WALLBRIDGE GILBERT AZTEC

Southern Launch

Proposed Whalers Way Development

PRELIMINARY GEOTECHNICAL INVESTIGATION

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CONTENTS

1 INTRODUCTION

A preliminary geotechnical investigation has been undertaken by Wallbridge Gilbert Aztec (WGA) for a proposed rocket launch facility south west of Port Lincoln, at Whalers Way.

The preliminary geotechnical investigation was conducted at three potential launch sites (denoted A1, A2 and B) a services/water storage area (Site D) and a range control site (Site E).

The launch site will include:

- A launch pad, expected to comprise a thick reinforced concrete slab;
- A flame trench up to about 5 m deep;
- An assembly shed;
- An elevated 50 kL water tank;
- An in-ground water storage up to 3 m deep;
- Ancillary infrastructure such as lighting towers, helipad, fuel storage, radar pad, septic tank and security fence; and
- Flexible and rigid pavements.

The services/water storage area (Site D) will comprise a lined storage approximately 100 m by 75 m in plan dimensions and a variety of small structures including storage sheds, a workshop and ancillary equipment such as pumps and a generator.

The range control site (Site E) will comprise an operations building, water tanks, a septic tank, a stormwater detention basin and a sealed car parking area.

The preliminary geotechnical investigation was commissioned by Southern Launch. The scope and extent of the preliminary geotechnical investigation was altered from that originally proposed, due to access restrictions for backhoes and excavators. The scope of the investigation performed is outlined in Section 2.

This report outlines the preliminary geotechnical investigation undertaken and summarises the subsurface conditions encountered. Preliminary recommendations relating to the design of footings, pavements and associated earthworks are presented in Section 4. Additional geotechnical investigations must be conducted as part of the detailed design phase.

2 SCOPE OF THE INVESTIGATION

2.1 FIELD INVESTIGATIONS

The field work for the preliminary geotechnical investigation was carried out from 21 to 23 July 2020 and comprised drilling 11 boreholes. The boreholes comprised:

- Site A1: 1 borehole (A1-4) to a depth of about 6 m;
- Site A2: 2 boreholes (denoted A2-1 and A2-3) to a depth of about 6 m;
- Site B: 4 boreholes (denoted B1 to B4) to depths of 3 m to 6 m;
- Site D: 3 boreholes (denoted D1 to D3) to a depth of 6 m; and
- Site E: 1 borehole (denoted E) to a depth of about 3.8 m.

The boreholes were drilled with a truck mounted Ezi-probe drilling rig using a combination of continuous push tubes, hollow flight augers and rotary air. During the course of drilling, Standard Penetration tests (SPTs) were performed at selected depth intervals.

The boreholes were positioned on site to provide a broad coverage of the proposed development areas, subject to restrictions imposed by the existing site features. It is noted that some sites were not readily accessible due to vegetation or uneven/rocky terrain.

The locations of the boreholes are shown approximately on Drawing WGA181404-SK-CC-006 in Appendix A. A summary of the SPT results is presented on Figure 2 in Appendix A.

The soil profile encountered in the boreholes was logged on site by a Hydrogeologist from WGA and is described on the engineering logs contained in Appendix B.

2.2 LABORATORY TESTING

Laboratory testing conducted on selected soil samples comprised:

- 4-day soaked CBR test and associated Standard compaction test on a soil sample recovered from BH B3; and
- Atterberg limits, particle size distribution and Emerson dispersion on 1 sample recovered from BH D1.

The sample for the soaked CBR test was conditioned to the optimum moisture content and remoulded to a target dry density ratio of 98% based on Standard compactive effort (AS 1289 5.1.1.) prior to soaking.

The laboratory testing was performed in the NATA accredited Adelaide laboratory of Lab and Field. The laboratory test results sheets are presented in Appendix C.

3 SITE CONDITIONS

3.1 SURFACE CONDITIONS

The surface conditions across the Whalers Way site include sparsely vegetated calcrete cap rock, low (0.5 to 3 m high) vegetated coastal dune shrub land, moss covered shallow organic soils and coastal cliffs typical of the southern Eyre Peninsula coastline.

- Site A1 consists of dense, low (>1.5 m) scrub covered coastal dunes of up to 3 m height.

Plate 1: Site A1, Note Sand Dunes

- Site A2 consists of patchy dense low (>1.5 m) scrub scattered amongst outcrops of calcrete. This site has a relatively thick layer of calcrete/limestone cap (~3 m thick).

- Site B can be broken into two distinct areas. The southern 30% of the site consists of calcrete outcrop with sparse low (<1 m) scrub, whilst the northern 70% consists of dense Mallee scrub (up to 2.5 m).

Plate 2: Site B, Note Calcrete Cap

- Site D consists of a broad depression within the landscape. The area is relatively damp and spongy underfoot with a thin layer (0.2 m to 0.5 m thick) of organic topsoil above calcrete. There is a slight slope towards the north of the site, which restricted access to the proposed borehole locations.

Plate 3: Site D1 Looking West

- Site E consist of dense Mallee scrub up to 2.5 m in height and a slight slope (low in the north-east and high toward the south-west).

Plate 4: Site E

3.2 REGIONAL GEOLOGY

Geology of the lower Eyre Peninsula is made up of three distinct geological units, the Semaphore Sand, Bridgewater Formation, and the Carnot Gneiss.

The Semaphore Sand member (of the Saint Kilda Formation) is the youngest geological unit and comprises unconsolidated quartz-carbonate sand of modern beaches and dunes (Cann & Gostin, 1985) within the region.

Underlying the Semaphore Sand is the Bridgewater Formation which dominates much of South-eastern Australia's coastline and is exposed in coastal cliffs which extend from the Great Ocean road through to the Great Australian Bight. The Bridgewater Formation is of Pleistocene age a poorly consolidated yellow-pinkish brown fine to coarse calcareous sand/calcarenite, locally capped by calcrete (Brown & Stephenson, 1991). The formation is of wind-blown origin and is commonly referred to as aeolian calcarenite (aeolianite). The material is variably cemented with zones of strongly cemented rock strength material. Solution features are known to occur in the formation in places.

The oldest geological unit is the Carnot Gneiss (of the Archean Sleaford Complex) which underlays much of the southern Eyre peninsula. It is typically only exposed at the base of coastal cliffs and comprises thinly layered quartzo-feldspathic gneiss (Fanning, 1981).

The geological survey of South Australia Lincoln Map Sheet (4 inch to 1 mile sheet, dated 1958) indicates that the site is underlain at shallow depth by calcareous aeolianite with a travertine crust (Qpe). An excerpt from the map sheet is shown in Figure 3.1.

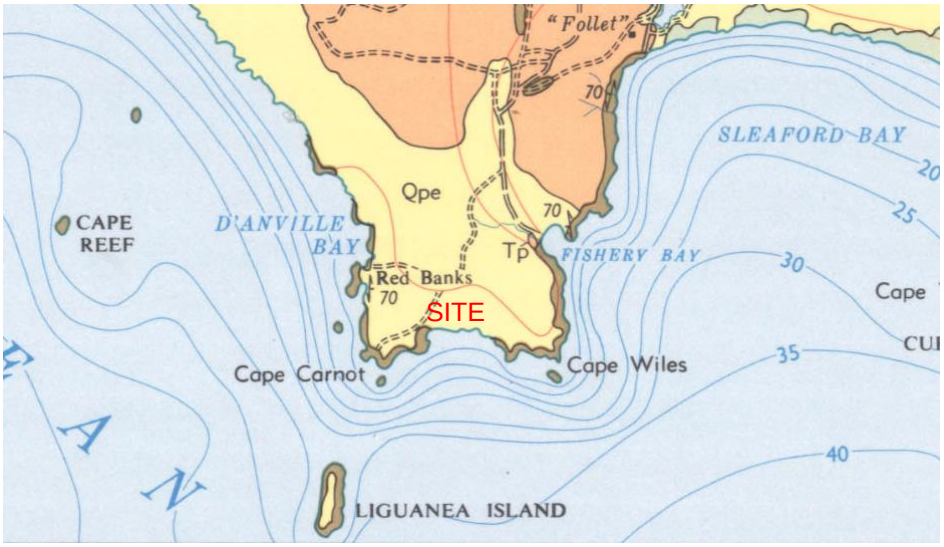


Figure 3.1 Excerpt from Lincoln Map Sheet (1958)

The 2003 version of the Lincoln map sheet indicates that the surface exposures at the site comprise Semaphore Sand (Qhcks), which is described as “foredune and dune sand, whit to cream quartz and shelly sand. Includes calcareous sand reworked from the Bridgewater Formation”. An excerpt from the map sheet is shown in Figure 3.2.

