

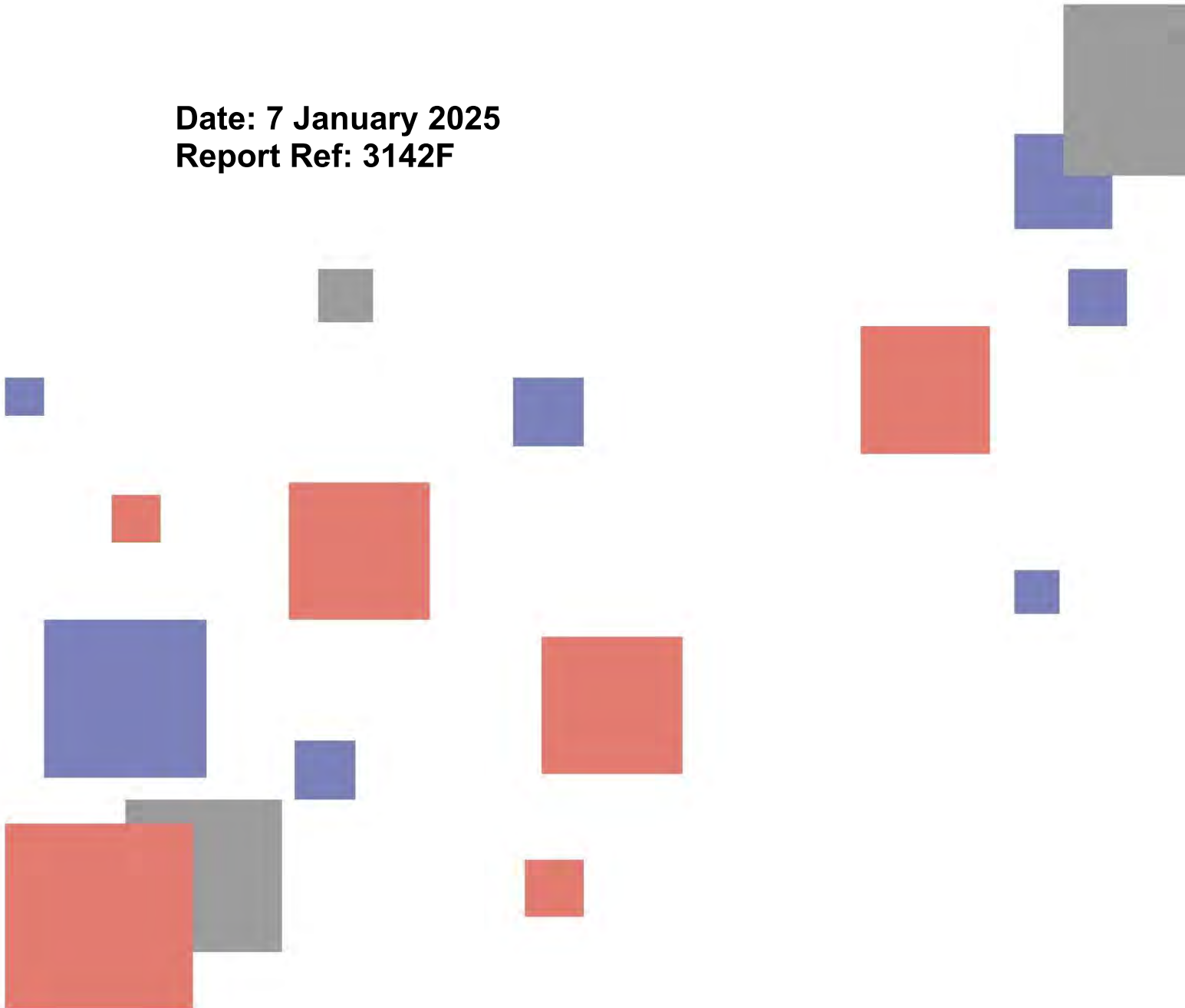
Report

Geotechnical Investigation for Coastal Erosion Vulnerability Assessment.

Rockingham, City of Rockingham WA.

Date: 7 January 2025

Report Ref: 3142F



DOCUMENT HISTORY

DETAILS

Project number	3142F
Document Title	Geotechnical Investigation for Coastal Erosion Vulnerability Assessment
Site Address	Rockingham, City of Rockingham WA
Report prepared for	The Government of Western Australia, Department of Transport

STATUS AND REVIEW

Revision	Prepared by	Reviewed by	Date issued
0	Baqir Al asadi	Peter Eccleston	7 January 2025

DISTRIBUTION

Revision	Electronic	Paper	Issued to
0	1	0	Michael Meuleners, Tim Stead - DoT

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EXECUTIVE SUMMARY

A geotechnical investigation has been carried out as part of a coastal erosion assessment at Rockingham in the City of Rockingham, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 3300m corridor of coastal beach and dune formation adjacent to the Rockingham settlement which has been identified as an at-risk site as part of Hotspot #35.

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 not observed along all the transects within the maximum target investigation depth of 10-15m below ground level except in minor areas.
- Interpreted rock level was generally very deep across the site and below the 0m AHD level.
- Cone Penetrometer testing results did not show refusal at any test locations, which is consistent with deep rock shown on MASW models.

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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 Rockingham, City of Rockingham in November 2024. During the investigation seismic geophysical testing and intrusive geotechnical testing was conducted within a 3300m corridor of coastal beach and dune formation which has been identified as an at risk site as part of Hotspot #35.

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 a 3300m corridor of coastal beach and dune formation in Warnbro Beach, the extents of which is shown as a yellow dashed area in Figure 1.

Data was acquired as a series of transects for the seismic geophysical 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 Figures 2 and 3.

Topography at the sites was generally flat to undulating and surface level ranged from 0mAHD to 17mAHD. Topographic maps showing surface level are provided in Appendix C drawings 3095F-12.



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

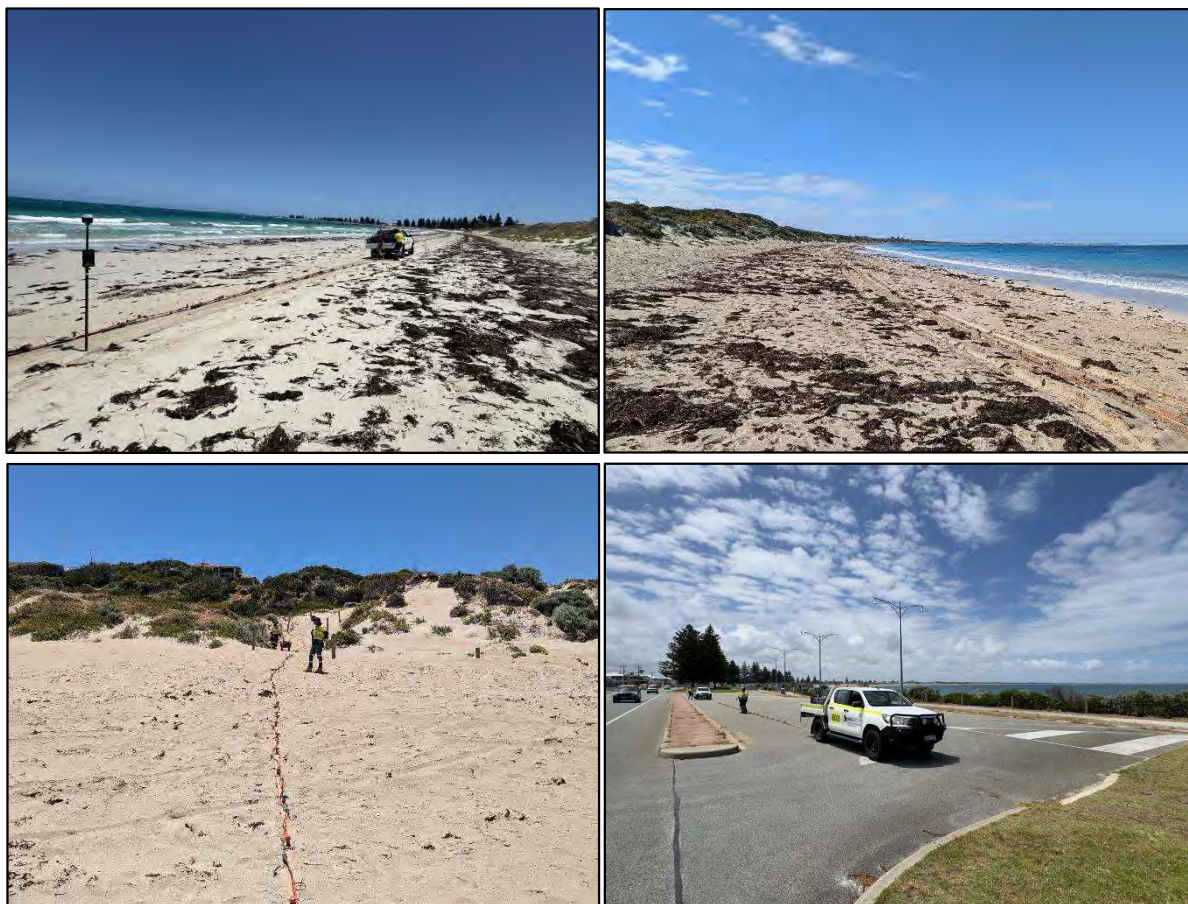


Figure 2: Example site conditions at Rockingham’s Warnbro Beach including beach along-shore (top images), cross-shore (bottom left) and road along-shore transects (bottom right).

3 INVESTIGATION METHODOLOGY

3.1 FIELD SURVEY LOGISTICS

Geophysical data acquisition was carried out from the 10th to 12th December 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 11th and 12th December 2024. Where required, the site work was carried out under appropriate traffic and pedestrian management commissioned by the City of Rockingham

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 7496m of MASW profiling acquired as 3 along-shore transects (parallel to the coast) and 8 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 drawings 3142F-01.

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

Transect ID	Orientation	Start Coordinate		End Coordinate		Length (m)
		East	North	East	North	
MASW-01	Along-shore	381771.8	6422437.8	380780.0	6424293.7	2256
MASW-02	Along-shore	380798.8	6424354.3	379645.2	6424796.4	1328
MASW-03	Along-shore	381685.5	6422441.0	379628.2	6424735.6	3312
MASW-04	Cross-shore	381684.6	6422457.2	381764.8	6422447.9	88
MASW-05	Cross-shore	381601.2	6422725.9	381658.3	6422659.2	88
MASW-06	Cross-shore	381595.7	6422795.4	381662.4	6422805.1	80
MASW-07	Cross-shore	381198.6	6423686.4	381292.5	6423691.6	120
MASW-08	Cross-shore	380774.1	6424303.3	380792.8	6424344.4	48
MASW-09	Cross-shore	380208.1	6424628.7	380163.8	6424686.4	72
MASW-10	Cross-shore	379804.9	6424701.3	379812.1	6424731.1	32
MASW-11	Cross-shore	379652.2	6424715.3	379651.2	6424788.0	72

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 receiver array. MASW acquisition parameters are provided in Table 2. A Photograph of MASW data acquisition is 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	0.25 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.

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).
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.

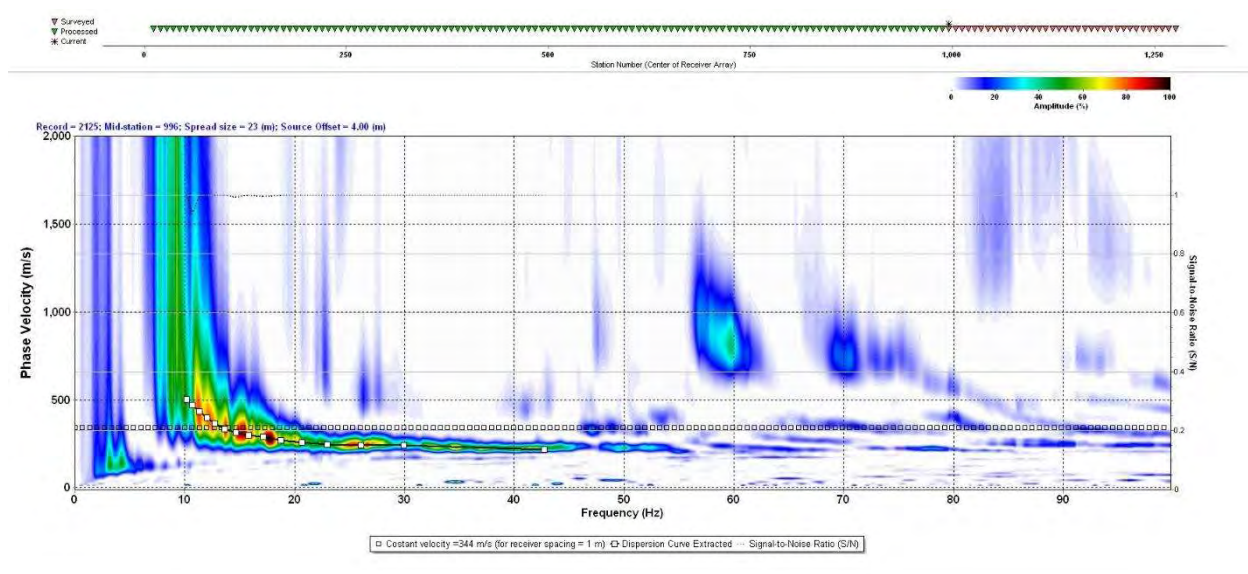


Figure 4: MASW overtone image with high signal to noise ratio and picked dispersion curve.

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 Whitby 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	WHIY00AUS0
Latitude	S 32° 17' 51.07968"
Longitude	E 116° 1' 41.07335"
Ellipsoidal height (m)	200.358

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 Rockingham, City of Rockingham are presented in Appendices B and C of this report as follows:

Appendix B – Geophysical and Interpreted Sections

- **3142F-02.** Transect 1 (0-1120m) seismic S-wave velocity model and interpreted geological section.
- **3142F-03.** Transect 1 (1120-2256m) seismic S-wave velocity model and interpreted geological section.
- **3142F-04.** Transect 2 (0-1000m) seismic S-wave velocity model and interpreted geological section.
- **3142F-05.** Transect 2 (1000-1328m) seismic S-wave velocity model and interpreted geological section.
- **3142F-06.** Transects 03 (0-1100m) seismic S-wave velocity model and interpreted geological section.
- **3142F-07.** Transects 03 (1100-2200m) seismic S-wave velocity model and interpreted geological section.
- **3142F-08.** Transects 03 (2200-3312m) seismic S-wave velocity model and interpreted geological section.
- **3142F-09.** Transect 04, 05, and 06 seismic S-wave velocity model and interpreted geological section.
- **3142F-10.** Transect 07, 08 and 09 seismic S-wave velocity model and interpreted geological section.
- **3142F-11.** Transect 10 and 11 seismic S-wave velocity model and interpreted geological section.

