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Annexure G: Hydrographic And Geophysical Survey at Latimer's Landing – Preliminary Report

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HYDROGRAPHIC AND GEOPHYSICAL SURVEY AT LATIMER'S LANDING, PORT OF EAST LONDON

AUGUST 2015

HYDROGRAPHIC AND GEOPHYSICAL SURVEY AT LATIMER'S LANDING, PORT OF EAST LONDON

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EXECUTIVE SUMMARY

- The Council for Scientific and Industrial Research (CSIR) was contracted by ECIJV to undertake a Hydrographic (multibeam echosounding) and Geophysical (sub-bottom profiling pinger and boomer) survey of a pre-determined area adjacent to Latimer's landing in the Port of East London.
- The bathymetric data collected ranged from 1.92 – 12.09 m below mean sea-level (BMSL).
- The morphology of the seafloor within the area surveyed presents as a generally smooth, gently undulating and progressively deepening towards the east.
- There is an elongated depression with approximate centreline 34 m away from the quayside that trends west – east, dipping towards the east at approximately 1°.
- Adjacent to the quay wall are three relative bathymetric highs that present as sediment mounds of varying size.
- Although only a pinger seismic system was specified in the scope of works, the CSIR took along another deeper penetration (boomer) system, anticipating the pinger to not achieve the desired penetration.
- The boomer system was required in the end and using both acquisition suites three sub-bottom units were identified.
- These units with tentative correlations are as follows:
    - Unit 1 – unconsolidated sediment
    - Unit 2 – weathered basement sediments; and
    - Unit 3 – competent basement which could be mudstone, dolerite or hornfels.
- These sub-bottom correlations remain tentative until direct samples of each unit can be attained.

1 TABLE OF CONTENTS

2 INTRODUCTION

The Council for Scientific and Industrial Research (CSIR) was contracted to undertake a multibeam echosounding and a sub-bottom profiling (pinger and boomer) survey of a pre-determined area adjacent to Latimer's Landing in East London Harbour (Figure 1). The survey took place on 30 July 2015. Hydrographic Multibeam data was acquired concurrently to the Geophysical sub-bottom profiling data.

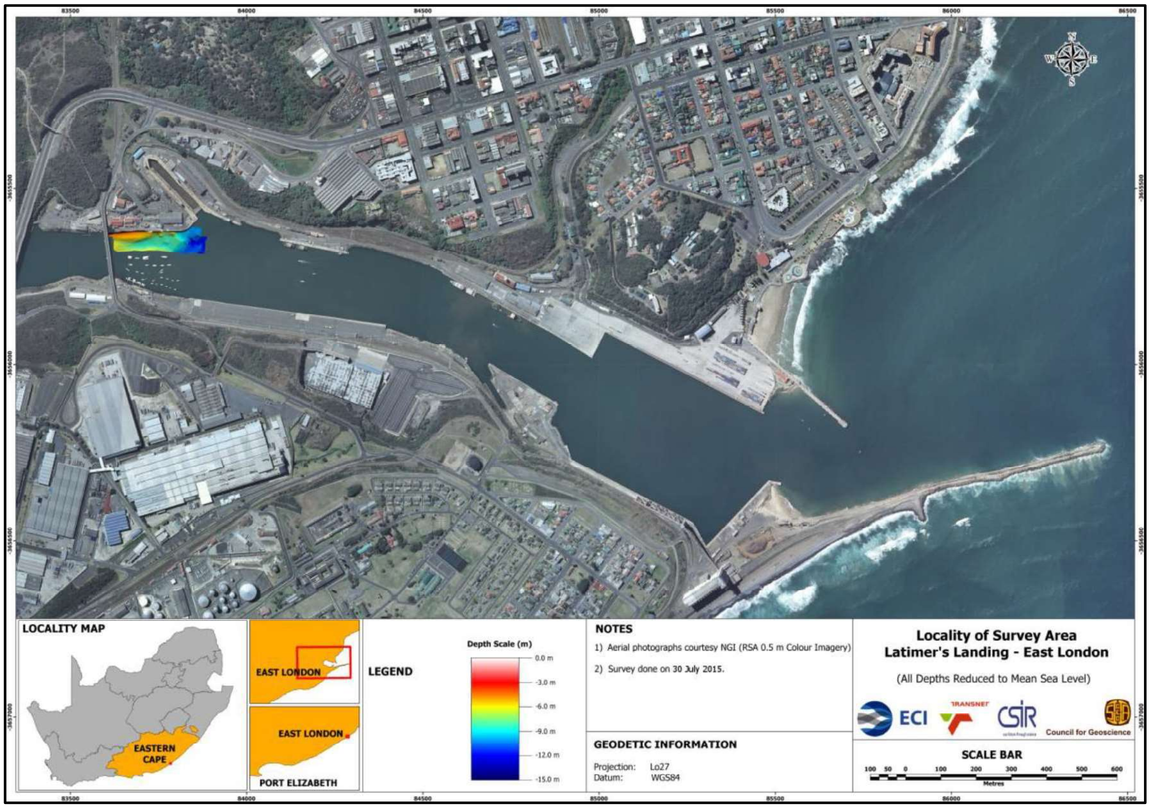

Figure 1. Chart depicting location of survey area relative to East London Harbour.

2.1 Multibeam Operating Principles

Multibeam echosounder (MBES) systems measure the oblique slant range to the seafloor of distances beyond the first arrival of echoes directly below the transducer (Galway, 2000). The systems are usually hull mounted (Jones, 1999) and based on a cross fan beam geometry generated by two transducer arrays orthogonally mounted to each other in an L or T configuration (de Moustier, 1988). The transmit array is placed parallel to the vessel's keel and projects a vertical fan beam that is narrow along track (1º - 3º) and broad across track (150º and more) (Farr, 1980). Galway (2000) and Jones (1999) describe the receiver array as consisting of a series of hydrophones mounted orthogonally to the vessel's direction of travel. This array generates a series of fan-shaped beams that are in planes parallel to the vessel's direction of travel, and is sensitive to the narrow rectangular window on the seafloor that intersects the transmit and receive beams (Figure 2). The receive beamwidths are typically 1° - 3° across track and 20° along track.

Conventionally echosounders determine the travel time of the acoustic pulse by detecting the sharp leading edge of the return echo (Mayer and Hughes-Clark, 1995). This method of bottom detection is referred to as amplitude detection. As the angle of incidence increases, the return echo loses this sharp leading edge and the accurate determination of depth via amplitude detection becomes more difficult (Galway, 2000). MBES systems overcome this problem by determining the phase difference between two beams pointing in the same direction over the duration of the return echo envelope (Galway, 2000). The point at which there is no phase difference, corresponds to the maximum response axis of the beam, providing a measure of two-way travel time for a known angle from which a depth to the seafloor can be determined (Mayer and Hughes-Clark, 1995). Most MBES systems will compute both amplitude and phase bottom detection for each beam and then the software will select the better of the two for that specific beam (Galway, 2000).

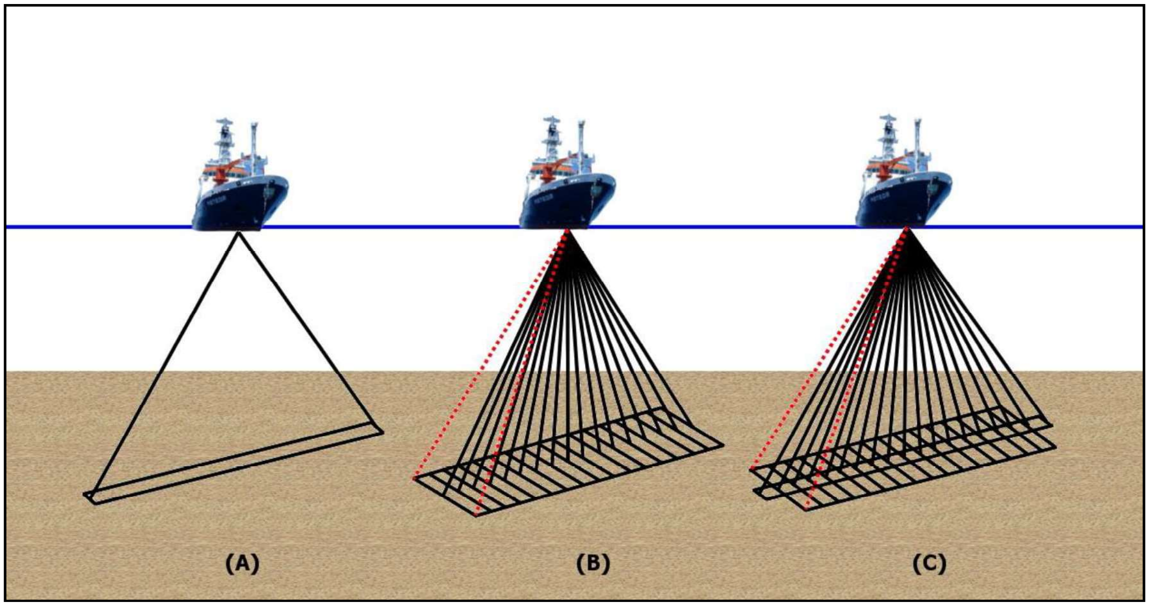

Figure 2. Relationship of the transmit and receive beams for MBES. (A) Area of seafloor insonified by transmission pulse, (B) Area of seafloor covered by receiving hydrophones, (C) Received acoustic energy. Modified from Renard and Allenou (1979).

2.2 Seismic Operating Principles

The principles of seismics are the following: A transducer "fires" sending a low frequency sound wave into the water column. Due to the low frequency, the sound wave is able to penetrate the sub-surface sediment. Wherever there is a marked difference in sediment density (the contact between different sediment types) part of the sound wave is reflected back towards the surface. This reflected wave is received by the transducers and digitized in the correct spatial frame. A simplified schematic of the process for oil and gas exploration is shown in Figure 3. The principles are the same for the CGS pinger and boomer system, in that there is a seismic source, which reflects off the internal layers of sediment and is recorded by a receiver.

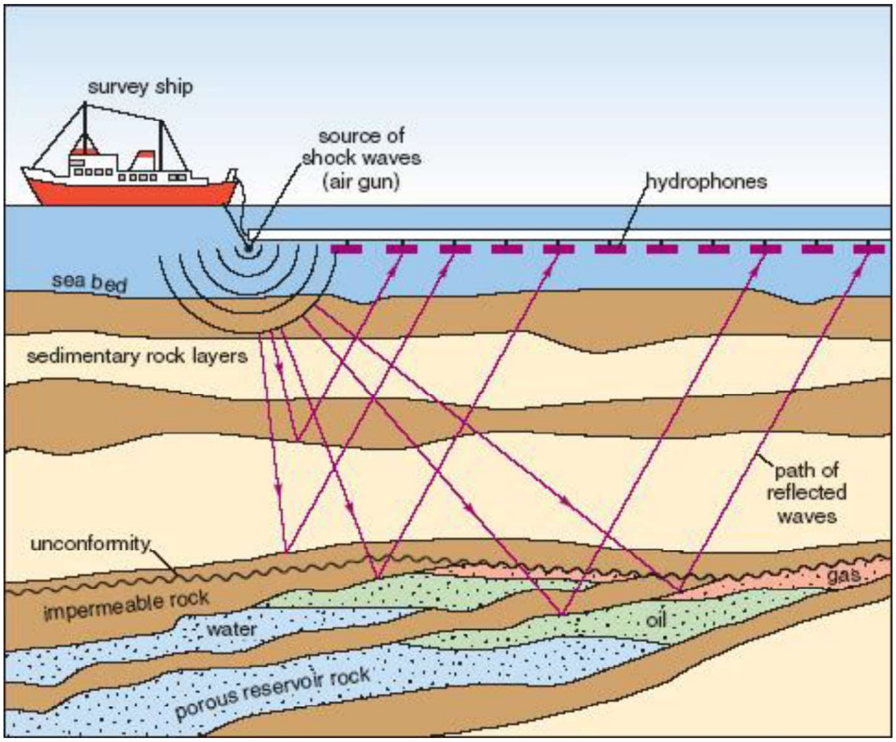

Figure 3. The principles of reflection seismics, as utilised by both seismic systems.

3 REGIONAL GEOLOGICAL SETTING

The generalised geology of the greater East London area is underlain by rocks of the Karoo Supergroup, capped by various Cenozoic deposits and intruded by dolerites (Johnson and le Roux, 1994) (Figure 4).

The basal units are from the Adelaide Subgroup of the Beaufort Group. These lithologies are 4000 – 5000 m thick and consist of alternating mudstones and subordinate sandstone units (Johnson and le Roux, 1994). The Beaufort Group has in turn been intruded by Jurassic dolerite dykes and sills. The various Cenozoic deposits rest on peneplaned surfaces in the area and collectively form the Algoa Group. The formation within this group that is closest to the study area is the Nanaga Formation, which comprises up to 250 m of semi-consolidated aeolianite (Johnson and le Roux, 1994).

3.1.1 Beaufort Group

The Adelaide Subgroup is Permian in age and made up of the Koonap, Middleton and Balfour Formations. Formations consist of alternating grey, moderately to well sorted, fine- to very fine grained, ultralithofelspathic sandstones and greenish-grey or greyish-red mudstones. The total thickness of this Subgroup is 4000 – 5000 m, although near East London it is just under 900 m thick (Leith, 1970). The sandstone and mudstone units typically form upward fining units, each comprising a sandstone with a sharp, erosive base which grades into the overlying mudstone unit, with average thickness of 10 – 20 m (Johnson and le Roux, 1994). The sandstone units are typically massive and a few metres thick presenting as subtabular to lenticular in form. The mudstones are generally massive.

3.1.2 Dolerite

The dolerites around East London are Jurassic in age and intrude the Beaufort Group strata as inclined sheets (sills) and dykes. Generally the mudstones adjacent to these dolerite intrusions have been metamorphosed to hornfels, the thickness of which is normally one-tenth the thickness of the dolerite sheet (Mountain, 1974).

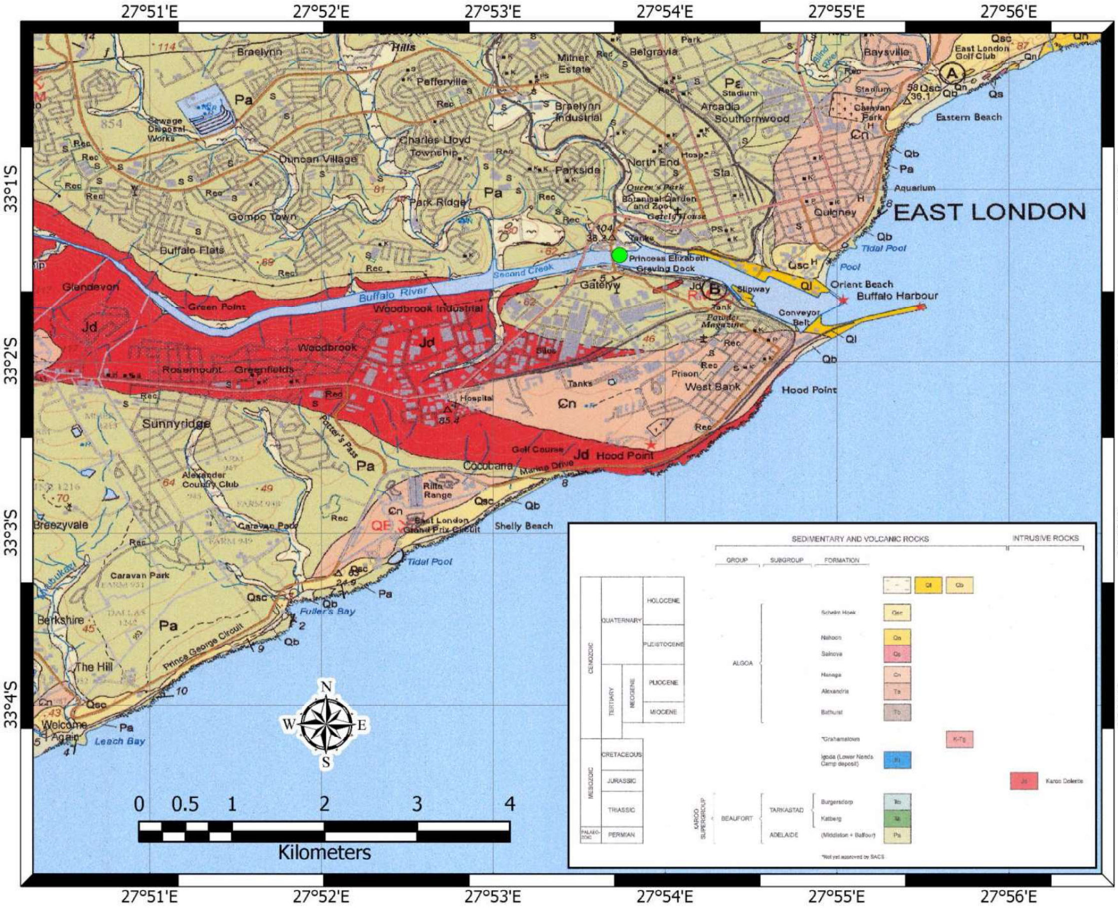

Figure 4. 1:50 000 Geological map of the greater East London area from 3327BB East London geological map published by the Council for Geoscience (Reddering and Brönn, 2001). The green circle represents the study area.

4 SURVEY PERSONNEL

Mr. Robert Vonk – (Hydrographic Surveyor)

Mr. Wilhelm van Zyl – (CGS sub-bottom profiling Geologist)

Mr. Hans Jelbert – (Skipper and Electronic Technician)

5 SURVEY EQUIPMENT SUITE

5.1 Survey Vessel

The nearshore vessel *R/V CSIR Surveyor* (Figure 5) was used for the collection of all geophysical data. She is an 8 m, custom-built, aluminium monohull. She is powered by two 100 Hp Yamaha four-stroke outboard motors. Due to her shallow draft of approximately 0.6 m she is able to safely navigate into extremely shallow water (surf permitting), to maximise data acquisition and area coverage.

Figure 5. The nearshore survey vessel *R/V CSIR Surveyor.*

5.2 Navigation Equipment

The navigation equipment used for the hydrographic and geophysical survey consisted of a Leica RTKGNSS system which uses two Leica global navigation satellite system (GNSS) GS15 receivers and built in radio transmitters (Figure 6). The superior GNSS technology allows for very low noise GNSS carrier phase measurements with less than 0.5 mm precision. The unit has 120 channels and can scan up to 60 satellites simultaneously on two frequencies. It can track a plethora of satellite signals including GLONASS and GPS L1 and L2. Dynamic accuracy of 1 cm horisontally and 2.5cm vertically can be achieved at 20Hz.

The positioning for the survey was done on the WGS84 Spheroid and WG29 LoGrid.

The survey positioning of the vessel was done with a Leica RTKGNSS receiver onboard receiving telemetric corrections from a Leica RTKGNSS basestation positioned on a survey mark at the ski boat club within 200m from the survey site. The basestation coordinates were transferred and derived from the following Trig Survey Published Town Survey Mark (TSM) in East London:

RM 187 -84818.36 Y, 3656387.04 X, 21.203 Z (MSL), WGS84, WG29

The precision of the horisontal and vertical positioning data was within 3 cm during the survey.

Figure 6: Leica base station (left) and GS15 controller and GNSS GS15 receiver (right).

5.3 Multibeam Acquisition System

A Reson SeaBat 8125 multibeam echosounder was used to chart the study area. This is an ultra-high resolution system with an operating frequency of 400 kHz. It is a wide sector, wide-band, multibeam sonar utilising 256 dynamically-focused receive beams at 0.5° across-track beamwidth separations. The system measures a 128° swath across the seafloor, detecting the bottom, and delivering the measured ranges at a depth resolution of 5 mm up to 50 times per second. The multibeam system is shown in Figure .

The SeaBat was interfaced to an Applanix POS MV 320 motion reference unit (MRU) with L1/L2 RTK capability. As an integrated GPS/inertial reference system, the POS MV outputs all motion variables at high rates of up to 200 Hz even in the presence of GPS dropouts or degraded differential GPS corrections. The data output variables include RTK positioning and elevation, velocity, 3D attitude (roll, pitch and true heading), heave (and true heave), acceleration vectors and angular rate vectors. This high-specification system is the highest precision motion reference unit for use with multibeam sonar systems. The multibeam system was calibrated with a Navitronic SVP-15 sound velocity probe (SVP), which can accurately measure the velocity of sound in the water column in 0.5 m increments down to a depth of 200 m. All data from these devices were acquired and processed using *Qinsy* software.

Figure 7. Multibeam acquisition system: Reson SeaBat 8125 sonar (top left), processing unit (top middle), Applanix POS MV motion reference unit (bottom right) and processor (top middle), Navitronic SVP-15 sound velocity probe (top right) and *Qinsy* acquisition and processing software (bottom left).

5.4 Pinger Seismic Profiler

A Massa transducer pinger array was used to collect shallow penetration seismic profiling data in the survey area. The unit is powered by a GeoAcoustics 5430A Geopulse transmitter. This unit has a maximum power output of 10 kW and a selectable operating frequency range of 2 – 15 kHz. The amplifier has a signal-to-noise ratio of 20 dB at 100 dB gain, a 1 kHz centre frequency and 1 kHz bandwidth. The transmit repetition rate can be controlled externally or internally and is operator selectable. Pulse length is selected by the number of cycles to improve efficiency of the transducers and to reduce "ringing".The

Octopus 760D seismic processor was used to acquire and store the seismic data in SEG-Y format. It is used for real-time processing, digital recording and as a post-processing workstation. Onboard processing facilities include swell filtering, stacking, water column blanking, time varied band pass filtering, time varied gain, and automatic bottom tracking.

Figure 7. Pinger seismic profiling equipment of Octopus 760D acquisition unit (left) and GeoAcoustics Geopulse transmitter (right).

5.5 Boomer Seismic Profiler

An Applied Acoustic Engineering AA251 350J (1 kHz) boomer plate powered by a CSP-P 300 power supply (manufactured by the same company) was used for the acquisition of the boomer sub-bottom profiling data. The plate was used in conjunction with a Design Projects eight element hydrophone array which was interfaced with an Octopus 760D seismic processor to acquire and store the seismic data in SEG-Y format. The Octopus was used for real-time processing, digital recording and as a post-processing workstation. Onboard processing facilities include swell filtering, stacking, water column blanking, time varied band pass filtering, time varied gain, and automatic bottom tracking.

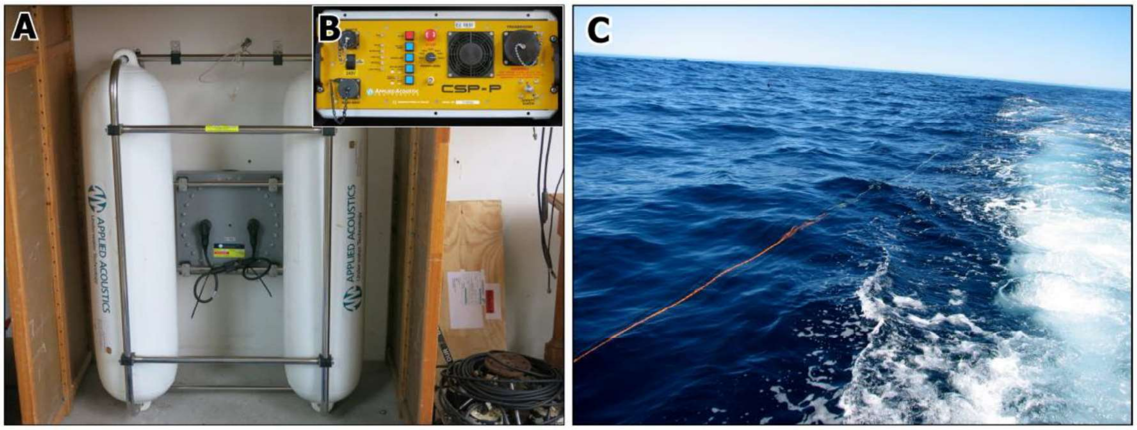

Figure 8. Boomer seismic profiling system comprising plate and catamaran (A), power supply (B) and towed hydrophone array (C).

6 HYDROGRAPHIC AND GEOPHYSICAL SURVEY PROCEDURE

6.1 Bathymetric Survey

The Reson SeaBAT 8125 multibeam echosounder used for acquisition was housed in a custom made aluminium shroud so that the transmit and receive arrays were orientated in the correct "Mills Cross" configuration. The shroud was fastened to the base of an aluminium cavity which filled the moon pool located mid ship in the vessel. The projector was orientated aft of the vessel. The deployment configuration was fabricated to rigidly return to the same mounting position whenever deployed and held firmly in place with stainless steel locking pins.

The inertial motion reference unit used to correct for the dynamic attitude of the vessel during data acquisition was installed on a plate immediately above the multibeam transducers inside the aluminium cavity that filled the moon pool. The GPS antennae used by the device were installed on the roof of the vessels (to ensure sufficient "sky" for both receivers). Both antennae were installed on a stainless steel bar ensuring a minimum separation (baseline) of 2.00 m.

The relative offsets between each device were determined using a Leica total station while the vessel was on the quayside (to eliminate any vessel movement due to sea surface perturbations). These offsets were entered into the relevant device software.

Survey lines were planned to ensure 100% seafloor coverage with adjacent lines overlapping by a minimum of 20%. The spacing between these lines varied depending on the water depth. Survey speed was dependant on sea conditions, prevailing currents and survey direction but was generally kept between 3 and 4 knots. Daily calibrations for sound velocity changes within the survey area were collected at half metre intervals for the entire water column (Figure 9). An additional sound velocity probe was interfaced with the sonar at the transducers to ensure realtime sound velocity input so that the correct arrival times and positioning of returning echoes could be accurately computed.

Calibration

The most important aspect of any multibeam survey is to calibrate (align) the minute misalignment of the transducer. This is done by collecting "patch test" lines over an object, sloping or flat seafloor (that is within the study area). These data are then used by the acquisition software to compute the relative corrections (pitch, roll and yaw) to the alignment of the transducer. Patch test values were determined and entered into the acquisition software prior to the collection of any bathymetric data. The following patch test values were used for the Latimer’s Landing survey:

Roll: 0.35°
Pitch: 0.47°
Yaw: 1.49°

All data were acquired and processed using *Qinsy* software.

The calibration of the echosounder through the water column was done using a sound velocity probe at the survey area. The sound velocity profile was used by *Qincy software* for calibration the echosounder data.

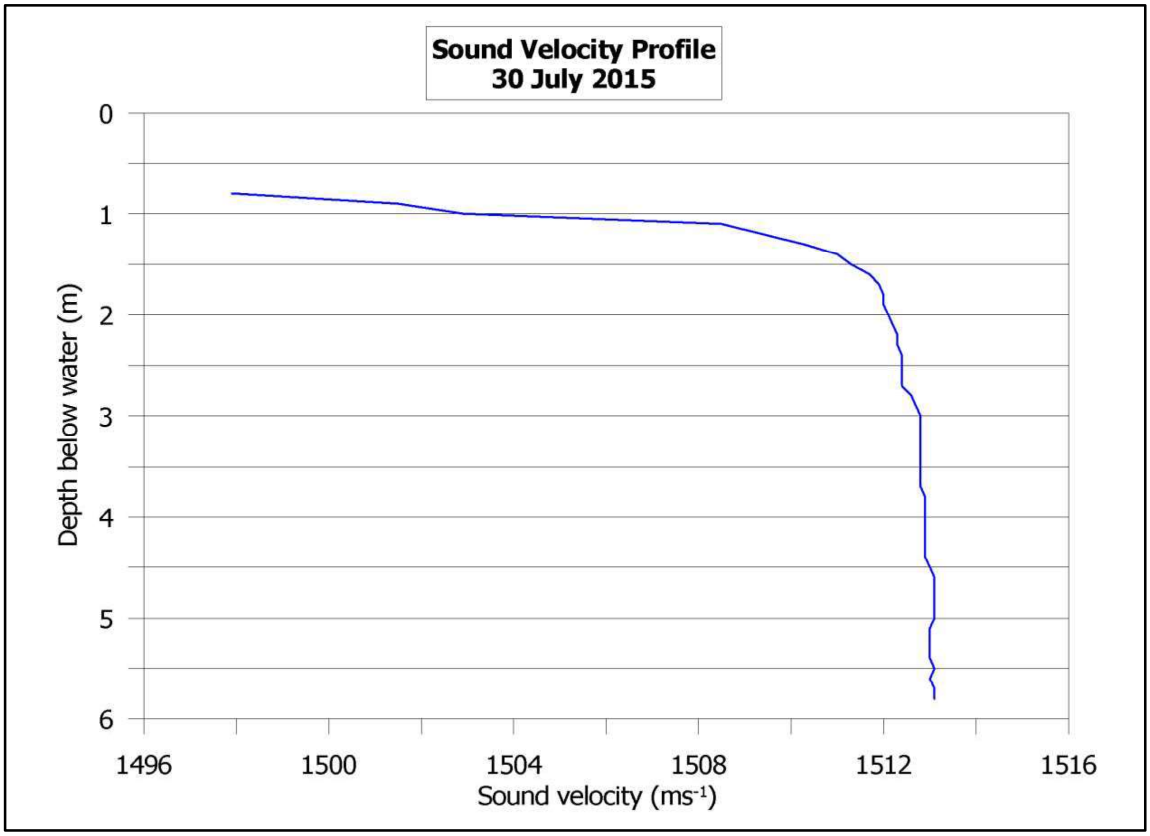

Figure 9. Sound velocity profile collected on site and used for the calibration of the geophysical equipment suites.

6.2 Pinger Seismic Profiling Survey

Two orientations of pinger seismic profiling survey lines were planned. The first were parallel to the quay wall planned at approximately 5 m intervals and the second set perpendicular to the quay wall at a spacing of 10 m (Figure 10).

The transducer array was fitted into a purpose built bracket and fastened to the base of a pole which was lowered over the port gunwale of the survey vessel. When lowered in place the RTK dGPS antenna was directly above the transducer array negating any positional layback needing to be applied to the seismic data. The draft of the transducer array was measured to be 84.2 cm and this value was applied during post processing to ensure correct depths were recorded. A speed of sound through sediment value of 1650 ms^{-1} was used when calculating the depth of seismic reflectors. Survey speed was kept between 3 and 4 knots to ensure sufficient resolution of sub-bottom reflectors.

The pinger system was triggered at 250 ms and run at variable power of between 50 and 30%, optimising penetration versus ringing for the different sediment types.

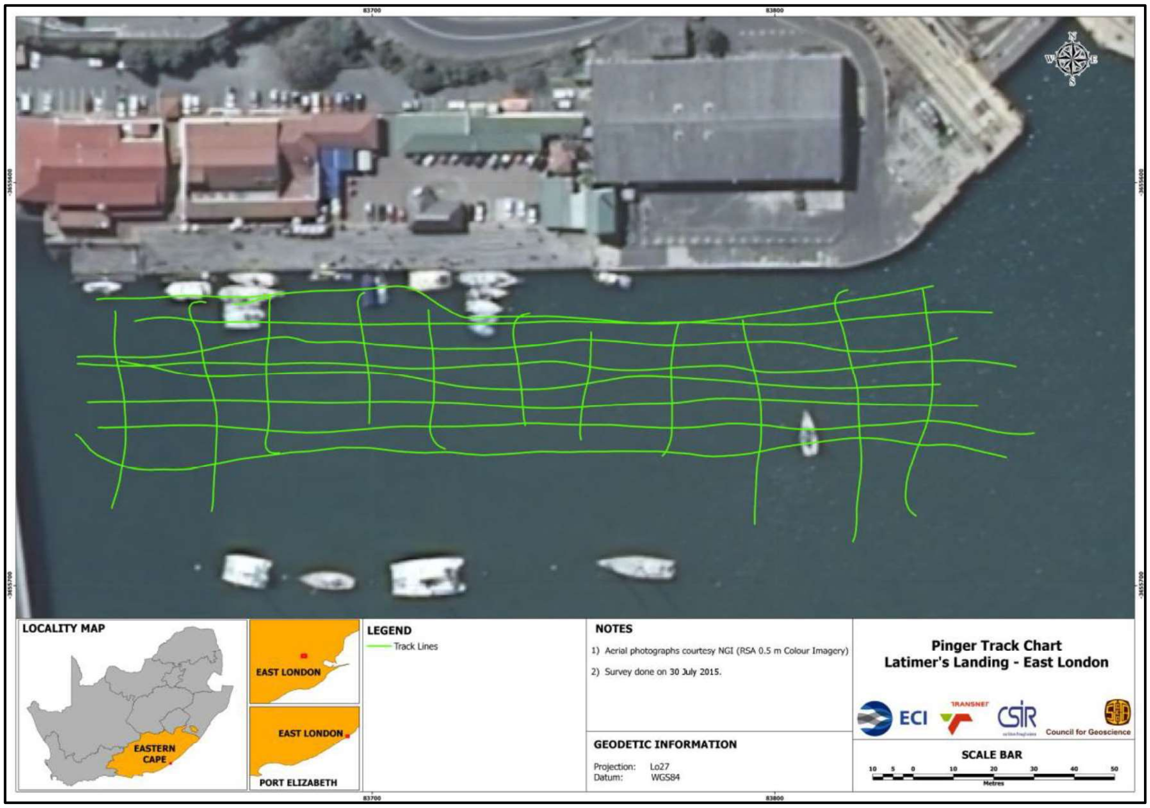

Figure 10. Pinger track chart.

