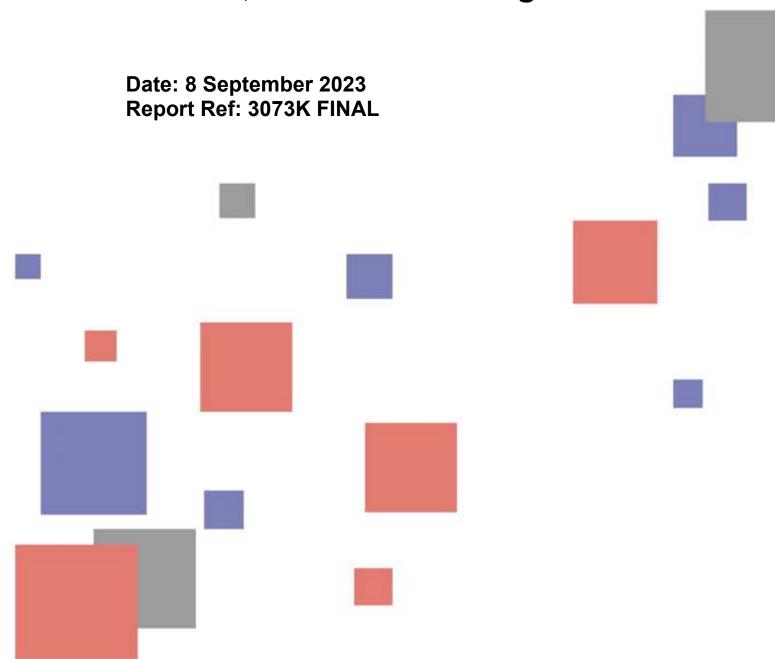


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# Report

# Geotechnical Investigation for Coastal Erosion Vulnerability Assessment.

Cervantes, Shire of Dandaragan WA.





# **DOCUMENT HISTORY**

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#### **EXECUTIVE SUMMARY**

A geotechnical investigation has been carried out as part of a coastal erosion assessment at Cervantes in the Shire of Dandaragan, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 900m corridor of coastal beach and dune formation adjacent to the Cervantes settlement which has been identified as an at-risk site as part of Coastal Hotspot #15.

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 -14mAHD to -4.5mAHD and averaged -10.5mAHD overlain by 5 to 14m of variably compacted sediment.
- Interpreted top of rock substrate on the along-shore transects adjacent to the settlement including on Catalonia Street and Corunna Road ranged from -12mAHD to -3.5mAHD and averaged approximately -7.5mAHD overlain by 4.5 to 13m of variably compacted sediment.
- Interpreted top of rock substrate for the cross-shore transects extending over the dune formation ranged from -13.5mAHD to -3.5mAHD and average approximately -8mAHD overlain by 4.5 to 15.5m of variably compacted sediment.



# **CONTENTS**

1	INTE	RODUCTION	4
2	INV	ESTIGATION SITE	4
3	INV	ESTIGATION METHODOLOGY	6
	3.1	FIELD SURVEY LOGISTICS	6
	3.2	MULTI-CHANNEL ANALYSIS OF SURFACE WAVES	7
	3.3	CONE PENETRATION TESTING	9
	3.4	SPATIAL POSITIONING AND PHOTOGRAMMETRY	9
4	RES	ULTS AND INTERPRETATION	10
	4.1	PRESENTATION OF RESULTS	10
	4.2	SEISIMC SHEAR WAVE VELOCITY SECTIONS	11
	4.3	INTERPRETED GEOLOGICAL SECTIONS	11
	4.4	CALIBRATION WITH GEOTECHNICAL TESTING AND ROCK MAPPING	12
	4.5	MODELLED LEVEL TO TOP OF ROCK AND SAND THICKNESS	13
5	PRC	DJECT SUMMARY	14
ΑP	PEND	DIX A – INVESTIGATION SITE MAP	16
ΑP	PEND	IX B – GEOPHYSICAL AND INTERPRETED SECTIONS	17
ΑP	PEND	IX C – MODELLED TOP OF ROCK AND SAND THICKNESS	18
ΔΡ	DENIC	NX D _ CONE PENETRATION TEST PLOTS	10



#### 1 INTRODUCTION

At the request of The Government of Western Australia Department of Transport (DoT), GBG Group carried out a geotechnical investigation at Cervantes, Shire of Dandaragan in June 2023. During the investigation, seismic geophysical testing and intrusive geotechnical testing was conducted within a 900m corridor of coastal beach and dune formation which has been identified as an at risk site as part of Coastal Hotspot #15.

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 900m corridor of coastal beach and dune formation extending from the foreshore to the west, and to Catalonia Street to the east from Corunna Road to Biscay 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 low lying with an elevation difference between the foreshore at ~0-2mAHD and the existing settlement at ~1-3mAHD. A topographic map showing surface level is provided in Appendix C drawing 3073K-11.

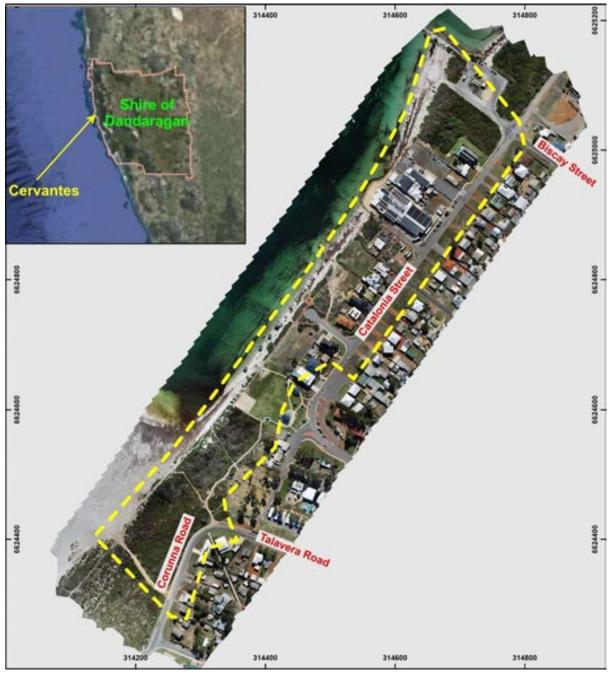


Figure 1: The extent of the geophysical investigation (yellow polygon) at Cervantes. Aerial imagery from drone photogrammetry (main image) and Google Maps (inset image).







Figure 2: Site conditions at Cervantes along the beach foreshore (left image) and on Catalonia Street (right image).

#### 3 INVESTIGATION METHODOLOGY

#### 3.1 FIELD SURVEY LOGISTICS

Geophysical data acquisition was carried out on the 13 to 15 June 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 12 and 13 July 2023. Where required, the site work was carried out under appropriate traffic and pedestrian management commissioned by the Shire of Dandaragan.

Prior to the commencement of data acquisition, a site assessment was carried out with representatives from the Shire of Dandaragan. 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 2000m of MASW profiling acquired as 6 alongshore transects (parallel to the coast) and 5 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 3073K-01.

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

Transect	Orientation	Start Coordinate		End Coordinate		Length
ID Orientation		East	North	East	North	(m)
MASW01	Along-shore	314174.8	6624428.0	314547.0	6624887.2	552
MASW02	Along-shore	314629.6	6625031.7	314676.2	6625152.0	120
MASW03a	Along-shore	314257.2	6624320.3	314329.7	6624426.1	128
MASW03bc	Along-shore	314320.8	6624425.1	314422.3	6624660.8	256
MASW03d	Along-shore	314416.1	6624664.3	314507.8	6624771.2	136
MASW04	Along-shore	314531.0	6624692.3	314780.7	6625029.1	392
MASW05	Cross-shore	314169.0	6624405.4	314243.8	6624321.8	112

GBG Group Ref: 3073K

MASW06	Cross-shore	314344.7	6624613.3	314400.8	6624579.9	64
MASW07	Cross-shore	314467.9	6624753.4	314508.1	6624722.6	48
MASW08	Cross-shore	314561.8	6624912.7	314630.3	6624855.8	88
MASW09	Cross-shore	314659.3	6625116.9	314747.4	6625053.1	104

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

СРТ	Coor	Coordinate		Probing
ID East North		Level (mAHD)	Depth (m)	
CPT01	314343	6624615	1.22	9.40
CPT02	314419	6624655	1.10	5.86
CPT03	314180	6624428	0.67	10.22
CPT04	314614	6625006	0.72	10.22
CPT05	314667	6625116	1.28	10.14

#### 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.

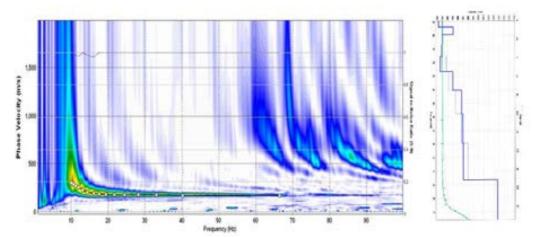


Figure 4: MASW overtone image with high signal to noise ratio and picked dispersion curve.



#### 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.



GBG Group Ref: 3073K

Table 4 - Details of Standard Survey Marker

Parameter	Value
Standard Survey Marker	HILL RIVER 27
Latitude	S 30 29 58.56669
Longitude	E 115 03 50.82315
Derived GDA94 ellipsoidal height (m)	-26.155
N-Value (m)	-29.460
Height (m) (AHD)	3.305

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 Lancelin, Shire of Dandaragan are presented in Appendices B and C of this report as follows:

#### Appendix B - Geophysical and Interpreted Sections

- **3073K-02 and 3073J-03.** Transect 1 seismic S-wave velocity model and interpreted geological section.
- 3073K-04. Transect 2 seismic S-wave velocity model and interpreted geological section.
- 3073K-05. Transect 3a seismic S-wave velocity model and interpreted geological section.
- 3073K-06. Transect 3bc seismic S-wave velocity model and interpreted geological section.
- **3073K-07.** Transects 3d and 4 (0-160m) seismic S-wave velocity model and interpreted geological section.
- **3073K-08.** Transect 4 (160-392m) seismic S-wave velocity model and interpreted geological section.

