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Report

Geotechnical Investigation for Coastal Erosion Vulnerability Assessment.

Doddi's Beach, City of Mandurah WA.

Date: 8 September 2023
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EXECUTIVE SUMMARY

A geotechnical investigation has been carried out as part of a coastal erosion assessment at Doddi's Beach in the City of Mandurah, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 600m corridor of coastal beach and dune formation adjacent to the Doddi's Beach settlement which has been identified as an at-risk site as part of Coastal Hotspot #37.

The investigation scope consisted of acquiring multi-channel analysis of surface waves data as a series of specified transects either along-shore (parallel to the coast) or cross-shore (perpendicular to the coast) and cone penetration testing at spot locations along these transects. This was supplemented with geological mapping of surface rock outcrops and topographic survey using high resolution aerial photogrammetry for the generation of a surface level model and orthomosaic image.

The acquired MASW dataset was processed for the generation of seismic velocity sections along the transects showing variations in the seismic shear wave velocity of the subsurface material to a target depth of 10-15m below ground level. The seismic velocity sections were calibrated with the CPT plots and demarcated into velocity ranges representing different material types and conditions for the generation of interpreted geological sections consisting of loose to compacted sediment and variably weathered to fresh rock.

The interpreted geological sections have been compiled to develop subsurface models of the level to rock substrate (relative to AHD) and overlying sand thickness within the region between the foreshore and the settlement. This model will be used to assess the potential vulnerability of the site to erosion and future inundation risk, and whether there is a continuous rock barrier located below the ground surface of sufficient strength and height that may prevent the advancement of erosion to the settlement.

The following observations have been made:

- Interpreted rock substrate was observed along the entirety of the transects and within the maximum target investigation depth of 10-15m below ground level.
- Interpreted top of rock substrate on the along-shore transects on the beach ranged from -3.5mAHD to 2.5mAHD and averaged -0.25mAHD overlain by up to 5m of variably compacted sediment.
- Interpreted top of rock substrate on the along-shore transects adjacent to the settlement on Halls Head Parade ranged from -1.75mAHD to 5.5mAHD and average approximately 2mAHD overlain by up to 5m of variably compacted sediment.
- Interpreted top of rock substrate for the cross-shore transects extending over the dune formation ranged from -1mAHD to 1mAHD and average approximately 0mAHD overlain by up to 3.5m of variably compacted sediment.

CONTENTS

1 INTRODUCTION

At the request of The Government of Western Australia Department of Transport (DoT), GBG Group carried out a geotechnical investigation at Doddi's Beach, City of Mandurah in July 2023. During the investigation, seismic geophysical testing and intrusive geotechnical testing was conducted within a 600m corridor of coastal beach and dune formation which has been identified as an at risk site as part of Coastal Hotspot #37.

The objective of the investigation was to provide detailed mapping of the extent, elevation and consistency/strength of the rock underlying the coastal beach and dune formation. In particular, the key outcome of the investigation was to develop a subsurface model of the level to competent rock substrate (relative to AHD) within the region between the foreshore and the settlement. This model will be used to assess the potential vulnerability of the site to erosion and future inundation risk, and whether there is a continuous rock barrier located below the ground surface of sufficient strength and height that may prevent the advancement of erosion to the settlement.

To achieve the project objectives, data from the following investigation methods was acquired, processed and analysed so as to obtain the required subsurface information within the anticipated geological conditions:

1. **Geological mapping** of surface rock outcrops within the study area using high resolution photogrammetry.
2. **Geophysical testing** by way of Multi-channel Analysis of Surface Waves (MASW) to obtain seismic shear wave velocity models related to variations in subsurface material stiffness.
3. **Intrusive geotechnical testing** by way of Cone Penetration Testing (CPT) to measure sediment strength and compressibility, and for calibration and ground truthing of the geophysical dataset.
4. **Topographic survey** using Differential GNSS receiver and photogrammetry.

2 INVESTIGATION SITE

The investigation was carried out within an approximate 600m corridor of coastal beach and dune formation extending from the foreshore to the north, and to Halls Head Parade to the South from Sharland Street to Peter Street. The extent of the investigation site is shown as a yellow dashed area in Figure 1.

Data was acquired as a series of transects for the seismic geophysical testing and point locations for the intrusive geotechnical testing. These were positioned so as to best utilise existing roads, tracks, and beach whilst not impacting native vegetation and in order to ensure the most optimal, efficient and economical acquisition methodology. Data was not acquired where surface obstructions were present such as thick vegetation, steep topography or where the beach was inundated with seawater. Photographs showing the typical site conditions are provided in Figure 2.

Topography at the site was undulating with an elevation difference between the foreshore at ~0-2mAHD, the dune formation including parklands at ~2-3mAHD, and the existing settlement including roadways and dwellings at greater than 3mAHD. A topographic map showing surface level is provided in Appendix C drawing 3073F-07.

Figure 1: The extent of the geophysical investigation (yellow polygon) at Doddi's Beach. Aerial imagery from drone photogrammetry (main image) and Google Maps (inset image).

Figure 2: Site conditions at Doddi's Beach including along the beach foreshore (left image) and the beach parkland (right image).

3 INVESTIGATION METHODOLOGY

3.1 FIELD SURVEY LOGISTICS

Geophysical data acquisition was carried out on the 3 and 6 July 2023 by a three-person crew from GBG Group consisting of a qualified geophysicist, geologist and field assistant. CPT data acquisition was carried out by a technician from Probedrill on the 5 and 6 July 2023. Where required, the site work was carried out under appropriate traffic and pedestrian management commissioned by the City of Mandurah.

Prior to the commencement of data acquisition, a site assessment was carried out with representatives from the City of Mandurah. Potential concerns and issues including the placement of and access to the MASW transects and CPT points were addressed and the initial indicative survey plan was adjusted, where necessary.

The site work for the investigation consisted of a total of 1152m of MASW profiling acquired as 3 along-shore transects (parallel to the coast) and 2 cross-shore transects (perpendicular to the coast), and a total of 5 CPT points along the transects. Details of the acquired MASW transects and CPT points are provided in Tables 1 and 2 respectively. The extents of the MASW transects and locations of the CPT points overlaid onto aerial imagery are shown in Appendix A drawing 3073F-01.

Table 1 – Acquired MASW Transects (Coordinates in GDA94, MGA Zone 50).

Transect ID	Orientation	Start Coordinate		End Coordinate		Length (m)
		East	North	East	North	
MASW01	Along-shore	378163.3	6401188.5	378449.5	6401038.9	328
MASW02	Along-shore	378483.5	6401000.1	378658.8	6400972.1	184
MASW03	Along-shore	378125.9	6401182.1	378602.5	6400890.9	560
MASW04	Cross-shore	378188.0	6401179.2	378161.5	6401135.7	48
MASW05	Cross-shore	378356.9	6401094.2	378343.1	6401067.8	32

Table 2 – Acquired CPT Points (Coordinates in GDA94, MGA Zone 50).

CPT ID	Coordinate		Surface Level (mAHD)	Probing Depth (m)
	East	North		
CPT-04	378601.1	6400991.0	1.6	3.0
CPT-05	378477.6	6400992.3	3.6	2.3
CPT-06	378251.4	6401122.4	3.4	2.7
CPT-07	378194.0	6401169.0	2.8	3.0
CPT-08	378361.0	6401087.2	2.2	3.2

3.2 MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

MASW is a seismic geophysical method that utilises phase and frequency information to calculate Shear wave (S-wave) velocities in vertical layer models averaged over an array of linearly spaced geophones. These 1D models can be laterally stacked to provide 2D cross-sections of S-wave velocity

in layers. Under most circumstances it is an indicator of material stiffness and as such the method can be used to provide quantitative results on the compaction of the subsurface material.

MASW data was acquired using a Geode (Geometrics) seismograph connected to a receiver array of 24 geophones set at 1m intervals for a total array length of 23m. The receiver array was mobilised on a land streamer whereby the geophones are mounted on base plates attached to webbing, and either towed behind a 4WD light vehicle or manually pulled by the field team. Seismic energy was generated using summed impacts from a PEG-40 (R.T. Clark) vehicle mounted accelerated weight drop or softened steel sledgehammer with source points made at a constant offset from receiver array. MASW acquisition parameters are provided in Table 3. Photographs of MASW data acquisition are shown in Figure 3.

Table 3 – MASW Acquisition Parameters

Parameter	Value
Number of geophones	24
Geophone spacing	1 m
Array length	23 m
Geophone frequency	4.5 Hz
Record length	1 s
Sample interval	0.25 ms
Source	40kg AWD or 6.35kg sledgehammer
Source offset	4 m
Sounding interval	8m
Source stacks	3

Figure 3: MASW data acquisition using a seismic streamer.

The MASW data was observed to be of high quality with the seismic records having high signal to noise ratio. The generated overtone images plotting phase velocity against frequency showed a prominent dispersion curve of the surface wave component. The MASW data was processed using SurfSeis version 6++ (Kansas Geological Survey, 2017) with the following processing routine:

1. Import acquired seismic data files and apply geometry including geophone spacing, source offset and sounding interval.
2. Generate overtone images giving the percentage intensity of phase velocity versus frequency for each seismic record (Figure 4, left image).
3. Pick the maximum intensity across the useful range of frequencies for each overtone image resulting in a dispersion curve.
4. Run the dispersion curves through a 10-layer inversion algorithm to produce 1D soundings plotting seismic S-wave velocity with depth (Figure 4, right image).

The S-wave velocity soundings were compiled with reference to distance along the transects and gridded with Surfer version 25 (Golden Software, 2023). The resulting contoured cross-sections show the variation in the modelled S-wave velocity of the subsurface material in metres per second laterally along each of the transects and with elevation.

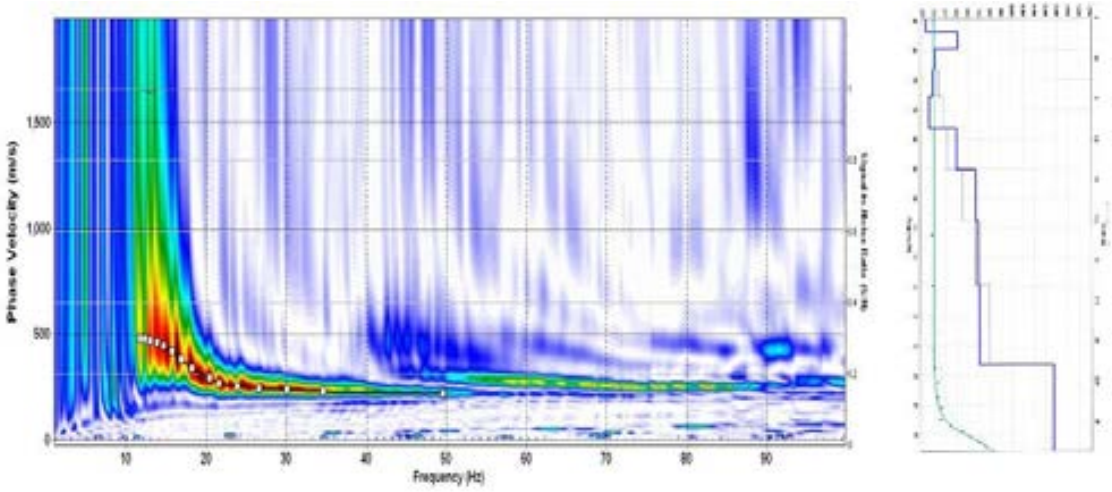

Figure 4: MASW overtone image with high signal to noise ratio and picked dispersion curve.

3.3 CONE PENETRATION TESTING

CPT is a geotechnical test method for evaluating the properties of soils and assessing subsurface stratigraphy including the sediment/rock interface at spot locations. The method involves pushing a calibrated cone and rod into the ground with a measured force with the resulting friction resistance plotted against depth to provide sediment compaction rates as well as the refusal depth indicating the depth to competent rock.

Testing was carried out using a M2 (Morooka) 11 tonne track mounted CPT Rig, specifications of which are provided in Appendix D. The test points were initially marked out at suitable locations within 2m of the intersecting geophysical transects. Dial Before You Dig enquiries and if necessary, utility locating was carried out prior to testing commencing.