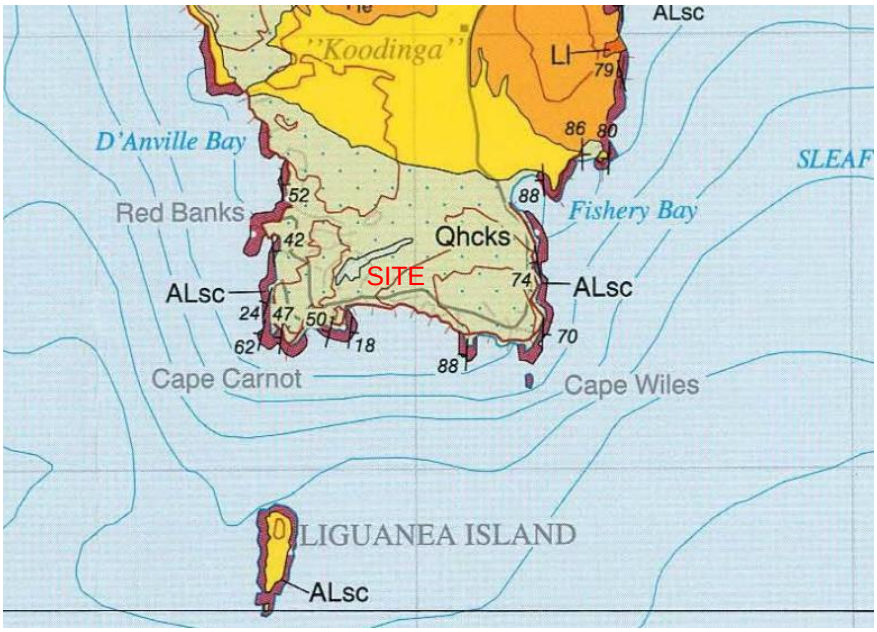
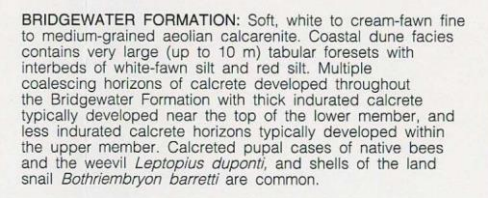


Figure 3.2 Excerpt from Lincoln Map Sheet (2003)

The 2003 map sheet describes the Bridgewater Formation as follows:



BRIDGEWATER FORMATION: Soft, white to cream-fawn fine to medium-grained aeolian calcarenite. Coastal dune facies contains very large (up to 10 m) tabular foresets with interbeds of white-fawn silt and red silt. Multiple coalescing horizons of calcrete developed throughout the Bridgewater Formation with thick indurated calcrete typically developed near the top of the lower member, and less indurated calcrete horizons typically developed within the upper member. Calcreted pupal cases of native bees and the weevil *Leptopius duponti*, and shells of the land snail *Bothriembryon barretti* are common.

3.3 SUBSURFACE CONDITIONS

Descriptions of the materials encountered in the boreholes drilled during the geotechnical investigation are summarised on the engineering logs contained in Appendix B.

The subsurface profile encountered was broadly consistent with the expected regional geology outlined in Section 3.2 and typically comprised shallow topsoil and dune sand overlying a calcrete cap of varying thickness and variably cemented calcareous aeolianite of the Bridgewater Formation. The aeolianite was typically sandy with more strongly cemented zones (rock strength material). Where push tube refusal was encountered in the calcrete or strongly cemented aeolianite auger and air hammer techniques were adopted to advance the borehole. Collapse of the borehole occurred in dry sandier layers of the aeolianite in places and the auger was used to case off the borehole. In some boreholes, silty and clayey zones were encountered and these may comprise shallow lagoonal deposits.

An outline of the stratigraphy encountered in the boreholes at each site is presented in Tables 1 to 5.

Table 1: Subsurface Profile at Site A1 Borehole (Depths Encountered, in metres

Material	BH A1-4
Dune Sand and Topsoil Sequences	0 to 2.6
Calcrete	2.6 to 3.6
Aeolianite	3.6 to 6.3

Table 2: Subsurface Profile at Site A2 Boreholes (Depths Encountered, in metres)

Material	BH A2-1	BH A2-3
Topsoil	0 to 0.1	0 to 0.1
Calcrete	0.1 to 0.9 (Push tube refusal 0.1 m)	0.1 to 0.85
Aeolianite (variably cemented sand with rock strength layers)	0.9 to 6.25 (Auger refusal 1.1 m, push tube from 3.3 m)	0.85 to 6.45

Table 3: Subsurface Profile at Site B Boreholes (Depths Encountered, in metres)

Material	BH B1	BH B2	BH B3	BH B4
Topsoil	NE	NE	0 to 0.4 (calcrete with topsoil layers interbedded)	0 to 0.3
Calcrete	0 to 0.2 (Push tube refusal 0.1 m)	0 to 0.7 (Air hammer from surface)		0.3 to 0.75
Aeolianite (variably cemented sand with rock strength layers)	0.2 to 6	0.7 to 4.65	0.4 to 6 (collapse at 3 m and 4.5 m)	0.75 to 3 (collapse at 1.5 m)

Table 4: Subsurface Profile at Site D Boreholes (Depths Encountered, in metres)

Material	BH D1	BH D2	BH D3
Topsoil	0 to 0.2	0 to 0.3	0 to 0.1
Calcrete	0.2 to 0.3	0.3 to 0.9	0.25 to 0.8 (push tube refusal 0.3 m) (auger refusal 0.5 m)
Aeolianite (variably cemented sand with rock strength layers)	0.3 to 6.18	0.9 to 6.15	0.8 to 6

Table 5: Subsurface Profile at Site E Borehole (Depths Encountered, in metres)

Material	BH E
Topsoil and Dune sand	0 to 0.7
Aeolianite (variably cemented sand with rock strength layers)	0.7 to 2.7
Clay and limestone fragments	2.7 to 3.8 (push tube refusal 3.8 m)

The dune sand encountered at the surface at Site A1 was assessed to be non-cemented and in a medium-dense condition. By comparison, the aeolianite encountered below the calcrete at Site B was assessed to be cemented, and typically caused refusal to the SPTs.

The calcrete was typically of high strength (rock strength material) and caused refusal to push tube drilling. In some boreholes (e.g. BH A2-1, BH B2 and BH D3) the calcrete also caused refusal to auger drilling, necessitating the use of rotary air (down-hole air hammer) to achieve penetration through the rock strength material.

The more clayey and silty soils encountered mostly in boreholes BH D1 and BH E were relatively dry (drier than plastic limit) and had a hard or very stiff consistency, although friable in places.

The majority of all SPT results ranged from 40 to refusal. One SPT 'N' value of 16 was recorded within the uncemented sand at Site A1. A summary of the SPT results is presented on Figure 2 in Appendix A. It should be noted that the interpretation of SPT data in gravelly or variably cemented materials (particularly rock strength materials) involves considerable uncertainty. SPT N-values less than those recorded on the borehole logs may be recorded in less cemented zones.

No evidence of open voids or cavities in the Bridgewater Formation was observed in the boreholes, although such features are known to exist in this formation.

The subsurface profile was in a relatively dry condition. Groundwater was not observed in the boreholes at the time of drilling. Seasonal variations in the groundwater levels may occur.

4 PRELIMINARY GEOTECHNICAL ASSESSMENT

4.1 GENERAL

The proposed launch pad sites will cover an area of approximately 100 m by 400 m, and will need to be relatively flat. Geotechnical issues to be considered in the site selection for the proposed launch pad are:

- the earthworks quantities required to generate a balanced cut-to-fill earthworks pad at each site;
- the presence of rock strength materials which may hamper excavations for bulk earthworks, footings, and service trenches;
- the suitability of the excavated soil and rock materials to be re-used as engineered fill beneath the development;
- allowable bearing pressures for footings within the natural materials and engineered fill;
- the stability of the soil and rock in short term excavations and permanent batter slopes;
- the potential for voids within the natural materials;
- the potential for erosion of the exposed soil surface;
- percolation rates for subsurface disposal of wastewater from septic tanks;
- site drainage to prevent the ingress of surface water which could result in softening of the uncemented or weakly cemented soils.

It is understood that all in-ground water storages will be lined with a synthetic liner, such that constructing low permeability soil liners will not be required.

Structural loads from the launch pad, assembly shed, and ancillary structures were not known at the time of reporting, however, shallow spread footings were envisaged. If a piled footing system is required for settlement sensitive or heavily loaded buildings, additional deeper geotechnical investigations will be required.

4.2 SITE CHARACTERISTICS

4.2.1 Shrink-Swell Movements

Based on a visual-tactile assessment, the soil profile at the site is assessed to be slightly reactive with respect to shrink-swell movements caused by changes in soil moisture content. The calcrete and sandy aeolianite are essentially non-reactive, whilst the clayey zones are judged to be slightly to moderately reactive.

Based on the design soil suction change profile for Adelaide presented in AS 2870-2011 *"Residential slabs and footings",* a characteristic surface movement (y_s) of less than 20 mm is predicted for the site at the current ground surface level. This shrink-swell soil movement estimate does not include elastic footing settlements, or long-term creep settlements of the natural soils.

In accordance with a classification system presented in AS 2870, a site classification of Class S (Slightly reactive) is considered appropriate for the soil profiles based on reactive soil movements below the current site levels.

Where uncontrolled fill over 0.4 m deep is present on the site, the overall site classification would be Class P (Filled site).

Where the site is in cut and the clays are exposed, larger shrink-swell movements may occur.

4.2.2 Earthquake Site Classification

The depth to bedrock was not assessed as part of this investigation. However, based on regional geological information, bedrock is expected to be present at or slightly above mean sea level.

Using the classification system presented in AS 1170.4-2007 *"Structural design actions Part 4: Earthquake actions in Australia"*, it is assessed that the site sub-soil class would be Class C_e (Shallow soil site).

4.2.3 Durability

The calcareous soil and rock materials are expected to be slightly alkaline.

No actual or potential acid sulphate soils are expected at the site.

4.3 NEAR SURFACE FOOTINGS

4.3.1 Pads and Strips

Depending on the applied structural loads and tolerance to differential settlement, near surface spread footings (strips or pads) may be considered to support buildings, tanks and towers.

It is recommended that footings supporting the more heavily loaded structures be founded in the calcrete or aeolianite, below the topsoil and Recent dune sand.

Lightly loaded footings and slabs may be founded on the dune sand, provided a reduced allowable bearing pressure is adopted.

The maximum allowable bearing pressure of footings founded on the calcrete and aeolianite would depend on factors such as:

- footing embedment depth;
- footing width;
- eccentricity of the applied load; and
- angle of internal friction of the foundation soils.

For preliminary design it is recommended that strip footings founded on uncemented to weakly cemented aeolianite (calcareous sand) be proportioned based on:

- a maximum allowable bearing pressure of 170 kPa, assuming a minimum footing width of 1 m, a minimum embedment depth of 0.6 m and no eccentric load; or
- a maximum allowable bearing pressure of 115 kPa, assuming a minimum footing width of 1.5 m, a minimum embedment depth of 0.6 m and a horizontal load equal to 20% of the vertical load.

Lower bearing pressures would typically be required for footings which are narrower, or founded at a shallower depth.

Where footings are founded on a layer of massive rock strength calcrete/aeolianite at least 300 mm thick, higher bearing pressures may be used. For preliminary design, a maximum allowable bearing pressure of 250 kPa may be adopted for such materials.

