GB Geotechnics (Australia) Pty Ltd
Web: gbg-group.com.au
E-Mail: info@gbgoz.com.au
ABN 77 009 550 869

Report

Geotechnical Investigation for Coastal Erosion Vulnerability Assessment.

Exmouth, Shire of Exmouth WA.

Date: 20 January 2023
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DOCUMENT HISTORY

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COMPANY DETAILS

Business name	GB Geotechnics (Australia) Pty Ltd
ABN	77 009 550 869
Business address	1/11 Gympie Way, Willetton WA 6155
Phone	0438 398 800
Web	gbg-group.com.au
Email	info@gbgoz.com.au

EXECUTIVE SUMMARY

A geotechnical investigation has been carried out as part of a coastal erosion assessment at Exmouth in the Shire of Exmouth, Western Australia. During the investigation ground geophysical testing was conducted within a 4000m corridor of coastal beach and dune formation adjacent to the Exmouth settlement which has been identified as an at-risk site as part of Coastal Hotspot #5.

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 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 10m below ground level. The seismic velocity sections were demarcated into velocity ranges representing different material types and conditions for the generation of interpreted geological sections consisting of loose to compacted sediment and variably weathered to fresh rock.

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

The following observations have been made:

- Interpreted rock substrate was observed along all the transects and within the maximum target investigation depth of 10-15m below ground level.
- Interpreted top of rock substrate for Exmouth South, south of the Exmouth Marina ranged from -1.85mAHD to 5.75mAHD with an average level of 1.85mAHD. The thickness of overlying sediment ranged from less than 0.25m to 4.5m and averaged 1.15m.
- Interpreted top of rock substrate for Exmouth North, north of the Exmouth Marina was generally deeper than Exmouth South ranging from -8mAHD to 6.5mAHD with an average level of 0.35mAHD. The thickness of overlying sediment ranged from less than 0.25m to 9.85m and averaged 3.85m.

CONTENTS

1 INTRODUCTION

At the request of The Government of Western Australia Department of Transport (DoT), GBG Group carried out a geotechnical investigation at Exmouth, Shire of Exmouth in December 2023. During the investigation seismic geophysical testing was conducted within a 4000m corridor of coastal beach and dune formation which has been identified as an at risk site as part of Coastal Hotspot #5.

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.

Note due to presence of heritage sites within the investigation area, intrusive geotechnical testing was not carried out, and as such calibration and ground truthing of the geophysical dataset was not possible for this investigation.

2 INVESTIGATION SITE

The investigation was carried out within approximate 4000m corridor of coastal beach and dune formation the extents of which are shown as yellow dashed areas in Figure 1 and 2 as follows;

- Exmouth South – 600m section south of Exmouth Marina and to the east of Neale Cove and Crevalle Way.
- Exmouth North – 3000m section north of Exmouth Marina, to the east of Madaffari Drive, Osprey Way, Truscott Crescent and Willersdorf Road, and south of the Exmouth Golf Club.

Data was acquired as a series of transects for the seismic geophysical testing. These were positioned to best utilise existing roads, tracks, and beach whilst not impacting 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 or steep topography. Photographs showing the typical site conditions are provided in Figure 3.

Topography at the sites was undulating with an elevation difference for the Exmouth South site between ~0-2mAHD at the foreshore, ~4-15mAHD at the dune formation, and ~4-6mAHD at the existing settlement. The elevation difference for the Exmouth North site was between ~0-2mAHD at the foreshore, ~4-15mAHD at the dune formation, and ~4-9mAHD at the existing settlement. Topographic maps showing surface level are provided in Appendix C drawings 3095B-19 to 3095B-21.

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

Figure 2: The extent of the geophysical investigation (yellow polygon) at Exmouth North. Aerial imagery from drone photogrammetry (main image) and Google Maps (inset image).

Figure 3 Site conditions at Exmouth including along the beach foreshore (top left image), road adjacent to the settlement (top right image) and dune formation (bottom left and right images)

3 INVESTIGATION METHODOLOGY

3.1 FIELD SURVEY LOGISTICS

Geophysical data acquisition was carried out on from the 4 to 11 December 2023 by a two-person team from GBG Group consisting of qualified geophysicists. Where required, the site work was carried out under appropriate traffic and pedestrian management commissioned by the Shire of Exmouth.

Prior to the commencement of data acquisition, a site assessment was carried out with representatives from the Shire of Exmouth. 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 8408m of MASW profiling acquired as 8 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 3095B-01 for Exmouth South and 3095B-02 and 3095B-03 for Exmouth North.

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

Transect ID	Orientation	Start Coordinate		End Coordinate		Length (m)
		East	North	East	North	
Exmouth South						
T1	Along-shore	204243.6	7568459.1	204415.5	7569029.8	600
T2a	Along-shore	204148.1	7568496.7	204188.3	7568603.0	112
T2b	Along-shore	204197.7	7568650.7	204408.7	7569081.5	552
T3	Cross-shore	204213.0	7568701.0	204303.9	7568742.6	104
T4	Cross-shore	204393.5	7569105.5	204410.5	7569008.7	96
Exmouth North						
T5	Along-shore	204505.9	7569531.6	204619.0	7570474.7	976
T6	Along-shore	204591.4	7570487.6	204451.6	7572407.7	1968
T7	Along-shore	204284.7	7569526.6	204433.5	7570240.4	744
T8	Along-shore	204396.5	7570243.9	204414.3	7570382.1	136
T9	Along-shore	204456.9	7570434.8	204379.4	7572422.5	2128
T10	Cross-shore	204293.9	7569732.0	204517.6	7569742.6	216
T11	Cross-shore	204452.8	7570446.0	204602.3	7570505.4	184
T12	Cross-shore	204400.0	7570873.9	204637.2	7570898.6	240
T13	Cross-shore	204453.7	7571252.0	204590.9	7571295.8	144
T14	Cross-shore	204274.5	7572409.2	204455.1	7572389.4	208

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 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 or 6.35kg sledgehammer
Source offset	4 m
Sounding interval	8m
Source stacks	3

Figure 4: MASW data acquisition using a seismic streamer.

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

1. Import acquired seismic data files and apply geometry including geophone spacing, source offset and sounding interval.
2. Generate overtone images giving the percentage intensity of phase velocity versus frequency for each seismic record (Figure 5, left image).
3. Pick the maximum intensity across the useful range of frequencies for each overtone image resulting in a dispersion curve.
4. Run the dispersion curves through a 10-layer inversion algorithm to produce 1D soundings plotting seismic S-wave velocity with depth (Figure 5, right image).

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

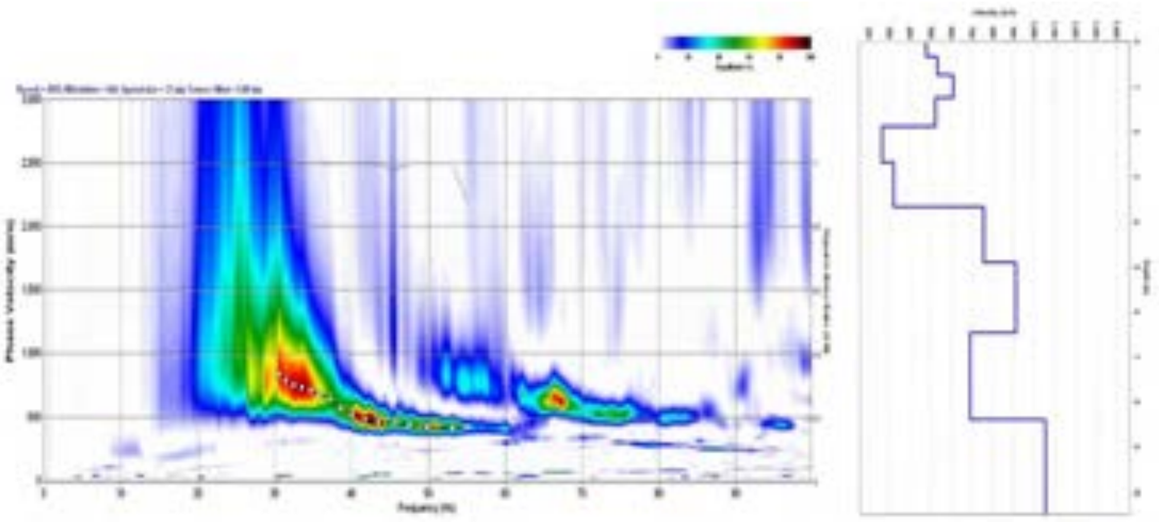


Figure 5: MASW overtone image with high signal to noise ratio and picked dispersion curve.

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 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 real-time corrected with GNSS data streams from Continuously Operating Reference Stations (CORS) using the Geoscience Australia AUSCORS NTRIP Broadcaster. Details of the AUSCORS correction used for this investigation are provided in Table 3.

Table 3 – Details of AUSCORS NTRIP

Parameter	Value
Latitude	-21.96067°
Longitude	114.11338°
Derived GDA94 ellipsoidal height (m)	16.433m
N-Value (m)	-13.91
Height (m) (AHD)	30.343

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, equipped with an integrated 20MP wide-angle camera for the capture of multiple overlapping images.

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

4 RESULTS AND INTERPRETATION

4.1 PRESENTATION OF RESULTS

The results of the geotechnical investigation at Exmouth, Shire of Exmouth are presented in Appendices B and E of this report as follows:

Appendix B – Geophysical and Interpreted Sections

- **3095B-04.** Transect 1 seismic S-wave velocity model and interpreted geological section.
- **3095B-05.** Transects 2a & 2b seismic S-wave velocity model and interpreted geological section.
- **3095B-06.** Transects 3 & 4 seismic S-wave velocity model and interpreted geological section.
- **3095B-07 and 3095B-08.** Transect 5 seismic S-wave velocity model and interpreted geological section.
- **3095B-09, 3095-10 and 3095B-11.** Transect 6 seismic S-wave velocity model and interpreted geological section.
- **3095B-12.** Transect 7 seismic S-wave velocity model and interpreted geological section.
- **3095B-13.** Transect 8 seismic S-wave velocity model and interpreted geological section.
- **3095B-14, 3095-15 and 3095B-16.** Transect 9 seismic S-wave velocity model and interpreted geological section.
- **3095B-17.** Transects 10, 11 & 12 seismic S-wave velocity model and interpreted geological section.
- **3095B-18.** Transects 13 & 14 seismic S-wave velocity model and interpreted geological section.

Appendix C – Surface Level Models

- **3095B-19 to 3095B-21.** Contoured surface level models derived from aerial photogrammetry.

Appendix D – Level to Top of Rock

- **3095B-22 to 3095B-24.** Contoured level to modelled top of rock.
- **3095B-25 to 3095B-27.** Class post map level to modelled top of rock.

Appendix E – Sand Thickness Over Rock

- **3095B-28 to 3095B-30.** Contoured modelled sand thickness over rock.
- **3095B-31 to 3095B-33.** Class post map modelled sand thickness over rock.

4.2 SEISIMC SHEAR WAVE VELOCITY SECTIONS

The seismic S-wave velocity (Vs) sections modelled from the MASW data acquired along the along-shore and cross-shore transects are presented at the top of each drawing in Appendix B. These sections show variations in the modelled Vs as per the colour scale with velocity ranging from 200m/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 for example 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 variably weathered rock of low material strength and stiffness. 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 competent (slightly weathered to fresh) rock of moderate material strength and stiffness. 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

Intrusive geotechnical methods such as cone penetrometer testing or boreholes were not carried out as part of the scope for this investigation due to restrictions on groundbreaking at the site. A review of existing historic borehole logs was conducted including from the Department of Water and Environmental Regulation (DWER) water information reporting database, however no suitable existing lithological logs within the investigation areas were available. Without intrusive geotechnical data, calibration and ground truthing of the geophysical dataset was not possible for this investigation.

From analysis of the aerial photogrammetry, surface outcropping rock extending approximately 80m north-south is present on the beach at Exmouth South adjacent to Crevalle Way. This corresponds to the interpreted shallow and very near surface rock at the end of Transect 3 and between 200m and 300m along Transect 1. Outcropping rock shelves were also observed offshore at Exmouth South adjacent and at 0m to 200m along Transect 1 and corresponds to the overall shallow rock in this area.

Analysis of the aerial photogrammetry indicates no evidence of outcropping rock at Exmouth North within the area between the coastal foreshore and settlement.

4.5 MODELLED LEVEL TO TOP OF ROCK AND SAND THICKNESS

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

- **Contoured Surface Level Model** (drawings 3095B-19 to 3095B-21) – generated from the aerial photogrammetry, this presents the level to ground surface ranging from -1mAHD to 12mAHD. Note: vegetation height has not been removed from these models.

- **Contoured Level to Top of Rock Substrate** (drawings 3095B-22 to 3095B-24) – this presents the level to the top of rock substrate ranging from -6mAHD to 6mAHD.

- **Classed Post Map Level to Top of Rock Substrate** (drawing 3095B-25 and 3095B-27) – 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 Over Rock** (drawings 3095B-28 to 3095B-30) – this presents the thickness of sand overlying the rock substrate ranging from 0mBGL to 6mBGL.

- **Classed Post Map Sand Thickness Over Rock** (drawings 3095B-31 and 3095B-33) – this presents the thickness of sand overlying the rock substrate along the acquired transects at 1m depth increments from 1mBGL to 6mBGL.

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

The expected accuracy of the top of rock substrate modelled from this investigation is +/-0.5mAHD. Similarly, an accuracy of +/-0.5m is expected for the modelled sand thickness over rock. The quoted accuracies have been based on consideration to the accuracy of the GNSS receivers using during the site work, the 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 it 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 Exmouth in the Shire of Exmouth, Western Australia. During the investigation ground geophysical testing was conducted within a 4000m corridor of coastal beach and dune formation to the north and south of the Exmouth Marina and adjacent to the Exmouth settlement which has been identified as an at risk site as part of Coastal Hotspot #5.

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 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 low strength to competent high strength rock.

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

The methods used during the investigation are geophysical and as such the results are based on indirect measurements and the processing and interpretation of seismic wave signals without calibration to 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)

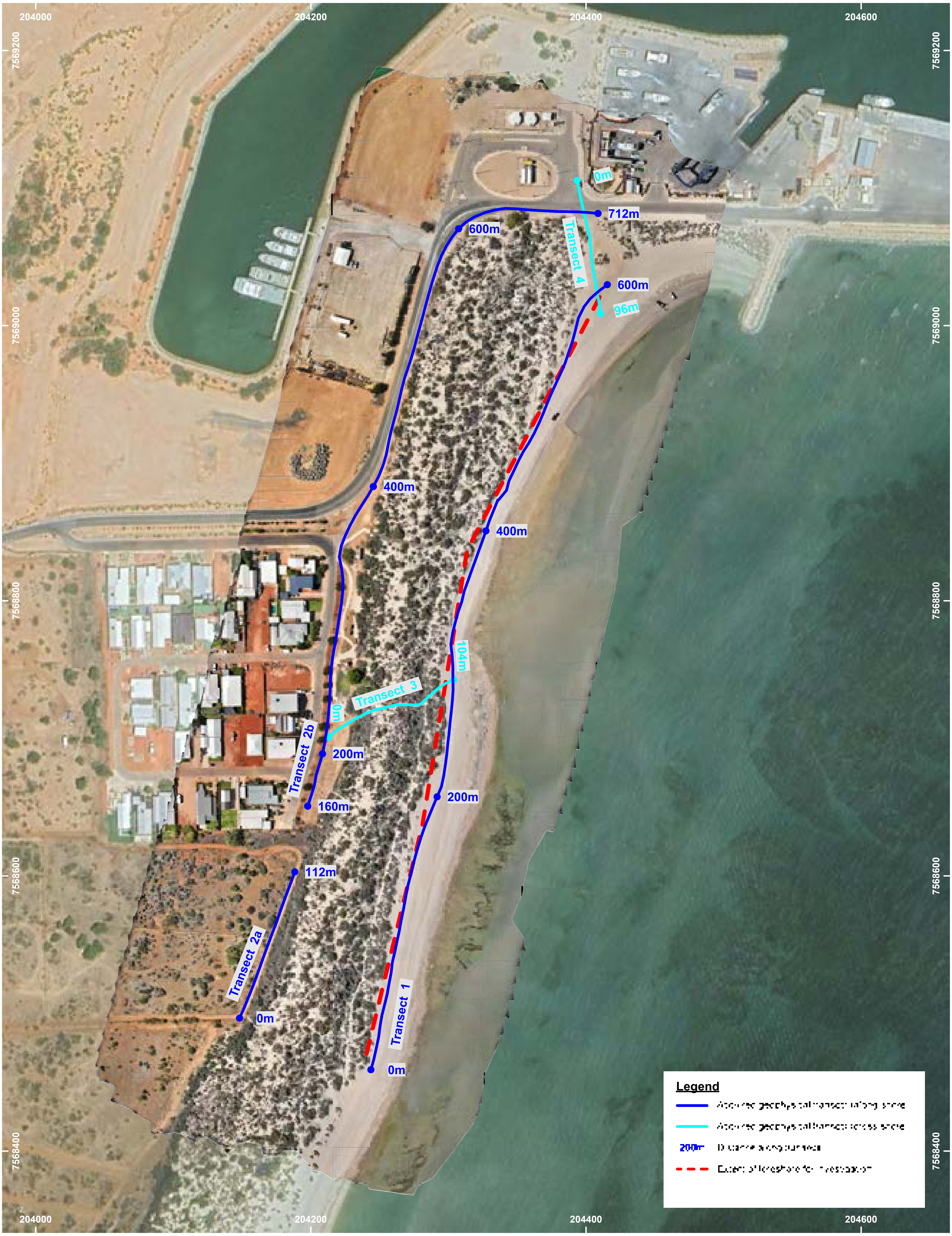
ANDREW SPYROU
Operations Manager, Western Australia / Senior Geophysicist