CPT readings were made with sufficient ground bearing pressure to obtain a target depth of 10m or prior refusal. Where shallow refusal depths of less than 2m was encountered, when deemed necessary,

an additional offset test was made to ascertain whether shallow refusal was due to a rock floater or other shallow obstruction. A photograph of CPT data acquisition is shown in Figure 5.

Figure 5: CPT data acquisition during a previous coastal investigation.

3.4 SPATIAL POSITIONING AND PHOTOGRAMMETRY

Spatial positioning of the acquired geophysical transects was achieved using Reach RS2 (Emlid) or S631 (Hemisphere) GNSS receivers with a coordinate recorded for each MASW sounding location and CPT point. Coordinates of the geophysical transects have been provided in GDA94, MGA zone 50 for horizontal component and Australian Height Datum (mAHD) for vertical component. An accuracy of +/- 0.2m is expected for both vertical and horizontal components.

To achieve precise reduced levels referenced to AHD, the positioning data was acquired with Real-Time Kinematics (RTK) using Standard Survey Markers (SSM) as known reference points for the base corrections. Details of the SSM used for this investigation are provided in Table 4.

Table 4 – Details of Standard Survey Marker

Parameter	Value
Standard Survey Marker	MANDURAH SW 88
Latitude	S 32 31 43.47469
Longitude	E 115 42 23.65523
Derived GDA94 ellipsoidal height (m)	-30.041
N-Value (m)	-32.587
Height (m) (AHD)	2.546

A reduced level of 0.0mAHD is considered to be the Mean Sea Level (MSL) for the purpose of this investigation. This relationship for Mean Sea Level was established by the Geoscience Australia Survey in 1971 (http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/datums-projections/australian-height-datum-ahd).

Aerial photogrammetry was carried out to obtain an up-to-date high-resolution aerial image and a surface level model of the survey area. Data was acquired with a Matrice 300 (DJI) multi-rotor drone, equipped with a L1 (Zenmuse) camera for the capture of multiple overlapping images.

The acquired photogrammetry images were processed using Metashape Professional (Agisoft) for the generation of a point cloud, surface level model and orthomosaic image of the survey area. Note: for this investigation, vegetation has not been removed during the processing stage and as such the height of existing vegetation needs to be considered when assessing surface levels.

4 RESULTS AND INTERPRETATION

4.1 PRESENTATION OF RESULTS

The results of the geotechnical investigation at Doddi's Beach, City of Mandurah are presented in Appendices B and C of this report as follows:

Appendix B – Geophysical and Interpreted Sections

- **3073F-02.** Transect 1 seismic S-wave velocity model and interpreted geological section.
- **3073F-03.** Transect 2 seismic S-wave velocity model and interpreted geological section.
- **3073F-04 and 3073F-05.** Transect 3 seismic S-wave velocity model and interpreted geological section.
- **3073F-06.** Transects 4 and 5 seismic S-wave velocity model and interpreted geological section.

Appendix C – Modelled Level to Top of Rock and Sand Thickness

- **3073F-07 and 3073F-08.** Contoured surface level model derived from aerial photogrammetry.
- **3073F-09 and 3073F -10.** Contoured level to modelled top of rock.
- **3073F-11.** Class post map level to modelled top of rock.
- **3073F-12 and 3073F -13.** Contoured modelled sand thickness over rock.
- **3073F-14.** Class post map modelled sand thickness over rock.

4.2 SEISIMC SHEAR WAVE VELOCITY SECTIONS

The seismic S-wave velocity (Vs) sections modelled from the MASW data acquired along the along-shore and cross-shore transects are presented at the top of each drawing in Appendix B. These sections show variations in the modelled Vs as per the colour scale with velocity ranging from 150m/s to 1000m/s representing a wide range of material types and conditions.

Seismic S-wave velocity is governed by the elastic properties of the medium that the wave propagates through as shown in the equation below. In particular, it is primarily a function of soil density, void ratio

and effective stress. As such calculated values can provide a useful guide to the subsurface material condition with increasing velocity an indication of increasing material stiffness.

Seismic S-wave velocity $$V_s = \sqrt{\frac{G}{\rho}}$$

where; G = Shear modulus,
ρ = In-situ material density

4.3 INTERPRETED GEOLOGICAL SECTIONS

Below the seismic S-wave velocity sections are the interpreted geological sections based on detectable seismic velocity contrasts correlated with the CPT. Four classes have been defined representing different subsurface material conditions as follows:

1. **Very low seismic S-wave velocity** (Vs <250m/s). Representing the lowest seismic velocities modelled during the investigation, this class is interpreted as sediment consisting of SAND of low compaction from either the beach or dune formation.

2. **Low seismic S-wave velocity** (Vs 250-350m/s). This class is interpreted as sediment consisting of SAND of moderate compaction either due to increased depth of cover on the beach and dune formation, or due to development adjacent to the settlement.

3. **Moderate seismic S-wave velocity** (Vs 350-475m/s). This class is interpreted as low strength rock consisting of variably weathered CALCARENITE. Where continuous and at base of the sections it likely represents a transitional zone to stronger, more competent underlying CALCARENITE. Where present as isolated anomalies within the interpreted SAND it is likely to represent partially lithified SAND and/or CALCARENITE lenses.

4. **Moderate to high seismic wave velocity** (Vs >475m/s). This class is interpreted as moderate strength rock consisting of slightly weathered to fresh CALCARENITE. It is typically observed at the base of the sections as competent rock underlying the variably weathered CALCARENITE.

4.4 CALIBRATION WITH GEOTECHNICAL TESTING AND ROCK MAPPING

The results of the CPTs are presented in Appendix D showing the plots of cone tip resistance in mega-pascals against depth in metres. The CPT plots are also shown in Appendix B and overlayed onto the interpreted geological sections with the following observations being made:

- **CPT-04 on Transect 2** – refusal of 80MPa plus rod friction was at a depth of 3 Below Ground Level (mBGL) which corresponds to the top of interpreted low strength rock.

- **CPT-05 on Transect 2** – refusal due to inclination was at 2.3mBGL which corresponds to the top of interpreted low strength rock.

- **CPT-06 on Transect 3** – refusal due to inclination was at 2.7mBGL, approximately 0.5m into interpreted low strength rock, and at the top of interpreted moderate strength rock. An increase in CPT tip resistance at 2.5mBGL corresponds to the top of interpreted low strength rock suggesting highly variable weathering.

- **CPT-07 on Transect 1** – refusal of 100MPa was at 3.0mBGL which corresponds to the top of interpreted low strength rock.

- **CPT-08 on Transect 1** – refusal due inclination was at 3.2mBGL approximately 0.8m into interpreted low strength rock, and at the top of interpreted moderate strength rock.

The differences in the modelled level to low strength and moderate strength rock as interpreted from the MASW transects and from the CPT data can be attributed to the fact that the geophysical methods used are broad scale whilst the CPT is a point method. Geophysical methods sample a volume of subsurface material with the calculated depths at any particular point representing an average value over this volume. The CPT method samples the subsurface directly below the probe and is influenced by local variations in the subsurface such as rock floaters, highly weathered zones or lenses of partially lithified sediment. The differences in the type of subsurface sampling of the methods will not adversely affect the results as the CPT results have been used to constrain the geophysics interpretation and as such the results represent the best modelled fit between the datasets.

No surface outcropping rock was observed onsite along the acquired MASW transects. Furthermore, analysis of the orthomosaic image from the aerial photogrammetry indicates no evidence of outcropping rock within the area between the coastal foreshore and settlement.

4.5 MODELLED LEVEL TO TOP OF ROCK AND SAND THICKNESS

Subsurface models for the level to top of rock substrate and overlying sand thickness within the region between the coastal foreshore and settlement are presented in Appendix C. These has been generated by digitising the interface between the interpreted sediment and underling rock profile from the interpreted geological sections along the acquired along-shore and cross-shore transects and calibrated with the CPT plots. The modelled sand thickness was then generated by subtracting this from the surface elevation. The following subsurface models have been provided:

- **Contoured Surface Level Model** (drawing 3073F-07 and 3073F-08) – generated from the aerial photogrammetry, this presents the level to ground surface ranging from 0mAHD to 11mAHD. Note: vegetation height has not been removed from these models.

- **Contoured Level to Top of Rock Substrate** (drawing 3073F-09 and 3073F-10) – this presents the level to the top of rock substrate ranging from -2mAHD to 3mAHD.

- **Classed Post Map Level to Top of Rock Substrate** (drawing 3073F-11) – this presents the level to the top of rock substrate along the acquired transects at 1m level increments from -3mAHD to 3mAHD.

- **Contoured Sand Thickness Over Rock** (drawing 3073F-12 and 3073F-13) – this presents the thickness of sand overlying the rock substrate ranging from 0mBGL to 6mBGL.

- **Classed Post Map Sand Thickness Over Rock** (drawing 3073F-14) – this presents the thickness of sand overlying the rock substrate along the acquired transects at 1m depth increments from 1mBGL to 6mBGL.

The following limitations should be considered when assessing the subsurface models for the level to top of rock substrate and overlying sand thickness:

The expected accuracy of the top of rock substrate modelled from this investigation is +/-0.5mAHD. Similarly, an accuracy of +/-0.5m is expected for the modelled sand thickness over rock. The quoted accuracies have been based on consideration to the accuracy of the GNSS receivers using during the site work, 1D inversion of the MASW dataset using a 10-layer model, and expected undulations in the sand/rock interface. Note the quoted accuracies are only valid along the geophysical transects. Values given between transects have been interpolated in the contour maps and as such the accuracy in this case is indeterminable.

The generated contours will give the general trend of the top of rock profile however will not image local variations when the extent of these is less than transect spacing. Spatially small features such as karst sinkholes or pinnacle features may not be imaged. The significance of this limitation is considered minor for this investigation since although local geological features such as pinnacles may not be represented in the data, the generated surface of the top of rock will show the broad trends in the geology over the site which is suitable for a coastal erosion assessment.

Transition zones including between fresh and weathered rock and between sediment and lithified/partially lithified sediment may be gradational and as such the interface between these layers are not well defined.

The calculated levels to the top of rock will only be valid along the geophysical transects. Values shown on the contour maps not on the transects have been interpolated using the krigging algorithm and as such the accuracy of these levels is indeterminable. The contour surface will give the general trend of the interface however may not image local variations, it is recommended that the interpreted geological sections presented in Appendix B be used to obtain more accurate top of rock levels and overlying sand thickness.

5 PROJECT SUMMARY

A geotechnical investigation has been carried out as part of a coastal erosion assessment at Doddi's Beach in the City of Mandurah, Western Australia. During the investigation ground geophysical and

intrusive geotechnical testing was conducted within a 600m corridor of coastal beach and dune formation adjacent to the Doddi's Beach settlement which has been identified as an at risk site as part of Coastal Hotspot #37.

The investigation scope consisted of acquiring multi-channel analysis of surface waves data as a series of specified transects either along-shore (parallel to the coast) or cross-shore (perpendicular to the coast) and cone penetration testing at spot locations along these transects. This was supplemented with geological mapping of surface rock outcrops and topographic survey using high resolution photogrammetry for the generation of a surface level model and orthomosaic image.

The acquired MASW dataset was processed for the generation of seismic velocity sections along the transects showing variations in the seismic shear wave velocity of the subsurface material to a target depth of 10-15m below ground level. The seismic velocity sections were calibrated with the CPT plots and demarcated into velocity ranges representing different material types and conditions for the generation of interpreted geological sections consisting of loose to compacted sediment and variably weathered to fresh rock.

The interpreted geological sections have been compiled to develop subsurface models of the level to rock substrate (relative to AHD) and overlying sand thickness within the region between the foreshore and the settlement. This model will be used to assess the potential vulnerability of the site to erosion and future inundation risk, and whether there is a continuous rock barrier located below the ground surface of sufficient strength and height that may prevent the advancement of erosion to the settlement.

The methods used during the investigation are geophysical and as such the results are based on indirect measurements and the processing and interpretation of seismic wave signals calibrated with limited intrusive geotechnical testing. The findings in this report represent the professional opinions of the authors, based on experience gained during previous similar investigations.

