environmental data for the proposed tidal lagoon project.
- Provide an interpretative report offering recommendations on site suitability for the proposed development with recommendations on geotechnical and environmental issues.

General notes on the techniques employed by Quantum Geotechnical are described in the Foreword together with the limitations inherent in carrying out ground investigation work.

2. SITE DETAIL

2.1. Site Description

The site is an area of relatively open land at the eastern end of the Port of Pembroke Dock, used primarily for the storage and logistical operations of the sand yard operated by LaFarge Tarmac at the most north-easterly extent of the site. The site also contains an existing hanger building, the afore-mentioned sand yard, Port authority offices, and a weigh bridge. Much of the site has tarmac cover or hard-core and concrete surfaces beneath a thin veneer of loose sand or gravel. To the north of the site is the dockside and Milford Haven water course.

Access to the site is through Dock Gate 1 from the town of Pembroke Dock. The whole site is accessible by ordinary vehicles, plant and on foot.

A Site Location Plan is presented as Figure 1 in Appendix I.

2.2. Topography

The site is at an elevation of between approximately 5 and 12.5 metres above ordnance datum (m AOD) and is generally flat lying. Changes in elevation are caused by different levels and elevations of concrete base or artificially engineered ground terraces.

2.3. Hydrology and Hydrogeology

The Environment Agency website “What’s in your backyard?” shows the site to be underlain by a Principal bedrock aquifer which is capable of supporting water supply and/or river base flow on a strategic scale and is noted as being of high vulnerability. The superficial deposits underlying the site are not recorded as an aquifer of any sort but superficial deposits in the Milford Haven watercourse north of the site is recorded as a secondary undifferentiated aquifer. The site is not recorded as being within a groundwater protection zone.

The site is not shown to be at risk from flooding from rivers, seas, surface water or reservoirs.

2.4. Statutory Service Information

QGL undertook full Cable Avoidance Tool (CAT) scans of each exploratory hole location as well as consulting detailed service plans prior to breaking ground. Safe digging practices in accordance with HS(G)47 were employed when breaking and excavating grounds with all traceable services demarcated prior to works commencing. A record of existing and former service plans were provided by the Client for use in conjunction with a CAT and signal generator.

2.5. Published Geology

The published geological map covering the site, British Geological Survey (BGS) Sheet 228 Haverfordwest (Solid and Drift) shows the site to be underlain by middle Carboniferous Main Limestone of the Lower- and Upper Avalonian.

Geological maps do not note any superficial deposits under the site, but it would not be unusual to find river terrace deposits or alluvial gravels due to the proximity of the Milford Haven water course. Additionally it is to be expected that there is Made Ground underlying the site due to the industrial history of the port.

An extract of Sheet 228 Solid edition is presented as Figure 2, Appendix I.

3. FIELDWORK

3.1. General

Trial pitting fieldworks were carried out between the 10th March and the 12th March 2015 inclusive and rotary drilling was carried out between 11th March and 16th March 2015 inclusive. Geophysical surveying was carried out on the 16th and 19th March 2015.

Site supervision and attendance by an Engineering Geologist from Quantum was undertaken on all aspects of the intrusive site works and subsequent reinstatement works of all exploratory hole locations.

A summary of the fieldworks is outlined below;

- 20 No. Machine excavated trial pits;
- 4 No. Rotary drilled boreholes;
- Geotechnical and geo-environmental laboratory soil testing sampling; and
- Geophysical survey of the site (full report presented within Appendix VI)

3.2. Exploratory Hole Locations

The exploratory hole locations were set out by a QGL Engineering Geologist in accordance with plans provided by the Client. Where services or unsuitable upper ground surface conditions were encountered trial pits were moved or surface obstructions broken out by hydraulic pecker.

An Exploratory Hole Location Plan is presented as Figure 3 in Appendix I, and exploratory hole coordinates to local grid are presented on the engineer's log sheets in Appendices II

3.3. Machine Excavated Trial Pits

20No. machine excavated trial pits were undertaken during the fieldwork period at locations detailed on the exploratory hole plan presented as Figure 3 in Appendix I. Table 1 details the termination depths of the trial pits, strata at the termination depth and reasons for termination.

In the course of the excavation of trial pits TP4, TP8, TP9, TP10 and TP14 a significant thickness of concrete was encountered at the near surface and at 0.5mBGL for TP14 and, in agreement with the Client, a hydraulic breaker was mobilised to site in order to excavate to depths beyond the obstruction should it be encountered in subsequent holes.

A complete set of engineer's trial pit logs are presented in Appendix II.

Table 1: *Machine excavated trial pits termination details*

Exploratory Hole ID	Termination Depth (mbgl)	Terminating Strata	Notes/Reason for Termination
TP1	0.65	Made Ground	Terminated on suspected bedrock.
TP2	0.3	Made Ground	Terminated on suspected bedrock.
TP3	2.1	Made Ground	Terminated on suspected bedrock.
TP4	3.9	Made Ground	Terminated on suspected bedrock.
TP5	2.55	Silty sandy CLAY with cobbles	Terminated on suspected bedrock.
TP6	2.6	Silty sandy clayey GRAVEL with cobbles	Terminated on suspected bedrock.
TP7	2.9	Silty SAND	Terminated due to pit collapse.
TP8	1.2	Made Ground	Terminated due to concrete obstruction.
TP9	3.5	COBBLES and BOULDERS	Terminated on suspected bedrock.
TP10	3.5	GRAVEL with boulders	Terminated on suspected bedrock.
TP11	1.0	Made Ground	Terminated due to rebar concrete obstruction.
TP12	0.3	Made Ground	Terminated due to relic service obstruction.
TP12A	1.2	Made Ground	Terminated due to limestone obstruction.
TP13	3.3	Made Ground	Terminated due to pit collapse.
TP14	3.5	Made Ground	Terminated due to hard digging.
TP15	3.2	Gravelly SAND with cobbles	Terminated due to pit collapse.
TP16	2.9	Made Ground	Terminated due to pit instability.
TP17	1.8	Made Ground	Terminated due to pit instability.
TP18	0.9	Made Ground	Terminated due to suspected bedrock.
TP19	1.3	Made Ground	Terminated to obstructions and hard digging.

3.4. Rotary drilling

4No. rotary drilled boreholes were undertaken to establish depth to bedrock using open-holing techniques and to recover between 3 and 5 metres of rock core using rotary coring techniques. Full Engineer's logs are presented within Appendix III and locations provided within Figure 3 Exploratory Hole Location Plan.

Table 2: *Rotary drilling termination details*

Exploratory Hole ID	Termination Depth (mbgl)	Terminating Strata	Notes/Reason for Termination
BH1	9.1	MUDSTONE / CLAY	5.5m of core drilled.
BH2	8.9	METAMORPHIC	5m of core drilled.
BH3	13.5	LIMESTONE	6.5m of core drilled.
BH5	20	POSSIBLE WEATHERED LIMESTONE[1.]	20m drilled, no core recovery.

[1.] *Denotes Driller's Description*

3.5. In-Situ Testing

3.5.1. Standard Penetration Testing

Standard penetration tests (SPTs) were undertaken throughout the made ground and superficial deposits at 1.00m centres within open-hole drilled boreholes.

This is a dynamic test as described in BS1377:1990 - Part 9 and is a measure of the density of the soil or rock. Within fine grained or cohesive soils, the test incorporates a small diameter tube (650mm length, 50mm external diameter and 35mm internal diameter) with a cutting shoe known as the 'split barrel sampler'. The sampler is forced into the soil dynamically using blows from a 63.5kg hammer dropped through 760mm.

The sampler is initially advanced 150mm into the soil with seating blows, then the number of blows required to advance the sampler each 75mm increment up to a depth of 300mm is recorded. This cumulative total number of blows over the 300mm test is referred to as the "N" value. For coarse gravels and bedrock the split barrel is replaced by a 60° cone. SPT results are detailed within the relevant Borehole Logs in appendix III.

3.6. Soil and Groundwater Sampling

Bulk, disturbed and environmental samples were taken within the overlying superficial / Made Ground deposits for strata identification and laboratory testing purposes. All samples are returned from site to Quantum's laboratory for controlled storage within 24 hours of sampling to await test scheduling/

requirements. Sample type and sample depth are all recorded on the Engineering Geologist's Exploratory Hole Logs found within the appropriate Appendix.

4. LABORATORY TESTING

4.1. General

The laboratory testing was scheduled by the Client and comprised a number of geotechnical and geo-environmental tests on selected soil samples obtained during the investigation.

4.2. Geotechnical Laboratory Testing

All the geotechnical soil testing work was carried out in accordance with the procedures stipulated in the various sections of BS 1377:1990 Parts 1 - 9 Methods of test for soils for civil engineering purposes. Table 3 details the tests undertaken.

Table 3: *Geotechnical laboratory testing summary*

Type of Test	Standard	Number of Tests
Moisture Content	BS1377:1990 Part 2	14
4 Point Liquid Limit and Plastic Limit	BS1377:1990 Part 2	2
Particle Size Distribution by Wet Sieve	BS1377:1990 Part 2	13
Particle Size Distribution: Sedimentation by hydrometer	BS1377:1990 Part 2	3
Point Load Testing (Rock)		5
Rock Moisture Content	ISRM/ BS1377/2/3.32/2	5

A full set of geotechnical laboratory test certificates are provided within Appendix IV.

4.3. Geo-environmental Laboratory Testing

Geo-environmental testing was carried out on selected soil samples gained from the ground investigation. Table 4 details the geo-environmental testing undertaken on samples obtained and results are included within Appendix V.

Table 4: *Geo-environmental laboratory testing summary*

Type of Test	Standard/ Accreditation	Number of Tests
Metals (As Ba Be Cd Cr Cu Hg Ni Pb Se Vn Zn B)	MCERTS	4 soil
Inorganics (SO_4 Sulphide S Cn Organic Matter)	MCERTS	4 soil
BRE SD1 – inc. Water Soluble Sulphate 2:1 extract & pH	BS1377:1990 Part 4	6 soil
Asbestos screen and ID	ISO 17025	2 soil

5. GROUND CONDITIONS ENCOUNTERED

5.1. General

The sequence of deposits encountered during the investigation is detailed within the Engineering Geologist's logs presented within Appendices II and III. The following sections summarise the findings of the exploratory holes.

5.2. Ground Conditions

A summary of the ground conditions encountered, including the depth to the base of each stratum, is provided in Table 5.

Table 5: *Generalised sequence of strata encountered*

Stratum	Typical Description	Typical Depth Ranges (mbgl)	Notes
MADE GROUND 1 – Granular	Loose to medium dense, brown grey, sandy, fine to coarse GRAVEL with frequent angular to subangular cobbles and boulders including slag and clinker material and pieces of broken brick and metalwork.	GL – 2.00m	Encountered in most trial pits
MADE GROUND – Obstructions	Sections of brick wall with mortar, limestone square-cut blockwork, and metal work and rebar concrete obstructions encountered in a number of pits.	0.50 – 1.50m	Encountered in TPs 8, 9, 10, 11, 12A
MADE GROUND 2– Cohesive	Firm, red brown, very gravelly CLAY with frequent to occasional angular to subangular cobbles.	1.00 – 3.00m	Encountered in most trial pits
WEATHERED BEDROCK	Angular to subangular limestone cobbles and boulders	0.65 – 4.00m	Highly variable throughout the site.
BEDROCK - Limestone	Strong to very strong, medium grey, fine grained, LIMESTONE with fractures indicating in-situ weathering. Occasional occurrence of calcite mineralisation within rock mass. Occasional occurrence of clay mineralisation along fracture planes.	3.60 – unknown	Encountered in all boreholes.
BEDROCK – Metamorphic	Very strong, medium yellow brown, thinly to thickly laminated, medium grained, METAMORPHIC rock with discolouration weathering and occasional occurrence of quartzite mineralisation nodules.	7.60 – 8.90m	Encountered in BH1 and BH2 only.

5.2.1. Made Ground

Made Ground was encountered in all exploratory holes undertaken as part of the fieldwork. Initial top layers of between 0.05 and 0.1m thick comprised tarmac or sub-base hard core cover sitting on top of a highly variable mixture of loose to medium dense sandy gravels, in some cases silty, and in all cases with frequent or occasional angular to subangular cobbles. Much of the made ground contained fragments of slag or clinker, brick work, concrete fragments, metal work, wood, and some derelict services. Standard Penetration Tests carried out during open-hole drilling through superficial deposits recorded values of between 19 and 48, with a mean value of 26 over measurements taken in the upper 3 metres of superficial deposits.

A number of trial pits encountered concrete slabs immediately below the surface which required breaking out by hydraulic pecker. Many trial pits encountered buried obstructions such as squared-off limestone blockwork, bricks and mortar wall structures, and large pieces of metal bars, rods and sheets. Some trial pits encountered relic buried services in the form of wires, drains and pipes.

Made ground in some pits, and at variable depths, has a more cohesive character. It is characterised as a firm, very gravelly clay with frequent cobbles and boulders. The cohesive strata are typically separated from the bedrock by a light grey yellow sandy coarse gravel.

5.2.2. Limestone Bedrock

Encountering what is interpreted as bedrock in the trial pits, was preceded by a weathered zone of fractured and broken up rock which was recovered by the machine bucket as angular to subangular cobbles and boulders amongst a sandy coarse gravel matrix.

5.2.3. Metamorphic Bedrock

BH1 and BH2 recovered rock which was mildly metamorphosed in nature, characterised by being very strong, thinly to thickly laminated medium to coarse grained sandstone which had been subjected to some mild metamorphosis. Such an interpretation has been made due to the very strong nature of the rock, mild foliation of minerals, and occasional nodules of pure quartzite mineralisation.

5.3. Groundwater Conditions

Groundwater ingress into exploratory holes was recorded and detailed on the exploratory hole logs presented in Appendices II and III and is summarised in Table 6. The groundwater conditions observed in these exploratory holes are those appertaining to the period of the investigation. However, it should be noted that groundwater levels are subject to diurnal, seasonal and climatic conditions or may vary due to other causes. No groundwater was encountered within the trial pits only the boreholes.

Table 6: *Summary of Groundwater within exploratory holes*

Exploratory Hole	Depth Encountered (mbgl)	Depth Following 20min Observation Period (mbgl)	Remarks
BH1	-	-	None encountered
BH2	7.9	7.1	Medium inflow
BH3	12.0	11.8	Slow inflow
BH5	3.8 & 9.0	3.6 & 7.6 respectively	Medium and fast inflow respectively

5.4. Visual Evidence of Soil Contamination

There was no visual evidence of contamination in any of the trial pits. In TP3 there was a faint odour of domestic refuse and rotting material but there was nothing uncovered in the ground which obviously corresponded to the smell. TP10 gave off an odour of burnt wood and there was associated burnt wood material recovered during excavations. Burnt wood recovered from the pit was in the form of individual items within the made ground and material arisings were not considered to be part of a larger strata of burnt material waste.

5.5. Visual Evidence of Contaminated Groundwater

No evidence of groundwater contamination was encountered during the fieldworks.

5.6. Visual Evidence of Contaminated Surface Water

There were no indications surface waters or controlled waterways were contaminated on or adjacent to site during the fieldworks.

5.7. Evidence of Buried Structures

Concrete required breaking out immediately below the upper ground surface in TPs 4, 8, 9, 10 and at a depth of approximately 0.5m in TP14. Although no identifiable structures were uncovered during trial pitting works, evidence of buried structures was found in the form of squared-off blocks of limestone block work, possibly part of the jetties and slipways which are known to lie under some parts of the site. Concrete pads and reinforcement bar were encountered in some pits as well are brick and mortar work, suggestive of relic structures under the site and since covered over by the made ground.

6. GEO-ENVIRONMENTAL CONSIDERATIONS

6.1. General

The proposed development, at time of writing, is a new tidal lagoon power generation facility.

The potential risks to the development have been assessed by consideration of the potential pollution linkages (PPL). For a risk to exist there must be a source of contamination, a receptor that may be harmed, and a pathway by which the receptor could be exposed to the contaminant. Only when all three factors are present can a pollution linkage, and consequently a risk, exist. The conceptual site model (CSM) considers all three elements and the potential for pollution linkages that may exist.

The information gained from the land use assessment has been collated to identify the potential pathways that may exist between any contamination source and its receptors. Each of these components is highlighted in Tables 7 to 9 below by considering past land uses of the site.

Table 7: *Conceptual Site Model: Existing Pollutant Linkages Onsite to Onsite*

Potential Sources onsite	**MADE GROUND -** Possible Heavy Metals, Total Petroleum Hydrocarbons, Polycyclic Aromatic Hydrocarbons and Asbestos
Potential Pathways and Receptors Onsite	
Dermal contact with contaminated soils – dermatitis. Inhalation of dust or land gas emissions from Made Ground and organic soils.	**Future Site End Users including Visitors, Workers and Construction Workers.**
Leaching of mobile contaminants.	**Groundwater and Milford Haven watercourse**
Chemically aggressive **contaminants** identified at raised concentrations.	**Buildings** and **services.**

Table 8: *Conceptual Site Model: Existing Pollutant Linkages Onsite to Offsite*

Potential Sources onsite	**MADE GROUND -** Possible Heavy Metals, Total Petroleum Hydrocarbons, Polycyclic Aromatic Hydrocarbons and Asbestos
Potential Pathways onsite to Receptors Offsite	
Inhalation of land gas emissions from Made Ground and organic soils. Dust migration and dust inhalation of Made Ground, particularly during construction phase.	**Future Site End Users including Visitors, Workers and Construction Workers.**
Leaching and aqueous phase migration of mobile contaminants, particularly during construction phase.	**Groundwater and Milford Haven watercourse**
Chemically aggressive mobile contaminants identified at raised concentrations.	**Buildings** and **services.**

Table 9: *Conceptual Site Model: Existing Pollutant Linkages Offsite to Onsite*

Potential Sources offsite	**POSSIBLE MADE GROUND -** Heavy Metals, Total Petroleum Hydrocarbons, Polycyclic Aromatic Hydrocarbons **CURRENT/HISTORIC INDUSTRIAL USAGE -** Heavy Metals, Total Petroleum Hydrocarbons, Polycyclic Aromatic Hydrocarbons
Potential Pathways offsite to Receptors onsite	
Leaching of mobile contaminants.	**Groundwater and Milford Haven watercourse**
Chemically aggressive mobile contaminants identified at raised concentrations.	**Buildings and services.**

By way of undertaking the intrusive site investigation including geo-environmental laboratory testing, the CSM can be revised and reviewed to take account of the investigation findings.

6.2. Risk to Human Health

By adopting the CLEA approach to human health risk assessment, the proposed development land use must first be accordingly classified. The least sensitive model, commercial/industrial guidelines, has been adopted for the Human Health Risk Assessment. Guidance notes on the CLEA assessment are provided in Appendix V along with the Geo-environmental Laboratory Test Results.

6.2.1. Heavy Metal and Inorganics

As indicated by the test certificates (summarised in Table 10) all concentrations of heavy metal and sulphate derived analytes are below the relevant Soil Guideline Values (SGV's) or Generic Assessment Criteria (GAC) for commercial/industrial site end use.

Table 10: *Summary of Metals and Inorganics Test Results*

Determinand	Results Range (mg/kg)	CLEA (2009), CLEA (2002) *& LQM/CIEH (2007)* Soil Guideline & Generic Assessment Criteria (mg/kg) Commercial Concentration Limits	Exceedances
Arsenic	9.3 - 34	640	no
Boron (water soluble)	0.9 – 1.	NYS	-
Cadmium	<0.2 – 1.3	230	no
Chromium	13 - 15	5,000	no
Copper	33 - 260	*71700*	no
Lead	60 - 980	1100-6000*	no
Mercury	<0.3 – 6.8	40	no
Nickel	17 - 32	1,800	no
Selenium	<1.0	13,000	no
Vanadium	17 - 21	*3160*	no

Zinc	76 - 340	*665,000*	no
Cyanide (Free)	<1	NYS	
Cyanide (Complex)	<1	NYS	
Cyanide (Total)	<1	NYS	
Total Sulphur as SO_4	140 - 1400	NYS	
Total Sulphate	440 - 1900	NYS	
pH Value	7.7 – 8.1	NYS	

Notes: 1. CLEA (2009) SGV's (Underlined) derived from Soil Guideline Values Science Report SC050021 and are based on a sandy loam soil as defined in Environment Agency (2009b) and 6% soil organic matter (SOM). 2. SGV's derived from CLEA 2002 in Normal Font. 3. SGV's derived from LQM/CIEH GAC in *Italics*. 4**.** NYS - Not Yet Specified. **5.** Petroleum Hydrocarbons should be assessed as Aliphatic and Aromatic compounds (C5 - C70), for 1%, 2.5% & 5% Soil Organic Matter Content respectively (SOM). For individual petroleum hydrocarbon compounds/fractions, refer to LQM/CIEH GAC document. 6. NT = Not Tested 7. * = Denotes provisional Category 4 Screening Level (C4SL) attained from SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination Rev02: Contaminated Land: Applications in Real Environments (CL:AIRE): September 2014

6.3. Risk to Controlled Waters

6.3.1. General

The risk to controlled waters, i.e. nearby watercourses, is defined by the potential for any contaminants present on site to leach from the soils beneath the site.

The Milford Haven watercourse to the north of the site is potentially a receptor of any hazardous contamination leaching from the site due to interaction of ground water and contaminated ground. The made ground on the site has the potential to be a source of such contamination. Once the leaching potential is known the risk from this can be assessed in terms of pathways by which it may migrate, the impact on the receptors and if need be, addressed by remedial actions.

6.3.2. Summary Assessment of Risk to Controlled Waters

The results summarised in Table 10 indicate that the Made Ground on site does not present containments of raised concentrations above recommended human health guidelines for commercial/ industrial end use and can be considered not a high risk source of potential controlled water contamination. No specific leachate testing has been carried out so firm conclusions cannot be drawn. However, the risk to controlled waters from contamination emanating from this site is not likely to be considered significant though care must be taken during excavation works to ensure that large areas of Made Ground are not exposed to water, thereby increasing leaching potential.

Without soil leachate or groundwater environmental testing a risk classification cannot be accurately applied, however, it should be recommended that any surface waters/ storm waters from the proposed development should be diverted to a sealed drain network rather than directed to onsite soakaways unless leachate testing of the made ground is undertaken to prove that the potential contaminants in the made ground are non-mobile. It is also worth noting that groundwater was encountered at its shallowest depth of 3.8m bgl with BH5.

6.4. Recommendations on Contaminated Land

6.4.1. Human Health of Site End Users

All potential contaminants tested for from within the near surface, shallow soils on site all recorded concentration values well within the specified guidelines for a commercial/industrial end use.

In summary, as the potential contaminants are below the relevant specified guideline values there is unlikely to be a possibility of significant harm to the health of future site users. The risk to future site users is considered low based on the test results in Table 10.

6.4.2. Human Health Risks during Construction

The geo-environmental laboratory test results indicate the risks posed to construction operatives from chemical contaminants within the Made Ground is low. However due to the variable nature of Made Ground and the industrial history of the area, there is potential for unidentified contamination to exist on the site and therefore during the earthwork phase, it is possible construction site workers may be exposed to soil contaminants. Operatives working with, or likely to come into contact with made ground with the potential to contain raised concentrations of contaminants, should observe particular precautions concerning personal hygiene. They should be issued with the appropriate personal protective equipment and should be instructed in safe working methods. Instructions should be issued in the recognition of potentially hazardous materials including oily and odorous soil and water and also any discoloured or fibrous substances for example. Operatives should be warned to avoid contact between hands and mouth before washing. The consumption of food must be confined to designated clean areas with suitable welfare including washing facilities should be provided.

6.4.3. Risk To Nearby Watercourses

No soil leachate testing was carried out but soil contamination testing of the Made Ground samples recorded low concentrations, which may indicate a low risk to controlled waters and aquifers. Future soil leachate testing may be required.

6.5. Revised Conceptual Site Model

6.5.1. Review of Conceptual Site Model

The on-site investigation and subsequent laboratory testing has concluded that no source of contaminants raised beyond the relevant thresholds is present on site to an extent that it allows a pollutant linkage of source-pathway-receptor to be realised. The risks to future site end users is therefore deemed low.

7. GEOTECHNICAL ENGINEERING APPRAISAL

7.1. General

The proposed development is for the construction of a tidal lagoon project to generated electricity from the riding and falling tide passing through turbines. A current proposal is to excavate the made ground, crush it further and grade it, and to then reuse it as an engineered fill for future construction works.

7.2. Engineering Properties of Strata

The soils at the site comprised varying thicknesses of granular made ground containing a very variable component of slag, concrete, brick fragments and clinker overlying gravelly clay materials in turn overlying bedrock of Carboniferous limestone. The engineering properties of each strata are summarised below:

7.2.1. Made Ground

The geotechnical test results, including in-situ SPTs in boreholes, for testing undertaken within the Made Ground and fill deposits are summarised in Table 11. Full test certificates can be found in Appendix IV.

Table 11: *Summary of Made Ground and Fill Laboratory Test Results*

Made Ground		Range	Mean	No. Tests
Particle Size Distribution	Cobbles (%)	0 - 34	7	13
	Gravel (%)	24 - 55	39	
	Sand (%)	6 - 38	21	
	Silt/Clay (%)	8 - 56	26	
Moisture Content	%	6.3 - 33	20	16
Sulphate as SO_4	g/l	440 - 1900	939	8
pH	N/A	7.7 – 8.1	8.0	8
SPT ‘N’ values	1.00m – 3.00mBGL	15 - 38	26	8
SPT ‘N’ values	3.00m – 6.00mBGL	19 - 50	31	10
SPT ‘N’ values	>6.00mBGL	19 - 50	43	17

The laboratory tests on the made ground deposits encountered correspond with the engineering descriptions presented on exploratory hole logs within Appendix II. The made ground is a broadly granular unit although with highly variable densities with localised hard and soft spots. In some areas increasing depth sees the Made Ground become a more clayey material, although still with a high gravel content.

7.2.2. Bedrock

The geotechnical test results for testing carried out on rock core recovered from boreholes are summarised in table 12. Full test certificates can be found in Appendix IV.

Table 12 *Summary of Rock Core Moisture Contents and Mean Point Load Index Values*

Sample number and depth	Moisture Content	Point Load Index MPa (mean value)	No. of determinations
BH1 8.10m	2.7	0.97	10
BH1 8.90m	8.9	0.6	7
BH2 7.90m	1.4	0.98	8
BH3 11.00m	4.1	0.45	6
BH3 12.00m	1.1	1.67	10

7.3. Earthworks

7.3.1. Site Preparation

Prior to commencing the earthworks/ groundwork for the development, all live services on and in the vicinity of the site should be accurately located and protected or, if required, diverted. The ends of existing drains or sewers, which will be made redundant by the development, should be sealed in order to prevent any residual or persisting seepages from adversely affecting the integrity and or stability of the formations/ foundations. Service conduits and surface voids resulting from the sites preparation works should be filled and well compacted with acceptable granular material.

Any exposed formations should be protected from the effects of the weather, site traffic, or water in order to prevent deterioration of this surface. It is recommended that any exposed formations be protected with a minimum thickness of 200mm of suitable granular material or a thin layer of blinding concrete, which should be placed immediately after excavation and exposure.

7.3.2. Cutting and Filling

It is envisaged that material may be excavated and processed to make an engineered fill of known properties and characteristics. Engineered fill material specifications ought to be designed in order that they meet the requirements and demands of the proposed structure. Appropriate permits and precautions need to be taken when dealing with potentially contaminated material and adequate testing may need to be carried out to confirm the contamination status of all excavated material. Appropriate geotechnical testing ought to be carried out throughout to ensure the end material is suitable to meet requirements.

7.3.3. Excavation Plant

On the basis of the observations made during the exploratory investigation it is considered that excavations within the Made Ground is likely to encounter layers of very coarse deposits, areas of concrete and very dense materials that excavating plant may have difficulties in penetrating and it would be prudent to make allowance for the use of breaking equipment.

7.3.4. Stability of Excavation Sides

The trial pits revealed the Made Ground to be variably stable and unstable in different parts of the site, so due to the predominately granular nature of Made Ground, the potential for collapse of the sides of excavations exist and therefore any excavations for foundation construction may require shoring or support if left open for a sustained period of time.

7.3.5. Control of Groundwater

No groundwater was encountered in any of the trial pits but it was encountered at shallowest depth of 3.80mBGL rising to 3.60mBGL after 20 minutes observation in the boreholes. Water was also struck at depths between 8 and 11 metres in boreholes.

Given the shallowest depth water was encountered, it is possible excavations within the Made Ground will encounter groundwater – particularly after periods of extended rainfall. Sump pumping should be adequate for dewatering excavations where groundwater is encountered, or where surface water ingress occurs.

7.3.6. Combustible Materials

There is not considered to be significant risk of combustion of materials of gases on site as there is no reported history of coal mining in the area or under the site. However, Made Ground can emit land gas which has the potential to pose a risk. This cannot be quantified as no installations or monitoring is taking place.

7.3.7. Former Mine Workings

The site is not underlain by coal bearing strata or within an area of surface quarrying activity or metalliferous mining.

7.4. Slope Stability

No major groundworks involving slopes or slope stability are anticipated or proposed for the site development.

7.5. Geotechnical Discussion

It is our understanding that a desired bearing capacity of 100kPa is sought, and that it is anticipated that the current Made Ground is to be excavated and replaced as an engineered fill. On that information we would comment as follows.

7.5.1. Made Ground Characterisation

The Made Ground contains variable granular deposits, areas of concrete floor slabs and coarse soil fractions such as cobbles and boulders. Also in the made ground are areas where there is significant debris including metal work, wood work and remnants of old structures suggested by the presence of brick and mortar work.

Given the planned removal of the Made Ground for its reuse as an engineered fill it has been classified according to Highway Specification 600 Series – Earthworks to allow a suitable characterisation of the material and appropriate recommendations for reuse and compacting. Based on the average particle size distributions of samples recovered, the material is characterised as being Class 2A according to tables 6/1 and 6/2 of the Highway Specification 600 Series for Earthworks. For reusing the material as engineered fill, the material will need to be compacted according to the specifications laid out in Table 6/4. In order to properly prepare the material, very large obstructions such as relic brick and mortar structures and any metal work ought to be removed through direct screening and onsite sorting.