APPENDIX A – INVESTIGATION SITE MAPS

GBGGROUP

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

INVESTIGATION SITE MAP (SOUTH)



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	GBGGROUP
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA	

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

INVESTIGATION SITE MAP (NORTH)

NOTES	Date	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	GBGGROUP
N		GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA	

GBGGROUP

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

INVESTIGATION SITE MAP (NORTH)

N

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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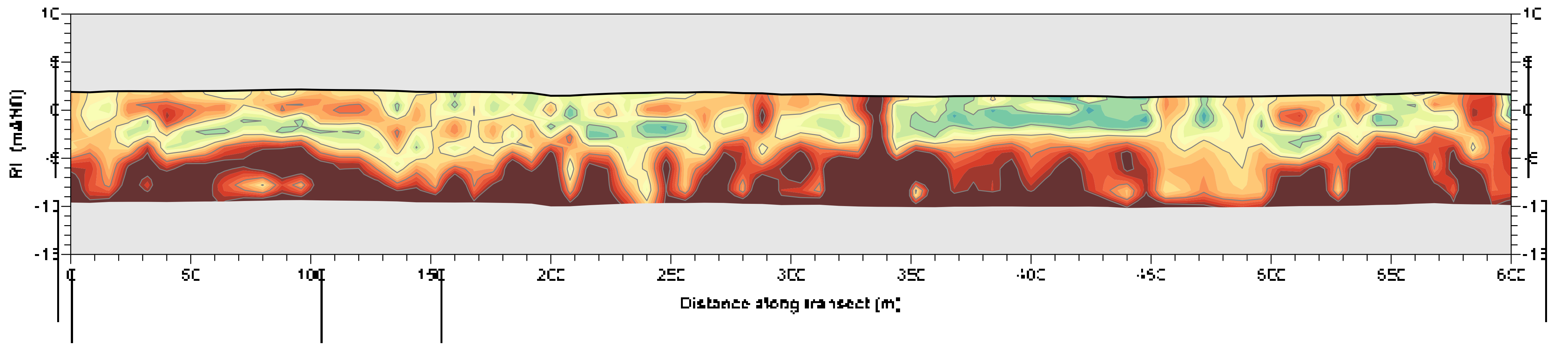
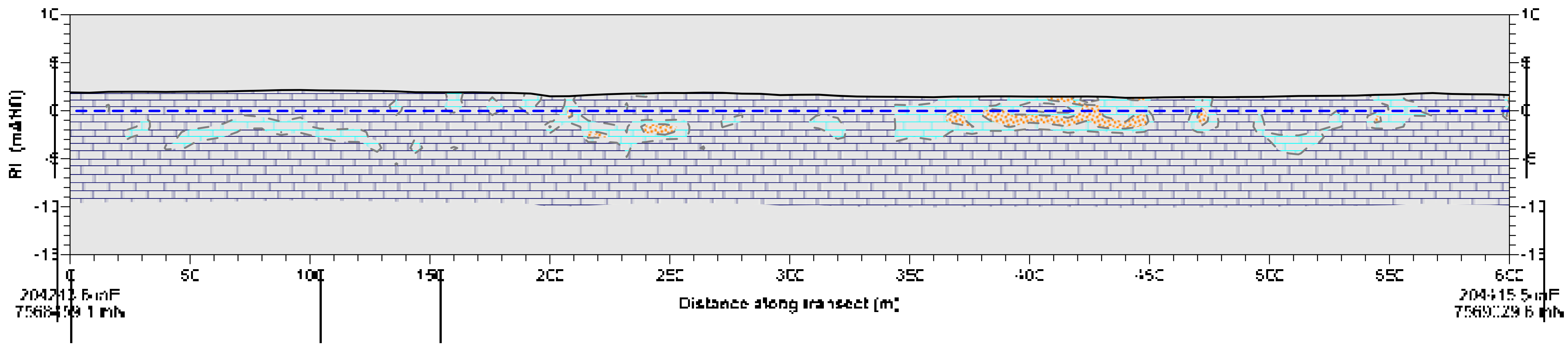
APPENDIX B – GEOPHYSICAL AND INTERPRETED SECTIONS

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

TRANSECT 1 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 1 - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)

INTERPRETED MATERIAL TYPE

- SAND - LOW COMPACTION
- SAND - MODERATE COMPACTION
- MODERATE STRENGTH COMPETENT ROCK
- 0m AUSTRALIAN HEIGHT DATUM

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date		
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA			

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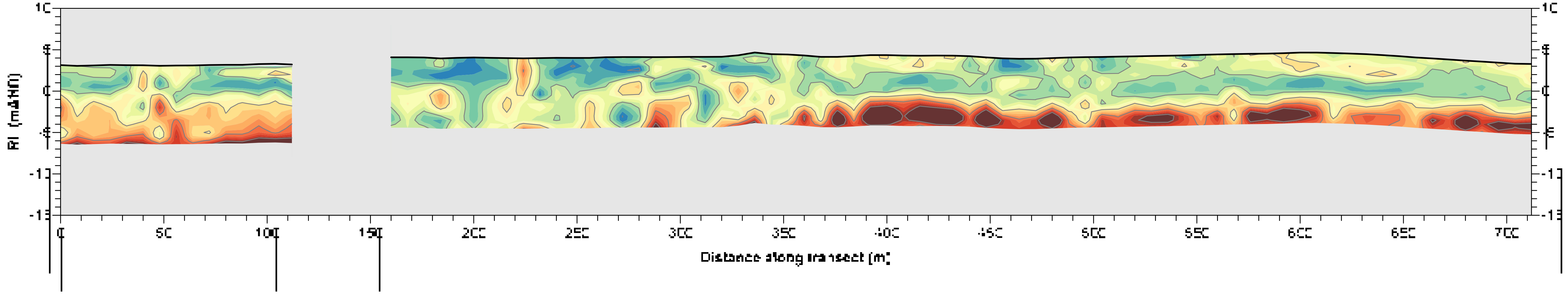
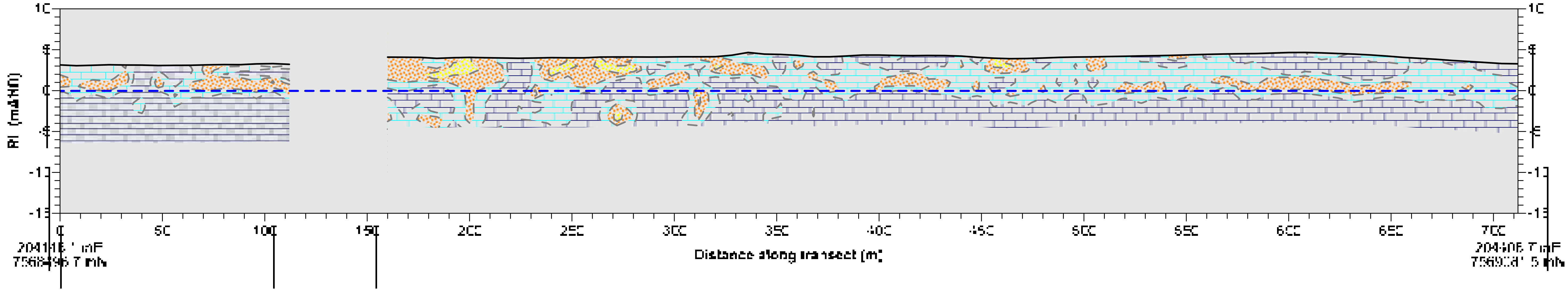
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

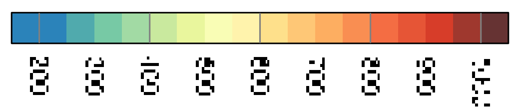
TRANSECT 2 - SEISMIC SHEAR WAVE VELOCITY MODEL



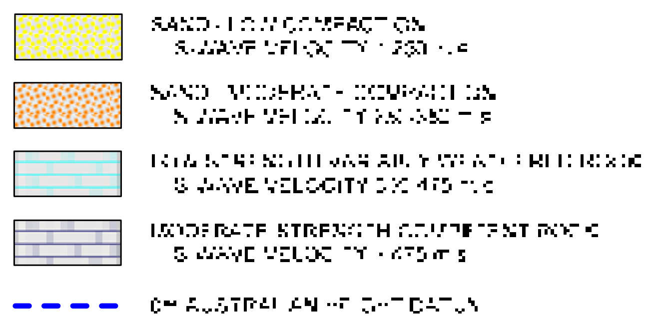
TRANSECT 2 - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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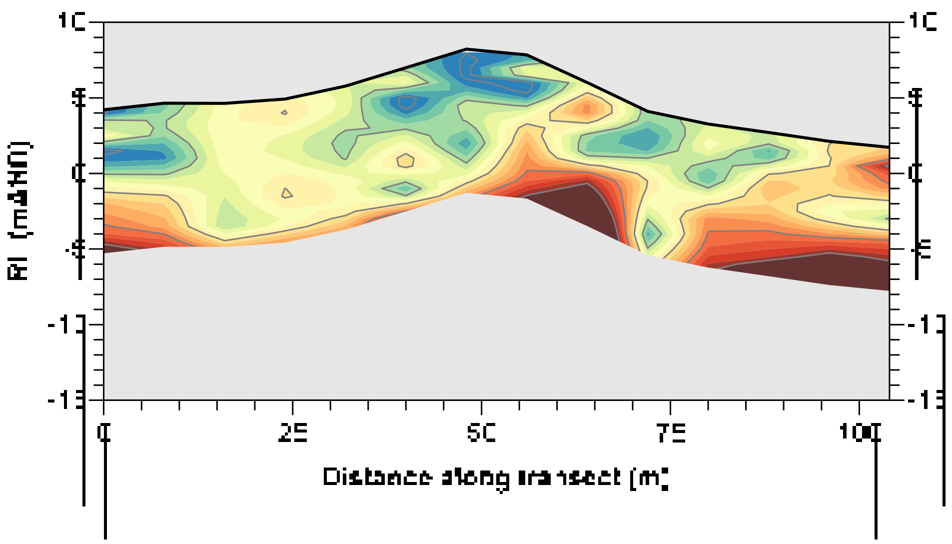
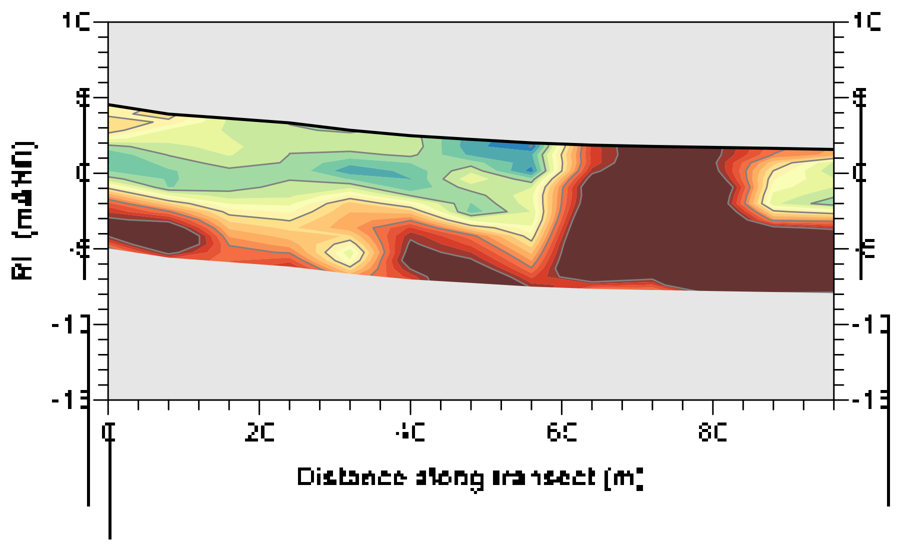
MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

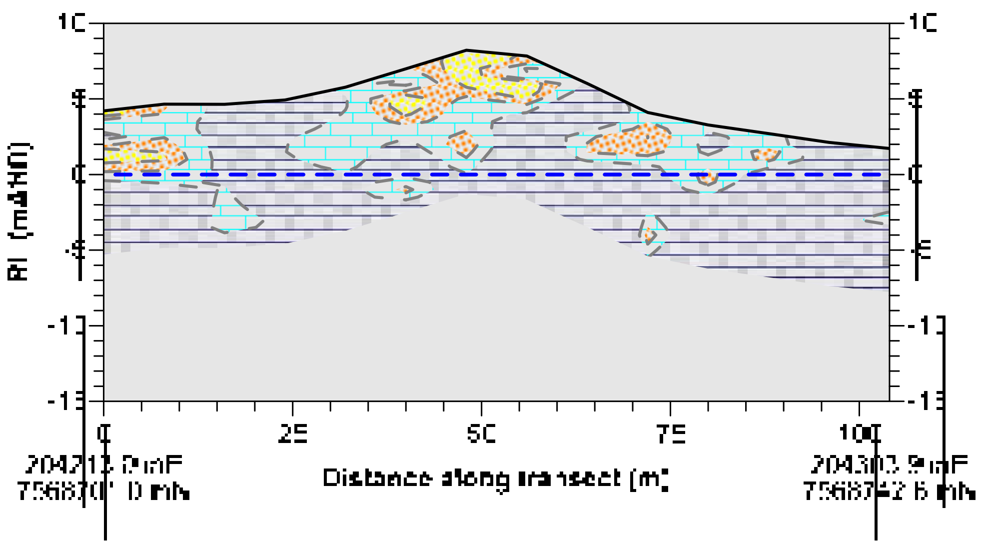
TRANSECT 3 - SEISMIC SHEAR WAVE VELOCITY MODEL



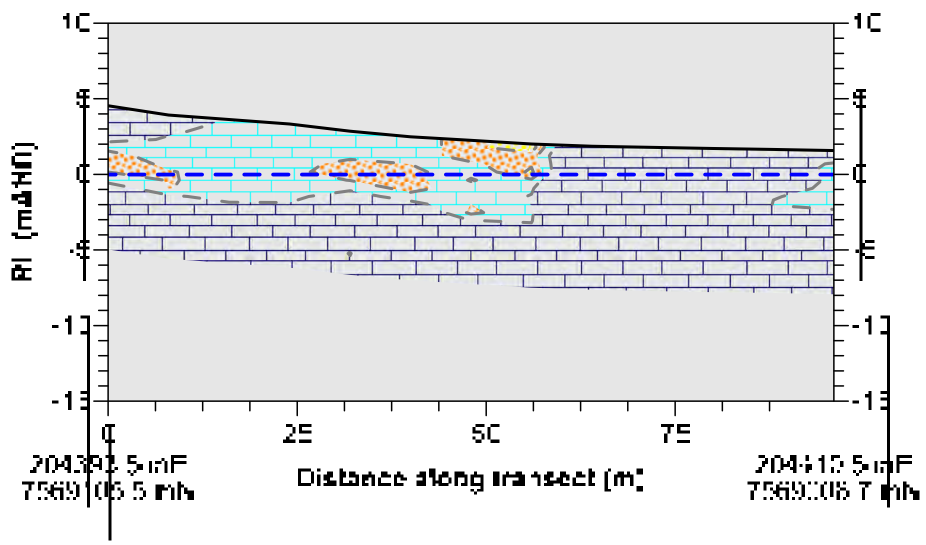
TRANSECT 4 - SEISMIC SHEAR WAVE VELOCITY MODEL

