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Report

Geotechnical Investigation for Coastal Erosion Vulnerability Assessment.

Denham, Shire of Shark Bay WA.

Date: 6 August 2024
Report Ref: 3095A

DOCUMENT HISTORY

DETAILS

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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 Denham in the Shire of Shark Bay, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 700m corridor and a 380m corridor of coastal beach and dune formation adjacent to the Denham settlement which has been identified as an at-risk site as part of Coastal Hotspot #8.

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. It should be noted that the seismic velocity sections were not calibrated with CPT data for the Denham sites. Velocity ranges representing different material types and conditions for the generation of interpreted geological sections were based on other similar sites, consisting of loose to compacted sediment and variably 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 below ground level except in small sections in the East Denham site.

- Interpreted top of rock substrate on the along-shore transects on the beach ranges from -9.0mAHD to 2.0mAHD and averages approximately -6mAHD and is overlain by an average of 6.0m of variably compacted sediment.

- Interpreted rock level was generally shallower in the West Denham site compared to the East Denham site.

- Interpreted top of rock substrate in the West Denham site including transects along the beach and in the caravan park ranges from -9mAHD to 6.0mAHD.

- Interpreted top of rock substrate in the East Denham site including transects along the beach and along the cross-shore transects ranges from -15mAHD to -1.7mAHD.

CONTENTS

1 INTRODUCTION

At the request of The Government of Western Australia Department of Transport (DoT), GBG Group carried out a geotechnical investigation at Denham, Shire of Shark Bay in October 2023. During the investigation seismic geophysical testing and intrusive geotechnical testing was conducted within a 700m corridor and a 380m corridor of coastal beach and dune formation which has been identified as an at risk site as part of Coastal Hotspot #8.

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

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

1. **Geological mapping** of surface rock outcrops within the study area using high resolution photogrammetry.
2. **Geophysical testing** by way of Multi-channel Analysis of Surface Waves (MASW) to obtain seismic shear wave velocity models related to variations in subsurface material stiffness.
3. **Topographic survey** using Differential GNSS receiver and photogrammetry.

2 INVESTIGATION SITE

The investigation was carried out within approximate 700m and 380m corridors of coastal beach and dune formation the extents of which are shown as yellow dashed areas in Figure 1 as follows;

- Denham East – 700m section from the Denham Road / Knight Terrace intersection to the eastern end of Knight Terrace.
- Denham West – 380m section from the Stella Rowley / Knight Terrace intersection westwards and including the Denham Seaside Holiday Park.

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 8mAHD. Topographic maps showing surface level are provided in Appendix C drawings 3095A-11 and 3095A-12.

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

Figure 2: Site conditions at Denham East including along the beach foreshore (left image) and eastern cross-shore track (right image).

Figure 3: Example site conditions at Denham West including beach-caravan park access (left image) and along the beach (right image).

3 INVESTIGATION METHODOLOGY

3.1 FIELD SURVEY LOGISTICS

Geophysical data acquisition was carried out from the 23rd to the 25th of July 2024 by a two-person team from GBG Group consisting of qualified geophysicists. CPT data acquisition was not carried out due to heritage site restrictions. Where required, the site work was carried out under appropriate traffic and pedestrian management commissioned by the Shire of Shark Bay.

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

The site work for the investigation consisted of a total of 2488m of MASW profiling acquired as 7 along-shore transects (parallel to the coast) and 7 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 3095A-01 for Denham West and 3095A-02 for Denham East.

Table 1 – Acquired MASW Transects (Coordinates in GDA94, MGA Zone 49).

Transect	Orientation	Start Coordinate		End Coordinate		Length
ID		East	North	East	North	(m)
MASW01	Along-shore	753090.7	7130259.6	7533990.9	7130025.7	384
MASW02	Along-shore	753219.0	7130261.4	753349.7	7130143.3	192
MASW03	Along-shore	753259.5	7130156.4	753326.2	7130131.3	72
MASW04	Along-shore	753309.8	7130127.9	753390.7	7130082.0	96
MASW05	Cross-shore	753142.2	7130216.7	753218.2	7130278.5	104
MASW06	Cross-shore	753257.9	7130124.1	753259.7	7130146.7	24

MASW07	Cross-shore	753399.6	7130040.4	753436.7	7130100.2	72
MASW08	Along-shore	754246.3	7129559.6	754753.3	7129327.2	600
MASW09	Along-shore	754799.9	7129324.0	754876.2	7129293.9	88
MASW10	Along-shore	754236.7	7129583.5	754767.5	7129339.1	592
MASW11	Cross-shore	754397.3	7129523.3	754425.3	7129580.8	64
MASW12	Cross-shore	754502.0	7129473.5	754533.0	7129538.0	72
MASW13	Cross-shore	754763.3	7129348.0	754789.0	7129424.8	80
MASW14	Cross-shore	754841.1	7129328.8	754856.5	7129372.2	48

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. Photographs of MASW data acquisition are shown in Figure 4.

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
Source offset	4 m
Sounding interval	8m
Source stacks	3

Figure 4: 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 5).
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.

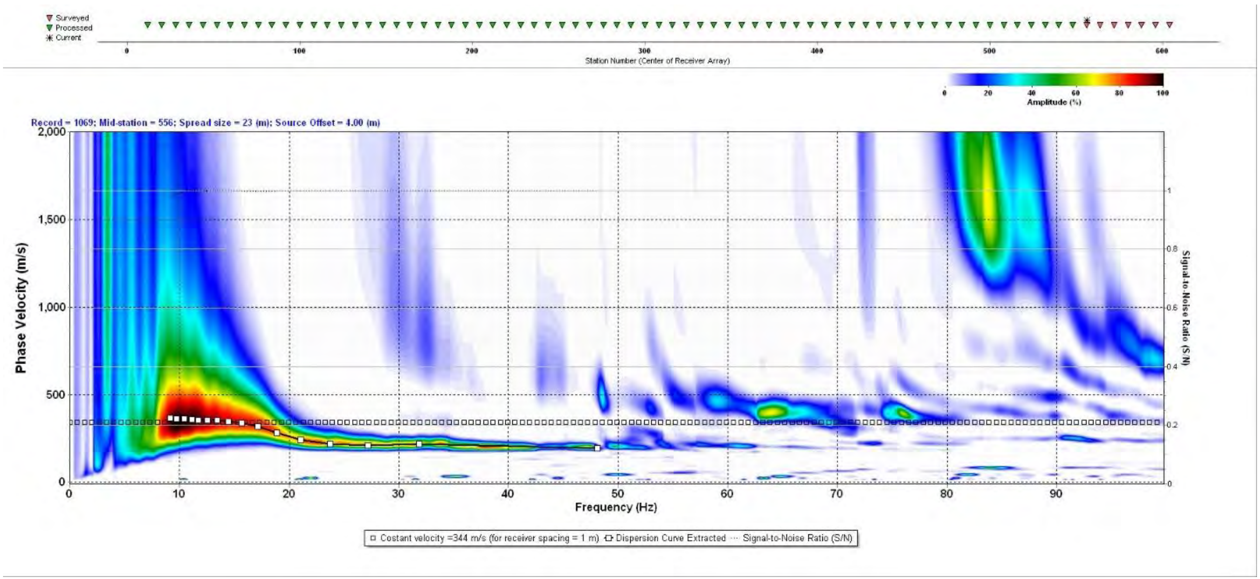


Figure 5: MASW overtone image with high signal to noise ratio and picked dispersion curve.

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 GDA94, MGA zone 49 for horizontal component and Australian Height Datum (mAHD) for vertical component. An accuracy of +/-0.2m is expected for both vertical and horizontal components.

To achieve precise reduced levels referenced to AHD, the positioning data was acquired with Real-Time Kinematics (RTK) using Standard Survey Markers (SSM) as known reference points for the base corrections. Details of the SSM used for this investigation are provided in Table 3.

Table 3 – Details of Standard Survey Marker

Parameter	Value (SSM-1)
Standard Survey Marker	SHARK BAY 10
Latitude	S 25 55 08.16815
Longitude	E 113 31 42.64441
Derived GDA94 ellipsoidal height (m)	-8.73
N-Value (m)	-22.401
Height (m) (AHD)	13.671

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 Denham, Shire of Shark Bay are presented in Appendices B and C of this report as follows:

Appendix B – Geophysical and Interpreted Sections

- **3095A-03.** Transects 1 and 2 seismic S-wave velocity model and interpreted geological section.
- **3095A-04.** Transects 3 and 4 seismic S-wave velocity model and interpreted geological section.
- **3095A-05.** Transects 5, 6 and 7 seismic S-wave velocity model and interpreted geological section.
- **3095A-06.** Transect 8 seismic S-wave velocity model and interpreted geological section.
- **3095A-07.** Transect 9 seismic S-wave velocity model and interpreted geological section.
- **3095A-08.** Transect 10 seismic S-wave velocity model and interpreted geological section.
- **3095A-09.** Transects 11 and 12 seismic S-wave velocity model and interpreted geological section.
- **3095A-10.** Transects 13 and 14 seismic S-wave velocity model and interpreted geological section.

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

- **3095A-11 and 3095A-12.** Contoured surface level models derived from aerial photogrammetry.
- **3095A-13 and 3095A-14.** Contoured level to modelled top of rock.
- **3095A-15 and 3095A-16.** Class post map level to modelled top of rock.
- **3095A-17 and 3095A-18.** Contoured modelled sand thickness over rock / Depth to top of rock.

- **3095A-19 and 3095A-20.** 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 (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

No Calibration was undertaken with CPTs at the Denham sites.

4.5 MODELLED LEVEL TO TOP OF ROCK AND SAND THICKNESS

Subsurface models for the level to top of rock substrate and overlying sand thickness within the region between the coastal foreshore and settlement are presented in Appendix C. These has been generated by digitising the interface between the interpreted sediment and underling rock profile from the interpreted geological sections along the acquired along-shore and cross-shore transects. 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 3095A-11 to 3095A-12) – generated from the aerial photogrammetry, this presents the level to ground surface ranging from 0mAHD to 9mAHD. Note: vegetation height has not been removed from these models.

- **Contoured Level to Top of Rock Substrate** (drawings 3095A-13 to 3095A-14) – this presents the level to the top of rock substrate ranging from -15mAHD to 6mAHD.

