Urban Land Development Authority

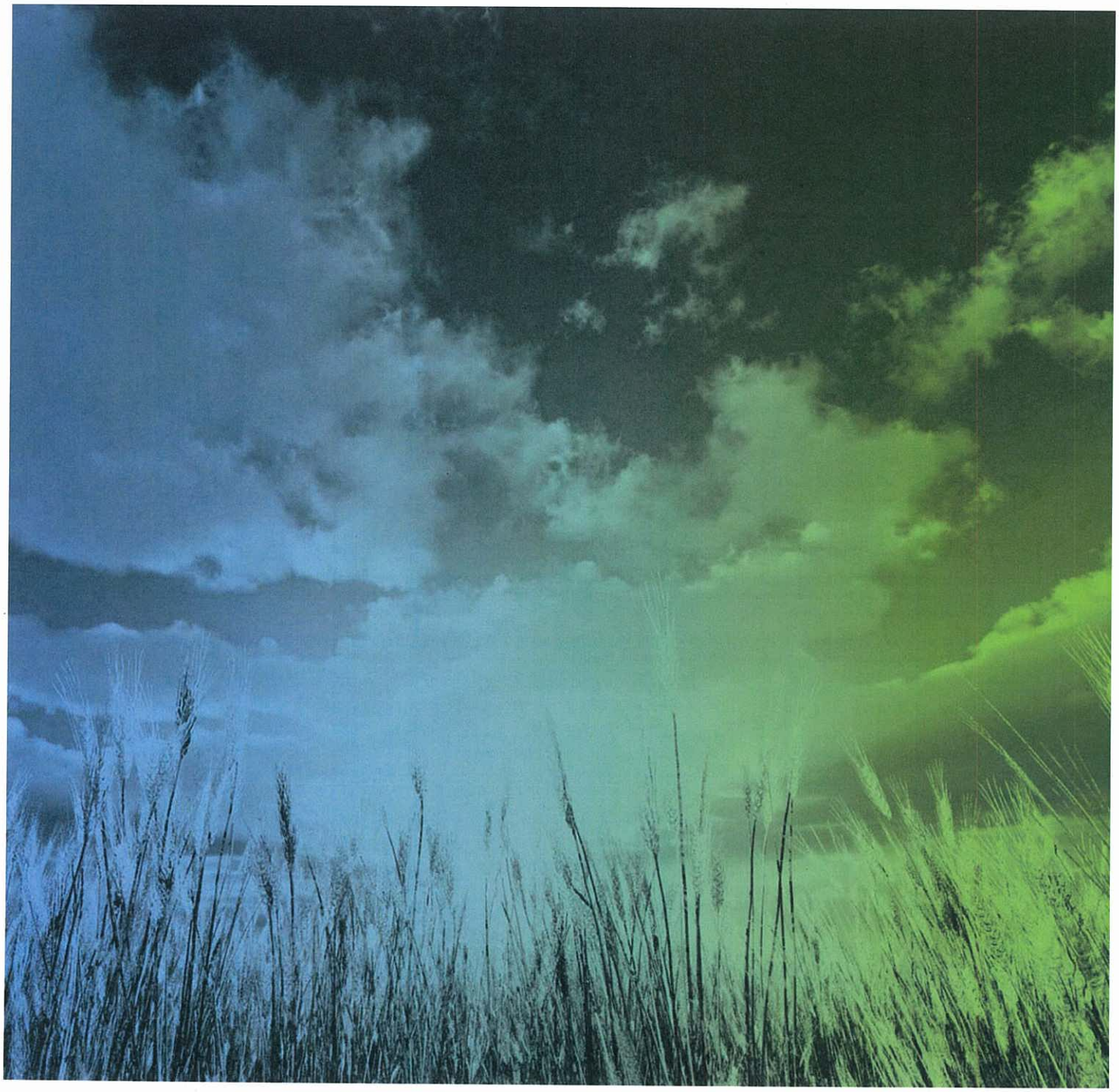
16 July2010

Document No. 60158509

AECOM

Oonoonba Site

Geotechnical Assessment of Land Suitability for Residential Development



Oonoonba Site

Geotechnical Assessment of Land Suitability for Residential Development

Prepared for

Urban Land Development Authority

Prepared by

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16 July2010

60158509

Quality Information

Document Oonoonba Site

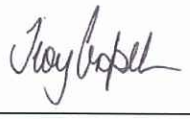
Ref 60158509

Date 16 July2010

Prepared by Michael Matheson

Reviewed by Markham Parker

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	04-Jun-2010	Final Copy	Troy Craperi Principal Engineer - Civil Infrastructure	Original previous signed
B	16-Jul-2010	Revised Final Copy	Troy Craperi Principal Engineer - Civil Infrastructure	

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1.0 Introduction

Figure 1 (in Appendix A) shows the location and extent of a parcel of land fronting Ross River in the suburb of Oonoonba in Townsville, which is the subject of an assessment to ascertain its suitability for residential development. For over 60 years, this site has operated as an animal research station and administrative centre for the DPI. As depicted in Figure 1, the block of land has been sub-divided into two study zones, referred to as Area 1 and Area 2.

This report contains the results of a geotechnical evaluation of Area 1 & 2, to establish the suitability of the two areas for sub-division development for residential housing. In the context of this report, the geotechnical assessment of suitability focuses on the following key issues:

- Whether excessive ground settlement would occur for residential buildings
- Do the natural soils provide adequate bearing capacity for building foundations
- Will the reactivity properties of the subsoils excessive, impacting the design of building foundations
- Whether the natural subsoil conditions pose any difficulties for earthworks operations, e.g.: is there a shallow water table level; are the natural subsoils unsuitable for use as fill once excavated; and are trench excavations for services and foundations likely to collapse.

The philosophy has been to establish how geotechnical conditions compare to those that would be considered typical in the region and whether the conditions would warrant "special" treatment or "special" foundation design. Australian Standard AS 2870 – Residential Slabs and Footings – Construction, provides clear guidelines on conditions considered suitable for residential building sites.

Code AS2870 stipulates that residential sites must be assigned a classification. Table 1 summarises these standard classifications.

Table 1 Site Classifications as per AS2870

Class	Description
A	Stable Conditions
S	Slightly Reactive Clay Sites
M	Moderately Reactive Clay Sites
H	Highly Reactive Clay Sites
E	Extremely Reactive Clay Sites
P	Problem Sites, e.g. soft soils, loose sands, collapsing soils, deep uncontrolled fill

In the local region, Site Classifications are mostly "S", "M" or "H", and as such the building foundation requirements for these classifications could be considered "normal". Where sites are classified "E" or "P", means that either ground treatment is necessary or special foundation strengthening is required, which adds a significant increase to the cost of residential construction.

Consequently, in this report the assessment has been undertaken to establish whether Areas 1 and 2 would be classed as either "S", "M" or "H" (indicating development requires no special treatment or special foundations), or whether an "E" or a "P" classification is appropriate (indicating special treatment works or special foundations would be necessary). In the latter case, the value of the land for residential sub-division is reduced, if compared to the value of alternative land sites in the region where sites would be typically classified "S", "M" or "H".

Development of a site also requires a degree of earthworks to provide acceptable flood immunity levels and to provide grade to aid drainage. In examining the extent of earthworks necessary to complete development of Areas 1 & 2, it has been assumed that the finished ground level would need to be a minimum of about RL 4.0 m.

2.0 Site Investigation

Geotechnical investigations were integrated with the environmental (contamination, UXO and Acid Sulphate Soils) investigations, for efficiency and economy. The environmental assessment assigned a total of 39 test locations where backhoe pits were carried out to establish ground profile and allow subsoil sampling. Figure 2 identifies the location of all 39 test points.

To supplement the information recorded in the environmental test holes, geotechnical investigation was performed at selected environmental test points. In Area 1 four tests sites were chosen for geotechnical logging, sampling and Dynamic Cone Penetromenter (DCP) testing, whilst a further seven locations were chosen for Cone Penetrometer Testing (CPT). A similar number of investigation locations were spread across Area 2. Table 2 lists the Environmental Test Sites where geotechnical investigations were performed.

Table 2 Geotechnical Investigation Locations

Area	Environmental Test Sites	
	Geotechnical Logging, Sampling & DCP Testing	CPT's
1	8, 12, 15, 17	6, 10, 13, 15, 18, 22, 27
2	2, 4, 25, 26	1, 20, 28, 29, 30, 31, 33, 35, 38, 39

Test pits were generally excavated to 1.5 m depth or more, whilst the CPT's generally extended to a depth of 10.6 m. The CPT's provide excellent and continuous data on the nature and engineering properties of the substrata materials intersected, whist the DCP test (extending to a depth of 3 m), provides an indication of relative density/consistency of the subsoils.

The CPT data logs, the DCP test results and logs describing the profiles in the geotechnical test pits, are all included in Appendix B.

To assist in the geotechnical evaluation, selected soil samples recovered from the geotechnical test pits have been subjected to laboratory tests. Soil classification tests (i.e. Particle Size Distribution, Atterberg Limits and Emerson Crumb Tests) and Soil Shrink/Swell tests have been undertaken on the sample locations listed in Table 3.

All laboratory test results appear in Appendix B.