The immediate (elastic) settlement of a 1 m wide, concentrically loaded strip footing is unlikely to exceed 10 mm to 15 mm at the maximum recommended allowable bearing pressure, provided saturation of the foundation soils does not occur. Significantly larger movements may occur if the foundation soils are inundated.

Footings founded on engineered fill constructed from site-won granular soils compacted to a dry density ratio of at least 98% based on Standard compaction (AS 1289 5.1.1) may be proportioned on the basis of a maximum allowable bearing pressure of 150 kPa.

Concentrically loaded spread footings founded on uncemented dune sand may be proportioned based on a maximum allowable bearing pressure of 120 kPa, assuming a minimum footing width of 0.5 m and a founding depth of at least 0.5 m.

Spread footings must not be founded on non-engineered fill, or softened or disturbed natural soils. Should such materials be encountered at the design founding level, footing excavations must be deepened.

4.3.2 Stiffened Raft Footings

Stiffened raft footings could be considered for buildings that are more sensitive to differential settlement, such as buildings with wet areas or internal partitions (e.g. the range control building at Site E).

It is recommended that a stiffened raft footing system be designed based on the guidelines of AS2870. It is also recommended that the raft be designed on the basis of a differential mound movement (y_m) of

20 mm to accommodate load induced differential settlement, shrink-swell effects and potential settlement in the highly calcareous soils upon inundation.

A soil swell stiffness of 1000 kPa/m is recommended.

A maximum allowable pressure of 90 kPa is recommended for narrow (0.3 m wide) footing beams founded at a depth of about 0.4 m in dune sand or aeolianite.

Footing beams may be locally widened to accommodate concentrated loads.

Footing beams must not be founded on non-engineered fill, topsoil, or softened / disturbed natural soils. Where encountered at the design founding level, footing excavations must be deepened.

4.4 PAVEMENT DESIGN

The material exposed at subgrade level is expected to vary depending on the extent of cut and fill at a particular location.

Laboratory testing of a sample of calcareous silty sand from BHB3 indicated a soaked CBR of 35%, together with a maximum dry density (relative to Standard compactive effort) of 1.77 t/m^3 and an optimum moisture content of 10%.

Based on the above laboratory CBR value and considering the potential variability in the subgrade soils, it is recommended that the preliminary design of flexible pavements be based on the following subgrade CBR values:

- weakly cemented calcareous sand and silt: 9%;
- loose dune sand, calcareous clay and silt: 4%;
- massive calcrete/aeolianite: >10%.

The design CBR value assumes that:

- all non-engineered fill, disturbed/softened natural soils and organic topsoil are stripped and the upper 200 mm of underlying subgrade is compacted to achieve a dry density ratio of at least 98% based on Standard compaction (AS 1289 5.1.1). Compaction of the subgrade is not required where rock strength calcrete materials are encountered;
- the pavement is adequately drained to prevent saturation of the pavement materials and underlying subgrade. Saturation of the highly calcareous soils could result in a CBR value significantly less than 5%.

Rigid pavements or floor slabs supported on the variably cemented aeolianite may be proportioned based on an average long term Young's Modulus value of 25 MPa.

It is recommended that QA / QC testing be undertaken on subgrade and pavement materials during construction.

4.5 RETAINING WALLS

It is understood that retaining walls up to about 5 m high will be required to support the sides of the flame trench. Such retaining walls are likely to be constructed in a variety of engineered fill, uncemented sand and calcareous soils, and cemented calcrete/limestone.

For flexible walls, such as cantilevered walls where lateral movement of the wall is permitted to occur, the preliminary design of such walls may be based on the range of active earth pressure coefficients and soil bulk unit weights presented in Table 6. For relatively rigid walls or where movement of the retaining wall is to be reduced, the at-rest earth pressure coefficients should be used.

Table 6: Preliminary Retaining Wall Design Parameters

Material	Apparent cohesion (kPa)	Internal Friction Angle, f (°)	Unit Weight (kN/m3)	Active Earth Pressure Coefficient, Ka	At Rest Earth Pressure Coefficient, K0
Engineered Fill (site won soils)	0	34	19	0.28	0.65
Uncemented Sand	0	32	16.5	0.31	0.5
Calcareous Clay and Silt	5	28	17.5	0.36	0.6
Weakly to Strongly Cemented Materials (calcrete and aeolianite)	10	34 to >40	18.5	0.28 to 0.20	0.35
Notes: **Values of Ka ignore any wall friction and assume a horizontal surface at the top of the wall**					

Where the retaining walls have significant compacted backfill placed after construction, it is expected that the compaction induced pressures will be much greater than the active or at-rest earth pressures presented in Table 6.

The load on the retaining wall due to compaction equipment may be estimated from Figure J5 in AS 4678-2002 *"Earth Retaining Structures".* For select free-draining granular backfill, an active coefficient, k_a, of 0.33 and an at rest coefficient, k_o, of 0.7 are recommended together with a bulk density of 21 kN/m^3.

The compaction equipment used to compact backfill behind the wall must be carefully selected and preferably light-weight compaction equipment should be used.

All retaining walls should be designed in accordance with the recommendations of AS 4678-2002 *"Earth Retaining Structures".*

In addition to the design earth pressures retaining walls would need to consider the following as appropriate:

- unintended over-excavation in front of the retaining wall, thereby reducing the available passive resistance;

- an unbalanced hydrostatic pressure;
- traffic/construction machinery loadings at the crest;
- surcharge loadings at the crest (e.g. construction materials or footings of adjacent buildings).

4.6 BATTER SLOPES

A maximum temporary batter slope of 1V:2H is recommended for natural topsoil and uncemented sands, above the groundwater. Temporary batter slopes of about 1V:1H are envisaged to be generally appropriate for cemented materials, depending on the depth of the excavation, degree of cementation, and the presence of defects or uncemented zones within the material.

Temporary batter faces must be protected against moisture scour and erosion by the use of a shotcrete facing or PVC membrane. Surface drainage must be provided at the crest of the batter slope to divert surface water away from the cut batter.

The stability of all excavations deeper than 1.5 m shall be assessed by a Geotechnical Engineer during construction.

4.7 WATER RETAINING STRUCTURES

The natural soil profile at the site presents a number of potential hazards for water retaining structures, including:

- the highly calcareous soils will be prone to significant softening if saturated, potentially resulting in settlement of the storage walls and any nearby footings;
- the calcrete and aeolianite are potentially karstic, and may contain voids. Zones of high permeability could result in a sudden loss of stored water and concentrated subsurface water flows could create piping failures in uncemented soils beneath the water storage and nearby infrastructure.
- uncemented dune sand will be relatively unstable on batter slopes in the presence of any leaks from the water storage.

Based on the above, it is recommended that:

- Any existing fill, organic topsoil and any wet, weak or disturbed natural soils be excavated from beneath the base and sides of the storage;
- The excavated base of all water retaining structures be proof rolled with a vibrating pad foot roller of at least 10 tonnes static weight to identify any soft, wet or weak areas which may require remedial works.
- Following proof rolling, any uncemented soils or weakly cemented soils exposed in the base or sides of the storage should be ripped to a depth of 250 mm, moisture conditioned to the range of -0% to +2% of the Standard optimum moisture content, and compacted to a dry density ratio of at least 95% based on Standard compaction.

Following the above site preparation, a synthetic liner (e.g. HDPE, GCL, or similar) must be provided to the base of the water storage. The liner must be fully welded (or otherwise joined in accordance with manufacturer's recommendations) and subject to QA/QC testing. Due to the potential geotechnical hazards outlined above, where structures are to be located close to water retaining features, consideration should also be given to construction of a double layer of synthetic liner, separated by a leak detection and recovery system. The synthetic liner should be covered by a protective layer of soil of sufficient thickness to prevent "whales" forming in any HDPE liner, particularly if no drainage system is provided under the liner.

An assessment of the in-situ permeability characteristics of the subsurface materials has been undertaken based on a visual-tactile assessment of the soils (indirect method) and the guidelines presented in Tables E1, 5.1 and 5.2 of AS/NZS 1547:2012 *"On-site domestic wastewater management".*

Infiltration rates in the dune sand and variably cemented calcareous aeolianite are expected to be generally relatively high (i.e. the permeability is relatively high). An assessment of the permeability characteristics of the subsurface materials is presented in Table 7.

Also presented in Table 7 is an indicative "design irrigation rate" (DIRs) suggested in Tables 5.2 and M1 of AS/NZS 1547 for primary treated effluent via drip or spray irrigation.

Table 7: Summary of in situ Permeability Characteristics (based on AS 1547)

Material	Soil Category / Soil Texture (AS 1547)	Interpreted soil texture (AS 1547)	Indicative Permeability (K_{sat}, m/d)	Design Irrigation Rate (DIR) (mm/d)
Dune sand	1 / sands	Structureless	>3	5
Aeolianite	2 / loamy sand to sandy loam	Weakly structured to / massive	1.4 to >3.0	5

A more reliable assessment of permeability and infiltration rates would require on site infiltration tests to be conducted.

With respect to Table 7, the following should be noted:

- the presence of a continuous or massive calcrete cap could markedly reduce the in situ permeability of the soils. Where such a cap is encountered at shallow depth, ripping of the calcrete could be considered to improve infiltration rates;
- soil permeability can vary locally by several orders of magnitude, depending on the fines content, making reliable predictions problematic; and
- the indicative permeability values presented in AS 1547 are for fully saturated soils. Soil permeability will vary with changes in soil moisture content, with generally higher rates of percolation expected for unsaturated soil.

4.8 EARTHWORKS

4.8.1 Excavatability

Uncemented sand and weakly cemented sand are expected to be readily excavatable using conventional earthmoving equipment such as large backhoes and tracked excavators (10 t or larger).

The more strongly cemented calcrete and aeolianite, however, are expected to require rock excavation techniques, such as ripping with a large dozer (Cat D9L or larger) or the use of a large hydraulic rock breaker fitted to a large excavator. Confined excavations, such as trenches, in rock strength materials are expected to be problematic. Trench over-break would also be expected in rubbly calcrete materails.