We trust that this report and the attached drawings provide you with the information required. If you require clarification on any points arising from this geophysical investigation, please do not hesitate to contact the undersigned on 08 9354 6300.

For and on behalf of
GBG GEOTECHNICS (AUSTRALIA)

ANDREW SPYROU
Operations Manager, Western Australia / Senior Geophysicist

APPENDIX A – INVESTIGATION SITE MAP

GBGGROUP

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

INVESTIGATION SITE MAP

NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

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	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawr	PJE
		Drawing	3073F-01	Revision	C

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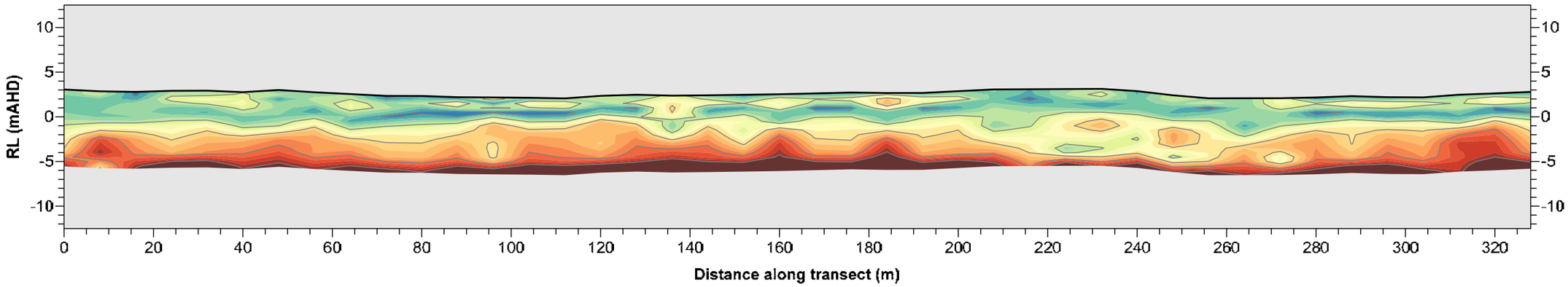
APPENDIX B – GEOPHYSICAL AND INTERPRETED SECTIONS

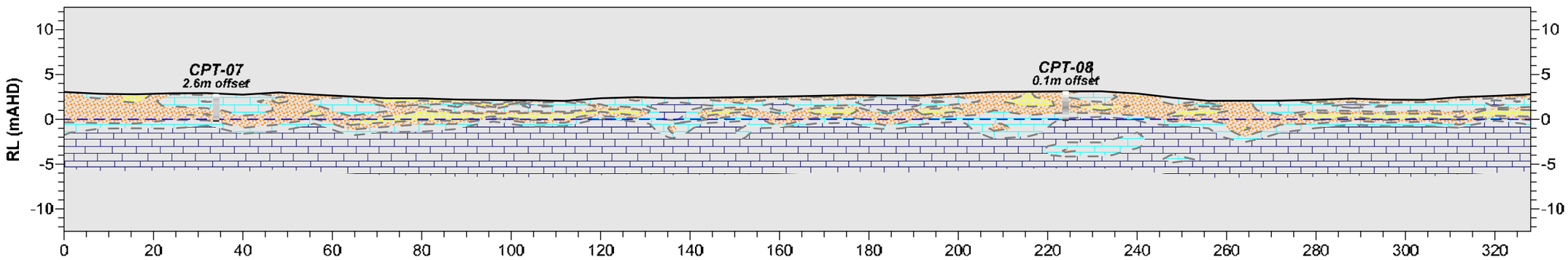
GBGGROUP

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURAH WESTERN AUSTRALIA

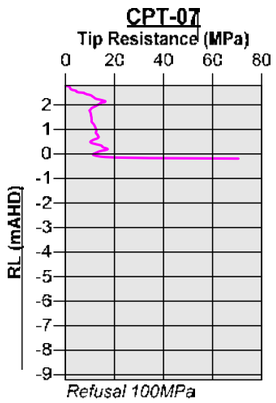
TRANSECT 1 - SEISMIC SHEAR WAVE VELOCITY MODEL



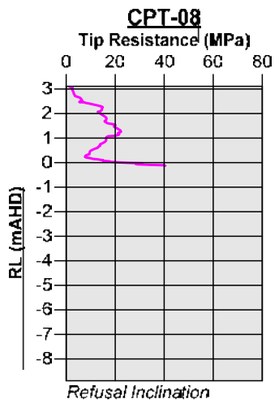
TRANSECT 1 - INTERPRETED GEOLOGICAL SECTION



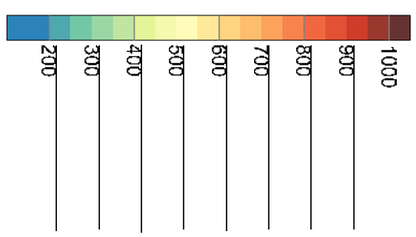
CPT-07



CPT-08



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

- SAND - LOW COMPACTION
  S-WAVE VELOCITY < 250 m/s
- SAND - MODERATE COMPACTION
  S-WAVE VELOCITY 250-350 m/s
- LOW STRENGTH WEATHERED ROCK
  S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK
  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

CONE PENETRATION TEST

Tip Resistance (MPa)

- 0 to <5
- 5 to <10
- 10 to <15
- 15 to <20
- 20 to <25
- 25 to <30
- 30 to <35
- 35 to <40
- 40 to <45
- 45 to <50
- Equal to or >50

NOTES

Drawing to be used in conjunction with Report 3073F.
Positioning is given in GDA 94 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:1000H, 1:500V	Drawn	PJE
		Drawing	3073F-02	Revision	C

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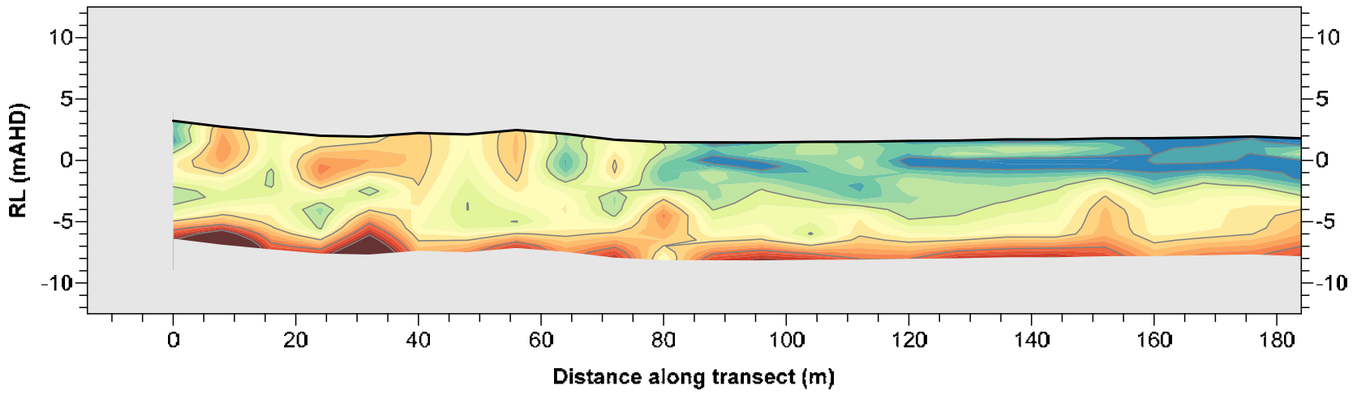
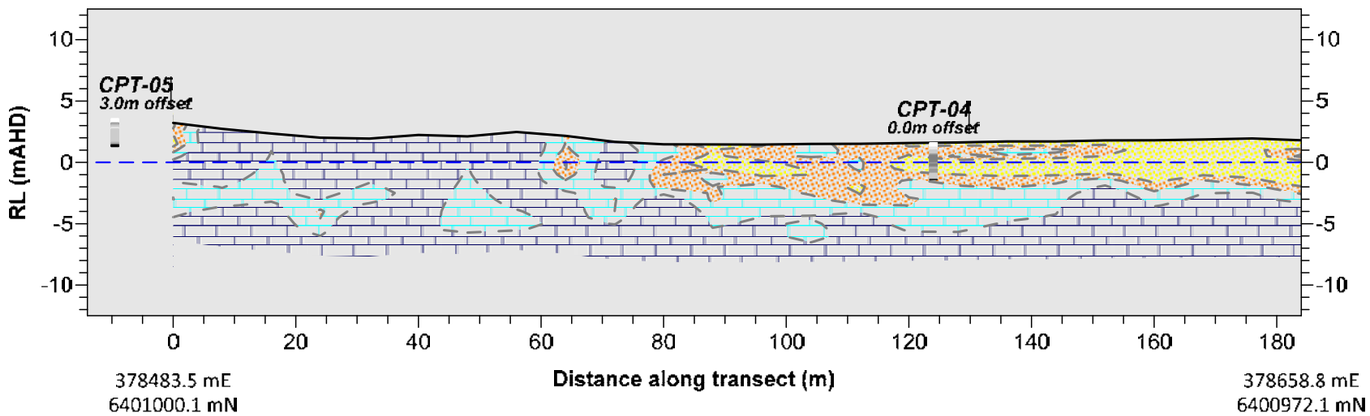
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURAH WESTERN AUSTRALIA

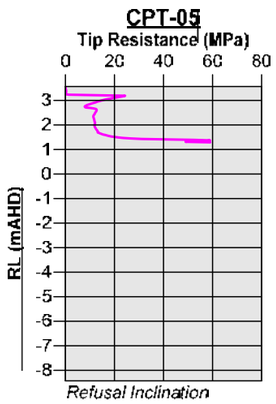
TRANSECT 2 - SEISMIC SHEAR WAVE VELOCITY MODEL



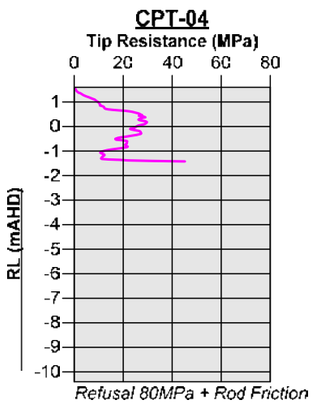
TRANSECT 2 - INTERPRETED GEOLOGICAL SECTION



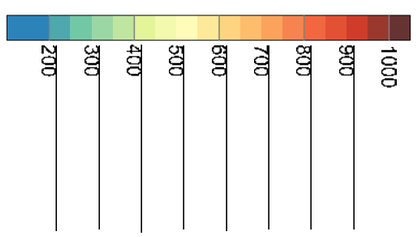
CPT-05



CPT-04



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

- SAND - LOW COMPACTION
  S-WAVE VELOCITY < 250 m/s
- SAND - MODERATE COMPACTION
  S-WAVE VELOCITY 250-350 m/s
- LOW STRENGTH WEATHERED ROCK
  S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK
  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

CONE PENETRATION TEST

Tip Resistance (MPa)

- 0 to <5
- 5 to <10
- 10 to <15
- 15 to <20
- 20 to <25
- 25 to <30
- 30 to <35
- 35 to <40
- 40 to <45
- 45 to <50
- Equal to or >50

NOTES

Drawing to be used in conjunction with Report 3073F.
Positioning is given in GDA 94 zone 50.
Levels are given in Australian Height Datum (AHD).