Table 3 Scope of Laboratory Testing

Classification Testing		Shrink/Swell Testing	
Test Site	**Depth (m)**	**Test Site**	**Depth (m)**
Area 1			
8	0.5 – 1.2		
8	1.2 – 3.0		
12	0.25		
12	0.75	12	0.75
17	0.15 – 1.3		
17	1.5	17	1.5
Area 2			
2	0.5	2	0.5
4	0.5	4	0.5
4	1.3 – 1.6		
25	0.0 – 0.6		
26	0.4 – 1.7		

3.0 Geotechnical Interpretations of Ground Conditions

3.1 Area

The ground surface level across Area 1 is undulating, with the majority of the area at gentle slopes with level varying between RL 4 m and RL 5 m. However, there is a prominent channel/gully running approximately north-south and bisecting Area 1, where water is permanently ponded and ground surface level drops from about RL 4 down to < RL 2 m. There is also another less prominent channel/gully, on the east side of the north-south gully, which runs south-east to north- west from the southeast corner of the parcel of land. Here ground level drops from RL 4 m down to around RL 3 m.

It is also important to acknowledge existence of a large diameter Council Sewer Pressure Main that traverses Area 1 from west to east, and is exposed across the north-south running gully referred to above.

Ground conditions comprise mostly weak alluvial sediments in the top 5 to 7 m, which is generally underlain by Very Stiff to Hard Clays. The constituents of the upper alluvial deposits across Area 1 vary considerably, with interlayered Sands, Silty Sands, Clayey Sands and some Sandy Clays/Clayey Sands.

For the Sandy strata (i.e. Sands, Silty Sands, Clayey Sands), the strengths range from Very Loose through to Medium Dense, with no consistent pattern recognizable, e.g. Very Loose zones are recorded in places at surface and elsewhere at depth, and in some locations both at surface and again at depth.

For the less evident Sandy Clay/Clayey Sand layers found in the upper 5 to 7 m of alluvial deposits, in most instances strength is of Stiff Consistency or better.

Groundwater levels recorded in test pit holes was unexpectedly variable. For example Test Pit location 8 (adjacent north-south running gully) was very high at RL 3.2 m (probably at or above water level in the adjacent gully), whilst elsewhere levels of RL 2.5 m and RL 0.85 m were recorded and in other places no water level was detected at all.

Laboratory testing indicates that in all instances, the fines in the alluvial deposits are of low plasticity. Also, the fines are classed as having low erodibility properties. The shrink/swell tests, in combination with the soil classification tests, clearly places the ground conditions as a Class A – Stable site, with respect to soil reactivity (i.e. ignoring soil strength and site fill influences on Site Classification).

Existing moisture contents in the subsoils range from about 11 % through to 26 %. For the low plasticity and non-plastic soils that are prevalent across the site, these moisture levels are relatively high and may be expected to be too wet to achieve compaction during earthworks operations. Admittedly, the investigations were carried out in mid April, towards the end of a solid wet season.

3.2 Area 2

The north-south running gully/channel described in Area 1, extends northwards through Area 2 dissecting the site and connecting to Ross River on the northern boundary, where two channels discharge into Ross River. A series of five ponds have been constructed adjacent the north-south running gully/channel, on the eastern side.

The base of the gully/channel appears to extend down to a level < RL 2 towards the southern end, falling to < RL 1 at the northern end. Either side of the gully/channel, ground levels vary mostly between RL 4 m and RL 5 m. Along the western boundary the surface level of the bank is a relatively uniform RL 5 m, whilst adjacent the Bruce Highway on the eastern boundary, for a width of 50 to 150 m, the surface level is mostly around RL 3 m. Along the northern boundary fronting Ross River, the surface level of the bank is mostly around RL 4 m, with some lower lying gullies and channels adjacent the bank.

The subsoil profiles identified in the investigation sites within Area 2 highlight even more variation than identified in Area 1. The consistently strong basement strata evident in Area 1, appears to only extend across part of Area 2. West of the north-south running gully/channel and along the northern frontage to Ross River (≈ 100 m wide strip), Medium Dense Sands extend to depth. Elsewhere, underlying hard strata is observed (similar to that recorded in Area 1 in places and in other places resulting in effective refusal of the CPT apparatus).

In the upper strata, Sandy soils (i.e. Sands, Silty Sands, Clayey Sands), are most prominent, although significant Clay layers are evident too. In most locations, there are significant depths (i.e. > 1 m thick) of Very Loose to Loose Sandy soils, which are sometimes evident at surface and elsewhere are below surface. In a few locations

(namely sites 20, 35 & 39 which are widely scattered across Area 2), significant thickness of Soft Clay was recorded.

Observed groundwater levels were again highly variable, with standing level as high as RL 4.1 m at the central location of test site 4, and elsewhere not observed to the base of investigation to as low as RL 1.0 m at location 2. At some locations, test pits had to be terminated due to collapse of the sides (e.g. locations 25 & 26 at depths of 1.7 & 1.8 m), where wet Sands existed.

Laboratory testing shows that apart from a medium plasticity clay recorded at 0.5 – 1.3 m depth at test location 4 (centrally positioned in Area 2), the soils were all of low plasticity fines, as observed for Area 1. Also, the soils tested as having low erodibility characteristics. As for Area 1, shrink/swell tests and soil classification tests, indicate that the ground conditions would be classified as a Class A – Stable site, with respect to soil reactivity (i.e. ignoring soil strength and site fill influences on Site Classification).

Insitu soil moisture levels varied widely, from excessively dry (e.g. locations 25 & 26, near surface), through to relatively wet (e.g. locations 2 & 4 around 1 m depth).

4.0 Impact of Ground Conditions on Suitability of Site for Development

As presented in Section 1 of this report, the geotechnical assessment of land suitability for residential sub-division is made by assessing:

(1) Potential settlement
(2) Adequacy of bearing capacity
(3) Level of soil reactivity
(4) Difficulties with earthwork operations

Each of these four attributes is discussed separately below for Area 1 & 2, and is then followed by a description of recommended treatments to render the site suitable for residential development.

4.1 Area 1

Settlement

- Investigation has identified near surface layers of Very Loose and/or Loose Sandy deposits in virtually all test locations. Whilst there are also medium dense layers and firm or better clayey strata, the Very Loose and Loose deposits present potential for significant settlement under building foundations. There is no clear pattern as to where and at what depth these weaker deposits occur, e.g. they are not isolated to low lying zones of the site.
- Australian Standard AS2870 identifies Very Loose and Loose Sands and Swampy Silts as posing potential settlement issues for residential building construction.
- Settlement in Sandy soils tends to occur immediately as loading is applied (c.f. Clay soils where settlement takes some time after first loading), hence a good proportion will develop harmlessly in construction. Notwithstanding this, it would be appropriate to adopt some form of site treatment for this site, in order to reduce the degree of settlement occurring with building construction. Furthermore, unless treatment is employed, it would be necessary to classify the site as a Class "P" (Problem Site), which means building foundations would need to be purposely designed for each residential block.
- Suitable treatment schemes, which would avoid classifying Area 1 as a Class "P" site are discussed further below.

Bearing Capacity

- Comments here are similar to those above for Settlement. The Very Loose and Loose Sandy soils allow only low bearing capacities, and consequently treatment of the site is needed to avoid a classification of Class "P".
- Suitable treatments are discussed further below.

Soil Reactivity

- Testing shows quite clearly that the soils across the site are of very low reactivity, and that the site would be classified as "non-reactive". Therefore, with respect to Soil Reactivity movements, this site is considered very stable.

Earthworks Difficulties

- Significant earthworks will be required to level the site and fill the low lying zones. The current development proposal plan implies that the north-south running gully/channel will be filled and developed over within Area 1. Filling operations will need to be undertaken carefully and thoroughly, first involving de-watering to drain the ponded areas, followed by a drying out period before any filling can commence. The floor of these currently ponded areas is likely to be weak and ground treatment will be required first before fill can be placed.
- Fill depths across the majority of the site would generally not exceed about 1 m, however backfilling of the areas currently ponded will involve fill depths in excess of 2 m.

- There are many mature trees across the site and some existing buildings. Where these must be removed, careful supervision of backfilling and compaction operations will be crucial, to avoid the site being downgraded to a Class "P" (Problem) Site.
- Collapsing ground conditions and water ingress in service trenches (down to about 1.5 m) are not expected to be major issues across the majority of Area 1. However, in the low lying gullies/channels, water levels will be much closer to surface and collapsing conditions will exist at these locations. Trench excavations below about 1.5 m depth, are likely to encounter seepage ingress and probable collapsing conditions.
- Some special protection works may be required along the length of the existing large diameter Council Sewer Pressure Main that traverses Area 1 from west to east. There may be severe limitations on allowable surcharge loading on this pipe, which may necessitate some form of bridging structure. Further investigation into the Pipe material, class and gradeline would be needed to establish whether any protection works were necessary.
- With respect to the suitability of the existing soils for cut/fill operations, some caution is expressed. Silty Sands, Clayey Sands and Sandy Silts are likely to be commonly encountered during the works, and may be difficult to work with and very sensitive to the level of moisture when attempting to compact. There could be delays in allowing these soils to dry sufficiently before adequate compaction can be achieved, depending on soil moisture conditions at the time of the works.
- It is anticipated that Sands/Silty Sands/Clayey Sands will be the dominant subgrade soils for road pavements across the sites, with minor amounts of Clay soils. The Sandy soils will provide reasonable subgrade support for pavements, and can be expected to achieve CBR strengths in excess of 7 %, which is better than typically experienced around Townsville. However, the soils may be highly moisture sensitive so extra efforts will be needed in preparation of these subgrade soils.