Production rates are likely to vary markedly depending on the degree of cementation and continuity of any defects.

Further investigations on site with a large excavator would be required to better assess excavatability characteristics.

4.8.2 Trafficability

Trafficability of the natural uncemented sand is likely to poor for rubber tyre vehicles. Provision for a trafficable bridging layer over the site is recommended in order to improve trafficability for construction equipment. The required thickness of the bridging layer will depend on the proposed construction equipment.

4.8.3 Re-use of Excavated Material

The organic topsoil encountered in the upper 0.1 m to 0.3 m in most boreholes is not suitable for re-use as an engineered fill material due to its organic content. The existing topsoil should be stripped and stockpiled separately from the underlying materials and only be re-used within landscaping areas.

The dune sand and cemented sands may be re-used as engineered fill. Such materials, however, are non-cohesive and will be somewhat difficult to re-use, as the upper layer of fill will tend to shove and rut under construction equipment. Density testing for QA/QC purposes may need to be performed on the second layer of fill below the surface, which will be confined by the top layer.

The more strongly cemented layers of calcrete and aeolianite are suitable for re-use as controlled fill but will need to be processed (crushed, blended and screened) to produce a well-graded gravelly material with a maximum particle size of about 100 mm and at least 80% (by dry weight) passing the 37.5 mm sieve. If processed to form a wearing course on unsealed roads, a maximum particle size of around 50 mm to 100 mm would need to be adopted.

A mobile crushing plant is likely to be required to adequately process the stronger rock strength materials. Some of the less cemented particles may break down sufficiently when compacted with a pad-foot or grid roller or by using a proprietary Rockbuster.

The materials are relatively dry and therefore extensive moisture conditioning will be required prior to re-use.

4.8.4 Site Preparation

It is recommended that all uncontrolled fill, organic or disturbed soils be stripped from proposed development areas. A depth of stripping of between about 0.1 m and 0.3 m is generally expected to be required below the existing ground level based on the boreholes, although deeper pockets of fill, topsoil and disturbed soils may be present in areas not investigated. The depth of stripping must be confirmed by a geotechnical engineer during the bulk earthworks.

Following stripping of unsuitable materials, it is recommended that the exposed surface be proof rolled with a smooth drum roller of at least 10 tonnes static weight to identify any soft, wet or weak areas which may require remedial works. The proof rolled surface shall be observed by a suitably experienced Engineer.

Following proof-rolling and remedial works, the site may be filled to the design levels using "*controlled fill*".

Any "controlled fill" may comprise site won soils, with the exception of highly organic or deleterious materials. Adequate moisture conditioning must be undertaken prior to compaction and oversized materials (>100 mm) must be removed or processed to smaller size. In addition, the site won soils must have less than 20% of particles greater than 37.5 mm in order to allow conventional density testing to be conducted. Due allowance must be made by contractors for crushing, screening and blending of site won materials prior to re-use.

Alternatively, an imported quarry product, pit sand or recycled pavement material with a CBR value of at least 15% could be used as controlled fill.

Prior to compaction, the fill shall be moisture conditioned to within 2% of the optimum moisture content and compacted in layers not exceeding 250 mm in loose thickness to achieve a dry density ratio of at least 98% based on Standard compaction (AS 1289 5.1.1).

It is recommended that the fill be placed under Level 1 overview, as outlined in AS 3798 *"Guidelines on earthworks for commercial and residential developments"*.

4.9 SAFETY IN DESIGN

This report presents factual information about the subsurface conditions at the site and an assessment of how these conditions might impact on the design and construction of the proposed development from a geotechnical perspective. At the time of reporting the design and documentation of the proposed development had not been finalised and as a result Safety in Design issues have not been considered in this report. It is the responsibility of the designer to use the information contained herein to prepare a Safety in Design Report which is appropriate for the proposed development.

Specific input on geotechnical issues for the Safety in Design report can be provided as part of the detailed design phase if required.

5 LIMITATIONS

The recommendations contained within this report have been based on the subsurface conditions encountered in a limited number of boreholes and the judgement and opinion of WGA. To the best of our knowledge, the subsurface conditions described in this report provide a reasonable interpretation of the typical subsurface conditions likely to be encountered at the site.

It must be accepted that variations in subsurface conditions are likely to occur at this site and such variations may impact on the design recommendations provided. Under no circumstances can it be assumed that this report represents the actual subsurface conditions at all locations over the site.

Further geotechnical investigations must be conducted during the detailed design phase to more reliably assess the ground conditions at the site and confirm the recommendations contained in this report.

Roger Grounds
For
WALLBRIDGE GILBERT AZTEC

5.1 REFERENCE

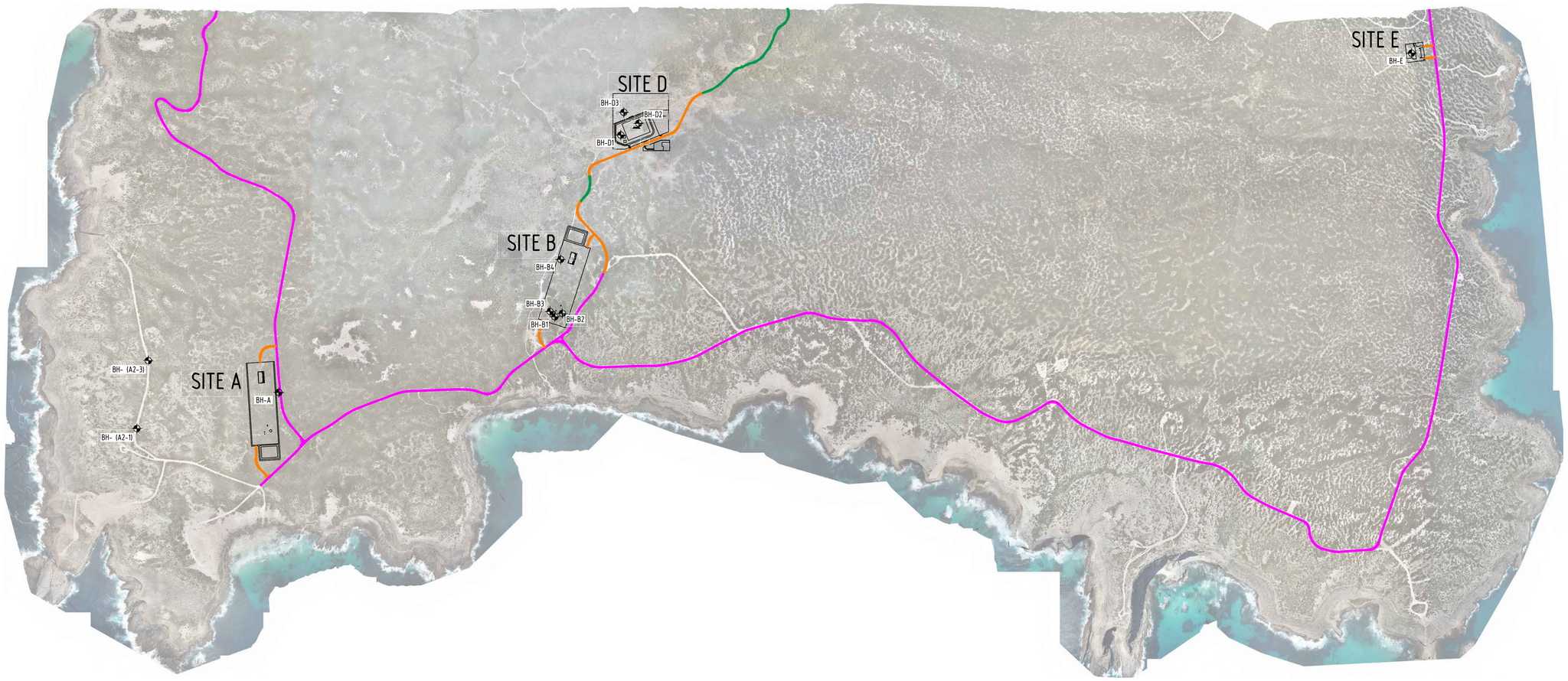
Brown, C.M., Stephenson, A.E., 1991, Geology of the Murray Basin, South-eastern Australia, Bureau of Mineral Resources, Australia. Bulletin, 235, 430pp

Cann, J.H., Gostin, V.A., 1985, Coastal sedimentary facies and foraminiferal biofacies of the St Kilda Formation at Port Gawler, South Australia, Royal Society of South Australia. Transactions, 109(4), p121-142

Fanning, C.M., 1981, The Carnot Gneisses, southern Eyre Peninsula., Geological Survey of South Australia, Quarterly Geological Notes, 80, p7-12

APPENDIX A

FIGURES



LEGEND

- EXISTING TRACK (TO BE MAINTAINED)
- EXISTING TRACK TO BE WIDENED TO 8.8m
- NEW 8.8m WIDE TRACK
- BH-X BOREHOLE LOCATIONS

SETOUT POINTS

SITE	EASTING	NORTHING
E	562420.18	6135302.14
D1	559048	6134.953
D2	559125	6135003
D3	559060.97	6135049.84
B1	558767.12	6134.177.5
B2	558798.96	6134.192.12
B3	558746.6	6134.200.19
B4	558791.59	6134.422.44
A	557590.11	6133855.09
A 2-1	556984.78	6133700.58
A 2-1	557033.43	6133990.45

NOTE: (S) DENOTES CBR SOAKED TEST TO BE UNDERTAKEN

V:\2018\181400-181499\181404 - Southern Launch\Drafting\WGA181404-SK-CC-0006.dwg, - , 12/8/2020 2:54 PM, Jhirbburn

When sheet printed full size, the scale bar is 100mm.