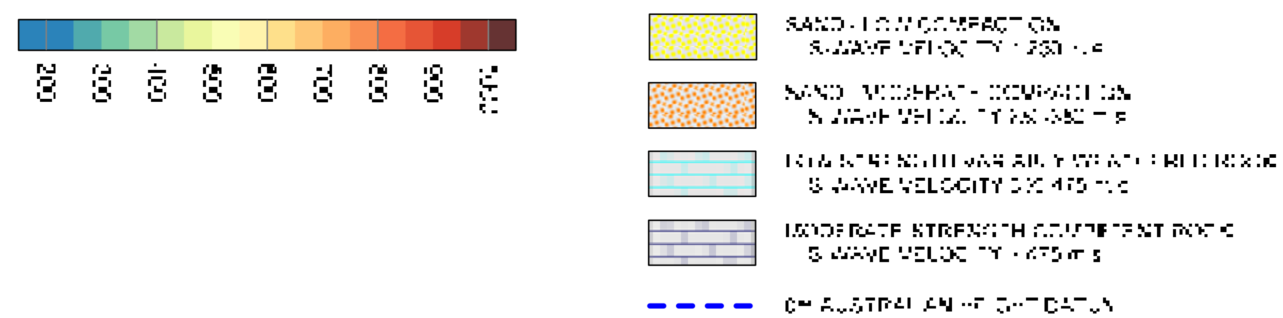


TRANSECT 3 - INTERPRETED GEOLOGICAL SECTION



TRANSECT 4 - INTERPRETED GEOLOGICAL SECTION





DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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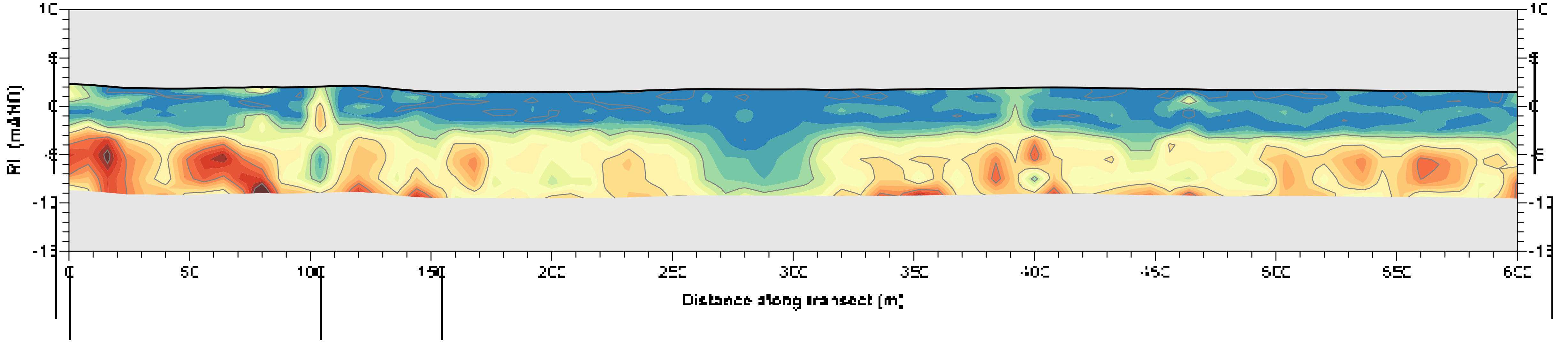
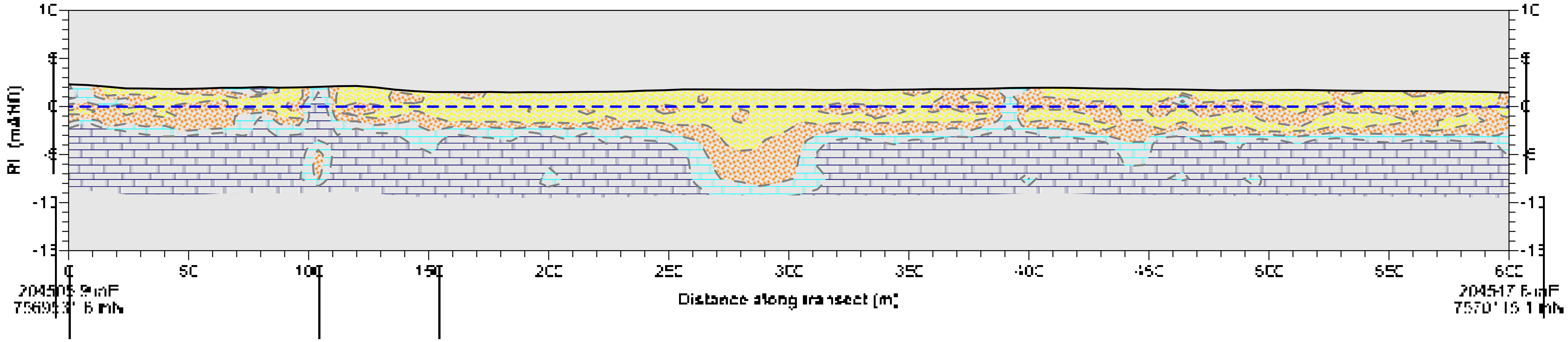
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

TRANSECT 5 (0-600m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 5 (0-600m) - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)

INTERPRETED MATERIAL TYPE

SAND - LOW COMPACTION [illegible]

SAND - MODERATE COMPACTION [illegible]

[illegible] S-WAVE VELOCITY [illegible] 475 m/s

MODERATE STRENGTH [illegible] S-WAVE VELOCITY [illegible] 475 m/s

0m AUSTRALIAN [illegible] DATUM

NOTES [illegible]

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	Date [illegible]	[illegible]	
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA	[illegible]	[illegible]	
	[illegible]	[illegible]	

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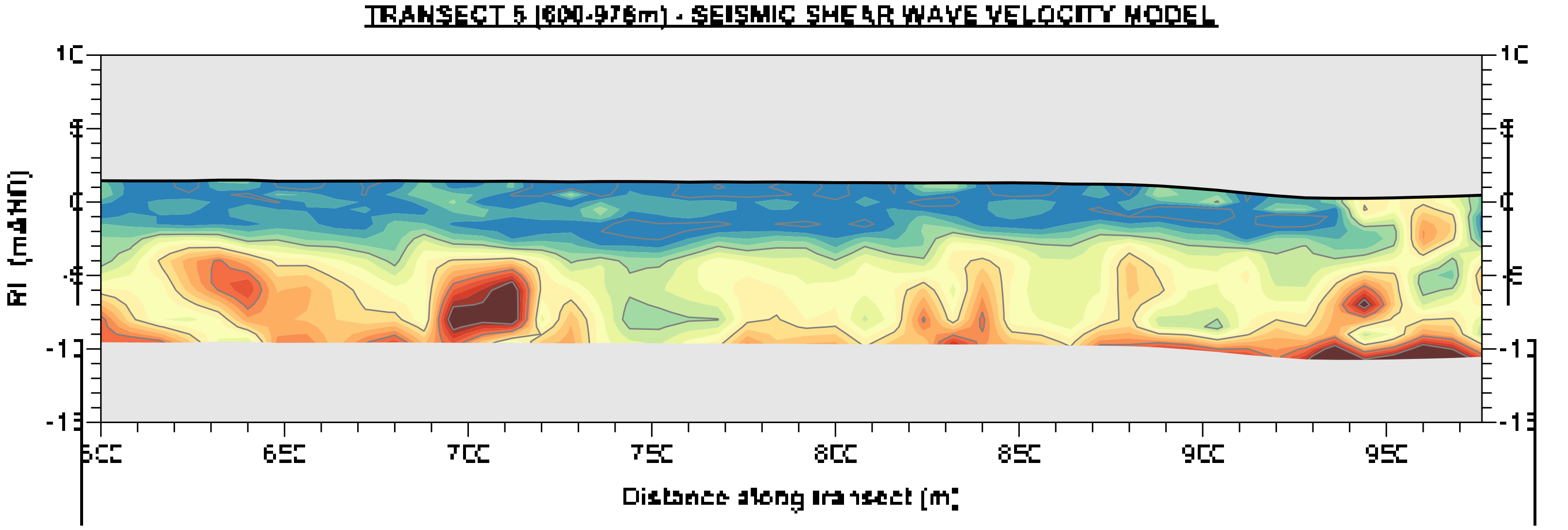
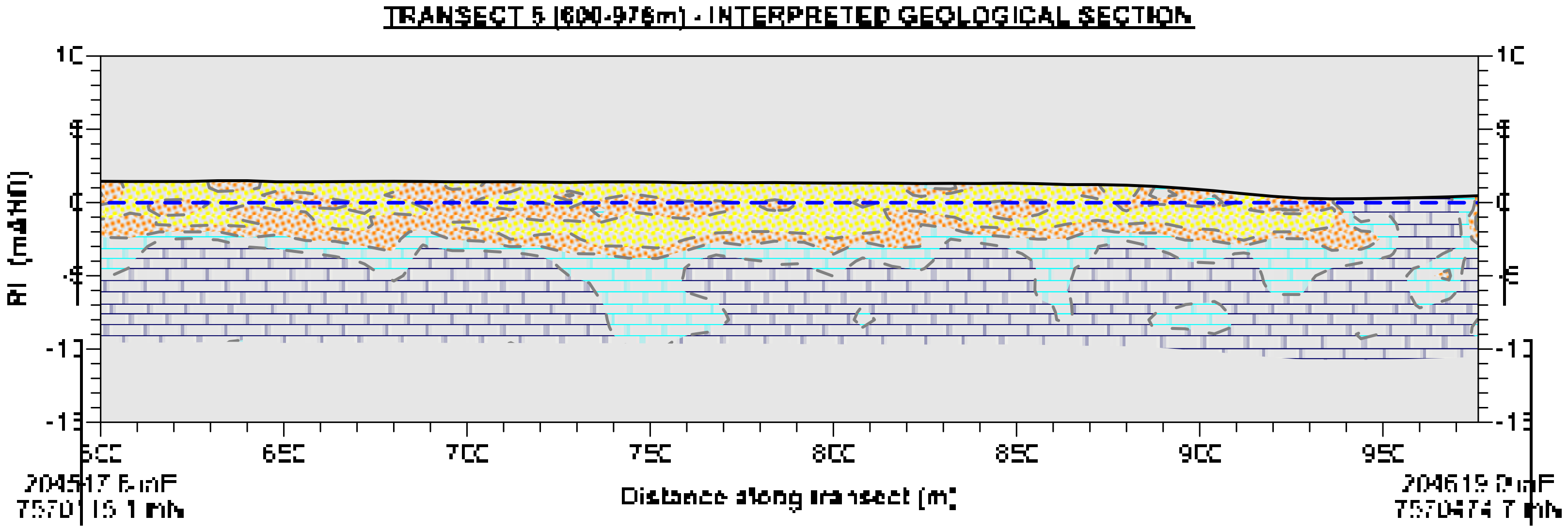
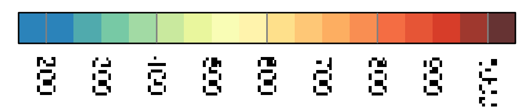
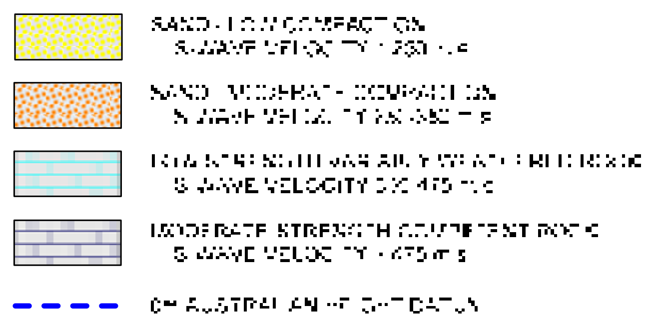
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES









NOTES	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA			GBGGROUP
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA			

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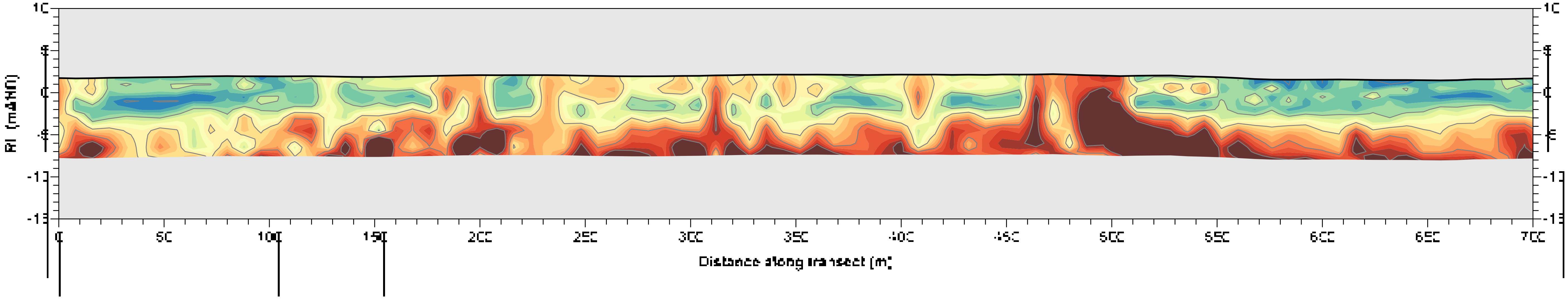
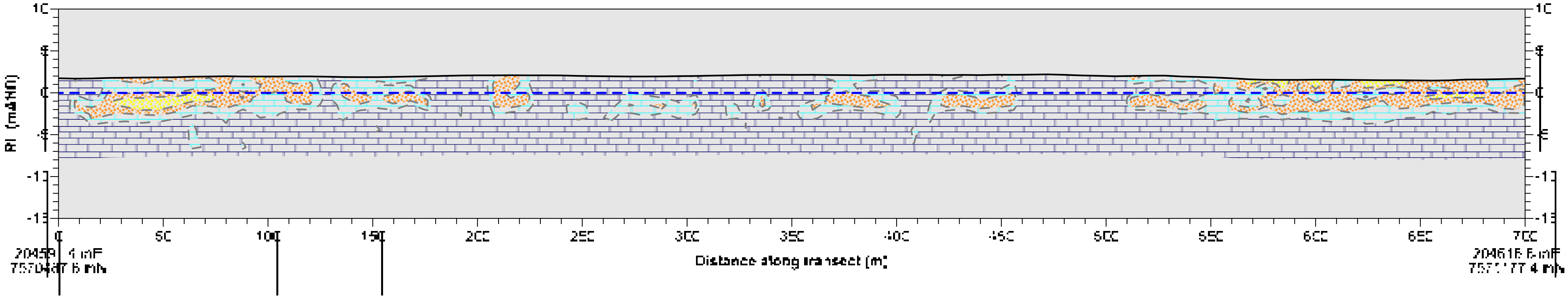
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

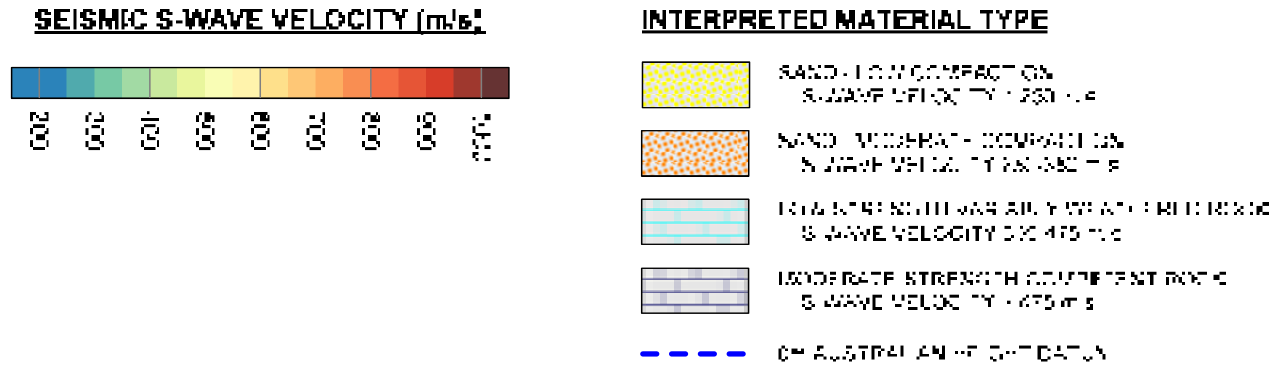
MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

TRANSECT 6 (0-700m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 6 (0-700m) - INTERPRETED GEOLOGICAL SECTION





DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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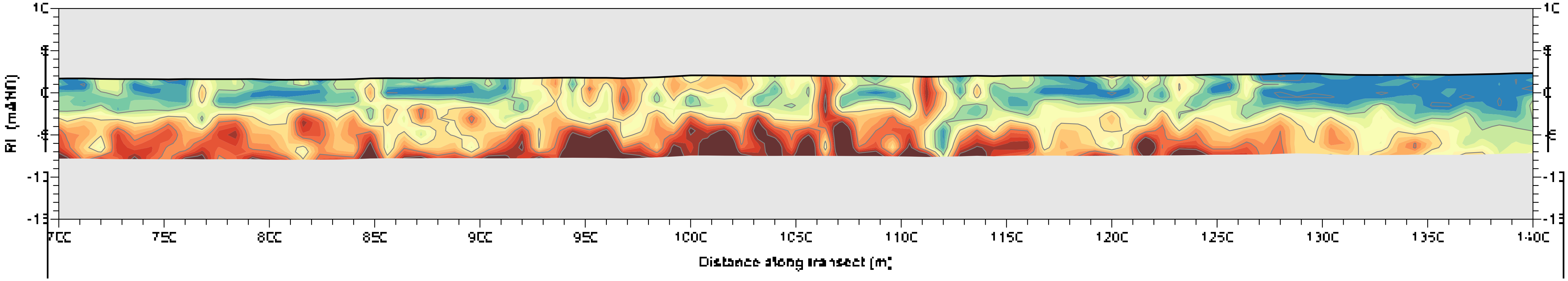
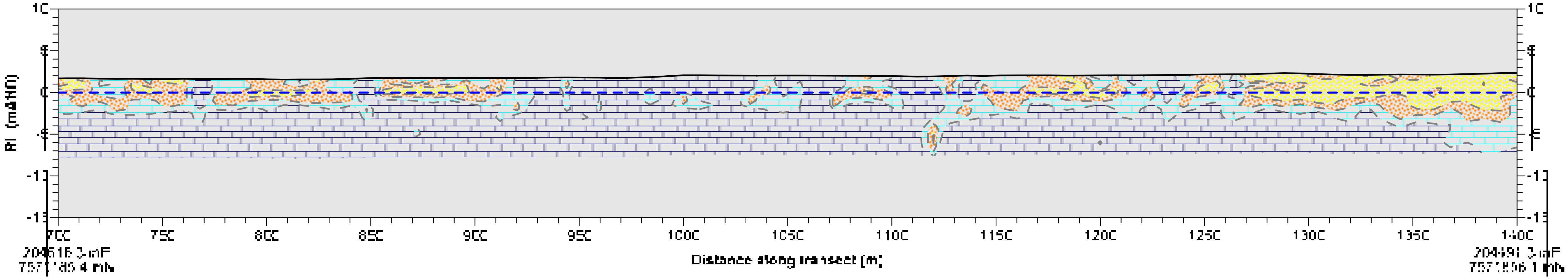
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