4.2 Area 2

Settlement

- As for Area 1, investigation has identified near surface layers of Very Loose and/or Loose Sandy deposits in virtually all test locations, which present potential for significant settlement under building foundations. There is no clear pattern as to where and at what depth these weaker deposits occur, e.g. they are not isolated to low lying zones of the site.
- Refer to the comments on Very Loose and Loose Sandy deposits given for Area 1 above, as they are equally appropriate here.
- At test locations 20, 35 and 39, significant layers of Soft Clays were recorded below about 1 m depth, which also pose potential settlement issues.
- Notably though, according to the current development proposal, most of the existing north-south running gully/channel would be retained as a "green" zone. Test locations 20 and 39 fall into the nominated "green" zone, however there may be other zones between locations 20 and 39 where residential development is proposed and which may sit on Soft Clay layers.
- At test site 35, residential development is proposed and ground settlement could be significant. Due to the weight of fill (likely to be around 1 m depth) and the weight of building construction, settlement in the order of 50 mm is possible.
- Further investigation would be necessary to delineate the extent of areas where settlement from Soft Clay layers will influence residential buildings. Once delineated, these zones could be preloaded for a period prior to building construction, to render the sites satisfactory for normal residential construction. Provided the investigation work is completed early on, the preloading work could be initiated and completed before these parcels of land are released to the market.

Bearing Capacity

- Comments here are similar to those above for Settlement. The Very Loose and Loose Sandy soils allow only low bearing capacities, and consequently treatment of the site is needed to avoid a classification of Class "P".
- Suitable treatments are discussed further below.

Soil Reactivity

- Testing shows quite clearly that the soils across the site are of low reactivity, and that the site would be classified as "non-reactive". Therefore, with respect to Soil Reactivity movements, this site is considered very stable.

Earthworks Difficulties

- Significant earthworks will be required to level the site and fill the low lying zones. Fill depths across the majority of the site would generally not exceed about 1 m, however backfilling of the areas currently ponded will involve greater depths
- The current development proposal plan implies that the north-south running gully/channel will remain as a "green" zone, although it appears as though there will be some backfilling and consequent narrowing of this channel in places.
- The existing man-made ponds that are adjacent the north-south gully/channel will be backfilled and remediated according to the current development proposals. The eastern side of these ponds would extend into proposed residential blocks.
- Where residential construction will occur over backfilling of the gully/channel or the man-made ponds, filling operations will need to be undertaken carefully and thoroughly, first involving de-watering to drain the ponded areas, followed by a drying out period before any filling can commence. The floor of these currently ponded areas is likely to be weak and ground treatment will be required first before fill can be placed.
- There are many mature trees across the site and some existing buildings. Where these must be removed, careful supervision of backfilling and compaction operations will be important.
- To avoid the site being downgraded to a Class "P" (Problem) Site, all filling operations must qualify as "engineered" placed fill.
- Collapsing ground conditions and water ingress in service trenches (down to about 1.5 m) are not expected to be major issues across the majority of Area 2. However, in the low lying gullies/channels, water levels will be much closer to surface and collapsing conditions will exist at these locations. In general, trench excavations below about 1.5 m depth are likely to encounter seepage ingress and probable collapsing conditions.
- With respect to the suitability of the existing soils for cut/fill operations, some caution is expressed. Silty Sands, Clayey Sands and Sandy Silts are likely to be commonly encountered during the works, and may be difficult to work with and very sensitive to the level of moisture when attempting to compact. There could be delays in allowing these soils to dry sufficiently before adequate compaction can be achieved, depending on soil moisture conditions at the time of the works.
- It is anticipated that Sands/Silty Sands/Clayey Sands will be the dominant subgrade soils for road pavements across the sites, with minor amounts of Clay soils. The Sandy soils will provide reasonable subgrade support for pavements, and can be expected to achieve CBR strengths in excess of 7 %, which is better than typically experienced around Townsville. However, the soils may be highly moisture sensitive so extra efforts will be needed in preparation of these subgrade soils.

4.3 Possible Treatments to Render the Site Suitable for Development

Given the presence of Very Loose and Loose Sandy sediments across the site, some form of treatment is considered warranted to avoid the site being classified as a Class "P" (Problem) Site in accordance with Australian Standard AS 2870.

The most cost effective means of treating the site would be to utilise a Broons Hire "Impact Roller", which achieves efficient compaction of substrata down to a depth of 1 m or more below surface. This machine has been used successfully on a number of sites in Townsville in the past. It successfully compacts the subsoil to a significant depth, and where near surface soft clays are encountered that do not respond to densification, it pinpoints their location and extent so that conventional remove and replace methods can be locally employed.

Treatment with the Impact Roller would best occur once all clearing has taken place, but before any earthworks filling operations commence. Subsequent filling operations should be undertaken in accordance with Australian Standard AS 3798 – Guidelines on Earthworks for Commercial and Residential Developments, and should involve "Level 1" supervision control of earthworks (as set out in AS 3798), to ensure all fill qualifies as "Controlled" fill, as defined in AS 2870. In this manner, classification of the land as Class "P" (Problem) Sites can be avoided.

With respect to the filling of areas that are currently ponded and are to be developed, a process involving de-watering, drying out, ground surface treatment and controlled backfilling will be needed to ensure these sites are acceptable for residential construction.

The natural soils across the site are considered suitable for use in cut/fill earthworks operations, however they are likely to be highly moisture sensitive, so will require more control than in normal situations.

Investigations suggest that Soft Clay strata (generally below at least 1 m depth), are present in places within Area 2, although they have not been identified within Area 1. Assessment has been inadequate to delineate the extent of these compressible soils in Area 2, and more intensive investigations are needed. For planning purposes, allowance could be made for preloading of these zones containing soft clay strata. This could involve, for example, completing all filling operations and then preloading the identified zones with an additional (say) 1 m height of fill for a nominal 3 month period before final subdivision of this sector of the site. The extent of Area 2 likely to be impacted by these soft clays is not expected to be more than about 20 % (given that some suspect zones will remain as "green" undeveloped areas).

In developing the site, it would be prudent to develop an Earthworks Management Plan with a clear set of protocols for all earthworks operations (covering Impact Rolling, all filing operations and zones for site preloading). This plan could be controlled and verified under a "Level 1" supervision and testing regime, as set down in Australian Standard AS 3798.

In this manner, classification of the residential building sites as Class "P" (Problem) Sites can be avoided. Furthermore, it would be most cost-effective if all residential blocks were classified in accordance with AS2870 by the "Level 1" geotechnical supervisor at the completion of all earthworks operations (rather than leaving classification to be performed individually by each block owner). Effectively the residential blocks would be sold with a pre-classification of the site. This practise has been successfully implemented in other residential developments in Townsville, and this approach is endorsed by AS 2870.

Finally, consideration must be given as to what provisions will be needed to protect the existing large diameter Council sewer pressure main that traverses Area 1. The requirements for protection cannot be determined on currently available information, but could warrant some form of bridging.

5.0 Summary and Conclusions

The presence of extensive zones of Very Loose and Loose Sandy deposits across both Area 1 and Area 2, suggest that some form of ground treatment is warranted to improve support capacity and reduce settlement potential. It is recommended that the site be subjected to improvement via an "Impact Roller", which can densify soils in the upper 1 m or so of the ground profile. This treatment should occur following clearing but prior to any filling operations, and should extend over the entire site, but could exclude zones that will not be developed.

In Area 2, significant Soft Clay strata have been intersected in a few places, generally found more than 1 m below surface. The extent of these compressible clay zones needs to be delineated by further investigation. Where they extend beneath sectors earmarked for development, then treatment in the form of preloading would be appropriate to reduce future settlement concerns.