0 50 100mm

200 100 0 200 400
SCALE BAR (m)

INFORMATION ISSUE
NOT FOR CONSTRUCTION

REV.	DATE	DESCRIPTION	DRAFT	ENG.	CHKD

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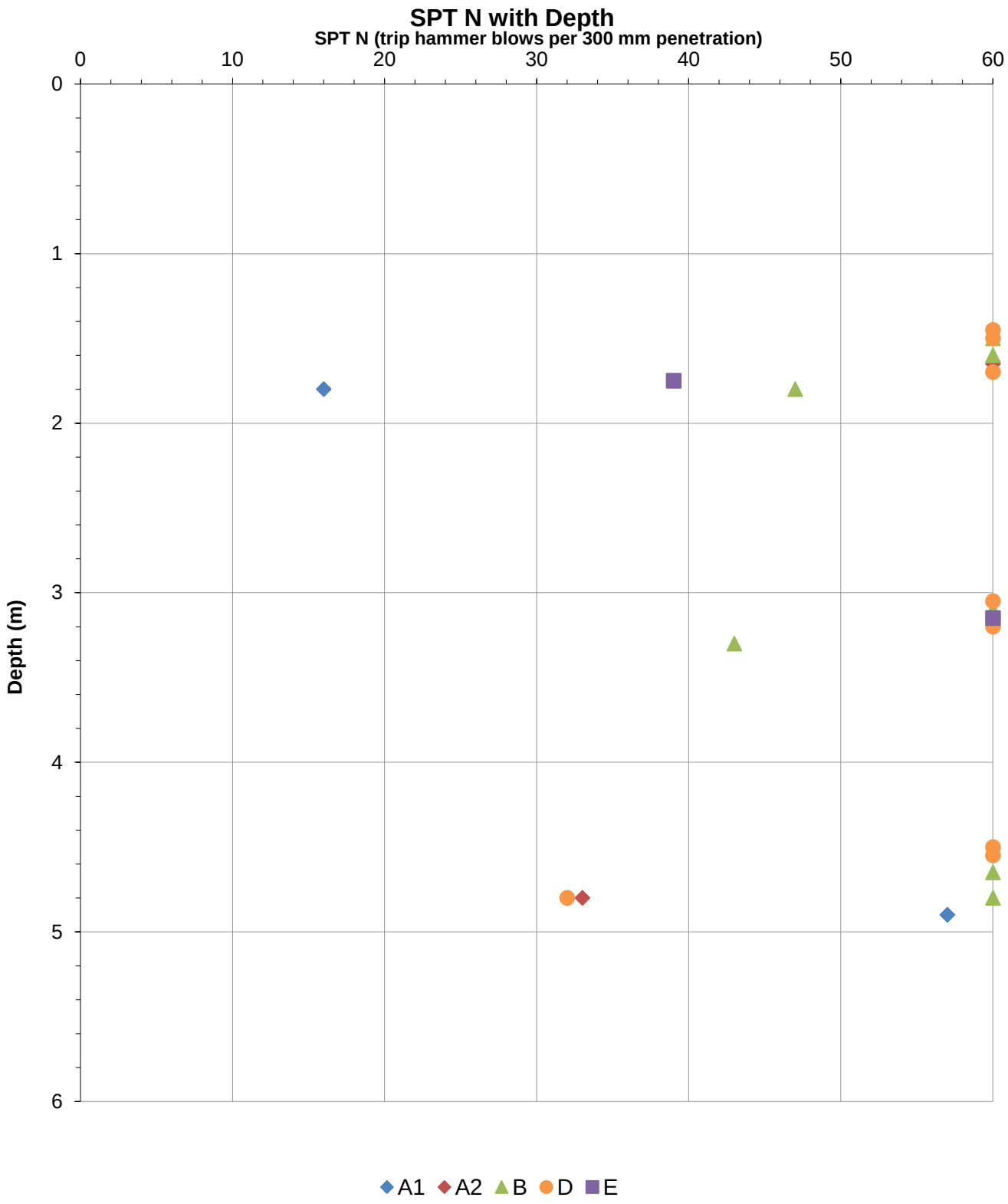
SOUTHERN LAUNCH
WHALERS WAY

BOREHOLE LOCATION PLAN

A1

DOCUMENT NUMBER
Project Number WGA181404-SK- CC-0006 Sheet No. - Rev.

Design HB Drawn JJF



Note:
N = 60 = Refusal

Prepared by	**BJH**	WGA WALLBRIDGE GILBERT AZTEC	**SOUTHERN LAUNCH** **WHALERS WAY**	
Checked by	RWG			
Date	**13-Aug-20**		**SUMMARY OF STANDARD PENETRATION DATA**	
Date tested				
Original Size	**A4**		**WGA181404**	**FIGURE 3**

\\wga-fs01\projects\2018\181400-181499\181404 - Southern Launch\Documents\Reports\Geotechnical\[181404 SPT Summary Data plot.xlsx]Report Figure - Depth

APPENDIX B

RESULTS OF FIELD INVESTIGATION

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Date Drilled:	23/07/2020
Date Logged:	23/07/2020
Logged by:	**MG**
Drilling Method:	Push Tube
Drill Rig/Mount:	Ezi-probe, Truck

Borehole No.

BH A1-4

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SP	SAND, fine to medium, pale grey brown, some silty fines	D	L/MD		NATURAL
						dune sand
0.5						
		root				
0.8						
	SM	silty SAND, fine to medium, dark grey-brown, organic	D	L/MD		NATURAL
1.0						relict topsoil
1.3						
	SP	SAND, fine to medium, pale grey, trace fines	D	MD		
1.5						
		root fibres and small root				SPT 1.5 to 1.95m
						6/7/9
		minor lithic inclusions				N=16
2.0						
2.2						
	SM	silty SAND, fine to medium, grey brown, organic				Relict topsoil
2.5						
2.6						
	GM	calcrete cap, high strength	D	D		
		recovered as sandy/silty GRAVEL, fine to coarse, pale grey brown,				
3.0		white				

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Logged:	23/07/2020	**Borehole No.**
Logged by:	**MG**	**BH A1-4**
Drilling Method:	Push Tube	
Drill Rig/Mount:	Ezi-probe, Truck	Page 2 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	GM	calcrete cap				SPT 3 to 3.1m
						30+
	SM	calcrete cap over limestone recovered as silty gravelly SAND, fine to	D	D		N=R
		fine to coarse, off-white, light grey, fine to coarse calcrete gravel,				
3.5		with a trace of low plasticity, clayey fines				
3.6						
4.0						
4.5						
						SPT 4.6 to 5.05m
		increasing cemented gravel				14/22/35
						N=57
5.0						
5.5						
						SPT 6 to 6.3m
						22/40
6.0		Borehole terminated at 6.3 m (Target depth)				N=R

Depth to Groundwater: None Observed **Trees at Site: Yes**

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Logged by: MG
Drilling Method: Push Tube/Auger/Air
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH A2-1

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
0.1	SM	silty SAND, fine to medium, dark brown, organic	D			NATURAL topsoil
	GP/GM	calcrete cap, high strength	D	D/VD		push tube refusal
		auger recovery: silty sandy GRAVEL, fine to coarse, white, pale				0.1m, commence
		brown, fine to coarse grained sand, non plastic, calcrete nodules				auger
0.5		and fragments				
1.0				MD		
						auger refusal 1.1m
		air recovery: silty SAND, fine to coarse, pale brown, non plastic				commence air
		with minor lithic fragments 1-5 mm, (black), cream/white colour,				hammer
		variable cemented fragments, highly calcareous		D/VD		
1.5						
						no SPT at 1.5 m
						too HARD
2.0						
		recovered as sandy GRAVEL, medium to high strength				
2.5						
3.0						

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Logged: 23/07/2020
Logged by: MG
Drilling Method: Push Tube/Auger/Air
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH A2-1

Legend:

Moisture Condition	Density Index - Granular	Consistency - Cohesive	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
		sandy GRAVEL, as above, increasing fines				
			D	D/VD		
3.3						
	SC/CL	clayey SAND, fine to coarse grained, white to pale grey, low	D	D		recommence push
3.5		plasticity fines, weak to moderately cemented in places, with pale brown				tube sampling
4.0						
		high strength fragments				
4.5						
						SPT 4.5 to 4.95m
						21/10/23
						N=33
5.0						
	SP/SM	SAND/silty SAND, fine to medium, pale brown to off white, non plastic fines, weakly to moderately cemented in places as medium gravel fragments	D	D		
5.5		cementation decreases, pale orange brown				
						SPT 6 to 6.25m
						27/30 for 100 mm
6.0		Borehole terminated at 6.25 m				N=R

Depth to Groundwater: None Observed **Trees at Site:** **Yes**

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Date Logged:	23/07/2020
Logged by:	**MG**
Drilling Method:	Push Tube
Drill Rig/Mount:	Ezi-probe, Truck

Borehole No.

BH A2-3

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
0.1	SM	silty SAND, fine to medium, brown, organic	D			NATURAL
	GM	thin calcrete cap over variably cemented limestone, recovered as				
		silty sandy GRAVEL, pale brown, fine to coarse grained sand,				
		fine to medium gravel fragments, non plastic, weakly to	D	MD		
0.5		moderately cemented, calcareous				
1.0	SM	recovered as silty SAND, fine grained, white, high drilling				
		resistance, loose structure in core tray, trace fine weakly				
		cemented fragments, highly calcareous				
1.5						
						SPT 1.5 to 1.77m
						19/36 for 120 mm
	SM/GM	recovered as gravelly silty SAND, fine to coarse, pale brown,				N=R
		white, weakly to strongly cemented, shell fragments up to				
2.0		5mm, minor lithic fragments, dark grey				
2.3						
	GM	more strongly cemented 2.2-2.5m	D			
2.5						
2.6						
	SM/GM	as above	D			
3.0						

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Logged:	23/07/2020	**Borehole No.**
Logged by:	**MG**	**BH A2-3**
Drilling Method:	Push Tube	
Drill Rig/Mount:	Ezi-probe, Truck	Page 2 of 3

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SM/GM	as above	D	D		SPT 3 to 3.25m
						12/30 for 100 mm
3.3						N=R
	SP/SM	SAND/silty SAND, fine to coarse, pale orange brown, white	D	MD		
3.5		non plastic, fine shell fragments				
4.0						
4.5						
		trace lithic fragments to fine gravel size				SPT 4.5 to 4.62m
						30 for 120 mm
						N= R
5.0						
5.25						
	SM	silty gravelly SAND, fine to coarse, pale brown to light grey,	D			
5.5		limestone fragments, fine to coarse, trace of low plasticity				
		clayey fines, very low to high strength				
6.0						

Depth to Groundwater: None Observed **Trees at Site: Yes**

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Date Logged:	23/07/2020
Logged by:	**MG**
Drilling Method:	Push Tube
Drill Rig/Mount:	Ezi-probe, Truck

Borehole No.