TRANSECT 6 (700-1400m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 6 (700-1400m) - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)

INTERPRETED MATERIAL TYPE

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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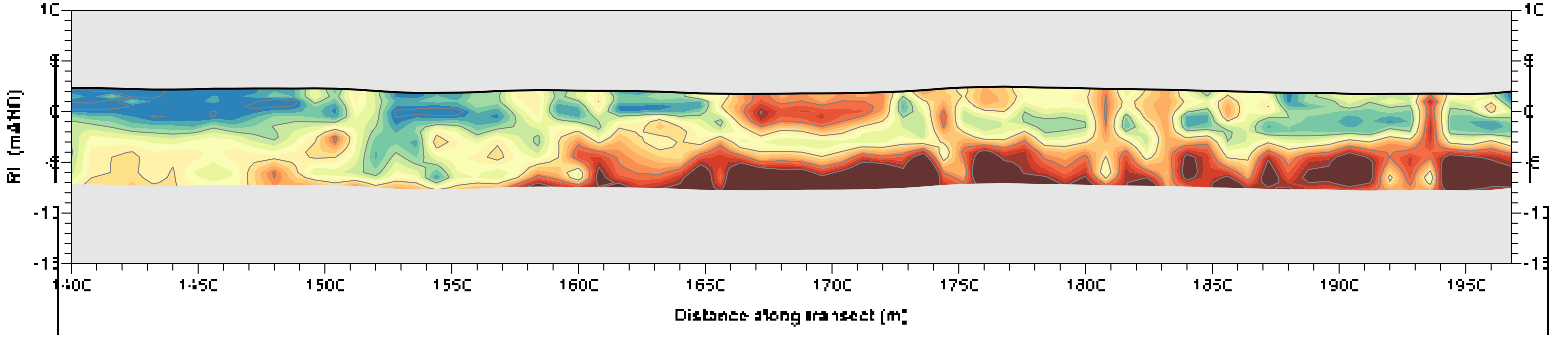
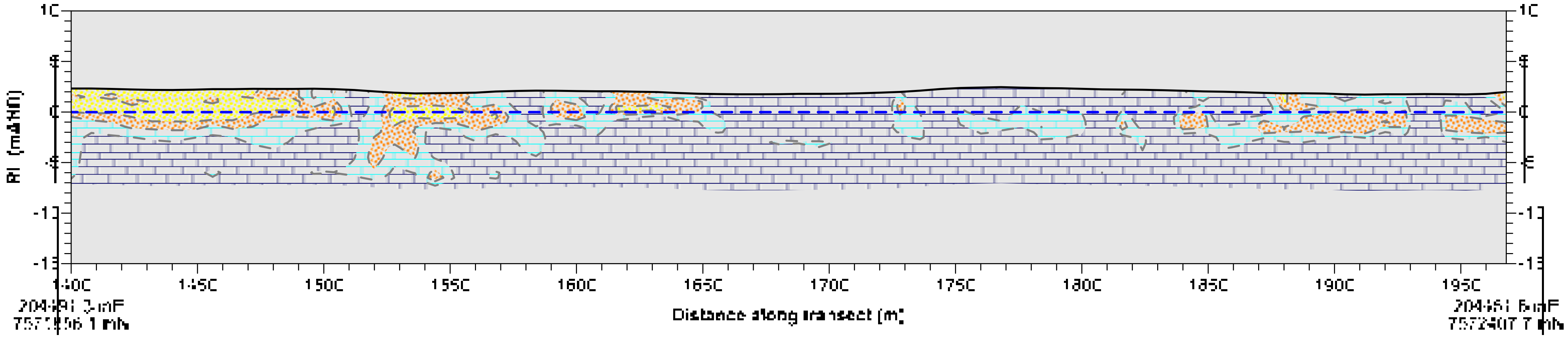
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

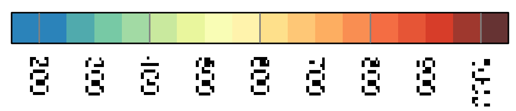
TRANSECT 6 (140-1968m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 6 (1400-1968m) - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

[illegible]

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA		
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA		

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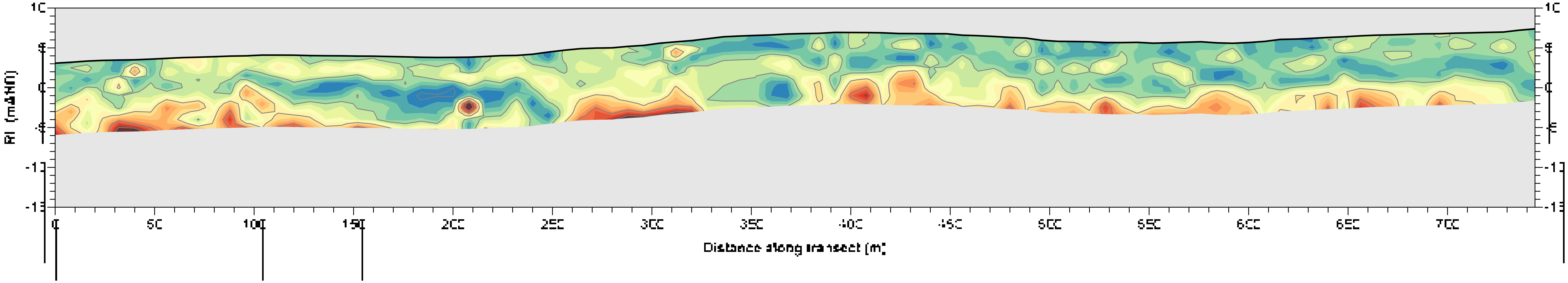
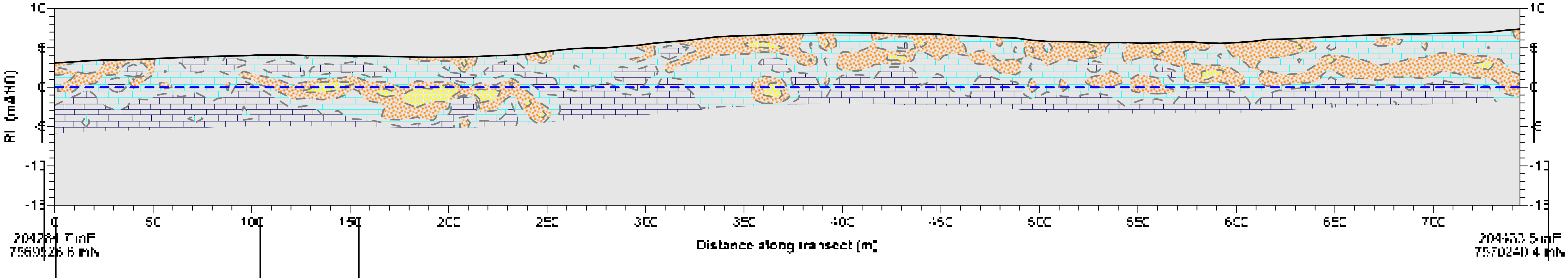
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

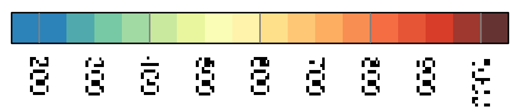
TRANSECT 7 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 7 - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

- SAND - LOW COMPACTION
- SAND - MODERATE COMPACTION
- S-WAVE VELOCITY 3?? 475 m/s
- MODERATE STRENGTH COMPETENT ROCK
- 0m AUSTRALIAN HEIGHT DATUM

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA	

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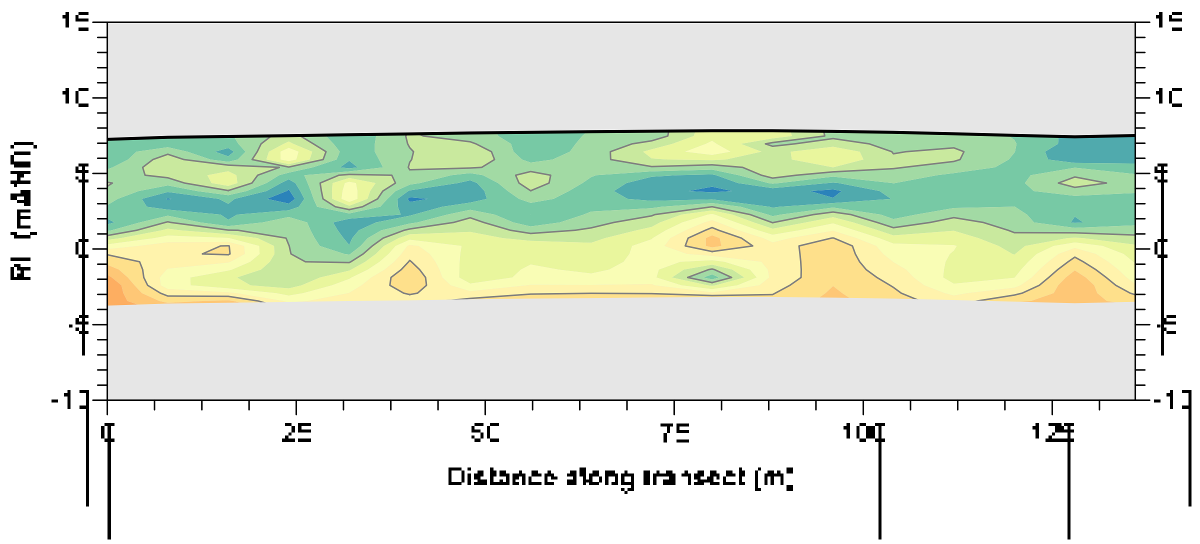
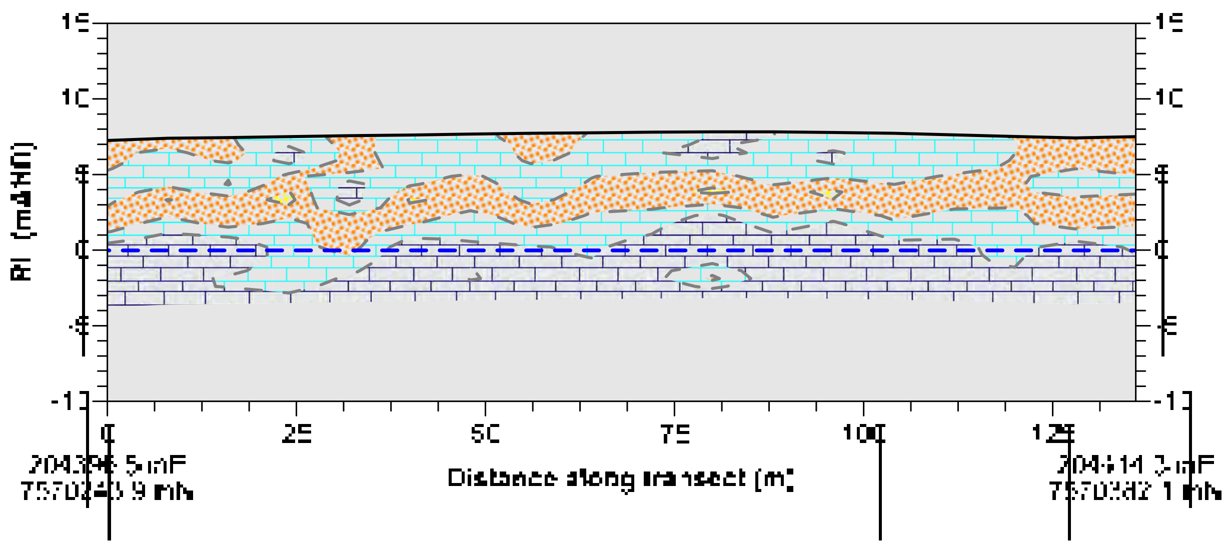
MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

TRANSECT 8 - SEISMIC SHEAR WAVE VELOCITY MODEL

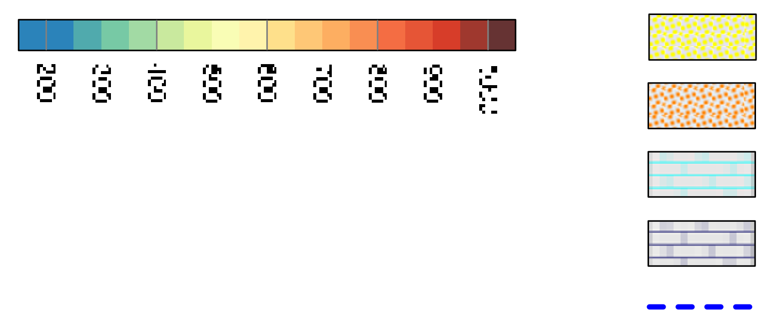


TRANSECT 8 - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)

INTERPRETED MATERIAL TYPE



NOTES

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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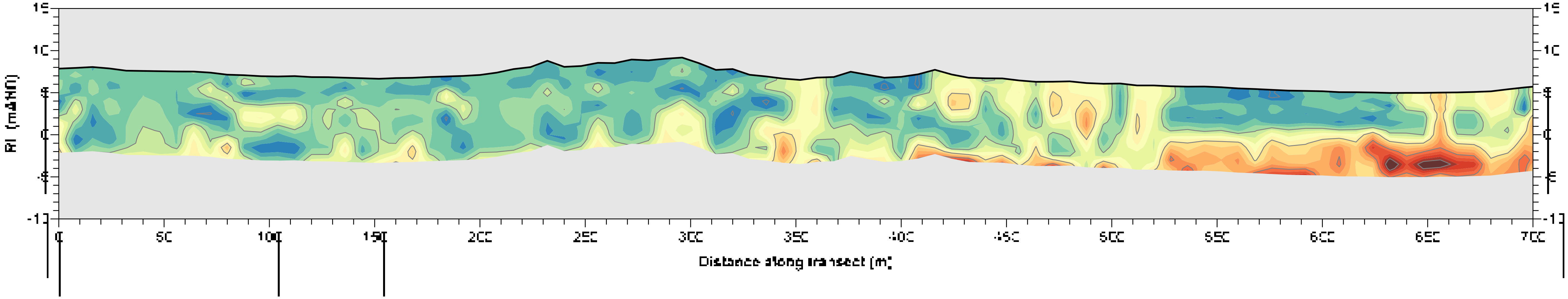
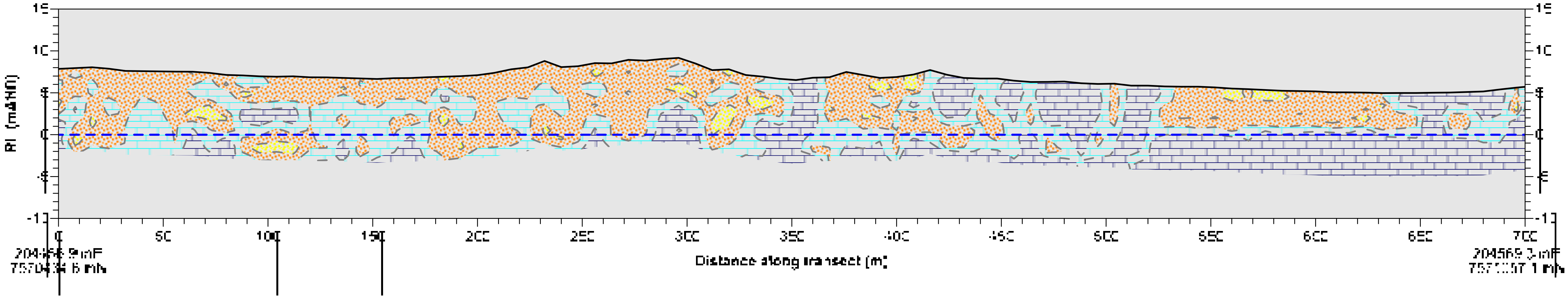
MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

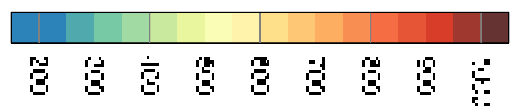
TRANSECT 9 (0-700m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 9 (0-700m) - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE

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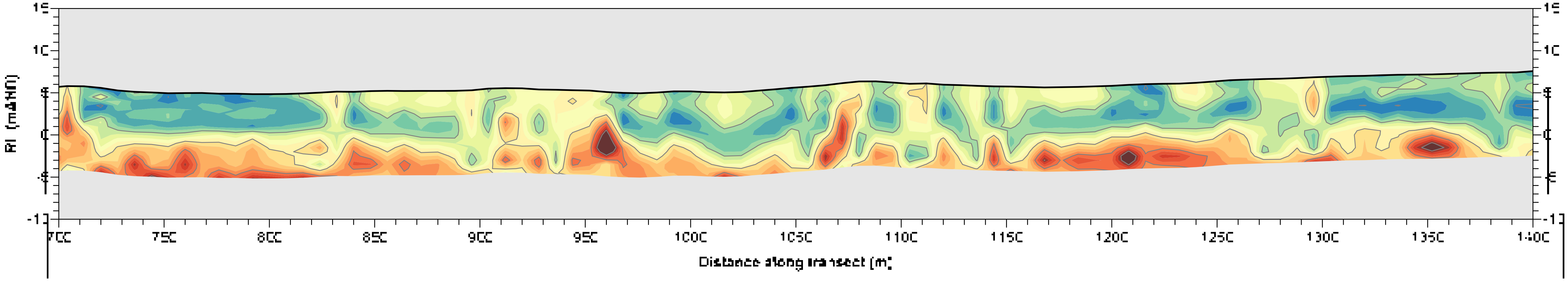
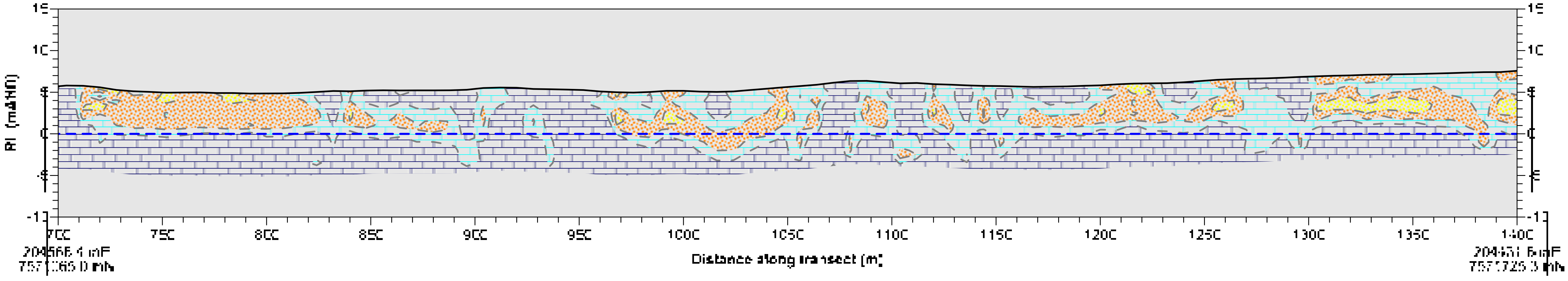
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

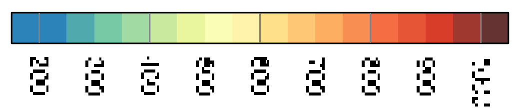
TRANSECT 9 (700-1400m) - SEISMIC SHEAR WAVE VELOCITY MODEL



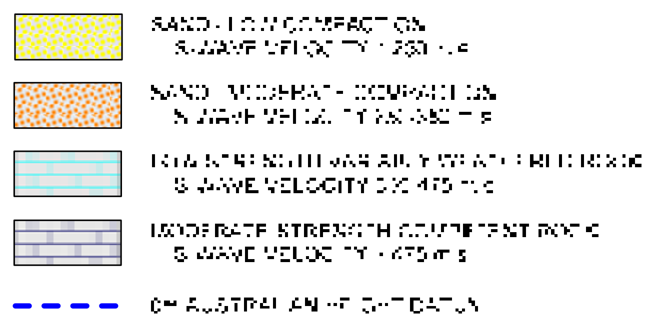
TRANSECT 9 (700-1400m) - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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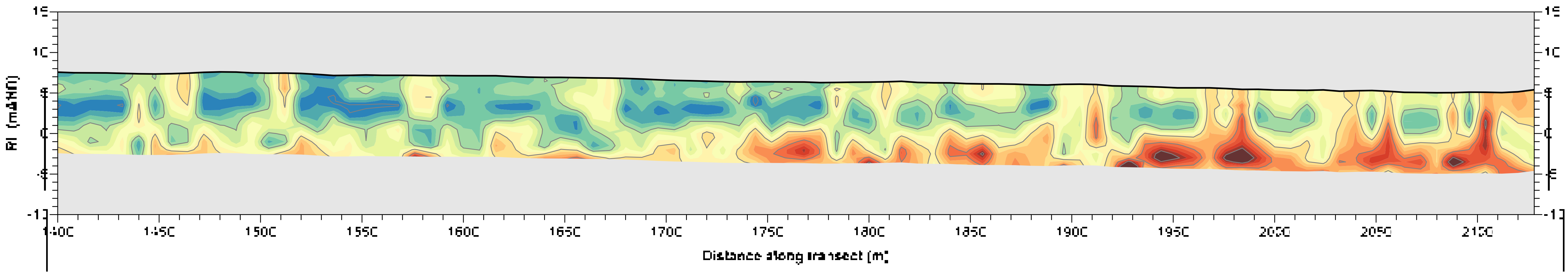
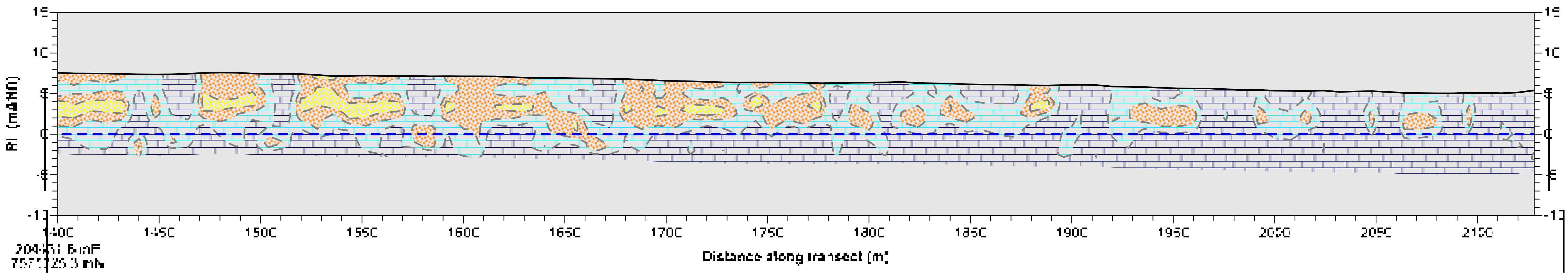
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

TRANSECT 9 (1400-2128m) - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 9 (1400-2128m) - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)

INTERPRETED MATERIAL TYPE

SAND - LOW COMPACTION [illegible]

SAND - MODERATE COMPACTION [illegible]

[illegible]

MODERATE STRENGTH [illegible]

[illegible] AUSTRALIAN [illegible] DATUM

NOTES [illegible]	DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA	[illegible]	[illegible]
	GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA	[illegible]	[illegible]

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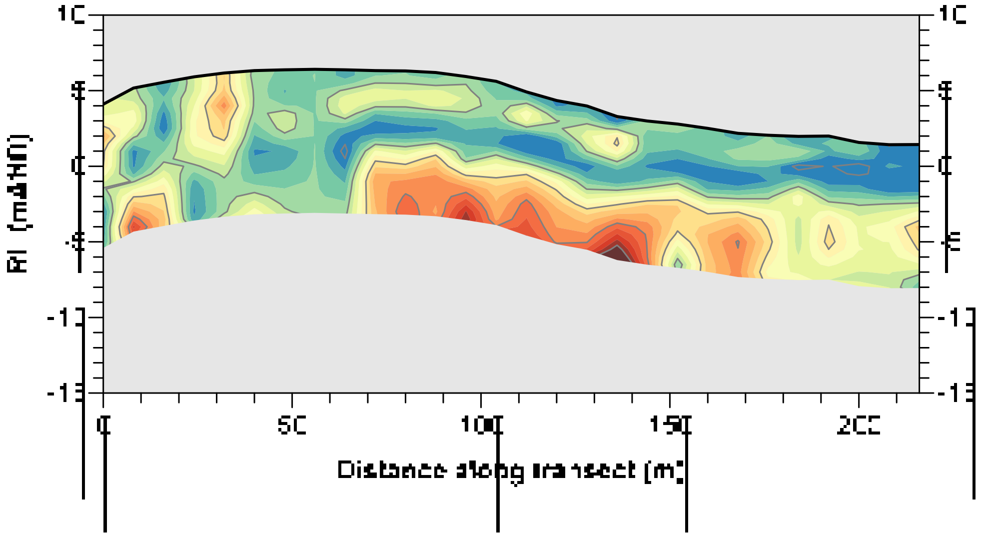
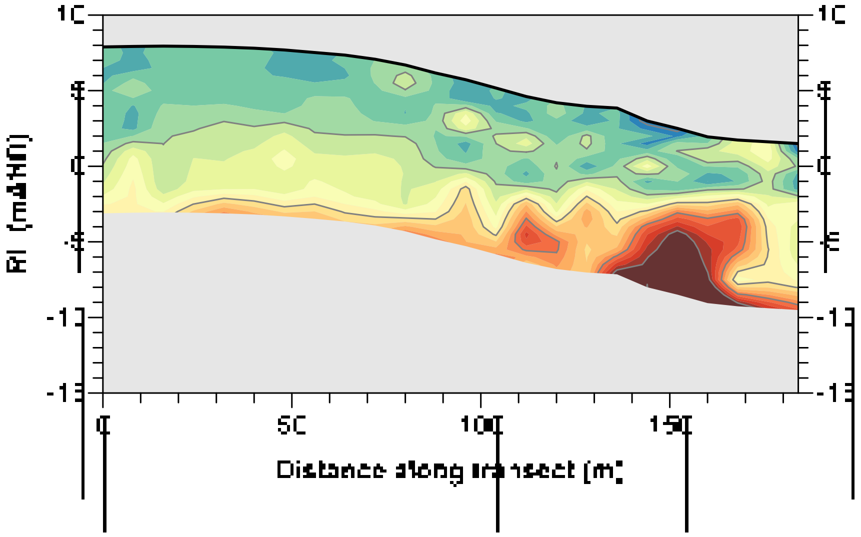
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

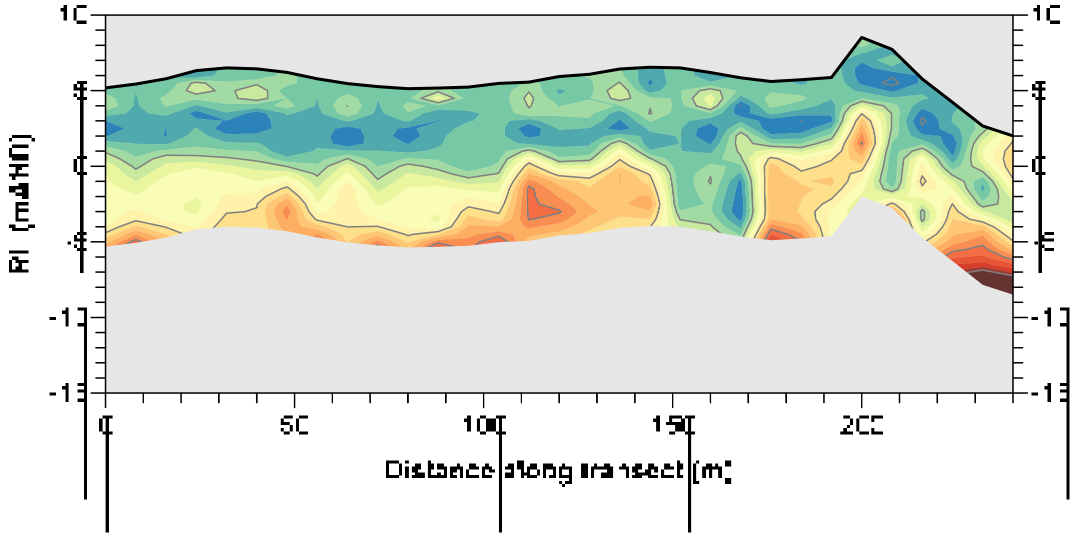
TRANSECT 10 - SEISMIC SHEAR WAVE VELOCITY MODEL



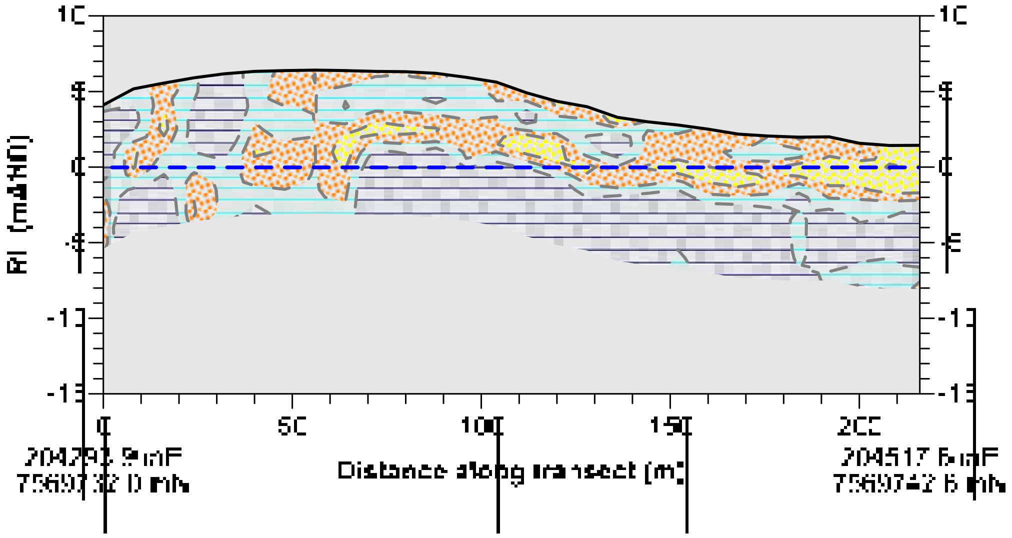
TRANSECT 11 - SEISMIC SHEAR WAVE VELOCITY MODEL



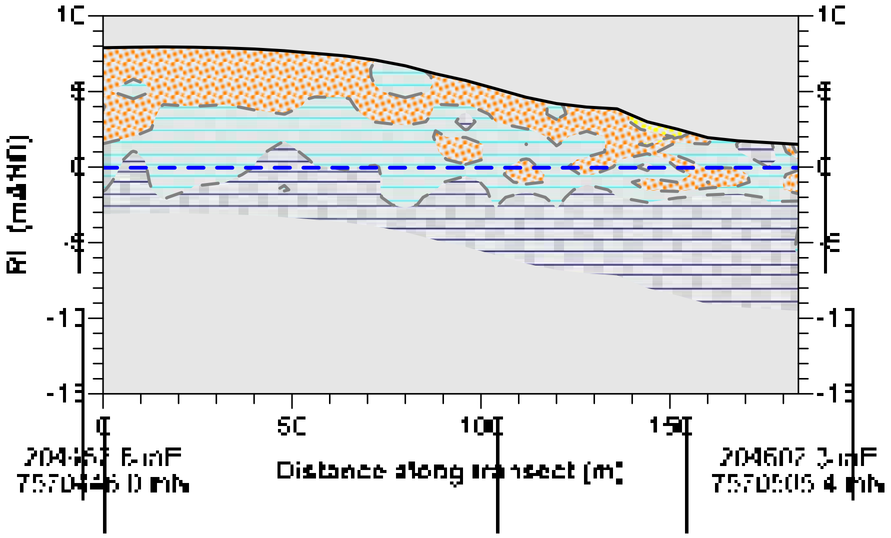
TRANSECT 12 - SEISMIC SHEAR WAVE VELOCITY MODEL