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

- **3142F -12.** Contoured surface level models derived from aerial photogrammetry.
- **3142F -13.** Contoured level to modelled top of rock.
- **3142F -14.** Class post map level to modelled top of rock.
- **3142F -15.** Contoured modelled sand thickness over rock / Depth to top of rock.
- **3142F -16.** Class post map modelled sand thickness over rock / Depth to top of rock.

4.2 SEISIMC SHEAR WAVE VELOCITY SECTIONS

The seismic S-wave velocity (V_s) 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 V_s 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.

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

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** ($V_s < 250\text{m/s}$). 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** ($V_s 250\text{--}400\text{m/s}$). 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** ($V_s 400\text{--}550\text{m/s}$). 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** ($V_s > 550\text{m/s}$). 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 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 03** – rod friction at 1.98m depth. This is unlikely to be due to rock.
- **CPT-02 on Transect 03 / 05** – no refusal to 12.2m depth.
- **CPT-03 on Transect 03** – no refusal to 12.32m depth.
- **CPT-04 on Transect 03** – no refusal to 12.2m depth.
- **CPT-05 on Transect 03 / 09** – no refusal to 12.2m depth.
- **CPT-06 on Transect 03** – no refusal to 12.2m depth.
- **CPT-07 on Transect 03 / 11** – no refusal to 12.2m depth.

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

No outcropping rock was observed in the Rockingham site.

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 underlying 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 elevation. The sand thickness can also be considered to be the depth to top of rock where rock exists within the depth of investigation. 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 3142F-12) – generated from the aerial photogrammetry, this presents the level to ground surface ranging from 0mAHD to 20mAHD. Note: vegetation height has not been removed from these models.
- **Contoured Level to Top of Rock Substrate** (drawings 3142F-13) – this presents the level to the top of rock substrate ranging from <-19mAHD to 2mAHD.
- **Classed Post Map Level to Top of Rock Substrate** (drawings 3142F-14) – 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 3142F-15) – this presents the thickness of sand overlying the rock substrate ranging from 6mBGL to >20mBGL.
- **Classed Post Map Sand Thickness / Depth to Top of Rock** (drawings 3142F-16) – this presents the thickness of sand overlying the rock substrate along the acquired transects at 2m depth increments from 6mBGL to >16mBGL.

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 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 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 Rockingham in the City of Rockingham, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 3300m corridor of coastal beach and dune formation adjacent to the Rockingham settlement which has been identified as an at risk site as part Hotspot #35.

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.

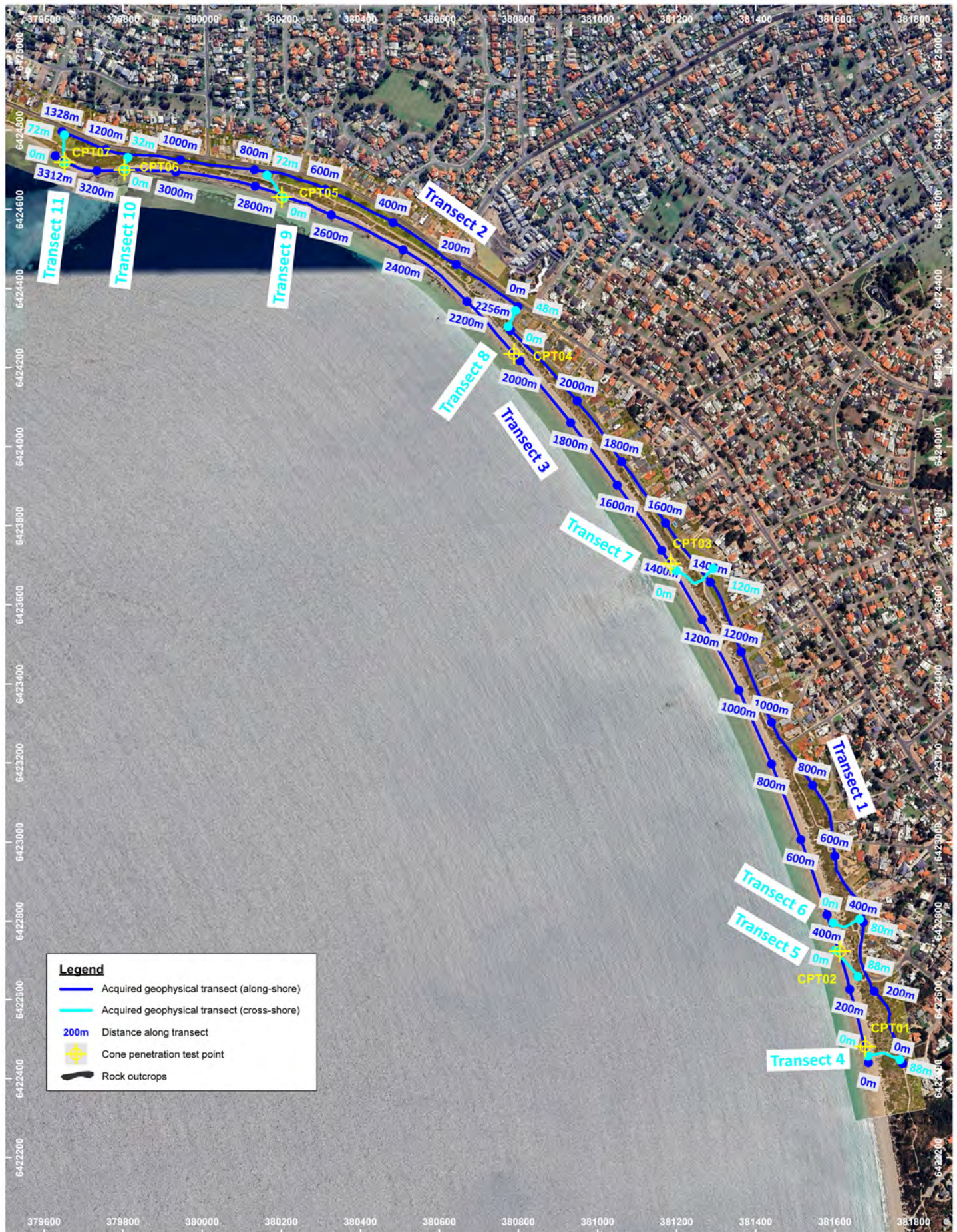
For and on behalf of
GBG GEOTECHNICS (AUSTRALIA)



BAQIR AL ASADI
Senior Geophysicist

APPENDIX A – INVESTIGATION SITE MAP

INVESTIGATION SITE MAP



NOTES

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



Date 27 November 2024
Scale 1:12000
Drawing 3142F-01

Paper Size A3
Drawn PJE
Revision 0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT.
ROCKINGHAM, CITY OF ROCKINGHAM WA



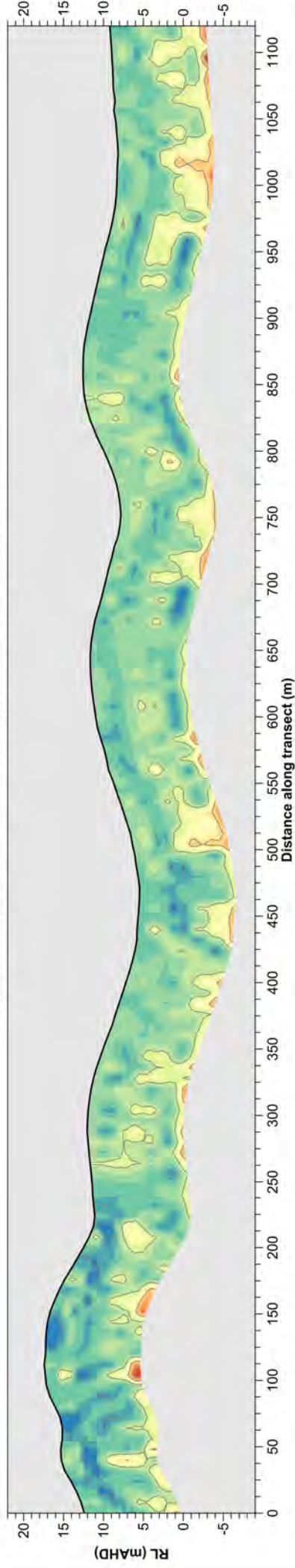
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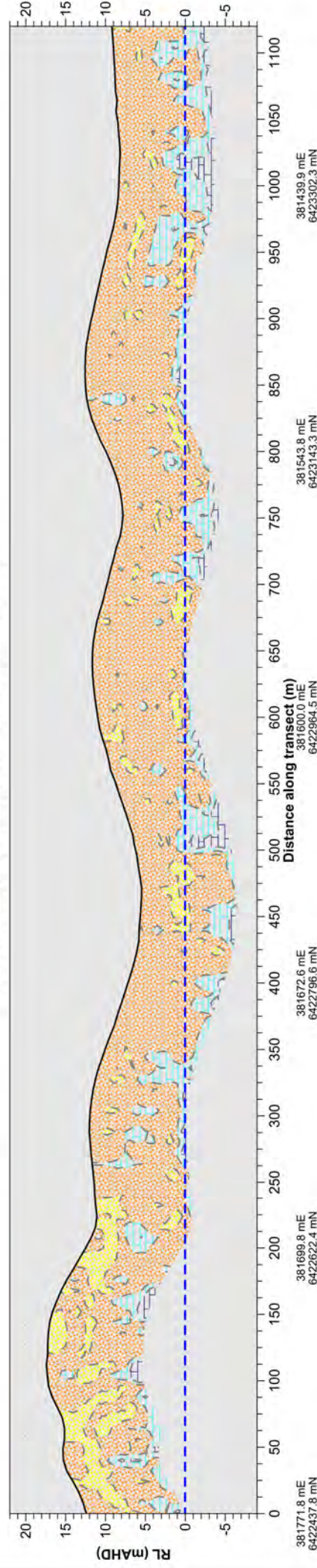
APPENDIX B – GEOPHYSICAL AND INTERPRETED SECTIONS

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

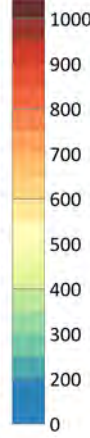
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TRANSECT 01 (0-1120m) - INTERPRETED GEOLOGICAL SECTION



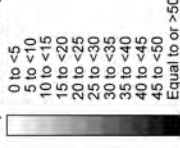
SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



CONE PENETRATION TEST
Tip Resistance (MPa)



NOTES
Drawing to be used in conjunction with Report 3142F.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT
DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
GEOTECHNICAL INVESTIGATION FOR COASTAL
EROSION VULNERABILITY ASSESSMENT.
ROCKINGHAM, CITY OF ROCKINGHAM WA

Date 18 December 2024
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Drawing 3142F-02

Paper Size A3
Drawn PJE
Revision 0

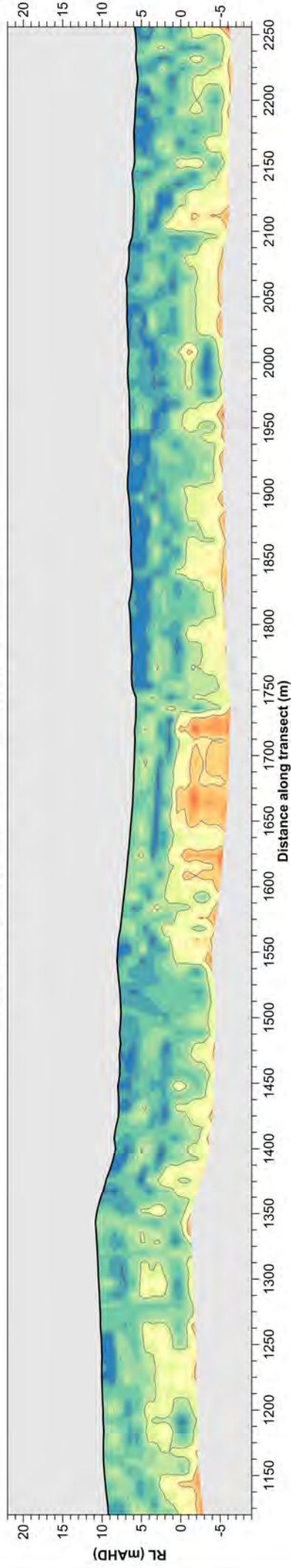


GBGGROUP

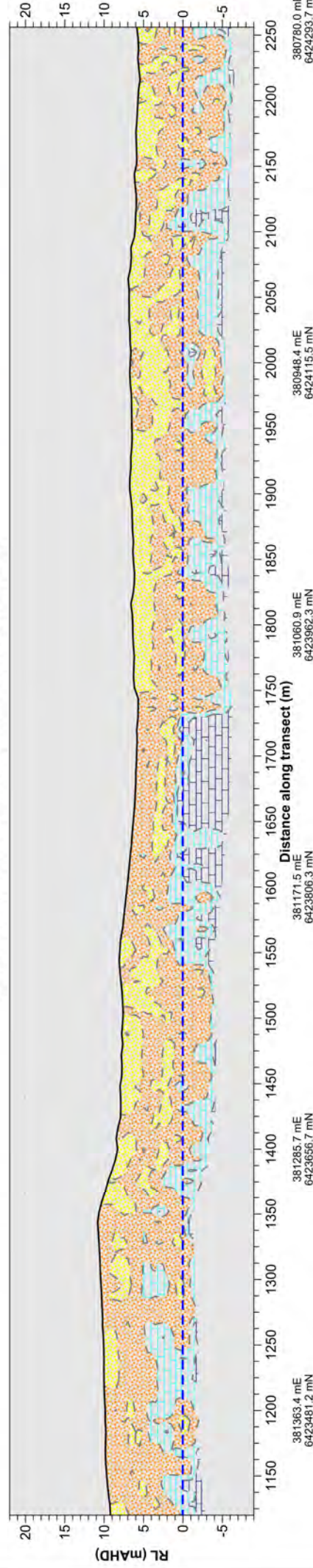
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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT ROCKINGHAM, CITY OF ROCKINGHAM WESTERN AUSTRALIA

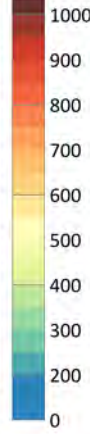
TRANSECT_01 (1120-2256m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT_01 (1120-2256m) - INTERPRETED GEOLOGICAL SECTION



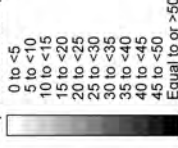
SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



CONE PENETRATION TEST Tip Resistance (MPa)



NOTES
Drawing to be used in conjunction with Report 3142F.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT
DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
GEOTECHNICAL INVESTIGATION FOR COASTAL
EROSION VULNERABILITY ASSESSMENT.
ROCKINGHAM, CITY OF ROCKINGHAM WA