BH A2-3

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**

Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	GP	silty gravelly SAND, as above	D			SPT 6 to 6.45m
						25/20/28
		gravel increasing high strength				N=48
		LIMESTONE, very high strength fragments				
6.5		borehole terminated 6.45m (target depth)				
7.0						
7.5						
8.0						
8.5						
9.0						

Depth to Groundwater: None Observed **Trees at Site:** **Yes**

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Date Drilled: 22/07/2020
Date Logged: 22/07/2020
Logged by: MG
Drilling Method: Push Tube/Auger
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH B1
Page 1 of 2

Legend:

Moisture Condition	Density Index - Granular	Consistency - Cohesive	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	GM	calcrete cap high strength	D			
		push tube refusal, commence auger				
0.2	SP/SM	Auger recovery: SAND/silty SAND, fine to coarse, light orange brown,	D	D		
		off white, with cemented fragments (fine to medium grained)				
0.5		throughout, shell fragments				
		recovered as sand with minor lithic fragments				
1.0		auger resistance reduces		L/MD		
1.5						
				D		SPT 1.5 to 1.95m
		auger resistance increases				15/24/23
						N=47
2.0						
2.5						
3.0						

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Drilled:	22/07/2020
Date Logged:	22/07/2020
Logged by:	**MG**
Drilling Method:	Push Tube/Auger
Drill Rig/Mount:	Ezi-probe, Truck

Borehole No.

BH B1

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SP/SM	as above	D	D		SPT 3 to 3.45m
						11/20/23
						N = 43
3.5						
		sand, with minor lithic fragments, creamy/white colour				
4.0						
4.5						
						SPT 4.5 to 4.9m
						20/30/30 for 100 mm
						N=R
5.0						
5.5						
						SPT 6 m
						30+
6.0		Borehole terminated at 6m				N=R

Depth to Groundwater: None Observed **Trees at Site: Yes**

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Date Drilled:	22/07/2020	
Date Logged:	22/07/2020	**Borehole No.**
Logged by:	**MG**	**BH B2**
Drilling Method:	Push Tube/Air	
Drill Rig/Mount:	Ezi-probe, Truck	Page 1 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
		Air recovery: calcrete cap over sandy GRAVEL, pale grey, pale brown calcareous	D	VD		Air Hammer from surface calcrete
0.5						
	SM	Air recovery: silty SAND, fine to coarse, pale orange brown, pale brown, white, non plastic, shell fragments, variables weakly to moderately cemented fragments, with minor lithic fragments	D	D		calcrete
1.0						adopt blade bit
						higher penetration resistance
1.5						
						SPT 1.5m 30+ N=R
2.0						
2.5						
3.0						

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Drilled:	22/07/2020	
Date Logged:	22/07/2020	**Borehole No.**
Logged by:	**MG**	**BH B2**
Drilling Method:	Push Tube/Air	
Drill Rig/Mount:	Ezi-probe, Truck	Page 2 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**

Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SM	silty SAND, fine to coarse, pale orange brown, lithic (amphibole)	D-M	D		SPT 3 to 3.25m
		fragments, non plastic, shell fragments with weakly to moderately				24/42+
		cemented fragments				N=R
						commence push
3.5						tube sampling
4.0	SM	silty SAND, fine to coarse brown, orange brown, non plastic, trace				
		limestone fragments, medium to high strength		MD		
	GP	GRAVEL, limestone fragments, medium to high strength, to cobble				
		size, pale brown, white, some sand				
4.5						collapse to 4 m twice
	SM	recovered as silty SAND, variably cemented				SPT 4.5 to 4.65m
						29/30+
						N=R
		borehole terminated 4.65m (target depth, borehole collapse)				
5.0						
5.5						
6.0						

Depth to Groundwater: None Observed **Trees at Site:** **Yes**

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Date Drilled: 22/07/2020
Date Logged: 22/07/2020
Logged by: MG
Drilling Method: Push Tube/Auger
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH B3
Page 1 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	GP/SM	thin CALCRETE cap over interbedded sequence of silty SAND, fine to medium, dark brown, low plastic organics with organic fibres and SAND, as below	D			NATURAL topsoil
0.4						
0.5	SP/SM	SAND/silty SAND, fine to coarse, pale orange brown, white, some weakly cemented fragments throughout, shell fragments, with minor black lithic fragments	D	MD		
1.0				D		
1.5						SPT 1.5 m 30+ N=R
2.0						
2.5						
3.0		borehole collapse to 1.9m with push tube, commence auger casing				

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Logged by: MG
Drilling Method: Push Tube/Auger
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH B3

Legend:

Moisture Condition	Density Index - Granular	Consistency - Cohesive	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SP/SM	SAND/silty SAND, as above	D	D		SPT 3 to 3.29m
						22/30
						N=R
3.5						
4.0						
		bulk sample taken from surface, spoil ≈ 3 - 4.5m				
4.5		collapse to ≈ 3.6m, commence auger casing				
						SPT 4.5m
		finer grained, increased proportion of weakly to moderately				22/30
		cemented fragments				N=R
5.0						
5.5						
6.0		Borehole terminated at 6 m (target depth)				

Depth to Groundwater: None Observed **Trees at Site:** **Yes**

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Date Drilled: 22/07/2020
Date Logged: 22/07/2020
Logged by: MG
Drilling Method: Push Tube
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH B4
Page 1 of 1

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SM	silty sand, fine to medium, dark brown grading to brown grey, highly				NATURAL
		organic	D	L		topsoil
0.3						
	SM/SP	Calcrete cap, coarse grained, medium strength, over silty/gravelly				Calcrete
0.5		SAND with minor dark lithic fragments, calcrete	D	D		
		fragments fine to coarse				
0.75						
	SM	silty SAND, fine to coarse, pale grey brown with some weakly				
		cemented, limestone fragments				
1.0						
1.5		collapsed back to 1m, clear on second push tube				
						SPT 1.5 to 1.62m
						30+N=R
		grades pale brown with medium to high strength fragments to				
		coarse gravel size				
2.0						
		pale grey				
2.5						
		grey brown				
						SPT 3 m
						bounced
3.0		Borehole terminated at 3m (target depth)				N=R

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Logged: 21/07/2020
Logged by: MG
Drilling Method: Push Tube
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH D1
Page 1 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SC	clayey SAND, fine to medium, dark brown, low plasticity,	M	L		NATURAL
		organic, moss covered				Topsoil
	SM	thin limestone cap over silty SAND, fine to coarse, pale brown,	D	MD		
		trace fine to medium gravel, grey, dark grey, moderately				
0.5		cemented fragments, shell fragments				
		with lithic fragments 1-5mm				
1.0						
1.5						
	CL	sandy CLAY, low plasticity, brown, light brown, fine to medium	<Wp	H		SPT 1.5 to 1.88 m
		grained sand, calcareous, high silt content				4,5,R
						N* = R
2.0		thin limestone cap, high strength over clayey SAND,		D		
	SC	creamy/white, pale brown, fine to coarse, cemented fragments	D			
2.5						
	SM	silty SAND, fine to coarse, pale brown, white, non plastic,				
		calcareous, fine shell fragments				
				MD		
3.0						

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Drilled:	21/07/2020	
Date Logged:	21/07/2020	**Borehole No.**
Logged by:	**MG**	**BH D1**
Drilling Method:	Push Tube	
Drill Rig/Mount:	Ezi-probe, Truck	Page 2 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SM	silty SAND, as above	D-M	D		SPT 3 to 3.3 m
						22,32,R
						N*= R
		3.35-3.45 silty SAND with seams sandy CLAY, low plasticity,				
3.5		brown, dark grey				
4.0	SM/SC	silty/clayey SAND, fine to coarse, brown, grey brown, low	D			
		plasticity				
4.5						
						SPT 4.5 to 4.95 m
	SC	clayey SAND, low plasticity, fine to coarse, grey brown, fine to				9,11,21
		medium grained, calcareous seams	<Wp/M	D		N*=32
5.0						
5.5						
	SM/SC	silty/clayey SAND, fine to coarse, pale brown, with calcrete gravel,	M	D		SPT 6 to 6.18 m
		fine to coarse, shell fragments and fine shells, cemented at base				10, R
6.0		Borehole terminated at 6.18 m (target depth)				N* = R

Depth to Groundwater: None Observed **Trees at Site: Yes**

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Date Drilled:	21/07/2020
Date Logged:	21/07/2020
Logged by:	**MG**
Drilling Method:	Push Tube
Drill Rig/Mount:	Ezi-probe, Truck

Borehole No.