- **Classed Post Map Level to Top of Rock Substrate** (drawing 3095A-15 and 3095A-16) – 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 3095A-17 to 3095A-18) – this presents the thickness of sand overlying the rock substrate ranging from 0mBGL to 20mBGL.

- **Classed Post Map Sand Thickness / Depth to Top of Rock** (drawings 3095A-19 and 3095A-20) – this presents the thickness of sand overlying the rock substrate along the acquired transects at 3m depth increments from 1mBGL 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 using during the site work, 1D inversion of the MASW dataset using a 10-layer model and expected undulations in the sand/rock interface. Note the quoted accuracies are only valid along the geophysical transects. Values given between transects have been interpolated in the contour maps and as such the accuracy in this case is indeterminable.

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

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

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

5 PROJECT SUMMARY

A geotechnical investigation has been carried out as part of a coastal erosion assessment at Denham in the Shire of Shark Bay, Western Australia. During the investigation ground geophysical and intrusive geotechnical testing was conducted within a 700m corridor and a 380m corridor of coastal beach and dune formation adjacent to the Denham settlement which has been identified as an at risk site as part Coastal Hotspot #8.

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 not calibrated with the CPT data for the Denham sites. Velocity ranges representing different material types and conditions for the generation of interpreted geological sections were based on other similar sites, 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 not 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)

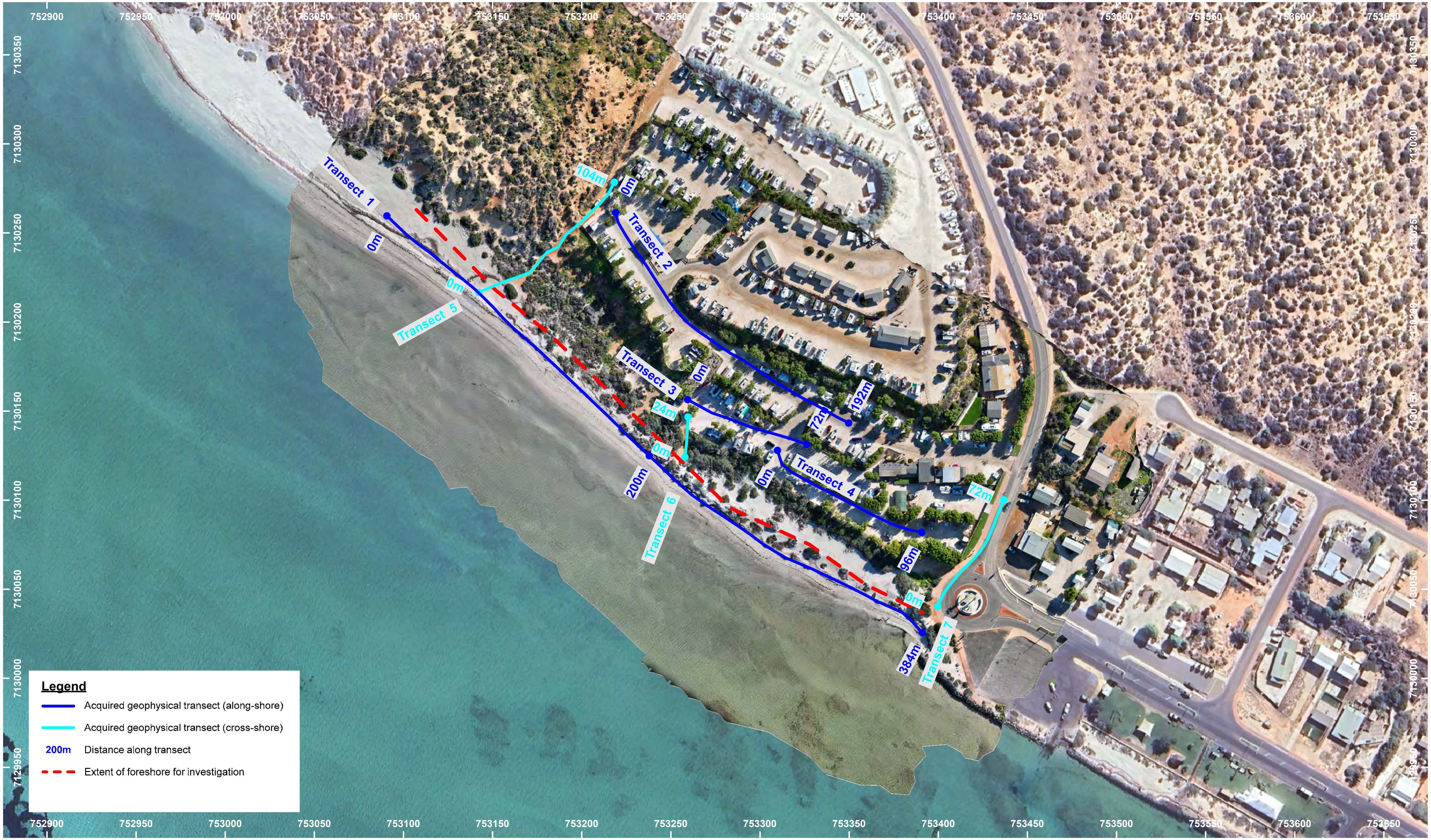
ANDREW SPYROU
Operations Manager, Western Australia / Senior Geophysicist

APPENDIX A – INVESTIGATION SITE MAP

GBGGROUP

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

INVESTIGATION SITE MAP (WEST)



NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	AHWS
		Drawing	3095A-01	Revision	0

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

INVESTIGATION SITE MAP (EAST)

NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

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CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	AHWS
		Drawing	3095A-02	Revision	0

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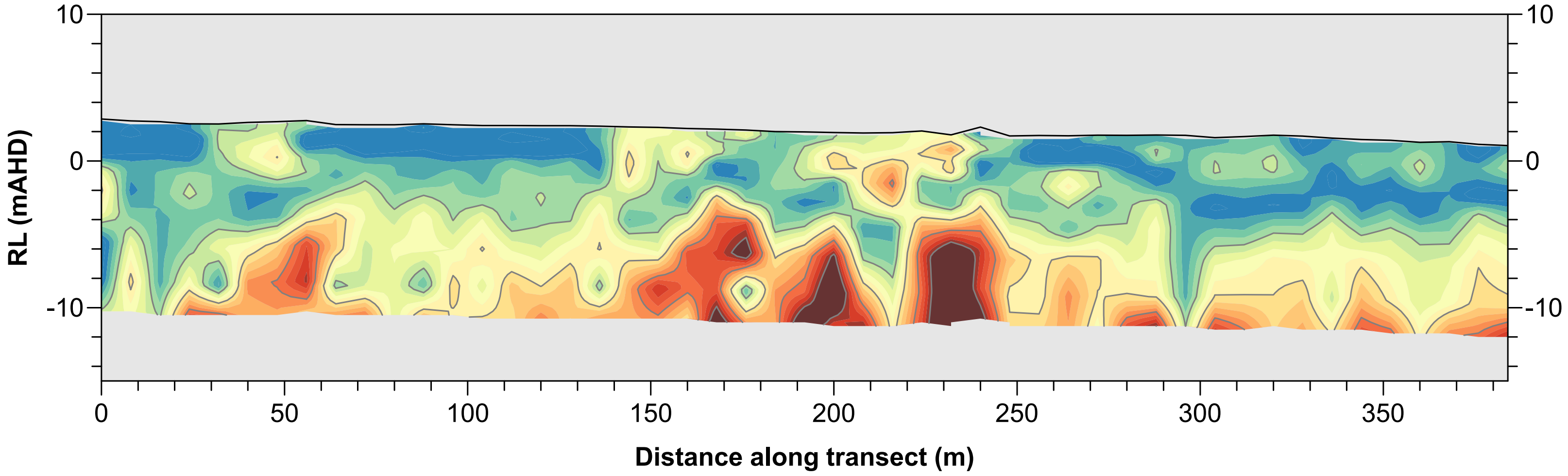
APPENDIX B – GEOPHYSICAL AND INTERPRETED SECTIONS

GBGGROUP

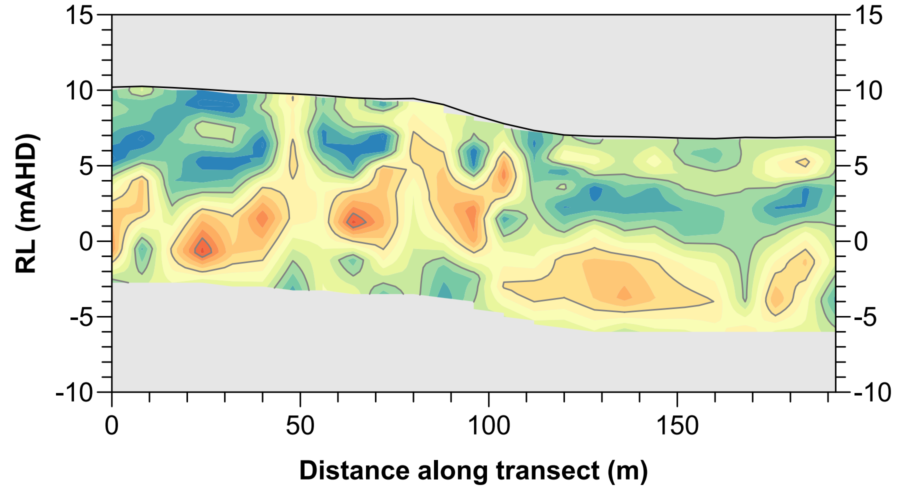
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