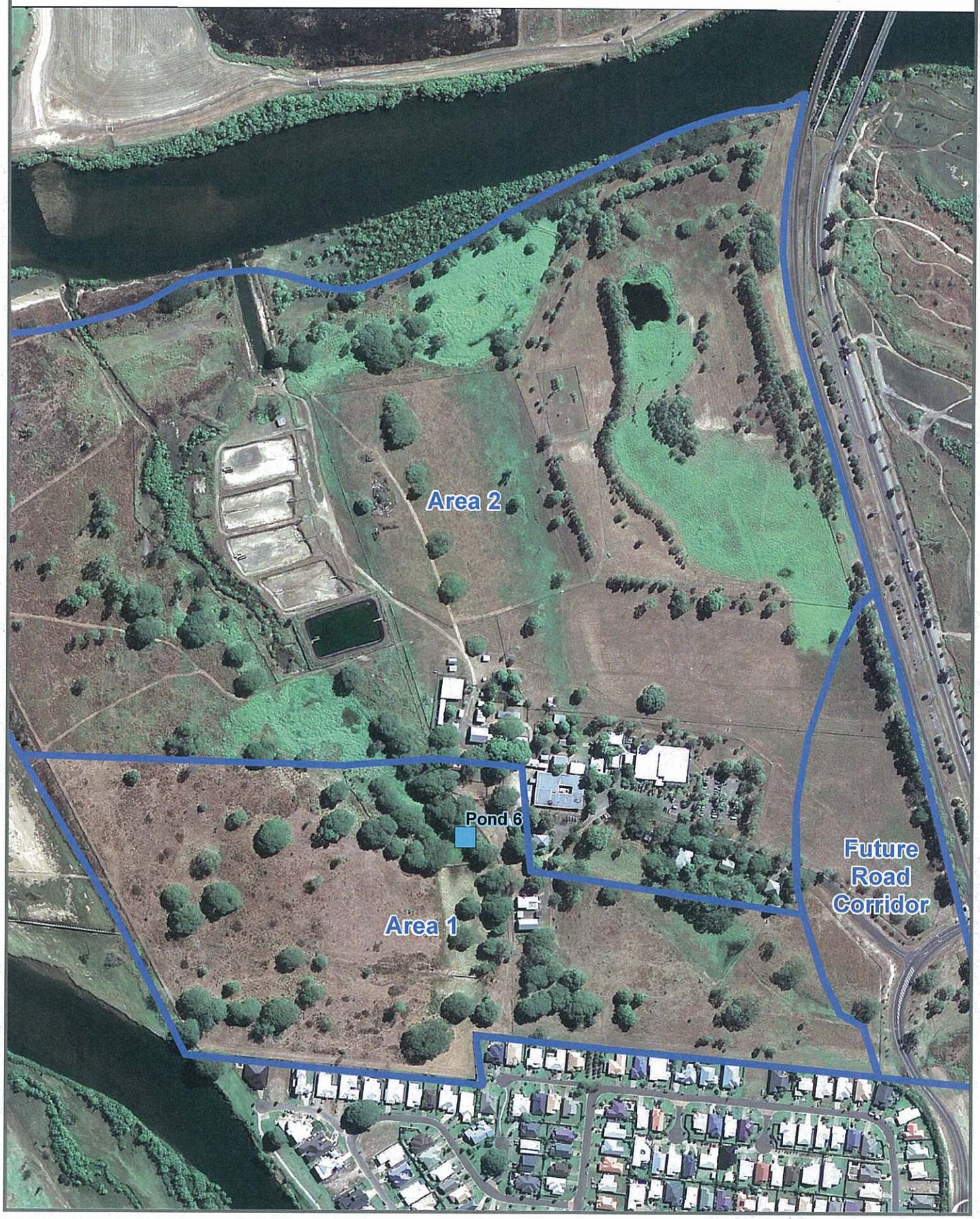
Levelling of the site will involve major earthworks operations. This will involve the need to drain and backfill currently ponded areas and fill other low lying zones, preloading of settlement prone areas in Area 2 and rectification of ground loosened by removal of trees and existing buildings. Consequently, it would be prudent to develop an earthworks management plan for the site, which would be implemented under a "Level 1" supervision by a Geotechnical Authority in accordance with Australian Standard AS 3798 - Guidelines on Earthworks for Commercial and Residential Developments. This plan would ensure that all filling operations meets the definition of "controlled" fill, as spelt out in Australian Standard AS 2870 – Residential Slabs and Footings – Construction.

In this manner, the building sites could avoid classification as Class "P" (Problem) Sites, which will reduce the costs of building foundations considerably. Furthermore, it would be beneficial for the Geotechnical Authority (undertaking the "Level 1" assessment), to provide pre-classification of all building sites in accordance with AS 2870, before land is released.

Finally, further assessment is needed to establish what special measures will be needed to preserve the integrity of the existing large diameter Council Sewer Pressure Main that traverses Area 1 from west to east.

Appendix A

Figures



PROJECT ID 6010xxxx DATASETS USED

LAST MODIFIED tom 23-Apr-2010

FILE NAME 6010##_ENV_09

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(when printed at A4)

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Metres

Surface Water Sample Locations

Oonoomba Contaminated Land Assessment
Surface Water Sample Locations
Figure 6

AECOM

Site Locality Plan

LEGEND

Test Pit Location

CPT Location

SCALE

0 500 m

NOTES: 1. Background imagery provided by Google Earth.
2. Test locations are approximate only and are shown with reference to existing site features.

Douglas Partners
Geotechnics · Environment · Groundwater

Sydney, Newcastle, Brisbane, Melbourne, Perth, Wyong, Wollongong, Cairns, Campbelltown, Darwin, Townsville, Sunshine Coast, Gold Coast, Canberra

TITLE: Test Location Plan
DPI Site - Oonoonba

CLIENT: AECOM Australia Pty Ltd			
DRAWN BY: HJL	SCALE: As shown	PROJECT NO: 50888	OFFICE: Townsville
APPROVED BY:		DATE: 18 May 2010	DRAWING No: 1

Appendix B

Test Data

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Integrated Practical Solutions

FACTUAL REPORT on GEOTECHNICAL INVESTIGATION

DPI SITE OFF ABBOTT STREET, OONOONBA

Prepared for
AECOM AUSTRALIA PTY LTD

PROJECT 50888
May, 2010

Douglas Partners
Geotechnics • Environment • Groundwater

FACTUAL REPORT on GEOTECHNICAL INVESTIGATION

DPI SITE OFF ABBOTT STREET, OONOONBA

Prepared for
AECOM AUSTRALIA PTY LTD

PROJECT 50888
May, 2010

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PSS:MAA
Project 50888
18 May 2010

FACTUAL REPORT ON GEOTECHNICAL INVESTIGATION
DPI SITE
OFF ABBOTT STREET, OONOONBA

1. INTRODUCTION

This factual report presents the results of a geotechnical investigation carried out at the Department of Primary Industries (DPI) site, off Abbott Street in Oonoonba. The work was undertaken at the request of Mr Markham Parker of AECOM Australia Pty Ltd (AECOM), the project design engineers.

It is understood that AECOM is currently assessing the potential for development of the site as a residential subdivision. Geotechnical investigation was carried out to provide information on the subsurface and groundwater conditions at the site for planning purposes.

The field investigation comprised the following:

- 17 static cone penetrometer tests (CPTs);
- 8 test pits; and
- 8 dynamic cone penetrometer tests (DCPs) adjacent to the test pits.

Representative disturbed and "undisturbed" tube samples were taken from the test pits for further laboratory testing. Details of the field work and laboratory test results are given in this report along with detailed logs of the CPTs, test pits and DCPs.

For the purposes of the investigation, AECOM provided a drawing based on an aerial photograph showing the layout of the existing DPI site and surrounding areas (AECOM Project ID 6010xxxx Figure 1, dated 2010).

2. SITE DESCRIPTION

The site is bordered to the north and west by Ross River, to the east by Abbott street and to the south by residential dwellings (refer Drawing 1 attached). Developments on the site are located predominantly in the central south eastern portion and include the Department of Primary Industry office facilities, the Tropical Animal Health Laboratory, and associated buildings including stock yards and sheds. To the north west of these structures are five aquaculture ponds, each of which are approximately 70 m long and 50 m wide.

Paved access roads are located in lower eastern portion of the site allowing vehicle access via River Boulevard. At the time of investigation, vegetation included scattered mature rain trees and long grass and weed species. Surface elevations are generally between RL 2 mAHD and RL 5 mAHD, however a small tidal creek system is located to the west and north of the existing aquaculture ponds.

3. FIELD WORK METHODS

3.1 Cone Penetration Tests (CPTs)

CPT testing was carried out on 15 and 16 March 2010. The CPTs were undertaken at 17 client nominated locations (designated as CPTs 1, 6, 10, 13, 15, 18, 20, 22, 27, 28, 29B, 30, 31, 33, 35, 38 and 39). Twelve of the CPTs reached the target depth of 10.6 m with refusal occurring between depths of 1.34 m and 8.12 m in CPTs 28, 29B, 30, 35 and 38.

Reaction for the CPTs was provided by a purpose built semi-portable test rig, ballasted and attached to a 16 tonne excavator. In the CPTs, a 35 mm diameter cone with a following 135 mm long friction sleeve is attached to rods of the same diameter, and pushed into the soil by the test rig. Strain gauges in the cone and sleeve measure resistance to penetration and the results are

displayed and stored on a computer for later plotting and interpretation. A geo-environmental scientist, operated the CPT computer, interpreted test results (including inferred soil behaviour types) and took groundwater measurements.

3.2 Test Pits

Eight test pits (designated as Pits 2, 4, 8, 12, 15, 17, 25 and 26) were excavated on 16 March 2010 to between 1.7 m and 3.0 m depth using a John Deere 315SJ backhoe fitted with a 450 mm wide toothed bucket. Disturbed, bulk and "undisturbed" tube samples were collected where possible at regular intervals for strata identification and laboratory testing purposes.

DCPs were completed to 1.2 m depth adjacent to each test pit location and pocket penetrometer tests were also carried out on block samples from the pits to supplement the DCPs. At the completion of the field work, the pits were reinstated with spoil from the excavations and wheel rolled using the backhoe.

The approximate test locations are shown on Drawing 1 attached. Surface levels at the test locations were interpolated from the orthophoto map provided by the client and coordinates determined by hand-held GPS unit using the GDA94 datum.

Conditions within the test pits were logged by a geotechnical engineer who took samples and performed DCPs.

4. FIELD WORK RESULTS

The results of the DCPs, subsurface conditions encountered in the test pits, and subsurface conditions inferred from the CPTs are presented in detail in the test report sheets and test pit logs in Appendix A. These should be read in conjunction with the general notes attached, which explain the descriptive terms and classification methods used in their preparation.

The voids remaining after the withdrawal of the CPT cone and rods were measured to record groundwater depths. A summary of the groundwater depths measured in these voids and those observed in the test pits are also presented in detail in the test report sheets and test pit logs in

Appendix A. It should be noted that groundwater levels are affected by climatic conditions, at this site possibly by tidal influence, and soil permeability and will therefore vary with time.

5. LABORATORY TESTING

A schedule of laboratory testing nominated by the client was completed on selected disturbed and undisturbed samples from the test pits, and comprised the following:

- 11 Atterberg limits and linear shrinkage tests;
- 4 Shrink/swell tests on 'undisturbed' tube samples. In this test, a core sample of the soil is measured for strain due to changes in moisture content after air and then oven drying, and separately by inundation with water under surcharge loading of 25 kPa;
- 11 Particle size distribution tests by wash sieve; and
- 11 Emerson Crumb (dispersion) tests.

