Clayey Sand and Sand: Clayey sand and sand, typically of medium density, was found overlying sandstone bedrock between the following depths:

BH1 16.0m – 22.1m

BH2 16.0m – 24.0m

BH3 16.8m – 22.9m

BH4 16.0m – 21.8m

Sandstone Bedrock

Sandstone was encountered below the natural soils at depths between 21.8m and 24.0m. The rock was of low to moderate strength upon initial contact and graded to high strength within 0.5m to 1.0m. From 25.0m depth the rock was of high strength and contained minimal defects. Classification of the rock in accordance with Pells et al. (1998) is summarised below:

Rock Class / Location	Class V Depth RL (below existing)	Class IV Depth RL (below existing)	Class III Depth RL (below existing)	Class II Depth RL (below existing)	Class I Depth RL (below existing)
BH1	-	-20.63 (22.23)	-	-	-22.33 (23.93)
BH2	-22.70 (23.00)	-	-	-23.18 (24.48)	-23.80 (25.10)
BH3	-	-	-21.56 (23.16)	-	-22.91 (24.51)
BH4	-	-	-20.89 (22.49)	-21.90 (23.50)	-22.20 (23.80)

Groundwater was encountered in all boreholes at between 0.8m and 0.9m below the existing ground surface.

3.3 Laboratory Test Results

The point load strength index test results generally showed good correlation with our field assessment of rock strength. The estimated Unconfined Compressive Strength (UCS) of the rock core generally ranged from 4MPa to 36MPa indicating low to high strength rock, with a few outlying values both higher and lower.

The soil pH values indicate that the soils are neutral to slightly alkaline. Based on the results, the soils would be classified as 'non-aggressive' to 'mild' exposure classification for concrete piles in accordance with Table 6.4.2(C) of AS2159-2009 'Piling – Design and Installation'. For steel piles, however, the soils would be classified as 'moderate' to 'severe' in accordance with Table 6.5.2(C) of AS2159-2009. This classification arises from the very low resistivity values which seem to reflect the relatively high chloride values (salty water is more conductive/less resistive than distilled water). The chloride values in themselves are not high enough to make much difference to the exposure classification.

4 COMMENTS AND RECOMMENDATIONS

4.1 Geotechnical Issues

The principal geotechnical issues associated with the proposed development at the subject site are:

- The proposed basement will require excavations in the order of 6m depth below existing surface levels. The excavations are likely to be entirely within the fill and silty sands.
- The basement excavations will extend well below the natural groundwater level which was recorded between 0.8m and 0.9m depth. Under the Rockdale Council guidelines *Rockdale Technical Specification – Stormwater Management* Section 2.1.2b it is not permitted to permanently dewater basement excavations and basements must consequently be designed as tanked structures. Basement walls and floor slabs will need to be designed to cater for groundwater pressures.
- A decision must be made at an early stage whether a raft foundation is feasible and economical or whether the structure should be piled to rock.
- A dewatering licence will be required for the construction period and a detailed application will have to be made to DPI Water.

4.2 Dilapidation Surveys

Prior to demolition, dilapidation reports should be completed, both externally and internally, on the adjoining property located to the west of the site as well as the road to the north. The respective owners should be asked to confirm that the dilapidation reports represent a fair record of actual conditions. The dilapidation reports may then be used as a benchmark against which to assess possible future claims for damage resulting from the works. Detailed surveys should also be carried out of the buried services and note made of any that are likely to be sensitive to displacement.

4.3 Excavation Conditions

Excavation to the required depths of about 6m, for the two-level basement, will encounter some surficial fill but predominantly very loose and loose marine sands. Excavation of the soils should be readily achievable using conventional excavation equipment, such as the buckets of hydraulic excavators. Excavation works should be complemented by reference to the Code of Practice 'Excavation Work' prepared by Safe Work Australia July 2014. The major difficulty with the excavation will be the wet condition of the soils and it may be necessary to dewater ahead of excavation to reduce this problem. A system where the sands are stockpiled and allowed to drain before being loaded out may be beneficial. The bearing capacity of the saturated sands will be low and care must be taken in choice and operation of plant.

4.4 Dewatering

Groundwater is expected to be a significant issue for this development due to the shallow water table across the site. Dewatering will thus be required for basement excavation and for trafficability of construction equipment. Since we expect that shoring will be constructed around the basement perimeter, we expect temporary dewatering should not cause excessive drawdown outside the site provided the cut-off is properly designed and constructed. Nevertheless, dewatering must be carefully controlled and monitored to reduce the risk of excessive drawdown outside of the basement causing settlement of adjoining buildings supported on shallow footings.

Detailed hydrogeological analysis of the dewatering will be required to assess the effect of dewatering on neighbouring properties and optimum depth of shoring cut-off. It may be necessary to embed the cut-off wall into the clay/clayey sand layers which occur below depths between 14.9m and 16.0m to keep flows blow acceptable levels.

Permanent dewatering systems are not likely to be approved, therefore the basement will need to be tanked and designed to take the hydrostatic lateral and uplift pressures into account.

Water quality must be determined to assess the need for treatment prior to discharge.

4.5 Retention

Since the basement will extend below the water table it will not be possible to form stable temporary batters. We expect therefore that the excavation will need to be supported by a properly designed shoring system, such as a secant pile wall or cutter soil mix (CSM) wall, installed prior to commencement of excavation. Jet grouted secant pile walls and driven sheet pile walls may be considered, but issues including ground disturbance, noise and vibration levels which could affect adjoining buildings and structures would need to be addressed. The "severe" exposure classification for buried steel would further mitigate against steel piles.