GBG Group Ref: 3073K

- **3073K-09.** Transects 5, 6 and 7 seismic S-wave velocity model and interpreted geological section.
- 3073K-10. Transects 8 and 9 seismic S-wave velocity model and interpreted geological section

#### Appendix C - Modelled Level to Top of Rock and Sand Thickness

- 3073J-11 and 3073J-12. Contoured surface level model derived from aerial photogrammetry.
- 3073J-13 and 3073J-14. Contoured level to modelled top of rock.
- 3073J-15. Class post map level to modelled top of rock.
- 3073J-16 and 3073J-17. Contoured modelled sand thickness over rock.
- 3073J-18. 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 alongshore 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 
$$V_{\scriptscriptstyle S} = \sqrt{\frac{G}{
ho}}$$

where; G =Shear modulus,  $\rho =$ 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:

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.</li>



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 megapascals 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-01 on Transect 1** refusal of 50MPa plus lateral rod support was at a depth of 9.5m Below Ground Level (BGL) within interpreted sand of moderate compaction. This is potentially due to a rock floater or partially lithified lens within the foreshore sand.
- **CPT-02 on Transect 3bc** refusal of 60MPa plus rod friction was at 5.75mBGL which corresponds to the top of interpreted low strength rock.
- **CPT-03 on Transect 1** reached a target depth of 10mBGL without refusal corresponding to sand of variable compaction and with no evidence of rock.
- **CPT-04 on Transect 2** reached a target depth of 10mBGL without refusal corresponding to sand of variable compaction and with no evidence of rock.
- **CPT-05 on Transects 2 and 9** refusal of 45MPa plus lateral rod support was at 10m BGL within interpreted sand of moderate compaction. This is potentially due to a rock floater or partially lithified lens within the foreshore sand.

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



GBG Group Ref: 3073K

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.

Surface outcropping rock was observed onsite along Transect 1 between Transects 7 and 8 on the beach on the edge of the dune formation. It is uncertain whether these rocks are natural features or related to the groyne located immediately to the north. Analysis of the orthomosaic image from the aerial photogrammetry indicates no additional 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 3073K-11 and 3073K-12) generated from the aerial photogrammetry, this presents the level to ground surface ranging from 0mAHD to 8mAHD. Note: vegetation height has not been removed from these models.
- Contoured Level to Top of Rock Substrate (drawing 3073K-13 and 3073K-14) this presents the level to the top of rock substrate ranging from -12mAHD to -4mAHD.
- Classed Post Map Level to Top of Rock Substrate (drawing 3073K-15) this presents the level to the top of rock substrate along the acquired transects at 1m level increments from -11mAHD to -5mAHD.
- Contoured Sand Thickness Over Rock (drawing 3073K-16 and 3073K-17) this presents the thickness of sand overlying the rock substrate ranging from 5mBGL to 15mBGL.
- Classed Post Map Sand Thickness Over Rock (drawing 3073K-18) this presents the
  thickness of sand overlying the rock substrate along the acquired transects at 2m depth
  increments from 4mBGL to 14mBGL.

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 Cervantes in the Shire of Dandaragan, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 900m corridor of coastal beach and dune formation adjacent to the Lancelin settlement which has been identified as an at risk site as part of Coastal Hotspot #15.

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** 

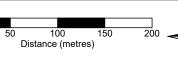


# **INVESTIGATION SITE MAP**



NOTES

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



CLIENT DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOPHYSICAL INVESTIGATION FOR COASTAL
EROSION VULNERABLITY ASSESSMENT
CERVANTES, SHIRE OF DANDARAGAN WA

 Date
 14 August 2023
 Paper Size
 A3

 Scale
 1:4000
 Drawn
 PJE

 Drawing
 3073K-01
 Revision
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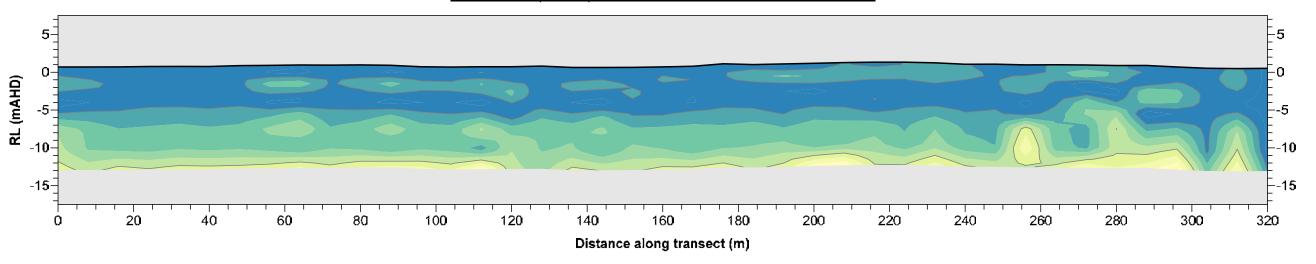




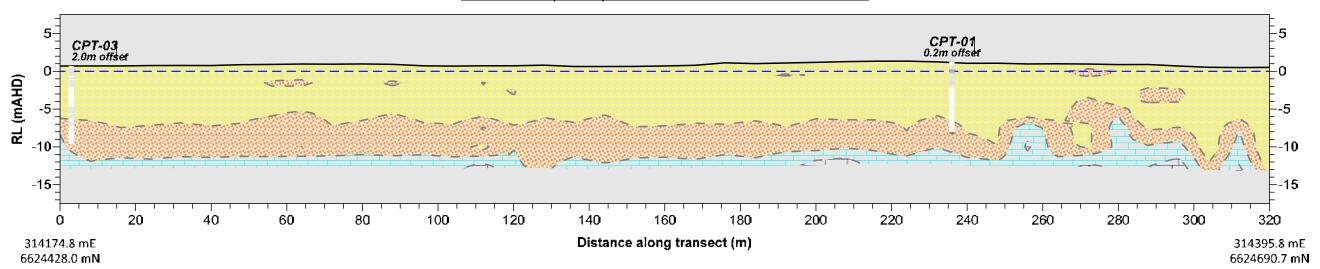
APPENDIX B - GEOPHYSICAL AND INTERPRETED SECTIONS

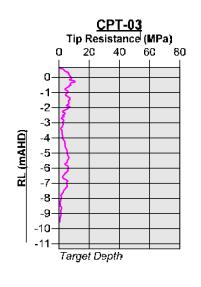


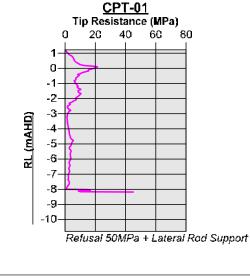
#### TRANSECT 1 (0-320m) - SEISMIC SHEAR WAVE VELOCITY MODEL

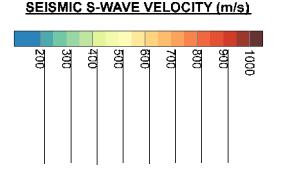


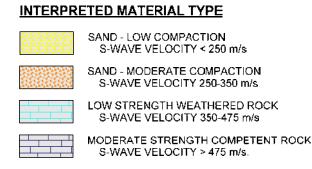
### TRANSECT 1 (0-320m) - INTERPRETED GEOLOGICAL SECTION



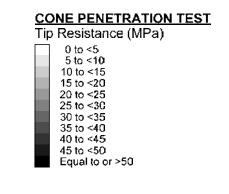








0m AUSTRALIAN HEIGHT DATUM



IOI	ES	

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

IENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT
	CERVANTES, SHIRE OF DANDARAGAN WA

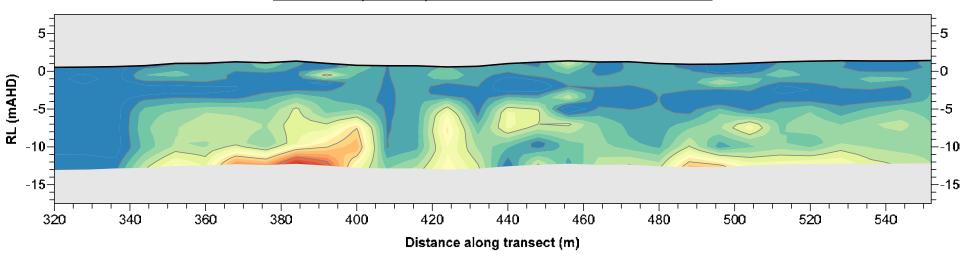
CLIENT

Date	14 August 2023	Paper Size	A3	
Scale	1:1000H, 1:500V	Drawn	PJE	
Drawing	3073K-02	Revision	С	

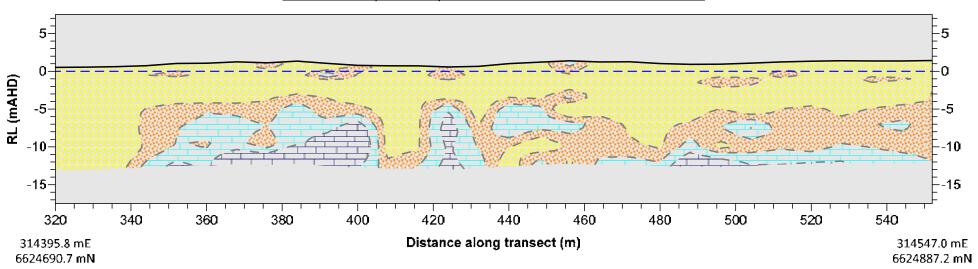




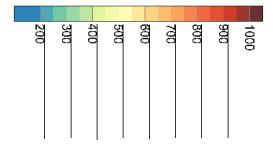
### TRANSECT 1 (320-552m) - SEISMIC SHEAR WAVE VELOCITY MODEL



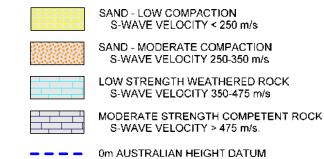
### TRANSECT 1 (320-552m) - INTERPRETED GEOLOGICAL SECTION



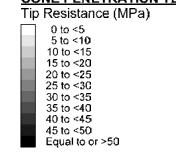
# SEISMIC S-WAVE VELOCITY (m/s)



#### **INTERPRETED MATERIAL TYPE**



# **CONE PENETRATION TEST**



NOTES

Drawing to be used in conjunction with Report 3073K Map Projection GDA94 MGA Zone 50.

