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Report

Geotechnical Investigation for Coastal Erosion Vulnerability Assessment.

Yallingup, City of Busselton WA.

Date: 12 February 2025
Report Ref: 3142C

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COMPANY DETAILS

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EXECUTIVE SUMMARY

A geotechnical investigation has been carried out as part of a coastal erosion assessment at Yallingup in the City of Busselton, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 960m corridor of coastal beach and dune formation along Yallingup Beach.

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 (BGL). 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 all the transects and within the maximum target investigation depth of 10-15m BGL, apart from a 250m section on Transect 02 along Yallingup beach where no rock was observed. In general, rock was significantly shallower on inland transects away from the beach.

- Interpreted top of rock substrate on the along-shore transects on the beach ranges from -16.0mAHD along sections of the beach to 45m AHD along the elevated walking trail to the north east.

- Sand thickness across the site ranged from 0 to greater than 16m generally decreasing further away from the shoreline.

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1 INTRODUCTION

At the request of The Government of Western Australia Department of Transport (DoT), GBG Group carried out a geotechnical investigation at Yallingup, City of Busselton in November 2024 and January 2025. During the investigation seismic geophysical testing and intrusive geotechnical testing was conducted within a 960m corridor of coastal beach and dune formation along Yallingup Beach.

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 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. **Topographic survey** using Differential GNSS receiver and photogrammetry.

2 INVESTIGATION SITE

The investigation was carried out within approximate 960m corridor of coastal beach and dune formation the extents of which are shown as yellow dashed area in Figure 1.

Data was acquired as a series of transects for the seismic geophysical testing. These were positioned to best utilise existing roads, tracks, and beach whilst not impacting on native vegetation and to ensure the most optimal, efficient and economic 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. An aerial photograph showing the site conditions is provided in Figure 2. Topography at the sites was generally steep and undulating from the beach eastward with surface level ranged from 0mAHD to 45mAHD. Topographic maps showing surface level are provided in Appendix C drawing 3142C-07.

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

Figure 2: Aerial view of Yallingup Beach showing the dune formation and the beach.

3 INVESTIGATION METHODOLOGY

3.1 FIELD SURVEY LOGISTICS

Geophysical data acquisition was carried out from the 12th to 15nd November 2024 by a two-person team from GBG Group consisting of qualified geophysicists. CPT data acquisition was carried out by a technician from Probedrill on 22th and 23rd January 2025. Where required, the site work was carried out under appropriate traffic and pedestrian management commissioned by the City of Busselton.

Prior to the commencement of data acquisition, a site assessment was carried out with the traffic management team. Potential concerns and issues including the placement of and access to the MASW transects were addressed.

The site work for the investigation consisted of a total of 2448m of MASW profiling acquired as two along-shore transects (parallel to the coast) and three cross-shore transects (perpendicular to the coast). Details of the acquired MASW transects are provided in Table 1. The extents of the MASW transects overlaid onto aerial imagery are shown in Appendix A drawing 3142C-01.

Table 1 – Acquired MASW Transects (Coordinates in GDA2020, MGA Zone 50).

Transect ID	Orientation	Start Coordinate East	Start Coordinate North	End Coordinate East	End Coordinate North	Length (m)
MASW-01	Along-shore	317001.1	6276079.2	317281.2	6277022.0	1128
MASW-02	Along-shore	316876.1	6276198.9	317110.9	6277052.0	984
MASW-03	Cross-shore	317065.2	6276380.0	317102.8	6276332.3	64
MASW-04	Cross-shore	317140.3	6276528.5	317235.4	6276568.0	128
MASW-05	Cross-shore	317113.4	6277041.5	317251.4	6277045.1	144

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 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 (AWD) or softened steel sledgehammer with source points made at a constant offset from the receiver array. MASW acquisition parameters are provided in Table 2. Photographs of MASW data acquisition are shown in Figure 3.

Table 2 – 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	0.125 ms
Source	40kg AWD / 5.9kg Sledgehammer
Source offset	4 m
Sounding interval	8m
Source stacks	3

Figure 3: MASW data acquisition using a seismic streamer and AWD (left) or sledgehammer (right).

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 mostly 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).
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.

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.

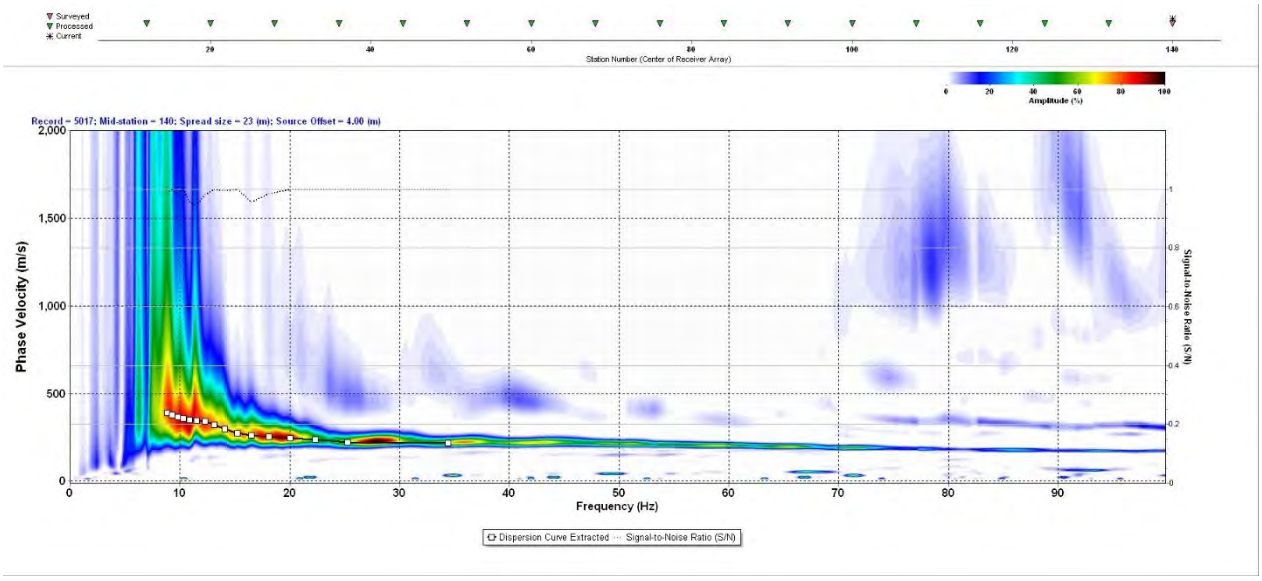


Figure 4: MASW overtone image with high signal to noise ratio and picked dispersion curve.

3.3 SPATIAL POSITIONING AND PHOTOGRAMMETRY

Spatial positioning of the acquired geophysical transects was achieved using Reach RS2+ (Emlid) GNSS receivers with a coordinate recorded for each MASW sounding location. Coordinates of the geophysical transects have been provided in GDA2020, 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 a Geoscience Australia AUSCORS station in Busselton for the base corrections. Details of the AUSCORS station used for this investigation are provided in Table 3.

Table 3 – Details of AUSCORS station

Parameter	Value
Mount Point	BUSS00AUS0
Latitude	S 33° 40' 27.66"
Longitude	E 115° 18' 31.788"
Ellipsoidal height (m)	-26

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 Mavic 3E (DJI) multi-rotor drone with RTK capability 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 Yallingup, City of Busselton are presented in Appendices B and C of this report as follows:

Appendix B – Geophysical and Interpreted Sections

- **3142C-02.** Transect 01 (0-600m) seismic S-wave velocity model and interpreted geological section.
- **3142C-03.** Transect 01 (600-1128m) seismic S-wave velocity model and interpreted geological section.
- **3142C-04.** Transect 02 (0-600m) seismic S-wave velocity model and interpreted geological section.
- **3142C-05.** Transect 02 (600-984m) seismic S-wave velocity model and interpreted geological section.
- **3142C-06.** Transects 03, 04, and 05 seismic S-wave velocity model and interpreted geological section.

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

- **3142C-07.** Contoured surface level models derived from aerial photogrammetry.
- **3142C-08.** Contoured level to modelled top of rock.
- **3142C-09.** Class post map level to modelled top of rock.
- **3142C-10.** Contoured modelled sand thickness over rock / Depth to top of rock.
- **3142C-11.** Class post map modelled sand thickness over rock / Depth to top of rock.

4.2 SEISMIC 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. 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 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 of moderate compaction 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 variably weathered rock. Where continuous and at base of the sections it likely represents a transitional zone to stronger, more competent underlying rock. Where present as isolated anomalies within the interpreted sediment, it is likely to represent partially lithified sediment or rock lenses.

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

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-01 on Transect 02** – refusal of 51MPa and rod friction at a depth of 2.8m Below Ground Level (BGL) which corresponds to an interpreted rock boulder weathered from the deeper limestone rock.
- **CPT-02 on Transect 02** – refusal of 52MPa and rod friction at a depth of 2.8m Below Ground Level (BGL) which corresponds to an interpreted rock boulder weathered from the deeper limestone rock.
- **CPT-03 on Transect 02 / 03** – refusal of 50MPa and rod friction was at a depth of 6.4m Below Ground Level (BGL) which corresponds to interpreted bedrock.
- **CPT-04 on Transect 02 / 04** – refusal due to rod friction at a depth of 6.3m Below Ground Level (BGL) which corresponds to interpreted bedrock.
- **CPT-05 on Transect 02** – refusal of 50MPa was at a depth of 3.86m Below Ground Level (BGL) which corresponds to interpreted bedrock.
- **CPT-06 on Transect 02** – No refusal to 10.2m Below Ground Level (BGL).
- **CPT-07 on Transect 02 / 05** – refusal of 50MPa at a depth of 2.36m Below Ground Level (BGL) which corresponds to interpreted bedrock.

The differences in the modelled level to compacted sediment and low 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.

Surface outcropping rock was observed at the northern end of Yallingup Beach which can be identified on the orthomosaic image from the aerial photogrammetry.

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 have 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. The modelled sand thickness was then generated by subtracting this from the surface level model obtained from the photogrammetry. Interpreted rock depths and levels should be analysed in conjunction with interpreted seismic sections in Appendix B. The following subsurface models have been provided:

- **Contoured Surface Level Model** (drawings 3142C-07) – generated from the aerial photogrammetry, this presents the level to ground surface ranging from 0mAHD to 45mAHD. Note: vegetation height has not been removed from these models.

- **Contoured Level to Top of Rock Substrate** (drawings 3142C-08) – this presents the level to the top of rock substrate ranging from -16mAHD to 40mAHD.

- **Classed Post Map Level to Top of Rock Substrate** (drawings 3142C-09) – this presents the level to the top of rock substrate along the acquired transects at 2m level increments from <-6mAHD to >6mAHD.

- **Contoured Sand Thickness / Depth to Top of Rock** (drawings 3142C-10) – this presents the thickness of sand overlying the rock substrate ranging from 0mBGL to 18mBGL.

- **Classed Post Map Sand Thickness / Depth to Top of Rock** (drawings 3142C-11) – this presents the thickness of sand overlying the rock substrate along the acquired transects at 2m depth increments from <2mBGL to >12mBGL.

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 of the accuracy of the GNSS receivers used 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 kriging 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 Yallingup in the City of Busselton, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 960m corridor of coastal beach and dune formation along Yallingup Beach.

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). 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/ depth to top of rock 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 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 investigation, please do not hesitate to contact the undersigned on 08 9354 6300.

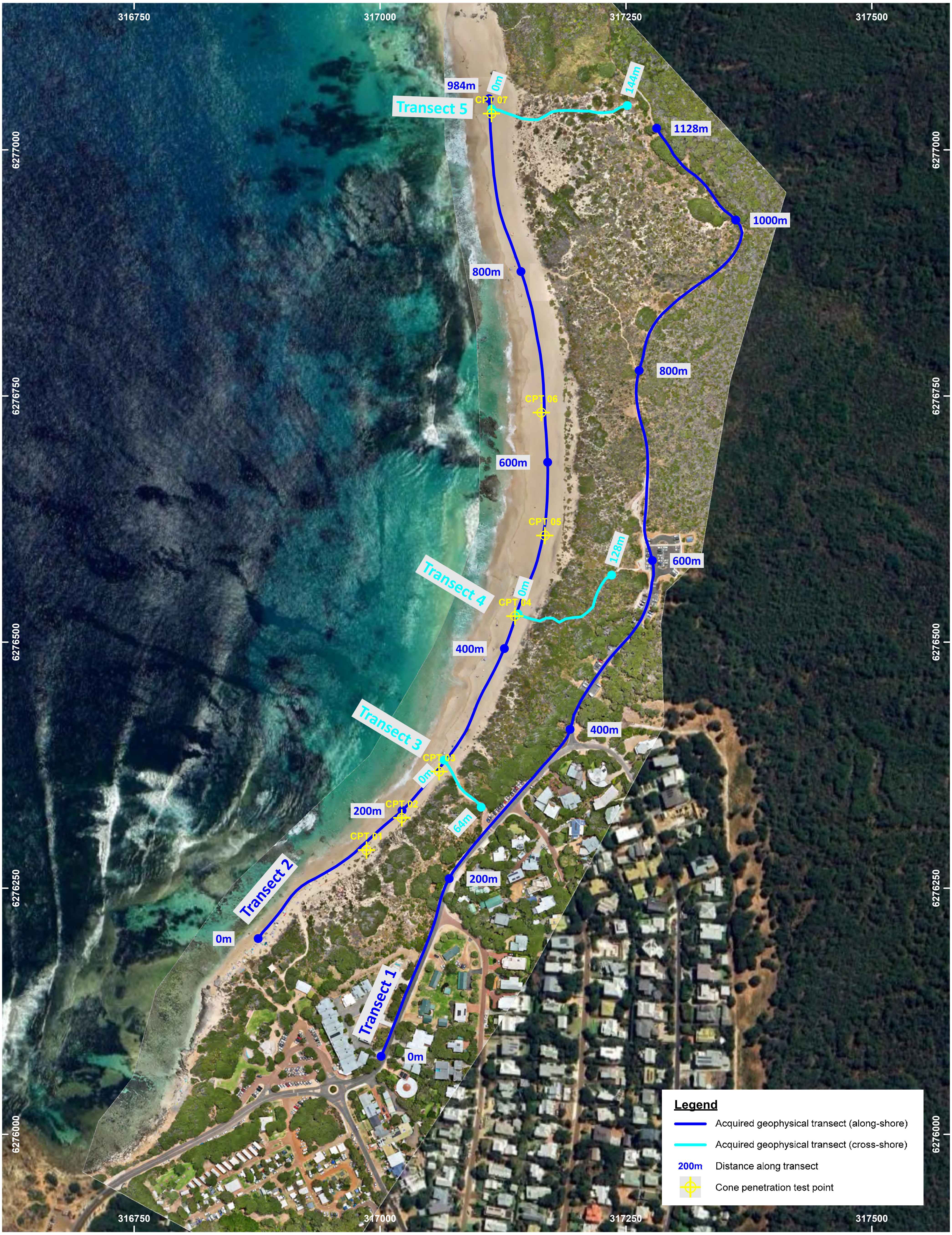
For and on behalf of
GBG GEOTECHNICS (AUSTRALIA)