7.5.2. Allowable Bearing Capacities

Although the limited SPT 'N' value information recorded from testing in the boreholes suggests that the shallow ground is able to sustain significant loads, it is not advised that this Made Ground be used as a founding strata in its current state. This being due to the variable and unpredictable nature of Made Ground which has been used without regard to future use or engineering properties. The anticipated removal of the Made Ground, its crushing and reworking and finally reuse as an engineered fill material would eliminate this problem. However, before any allowable bearing capacity recommendations can be given, it is suggested that Plate Load Testing is carried out to quantify an accurate bearing capacity. Without such testing, it is not considered safe to apply more than a 50kPa as an allowable bearing capacity.

7.5.3. Foundation Concrete Class Designation

The Aggressive Chemical Environment for Concrete (ACEC) classification for the site has been assessed according to the guidelines within BRE Special Digest 1 (2005). For classification purposes, based on the BRE guidance, the groundwater must be classed as 'mobile' unless proven to be 'static' over a 24hr period.

The pH values of the soil samples taken from across the site ranged from 7.7 – 8.1 indicating slightly alkaline conditions. The levels of water-soluble sulphate (SO_4) content of the tested soil samples varied between 0.046g/l (46mg/l) to 0.88g/l (880mg/l).

Based on the above, the Design Sulphate (DS) class for the site using the most aggressive pH and sulphate values is DS-2, and the Aggressive Chemical Environment for Concrete (ACEC) site classification is AC-2, assuming mobile groundwater conditions.

8. RECOMMENDATIONS AND CONCLUSIONS

8.1. Conclusions

The site is overlain by significant thicknesses of made ground associated with former industrial land uses with many obstructions encountered during the formation of the exploratory holes including concrete slabs, bricks and mortar-work, metal work and legacy services. The Made Ground becomes more clay-rich with depth, and although it is considered that the material is of natural origin, it has been placed there as a fill material so can still be very variable.

Beneath the Made Ground strata are coarse gravels and boulders of the weathered bedrock zone. Limestone fragments have become weathered and loosened and form a gravel. The weathered zone is of variable thickness and this could not be accurately determined by trial pitting or drilling due to the fractured nature of rock recovery.

The Made Ground is not considered suitable for founding structures on due to the very variable nature and unpredictable engineering properties of the material across the site. Excavation and processing of the material to change its grading is likely to improve its bearing capacity and performance as an engineered fill, however, no comment can be made on its specific engineering character in its current or modified state without appropriate plate load testing.

Excavations should be achievable with standard plant but allowances should be made for breaking equipment due to the number of shallow obstructions encountered within the granular made ground. Shoring and pumping equipment should be available.

Concrete used in the construction of the development should conform to design sulphate class DS-2 and Aggressive Chemical Environment for Concrete (ACEC) classification of AC-2.

8.2. Recommendations

- It is recommend that plate load testing is carried out on the engineered fill once re-laid in order to accurately determine safe bearing capacities and to correctly determine its properties for engineering design purposes.
- Soil leachate testing of the Made Ground material may also be required to determine the risk of the Made Ground as a potential contaminant source to controlled waters.

9. REFERENCES

British Geological Survey:-

- British Geological Survey (BGS) Sheet 228 Haverfordwest (Solid and Drift) – 1:50 000 Series.

Environment Agency Publications:-

- Aquifer Designation Maps – 1:100,000 Scale.

Specialist Publications:-

- British Code of Practice BS 5930:1999+A2:2010 *'Code of Practice for Site Investigations'*
- British Code of Practice BS 1377:1990 *'Methods of test for soils for civil engineering purposes'.*
- British Code of Practice BS 10175:2001 *'Code of Practice for Investigation of Potentially Contaminated Sites'*
- British Code of Practice BS EN ISO 14688-1:2002+A2:2013 Geotechnical investigation and testing. Identification and classification of soil. Identification and description
- British Code of Practice BS EN ISO 14688-2:2004+A2:2013 Geotechnical investigation and testing. Identification and classification of soil. Principles for a classification.
- British Code of Practice BS EN ISO 14689-1:2003 Ground Investigation and Testing – Identification and classification of rock
- Health and Safety Executive Guidance Note EH40/90
- EA: '*Dealing with contaminated land in England and Wales*', 2009
- EA: Science Report: SC050021/SR3, 2009 '*Updated Technical Background to the CLEA Model*'
- *CIRIA Report 143* 'The Standard Penetration Test (SPT): Methods and Use, 1995.
- Highway Specification 600 Series Earthworks

For and on behalf of Quantum Geotechnical Ltd,

Written by:

L W de Leeuw BSc MSc FGS — Date
Engineering Geologist

Checked by

R. McDERMOTT, B.Sc. (Hons), M.Sc., C.Geol., F.G.S — Date
Principal Engineering Geologist

Approved by:

J.E. STARK, B.Sc. (Hons), C.Geol., F.G.S. — Date
Technical Director

QUANTUM GEOTECHNICAL

Digitally signed by Miles Davis
Date: 2015.04.30 09:56:26 +01'00'

APPENDIX I – SITE PLANS AND FIGURES

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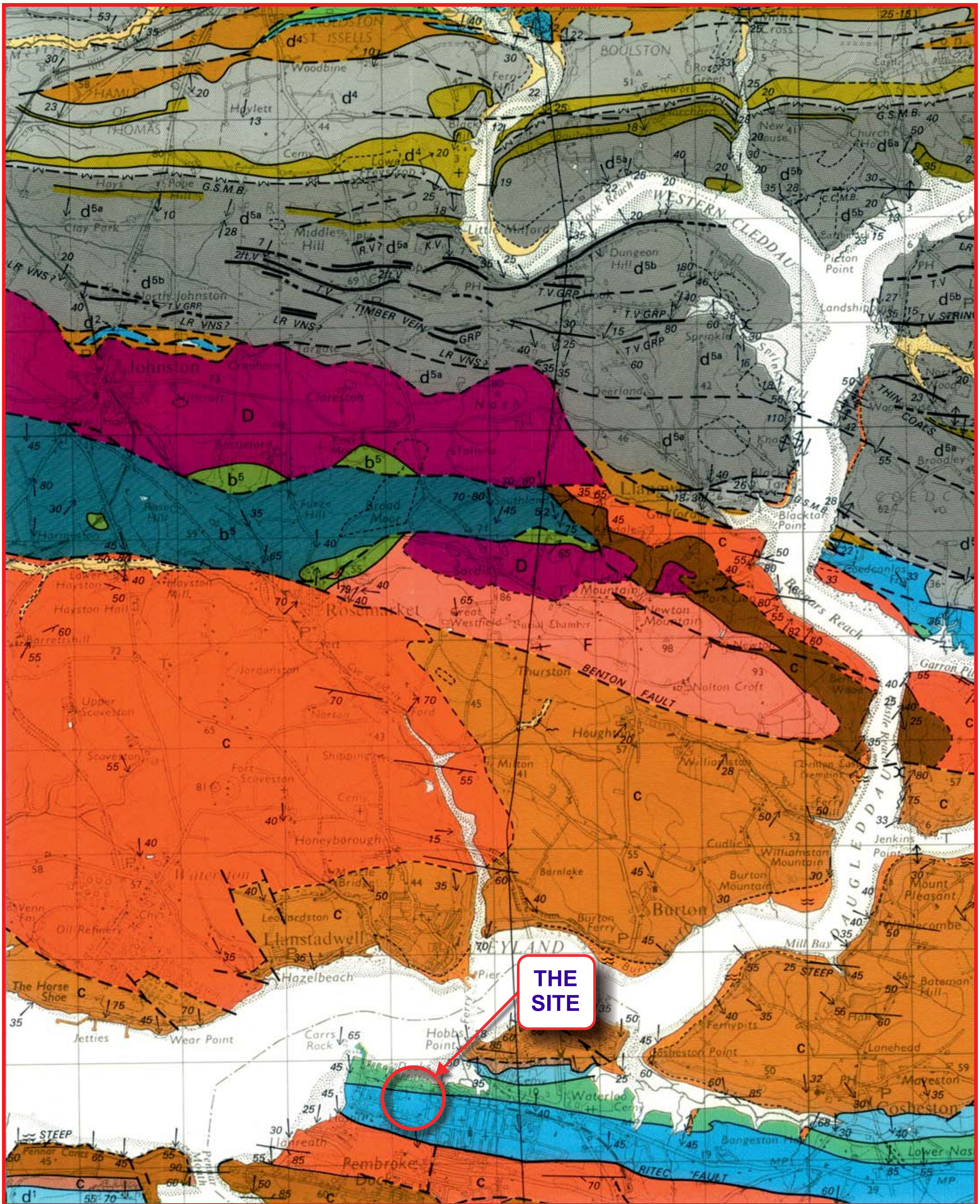
PEMBROKE DOCK PORT

SITE LOCATION PLAN

FIGURE 1

SCALE: 1 : 25000

JOB No. G624



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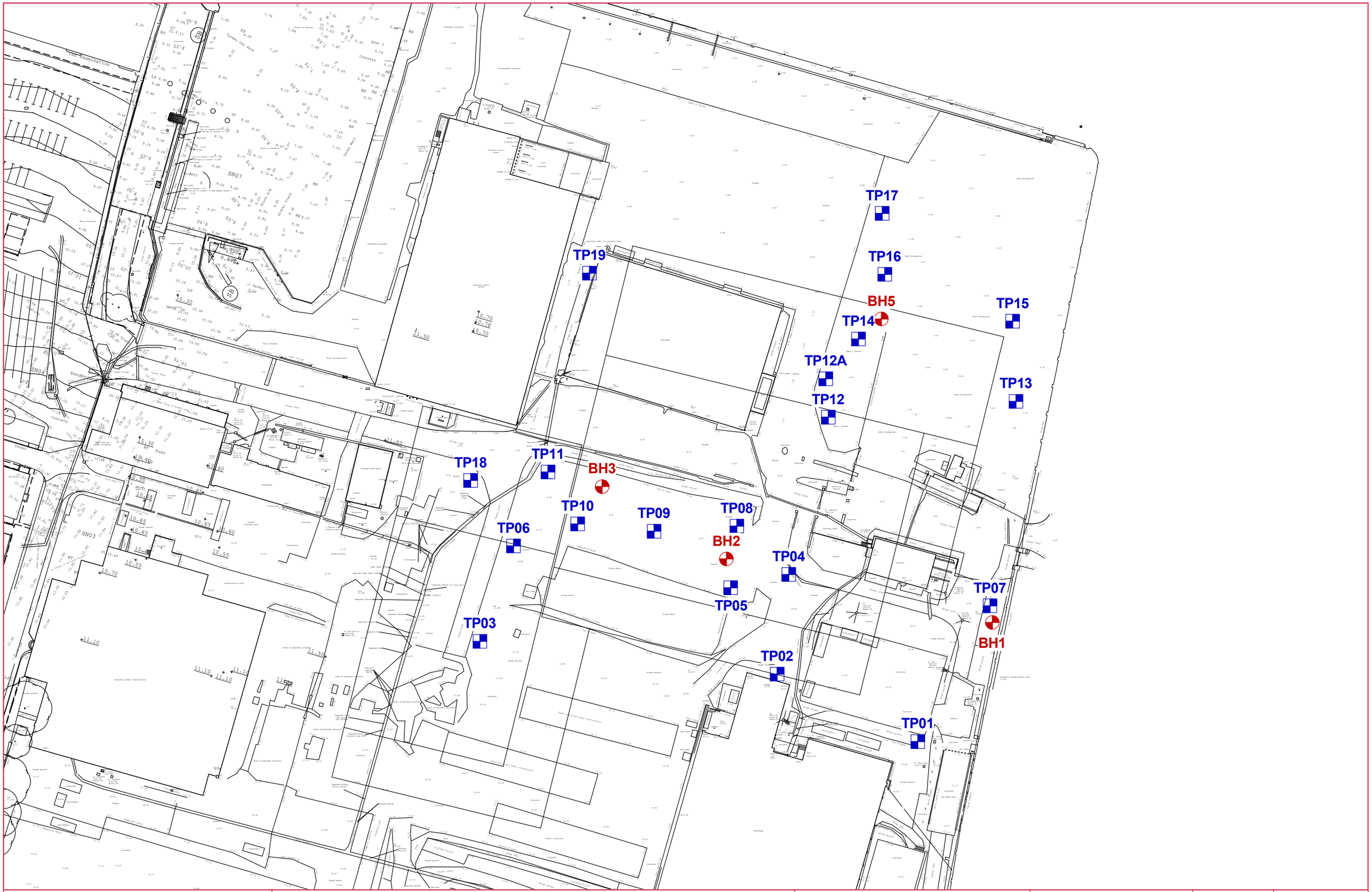
PEMBROKE DOCK PORT

GEOLOGICAL MAP EXTRACT SHEET 228 SOLID EDITION

FIGURE 2

SCALE: 1 : 50000

JOB No. G624



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KEY
Borehole
Trial Pit
Monitoring / Test Point
Window Sample
Dynamic Probe
Historical Hole
Sampling Point

PROJECT
PEMBROKE DOCK PORT

DRAWING TITLE:
EXPLORATORY HOLE LOCATION PLAN

JOB NO.	FIGURE NO.
G624	3
DATE	SCALE
23/03/15	1:1000

APPENDIX II – MACHINE EXCAVATED TRIAL PIT LOGS

KEY TO BOREHOLE AND TRIAL PIT LOGS

SAMPLE AND TEST TYPES

U	Undisturbed driven tube sample - 102mm diameter, 450mm long.
P	Undisturbed pushed piston sample - 102mm diameter, 1000mm long.
TW	Undisturbed thin walled push in sample - 100mm diameter, 750mm long.
B	Bulk disturbed sample.
BLK	Block Sample
CBR	Heavy duty undisturbed sample - 154 mm diameter (CBR mould).
D	Small disturbed sample.
LB	Large Bulk disturbed sample (for earthworks testing)
C	Core sample
W	Water sample
G	Gas sample
j	Jar sample
t	Tub sample
p	Pot sample
s	Small sample
v	Vial sample

S	Standard Penetration Test using split spoon sampler. (See Note).
C	Standard Penetration Test using a solid 60 degree cone. (See Note).

NOTE: Where a single value is quoted this is the N value for 300 mm penetration following a seating drive of 150 mm. Where this full penetration is not achieved the number of blows is quoted for the penetration below the seating drive eg. 63/160 mm.
Where total penetration is less than the seating drive this is indicated by a + and the number of blows for total penetration is quoted eg. +50/75 mm.

HV	Hand Vane Test. Vane undrained shear strength, c_u, quoted in kPa.
V	Borehole Vane Test. Vane undrained shear strength, c_u, quoted in kPa.
FHT/RHT	Falling / Rising Head Permeability Test.

CORE RUN DETAILS

TCR	Total Core Recovery, %
SCR	Solid Core Recovery, %
RQD	Rock Quality Designation, %
FI	Fracture Index. NI - Non intact where > 25 No. per metre length.

WATER COLUMN SYMBOLS

First water strike, second water strike etc.

Standing water level after first strike, second strike etc.

Seepage.

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NOTE:
Legend symbols in accordance with BS 5930 (1999)

KEY TO BOREHOLE AND TRIAL PIT LOGS

MATERIAL LEGENDS

 Made Ground	 Topsoil	 Clay
 Gravel	 Sand	 Silt
 Peat	 Boulders	 Cobbles
 Chalk	 Conglomerate	 Volcaniclastic
 Asphalt	 Void	 Mudstone
 Siltstone	 Sandstone	 Limestone
 Ironstone	 Mudstone / Siltstone	 Breccia
 Coal	 Coral	 Bedrock
 Shale	 Gypsum	 Igneous (Coarse Grained)
 Igneous (Fine Grained)	 Igneous (Medium Grained)	 Metamorphic (Coarse Grained)
 Metamorphic (Fine Grained)	 Metamorphic (Medium Grained)	

INSTALLATION / BACKFILL DETAILS

 Arisings	 Concrete	 Bentonite cement grout
 Bentonite seal	 Filter	 Pea Gravel
 Plain pipe	 Slotted pipe	Piezometer / Standpipe tip

QUANTUM

NOTE:
Legend symbols in accordance with BS 5930 (1999)

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP01

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

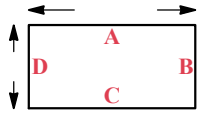
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 148.00 E
23.47 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
					0.01	clayey sandy HARDCORE top		(0.01)	
						MADE GROUND: loose, brown black, silty sandy GRAVEL with cobbles.		0.01 (0.29)	
	0.30 -	B1 D2			0.30	cobbles: 4-8cm, angular to subangular and of slag, clinker and brick fragments.		0.30 (0.20)	
					0.50	slag and clinker amalgamated into larger blocks of 15-20cm in places.		0.50	
						light brown, broken weathered suspected bedrock LIMESTONE with a sandy matrix amongst weathering fractures.			
						0.5m: suspected competent bedrock LIMESTONE			

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port Client : Milford Haven Port Authority		Trial Pit No. TP01
Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 148.00 E 23.47 N *Co-ordinates to Local Grid*

Above:- TP01 spoil

Right:-
TP01 pit

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Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No.
TP02

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

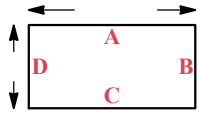
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 106.79 E
43.26 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
	0.20 -	B1 D2			0.05	HARD CORE and sandy GRAVEL top		(0.05)	
						MADE GROUND: medium dense, black and white patchy, sandy, fine to coarse GRAVEL with cobbles.		0.05 (0.25)	
					0.30	cobbles: 4-8cm, subangular to subrounded and of slag and clinker 0.3m: suspected bedrock LIMESTONE		0.30	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP02**

Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 106.79 E 43.26 N *Co-ordinates to Local Grid*

Above:- TP02 spoil

Right:- TP02 pit

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Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP03

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

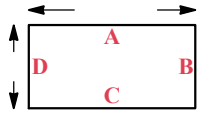
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 19.65 E
52.86 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	Legend	STRATA Depth (Thick-ness)	Water
					0.05	GRAVEL TOPSOIL		(0.05)	
	0.30 -	B1 D2			0.15	MADE GROUND: grey, medium to coarse GRAVEL, 2-6cm angular to subangular fragments of very hard limestone.		0.05 (0.10)	
						MADE GROUND: medium dense, brown, sandy coarse to fine GRAVEL with cobbles		0.15	
						cobbles: 5-8cm, angular, of limestone and brick fragments and some slag/clinker.		(0.85)	
						block: 20cm, angular, of concrete			
1	1.00 -	B3 D4				0.5m: Plastic sheeting and plate metal iron work debris			
					1.00	LIMESTONE cobbles, 5-15cm, angular		1.00	
						0.8m: layer of black material and broken brick work, metal pipework and odour of domestic waste			
						MADE GROUND: loose, black, silty sandy, fine to coarse, GRAVEL with cobbles		(1.10)	
						cobbles: 5-15cm, angular to subangular			
2						Broken wall sections and wooden beam, flat/straight wall surface suggests a buried structure.			
					2.10	Terminated on suspected bedrock.		2.10	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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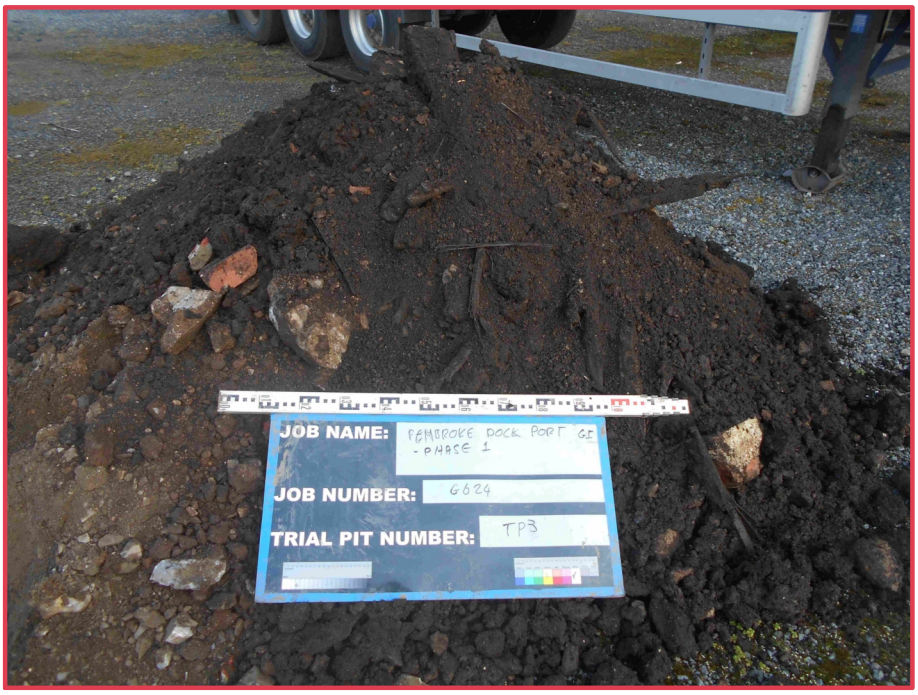
Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP03**

Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 19.65 E 52.86 N *Co-ordinates to Local Grid*



Above:- TP03 spoil

Right:- TP03 pit

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Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP04

Dates : 12/03/15 - 12/03/15

Location : Pembroke Dock Port

Job Number : G624

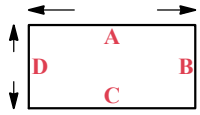
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 110.18 E
72.48 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	Legend	Depth (Thick-ness)	Water
						TARMAC		(0.10)	
	0.20 -	B1 D2 D2a			0.10	MADE GROUND: browny yellow, sandy coarse GRAVEL and occasional cobbles.		0.10 (0.10)	
					0.20			0.20	
					0.30	cobbles: 1-3cm, angular to subangular and of limestone		(0.10)	
						CONCRETE		0.30	
	0.70 -	B3 D4 D4a				MADE GROUND: dense, red brown, slightly sandy GRAVEL with some cobbles and boulders. cobbles and boulders: 5-35cm, angular to subangular, and of limestone and assorted sedimentary lithologies.		(0.70)	
1					1.00	MADE GROUND: firm, red brown, sandy gravelly CLAY. gravel: fine to coarse and angular		1.00 (1.00)	
2	2.00 -	B5 D6			2.00	MADE GROUND: medium dense, red brown, clayey gravelly SAND		2.00 (1.00)	
3	3.00 -	B7 D8			3.00	MADE GROUND: grey yellow, silty sandy, fine to coarse angular GRAVEL. gravel: suspected weathered limestone bedrock cobbles Terminated on suspected bedrock.		3.00 (0.90)	
					3.90			3.90	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port Client : Milford Haven Port Authority		Trial Pit No. TP04
Dates : 12/03/15 - 12/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 110.18 E 72.48 N *Co-ordinates to Local Grid*

Above:- TP04 spoil

Right:- TP04 pit

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Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP05

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

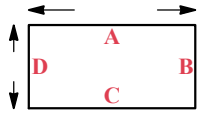
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 93.14 E
68.59 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	Legend	STRATA Depth (Thick-ness)	Water
					0.05	MADE GROUND: broken weathered limestone, angular to subangular, 10cm, COBBLES		(0.05)	
	0.30 -	B1 D2				MADE GROUND: grey, very gravelly SAND with boulders. boulders: 20-25cm, angular, of limestone		0.05 (0.35)	
					0.40	MADE GROUND: black, slightly silty sandy GRAVEL with frequent boulders.		0.40 (0.20)	
					0.60	boulders: angular to subrounded and of limestone.		0.60 (0.20)	
	0.80 -	B3 D4			0.80	MADE GROUND: grey coarse sandy coarse GRAVEL with cobbles. cobbles: 5-15cm, angular to subangular, and of limestone.		0.80	
1						firm, red brown, silty slightly sandy slightly gravelly CLAY 1.3m: soil becoming looser and sandier, less clay 2.0m: red brown, very stiff, silty sandy CLAY		(1.40)	
2									
	2.20 -	B5 D6			2.20	yellow grey, silty sandy CLAY with frequent cobbles. cobbles: 4-10cm, angular to subangular limestone. Suspected broken weathered limestone bedrock.		2.20 (0.35)	
					2.55	Terminated due to suspected bedrock.		2.55	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP05**

Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 93.14 E 68.59 N *Co-ordinates to Local Grid*

Above:- TP05 spoil

Right:- TP05 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP06

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

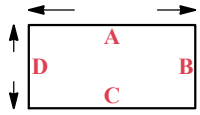
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 29.50 E
80.84 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	Legend	Depth (Thick-ness)	Water
					0.01	HARDCORE GRAVEL		(0.01)	
						MADE GROUND: medium dense, brown, sandy GRAVEL with frequent boulders.		0.01 (0.29)	
	0.30 -	B1 D2			0.30	boulders: 10-35cm, angular, and of limestone		0.30 (0.15)	
					0.45	MADE GROUND: grey brown, very sandy very gravelly COBBLES and BOULDERS.		0.45	
						cobbles and boulders are angular to subangular limestone.			
						MADE GROUND: black fine to coarse GRAVEL.			
1	1.00 -	B3 D4				gravel: 4-6cm, angular to subangular, of limestone and brick		(1.05)	
						cobbles of sandstone and shaley material.			
	1.50 -	B5 D6			1.50	stiff, red brown, silty sandy slightly gravelly, CLAY		1.50 (0.70)	
2									
					2.20	yellow grey, very clayey silty sandy, fine to coarse, angular to subangular, GRAVEL with some cobbles.		2.20 (0.20)	
	2.40 -	B7 D8			2.40	cobbles: 4-8cm, angular, and of limestone.		2.40 (0.20)	
						COBBLES of weathered suspected limestone bedrock.			
					2.60	Terminated due to suspected bedrock.		2.60	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP06**

Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 29.50 E 80.84 N *Co-ordinates to Local Grid*

Above:- TP06 spoil

Right:- TP06 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP07

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

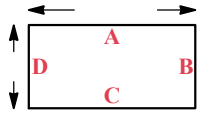
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 169.18 E
63.29 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	Legend	Depth (Thick-ness)	Water
	0.30 -	B1 D2				MADE GROUND: loose, brown grey SAND with angular to subangular cobbles of broken brick and boulders. 0.2m: 8-10cm diameter cable - derelict service boulders 60cm, angular to subangular, broken concrete		(0.60)	
					0.60	cobbles: 20-30cm, angular to subangular, brick and slag clinker		0.60	
						MADE GROUND: red brown, sandy, fine to coarse GRAVEL. 5cm diameter metal pipe parallel to length of trench.		(0.40)	
1	1.00 -	B3 D4			1.00	soft,red brown silty sandy fine to coarse slightly gravelly CLAY		1.00 (0.30)	
					1.30	stiff, red, sandy clayey SILT		1.30 (0.70)	
2	2.10 -	B5 D6			2.00	red brown, slightly clayey slightly gravelly very sandy SILT. gravel: fine, subangular to subrounded		2.00 (0.50)	
					2.50	red brown, loose, slightly silty SAND with occasional boulders. boulders: 20cm, subangular.		2.50 (0.40)	
					2.90	Terminated due to pit collapse.		2.90	

PLAN



Groundwater: None Encountered

Stability: Unstable

Shoring: None

Remarks : Terminated due to pit collapse.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP07**

Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 169.18 E 63.29 N *Co-ordinates to Local Grid*

Above:- TP07 spoil

Right:- TP07 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP08

Dates : 12/03/15 - 12/03/15

Location : Pembroke Dock Port

Job Number : G624

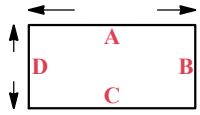
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 94.96 E
86.64 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
						TARMAC		(0.10)	
					0.10	CONCRETE		0.10	
					0.20	MADE GROUND: black grey, sandy, fine to coarse, angular to subangular GRAVEL with cobbles.		(0.10)	
	0.40 -	B1 D2						0.20	
					0.40	cobbles: 4-8cm, angular to subangular.		(0.20)	
						0.4m: 20-40cm, angular to subangular, squared concrete blocks.		0.40	
						MADE GROUND: black grey, sandy fine to coarse GRAVEL		(0.80)	
1	1.00 -	B3 D4				1.2m: Terminated on concrete obstruction.			
					1.20			1.20	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated due to concrete obstruction.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP08**

Dates : 12/03/15 - 12/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 94.96 E 86.64 N *Co-ordinates to Local Grid*

Above:- TP08 spoil

Right:-
TP08 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP09

Dates : 12/03/15 - 12/03/15

Location : Pembroke Dock Port

Job Number : G624

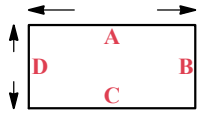
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 70.71 E
85.15 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	Legend	STRATA Depth (Thick-ness)	Water
						TARMAC		(0.10)	
					0.10	MADE GROUND: loose, yellow brown, sandy slightly clayey coarse, subangular to subrounded GRAVEL.		0.10 (0.10)	
	0.30 -	B1 D2 D2a			0.20	MADE GROUND: brown black, slightly gravelly, fine SAND with cobbles.		0.20 (0.20)	
					0.40	cobbles: 5-10cm, angular to subangular, broken brick work. ironwork found in pit.		0.40 (0.40)	
	0.70 -	B3 D4 D4a			0.80	red brown, silty sandy GRAVEL and occasional cobbles. cobbles: 5-15cm, angular to subangular, and of limestone.		0.80 (0.20)	
1					1.00	red brown sandy, fine to coarse, angular to subangular, GRAVEL with frequent fragmented broken limestone cobbles. cobbles: 4-10cm, angular to subangular.		1.00	
	1.50 -	B5 D6 D6a				stiff, red brown, slightly silty gravelly CLAY. gravel: fine to medium, angular to subangular becoming gravelly, medium firm, CLAY with occasional boulders of limestone, 10-20cm, angular.		(1.00)	
2					2.00	COBBLES and BOULDERS of limestone, 5-25cm, angular		2.00 (0.80)	
	2.50 -	B7 D8 D8a			2.80	weathered broken limestone recovered as angular COBBLES and BOULDERS, possibly approaching bedrock Terminated on suspected bedrock.		2.80 (0.70)	
3					3.50			3.50	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP09**

Dates : 12/03/15 - 12/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 70.71 E 85.15 N *Co-ordinates to Local Grid*