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	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:1000H, 1:500V	Drawn	PJE
		Drawing	3073F-03	Revision	C

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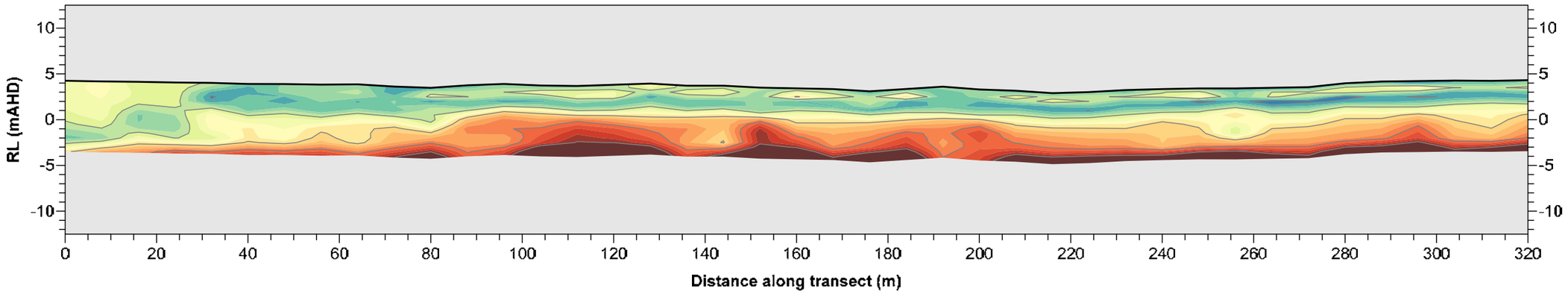
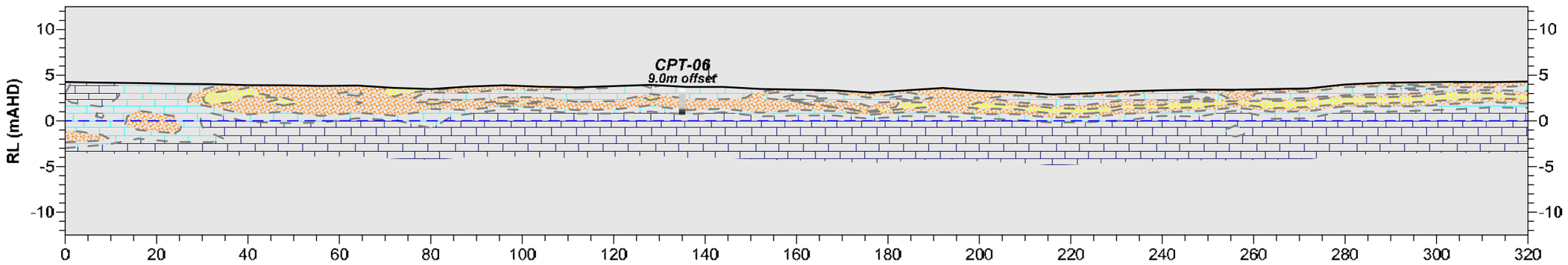
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURAH WESTERN AUSTRALIA

TRANSECT 3 (0-320m) - SEISMIC SHEAR WAVE VELOCITY MODEL



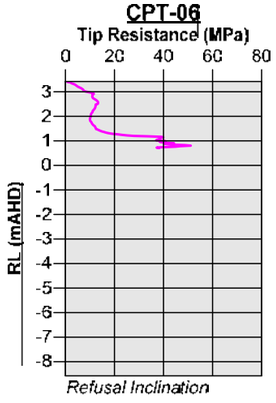
TRANSECT 3 (0-320m) - INTERPRETED GEOLOGICAL SECTION



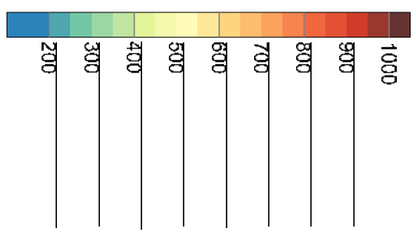
378125.9 mE
6401182.1 mN

378403.6 mE
6401023.8 mN

CPT-06



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

- SAND - LOW COMPACTION
  S-WAVE VELOCITY < 250 m/s
- SAND - MODERATE COMPACTION
  S-WAVE VELOCITY 250-350 m/s
- LOW STRENGTH WEATHERED ROCK
  S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK
  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

CONE PENETRATION TEST

Tip Resistance (MPa)

- 0 to <5
- 5 to <10
- 10 to <15
- 15 to <20
- 20 to <25
- 25 to <30
- 30 to <35
- 35 to <40
- 40 to <45
- 45 to <50
- Equal to or >50

NOTES

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Levels are given in Australian Height Datum (AHD).

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	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:1000H, 1:500V	Drawn	PJE
		Drawing	3073F-04	Revision	C

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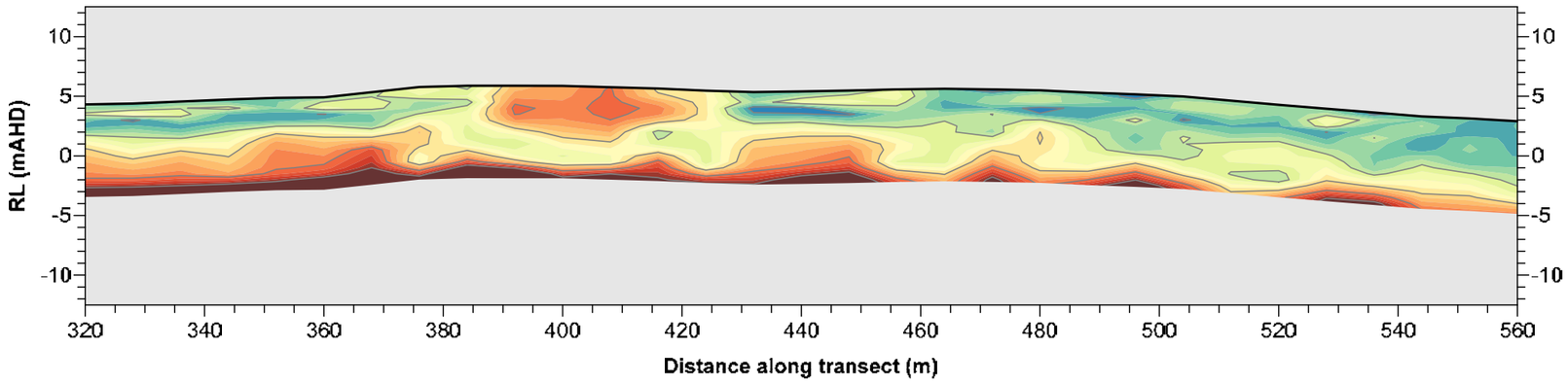
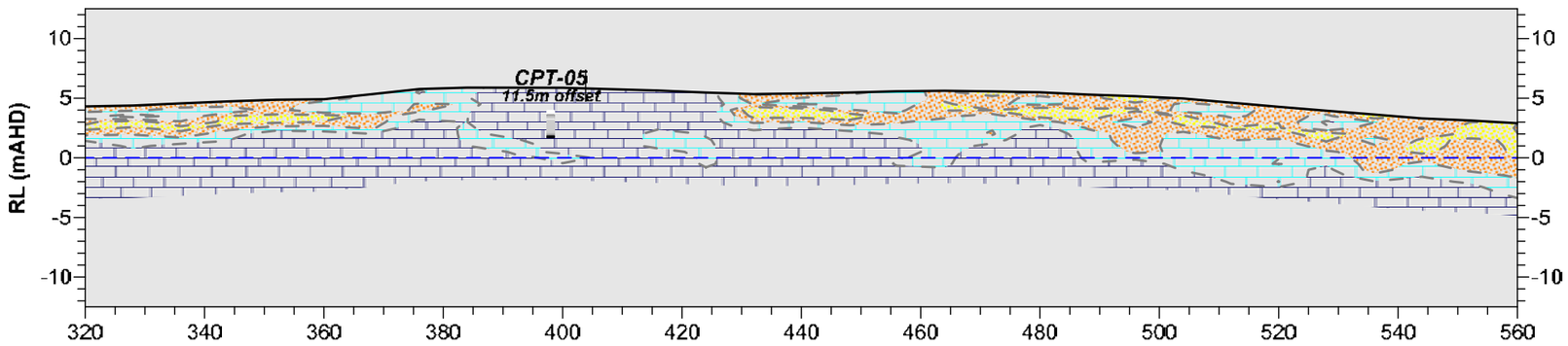
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURAH WESTERN AUSTRALIA

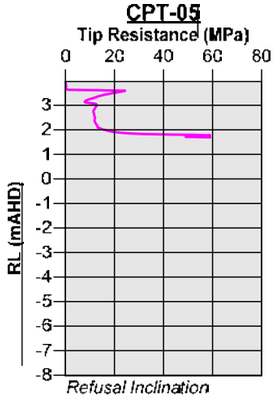
TRANSECT 3 (320-560m) - SEISMIC SHEAR WAVE VELOCITY MODEL



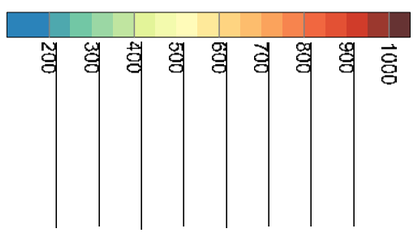
TRANSECT 3 (320-560m) - INTERPRETED GEOLOGICAL SECTION



CPT-05



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

- SAND - LOW COMPACTION
  S-WAVE VELOCITY < 250 m/s
- SAND - MODERATE COMPACTION
  S-WAVE VELOCITY 250-350 m/s
- LOW STRENGTH WEATHERED ROCK
  S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK
  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

CONE PENETRATION TEST

Tip Resistance (MPa)

- 0 to <5
- 5 to <10
- 10 to <15
- 15 to <20
- 20 to <25
- 25 to <30
- 30 to <35
- 35 to <40
- 40 to <45
- 45 to <50
- Equal to or >50

NOTES

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Positioning is given in GDA 94 zone 50.
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	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:1000H, 1:500V	Drawn	PJE
		Drawing	3073F-05	Revision	C

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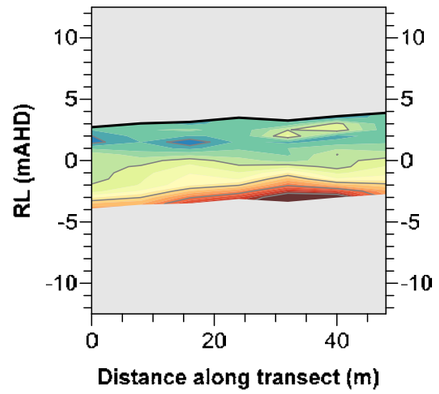
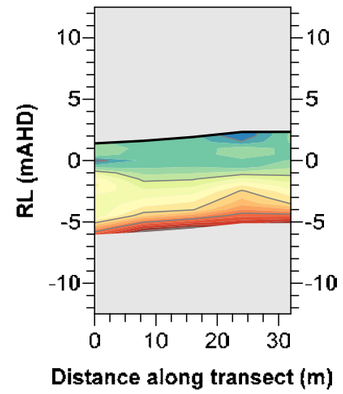
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURAH WESTERN AUSTRALIA

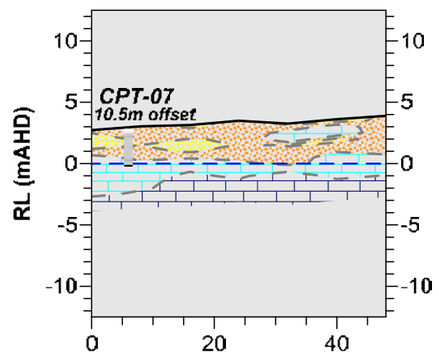
TRANSECT 4 - SEISMIC SHEAR WAVE VELOCITY MODEL



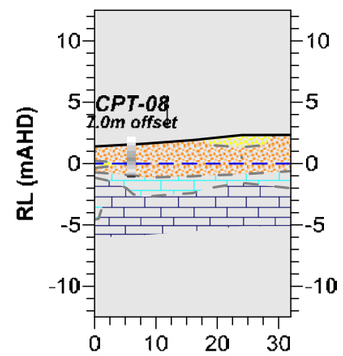
TRANSECT 5 - SEISMIC SHEAR WAVE VELOCITY MODEL



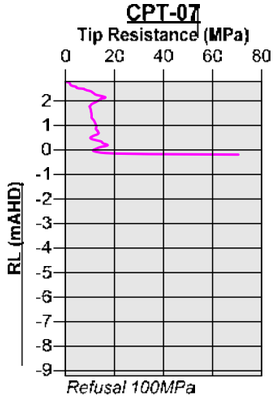
TRANSECT 4 - INTERPRETED GEOLOGICAL SECTION



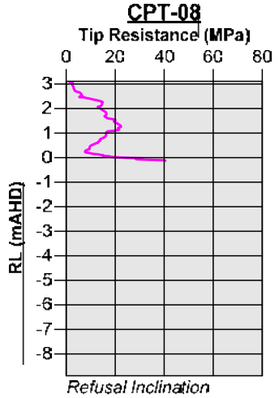
TRANSECT 5 - INTERPRETED GEOLOGICAL SECTION



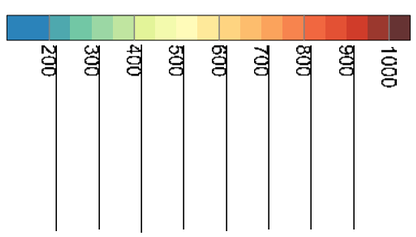
CPT-07



CPT-08



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

- SAND - LOW COMPACTION
  S-WAVE VELOCITY < 250 m/s
- SAND - MODERATE COMPACTION
  S-WAVE VELOCITY 250-350 m/s
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  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