BAQIR AL ASADI
Senior Geophysicist

APPENDIX A – INVESTIGATION SITE MAP

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

INVESTIGATION SITE MAP



NOTES
Drawing to be used in conjunction with GBG report 3142C.
Map Projection GDA2020 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

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Date	14 November 2024	Paper Size	A3
Scale	1:3500	Drawn	AHWS
Drawing	3142C-01	Revision	0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT.
YALLINGUP, CITY OF BUSSELTON WA

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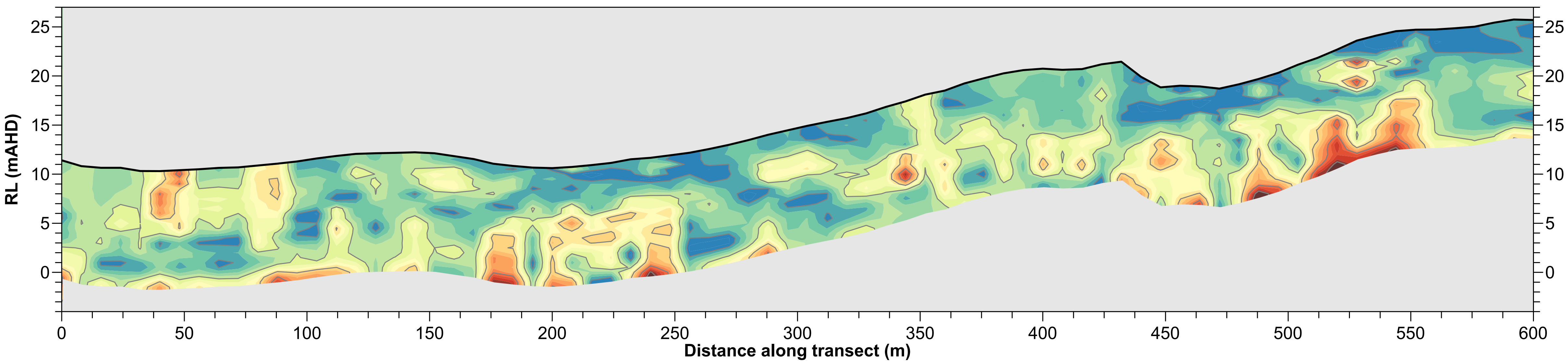
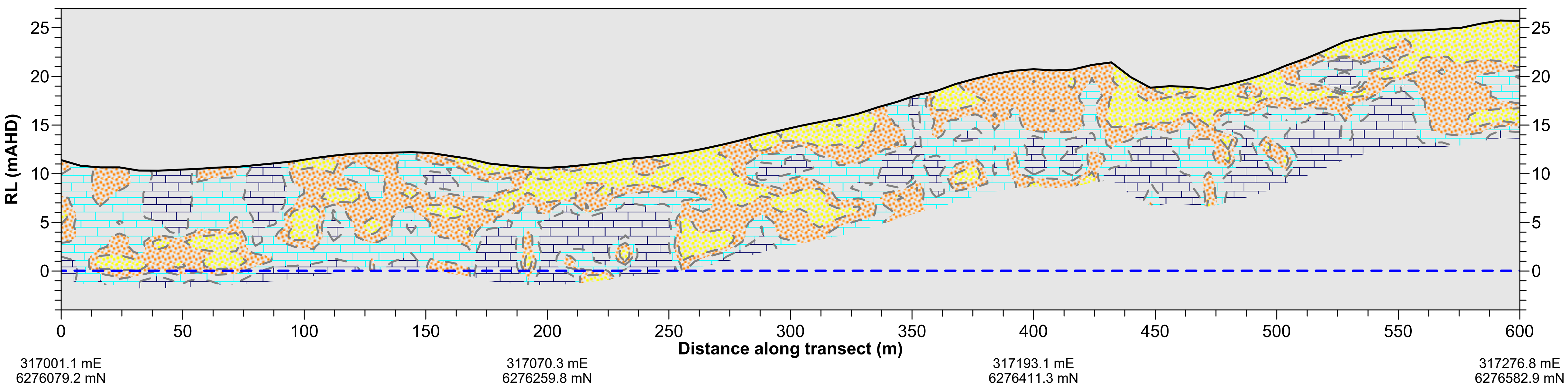
APPENDIX B – GEOPHYSICAL AND INTERPRETED SECTIONS

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

TRANSECT 01 (0-600m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 01 (0-600m) - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)

0, 200, 300, 400, 500, 600, 700, 800, 900, 1000

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 3142C.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	3 Dec 2024	Paper Size	A3
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA	Scale	1:2000H, 1:500V	Drawn	PJE
		Drawing	3142C-02	Revision	0

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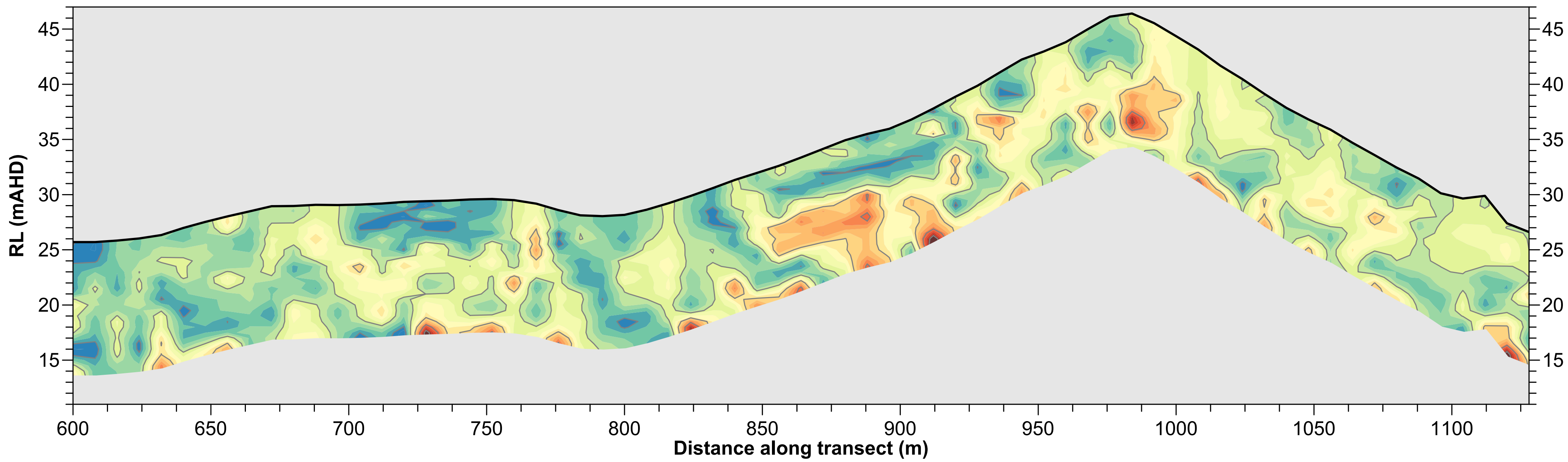
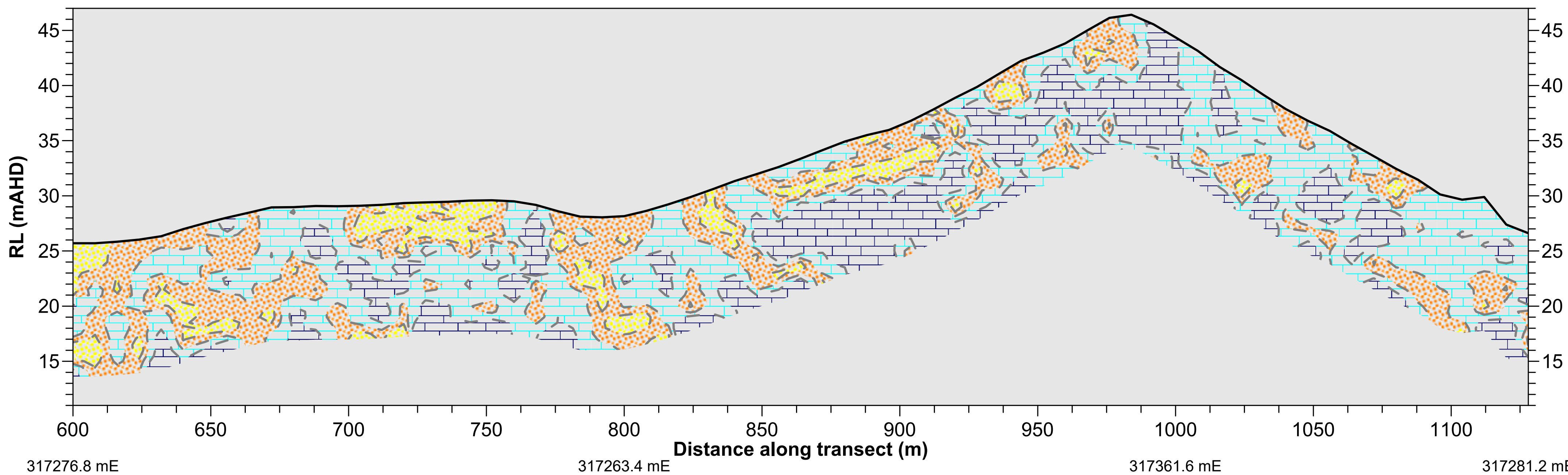
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

TRANSECT 01 (600-1128m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 01 (600-1128m) - INTERPRETED GEOLOGICAL SECTION



317276.8 mE
6276582.9 mN

317263.4 mE
6276775.9 mN

317361.6 mE
6276928.7 mN

317281.2 mE
6277022.0 mN

SEISMIC S-WAVE VELOCITY (m/s)

0 200 300 400 500 600 700 800 900 1000

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 3142C.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date 3 Dec 2024	Paper Size A3	GBGGROUP
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA	Scale 1:2000H, 1:500V	Drawn PJE	
		Drawing 3142C-03	Revision 0	