Above:- TP09 spoil

Right:- TP09 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP10

Dates : 12/03/15 - 12/03/15

Location : Pembroke Dock Port

Job Number : G624

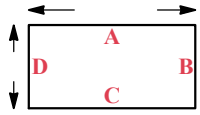
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 48.29 E
87.30 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	Depth (Thick-ness)	STRATA DESCRIPTION	Legend	Depth (Thick-ness)	Water
						TARMAC		(0.10)	
					0.10	MADE GROUND: red brown, sandy fine to coarse GRAVEL with 5-10cm angular to subangular cobbles of concrete and brick.		0.10 (0.20)	
	0.30 -	B1 D2			0.30			0.30	
					0.40	MADE GROUND: medium dense, black, fine silty sandy GRAVEL with angular to subangular cobbles.		(0.10) 0.40	
	0.70 -	B3 D4			0.60	Odour of burnt wood and blackened pieces of wood uncovered.		(0.20) 0.60	
					0.80	MADE GROUND: grey, sandy coarse GRAVEL with cobbles.		(0.20) 0.80	
1						gravel is made of limestone. cobbles are 5-15cm, angular to subangular and of clinker/slag.			
						MADE GROUND: brown grey, sandy fine to coarse GRAVEL with occasional cobbles of limestone and slag			
	1.50 -	B5 D6				red brown, slightly silty fine to medium subangular to subrounded GRAVEL with 5-8cm angular to subangular limestone cobbles.		(1.70)	
2									
	2.50 -	B7 D8			2.50	grey yellow sandy fine to coarse angular to subangular GRAVEL with occasional 4-10cm angular to subangular cobbles.		2.50 (0.70)	
3									
					3.20	yellow brown sandy GRAVEL and 5-15cm angular to subangular COBBLES of broken weathered fragments of suspected bedrock limestone.		3.20 (0.30)	
					3.50	Terminated on suspected bedrock.		3.50	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP10**

Dates : 12/03/15 - 12/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 48.29 E 87.30 N *Co-ordinates to Local Grid*

Above:- TP10 spoil

Right:- TP10 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No.
TP11

Dates : 11/03/15 - 11/03/15

Location : Pembroke Dock Port

Job Number : G624

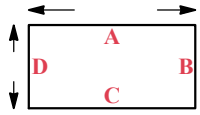
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 39.60 E
102.53 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
	0.30 -	B1 D2 D2a				brown grey, coarse sandy coarse GRAVEL with 2-6cm angular limestone and broken brick cobbles and 10-12cm angular limestone boulders. 0.5m: Terminated due to metalwork in pit, rebar concrete, metal rods and brickwork		*(1.05)*	
1					1.05			1.05	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated due to rebar concrete obstruction.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP11**

Dates : 11/03/15 - 11/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 39.60 E 102.53 N *Co-ordinates to Local Grid*

Above:- TP11 spoil

Right:- TP11 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP12

Dates : 11/03/15 - 11/03/15

Location : Pembroke Dock Port

Job Number : G624

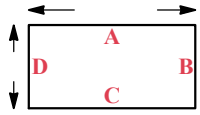
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 121.77 E
118.59 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
	0.30 -	B1 D2 D2a			0.30	yellow brown sandy fine to coarse GRAVEL with occasional 2-6cm angular to subangular limestone and brick cobbles. 0.3m: Iron 6cm diameter pipe encountered. 0.5m: Ceramic 10cm pipe encountered and top surface partially breached. Trial pit abandoned and relocated, designated TP12A.		*(0.30)* 0.30	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated due to relic service obstruction.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP12A

Dates : 12/03/15 - 12/03/15

Location : Pembroke Dock Port

Job Number : G624

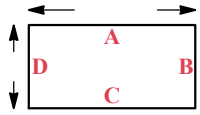
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 121.02 E
129.85 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	Legend	Depth (Thick-ness)	Water
						sandy fine to coarse angular to subangular GRAVEL			
	0.30 -	B1 D2						(0.60)	
					0.60	large 10-30cm angular to subangular BOULDERS		0.60 (0.15)	
					0.75	5-15cm limestone COBBLES		0.75 (0.25)	
1	1.00 -	B3 D4			1.00	MADE GROUND: brown sandy fine to coarse angular to subangular GRAVEL with occasional limestone 5-10cm angular to subangular cobbles.		1.00 (0.20)	
					1.20	1.20m: square cut suspected limestone bricks/blocks ~20x30cm, potential buried structure or relic building footings. Terminated due to limestone obstructions.		1.20	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated due to limestone obstruction.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP12A**

Dates : 12/03/15 - 12/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 121.02 E 129.85 N *Co-ordinates to Local Grid*

Above:- TP12A spoil

Right:- TP12A pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP13

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

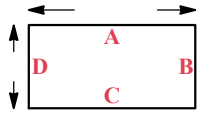
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 176.80 E
123.23 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thickness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thickness)	Water
					0.01	MADE GROUND: SAND from sand yard		(0.01)	
						MADE GROUND: grey sandy GRAVEL with occasional 2-6cm angular to subangular cobbles of clinker.		0.01	
	0.20 -	B1 D2			0.20	MADE GROUND: firm, red brown, very gravelly CLAY with occasional angular to subangular cobbles.		(0.19)	
					0.40	MADE GROUND: black silty, fine to coarse GRAVEL with occasional cobbles of 4-5cm angular fissile shale.		0.20	
	0.50 -	B3 D4						(0.20)	
								0.40	
1								(0.80)	
					1.20	MADE GROUND: brown, silty, fine to coarse GRAVEL.		1.20	
	1.50 -	B5 D6						(1.00)	
2									
	2.20 -	B7 D8			2.20	MADE GROUND: 2-6cm angular to subangular limestone COBBLES and 8-15cm angular to subangular COBBLES of shale. Terminated due to pit collapse.		2.20	
								(1.10)	
3									
					3.30			3.30	

PLAN



Groundwater: None Encountered

Stability: Unstable

Shoring: None

Remarks : Terminated due to pit collapse.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP13**

Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 176.80 E 123.23 N *Co-ordinates to Local Grid*

Above:- TP13 spoil

Right:- TP13 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP14

Dates : 12/03/15 - 12/03/15

Location : Pembroke Dock Port

Job Number : G624

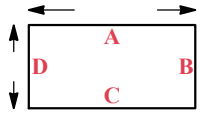
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 130.62 E
141.52 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
					0.05	MADE GROUND: sandy fine to coarse GRAVEL		(0.05)	
	0.30 -	B1 D2 D2a			0.08	MADE GROUND: sandy fine to coarse GRAVEL with occasional 2-8cm angular to subangular cobbles of limestone and broken brick.		0.05 (0.03)	
					0.15	MADE GROUND: very hard obstruction, suspected concrete		0.08 (0.07)	
					0.25	MADE GROUND: 5-15cm angular to subangular brick and limestone sandy COBBLES		0.15 (0.10)	
					0.50	MADE GROUND: sandy fine to coarse GRAVEL. 0.50m: limestone boulder encountered - breaking out required.		0.25 (0.25)	
1	1.00 -	B3 D4				MADE GROUND: light brown grey clayey sandy GRAVEL with frequent 2-25cm angular to subangular cobbles and 20-50cm angular to subangular boulders.		0.50 (2.00)	
2	2.00 -	B5 D6							
					2.50	MADE GROUND: very sandy very gravelly CLAY with frequent 2-4cm angular to subangular cobbles including some broken brick. Terminated due to hard digging.		2.50 (1.00)	
3	3.00 -	B7 D8							
					3.50			3.50	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated due to hard digging.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port Client : Milford Haven Port Authority		Trial Pit No. TP14
Dates : 12/03/15 - 12/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 130.62 E 141.52 N *Co-ordinates to Local Grid*

Above:- TP14 spoil

Right:- TP14 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP15

Dates : 11/03/15 - 11/03/15

Location : Pembroke Dock Port

Job Number : G624

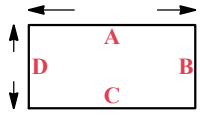
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 175.80 E
146.74 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thickness)	STRATA DESCRIPTION	Legend	STRATA Depth (Thickness)	Water
					0.02	MADE GROUND: SAND top cover		(0.02)	
						very sandy fine to coarse GRAVEL with 2-8cm angular to subangular cobbles and 20-30cm angular boulders.		0.02	
					0.20			(0.18)	
	0.30 -	B1 D2 D2a				0.10m: brick and mortar work fragments.		0.20	
						MADE GROUND: brown sandy fine to coarse GRAVEL with frequent 5-10cm angular to subangular limestone cobbles.		(0.40)	
					0.60	MADE GROUND: light brown, sandy fine to coarse GRAVEL with 5-10cm angular to subangular limestone and shale and sandstone cobbles.		0.60	
	0.70 -	B3 D4 D4a						(0.20)	
					0.80	MADE GROUND: red, very sandy coarse angular to subangular GRAVEL with occasional angular to subangular limestone or shale cobbles and boulders.		0.80	
1								(0.80)	
					1.60	loose, light yellow, fine to coarse gravelly SAND.		1.60	
								(0.60)	
2	2.00 -	B5 D6 D6a			2.20	loose, brown, fine to coarse gravelly SAND with cobbles of angular shale.		2.20	
						Terminated due to pit collapse.			
								(1.40)	
3									
					3.60			3.60	

PLAN



Groundwater: None Encountered

Stability: Unstable

Shoring: None

Remarks : Terminated due to pit collapse.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP15**

Dates : 11/03/15 - 11/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 175.80 E 146.74 N *Co-ordinates to Local Grid*

Above:- TP15 spoil

Right:- TP15 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP16

Dates : 11/03/15 - 11/03/15

Location : Pembroke Dock Port

Job Number : G624

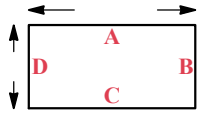
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 138.32 E
160.48 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	Depth (Thick-ness)	STRATA DESCRIPTION	Legend	Depth (Thick-ness)	Water
						MADE GROUND: SAND		(0.10)	
					0.10	MADE GROUND: very sandy coarse GRAVEL with frequent 2-10cm angular to subangular cobbles and frequent boulders.		0.10 (0.30)	
	0.40 -	B1 D2 D2a			0.40	MADE GROUND: sandy fine to coarse GRAVEL with very frequent 10-25cm angular to subangular limestone cobbles and boulders.		0.40 (0.80)	
1	1.00 -	B3 D4 D4a							
					1.20	MADE GROUND: red brown silty sandy fine to coarse angular to subangular GRAVEL with frequent 2-20cm angular to subangular cobbles and boulders.		1.20 (0.40)	
					1.60	MADE GROUND: medium dense, yellow grey, silty SAND		1.60 (0.60)	
	1.80 -	B5 D6 D6a							
2									
					2.20	MADE GROUND: 20-30cm angular COBBLES and BOULDERS		2.20 (0.30)	
	2.50 -	B7 D8 D8a			2.50	MADE GROUND: dark grey brown slight sandy silty gravelly CLAY with occasional 4-8cm subangular cobbles. 2.50m: brick and mortar structure.		2.50 (0.40)	
					2.90	Terminated due to pit instability.		2.90	

PLAN



Groundwater: None Encountered

Stability: Unstable

Shoring: None

Remarks : Terminated due to pit instability.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP16**

Dates : 11/03/15 - 11/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 138.32 E 160.48 N *Co-ordinates to Local Grid*

Above:- TP16 spoil

Right:- TP16 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP17

Dates : 11/03/15 - 11/03/15

Location : Pembroke Dock Port

Job Number : G624

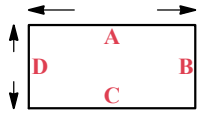
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 137.57 E
178.36 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
					0.05	MADE GROUND: SAND top layer		(0.05)	
						MADE GROUND: brown, very sandy coarse GRAVEL with frequent 4-10cm angular to subangular cobbles and occasional 30-40cm very angular boulders.		0.05	
	0.40 -	B1 D2 D2a						(1.15)	
1									
	1.20 -	B3 D4 D4a			1.20	MADE GROUND: brown very sandy GRAVEL with 5-25cm angular to subangular cobbles Terminated due to pit instability.		1.20 (0.60)	
					1.80			1.80	

PLAN



Groundwater: None Encountered

Stability: Unstable

Shoring: None

Remarks : Terminated due to pit instability.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP17**

Dates : 11/03/15 - 11/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 137.57 E 178.36 N *Co-ordinates to Local Grid*

Above:- TP17 spoil

Right:- TP17 pit

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Operator:	Logged By.	Sheet No.	m Per Page	
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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP18

Dates : 10/03/15 - 10/03/15

Location : Pembroke Dock Port

Job Number : G624

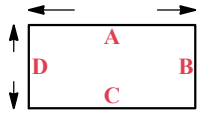
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 16.92 E
100.05 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	STRATA DESCRIPTION	STRATA Legend	STRATA Depth (Thick-ness)	Water
						MADE GROUND hardcore surface: sandy fine to coarse GRAVEL with frequent 3-10cm angular to subangular cobbles.		(0.20)	
					0.20			0.20	
	0.30 -	B1 D2			0.30	MADE GROUND: black brown and grey white silty fine to coarse GRAVEL with occasional 5cm angular to subangular limestone cobbles.		(0.10)	
					0.40			0.30 (0.10)	
	0.60 -	B3 D4				MADE GROUND: red sandy fine to coarse GRAVEL and occasional 2-8cm angular to subangular cobbles.		0.40 (0.50)	
						MADE GROUND: slighty sandy silty CLAY with frequent cobbles			
					0.90	Terminated due to suspected bedrock or flat concrete obstruction.		0.90	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated on suspected bedrock.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP18**

Dates : 10/03/15 - 10/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 16.92 E 100.05 N *Co-ordinates to Local Grid*

Above:- TP18 spoil

Right:- TP18 pit

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AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Trial Pit No. TP19

Dates : 11/03/15 - 11/03/15

Location : Pembroke Dock Port

Job Number : G624

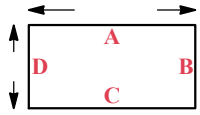
Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 51.76 E
160.81 N
Co-ordinates to Local Grid

m B.G.L.	Samples Depth	Samples Type No.	Tests Depth	Tests Test Results	STRATA Depth (Thick-ness)	DESCRIPTION	Legend	Depth (Thick-ness)	Water
						MADE GROUND: silty SAND topsoil		(0.10)	
					0.10	MADE GROUND: sandy fine to coarse GRAVEL with 2-10cm angular to subangular limestone cobbles.		0.10 (0.10)	
					0.20	MADE GROUND: 5-15cm angular to subangular limestone COBBLES and BOULDERS.		0.20 (0.60)	
	0.50 -	B1 D2 D2a							
1					0.80	MADE GROUND: 30-40cm angular to subangular gravelly limestone BOULDERS.		0.80 (0.20)	
					1.00	MADE GROUND: black very coarse gravelly slag/clinker and brick COBBLES.		1.00 (0.30)	
	1.20 -	B3 D4 D4a				1.20m: Terminated due to brick wall obstruction.			
					1.30			1.30	

PLAN



Groundwater: None Encountered

Stability: Stable

Shoring: None

Remarks : Terminated due to obstructions and impossible digging.

Equipment Used: JCB 3CX with 600mm bucket. CAT Detector and Genny used.

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AGS

Contract : Pembroke Dock Port **Client : Milford Haven Port Authority**	**Trial Pit No.** **TP19**

Dates : 11/03/15 - 11/03/15 Location : Pembroke Dock Port	Job Number : G624 Engineer : Milford Haven Port Authority	Ground Level : Coordinates: 51.76 E 160.81 N *Co-ordinates to Local Grid*

Above:- TP19 spoil

Right:- TP19 pit

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AGS

APPENDIX III – ROTARY BOREHOLE LOGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH1

Dates : 11/03/15 - 11/03/15

Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 169.85 E
58.41 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness)	Description	Legend	Depth (Thick-ness)	Water
									(0.10)	(Driller: TARMAC)		(0.10)	
									0.10 (0.60)	(Driller: HARDCORE subbase)		0.10 (0.60)	
					1.2	SPT () 27 (2-4-**6-6-7-8**)			0.70	(Driller: red silty sandy CLAY and GRAVEL)		0.70	
					2	SPT () 38 (7-7-**9-9-9-11**)			(2.90)			(2.90)	
					3	SPT () 48 (7-9-**11-12-11-14**)							
3.60					3.6	SPT () 50/200mm (10-13-**17-18-15/50mm**-)			3.60	strong, medium grey, fine grained, LIMESTONE. Rock mass is non-intact. Fractures are stepped rough and undulating rough with orange surface straining indicating weathering discolouration and suggesting rock was fractured in-situ.		3.60	
	30	5	0						(1.00)			(1.00)	
4.60									4.60	strong, medium grey, fine grained, LIMESTONE. Rock mass is non-intact. Fractures are stepped rough with orange surface staining indicating discolouration weathering.		4.60	
	27	2	0						(1.50)			(1.50)	
6.10					6.1	SPT () 50/30mm (25/20mm-0/0mm-**50/30mm**---)			6.10	medium strong to strong, yellow brown with yellow brown banding, thickly laminated, medium to coarse grained, foliated, mildly METAMORPHIC rock. Rock mass is generally non-intact. Fracture apertures are wide, stepped rough and exhibit mineralised coatings.		6.10	
	100	57	27						(1.50)			(1.50)	
7.60									7.60	very strong, brown yellow with brown and yellow banding, thickly laminated, fine to medium grained, foliated mildly METAMORPHIC rock with 1-2mm quartzite nodules. Rock is generally non-intact. Fractures are undulating rough.		7.60	
	93	93	40						(1.00)			(1.00)	
									8.60 (0.50)	very stiff, yellow browny red, thinly to thickly laminated, slightly sandy silty CLAY with planar rough fractures.		8.60 (0.50)	
9.1									9.10	becoming weak to medium strong, grey, thinly laminated MUDSTONE.		9.10	

Drilling Progress and Water Observations

Date / Time	Depth	Casing	Case Dia.	Water
11/03/2015 00:00	9.10	4.00		

Groundwater

Struck	Rise	Sealed	Flow Rate Remarks

Flush

Depth	Type	Returns

Remarks: Hands England 36 Lorry Rig Poor core recovery.

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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	1 Of 1	10	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No.
BH1

Dates : 11/03/15 - 11/03/15

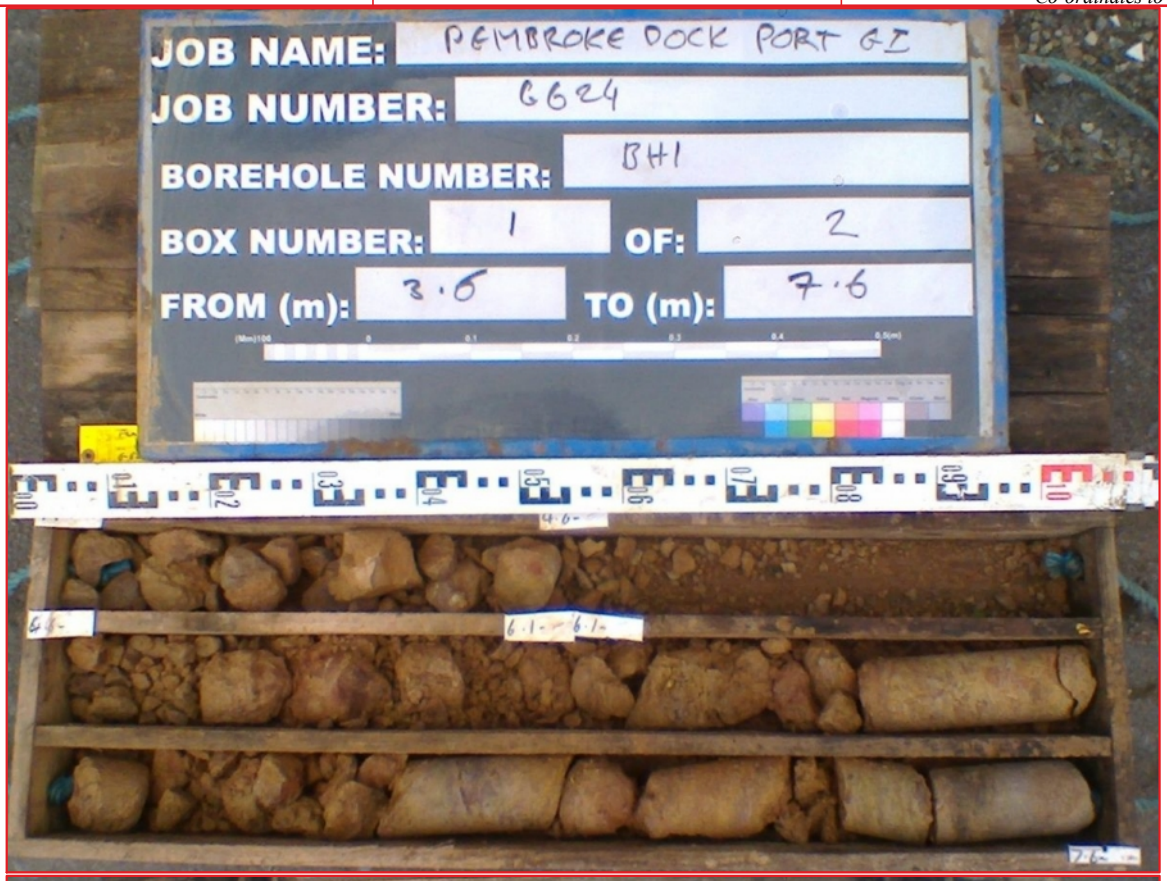
Location : Pembroke Dock Port

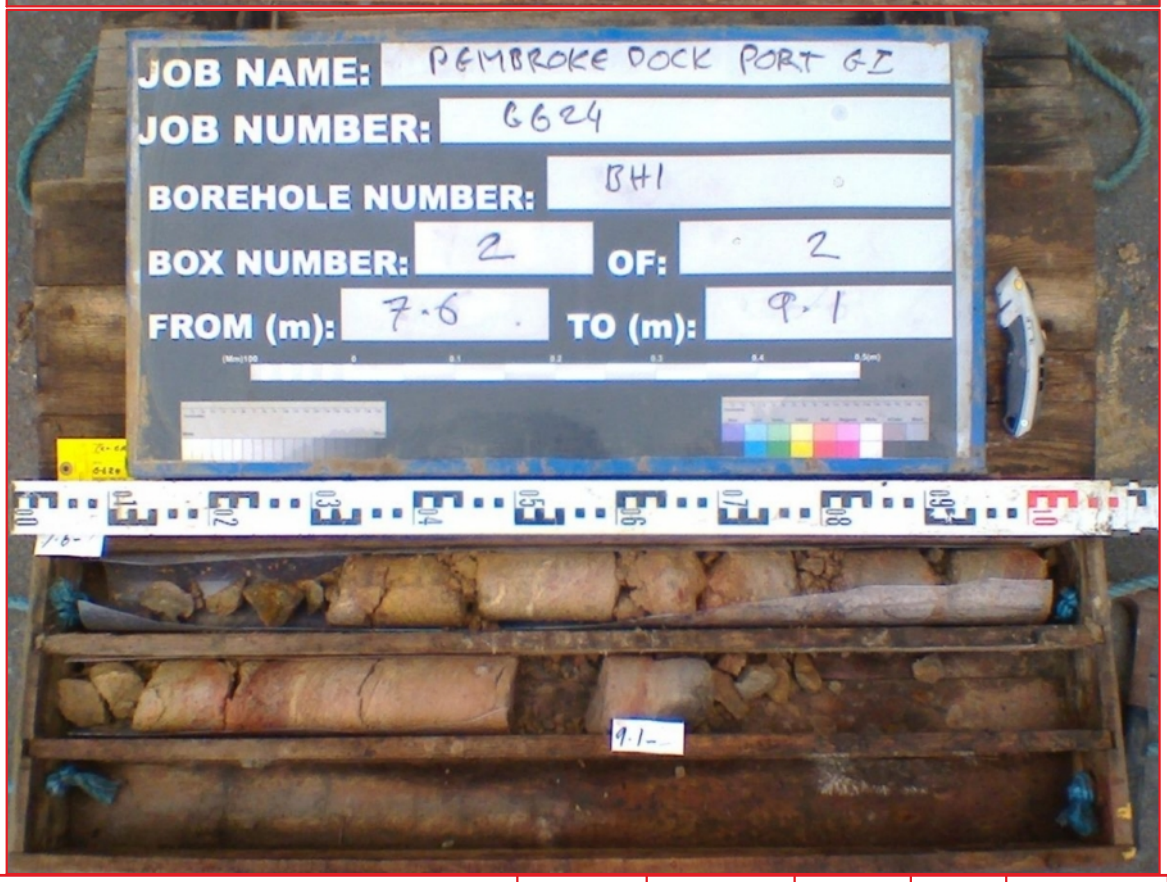
Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 169.85 E
58.41 N
Co-ordinates to Local Grid





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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	1 Of 1	2	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH2

Dates : 11/03/15 - 12/03/15

Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 91.90 E
77.03 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				Water
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness)	Description	Legend	Depth (Thick-ness)	
									(0.40)	(Driller: hardcore Subbase and TARMAC)		(0.40)	
									0.40	(Driller: MADE GROUND time and clay)		0.40	
1					1.2	SPT () 35 (3-7-**8-9-9-9**)							
2					2	SPT () 21 (4-4-**5-6-5-5**)			(2.70)			(2.70)	
3					3	SPT () 19 (2-4-**3-4-6-6**)							
					3.7	SPT () 50/105mm (20-5/0mm-**24-26/30mm**--)			3.10	(Driller: small limestone GRAVEL and some red silty CLAY)		3.10	
4	3.90								(0.80)			(0.80)	
		65	8	0					3.90	very weak to weak, black grey with brown bands, thinly to thickly laminated fine grained SILTSTONE. Ross mass is generally non-intact. Fractures are planar rough and surfaces have orange staining indicating discolouration weathering.		3.90	
5	4.90								(1.00)			(1.00)	
		50	5	0					4.90	very strong, medium to dark grey, fine to medium grained, LIMESTONE. Rock mass is generally non-intact. Fractures are planar rough and undulating rough, wide apertured, and surfaces have orange staining indicating discolouration weathering.		4.90	
6	5.90								(1.00)			(1.00)	
		33	3	0					5.90	strong to very strong, medium to dark grey, medium grained and slightly welded, slightly metamorphosed LIMESTONE. Fractures are planar rough and undulating rough with orange surface staining indicating discolouration weathering.		5.90	
7					7.4	SPT () 50/30mm (25/50mm-0/0mm-**50/30mm**---)			(1.50)			(1.50)	
	7.40								7.40	strong, medium grey, fine to medium grained, LIMESTONE with surface orange and brown weathering discolouration. Fractures are undulating rough and planar rough with orange staining indicating discolouration weathering. Rock mass has infrequent 2-3mm aperture lamina of crystalised calcite.		7.40	
8		80	19	15					(0.40)			(0.40)	
									7.80	medium brown yellow, thinly to thickly laminated medium grained, METAMORPHIC rock with some orange surface discolouration weathering and occasional zones of slightly welded quartzite.		7.80	
	8.9								(1.10)			(1.10)	
									8.90	mid brown yellow, medium grained, thinly to		8.90	

Drilling Progress and Water Observations						Groundwater				Flush		
Date / Time		Depth	Casing	Case Dia.	Water	Struck	Rise	Sealed	Flow Rate Remarks	Depth	Type	Returns
11/03/2015	00:00	1.20	1.20			7.90	7.10		medium inflow			
12/03/2015	00:00	8.90	5.00									

Remarks: Hands England 36 Lorry Rig Poor core recovery.

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Operator:	Logged By.	Sheet No.	m Per Page	All measurements in metres unless otherwise stated	AGS
K Osborne	L de Leeuw 12/03/2015	1 Of 2	10		

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH2

Dates : 11/03/15 - 12/03/15

Job Number : G624

Ground Level :

Location : Pembroke Dock Port

Engineer : Milford Haven Port Authority

Coordinates: 91.90 E
77.03 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				Water
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness	Description	Legend	Depth (Thick-ness	
										thickly laminated METASEDIMENTARY sammite with some surface orange discolouration weathering and occasional zones of slightly welded quartzite.			

Drilling Progress and Water Observations					Groundwater				Flush		
Date / Time	Depth	Casing	Case Dia.	Water	Struck	Rise	Sealed	Flow Rate Remarks	Depth	Type	Returns

Remarks: Hands England 36 Lorry Rig Poor core recovery.