The results of the laboratory testing are provided in detail in the test report sheets shown in Appendix B and are summarised in Tables 1 to 3.

Table 1 – Results of Plasticity and Emerson Crumb Testing

Pit	Depth (m)	Description	W_F (%)	W_L (%)	W_P (%)	PI (%)	LS (%)	Emerson Class No.
2	0.5-0.95	Sandy gravelly silt	23.5	26	21	6	4	6
4	0.5-0.95	Slightly sandy clay	18.5	40	17	23	8	5
4	1.5	Sand	20.0	22	NP	NP	0	5
8	1.0	Sand and silty clay	11.6	33	15	18	10	5
8	2.0	Slightly silty sand	16.0	23	NP	NP	1	5
12	0.25	Silt and sand	16.6	23	22	1	3	6
12	0.75-1.2	Silt and sand	25.7	23	20	3	3	6
17	1.0	Silty sand	22.3	37	NP	NP	0	6
17	1.5-1.95	Sandy clay	22.7	28	21	7	5	6
25	0.3	Sand	3.1	28	NP	NP	0	6
26	0.6	Sand	6.3	31	NP	NP	0	6

Legend : W_F – field moisture content; W_L – liquid limit; W_P – plastic limit; PI – plasticity index; LS – linear shrinkage; NP – Non plastic

Table 2 – Results of Shrink-Swell Index (I_{ss}) Testing

Pit	Depth (m)	Description	Shrinkage (%)	Swell under 25 kPa (%)	Pocket Penetrometer (kPa)		I_{ss} (% per ΔpF)
					Initial	Final	
2	0.5-0.95	Sandy gravelly silt	2.0	-0.3	200	160	1.1
4	0.5-0.95	Slightly sandy clay	1.2	0.0	140	110	0.7
12	0.75-1.2	Silt and sand	0.7	0.0	170	110	0.4
17	1.5-1.95	Sandy clay	0.4	-0.2	100	100	0.2

Table 3 – Results of Particle Size Distribution Testing

Pit	Depth (m)	Description	Silt / Clay (%)	Sand (%)	Gravel (%)
2	0.5-0.95	Sandy gravelly silt	53	24	23
4	0.5-0.95	Slightly sandy clay	84	16	0
4	1.5	Sand	9	89	2
8	1.0	Sand and silty clay	43	55	2
8	2.0	Slightly silty sand	14	84	2
12	0.25	Silt and sand	46	50	4
12	0.75-1.2	Silt and sand	46	52	2
17	1.0	Silty sand	32	68	0
17	1.5-1.95	Sandy clay	63	36	1
25	0.3	Sand	3	88	9
26	0.6	Sand	3	93	4

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Paul Southwell

Paul Southwell
Geo-environmental Scientist

Reviewed by

Mark Arnold
Associate

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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigations Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00 mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Undrained Shear Strength kPa
Very soft	less than 12
Soft	12—25
Firm	25—50
Stiff	50—100
Very stiff	100—200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300 mm)	CPT Cone Value (q_c — MPa)
Very loose	less than 5	less than 2
Loose	5—10	2—5
Medium dense	10—30	5—15
Dense	30—50	15—25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing with a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

Drilling Methods.

The following is a brief summary of drilling methods currently adopted by the Company and some comments on their use and application.

Test Pits — these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils if it is safe to descent into the pit. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) — the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling — the hole is advanced by pushing a 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers — the hole is advanced using 90—115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water

table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling — the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling — similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling — a continuous core sample is obtained using a diamond-tipped core barrel, usually 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" — Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7

  as 4, 6, 7
  N = 13

- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm

  as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil.

Occasionally, the test method is used to obtain samples in 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch cone — abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australian Standard 1289, Test 6.4.1.

In the tests, a 35 mm diameter rod with a cone-tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20 mm per second) the information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: —

- Cone resistance — the actual end bearing force divided by the cross sectional area of the cone — expressed in MPa.
- Sleeve friction — the frictional force on the sleeve divided by the surface area — expressed in kPa.
- Friction ratio — the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0—5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0—50 MPa) is less sensitive and is shown as a full line.

The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1%—2% are commonly encountered in sands and very soft clays rising to 4%—10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:—

q_c (MPa) = (0.4 to 0.6) N (blows per 300 mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:—

q_c = (12 to 18) c_u

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Hand Penetrometers

Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150 mm increments of penetration. Normally, there is a depth limitation of 1.2 m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer — a 16 mm diameter flat-ended rod is driven with a 9 kg hammer, dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as the Scala Penetrometer) — a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). The test was developed initially for pavement subgrade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Bore Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Ground Water

Where ground water levels are measured in boreholes, there are several potential problems;

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions — the potential for this will depend partly on bore spacing and sampling frequency
- changes in policy or interpretation of policy by statutory authorities
- the actions of contractors responding to commercial pressures.

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

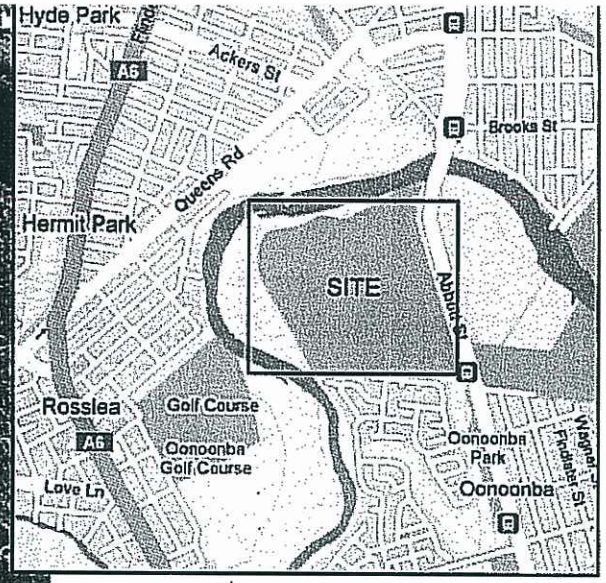
Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section

is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



Site Locality Plan

LEGEND

Test Pit Location

CPT Location

SCALE

0 500 m

NOTES: 1. Background imagery provided by Google Earth.
2. Test locations are approximate only and are shown with reference to existing site features.

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Sydney, Newcastle, Brisbane, Melbourne, Perth, Wyong, Wollongong, Cairns, Campbelltown, Darwin, Townsville, Sunshine Coast, Gold Coast, Canberra

TITLE: Test Location Plan
DPI Site - Oonoonba

CLIENT: AECOM Australia Pty Ltd			
DRAWN BY: HJL	SCALE: As shown	PROJECT NO: 50888	OFFICE: Townsville
APPROVED BY:		DATE: 18 May 2010	DRAWING No: 1