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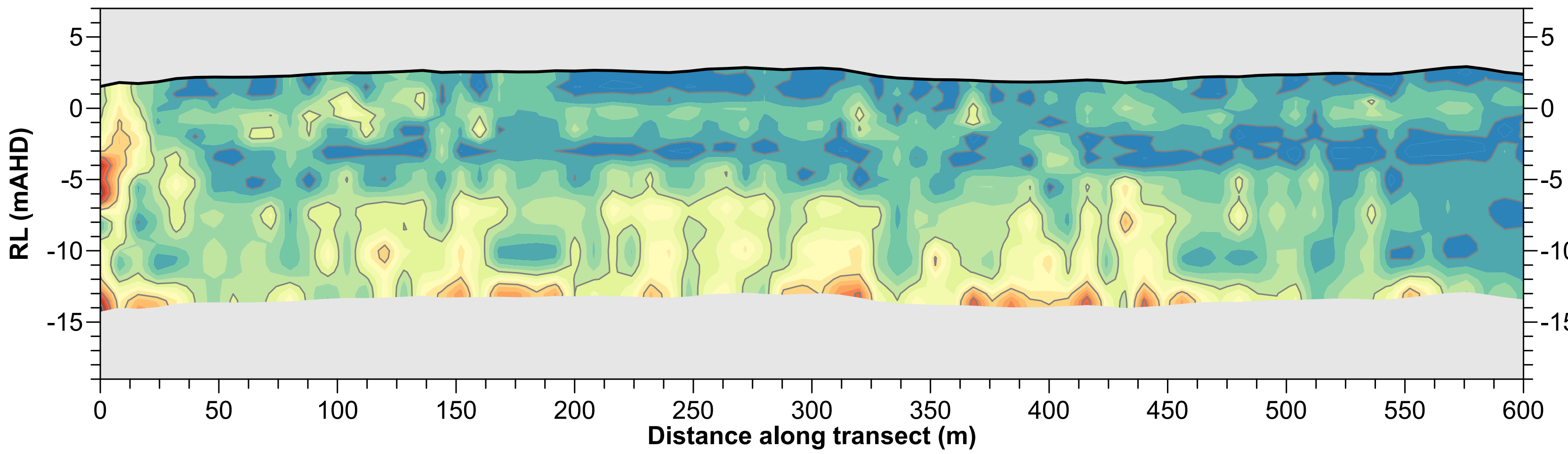
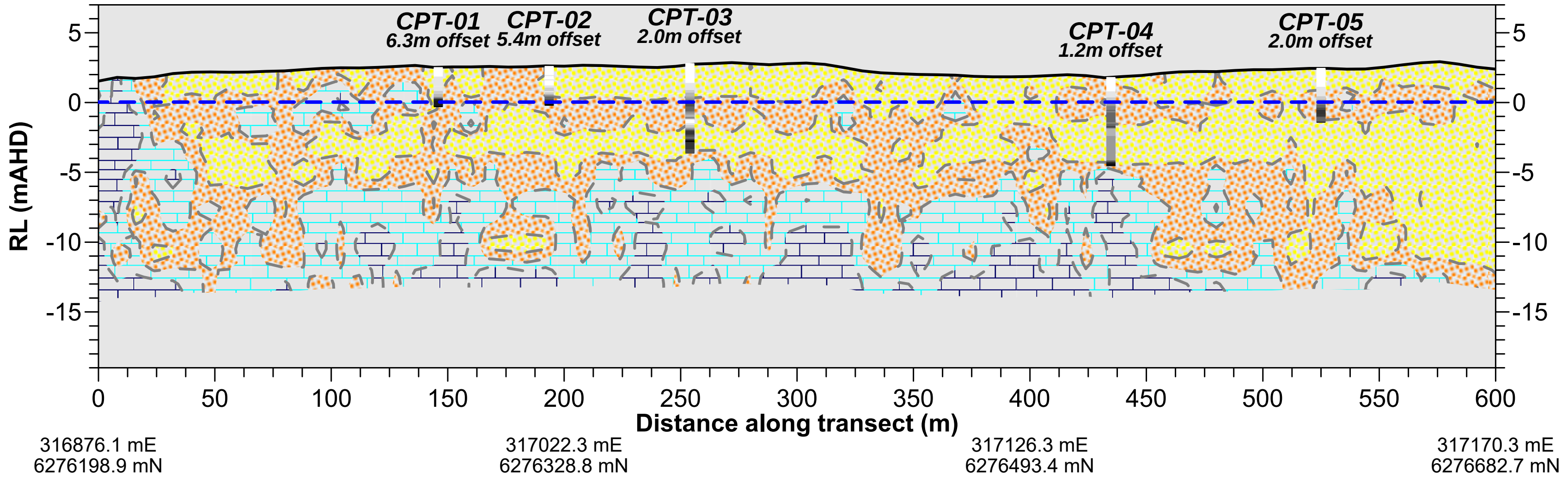
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

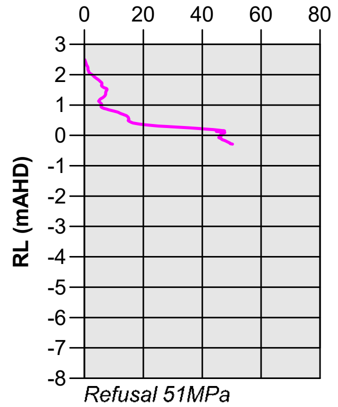
TRANSECT 02 (0-600m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 02 (0-600m) - INTERPRETED GEOLOGICAL SECTION

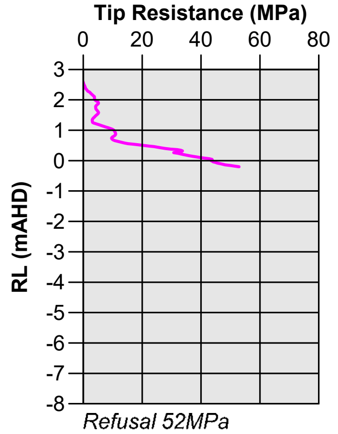


CPT-01
Tip Resistance (MPa)



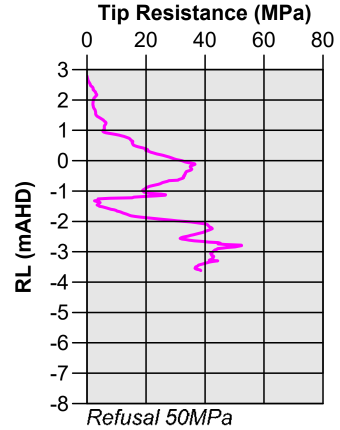
Refusal 51MPa Rod Friction

CPT-02
Tip Resistance (MPa)



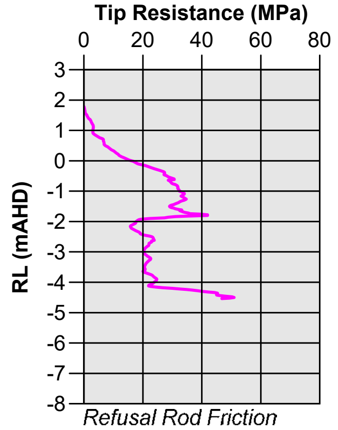
Refusal 52MPa Rod Friction

CPT-03
Tip Resistance (MPa)



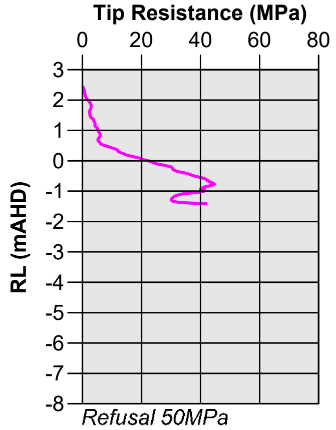
Refusal 50MPa Rod Friction

CPT-04
Tip Resistance (MPa)



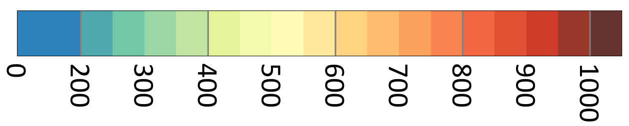
Refusal Rod Friction

CPT-05
Tip Resistance (MPa)



Refusal 50MPa Rod Friction

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 3142C.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	3 Dec 2024	Paper Size	A3
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA	Scale	1:3000H, 1:500V	Drawn	PJE
		Drawing	3142C-04	Revision	0

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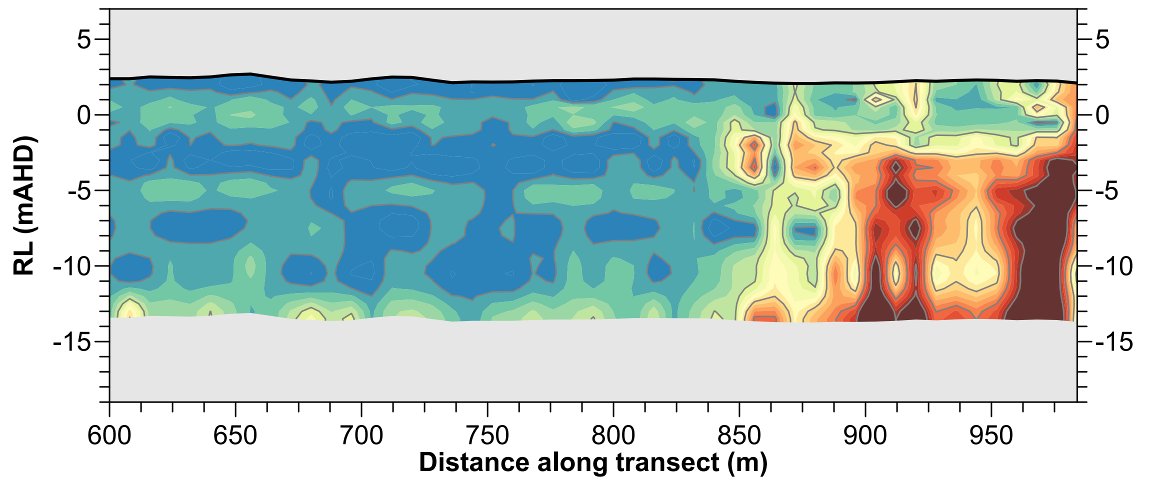
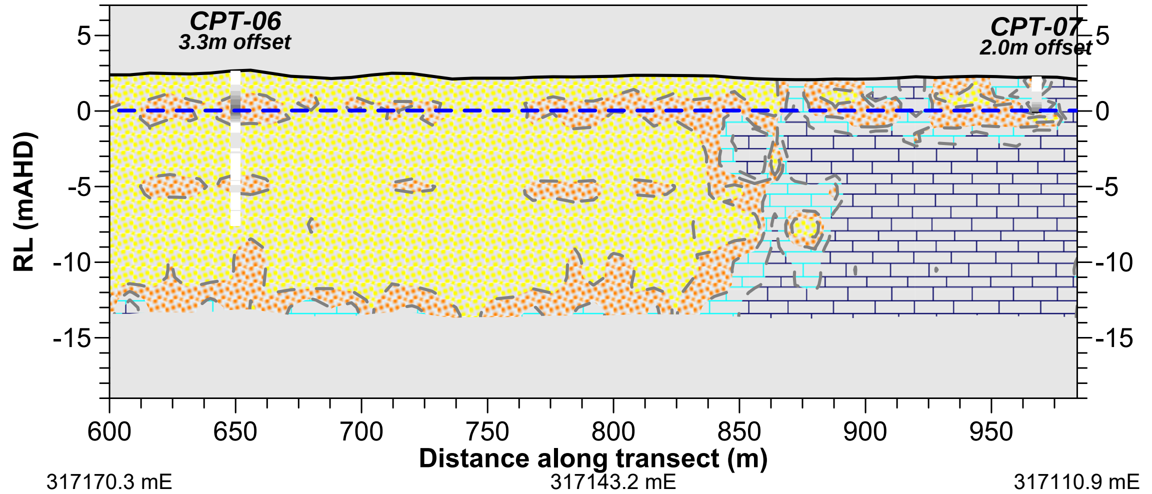
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

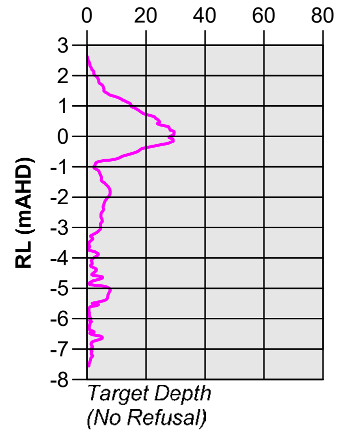
TRANSECT 02 (600-984m) - SEISMIC SHEAR WAVE VELOCITY MODEL



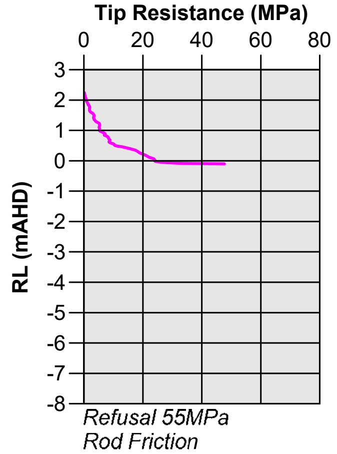
TRANSECT 02 (600-984m) - INTERPRETED GEOLOGICAL SECTION



CPT-06

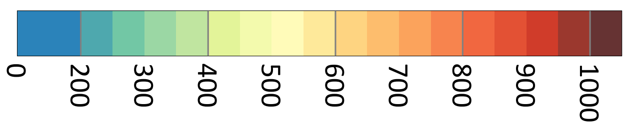


CPT-07



Refusal rod friction

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 3142C.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT: DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date: 3 Dec 2024	Paper Size: A3	
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA	Scale: 1:3000H, 1:500V	Drawn: PJE	
	Drawing: 3142C-05	Revision: 0	