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K Osborne	L de Leeuw 12/03/2015	2 Of 2	10	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No.
BH2

Dates : 11/03/15 - 12/03/15

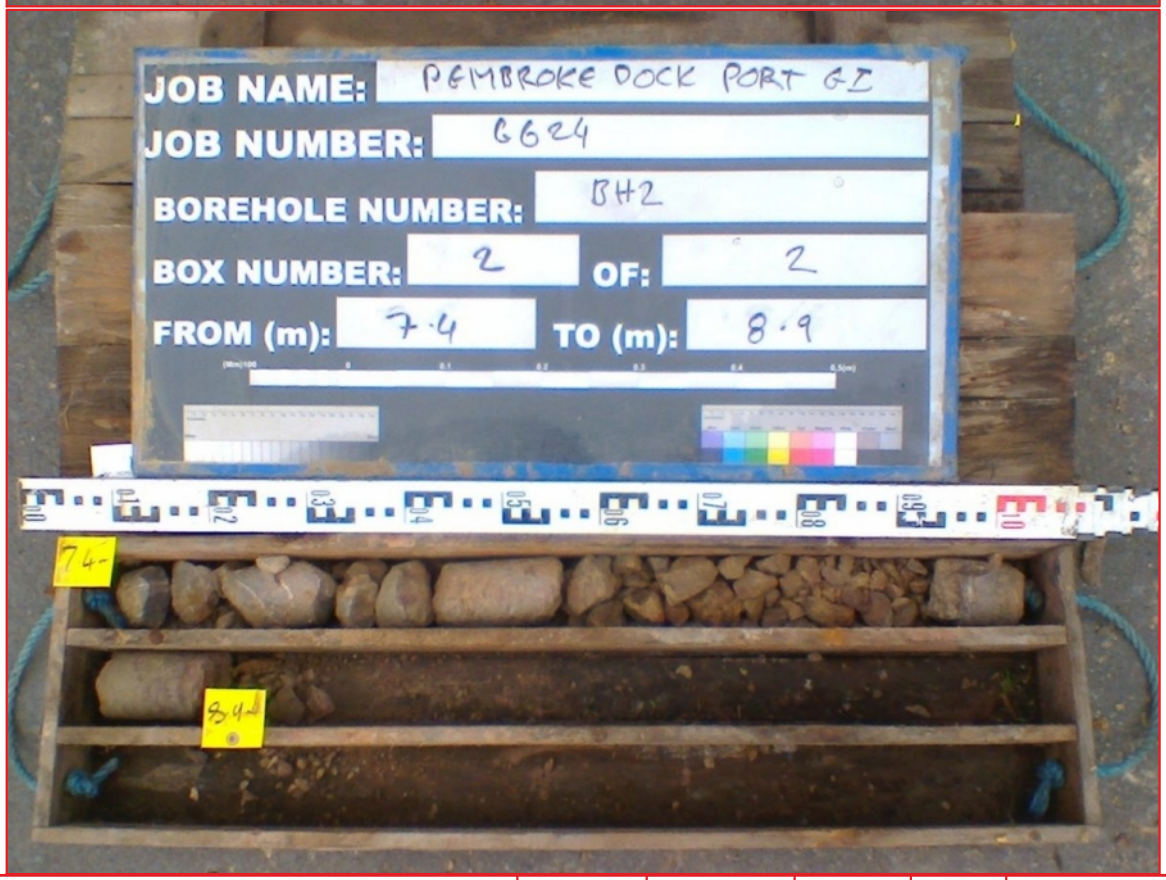
Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 91.90 E
77.03 N
Co-ordinates to Local Grid



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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	1 Of 1	2	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH3

Dates : 16/03/15 - 16/03/15

Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 55.48 E
98.23 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				Water
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness	Description	Legend	Depth (Thick-ness	
									(0.30)	(Driller: TARMAC)		(0.30)	
									0.30	(Driller: MADE GROUND: clay limestone boulders and black ash)		0.30	
1					1.2	SPT () 25 (3-7-**5-6-7-7**)							
2					2	SPT () 31 (5-6-**8-8-8-7**)			(3.10)			(3.10)	
3					3	SPT () 22 (3-5-**4-6-6-6**)							
									3.40	(Driller: brown SAND and some small gravel)		3.40	
4					4	SPT () 18 (4-4-**4-5-4-5**)							
5					5	SPT () 34 (7-6-**7-9-9-9**)			(2.60)			(2.60)	
6	6.00				6	SPT () 40 (10-9-**11-11-9-9**)			6.00	(Driller: highly weathered limestone)		6.00	
		0	0	0					(1.00)			(1.00)	
7	7.00				7	SPT () 50/115mm (25/50mm-0/0mm-**28-22/40mm**-)			7.00	very strong, dark grey, fine grained LIMESTONE with some calcite mineralisation. Fractures have orange staining indicating discolouration weathering.		7.00	
		25	4	0									
8	8.00								(2.00)			(2.00)	
		20	0	0									
9	9.00								9.00	weak to medium strong, grey black, thickly laminated, fractured, PHYLITE.		9.00	
		20	0	0					(1.50)			(1.50)	

Drilling Progress and Water Observations					Groundwater				Flush		
Date / Time	Depth	Casing	Case Dia.	Water	Struck	Rise	Sealed	Flow Rate Remarks	Depth	Type	Returns

Remarks: Hands England 36 Lorry Rig Very poor core recovery.

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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	1 Of 2	10	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH3

Dates : 16/03/15 - 16/03/15

Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 55.48 E
98.23 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				Water
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness	Description	Legend	Depth (Thick-ness	
	20	0	0							weak to medium strong, grey black, thickly laminated, fractured, PHYLITE.			
10.50									10.50	very strong, orange grey, fine grained LIMESTONE with some evidence of potential dolomitisation in places. Fractures have orange discolouration weathering.		10.50	
11	60	10	7						(1.00)			(1.00)	
									11.50	grey yellow sandy GRAVEL with some 4-5cm angular to subangular cobbles.		11.50	
12 12.00									(0.50)			(0.50)	
	33	17	10						12.00	very strong, orange grey, fine grained LIMESTONE with some evidence of potential dolomitisation in places and calcite mineralisation, 1-3mm aperture band. Fractures have orange discolouration weathering.		12.00	
13									(1.50)			(1.50)	
13.5									13.50			13.50	

Drilling Progress and Water Observations

Date / Time	Depth	Casing	Case Dia.	Water
16/03/2015 00:00	13.50	6.00		

Groundwater

Struck	Rise	Sealed	Flow Rate Remarks
12.00	11.80		Slow inflow

Flush

Depth	Type	Returns

Remarks: Hands England 36 Lorry Rig Very poor core recovery.

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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	2 Of 2	10	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No.
BH3

Dates : 16/03/15 - 16/03/15	Job Number : G624	Ground Level :
Location : Pembroke Dock Port	Engineer : Milford Haven Port Authority	Coordinates: 55.48 E 98.23 N *Co-ordinates to Local Grid*

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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	1 Of 1	2	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH5

Dates : 12/03/15 - 13/03/15

Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 137.33 E
147.40 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				Water
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness	Description	Legend	Depth (Thick-ness	
									(0.40)	(Driller: hardcore Subbase and TARMAC)		(0.40)	
									0.40	(Driller: MADE GROUND timber and clay)		0.40	
					1.2	SPT () 16 (3-4-**4-4-4-4**)							
					2	SPT () 15 (2-3-**3-3-5-4**)			(3.10)			(3.10)	
					3	SPT () 19 (1-3-**4-5-5-5**)							
					4	SPT () 28 (4-5-**6-7-7-8**)			3.50	(Driller: small limestone GRAVEL and black SILT)		3.50	
					5	SPT () 25 (4-4-**6-6-6-7**)							
					6	SPT () 19 (3-5-**6-4-4-5**)							
					7	SPT () 20 (2-3-**5-5-4-6**)							
					8	SPT () 30 (4-6-**7-7-8-8**)			(8.50)			(8.50)	
					9	SPT () 50/190mm (5-9-**20-16-14/40mm**-)							

Drilling Progress and Water Observations

Date / Time	Depth	Casing	Case Dia.	Water

Groundwater

Struck	Rise	Sealed	Flow Rate Remarks
3.80	3.60		Medium inflow
9.00	7.60		Fast inflow

Flush

Depth	Type	Returns

Remarks: Hands England 36 Lorry Rig No core recovery.

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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	1 Of 3	10	All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH5

Dates : 12/03/15 - 13/03/15

Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 137.33 E
147.40 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				Water
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness	Description	Legend	Depth (Thick-ness	
					10	SPT () 46 (10-12-**10-9-12-15**)				(Driller: small limestone GRAVEL and black SILT)			
					11	SPT () 41 (8-9-**8-9-12-12**)							
					12	SPT () 34 (5-7-**8-8-8-10**)			12.00	(Driller: grey and brown limestone angular GRAVEL possibly highly weathered limestone)		12.00	
					13	SPT () 44 (8-8-**9-11-12-12**)							
					14	SPT () 49 (4-6-**10-10-14-15**)							
					15	SPT () 50/105mm (25/55mm-0/0mm-**31-19/30mm**-)							
					16	SPT () 50/285mm (9-9-**12-13-13-12/60mm**)			(8.00)			(8.00)	
					17	SPT () 50/150mm (6-14-**20-23-7/0mm**-)							
					18	SPT () 50/205mm (13-12/40mm-**15-17-18/55mm**-)							
					19								

Drilling Progress and Water Observations

Date / Time	Depth	Casing	Case Dia.	Water
12/03/2015 00:00	12.00	12.00		
13/03/2015 00:00	20.00	18.00		

Groundwater

Struck	Rise	Sealed	Flow Rate Remarks

Flush

Depth	Type	Returns

Remarks: Hands England 36 Lorry Rig No core recovery.

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Operator: K Osborne

Logged By: L de Leeuw 12/03/2015

Sheet No. 2 Of 3

m Per Page 10

All measurements in metres unless otherwise stated

AGS

Contract : Pembroke Dock Port

Client : Milford Haven Port Authority

Borehole No. BH5

Dates : 12/03/15 - 13/03/15

Location : Pembroke Dock Port

Job Number : G624

Engineer : Milford Haven Port Authority

Ground Level :

Coordinates: 137.33 E
147.40 N
Co-ordinates to Local Grid

Run Details					Test Details		Samples		STRATA				Water
Core Run	TCR	SCR	RQD	FI	Depth	Test Results	Depth	Type-No.	Depth (Thick-ness	Description	Legend	Depth (Thick-ness	
									20.00			20.00	

Drilling Progress and Water Observations					Groundwater				Flush		
Date / Time	Depth	Casing	Case Dia.	Water	Struck	Rise	Sealed	Flow Rate Remarks	Depth	Type	Returns

Remarks: Hands England 36 Lorry Rig No core recovery.

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Operator:	Logged By.	Sheet No.	m Per Page	
K Osborne	L de Leeuw 12/03/2015	3 Of 3	10	All measurements in metres unless otherwise stated

AGS

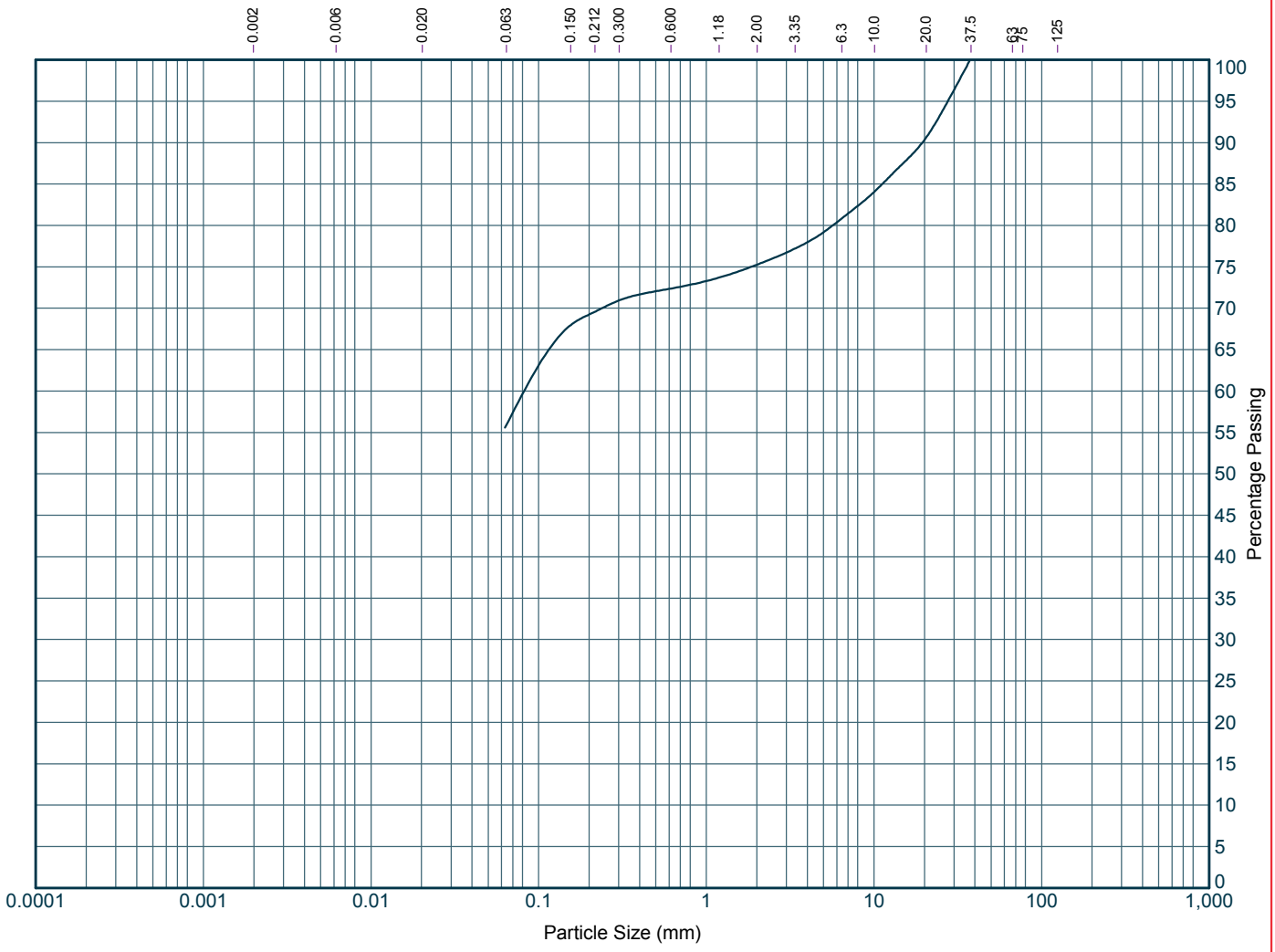
APPENDIX IV – GEOTECHNICAL LABORATORY TEST RESULTS

Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP04 / 7 Depth (m) 3 -



BS Test Sieve	Percentage Passing
125	100.00
75	100.00
63	100.00
37.5	100.00
20	95.23
10	90.32
6.3	86.96
3.35	84.03
2	79.17
1.18	77.17
0.6	73.67
0.3	71.78
0.212	69.49
0.15	67.72
0.063	55.58

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	31
Gravel	-18
Sand	-13
Silt/Clay	100

Remarks :

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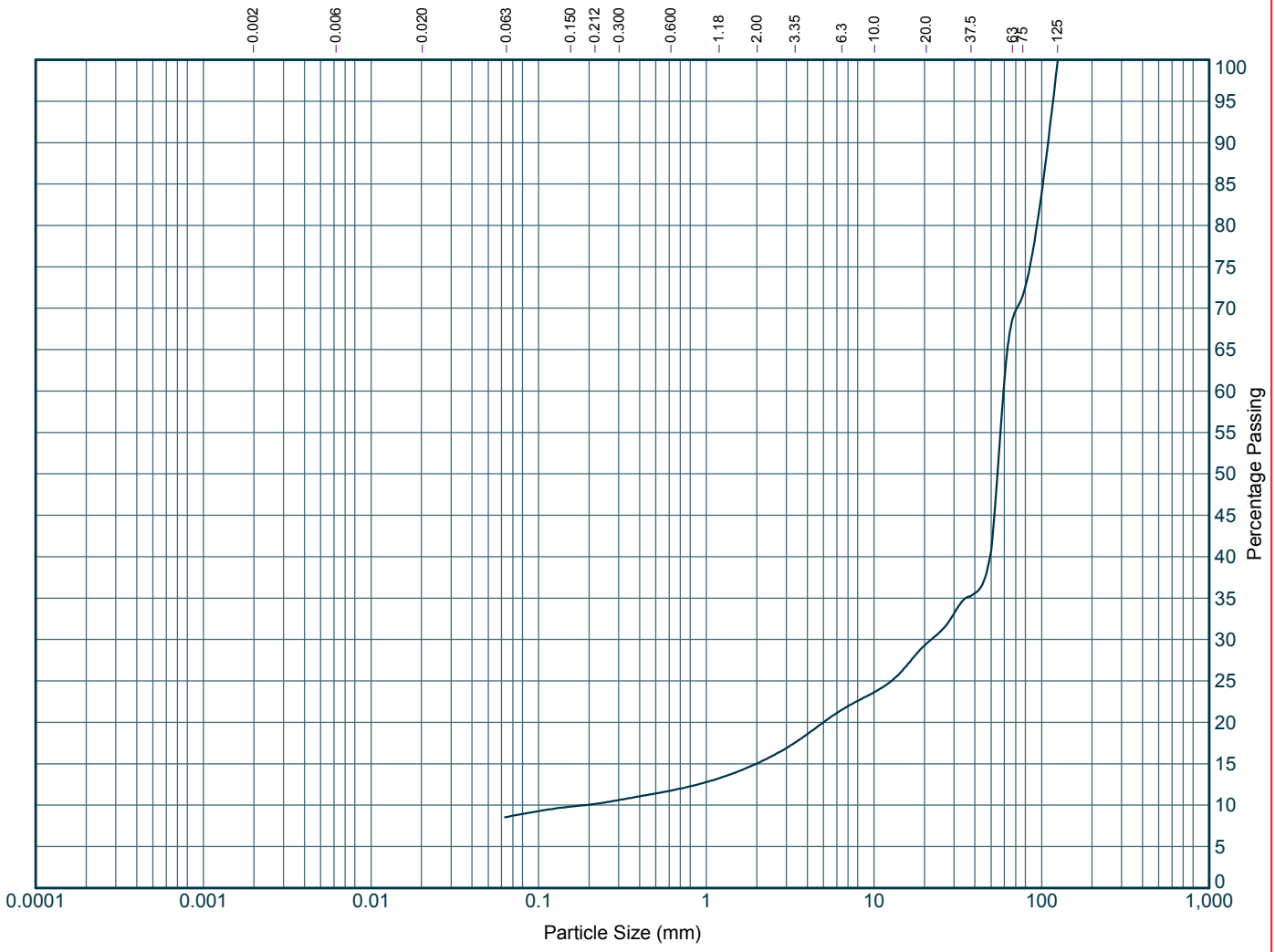
AGS

Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP06 / 3 Depth (m) 1 -



BS Test Sieve	Percentage Passing
125	100.00
75	70.89
63	65.53
37.5	40.75
20	32.18
10	29.28
6.3	25.76
3.35	23.62
2	20.00
1.18	17.50
0.6	13.22
0.3	11.16
0.212	10.12
0.15	9.79
0.063	8.54

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	90
Gravel	-16
Sand	-74
Silt/Clay	100

Remarks :

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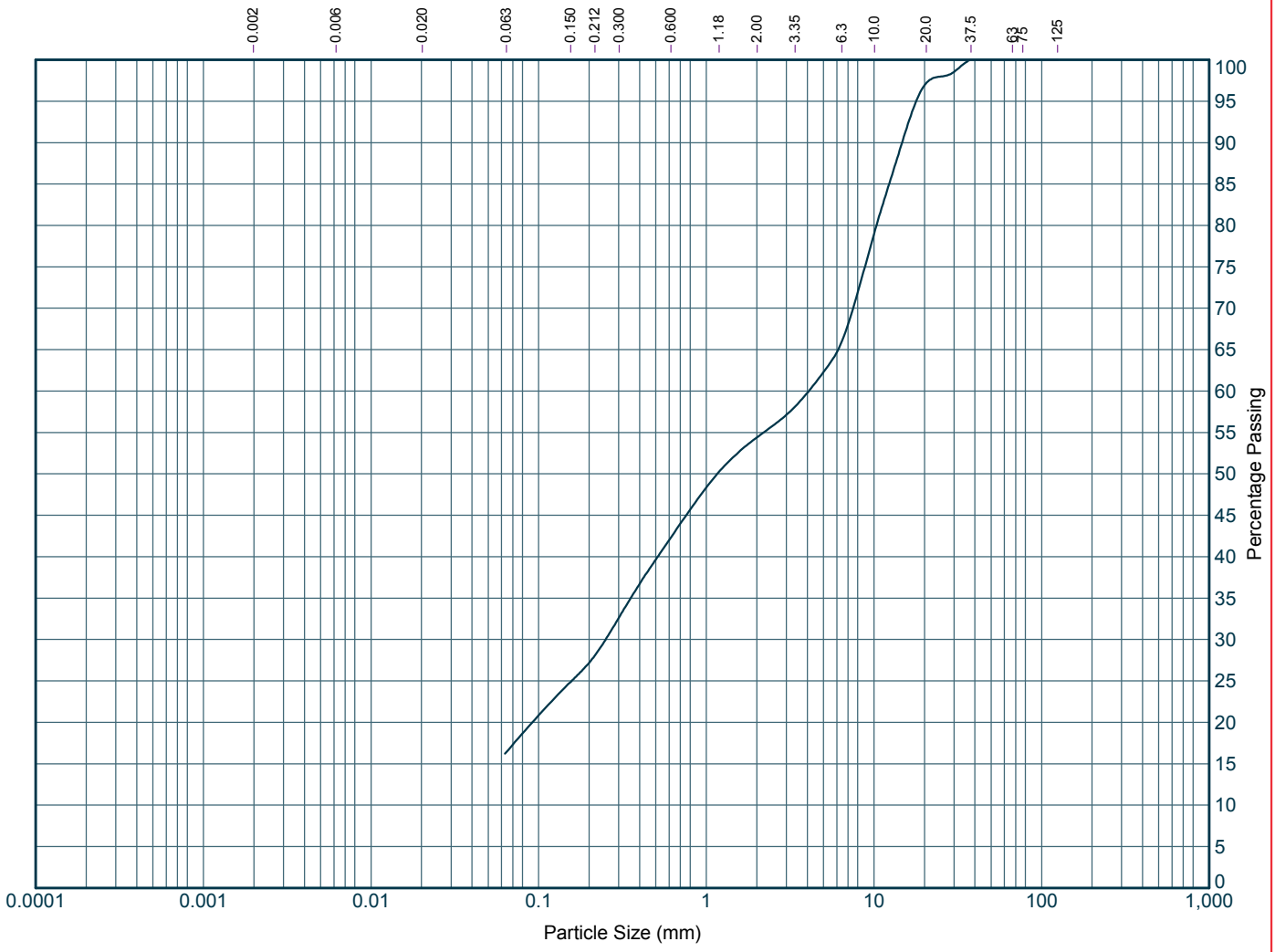
Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP09 / 1 Depth (m) 0.3 -



BS Test Sieve	Percentage Passing
125	100.00
75	100.00
63	100.00
37.5	100.00
20	98.19
10	96.92
6.3	88.59
3.35	78.95
2	62.28
1.18	58.03
0.6	50.15
0.3	37.55
0.212	27.84
0.15	24.60
0.063	16.22

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	72
Gravel	-61
Sand	-11
Silt/Clay	100

Remarks :

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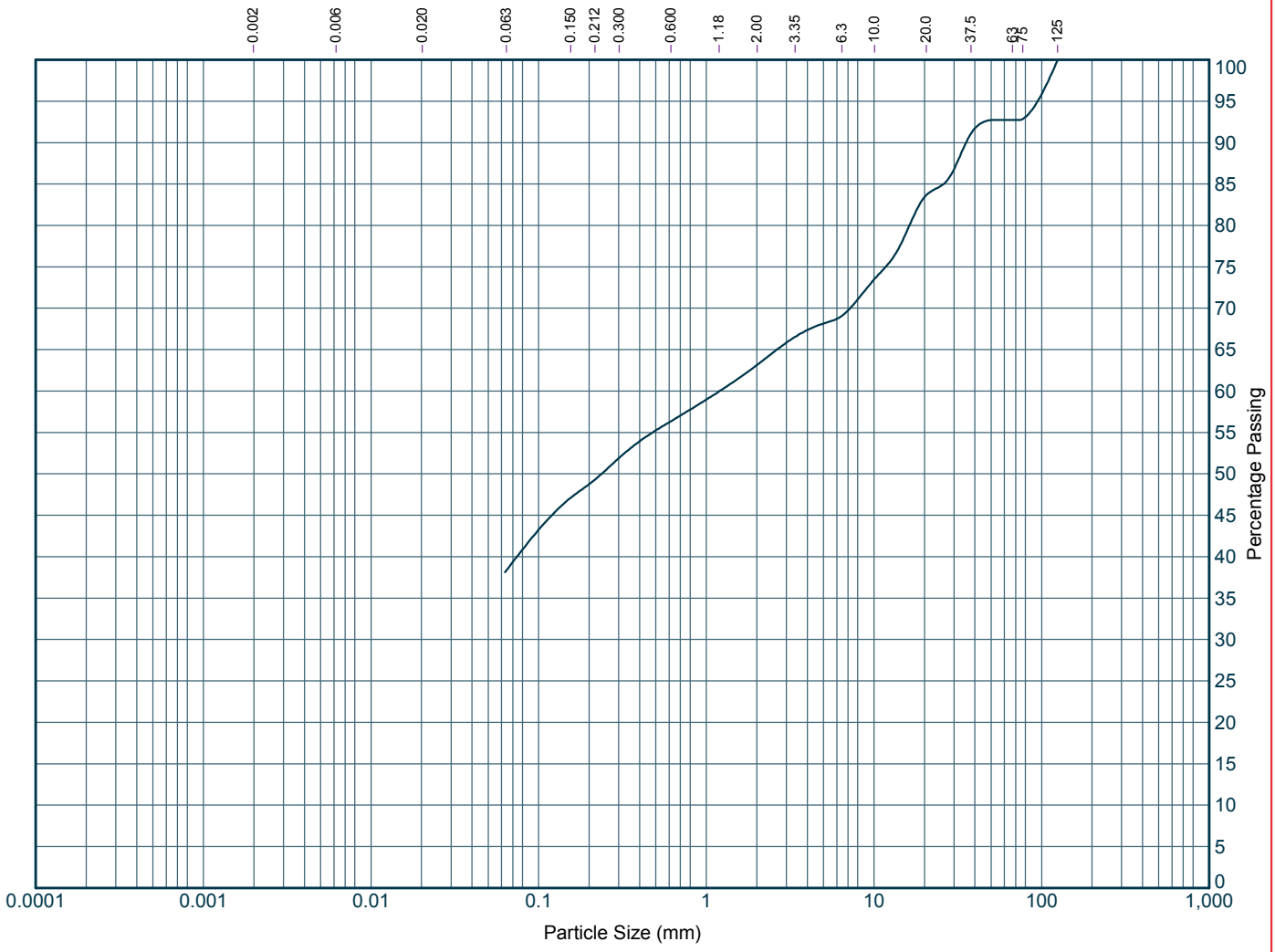
AGS

Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP09 / 3 Depth (m) 0.7 -



BS Test Sieve	Percentage Passing
125	100.00
75	92.73
63	92.73
37.5	92.73
20	85.71
10	83.41
6.3	77.19
3.35	73.46
2	68.15
1.18	66.49
0.6	59.90
0.3	54.32
0.212	49.16
0.15	46.87
0.063	38.14

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	51
Gravel	-28
Sand	-23
Silt/Clay	100

Remarks :

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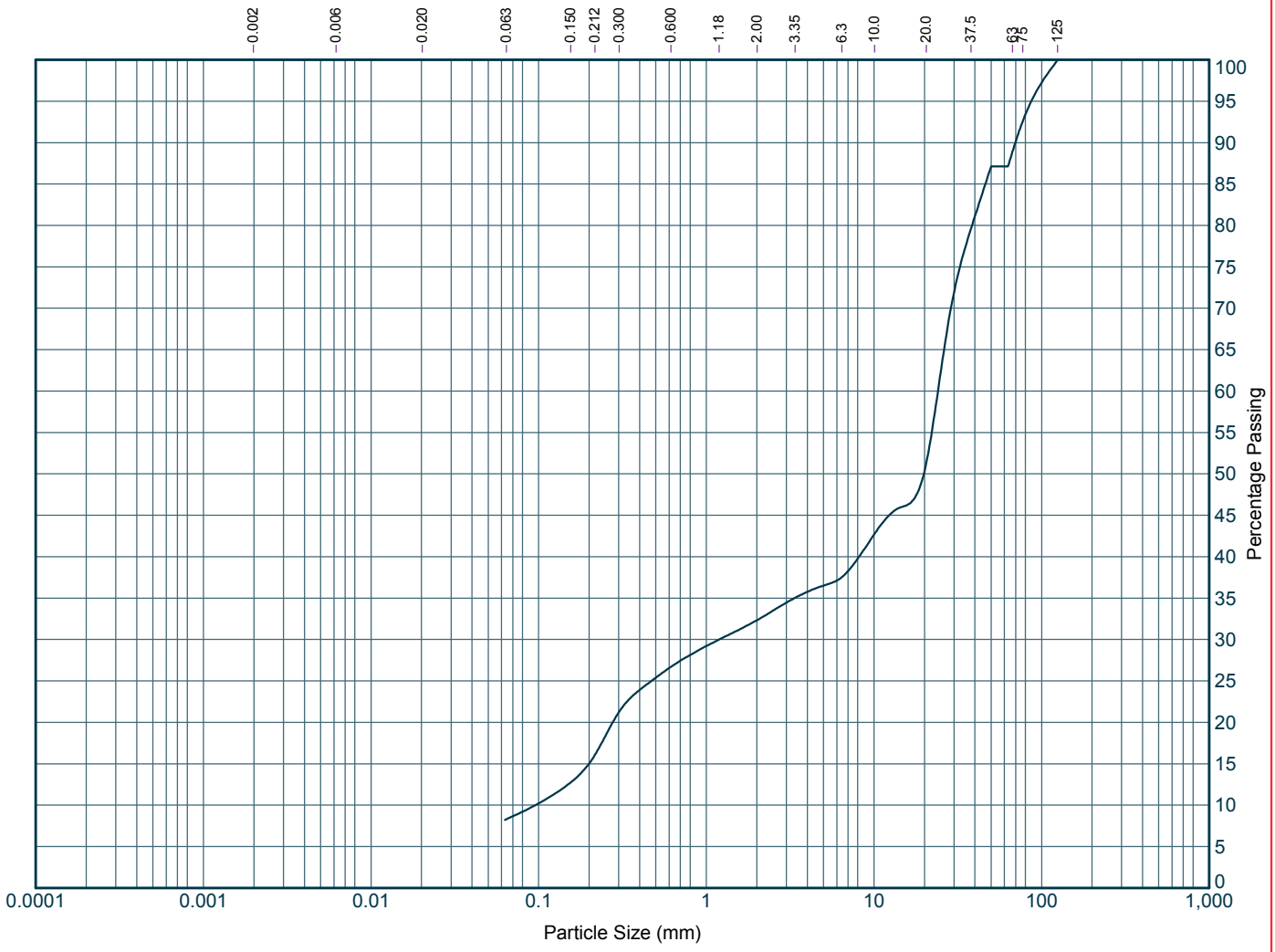
Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP10 / 1 Depth (m) 0.3 -



BS Test Sieve	Percentage Passing
125	100.00
75	91.91
63	87.11
37.5	87.11
20	68.69
10	50.30
6.3	45.85
3.35	42.66
2	36.51
1.18	34.99
0.6	29.95
0.3	24.32
0.212	15.77
0.15	12.51
0.063	8.22

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	84
Gravel	-30
Sand	-54
Silt/Clay	100

Remarks :