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APPENDIX A

RESULTS OF FIELD WORK

CONE PENETRATION TEST

CLIENT: AECOM Australia Pty Ltd

PROJECT: Department of Primary Industries

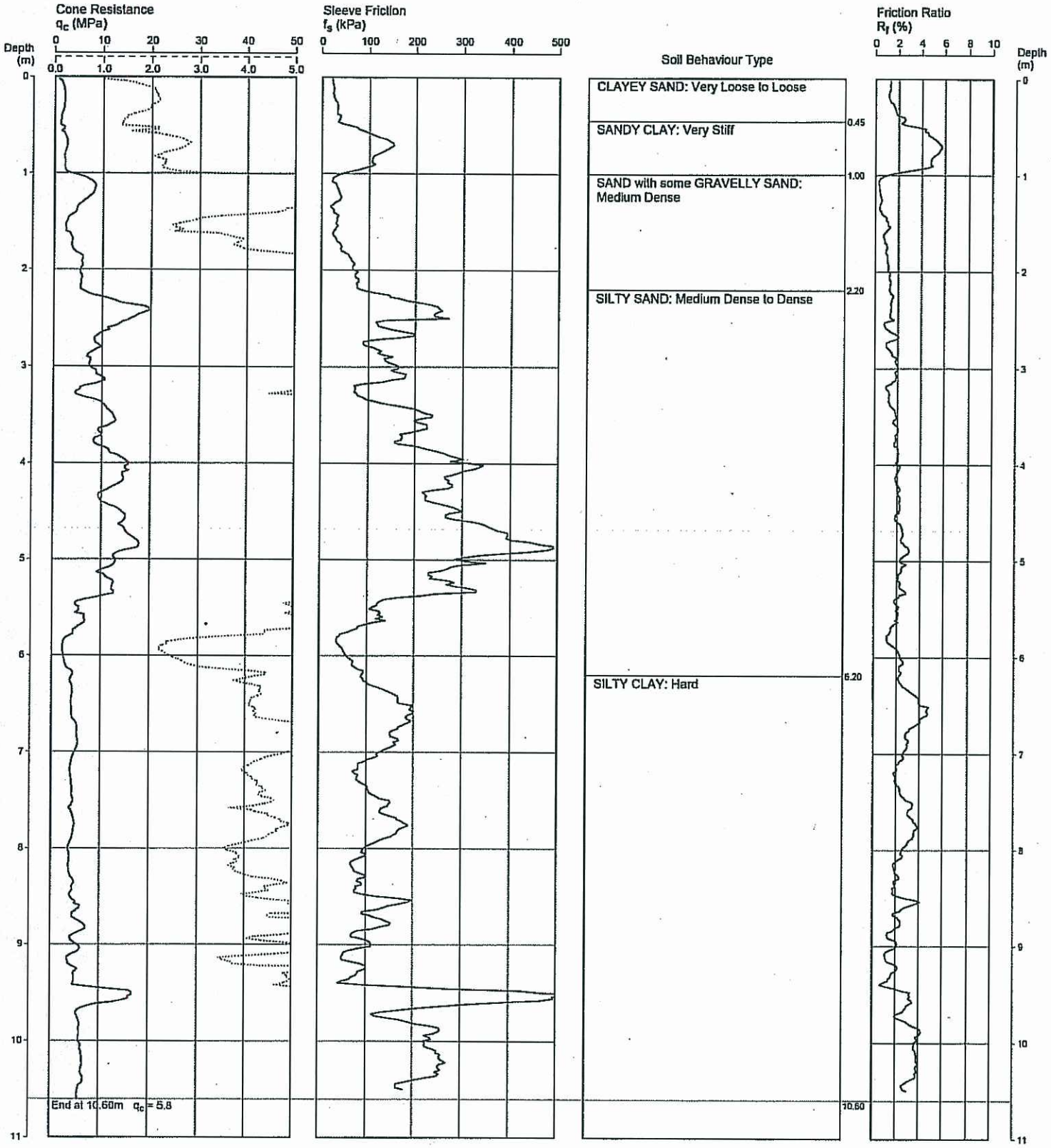
LOCATION: off Abbott Street, Ooncoonba

PROJECT No: 50888

1
Page 1 of 1

DATE 15/04/2010

SURFACE RL: 4.5m AHD



REMARKS: Hole cave in at 1.05m - dry. GPS: 480304E, 7866944N

Date
Plotted
Checked

File: P:\50888 - OONOONBA, Factual Geotechnical Investigation, DPI Site\Gint or CPT logs\50888-1
Cone ID: CONE-152 Type: 2 Standard

ConePlot Version 5.8.1

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CONE PENETRATION TEST

CLIENT: AECOM Australia Pty Ltd

PROJECT: Department of Primary Industries

LOCATION: off Abbott Street, Oonoonba

PROJECT No: 50888

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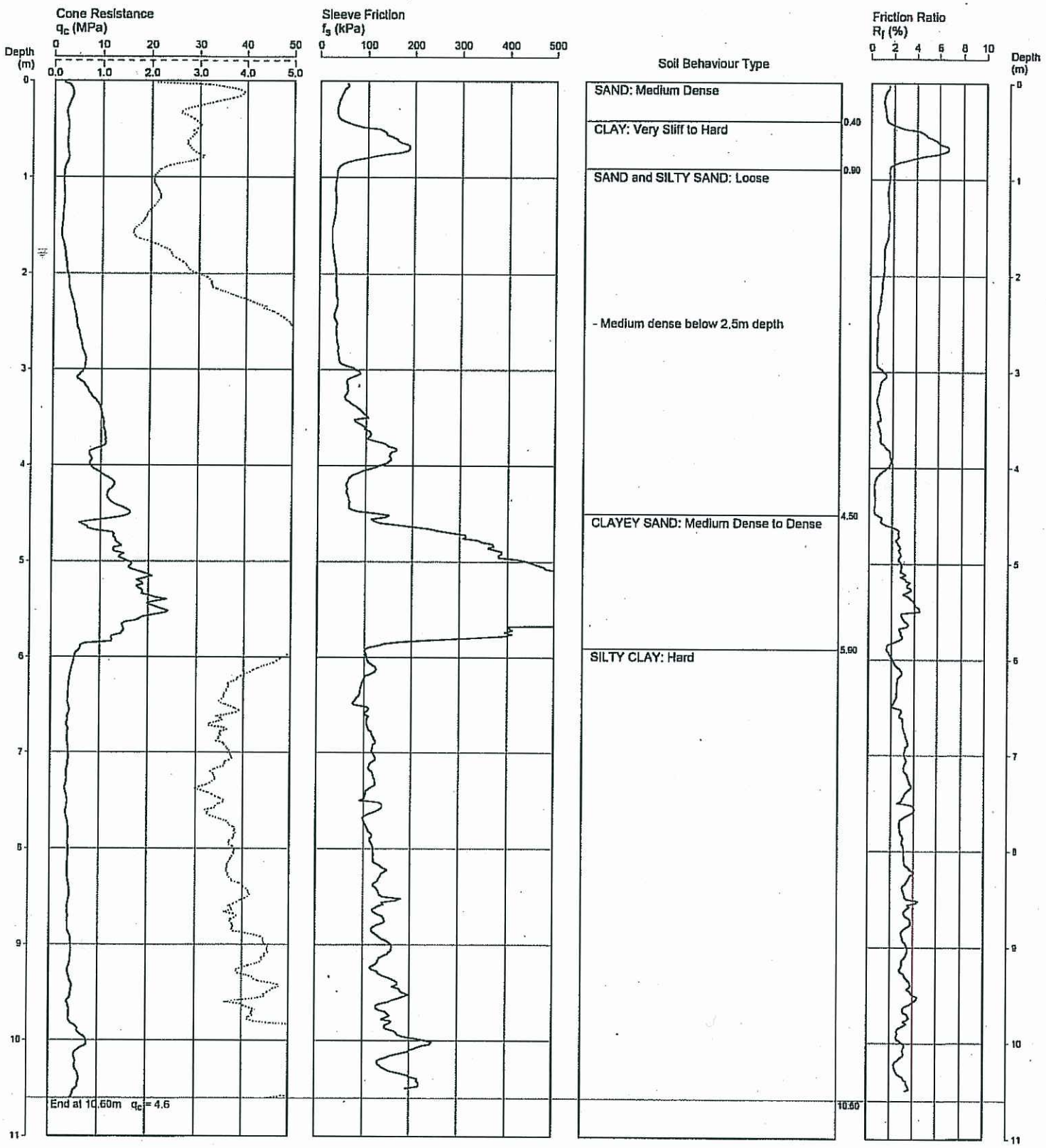
Page 1 of 1

DATE 15/04/2010

SURFACE RL: 5.4m AHD



REMARKS: GPS: 480175E, 7866902N

Date
Plotted
Checked

File: P:\50888 - OONOONBA, Factual Geotechnical Investigation, DPI Site\Gint or CPT logs\50888-0
Cone ID: CONE-152 Type: 2 Standard

ConePlot Version 5.8.1

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CONE PENETRATION TEST

CLIENT: AECOM Australia Pty Ltd

PROJECT: Department of PRImary Industries

LOCATION: Off Abbott Street, Oonoonba

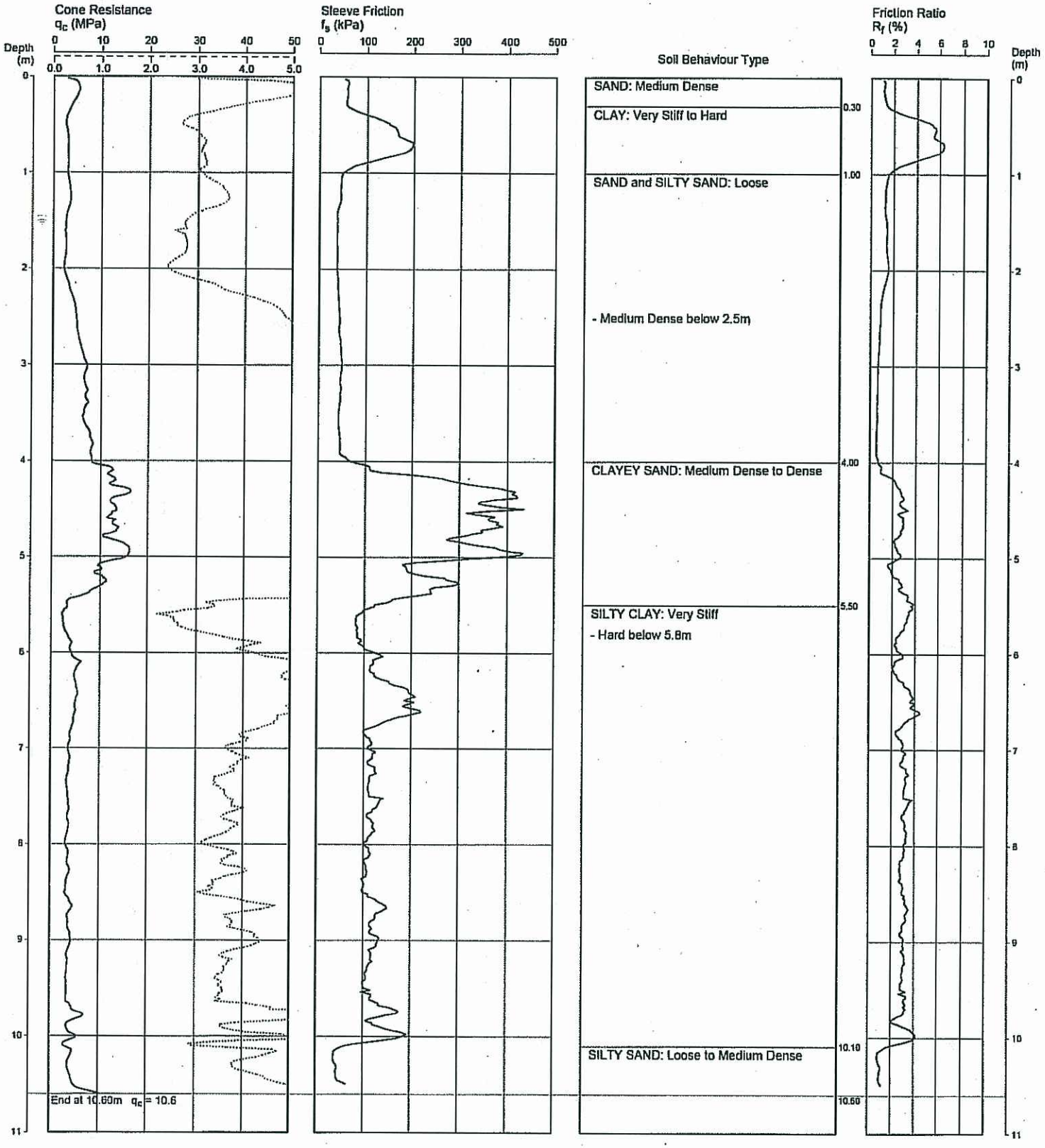
PROJECT No: 50888

CPT 10

Page 1 of 1

DATE 15/04/2010

SURFACE RL: 3.75m AHD



REMARKS: GPS: 480315E, 7866805N

Date
Plotted
Checked

File: P:\50888 - OONOONBA, Factual Geotechnical Investigation, DPI Site\Gint or CPT logs\50888-1
Cone ID: CONE-152 Type: 2 Standard