Aerial image from Google Earth Pro and GBG photogrammetry.

IENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRAL	
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	EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA	

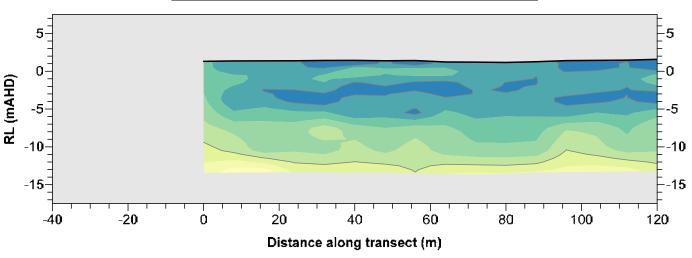
CLIENT

Date	14 August 2023	Paper Size	A3	
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Drawing	3073K-03	Revision	С	

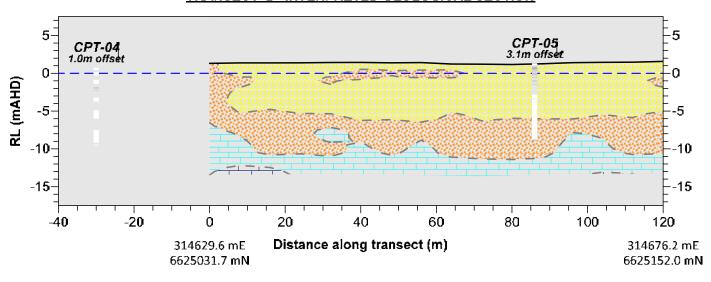


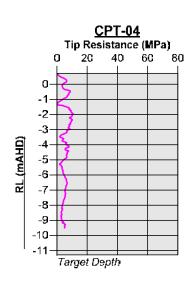


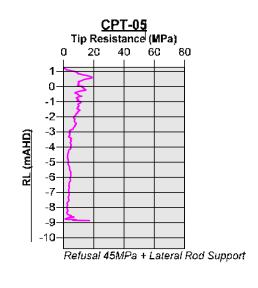
#### TRANSECT 2 - SEISMIC SHEAR WAVE VELOCITY MODEL

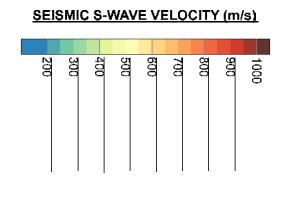


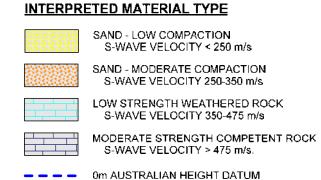
#### TRANSECT 2 - INTERPRETED GEOLOGICAL SECTION

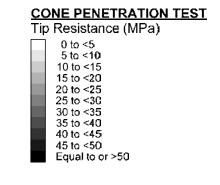












Drawing to be used in conjunction with Report 3073K Map Projection GDA94 MGA Zone 50. Aerial image from Google Earth Pro and GBG photogrammetry.

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
	GEOPHYSICAL INVESTIGATION FOR COASTAL
	EROSION VULNERABLITY ASSESSMENT
	CERVANTES, SHIRE OF DANDARAGAN WA

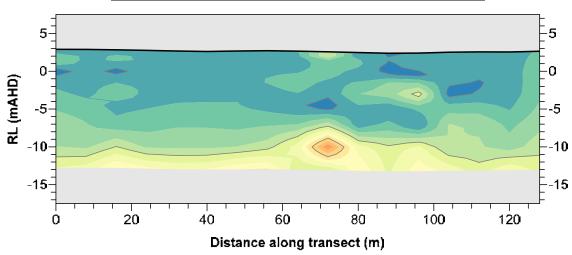
CLIENT

Date	14 August 2023	Paper Size	A3	
Scale	1:1000H, 1:500V	Drawn	PJE	
Drawing	3073K-0 <b>4</b>	Revision	С	

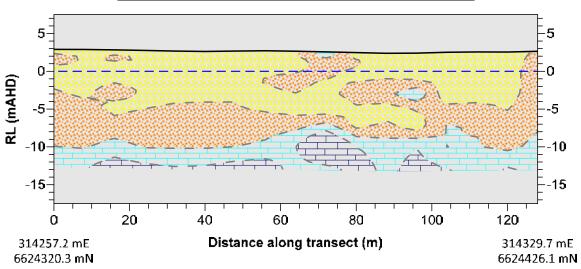




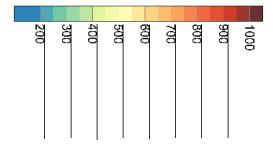
#### TRANSECT 3a - SEISMIC SHEAR WAVE VELOCITY MODEL



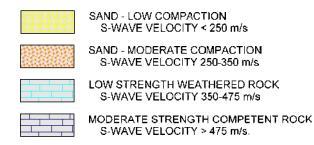
### TRANSECT 3a - INTERPRETED GEOLOGICAL SECTION



#### SEISMIC S-WAVE VELOCITY (m/s)

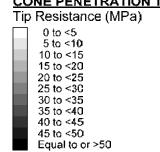


### INTERPRETED MATERIAL TYPE



0m AUSTRALIAN HEIGHT DATUM

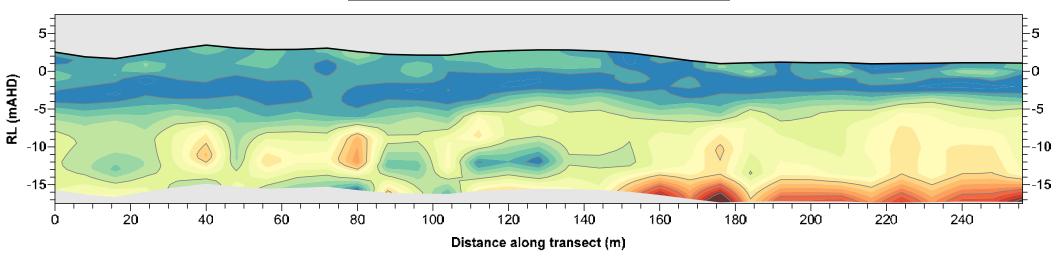
# **CONE PENETRATION TEST**



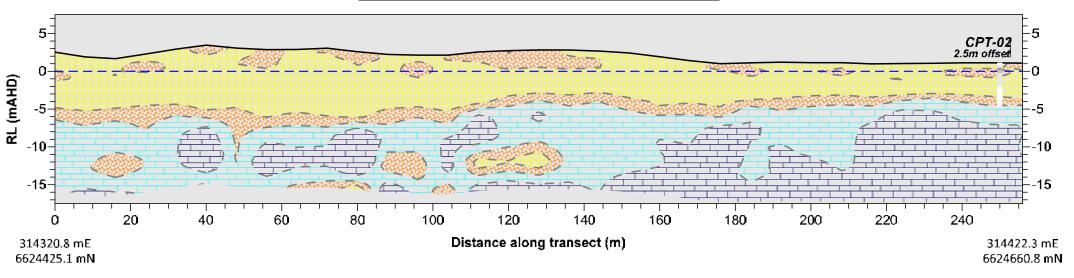
CLIENT

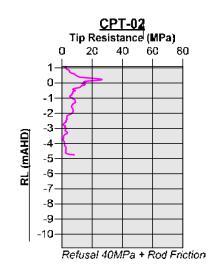


#### TRANSECT 3bc - SEISMIC SHEAR WAVE VELOCITY MODEL

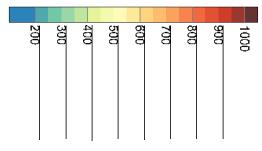


### TRANSECT 3bc - INTERPRETED GEOLOGICAL SECTION

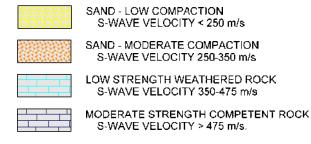




# SEISMIC S-WAVE VELOCITY (m/s)



#### **INTERPRETED MATERIAL TYPE**



0m AUSTRALIAN HEIGHT DATUM

# CONE PENETRATION TEST

<u>CC</u>	<u>ONE PENETRATION TE</u>
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
	•