Quantum Geotechnical

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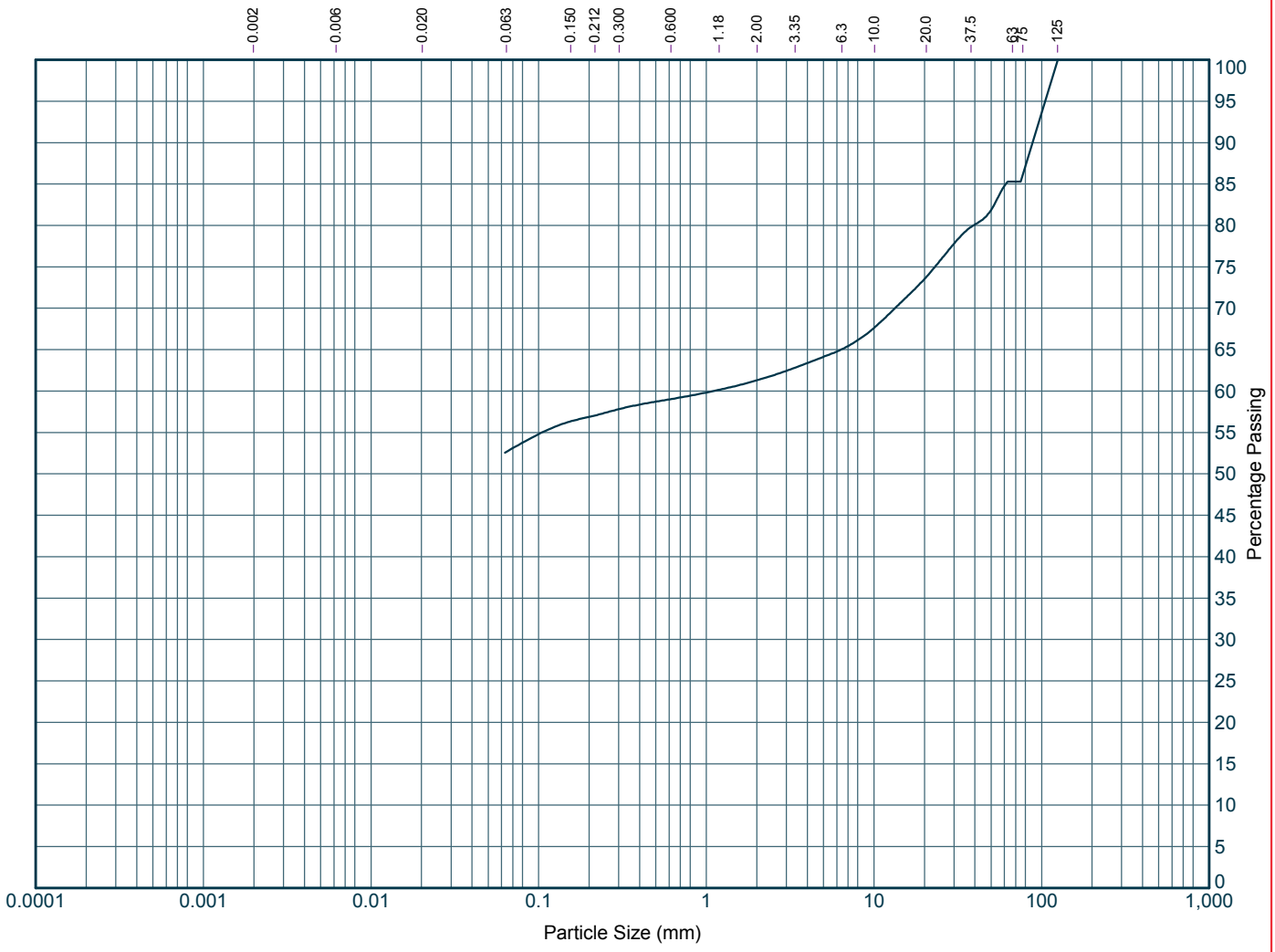
AGS

Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP10 / 7 Depth (m) 2.5 -



BS Test Sieve	Percentage Passing
125	100.00
75	85.28
63	85.28
37.5	81.87
20	77.06
10	73.53
6.3	70.41
3.35	67.62
2	64.14
1.18	62.79
0.6	60.13
0.3	58.47
0.212	57.00
0.15	56.26
0.063	52.57

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	43
Gravel	-13
Sand	-30
Silt/Clay	100

Remarks :

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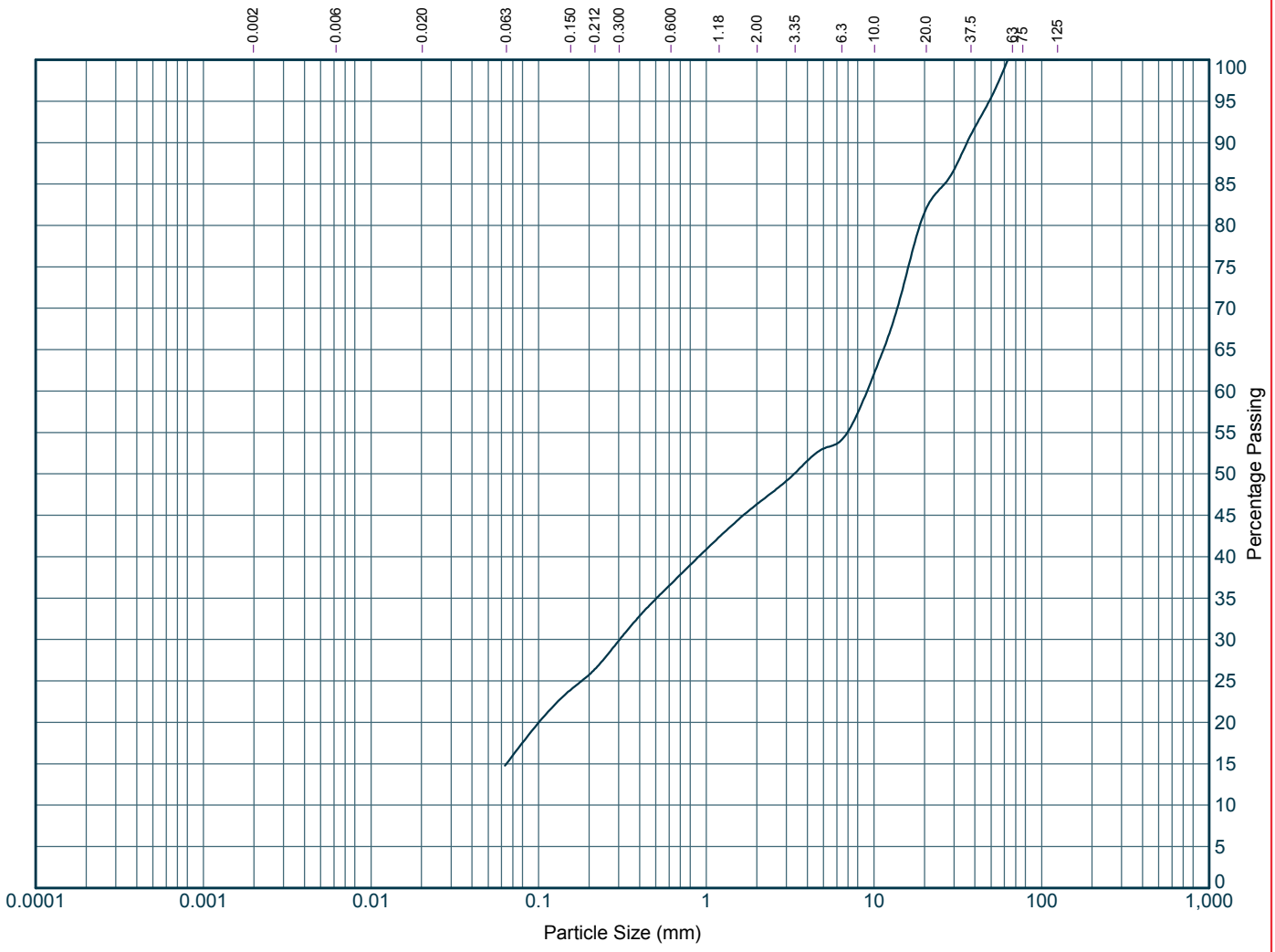
Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP11 / 1 Depth (m) 0.3 -



BS Test Sieve	Percentage Passing
125	100.00
75	100.00
63	100.00
37.5	95.44
20	85.69
10	81.55
6.3	70.47
3.35	62.08
2	53.05
1.18	50.02
0.6	42.28
0.3	33.43
0.212	26.24
0.15	23.68
0.063	14.78

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	74
Gravel	-44
Sand	-30
Silt/Clay	100

Remarks :

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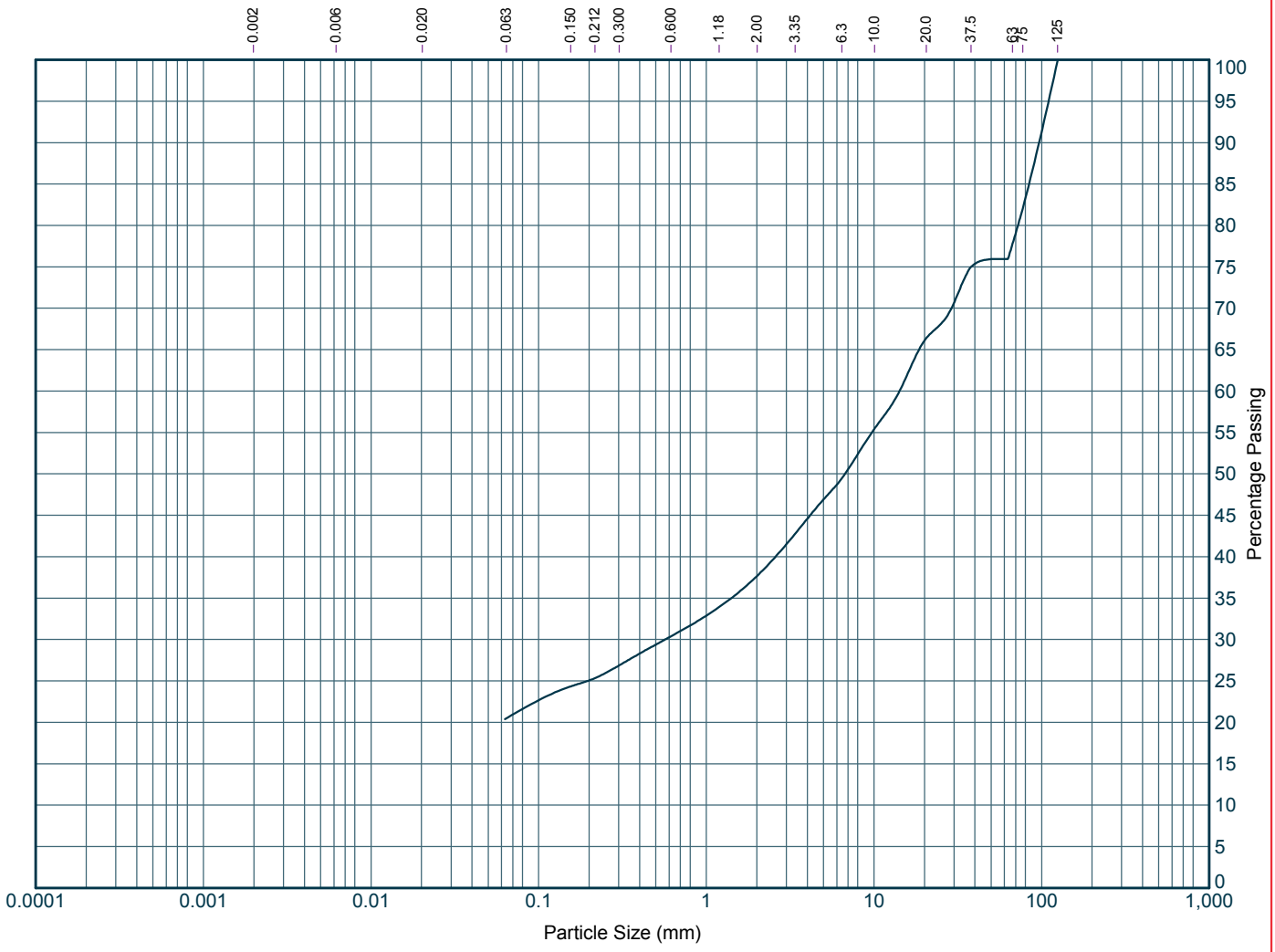
AGS

Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP14 / 1 Depth (m) 0.3 -



BS Test Sieve	Percentage Passing
125	100.00
75	81.16
63	75.94
37.5	75.94
20	69.41
10	66.09
6.3	59.74
3.35	55.38
2	46.90
1.18	42.65
0.6	33.85
0.3	28.60
0.212	25.26
0.15	24.24
0.063	20.39

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	75
Gravel	-35
Sand	-40
Silt/Clay	100

Remarks :

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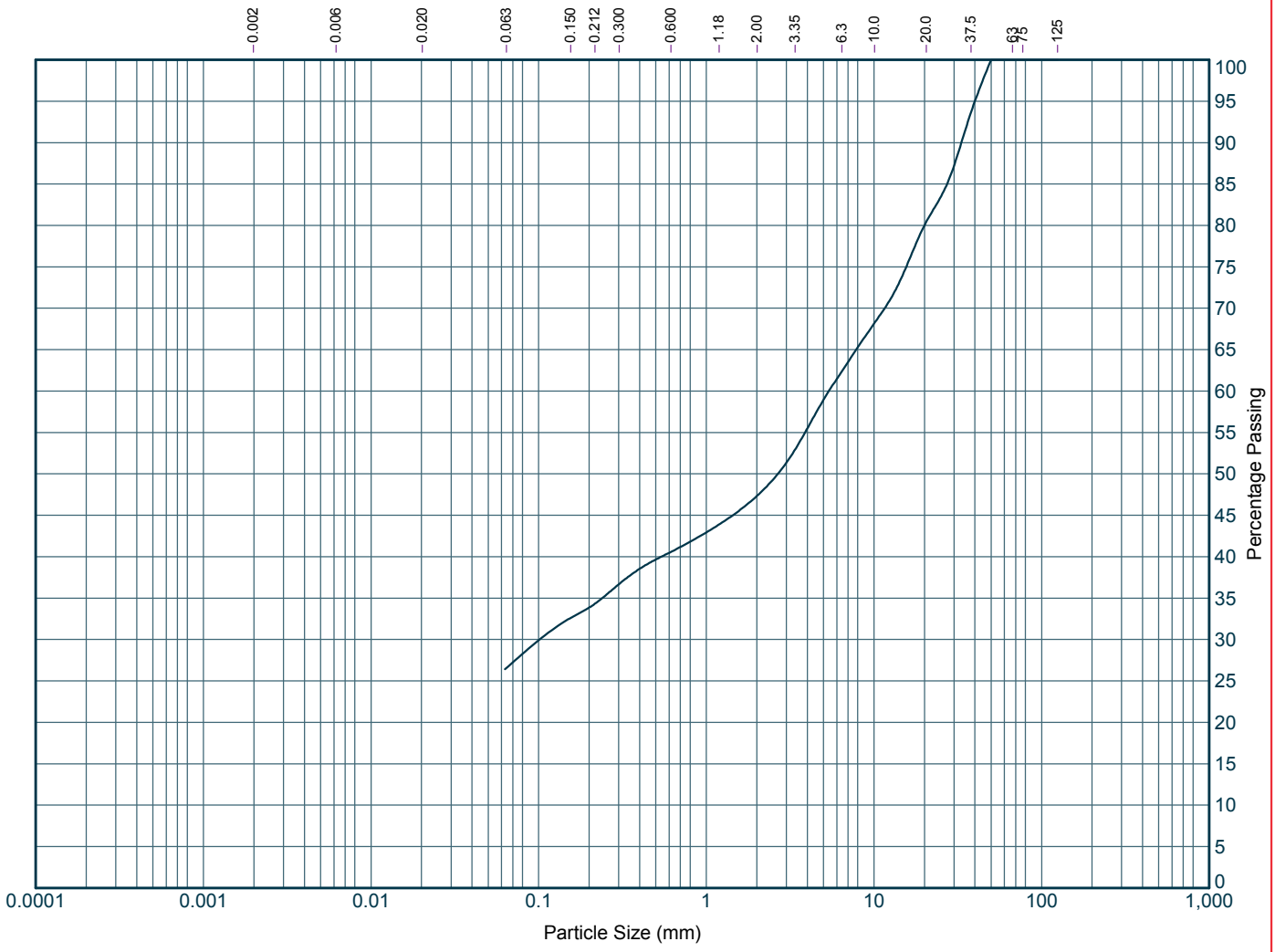
AGS

Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP15 / 1 Depth (m) 0.3 -



BS Test Sieve	Percentage Passing
125	100.00
75	100.00
63	100.00
37.5	100.00
20	85.54
10	80.01
6.3	72.90
3.35	68.13
2	58.95
1.18	52.79
0.6	43.83
0.3	38.87
0.212	34.19
0.15	32.43
0.063	26.40

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	66
Gravel	-39
Sand	-27
Silt/Clay	100

Remarks :

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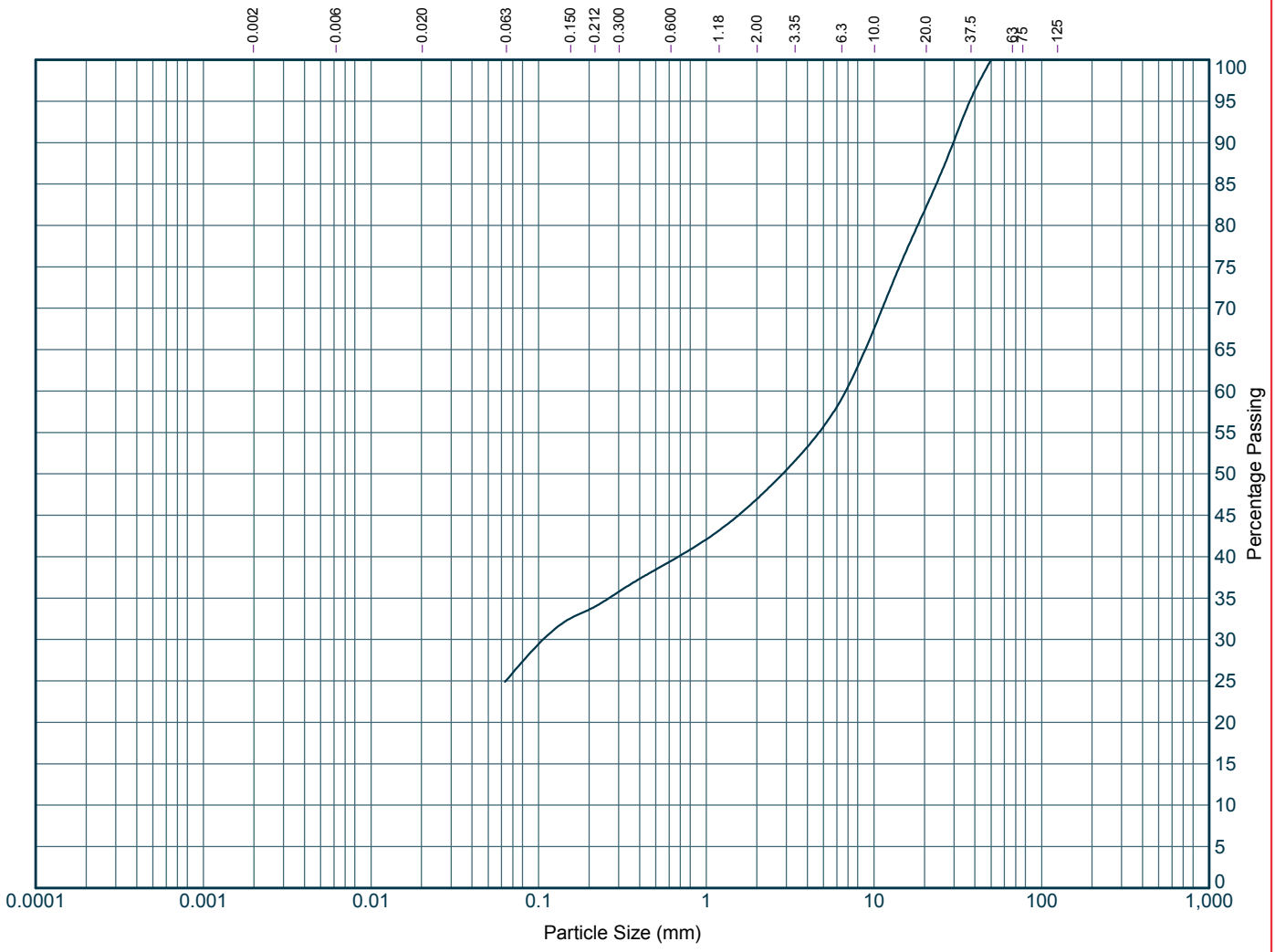
Contract : Pembroke Dock Port	Client : Milford Haven Port Authority
Contract Number : G624	

PARTICLE SIZE DISTRIBUTION TEST

BS1377:Part 2:1990

Borehole / Sample Number TP16 / 3 Depth (m) 1 -



BS Test Sieve	Percentage Passing
125	100.00
75	100.00
63	100.00
37.5	100.00
20	88.64
10	81.78
6.3	74.75
3.35	67.50
2	55.71
1.18	51.50
0.6	43.11
0.3	37.64
0.212	33.87
0.15	32.40
0.063	24.88

Particle Diameter	Percentage Passing
0.02	
0.006	
0.002	

Soil Fraction	Total Percentage
Cobbles	66
Gravel	-41
Sand	-25
Silt/Clay	100

Remarks :

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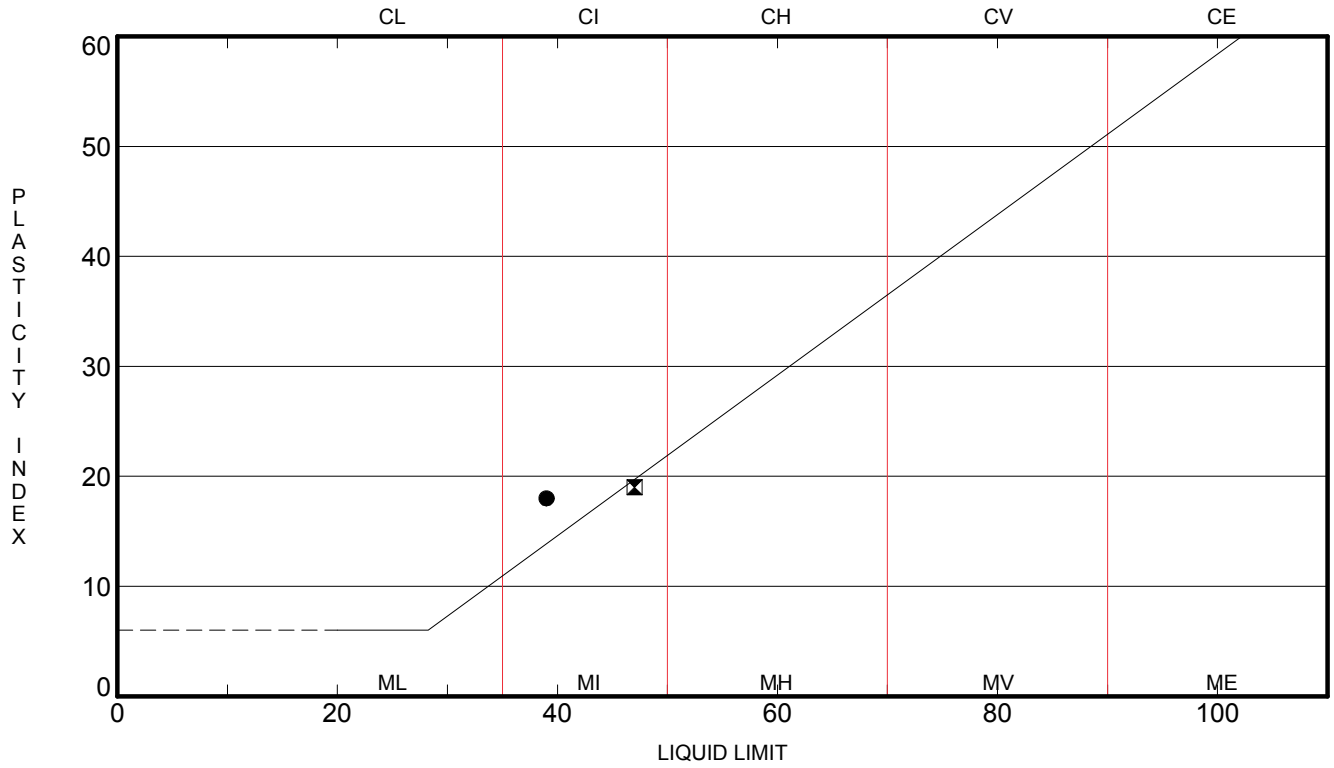

Hole ID	Sample Number	Depth (m)	Moisture Content % Clause 3.2	Liquid Limit % Clause 4.3/4.4	Plastic Limit % Clause 5.3	Plasticity Index % Clause 5.4	% Passing .425mm	Classification
● **TP05**	**3**	**0.80**	**27.00**	**39**	**21**	**18**	**84.00**	**CI Clay Intermediate**
⊠ **TP09**	**5**	**1.50**	**25.00**	**47**	**28**	**19**	**79.00**	**MI Silt Intermediate**

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AGS

SUMMARY OF SOIL CLASSIFICATION TESTS

(B.S. 1377 : PART 2 : 1990)

Client: Milford Haven Port Authority

Project: Pembroke Dock Port

Number: G624

SUMMARY OF SOIL CLASSIFICATION TESTS

(B.S. 1377 : PART 2 : 1990)

Borehole Number	Sample Number	Depth (m)	Moisture Content (%) Clause 3.2	Bulk Density (Mg/m^3) Clause 7.2	Dry Density (Mg/m^3) Clause 7.2	Particle Density (Mg/m^3) Clause 8.	Liquid Limit (%) Clause 4.3/4.4	Plastic Limit (%) Clause 5.	Plasticity Index (%) Clause 6.	% Passing .425mm	Remarks
TP04	7	3	16								
TP05	3	0.8	27				39	21	18	84	
TP06	3	1	6.3								
TP09	1	0.3	33								
TP09	3	0.7	17								
TP09	5	1.5	25				47	28	19	79	
TP09	7	2.5	17								
TP10	1	0.3	18								
TP10	7	2.5	19								
TP11	1	0.3	11								
TP14	1	0.3	9.5								
TP15	1	0.3	21								
TP16	3	1	15								

SYMBOLS: NP - Non Plastic ***: Liquid Limit and Plastic Limit Wet Sieved**

Checked by:		Date:	
Approved by:		Date:	
Contract No.:	**G624**	Page 1 of 1	

QUANTUM
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Tel: 01554 776150
email: enquiries@quantum-geotech.co.uk

Laboratory Report

2788

GEO Site & Testing Services Ltd

Contract Number: 26348

Client's Reference: **G624**

Report Date: **08-04-2015**

Client **Dawnus Construction Limited C/O Quantum Geotechnic**
Ty Berwig
Bynea
Llanelli.
Carmarthenshire.
SA14 9ST

Contract Title: **Pembroke Dock Port GI**

For the attention of: **A Ferrier**

Date Received: **24-03-2015**

Date Commenced: **24-03-2015**

Date Completed: **08-04-2015**

Test Description	Qty
Moisture Content 1377 : 1990 Part 2 : 3.2 - * UKAS	3
PSD Wet Sieve method 1377 : 1990 Part 2 : 9.2 - * UKAS	3
PSD: Sedimentation by hydrometer 1377 : 1990 Part 2 : 9.5 - @ Non Accredited Test	3
Determination of moisture content of a Rock Specimen. ISRM / BS 1377/2/3.3 2/2 - @ Non Accredited Test	5
Point load strength index test 10 Determinations. ISRM / BS 1377/2/3.3 Brock & Franklin 1972. - * UKAS	3
Determination of Point Load Value Axial or Diametrical - * UKAS	22
Disposal of Samples on Project	1

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

Approved Signatories:
Alex Wynn (Associate Director) - Benjamin Sharp (Contracts Manager) - D V Edwards (Managing Director)
Emma Williams (Office Manager) - Paul Evans (Quality/Technical Manager)

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

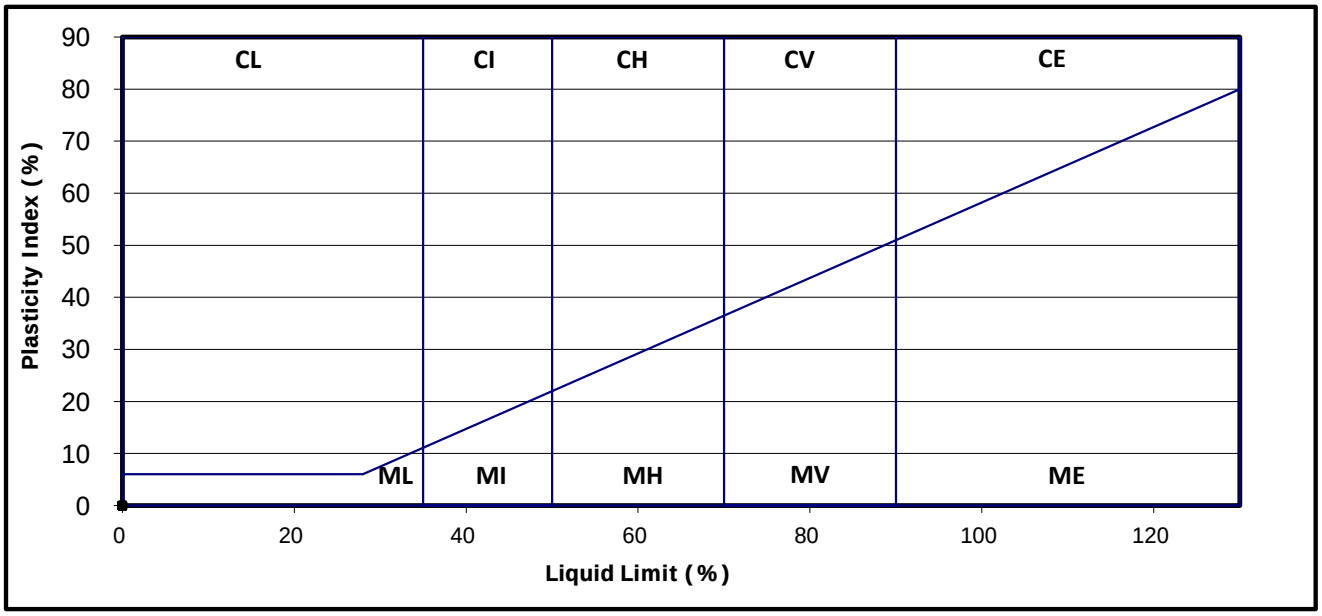
Test Report: **Method of the Determination of the plastic limit and plasticity index**
BS 1377 : Part 2 : 1990 Method 5

Client ref: **G624**
Location: **Pembroke Dock Port GI**
Contract Number: **26348-260315**

Hole / Sample Number	Sample Type	Depth m	Moisture Content % Cl. 3.2	Liquid Limit % Cl. 4.3/4.4	Plastic Limit % Cl. 5.	Plasticity Index % Cl. 6.	% Passing .425mm	Remarks
TP04/5	B	2.00	23					
TP05/3	B	0.80	28					
TP09/5	B	1.50	31					
BH1		8.10	2.7					
BH1		8.90	8.9					
BH2		7.90	1.4					
BH3		11.00	4.1					
BH3		12.00	1.1					

Symbols: **NP : Non Plastic** **# : Liquid Limit and Plastic Limit Wet Sieved**

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



GSTL
GEO SITE & TESTING SERVICES LTD

For and behalf of GEO Site & Testing Services Ltd

Authorised By:
Jonathan Tatam (Admin/Quality Assistant)
Date: 7.4.15

UKAS TESTING
2788

Test Report:

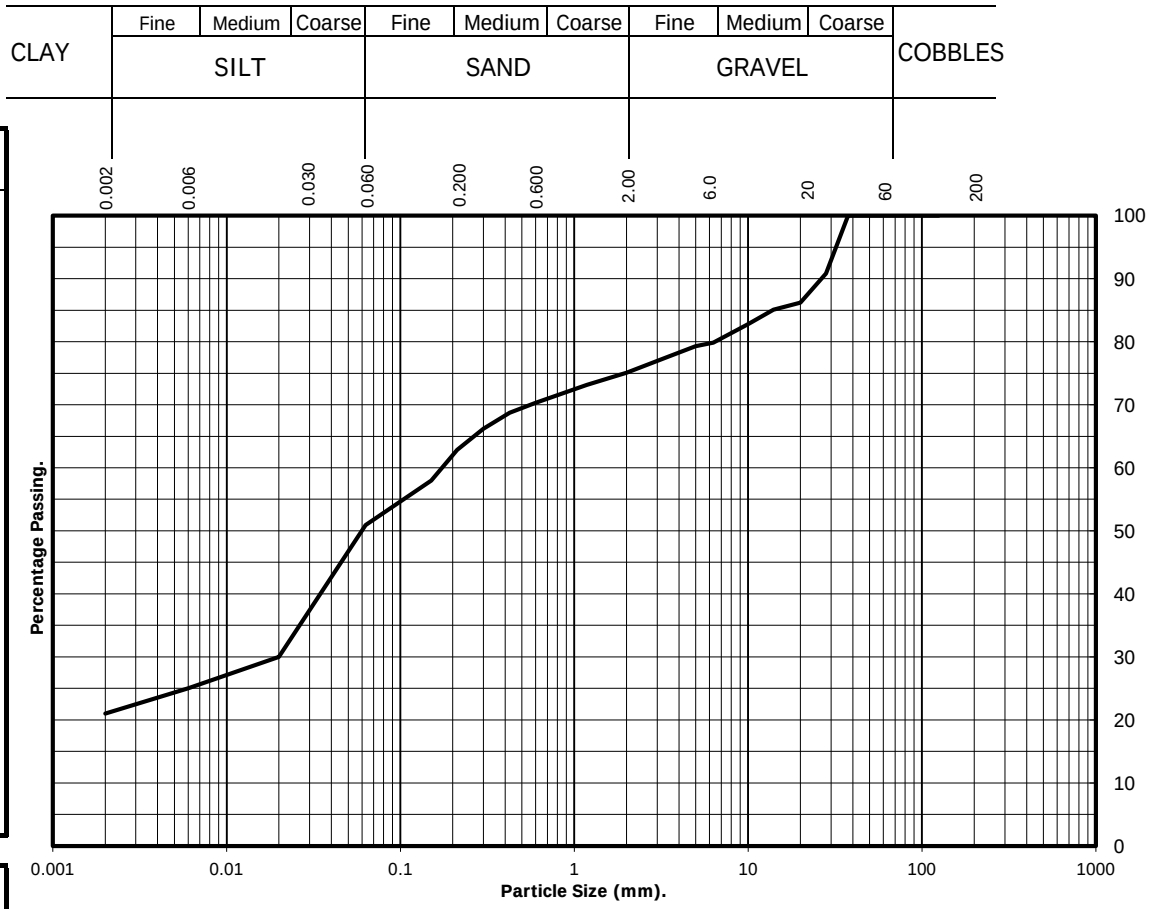
Particle Size Distribution Test
BS 1377 Part 2:1990.