Date 18 December 2024
Scale 1:3000H, 1:500V
Drawing 3142F-03

Paper Size A3
Drawn PJE
Revision 0

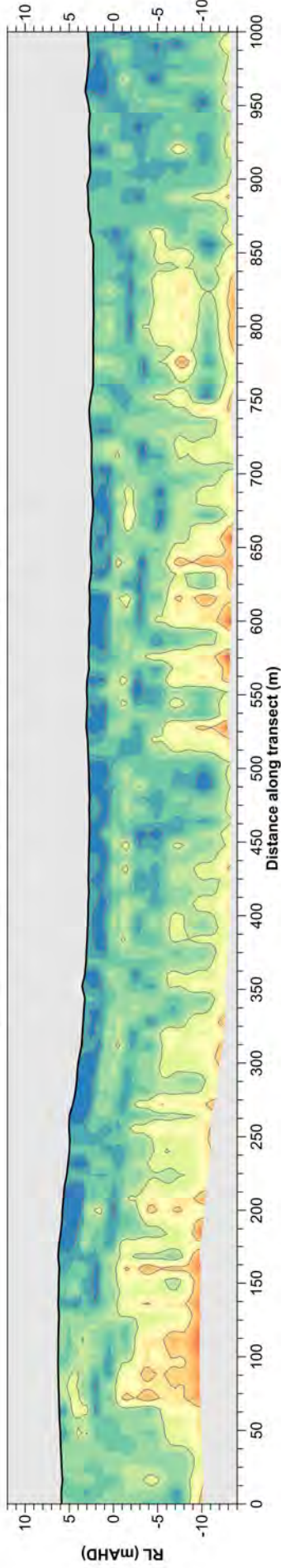


GBGGROUP

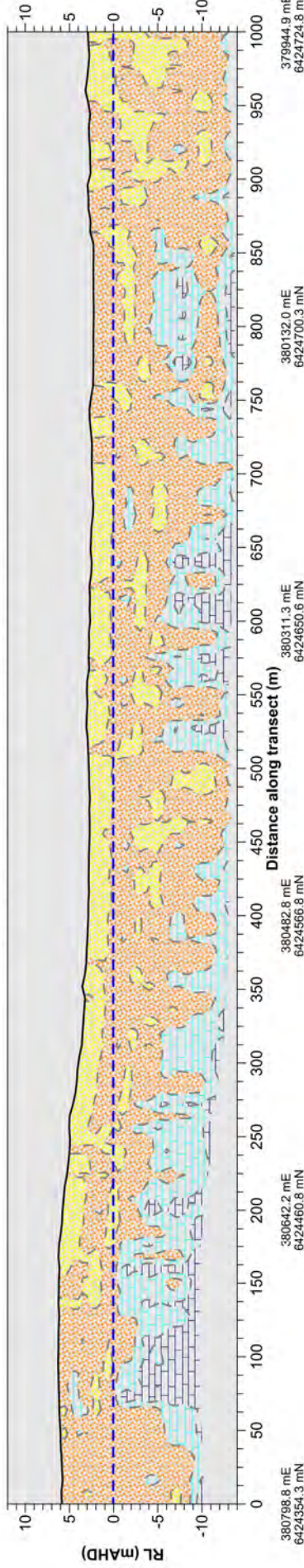
G.B. Geotechnics (Australia) Pty Ltd
1111 Gorge Way, Victoria Park WA 6155
ABN 77 009 550 869
Telephone 02 9690 2122
Email info@gbgoc.com.au

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

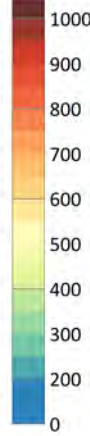
TRANSECT 02 (0-1000m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 01 (0-1000m) - INTERPRETED GEOLOGICAL SECTION



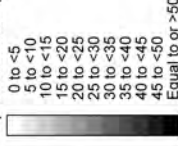
SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



CONE PENETRATION TEST
Tip Resistance (MPa)



NOTES
Drawing to be used in conjunction with Report 3142F.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT
DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
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ROCKINGHAM, CITY OF ROCKINGHAM WA

Date 18 December 2024
Scale 1:3000H, 1:500V
Drawing 3142F-04

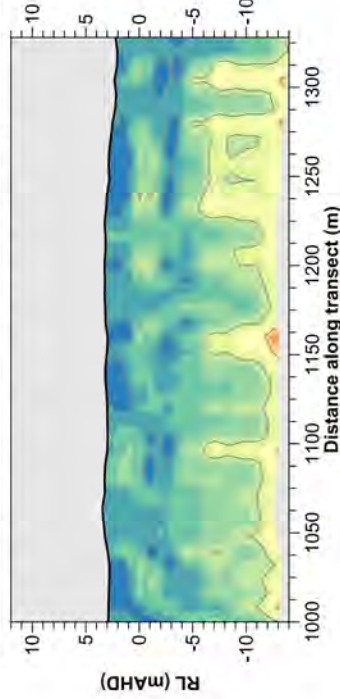
Paper Size A3
Drawn PJE
Revision 0

GBGGROUP

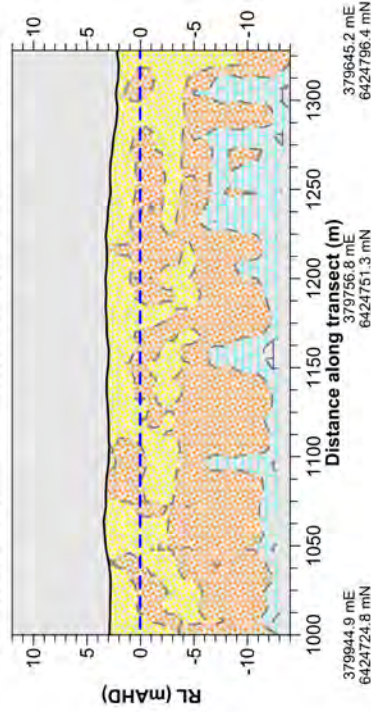
G.B. Geotechnics (Australia) Pty Ltd
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ABN 77 009 550 869
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Email info@gbgpc.com.au

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

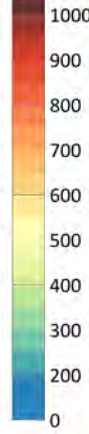
TRANSECT 02 (1000-1328m) - SEISMIC SHEAR WAVE VELOCITY MODEL



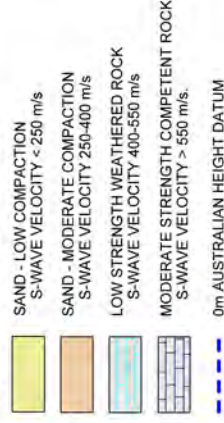
TRANSECT 01 (1000-1328m) - INTERPRETED GEOLOGICAL SECTION



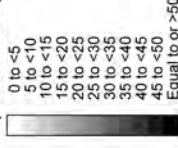
SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



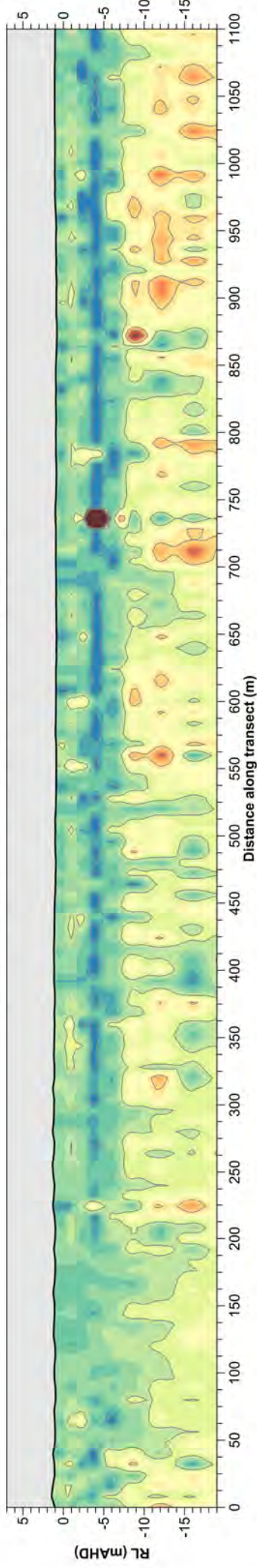
CONE PENETRATION TEST
Tip Resistance (MPa)



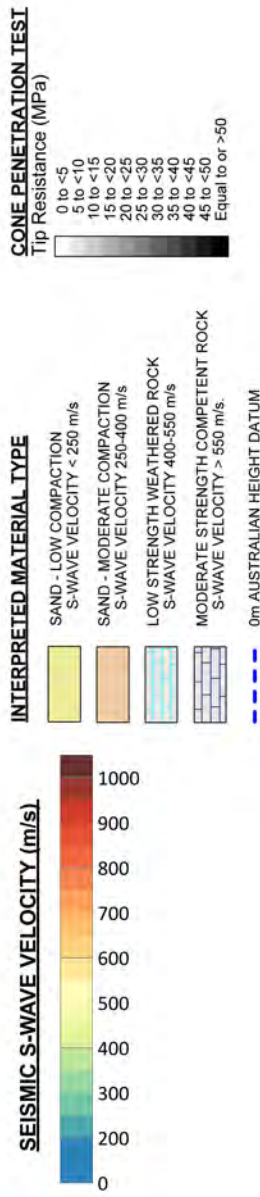
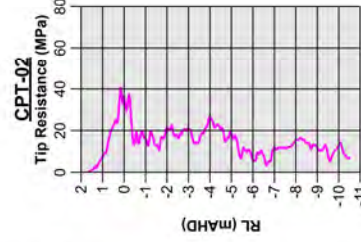
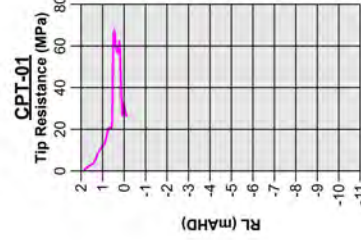
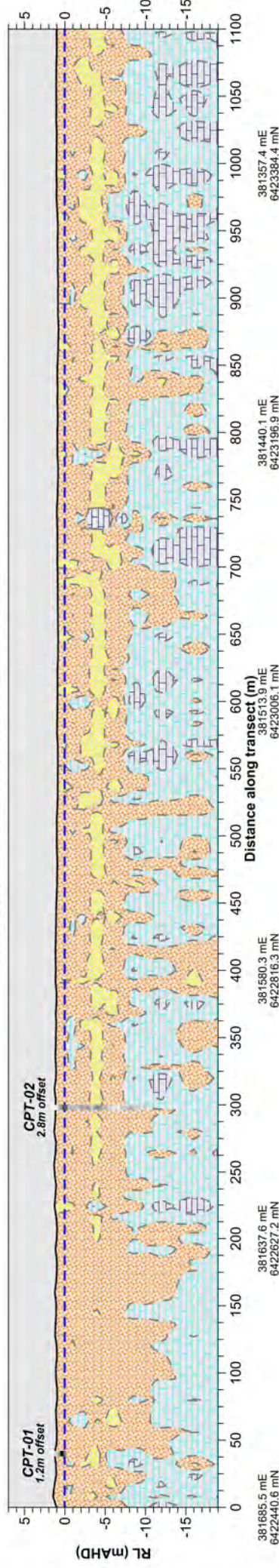
NOTES
Drawing to be used in conjunction with Report 3142F.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	18 December 2024	Paper Size	A3
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT, ROCKINGHAM, CITY OF ROCKINGHAM WA	Scale	1:3000H, 1:500V	Drawn	PJE
		Drawing	3142F-05	Revision	0

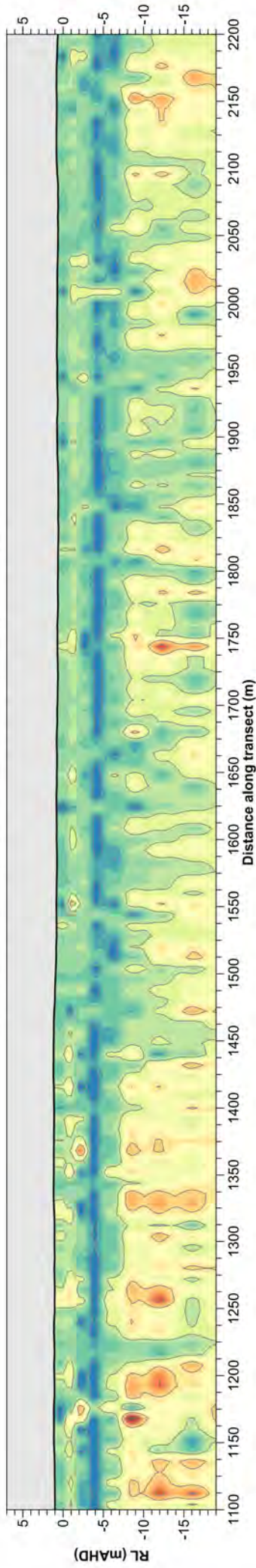
TRANSECT 03 (0-1100m) - SEISMIC SHEAR WAVE VELOCITY MODEL



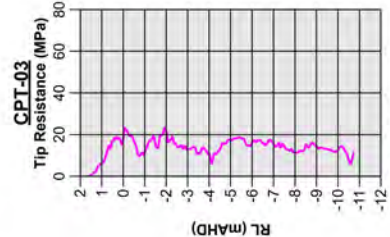
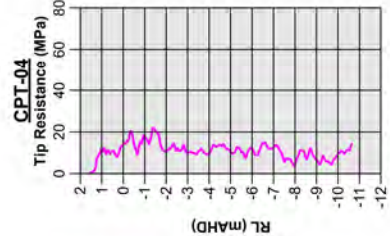
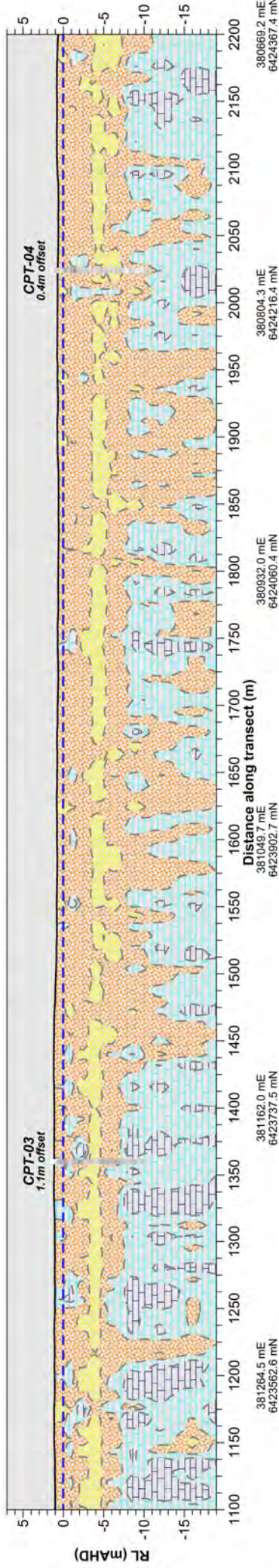
TRANSECT 03 (0-1100m) - INTERPRETED GEOLOGICAL SECTION



TRANSECT 03 (1100-2200m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 03 (1100-2200m) - INTERPRETED GEOLOGICAL SECTION



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

INTERPRETED MATERIAL TYPE

SAND - LOW COMPACTION
S-WAVE VELOCITY < 250 m/s

SAND - MODERATE COMPACTION
S-WAVE VELOCITY 250-400 m/s

LOW STRENGTH WEATHERED ROCK
S-WAVE VELOCITY 400-550 m/s

MODERATE STRENGTH COMPETENT ROCK
S-WAVE VELOCITY > 550 m/s.