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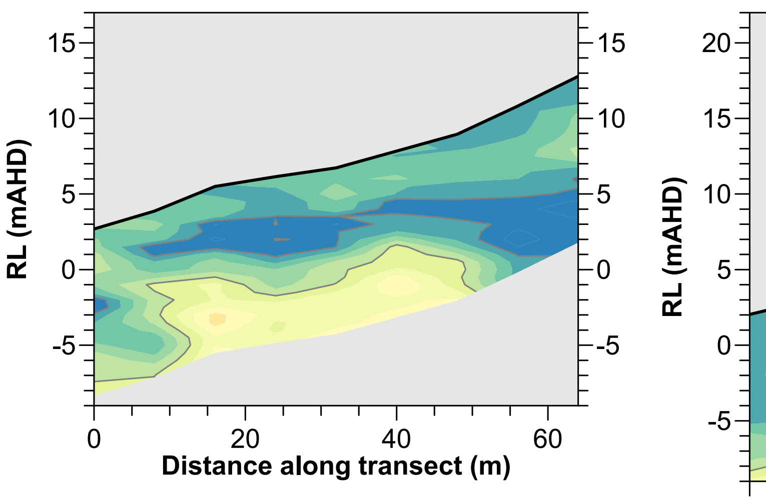
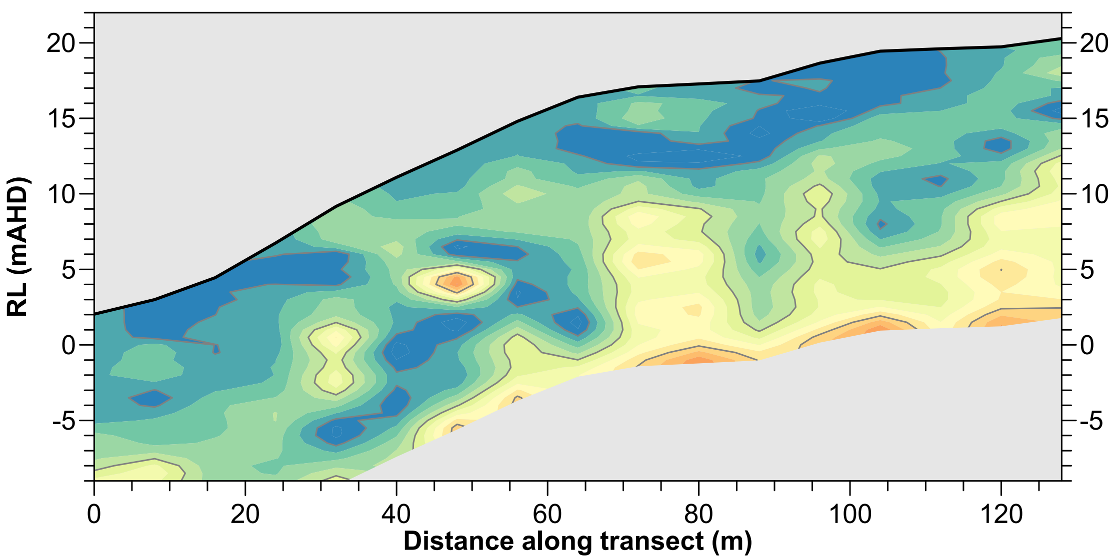
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

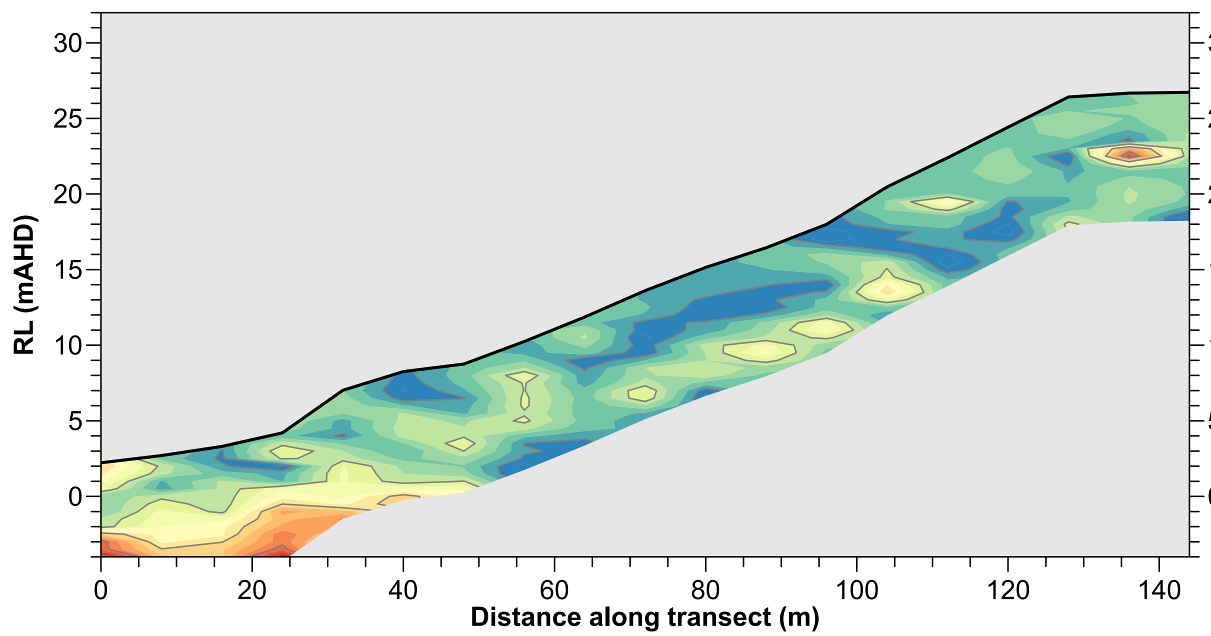
TRANSECT 03 - SEISMIC SHEAR WAVE VELOCITY MODEL



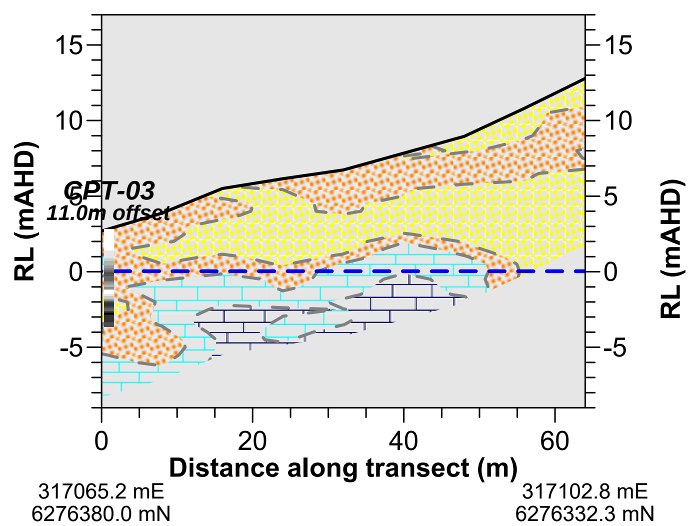
TRANSECT 04 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 05 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 03 - INTERPRETED GEOLOGICAL SECTION



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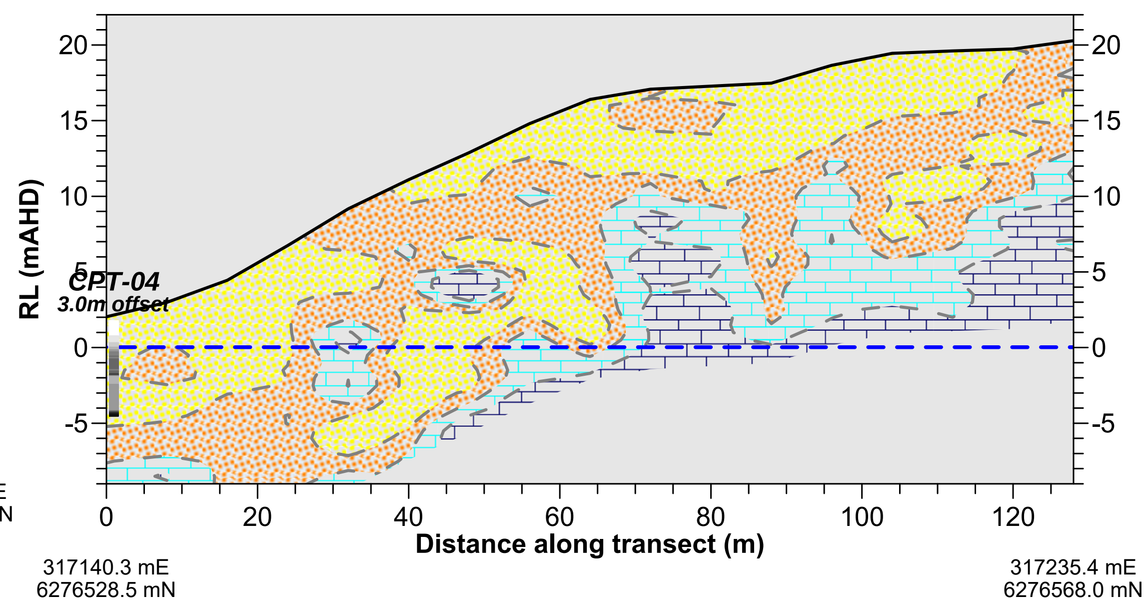
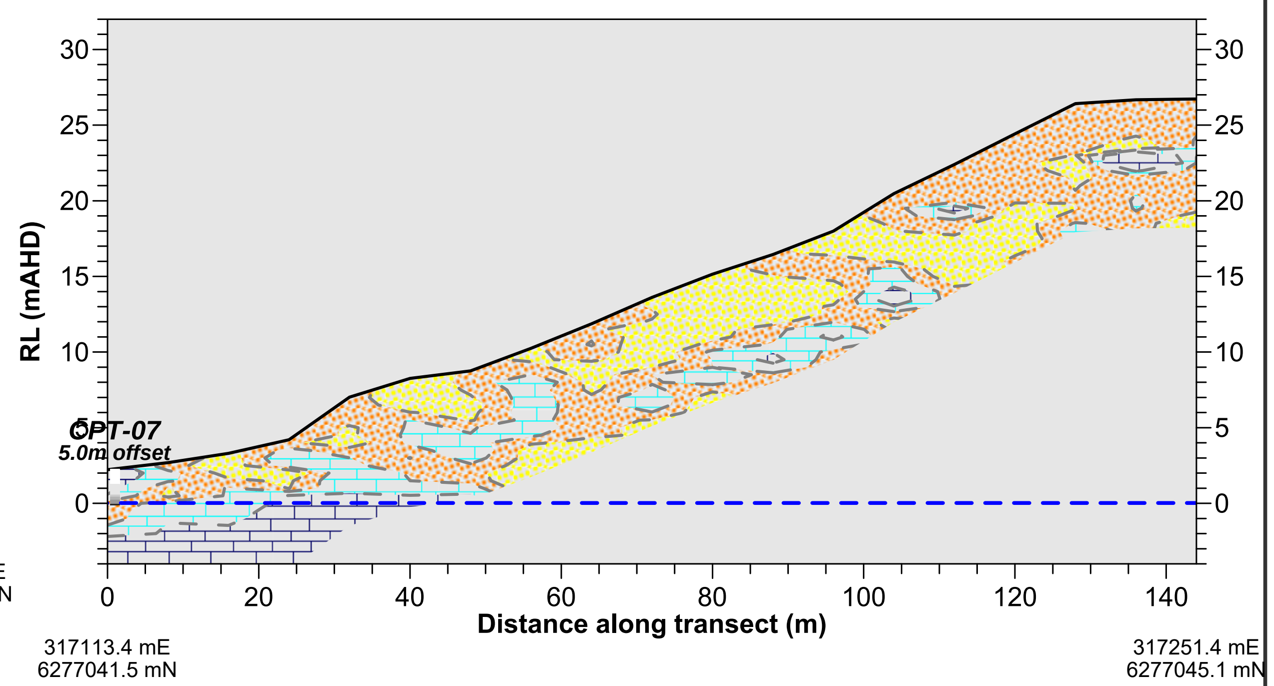
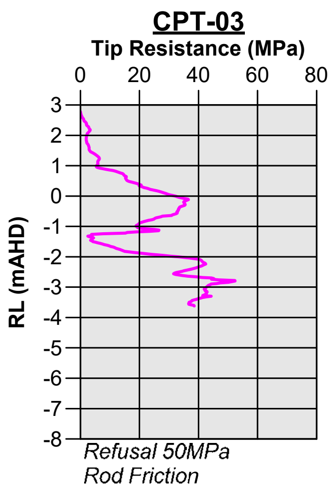
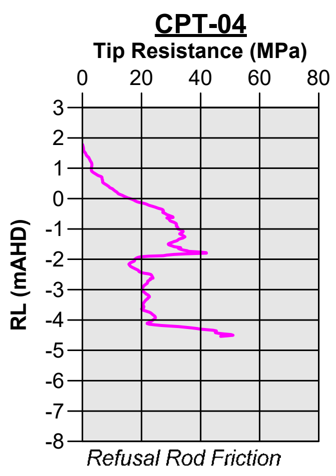
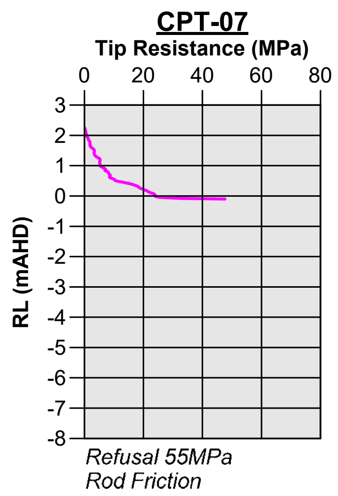


TRANSECT 05 - INTERPRETED GEOLOGICAL SECTION

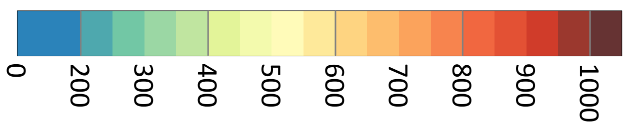








SEISMIC S-WAVE VELOCITY (m/s)



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 3142C.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	3 Dec 2024	Paper Size	A3
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA	Scale	1:1000H, 1:500V	Drawn	PJE
		Drawing	3142C-06	Revision	0