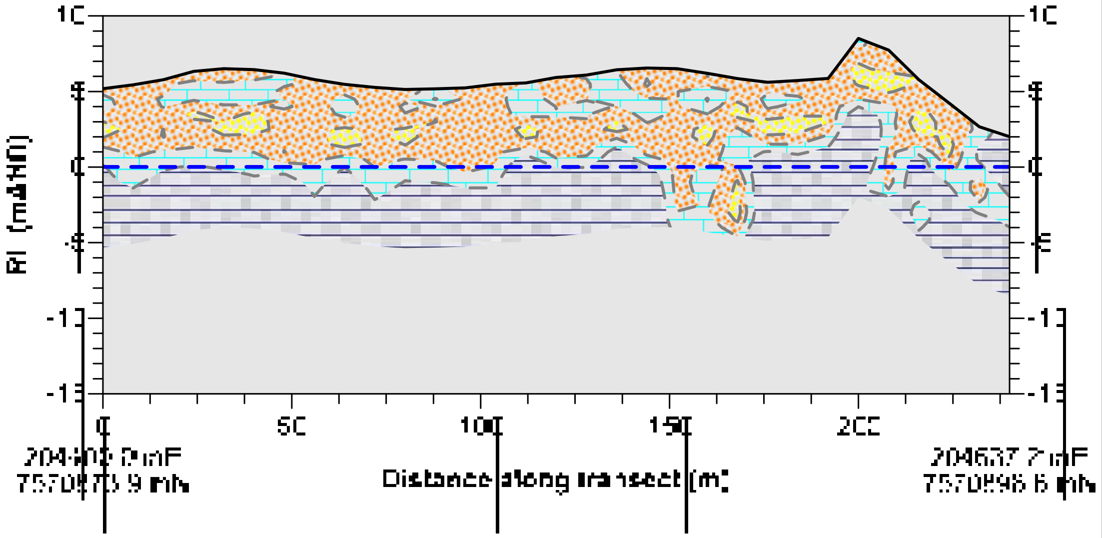
TRANSECT 10 - INTERPRETED GEOLOGICAL SECTION



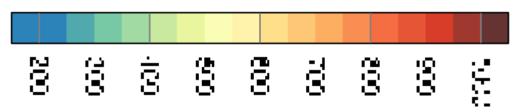
TRANSECT 11 - INTERPRETED GEOLOGICAL SECTION



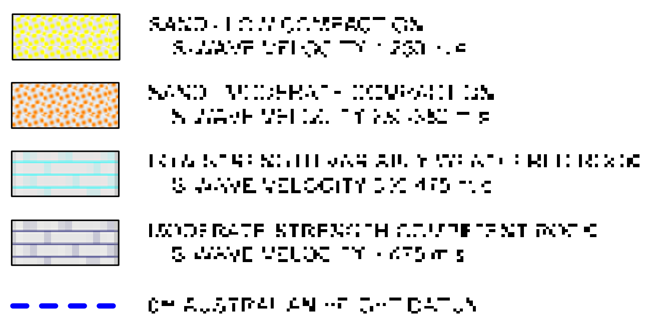
TRANSECT 12 - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)



INTERPRETED MATERIAL TYPE



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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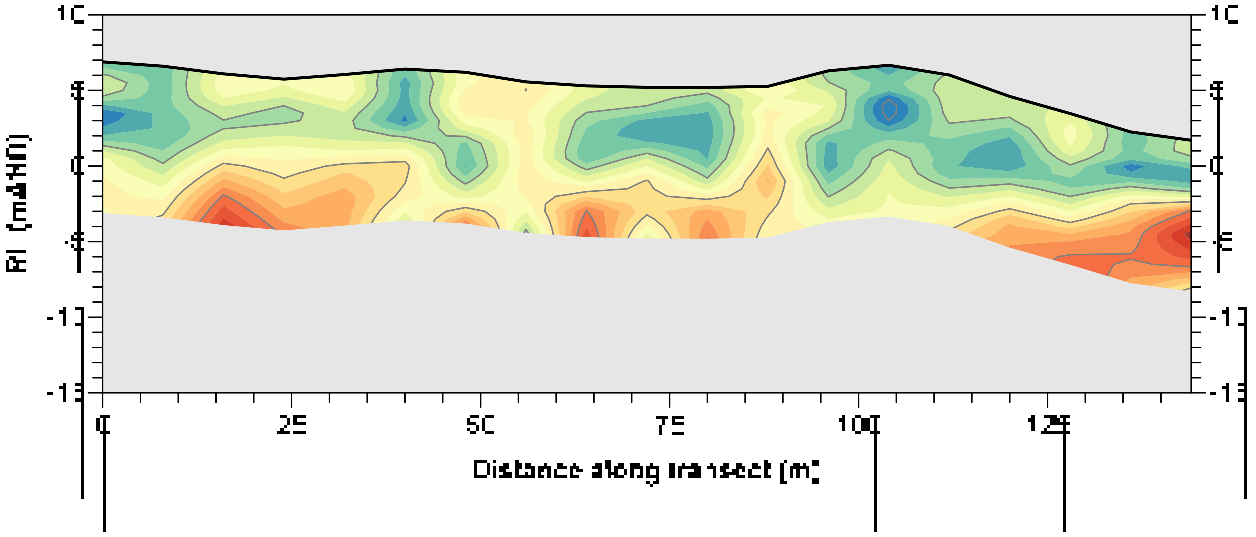
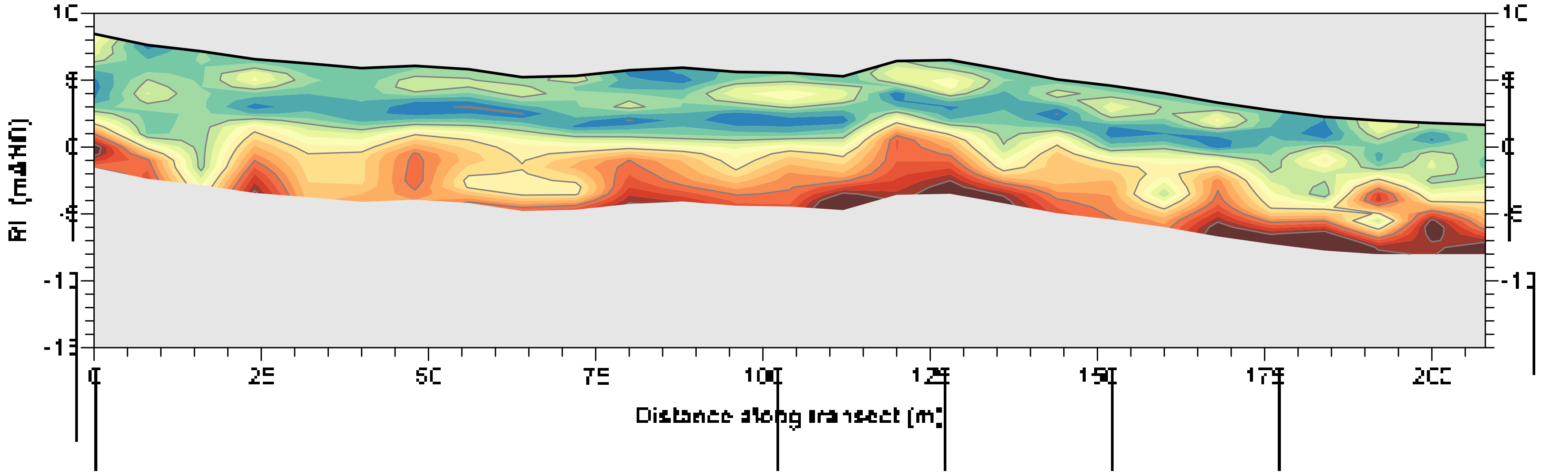
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT - EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

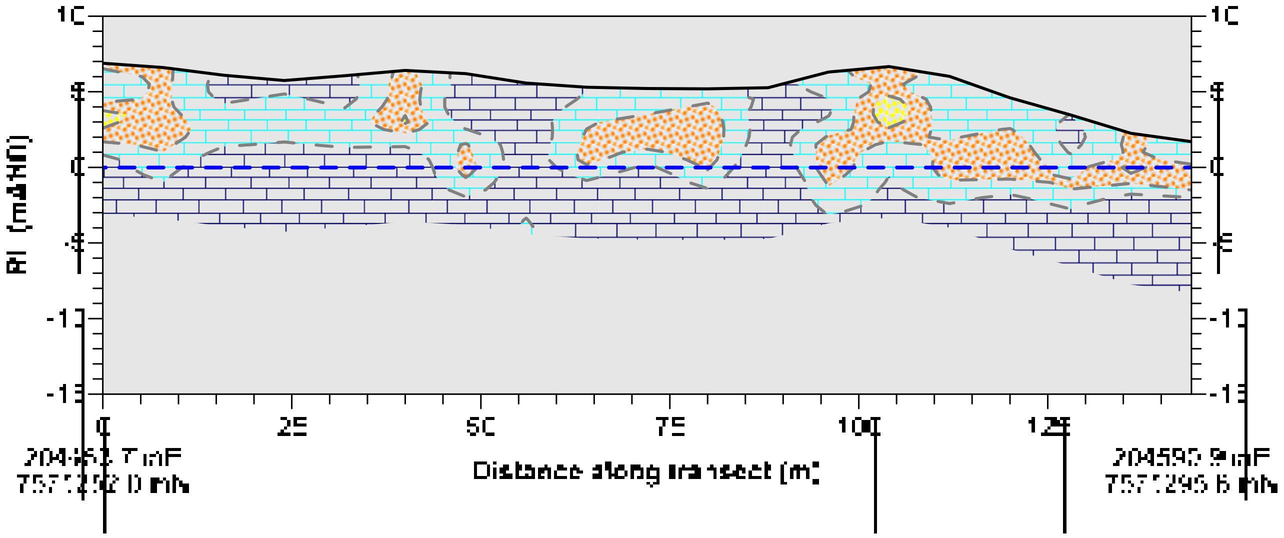
TRANSECT 13 - SEISMIC SHEAR WAVE VELOCITY MODEL



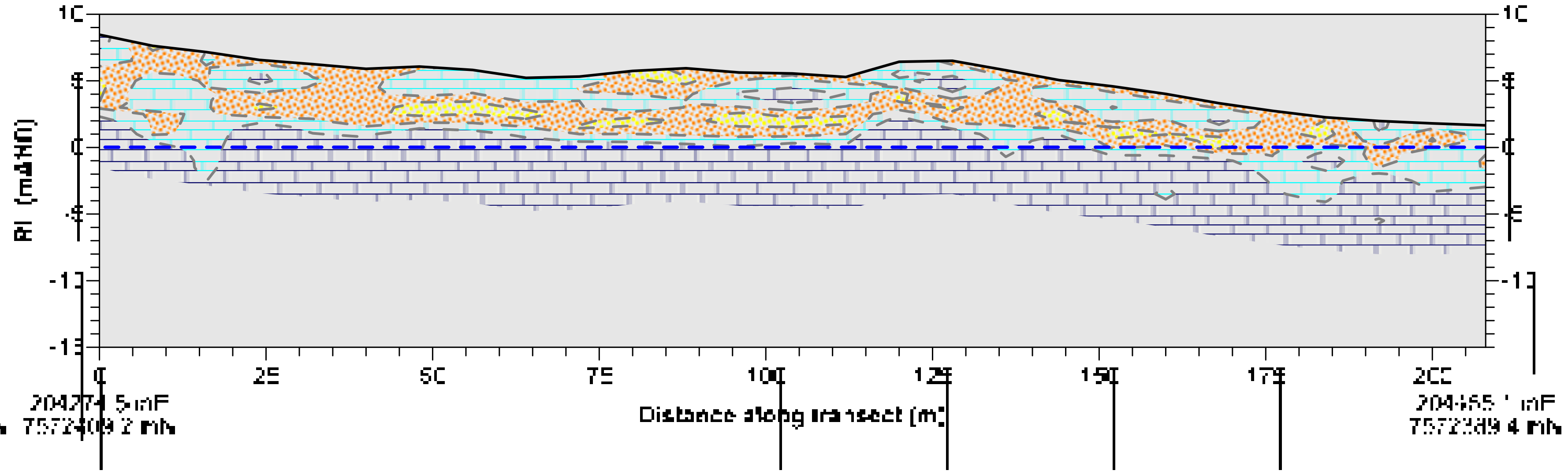
TRANSECT 14 - SEISMIC SHEAR WAVE VELOCITY MODEL



TRANSECT 13 - INTERPRETED GEOLOGICAL SECTION



TRANSECT 14 - INTERPRETED GEOLOGICAL SECTION



SEISMIC S-WAVE VELOCITY (m/s)

INTERPRETED MATERIAL TYPE

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

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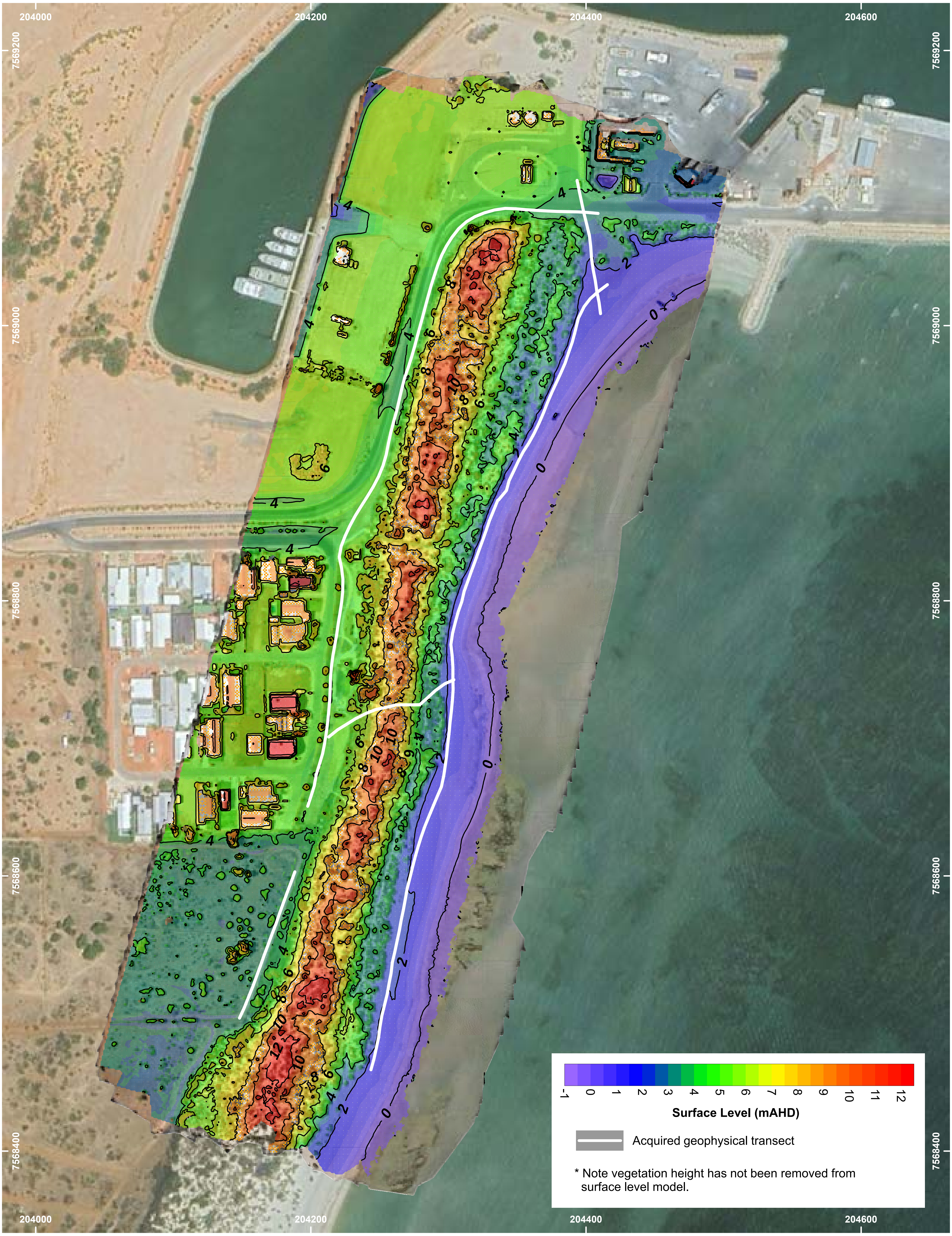
APPENDIX C – SURFACE LEVEL MODELS

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

SURFACE LEVEL MODEL (SOUTH)