CONE PENETRATION TEST

Tip Resistance (MPa)

- 0 to <5
- 5 to <10
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- 35 to <40
- 40 to <45
- 45 to <50
- Equal to or >50

NOTES

Drawing to be used in conjunction with Report 3073F.
Positioning is given in GDA 94 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:1000H, 1:500V	Drawn	PJE
		Drawing	3073F-06	Revision	C

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APPENDIX C – MODELLED TOP OF ROCK AND SAND THICKNESS

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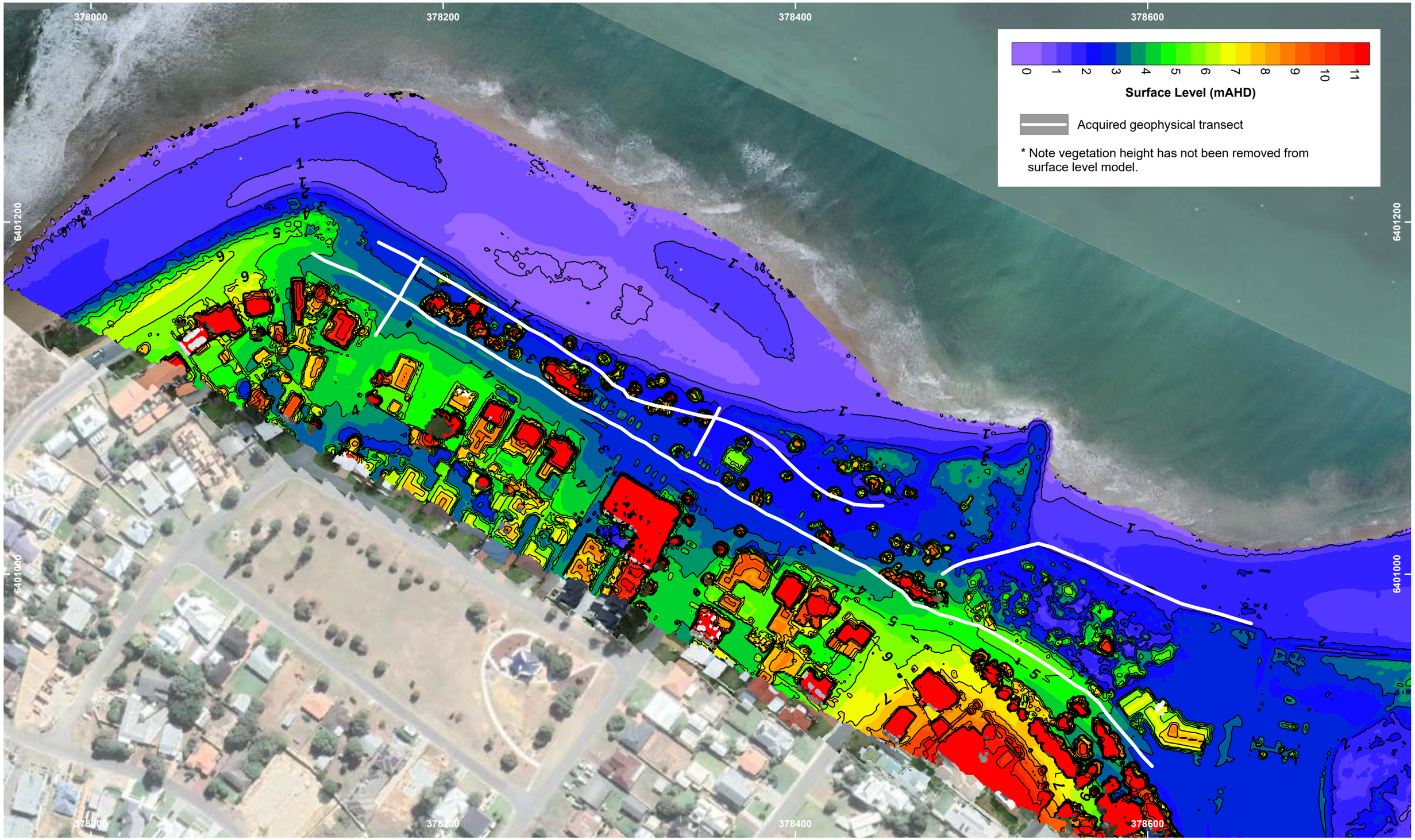
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

SURFACE LEVEL MODEL



NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-07	Revision	C

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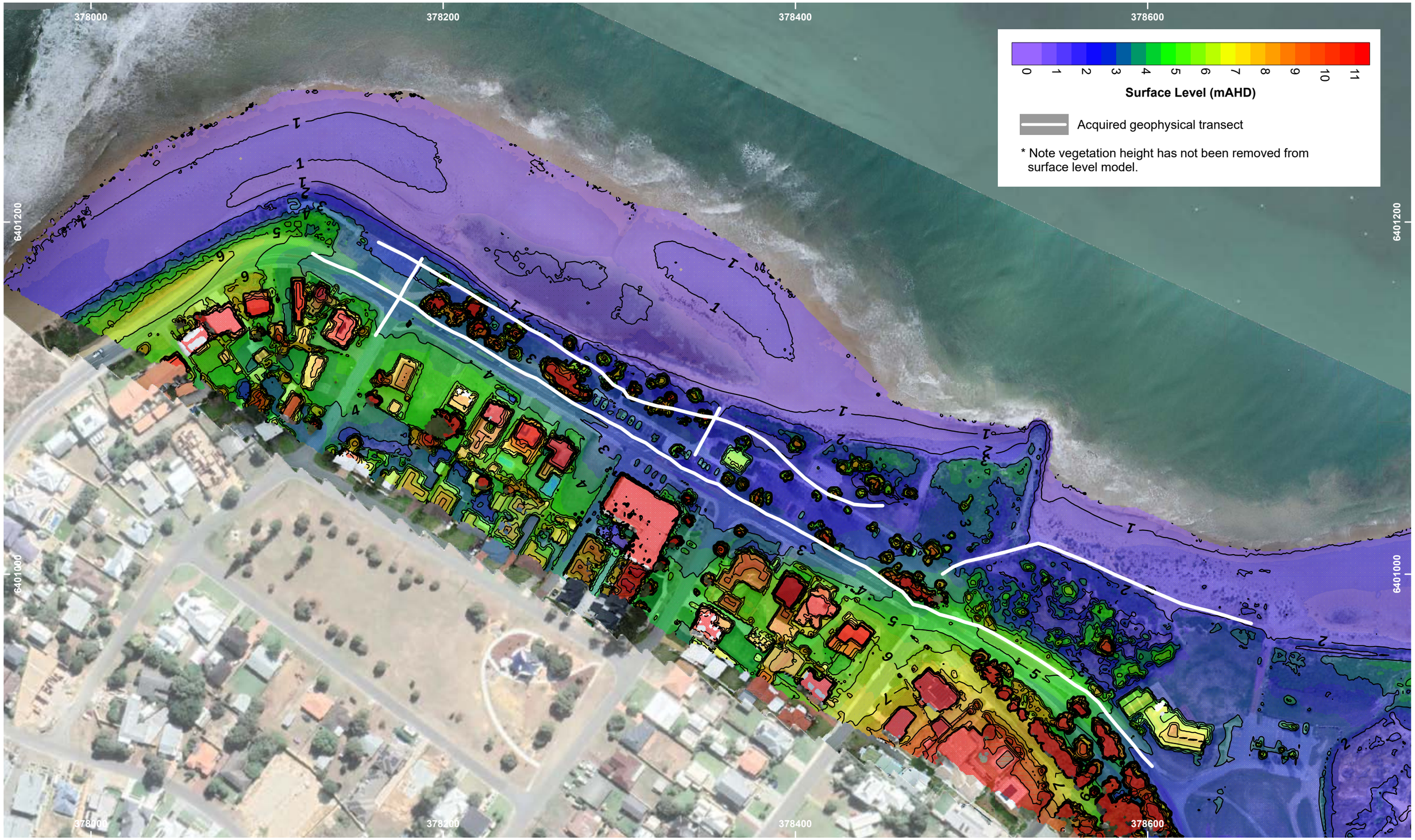
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

SURFACE LEVEL MODEL



NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-08	Revision	C

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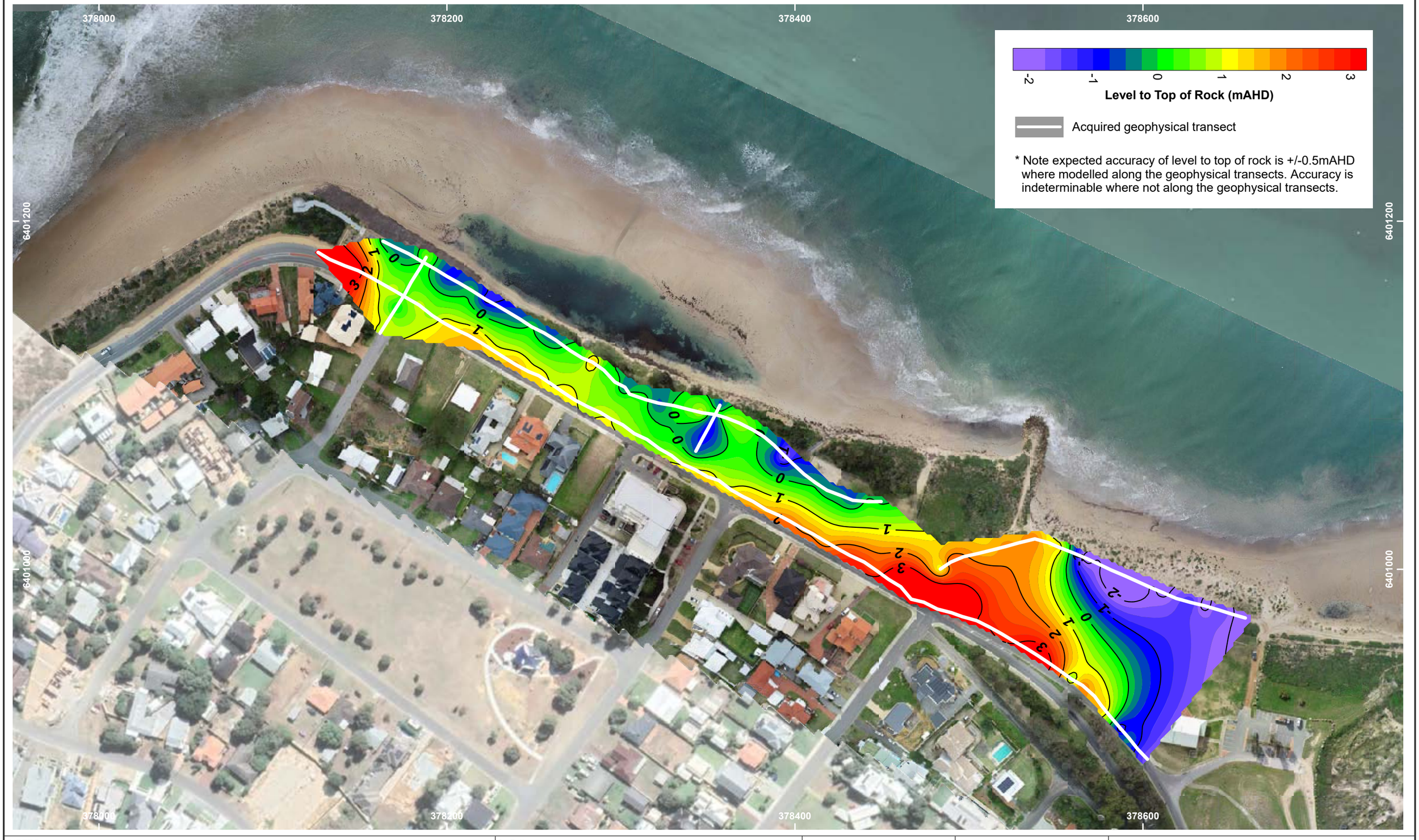
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK



NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-09	Revision	C

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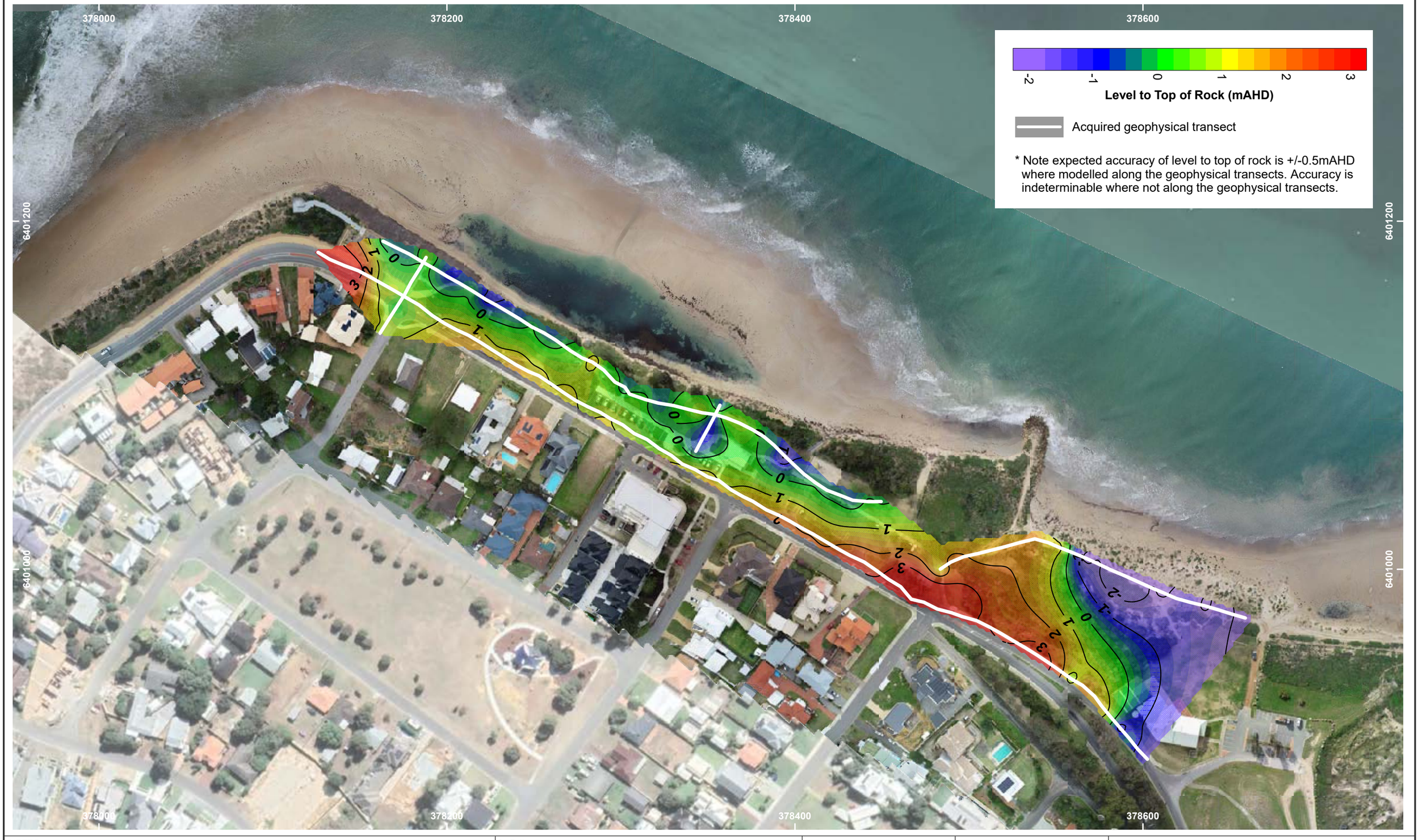
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK



NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-10	Revision	C

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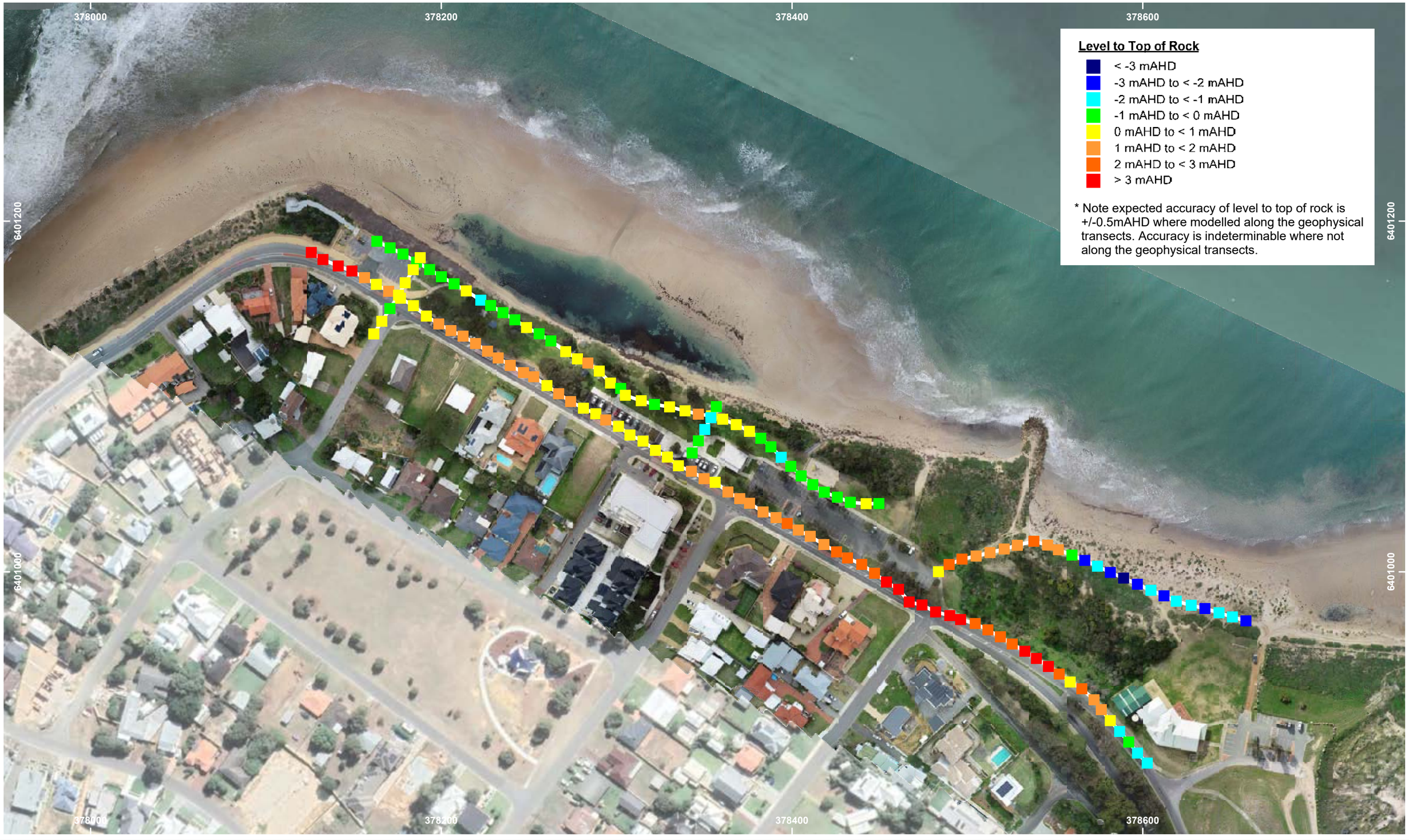
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

CLASSED POST MAP LEVEL TO TOP OF ROCK



NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-11	Revision	C

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

CONTOURED SAND THICKNESS OVER ROCK

NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-12	Revision	C

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

CONTOURED SAND THICKNESS OVER ROCK

NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-13	Revision	C

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DODDI'S BEACH, CITY OF MANDURH WESTERN AUSTRALIA

CLASSED POST MAP SAND THICKNESS OVER ROCK

NOTES

Drawing to be used in conjunction with Report 3073F.
Map Projection GDA94 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	1 September 2023	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DODDI'S BEACH, CITY OF MANDURAH WA	Scale	1:2000	Drawn	PJE
		Drawing	3073F-14	Revision	C

GBGGROUP
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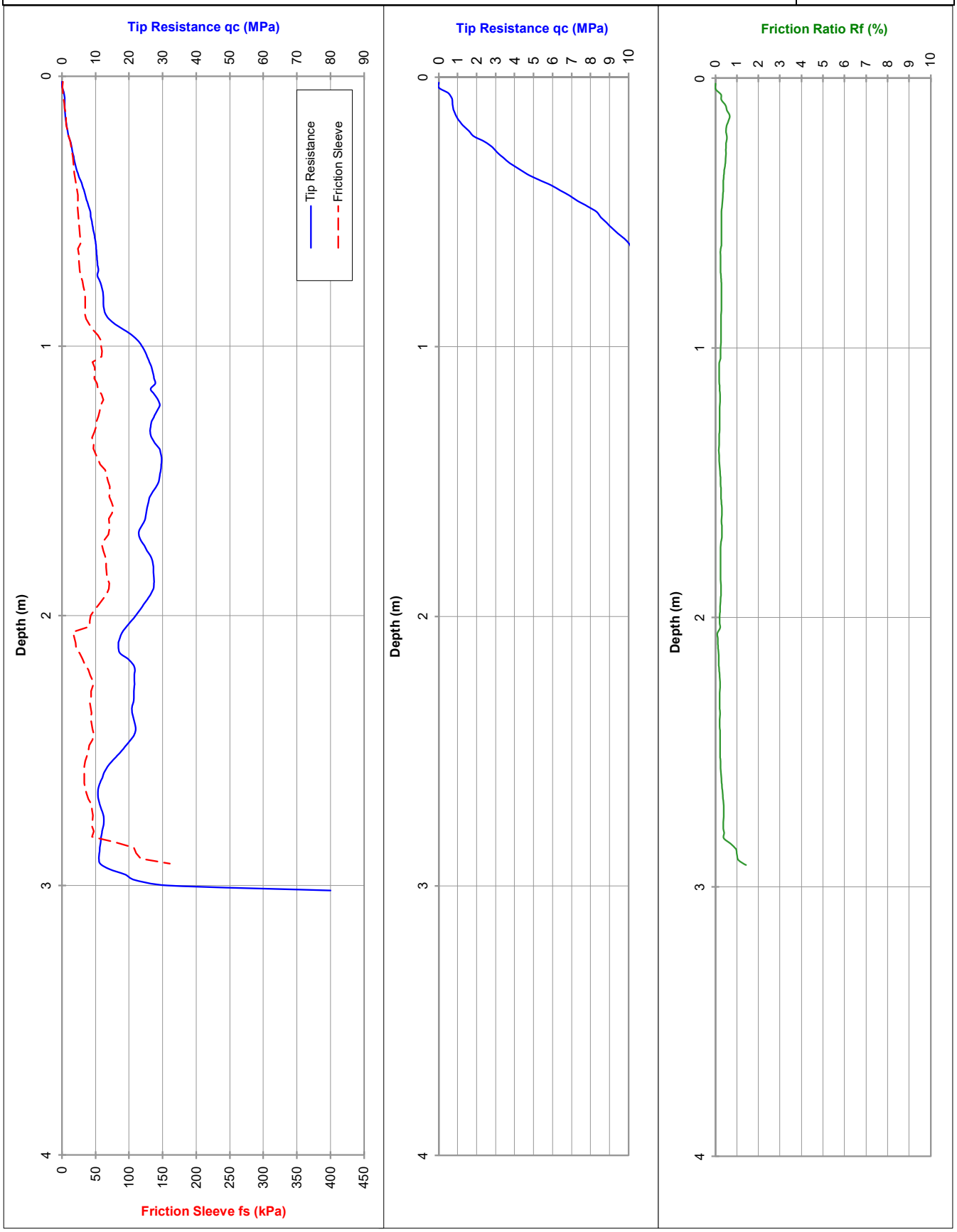
APPENDIX D – CONE PENETRATION TEST PLOTS