6.3 Boomer Seismic Profiling Survey

As with the pinger data, boomer lines were planned in two orientations; parallel to the quayside and perpendicular to the quayside. The lines were planned to be much longer than the survey block requirement as boomer seismics lend themselves better to regional geological changes (Figure 11).

The plate was housed in a purpose built catamaran float. The float was then tethered to the aft port gunwale of the survey vessel and towed approximately 10 m behind it. The boomer plate (transducer) was connected via a high voltage cable and junction box to its power supply which was safely housed inside the cabin of the survey vessel and adequately earthed to the surrounding seawater. The hydrophone array was towed off a custom built outrigger from the starboard gunwale. The outrigger ensured that the array was offset from the vessel by approximately 2.5 m with sufficient cable played out so that the hydrophone receiving elements were positioned symmetrically opposite the seismic source (boomer plate). The propeller swash generated from the outboard motors was angled slightly towards the sea surface so as to interfere with the first (direct) return of the seismic source and aid in bottom reflector clarity.

The system was fired at full power with a trigger interval of 500 ms for the 350 J plate.

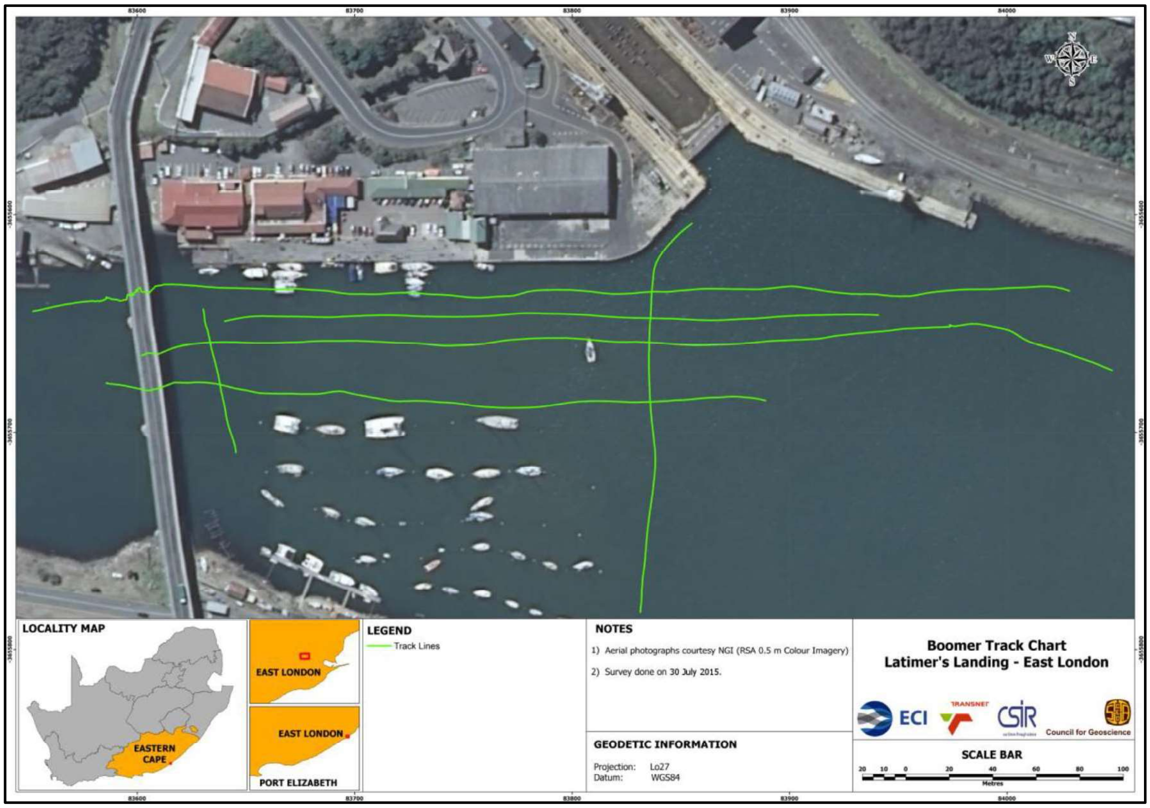

Figure 11. Boomer track chart.

7 RESULTS

7.1 Bathymetric Data

The bathymetric data collected ranged from 1.92 – 12.09 m below mean sea-level (BMSL) extended from the floating jetty in the west to past the curvature of the harbour wall towards the dry dock in the east. Data were collected from as close to the quayside as possible to approximately 60 m away from this relative baseline (Figure 12).

The morphology of the seafloor within the area surveyed presents as a generally smooth, gently undulating surface which progressively deepens towards the east. There is an elongated depression with an approximate centreline 34 m away from the quayside that trends west – east, dipping towards the east at approximately 1°. The average depth of this depression is approximately 8.5 m BMSL. Adjacent to the quay wall are three relative bathymetric highs. The largest extends from the western edge of the survey block approximately 117 m along the quayside and 30 m off at its maximum point. This high presents as a large sediment mound sloping into the middle of the survey block at angles of approximately 14°. The top of the sediment mound is located at 5.5 m BMSL. To the east of this mound is another mound located at the transition between caisson quay wall and piled quay wall. This mound is smaller, measuring 16 x 13 m. Its morphology is indicative of sediment mantling a hard substrate such as rock outcrop. The easternmost high is located 30 m to the east of the central high and presents as a smoother sediment mound with dimensions similar to the middle mound. From this point onwards in an easterly direction the seafloor deepens to 10 m BMSL with abundant irregular depressions towards the centre line described above, which is most commonly associated with dredge scars/holes.

There are notable anthropogenic features on the seafloor throughout the study area. There are two large fender tyres on the bottom, one 14 m off the harbour wall in the eastern side of the survey block (X: 83817.29; Y: -3655636.11) and one immediately adjacent to the floating jetty (X: 83621.65; Y: -3655627.64) (Figure 12). Along the southern margin of the survey block there are anchor blocks associated with the swing moorings demarcated for recreational craft. Eight blocks can be identified, some more exposed than others with mooring lines coming off most yet lying on the seafloor. Adjacent to the floating jetty there are numerous rod like objects either on the seafloor or protruding out from under the jetty. There appears to be a chain/rope lying on the seafloor making a sigmoidal shape protruding from under the floating jetty approximately 16 m towards the middle of the river channel.

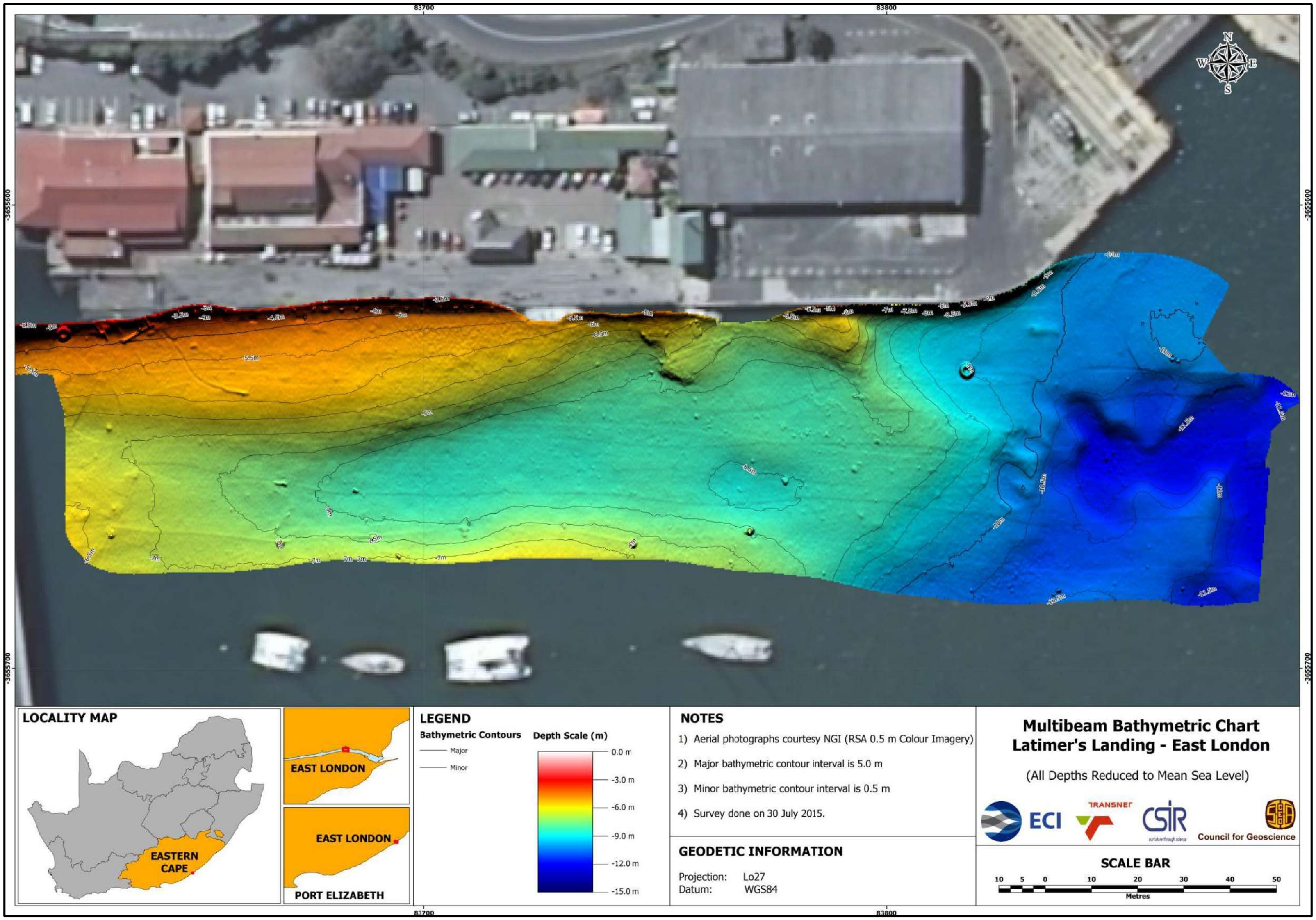

Figure 12. Multibeam bathymetric chart of the area adjacent to Latimer's Landing.

7.2 Sub-bottom Profiling Data

7.2.1 Pinger Data

From the pinger data two charts have been produced, namely the elevation surface defining the base of an acoustically transparent unit which has been defined as Unit 1 within the study area (Figure 13) and the sediment isopach (thickness) which defines this unit (Figure 14). The elevation surface which defines the base of Unit 1 varies from 4 – 12 m BMSL. The basement follows a similar pattern to the bathymetry, with a slight depression along the centre line of the survey block, deepening towards the east. The basement is shallowest adjacent to the jetty with an elevation of 4 m BMSL in the west, dipping slightly to 7 m BMSL in the east. The sediment isopach displays a variable thickness from 0.1 – 1.6 m within the study area. Thicker accumulation of sediment of up to 1.4 m can be seen on the western margin close to the rail road bridge. There are smaller, isolated patches of sediment accumulation of up to 1.6 m in the central and eastern areas of the survey block. Adjacent to Latimer's Landing the sediment is generally less than 1 m thick and varies from 0.4 – 0.8 m. Further away from the jetty towards the centre of the channel a very thin veneer of unconsolidated sediment (0.2 m) mantles the unit below.

7.2.2 Boomer Data

The boomer was used to delineate the sub-bottom units found within the study area. The basal reflector identified from these data defined the top of the lithological basement within the survey block and has been interpreted as Unit 3 (Figure 15). The depth to this surface adjacent to the jetty is between 6 – 8 m BMSL and dips down to 12 m BMSL in the central channel. Towards the turning basin in the eastern margin of the survey block the depth increases to 16 m BMSL. Consistent with the other surfaces identified from the sub-bottom data, it appears to show a similar morphological trend to the bathymetry, with a west – east trending channel deepening towards the east.

A consequence of defining the elevation of Unit 3 and the base of Unit 1 is that there exists a layer between these two surfaces which has been interpreted as Unit 2 and shown graphically by its relative isopach (Figure 16). This unit varies in thickness from 1.2 – 4.5 m with thicker accumulations found along the central channel becoming much thinner along the northern margin of the study area immediately adjacent to the jetty and quayside. As with the sediment isoapch of Unit 1, Unit 2 displays isolated pockets of thicker accumulations. One pocket lies immediately adjacent to the caisson quayside and the other to the extreme northwest of the survey block.

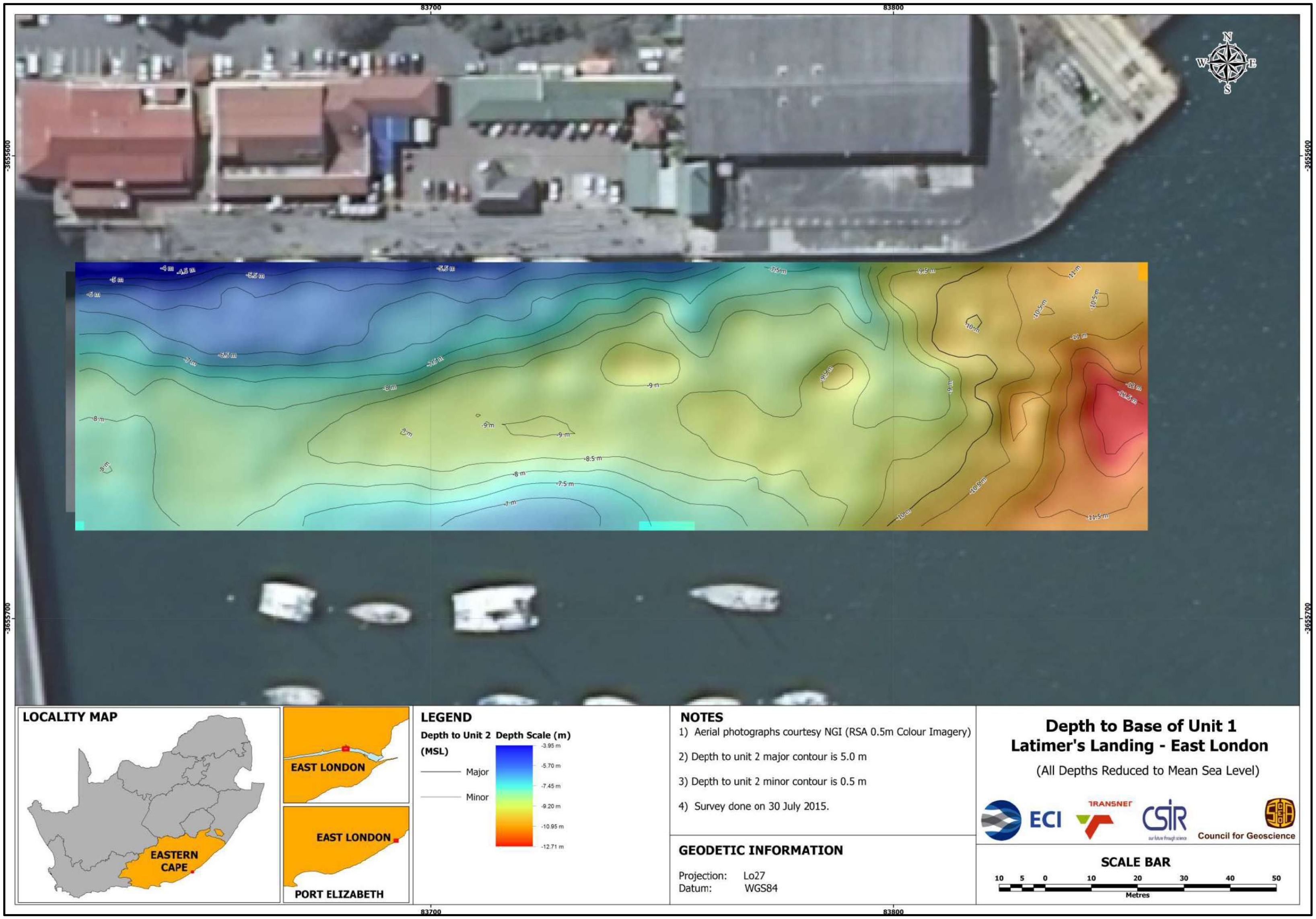

Figure 13. Depth to base of Unit 1 for the area adjacent to Latimer's Landing.

Figure 14. Unit 1 isopach for the area adjacent to Latimer's Landing.

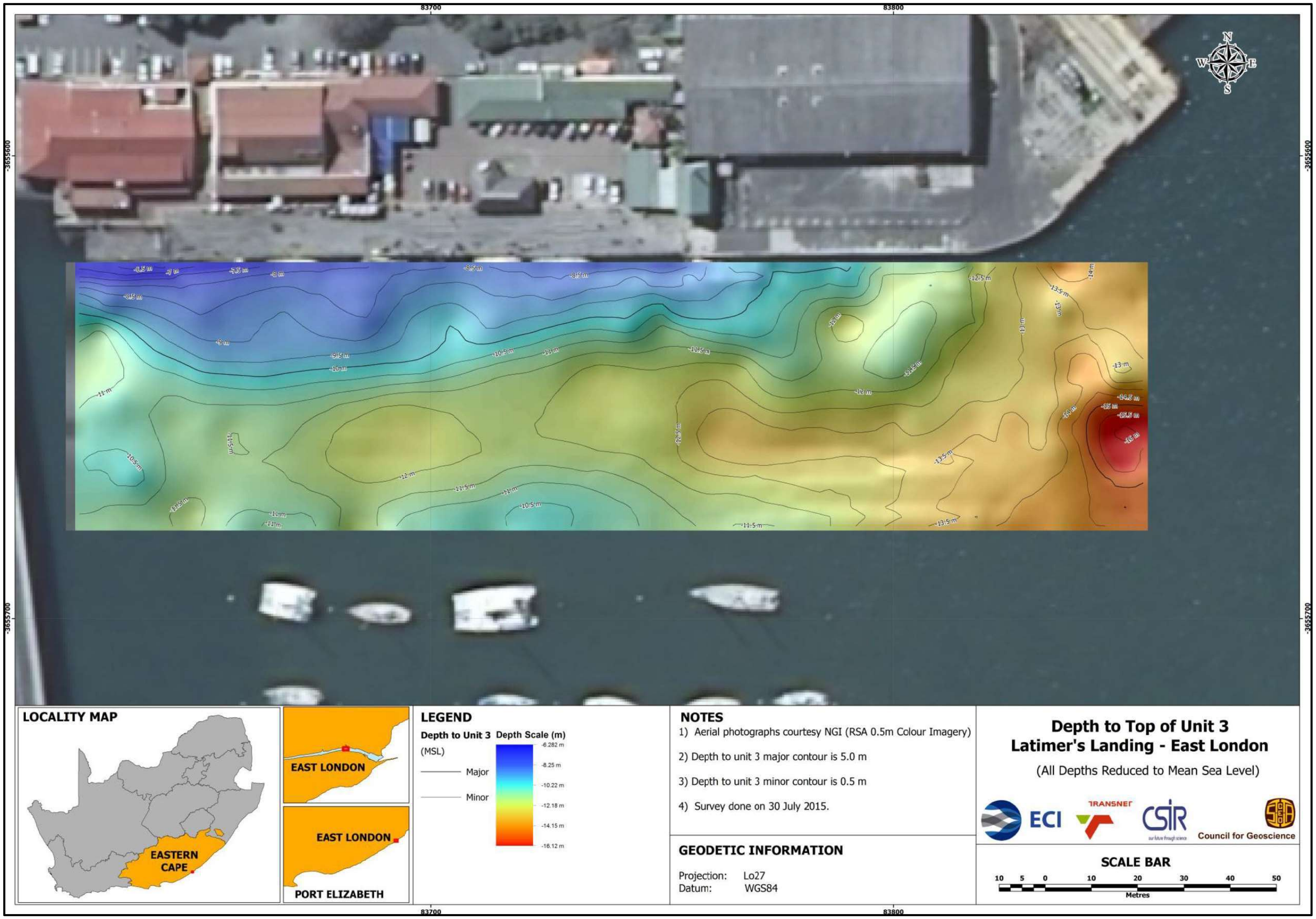

Figure 15. Depth to the top of Unit 3 for the area adjacent to Latimer's Landing.

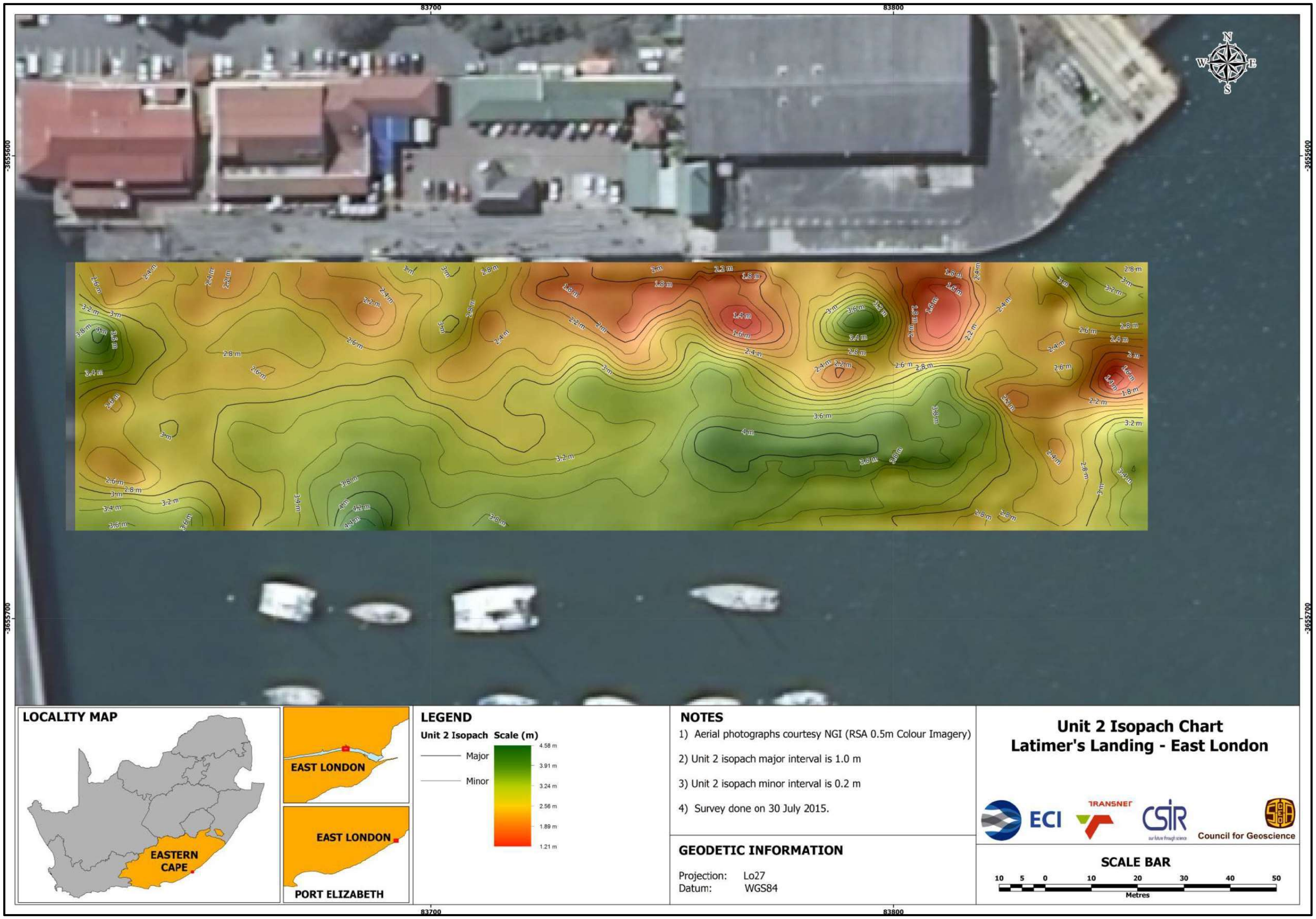

Figure 16. Unit 2 Isopach for the area adjacent to Latimer's Landing.

8 DISCUSSION & CONCLUSIONS

From the bathymetric data it can be concluded that the seafloor in the survey block has no notable rock outcrops or any high relief structures that could pose a hazard to safe vessel navigation. There is evidence of the central channel of the Buffalo River which meanders approximately west – east, deepening towards the harbour mouth in the east. Dredging activities can be seen adjacent to the turning basin associated with the dry dock.

The scope of work for the seismic data was to delineate subtle changes in the constituent lithologies adjacent to the quay wall and the frequency of the system stipulated that a pinger be used. Anticipating not fulfilling the scope using a pinger alone the CGS took along another lower frequency seismic systems to achieve the desired goal. It was discovered while doing a sound velocity calibration that the sediment mantling the local basement was very fine grained mud. This type of sediment obscures a seismic record as demonstrated by MacHutchon (2013) in that the gases produced by the organisms living in the mud tend to cause a washout signal which obscures small scale detail from any and all reflectors beneath this. The result of this signal blanking is that using the pinger system alone the CGS has only been able to delineate the base of unconsolidated sediment. The boomer data was used to delineate the two basal layers found below the unconsolidated sediment wedge.

From the sub-bottom profiling datasets three units have been identified. Selected profiles have been constructed through the survey area to help visualise the morphology and thickness of the various units (Figure 17). The authors would tentatively correlate Unit 3 to the basal lithologies prevalent in the study area. The composition of this basement is however impossible to quantify without *in situ* samples being collected yet based on the constituent lithologies around the survey site the CGS would propose that this basement is composed of either mudstone, dolerite or hornfels. There is a large dolerite sill to the south of the study area (Figure 4) and extrapolating from the change in orientation of the Buffalo River at the study area one could infer that the sill is either present in the basal units of the survey block or extremely close to them (pers. comm. Cawthra, 2015). If this is indeed the case, a margin of metamorphic alteration bordering the sill in the form of hornfels would be expected. However, if this margin is not present and the sill does not crop out where anticipated, then the basal mudstone units of the Adelaide Subgroup will likely form the basal lithology in the mapped area.

Unit 2 has been tentatively correlated to the zone of weathering associated with the local basement. The same argument employed above is relevant here in that the composition of this unit is impossible to identify without direct sampling.

Unit 1 however is rather confidently correlated by the authors to represent the unconsolidated sediment that would accumulate in any modern riverine system.

The morphology of the basement has been formed and altered primarily by the erosive power of the Buffalo River with the palaeo-channel and thalweg of the river evident from the seismic surfaces. This basement morphology appears to be the controlling factor in the morphology of all of the layers above it with all exhibiting similar morphological trends. There are instances of isolated basement depressions which the authors would attribute to potholes which have developed in the basement.

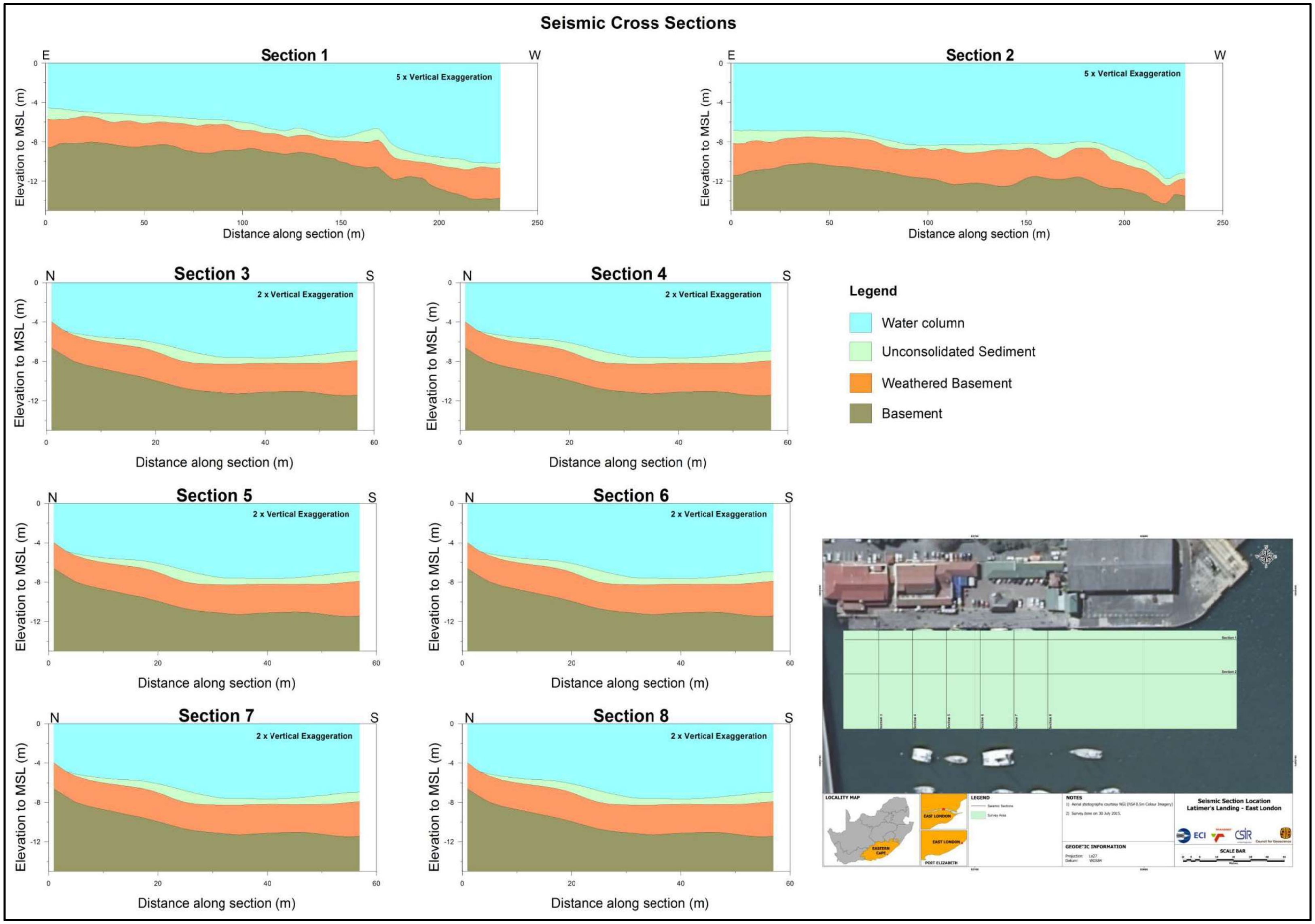

Figure 17. Cross sectional profiles of the sub-bottom geology.

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Annexure H: Hydrographic And Geophysical Survey at Latimer's Landing – Final Report

Project:

East London Quay Wall

East London Quay Wall: Final Geotechnical Report

Reference: 109552-G1-01

Prepared for: Mr Lwanda Sidlayi

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Longitude	27°53'48.82"E	**Latitude**	33° 1'22.31"S

Key Words			
Hornfels	Sandy clay	Quay wall	Geotechnical investigation

Location	East London: Latimer's Landing	**Date**	January 2014

Approval

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Revision	00		

East London Quay Wall: Final Geotechnical Report

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Aurecon South Africa (Pty) Ltd

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Executive Summary

A geotechnical investigation was conducted to assess the geotechnical conditions for the proposed quay wall rehabilitation at the Port of East London. This is a factual geotechnical report including the following information; engineering geological desk studies, field investigations, field test results and laboratory test results. The purpose of the investigation was to identify and assess the geotechnical considerations that may influence the proposed development.

The geological map of the area indicates that the site is underlain by grey and red Mudstone, and Sandstone of the Beaufort Group of the Karoo Sequence. Post-Karoo dolerite dykes and sills intrusive into the Beaufort Group rocks are common to the general area.