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APPENDIX C – MODELLED LEVELTO TOP OF ROCK AND SAND THICKNESS

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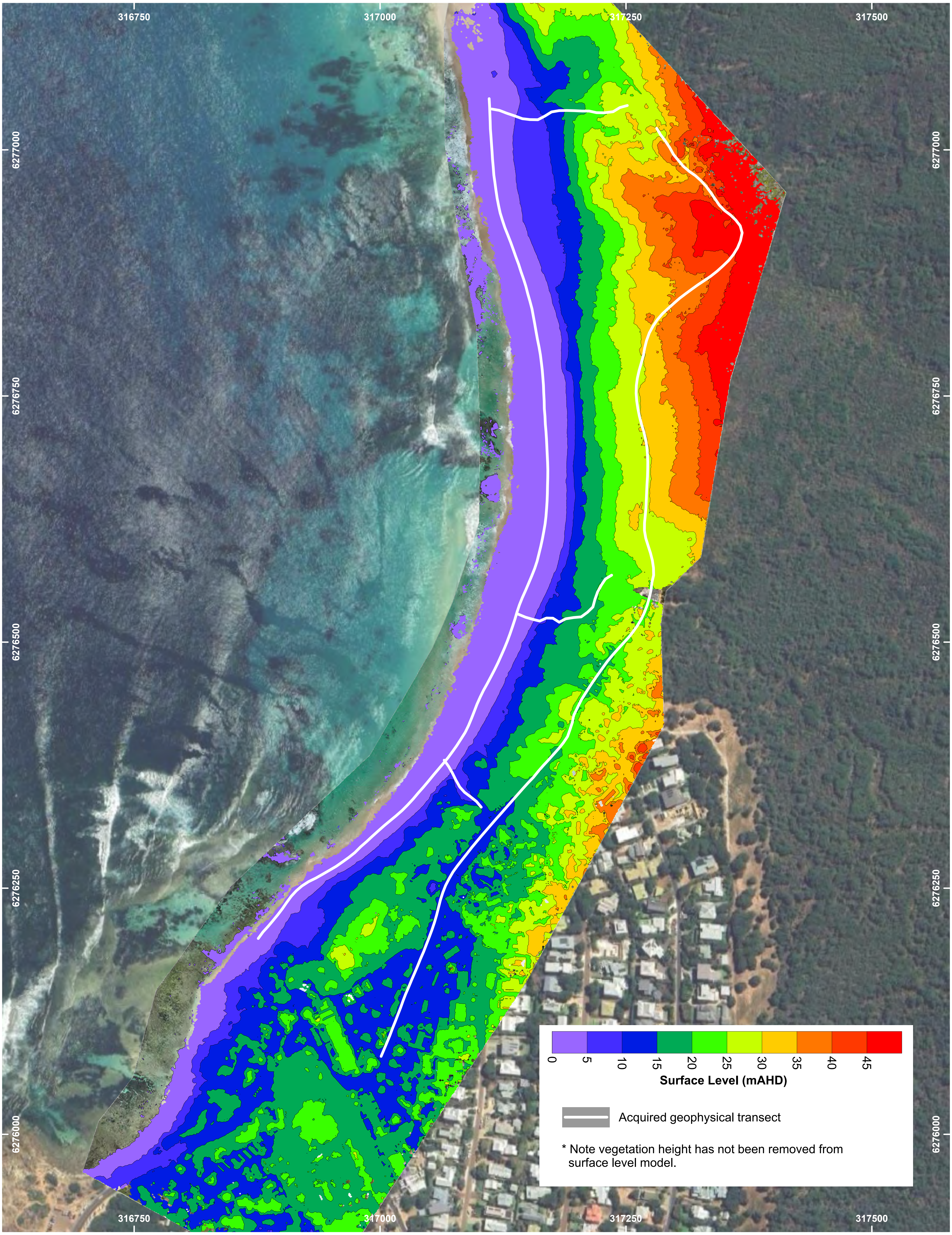
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

SURFACE LEVEL MODEL



NOTES
Drawing to be used in conjunction with GBG report 3142C.
Map Projection GDA2020 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

Date	4 February 2025	Paper Size	A3
Scale	1:3500	Drawn	AHWS
Drawing	3142C-07	Revision	0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA

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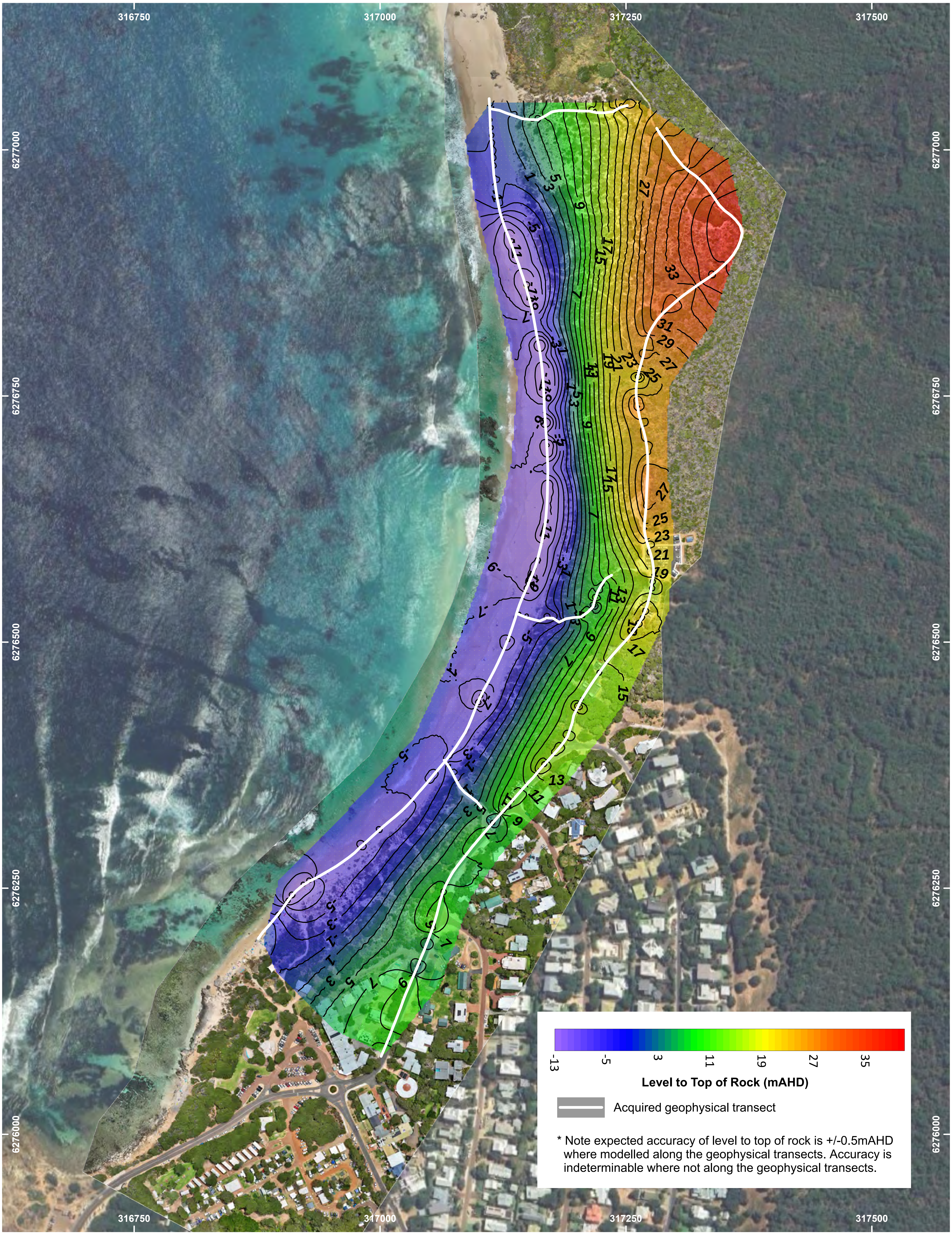
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK



NOTES
Drawing to be used in conjunction with GBG report 3142C.
Map Projection GDA2020 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

N

Date	11 February 2024	Paper Size	A3
Scale	1:3500	Drawn	PJE
Drawing	3142C-08	Revision	0

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA

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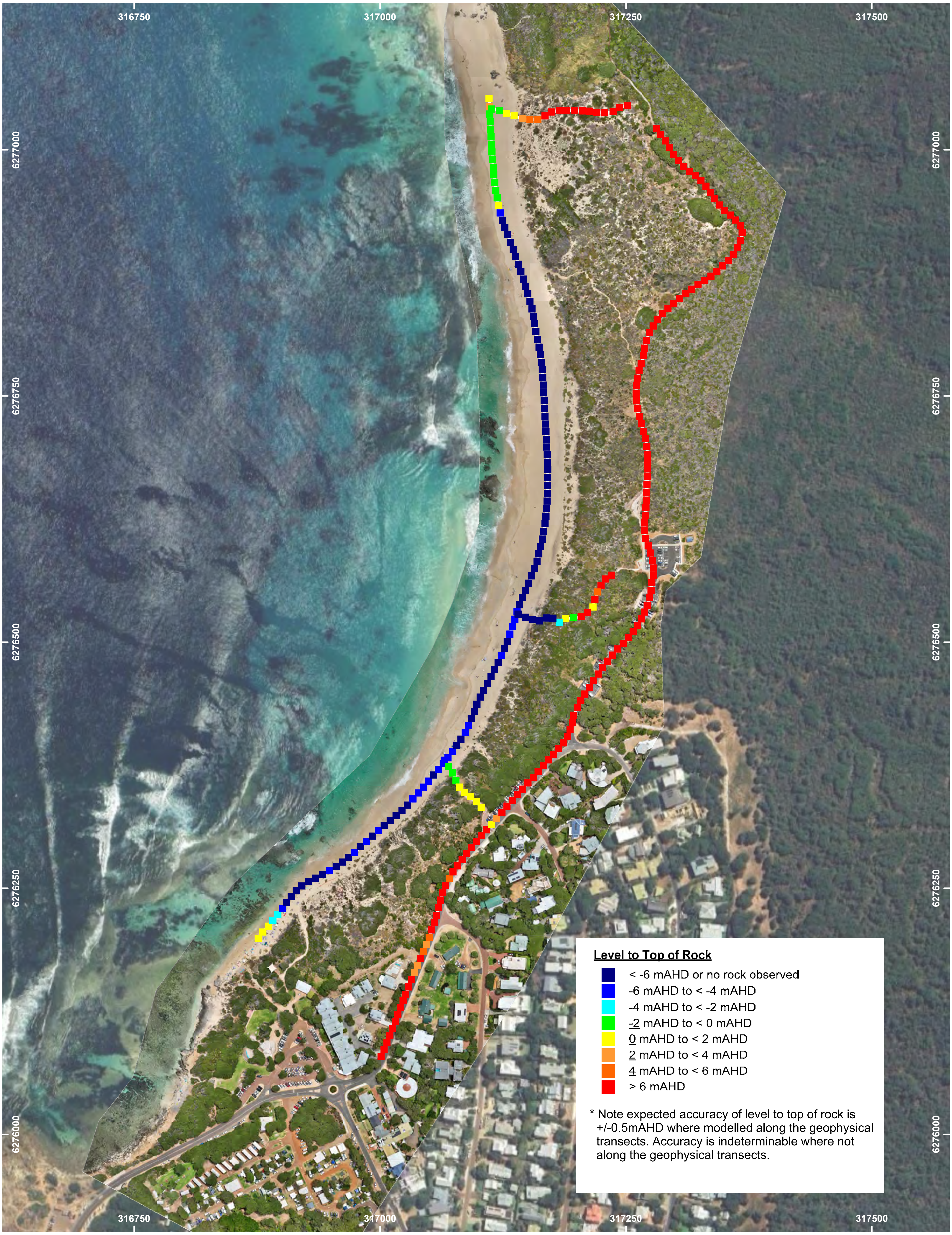
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

CLASSED POST MAP LEVEL TO TOP OF ROCK



Level to Top of Rock

- < -6 mAHD or no rock observed
- -6 mAHD to < -4 mAHD
- -4 mAHD to < -2 mAHD
- -2 mAHD to < 0 mAHD
- 0 mAHD to < 2 mAHD
- 2 mAHD to < 4 mAHD
- 4 mAHD to < 6 mAHD
- > 6 mAHD

* Note expected accuracy of level to top of rock is +/-0.5mAHD where modelled along the geophysical transects. Accuracy is indeterminable where not along the geophysical transects.