OTES

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

GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

CLIENT

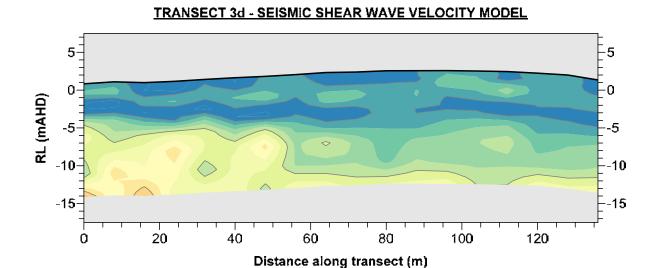
 Date
 14 August 2023
 Paper Size
 A3

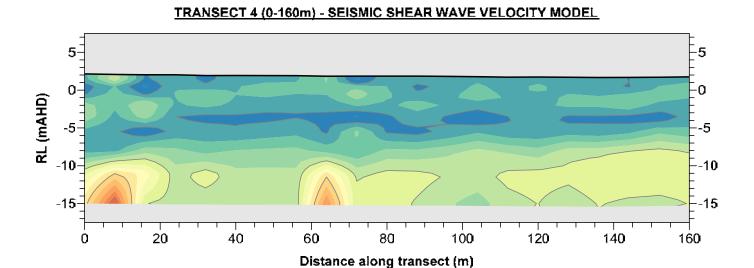
 Scale
 1:1000H, 1:500V
 Drawn
 PJE

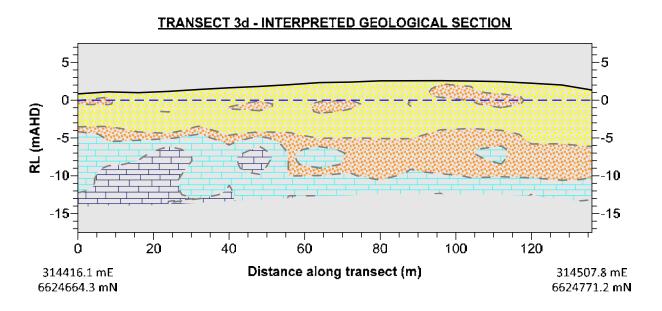
 Drawing
 3073K-06
 Revision
 C

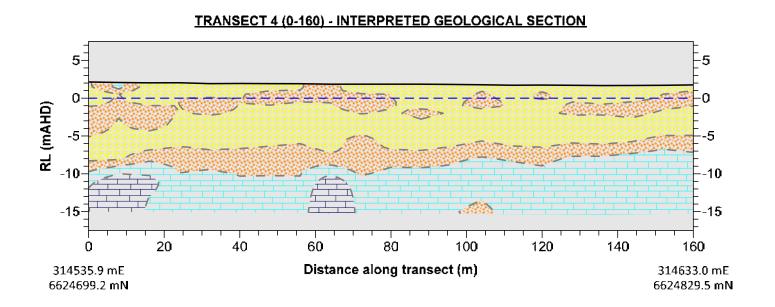


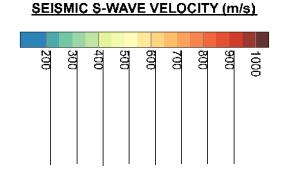


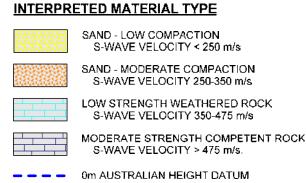


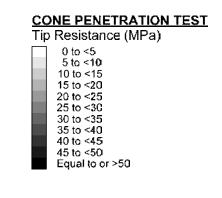












IOTES

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

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	EROSION VULNERABLITY ASSESSMENT
	CERVANTES, SHIRE OF DANDARAGAN WA

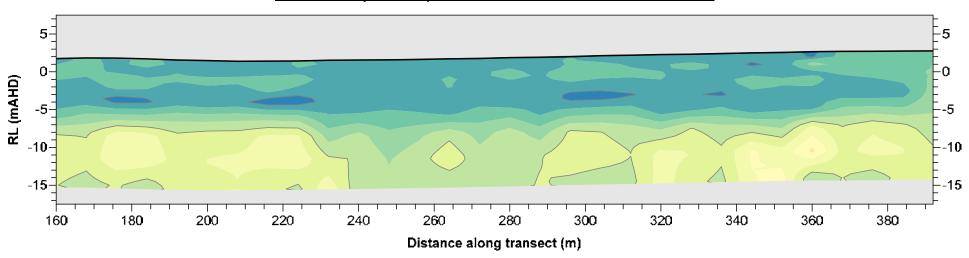
CLIENT

Date	14 August 2023	Paper Size	A3
Scale	1:1000H, 1:500V	Drawn	PJE
Drawing	3073K-07	Revision	С

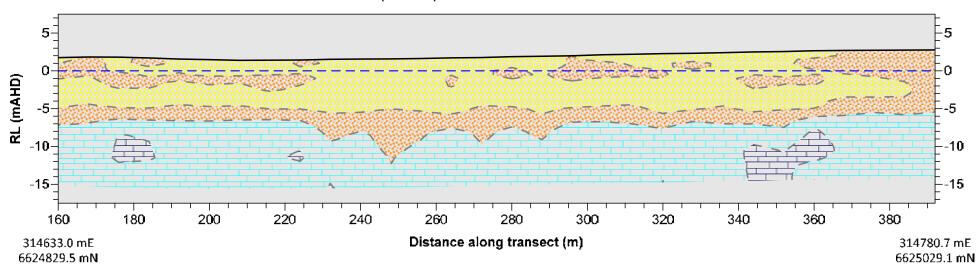




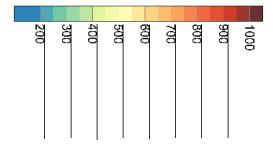
#### TRANSECT 4 (160-392m) - SEISMIC SHEAR WAVE VELOCITY MODEL



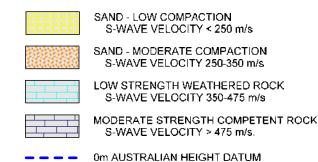
### TRANSECT 4 (160-392) - INTERPRETED GEOLOGICAL SECTION



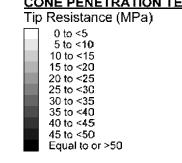
# SEISMIC S-WAVE VELOCITY (m/s)