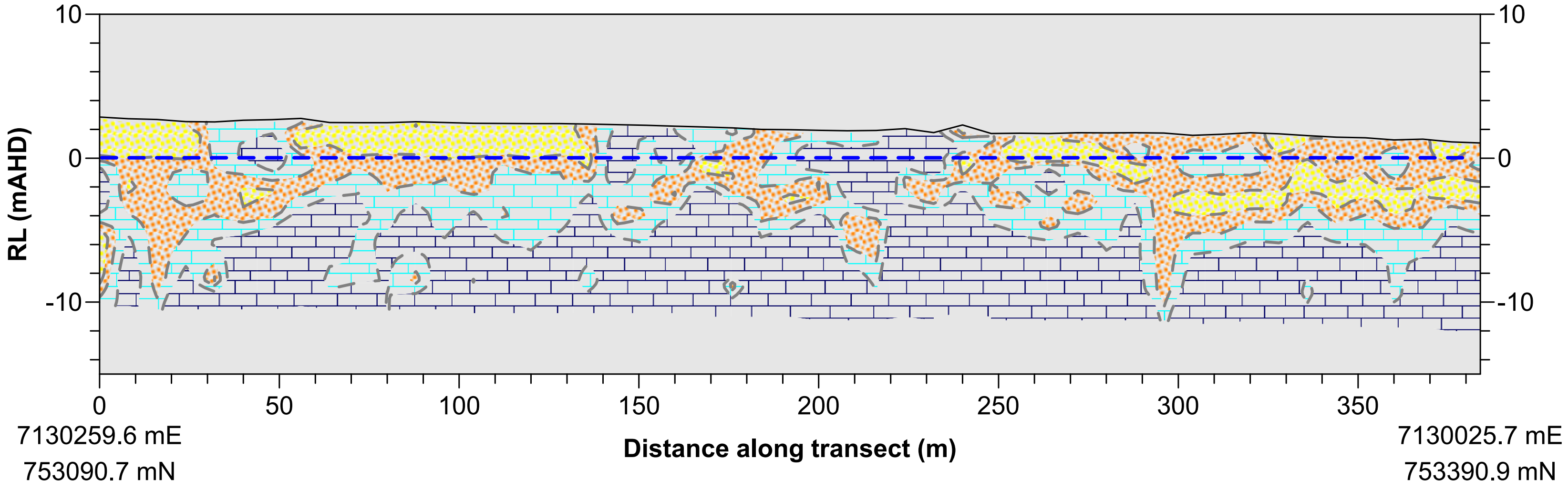
TRANSECT 1 - SEISMIC SHEAR WAVE VELOCITY MODEL



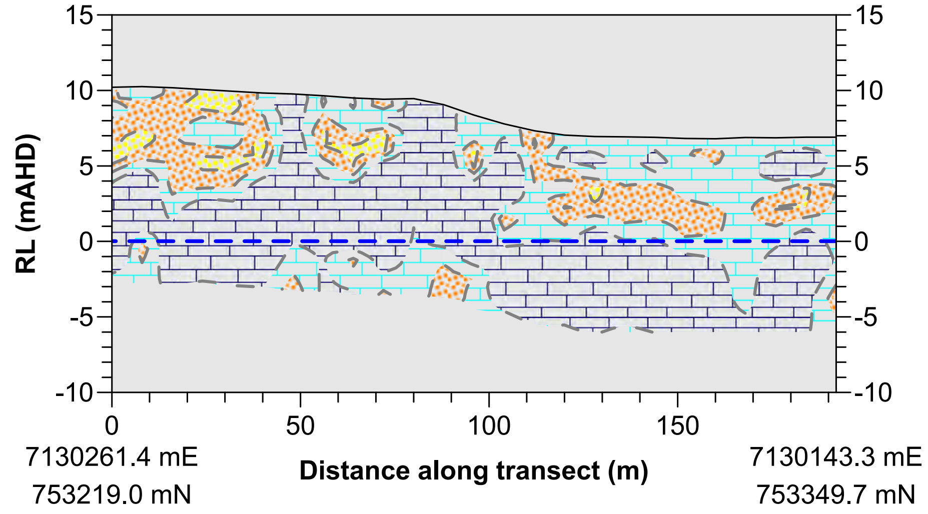
TRANSECT 2 - SEISMIC SHEAR WAVE VELOCITY MODEL



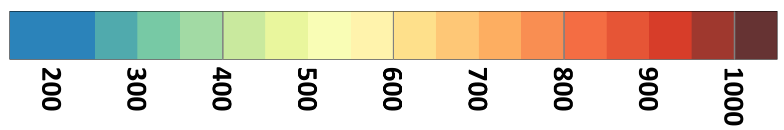
TRANSECT 1 - INTERPRETED GEOLOGICAL SECTION



TRANSECT 2 - 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 VARIABLY WEATHERED ROCK S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

NOTES

Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	26 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000H, 1:500V	Drawn	OMLE
		Drawing	3095A-03	Revision	0

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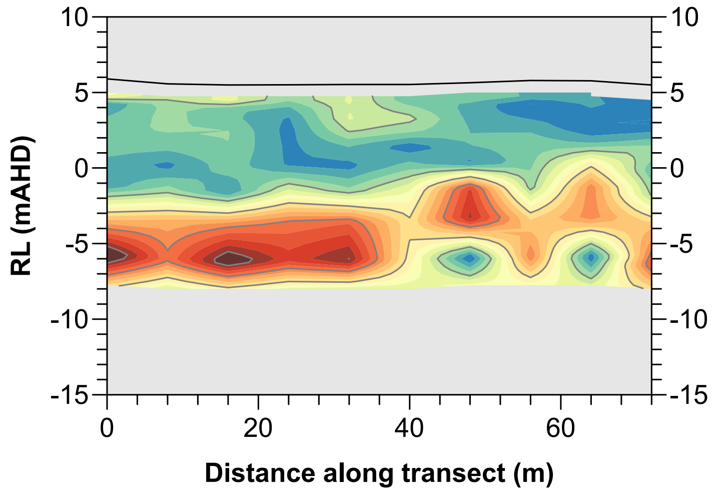
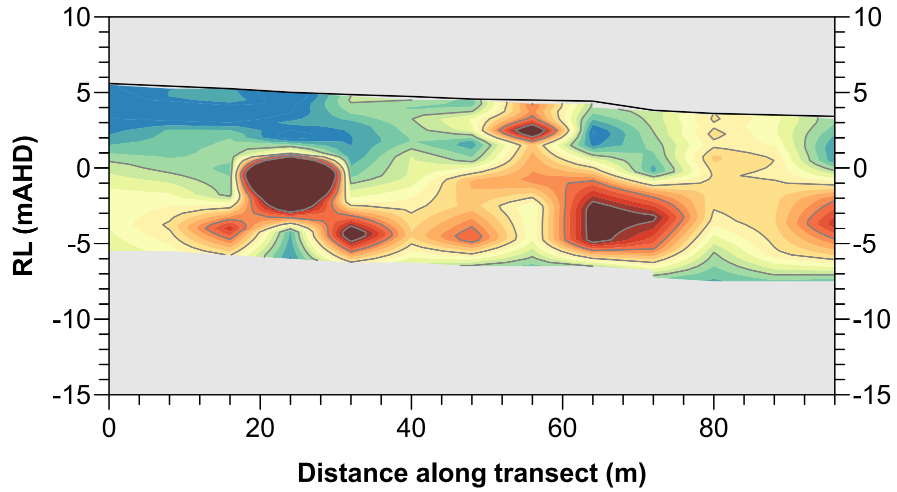
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

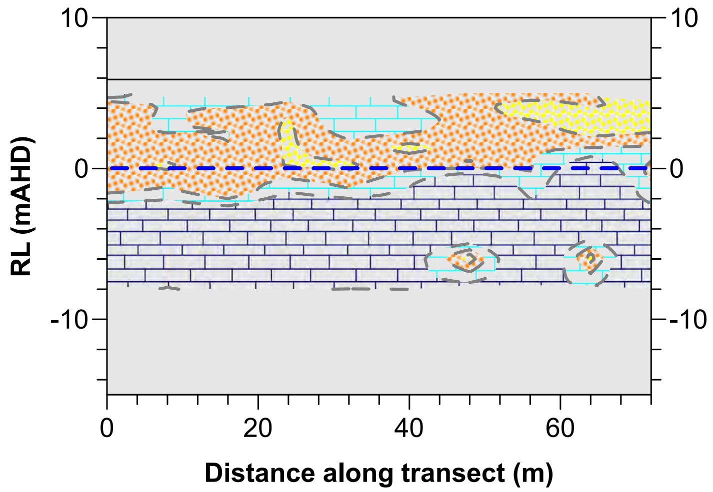
TRANSECT 3 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 4 - SEISMIC SHEAR WAVE VELOCITY MODEL



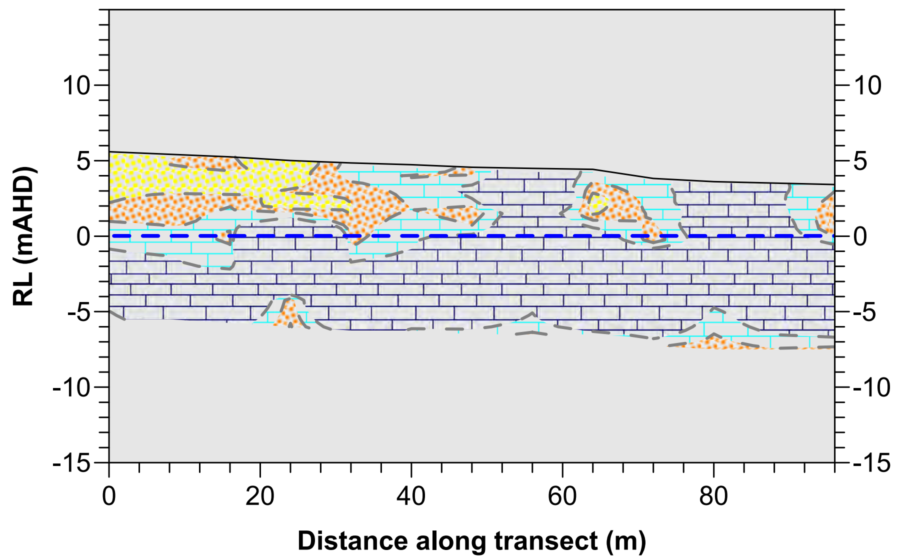
TRANSECT 3 - INTERPRETED GEOLOGICAL SECTION



7130156.4 mE
753259.4 mN

7130131.3 mE
753326.2 mN

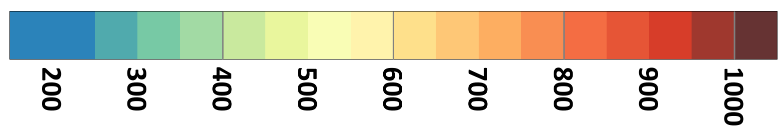
TRANSECT 4 - INTERPRETED GEOLOGICAL SECTION



7130127.9 mE
753309.8 mN

7130082.0 mE
753390.7 mN

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 VARIABLY WEATHERED ROCK
  S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK
  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

NOTES
Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	26 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:1000H, 1:500V	Drawn	OMLE
		Drawing	3095A-04	Revision	0