ConePlot Version 5.8.1

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CONE PENETRATION TEST

CLIENT: AECOM Australia Pty Ltd

PROJECT: Department of Primary Industries

LOCATION: off Abbott Street, Ooncoonba

PROJECT No: 50888

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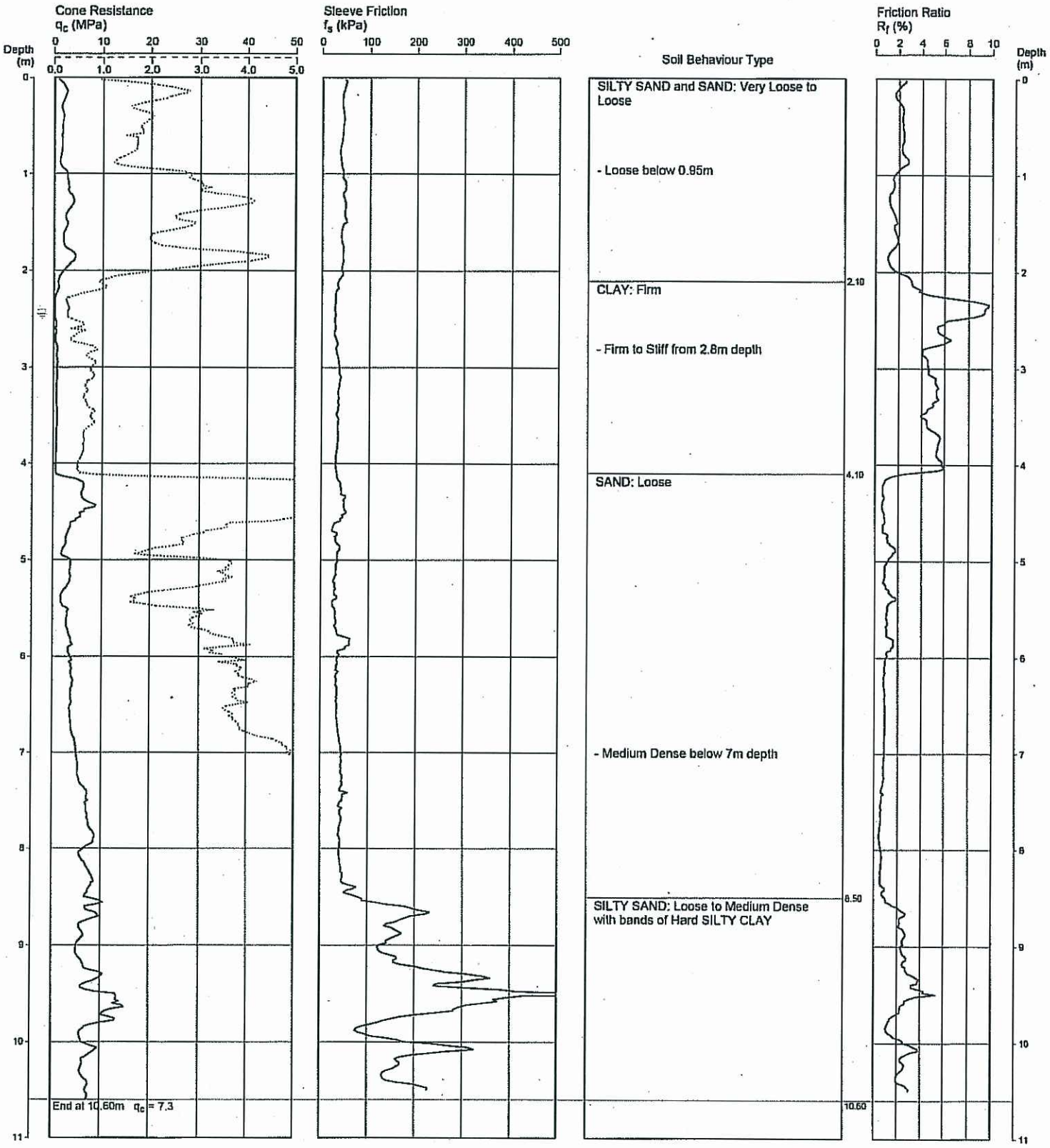
DATE 15/04/2010

SURFACE RL: 4.5m AHD



REMARKS: GPS: 479987E, 7866708N

Date
Plotted
Checked

File: P:\50888 - OONOONBA, Factual Geotechnical Investigation, DPI Site\Gint or CPT logs\50888-1
Cone ID: CONE-152 Type: 2 Standard

ConePlot Version 5.8.1

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CONE PENETRATION TEST

CLIENT: AECOM Australia Pty Ltd

PROJECT: Department of Primary Industries

LOCATION: off Abbott Street, Oonoonba

PROJECT No: 50888

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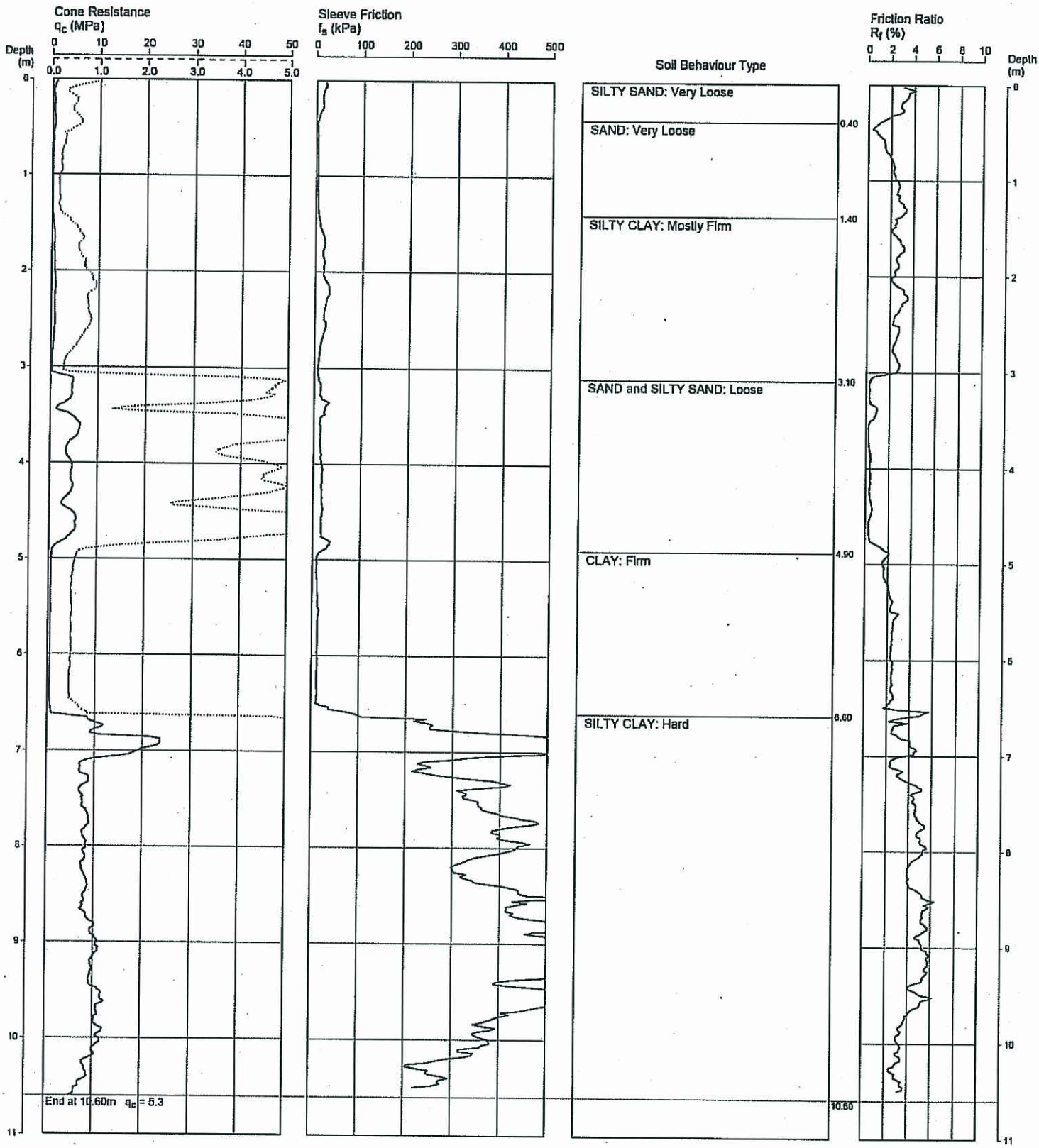
DATE 15/04/2010

SURFACE RL: 3.6m AHD



REMARKS: Test pit excavated at site following cpt and prior to groundwater measurement. GPS: 480115E, 7866764N.