Wet Sieve & Pipette Analysis, Clause 9.2 & 9.4

Client ref:	**G624**	**Sample Number:**	**5**
Contract Number:	**26348-260315**	**Depth from (m):**	**2.00**
Hole Number:	**TP04**	**Depth to (m):**	
		Sample Type:	**B**
Location:	**Pembroke Dock Port GI**		
Description:	**Brown clayey sandy gravelly (fine-coarse) SILT**		

BS Test Sieve	% Passing
125	100
90	100
75	100
63	100
50	100
37.5	100
28	91
20	86
14	85
10	83
6.3	80
5.0	79
3.35	77
2.00	75
1.18	73
0.60	70
0.425	69
0.300	66
0.212	63
0.150	58
0.063	51

Particle Diameter	% Passing
0.02	30
0.006	25
0.002	21



Clay	Silt	Sand	Gravel	Cobbles	Soil Fraction
21	30	24	25	0	Total Percentage

Remarks:

Cl 9.4.8 - Sample has not been pretreated

For and behalf of GEO Site & Testing Services Ltd

Authorised By:
Jonathan Tatam (Admin/Quality Assistant)

Date: 8.4.15

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GEO SITE & TESTING SERVICES LTD

UKAS TESTING 2788

Test Report:

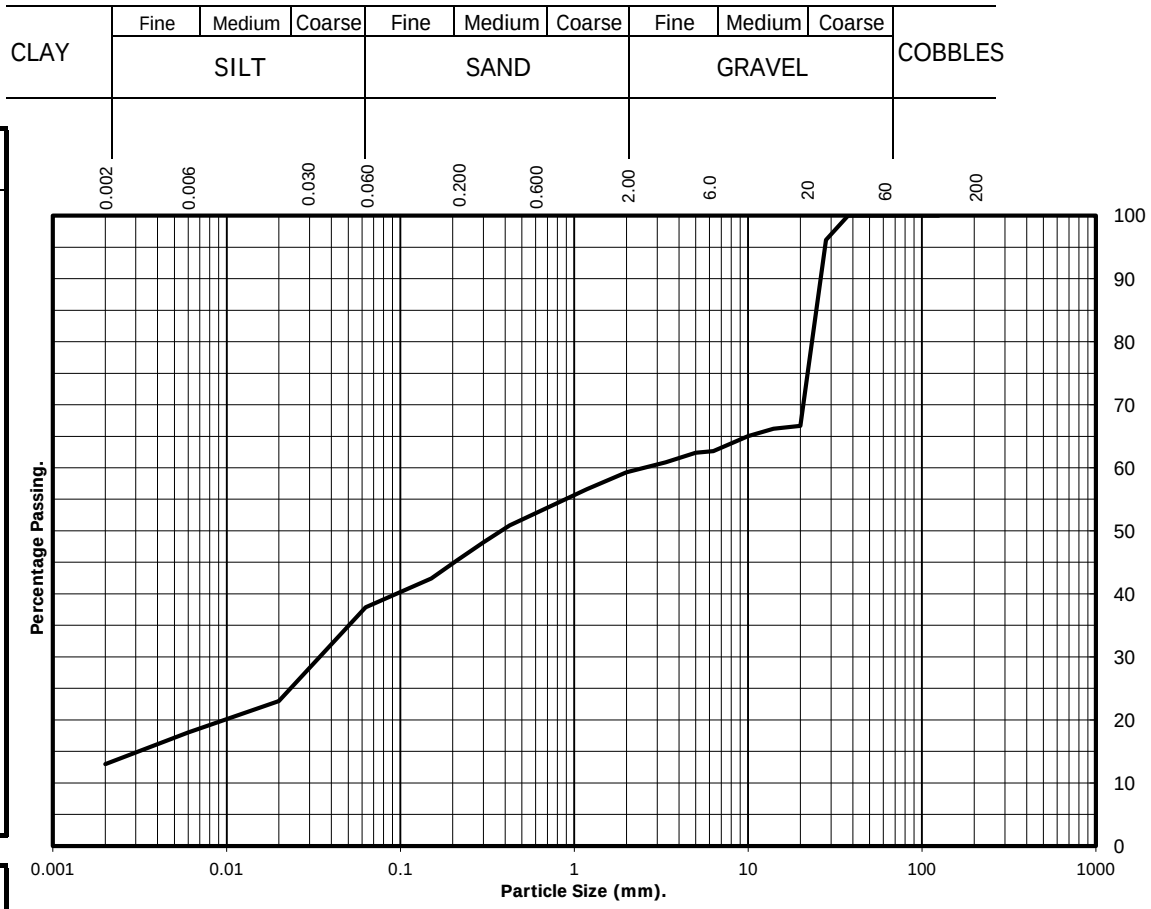
Particle Size Distribution Test
BS 1377 Part 2:1990.

Wet Sieve & Pipette Analysis, Clause 9.2 & 9.4

Client ref:	**G624**	**Sample Number:**	**3**
Contract Number:	**26348-260315**	**Depth from (m):**	**0.80**
Hole Number:	**TP05**	**Depth to (m):**	
		Sample Type:	**B**
Location:	**Pembroke Dock Port GI**		
Description:	**Brown clayey sandy silty GRAVEL (fine-coarse)**		

BS Test Sieve	% Passing
125	100
90	100
75	100
63	100
50	100
37.5	100
28	96
20	67
14	66
10	65
6.3	63
5.0	62
3.35	61
2.00	59
1.18	57
0.60	53
0.425	51
0.300	48
0.212	45
0.150	42
0.063	38

Particle Diameter	% Passing
0.02	23
0.006	18
0.002	13



Clay	Silt	Sand	Gravel	Cobbles	Soil Fraction
13	25	21	41	0	Total Percentage

Remarks:

Cl 9.4.8 - Sample has not been pretreated

For and behalf of GEO Site & Testing Services Ltd

Authorised By:
Jonathan Tatam (Admin/Quality Assistant)

Date: 8.4.15

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GEO SITE & TESTING SERVICES LTD

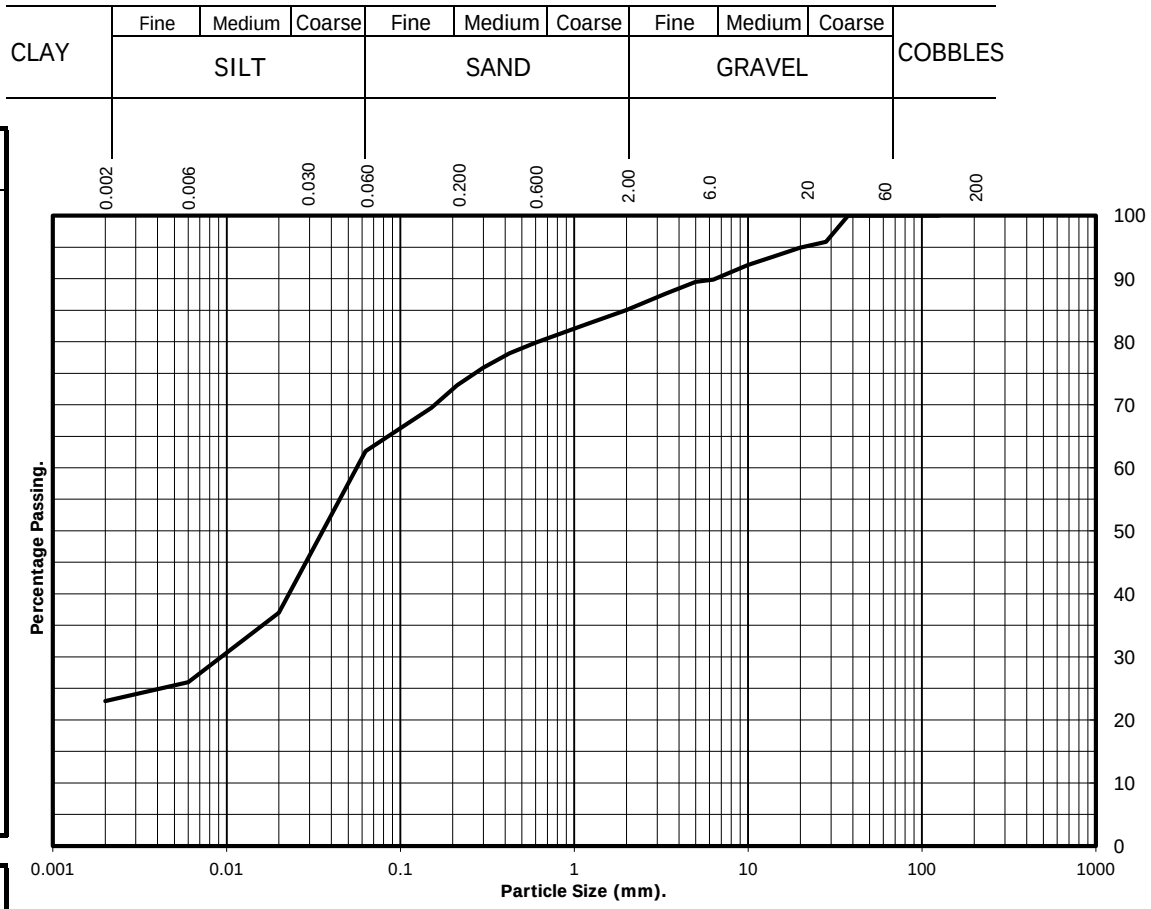
UKAS TESTING 2788

Test Report:

Particle Size Distribution Test
BS 1377 Part 2:1990.

Wet Sieve & Pipette Analysis, Clause 9.2 & 9.4

Client ref:	**G624**	**Sample Number:**	**5**
Contract Number:	**26348-260315**	**Depth from (m):**	**1.50**
Hole Number:	**TP09**	**Depth to (m):**	
		Sample Type:	**B**
Location:	**Pembroke Dock Port GI**		
Description:	**Brown gravelly (fine-coarse) sandy clayey SILT**		



BS Test Sieve	% Passing
125	100
90	100
75	100
63	100
50	100
37.5	100
28	96
20	95
14	93
10	92
6.3	90
5.0	89
3.35	88
2.00	85
1.18	83
0.60	80
0.425	78
0.300	76
0.212	73
0.150	69
0.063	63

Particle Diameter	% Passing
0.02	37
0.006	26
0.002	23

Clay	Silt	Sand	Gravel	Cobbles	Soil Fraction
23	40	22	15	0	Total Percentage

Remarks:

Cl 9.4.8 - Sample has not been pretreated

For and behalf of GEO Site & Testing Services Ltd

Authorised By:
Jonathan Tatam (Admin/Quality Assistant)

Date: 8.4.15

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GEO SITE & TESTING SERVICES LTD

UKAS TESTING 2788

Test Report: Point Load Test

Int. J. Rock Mech. Sci. & Geomech. Abstr. Vol. 22, No. 2, pp. 51 - 60, 1985.

Client: Quantum Geotechnical
Location: Pembroke Dock Port GI
Client Ref: G624
Contract Number: 26348-260315
Borehole Number: As stated below
Core Box Number: As stated below
Depth (m): As stated below

Borehole Number	Depth (m)	Type of Test d a b/i	Type of Test I //	Width (W) (mm)	Platen Separation (D) (mm)	Failure Load (P) (kN)	Equivalent Diameter (D_e) (mm)	Point Load (I_s) (MPa)	Size Factor (F)	Point Load Index ($I_{s(50)}$) (MPa)	Moisture Content (MC) (%)	Description (SC)	Angle between plane of anisotropy & core axis.	Type of anisotropy (Bedding or Cleavage).
BH1	8.10	i		73	36	3.04	58	0.91	1.07	0.97				
		i		69	39	2.23	59	0.65	1.07	0.70				
		i		73	39	0.63	60	0.17	1.09	0.19				
		i		42	35	3.50	43	1.87	0.94	1.75				
		i		35	45	2.90	45	1.45	0.95	1.38				
		a		73	49	3.11	67	0.68	1.14	0.78				
		i		60	44	2.27	58	0.68	1.07	0.72				
		i		54	39	4.21	52	1.57	1.02	1.59				
		i		44	43	2.87	49	1.19	0.99	1.18				
		i		43	35	0.84	44	0.44	0.94	0.41				
BH1	8.90	d			73	0.23		0.04	1.19	0.05				
		a		73	32	0.03	55	0.01	1.04	0.01				
		d			72	0.22		0.04	1.18	0.05				
		a		72	55	0.73	71	0.14	1.17	0.17				
		a		72	54	0.34	70	0.07	1.17	0.08				
		i		39	32	0.05	40	0.03	0.90	0.03				
		i		43	36	0.04	44	0.02	0.95	0.02				
BH2	7.90	a		74	55	6.84	72	1.32	1.18	1.56				
		i		57	48	5.53	59	1.59	1.08	1.71				
		i		47	37	0.37	47	0.17	0.97	0.16				
		i		45	40	4.65	48	2.03	0.98	1.99				
		i		56	52	0.34	61	0.09	1.09	0.10				
		i		55	22	0.30	39	0.19	0.90	0.17				
		i		43	27	1.08	38	0.73	0.89	0.65				
		i		42	30	2.60	40	1.62	0.91	1.47				
BH3	11.00	d			73	0.51		0.10	1.19	0.11				
		a		73	48	0.21	67	0.05	1.14	0.05				
		a		73	66	0.53	78	0.09	1.22	0.11				
		a		73	61	3.29	75	0.58	1.20	0.70				
		a		73	63	0.60	77	0.10	1.21	0.12				
		i		56	53	4.60	61	1.22	1.10	1.34				
		i		52	46	0.73	55	0.24	1.05	0.25				
BH3	12.00	d			73	15.69		2.94	1.19	3.49				
		a		73	44	11.35	64	2.78	1.12	3.10				
		d			73	11.17		2.10	1.19	2.49				
		a		73	27	6.06	50	2.41	1.00	2.42				
		d			73	7.05		1.32	1.19	1.57				
		a		73	60	1.97	75	0.35	1.20	0.42				
		a		73	42	5.22	62	1.34	1.11	1.48				
		a		73	49	1.85	67	0.41	1.14	0.46				
		a		73	57	3.58	73	0.68	1.18	0.80				
		i		71	51	1.85	68	0.40	1.15	0.46				

Key : d = diametral; a = axial; b = block; i = irregular lump test; I = perpendicular; // = parallel to planes of weakness.

Remarks:

GSTL
GEO SITE & TESTING SERVICES LTD

Checked By: Matam **Date** 07/04/15

Approved By: D P Evans **Date** 07/04/15

UKAS TESTING 2788

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APPENDIX V – GEO-ENVIRONMENTAL LABORATORY TEST RESULTS

V.I RISK TO HUMAN HEALTH

The Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency published a series of reports in 2002 that provide a scientifically based framework for the assessment of risks to human health from land contamination. By providing a consistent approach to risk assessment, the framework facilitates the rapid identification of sites that pose a significant risk to human health and help avoid blight on other sites. This framework does not consider risks to other receptors such as plants and animals, buildings and controlled waters.

The Soil Guideline Values (SGVs) are a tool that can be used to assess the risks posed to human health from exposure to soil contamination resulting from land use. They represent 'intervention values', which indicate to an assessor that soil concentrations above this level could pose an unacceptable risk to the health of site users and that further investigation and/or remediation is required. Soil Guideline Values combine both authoritative science and policy judgements.

Soil Guideline Values have been derived using the CLEA (Contaminated Land Exposure Assessment) model according to three typical land uses:

- Residential (with and without vegetable growing)
- Allotments
- Commercial / industrial

The proposed site development and remedial works classifies the site in terms of CLEA, as the least sensitive model; Commercial/ Industrial -

Where applied appropriately, exceeding a Soil Guideline Value suggests the need for either further investigation and/ or remediation. Soil Guideline Values can be used in connection with the formal requirements of Part IIA of the Environmental Protection Act 1990 ("the contaminated land regime"). However, they will also be relevant to many situations where the effect of land contamination on human health is an issue such as in planning applications when judging the need for action to ensure that a new use of land does not pose unacceptable risks to health.

The CLEA Soil Guideline Values (SGV) provide thresholds to undertake generic risk assessments of sites in respect of risks to human health. The issuing of SGV's by DEFRA/ EA is an ongoing process, with the suite of analytes for which published results are available being updated at regular intervals. The list of published SGV's is not complete when compared to the list of potential contaminants as detailed in the earlier CLEA publication CLR8, from which the suggested suite of contaminants tested for is derived. As a result the Chartered Institute of Environmental Health (CIEH) have collaborated with Land Quality Management Ltd (LQM) to provide a set of generic assessment criteria for soil contaminants for which there are no DEFRA/Environment Agency soil guideline values. These are intended to be intervention values above which further assessment of the risk or remedial action may be necessary. These values were published in 2009 within document: 'LQM/CIEH Generic Assessmet Criteria for Human Health Risk Assessment (2nd Edition)'.

Continued research and review of these soil contaminant assessment criteria and GAC values has resulted in the publication of 'LQM/CIEH Suitable 4 Use Levels' (2015) establishing new and revised S4UL soil values which may be used as a superseding document to LQM/CIEH Generic Assessmet Criteria for Human Health Risk Assessment (2nd Edition).

There have been several major changes in Contaminated Land non-statutory guidance in recent years, in particular relating to CLR documentation and their derivatives i.e. Soil Guideline Values and Toxicological Reports. In 2006, DEFRA commenced work on their 'Way Forward' exercise which aimed to redefine the way contaminated land is assessed with the aid of devising revamped technical guidance and soil guideline values. A working group of various environmental consultancies/ establishments/ stakeholders set about determining how the non-statutory guidance of CLEA 2002 may be amended to be increasingly user friendly for assessors of contaminated land and ultimately to help in defining whether land qualifies as contaminated land under Part IIA Environmental Protection Act 1990. July 2008 saw the findings of this exercise published. Firstly the document entitled *'Guidance on the Legal Definition of Contaminated Land'* was published followed closely by the publication of the fourteen measures derived to improve contaminated land non-statutory technical guidance i.e. CLR Publications.

In light of these improvements, the toxicology of various contaminants and therefore the generic soil guideline values, has been revised by EA and DEFRA. The revised paper published in August 2008 is entitled *'Human Health Toxicological Assessment of Contaminants in Soil'*. Based on the findings of this paper, EA are developing a new set of Toxicological Reports and subsequently a new, expanded set of SGV'. Upon publishing, these new SGV's may then be used in assessing risks to human health.

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Analytical Report Number : 15-69002

Replaces Analytical Report Number : 15-69002, issue no. 1

Project / Site name:	Pembroke Dock Port GI	**Samples received on:**	26/03/2015
Your job number:	G624	**Samples instructed on:**	26/03/2015
Your order number:		**Analysis completed by:**	07/04/2015
Report Issue Number:	2	**Report issued on:**	07/04/2015
Samples Analysed:	8 soil samples		

Signed:

Dr Claire Stone
Quality Manager
For & on behalf of i2 Analytical Ltd.

Signed:

Rexona Rahman
Reporting Manager
For & on behalf of i2 Analytical Ltd.

Other office located at: ul. Pionierów 39, 41 -711 Ruda Śląska, Poland

Standard sample disposal times, unless otherwise agreed with the laboratory, are :

soils	- 4 weeks from reporting
leachates	- 2 weeks from reporting
waters	- 2 weeks from reporting
asbestos	- 6 months from reporting

Excel copies of reports are only valid when accompanied by this PDF certificate.

Analytical Report Number: 15-69002

Project / Site name: Pembroke Dock Port GI

Lab Sample Number				429228	429229	429230	429231	429232
Sample Reference				TP04	TP05	TP06	TP09	TP10
Sample Number				6a	4a	4a	8a	2a
Depth (m)				2.00	0.80	1.00	2.50	0.30
Date Sampled				10/03/2015	10/03/2015	10/03/2015	10/03/2015	10/03/2015
Time Taken				None Supplied	None Supplied	None Supplied	None Supplied	None Supplied
Analytical Parameter (Soil Analysis)	**Units**	**Limit of detection**	**Accreditation Status**					
Stone Content	%	0.1	NONE	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Moisture Content	%	N/A	NONE	15	21	9.6	24	16
Total mass of sample received	kg	0.001	NONE	0.45	1.5	1.4	1.7	1.6
Asbestos in Soil Screen / Identification Name	Type	N/A	ISO 17025	-	-	-	-	Chrysotile
Asbestos in Soil	Type	N/A	ISO 17025	-	-	Not-detected	-	Detected
Asbestos Quantification	%	0.001	ISO 17025	-	-	-	-	0.001
General Inorganics								
pH	pH Units	N/A	MCERTS	7.7	8.1	7.9	8.1	7.8
Total Cyanide	mg/kg	1	MCERTS	-	-	< 1	-	< 1
Complex Cyanide	mg/kg	1	NONE	-	-	< 1	-	< 1
Free Cyanide	mg/kg	1	NONE	-	-	< 1	-	< 1
Total Sulphate as SO_4	mg/kg	50	ISO 17025	450	440	730	720	1100
Water Soluble Sulphate (Soil Equivalent)	g/l	0.0025	MCERTS	0.097	0.10	0.38	0.14	0.19
Water Soluble Sulphate as SO_4 (2:1)	mg/kg	2.5	MCERTS	-	-	380	-	190
Water Soluble SO4 (BRE SD 2:1 Leach Equivalent)	g/l	0.00125	MCERTS	0.049	0.051	0.19	0.072	0.095
Sulphide	mg/kg	1	MCERTS	-	-	1.3	-	4.5
Water Soluble Chloride (2:1)	mg/kg	1	MCERTS	99	58	250	150	-
Elemental Sulphur	mg/kg	20	NONE	-	-	22	-	32
Total Sulphur	mg/kg	50	NONE	140	260	320	310	-
Ammonium as NH_4	mg/kg	0.5	MCERTS	< 0.5	1.2	< 0.5	0.6	-
Organic Matter	%	0.1	MCERTS	-	-	0.5	-	4.6
Water Soluble Nitrate (2:1) as N	mg/kg	2	NONE	< 2.0	< 2.0	13	< 2.0	-
Heavy Metals / Metalloids								
Arsenic (aqua regia extractable)	mg/kg	1	MCERTS	-	-	14	-	34
Barium (aqua regia extractable)	mg/kg	1	MCERTS	-	-	56	-	160
Beryllium (aqua regia extractable)	mg/kg	0.06	MCERTS	-	-	0.5	-	0.4
Boron (water soluble)	mg/kg	0.2	MCERTS	-	-	1.2	-	0.9
Cadmium (aqua regia extractable)	mg/kg	0.2	MCERTS	-	-	0.3	-	1.3
Chromium (aqua regia extractable)	mg/kg	1	MCERTS	-	-	14	-	13
Copper (aqua regia extractable)	mg/kg	1	MCERTS	-	-	150	-	260
Lead (aqua regia extractable)	mg/kg	1	MCERTS	-	-	160	-	980
Mercury (aqua regia extractable)	mg/kg	0.3	MCERTS	-	-	< 0.3	-	6.8
Nickel (aqua regia extractable)	mg/kg	1	MCERTS	-	-	22	-	32
Selenium (aqua regia extractable)	mg/kg	1	MCERTS	-	-	< 1.0	-	< 1.0
Vanadium (aqua regia extractable)	mg/kg	1	MCERTS	-	-	17	-	19
Zinc (aqua regia extractable)	mg/kg	1	MCERTS	-	-	76	-	340

Analytical Report Number: 15-69002

Project / Site name: Pembroke Dock Port GI

Lab Sample Number				429233	429234	429235		
Sample Reference				TP10	TP14	TP16		
Sample Number				8a	2a	4a		
Depth (m)				2.50	0.30	1.00		
Date Sampled				10/03/2015	10/03/2015	10/03/2015		
Time Taken				None Supplied	None Supplied	None Supplied		
Analytical Parameter (Soil Analysis)	**Units**	**Limit of detection**	**Accreditation Status**					
Stone Content	%	0.1	NONE	< 0.1	< 0.1	< 0.1		
Moisture Content	%	N/A	NONE	19	6.5	12		
Total mass of sample received	kg	0.001	NONE	1.4	1.7	0.42		
Asbestos in Soil Screen / Identification Name	Type	N/A	ISO 17025	-	-	-		
Asbestos in Soil	Type	N/A	ISO 17025	-	-	-		
Asbestos Quantification	%	0.001	ISO 17025	-	-	-		
General Inorganics								
pH	pH Units	N/A	MCERTS	7.9	8.0	8.1		
Total Cyanide	mg/kg	1	MCERTS	-	< 1	< 1		
Complex Cyanide	mg/kg	1	NONE	-	< 1	< 1		
Free Cyanide	mg/kg	1	NONE	-	< 1	< 1		
Total Sulphate as SO_4	mg/kg	50	ISO 17025	570	1900	1600		
Water Soluble Sulphate (Soil Equivalent)	g/l	0.0025	MCERTS	0.091	1.8	1.0		
Water Soluble Sulphate as SO_4 (2:1)	mg/kg	2.5	MCERTS	-	1800	1000		
Water Soluble SO4 (BRE SD 2:1 Leach Equivalent)	g/l	0.00125	MCERTS	0.046	0.88	0.52		
Sulphide	mg/kg	1	MCERTS	-	1.3	6.0		
Water Soluble Chloride (2:1)	mg/kg	1	MCERTS	180	1200	-		
Elemental Sulphur	mg/kg	20	NONE	-	56	100		
Total Sulphur	mg/kg	50	NONE	290	1400	-		
Ammonium as NH_4	mg/kg	0.5	MCERTS	1.4	< 0.5	-		
Organic Matter	%	0.1	MCERTS	-	0.6	0.8		
Water Soluble Nitrate (2:1) as N	mg/kg	2	NONE	< 2.0	9.4	-		
Heavy Metals / Metalloids								
Arsenic (aqua regia extractable)	mg/kg	1	MCERTS	-	9.3	13		
Barium (aqua regia extractable)	mg/kg	1	MCERTS	-	46	61		
Beryllium (aqua regia extractable)	mg/kg	0.06	MCERTS	-	0.6	0.7		
Boron (water soluble)	mg/kg	0.2	MCERTS	-	1.1	1.0		
Cadmium (aqua regia extractable)	mg/kg	0.2	MCERTS	-	< 0.2	< 0.2		
Chromium (aqua regia extractable)	mg/kg	1	MCERTS	-	15	19		
Copper (aqua regia extractable)	mg/kg	1	MCERTS	-	33	59		
Lead (aqua regia extractable)	mg/kg	1	MCERTS	-	60	120		
Mercury (aqua regia extractable)	mg/kg	0.3	MCERTS	-	< 0.3	0.3		
Nickel (aqua regia extractable)	mg/kg	1	MCERTS	-	17	20		
Selenium (aqua regia extractable)	mg/kg	1	MCERTS	-	< 1.0	< 1.0		
Vanadium (aqua regia extractable)	mg/kg	1	MCERTS	-	19	21		
Zinc (aqua regia extractable)	mg/kg	1	MCERTS	-	81	170		

Analytical Report Number: 15-69002
Project / Site name: Pembroke Dock Port GI
Your Order No:

Certificate of Analysis - Asbestos Quantification

Methods:

Qualitative Analysis

The samples were analysed qualitatively for asbestos by polarising light and dispersion staining as described by the Health and Safety Executive in HSG 248.