0m AUSTRALIAN HEIGHT DATUM

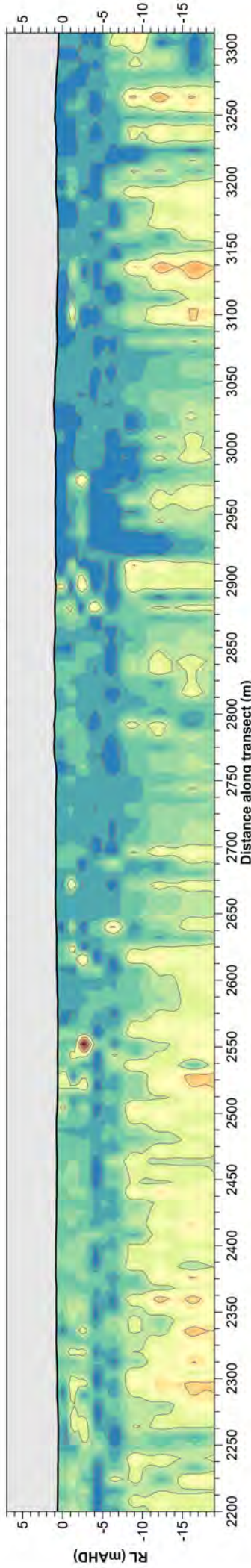
SEISMIC S-WAVE VELOCITY (m/s)

0 100 200 300 400 500 600 700 800 900 1000

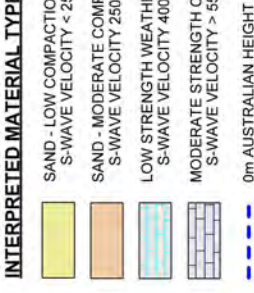
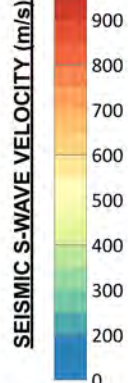
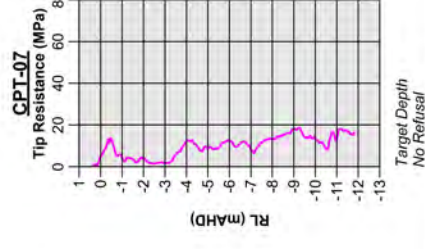
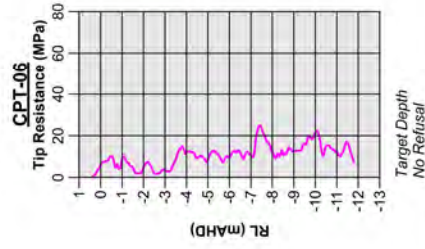
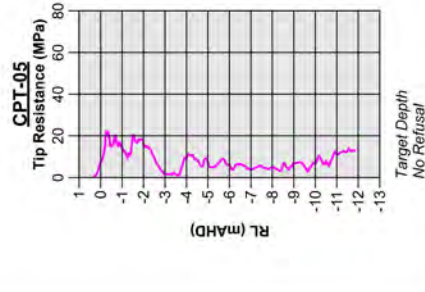
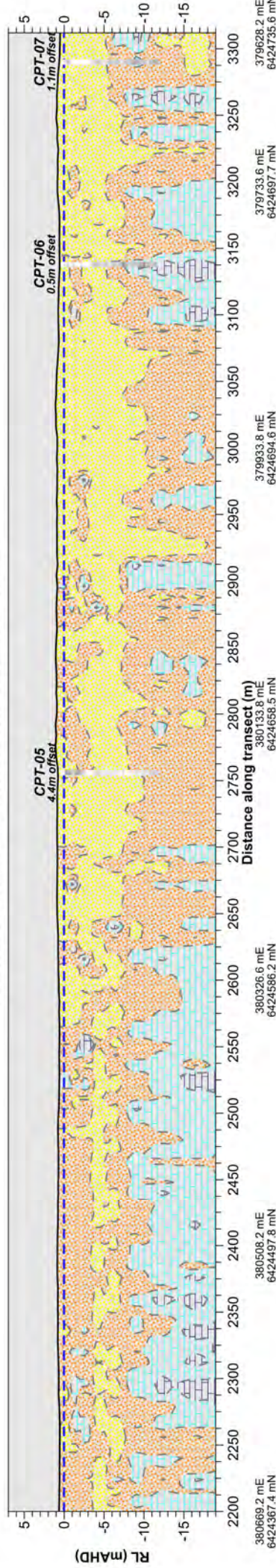
NOTES
Drawing to be used in conjunction with Report 3142F.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	18 December 2024	Paper Size	A3
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT, ROCKINGHAM, CITY OF ROCKINGHAM WA	Scale	1:3000H, 1:500V	Drawn	PJE
		Drawing	3142F-07	Revision	0

TRANSECT 03 (2200-3312m) - SEISMIC SHEAR WAVE VELOCITY MODEL



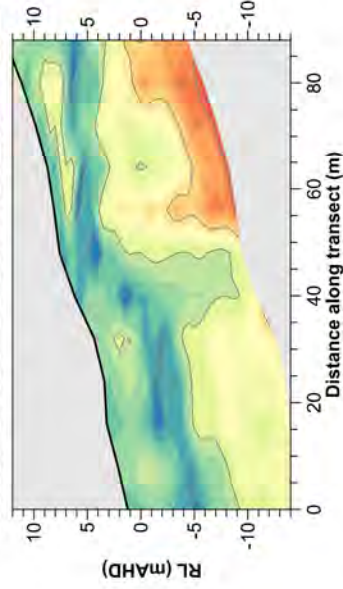
TRANSECT 03 (2200-3312m) - INTERPRETED GEOLOGICAL SECTION



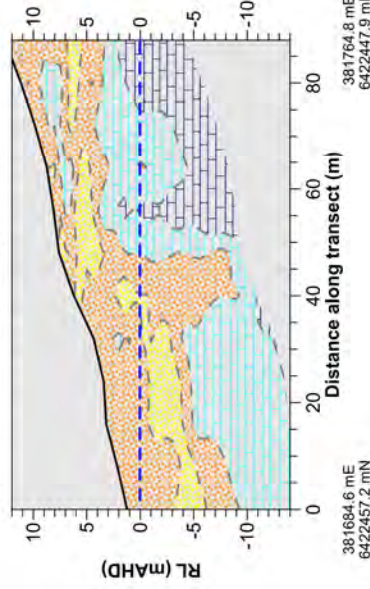
NOTES
Drawing to be used in conjunction with Report 3142F.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	19 December 2024	Paper Size	A3
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT, ROCKINGHAM, CITY OF ROCKINGHAM WA	Scale	1:3000H, 1:500V	Drawn	PJE
		Drawing	3142F-06	Revision	0

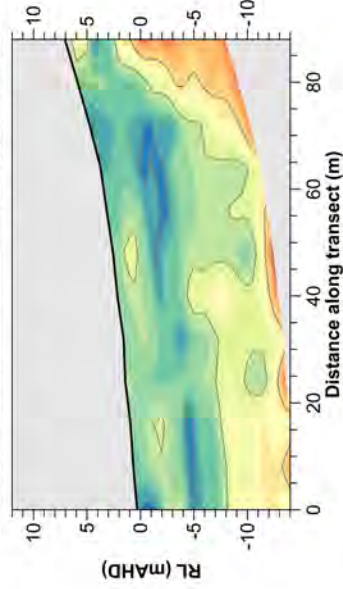
TRANSECT 04 - SEISMIC SHEAR WAVE VELOCITY MODEL



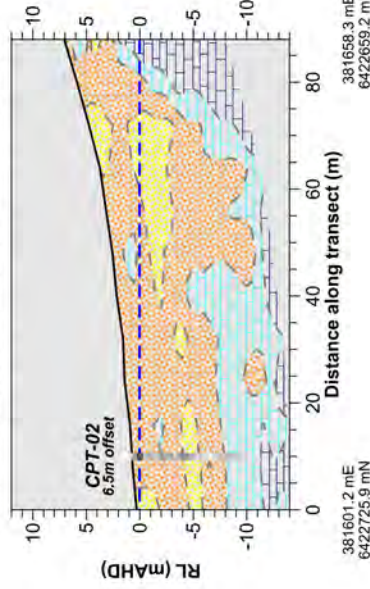
TRANSECT 04 - INTERPRETED GEOLOGICAL SECTION



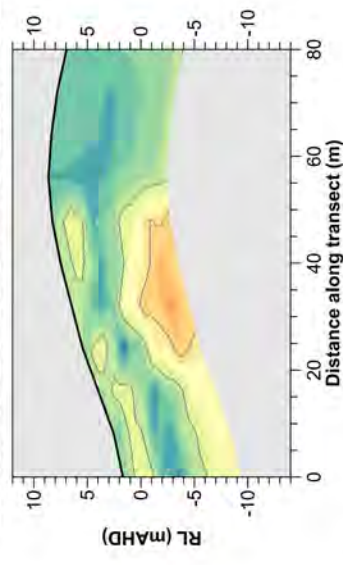
TRANSECT 05 - SEISMIC SHEAR WAVE VELOCITY MODEL



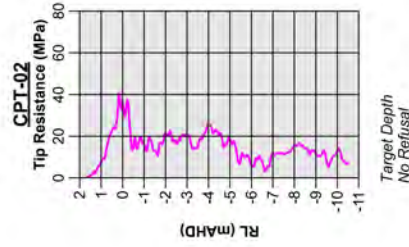
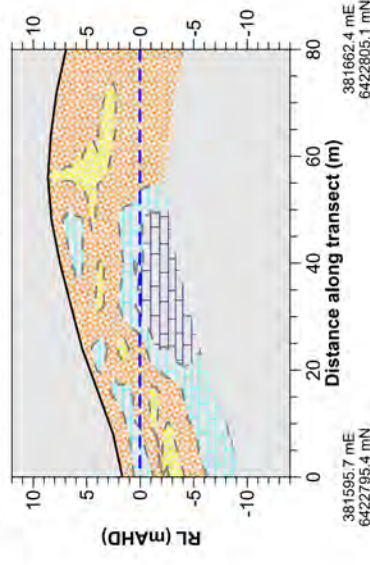
TRANSECT 05 - INTERPRETED GEOLOGICAL SECTION



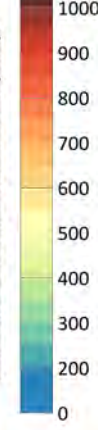
TRANSECT 06 - SEISMIC SHEAR WAVE VELOCITY MODEL



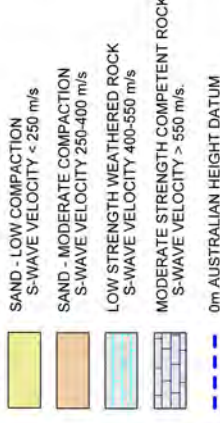
TRANSECT 06 - INTERPRETED GEOLOGICAL SECTION



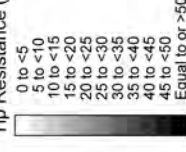
SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



CONE PENETRATION TEST
Tip Resistance (MPa)



NOTES
Drawing to be used in conjunction with Report 3142F.
Positioning is given in GDA2020 zone 50.
Levels are given in Australian Height Datum (AHD).

CLIENT
DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
GEOTECHNICAL INVESTIGATION FOR COASTAL
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ROCKINGHAM, CITY OF ROCKINGHAM WA

Date 18 December 2024
Scale 1:1000H, 1:500V
Drawing 3142F-09

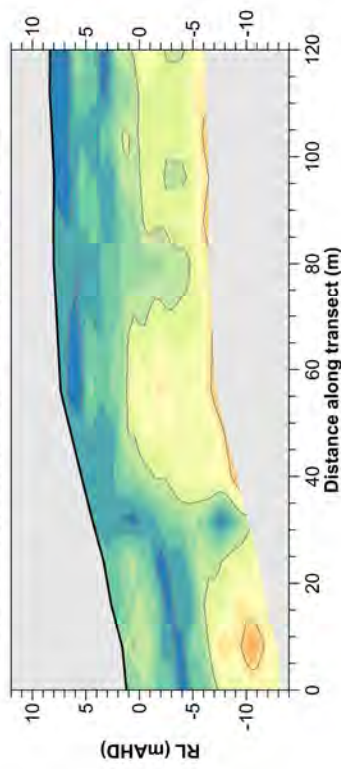
Paper Size A3
Drawn PJE
Revision 0



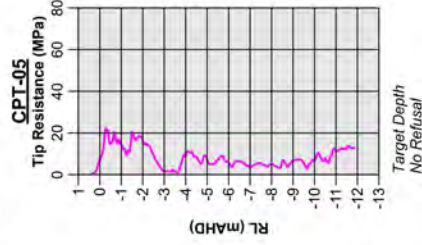
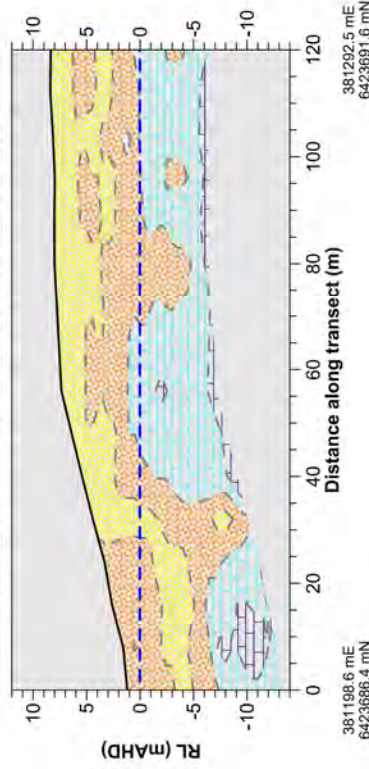
GBGGROUP

G.B. Geotechnics (Australia) Pty Ltd
1/11 Gorge Way, Victoria Park, WA 6155
ABN 77 009 550 869
Telephone 02 9950 2122
Email info@gbgpc.com.au