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: Department of Transport	Job No.: 3073	Probe I.D
PROJECT: Geophysical Investigation for Coastal Erosion Study	RL (m):	**CPT 04**
LOCATION: Doddis Beach Halls Head	Co-ords:	5-Jul-23



PROBEDRILL GEOTECHNICAL SURVEY

Tested in accordance with AS 1289.6.5.1-1999 and IRTP 2001 for friction reducer

Approx. water (m): -

Dummy probe to (m):

Refusal: 80 MPa + Rod Friction

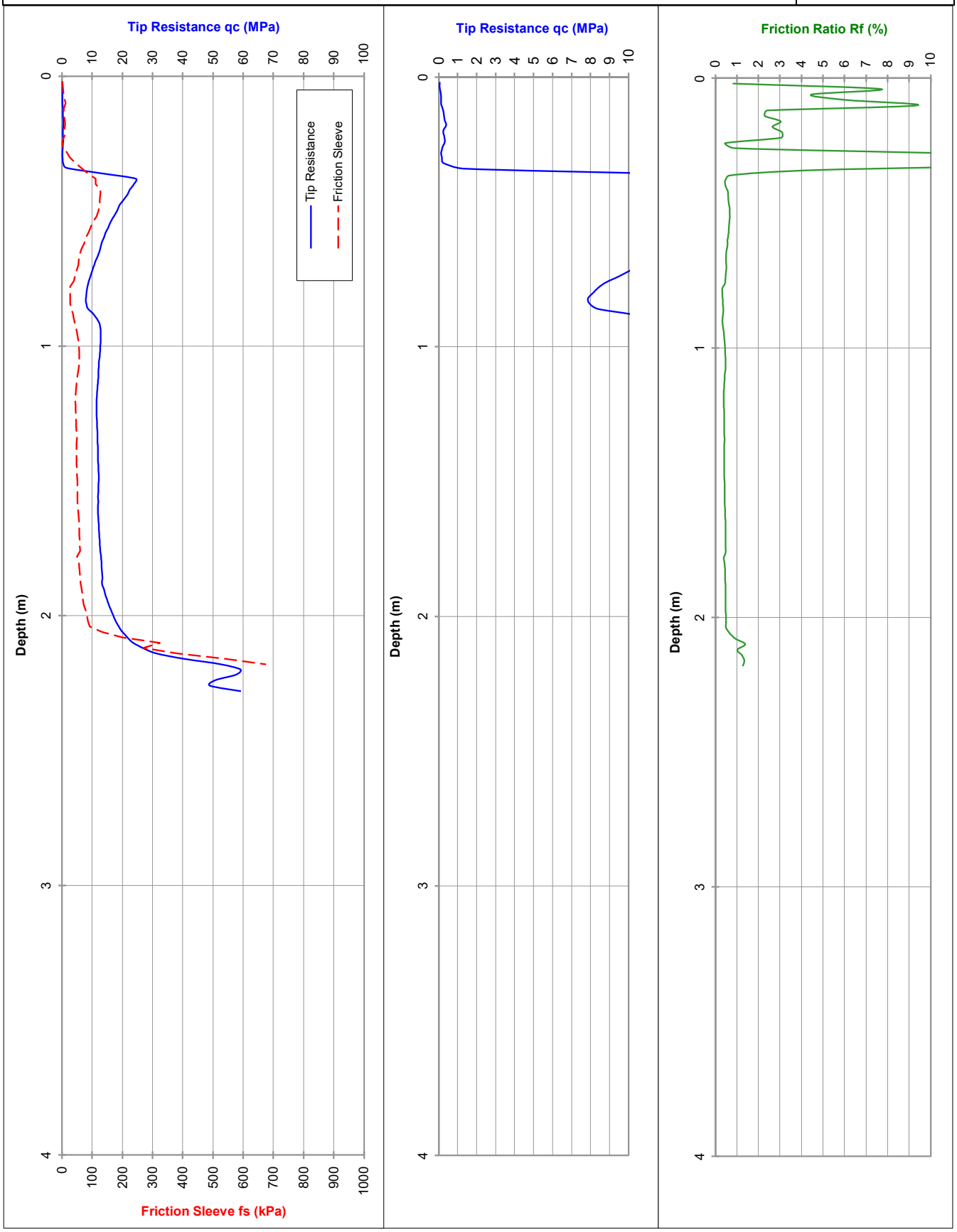
Cone I.D.: EC16

File: GB0029M2

Rig Type: 11t track (M2)

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: Department of Transport	Job No.: 3073	Probe I.D
PROJECT: Geophysical Investigation for Coastal Erosion Study	RL (m):	**CPT 05**
LOCATION: Doddis Beach Halls Head	Co-ords:	6-Jul-23



PROBEDRILL GEOTECHNICAL SURVEY

Tested in accordance with AS 1289.6.5.1-1999 and IRTP 2001 for friction reducer

Approx. water (m): 2.0

Dummy probe to (m): 0.4

Refusal: Inclination

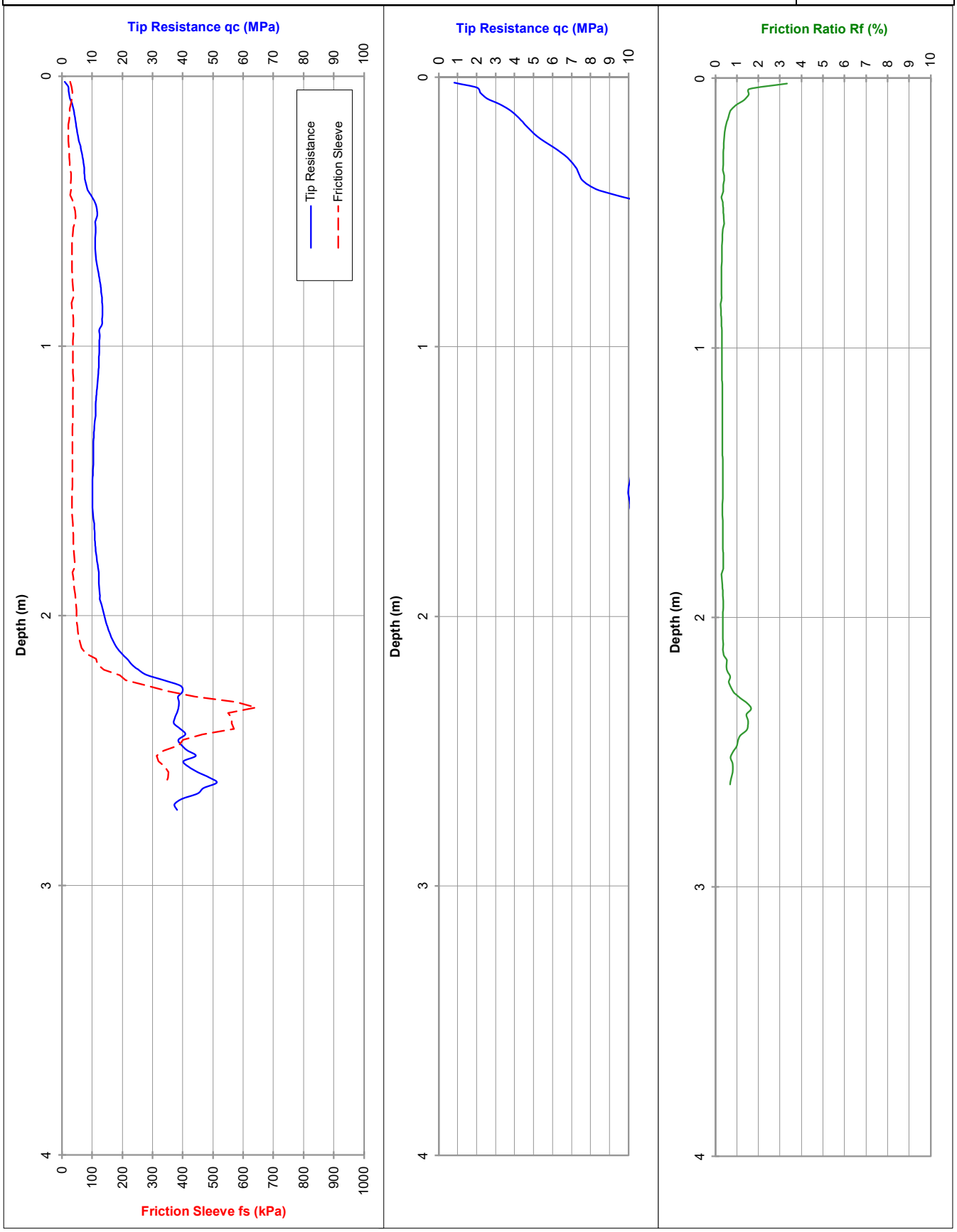
Cone I.D.: EC46

File: GB0021TT

Rig Type: 22t truck (Track-Truck)

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: Department of Transport	Job No.: 3073	Probe I.D
PROJECT: Geophysical Investigation for Coastal Erosion Study	RL (m):	**CPT 06**
LOCATION: Doddis Beach Halls Head	Co-ords:	6-Jul-23



PROBEDRILL GEOTECHNICAL SURVEY

Tested in accordance with AS 1289.6.5.1-1999 and IRTP 2001 for friction reducer

Approx. water (m): 2.2

Dummy probe to (m):