N

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WA

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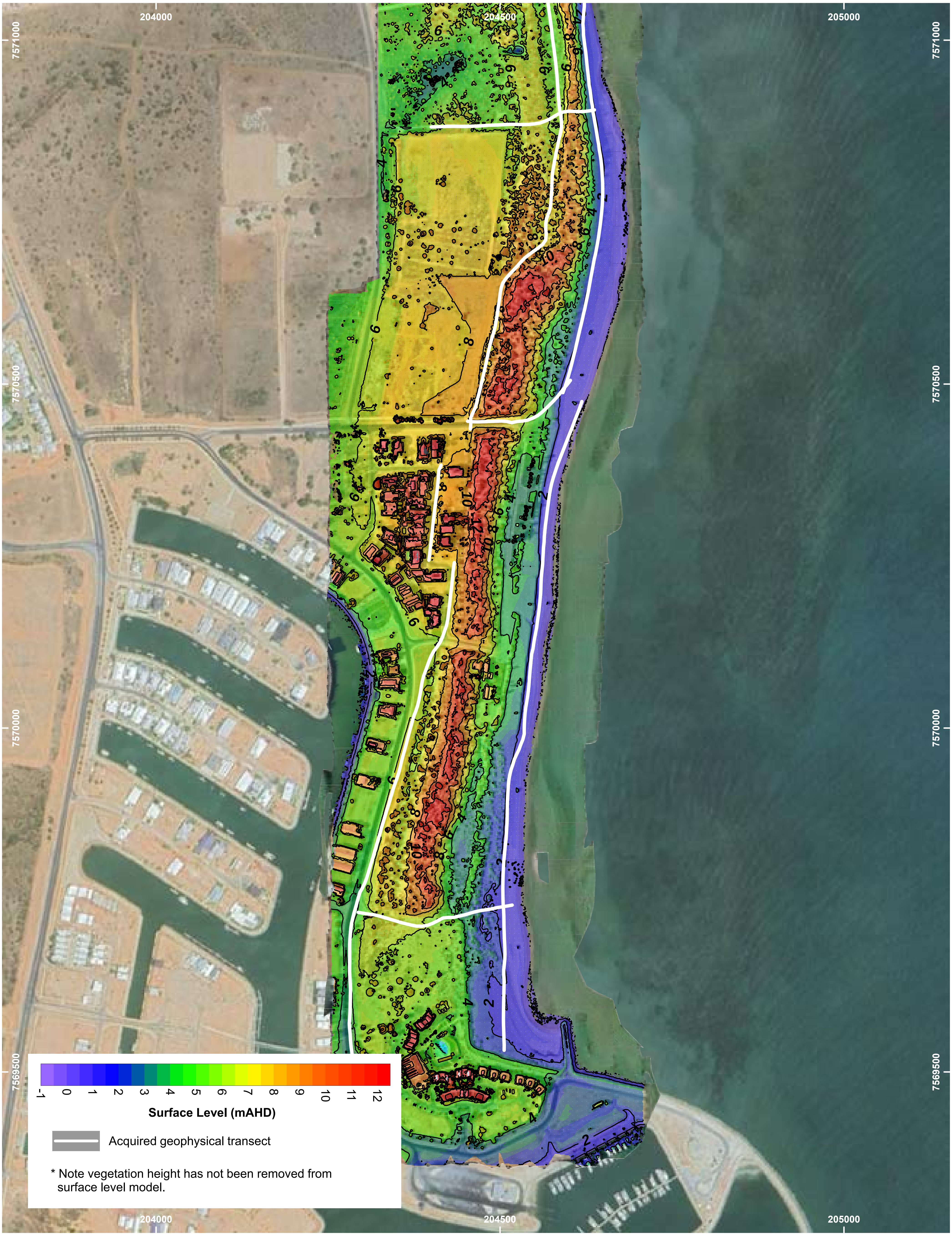
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

SURFACE LEVEL MODEL (NORTH)



N

DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WA

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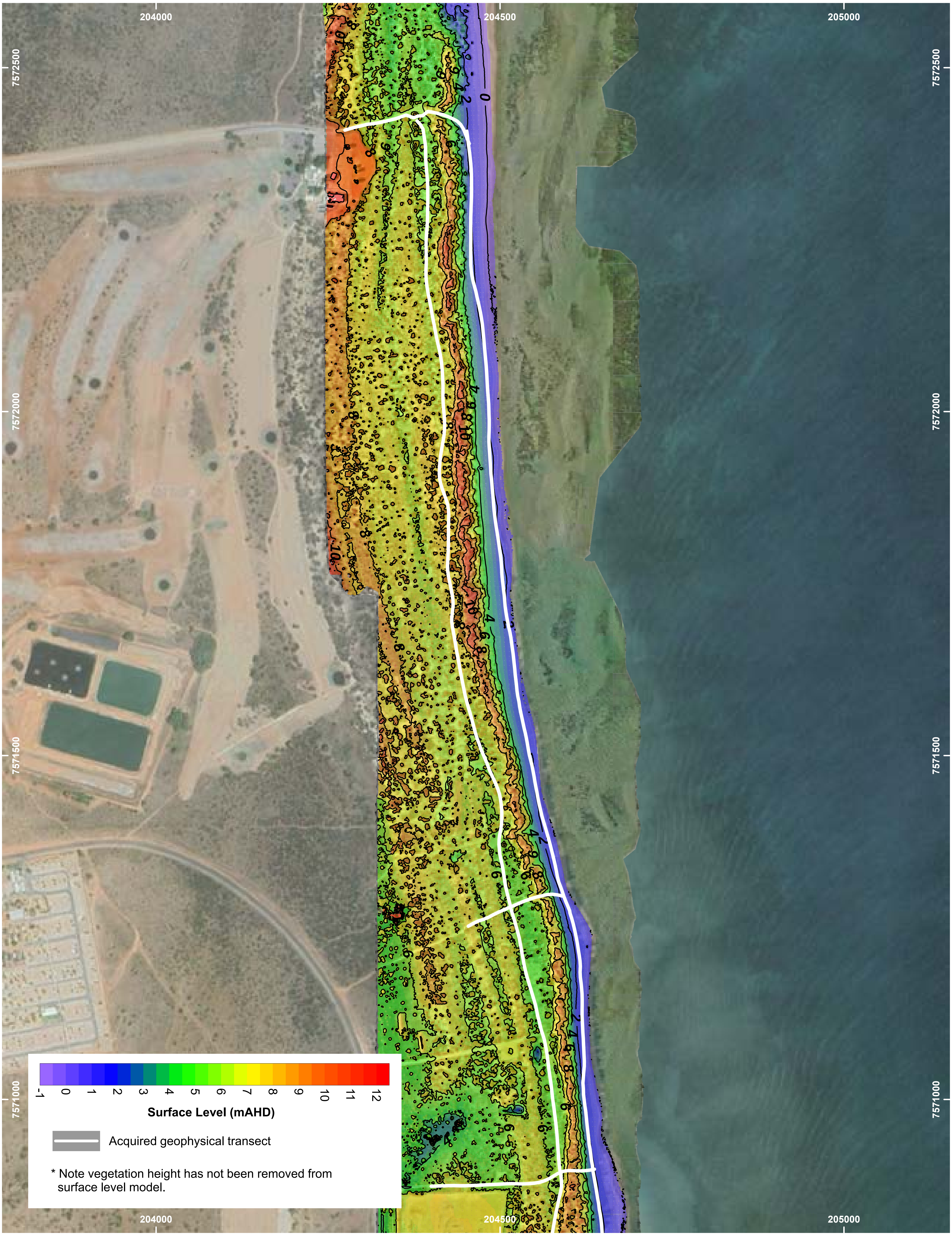
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

SURFACE LEVEL MODEL (NORTH)



DEPARTMENT OF TRANSPORT, WESTERN AUSTRALIA

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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APPENDIX D – LEVEL TO TOP OF ROCK

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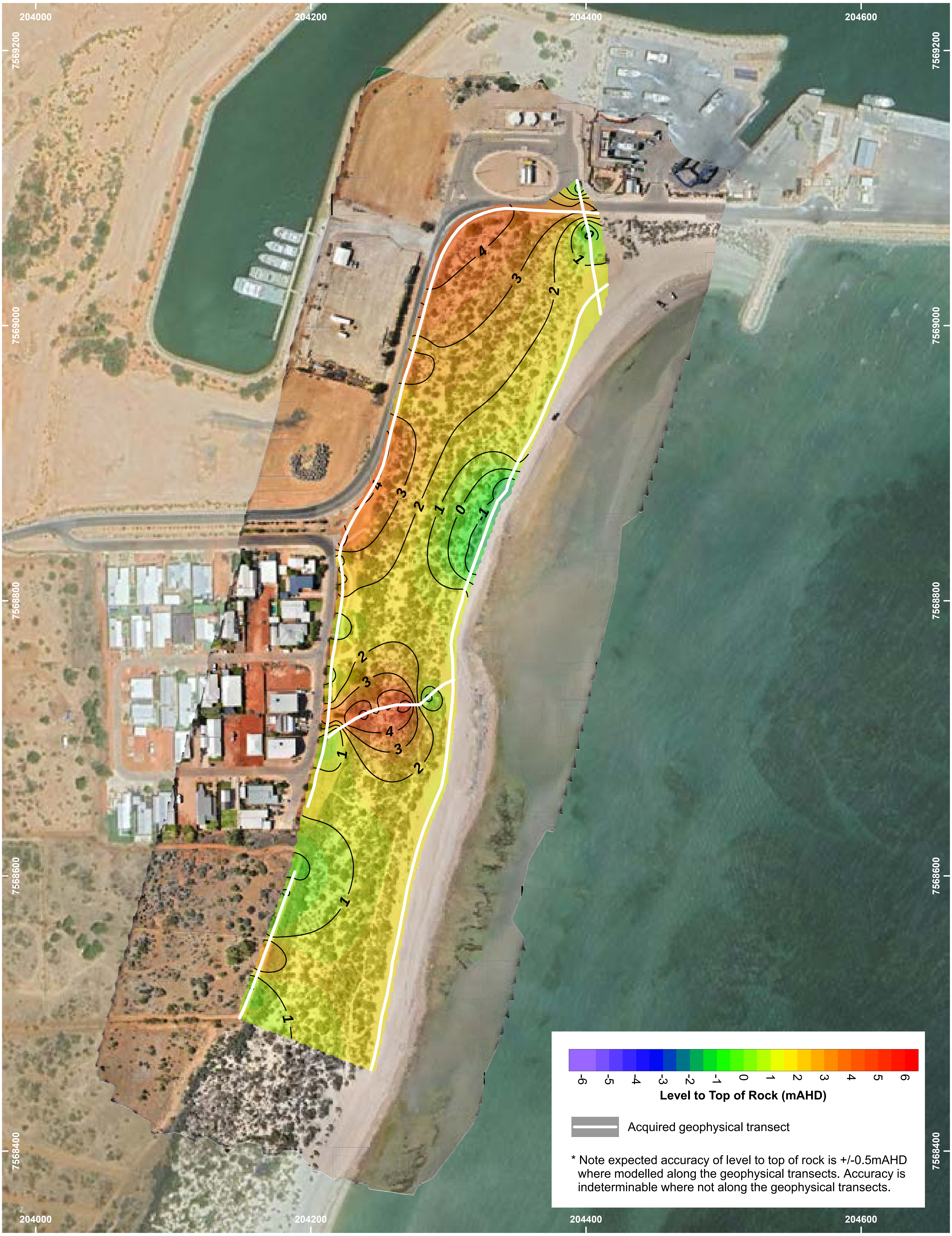
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK (SOUTH)



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DEPARTMENT OF [illegible]RANSPORT, WESTERN AUSTRAL[illegible]

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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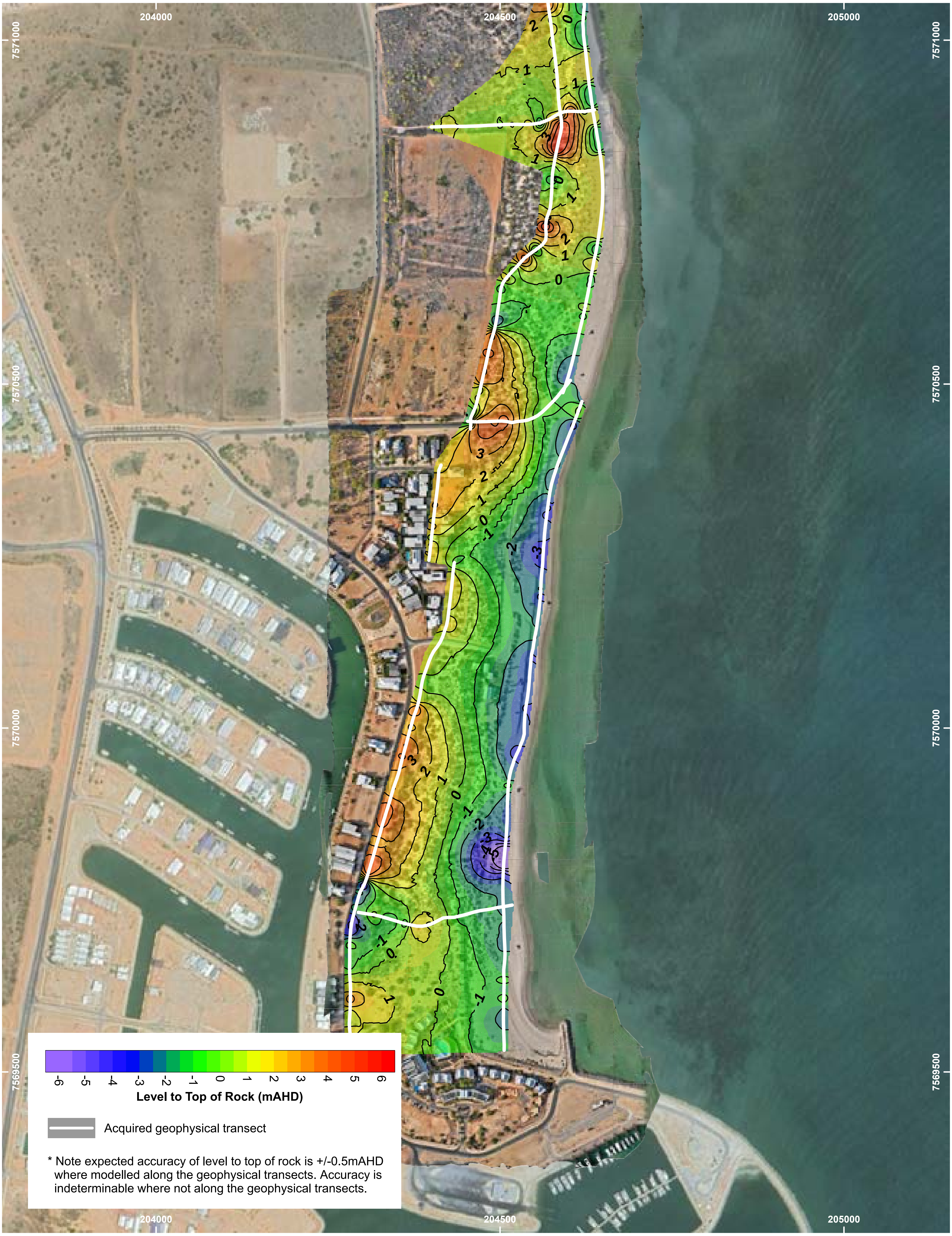
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK (NORTH)



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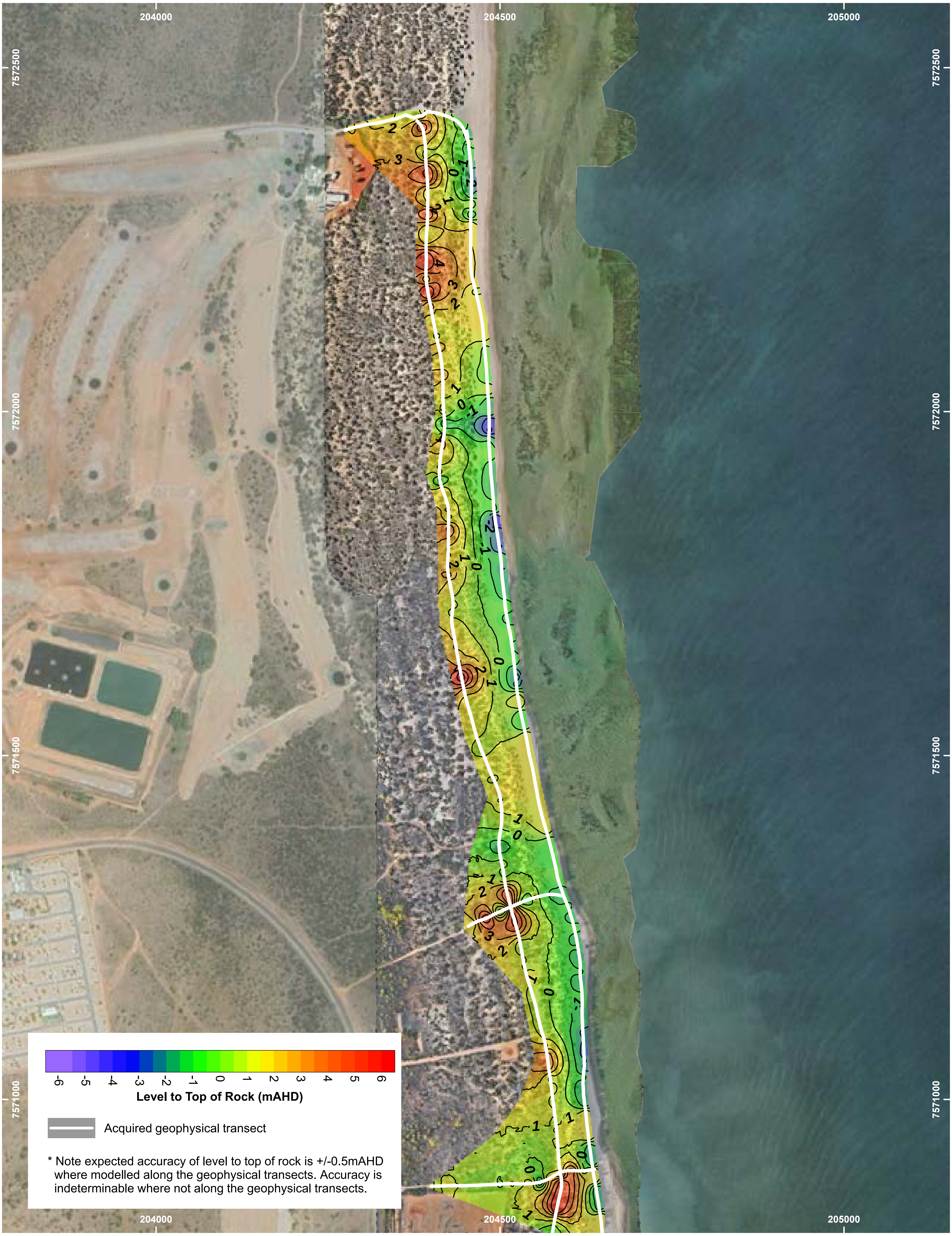
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CONTOURED LEVEL TO TOP OF ROCK (NORTH)