The investigation comprised 12 boreholes drilled using P-size Triple Tube drilling, field tests comprising of DPSH testing, SPT testing and Vane shear testing. To confirm the visual assessments of the engineering properties of the material, a number of representative soil, water and rock samples were taken, to be submitted for laboratory testing for UCS, shear strength parameters and corrosivity .

Geological conditions at the site comprised of:

- Gravel fill to a depth of approximately 6m below quay platform level
- Sandy Clay alluvium below the fill and harbour water
- Hornfels bedrock (metamorphosed mudrock and sandstone) found at depths varying between 6m to 10m below the quay platform and 15m under the harbour water adjacent to the quay platform.

The geotechnical preliminary recommendations regarding the proposed development are:

- The new piled wall combination of tube and sheet piles placed approximately 1m in front of the existing sheet piled wall and back filled with clean sand.
- Excavation of approximately 3m from the top of quay wall and replace with suitable gravel material compacted in layers to act as a soil mattress.
- The new wall will require restraint at the top of the wall to minimise deflections. Studies show that a fixed length tendon anchors at each tube pile angled about 30 degrees to the horizontal and anchored into the rock profile will be required.

1 INTRODUCTION

Aurecon South Africa (Pty) Ltd was appointed by Transnet National Ports Authority (TNPA) to carry out further investigative work in the area of the existing old tug wharf in the Port of East London. The investigative work included marine geological investigation (offshore and onshore) which would guide the rehabilitation design of the proposed new quay structure.

This report details the findings of the geotechnical investigations carried out on the proposed site of the Port.

The primary objectives of the geotechnical investigation were to:

- Provide an overview of the geology of the site;
- Present a description of soil material on the wharf platform as well as the soil material below the water and bedrock profiles;
- Present a description of the rock mass below the soil material mentioned above
- Assess the engineering properties of the soil and the rock;
- Identify geotechnical considerations that may influence the proposed development; and
- Provide geotechnical-related recommendations for design and construction.

The geotechnical investigation was executed from the 12th of June 2013 to the 16th of July 2013 by a geotechnical team comprising Geomech Africa (Sub-contracted driller), Mr Andy Schulze-Hulbe (senior engineering geologist) and Mr Katlego Magoro (junior geotechnical engineer).

2 AVAILABLE INFORMATION

At the time of the investigation the following information was available:

- The published 1:250 000 scale geological map of Grahamstown (Council for Geoscience, 1995)
- Site layout plans from TNPA
- Coordinates of the site
- Geotechnical drilling report by Terreco Geotechnical cc (November 2012)

3 REGIONAL GEOLOGY AND CLIMATE

The published 1:250 000 Geological Map of Grahamstown shows that the proposed site area is underlain by grey and red Mudstone, Sandstone of the Beaufort Group, Karoo Sequence. Post-Karoo dolerite dykes and sills intrusive into the mudrock and the sandstone layers are common to the general area. The mudstones alternate with sandstone units and vary in thickness from less than a metre to tens of metres The sandstone units consist of grey, fine grained quartz feldspathic sandstone. The sandstones commonly display flat-bedding, cross bedding and micro cross-lamination while the mudstone is usually poorly stratified of massive. On site the contact metamorphism resulting from dolerite intrusions has affected both the sandstone as well as the mudstone imparting a fine grained glassy nature to the rock.

The area is classified as having a climatic N-value (Weinert, 1980) of 1.6, which indicates that chemical weathering (decomposition) is predominant. As a general rule this further implies that residual soils with deep profiles might be expected.

4 SITE LOCATION AND DESCRIPTION

The site is located in the Latimer's landing area at the Port of East London, as indicated on the locality plan (Drawing No 109552-G1-01, Appendix E). East London is located along the southern east coast of South Africa, about 300km north east of Port Elizabeth.

The site is located in the west bank area adjacent the Latimer's landing dock and the dry dock area along and behind the existing sheet pile wharf.

The site is completely paved with no visible vegetation in and around the site. **Figure 1** below illustrates the aerial view of the site.

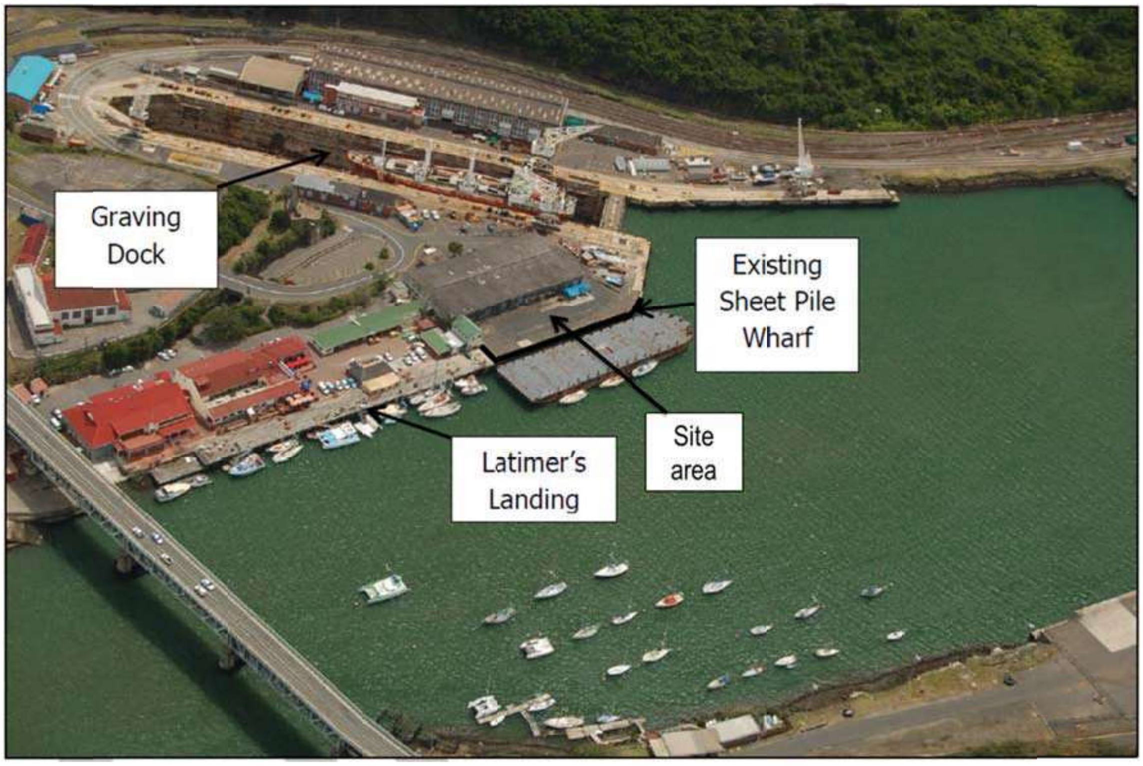

Figure 1: Aerial view of the site

5 INVESTIGATION METHODOLOGY

The geotechnical investigation methodology comprised a desktop study followed by intrusive field investigations. The desktop study included acquiring geological information of the proposed site, including the 1:250 000 geological map of Grahamstown.

The field work included rotary core drilling, core logging, field testing and sampling.

The field work was carried out by a geotechnical investigation team consisting of 2 site supervisors from Aurecon and drillers and DPSH operators from Geomech Africa. Triple Tube rotary core drilling was done using 2 drill rigs (one for onshore drilling and another of offshore drilling), provided by the appointed subcontractor. The contractor also provided a Dynamic Probe Super Heavy (DPSH) rig for all the DPSH testing. The drilling contract supervision as well as the core logging was done by Aurecon's Katlego Magoro and Andy Schulze-Hulbe.

A site layout plan and photographs were obtained from the Terreco geotechnical investigation report, which was dated November 2012. These were used to set preliminary positions of the initial 10 proposed boreholes. The final borehole positions were set out by Aurecon's representatives using a hand held GPS. Two additional boreholes were set out , following a request from TNPA. The off-shore boreholes were drilled off a drilling platform about 0.5m over the edge of the quay wall in the harbour basin. A total of 12 No boreholes were drilled and 8 No DPSH tests were conducted. The positions of the boreholes are shown in **Figure 2** below. Please note that the positions of boreholes BH1 to BH4, which were drilled for the Terreco investigation, are not shown on the figure below and these logs and have not been included in this report.

Figure 2: Borehole positions

The boreholes were drilled to a depth where bedrock could be proved for at least 3m and backfilled upon completion of the core logging and sampling. **Table 1** provides a summary of the information obtained from the boreholes. The borehole were logged in accordance with the standard methodology as outlined in the South African National Standard (SANS 633, 2012), as outlined in Appendix A.

Table 1: Borehole summary

Borehole No.	Coordinates (WGS84, Lo 27)		Total depth (m)	Position	Remarks
	X	Y			
BH5	583737.6	6345856	13.00	Onshore	Terminated hole after recovering 7m bedrock
BH6	583747.5	6345861	13.02	Onshore	Terminated hole after recovering 7m bedrock
BH7	583766.1	6345859	13.00	Onshore	Terminated hole after recovering 5m bedrock
BH8	583773.3	6345860	13.25	Onshore	Terminated hole after recovering 3m bedrock
BH9	583787.8	6345861	11.83	Onshore	Terminated hole after recovering 3m bedrock
BH10	583792.4	6345841	20.64	Offshore	Terminated hole after recovering 5m bedrock
BH11	583781	6345839	16.04	Offshore	Shallow refusal on what was presumed to be a piece of metal.
BH11A	583781	6345839	20.40	Offshore	Drilled 60cm from BH11. Terminated hole after recovering 3m bedrock
BH12	583761.7	6345840	20.80	Offshore	Terminated hole after recovering 4m bedrock
BH13	583753.7	6345837	20.05	Offshore	Terminated hole after recovering 5m bedrock
BH14	583731.5	6345837	18.55	Offshore	Terminated hole after recovering 3m bedrock
BH15	583755.4	6345850	13.02	Onshore	Terminated hole after recovering 4m bedrock
BH16	583775.9	6345851	13.00	Onshore	Terminated hole after recovering 3m bedrock

The coordinates in Table 1 were obtained with a hand-held GPS using the South African grid and the WGS 84 datum.

To confirm the visual assessments of the engineering properties of the soil, a limited number of representative soil samples were taken for testing at a laboratory.

The geotechnical data is presented in this report as follows:

- Summary of standard soil and rock profile description terminology - Appendix A
- Borehole logs - Appendix B
- Field test results - Appendix C
- Laboratory test results - Appendix D
- Drawings - Appendix E
- Geological sections - Appendix F

6 STRATIGRAPHY

The geological profile of the site was found to be relatively uniform, with varying depths of the sandy clay material between the onshore boreholes and the offshore boreholes.

The following horizons were encountered in the onshore boreholes;

- Fill
- Alluvium
- Bedrock

The following horizons were encountered in the offshore boreholes;

- Water
- Alluvium
- Bedrock

Table 2 and **Table 3** below summarises the depths of each horizon in boreholes profiled. The respective horizons are also described in detail in the following sub-sections.

Table 2: Summary of horizons encountered in the onshore boreholes

Borehole No.	Fill (m)	Alluvium (m)	Bedrock (m)
BH5	0 – 6.18	-	6.18 – 13.00+
BH6	0 – 6.13	-	6.13 – 13.02+
BH7	0 – 6.00	6.00 – 7.95	7.95 – 13.00+
BH8	0 – 6.00	6.00 – 10.07	10.07 – 13.25+
BH9	0 – 5.17	-	5.17 – 11.83+
BH15	0 – 7.97	7.97 – 9.42	9.42 – 13.02
BH16	0 – 9.00	9.00 – 10.00	10.00 – 13.00

Notes: Termination recorded in all boreholes, at depths indicated with '+'

Table 3: Summary of horizons encountered in the offshore boreholes

Borehole No.	Water (m) below Quay platform level	Alluvium (m) below Quay platform level	Fill (m) below Quay platform level	Bedrock (m) below Quay platform level
BH10	4 – 11.97	11.97 – 15.00	15.00 – 15.64	15.64 – 20.64+
BH11	4 – 13.65	13.65 – 14.81	14.81 – 16.04	-
BH11A	4 – 13.65	13.65 – 16.50	16.50 – 17.59	17.59 – 20.40+
BH12	4 – 12.30	12.30 – 14.00	14.00 – 16.40	16.40 – 20.80+
BH13	4 – 11.00	11.00 – 14.05	14.05 – 15.27	15.27 – 20.05+
BH14	4 – 10.50	10.50 – 14.40	14.40 – 15.50	15.50 – 18.55+

Notes: Termination recorded in all boreholes, at depths indicated with '+'

6.1 Fill

The fill material found in the quay platform area is medium dense to very dense, intact, sandy hornfels gravel. The upper 600mm below the quay platform comprises compacted gravelly fill and forms part of the layerworks for the pavement of the platform (Figure 3). In general the gravel below the pavement layers is tightly packed, rounded to sub-rounded, mediumdense, with occasional boulders and cobbles (up to 20cm in diameter). It is typically between 5m and 6m thick. Typically this horizon is compacted but a less competent zone occurs between 3m and 6m below the surface level. This zone coincides with the zone affected by tidal fluctuations.

The fill in the offshore boreholes is of a similar composition to the fill in the quay platform (hornfels gravel) but it is of a much smaller in thickness, typically between 0.6m and 2.4m. This fill layer was placed possibly to reduce the scouring of the alluvium layer caused by ships propellers in the harbour basin adjacent to the quay wall. It was also noted that alluvial deposits overlie the fill adjacent to the quay wall. These sediments were deposited by the river after construction of the quay wall.

6.2 Alluvium

An alluvium layer was found above the fill layer in the offshore boreholes and below the fill layer in boreholes drilled in the quay platform. The material mostly consists of firm to stiff, sandy clay and occasional, angular gravel can be found within the alluvium material horizon.

The overall thickness of these alluvium horizons is between 1m and 4m.

6.3 Bedrock

The bedrock encountered in all the boreholes was found to be hornfels. The bedrock was found to be moderately weathered to highly weathered, closely to medium jointed, hard rock hornfels.

Figure 3 below shows a picture of a trial hole excavated on the BH5 location. The compacted fill material of the quay platform is illustrated.

Figure 3: BH5 Trial hole

7 GROUNDWATER CONDITIONS

Ground water condition within the quay platform is expected to be similar to the sea water levels due to the porous sheet pile quay wall. Tidal fluctuations, similar to those in the harbor, are expected to occur in the boreholes. The fill in the zone affected by tidal water table fluctuations has a lower consistency than the material above or below this zone.

8 FIELD TESTING

Three field tests were performed on site to obtain the consistency and shear characteristics of the fill and in situ material found on site. The field tests comprise:

- Standard Penetration Test (SPT)
- Dynamic Probe Super Heavy Test (DPSH); and
- Vane Shear Test

8.1 Standard Penetration Test

The Standard Penetration Tests was carried out in accordance with Section 23.1 of the Standard Specifications for Subsurface Investigations (SANRAL, 2010). SPTs were done in the onshore boreholes and most of the offshore boreholes at 1.5m interval depths until refusal.

The results of the SPT tests are shown in Table 4 below.

Table 4: SPT results

Depth (m)	BH5	BH6	BH7	BH8	BH9	BH11	BH12	BH13	BH14	BH15	BH16
1.5 – 1.95	N=4	N=10	N=10	N=12		-	-	-	-	N=10	N=18
3 – 3.45	N=30	N=7	N=20	N=11	N=9	-	-	-	-	N=15	N=11
4.5 – 4.95	N=10	N=14	N=9	N=42	N=49	-	-	-	-	REF	REF
6 – 6.45	REF	REF	N=8	N=7	-	-	-	-	-	N=10	N=8
7.5 – 7.95	-	-	N=13	REF	-	-	-	-	-	N=4	-
9 – 9.45	-	-	-	-	-	-	-	-	-	N=4	N=6
13.41 – 13.86	-	-	-	-	-	N=5	-	-	-	-	-
13.5 – 13.95	-	-	-	-	-	-	N=26	-	N=41	-	-
14.05 – 14.5	-	-	-	-	-	-	-	N=40	-	-	-
14.96 – 15.41	-	-	-	-	-	REF	-	-	REF	-	-

Note: REF = Refusal

From the SPT results above it is evident that the quay platform fill is fairly inconsistent ranging from loose to dense. This can be attributed to the number cobbles and boulders that were found in the boreholes. The consistency of the sandy clay alluvium material below the fill layer is firm to stiff.

The consistency of the sandy clay alluvium below the water in the harbour is more pronounced, ranging from firm to very stiff.

The SPT results are indicated in the borehole logs in Appendix B

8.2 Dynamic Probe Super Heavy Test

The DPSH Tests were carried out in accordance with Section 24.1 of the Standard Specifications for Subsurface Investigations (SANRAL, 2010). Eight DPSH tests were done at the edge of the quay wall. The positions of the DPSH tests are shown on Drawing No 109552-G1-01, Appendix E. The results of the DPSH test are shown in **Table 5** below. DPSH 1 was retested by moving the position slightly to DPSH1A as it was considered that the cone was pushing against cobbles with depth in DPSH1. DPSH 7 refused at shallow depth and was not considered for retesting.

Table 5: DPSH test results

Depth (m)	DPSH1	DPSH1A	DPSH2	DPSH3	DPSH4	DPSH5	DPSH6	DPSH7
0	0	0	0	0	0	0	0	0
0.3	37	47	55	37	52	57	72	90
0.6	17	27	48	18	29	37	25	100
0.9	25	29	17	11	30	39	39	
1.2	50	29	16	7	19	23	27	
1.5	23	35	19	9	21	21	24	
1.8	23	32	14	10	32	62	16	
2.1	22	15	24	23	35	14	28	
2.4	23	15	20	7	27	23	23	

Depth (m)	DPSH1	DPSH1A	DPSH2	DPSH3	DPSH4	DPSH5	DPSH6	DPSH7
2.7	37	15	18	9	33	33	44	
3.0	36	14	10	6	13	28	32	
3.3	20	17	10	6	9	31	24	
3.6	16	23	18	12	21	32	72	
3.9	100	16	24	20	14	9	64	
4.2		9	27	31	23	53	52	
4.5		10	20	19	17	47	11	
4.8		20	11	27	28	40	20	
5.1		10	24	15	35	37	35	
5.4		100	28	23	28	43	45	
5.7			25	31	44	57	65	
6.0			52	41	55	49	72	
6.3			27	34	48	65	100	
6.6			14	26	70	60		
6.9			15	47	62	100		
7.2			24	100	100			
7.5			100					

Eight DPSH tests were carried out behind the quay wall. The DPSH gives a reading of blow counts for every 300mm penetrated. In this regard they are similar to the SPT readings without the option of a sample.

The DPSH test results confirm the SPT results done in the boreholes. The fill has consistencies ranging from loose to very dense. The DPSH penetrometer that refused on shallow depths probably refused on cobbles or boulders located within the fill material.

The DPSH test results are included in Appendix C.

8.3 Vane Shear Test

A vane shear test was done at position BH11 in accordance with SANRAL standard specifications for Subsurface Investigations, 2010. The vane shear test results were inconclusive because as it was found that the thickness of the sandy clay alluvium was not enough to perform the test in accordance with the SANRAL standard specification for Subsurface Investigations, 2010.

The inconclusive vane shear test result is included in Appendix C

9 LABORATORY TEST RESULTS

9.1 Unconfined Compressive Strength Tests

Ten core samples taken at different boreholes and varying depths were taken to the laboratory for unconfined compressive strength (UCS) testing to confirm the rock strength properties. The results of these tests are summarised as follows (see detail test results in Appendix D):

Table 6: UCS test results

BH No.	Sample depth (m)	Core diameter (mm)	UCS (MPa)
BH5	11.05 – 11.34	60	66.5
BH6	11.49 – 12.17	60	36.1
BH7	11.93 – 12.17	60	52
BH8	12.62 – 12.87	60	68.6
BH9	11.35 – 11.68	60	35.7
BH10	18.79 – 18.94	60	33.2
BH11A	17.93 – 18.34	60	62.9
BH12	18.15 – 18.35	60	68.6
BH13	18 – 18.24	60	61.9
BH14	16.77 – 16.93	60	54.5

Table 6 indicates that all the bedrock on the site is of hard rock quality (25 – 70 MPa UCS strength)

9.2 Water Corrosivity Tests

Two water samples were taken from the water in the harbour adjacent to the quay wall for corrosivity testing in the laboratory. The results of these tests are summarised as follows (see detail test results in Appendix C):

Table 7: Water corrosivity test results

Parameter	Sample 1	Sample 2
pH	7.1	7.15
Conductivity (mS/m)	5080	5110
Total dissolved solids (mg/l)	32512	32704
Alkalinity (mg/l)	126	128
Calcium, Ca (mg/l)	300	319
Calcium, $CaCO_3$ (mg/l)	749.1	796.5
Saturation pH	7.63	7.35
Saturation Index	-0.53	0.2
Ryznar Index	8.16	7.55

The test results indicate that the both these water samples are aggressive towards cement and very corrosive towards metal.

9.3 Soil Corrosivity Tests

Three Shelby tube samples taken from the sandy clay material found within the fill in the quay platform and the sandy clay found below the water in the harbour were submitted for soil corrosivity testing. The results of these tests are summarised in **Table 8**. For detailed results see Appendix C.

Table 8: Soil corrosivity test results

Parameter	BH14 (13.5m – 13.95m)	BH15 (1.95m – 2.13m)	BH11 (13.0m – 13.1m)
pH	8.57	9.22	6.52
Conductivity (mS/m)	1512	524	1536
Total dissolved solids (mg/l)	9677	3354	9830

Parameter	BH14 (13.5m – 13.95m)	BH15 (1.95m – 2.13m)	BH11 (13.0m – 13.1m)
Alkalinity (mg/l)	175	51	27
Calcium, Ca (mg/l)	122	59.5	487
Calcium, $CaCO_3$ (mg/l)	304.6	148.5	1216.0
Saturation pH	7.84	8.08	7.89
Saturation Index	0.73	1.14	-1.37
Ryznar Index	7.11	6.94	9.26

The test results indicate that the sandy clay material found in BH 14 is scale forming towards the cement and slightly corrosive towards metal while the sandy clay material found in BH11 is aggressive towards cement and highly corrosive towards metal. BH14 and BH11 are boreholes drilled offshore. The sandy clay material found within the fill in BH15 was found to be scale forming towards cement and neutral with metal.

10 GEOTECHNICAL RECOMMENDATIONS

10.1 Foundation considerations

10.1.1 Existing sheet pile wall- Boreholes 10-14

The existing sheet pile wall has deteriorated considerably with corrosion ostensiblybetween the high and low water levels. The sheet pile extends to bedrock and it is understood that it has been socketed into the rock. The strength of the hornfels rock with UCS values averaging 54MPa (range 33-68MPA) suggests that the depth of socket may not be deep and that the sheet pile has been strengthened to penetrate the hard rock.

Tie back anchors are placed at approximately 1m intervals along the sheet pile wall and extend to approximately 15m horizontally and secured to deadman weights. The anchor heads are positioned 4m below the quay wall and therefore are within the tidal range.

The depth of hard rock along the quay wall varies from15.3m below the quay wall (approximately -11.3m CD) in borehole 13 to 16.5m (approximately -12.5m CD) in borehole 10.

Above the bedrock there are indications of scour protection in the way of a hard gravelly hornfels layer of approximately 1.0m in thickness.

A stiff to very stiff sandy clay of alluvium varying from 300mm to 1.0m in thickness overlies the gravels. There appears to be a discontinuity between the alluvium behind the wall and of that in front. It is considered that the alluvium in front of the wall is from wash down from upstream as it is deposited on what would be the remnants of the scour protection, whereas the alluvium behind the wall is below the gravel fill.

10.1.2 Quay platform - Boreholes 5-9 and 15 -16

Boreholes 5 to 9 were positioned 15m back from the quay wall in order to miss the anchor rods tied to the “deadmen”. However two further holes were drilled within the 15m range (15 and 16) at a later stage to enable better cross section profiles of the horizons and rock levels.

The general profile shows that the fill behind the wall is predominately made up of hard hornfels gravels in a sandy clay matrix overlying the soft sandy clay alluvium overlying hard rock hornfels bedrock.

Two cross sections and a fence map are shown in Appendix E. The sections show the gently sloping rock line varying from 6m to 9m depth before dropping sharply down from approximately 7m behind the quay to about 15m below the quay wall.

Standard penetration tests (SPT) performed in the boreholes show that the fill is of loose to medium dense consistency in general and can be completely random with depth i.e. density does not increase with depth. This was confirmed by the DPSH tests taken immediately behind the wall adjacent to the quay wall boreholes.

10.1.3 Dynamic Probe Super Heavy (DPSH) Results

Eight DPSH tests were carried out behind the quay wall and adjacent boreholes 10 to 14. The DPSH gives a continuous reading of blow counts for every 300mm penetrated. In this regard they are similar to the SPT readings without the option of a sample. DPSH 1 was retested by moving the position slightly to DPSH1A as it was considered that the cone was pushing against cobbles with depth in DPSH1. DPSH 7 refused at shallow depth and was not considered for retesting.

In general the top 600mm shows a medium dense to very dense horizon consistent with compaction of the fill over the years from being trafficked.

The DPSH depths attained varied from 5.4m (DPSH1A) to 7.5m (DPSH2) where refusal is taken as 100+ blows per 300mm. DPSH 3 in particular show loose material from about 600mm to 3.9m depth. This may be consistent with the loss of fines through the corroded sheet pile.

The range of DPSH numbers was averaged over the tidal range of between 3 to 5m depth and gave values of 16, 17, 17, 18, 39 and 39 for DPSH 1A to DPSH6 respectively. The tends to suggest that fines may have been washed out in the more exposed portion of the sheet pile wall further to the east and downstream.

10.1.4 In Situ Treatment

10.1.4.1 Soil Raft

If consideration is to be given to applying heavier loadings on the quay then the fill will require treatment to provide a consistent subbase to found on. This would be in tandem with the repair /rehabilitation of the sheet pile wall. The top 3 m is of variable material and in order to provide a uniform subgrade it is recommended that the in situ material be excavated to 3m depth – just above the water line and above the deadmen anchors then import gravel material to create a compacted soil raft

This material should be :

- G5 quality material
- Compacted in 150mm layers up to underside of the proposed layerworks

- The compaction density should be at 95% of Modified AASHTO density at omc +2%,-1%
- Where the excavation impacts any structure, then the slope of the excavation should not be less than 1:1

10.1.4.2 Compaction grouting

Compaction grouting behind the original sheet piled wall Is recommended in order to fill cavities behind the sheet pile wall and for a distance of 15m back from the quay wall.

The compaction grouting will be set out in a primary grid spacing of 5 m, secondary spacing of 2.5m and tertiary spacing if and where required along the entire length of the quay wall under rehabilitation, Tertiary grouting will be carried out based on the grout take of the primary and secondary phases. In order to prevent leakage through the holes in the sheet pile it will be necessary to tailor and cut sheet piles to cover the holes in the same pattern as the sheet pile ridgeing so that a tight fit over the hole is achieved.

The advantages of compaction grouting are:

1. Can be tailored to meet site conditions, i.e. in this case the grout acceptance could be regulated to allow more grout to be pumped into softer areas. Also, any cavities in the vicinity of a grout column would be filled (such as near the concrete drainage pipe), resulting in soil with much improved stiffness.

2. A wide range of soils can be treated

3. It is a vibrationless system, which avoids potential damage to nearby structures such as drainage structures

4. Noise levels are low and limited to engine noise only

5. It can be tailored to be relatively non-destructive to the overlying pavement layers

6 The fill is not only improved vertically, but also laterally The disadvantage is that compaction grouting is relatively expensive. The type of existing fill indicates that high volumes of grout may be required. It also generates large amounts of sand and cement laden liquid spoils which would have to be contained.

10.2 Rehabilitation of sheet piled wall

The existing sheet piled wall is at the end of its life and it will be necessary to replace the wall with a new sheet pile system. As the removal of the existing wall would prove difficult without a collapse of the quay, the method considered by the marine engineers is to build a new sheet piled wall in front of the existing wall.

The analyses show that a combination of sheet pile between tube piles with a span of approximately 2.5m centre to centre of tube pile would be used with a capping beam.

This system will require anchoring at each tube pile using a tendon and fixed length anchor drilled into the bedrock at a prescribed angle to the horizontal through the new sheet pile. In this way the existing dead men anchors will not be disturbed. The area between the two walls will be backfilled with self-compacting clean gravels of approximately 25 to 32mmin size.

The analyses of the new wall showed that in order to minimize top of pile deflections to less than 20mm, a 5 strand anchor with a 5m fixed length angled at 30 degrees to the horizontal will be required. The fixed length will be grouted into the bedrock the depth of which may vary along the length of the wall. Appendix G discusses the analyses of the anchoring system to be used.

11 REFERENCES

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2. Weinert, H.H, 1980. The natural road construction materials of Southern Africa. Academica. Pretoria, Cape Town.
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4. The South African National Standard, 1988 SANS 1200 D. Standardized Specification for Civil Engineering Construction. D: Earthworks. SABS Standards Division.
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6. Byrne, G,Berry, A.D, 2008. A Guide to Practical Geotechnical Engineering in Southern Africa. Franki. South Africa.
7. South African National Roads Authority Limited, 2010. Standard Specifications for Subsurface Investigations.
8. Lateral Support in Excavations Code of Practice 1989 , South Africa Institution of Civil Engineers Geotechnical Division
9. BS8081:1989 British Standard Code of Practice for Ground anchorages

Appendices

APPENDIX A

Summary of standard soil and rock profile description terminology

STANDARD DESCRIPTIONS USED IN SOIL PROFILING

1. MOISTURE CONDITION

Term	Description
Dry	
Slightly moist	Requires addition of water to reach optimum moisture content for compaction
Moist	Near optimum content
Very Moist	Requires drying to attain optimum content
Wet	Fully saturated and generally below water table

2. COLOUR

The Predominant colours or colour combinations are described including secondary coloration described as banded, streaked, blotched, mottled, speckled or stained.

3. CONSISTENCY

3.1 Non-Cohesive Soils

Term	Description
Very Loose	Crumbles very easily when scraped with geological pick
Loose	Small resistance to penetration by sharp end of geological pick
Medium Dense	Considerable resistance to penetration by sharp end of geological pick
Dense	Very high resistance to penetration to sharp end of geological pick. Requires many blows of hand pick for excavation.
Very Dense	High resistance to repeated blows of geological pick. Requires power tools for excavation

3.2 Cohesive Soils

Term	Description
Very soft	Easily penetrated by thumb. Sharp end of pick can be pushed in 30 - 40mm. Easily moulded by fingers.
Soft	Pick head can easily be pushed into the shaft of handle. Moulded by fingers with some pressure.
Firm	Indented by thumb with effort. Sharp end of pick can be pushed in up to 10mm. Can just be penetrated with an ordinary spade.
Stiff	Penetrated by thumbnail. Slight indentation produced by pushing pick point into soil. Cannot be moulded by fingers. Requires hand pick for excavation.
Very Stiff	Indented by thumbnail. Slight indentation produced by blow of pick point. Requires power tools for excavation.

4. STRUCTURE

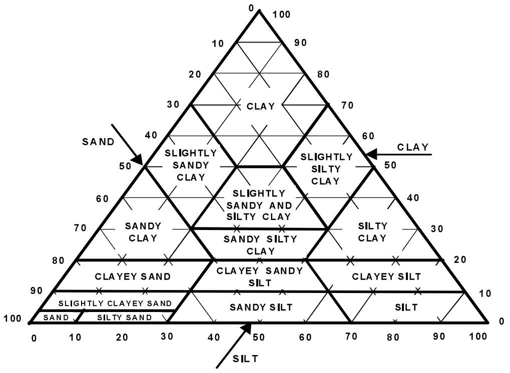
Term	Description
Intact	Absence of fissures or joints
Fissured	Presence of closed joints
Shattered	Presence of closely spaced air filled joints giving cubical fragments
Micro-shattered	Small scale shattering with shattered fragments the size of sand grains
Slickensided	Polished planar surfaces representing shear movement in soil
Bedded Foliated	Many residual soils show structures of parent rock.

5. SOIL TYPE

5.1 Particle Size

Term	Size (mm)
Boulder	>200
Pebbles	60 – 200
Gravel	60 – 2
Sand	2 – 0,06
Silt	0,06 – 0,002
Clay	<0,002

5.2 Soil Classification



6. ORIGIN

6.1 Transported Soils

Term	Agency of Transportation
Colluvium	Gravity deposits
Talus	Scree or coarse colluvium
Hillwash	Fine colluvium
Alluvial	River deposits
Aeolian	Wind deposits
Littoral	Beach deposits
Estuarine	Tidal – river deposits
Lacustine	Lake deposits

6.2 Residual soils

These are products of in situ weathering of rocks and are described as e.g. Residual Shale

6.3 Pedocretes

Formed in transported and residual soils etc.
calcrete, silcrete, manganocrete and ferricrete.