Date
Plotted
Checked

File: P:\50888 - OONOONBA, Factual Geotechnical Investigation, DPI Site\Gint or CPT logs\50888-1
Cone ID: CONE-152 Type: 2 Standard

ConePlot Version 5.8.1

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CONE PENETRATION TEST

CLIENT: AECOM Australia Pty Ltd

PROJECT: Department of Primary Industries

LOCATION: off Abbott Street, Ooncoonba

PROJECT No: 50888

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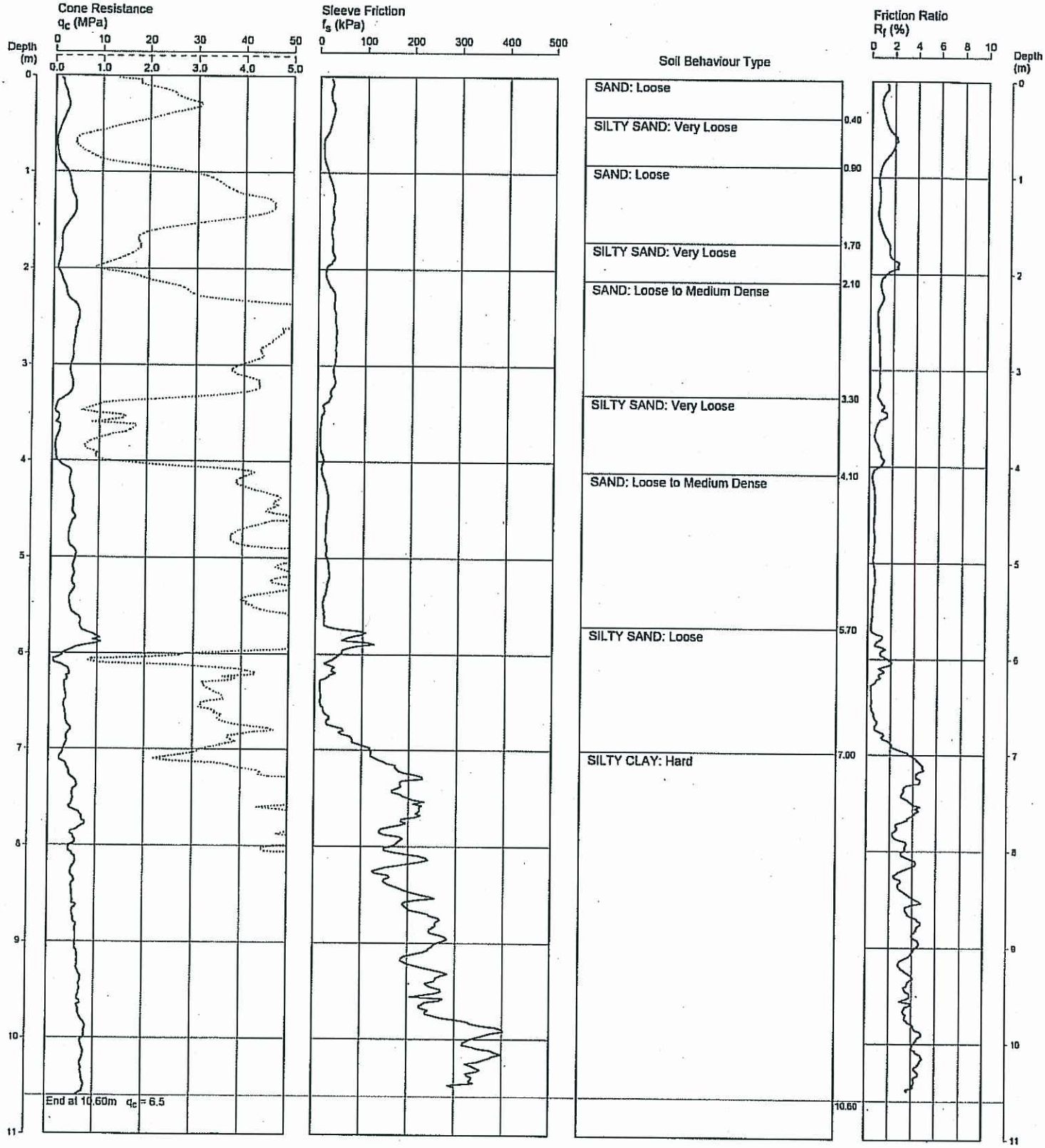
DATE 15/04/2010

SURFACE RL: 5.6mAHD



REMARKS: SWL: Cave in of CPT hole at 2.85m - dry. GPS: 479844E, 7866905N.

Date	
Plotted	
Checked	

File: P:\50888 - OONOONBA, Factual Geotechnical Investigation, DPI Site\Gint or CPT logs\50888-1
Cone ID: CONE-152 Type: 2 Standard

ConePlot Version 5.8.1

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CONE PENETRATION TEST

CLIENT: AECOM Australia Pty Ltd

PROJECT: Department of Primary Industries

LOCATION: off Abbott Street, Oonoonba

PROJECT No: 50888

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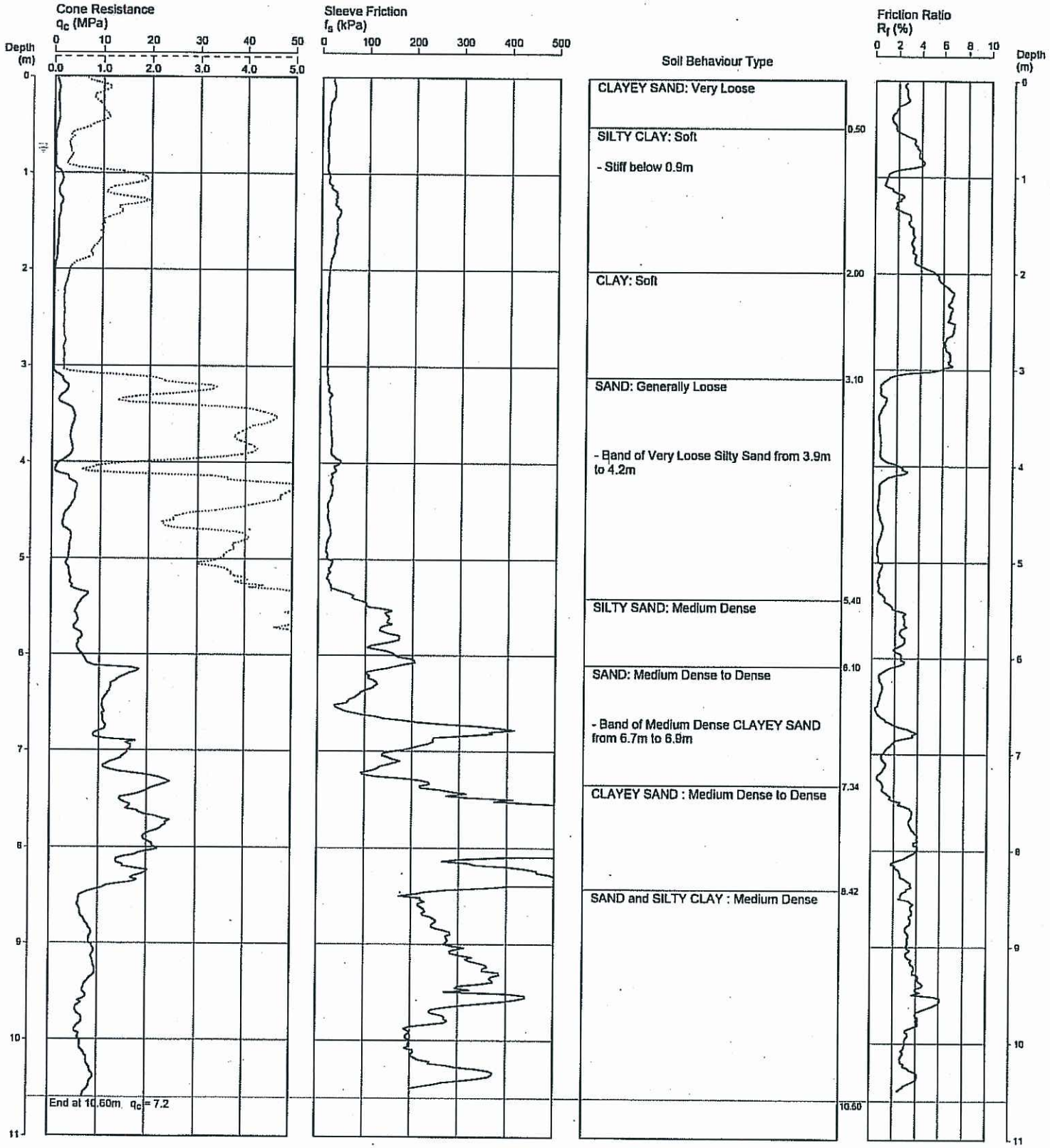
Page 1 of 1

DATE 15/04/2010

SURFACE RL: 2.9m AHD



REMARKS: GPS: 479930E, 7867106N.

Date
Plotted
Checked

File: P:\50888 - OONOONBA, Factual Geotechnical Investigation, DPI Site\Gint or CPT logs\50888-2
Cone ID: CONE-152 Type: 2 Standard

ConePlot Version 5.8.1

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