Quantitative Analysis

"The analysis was carried out using our documented in-house method A006 based on HSE Contract Research Report No: 83/1996: Development and Validation of an analytical method to determine the amount of asbestos in soils and loose aggregates (Davies et al, 1996) and HSG 248. Our method includes initial examination of the entire representative sample, then fractionation and detailed analysis of each fraction, with quantification by hand picking and weighing.

Any material greater than 16mm is considered as Bulk sample and reported separately, asbestos content (if any) is not included in the final Quantitative analysis. The limit of detection (reporting limit) of this method is 0.001 %.

The method has been validated using samples of at least 100 g, results for samples smaller than this should be interpreted with caution.

Both Qualitative and Quantitative Analyses are UKAS accredited.

Sample Number	Sample ID	Sample Depth (m)	Sample Weight (g)	Asbestos Containing Material Types Detected (ACM)	PLM Results	Asbestos by hand picking/weighing (%)	Total % Asbestos in Sample
429232	TP10	0.30	102	Loose Fibres	**Chrysotile**	0.001	**0.001**

Opinions and interpretations expressed herein are outside the scope of UKAS accreditatior

Analytical Report Number : 15-69002

Project / Site name: Pembroke Dock Port GI

* These descriptions are only intended to act as a cross check if sample identities are questioned. The major constituent of the sample is intended to act with respect to MCERTS validation. The laboratory is accredited for sand, clay and topsoil/loam soil types. Data for unaccredited types of solid should be interpreted with care.

Stone content of a sample is calculated as the % weight of the stones not passing a 10 mm sieve. Results are not corrected for stone content.

Lab Sample Number	Sample Reference	Sample Number	Depth (m)	Sample Description *
429228	TP04	6a	2.00	Brown clay and sand.
429229	TP05	4a	0.80	Brown clay and sand.
429230	TP06	4a	1.00	Light brown clay and sand.
429231	TP09	8a	2.50	Light brown clay and sand.
429232	TP10	2a	0.30	Brown topsoil and sand with gravel.
429233	TP10	8a	2.50	Light brown clay and sand.
429234	TP14	2a	0.30	Light brown sandy topsoil with gravel.
429235	TP16	4a	1.00	Light brown clay and sand with vegetation.

Analytical Report Number : 15-69002

Project / Site name: Pembroke Dock Port GI

Water matrix abbreviations: Surface Water (SW) Potable Water (PW) Ground Water (GW)

Analytical Test Name	Analytical Method Description	Analytical Method Reference	Method number	Wet / Dry Analysis	Accreditation Status
Ammonium as NH4 in soil	Determination of Ammonium/Ammonia/Ammoniacal Nitrogen by the colorimetric salicylate/nitroprusside method.	In-house method based on Examination of Water and Wastewater 20th Edition: Clesceri, Greenberg & Eaton	L082-PL	W	MCERTS
Asbestos identification in soil	Asbestos Identification with the use of polarised light microscopy in conjunction with disperion staining techniques.	In house method based on HSG 248	A001-PL	D	ISO 17025
Asbestos Quantification	The analysis was carried out using our documented in-house method based on HSE Contract Research Report No: 83/1996: Development and Validation of an analytical method to determine the amount of asbestos in soils and loose aggregates (Davies et al, 1996) and HSG 248	HSE Contract Research Report No: 83/1996: Development and Validation of an analytical method to determine the amount of asbestos in soils and loose aggregates (Davies et al, 1996) and HSG 248	A006	D	ISO 17025
Boron, water soluble, in soil	Determination of water soluble boron in soil by hot water extract followed by ICP-OES.	In-house method based on Second Site Properties version 3	L038-PL	D	MCERTS
Chloride, water soluble, in soil	Determination of chloride colorimetrically by discrete analyser.	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests	L082-PL	D	MCERTS
Complex cyanide in soil	Determination of complex cyanide by distillation followed by colorimetry.	In-house method based on Examination of Water and Wastewater 20th Edition: Clesceri, Greenberg & Eaton (Skalar)	L080-PL	W	NONE
Elemental sulphur in soil	Determination of elemental sulphur in soil by extraction in dichloromethane followed by HPLC.	In-house method based on Secondsite Property Holdings Guidance for Assessing and Managing Potential	L021-PL	D	NONE
Free cyanide in soil	Determination of free cyanide by distillation followed by colorimetry.	In-house method based on Examination of Water and Wastewater 20th Edition: Clesceri, Greenberg & Eaton (Skalar)	L080-PL	W	NONE
Metals in soil by ICP-OES	Determination of metals in soil by aqua-regia digestion followed by ICP-OES.	In-house method based on MEWAM 2006 Methods for the Determination of Metals in Soil.	L038-PL	D	MCERTS
Moisture Content	Moisture content, determined gravimetrically.	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests	L019-UK/PL	W	NONE
Organic matter in soil	Determination of organic matter in soil by oxidising with potassium dichromate followed by titration with iron (II) sulphate.	BS1377 Part 3, 1990, Chemical and Electrochemical Tests	L023-PL	D	MCERTS
pH in soil	Determination of pH in soil by addition of water followed by electrometric measurement.	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests	L005-PL	W	MCERTS
Stones content of soil	Standard preparation for all samples unless otherwise detailed. Stones not passing through a 10 mm sieve is determined gravimetrically and reported as a percentage of the dry weight. Sample results are not corrected for the stone content of the sample.	In-house method based on British Standard Methods and MCERTS requirements.	L019-UK/PL	D	NONE
Sulphate, water soluble, in soil	Determination of water soluble sulphate by extraction with water followed by ICP-OES. Results reported corrected for extraction ratio (soil equivalent) as g/l and mg/kg; and upon the 2:1 leachate (g/l)	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests	L038-PL	D	MCERTS
Sulphide in soil	Determination of sulphide in soil by acidification and heating to liberate hydrogen sulphide, trapped in an alkaline solution then assayed by ion selective electrode.	In-house method	L010-PL	D	MCERTS
Total cyanide in soil	Determination of total cyanide by distillation followed by colorimetry.	In-house method based on Examination of Water and Wastewater 20th Edition: Clesceri, Greenberg & Eaton (Skalar)	L080-PL	W	MCERTS

Analytical Report Number : 15-69002

Project / Site name: Pembroke Dock Port GI

Water matrix abbreviations: Surface Water (SW) Potable Water (PW) Ground Water (GW)

Analytical Test Name	Analytical Method Description	Analytical Method Reference	Method number	Wet / Dry Analysis	Accreditation Status
Total sulphate (as SO4 in soil)	Determination of total sulphate in soil by extraction with 10% HCl followed by ICP-OES.	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests	L038-PL	D	ISO 17025
Total Sulphur in soil	Determination of total sulphur in soil by extraction with aqua-regia, potassium bromide/bromate followed by ICP-OES.	In-house method based on BS1377 Part 3, 1990, and MEWAM 2006 Methods for the Determination of Metals in Soil	L038-PL	D	NONE
Water Soluble Nitrate (2:1) as N in soil	Determination of nitrate in soil by extraction in water followed by reaction with sodium salicilate in the presence of sulphuric acid. The reaction product is nitrosalicylic acid, which forms a yellow chromophore upon the addition of alkali, the intensity of which is measured by spectrophotometry.	In-house method based on Polish Standard Method PN-82/C-04579.08.	L078-PL	D	NONE

For method numbers ending in 'UK' analysis have been carried out in our laboratory in the United Kingdom.
For method numbers ending in 'PL' analysis have been carried out in our laboratory in Poland.
Soil analytical results are expressed on a dry weight basis. Where analysis is carried out on as-received the results obtained are multiplied by a moisture correction factor that is determined gravimetrically using the moisture content which is carried out at a maximum of 30oC.

APPENDIX VI – GEOPHYSICAL SURVEY REPORT

GEOPHYSICAL SURVEY REPORT

Project
Ground Investigation for buried objects/structures and possible solution features

Location
Pembroke Dock
Pembroke

Client
Quantum Geotechnical Ltd

Unit 2
Ocean House
Hunter Street
Cardiff
CF10 5FR
United Kingdom

Tel: +44 (0)8707 303050
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Web: www.terradat.com

Job reference: 4653
Date: April 2015
Version: 1

GEOPHYSICAL SURVEY REPORT

Project
Ground Investigation for buried objects/structures and possible solution features

Location
Pembroke Dock
Pembroke

Client
Quantum Geotechnical Ltd

Project geophysicist: A R Lewis BEng MSc _____

Reviewer: C L Bird BSc FGS _____

Job Reference: 4653

Date: March 2015

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Figures

Appendices

1 Introduction

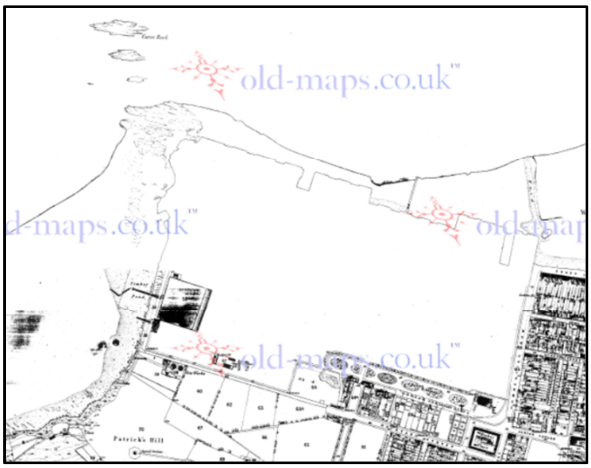
This report describes a geophysical survey that was carried out on the 16th and 19th of March 2015 at Pembroke Port, Pembroke Dock. The survey work was commissioned by Quantum as part of a ground investigation for redevelopment of the site. The aim of the survey was to investigate part of the former port area for buried structures and possible solution features in the underlying limestone.

1.1 Site/geological setting

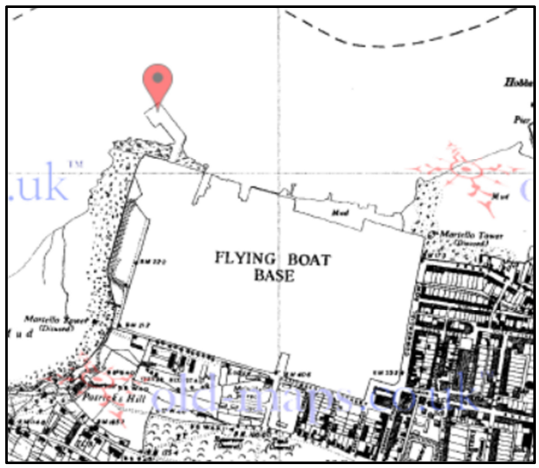
The Client has requested the investigation to cover the survey area as shown in Plate 1.

Plate 1 – Area surveyed outlined in red

The site was originally a dockyard but was then used as a flying boat station during and after the Second World War before returning to a cargo dock. Plate 2 shows three historical maps of the site, these show railway lines and several ramps and docks on the northern harbour edge. These have progressively been filled in to make the squared off dock wall that exists today.



1869



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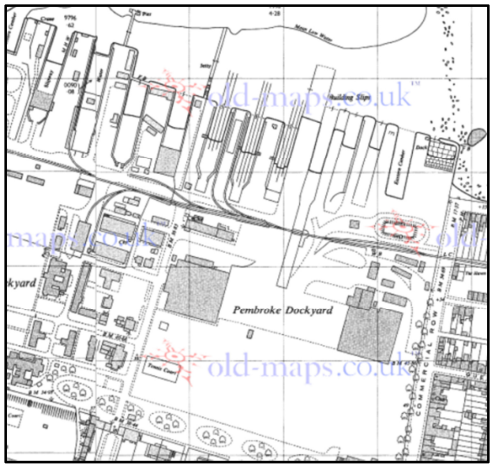


1967

Plate 2 – Historical maps of the survey area. The 1967 map shows a rail line and multiple ramps and docks along the north harbour edge that have since been backfilled.

The site is underlain by Black Rock Subgroup and Gully Oolite Formation (undifferentiated) – Limestone bedrock. This has been overlain by back fill material to level the site and is comprised of made ground/sand/silt.

Four boreholes were drilled at the site and indicate bedrock is shallower to the south, approximately 3-4m bgl, and of unknown depth towards the north harbour wall.

1.2 Survey objectives

The primary objective of the survey:

- Investigate the shallow subsurface for buried services and structures.
- Investigate the shallow subsurface to try and image the bedrock topography and possible solution features.

1.3 1.3 Survey design

Given the nature of the targets under investigation, it was decided to adopt an integrated survey approach that was aimed at exploiting ground material variations within the shallow sub-surface. The geophysical survey comprised of the following techniques:

- ***Magnetic Survey (Geonics G-858)*** – to map any buried ferrous metal that may be associated with historic buildings or structures.

- ***Electromagnetic Survey (Geophex GEM-2)*** – to map the ground conductivity variations in the near surface material across the site and characterise materials using the inphase component of the electromagnetic measurements. This survey technique can also detect localised areas of contrasting ground conductivity that may be associated with solution features.

- ***Ground Penetrating Radar (Mala Ramac 250MHz)*** – to provide detailed time-slice plans and/or radargrams to a depth of ~3m below ground level, in order to identify buried objects and changes in ground type/character. A rockhead boundary may be identifiable if the signal penetration is sufficient.

NOTE

It should be noted that resistivity tomography was originally proposed as a follow up technique to identify depth to bedrock and investigate any anomalous features discovered in the electromagnetic and magnet surveys that may relate to solution features. However, most of the surface of the site was comprised of concrete and tarmac and it was therefore not

possible to carry out this type of technique. It was therefore agreed with the client to trial the use of GPR as a possible means of mapping bedrock.

2 Survey description

The survey was carried out measuring the following geophysical properties:

- Magnetometer (magnetic)
- Ground conductivity (electromagnetic)
- Ground Penetrating Radar (electromagnetic)

The magnetic survey data were acquired using a quad bike along approximately 3m spaced survey traverses under positional control of a dGPS system. The Gem-2 data were acquired on a walked 3m survey grid. GPR was done on a 1m spaced grid over selected areas.

The results are presented in the form of interpreted data plots indicating the location and physical characteristics of subsurface anomalous zones together with a text description. Background information for each of the survey methods is provided in the appendices and descriptions of the actual survey work carried out on site are provided in the sections below.

2.1 Data measurement layout / Topographic survey

The magnetic and electromagnetic datasets were acquired by quad bike and in 'walking' mode using a Trimble ProXT DGPS system for data location. A Topcon Hyper+ DGPS was used to locate site features and the GPR grids.

All GPS data was acquired in OS National Grid coordinates.

2.2 Geometrics G-858 magnetometer survey (magnetic survey)

The magnetic survey technique is based on mapping localised variations in the Earth's magnetic field caused sub-surface magnetic materials, which range from naturally occurring magnetic minerals to man-made ferrous objects. Data are acquired on a grid covering the area of interest and a contoured plan of the variation in ferrous material across the site is produced.

2.2.1 Magnetic survey field activity

A *GEOMETRICS G858* magnetic gradiometer was towed behind a quad bike to acquire total magnetic field data along a series of approximate 3m spaced survey lines (Plate 1). Readings along the survey lines were taken at approximately 0.2m intervals and positioned using a GPS NMEA string from a Trimble ProXT DGPS system mounted above the sensors.

Plate 1 – Towed G858 Magnetic Gradiometer being used at the site

2.2.2 Magnetic survey data processing

The magnetic data is downloaded from the data logger and compiled using dedicated software *MagMap2000*. Initial editing is then carried out to remove positional errors and rogue values. The data is then exported as a 'xyz' file and if required, translated to the appropriate coordinate system. The next step is to bring the data into *OASIS MONTAJ*, where it can be edited and manipulated to enhance any features of interest. The colour contour plots are then integrated with the base plan information and the resulting plans are exported to CORELDRAW for final annotation.

2.3 Geophex Gem-2 electromagnetic survey

A Gem-2 ground conductivity survey involves transmitting multiple electromagnetic frequencies into the subsurface and then recording the returning signals via a receiver in the same instrument (Plate 2).

Data acquired over the survey area is colour contoured to produce a plan of the variation in ground conductivity across the site. The presence of conductive materials in the subsurface

such as clay, water, ash or metal (cultural noise) will be evident as regions of high values on the ground conductivity plan, while materials such as coarse grained sediments and dry zones will appear as regions of low values. A description of the field activity is provided below and some background information on the survey methods can be found in the Appendix.

The instrument was configured to transmit five frequencies effectively investigating different depth ranges from approximately 0-7m bgl. The actual depth of investigation is a function of the selected frequency and resistivity of the underlying geology. Deeper frequencies tend to suffer from a high signal-to-noise ratio making the results uninterpretable. In practical terms a particular frequency is used for interpretation that most clearly shows subsurface responses.

Plate 2 - Geophex GEM-2 with Trimble DGPS positioning being used at the site

2.3.1 Gem-2 survey field activity

The Gem-2 ground conductivity data was acquired in walking mode along approximately 3m spaced parallel survey lines. Readings along the survey lines were taken at approximately 0.2m intervals and positioned using a GPS NMEA string from a Trimble ProXT DGPS system.

2.3.2 Gem-2 survey data processing

The data was downloaded from the data logger and compiled using dedicated software *WINGEM v3*. Initial editing was then carried out to remove positional errors and rogue values. The data was then exported as a 'xyz' file and if required, translated to the appropriate coordinate system. The next step was to bring the data into *OASIS MONTAJ*, where it can be edited and manipulated to enhance any features of interest. The colour contour plots were then integrated with the base plan information and the resulting plans are exported to CORELDRAW for final annotation.

2.4 Ground Penetrating Radar (GPR)

A Ground Penetrating Radar (GPR) survey involves the transmission of a pulsed electromagnetic (radio) wave and the recording of any returning reflection events. The transmitted waves are focused into the ground and can penetrate soils, rock, concrete, and many other natural and man-made materials. Given a sufficient contrast, reflection events from geological or hydrological boundaries can be observed together with 'point' sources such as buried services, rebar, voids and large boulders.

2.4.1 GPR survey field activity

A *MALA RAMAC* radar system with shielded 250MHz antennae mounted within a cart was used to acquire grids of radar data over the selected areas as shown in Figure 1. The survey grids comprised local grids of parallel 1m spaced profile lines which were subsequently translated to OS coordinates for presentation (Plate 3).

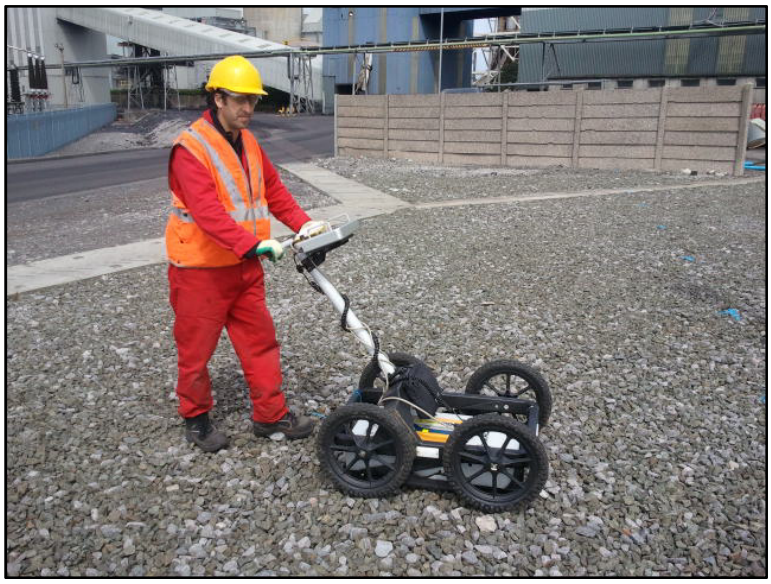


Plate 3 – MALA RAMAC 250MHz GPR cart system (library photograph)

2.4.2 GPR survey data processing

The data processing was carried out using GPR Slice v7 software. Each radargram is first processed with an appropriate gain function to enhance features of interest and increase the signal from weak responses at depth. The radargram is then 'time zero' corrected to allow a depth conversion to be calculated using a nominal velocity of 0.1m/nanosecond that is usually suitable for made ground conditions. Additional processing routines (e.g. background removal, deconvolution, FK filtering, migration etc) may be applied to improve the coherency of the reflection events and remove any multiple reflections and diffractions. The radargrams are then resampled to provide same size data blocks that can be gridded using a squared amplitude function to produce a 3D block of radar signal response. This block is then time sliced to produce interpretable depth slices between 15 and 20cm thick. All the depth slices are analysed and then specific slices showing significant features and anomalies are used for the interpretation plots. The final depth slice plots are exported to CorelDraw for annotation and presentation.

Results and Interpretation

The results of the electromagnetic and magnetic surveys are presented as a series of colour contour plots in Figure 2, and selected GPR radargrams have been shown in Figure 3.

2.5 Magnetic survey - ferrous metal detection (Figure 2c)

Figure 2c shows the analytical signal of the magnetic total field survey which responds to ferrous metal material. To simplify the positioning of the anomaly, an analytical signal routine is applied which converts magnetic pole and dipole anomalies in to positive values centred on the location of the source producing the response. Background values have been assigned a grey colour, with increased magnetic response shown as red and very low response, usually associated with surface objects, as blue.

Large areas of extreme response can be seen which are associated with the extensive reinforced concrete present on the site. However, some linear anomalies have been identified as indicated on the figure and may relate to historic rail lines or services and may warrant further investigation.

There appears to be a curved linear feature in the south of the survey area that looks indicative of a rail line, however no evidence of this can be seen in historic plans.

An area in the north adjacent to the existing building can be seen to have a generally higher response than the surrounding area and is indicative of a change in ground character that may be associated with the nature of the made ground material.

Isolated anomalies are indicative of buried ferrous objects or remnant structures and services.

2.6 Electromagnetic survey - ground conductivity (Figure 2a)

Following a review of the five Gem-2 electromagnetic data frequencies, it was decided to consider the ground conductivity response from the 15025Hz frequency of the instrument as this provided the best feature resolution whilst still identifying all significant variations in

response. The depth range of the measurements depends on the grounds resistivity but is approximately to a depth of 4-5m bgl. Table 1 is a useful guide to typical responses to different geological materials.

A relative increase in conductivity values usually indicates a localised increase in the clay content or groundwater saturation. However, an increase in conductivity may also occur if there is ash, metalliferous slag and/or metal present within the range of the instrument. Extreme fluctuations in conductivity values is usually indicative of instrument 'overload' (very high or negative readings) due to nearby metal structures/ debris and usually correlates with high in-phase response (sensitive to the influence of cultural noise), at the same location.

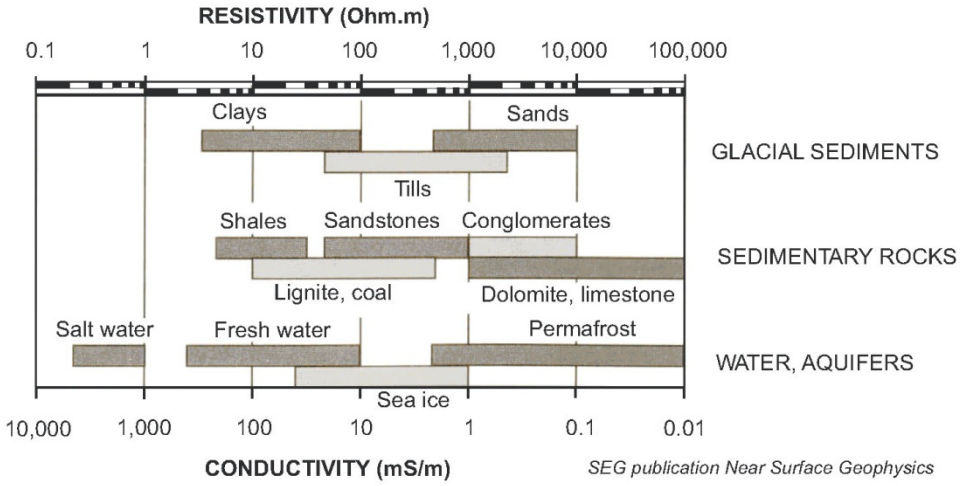


Table 1- A simplified relationship between conductivity/resistivity and geological setting

The survey shows increased ground conductivity in the sand storage area and may be due to the predominantly wet sand of varying thickness and an increase in salinity in this area.

A broad zone of elevated response can be seen around the weigh bridge area and extending towards to the building in the north west. This correlates with a linear feature identified by the magnetic survey and may also indicate an increase of more conductive material within the made ground.

A subtle linear high response can be seen traversing approximately east to west through the middle of the site. This may be associated with the route of historic rail lines.

Another subtle high response can be seen to follow the road in the west of the survey area, and probably is caused by a change in ground composition associated with the road construction.

Isolated anomalies not coincident with surface features are indicative of buried objects or remnant structures and services.

2.7 Electromagnetic survey – In-phase response (Figure 2b)

Figure 2d shows an isolated component of the electromagnetic signal known as the in-phase response, which is typically more sensitive to the presence of heterogeneous made ground and metal objects.

The plot shows the same significant anomalies as the ground conductivity survey but in some cases has better resolution of the features. An additional linear feature traversing approximately east-west can be seen a few meters south of TP5 which may be indicative of a structure or service

2.8 Ground Penetrating Radar survey (GPR) (Figure 3)

The GPR technique was carried out across four areas in the north of the survey area. These areas were away from known/interpreted concrete reinforced slabs and where it was thought that the made ground might be thinner. These areas were thought likely to provide optimum trial areas in order to try and map the limestone bedrock. Due to the conductive nature of the ground material, the maximum depth of signal penetration is approximately 1.75m bgl and therefore is unlikely to have mapped shallow bedrock as recent borehole information suggests the made ground has a depth of 3-4m generally and may be considerably deeper in this area.

Some selected radargrams from the 250MHz antennae, that indicate features of interest in the shallow subsurface have been shown in Figure 3.. Possible buried services can be seen as discreet hyperbolae. Changes in ground character of the fill material can also be seen as changes in the character of the GPR response, in particular the presence of blocky material giving rise to multiple diffractions. Some lateral and dipping boundaries are also visible that may be associated with historical structures such as hard standings or ramps, or possible phases of backfilling that have taken place.

3 CONCLUSIONS

- The geophysical survey has provided a rapid non-intrusive method for characterising the subsurface.

- The electromagnetic and magnetic surveys have characterised the site to show areas of reinforced ground and broad areas with changes in ground character. A number of anomalies have been shown such as linear features that may be related to historic rail lines, isolated features and changes in ground character may warrant further investigation to establish their exact nature.

- It was not possible to use resistivity tomography at the site to investigate ground conductivity anomalies with regard to solution features and establish bedrock profiles, due to the amount of hard standing and tarmac present in the survey area. A trial using ground penetrating radar was used instead to see if this technique could help in bedrock imaging, however the signal penetration was too poor due to clay rich and salt rich ground.

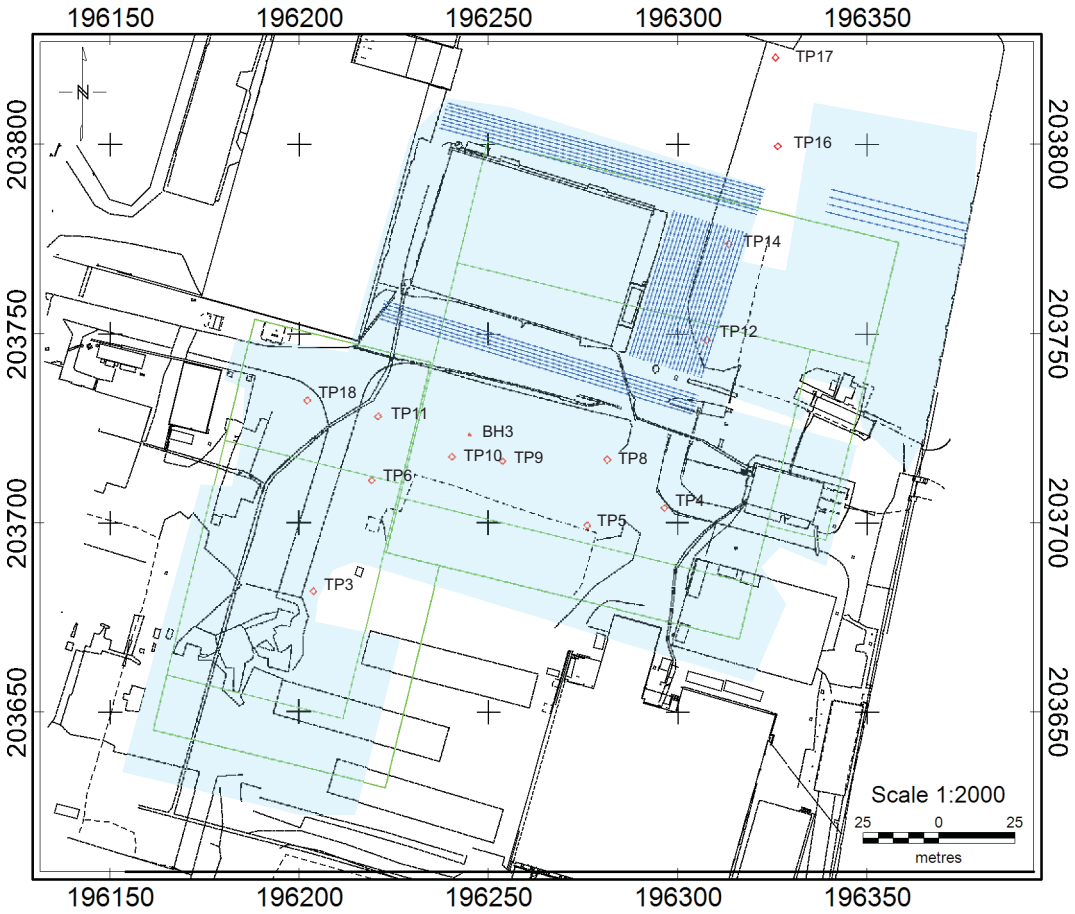
- The GPR survey penetration was limited by ground conditions and has not been able to map limestone bedrock, however features and changes in ground character in the first 1.75m of the subsurface have been shown and more detailed and extensive surveys may be of use in determining ground conditions and character across the site.