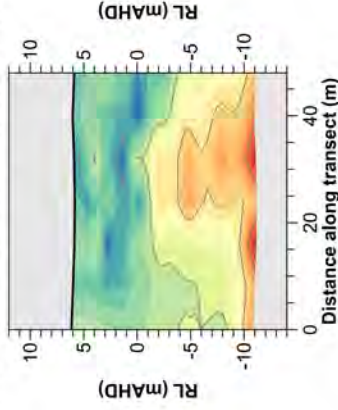
TRANSECT 07 - SEISMIC SHEAR WAVE VELOCITY MODEL



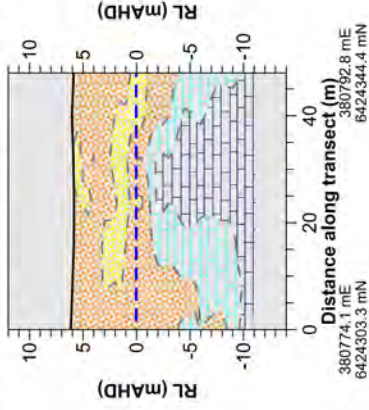
TRANSECT 07 - INTERPRETED GEOLOGICAL SECTION



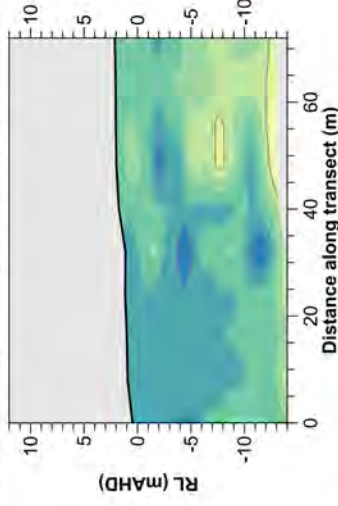
TRANSECT 08 - SEISMIC SHEAR WAVE VELOCITY MODEL



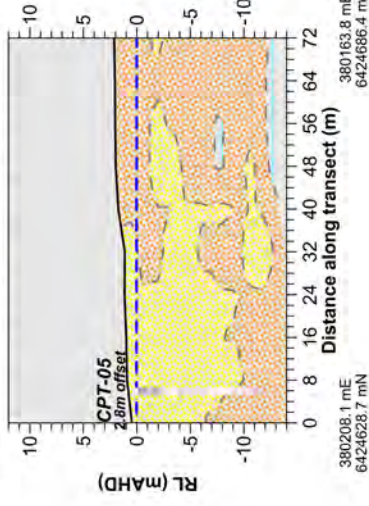
TRANSECT 08 - INTERPRETED GEOLOGICAL SECTION



TRANSECT 09 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 09 - INTERPRETED GEOLOGICAL SECTION



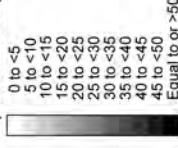
SEISMIC S-WAVE VELOCITY (m/s)



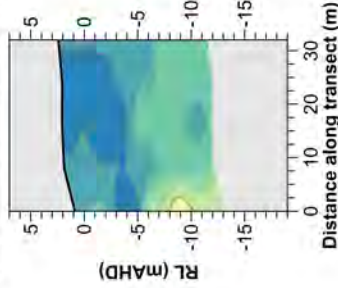
INTERPRETED MATERIAL TYPE



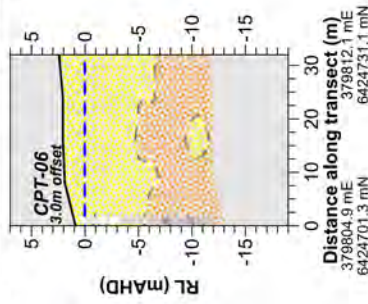
CONE PENETRATION TEST
Tip Resistance (MPa)



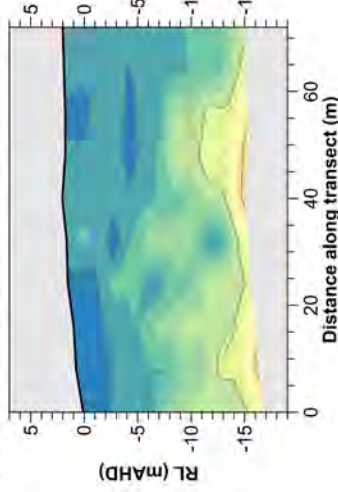
TRANSECT 10 - SEISMIC SHEAR WAVE VELOCITY MODEL



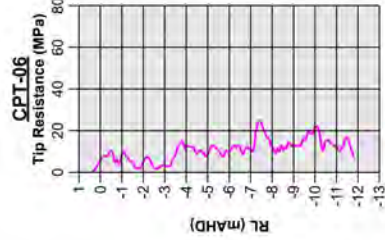
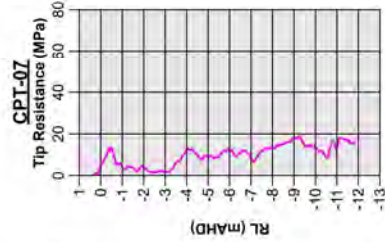
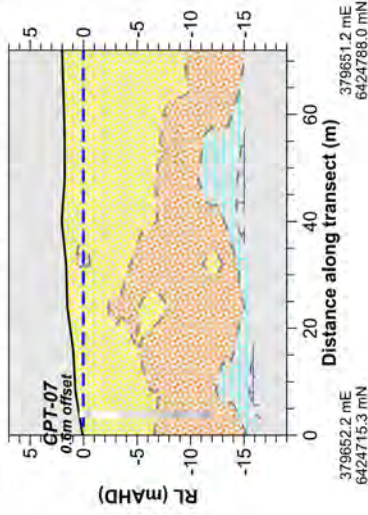
TRANSECT 10 - INTERPRETED GEOLOGICAL SECTION



TRANSECT 11 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 11 - INTERPRETED GEOLOGICAL SECTION



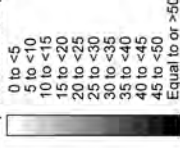
SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

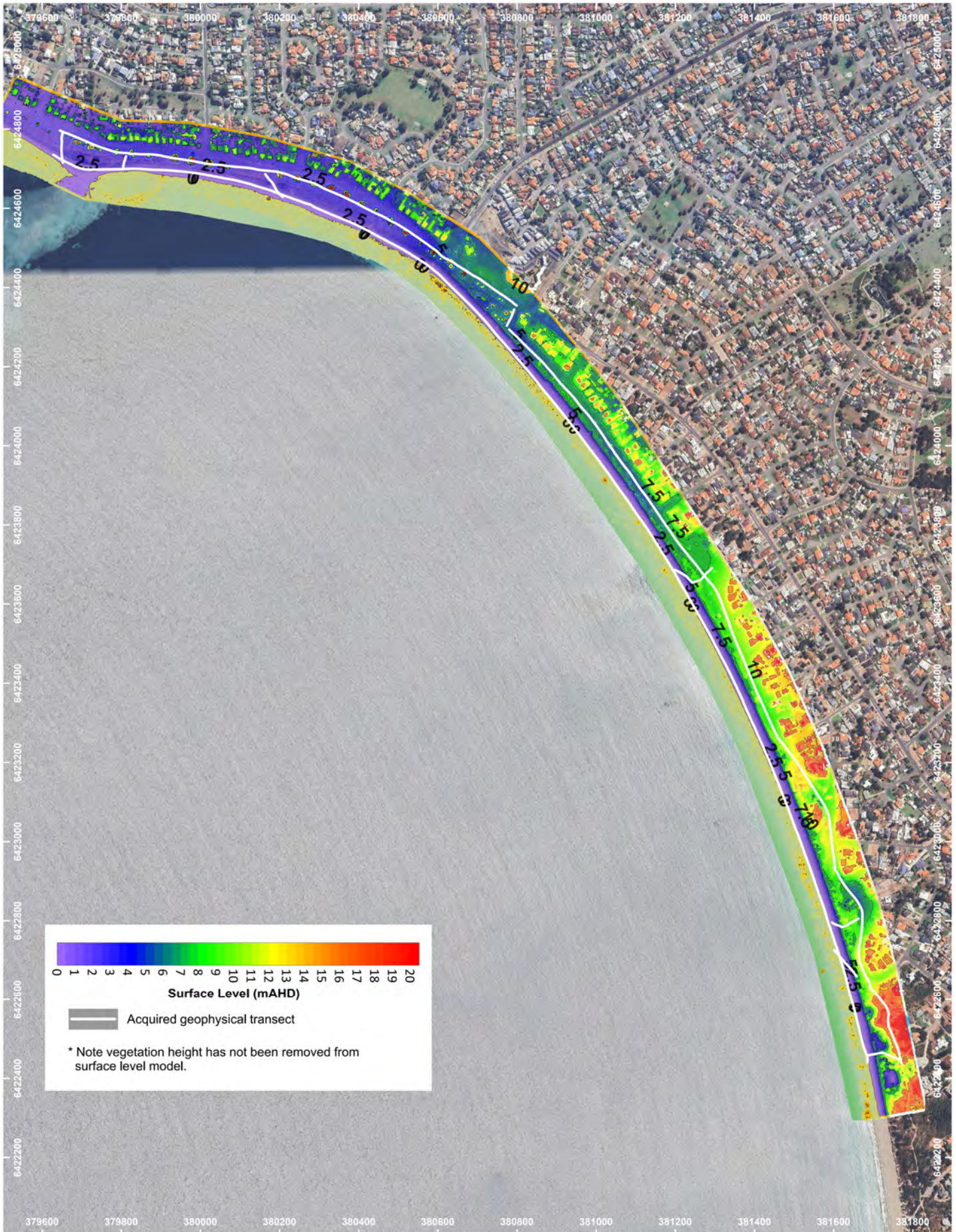


CONE PENETRATION TEST
Tip Resistance (MPa)



APPENDIX C – MODELLED LEVEL TO TOP OF ROCK AND SAND THICKNESS

SURFACE LEVEL MODEL



NOTES

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



Date 12 December 2024

Paper Size A3

Scale 1:12000

Drawn PJE

Drawing 3142F-12

Revision 0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

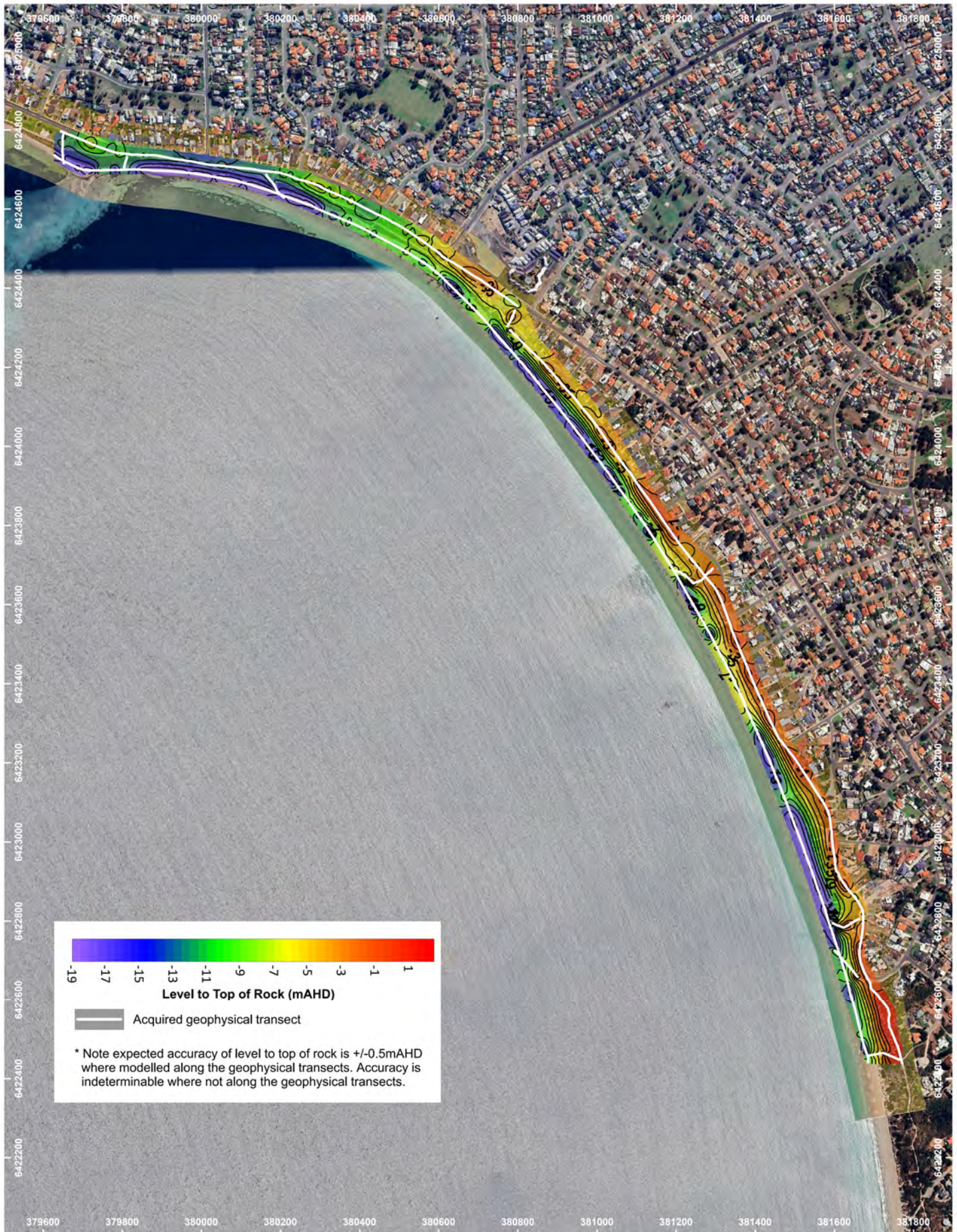
GEOTECHNICAL INVESTIGATION FOR COASTAL
EROSION VULNERABILITY ASSESSMENT.
ROCKINGHAM, CITY OF ROCKINGHAM WA



GBGGROUP
GB Geotechnics (Australia) Pty Ltd

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Web: gbg-group.com.au

CONTOURED LEVEL TO TOP OF ROCK



NOTES

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



Date	12 December 2024	Paper Size	A3
Scale	1:12000	Drawn	PJE
Drawing	3142F-13	Revision	0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