SUMMARY OF DESCRIPTIONS USED IN ROCK CORE LOGGING

1. WEATHERING

Term	Symbol	Diagnostic Features
Residual Soil	W5	Rock is discoloured and completely changed to a soil in which original rock fabric is completely destroyed. There is a large change in volume.
Completely Weathered	W5	Rock is discoloured and changed to a soil but original fabric is mainly preserved. There may be occasional small corestones.
Highly Weathered	W4	Rock is discoloured, discontinuities may be open and have discoloured surfaces, and the original fabric of the rock near the discontinuities may be altered; alternation penetrates deeply inwards, but corestones are still present.
Moderately Weathered	W3	Rock is discoloured, discontinuities may be open and will have discoloured surfaces with alteration starting to penetrate inwards, intact rock is noticeably weaker than the fresh rock.
Slightly Weathered	W2	Rock may be slightly discoloured, particularly adjacent to discontinuities, which may be open and will have slightly discoloured surfaces, the intact rock is not noticeably weaker than the fresh rock.
Unweathered	W1	Parent rock showing no discolouration, loss of strength or any other weathering effects.

2. HARDNESS

Classification	Field Test	Compressive Strength Range MPa
Extremely Soft Rock	Easily peeled with a knife	<1
Very Soft Rock	Can be peeled with a knife. Material crumbles under firm blows with the sharp end of a geological pick.	1 to 3
Soft Rock	Can be scraped with a knife, indentation of 2 to 4 mm with firm blows of the pick point.	3 to 10
Medium Hard Rock	Cannot be scraped or peeled with a knife. Hand held specimen breaks with firm blows of the pick.	10 to 25
Hard Rock	Point load tests must be carried out in order to distinguish between these classifications	25 - 70
Very Hard Rock	These results may be verified by uniaxial compressive strength tests on selected samples.	70 - 200
Extremely Hard Rock		>200

3. COLOUR

The predominant colours or colour combination are described including secondary colouration described as banded, streaked, blotched, mottled, speckled or stained.

4. FABRIC

4.1 Grain Size

Term	Size (mm)
Very Coarse	>2,0
Coarse	0,6 – 2,0
Medium	0,2 – 0,6
Fine	0,06 – 0,2
Very Fine	< 0,06

4.2 Discontinuity Spacing

Description for: Bedding, foliation, laminations	Spacing (mm)	Descriptions for joints, faults, etc.
Very Thickly Bedded	> 1000	Very Widely
Thickly Bedded	300 – 1000	Widely
Medium Bedded	100 – 300	Medium
Thinly Bedded	10 – 30	Closely
Laminated	3 – 10	Very closely
Thinly Laminated	<3	

5. ROCK NAME

Classified in terms of origin:

IGNEOUS	Granite, Diorite, Gabbro, Syenite, Diabase, Dolerite, Trachyte, Andesite, Basalt.
METAMORPHIC	Slate, Felsite, Gneiss, Cheroot, Sandstone
SEDIMENTARY	Shale, Mudstone, Siltstone, Sandstone, Dolomite, Conglomerate, Tillite, Felsite, Limestone.

6. STRATIGRAPHIC HORIZON

Identification of rock type in terms of stratigraphic horizons.

APPENDIX B
Borehole profiles

HOLE No: **BH-11A**
Sheet 1 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-11A**
Sheet 1 of 2

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	DEPTH Scale 1:75		Description
														0.00		
														4.00		Water.
		N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A				
		47	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		13.65		No recovery. VERY SOFT material (presumed to have washed away).
														16.50		

Scale 1:75

HOLE No: **BH-11A**	Sheet 2 of 2
JOB NUMBER: 109552	

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	DEPTH Scale 1:75	
17		31 63	N/A N/A	N/A N/A			N/A	N/A	N/A	N/A	N/A	N/A		17 17.59	Moderately weathered, greenish grey, HARDROCK, hornfel gravel. Fill, assumed to be in sandy clay matrix (washed away).
18		102	102	69				3	10 20 80	CJ WJ WJ	RJ RJ RJ	SC SC SC	▨	18	Moderately weathered , medium jointed, greenish grey, thinly bedded, HARD ROCK, very fine grained. Hornfels.
19		91	91	73									▨	19 19.23	
20		98	98	22				3	10 20 30	CJ MJ MJ	RJ RJ RJ	SC SC SC	▨	20 20.40	Moderately weathered and highly weathered along joints, brownish grey and stained brown in joints, thinly bedded, HARDROCK, very fine grained. Hornfels.

END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 27/06/2013-28/06/13
DATE : 09/07/13

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583781
Y-COORD : 6345839

HOLE No: **BH-11A**

HOLE No: **BH-05**
Sheet 1 of 1

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

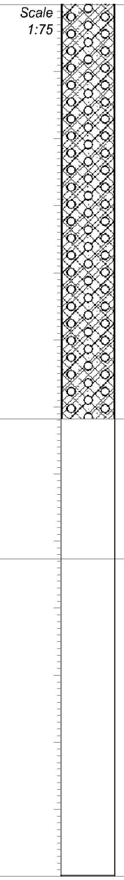
East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-05**
Sheet 1 of 1

JOB NUMBER: 109552

Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.
	0	0	0		
	0	0	0		
	100	0	0	N=4	
	38	0	0		
	100	0	0	N=30	
	67	0	0		
	100	0	0	N=10	
	76	0	0		
	92	73	0	N=REF	>20
	100	100	30		>20
	91	91	0		>20
	100	100	0		9
	100	100	0		
	100	100	45		10
	100	100	72		12
	100	100	89		8

Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling
N/A	N/A	N/A	N/A	N/A	N/A
	4	10 20 60 80	CJ MJ WJ WJ	RJ RJ RJ RJ	SAND SAND SAND SAND
	4	10 20 60 80	MJ WJ MJ MJ	I I I I	stain stain stain stain



Depth	Description
0.00	Moderately weathered, black grey, HARD ROCK, Hornfels gravel, Fill, assumed to be in a sandy clay matrix (washed away).
6.18	Moderately weathered, closely jointed, black grey, thinly bedded, HARD ROCK, very fine grained. Hornfels.
8.27	Moderately weathered and highly weathered at joints, medium to widely jointed, light grey and blotched black at places, thinly bedded, HARD ROCK, very fine grained. Hornfels.
13.00	END OF HOLE.

REDUCED LEVEL | Drill method | Material Recovery (%) | Core Recovery (%) | RQD (%) | SPT N-Value | Joint frac. freq. | Rock fabric and grain | Joint no of sets | Joint inclin (deg) | Joint spacing | Joint rough-ness | Joint filling | Weathering | DEPTH Scale 1:75

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

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DATE : 09/07/13

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ELEVATION :
X-COORD : 583737.6
Y-COORD : 6345856

HOLE No: **BH-05**

HOLE No: **BH-06**
Sheet 1 of 1

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

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Quaywall Geotechnical Investigation.

HOLE No: **BH-06**
Sheet 1 of 1

JOB NUMBER: 109552

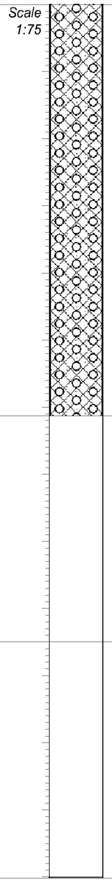
Material Recovery (%)	Core Recovery (%)	RQD (%)
0	0	0
80	0	0
100	0	0
19	0	0
100	0	0
73	0	0
100	0	0
100	0	0
76	0	0
48	38	14
50	50	0
100	100	0
100	100	0
80	80	0
100	100	0
86	86	0
100	100	0
60	100	0
12	100	41
100	100	43
100	100	79

SPT N-Value: N=10, N=7, N=14, N=REF

Joint frac. freq.: 3, >20, >20, >20, >20, >20, 15

Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling
3	10 60 80	CJ WJ WJ	RS RS RS	SAND SAND SAND
3	10 20 80	CJ WJ WJ	RJ RJ RJ	SAND SAND SAND

REDUCED LEVEL | Drill method | Weath-ering | DEPTH Scale 1:75



Depth	Description
0.00	Moderately weathered, black grey and stained brown at places, HARDROCK, hornfels gravel. Fill. Assumed to be in a sandy matrix (washed away)
6.13	Moderately weathered and highly weathered at joints, closely jointed, black grey and stained brown at joints, thinly bedded, HARDROCK, finely grained. Hornfels.
9.50	Moderately weathered, closely to medium jointed, light grey blotched black at places and stained brown at joints, thinly bedded, HARDROCK, very fine grained. hornfels.
13.02	END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
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DATE : 09/07/13

DATE : 08/08/2013 15:52
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ELEVATION :
X-COORD : 583747.5
Y-COORD : 6345861

HOLE No: **BH-06**

HOLE No: **BH-07**
Sheet 1 of 1

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

aurecon

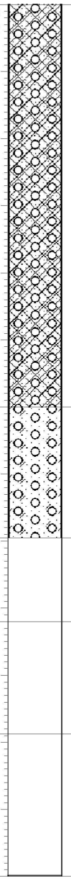
East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-07**
Sheet 1 of 1

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering
1		0	0	0			N/A	N/A	N/A	N/A	N/A	N/A	
		70	0	0									
2		100	0	2222	N=10								
		29	0	0									
3		100	0	4444	N=20								
4		24	0	0									
5		100	0	2000	N=9								
		14	0	0									
6		100	0	1778	N=8		N/A	N/A	N/A	N/A	N/A	N/A	
7		0	0	0									
8		100	0	2889	N=13								
9		76	76	0		>20		2	10 20	CJ MJ	RJ RJ	SC SC	▨
		100	100	0		>20		2	10 60	CJ MJ	RJ RJ	SC SC	▨
10		39	39	0									▨
		100	85	0		>20							▨
11		100	100	60				2	10 30	MJ CJ	RJ RJ	Stain Stain	▨
		100	100	37		10							▨
12		80	80	80									▨
13		100	97	54		12							▨

DEPTH
Scale 1:75



0.00	Moderately weathered, greenish grey blotched brown at places, MEDIUM HARD to HARD ROCK, Hornfels gravel. Fill. Assumed to be in a matrix of clayey sand and sandy clay (washed away, but some recovered in SPT Samples).
6.00	Wet, brown, LOOSE to MEDIUM DENSE, clayey sand with sporadic gravels, Transported.
7.95	Moderately weathered, closely jointed, brown grey, thinly bedded, HARDROCK, very fine grained. Hornfels.
9.20	Moderately weathered, closely jointed, greenish grey and stained brown in joints, thinly bedded, HARDROCK, very fine grained, Hornfels.
10.88	Slightly to moderately weathered, widely jointed, grey speckled green and brown, thinly bedded, HARDROCK, fine grained. Hornfels.
13.00	END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 26/06/13 - 24/06/13
DATE : 09/07/13

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ELEVATION :
X-COORD : 5837661
Y-COORD : 6345859

HOLE No: **BH-07**

HOLE No: BH-08
Sheet 1 of 1

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

aurecon

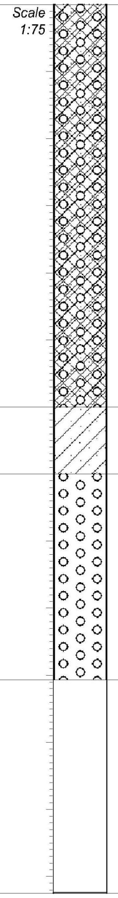
East London
Quaywall Geotechnical Investigation.

HOLE No: BH-08
Sheet 1 of 1

JOB NUMBER: 109552

Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling
0	0	0								
80	0	0								
0	0	0	N=12							
24	0	0			N/A	N/A	N/A	N/A	N/A	N/A
0	0	0	N=11							
38	0	0								
100	0	0	N=42							
29	0	0								
100	0	0	N=7		N/A	N/A	N/A	N/A	N/A	
100	0	0								
60	0	0	N=REF							
33	0	0			N/A	N/A	N/A	N/A	N/A	N/A
70	0	0								
50	0	0								
100	0	0								
92	92	43		11						
36	36	94				4	10 30 45 80	MJ MJ WJ WJ	RJ RJ RJ RJ	SC SC SC SC
100	100	57		>20						

REDUCED LEVEL | Drill method | Weath-ering | DEPTH Scale 1:75



0.00 Moderately weathered, greenish grey speckled brown at places, HARDROCK, hornfels gravel. Fill, assumed to be in a sandy clay matrix (washed away).

6.00 Very Moist, brown black, FIRM, sandy clay. Alluvium.

7.00 Moderately weathered, black grey, HARDROCK, hornfel gravel with cobbles at places. Alluvium (insitu material).

10.07 Moderately weathered, medium jointed, black grey and stained brown in joints, thinly bedded, HARDROCK, very fine grained. Hornfels.

13.25 END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 29/06/2013-03/07/13
DATE : 09/07/13

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583773.3
Y-COORD : 6345860

HOLE No: **BH-08**

HOLE No: BH-09
Sheet 1 of 1

JOB NUMBER: 109552

East London
Quaywall Geotechnical Investigation.

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

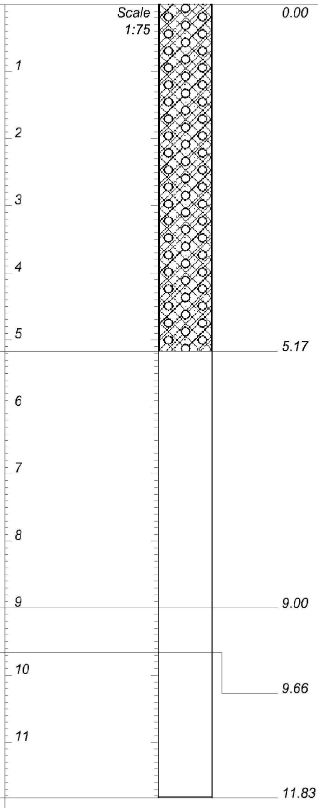
JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.
	0	0	0		
	60	0	0		
	0	0	0		
	33	0	0		
	100	0	0	N=9	
	29	0	0		
	100	0	0	N=49	
	100	80	54		12
	17	17	0		>20
	54	54	37		>20 >20
	100	100	0		
	100	100	41		>20
	83	83	20		14
	95	95	69		6

DEPTH	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Description
0.00	N/A	N/A	N/A	N/A	N/A	N/A	Moderately weathered, greenish grey speckled brown at places, MEDIUM HARDROCK, hornfels gravel. Fill, assumed to be in a sandy clay matrix (washed away).
5.17	N/A	3	10 30 80	CJ MJ WJ	RJ RJ RJ	SC SC SC	Moderately weathered, closely to medium jointed, black grey stained green at places, thinly bedded, HARDROCK, very fine grained. Hornfels.
9.00	N/A	3	10 30 80	CJ WJ CJ	RJ RJ RJ	SC SC SC	Moderately to highly weathered, very closely jointed, black grey stained green at places, thinly bedded, MEDIUM HARDROCK to HARDROCK, very fine grained. Hornfels.
9.66		3	10 20 70	CJ WJ WJ	RJ RJ RJ	SC SC SC	Moderately weathered, medium jointed, black grey and stained brown in joints, thinly bedded, HARDROCK, very fine grained. Hornfels.
11.83							END OF HOLE.



REDUCED LEVEL

DEPTH Scale 1:75

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 04/07/13 - 05/07/13
DATE : 09/07/13

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583787.8
Y-COORD : 6345861

HOLE No: BH-09

HOLE No: BH-10
Sheet 1 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: BH-10
Sheet 1 of 2

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	DEPTH Scale 1:75
		N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		
		N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		
		60	60	0		>20								
		47	47	0		>20		2	10 20	CJ CJ	RJ RJ	Stain Stain		

Scale
1:75

0.00	
4.00	Water
11.97	No recovery. Very soft material (presumed to have washed away)
15.00	Moderately weathered, greyish black, HARDROCK, hornfels gravel.Fill, assumed to be in a sandy clay matrix (washed away).
15.64	

HOLE No: **BH-10**
Sheet 2 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

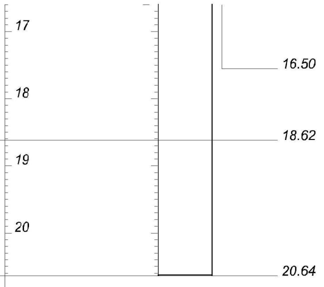
WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-10**
Sheet 2 of 2

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering
17		111	111	0		>20							▨
18		98	96	0		>20 >20		3	10 30 80	WJ WJ MJ	RJ RJ RJ	SC SC SC	▨
19		103	103	56		2							▨
20		79	79	64		2 2		2	10 80	WJ WJ	RJ RJ	SC SC	▨



Depth	Description
16.50	Moderately weathered, very closely to closely jointed, greenish grey, thinly bedded, HARDROCK, fine grained. Hornfels.
18.62	Moderately weathered closely jointed, greenish grey speckled brown, thinly bedded, HARDROCK, fine grained. hornfels.
20.64	Moderately weathered, medium to widely jointed, grey and brown in joints, very thinly bedded, HARDROCK, fine grained. Hornfels.
	END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 17/06/2013 - 19/06/13
DATE : 09/07/13

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583292.4
Y-COORD : 6345841

HOLE No: **BH-10**

HOLE No: **BH-11**
Sheet 1 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-11**
Sheet 1 of 2

JOB NUMBER: 109552

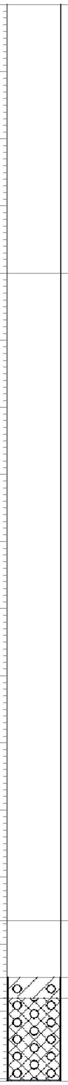
Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering
0	0	0			N/A	N/A	N/A	N/A	N/A	N/A	
100	0	0									
0	0	0			N/A	N/A	N/A	N/A	N/A	N/A	
35	0	0			N/A	N/A	N/A	N/A	N/A	N/A	
11	0	0									
65	0	0									

REDUCED LEVEL: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Drill method

DEPTH Scale 1:75: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Scale 1:75



Depth	Description
0.00	
4.00	Water.
13.65	No recovey. Very soft material (presumed to have washed away)
14.50	Wet, brown, SOFT, gravelly clay. Alluvium.
14.81	Moderately weathered, greenish grey, HARDROCK hornfel gravel. Fill (possibly to prevent scour)
16.04	

HOLE No: **BH-11**
Sheet 2 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-11**
Sheet 2 of 2

JOB NUMBER: 109552

END OF HOLE.

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	DEPTH Scale 1:75

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 21/06/2013-24/06/13
DATE : 09/07/13

DATE : 08/08/2013 15:52
TEXT : ..o\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583781
Y-COORD : 6345839

HOLE No: **BH-11**

HOLE No: **BH-12**
Sheet 1 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

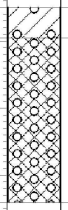
WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-12**
Sheet 1 of 2

JOB NUMBER: 109552

DEPTH Scale 1:75	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	Description
0.00		N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		
4.00														Water.
12.30		N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		No recover. Very soft material (presumed to have washed away).
13.50		100	N/A	N/A	N=26		N/A	N/A	N/A	N/A	N/A	N/A		Wet, brown, VERY STIFF, gravelly clay. Alluvium.
13.95		50	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		Moderately weathered, greenish grey, HARDROCK, hornfel gravel. Fill (possibly to prevent scour).
		44	N/A	N/A										
		78	78	N/A		>20							▨	
16.40														


Scale
1:75

HOLE No: **BH-12**
Sheet 2 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-12**
Sheet 2 of 2

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value
17		110	110	0	
		98	98	46	
18		97	97	46	
19		107	107	61	
20		102	102	62	

Joint frac. freq.
>20
13
>20
>20
13

Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering
	2	10 45	CJ CJ	RJ RJ	SC SC	
	3	10 30 60	CJ MJ CJ	RJ RJ RJ	stain stain stain	

DEPTH Scale 1:75	Depth	Description
17		Moderately weathered and highly weathered at joints, closely jointed, black grey stained brown in joints, thinly bedded, HARDROCK, very fine grained. Hornfels.
18	17.31	Moderately weathered and highly weathered at joints, medium jointed, black grey stained brown in joints thinly bedded, HARDROCK, very fine grained. Hornfels.
19 20	20.80	END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 01/07/2013-02/07/13
DATE :

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583761.7
Y-COORD : 6345840

HOLE No: **BH-12**

HOLE No: **BH-13**
Sheet 1 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

aurecon

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-13**
Sheet 1 of 2

JOB NUMBER: 109552

Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	DEPTH Scale 1:75	Description
	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		0.00	
													4.00	Water.
	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		11.00	No recovery. Very soft material (presumed to have washed away).
	100	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		13.50	Wet, black, VERY STIFF, sandy clay with sporadic gravels. Alluvium.
	0	0	0	N=40		N/A	N/A	N/A	N/A	N/A	N/A			
	35	0	0										14.50	Moderately weathered, greenish grey, HARD ROCK hornfels gravel. Fill assumed to be in a sandy clay matrix, (washed away during drilling).
	100	100	0		>20 10		4	10 30 45	CJ CJ CJ	RJ RJ RJ	SC SC SC	▒	15.27	Moderately weathered, very closely jointed, brown grey, thinly bedded, HARD ROCK, very fine grained. Hornfels.

REDUCED LEVEL

Scale 1:75

HOLE No: **BH-13**
Sheet 2 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

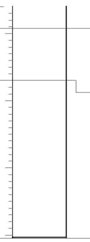
WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-13**
Sheet 2 of 2

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	DEPTH Scale 1:75
						10			70	CJ	RJ	SC	▨	
17		95	95	58		>20		3	30 10 80	MJ CJ WJ	RJ RJ RJ	SC SC SC	▨	17
18		124	124	48		15		4	10 45 60 80	CJ WJ CJ WJ	RJ RJ RJ RJ	SC SC SC SC	▨	18
19		90	90	0										19
20		87	87	0		10								20



Depth	Description
16.92	Moderately weathered, closely jointed, grey, finely bedded, HARD ROCK, very fine grained. Hornfels.
17.70	Moderately weathered closely jointed, grey, finely bedded, HARD ROCK, very fine grained. Hornfels.
20.05	END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 04/07/2013 - 06/07/13
DATE :

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583753.7
Y-COORD : 6345837

HOLE No: **BH-13**

HOLE No: **BH-14**
Sheet 1 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-14**
Sheet 1 of 2

JOB NUMBER: 109552

DEPTH Scale 1:75	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	
0.00		N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		
4.00														Water.
10.50		N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A		No recovery. Very soft material presumed to have washed away.
13.50		100 100	0 0	0 0	N=41		N/A	N/A	N/A	N/A	N/A	N/A		Wet, brown, VERY STIFF, sandy clay. Alluvium.
14.40		9	0	0	N=REF		N/A	N/A	N/A	N/A	N/A	N/A		Moderately weathered, greenish grey, HARD ROCK. Hornfels gravel. Fill (possibly LOOSE material that fell back into the hole).
15.50		110	87	13		>20 >20	N/A	N/A 2	N/A 10 60	N/A CJ MJ	N/A RJ RJ	N/A stain stain	▩	Moderately to highly weathered, very closely jointed, brown speckled green at places, thinly bedded, HARD ROCK, very fine grained, Hornfels.
15.75														

REDUCED LEVEL
583731
583730
583729
583728
583727
583726
583725
583724
583723
583722
583721
583720
583719
583718
583717
583716
583715

HOLE No: **BH-14**
Sheet 2 of 2

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-14**
Sheet 2 of 2

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weath-ering	DEPTH Scale 1:75		
583714		107	107	28		>20 14		3	10 30 60	CJ MJ WJ	RJ RJ RJ	stain stain stain	▨	17	16.23	Moderately weathered, closely jointed, grey black, thinly bedded, HARD ROCK, very fine grained. Hornfels.
583713		103	103	76		6							▨	18	18.55	Moderately weathered, medium jointed, greyish brown, thinly bedded, HARD ROCK, very fine grained. Hornfels.
																END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY :

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 04/07/2013-10/07/13
DATE : 15/07/13

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION : 583731.5
X-COORD : 6345837
Y-COORD :

HOLE No: **BH-14**

HOLE No: BH-15
Sheet 1 of 1

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

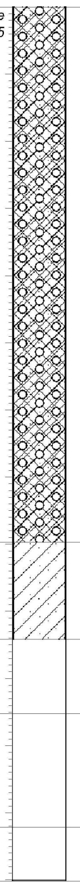
WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

East London
Quaywall Geotechnical Investigation.

HOLE No: BH-15
Sheet 1 of 1

JOB NUMBER: 109552

Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling
	N/A	N/A	N/A								
	60	0	0								
	100	0	0	N=10							
	100	0	0								
	100	0	0								
	100	0	0								
	100	0	0	N=15							
	100	0	0								
	67	0	0			N/A	N/A	N/A	N/A	N/A	N/A
	85	0	0								
	55	0	0	N=REF							
	0	0	0								
	96	0	0								
	54	0	0	N=10							
	61	0	0								
	145	0	0								
	94	0	0								
	100	0	0								
	40	0	0	N=4							
	721	0	0			N/A	N/A	N/A	N/A	N/A	N/A
	27	0	0				2	10 30	CJ CJ	RJ RJ	SC SC
	100	100	49		>20						
	35	35	0								
	57	57	0		>20		2	10 70	CJ MJ	RJ RJ	SC SC
	100	100	0								
	100	100	0		>20		3	10 70 80	CJ MJ CJ	RJ RJ RJ	SC SC SC
	100	100	0								



Depth	Description
0.00	Moderately to highly weathered, greyish brown speckled green at places, HARD ROCK, Hornfels gravel. Fill assumed to be in a sandy clay matrix (washed away).
7.97	Slightly moist, black, SOFT, sandy clay. Alluvium.
9.42	Moderately weathered, closely jointed, black grey, thinly bedded, HARD ROCK, very fine grained. Hornfels.
10.52	Moderately weathered, closely jointed, greyish brown and black at places, thinly bedded, HARD ROCK, very fine grained. Hornfels.
12.22	Moderately weathered, closely jointed blackish brown, thinly bedded, HARD ROCK, very fine grained. Hornfels.
13.02	END OF HOLE.

REDUCED LEVEL

DEPTH Scale 1:75

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 09/07/2013-12/07/13
DATE : 15/07/13

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 583755.4
Y-COORD : 6345850

HOLE No: BH-15

HOLE No: **BH-16**
Sheet 1 of 1

JOB NUMBER: 109552

GRAIN SIZE
FG -fine grained
MG -medium grain
CG -coarse grain

JOINT SPACING
VCJ-very close spacg
CJ -close spacing
MJ -medium spacing
WJ -wide spacing
VWJ-very wide spacng

JOINT ROUGHNESS
SLJ-slickensided
SJ -smooth
RJ -rough

JOINT INFILL
Cl-Clay
Slt-Silt
Snd-Sand
FeO-Iron Oxide
Chl-Chlorite

WEATHERING GRAPH
100%-Completely weathered
75%-Highly weathered
50%-Moderately weathered
25%-Slightly weathered
0%-Unweathered
Hatching-Soil/Unconsolidated

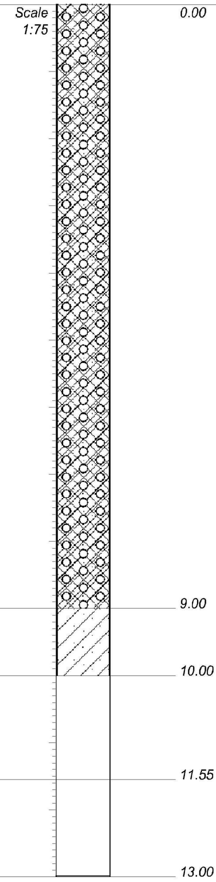
East London
Quaywall Geotechnical Investigation.

HOLE No: **BH-16**
Sheet 1 of 1

JOB NUMBER: 109552

REDUCED LEVEL	Drill method	Material Recovery (%)	Core Recovery (%)	RQD (%)	SPT N-Value	Joint frac. freq.	Rock fabric and grain	Joint no of sets	Joint inclin (deg)	Joint spacing	Joint rough-ness	Joint filling	Weathering
		N/A	N/A	N/A									
		60	0	0	N=18								
		0	0	0									
		38	0	0	N=11								
		100	0	0									
		33	0	0									
		0	0	0	N=REF								
		64	0	0			N/A	N/A	N/A	N/A	N/A	N/A	
		29	0	0	N=8								
		100	0	0									
		24	0	0									
		36	0	0									
		87	0	0	N=6								
		100	0	0									
		83	83	28		>20		2	16 30	CJ MJ	RJ RJ	SC SC	
		87	87	0		>20							
		125	125	85				3	10 30 70	MJ MJ MJ	RJ RJ RJ	SC SC SC	
		93	93	22		>20							

DEPTH Scale 1:75



DEPTH	
0.00	Moderately weathered, greenish grey, HARD ROCK. Hornfel gravel. Fill assumed to be in a matrix of sandy clay (washed away).
9.00	Moist, brown black, SOFT, sandy clay. Alluvium.
10.00	Moderately weathered, closely to medium jointed, grey black, thinly bedded, HARD ROCK, very fine grained. Hornfels.
11.55	Moderately weathered, closely to medium jointed, blackish grey and stained brown in joints, thinly bedded, HARD ROCK, very fine grained. Hornfels.
13.00	END OF HOLE.

CONTRACTOR : Geomechanics
MACHINE :
DRILLED BY :
PROFILED BY : Katlego Magoro

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION : 90
DIAM :
DATE : 12/07/2013-15/07/13
DATE : 16/07/13

DATE : 08/08/2013 15:52
TEXT : ..c\EastLondonQuaywall.doc

ELEVATION :
X-COORD : 538775.9
Y-COORD : 6345851

HOLE No: **BH-16**

aurecon

East London
Quaywall Geotechnical Investigation.