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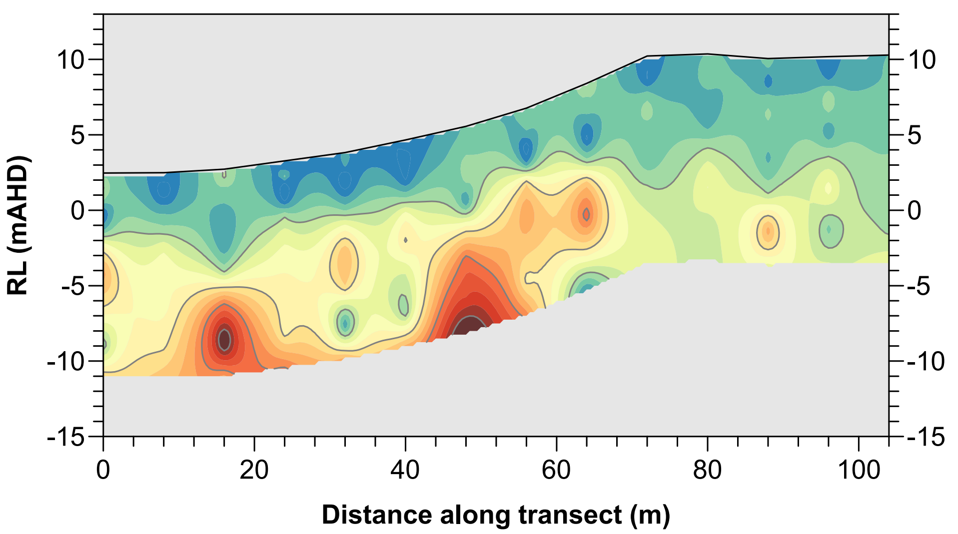
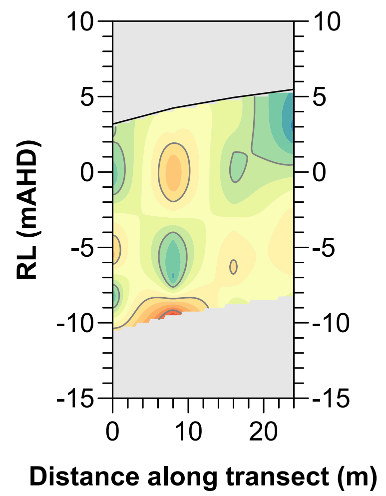
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

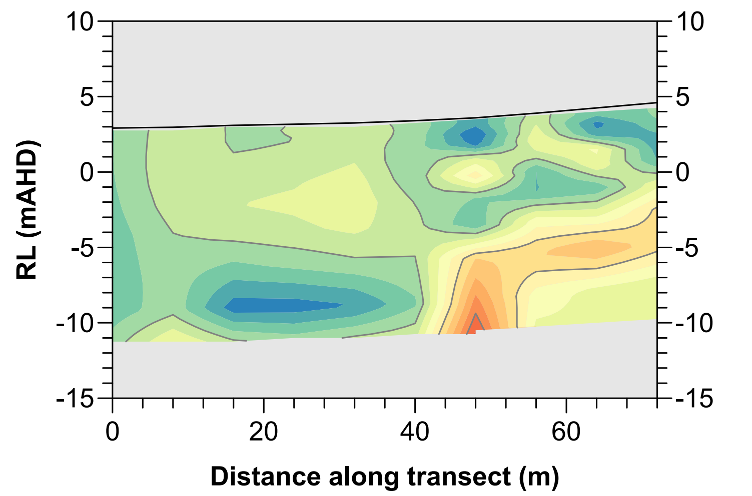
TRANSECT 5 - SEISMIC SHEAR WAVE VELOCITY MODEL



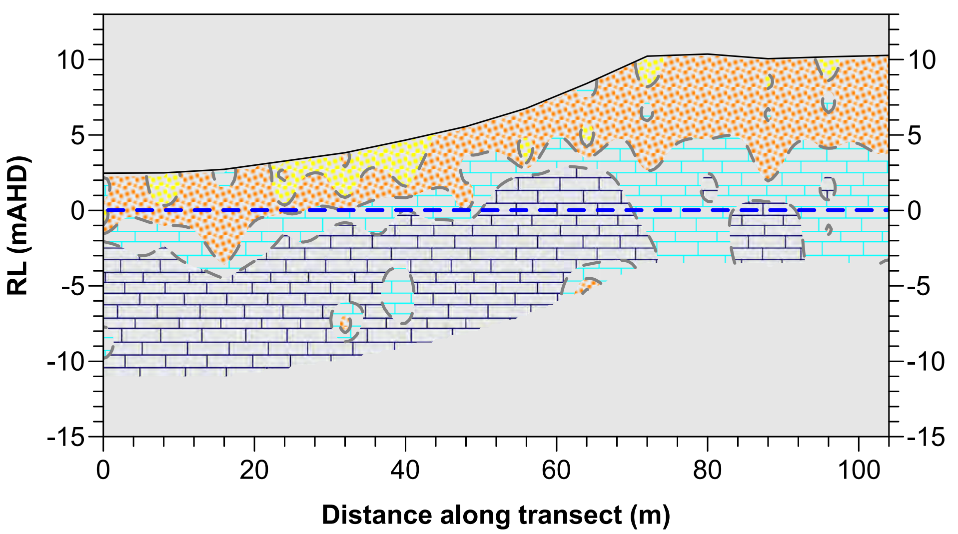
TRANSECT 6 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 7 - SEISMIC SHEAR WAVE VELOCITY MODEL



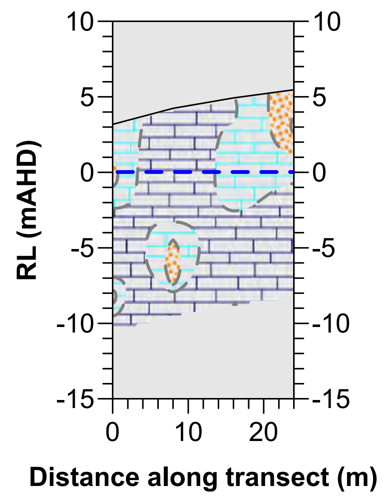
TRANSECT 5 - INTERPRETED GEOLOGICAL SECTION



7130216.6 mE
753142.2 mN

7130278.5 mE
753218.2 mN

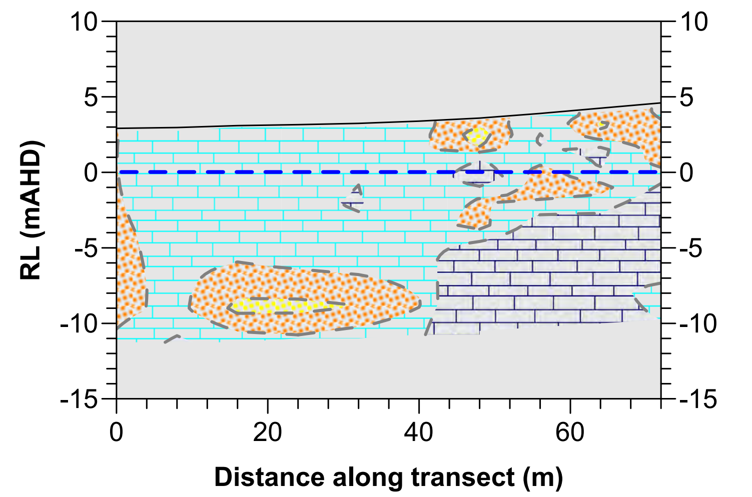
TRANSECT 6 - INTERPRETED GEOLOGICAL SECTION



7130124.1 mE
753257.9 mN

7130146.7 mE
753259.7 mN

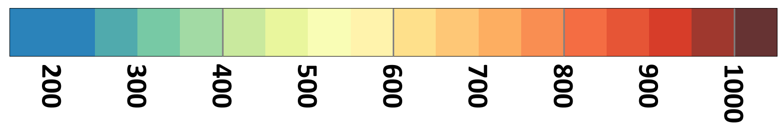
TRANSECT 7 - INTERPRETED GEOLOGICAL SECTION



7130040.3 mE
753399.6 mN

7130100.2 mE
753436.7 mN

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 VARIABLY WEATHERED ROCK
S-WAVE VELOCITY 350-475 m/s

MODERATE STRENGTH COMPETENT ROCK
S-WAVE VELOCITY > 475 m/s.

0m AUSTRALIAN HEIGHT DATUM

NOTES

Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOPHYSICAL INVESTIGATION FOR COASTAL
EROSION VULNERABLITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WA

Date	26 July 2024	Paper Size	A3
Scale	1:1000H, 1:500V	Drawn	OMLE
Drawing	3095A-05	Revision	0