NOTES
Drawing to be used in conjunction with GBG report 3142C.
Map Projection GDA2020 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

N

Date	11 February 2025	Paper Size	A3
Scale	1:3500	Drawn	PJE
Drawing	3142C-09	Revision	0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA

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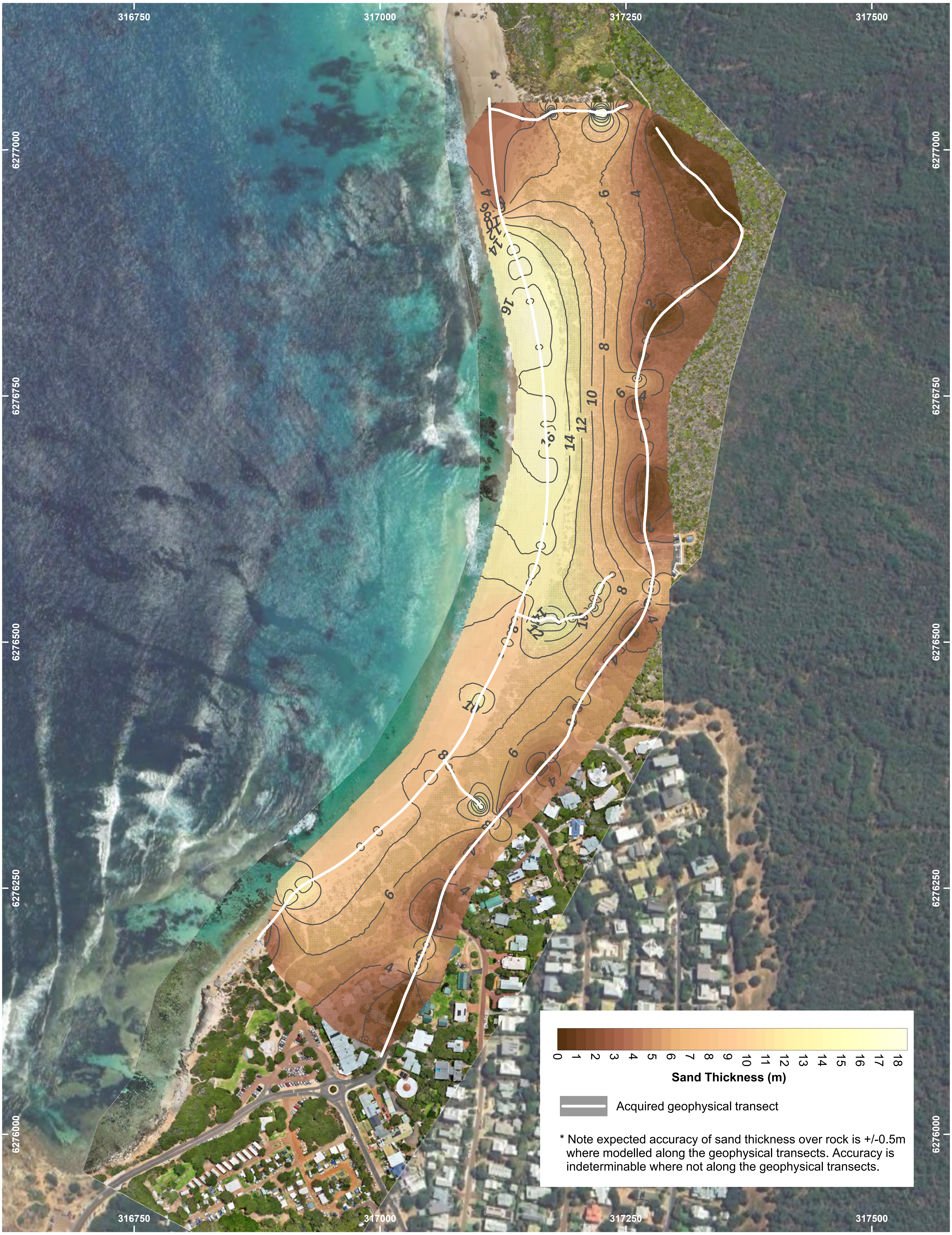
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

CONTOURED SAND THICKNESS OVER ROCK



NOTES
Drawing to be used in conjunction with GBG report 3142C.
Map Projection GDA2020 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

N

Date	11 February 2025	Paper Size	A3
Scale	1:3500	Drawn	PJE
Drawing	3142C-10	Revision	0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA

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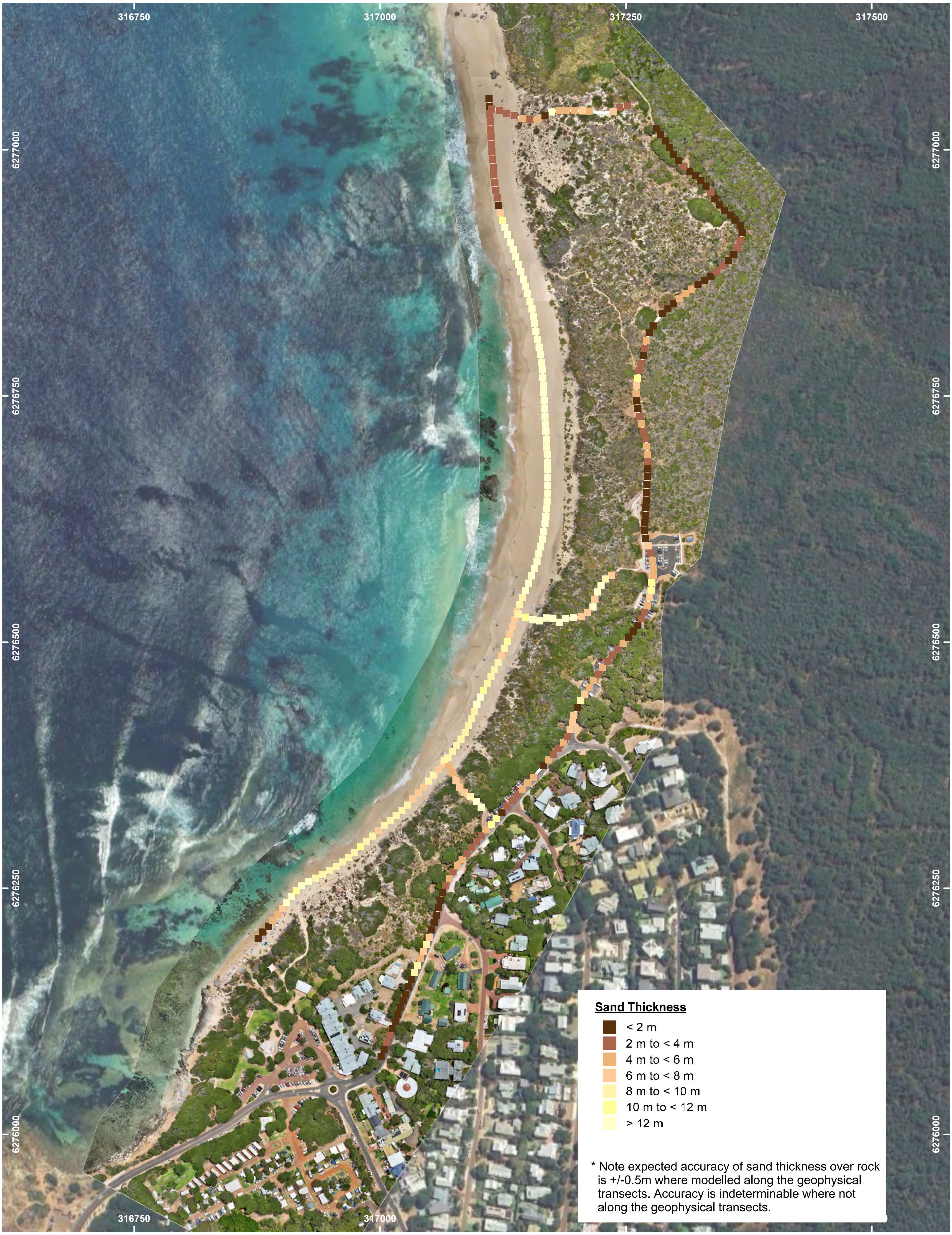
Web: gbg-group.com.au

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT YALLINGUP, CITY OF BUSSELTON WESTERN AUSTRALIA

CLASSED POST MAP SAND THICKNESS OVER ROCK



NOTES
Drawing to be used in conjunction with GBG report 3142C.
Map Projection GDA2020 MGA Zone 50.
Aerial image from Google Earth Pro and GBG photogrammetry.

N

Date	11 February 2024	Paper Size	A3
Scale	1:3500	Drawn	PJE
Drawing	3142C-11	Revision	0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT. YALLINGUP, CITY OF BUSSELTON WA

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APPENDIX D – CONE PENETRATION TEST PLOTS

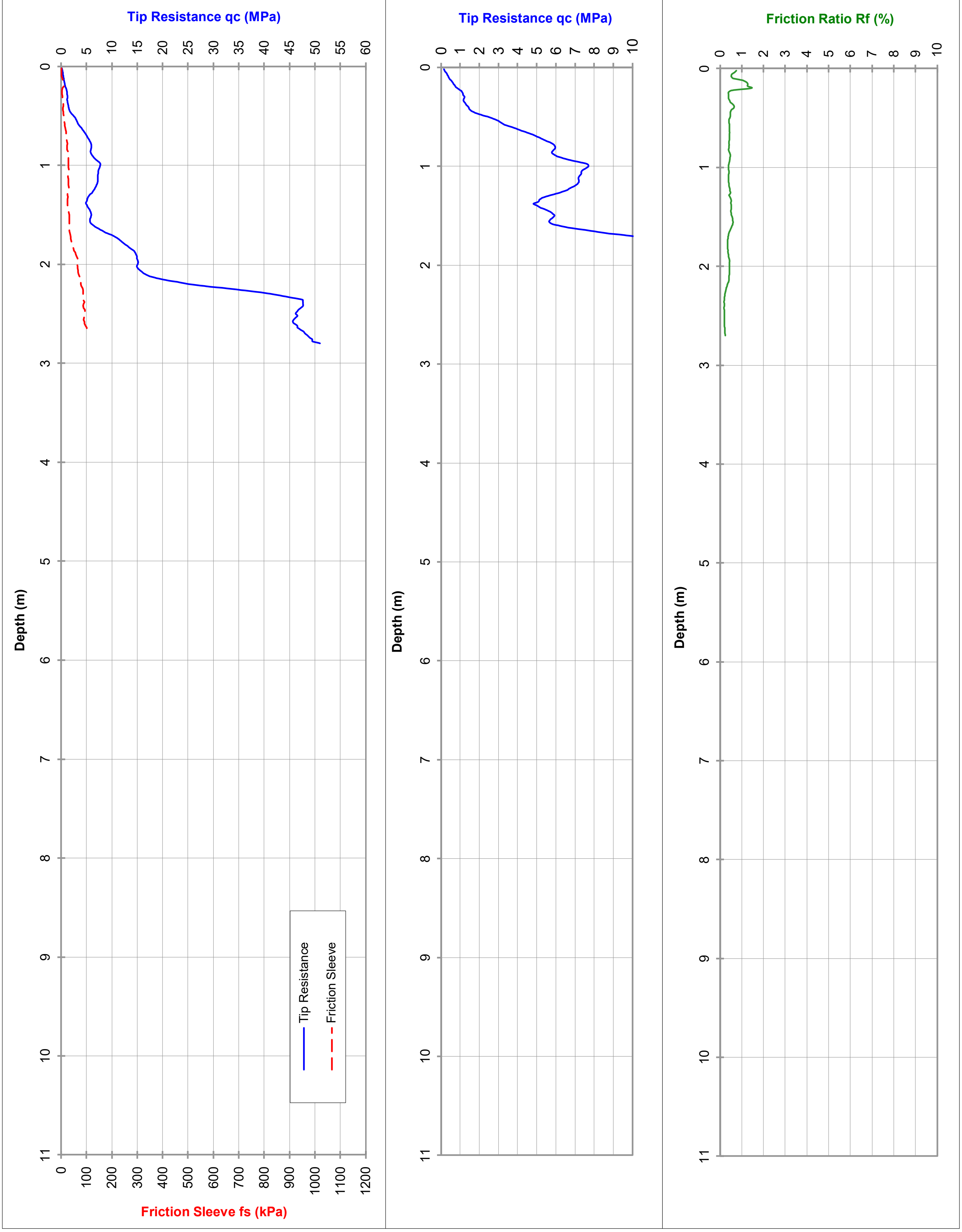
ELECTRIC FRICTION-CONE PENETROMETER

CLIENT:	Department of Transport	Job No.:	3142
PROJECT:	Southern & Southwest Coastal	RL (m):	4.4
LOCATION:	Yallingup	Co-ords:	316986.27mE, 6276288.64mN

Probe I.D

CPT 01

23-Jan-25



PROBEDRILL GEOTECHNICAL SURVEY

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

Approx. water (m): Dry to 2.3

Dummy probe to (m):