To reduce the effects of dewatering on the neighbouring property, the retention system must be installed to a minimum depth which satisfies stability and dewatering considerations. It must also be decided whether the shoring system is to support structural loads as founding the shoring wall in the clay soil layers will result in a low bearing capacity and it may become necessary to found the wall on rock if this becomes an issue.

Lateral restraint in the form of soil anchors will probably be required to reduce deflections, and these must be installed progressively as excavation proceeds. If anchors are to be installed, they will extend beyond the site boundaries, and permission of the owners and authorities must be obtained before installation. If approval is not forthcoming then walls will need to be laterally supported by alternative methods, such as berms or props which would cause difficulties in construction of the proposed raft slab. We note the sands are of very low density to depths of about 6m and this will severely limit the capacity of anchors. It may be necessary to install anchors at greater decline angles than normal such that they form a bond length in the more competent medium dense sands.

For preliminary design of propped or anchored walls, we recommend the use of a rectangular envelope of lateral pressure of 6H (kPa), where H is the retained height in metres. In areas that are sensitive to adjacent movements, such as where structures or movement sensitive services are located within 2H of the wall, a higher earth pressure distribution of 8H kPa should be used. Design using more sophisticated software, such as Wallap and Plaxis, is likely to result in more economical design.

The lateral toe resistance of shoring walls can be calculated using a passive earth pressure coefficient, K_p, of 3.0 for stiff clay and clayey sand and 3.5 for medium dense and dense sand. A factor of safety of 2 should be applied to the calculated resistance due to the large strains necessary to generate the full pressure.

All surcharge loads and hydrostatic pressures should be allowed for in the shoring design. The design must also take into account the groundwater situation where there will be differential water levels on the active and passive sides of the wall.

As a guide soil anchors bonded into the sands may be designed (if required) based on an effective friction angle of 28° for sands of very loose to loose relative density, 32° for medium dense sands or 34° for dense sands. Uncased anchor holes within the sands will almost certainly collapse and temporary casing of these holes will be required. Anchors with penetrations through the wall below the water table would be subject to inflows of both soil and water which would cause subsidence outside the excavation and would be very difficult to control. The most obvious solutions to this are to use only a single row of anchors with heads above the water table or possibly to use long inclined casings with the top above the water table through which the anchors are drilled and the casing only removed once the anchor has been grouted and the groundwater sealed off.

Only expert contractors should be used for this type of anchor construction as poor techniques can result in damage to adjoining properties. Anchor bond lengths should be proof-tested to 1.3 times the working load under the direction of an experienced engineer of construction superintendent, independent of the anchor contractor. Lift-off tests should be carried out on 10% of anchors after 72 hours from initial tensioning to check that the anchors are holding their loads.

It is normal good practice for anchors to be a specialist design and construct sub-contract to avoid disputes if anchors fail to hold their test load.

4.6 Footings

There are a number of potential options for the footings for the proposed structure. These comprise piles to rock, a stiffened raft slab and a piled raft slab. The design of the footing system should take into account the silty clay and clayey sand layers encountered within the sandy profile. The footing options are discussed in more detail forthwith.

4.6.1 Piles to Rock

The proposed structure may be supported using piled footings founded in the underlying sandstone though we note that the rock is moderately deep. The rock appears to dip slightly towards the east but variations in the buried topography could result in irregular depths to rock and to date there has been no investigation of the south-eastern corner of the site due to lack of access..

We assume that all piles will be uniformly founded within the underlying sandstone bedrock. Where an ultimate limit state approach is adopted the following ultimate base resistance and shaft frictions may be used. For piles founded within the rock, skin friction within the upper 0.3m of rock socket should be ignored. A geotechnical strength reduction factor (ϕ_g) of 0.60 for the wall (ie high redundancy) and 0.52 for individual piles with low redundancy should be adopted where a limit state design approach is used in accordance with AS2159-2009, subject to further investigation to complete coverage of the site to the required standard. The following parameters may be adopted:

Rock Class	Ultimate End Bearing Pressure (MPa)	Serviceability End Bearing Pressure (MPa)	Ultimate Shaft Adhesion (kPa)	Serviceability Shaft Adhesion (MPa)
IV	8	2	450	0.2
III	28	4	1100	0.4
II	40	6	1500	0.6
I	80	10	3000	0.6

Classification in accordance with Foundations on Sandstone and Shale in the Sydney Region, Pells, Mostyn and Walker, Australian Geomechanics, Dec 1998.

Substantially more investigation will be necessary to confirm the rock quality for Class I and II rock and some additional investigation to confirm Class III rock.

4.6.2 Raft Slabs

As medium dense sands will be encountered at or a little below the bulk excavation level, the use of a raft slab may be considered. A piled raft slab is also possible, but as the piles will probably need to bear upon rock it may make this a less economical option compared with transferring all loads to rock and not needing to construct a raft.

The design of a raft slab would need to take into consideration the potential for large settlements due to the very loose to loose layers such as that between 13.2m and 14.7m in BH4, the firm to stiff and stiff clays found in BH1 and BH3 and the clayey sand/sandy clay found in all locations below about 16m.

As discussed in Section 4.5, the shoring system is likely to terminate in the medium dense clayey sand stratum, and may not be suitable for bearing substantial loads. Therefore, column and line loads around the perimeter of raft may be high, which is difficult to accommodate economically in raft design. The alternative would be to push the shoring wall even deeper but this would be costly.