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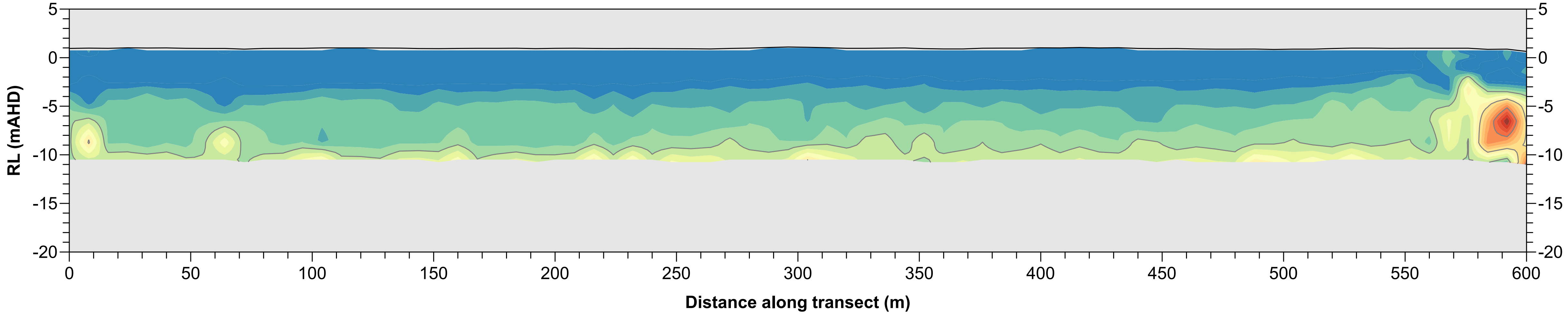
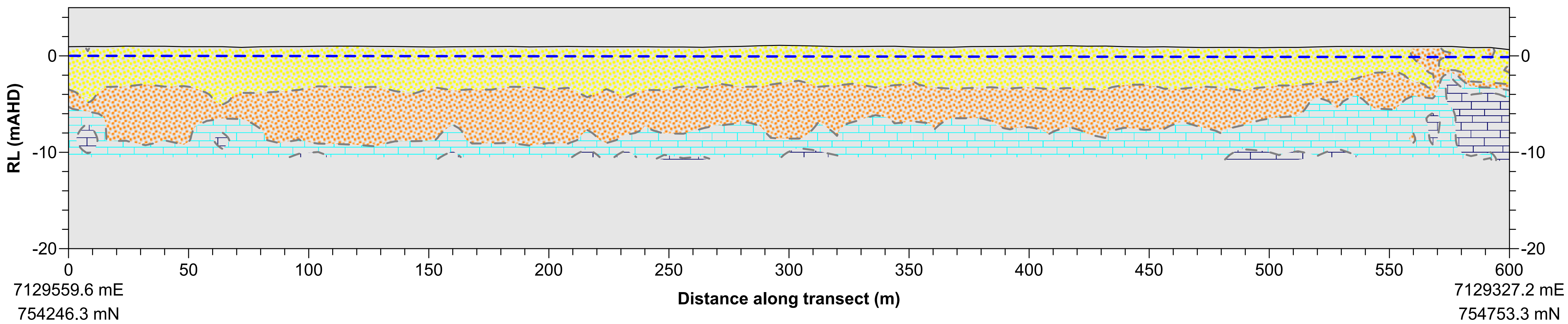
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

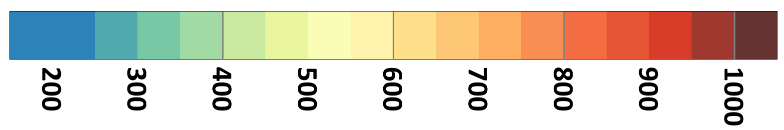
TRANSECT 8 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 8 - 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 VARIABLY WEATHERED ROCK
  S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK
  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

NOTES

Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	26 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000H, 1:500V	Drawn	OMLE
		Drawing	3095A-06	Revision	0

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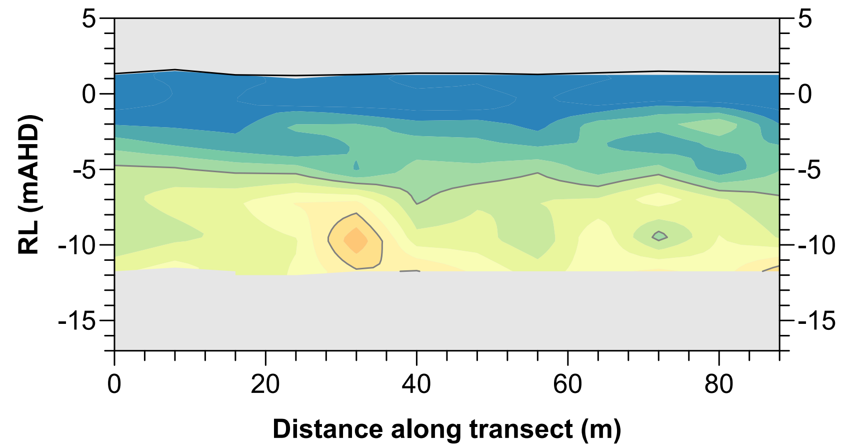
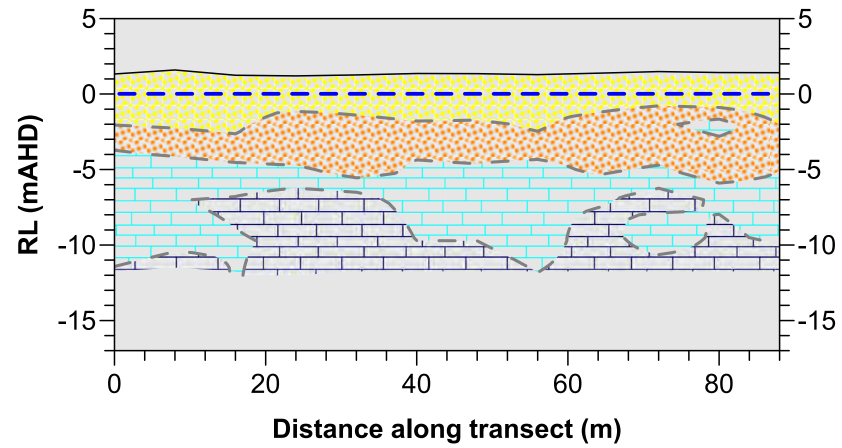
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

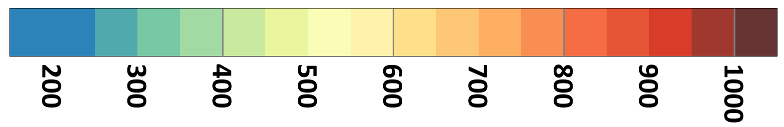
TRANSECT 9 - SEISMIC SHEAR WAVE VELOCITY MODEL



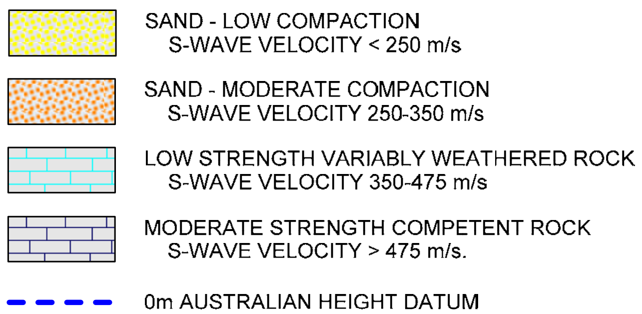
TRANSECT 9 - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



NOTES

Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	26 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:1000H, 1:500V	Drawn	OMLE
		Drawing	3095A-07	Revision	0

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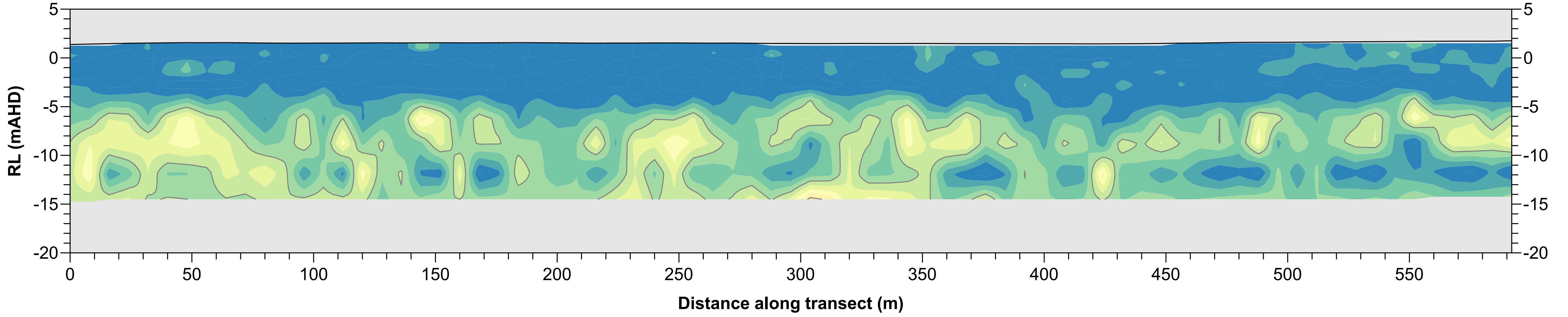
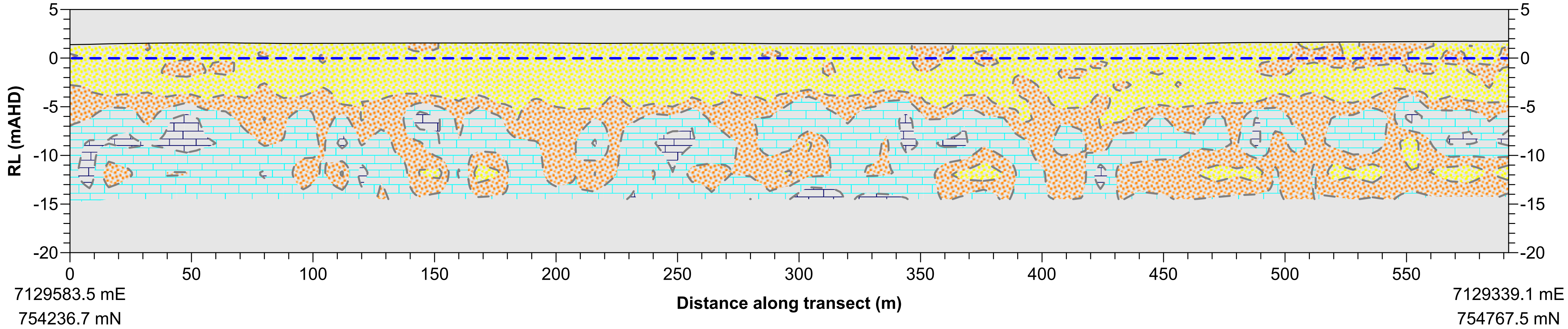
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

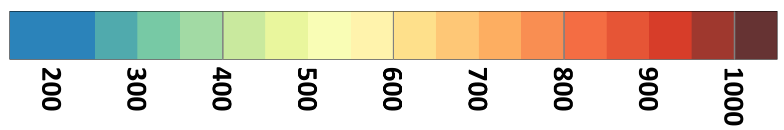
TRANSECT 10 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 10 - 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 VARIABLY WEATHERED ROCK S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

NOTES
Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT: DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date: 26 July 2024	Paper Size: A3	
GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale: 1:2000H, 1:500V	Drawn: OMLE	
	Drawing: 3095A-08	Revision: 0	