Refusal: Inclination

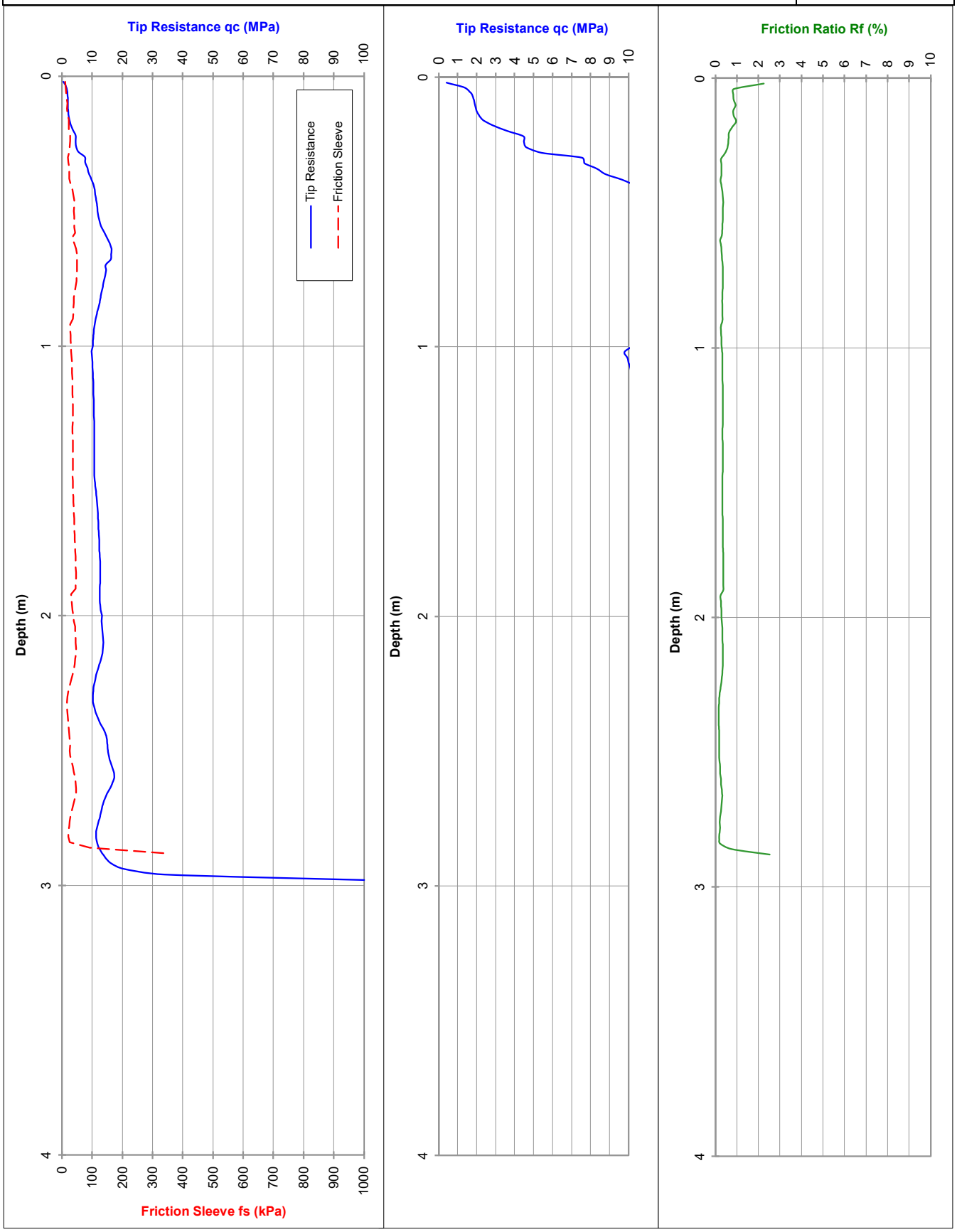
Cone I.D.: EC46

File: GB0022TT

Rig Type: 22t truck (Track-Truck)

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: Department of Transport	Job No.: 3073	Probe I.D
PROJECT: Geophysical Investigation for Coastal Erosion Study	RL (m):	**CPT 07**
LOCATION: Doddis Beach Halls Head	Co-ords:	6-Jul-23



PROBEDRILL GEOTECHNICAL SURVEY

Tested in accordance with AS 1289.6.5.1-1999 and IRTP 2001 for friction reducer

Approx. water (m): 2.2

Dummy probe to (m):

Refusal: 100 MPa

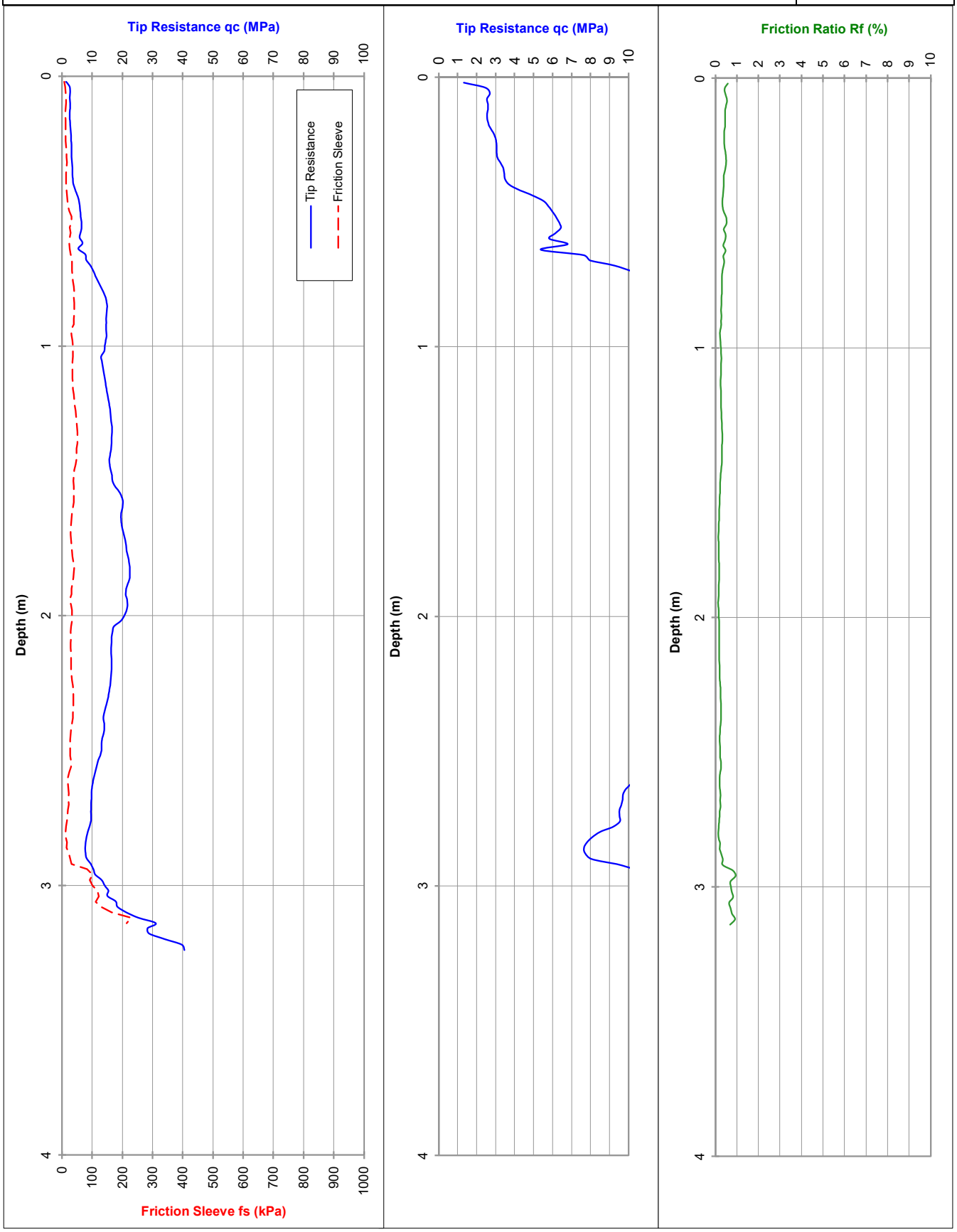
Cone I.D.: EC46

File: GB0023TT

Rig Type: 22t truck (Track-Truck)

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: Department of Transport	Job No.: 3073	Probe I.D
PROJECT: Geophysical Investigation for Coastal Erosion Study	RL (m):	**CPT 08**
LOCATION: Doddis Beach Halls Head	Co-ords:	6-Jul-23



PROBEDRILL GEOTECHNICAL SURVEY

Tested in accordance with AS 1289.6.5.1-1999 and IRTP 2001 for friction reducer

Approx. water (m): 2.4

Dummy probe to (m):

Refusal: Inclination

Cone I.D.: EC46

File: GB0024TT

Rig Type: 22t truck (Track-Truck)

PROBEDRILL
GEOTECHNICAL SURVEY

CALIBRATION CERTIFICATE

CONE ID: EC16

Cone Type:	Compression
Calibration Date (qc/fs):	10 May 2023
Calibration Date (u):	10 February 2023
Preliminary Inspection:	Pass
Calibrated By:	Henky Lawer
Calibration Procedure:	ISO 22476-1:2012, IRTP 2001
Force Application:	Compression
Reference Equipment:	PT - S type 100kN Serial # 5126009 (Calibrated 10/03/23 - NATA approved Cert. No. 230664) Bongshin - S type 50kN Serial #W05345 (Calibrated 10/03/23 - NATA approved Cert. No. 230663) Digitron Panel Meter Serial #: 060213/01 (Calibrated 09/03/23 - NATA endorsed Report No. 230658, 230659, 230660)

Note: In accordance with AS1289 F5.1 the force calibration derived by NATA Calibration Certificates are converted to a qc reading in MPa and fs reading in kPa by dividing by 1000 mm^2 and 15000mm^2 respectively.

Results of Calibration:

qc (tip resistance):

Capacity: 100 (MPa)
Area 1000 (mm^2)

Applied Load kN	Eqv. Pressure MPa	Mean Observed Reading Volts
0	0	0.000
10	10	0.757
20	20	1.517
30	30	2.279
40	40	3.040
50	50	3.802
60	60	4.564
70	70	5.326
80	80	6.088
90	90	6.850
100	100	7.613
90	90	6.862
80	80	6.108
70	70	5.351
60	60	4.591
50	50	3.830
40	40	3.067
30	30	2.303
20	20	1.536
10	10	0.769
0	0	0.002
R^2 Value =	1.000	

Zero Load Error: 0.02%
Max. Linearity 0.26%
Max. Hysteris 0.38%

MPa/Volt: 13.126

fs (sleeve friction):

Capacity: 2000 (kPa)
Area 15000 (mm^2)

Applied Force kN	Eqv. Load kPa	Mean Observed Reading Volts
0	0	0.000
3	200	0.753
6	400	1.512
9	600	2.267
12	800	3.025
15	1000	3.784
18	1200	4.544
21	1400	5.302
24	1600	6.067
27	1800	6.829
30	2000	7.592
27	1800	6.843
24	1600	6.088
21	1400	5.332
18	1200	4.574
15	1000	3.814
12	800	3.054
9	600	2.292
6	400	1.529
3	200	0.764
0	0	0.004
R^2 Value =	1.000	

Zero Load Error: 0.05%
Max. Linearity 0.23%
Max. Hysteris 0.40%

kPa/Volt: 263.37

u (pore pressure):

Capacity: 3500 (kPa)
Position u2

Applied Pressure bar	Eqv. Pressure kPa	Mean Observed Reading Volts
0	0	0.000
3	300	0.415
6	600	0.830
9	900	1.245
12	1200	1.662
15	1500	2.077
18	1800	2.492
21	2100	2.907
25	2500	3.462
30	3000	4.153
35	3500	4.843
30	3000	4.157
25	2500	3.467
21	2100	2.912
18	1800	2.497
15	1500	2.082
12	1200	1.667
9	900	1.250
6	600	0.834
3	300	0.418
0	0	0.001
R^2 Value =	1.000	

Zero Load Error: 0.01%
Max. Linearity 0.12%
Max. Hysteris 0.14%

kPa/Volt: 722.25
Net Area (calibrated): 0.81

"Class 1" Application Accuracy achieved (in accordance with ISO 22476:2012 classification)

Calibration Checked & Authorised: Kylie Walker

Job Details

Client:	GB Geotechnics	**Date of Job:**	05/07/2023
Rep:	Andrew Spyrou	**Tip Diameter:**	35.6
Location:	Falcon Beach	**Sleeve Diameter:**	35.95

PROBEDRILL
GEOTECHNICAL SURVEY

MOROOKA (M2)

11 tonne track mounted CPT Rig

SPECIFICATIONS

Overall Dimensions	Width: 2.3m; Length: 5.3m; Height: 3.2m (while travelling) Height: 4.4m (while probing)
Gross Weight	11 tonne
Ground Bearing Capacity	0.38 kg/cm^2 (37kPa / 5.4psi)
Speed (Low/High)	Low gear: 8.3km High gear: 12km/h on level ground
Grade ability	60%
Engine	Mitsubishi (3910cc) 110 HP @ 2,800 rpm
Fuel Tank	80 L (Diesel)
Drive System	HST
Tracks	600mm wide rubber tracks
Levelling Jacks	0.8m stroke

EQUIPMENT / FEATURES

Other Equipment / Features	2.4m x 1.2m Plastic Bog Boards 1 x 9kg ABE Fire extinguisher Air conditioned work cabin and drive cabin
Transport	Prime Mover & 10m Drop-deck trailer with ramps

SERVICES

Geotechnical Services provided	CPT, CPTu, SCPT, SCPTu (1, 5, 10, & 15 tonne cones) DMT, SDMT Dissipation Testing Ball Penetrometer CPT casing for additional rod support Dual Tube (percussion) sampling Piston Sampling MOSTAP and PROBEDRILL soil sampling Vane Shear Testing (Electronically driven) Vibrating Wire Installation Water Sampling Standpipe Installation (20mm; 32mm & 50mm)