Refusal: 51 MPa + Rod Friction

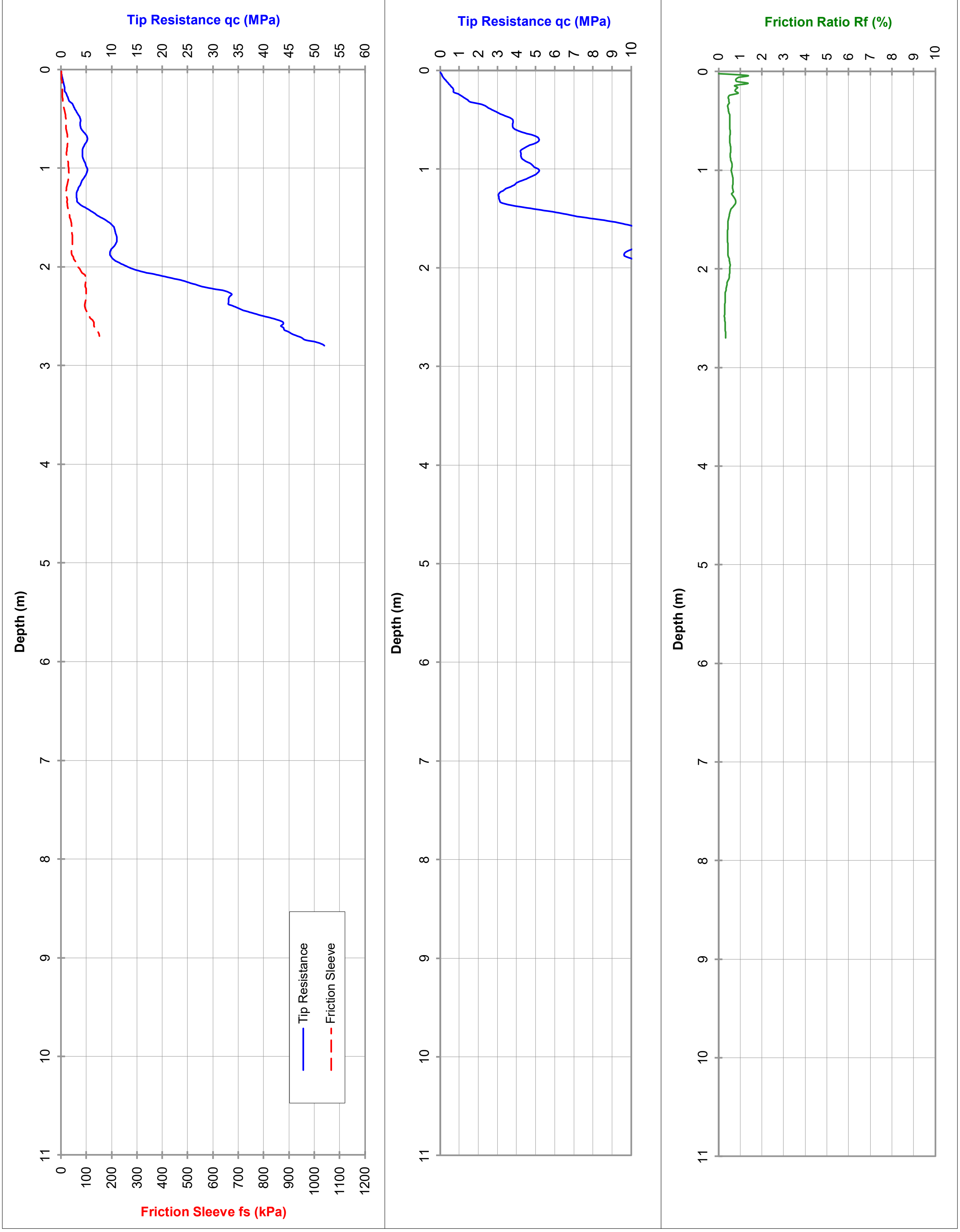
Cone I.D.: EC47

File: GB0091T

Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT:	Department of Transport	Job No.:	3142	Probe I.D
PROJECT:	Southern & Southwest Coastal	RL (m):	4.64	**CPT 02**
LOCATION:	Yallingup	Co-ords:	317022.12mE, 6276321.3mN	23-Jan-25



PROBEDRILL GEOTECHNICAL SURVEY

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

Approx. water (m): Dry to 2.8

Dummy probe to (m):

Refusal: 52 MPa + Rod Friction

Cone I.D.: EC47

File: GB0090T

Rig Type: 7t track

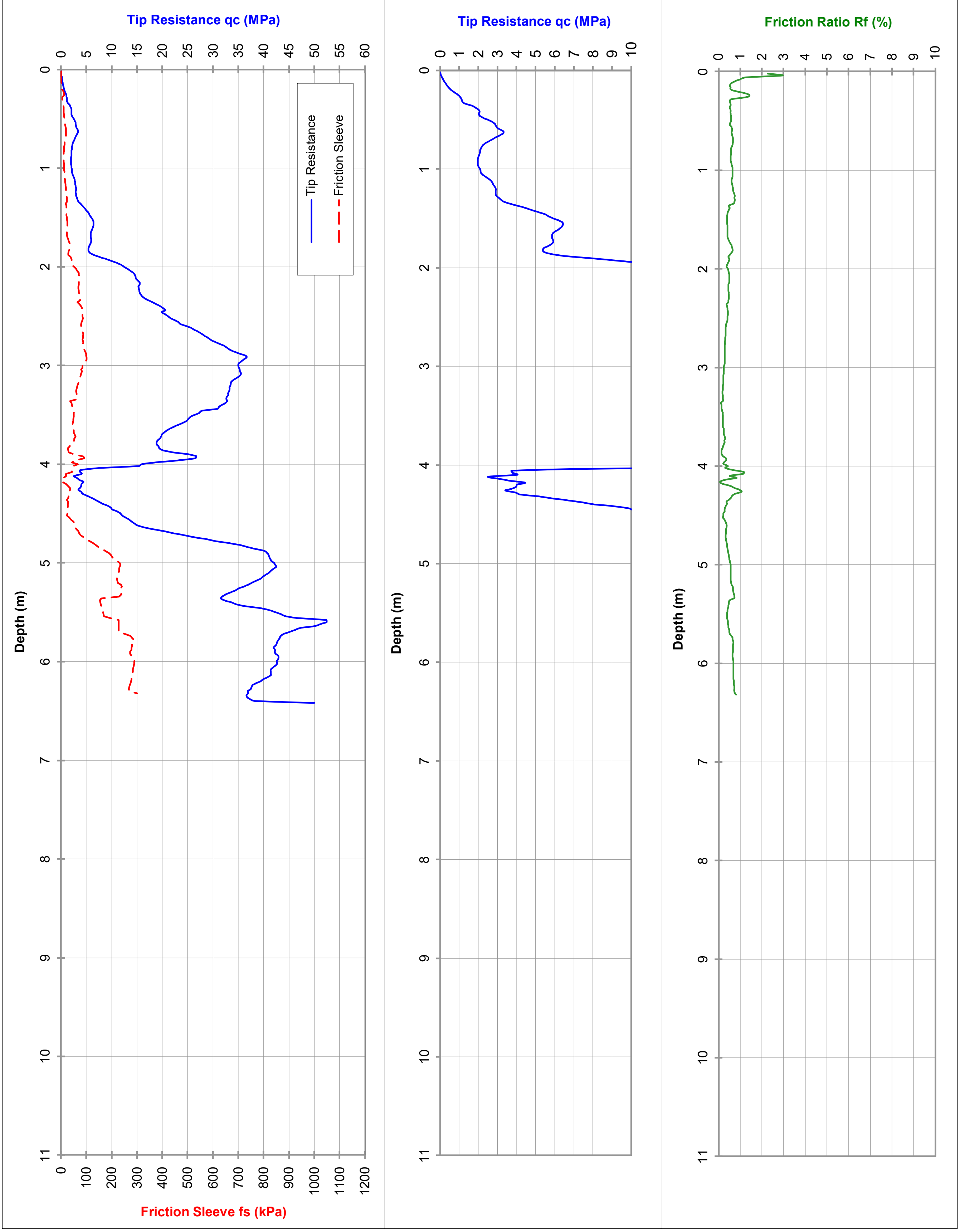
ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: Department of Transport	Job No.: 3142
PROJECT: Southern & Southwest Coastal	RL (m): 4.16
LOCATION: Yallingup	Co-ords: 317060.05mE, 6276368.31mN

Probe I.D

CPT 03

22-Jan-25



PROBEDRILL GEOTECHNICAL SURVEY

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

Approx. water (m): 2.9

Dummy probe to (m):

Refusal: 50 MPa + Rod Friction

Cone I.D.: EC47

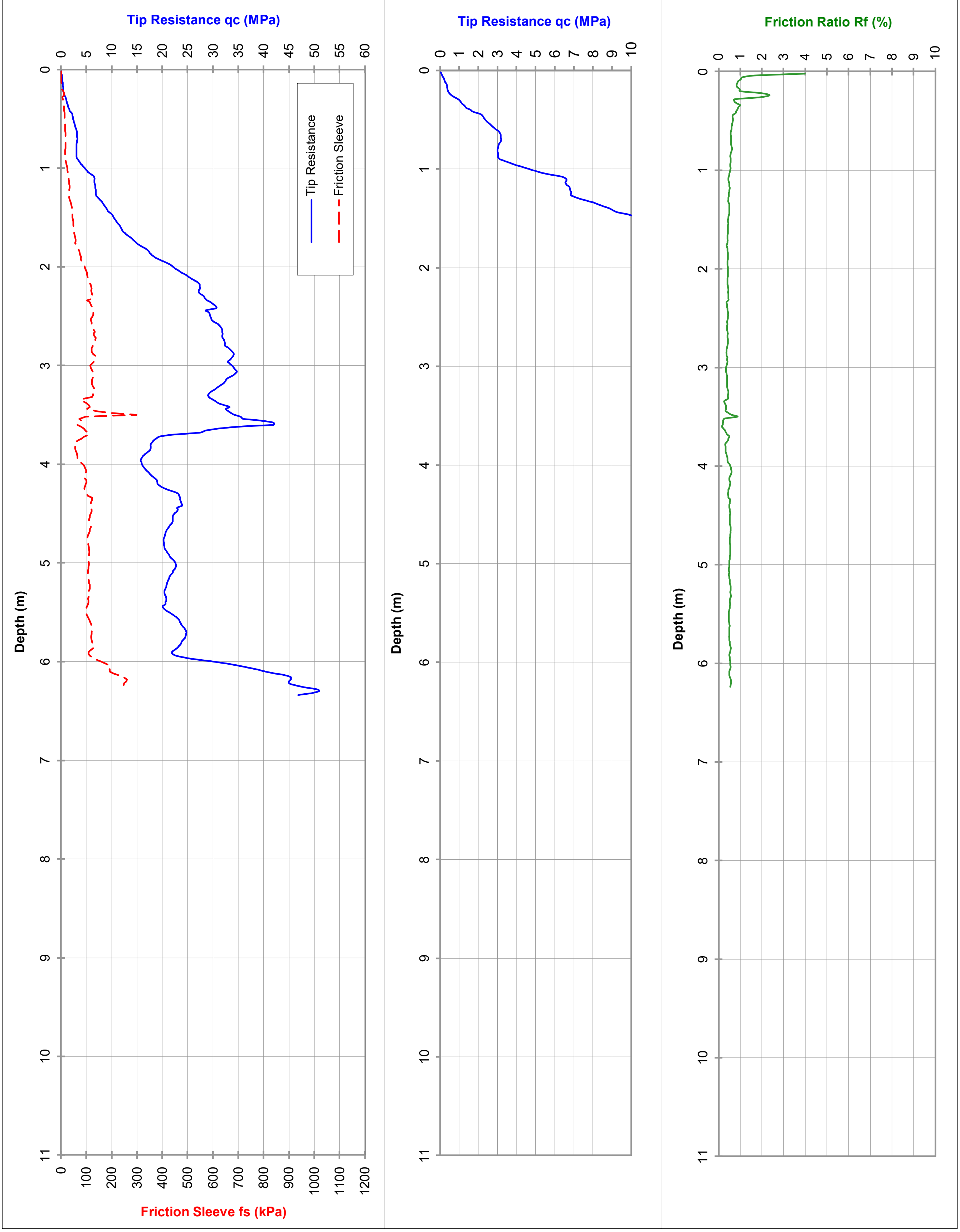
File: GB0085T

Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: Department of Transport | Job No.: 3142
PROJECT: Southern & Southwest Coastal | RL (m): 3.6
LOCATION: Yallingup | Co-ords: 317137.17mE, 6276526.2mN

Probe I.D
CPT 04
22-Jan-25



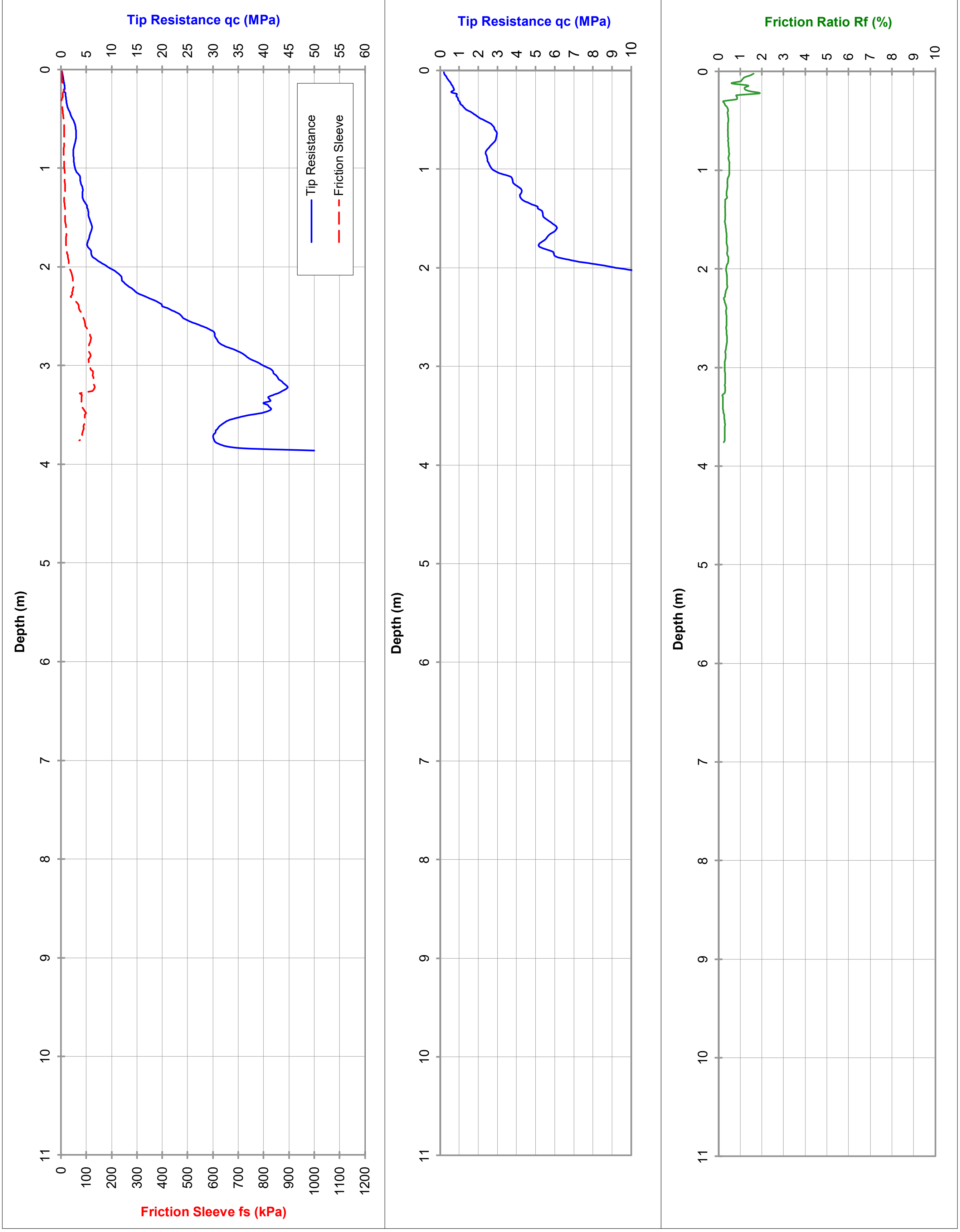
PROBEDRILL GEOTECHNICAL SURVEY
Tested in accordance with AS 1289.6.5.1-1999 and IRTP 2001 for friction reducer