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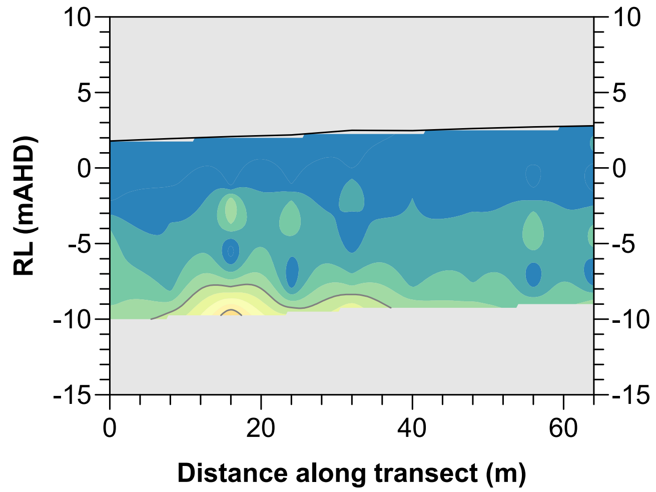
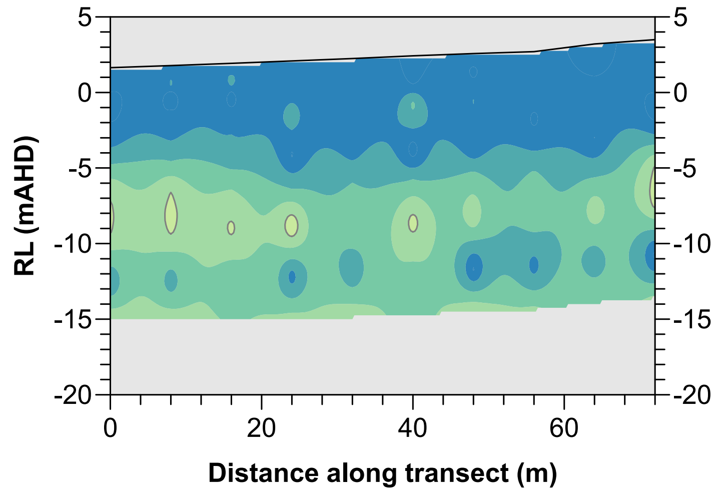
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

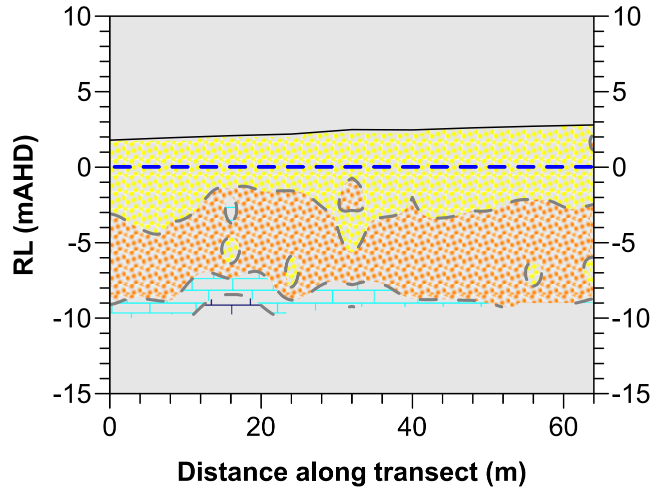
TRANSECT 11 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 12 - SEISMIC SHEAR WAVE VELOCITY MODEL



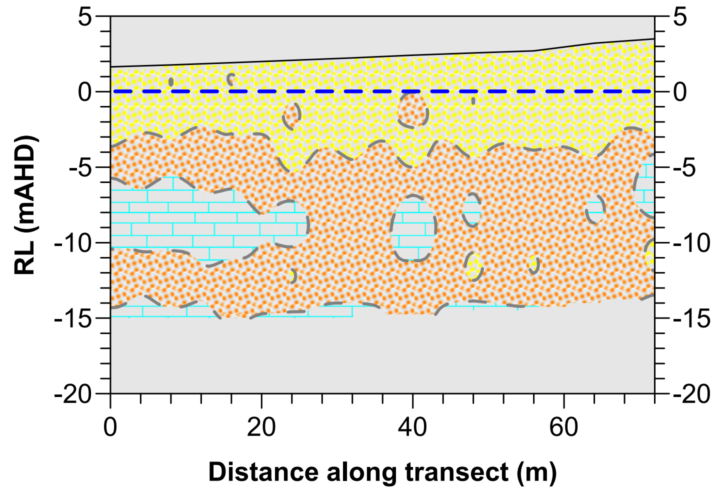
TRANSECT11 - INTERPRETED GEOLOGICAL SECTION



7129523.3 mE
754397.2 mN

7129580.8 mE
754425.3 mN

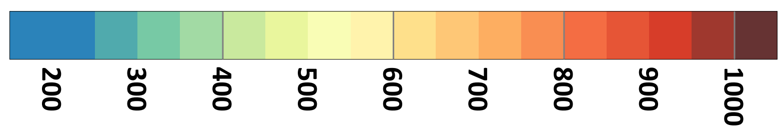
TRANSECT 12 - INTERPRETED GEOLOGICAL SECTION



7129473.4 mE
754502.0 mN

7129538.0 mE
754533.0 mN

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 VARIABLY WEATHERED ROCK
  S-WAVE VELOCITY 350-475 m/s
- MODERATE STRENGTH COMPETENT ROCK
  S-WAVE VELOCITY > 475 m/s.
- 0m AUSTRALIAN HEIGHT DATUM

NOTES
Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	26 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000H, 1:500V	Drawn	OMLE
		Drawing	3095A-09	Revision	0

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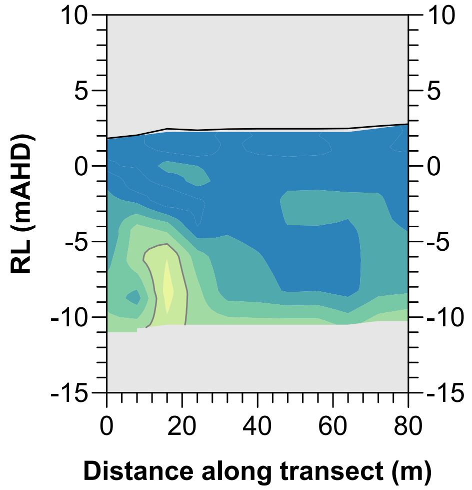
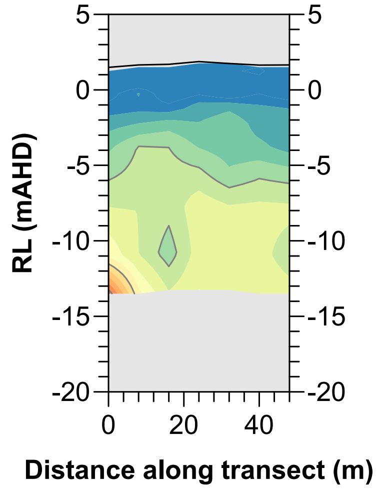
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

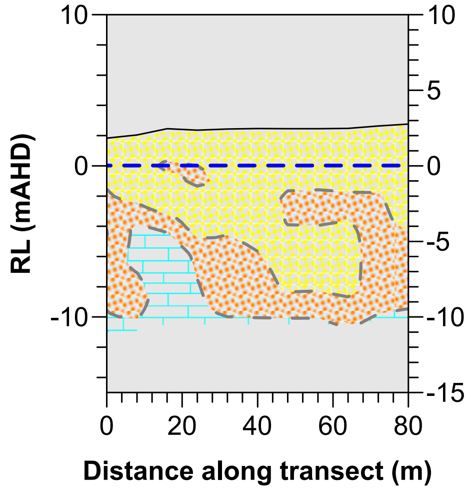
TRANSECT 13 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 14 - SEISMIC SHEAR WAVE VELOCITY MODEL



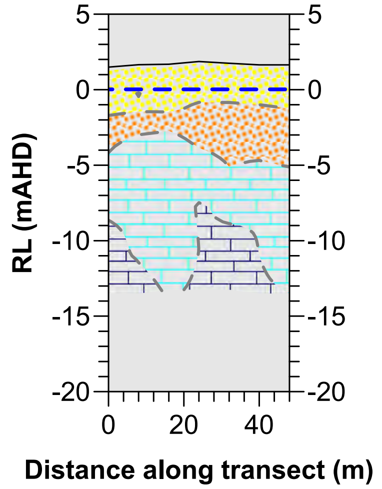
TRANSECT 13 - INTERPRETED GEOLOGICAL SECTION



7129348.0 mE
754763.3 mN

7129424.8 mE
754789.0 mN

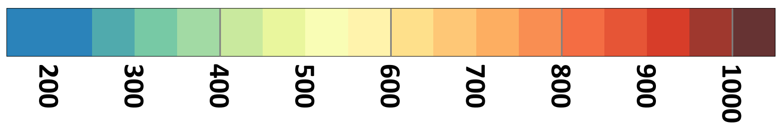
TRANSECT 14 - INTERPRETED GEOLOGICAL SECTION



7129328.8 mE
754841.1 mN

7129372.2 mE
754856.5 mN

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 VARIABLY WEATHERED ROCK
S-WAVE VELOCITY 350-475 m/s

MODERATE STRENGTH COMPETENT ROCK
S-WAVE VELOCITY > 475 m/s.

0m AUSTRALIAN HEIGHT DATUM

NOTES

Drawing to be used in conjunction with Report 3095A.
Positioning is given in GDA94 zone 49.
Levels are given in Australian Height Datum (AHD).