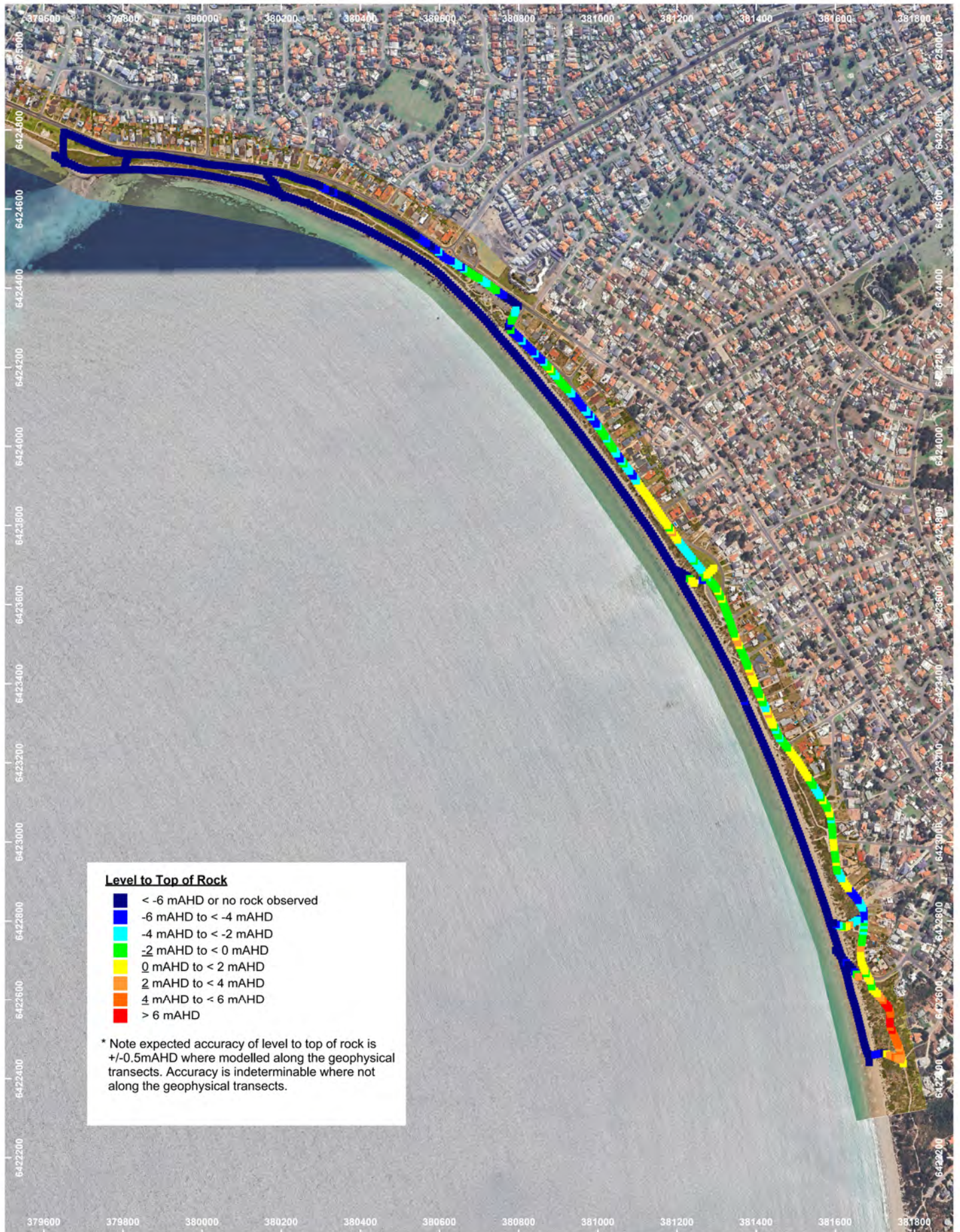
GEOTECHNICAL INVESTIGATION FOR COASTAL
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ROCKINGHAM, CITY OF ROCKINGHAM WA



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Web: gb-group.com.au

CLASSED POST MAP LEVEL TO TOP OF ROCK



NOTES

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



Date 18 December 2024
Scale 1:12000
Drawing 3142F-14

Paper Size A3
Drawn PJE
Revision 0

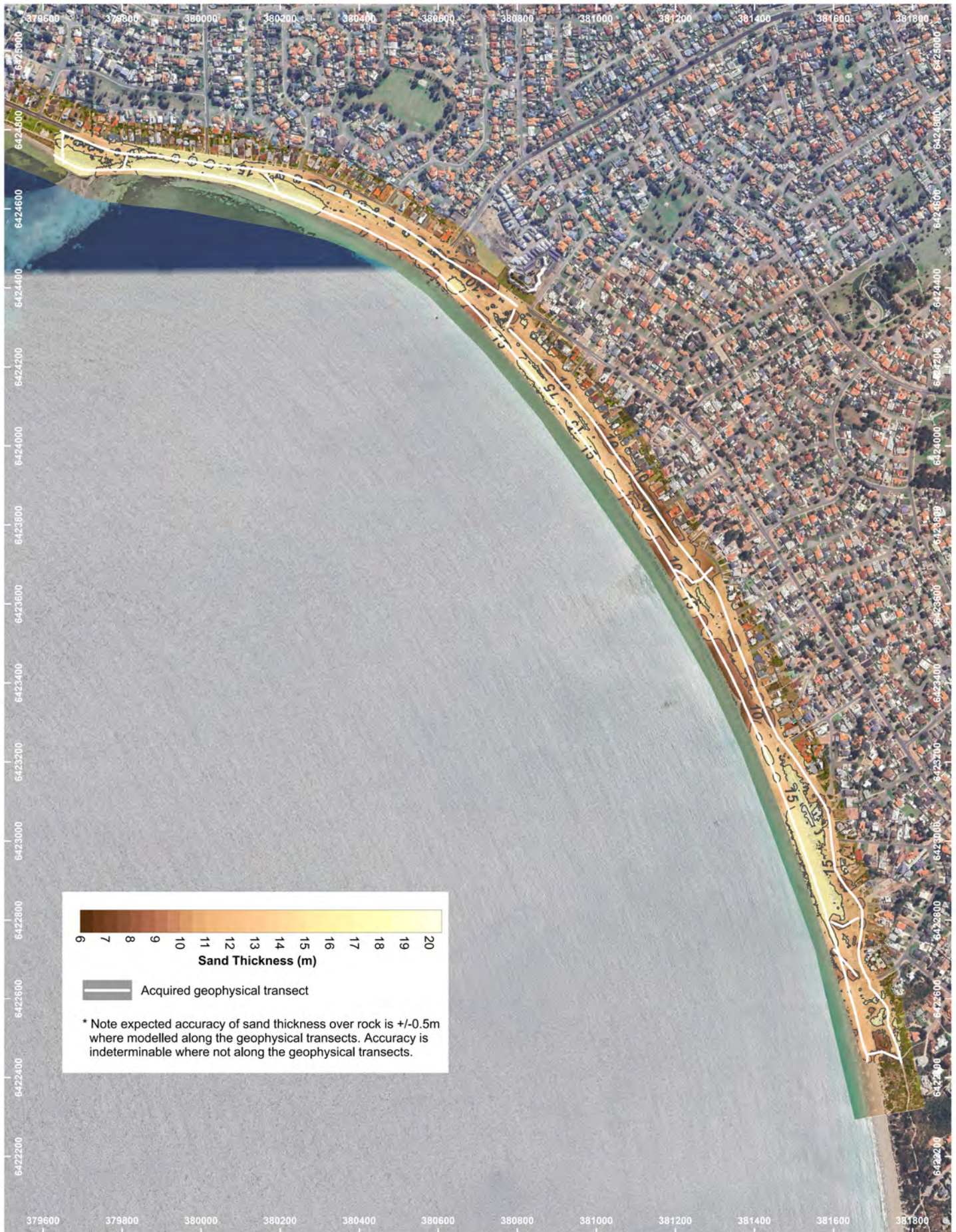
DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT.
ROCKINGHAM, CITY OF ROCKINGHAM WA



GBG GROUP
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Web: gb-group.com.au

CONTOURED SAND THICKNESS OVER ROCK



NOTES

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



Date 12 December 2024

Paper Size A3

Scale 1:12000

Drawn PJE

Drawing 3142F-15

Revision 0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

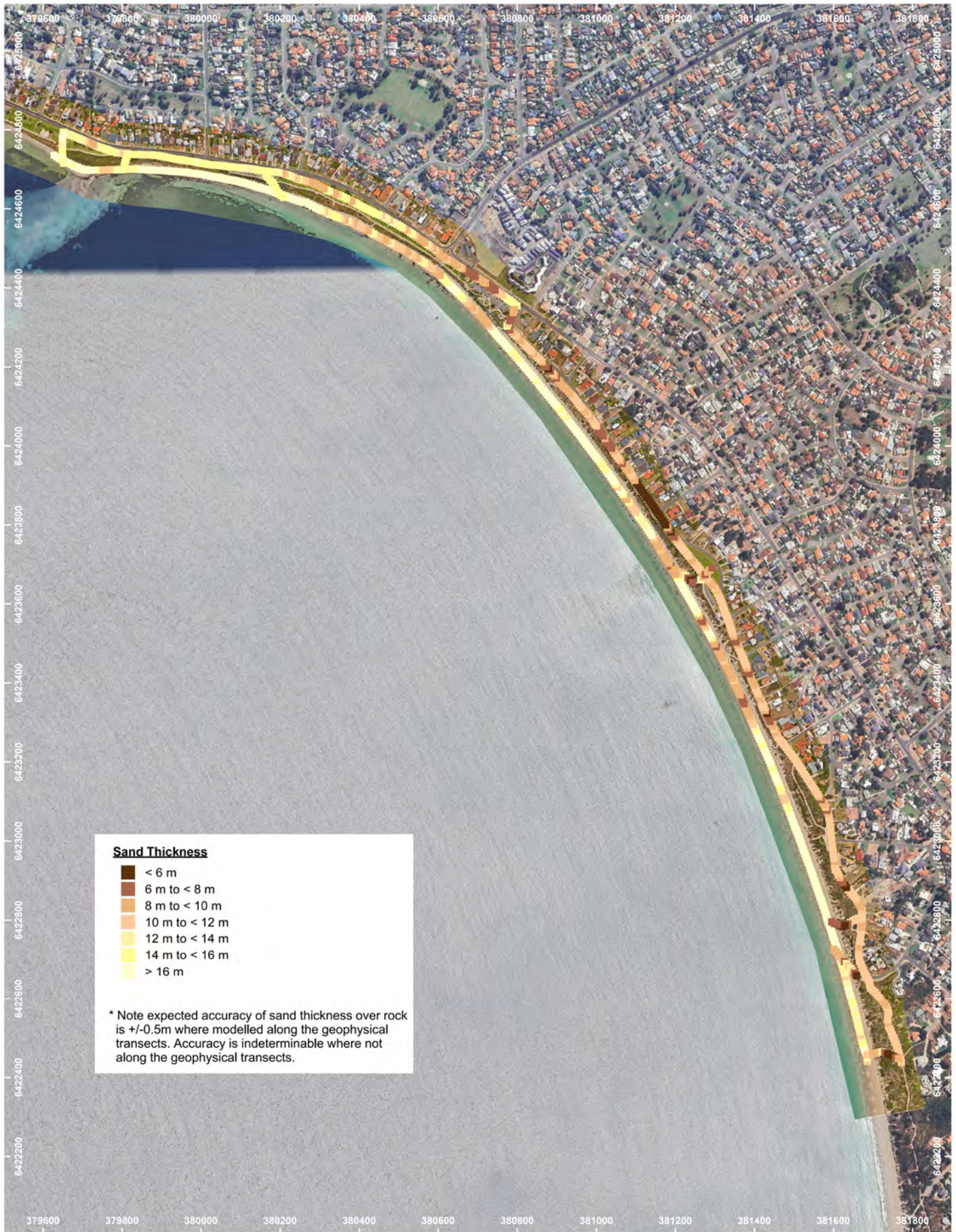
GEOTECHNICAL INVESTIGATION FOR COASTAL
EROSION VULNERABILITY ASSESSMENT.
ROCKINGHAM, CITY OF ROCKINGHAM WA



GBG GROUP
GB Geotechnics (Australia) Pty Ltd

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Telephone: 08 9354 6300
Email: info@gbggroup.com.au
Web: gbg-group.com.au

CLASSED POST MAP SAND THICKNESS OVER ROCK



NOTES

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



Date 18 December 2024

Paper Size A3

Scale 1:12000

Drawn PJE

Drawing 3142F-16

Revision 0

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

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



GBG GROUP
GB Geotechnics (Australia) Pty Ltd

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Web: gb-group.com.au

APPENDIX D – CONE PENETRATION TEST PLOTS

ELECTRIC FRICTION-CONE PENETROMETER

Probe I.D

CLIENT: GBG Group

Job No.: 3142

PROJECT: Southern and Southwest Coastal

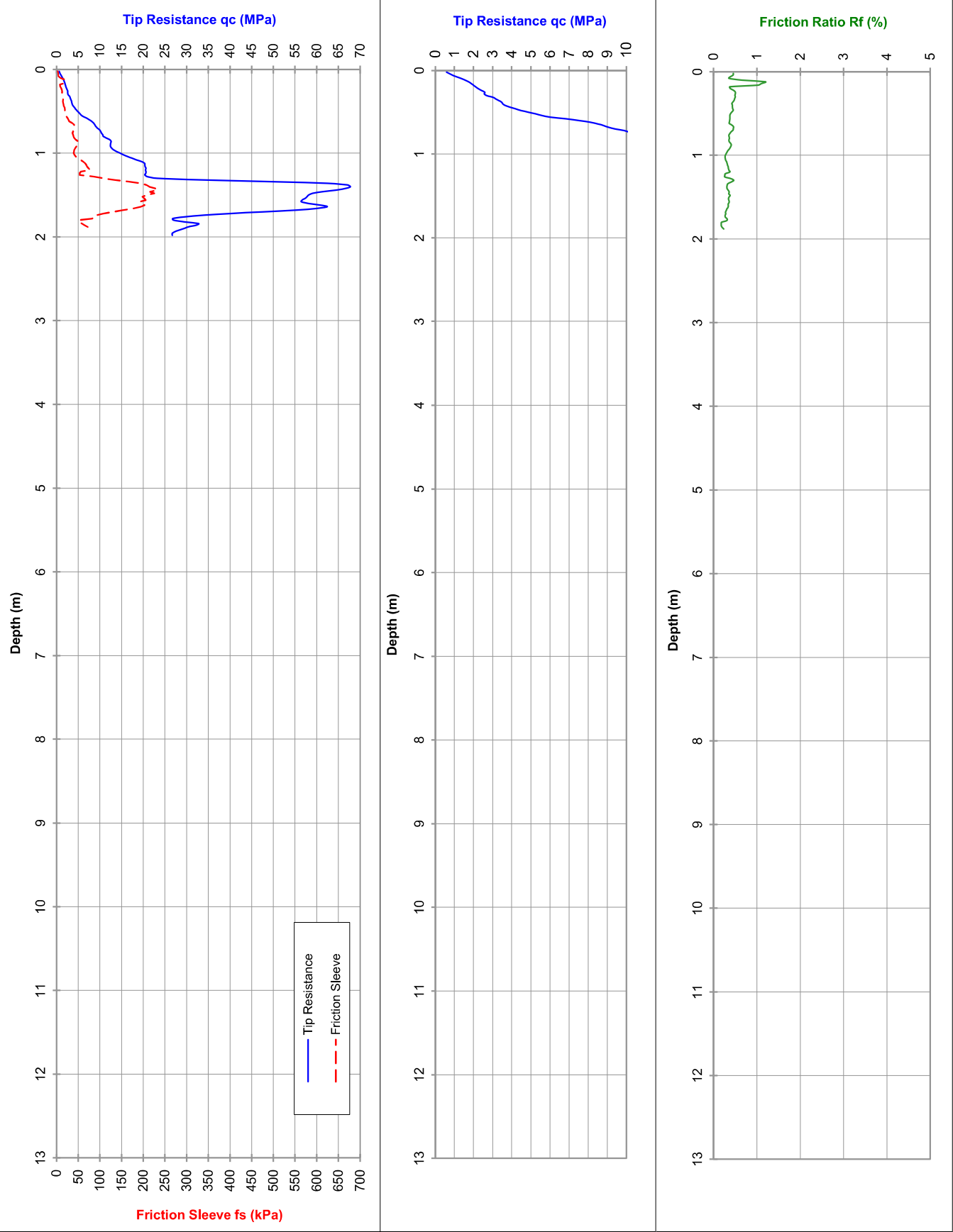
RL (m): 1.86

LOCATION: Rockingham

Co-ords: 381676.97mE, 6422480.78mN

CPT 01

10-Dec-24



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

Approx. water (m): Dry to 0.0

Dummy probe to (m):