BH D2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SC	clayey SAND, fine to medium, dark brown, low plasticity	M	L		NATURAL
		moss covered peaty soil, organic				Topsoil
		organics reduce				
	GP	sandy GRAVEL, fine to coarse, grey, pale grey, fine to coarse	D	D		Calcrete
0.5		grained sand, some fines, calcrete, calcareous				
1.0	GM	silty sandy GRAVEL, fine to coarse, pale brown, grey brown, fine				limestone
		to coarse grained sand, non plastic, limestone fragments				
		variably cemented, high strength cap over mainly low strength,				
		limestone				
	SM	recovered as silty SAND, trace gravel		MD		
1.5						
						SPT 1.5 m
						N* = R
						Bounced off limestone
		high strength limestone fragment over silty SAND, fine to coarse,		D		
2.0		pale grey, non plastic, with weakly cemented fragments				
2.5						
3.0						

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Drilled:	21/07/2020	**Borehole No.**
Date Logged:	21/07/2020	
Logged by:	**MG**	**BH D2**
Drilling Method:	Push Tube	
Drill Rig/Mount:	Ezi-probe, Truck	Page 2 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
		as above	D			SPT 3 to 3.125 m
						N=R
	SM	silty SAND, fine to coarse, pale orange brown, non plastic,	D	D		
3.5		weakly cemented fragments, fine shell fragments				
		slow penetration rate, abundant dark lithic fragments				
4.0						
4.5						
						SPT 4.5 to 4.61 m
						R
						N*= R
5.0						
				MD		
5.5						
	SC	clayey SAND, fine to coarse, brown, low to medium plasticity				SPT 6 to 6.15 m
		silty SAND fine to coarse, pale grey/white, non plastic, weakly to				R
6.0	SM	moderately cemented fragments. Borehole terminated 6.15 m		MD		N* = R

Depth to Groundwater: None Observed **Trees at Site: Yes**

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Date Drilled: 21/07/2020
Date Logged: 21/07/2020
Logged by: MG
Drilling Method: Push Tube/Auger/Air
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH D3

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SC	clayey SAND, fine to medium, dark brown, low plasticity,	M	L		NATURAL topsoil
		organics, moss covered				
		calcrete cap, high strength, pale brown, coarse grained, sheet				
	GP	fragments recovery with layers clayey SAND, interbedded	D	D		push tube refusal at
0.5						0.3m
						commence auger
		air recovery: white and pale orange brown limestone fragments				auger refusal at 0.5m
						commence air
		air recovery: silty SAND, fine to coarse, pale orange brown,				hammer
1.0	SP/SM	white with minor dark sand sized lithic fragments, shell				
		fragments				
		variably cemented, some layers of calcrete, low to high				
		strength				
1.5						
						SPT 1.5 m
						30 blows
						N=R
2.0						
2.5						
3.0						

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Drilled: 21/07/2020
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Logged by: MG
Drilling Method: Push Tube/Auger/Air
Drill Rig/Mount: Ezi-probe, Truck

Borehole No.
BH D3

Legend:

Moisture Condition	Density Index - Granular	Consistency - Cohesive	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: **WGA181404**
Location: **PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY**

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SM	silty SAND, as above	D	D		
3.5						
4.0						
4.5						
						SPT 4.5 to 4.64 m
						30 for 140 mm
						N = R
5.0						
5.5						
6.0		Borehole terminated at 6m (target depth)				No SPT

Depth to Groundwater: None Observed **Trees at Site:** **Yes**

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Date Drilled:	21/07/2020	
Date Logged:	21/07/2020	**Borehole No.**
Logged by:	**MG**	**BH E**
Drilling Method:	Push Tube	
Drill Rig/Mount:	Ezi-probe, Truck	Page 1 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	SM	silty SAND, fine to coarse, grey, brown, low plasticity, minor				NATURAL
0.15		organic and trace (5%) clay				Topsoil
	SM	silty SAND, fine to coarse, pale grey, non plastic, shell fragments	D	L/MD		
		root fibres, calcareous weakly cemented fragments				probable dune sand
0.5						
		grades pale orange, with lithic amphibole inclusions				
1.0						
			D	D		
		slow penetration rate				
1.5						SPT 1.45 to 1.9 m
						14,21,18
						N*=39
2.0						
2.5						
		matrix of CLAY, high plasticity, brown with some calcareous				silty
	CH	seams and limestone fragments (1-20mm), creamy brown,	<Wp	H		
3.0		medium to high strength				

Depth to Groundwater: None Observed **Trees at Site:** Yes

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Date Logged:	21/07/2020	**Borehole No.**
Logged by:	**MG**	**BH E**
Drilling Method:	Push Tube	
Drill Rig/Mount:	Ezi-probe, Truck	Page 2 of 2

Legend:

Moisture Condition	**Density Index - Granular**	**Consistency - Cohesive**	
D - Dry	VL/L - Very Loose/Loose	VS - Very Soft	Vst-Very Stiff
M - Moist	MD- Medium Dense	S - Soft	H - Hard
W - Wet	D/VD- Dense/Very Dense	F - Firm	Fb - Friable
Wp - Plastic Limit		St - Stiff	
USCS: Unified Soil Classification System		↓GW = Groundwater	

Project Number: WGA181404

Location: PROPOSED SOUTHERN LAUNCH FACILITY, WHALERS WAY

		Composition of soil	Condition of soil			Structure and additional observations
Depth below surface (m)	USCS Symbol	Soil Description (type, plasticity, grading, colour, secondary and minor components)	Moisture Condition	Consistency or Density Index	Hand Penetrometer Reading (kPa)	(e.g. soil origin, defects, cementing, likely I_{pt} (%))
	CH	CLAY, limestone matrix as above	>Wp	H		SPT 3 to 3.19 m
						16, 30 for 40 mm
						N= R
		clay grey and brown				
3.5						
		high strength LIMESTONE fragments at base				
4.0		Borehole terminated at 3.8m (refusal and target depth)				
4.5						
5.0						
5.5						
6.0						

Depth to Groundwater: None Observed **Trees at Site: Yes**

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DESCRIPTION AND CLASSIFICATION OF SOILS(1) FOR ENGINEERING PURPOSES
EXPLANATION SHEET TO ACCOMPANY ENGINEERING LOGS (SHEET 1)

CLASSIFICATION SYMBOL & SOIL NAME
Soils are described in general accordance with the Unified Soil Classification (UCS) as shown in Table 1 on Sheet 2 using visual-tactile methods.

PARTICLE SIZES

NAME	FRACTION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6.7 mm to 20 mm
	fine	2.36 mm to 6.7 mm
Sand	coarse	600 µm to 2.36 mm
	medium	210 µm to 600 µm
	fine	75 µm to 210 µm

MOISTURE CONDITION

Dry Looks and feels dry. Cohesive soils are hard, friable or powdery. Uncemented granular soils run freely through hands.

Moist Soil feels cool and darkened in colour. Cohesive soils can be mounded. Granular soils tend to cohere.

Wet Similar to moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH Su (kPa)	FIELD ASSESSMENT
Very Soft	≤12	A finger can be pushed well into the soil with little effort.
Soft	12 to 25	A finger can be pushed into the soil to about 25 mm depth.
Firm	25 to 50	The soil can be indented about 5 mm with the thumb.
Stiff	50 to 100	The surface of the soil can be indented with the thumb.
Very Stiff	100 to200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	Not able to be measured	Crumbles or powders when scraped by thumbnail.

The undrained shear strength is assessed in the field using a pocket or hand penetrometer (PP). The undrained shear strength is approximately one half of the hand penetrometer reading.

DENSITY INDEX OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 to 35
Medium Dense	35 to 65
Dense	65 to 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	FIELD ASSESSMENT	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye.	Coarse grained soils: ≤5% Fine grained soils: ≤15%
With some	Presence easily detected by feel or eye.	Coarse grained soils: >5 to≤12% Fine grained soils: >15 to ≤30%

SOIL STRUCTURE

INCLUSIONS		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly Cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately Cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

SOIL ORIGIN

MATERIALS WEATHERED IN-SITU

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian	Deposited by wind.
Alluvial	Deposited by streams and rivers.
Colluvial	Deposited on slopes (transported downslope by gravity)
Fill	Placed by man. Fill may be markedly more variable between tested locations than naturally occurring soils.
Marine	Deposited in ocean basins, bays, beaches and estuaries.

Note: (1) materials found in the ground are generally described as a soil if the material can be remoulded or disintegrated by hand in the field condition or in water. Other materials are described using rock description terms.

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Table 1: SOIL CLASSIFICATION AND FIELD IDENTIFICATION AND DESCRIPTION (SHEET 2)

FIELD IDENTIFICATION PROCEDURES (excluding particles larger than 60 mm and basing fractions on estimated mass)						**USC**	**PRIMARY NAME**
COARSE GRAINED SOILS More than 65% of material less than 63 mm is larger than 0.075 mm	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.			GW	GRAVEL
			Predominantly one size or a range of sizes with more intermediate sizes missing.			GP	GRAVEL
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			GM	SILTY GRAVEL
			Plastic fines (for identification procedures see CL below)			GC	CLAYEY GRAVEL
	SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Well graded. Wide range in grain sizes and substantial amounts of all intermediate sizes.			SW	SAND
			Poorly graded. Predominantly one size or a range of sizes with some intermediate sizes missing			SP	SAND
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML Below)			SM	SILTY SAND
			Plastic fines (for identification procedures see CL below)			SC	CLAYEY SAND
	IDENTIFICATION PROCEDURES ON PARTICLES <0.2 mm						
FINE GRAINED SOILS More than 35% of material less than 63 mm is smaller than 0.075 mm	SILTS & CLAYS Liquid limit less than or equal to 50	**DRY STRENGTH**	**DILATANCY**	**TOUGHNESS**			
		None to low	Quick to slow	None		ML	SILT
		Medium to high	None	Medium		CL	CLAY
		Low to medium	Slow to very slow	Low		OL	ORGANIC SILT
	SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium		MH	SILT
		High	None	High		CH	CLAY
		Medium to high	None	Low to medium		OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS		Identified by colour, odour, spongy feel and frequently by fibrous texture.				Pt	PEAT

* Low plasticity – Liquid Limit W_L Less than 35 % * Medium plasticity - W_L between 35% and 50%

APPENDIX C

LABRATORY TEST RESULTS

LAB AND FIELD PTY LTD

ABN 12 113 330 073
30 HUDSON ROAD
MAWSON LAKES SA 5095
Tel: 08 8258 5594
WEB: www.labfield.com.au

California Bearing Ratio Test Report

Report No: CBR:PR-20/0396-1
Issue No: 1
This report replaces all previous issues of report no 'CBR:PR-20/0396-1'.