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	26 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000H, 1:500V	Drawn	OMLE
		Drawing	3095A-10	Revision	0

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APPENDIX C – MODELLED LEVELTO TOP OF ROCK AND SAND THICKNESS

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

SURFACE LEVEL MODEL (EAST)

NOTES

Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	OMLE
		Drawing	3095A-11	Revision	0

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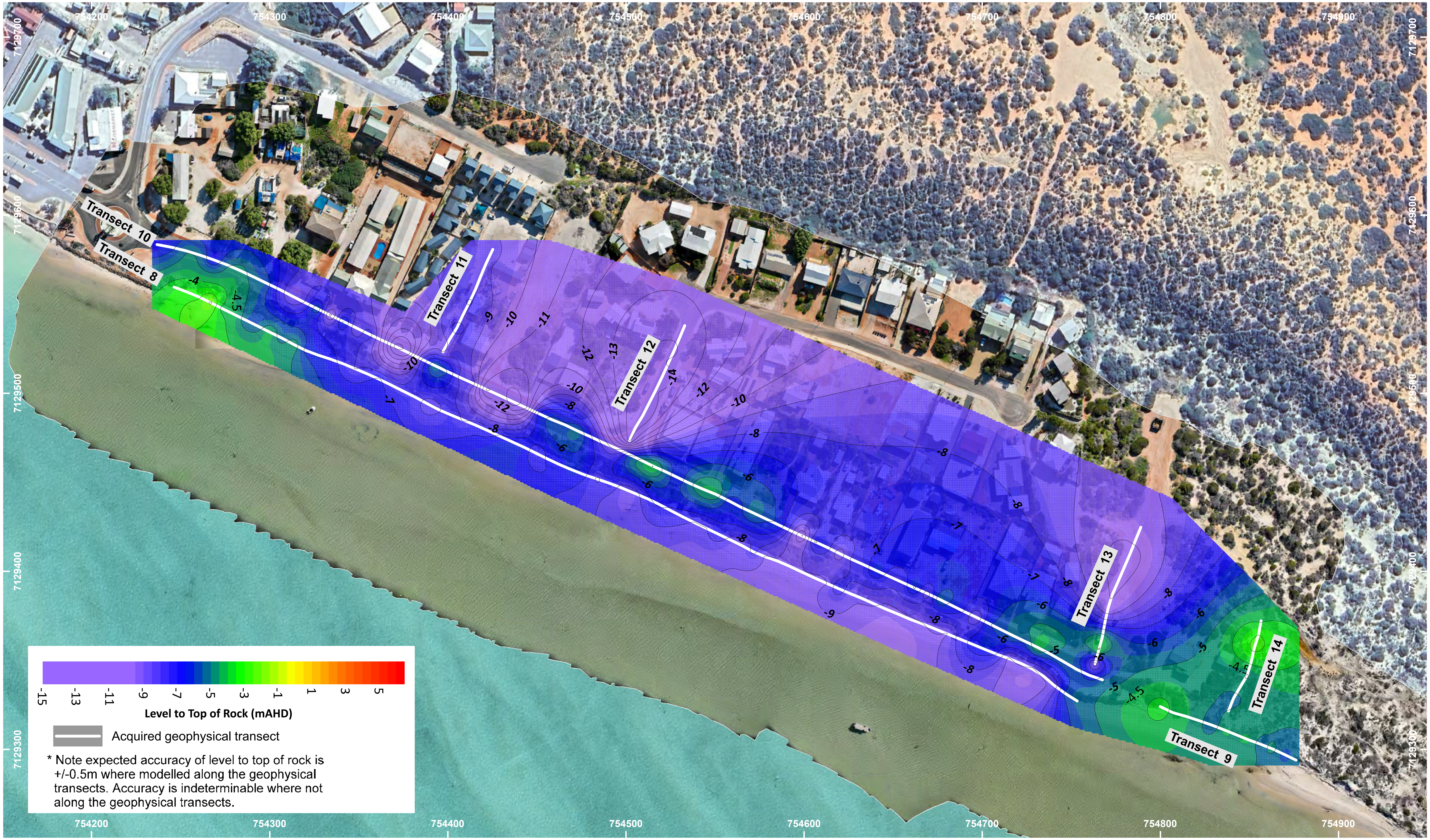
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK (EAST)



NOTES

Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	OMLE
		Drawing	3095A-13	Revision	0

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CLASSED POST MAP LEVEL TO TOP OF ROCK (EAST)

NOTES

Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	OMLE
		Drawing	3095A-15	Revision	0

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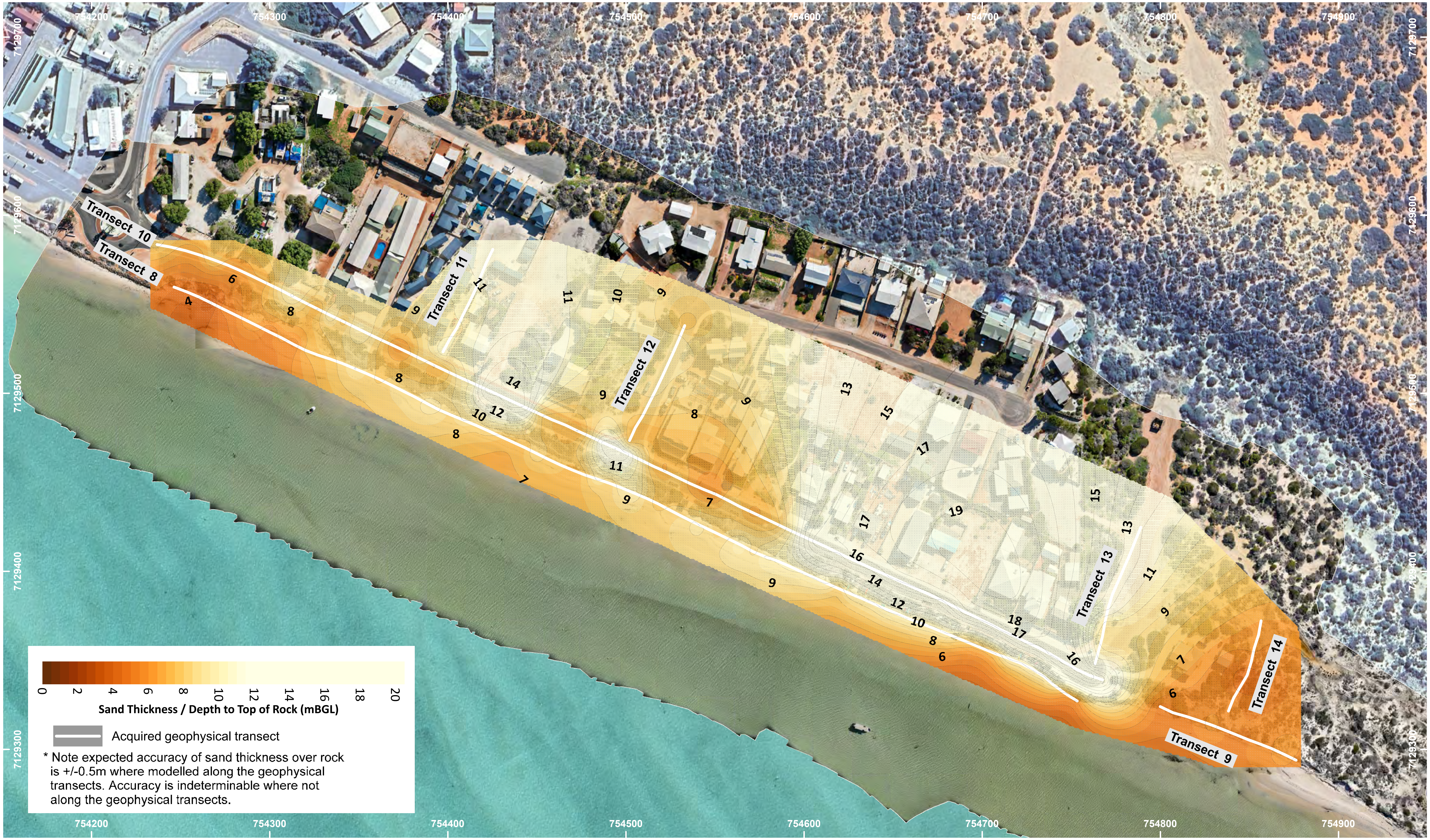
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CONTOUR SAND THICKNESS / DEPTH TO TOP OF ROCK (EAST)



NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	OMLE
		Drawing	3095A-17	Revision	0

GBGGROUP

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CLASS POST MAP SAND THICKNESS / DEPTH TO TOP OF ROCK (EAST)

NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

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	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	OMLE
		Drawing	3095A-19	Revision	0

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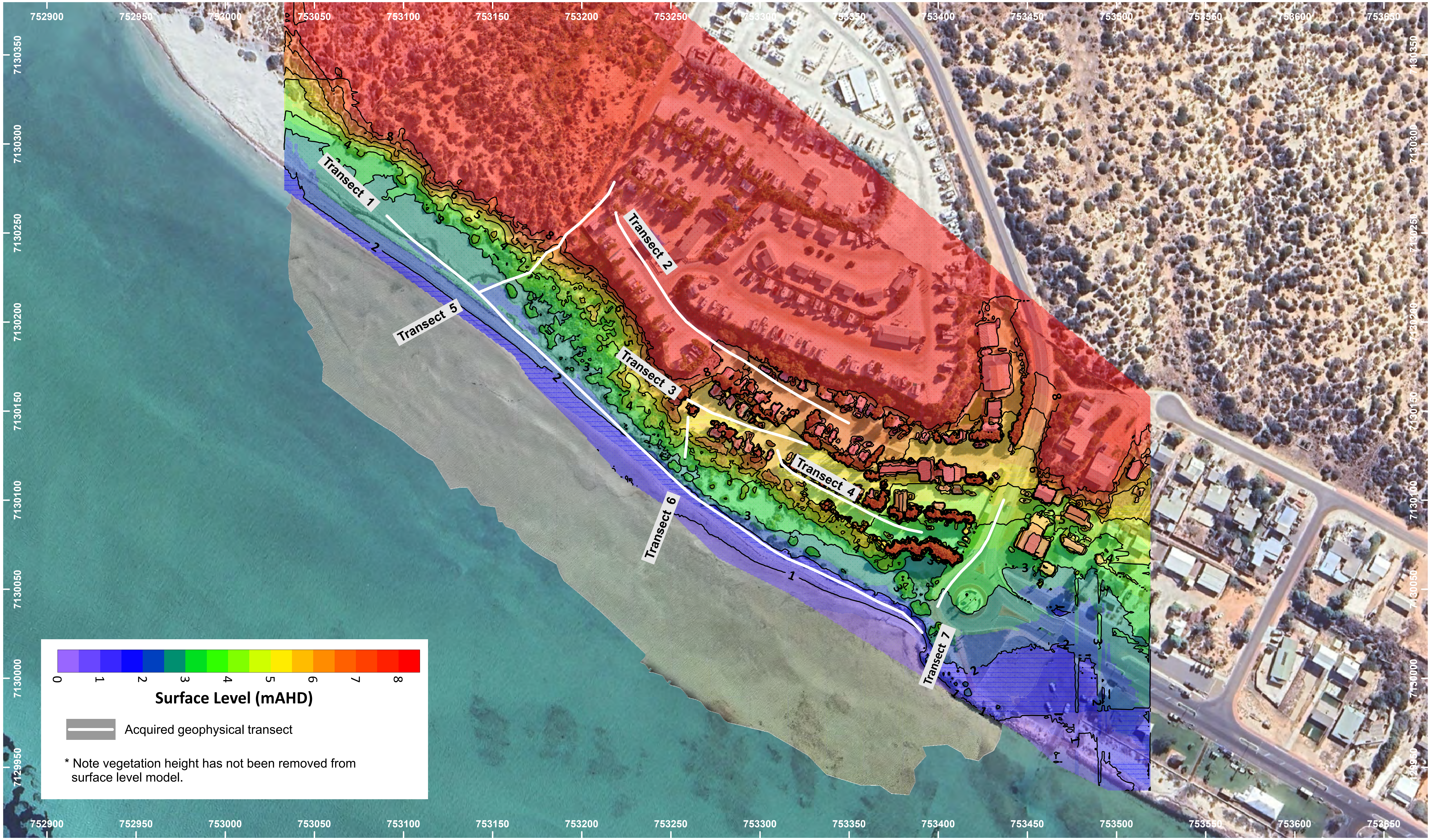
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