- **Should more detailed analysis of bedrock depth, profiles and engineering properties be required, it is recommended Terradat carry out seismic refraction and/or seismic cross hole surveys.**

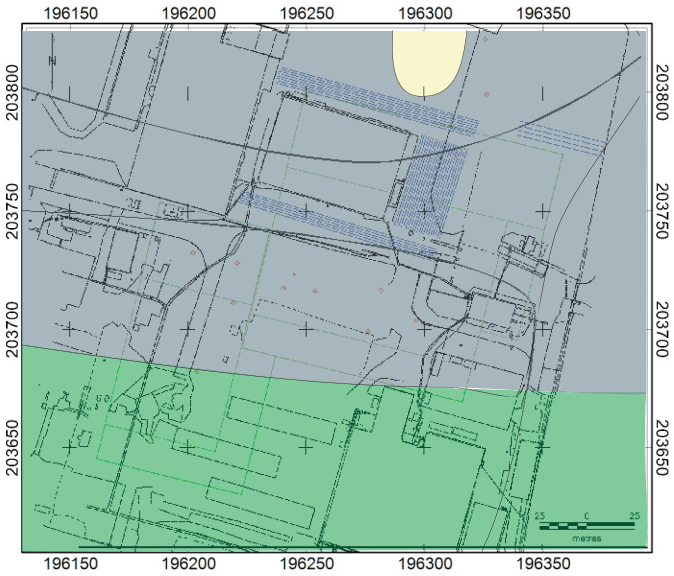
Disclaimer

This report represents an opinionated interpretation of the geophysical data. It is intended for guidance with follow-up invasive investigation. Features that do not produce measurable geophysical anomalies or are hidden by other features may remain undetected. Geophysical surveys compliment invasive/destructive methods and provide a tool for investigating the subsurface; they do not produce data that can be taken to represent all of the ground conditions found within the surveyed area. Areas that have not been surveyed due to obstructed access or any other reason are excluded from the interpretation.

FIGURES



Geology map



Key

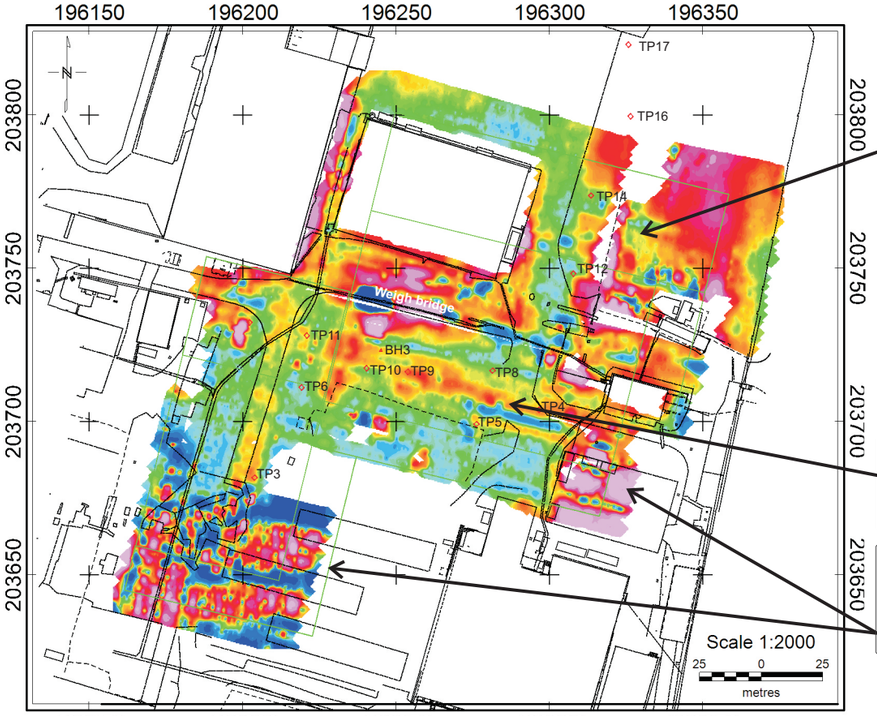
- Proposed Tidal Lagoon Building
- Located trial pits
- Located boreholes
- Area covered by Conductivity and Magnetic survey
- Ground Penetrating Radar (GPR) survey profile
- Tidal Flat Deposits
- Black Rock Subgroup And Gully Oolite Formation (undifferentiated) Limestone
- Pembroke Limestone Group

Location and geology map

Pembroke Dock

1:2000 at A4	Drawn by/Ref: AL/4653/1
TERRA DAT geophysical innovation	Date: 25 MAR 2015
Tel: +44 (0) 8707 303050	**FIGURE 1**

A) Quad-phase Component at 15025Hz frequency

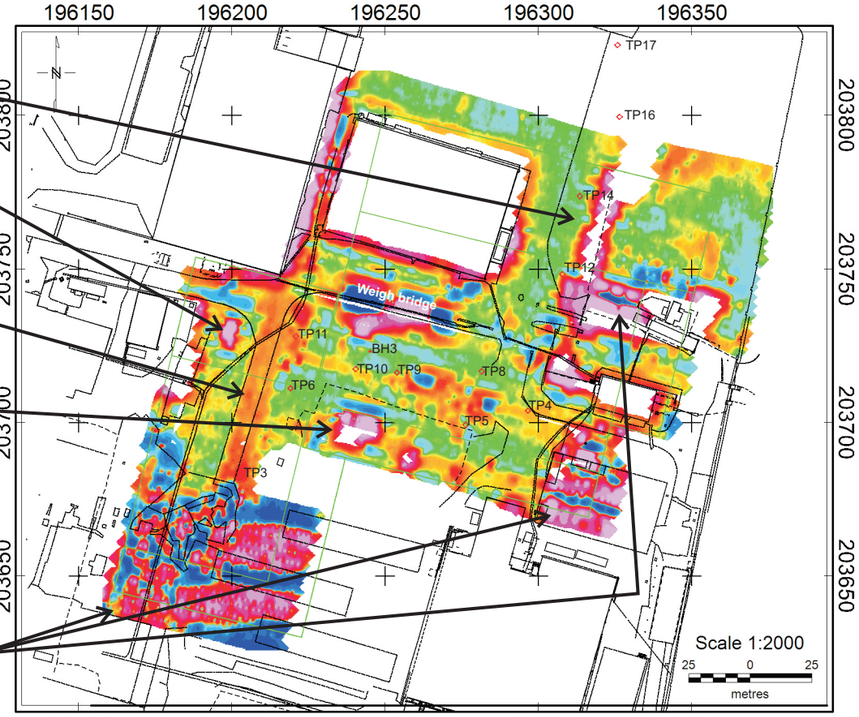


Relativity high ground conductivity

815
338
162
96
65
46
33
24
17
13
9
6
4
2
1
-0
-3
-8
-64

Ground conductivity (mS/m)

B) In-phase Component at 15025Hz frequency



26612
13457
5022
-471
-2991
-4107
-4726
-5119
-5361
-5545
-5702
-5838
-5956
-6062
-6173
-6322
-6901
-10636
-23865

ppm

Linear anomalies correspond with fence lines.

Isolated anomaly

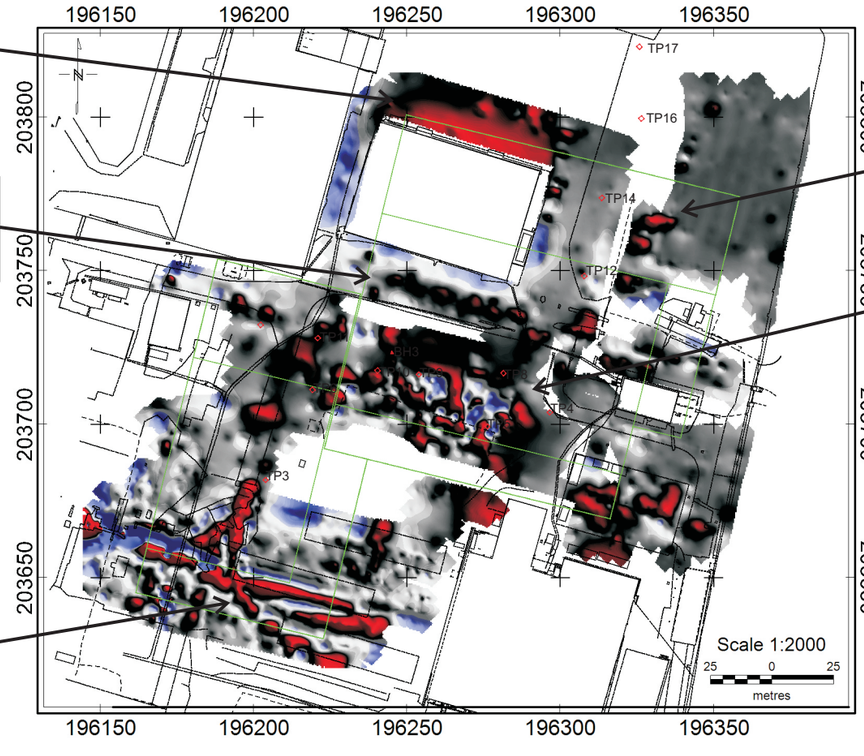
Linear response possibly filled in slipway

High In-phase response from surface metal

Linear response possibly historic railway

Extreme response indicating presence of reinforced concrete slabs

C) G858 Magnetic Survey - Analytical response



Change in ground characteristics of unknown origin

Linear anomalies possibly indicative of buried services, possibly the railway.

Curved and linear features with a high magnetic response possibly represents railway lines, however, there is no evidence in historical photos, or possible buried services

Isolated anomaly of unknown origin

Multiple high responses, possible presence of reinforced concrete

51901
50056
49402
49067
48850
48667
48543
48487
48421
48330
48227
48121
48004
47869
47711
47501
47238
46874
46345
45410
43660

Increase in response

Analytical Signal Response (nT/m)

Key

- Proposed Tidal Lagoon Building
- Located trial pits
- Located boreholes

Conductivity and Magnetic survey

Pembroke Dock

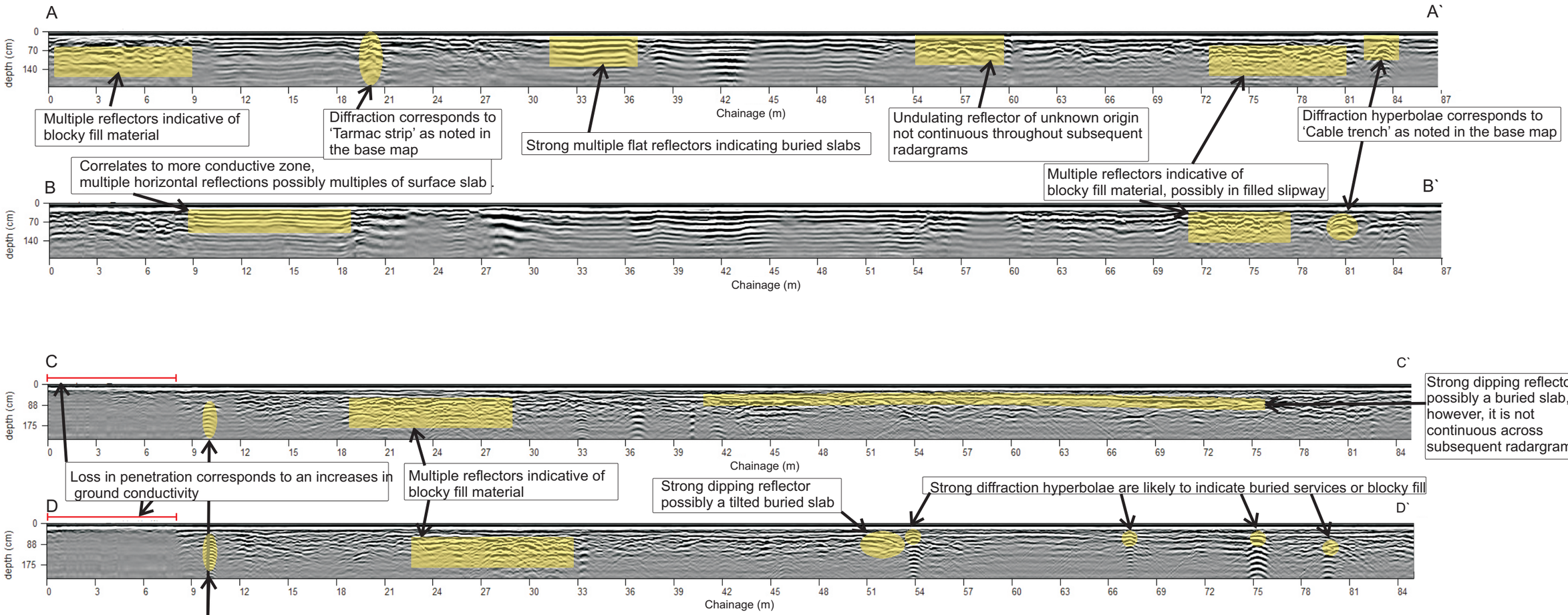
1:2000 at A3

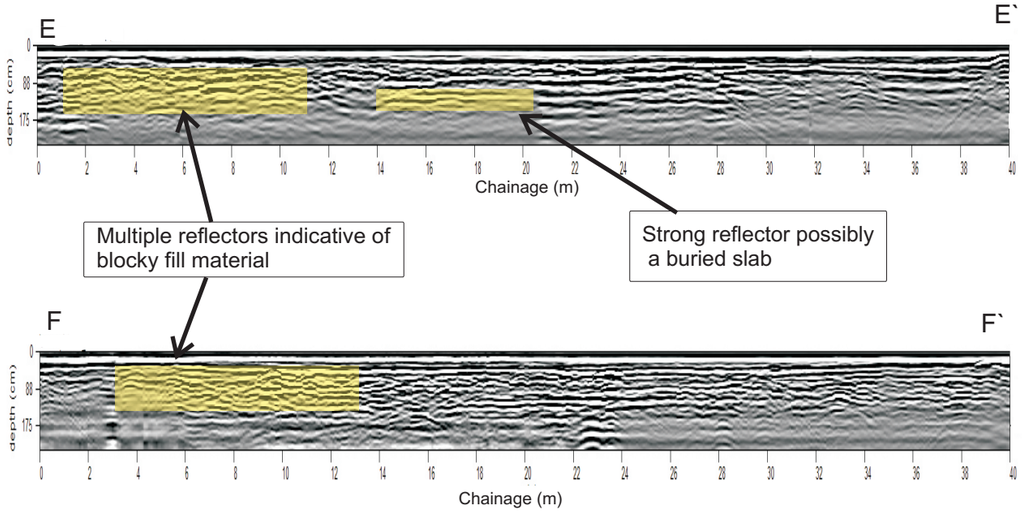
Drawn by/Ref: AL/4653/1

Date: 25 MAR 2015

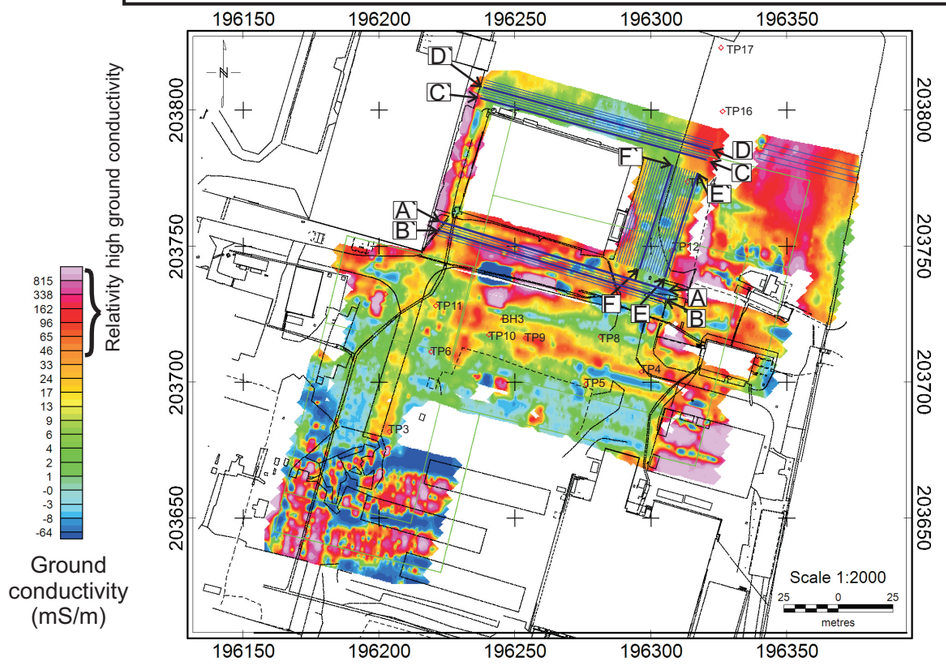
TERRA DAT
geophysical innovation
Tel: +44 (0) 8707 303050

FIGURE 2





Quad-phase Component at 15025Hz frequency with radar lines overlaid



Key

- Proposed Tidal Lagoon Building
- Located trial pits
- Located boreholes
- Ground Penetrating Radar (GPR) survey profile

Examples of 250MHz GPR profiles

Pembroke Dock

Drawn by/Ref: AL/4653/1

Date: 25 MAR 2015

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FIGURE 3

APPENDICES

Appendix - Electromagnetic Survey

The electromagnetic (EM) technique involves the generation of an EM field at the surface and measuring the response of the ground as it propagates into the subsurface. The main components of an EM survey instrument are a transmitter (for the generation of primary field) and receiver (for measuring the induced secondary field). The instrument functions by inducing current into the ground via a transmitter coil which causes the generation of secondary electromagnetic fields in any ground conductors present within the depth range of the particular instrument. These secondary fields are measured at a receiver coil and the instrument can record ground conductivity and in-phase component (metal indicator) at each survey station.

Electromagnetic (EM) surveys are carried out using man-portable instruments with readings taken on a regular grid or along selected traverse lines. If site conditions permit, the EM instrument may be mounted/towed behind a quad bike and positional control is provided by dGPS. The selection of the particular EM instrument (GEM2/EM-38/EM-31/EM-34) is based on the required penetration depth of the survey.

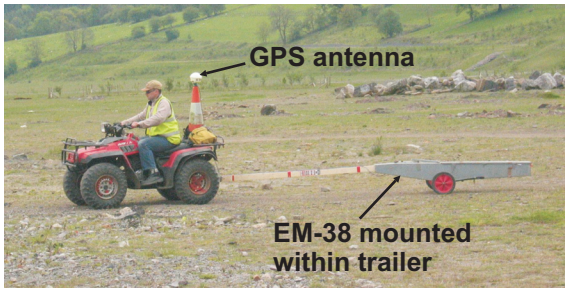
The results from the EM survey can be presented as colour contoured plots of conductivity and inphase (metal response) data. In general terms, a relative increase in conductivity values usually indicates a local increase in clay content or water saturation. However, if there is a corresponding increase in the inphase response, the influence of some artificial source is likely (i.e. metal).

EM-38
(Exploration depth ~1.5m)

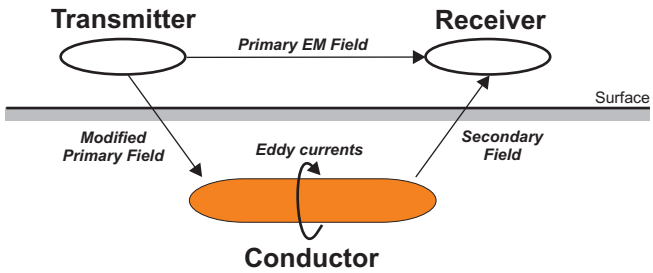
EM-31
(Exploration depth ~3 to 5m)

EM-34
(Exploration depth ~7.5 to 60m)

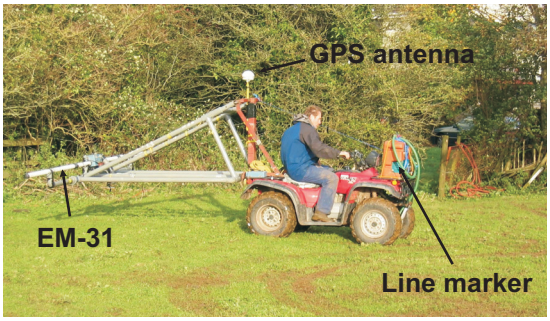
Towed EM-38 with dGPS



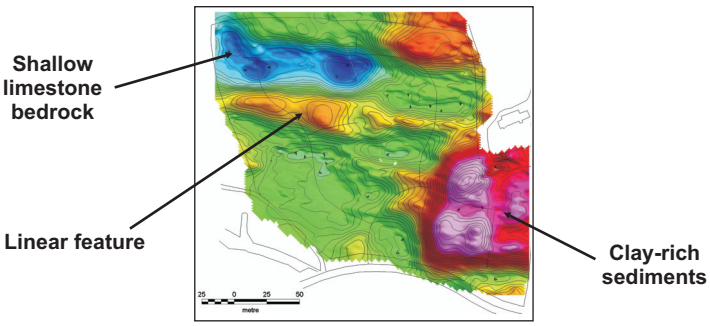
General principle of EM surveying



Mounted EM-31 with dGPS



Conductivity data plot



At the end of the survey, the data are downloaded to a field computer and corrected for instrument, diurnal and positional shifts. Additional editing may be carried out to remove non-essential or 'noisy' data values/positions. The dataset is then processed to enhance any identifiable anomalies .

Constraints

Power lines, buildings, metal structures (fences, rebar, vehicles, debris etc.) and buried services can interfere with the electro-magnetic measurements.

TERRA DAT

Appendix - Magnetic Survey

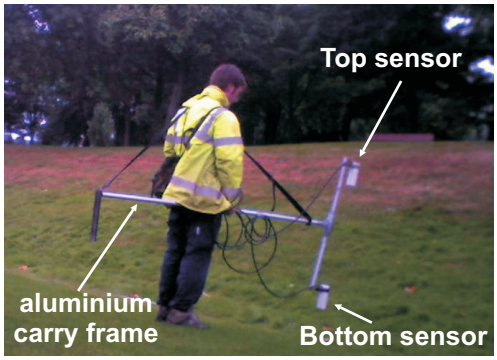
The Magnetic survey technique is based on mapping localised variations in the Earth's magnetic field caused sub-surface magnetic materials, which range from naturally occurring magnetic minerals to man-made ferrous objects. This leads to a wide range of applications from small-scale archeology and engineering surveys to detect buried metallic objects, to large-scale surveys carried out to investigate regional geological trends or mineralisation.

Magnetic surveys are carried out using a man-portable instrument with readings taken on a regular grid or along selected traverse lines. The equipment functions by measuring the Earth's magnetic field to a very high precision at each survey station. Ferrous materials in the subsurface have an induced magnetic field that is superimposed on the Earth's field at that location creating a magnetic anomaly. The spacing of survey stations depends on the width of the expected anomaly, which broadens with the size, and depth of burial of the targeted feature. Continuous profiling methods may be used for a high-resolution dataset.

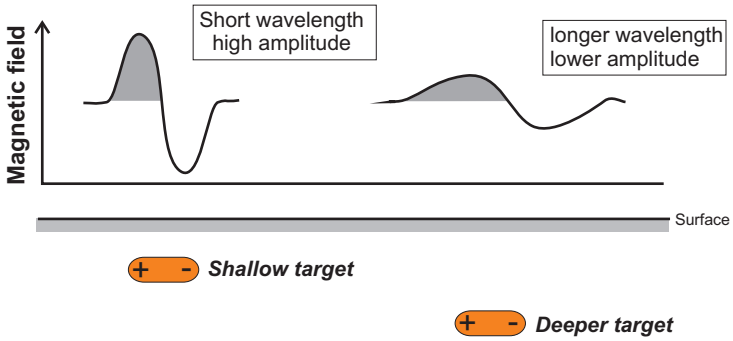
Magnetometer data are stored digitally by the survey instrument and down loaded to a field computer at the end of each day. The magnetic data are then processed to enhance any identifiable anomalies and presented on colour-contoured plots overlain with site maps (when available).

The results of the magnetic survey are usually presented as total field and analytical signal plots . The total field data may be used to observe the general character of the magnetic field across the survey area while the peak values (pink) displayed on the analytical signal plot indicate the source positions for dipole type magnetic anomalies. In general terms, the interpretation of a magnetic anomaly is based on observing the type (pole/dipole), amplitude and wavelength of the anomalous features.

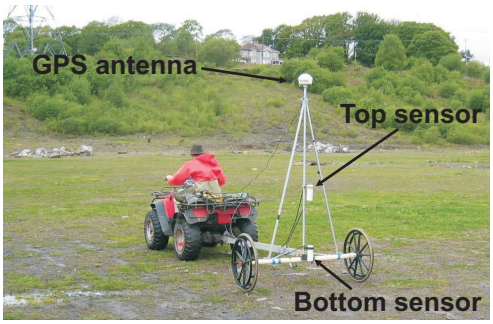
Gradiometer survey



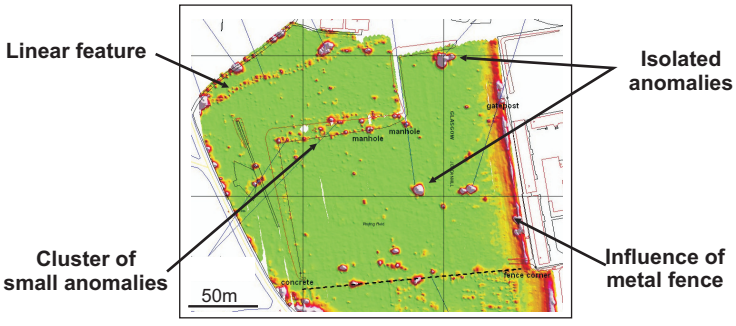
General principle of Magnetic surveying



Towed gradiometer with dGPS



Analytical signal plot



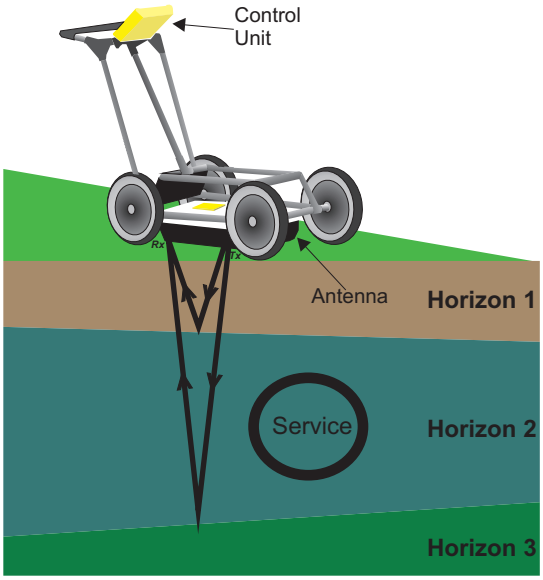
Constraints

Metal objects or structures close to the survey area (fences, vehicles, debris etc.) produce a strong signal that can overshadow more subtle effects of sub-surface anomalies.

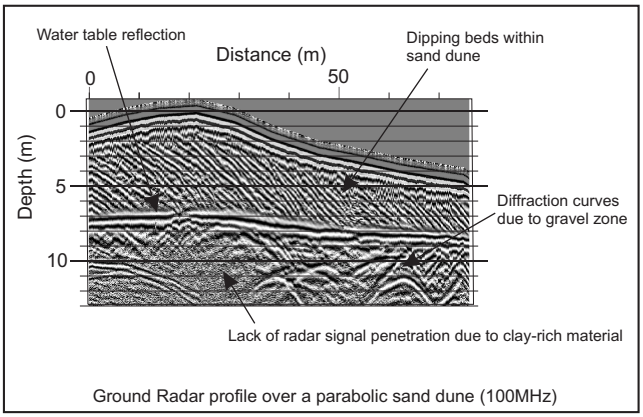
Appendix - Ground Penetrating Radar (GPR)

A Ground Penetrating Radar (GPR) survey involves one or two people either continuously towing a radar system or taking readings at very closely spaced intervals along selected traverse lines. GPR systems use a pulsed electromagnetic (radio wave) transmitted via a tuned frequency antenna that can penetrate soils, rock, concrete, and many other natural and man-made materials. Reflection events from geological or hydrological boundaries between sufficiently contrasting materials are recorded via a receiver antenna. A time-depth cross-section (radargram) of the shallow subsurface is constructed as the radar system is moved along a survey line. The radargram can be depth calibrated to enable detailed interpretation given known or measured velocities for the materials being investigated. While viewing relatively raw radar data can prove useful in the field there are numerous processing routines that can be employed to significantly improve the results. Final sections are presented showing annotated features of interest with apparent depth calibration.

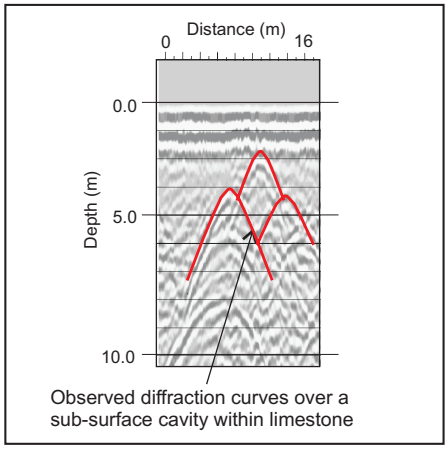
General principle of Ground Radar



GPR Survey in progress



Ground Radar profile over a parabolic sand dune (100MHz)



In order to improve the quality of the recorded radar data, a number of processing routines can be applied to the data using dedicated software (REFLEX). The final radar sections are converted to depth by applying a conversion velocity, which is usually based on an average velocity value for the local sediments. Without any additional calibration the measured depth to a particular feature is likely to be resolved within a 20% error margin depending on the local velocity structure.

Constraints:

The main limitations affecting radar surveys are the presence of conductive materials near surface (e.g., clay and water) which reduce penetration, and blocky material which scatters signal.

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