Approx. water (m): -
Dummy probe to (m):
Refusal: Rod Friction

Cone I.D.: EC47
File: GB0086T
Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT:	Department of Transport	Job No.:	3142	Probe I.D
PROJECT:	Southern & Southwest Coastal	RL (m):	3.27	**CPT 05**
LOCATION:	Yallingup	Co-ords:	317167.56mE, 6276608.09mN	23-Jan-25



PROBEDRILL GEOTECHNICAL SURVEY

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

Approx. water (m): Dry to 2.4

Dummy probe to (m):

Refusal: 50 MPa + Rod Friction

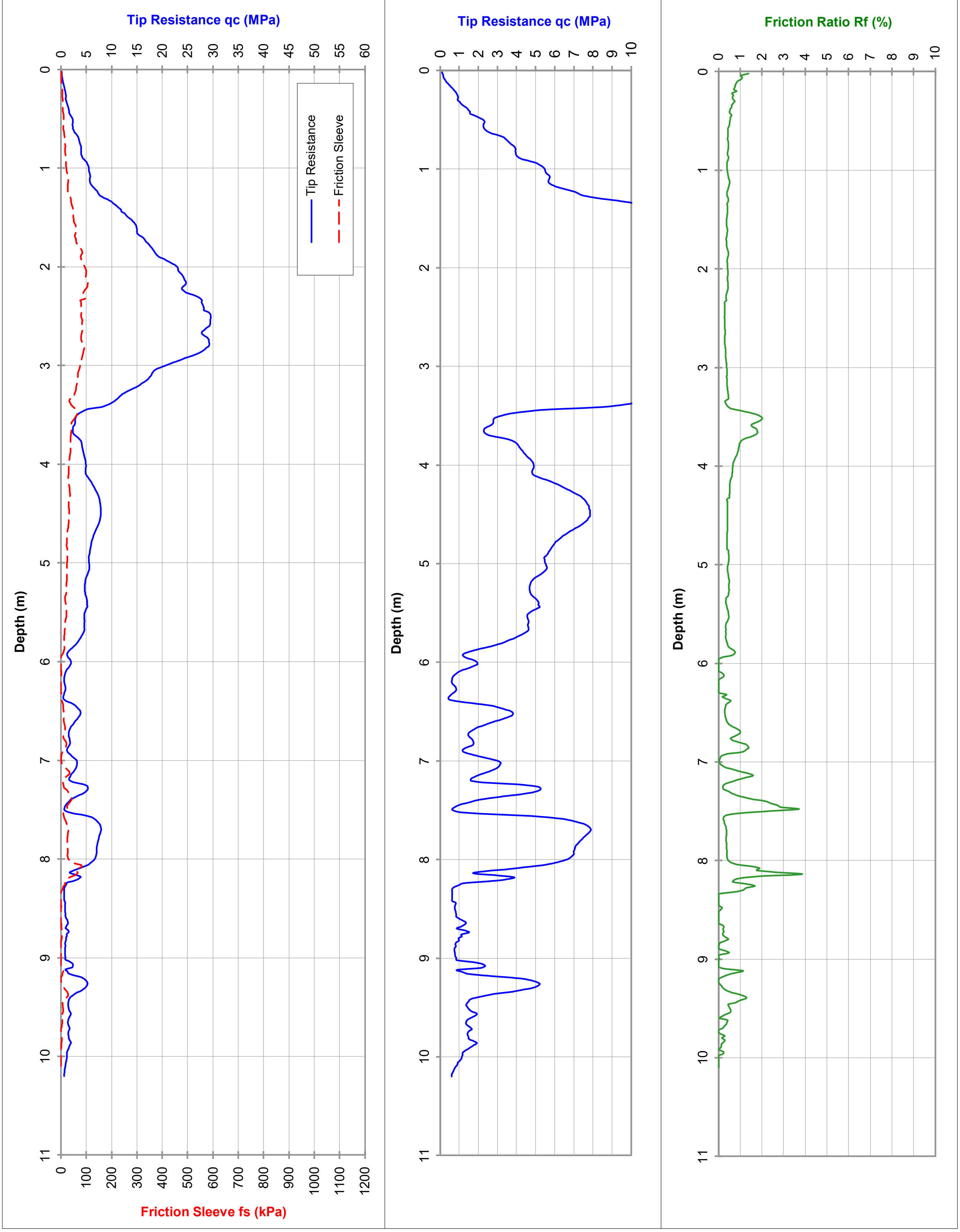
Cone I.D.: EC47

File: GB0087T

Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT:	Department of Transport	Job No.: 3142	Probe I.D
PROJECT:	Southern & Southwest Coastal	RL (m): 3.76	**CPT 06**
LOCATION:	Yallingup	Co-ords: 317163.99mE, 6276732.99mN	23-Jan-25



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

Approx. water (m): Dry to 2.7

Dummy probe to (m):

Refusal:

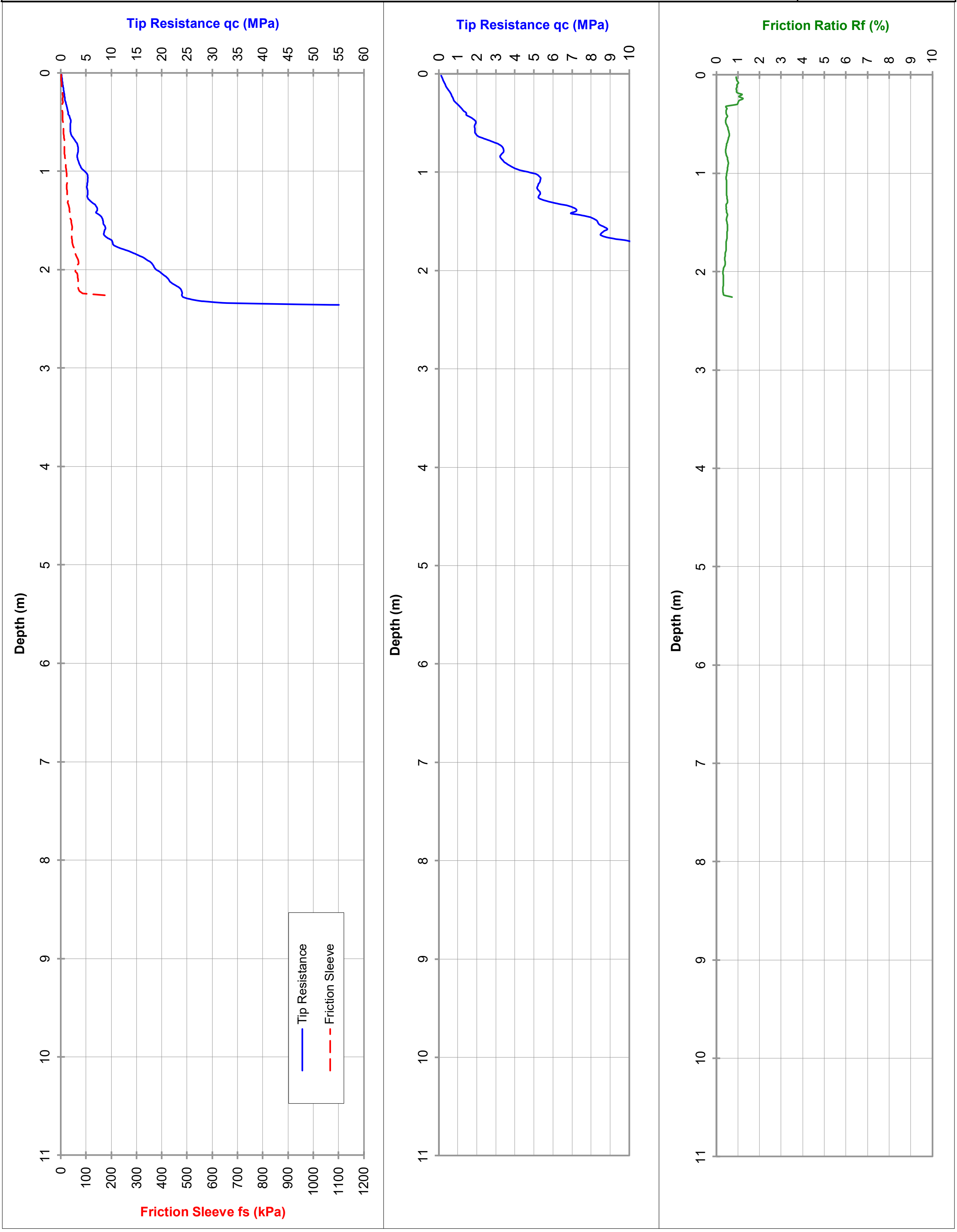
Cone I.D.: EC47

File: GB0088T

Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT:	Department of Transport	Job No.: 3142	Probe I.D
PROJECT:	Southern & Southwest Coastal	RL (m): 3.2	**CPT 07**
LOCATION:	Yallingup	Co-ords: 317113.31mE, 6277036.71mN	23-Jan-25



PROBEDRILL GEOTECHNICAL SURVEY

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

Approx. water (m): Dry to 1.5

Dummy probe to (m):

Refusal: 55 MPa + Rod Friction

Cone I.D.: EC47

File: GB0089T

Rig Type: 7t track

PROBEDRILL GEOTECHNICAL SURVEY

CALIBRATION CERTIFICATE

CONE ID: EC47

Cone Type:	Compression
Calibration Date (qc/fs):	20 November 2024
Calibration Date (u):	25 November 2024
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 #I44427 (Calibrated 05/06/24 - NATA approved Cert. No. 241683) 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.

Results of Calibration:

qc (tip resistance):

Capacity:	100 (MPa)	
Area	1000 (mm²)	
Applied Load kN	**Eqv. Pressure MPa**	**Mean Observed Reading Volts**
0	0	0.000
10	10	0.757
20	20	1.514
30	30	2.273
40	40	3.033
50	50	3.797
60	60	4.562
70	70	5.330
80	80	6.100
90	90	6.865
100	100	7.634
90	90	6.889
80	80	6.131
70	70	5.372
60	60	4.610
50	50	3.850
40	40	3.084
30	30	2.318
20	20	1.549
10	10	0.780
0	0	0.004
R^2 Value =	1.000	

Zero Load Error: 0.06%
Max. Linearity 0.38%
Max. Hysteris 0.70%

MPa/Volt: 13.094

fs (sleeve friction):

Capacity:	2000 (kPa)	
Area	15000 (mm²)	
Applied Force kN	**Eqv. Load kPa**	**Mean Observed Reading Volts**
0	0	0.000
3	200	0.746
6	400	1.502
9	600	2.259
12	800	3.014
15	1000	3.766
18	1200	4.517
21	1400	5.270
24	1600	6.022
27	1800	6.780
30	2000	7.540
27	1800	6.814
24	1600	6.067
21	1400	5.315
18	1200	4.563
15	1000	3.809
12	800	3.055
9	600	2.296
6	400	1.528
3	200	0.765
0	0	0.002
R^2 Value =	1.000	

Zero Load Error: 0.03%
Max. Linearity 0.47%
Max. Hysteris 0.61%

kPa/Volt: 264.97

u (pore pressure):

Capacity:	3500 (kPa)	
Position	u2	
Applied Pressure bar	**Eqv. Pressure kPa**	**Mean Observed Reading Volts**
0	0	0.000
3	300	0.351
6	600	0.700
9	900	1.050
12	1200	1.399
15	1500	1.749
18	1800	2.098
21	2100	2.443
25	2500	2.909
30	3000	3.488
35	3500	4.066
30	3000	3.495
25	2500	2.916
21	2100	2.452
18	1800	2.103
15	1500	1.754
12	1200	1.405
9	900	1.053
6	600	0.702
3	300	0.352
0	0	0.001
R^2 Value =	1.000	

Zero Load Error: 0.01%
Max. Linearity 0.25%
Max. Hysteris 0.22%

kPa/Volt: 859.97
Net Area (calibrated): 0.81

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

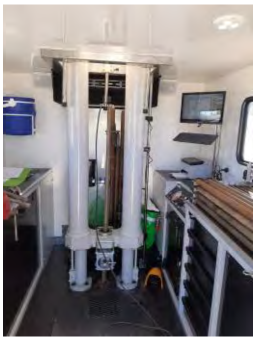
Calibration Checked & Authorised: Kylie Walker

Job Details

Client:	GBG Maps	Date of Job:	22/01/2025
Rep:	Stephen Kelly	Tip Diameter:	35.8
Location:	Yallingup	Sleeve Diameter:	35.86

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)