SURFACE LEVEL MODEL (WEST)



NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date: 27 July 2024	Paper Size: A3	
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale: 1:2000	Drawn: OMLE	
		Drawing: 3095A-12	Revision: 0	

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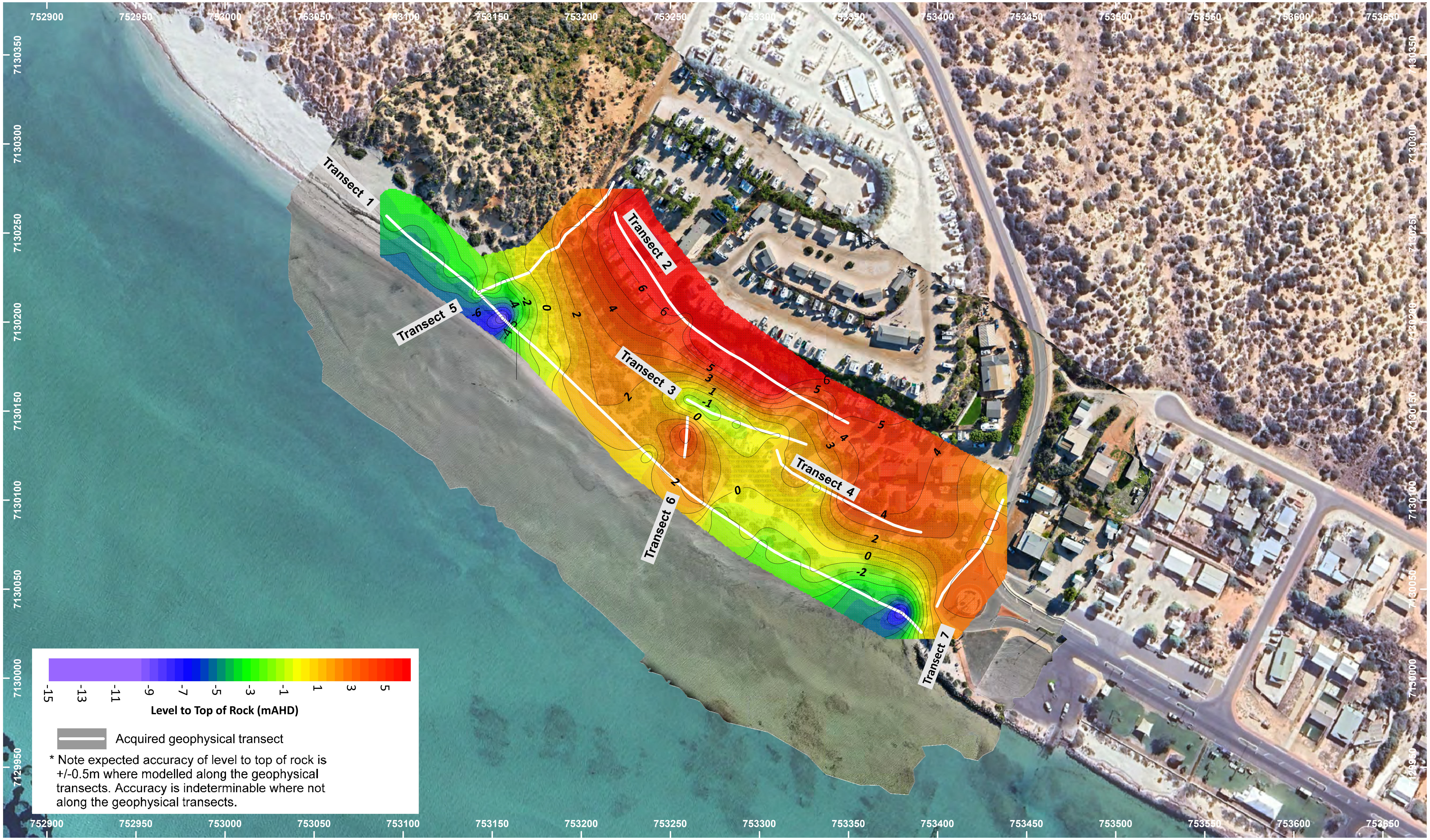
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK (WEST)



NOTES

Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	OMLE
		Drawing	3095A-14	Revision	0

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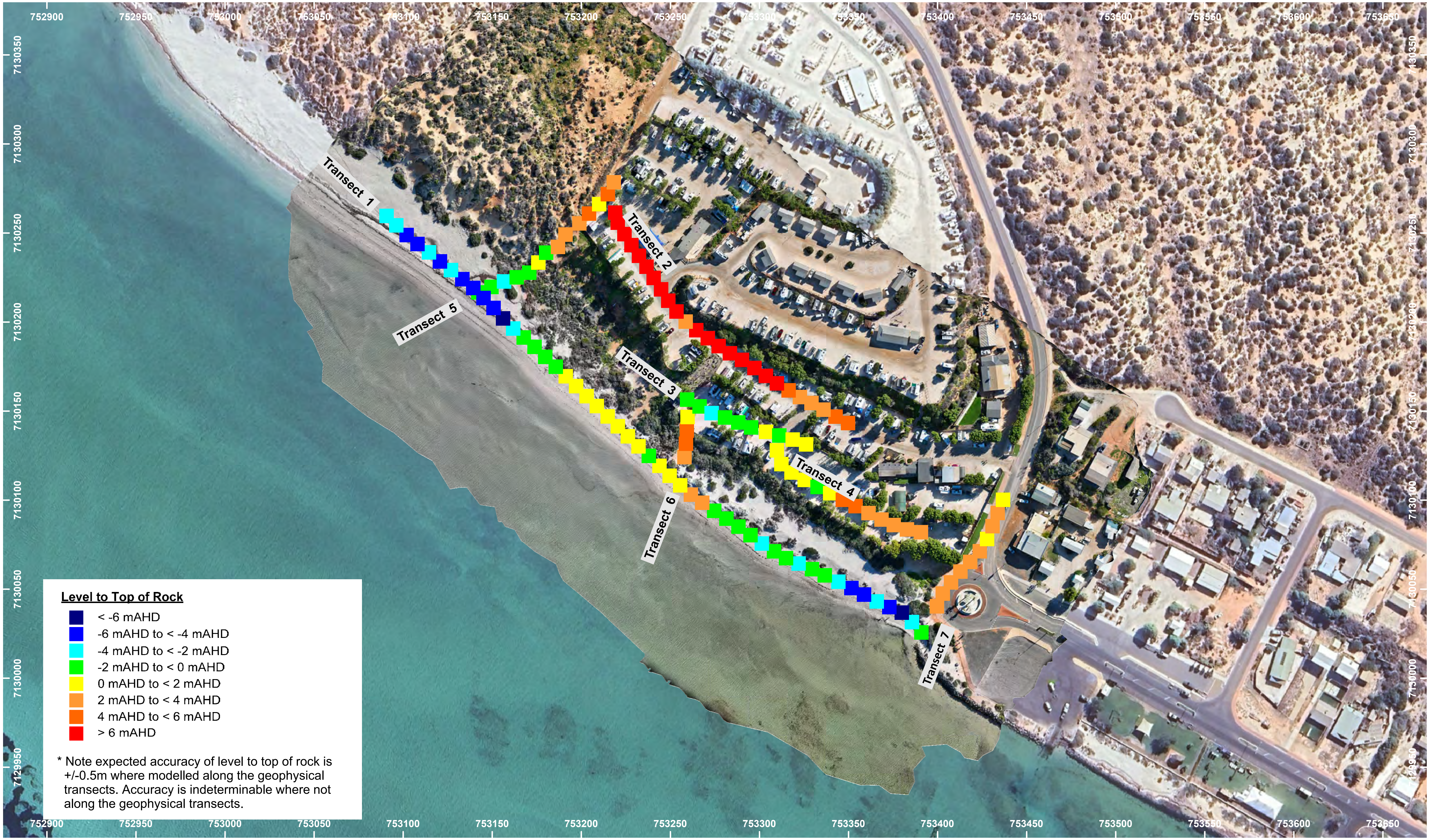
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CLASSED POST MAP LEVEL TO TOP OF ROCK (WEST)



NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA

Date	27 July 2024	Paper Size	A3
Scale	1:2000	Drawn	OMLE
Drawing	3095A-16	Revision	0

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CONTOUR SAND THICKNESS / DEPTH TO TOP OF ROCK (WEST)

NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date	27 July 2024	Paper Size	A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale	1:2000	Drawn	OMLE
		Drawing	3095A-18	Revision	0

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
DENHAM, SHIRE OF SHARK BAY WESTERN AUSTRALIA

CLASS POST MAP LEVEL SAND THICKNESS / DEPTH TO TOP OF ROCK (WEST)

NOTES
Drawing to be used in conjunction with Report 3095A.
Map Projection GDA94 MGA Zone 49.
Aerial image from Google Earth Pro and GBG photogrammetry.

0 25 50 75 100
Distance (metres)

N

CLIENT	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date 27 July 2024	Paper Size A3
	GEOPHYSICAL INVESTIGATION FOR COASTAL EROSION VULNERABLITY ASSESSMENT DENHAM, SHIRE OF SHARK BAY WA	Scale 1:2000	Drawn OMLE
		Drawing 3095A-20	Revision 0

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