LEGEND
Sheet 1 of 1

JOB NUMBER: 109552

○○○	GRAVEL	{SA02}
○○○	GRAVELS	{SA02}
○	GRAVELLY	{SA03}
⁙	SAND	{SA04}
∴	SANDY	{SA05}
▨	CLAY	{SA08}
⁄	CLAYEY	{SA09}
▦	FILL	{SA32}

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY :

TYPE SET BY : K.M
SETUP FILE : AUREBH.SET

INCLINATION :
DIAM :
DATE :
DATE :

DATE : 08/08/2013 15:52
TEXT : ..o\EastLondonQuaywall.doc

ELEVATION :
X-COORD :
Y-COORD :

LEGEND
SUMMARY OF SYMBOLS

APPENDIX C
Field test results

ControLab South Africa (Pty) Ltd

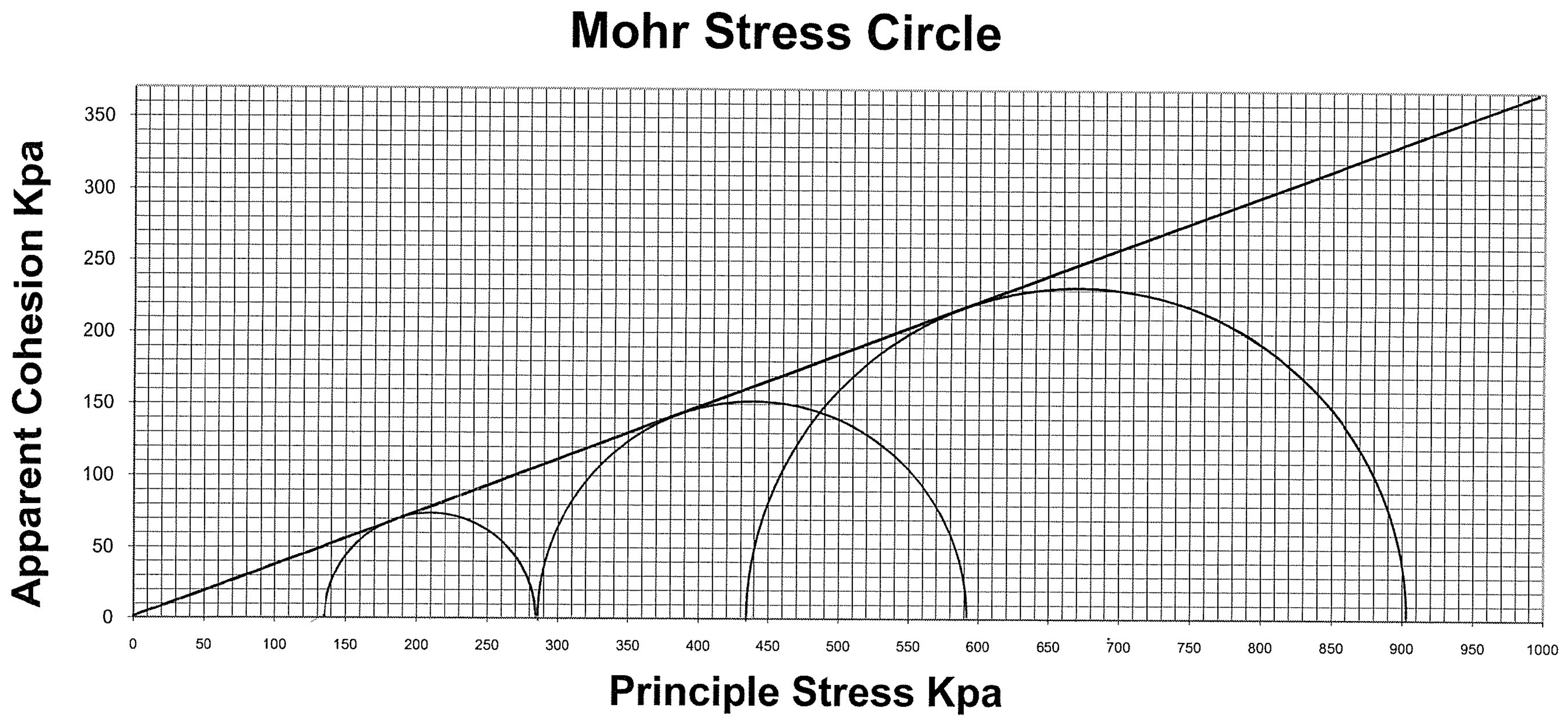
201000682907

CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY

Date : 12 August 2013
Client : Aurecon Consulting
Project : EL DRY DOCK QUAY
Test Conditions: Undisturbed

Position : BH 15 @ 8.42 - 8.97m (S/N:5747)
Description : dk Br Bl - sdy cl
Test Type : Consolidated Undrained with PWP - Effective Stress Analysis
In-Situ Dry Density : Kg/m3 1153
In-Situ MC: % 50.9 **Final MC: %** 26.0

Apparent Cohesion (C´) = 0Kpa **Angle of Internal Friction (Ø´) = 20°**



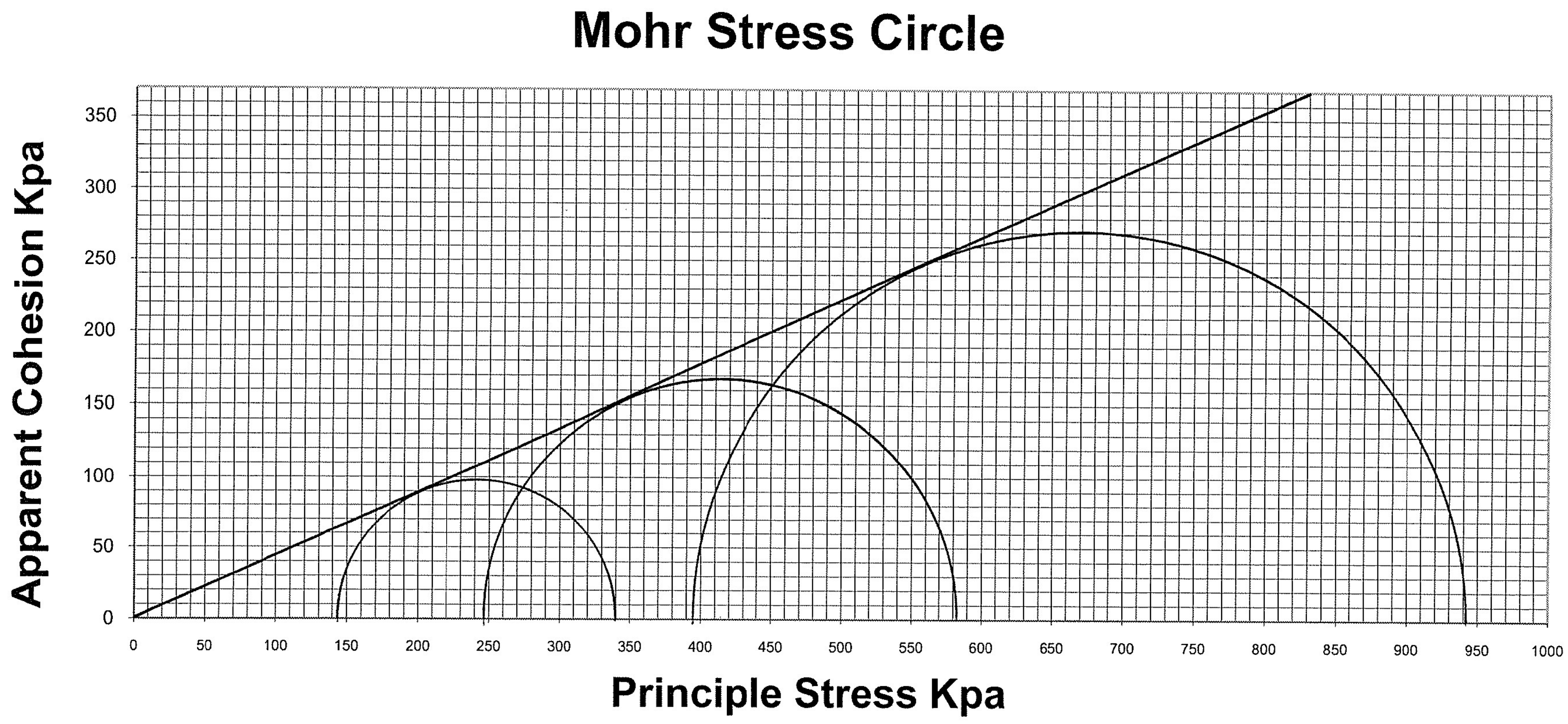
ControLab South Africa (Pty) Ltd

CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY

201000682907

Date :	12 August 2013	**Position :**	BH 16 @ 9.45 - 10m (S/N:5748)	
Client :	Aurecon Consulting	**Description :**	dk Br Bl - cly s	
Project :	EL DRY DOCK QUAY	**Test Type :**	Consolidated Undrained with PWP - Effective Stress Analysis	
Test Conditions:	Undisturbed	**In-Situ Dry Density : Kg/m3**	1248	
		In-Situ MC: %	35.8	**Final MC: %** 20.0

Apparent Cohesion (C´) = 0Kpa **Angle of Internal Friction (Ø´) = 24°**



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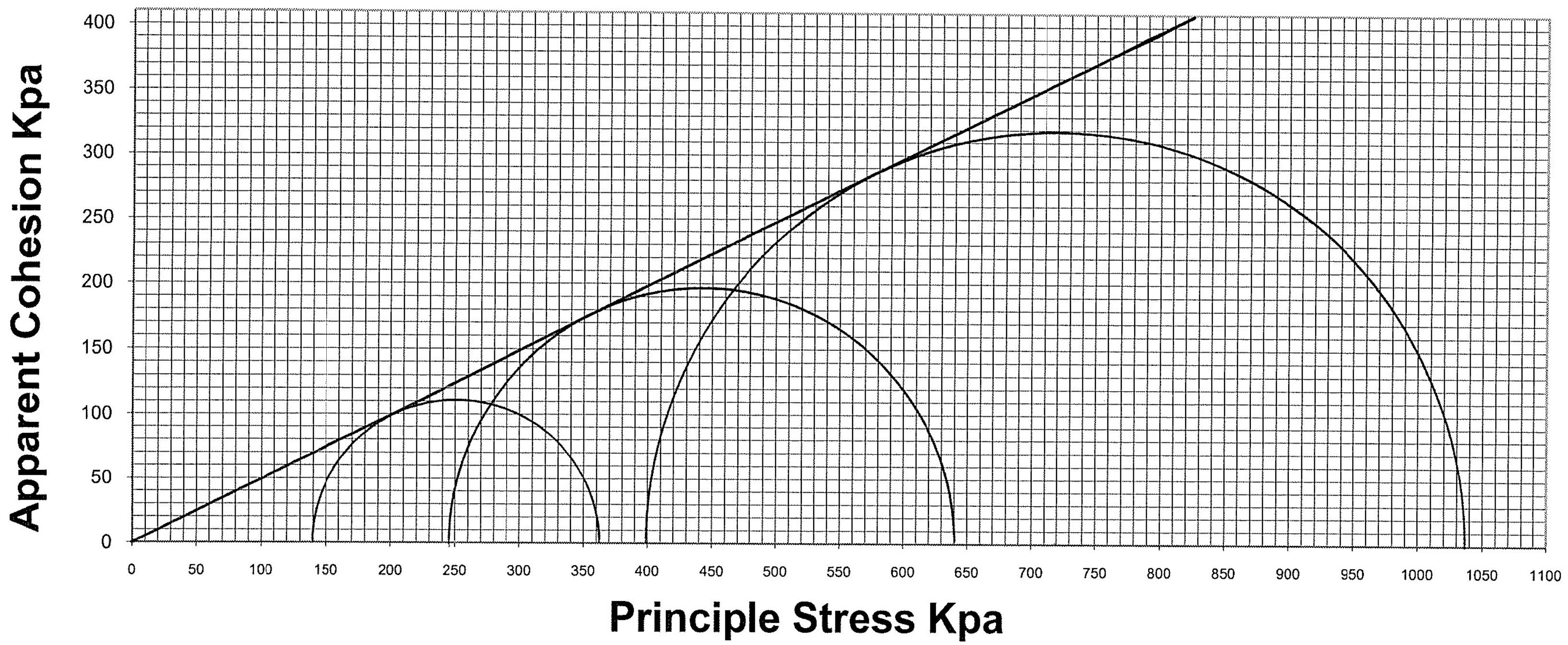
201000682907

CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY

Date :	12 August 2013	**Position :**	BH 8 @ 6.45 - 7m (S/N:5749)
Client :	Aurecon Consulting	**Description :**	dk Br Bl - sty s
Project :	EL DRY DOCK QUAY	**Test Type :**	Consolidated Undrained with PWP - Effective Stress Analysis
Test Conditions:	Undisturbed	**In-Situ Dry Density : Kg/m3**	1261
		In-Situ MC: %	45.0 **Final MC: %** 22.9

Apparent Cohesion (C´) = 0Kpa **Angle of Internal Friction (Ø´) = 26°**

Mohr Stress Circle



ControLab South Africa (Pty) Ltd

201000682907

CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY

www.controlab.co.za

HEAD OFFICE : 1 Alfred Road, Vincent, 5247 Tel: 043 726 7859, Fax: 043 726 7426
BRANCH OFFICE: U9/A1 Kalika Street, Mthatha, 5100 Tel: (047) 531 4721, Fax: (047) 531 4640
OTHER BRANCH OFFICES: Cape Town, Kokstad, Port Elizabeth

CLIENT: Aurecon SA (Pty) Ltd
Aurecon Centre
Lynnwood Bridge Office Park
4 Daventry Street
LYNNWOOD PARK
0081

ATT : Mr A Schulze-Hulbe

PROJECT: EAST LONDON DRY DOCK QUAY

DATE RECEIVED: 2013-07-16
DATE TESTED: 2013-07-31
DATE REPORTED: 2013-08-06
TEST REPORT NO.: 64657

FOUNDATION INDICATOR REPORT

SAMPLE NO	5747	5748	5749			
POSITION	BH 15	BH 16	BH 8			
DEPTH	8.42 - 8.97	9.45 - 10	6.45 - 7			
DESCRIPTION	dk Br Bl	dk Br Bl	dk Br Bl			
	sdy cl	cly s	sty s			

SIEVE ANALYSIS % PASSING SIEVES: Method :TMH1 A1(a) & A5

% PASSING 75 mm	100					
37.5 mm	74	100	100			
19 mm	74	81	83			
9.5 mm	74	67	65			
4.75 mm	73	61	52			
2.36 mm	72	59	47			
1.18 mm	71	57	44			
0.600 mm	70	56	43			
0.425 mm	69	56	42			
0.300 mm	69	56	40			
0.150 mm	65	53	32			
0.075 mm	53.5	46.8	18.5			

HYDROMETER ANALYSIS: Method ASTM D422

0.06 mm	45	40	15			
0.02 mm	26	28	5			
0.006 mm	15	21	2			
0.002 mm	11	18	1			

ATTERBERG LIMITS: Method: TMH1 A2 ; A3 & A4

LIQUID LIMIT	29	40	CBD			
PLASTICITY INDEX	10	25	SP			
LINEAR SHRINKAGE	5.0	12.0	1.0			

PREDICTION OF HEAVE (VAN DER MERWE METHOD)

PI WHOLE SAMPLE	7.0	14.0	0.0			
POTENTIAL EXPANSIVENESS	LOW	MED	LOW			

Technical Signatory:
J Atterbury

Remarks:

Samples Delivered by Customer

Sampled by Controlab: YES

ControLab South Africa (Pty) Ltd
201000682907
CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY
www.controlab.co.za

HEAD OFFICE : 1 Alfred Road, Vincent, 5247, Tel: 043 726 7859, Fax: 043 726 7426
CENTRAL LABORATORY : 10 St Pauls Road, East London, 5201, Tel: 043 722 5420 / 722 8565, Fax: 043 743 9942, P O Box 346, East London, 5200
OTHER BRANCH OFFICES: Cape Town, Kokstad, Mthatha, Lusaka - Zambia

CLIENT: Aurecon SA (Pty)
Aurecon Centre
Lynnwood Bridge Office Park
4 Daventry Street
LYNNWOOD PARK
0081

ATT : Mr A Schulze-Hulbe

PROJECT: EAST LONDON DRY DOCK QUAY

DATE: 2013-07-30

TEST REPORT NO. 64657

ROCK UCS CORE STRENGTH TEST

CORE TEST DATA

BH NO.	DEPTH	TOTAL LENGTH OF CORE SUBMITTED mm	LENGTH OF CORE AFTER TRIMMINGS mm	CORE DIAMETER (mm)	DENSITY (Kg/m^3)	STRENGTH UCS (MPa)	COMMENTS
BH 5	11.05 - 11.34	214	120	60	2624	66.5	Core full of cracks
BH 6	11.49 - 12.17	164	120	60	2650	36.1	Broken before testing
BH 7	11.93 - 12.17	200	120	60	2681	52.0	Broken before testing
BH 8	12.62 - 12.87	189	120	60	2723	68.6	Core full of cracks
BH 9	11.35 - 11.68	194	120	60	2775	35.7	Broken before testing
BH 10	18.79 - 18.94	141	120	60	2353	33.2	Broken before testing
BH 11A	17.93 - 18.34	203	120	60	2695	62.9	Core full of cracks
BH 12	18.15 - 18.35	236	120	60	2695	68.6	Core full of cracks
BH 13	18 - 18.24	241	120	60	2657	61.9	Core full of cracks
BH 14	16.77 - 16.93	198	120	60	2725	54.5	Core full of cracks

Technical Signatory: ______________________
J Atterbury

ControLab South Africa (Pty) Ltd
201000682907
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OTHER BRANCH OFFICES: Cape Town, Kokstad, Mthatha, Lusaka - Zambia

TESTING OUTSOURCED TO MONITOR LABORATORIES
TEST RESULTS AS SUPPLIED BY MONITOR LABORATORIES

CLIENT:	Aurecon SA (Pty) Ltd	**PROJECT:**	EAST LONDON DRY
	Aurecon Centre,		DOCK QUAY
	Lynnwood Bridge, Office Park		
	4 Daventry Street		
	LYNNWOOD MANOR		
	0081	**DATE:**	2013-07-30
ATT:	Mr A Schulze-Hulbe	**REF:**	64657

Sample 1	BH 13 EL QUAY WALL NO. 1
Sample 2	BH 14 EL QUAY WALL NO. 2

Parameter	NO. 1	NO. 2	UNITS
pH	7.10	7.15	
Conductivity	5080	5110	mS/m
Total dissolved solids	32512	32704	mg/*l*
Alkalinity	126	128	mg/*l*
Calcium (as Ca)	300	319	mg/*l*
Calcium (as $CaCO_3$)	749.1	796.5	mg/*l*
Saturation pH ($pH_{(S)}$)	7.63	7.35	-
Saturation Index (SI)	-0.53	0.2	-
Ryznar Index (I_R)	8.16	7.55	-

REMARKS: Both of these water samples are aggressive towards cement and very corrosive towards metal pipes

Technical Signatory:__________J Atterbury

ControLab South Africa (Pty) Ltd
201000682907
CIVIL ENGINEERING MATERIALS AND GEOTECHNICAL LABORATORY
www.controlab.co.za

HEAD OFFICE : 1 Alfred Road, Vincent, 5247, Tel: 043 726 7859, Fax: 043 726 7426
CENTRAL LABORATORY : 10 St Pauls Road, East London, 5201, Tel: 043 722 5420 / 722 8565, Fax: 043 743 9942, P O Box 346, East London, 5200
OTHER BRANCH OFFICES: Cape Town, Kokstad, Mthatha, Lusaka - Zambia

TESTING OUTSOURCED TO MONITOR LABORATORIES
TEST RESULTS AS SUPPLIED BY MONITOR LABORATORIES

CLIENT:	Aurecon SA (Pty) Ltd	**PROJECT:**	EAST LONDON DRY
	Aurecon Centre,		DOCK QUAY
	Lynnwood Bridge, Office Park		
	4 Daventry Street		
	LYNNWOOD MANOR		
	0081	**DATE:**	2013-07-30
ATT:	Mr A Schulze-Hulbe	**REF:**	64657

Sample 1 (5750)	BH 14 DEPTH 13.5 – 13.95
Sample 2 (5751)	BH 15 DEPTH 1.95 – 2.13
Sample 3 (5752)	BH 11 DEPTH 13 – 13.1

Parameter	NO. 1	NO. 2	NO. 3	UNITS
pH	8.57	9.22	6.52	
Conductivity	1512	524	1536	mS/m
Total dissolved solids	9677	3354	9830	mg/kg
Alkalinity	175	51	27	mg/kg
Calcium (as Ca)	122	59.5	487	mg/kg
Calcium (as $CaCO_3$)	304.6	148.5	1216.0	mg/kg
Saturation pH ($pH_{(S)}$)	7.84	8.08	7.89	-
Saturation Index (SI)	0.73	1.14	-1.37	-
Ryznar Index (I_R)	7.11	6.94	9.26	-

REMARKS: Soil sample No. 1 is scale forming towards cement and slightly corrosive towards metal pipes. Soil sample No. 2 is scale forming towards cement and in equilibrium with metal pipes, while soil sample No. 3 is aggressive towards cement and highly corrosive towards metal pipes.

Technical Signatory:__________J Atterbury

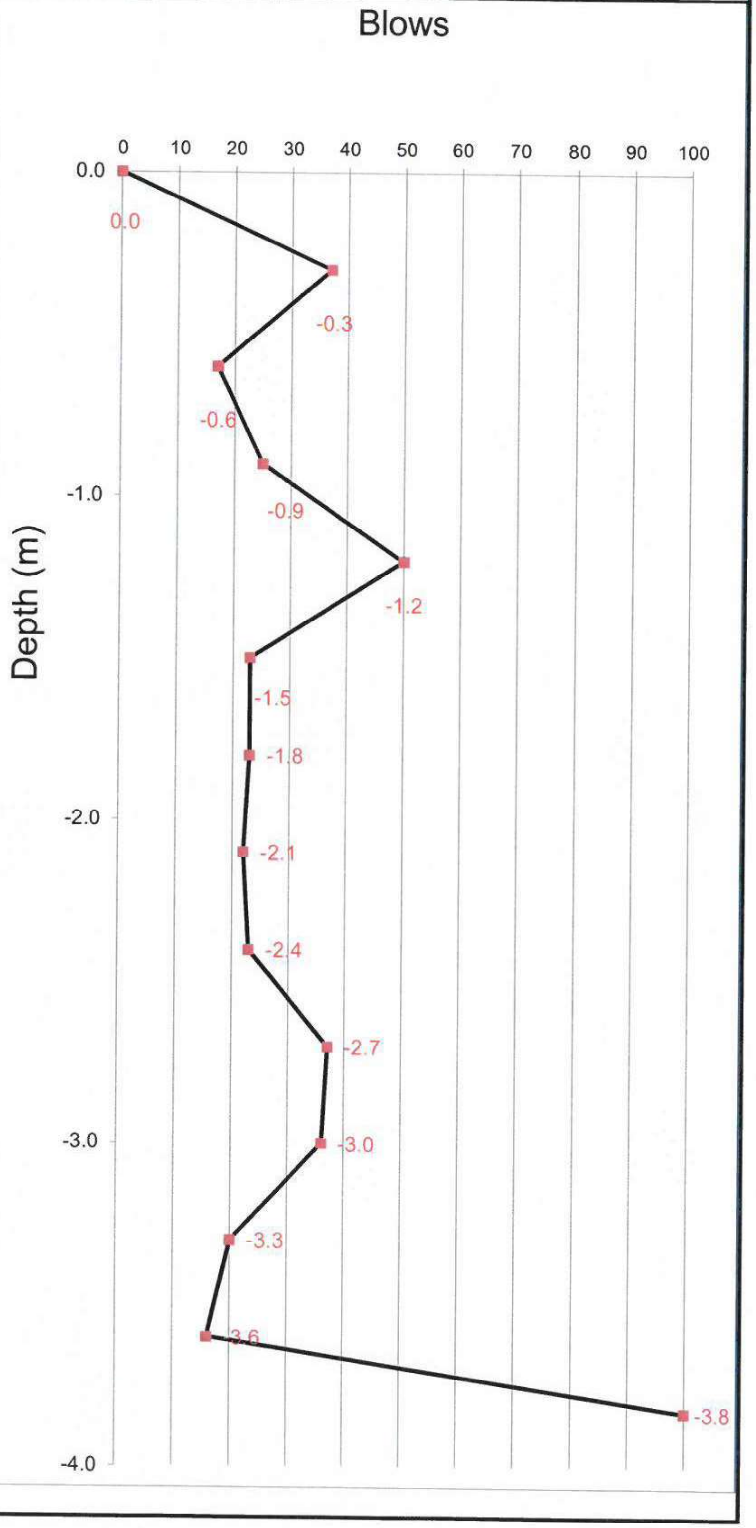
APPENDIX D

Laboratory test results

DYNAMIC PROBE SUPER HEAVY (DPSH) TEST RESULT

Client: Aurecon
Project: East London Quay Wall
Cont. No: 109552
Operator: E. Mbhele
Test poition: DPSH 1
Date: 6/15/2013
REFUSAL DEPTH 3.83m

Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	37	-17.7	
-0.6	17	-18.0	
-0.9	25	-18.3	
-1.2	50	-18.6	
-1.5	23	-18.9	
-1.8	23	-19.2	
-2.1	22	-19.5	
-2.4	23	-19.8	
-2.7	37	-20.1	
-3.0	36	-20.4	
-3.3	20	-20.7	
-3.6	16	-21.0	
-3.8	100	-21.3	
-4.2		-21.6	
-4.5		-21.9	
-4.8		-22.2	
-5.1		-22.5	
-5.4		-22.8	
-5.7		-23.1	
-6.0		-23.4	
-6.3		-23.7	
-6.6		-24.0	
-6.9		-24.3	
-7.2		-24.6	
-7.5		-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
-16.2		-33.6	
-16.5		-33.9	
-16.8		-34.2	
-17.1		-34.5	



DYNAMIC PROBE SUPER HEAVY (DPSH)
TEST RESULT

Client: Aurecon
Project: East London Quay Wall
Cont. No: 109552
Operator: E. Mbhele
Test poition: DPSH 1A
Date: 6/15/2013
REFUSAL DEPTH 5.4 m

Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	47	-17.7	
-0.6	27	-18.0	
-0.9	29	-18.3	
-1.2	29	-18.6	
-1.5	35	-18.9	
-1.8	32	-19.2	
-2.1	15	-19.5	
-2.4	15	-19.8	
-2.7	15	-20.1	
-3.0	14	-20.4	
-3.3	17	-20.7	
-3.6	23	-21.0	
-3.9	16	-21.3	
-4.2	9	-21.6	
-4.5	10	-21.9	
-4.8	20	-22.2	
-5.1	10	-22.5	
-5.4	100	-22.8	
-5.7		-23.1	
-6.0		-23.4	
-6.3		-23.7	
-6.6		-24.0	
-6.9		-24.3	
-7.2		-24.6	
-7.5		-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
-16.2		-33.6	
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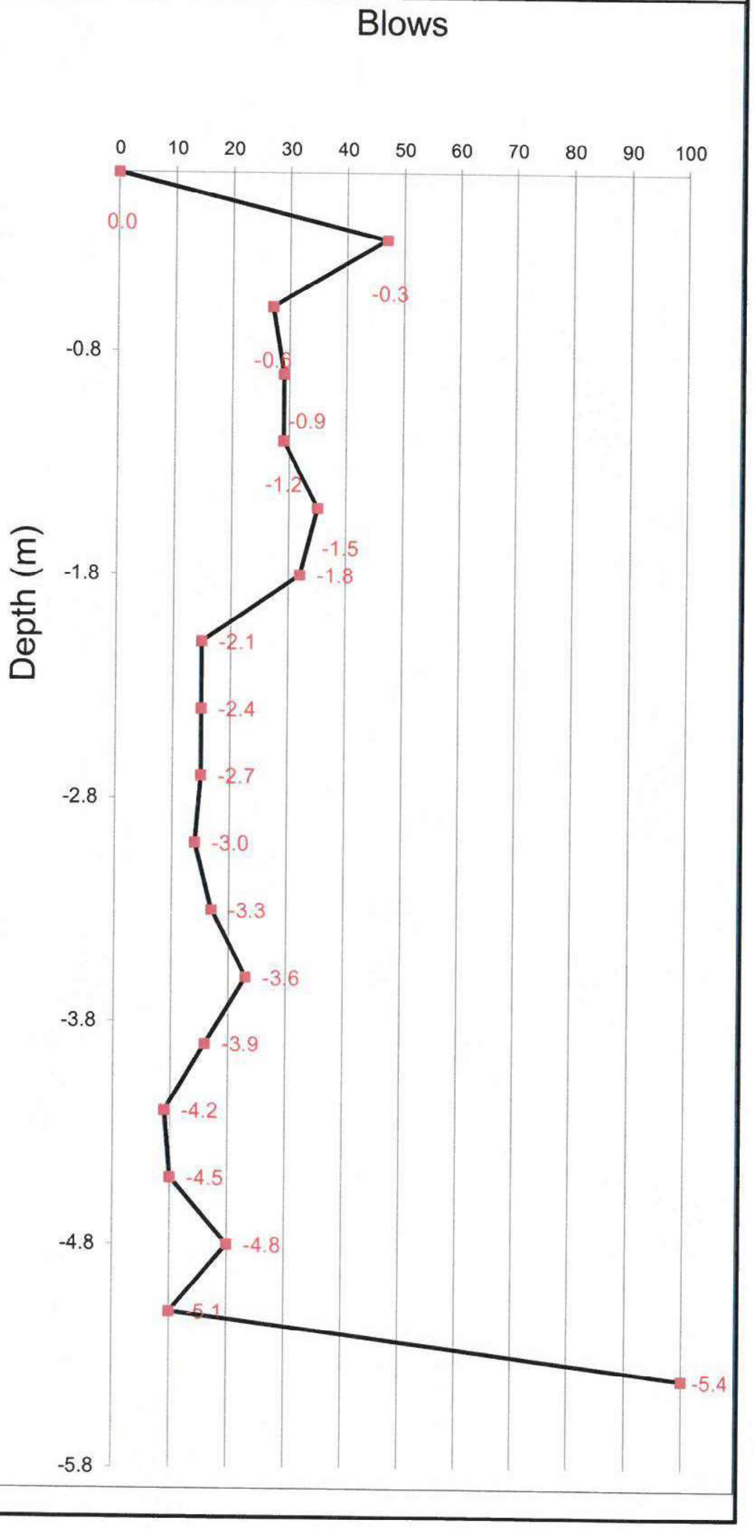
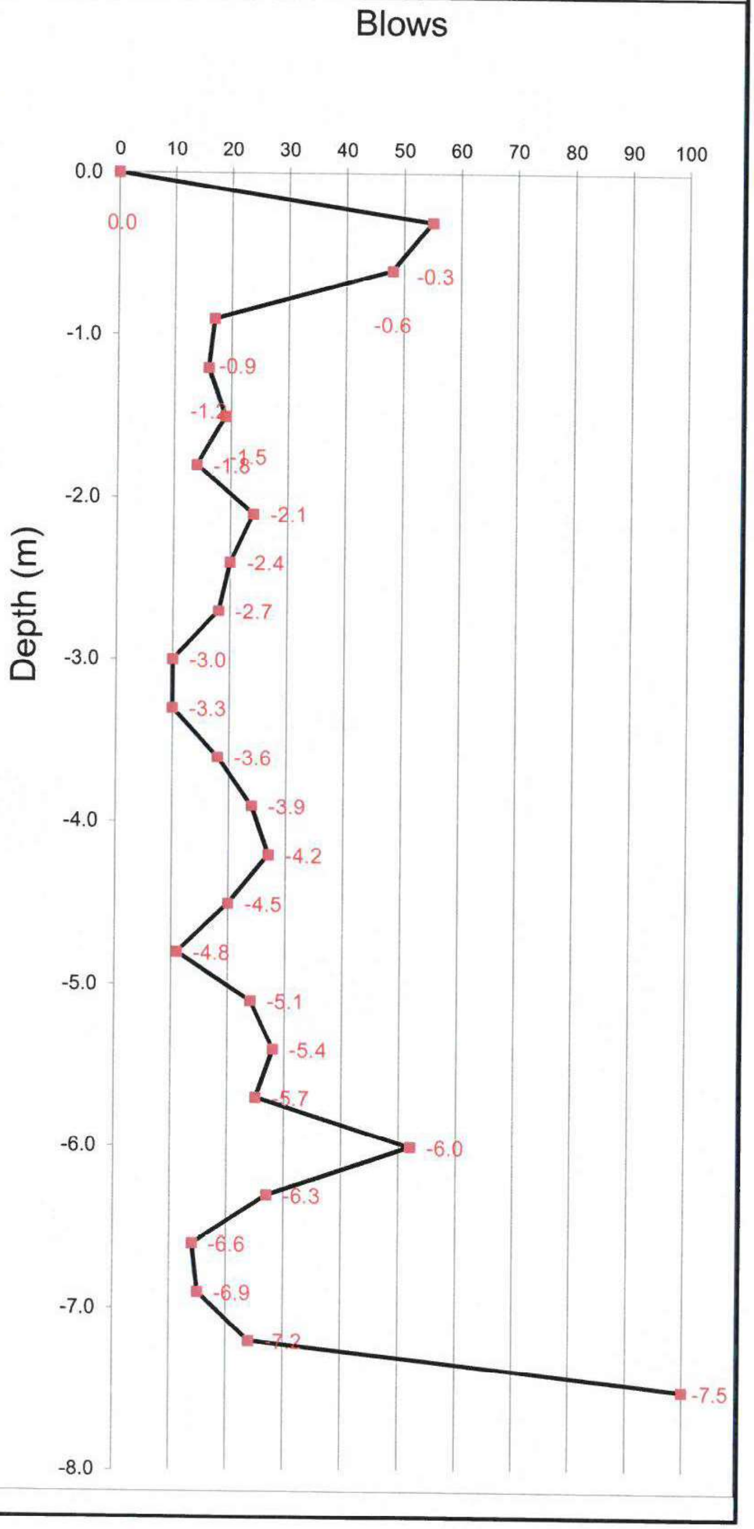
-16.8		-34.2	
-17.1		-34.5	



DYNAMIC PROBE SUPER HEAVY (DPSH)
TEST RESULT

Client: Aurecon
Project: East London Quay Wall
Cont. No: 109552 Operator: E. Mbhele
Test poition: DPSH 2
Date: 6/17/2013
REFUSAL DEPTH 7.5 m