#### **INTERPRETED MATERIAL TYPE**



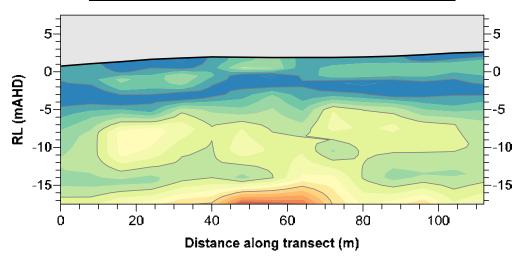
# **CONE PENETRATION TEST**

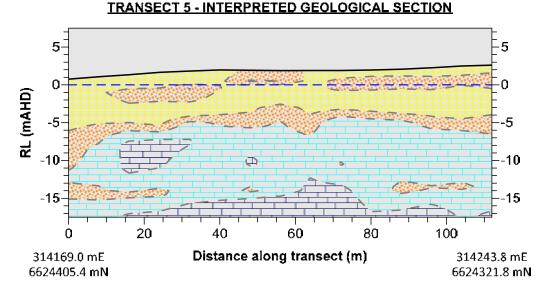


CLIENT

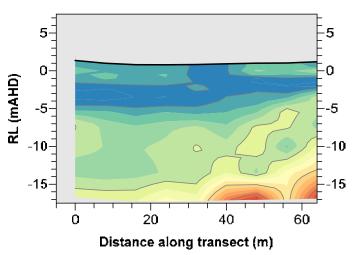


#### TRANSECT 5 - SEISMIC SHEAR WAVE VELOCITY MODEL

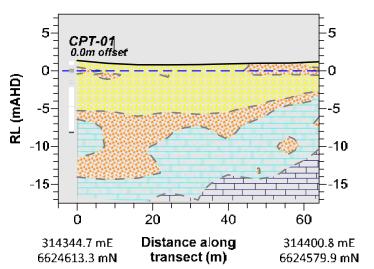




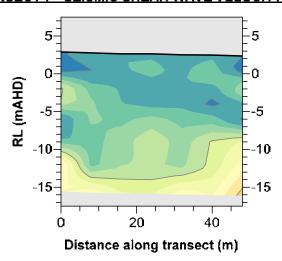
#### TRANSECT 6 - SEISMIC SHEAR WAVE VELOCITY MODEL



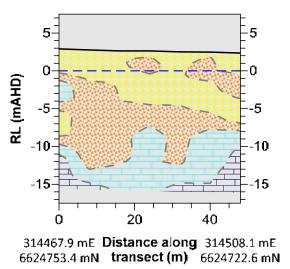
#### **TRANSECT 6 - INTERPRETED GEOLOGICAL SECTION**



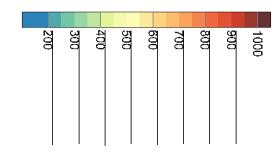
#### TRANSECT 7 - SEISMIC SHEAR WAVE VELOCITY MODEL



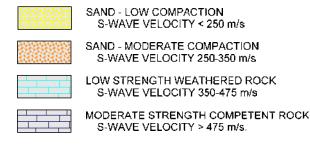
#### TRANSECT 7 - INTERPRETED GEOLOGICAL SECTION



# SEISMIC S-WAVE VELOCITY (m/s)

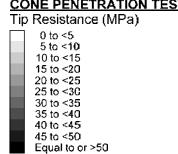


# **INTERPRETED MATERIAL TYPE**



0m AUSTRALIAN HEIGHT DATUM

# **CONE PENETRATION TEST**



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

**CPT-01** Tip Resistance (MPa)

40 60

Refusal 50MPa + Lateral Rod Support

80

20

-5--6-

-7-

-8-

-9-

-10-

GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

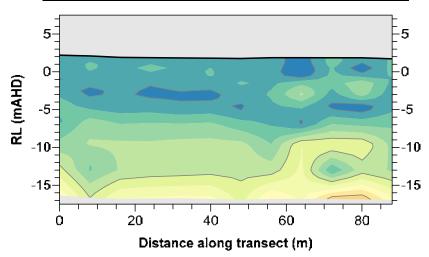
CLIENT

14 August 2023 Paper Size АЗ Date 1:1000H, 1:500V Drawn Drawing 3073K-09 Revision

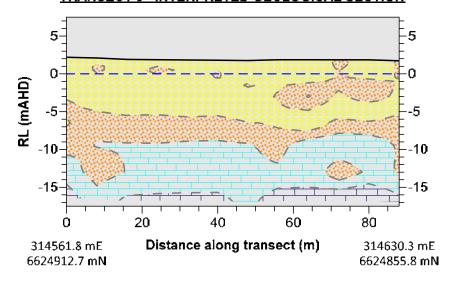




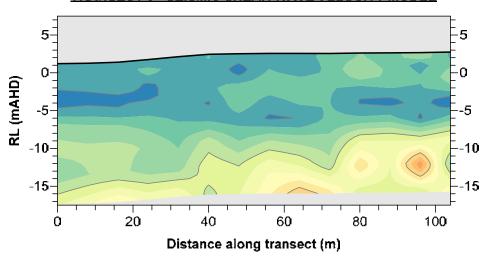




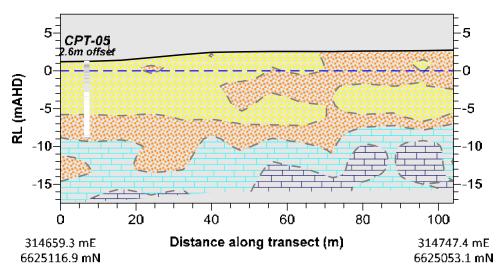
#### TRANSECT 8 - INTERPRETED GEOLOGICAL SECTION

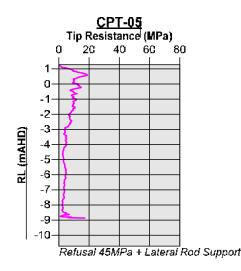


#### TRANSECT 9 - SEISMIC SHEAR WAVE VELOCITY MODEL

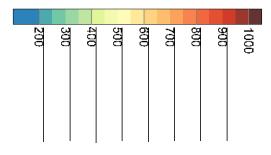


### **TRANSECT 9 - INTERPRETED GEOLOGICAL SECTION**

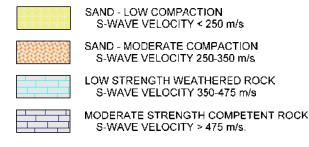




#### SEISMIC S-WAVE VELOCITY (m/s)

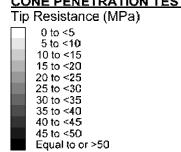


# **INTERPRETED MATERIAL TYPE**



0m AUSTRALIAN HEIGHT DATUM

# **CONE PENETRATION TEST**



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

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

CLIENT

Date 14 August 2023 Paper Size АЗ 1:1000H, 1:500V Drawn Drawing 3073K-10 Revision

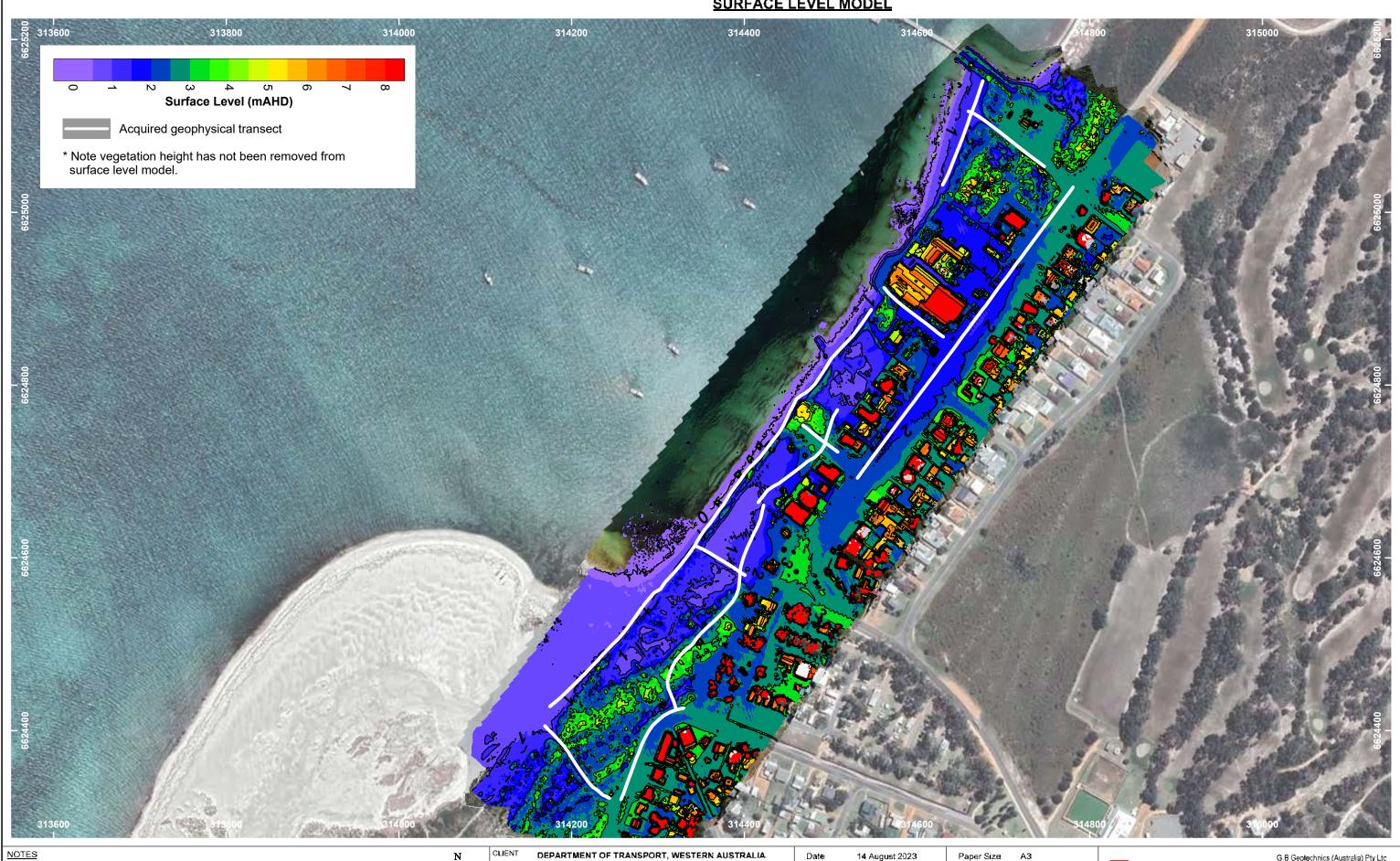




APPENDIX C -	- MODELLED	<b>TOP OF RO</b>	CK AND S	AND TH	<b>IICKNESS</b>
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# **SURFACE LEVEL MODEL**



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



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

14 August 2023 1:4000 Drawing 3073K-11 Revision

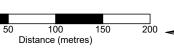




# **SURFACE LEVEL MODEL**



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



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

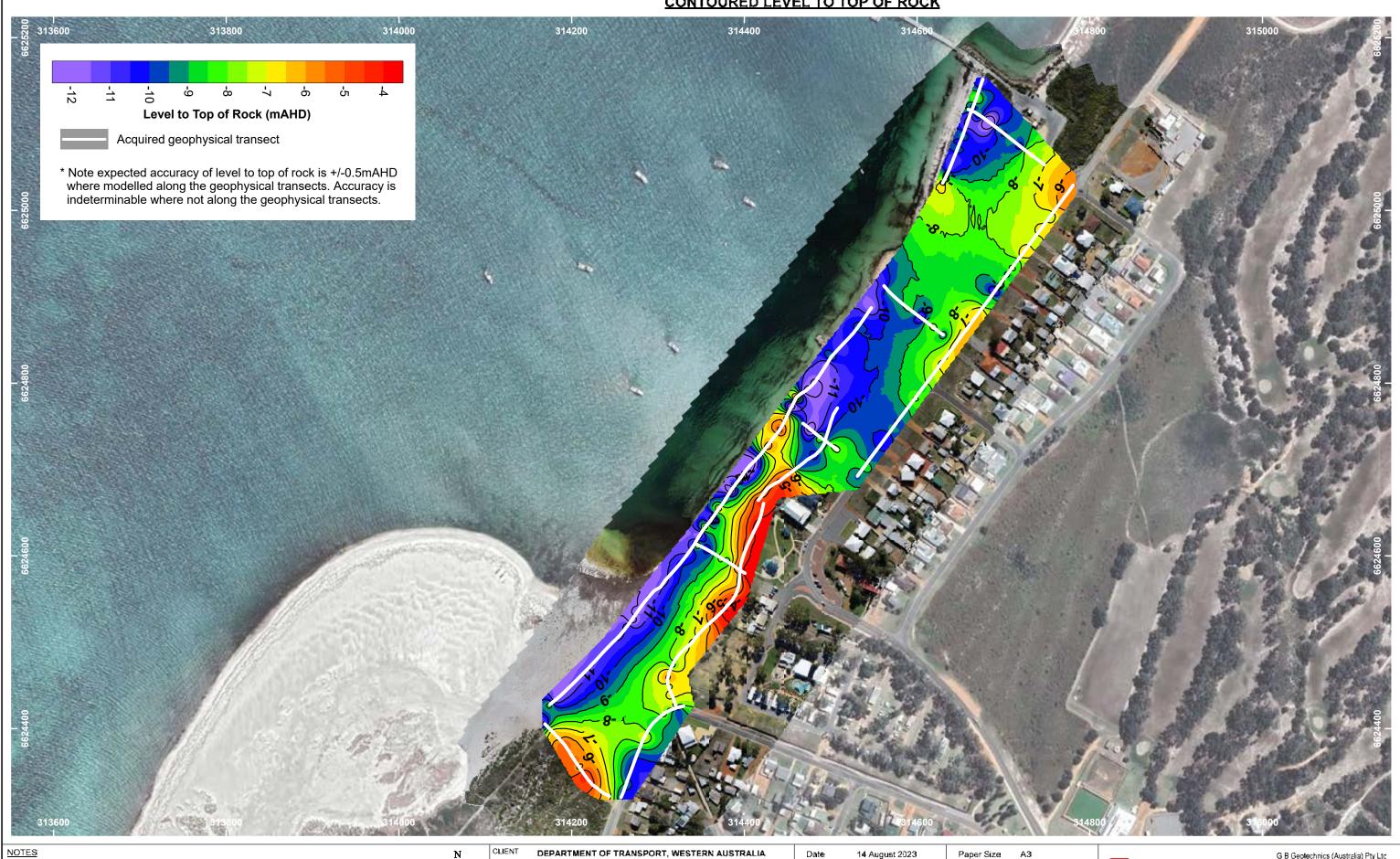
GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