Refusal: Rod Friction

Cone I.D.: EC39

File: GB0055T

Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

Probe I.D

CLIENT: GBG Group

Job No.: 3142

PROJECT: Southern and Southwest Coastal

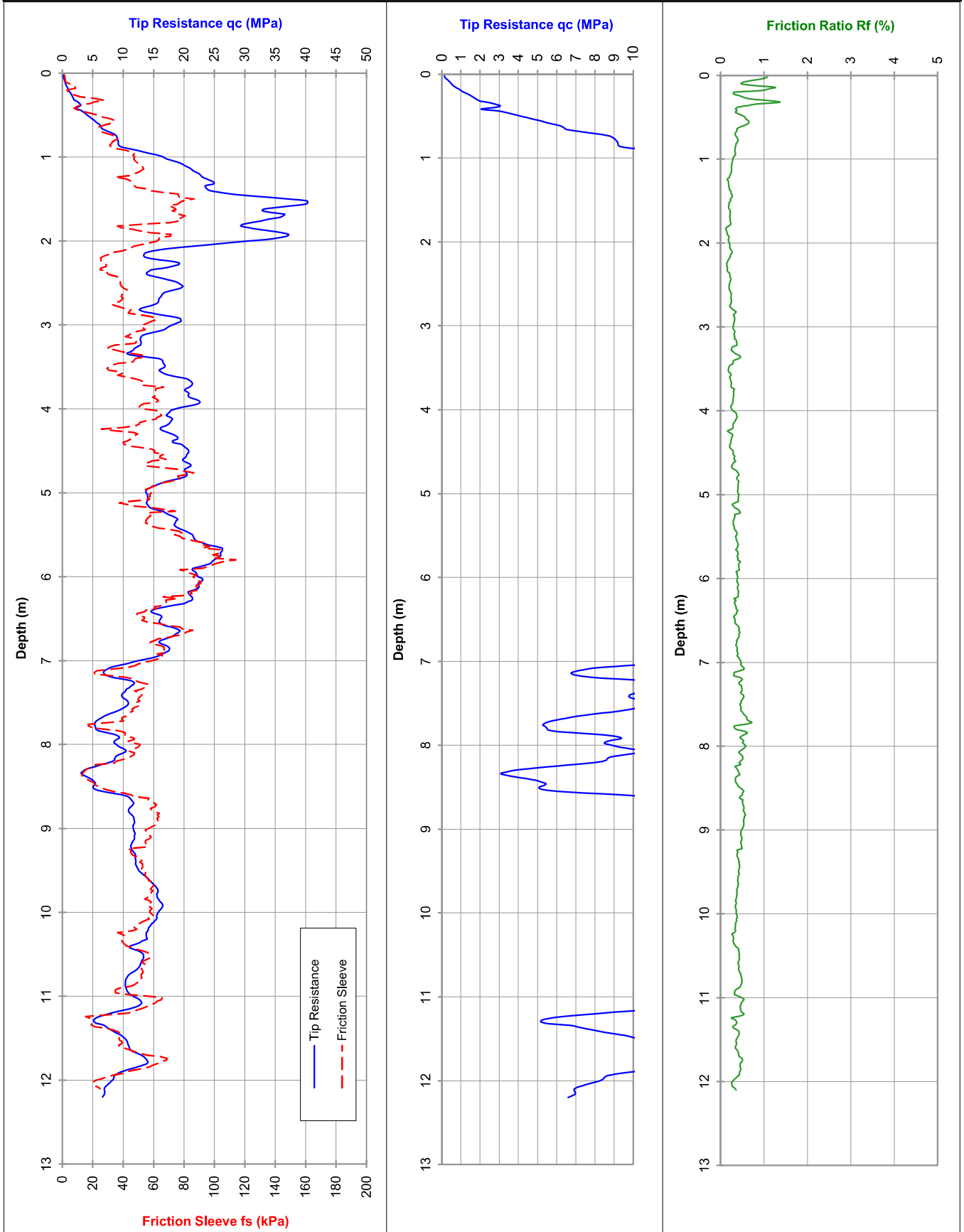
RL (m): 1.7

LOCATION: Rockingham

Co-ords: 381612.88mE, 6422722.97mN

CPT 02

10-Dec-24



ELECTRIC FRICTION-CONE PENETROMETER

Probe I.D

CLIENT: GBG Group

Job No.: 3142

PROJECT: Southern and Southwest Coastal

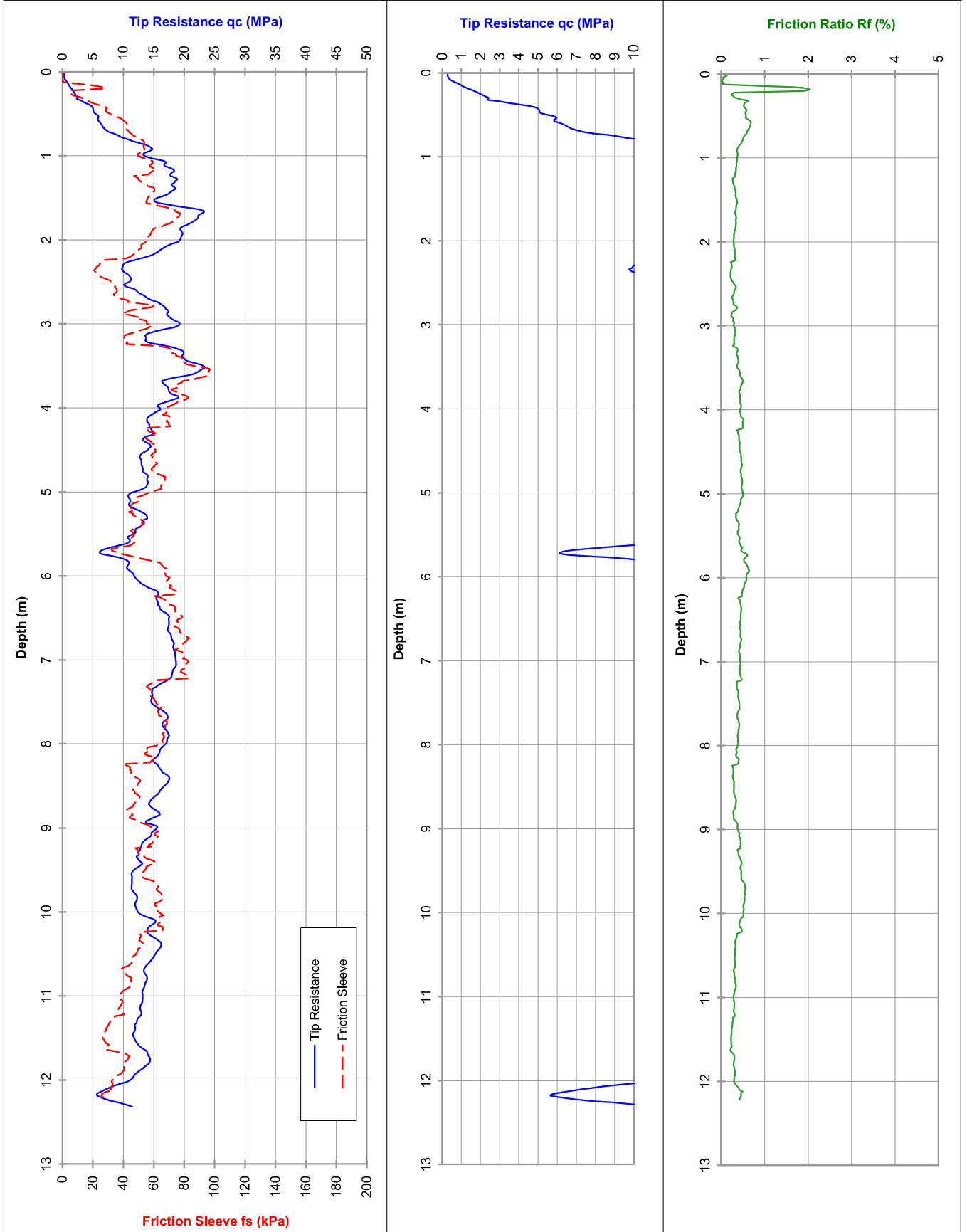
RL (m): 0.9

LOCATION: Rockingham

Co-ords: 381185.35mE, 6423703.06mN

CPT 03

10-Dec-24



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

Approx. water (m): Dry to 0.0

Dummy probe to (m):

Refusal:

Cone I.D.: EC39

File: GB0056T

Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

Probe I.D

CLIENT: GBG Group

Job No.: 3142

PROJECT: Southern and Southwest Coastal

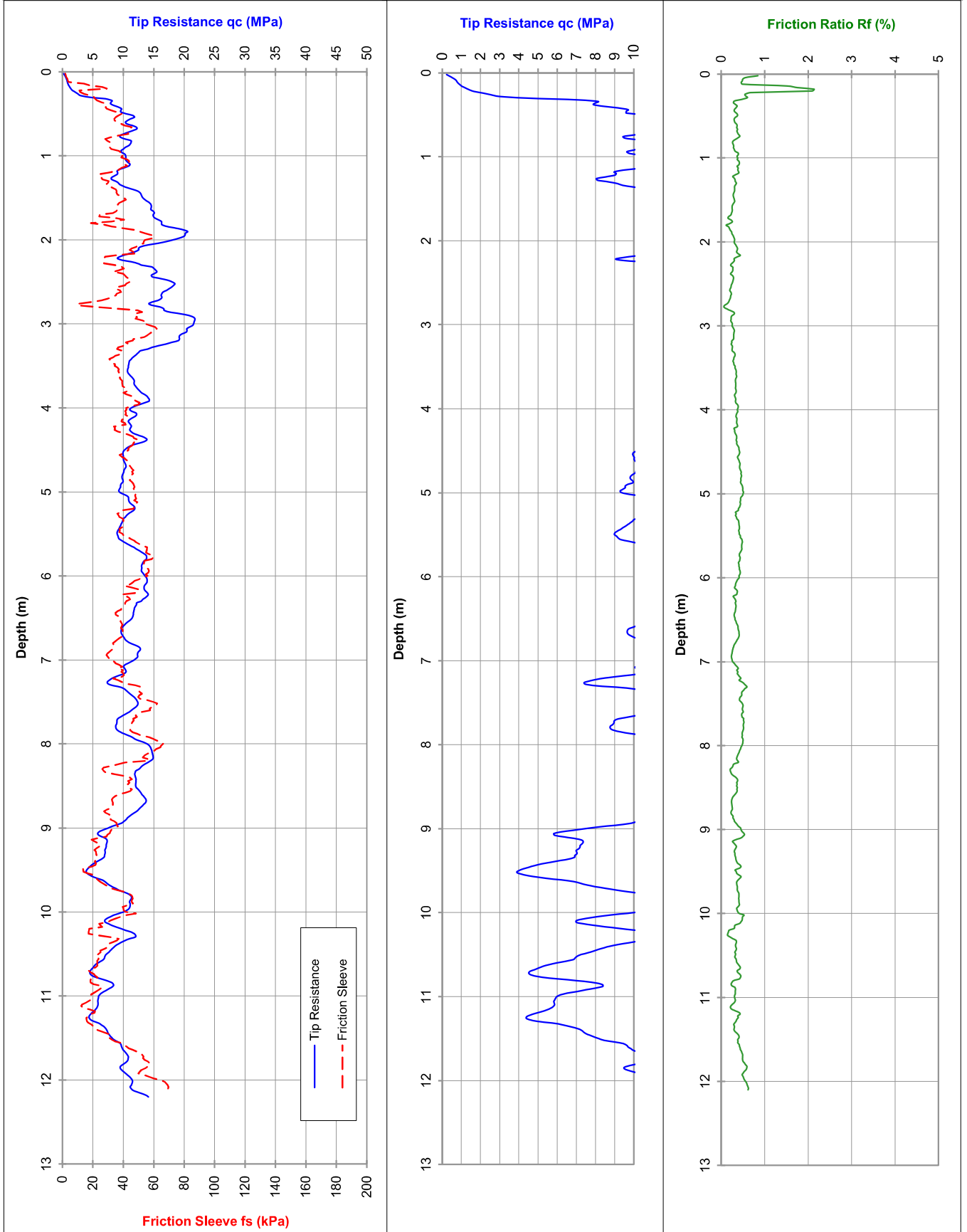
RL (m): 1.56

LOCATION: Rockingham

Co-ords: 380789.1mE, 6424233.94mN

CPT 04

10-Dec-24



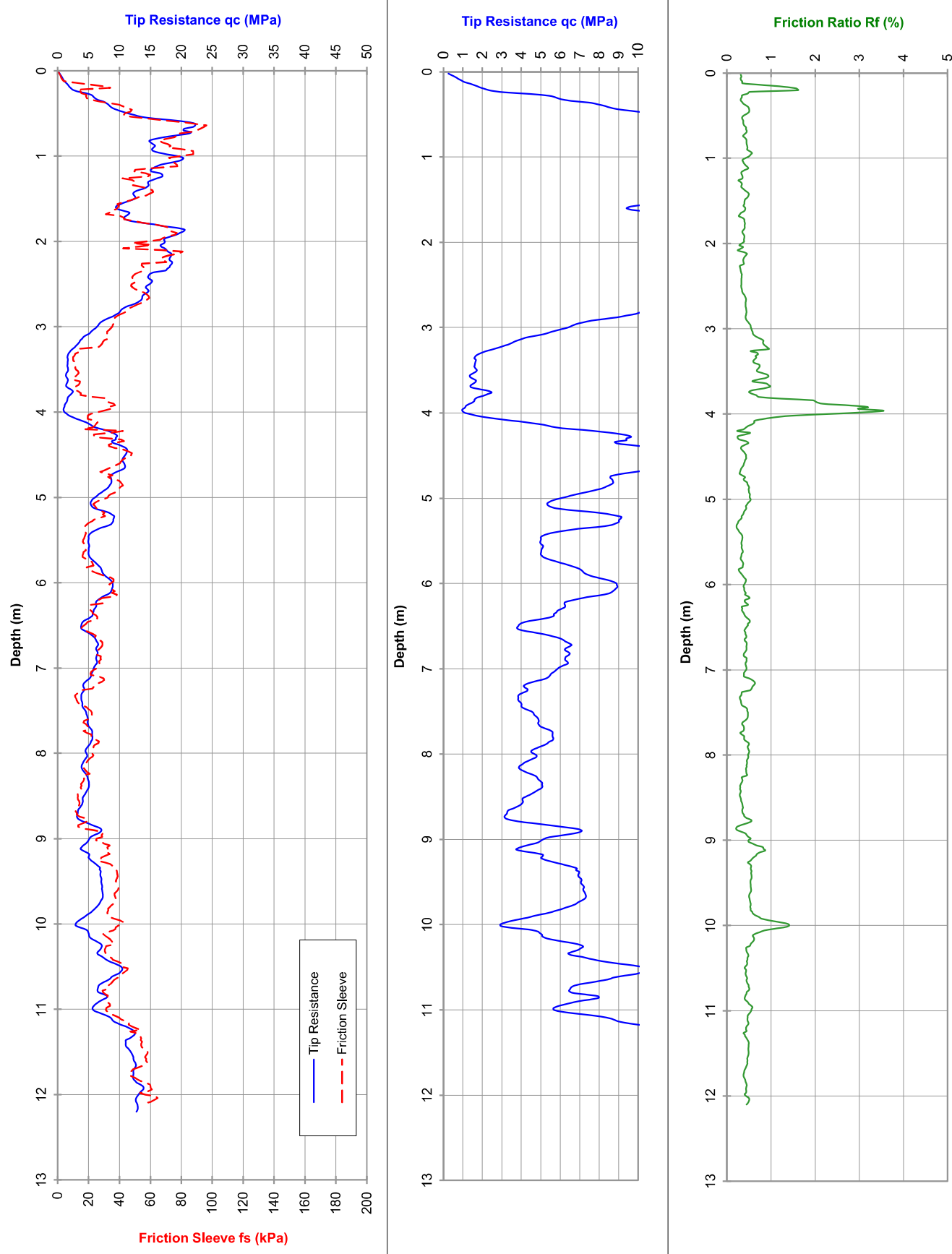
ELECTRIC FRICTION-CONE PENETROMETER

Probe I.D

CLIENT: GBG Group
PROJECT: Southern and Southwest Coastal
LOCATION: Rockingham

Job No.: 3142
RL (m): 1.23
Co-ords: 380203.36mE, 6424635mN

CPT 05
10-Dec-24



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

Approx. water (m): Dry to 0.0
Dummy probe to (m):
Refusal:

Cone I.D.: EC39
File: GB0058T
Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

CLIENT: GBG Group

PROJECT: Southern and Southwest Coastal

LOCATION: Rockingham

Job No.: 3142

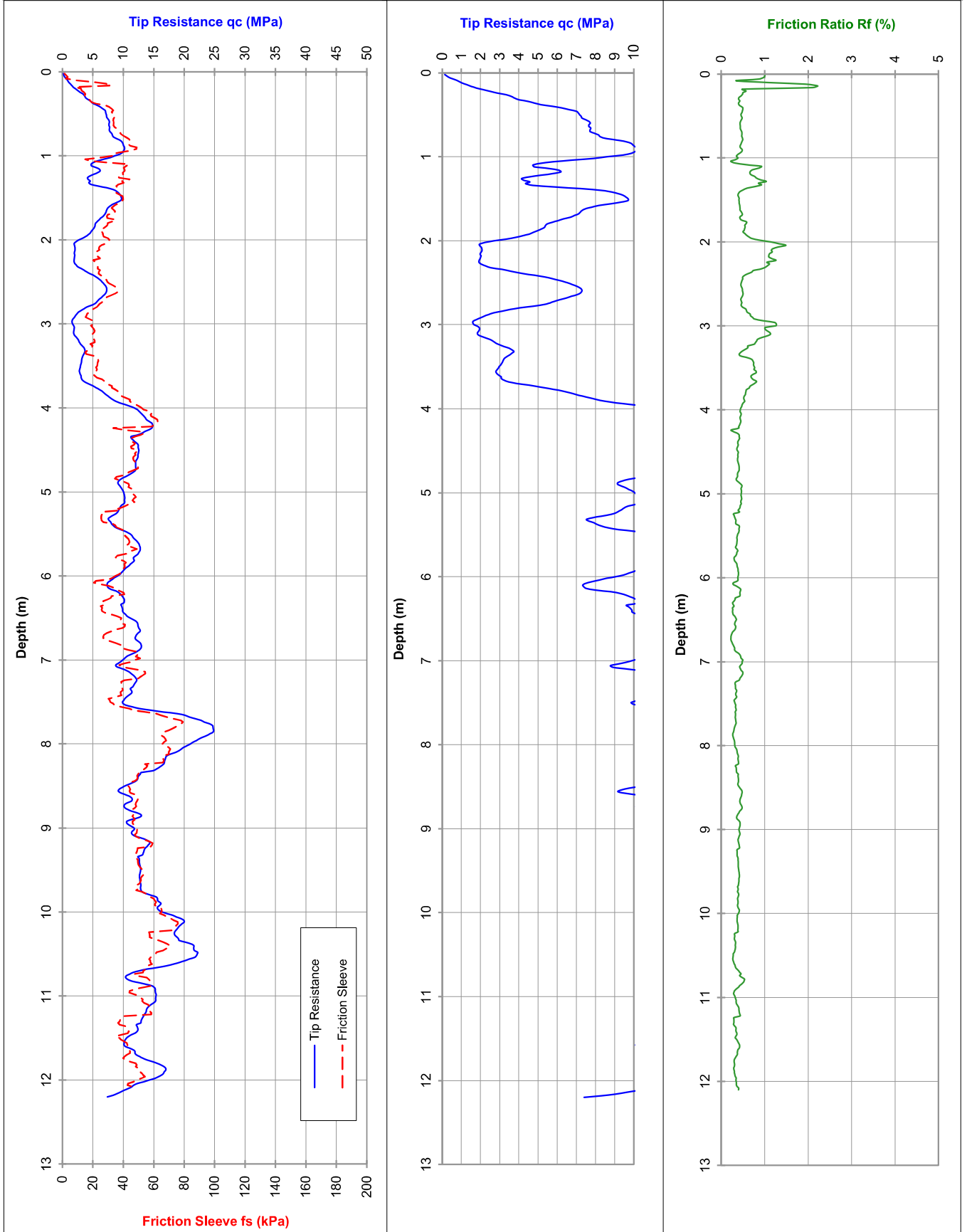
RL (m): 0.86

Co-ords: 379803.59mE, 6424699.16mN

Probe I.D

CPT 06

11-Dec-24



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

Approx. water (m): 0.0

Dummy probe to (m):

Refusal:

Cone I.D.: EC39

File: GB0060T

Rig Type: 7t track

ELECTRIC FRICTION-CONE PENETROMETER

Probe I.D

CLIENT: GBG Group

Job No.: 3142

PROJECT: Southern and Southwest Coastal

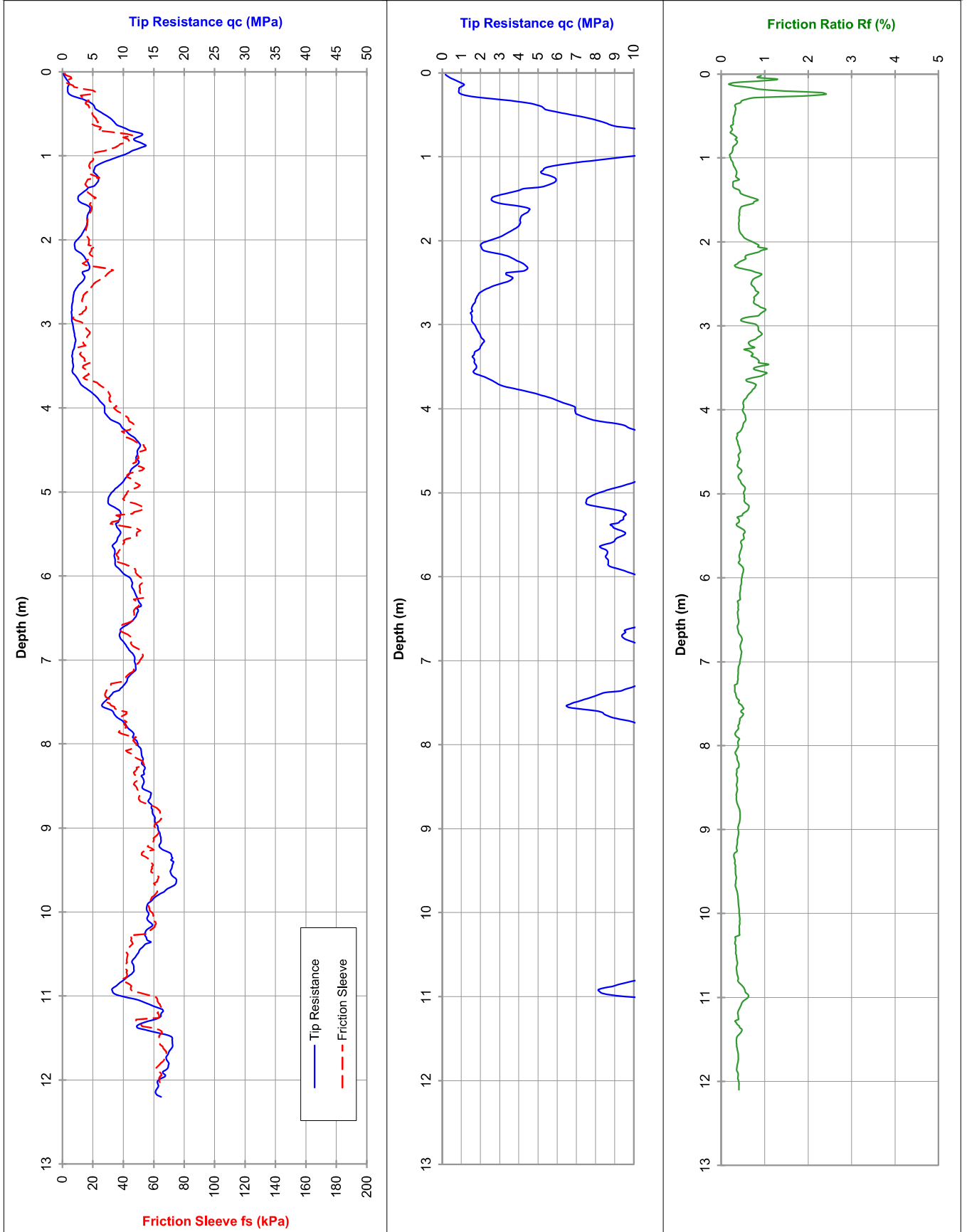
RL (m): 0.34

LOCATION: Rockingham

Co-ords: 379650.61mE, 6424720.75mN

CPT 07

11-Dec-24



CALIBRATION CERTIFICATE

CONE ID:

EC39

Cone Type:
Calibration Date (qc/fs):
Calibration Date (u):
Preliminary Inspection:
Calibrated By:
Calibration Procedure:
Force Application:
Reference Equipment:

Compression
17 December 2024
25 October 2024
Pass
Sesan Wilkins
ISO 22476-1:2012, IRTP 2001
Compression
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 (mm ²)	
Applied Load kN	Eqv. Pressure MPa	Mean Observed Reading Volts
0	0	0.000
10	10	0.782
20	20	1.567
30	30	2.349
40	40	3.129
50	50	3.911
60	60	4.688
70	70	5.466
80	80	6.245
90	90	7.022
100	100	7.800
90	90	7.027
80	80	6.252
70	70	5.475
60	60	4.696
50	50	3.917
40	40	3.136
30	30	2.355
20	20	1.572
10	10	0.789
0	0	0.001
R ² Value =	1.000	

Zero Load Error: 0.01%
Max. Linearity 0.17%
Max. Hysteresis 0.11%

MPa/Volt: **12.817**

fs (sleeve friction):		
Capacity:	2000 (kPa)	
Area	15000 (mm ²)	
Applied Force kN	Eqv. Load kPa	Mean Observed Reading Volts
0	0	0.000
3	200	0.790
6	400	1.594
9	600	2.399
12	800	3.203
15	1000	4.005
18	1200	4.810
21	1400	5.613
24	1600	6.418
27	1800	7.222
30	2000	8.024
27	1800	7.231
24	1600	6.430
21	1400	5.629
18	1200	4.823
15	1000	4.022
12	800	3.217
9	600	2.411
6	400	1.605
3	200	0.797
0	0	0.002
R ² Value =	1.000	

Zero Load Error: 0.03%
Max. Linearity 0.17%
Max. Hysteresis 0.21%

kPa/Volt: **248.95**

u (pore pressure):		
Capacity:	3500 (kPa)	
Position	u2	
Applied Pressure bar	Eqv. Pressure kPa	Mean Observed Reading Volts
0	0	0.000
3	300	0.477
6	600	0.953
9	900	1.431
12	1200	1.912
15	1500	2.390
18	1800	2.870
21	2100	3.349
25	2500	3.989
30	3000	4.791
35	3500	5.591
30	3000	4.797
25	2500	3.999
21	2100	3.360
18	1800	2.879
15	1500	2.399
12	1200	1.922
9	900	1.442
6	600	0.963
3	300	0.483
0	0	0.002
R ² Value =	1.000	

Zero Load Error: 0.04%
Max. Linearity 0.12%
Max. Hysteresis 0.20%

kPa/Volt: **625.99**
Net Area (calibrated): **0.83**

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

Calibration Checked & Authorised: Nicole London

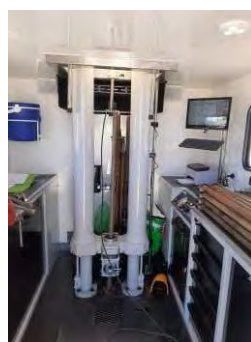
Job Details

Client: GBG
Rep: Qasim Asad
Location: Rockingham

Date of Job: 10/12/24
Tip Diameter: 35.6
Sleeve Diameter: 35.9

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)
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