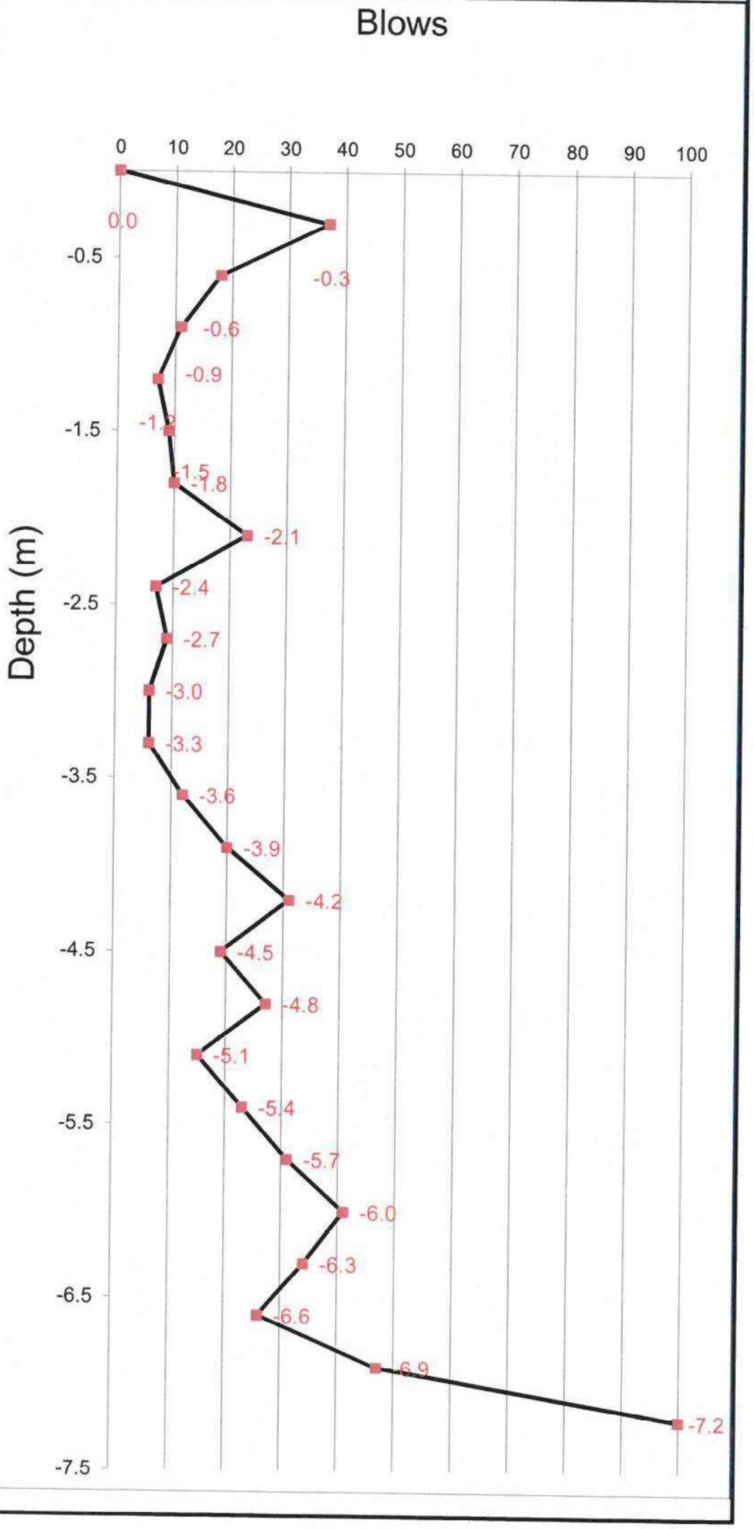
Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	55	-17.7	
-0.6	48	-18.0	
-0.9	17	-18.3	
-1.2	16	-18.6	
-1.5	19	-18.9	
-1.8	14	-19.2	
-2.1	24	-19.5	
-2.4	20	-19.8	
-2.7	18	-20.1	
-3.0	10	-20.4	
-3.3	10	-20.7	
-3.6	18	-21.0	
-3.9	24	-21.3	
-4.2	27	-21.6	
-4.5	20	-21.9	
-4.8	11	-22.2	
-5.1	24	-22.5	
-5.4	28	-22.8	
-5.7	25	-23.1	
-6.0	52	-23.4	
-6.3	27	-23.7	
-6.6	14	-24.0	
-6.9	15	-24.3	
-7.2	24	-24.6	
-7.5	100	-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
-16.2		-33.6	
-16.5		-33.9	
-16.8		-34.2	
-17.1		-34.5	



DYNAMIC PROBE SUPER HEAVY (DPSH)
TEST RESULT

Client: Aurecon
Project: East London Quay Wall
Cont. No: 109552 Operator: E. Mbhele
Test poition: DPSH 3
Date: 6/18/2013
REFUSAL DEPTH 7.2m

Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	37	-17.7	
-0.6	18	-18.0	
-0.9	11	-18.3	
-1.2	7	-18.6	
-1.5	9	-18.9	
-1.8	10	-19.2	
-2.1	23	-19.5	
-2.4	7	-19.8	
-2.7	9	-20.1	
-3.0	6	-20.4	
-3.3	6	-20.7	
-3.6	12	-21.0	
-3.9	20	-21.3	
-4.2	31	-21.6	
-4.5	19	-21.9	
-4.8	27	-22.2	
-5.1	15	-22.5	
-5.4	23	-22.8	
-5.7	31	-23.1	
-6.0	41	-23.4	
-6.3	34	-23.7	
-6.6	26	-24.0	
-6.9	47	-24.3	
-7.2	100	-24.6	
-7.5		-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
-16.2		-33.6	
-16.5		-33.9	
-16.8		-34.2	
-17.1		-34.5	



DYNAMIC PROBE SUPER HEAVY (DPSH) TEST RESULT

Client: Aurecon

Project: East London Quay Wall

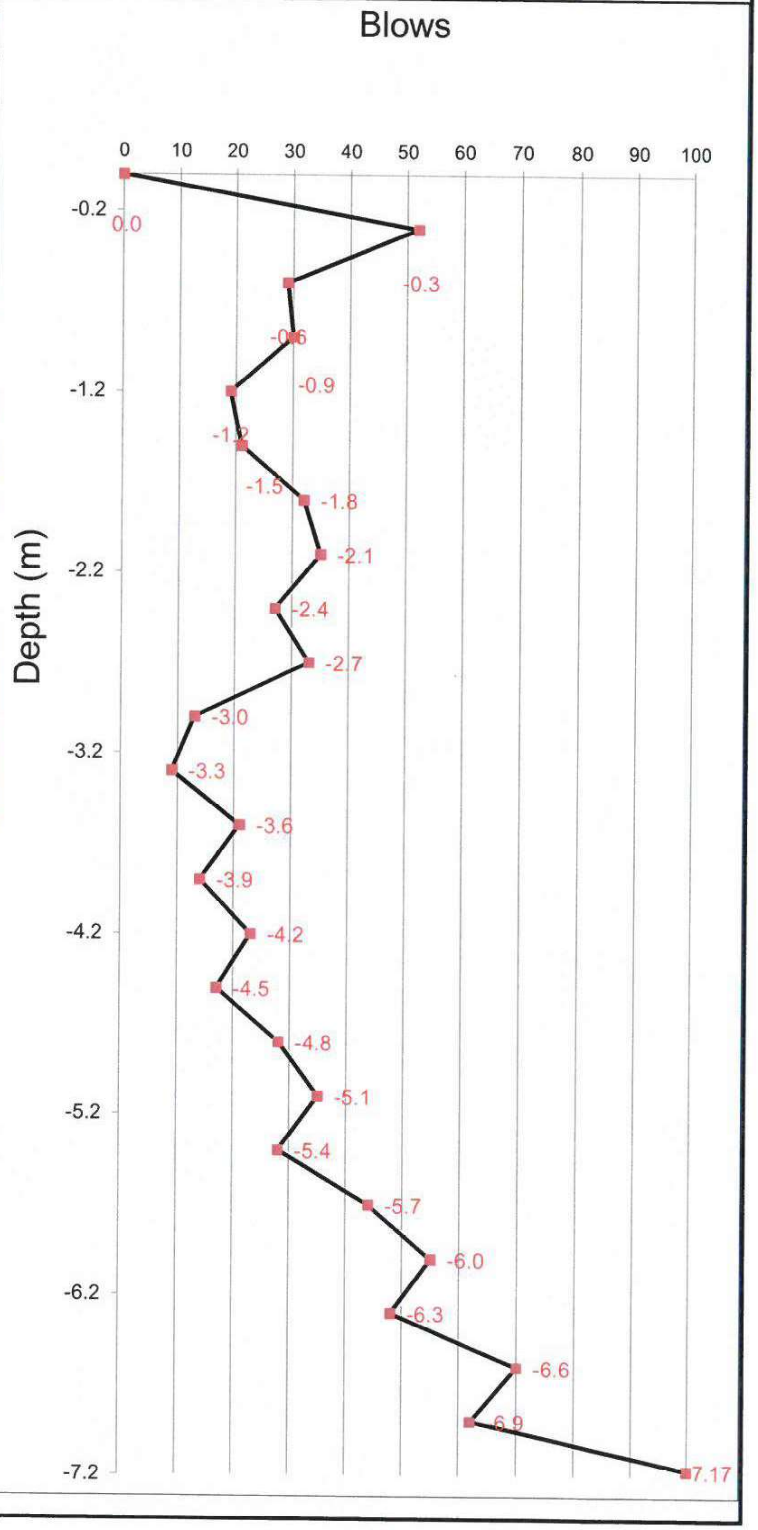
Cont. No: 109552 Operator: E. Mbhele

Test poition: DPSH 4

Date: 6/15/2013

REFUSAL DEPTH 7.17 m

Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	52	-17.7	
-0.6	29	-18.0	
-0.9	30	-18.3	
-1.2	19	-18.6	
-1.5	21	-18.9	
-1.8	32	-19.2	
-2.1	35	-19.5	
-2.4	27	-19.8	
-2.7	33	-20.1	
-3.0	13	-20.4	
-3.3	9	-20.7	
-3.6	21	-21.0	
-3.9	14	-21.3	
-4.2	23	-21.6	
-4.5	17	-21.9	
-4.8	28	-22.2	
-5.1	35	-22.5	
-5.4	28	-22.8	
-5.7	44	-23.1	
-6.0	55	-23.4	
-6.3	48	-23.7	
-6.6	70	-24.0	
-6.9	62	-24.3	
-7.17	100	-24.6	
-7.5		-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
-16.2		-33.6	
-16.5		-33.9	
-16.8		-34.2	
-17.1		-34.5	



DYNAMIC PROBE SUPER HEAVY (DPSH) TEST RESULT

Client: Aurecon
Project: East London Quay Wall
Cont. No: 109552 Operator: E. Mbhele
Test poition: DPSH 5
Date: 6/18/2013
REFUSAL DEPTH 6.9 m

Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	57	-17.7	
-0.6	37	-18.0	
-0.9	39	-18.3	
-1.2	23	-18.6	
-1.5	21	-18.9	
-1.8	62	-19.2	
-2.1	14	-19.5	
-2.4	23	-19.8	
-2.7	33	-20.1	
-3.0	28	-20.4	
-3.3	31	-20.7	
-3.6	32	-21.0	
-3.9	9	-21.3	
-4.2	53	-21.6	
-4.5	47	-21.9	
-4.8	40	-22.2	
-5.1	37	-22.5	
-5.4	43	-22.8	
-5.7	57	-23.1	
-6.0	49	-23.4	
-6.3	65	-23.7	
-6.6	60	-24.0	
-6.9	100	-24.3	
-7.2		-24.6	
-7.5		-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
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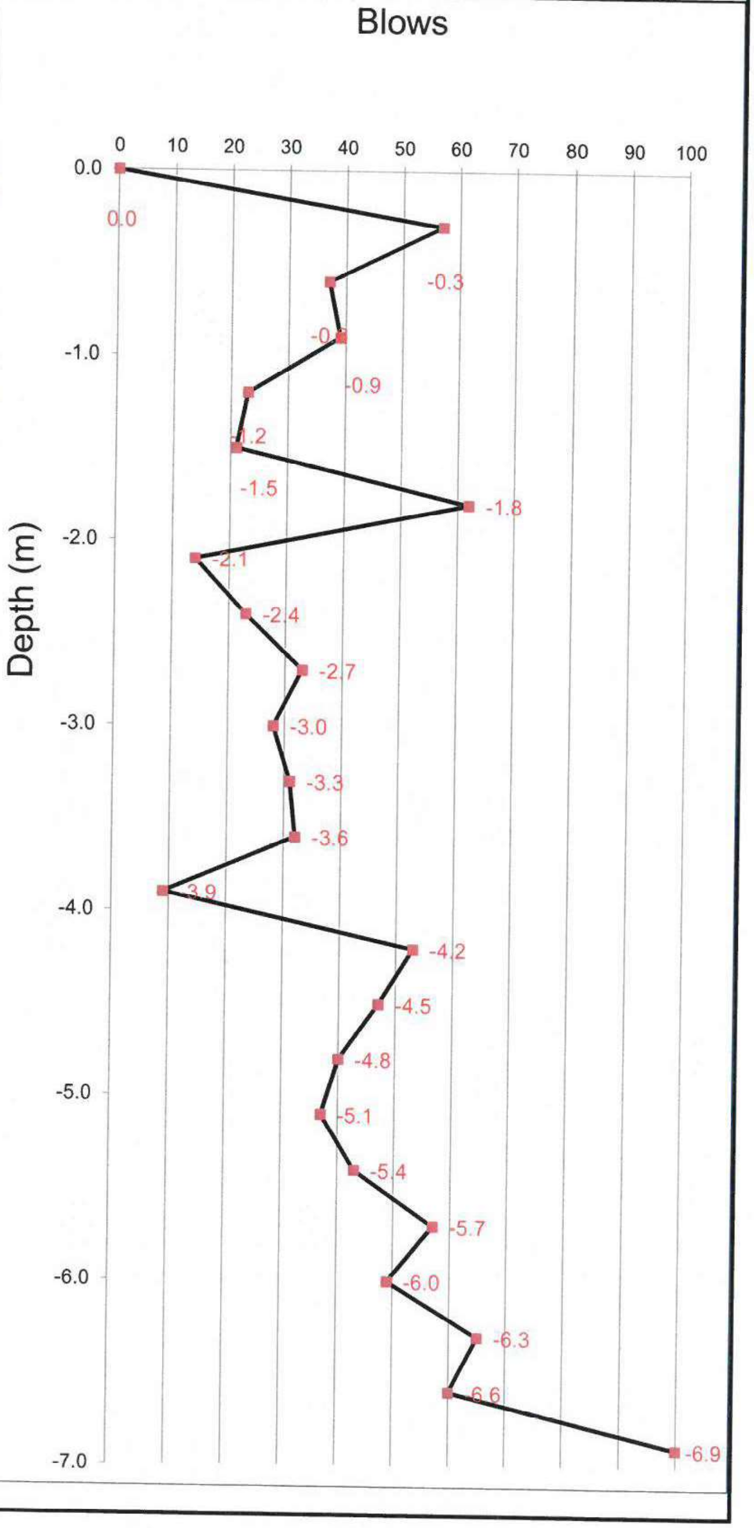
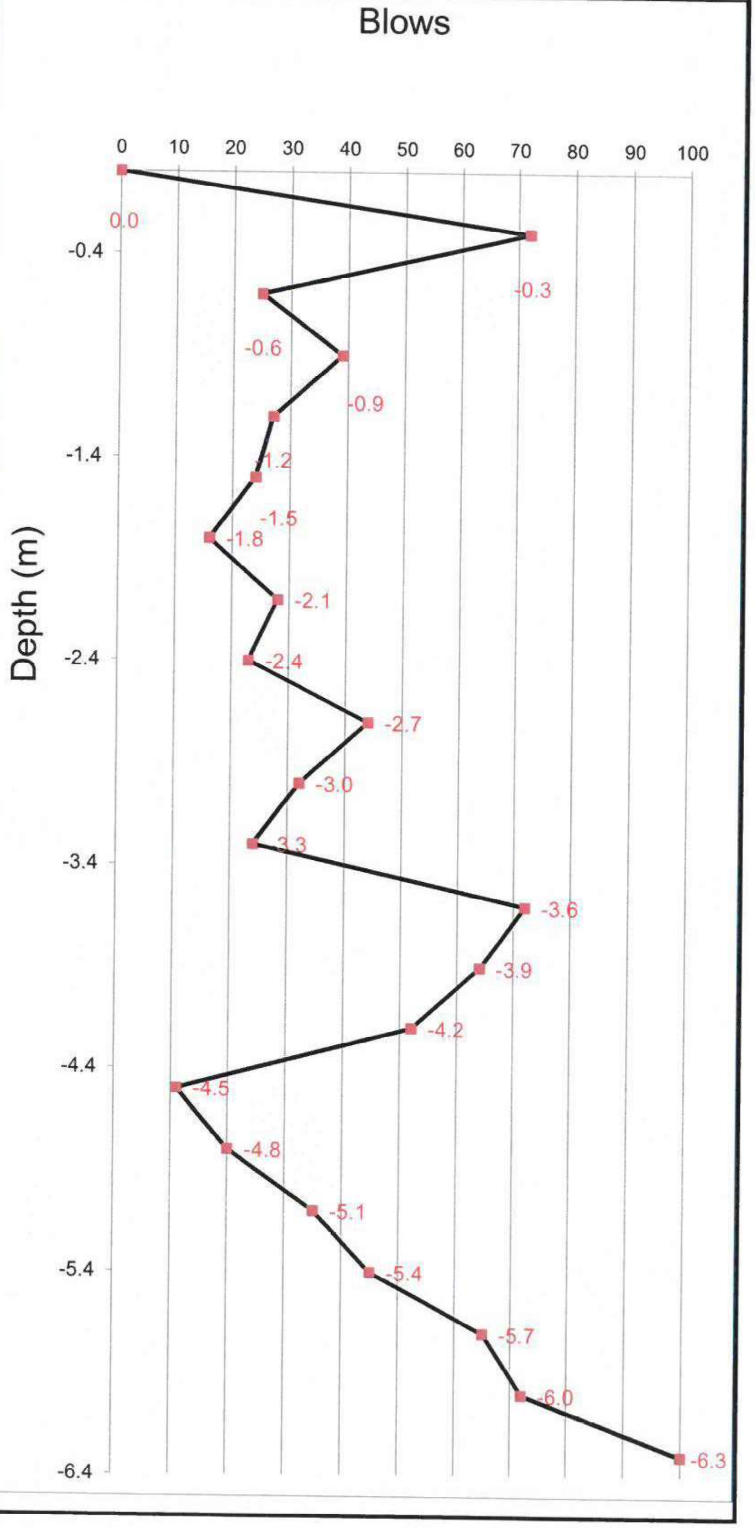
-16.5		-33.9	
-16.8		-34.2	
-17.1		-34.5	



DYNAMIC PROBE SUPER HEAVY (DPSH) TEST RESULT

Client: Aurecon
Project: East London Quay Wall
Cont. No: 109552
Operator: E. Mbhele
Test poition: DPSH 6
Date: 6/19/2013
REFUSAL DEPTH 6.3m

Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	72	-17.7	
-0.6	25	-18.0	
-0.9	39	-18.3	
-1.2	27	-18.6	
-1.5	24	-18.9	
-1.8	16	-19.2	
-2.1	28	-19.5	
-2.4	23	-19.8	
-2.7	44	-20.1	
-3.0	32	-20.4	
-3.3	24	-20.7	
-3.6	72	-21.0	
-3.9	64	-21.3	
-4.2	52	-21.6	
-4.5	11	-21.9	
-4.8	20	-22.2	
-5.1	35	-22.5	
-5.4	45	-22.8	
-5.7	65	-23.1	
-6.0	72	-23.4	
-6.3	100	-23.7	
-6.6		-24.0	
-6.9		-24.3	
-7.2		-24.6	
-7.5		-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
-16.2		-33.6	
-16.5		-33.9	
-16.8		-34.2	
-17.1		-34.5	



DYNAMIC PROBE SUPER HEAVY (DPSH)
TEST RESULT

Client:	Aurecon	Test poition:	DPSH 7
Project:	East London Quay Wall	Date:	7/3/2013
Cont. No:	109552 Operator: E. Mbhele	REFUSAL DEPTH	0.6m

Depth (m)	Number of Blows	Depth (m)	Number of Blows
0.0	0	-17.4	
-0.3	90	-17.7	
-0.6	100	-18.0	
-0.9		-18.3	
-1.2		-18.6	
-1.5		-18.9	
-1.8		-19.2	
-2.1		-19.5	
-2.4		-19.8	
-2.7		-20.1	
-3.0		-20.4	
-3.3		-20.7	
-3.6		-21.0	
-3.9		-21.3	
-4.2		-21.6	
-4.5		-21.9	
-4.8		-22.2	
-5.1		-22.5	
-5.4		-22.8	
-5.7		-23.1	
-6.0		-23.4	
-6.3		-23.7	
-6.6		-24.0	
-6.9		-24.3	
-7.2		-24.6	
-7.5		-24.9	
-7.8		-25.2	
-8.1		-25.5	
-8.4		-25.8	
-8.7		-26.1	
-9.0		-26.4	
-9.3		-26.7	
-9.6		-27.0	
-9.9		-27.3	
-10.2		-27.6	
-10.5		-27.9	
-10.8		-28.2	
-11.1		-28.5	
-11.4		-28.8	
-11.7		-29.1	
-12.0		-29.4	
-12.3		-29.7	
-12.6		-30.0	
-12.9		-30.3	
-13.2		-30.6	
-13.5		-30.9	
-13.8		-31.2	
-14.1		-31.5	
-14.4		-31.8	
-14.7		-32.1	
-15.0		-32.4	
-15.3		-32.7	
-15.6		-33.0	
-15.9		-33.3	
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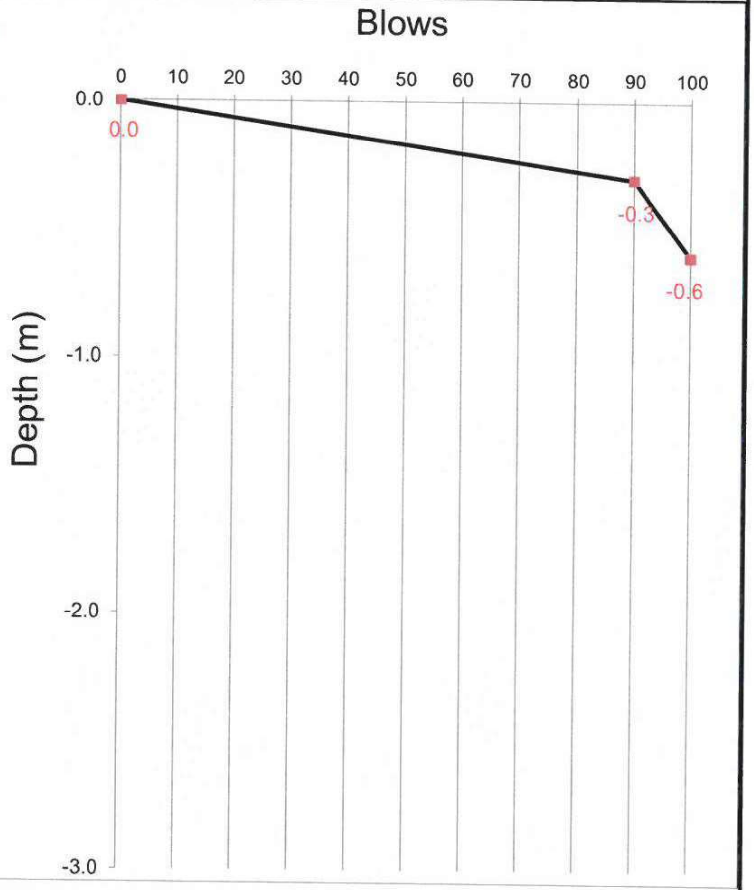
-17.1		-34.5	



VANE SHEAR TEST

VANE LENGTH: 120mm

VANE DIAMETER: 60mm

BH No: 11 **DATE: 21\06\2013**

DEPTH OF VANE: 14.81m

INITIAL TEST

DEGREES	READING	DEGREES	READING	DEGREES	READING
5	13	105	35	205	45
10	15	110	35	210	45
15	17	115	31	215	45
20	18	120	36	220	46
25	20	125	36	225	46
30	21	130	37	230	47
35	23	135	37	235	48
40	24	140	38	240	48
45	25	145	39	245	48
50	26	150	39	250	50
55	27	155	40	255	50
60	28	160	40	260	50
65	29	165	41	265	49
70	30	170	41	270	49
75	30	175	42	275	49
80	31	180	43	280	
85	32	185	44	285	
90	33	190	44	290	
95	34	195	44	295	
100	34	200	44	300	

REMOULDED TEST

5	95
10	20
15	75
20	100
25	120
30	
35	
40	
45	
50	
55	
65	
70	
75	
80	
85	
90	

APPENDIX E
Drawings

LEGEND:
- ⊕ BOREHOLES
- ● DPSH HOLES

LIST OF CO-ORDINATES

POINT	Y	X
DPSH1	-83 833.21	3 655 615.22
DPSH2	-83 817.11	3 655 616.66
DPSH3	-83 798.08	3 655 617.12
DPSH4	-83 792.53	3 655 617.17
DPSH5	-83 784.53	3 655 617.15
DPSH6	-83 766.76	3 655 616.75
BH5	-83 771.16	3 655 601.46
BH6	-83 781.02	3 655 601.70
BH7	-83 799.59	3 655 603.52
BH8	-83 806.80	3 655 602.37
BH9	-83 821.29	3 655 601.38
BH10	-83 825.88	3 655 621.38
BH11	-83 814.47	3 655 623.06
BH12	-83 795.23	3 655 622.45
BH13	-83 787.17	3 655 625.05
BH14	-83 765.02	3 655 625.74
BH15	-83 788.86	3 655 612.53
BH16	-83 809.44	3 655 611.16

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CLIENT

REV	DATE	REVISION DETAILS	APPROVED
0	17/07/13	FOR APPROVAL	A. Schulze-Hulbe

DRAWN: M. Mostert
DESIGNED: K. Magoro
CHECKED: A. Schulze-Hulbe
APPROVED: T.E.B. VORSTER
DATE: 17/07/13

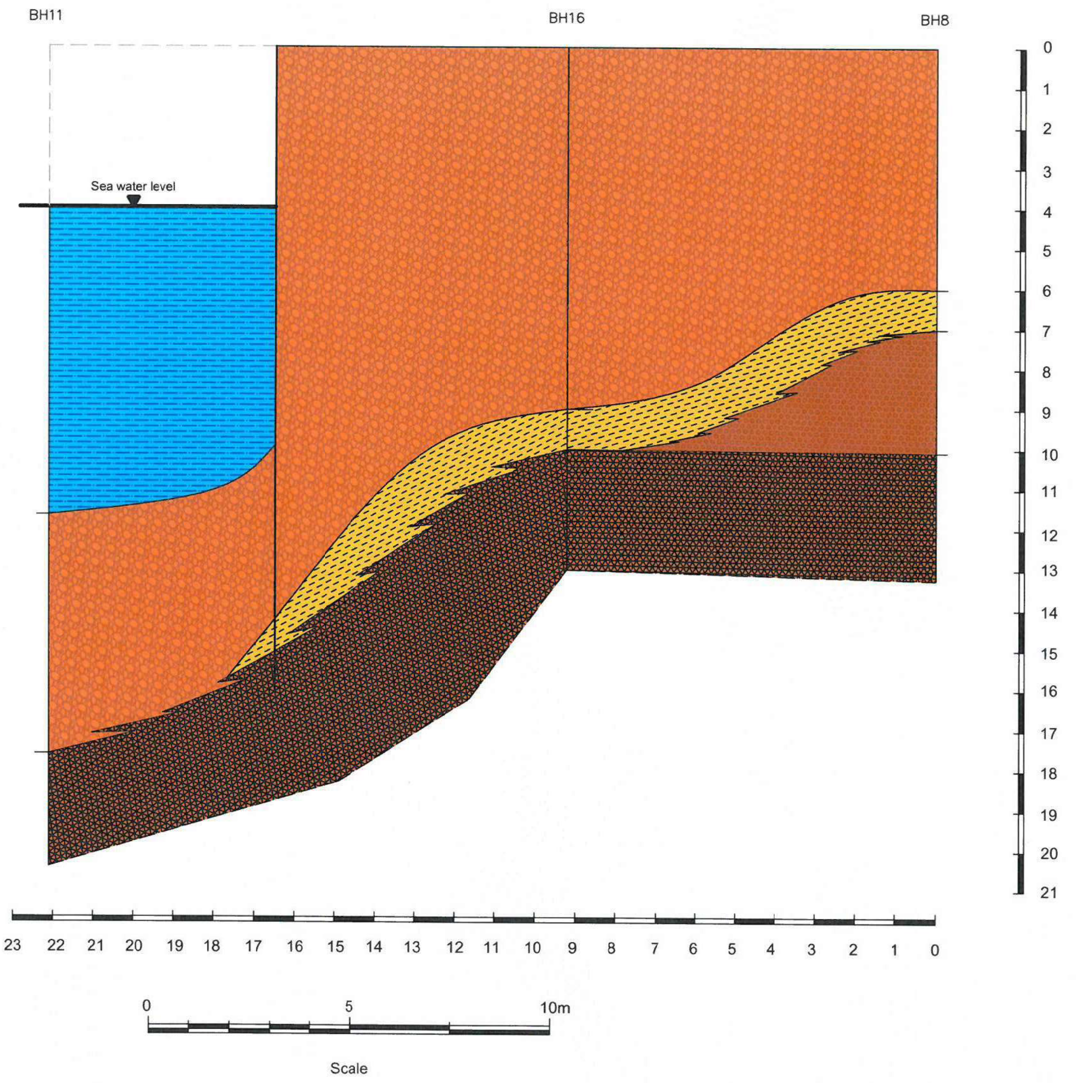
PROJECT
EAST LONDEN QUAY WALL:
GEOTECHNICAL INVESTIGATION

TITLE
BOREHOLE AND DPSH POSITIONS

PRELIMINARY
NOT FOR CONSTRUCTION

PROJECT No.: 109552
SCALE: 1:1000
SIZE: A3
DRAWING No.: 109552-G1-001
REV: 0

00/00/00



LEGEND:

▨	Fill materials, weathered, black grey Hornfels gravel, assumed to be in a sandy clay matrix (washed away)
▨	Sandy clay/ clayey sand with sporadic gravel, brown, Firm to Stiff
▨	Hornfels gravel with cobbles, moderately weathered, black grey
▨	Highly to moderately weathered Hornfels, closely to widely jointed, very fine grained, Hard rock
▨	Sea water
—	Soil/Rock boundary