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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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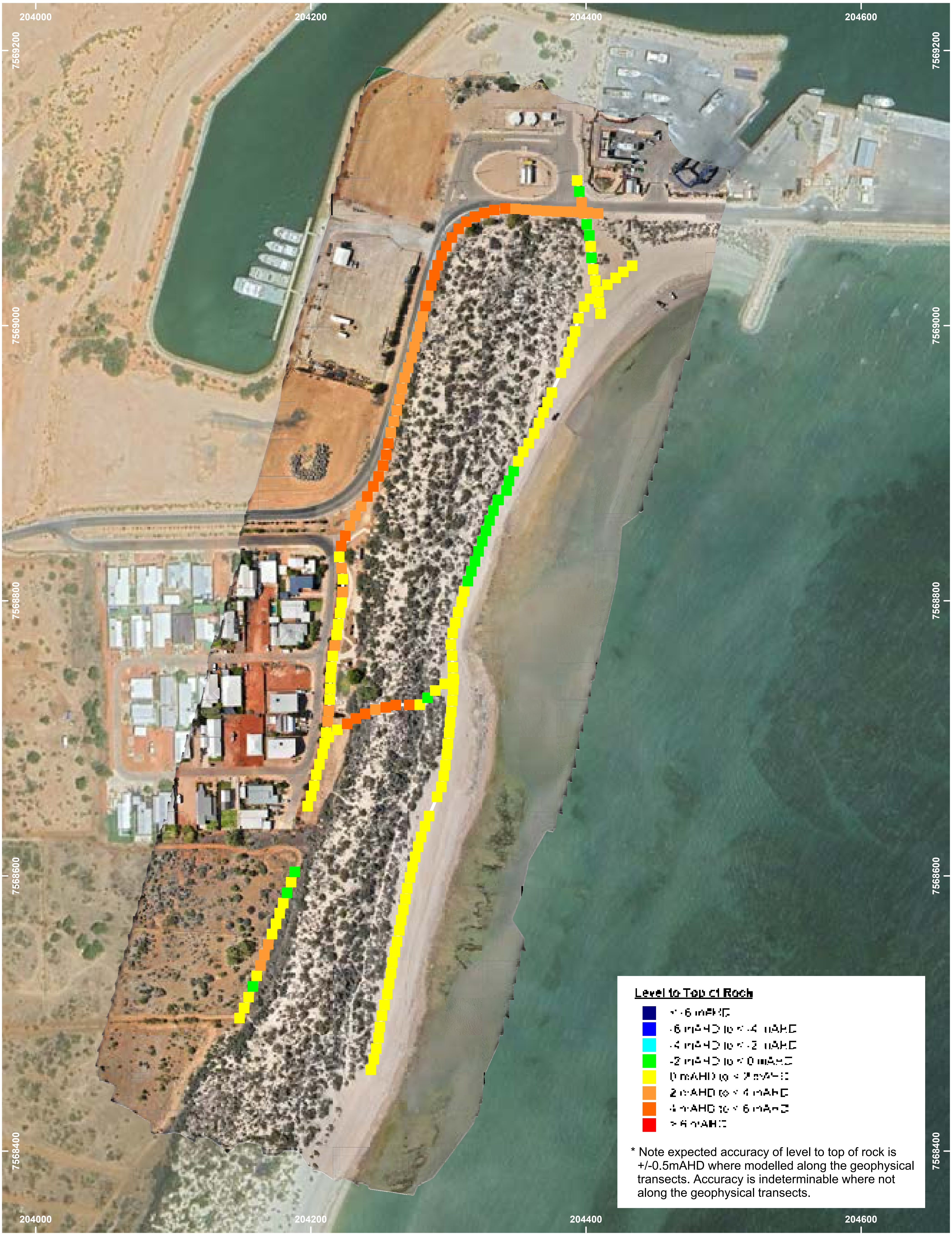
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CLASSED POST MAP LEVEL TO TOP OF ROCK (SOUTH)



Level to Top of Rock

- < -6 mAHD
- -6 mAHD to < -4 mAHD
- -4 mAHD to < -2 mAHD
- -2 mAHD to < 0 mAHD
- 0 mAHD to < 2 mAHD
- 2 mAHD to < 4 mAHD
- 4 mAHD to < 6 mAHD
- > 6 mAHD

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

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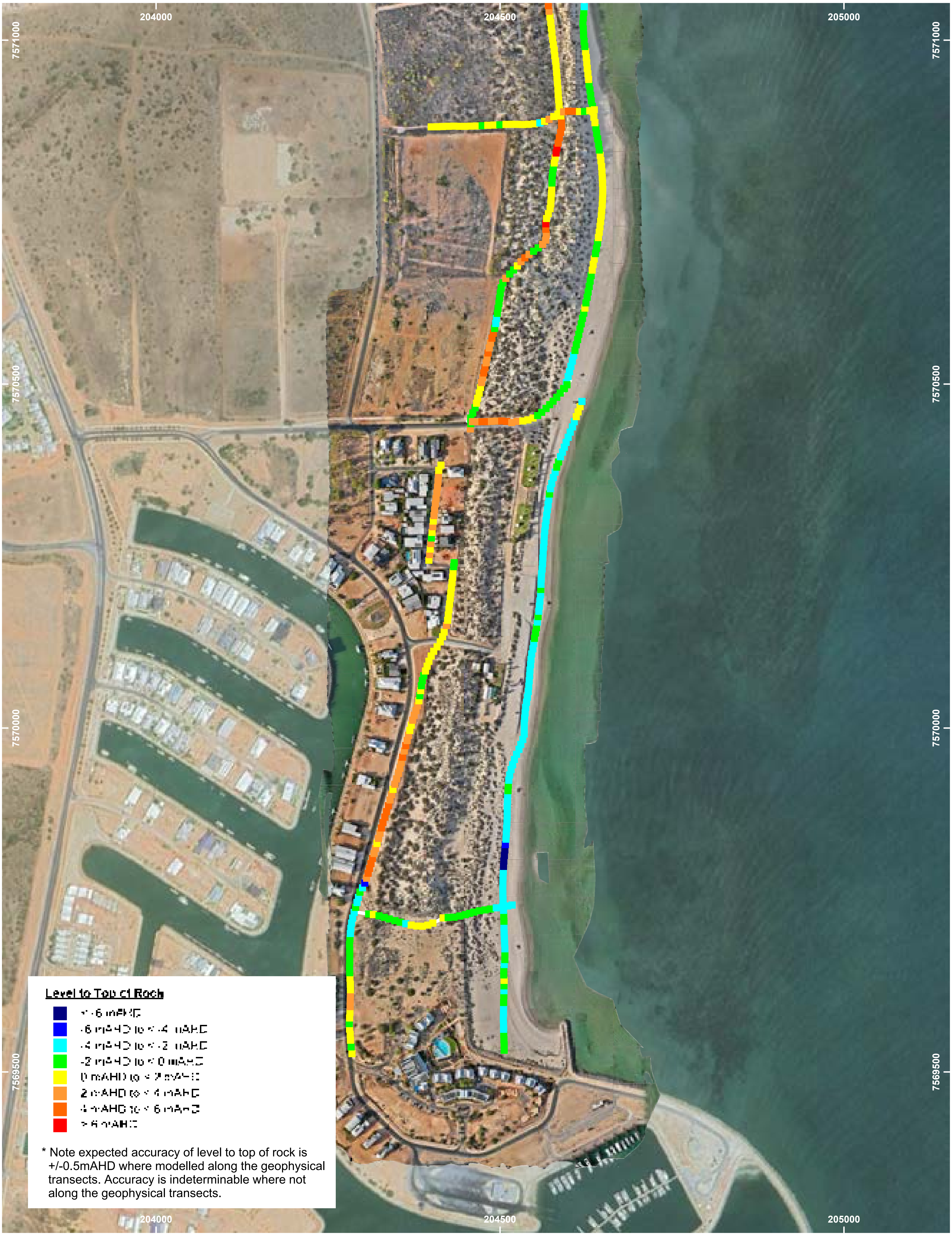
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CLASSED POST MAP LEVEL TO TOP OF ROCK (NORTH)



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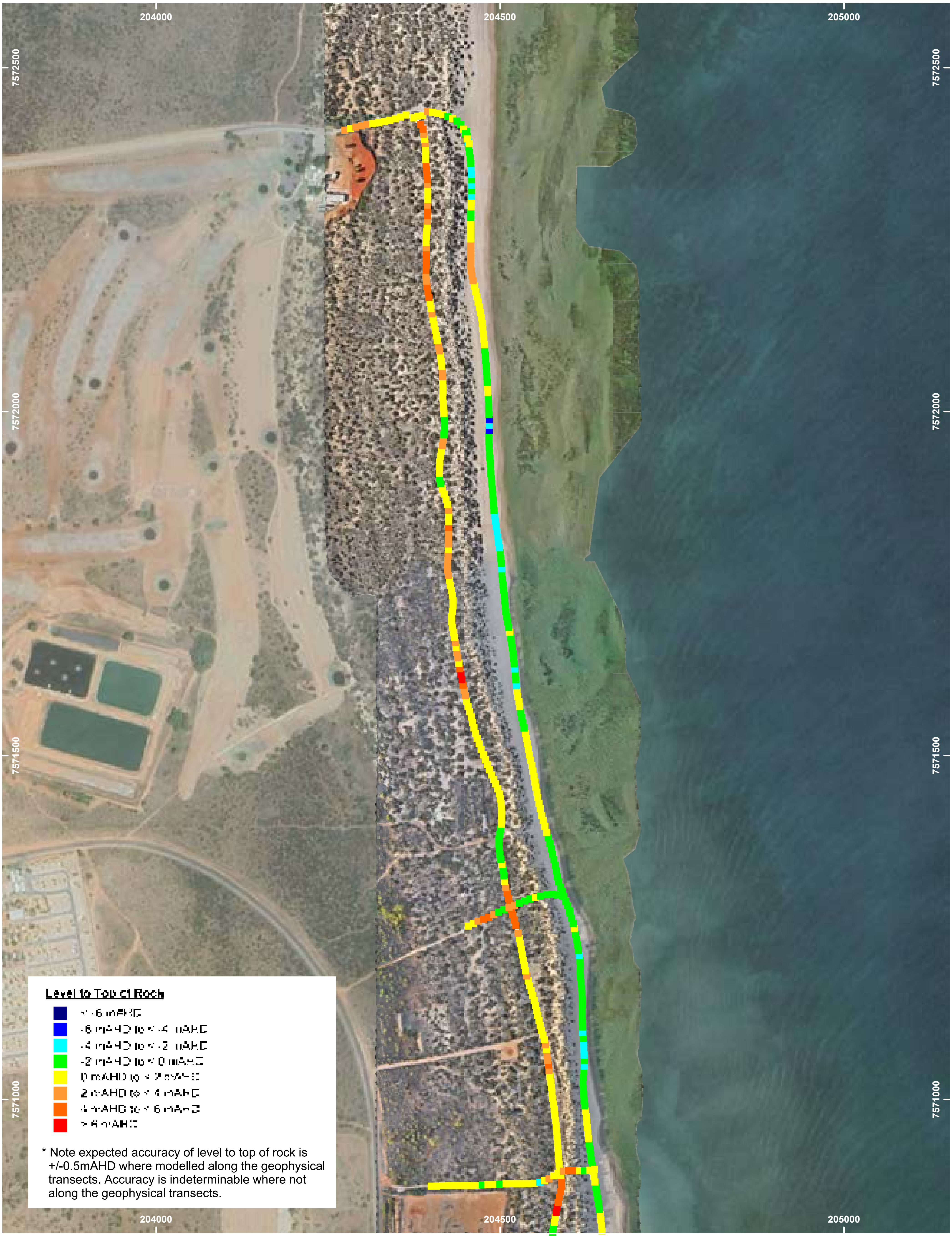
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CLASSED POST MAP LEVEL TO TOP OF ROCK (NORTH)



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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WA

APPENDIX E – SAND THICKNESS OVER ROCK

GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CONTOURED SAND THICKNESS OVER ROCK (SOUTH)

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WA

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CLASSED POST MAP SAND THICKNESS OVER ROCK (NORTH)

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CLASSED POST MAP SAND THICKNESS OVER ROCK (NORTH)

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GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT
EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CLASSED POST MAP SAND THICKNESS OVER ROCK (SOUTH)

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CLASSED POST MAP SAND THICKNESS OVER ROCK (NORTH)

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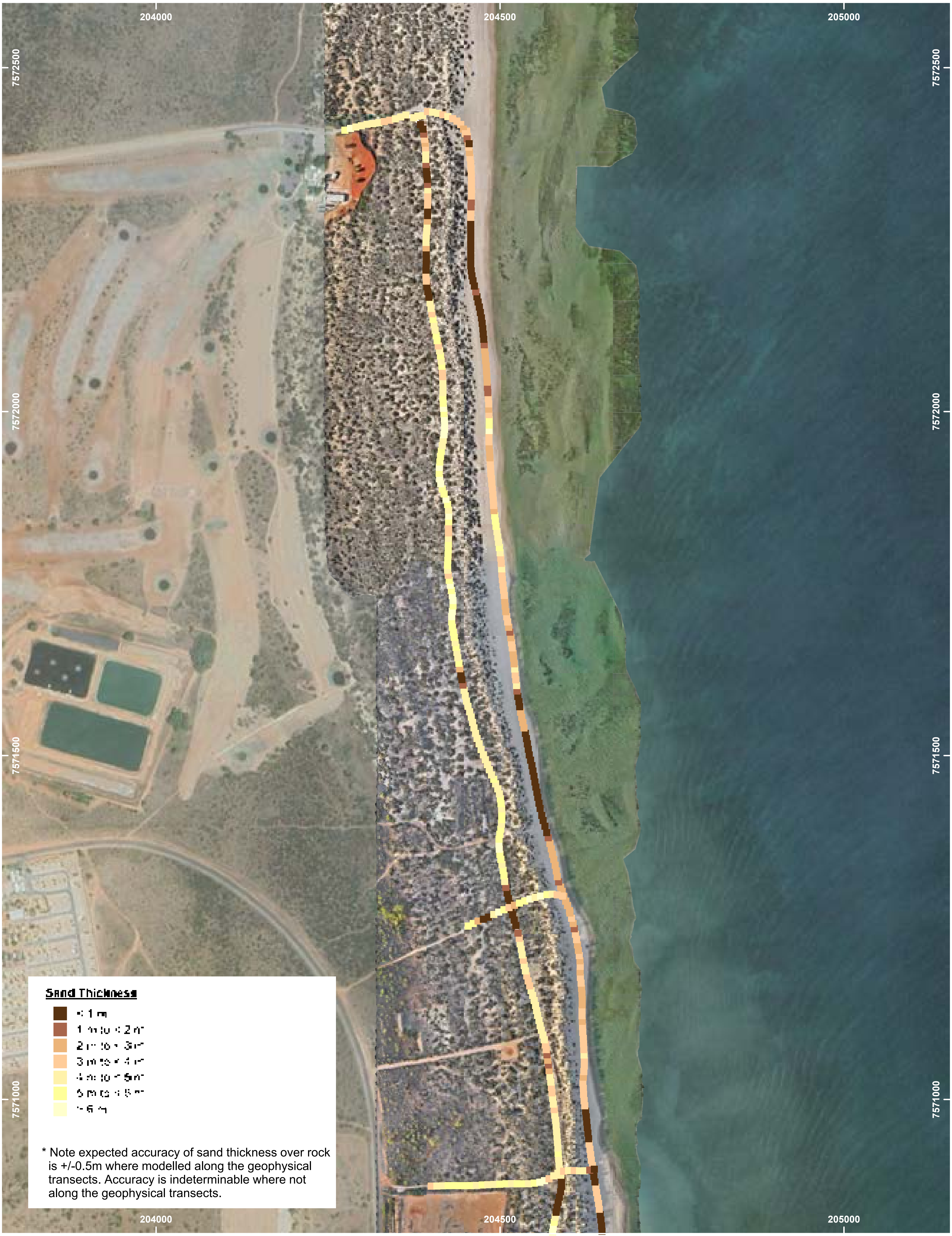
GEOTECHNICAL INVESTIGATION FOR COASTAL EROSION VULNERABILITY ASSESSMENT EXMOUTH, SHIRE OF EXMOUTH WESTERN AUSTRALIA

CLASSED POST MAP SAND THICKNESS OVER ROCK (NORTH)



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