Client: Wallbridge & Gilbert
60 Wyatt Street
Adelaide SA 5000

Project No.: PR-20/0396

Project: Whalers Way - Proposed Development

Lot No: **TRN:**

Accredited for compliance with ISO/IEC 17025 - Testing

NATA Accredited Laboratory Number: 375

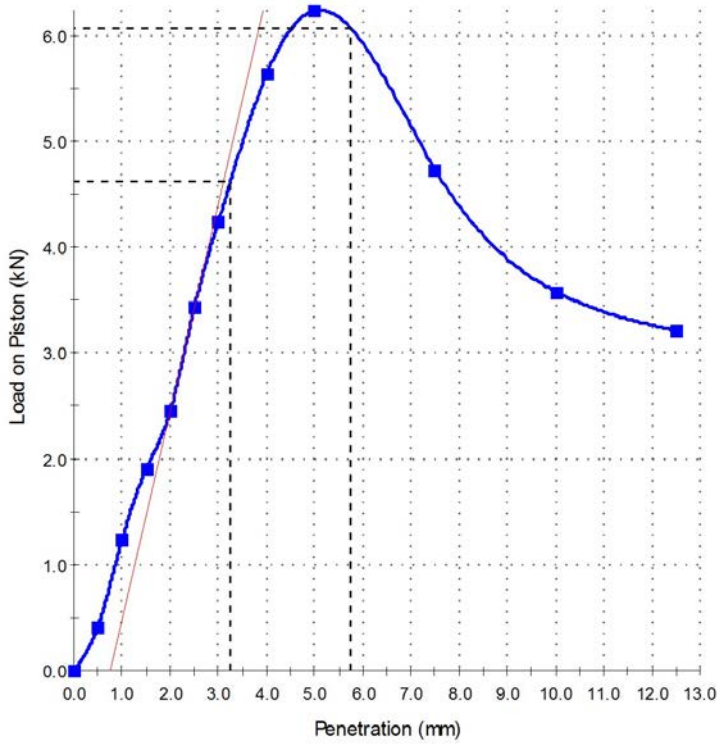
Approved Signatory: Darren Neale (Senior Technical Officer)

Date of Issue: 11/08/2020

Sample Details

Sample ID:	PR-20/0396-1	**Date Sampled:**	30/07/2020
Client Sample ID:	B3 (3-4.5)m		
Field Sample ID:		**Sampled By:**	submitted by Client
Sampling Method:	Sample submitted by client		
Source:	On site	**Material:**	Soil Investigation Sample
Specification:		**Location:**	
Tested By:	Jordan Michalanney	**Date Tested:**	10/08/2020

Load vs Penetration



Test Results

AS 1289.6.1.1 - 2014

CBR At 2.5mm (%):	**35**
Maximum Dry Density (t/m³):	1.77
Optimum Moisture Content (%):	10.0
Dry Density before Soaking (t/m³):	1.72
Density Ratio before Soaking (%):	97.5
Moisture Content before Soaking (%):	9.7
Moisture Ratio before Soaking (%):	97.5
Dry Density after Soaking (t/m³):	1.72
Density Ratio after Soaking (%):	97.5
Swell (%):	0.0
Moisture Content of Top 30mm (%):	13.5
Compactive Effort:	Standard
	AS 1289.5.1.1
Surcharge Mass (kg):	9.00
Period of Soaking (Days):	4
Oversize Material (%):	0
CBR Moisture Content Method:	AS 1289.2.1.1
Curing Time (h) :	24

Comments

LAB AND FIELD PTY LTD

ABN 12 113 330 073
30 HUDSON ROAD
MAWSON LAKES SA 5095
Tel: 08 8258 5594
WEB: www.labfield.com.au

Aggregate/Soil Test Report

Report No: MAT:PR-20/0396-2
Issue No: 1
This report replaces all previous issues of report no 'MAT:PR-20/0396-2'.

Client: Wallbridge & Gilbert
60 Wyatt Street
Adelaide SA 5000

Project No.: PR-20/0396

Project: Whalers Way - Proposed Development

Lot No:

TRN:

Accredited for compliance with ISO/IEC 17025 - Testing

NATA Accredited Laboratory Number: 375

Approved Signatory: Westley Fieldhouse (Laboratory Manager)

Date of Issue: 11/08/2020

Sample Details

Sample ID:	PR-20/0396-2
Lot No.:	
Client Sample ID:	D1 (1.5-1.9)m
Date Received:	31/07/2020
Date Sampled:	30/07/2020
Source:	On site
Material:	Soil Investigation Sample
Specification:	Soil Investigation Sample
Location:	Whalers Way
Sampling Method:	Sample submitted by client
Sampled From:	Insitu

Other Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	3.5	
Mould Length (mm)		250	
Crumbling		No	
Curling		No	
Cracking		Yes	
Liquid Limit (%)	AS 1289.3.1.2	41	
Plastic Limit (%)	AS 1289.3.2.1	32	
Plasticity Index (%)	AS 1289.3.3.1	9	
Emerson Class Number	AS 1289.3.8.1	4	
Soil Description		Pale Brown Sandy SILT	
Type of Water		Distilled	
Temperature of Water (°C)		22.0	

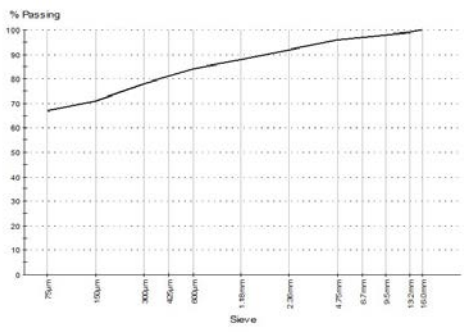
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven

Note: Sample Washed

Sieve Size	% Passing	Limits
16.0mm	100	
13.2mm	99	
9.5mm	98	
6.7mm	97	
4.75mm	96	
2.36mm	92	
1.18mm	88	
600µm	84	
425µm	81	
300µm	78	
150µm	71	
75µm	67	

Chart



Comments

N/A

WGA

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GUIDE TO INTERPRETING YOUR **WGA GEOTECHNICAL REPORT**

This geotechnical report has been prepared by an experienced WGA Engineer. These notes have been prepared by WGA to assist the Client interpret and understand the report limitations.

SCOPE OF SERVICES

This report has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and WGA. In some circumstances, the scope of the services may have been altered by a range of factors such as time, budget and access restrictions.

GEOTECHNICAL INVESTIGATIONS

Geotechnical engineering is based extensively on professional judgment and opinion. It is far less precise than other engineering disciplines.

Geotechnical engineering reports are prepared to meet the specific needs of individual clients. This report was prepared expressly for the Client for the purposes indicated in the agreed scope of services. Use by any other persons for any purpose, or by the Client for a different purpose, may result in problems.

For example, a report prepared for a consulting civil engineer may not be adequate for a construction contractor or even another consulting engineer.

This report must not be used for any project other than that originally specified at the time the report was prepared, without seeking additional geotechnical advice.

PROJECT-SPECIFIC FACTORS

This report is based on a subsurface investigation designed to meet the requirements of a specific project. The subsurface investigation was formulated based on factors which include the nature of the development, its size and configuration, the location of any existing development on the site, and the location of access roads and parking areas. Unless further geotechnical advice is obtained in writing, this report may not provide appropriate recommendations if:

- the nature of the proposed development is changed; or
- the size, configuration, location or orientation of the proposed development is modified.

The report findings cannot be applied to any other sites, including adjacent sites.

SUBSURFACE CONDITIONS

Subsurface conditions are created by natural processes and the activity of man and may, therefore, be modified by changing natural forces or man-made influences. For example, water levels can vary with time and fill may be placed on a site. The report is based on conditions which existed at the time of subsurface exploration.

Construction operations at, or adjacent to, the site and natural events such as floods or groundwater fluctuations may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. WGA should be kept informed of any such events and should be consulted to determine if additional investigations are necessary

THIRD PARTY INTERPRETATION OF FINDINGS

WGA should be retained to assist other design professionals in the interpretation of relevant geotechnical findings, and to review the adequacy of plans and specifications relative to geotechnical issues. Costly problems can occur when other design professionals develop plans based on misinterpretations of a geotechnical report.

ENGINEERING LOGS SHOULD NOT BE SEPARATED FROM THE REPORT

The report presents the findings of the geotechnical investigation and must not be copied or altered in any way.

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Engineering logs and cross-sections are developed by geotechnical engineers based upon their interpretation of field logs and laboratory testing of samples. These logs and figures should not be redrawn for inclusion in other documents or separated from the report in any way.

To reduce the likelihood of misinterpretation, contractors should be given access to the complete geotechnical report prepared or authorised for use. The following publication should be referenced for further information.
Guidelines for the Provision of Geotechnical Information in construction Contracts (Engineers Australia, National Headquarters, Canberra 1987).

RELIANCE ON SUPPLIED DATA

In preparing the report, WGA may have relied upon data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations. Unless otherwise stated in the report, WGA has not verified the accuracy or completeness of such data. WGA will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misinterpreted or otherwise not fully disclosed to WGA.

LIMITATIONS OF SITE INVESTIGATIONS

In making an assessment of a site from a limited number of boreholes or test pits it is inevitable that variations will occur between test locations. Subsurface exploration identifies specific subsurface conditions only at those points from which samples have been taken. The likelihood that subsurface variations will not be detected can be reduced by increasing the frequency of test locations, although this has cost implications. The investigation program undertaken is a professional estimate of a reasonable scope of investigation required to provide a general profile of the subsurface conditions. The data derived from the site investigation program and subsequent laboratory testing are extrapolated across the site to form an inferred geotechnical model and an engineering opinion is formed about overall subsurface conditions and their likely behaviour with regard to the proposed development.

Despite subsurface exploration, the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface conditions and anomalies.

The engineering logs are the subjective interpretation of the subsurface conditions encountered at a particular location, made by experienced personnel. The interpretation may be limited by the method of investigation, and cannot always be definitive. For example, inspection of an excavation or test pit allows a greater area of the subsurface profile to be inspected than borehole investigations, however, such methods are limited by depth and site disturbance restrictions.

The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained from the subsurface exploration. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, the services of WGA should be retained through design and construction stages, to identify variances, conduct additional tests if required and recommend solutions to any problems encountered on site.

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