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CLIENT

REV	DATE	REVISION DETAILS	APPROVED
0	15/08/13	FOR APPROVAL	A. Schulze-Hulbe

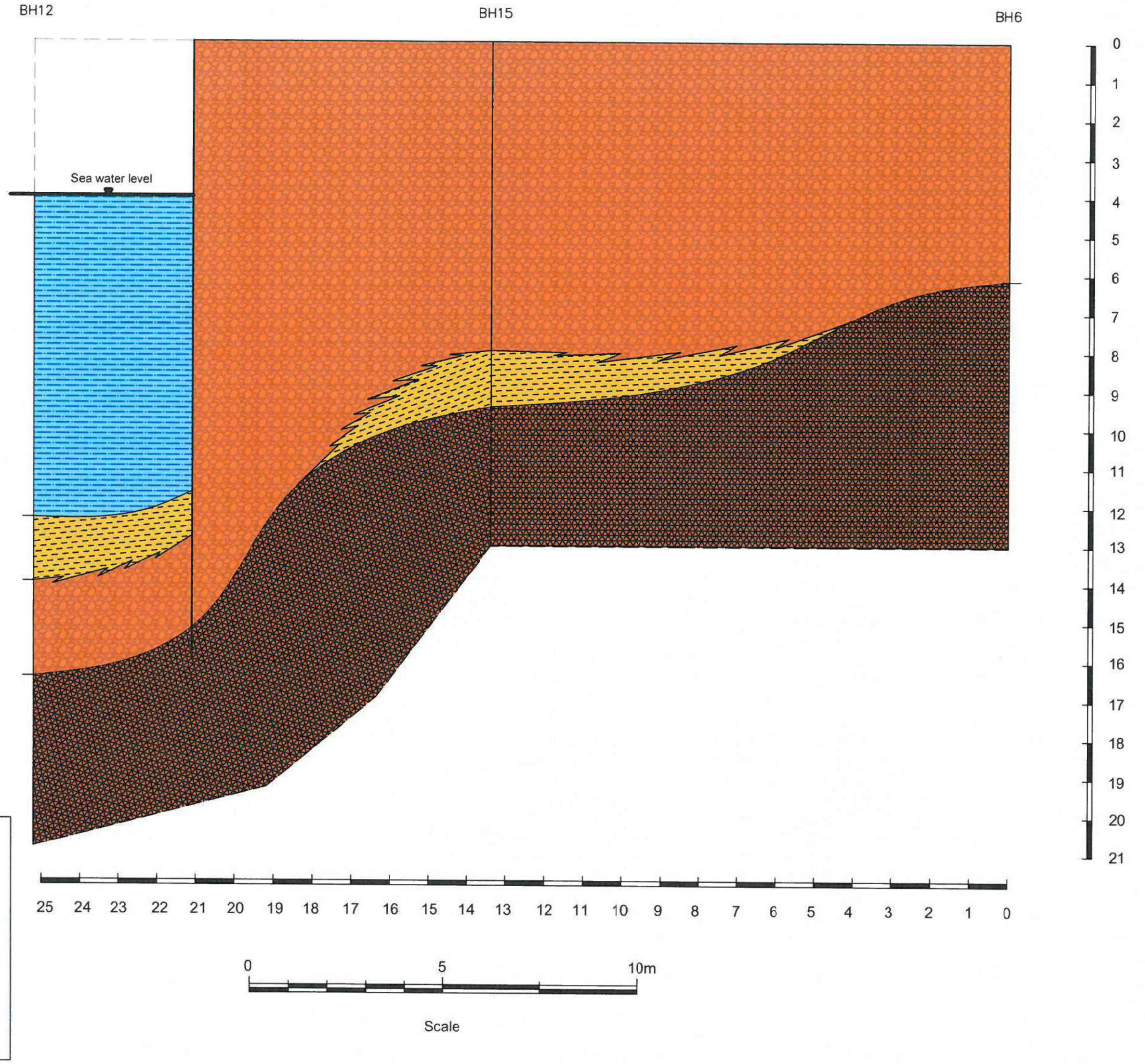
DRAWN: M. Koleini
DESIGNED: M. Koleini
CHECKED: A. Schulze-Hulbe
APPROVED: T.E.B. VORSTER
DATE: 17/07/13

PROJECT
EAST LONDEN QUAY WALL:
GEOTECHNICAL INVESTIGATION

TITLE
GEOLOGICAL CROSS SECTION ALONG BH8, BH16 AND BH11

PRELIMINARY
NOT FOR CONSTRUCTION

PROJECT No.: 109552
SCALE: 1:1500
SIZE: A3
DRAWING No.: 109552-G1-002
REV: 0



LEGEND:

- 🟧 Fill materials, weathered, black grey Hornfels gravel, assumed to be in a sandy clay matrix (washed away)
- 🟨 Sandy clay/ clayey sand with sporadic gravel, brown, 27 Firm to Stiff
- 🟫 Hornfels gravel with cobbles, moderately weathered, black grey
- ▩ Highly to moderately weathered Hornfels, closely to widely jointed, very fine grained, Hard rock
- 🟦 Sea water
- — Soil/Rock boundary

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CLIENT	REV	DATE	REVISION DETAILS	APPROVED
	0	15/08/13	FOR APPROVAL	A. Schulze-Hulbe

DRAWN: M. Koleini
DESIGNED: M. Koleini
CHECKED: A. Schulze-Hulbe
APPROVED: T.E.B. VORSTER
DATE 17/07/13

PROJECT
EAST LONDEN QUAY WALL:
GEOTECHNICAL INVESTIGATION

TITLE
GEOLOGICAL CROSS SECTION ALONG BH6, BH15 AND BH12

PRELIMINARY
NOT FOR CONSTRUCTION
PROJECT No. 109552
SCALE 1:1500
SIZE A3
DRAWING No. 109552-G1-003
REV 0

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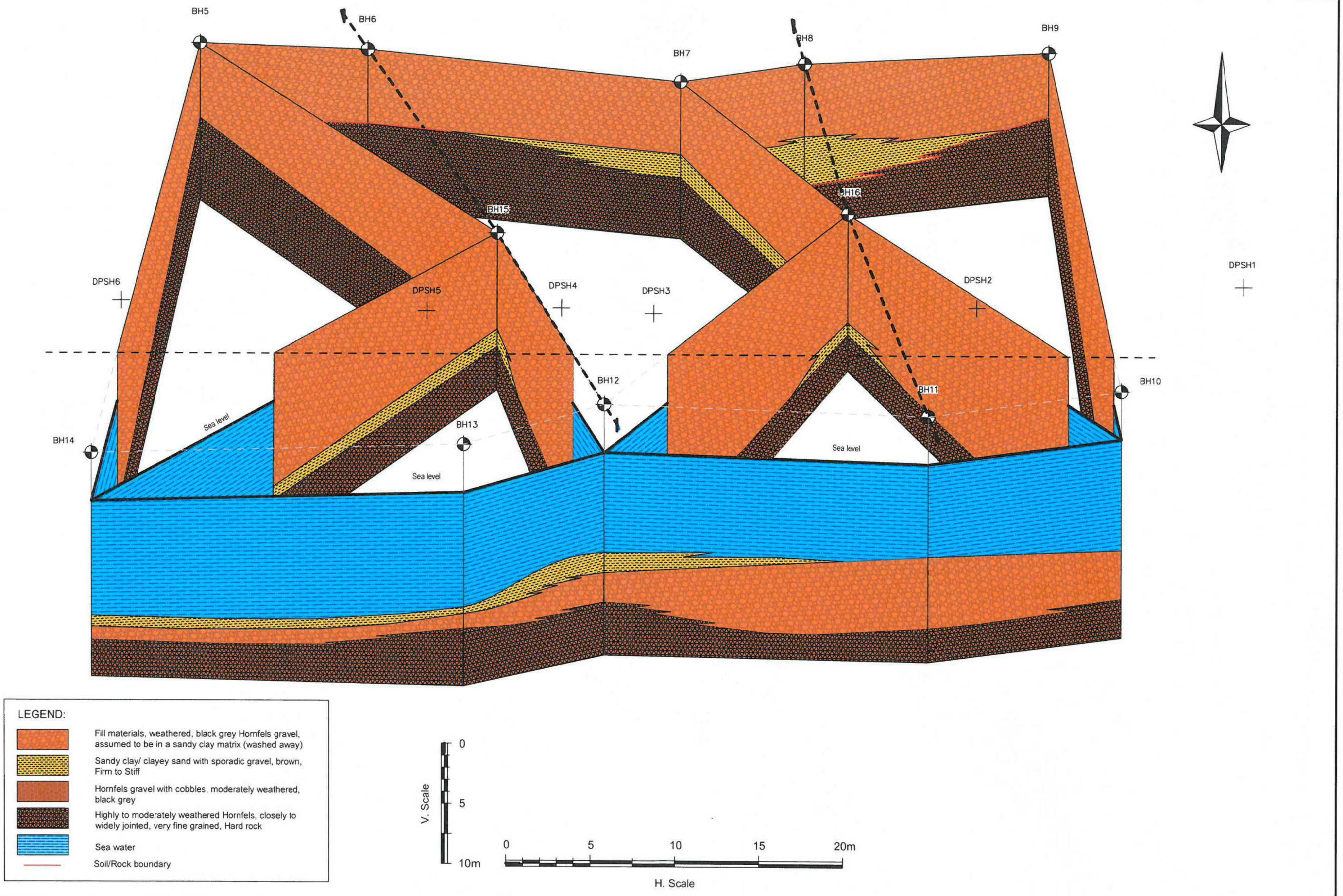

LEGEND:

🟧	Fill materials, weathered, black grey Hornfels gravel, assumed to be in a sandy clay matrix (washed away)
🟨	Sandy clay/ clayey sand with sporadic gravel, brown, Firm to Stiff
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⬛	Highly to moderately weathered Hornfels, closely to widely jointed, very fine grained, Hard rock
🟦	Sea water
—	Soil/Rock boundary

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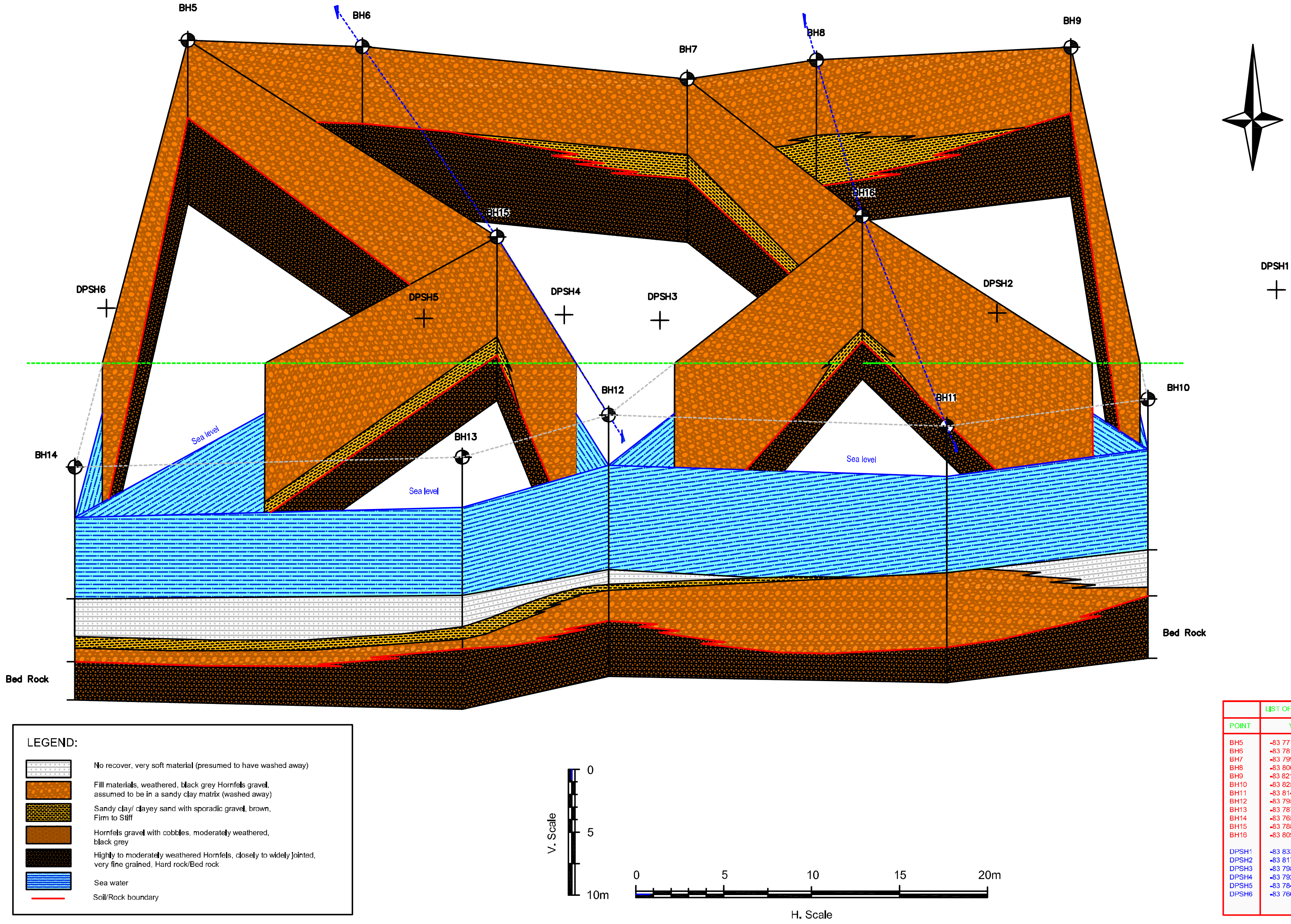
REV	DATE	REVISION DETAILS	APPROVED
0	15/08/13	FOR APPROVAL	A. Schulze-Hulbe

DRAWN: M. Koleini
DESIGNED: M. Koleini
CHECKED: A. Schulze-Hulbe
APPROVED: T.E.B. VORSTER
DATE: 17/07/13

PROJECT: EAST LONDEN QUAY WALL: GEOTECHNICAL INVESTIGATION
TITLE: GEOLOGICAL FENCE MAP

PRELIMINARY
NOT FOR CONSTRUCTION
PROJECT No.: 109552
SCALE: 1:1500
SIZE: A3
DRAWING No.: 109552-G1-004
REV: 0

APPENDIX F
Geological Sections



LEGEND:

- ▨ No recover, very soft material (presumed to have washed away)
- ▨ Fill materials, weathered, black grey Hornfels gravel, assumed to be in a sandy clay matrix (washed away)
- ▨ Sandy clay/ clayey sand with sporadic gravel, brown, Firm to Stiff
- ▨ Hornfels gravel with cobbles, moderately weathered, black grey
- ▨ Highly to moderately weathered Hornfels, closely to widely jointed, very fine grained, Hard rock/Bed rock
- ▨ Sea water
- — Soil/Rock boundary

	LIST OF CO-ORDINATES	
POINT	Y	X
BH5	-83 771.16	3 655 601.46
BH6	-83 781.02	3 655 601.70
BH7	-83 799.59	3 655 603.52
BH8	-83 806.80	3 655 602.37
BH9	-83 821.29	3 655 601.38
BH10	-83 825.88	3 655 621.38
BH11	-83 814.47	3 655 623.06
BH12	-83 795.23	3 655 622.45
BH13	-83 787.17	3 655 625.05
BH14	-83 765.02	3 655 625.74
BH15	-83 788.86	3 655 612.53
BH16	-83 809.44	3 655 611.16
DPSH1	-83 833.21	3 655 615.22
DPSH2	-83 817.11	3 655 616.88
DPSH3	-83 798.08	3 655 617.12
DPSH4	-83 792.53	3 655 601.46
DPSH5	-83 784.53	3 655 617.15
DPSH6	-83 766.76	3 655 616.75

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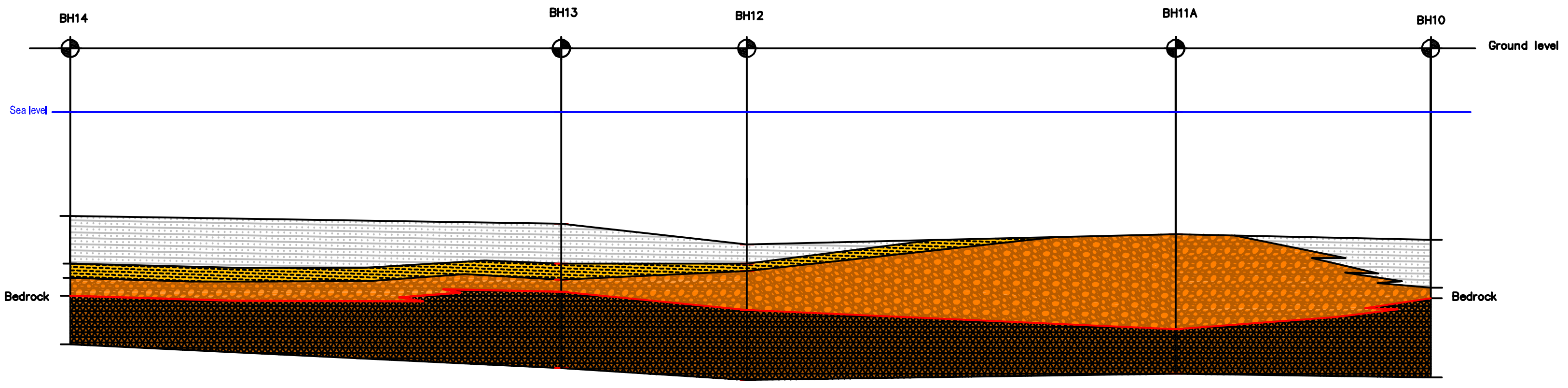
DRAWN
M. Koleini, M. Mostert
DESIGNED
M. Koleini
CHECKED
APPROVED
T.E.B. Vorster
DATE
August 2013

PROJECT
EAST LONDON SHEET PILE WHARF REHAB

TITLE
GEOTECHNICAL SITE INVESTIGATION
GEOLOGICAL FENCE MAP

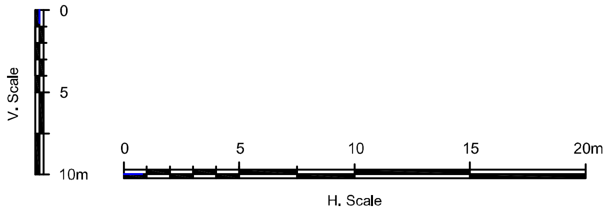
PRELIMINARY
NOT FOR CONSTRUCTION
PROJECT No.
109552
SCALE
SIZE
A0
DRAWING No.
109552-G1-001
REV
A



LEGEND:

▨	No recover, very soft material (presumed to have washed away) (alluvium)
🟧	Fill materials, weathered, black grey Hornfels gravel, assumed to be in a sandy clay matrix (washed away)
🟨	Sandy clay/ clayey sand with sporadic gravel, brown, Firm to Stiff (alluvium)
🟫	Hornfels gravel with cobbles, moderately weathered, black grey
⬛	Highly to moderately weathered Hornfels, closely to widely jointed, very fine grained, Hard rock/Bed rock
🟦	Sea water
—	Soil/Rock boundary

Borehole No.	Alluvium (m) below quay platform level	Fill (m) below quay platform level	Bedrock (m) below quay platform level
BH 14	10.5 - 14.4	14.4 - 15.5	15.5 - 18.55
BH 13	11.0 - 14.5	14.5 - 15.3	15.3 - 20.05
BH 12	12.30 - 13.95	13.95 - 16.4	16.4 - 20.8
BH 11A	11.7 - 17.6	11.7 - 17.6	17.6 - 20.4
BH 10	11.97 - 15.0	15.0 - 15.64	15.64 - 20.64



	LIST OF CO-ORDINATES	
POINT	Y	X
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BH6	-83 781.02	3 655 601.70
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DPSH2	-83 817.11	3 655 616.88
DPSH3	-83 798.08	3 655 617.12
DPSH4	-83 792.53	3 655 601.46
DPSH5	-83 784.53	3 655 617.15
DPSH6	-83 766.76	3 655 616.75

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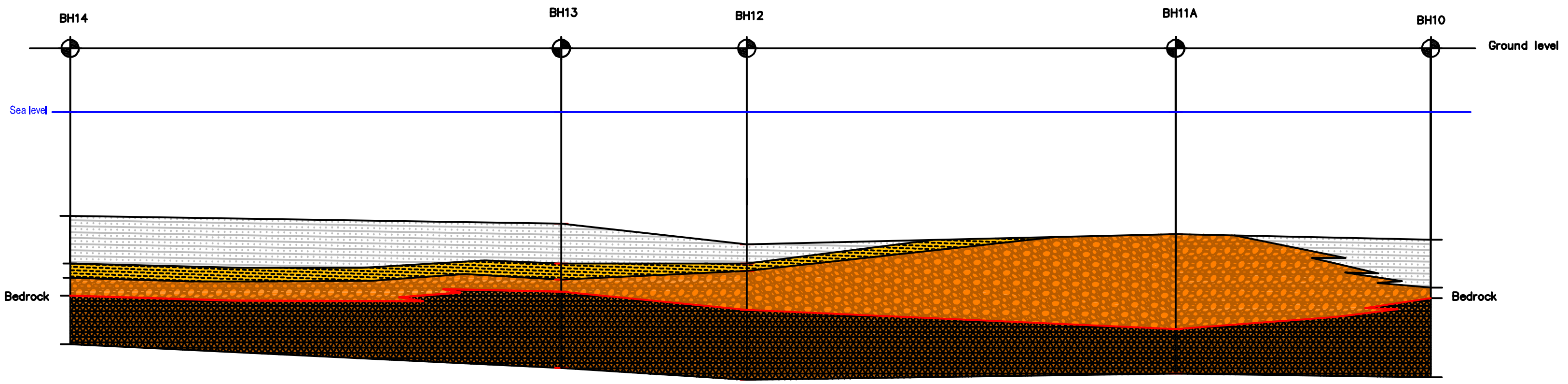
DRAWN: M. Koleini, M. Mostert
DESIGNED: M. Koleini
CHECKED
APPROVED: T.E.B. Vorster
DATE: August 2013

PROJECT: EAST LONDON SHEET PILE WHARF REHAB

TITLE: GEOTECHNICAL SITE INVESTIGATION
GEOLOGICAL FENCE MAP

PRELIMINARY
NOT FOR CONSTRUCTION

PROJECT No.: 109552
SCALE
SIZE: A0
DRAWING No.: 109552-G1-001
REV: A



LEGEND:

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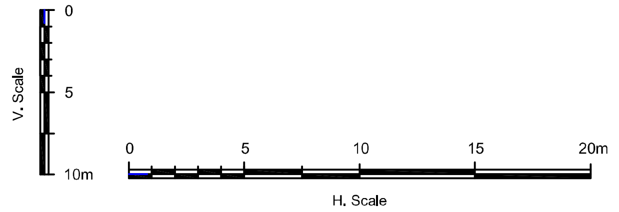
BH 14	10.5 - 14.4	14.4 - 15.5	15.5 - 18.55
BH 13	11.0 - 14.5	14.5 - 15.3	15.3 - 20.05
BH 12	12.30 - 13.95	13.95 - 16.4	16.4 - 20.8
BH 11A	11.7 - 17.6	11.7 - 17.6	17.6 - 20.4
BH 10	11.97 - 15.0	15.0 - 15.64	15.64 - 20.64



	LIST OF CO-ORDINATES	
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DPSH6	-83 766.76	3 655 616.75

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DRAWN: M. Koleini, M. Mostert
DESIGNED: M. Koleini
CHECKED
APPROVED: T.E.B. Vorster
DATE: August 2013

PROJECT: EAST LONDON SHEET PILE WHARF REHAB

TITLE: GEOTECHNICAL SITE INVESTIGATION
GEOLOGICAL FENCE MAP

PRELIMINARY
NOT FOR CONSTRUCTION

PROJECT No.: 109552
SCALE
SIZE: A0
DRAWING No.: 109552-G1-001
REV: A

APPENDIX G
Anchor Analyses

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Project:

East London Quay Wall

East London Quay Wall: Geotechnical Report (Design)

Reference: 109552-G2-00
Prepared for: Mr Lwanda Sidlayi
Revision: 00
16 September 2013

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Document Control Record

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Document control			aurecon
Report Title	East London Quay Wall: Geotechnical Report (Design)		
Prepared For	Transnet National Port Authority		
Client Contact Person	Mr Lwanda Sidlayi	**Tel No.**	078 674 9606
Aurecon Contact Person	Doug Dorren	**Tel No.**	+27 12 427 2000
Aurecon Report No.	8424	**Ground Engineering Document Number**	109552-G2-00

Project Team	
Project Director	Dr T E B Vorster Pr Eng
Senior Geotechnical Engineer	D Dorren Pr Eng
Junior Geotechnical Engineer	Katlego Magoro

Coordinates			
Longitude	27°53'48E	**Latitude**	33° 1'22"S

Key Words			
Anchor	Pre-stressed	Quay wall	Displacements

Location	East London: Latimer's Landing	**Date**	09 December 2013

Approval			
	Compiled by	**Checked by**	**Approved by**
Name	K Magoro	D Dorren Pr Eng	TEB Vorster Pr Eng
Signature			
Date	20 January 2014	20 January 2014	20 January 2014
Revision	**00**		

Contents

Figures

Tables

Background and Summary

Aurecon South Africa (Pty) Ltd was appointed by Transnet National Ports Authority (TNPA) to conduct a geotechnical analysis and design to rehabilitate the existing sheet pile wharf in East London South Africa. The geotechnical analysis and design was carried out following a geotechnical investigation of the study area and a structural analysis of the proposed pile sheet wall.

This report is the first revision of the geotechnical design report and details the findings of the adjusted geotechnical model, in accordance with the revised structural report, and the recommendations for the types of anchors to be used during the construction of the proposed quay wall structure.

The primary objectives of the geotechnical modelling were to:

- Calculate and specify geotechnical material parameters;
- Create a two dimensional (2D) finite element analyses (FEA) model with the various load combinations provided
- Select anchor parameters
- Check the wall deflections
- Check pavement settlements
- Provide final recommendations of the type of anchoring system to be used in construction

Available Information

At the time of developing the geotechnical model the following information was available:

- The factual geotechnical report (109552-G2-00). Titled "East London Quay wall: Geotechnical Report (Factual)" compiled by Aurecon in August 2013.
- The structural design report (109552-SDR-002 Rev 0). Titled "East London Sheet Pile Wall Rehabilitation. Structural Design Report." Compiled by Aurecon in August 2013
- Scaw Metals Group wire and strand approved "stress-strain" test results obtained from Scaw Metals Group

The following documents and codes were referenced for this report:

1. BS 8081:1989, Ground anchorages
2. A Guide to Practical Geotechnical Engineering in Southern Africa. Franki. 4th Edition, 2008.
3. CIRIA Report 143. 1995. The Standard Penetration Test (SPT): methods and use. London. CIRIA.
4. Wyllie DC. 1992. Foundations on Rock. London. Chapman and Hall.
5. Bieniawski, Z.T. (1984), Rock mechanics in mining and tunnelling, A.A. Balkema, Rotterdam/Boston
6. Swiss Norm (or Standard) SN 670 010b (1993). Bodenkennziffern / Coefficients caractéristiques des sols. Translated from German / French: Typical Soil Properties.
7. Read j, Stacey P. 2009. Guidelines for open pit slope design. Netherlands. CSIRO.
8. SAICE Code of Practice for Lateral Support in Surface Excavations. 1989. Geotechnical Division, SAICE.
9. Cobb, F. (2009). Structural Engineer's Pocket Book, Second Edition. London, Butterworth-Heinemann.
10. Software:
    - (a) Plaxis 2D
    - (b) Roclab (RocScience)

3 Units

The following units are applicable to this report:

Description	Unit
Unit weight	Kilo Newton per cubic metre (kN/m3)
Young’s Modulus	Mega Pascal (MPa)
Area (A)	Millimetre squared (mm2)
Moment of Inertia (I)	Millimetre to the forth power (mm4)
Length	Millimetre (mm)
Friction angle	Degrees (°)
Stress	Kilo Pascal (kPa)
Displacement/Deflection	Millimetre (mm)
Cohesion	Kilo Pascal (kPa)
Skin Friction (Sn)	Kilo Newton per metre (kN/m)
Permeability	Metres per day (m/day)

Table 1: Units

4 Material properties

The following material parameters were allocated to the various materials incorporated into the FEA model

Property	Unit	Existing Fill	G5 Fill	Silty Clay	Hornfels Bedrock
Unsaturated unit weight (γ_{unsat})	kN/m^3	19	19	16	22
Saturated unit weight(γ_{sat})	kN/m^3	20	20	18	23
Young's Modulus (E)	MPa	25	30	6	1400
Poisson's Ratio	-	0.3	0.3	0.3	0.2
Cohesion (c')	kPa	0	0	5	447
Friction angle (°)	degrees	35	38	26	52
Permeability (k)	m/day	0.6	0.6	8.6×10^{-4}	8.6×10^{-4}

Table 2: Soil and rock parameters

4.1 Soil and rock material parameters

The fill and silty clay material parameters were obtained from the Swiss standard, 1993 (ref 6) together with a careful consideration of the field test and laboratory test results stipulated in the factual geotechnical report.

The hornfels rock parameters were obtained by using a combination of Roclab (ref 10b) and empirical methods by Bieniawski, Peck and Deere.

In order to determine the rock mass ground modulus, denoted E_{mass}, for the rock profile, the modulus parameters for the rock layer in the ground profile are required. Rock mass moduli for the rock layer within the ground profile were assessed using principles based on Bieniawski (1984) (ref 5) and a representative Unconfined Compressive Strength (UCS) value. Based on the UCS laboratory tests, UCS values of 35MPa for hard rock were assigned. The deformation modulus E_i for intact rock is then calculated using the correlation after Peck (1976) and Deere (1968) (ref 2):

$$\mathrm{E_i} = 200\mathrm{UCS}$$

Where E_i is the Young's modulus for intact rock

UCS is the Unconfined Compressive Strength of rock

To account for the weathered and jointed nature of the rock observed at the sites, a modulus reduction factor (ERM/E_i) was applied to the deformation modulus determined for intact rock (Ei) as shown in the following equation:

$$\mathrm{E_{RM}} = \text{Modulus reduction factor}.\,\mathrm{E_i}$$

Where: E_{RM} is the Young's modulus for the rock accounting for effects of jointing etc.

Using the RQD value, the modulus reduction factor was determined using Bieniawski's (1984) principles (ref 5). However for this application, the maximum modulus reduction factor was capped at 0.2 for low RQD values. Using this procedure, Young's Modulus (E) values for the rock layer in the ground profile was determined.

4.2 Wall and Anchor material parameters

The following properties were assigned to the wall and anchor elements:

Table 3: Wall and anchor material properties

Property	Unit	Steel Wall	Steel Anchors	Grout
Young's Modulus (E)	MPa	200 000	190 000	30 000
Area (A)	mm^2/m	30.6×10^3	750	31.4 x 103
Moment of Inertia (I)	mm^4/m	2846.4×10^6	-	78.54
EA (wall)	kN/m	6.12×10^6	-	-
EA (anchor)	kN	-	142.5×10^3	-
EI (wall)	$kN.m^2/m$	569.3×10^3	-	-
Mass (m)	kg/m	600.8	-	-
Unit weight (w)	kN/m/m	2.4	-	-
Unit weight (w)	kN/m^3	-	-	24
Poisson's Ratio	-	0.3	-	-
Diameter (D)	mm	-	5 x 15.7mm	200

Property	Unit	Steel Wall	Steel Anchors	Grout
			strands	
Skin Friction (S_n)	kN/m	-	-	733
Maximum tension force (F_{max})	kN	-	1165	-

The wall parameters were obtained from the structural engineer for the chosen sheet piles detailed in the structural design report (109552-SDR-002 Rev 0). Figure 1 below shows a section through the sheet pile wall

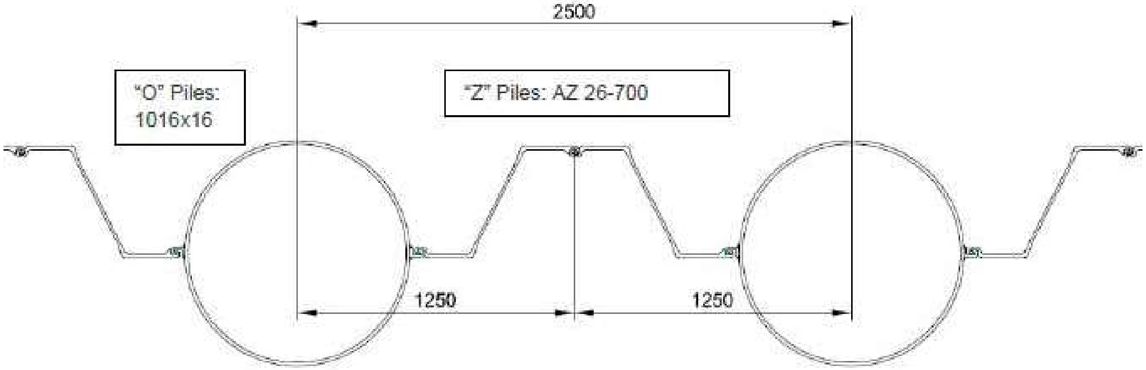


Figure 1: Plan view section of proposed wall solution

The wall consists of two circular-piles (O piles) spaced 2.5m apart and with two Z-profile piles (Z piles) between the O-piles. The parameters of the wall are as follows:

O Pile: A = 50.3x103 mm^2.
I = 6280x106 mm^4.
M = 395 kg/m

Pile: A = 13.1x103 mm2.
I = 418x106 mm4.
M = 102.9 kg/m

Where:
A = Cross sectional area
I = Moment of Inertia

In each 2.5m segment the "system" consists of one O pile and Z piles:

Isys = 6280 + 2x418 = 7116 x10^6 mm^4.

Asys = 50.3 + 2x13.1 = 76.5 x10^3 mm^2.