Date	14 August 2023	Paper Size	A3
Scale	1:4000	Drawn	PJE
Drawing	3073K-12	Revision	С

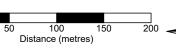




# **CONTOURED LEVEL TO TOP OF ROCK**



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



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

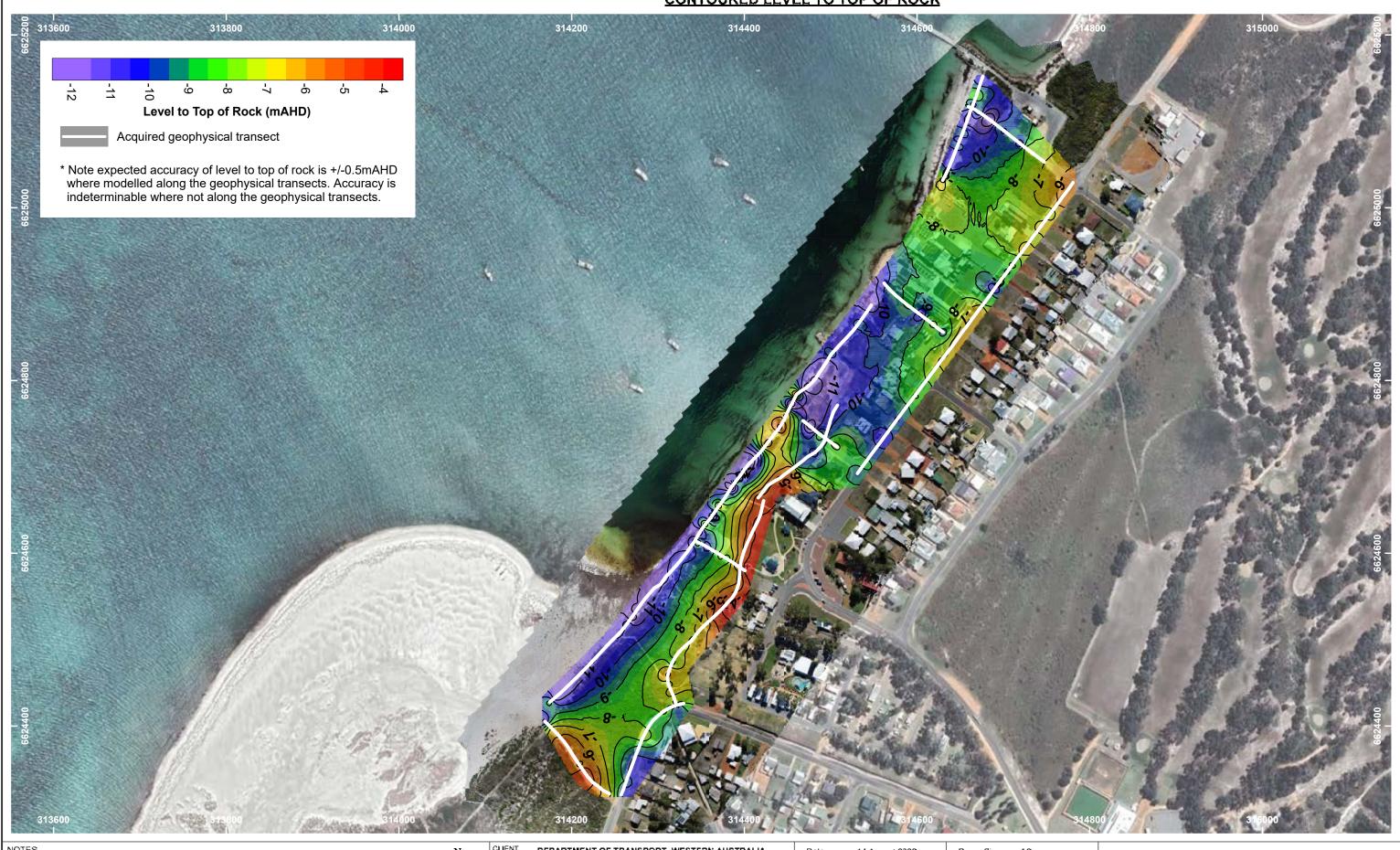
GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

14 August 2023 1:4000 Drawing Revision 3073K-13



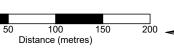


# **CONTOURED LEVEL TO TOP OF ROCK**



NOTES

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



CLIENT DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA 
 Date
 14 August 2923
 Paper Size
 A3

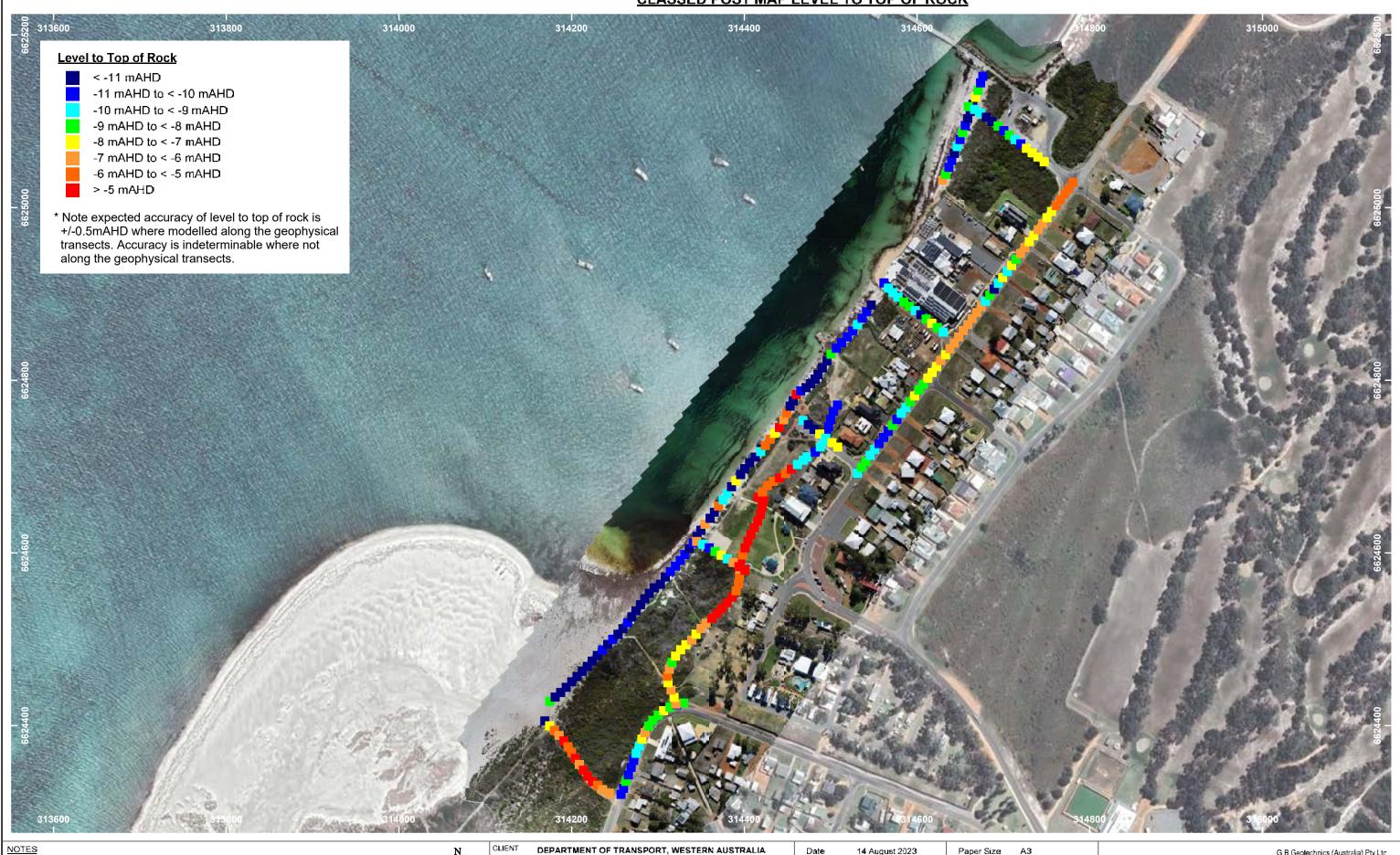
 Scale
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 Drawn
 PJE