Where:

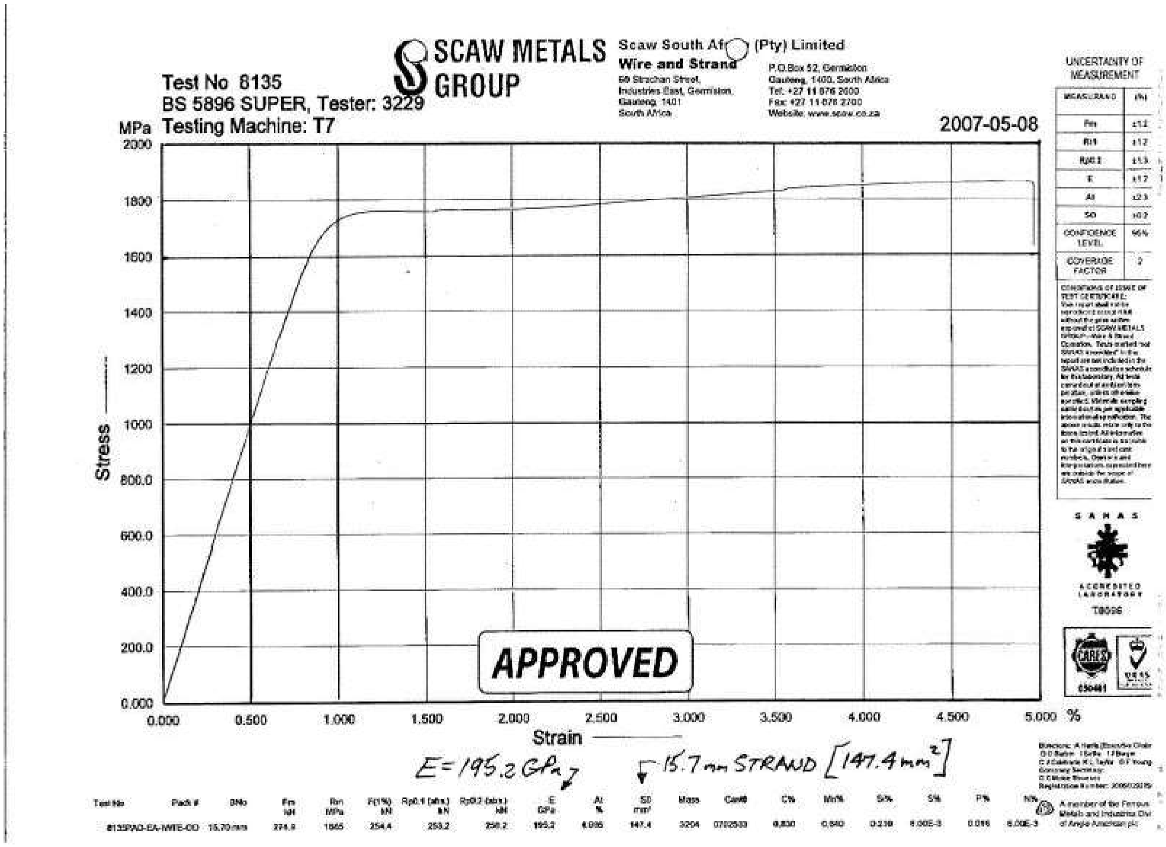
Isys = Moment of Inertia of the system

Asys = Area of the system

The type of anchor to be used was chosen from BS 8081: 1989 (ref 1) and the Scaw Metals Group approved test (Figure 2). Five 15.7 mm nominal diameter strands were chosen for the design. Table 4 below shows the material properties for these anchor strands. Figure 2 shows the approved Stress/Strain curve for the particular strand chosen for the design.

Table 4: Material specifications for strand anchors

Anchor type (nominal diameter)	Strand area (mm^2)	Ultimate Tensile Load (kN)	Yield Load (kN)	Elastic Modulus (GPa)
15.7mm	150	265	233	190



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Website: www.scaw.co.za

Test No 8135
BS 5896 SUPER, Tester: 3229
Testing Machine: T7

2007-05-08

UNCERTAINTY OF MEASUREMENT

MEASURAND	(%)
Fm	±1.1
Rt1	±1.2
Rp0.2	±1.5
E	±1.7
At	±2.3
S0	±0.2
CONFIDENCE LEVEL	95%
COVERAGE FACTOR	2

E=195.2 GPa

15.7mm STRAND [147.4mm²]

Test No	Pack #	BNo	Fm kN	Rm MPa	F(1%) kN	Rp0.1 (abs.) kN	Rp0.2 (abs.) kN	E GPa	At %	S0 mm²	Mass	Cast#	C%	Mn%	Si%	S%	P%	N%
8135PAO-EA-WTE-OD	15.70 mm		274.9	1865	254.4	253.2	250.2	195.2	4.036	147.4	3204	0702533	0.830	0.840	0.230	8.00E-3	0.016	6.00E-3

A member of the Ferrous Metals and Industries Div of Anglo American plc

Figure 2: Approved Stress/Strain test for 15.7mm strand

The combination of five 15.7mm strands gave the anchor tensile load properties shown in Table 3.

The grouting properties were specified according to BS 8081: 1989 (ref 1). A 200mm diameter grout hole was chosen with a fixed length of 5m into the hornfels Bedrock. The Type A tensioned anchor system specified is a straight shafted anchor of five 15.7mm strands each a diameter of 150mm^2. The anchors are gravity grouted into boreholes which maybe lined, depending on hole stability. This type of anchor is commonly installed in rock and very stiff cohesive deposits. Pull-out resistance is generally dependent on the shear resistance at the ground/grout interface. The shear strength of the grout/tendon interface is usually greater than the ground/grout interface (SAICE code of practice, 1989. Ref 8). The design skin friction (Su) between the grouting and the rock was determined using the formula in BS 8081:1989 (ref 1):

$$T_f = \pi D L \tau_{ult}$$

$T_f = Pull\ out\ capacity$

$D = Diameter$

$L = Fixed\ Length$

$\tau_{ult} = Ultimate\ skin\ friction$

The code further states that the ultimate skin friction maybe taken as 10% of the UCS of the rock up to a maximum value of 4MPa. Therefore:

$$T_f = \pi \times 200 \times 5000 \times 3.5 = 10995.6\ kN$$

$$T_f = \frac{10995.6}{5} = 2199\ kN/m$$

With a factor of safety of 3

$$S_u = \frac{2199}{3} = 733\ kN/m$$

The elastic modulus of grout is estimated from a specified grout UCS of 40 MPa (BS 8081:1989, ref 1). Using the following correlation by Cobb, 2009 (ref 9) for concrete stiffness:

$$E = 4700 \times \sqrt{ucs} = 30\ 000\ MPa$$

A 40MPa 28 day cube strength grout is therefore specified.

5 Design Assumptions

The following assumptions were made when creating the 2D FEA model using Plaxis 2D (ref 10a):

- The material model Mohr-Coloumb was used for the G5 fill material, existing fill material, silty clay material and hornfels bedrock
- The wall was modelled as a plate with the given stiffness characteristics
- The anchors were modelled as node to node anchors with the given stiffness and strength value and pretension to a specified force
- The grout was modelled as an embedded concrete pile connected to the node to node anchor
- The worst case water table was modelled as being -4.5m (from the top of the wall) in front of the wall and -4m (from the top of the wall) at the back of the wall giving a head difference of 0.5m
- The wall was embedded 2m into the rock
- Anchors were installed at the top of the wall at an inclination of 30° from the horizontal
- Anchors tensioned to 34% of the yield strength (160kN/m)
- A 20kPa surcharge load was applied at the top of the wall
- 60kN/m horizontal berthing force was applied to the side of the wall, 3m below the wall
- 30kN/m horizontal mooring force was applied at the top of the wall
- Horizontal distributed load, from the backfill behind the new wall before the anchors are tensioned, applied to the wall: increasing from 0kPa to 30kPa from 8m above the base of the wall to the base of the wall
- The loads used were specified by the structural engineer as detailed in the Structural design report

6 Model Results

A Plaxis 2D model of the wall was created to model the behaviour of the wall and backfill materials. The five load cases considered were:

- Load case 1: Distributed load, increasing from 0kPa to 30kPa from 8m above the base of the wall to the base of the wall. Embedded 2m into the founding rock (without anchors).
- Load case 2: Distributed load, increasing from 0kPa to 30kPa from 8m above the base of the wall to the base of the wall. Embedded 4m into the founding rock (without anchors).
- Load case 3: 20kPa UDL load on top of the fill material.
- Load case 4: 20kPa UDL + 60kN/m berthing force on the wall
- Load case 5: 20kPa UDL + 30kN/m mooring force on the wall

Figure 3 and Figure 4 below shows the Plaxis 2D model of the wall with anchors installed and the "cantilever" wall before anchors are installed. The results of each load case are shown in the subsections that follow.

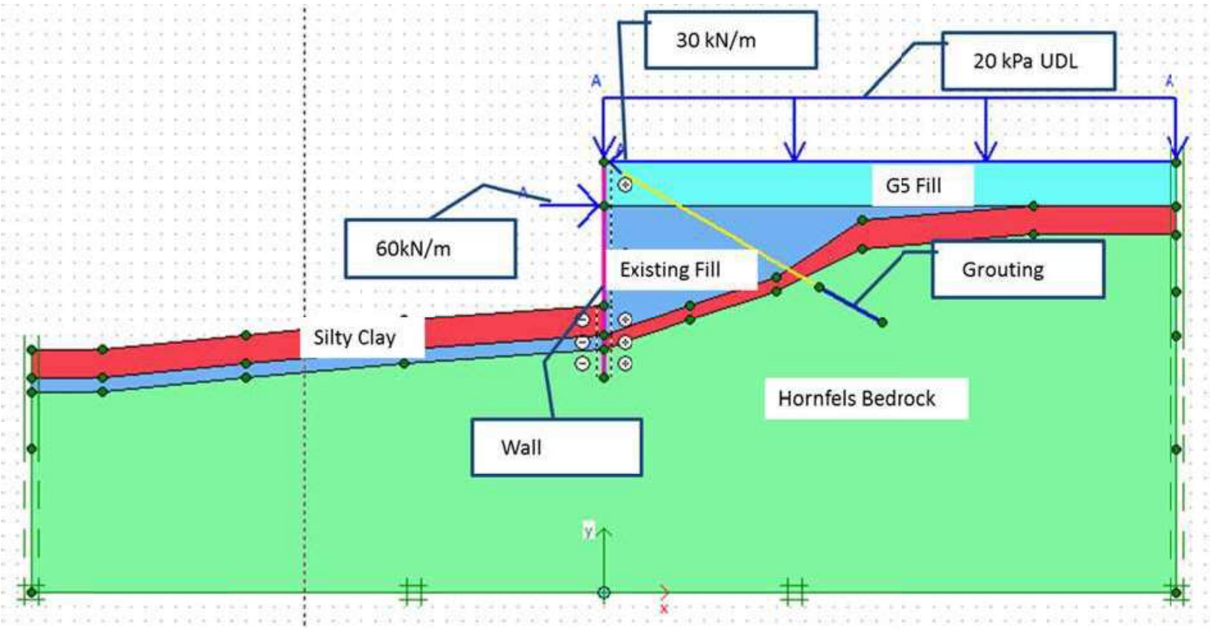

Figure 3: Plaxis 2D model of wall with anchors

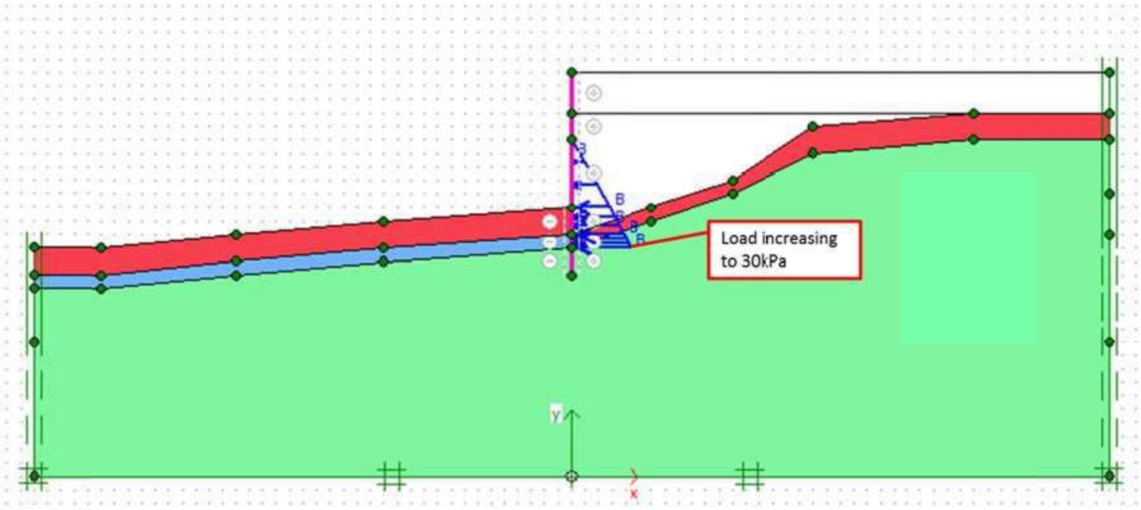

Figure 4: Plaxis 2D model of wall without anchors

6.1 Load Case 1

Distributed load: increasing from 0kPa to 30kPa from 8m above the base of the wall to the base of the wall. Embedded 2m into the founding rock (without anchors).

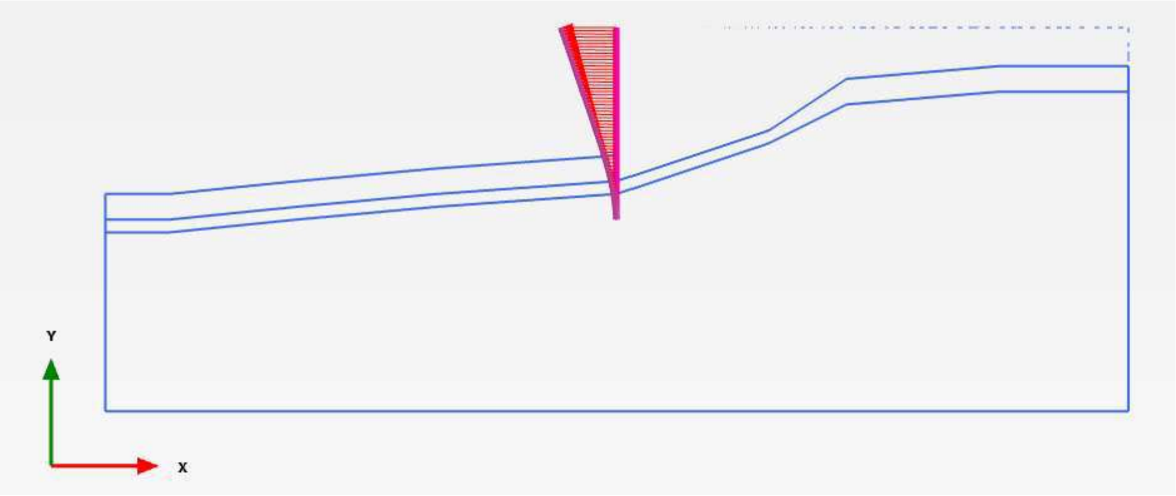

Figure 5:LC1- Horizontal wall displacements

Total maximum horizontal displacements = 44mm

6.2 Load Case 2

Distributed load: increasing from 0kPa to 30kPa from 8m above the base of the wall to the base of the wall. Embedded 4m into the founding rock (without anchors).

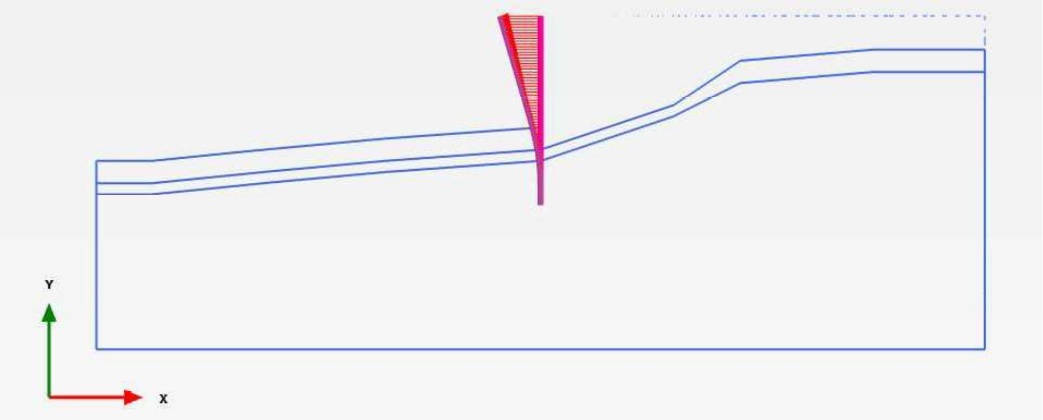

Figure 6: LC2- horizontal wall displacements

Total maximum horizontal displacements = 37mm

From the above model results it seems like the wall would be able to stand as a cantilever with the 2m socket when considering stability and equilibrium. The deflection of the wall at 2m wall socket is 43mm. From the sensitivity analysis the deflections are dependent on the socket length only to about 4m, from that point the deflections are solely dependent the stiffness of the wall.

6.3 Load Case 3

20kPa UDL load on top of the fill material.

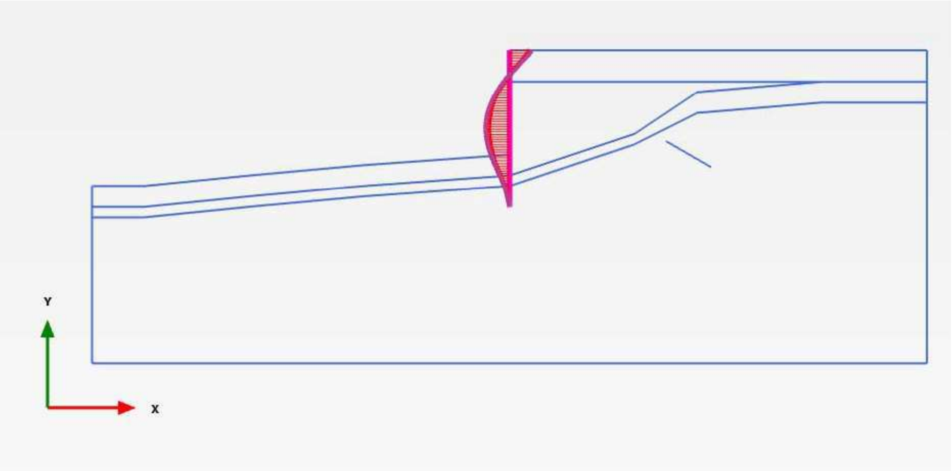

Figure 7: LC3- Horizontal wall displacements

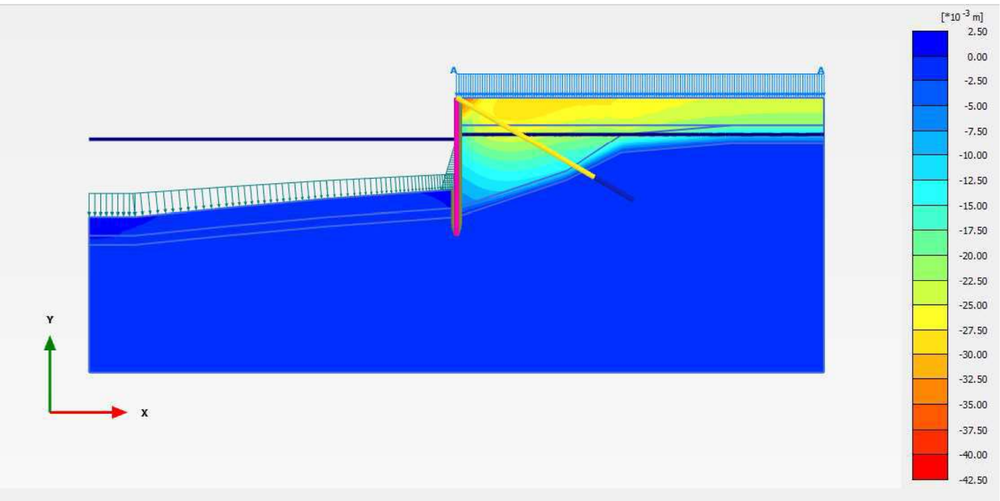

Figure 8: LC3- Vertical pavement settlements

The results obtained from the analyses can be summarised as follows:

- **Total maximum horizontal displacements = 11mm**
- **Total maximum horizontal displacements without 20kPa UDL = 23mm**
- **Maximum vertical settlements = 41mm (at the point where the wall displaces)**
- **Maximum bending moment = 557 kN.m/m**
- **Maximum shear force = 267 kN/m**

6.4 Load Case 4

20kPa UDL + 60kN/m berthing force on the wall

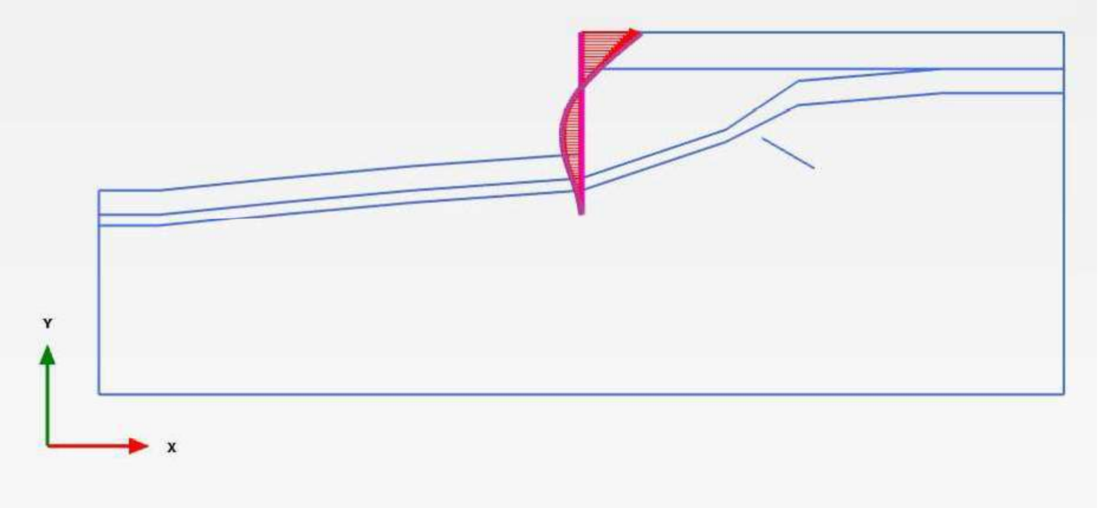

Figure 9: LC4- Horizontal wall displacements

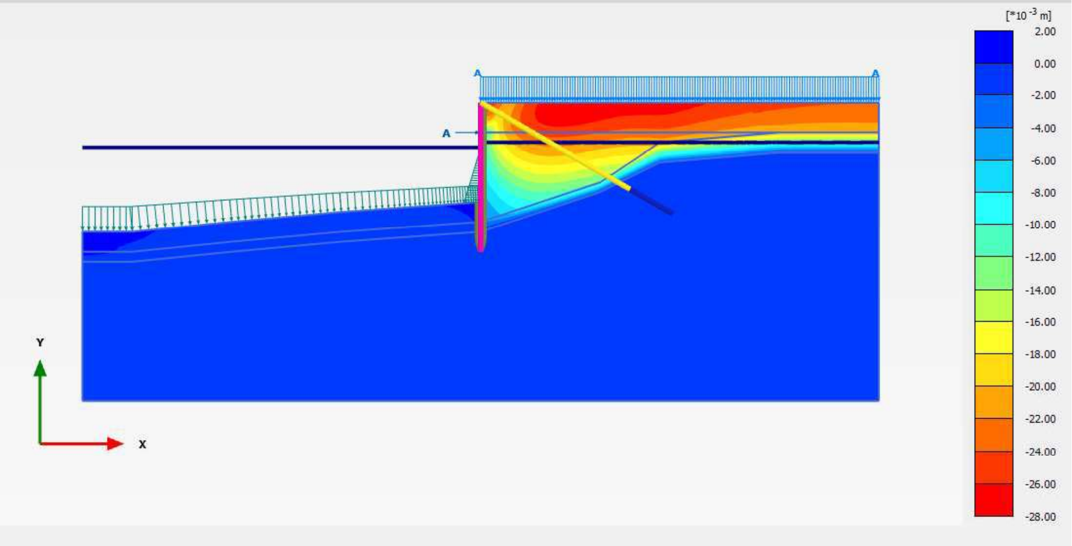

Figure 10: LC4- vertical pavement settlements

The results obtained from the analyses can be summarised as follows:

- **Total maximum horizontal displacements = 25mm**
- **Maximum vertical settlements = 28mm**
- **Maximum bending moment = 651kN.m/m**
- **Maximum shear force = 270 kN/m**

6.5 Load Case 5

20kPa UDL + 30kN/m mooring force on the wall

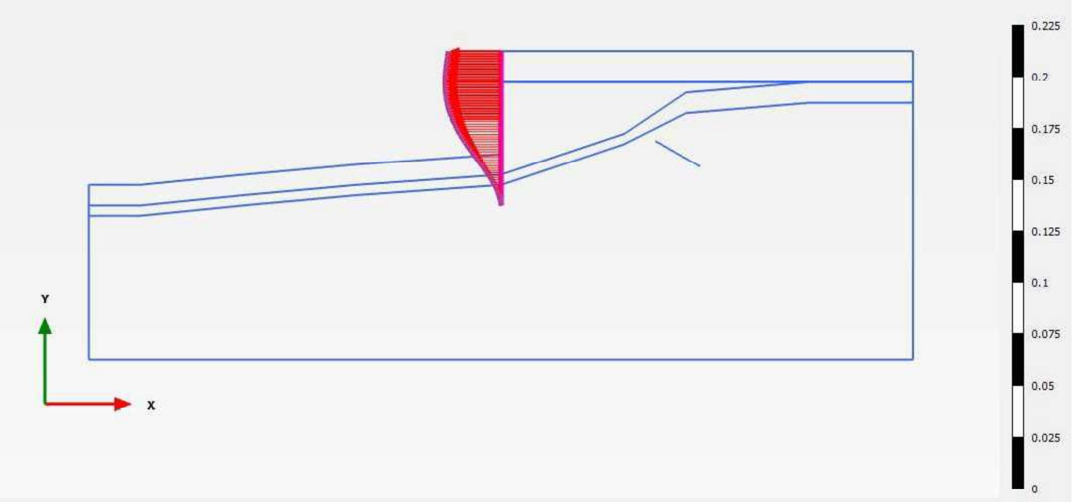

Figure 11: LC5- Horizontal wall displacements

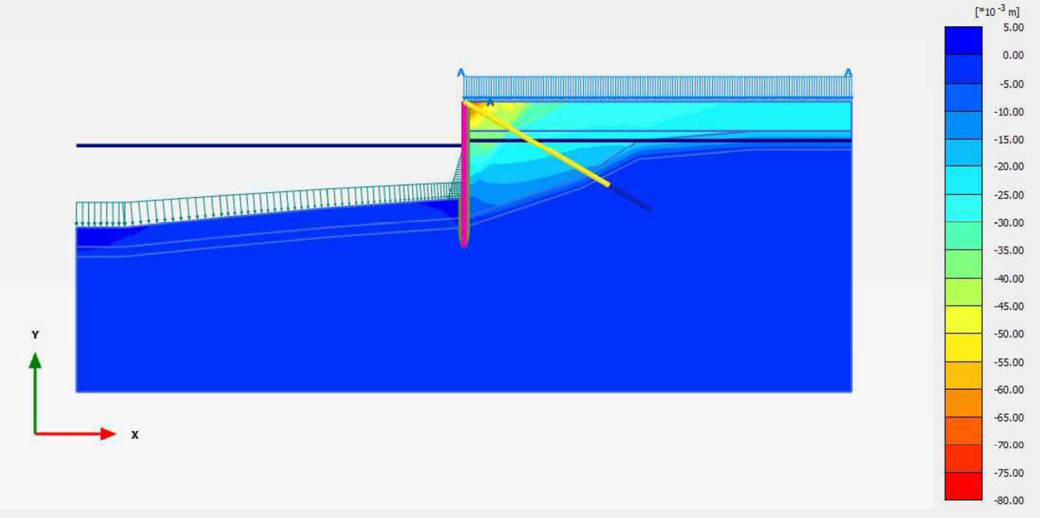

Figure 12: LC5- vertical pavement settlements

The results obtained from the analyses can be summarised as follows:

- **Total maximum horizontal displacements = 27mm**
- **Maximum vertical settlements = 78mm (at the point where the wall displaces)**
- **Maximum bending moment = 547N.m/m**
- **Maximum shear force = 329kN/m**

7 Recommendations

The following anchor specifications and fill material are recommended:

7.1 Anchors

- Type A anchor system is recommended. The Type A tensioned anchor system specified is a straight shafted anchor. The anchors are gravity grouted into boreholes which maybe lined, depending on hole stability. This type of anchor is commonly installed in rock and very stiff cohesive deposits. Pull-out resistance is generally dependent on the shear resistance at the ground/grout interface. The shear strength of the grout/tendon interface is usually greater than the ground/grout interface (SAICE code of practice, 1989. Ref 8).
- Five 15.7mm strands are recommended for the anchors. Each strand should have an ultimate tensile strength of at least 265kN and yield strength of 233kN.
- The young's modulus of each strand should be 190 000 MPa.
- The anchors should be spaced at 2.5m centres (at every O-pile in accordance with the structural design).
- The anchors should be installed at the top of the O-pile at an angle of 30° from the horizontal.
- The fixed length of each anchor should be 5m into solid competent rock (hard rock hornfels, unweathered to slightly weathered).
- The fixed length should be grouted with a grout stiffness of 40MPa cube strength.
- The free length of the anchors cannot be specified without the knowledge of the exact point where competent rock will be found. The fixed length should, however, be approximately 17m long.
- Each anchor should be prestressed to 400kN. This is 34% of the anchor yield strength. The factor of safety is 2.9.
- The anchor strands should be locked off using an anchor head with a bearing plate capable of sustaining twice the working load (2650kN). The strands must be re-stressable and should be protected with a painted removable steel cap filled with anti-corrosion grease. See Figure 10 below for typical detail for re-stressable permanent strand anchors.

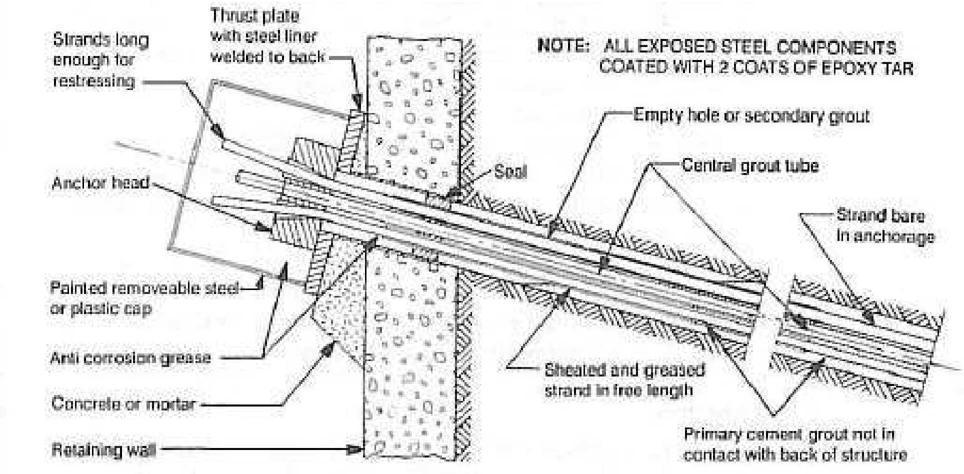

Figure 13: Typical detail for restressable permanent strand anchors (SAICE code of practice, ref 8)

7.2 Corrosion protection

- For the fixed length of the anchor corrugated sheathing is recommended to protect against corrosion. The corrugated sheath should be of high density polyethylene or polypropylene with a minimum wall thickness of 1mm. The annulus between the tendon and the corrugated sheathing should be filled with a cement grout.
- The free length of the anchor should be sheathed with a high density polyethylene or polypropylene sheath with a minimum wall thickness of 1mm and should be applied under factory conditions. The annulus between the tendon and the sheathing should be completely filled with a grease, resin or cementitious material.
- The anchor head should be covered with a cap filled with grease

7.3 Backfill material

The top 3m of the existing fill material must be replaced with a G5 material compacted at 95% Mod AASHTO density. The detailed pavement design was not available at the time of compiling this report. The pavement design will not have a significant influence on the model and the results as shown in this report. A design check, however, will be done once the pavement design is available.

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