 Drawing
 3073K-14
 Revision
 C

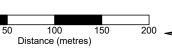




# **CLASSED POST MAP LEVEL TO TOP OF ROCK**



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



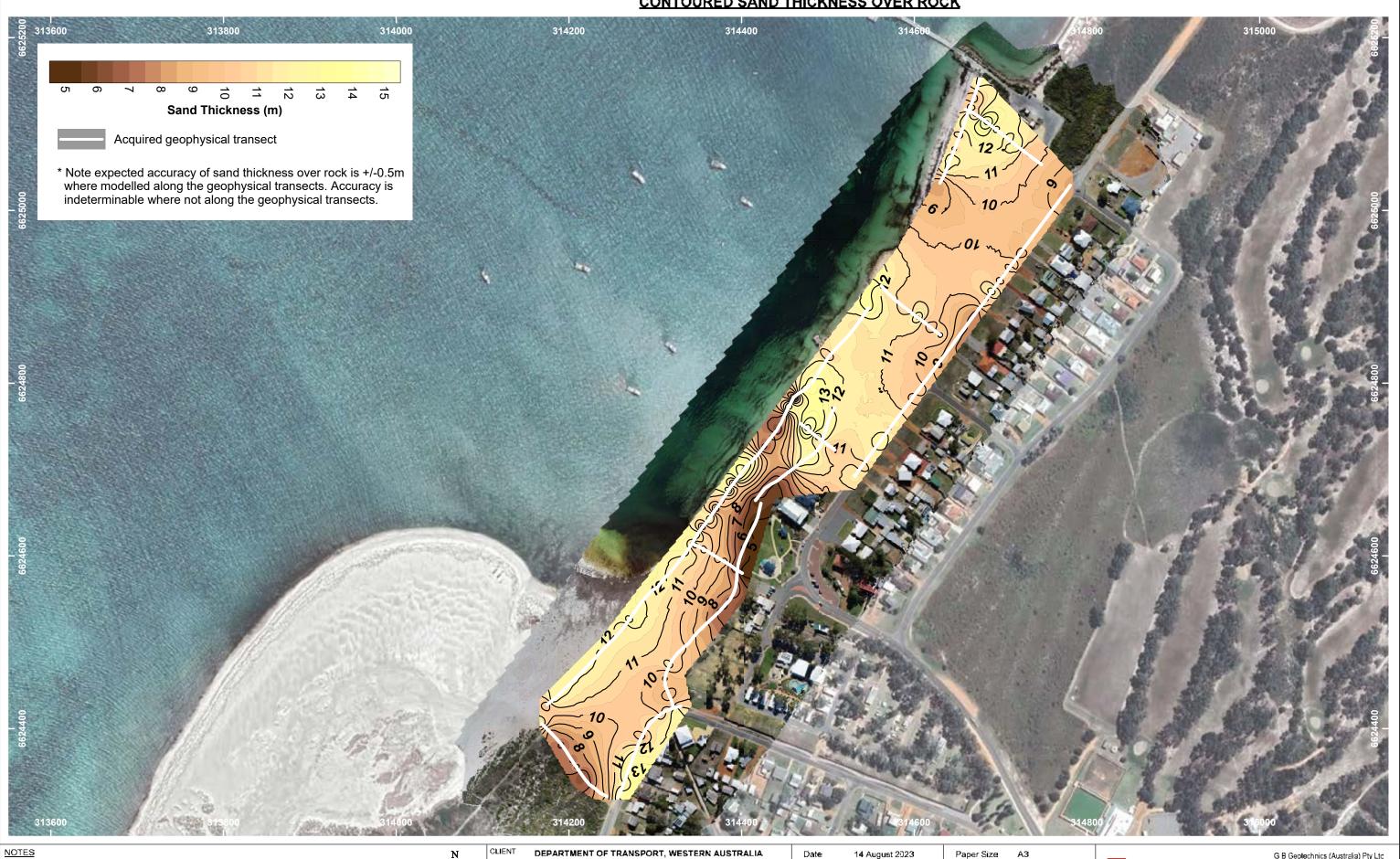
GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

Date 14 August 2023 Paper Size АЗ 1:4000 Revision Drawing 3073K-15

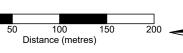




# **CONTOURED SAND THICKNESS OVER ROCK**



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



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

1:4000 Drawing Revision 3073K-16



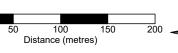


# **CONTOURED SAND THICKNESS OVER ROCK**



NOTES

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



CLIENT DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA 
 Date
 14 August 2023
 Paper Size
 A3

 Scale
 1:4000
 Drawn
 PJE

 Drawing
 3073K-17
 Revision
 C

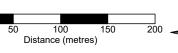




# **CLASSED POST MAP SAND THICKNESS OVER ROCK**



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



CLIENT DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT CERVANTES, SHIRE OF DANDARAGAN WA

Date 14 August 2023 Paper Size АЗ 1:4000 Drawing 3073K-18 Revision





**APPENDIX D - CONE PENETRATION TEST PLOTS** 

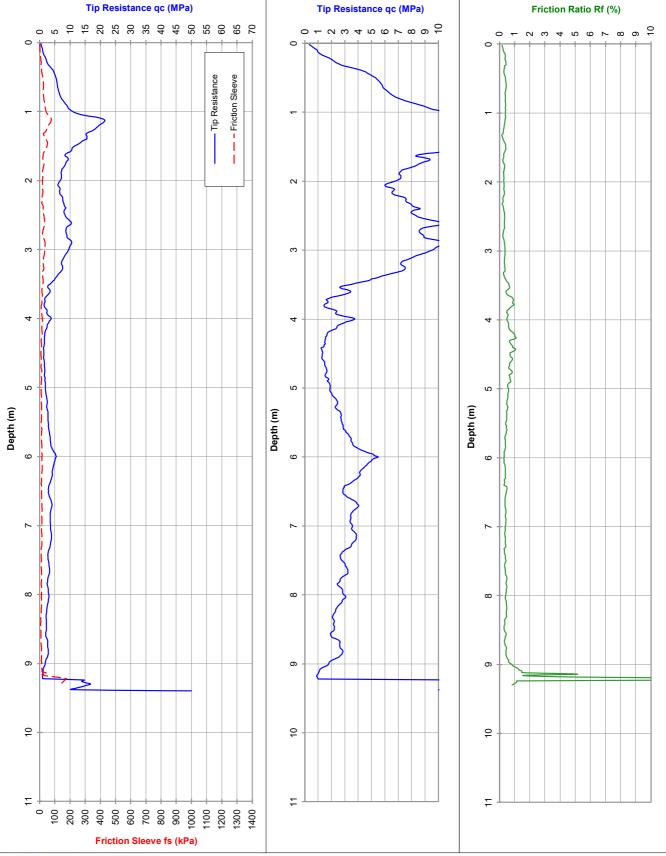
CLIENT: Department of Transport Job No.: 3073

PROJECT: Geophysical Investigation of Coastal Erosion Study RL (m): LOCATION: Cervantes Co-ords:

Probe I.D

**CPT 01** 

12-Jul-23



and IRTP 2001 for friction reducer

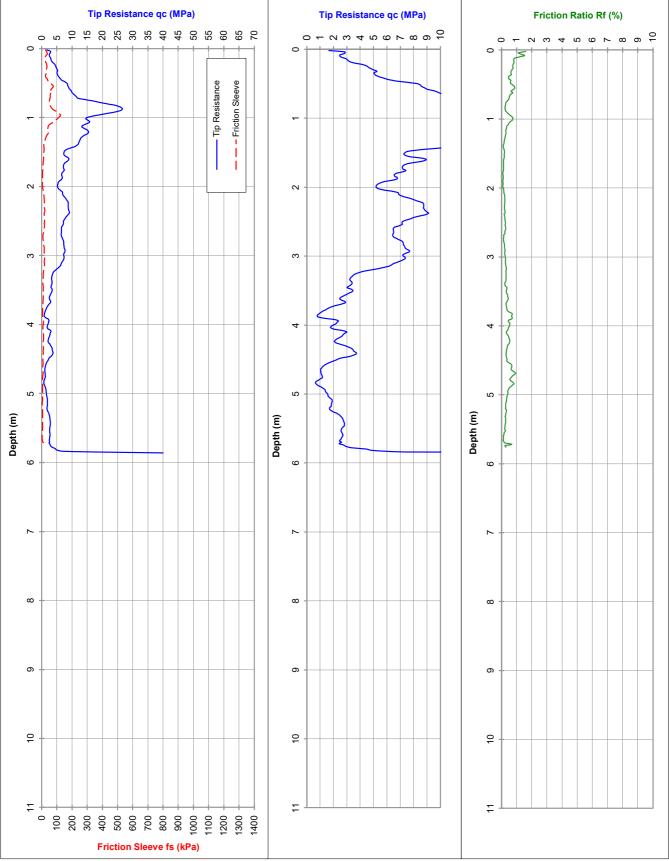
CLIENT: Department of Transport Job No.: 3073

PROJECT: Geophysical Investigation of Coastal Erosion Study RL (m): LOCATION: Cervantes Co-ords:

Probe I.D

**CPT 02** 

12-Jul-23



and IRTP 2001 for friction reducer

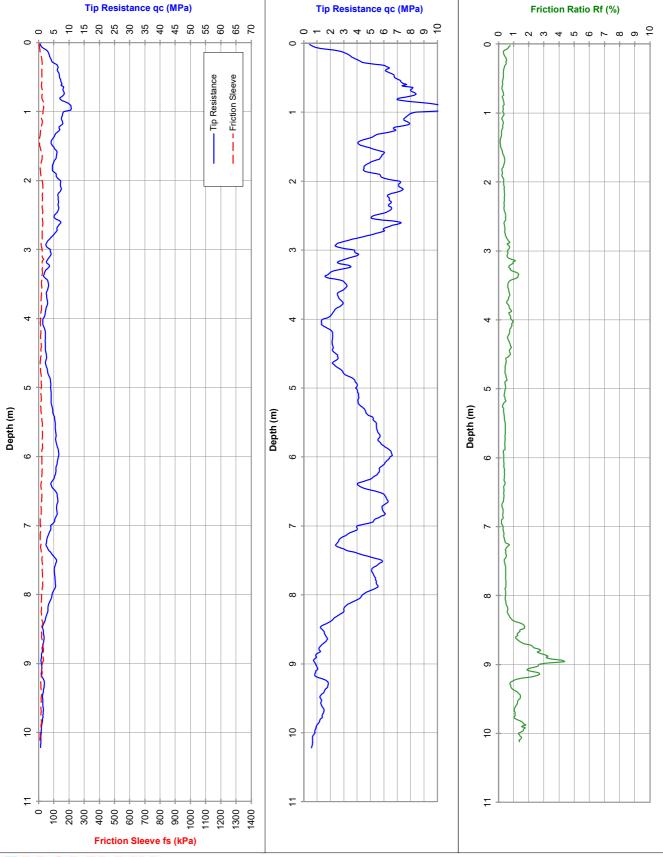
CLIENT: Department of Transport Job No.: 3073

PROJECT: Geophysical Investigation of Coastal Erosion Study RL (m): LOCATION: Cervantes Co-ords:

Probe I.D

**CPT 03** 

13-Jul-23





Approx. water (m): 1.0

Dummy probe to (m):

Refusal:

Cone I.D.: EC46

File: GB0044TT

Rig Type: 22t truck (Track-Truck)

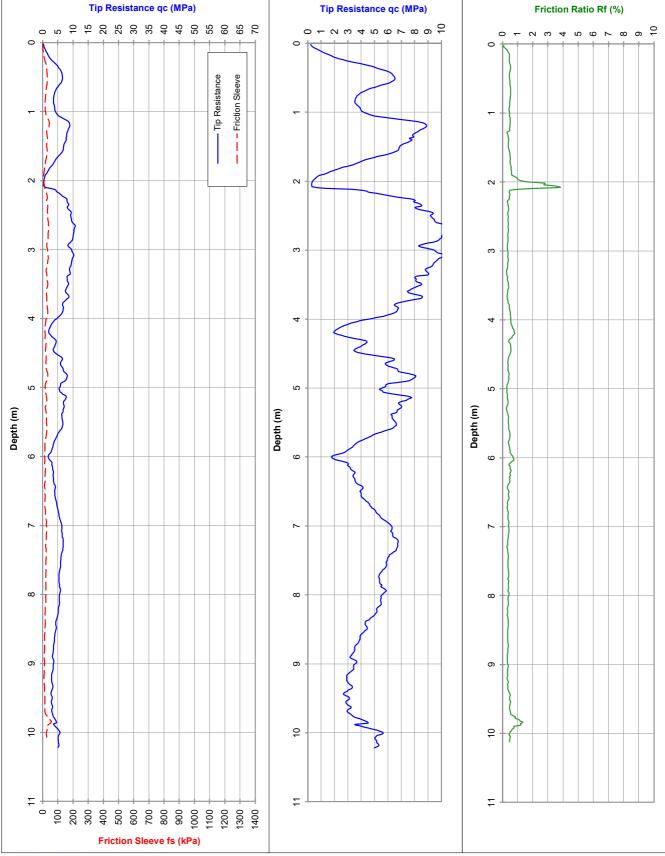
CLIENT: Department of Transport Job No.: 3073

PROJECT: Geophysical Investigation of Coastal Erosion Study RL (m): LOCATION: Cervantes Co-ords:

Probe I.D

**CPT 04** 

12-Jul-23





Approx. water (m): -

Dummy probe to (m):

Refusal:

Cone I.D.: EC46

File: GB0043T

Rig Type: 7t track

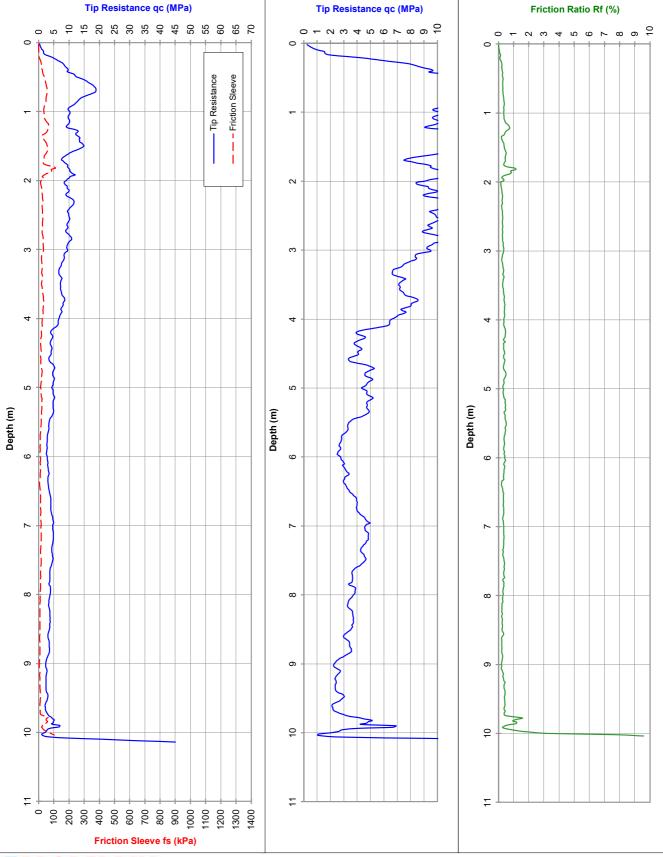
CLIENT: Department of Transport Job No.: 3073

PROJECT: Geophysical Investigation of Coastal Erosion Study RL (m): LOCATION: Cervantes Co-ords:

Probe I.D

**CPT 05** 

12-Jul-23





Approx. water (m): 0.9

Dummy probe to (m):

Refusal: 45MPa + Lateral Rod Support

Cone I.D.: EC46

File: GB0042T

Rig Type: 7t track



# CALIBRATION CERTIFICATE

**CONE ID: EC46** 

Cone Type: Compression 9 May 2023 Calibration Date (qc/fs): Calibration Date (u): 7 December 2022 **Preliminary Inspection:** Pass

Calibrated By: Henky Lawer

**Calibration Procedure:** ISO 22476-1:2012, IRTP 2001

Force Application: Compression

PT - S type 100kN Serial # 5126009 (Calibrated 10/03/23 - NATA approved Cert. No. 230664) Reference Equipment:

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 mm² and 15000mm² respectively.

u (pore pressure):

Capacity:

#### **Results of Calibration:**

qc (tip resistance):			
Capacity:	100 (MPa)		
Area	1000	(mm²)	
Applied	Eqv.	Mean	
Load	Pressure	Observed	
kN	MPa	Reading	
		Volts	
0	0	0.000	
10	10	0.742	
20	20	1.502	
30	30	2.267	
40	40	3.035	
50	50	3.800	
60	60	4.564	
70	70	5.324	
80	80	6.087	
90	90	6.852	
100	100	7.616	
90	90	6.860	
80	80	6.101	
70	70	5.343	
60	60	4.582	
50	50	3.820	
40	40	3.058	
30	30	2.291	
20	20	1.523	
10	10	0.753	
0	0	0.002	
R^2 Value =	1.000		

fs (sleeve fi	fs (sleeve friction):				
Capacity:	2000 (kPa)				
Area	15000	(mm²)			
Applied	Eqv.	Mean			
Force	Load	Observed			
kN	kPa	Reading			
		Volts			
0	0	0.000			
3	200	0.738			
6	400	1.498			
9	600	2.265			
12	800	3.022			
15	1000	3.776			
18	1200	4.531			
21	1400	5.286			
24	1600	6.042			
27	1800	6.800			
30	2000	7.558			
27	1800	6.835			
24	1600	6.085			
21	1400	5.332			
18	1200	4.577			
15	1000	3.821			
12	800	3.064			
9	600	2.302			
6	400	1.535			
3	200	0.772			
0	0	0.003			
R^2 Value =	1.000				

Position	u2	
Applied	Eqv.	Mean
Pressure	Pressure	Observed
bar	kPa	Reading
		Volts
0	0	0.000
3	300	0.414
6	600	0.830
9	900	1.243
12	1200	1.656
15	1500	2.070
18	1800	2.483
21	2100	2.895
25	2500	3.444
30	3000	4.130
35	3500	4.816
30	3000	4.137
25	2500	3.455
21	2100	2.900
18	1800	2.489
15	1500	2.074
12	1200	1.660
9	900	1.246
6	600	0.830
3	300	0.416
0	0	0.000
R^2 Value =	1.000	

3500 (kPa)

Zero Load Error: 0.03% Max. Linearity 0.31% Max. Hysteris 0.33%

MPa/Volt:

Max. Hysteris 0.62% kPa/Volt: 264.13

0.03%

0.47%

0.01% Zero Load Error: Max. Linearity 0.24% Max. Hysteris 0.23%

kPa/Volt: 726.10 Net Area (calibrated): 0.83

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

13.109

Zero Load Error:

Max. Linearity

Calibration Checked & Authorised:	Kylle vvalker		
Job Details			
Client:	GB Geotechnics	Date of Job:	10/07/23
Rep:	Stephen Kelly	Tip Diameter:	35.52
Location:	Seabird	Sleeve Diameter	35.81



# **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 <sup>2</sup> (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**

0	ODT ODT CODT CODT /4 5 40 0 45 /
Geotechnical Services	CPT, CPTu, SCPT, SCPTu (1, 5, 10, & 15 tonne cones)
provided	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)