Appendix A

Geotechnical Investigation Report (PSM, 2021)

Eurobodalla's Open Coast Coastal Management Plan

Geotechnical Investigation Report

PSM4238-005R REV 1 1 December 2021

Table of Contents

List of Tables

List of Figures

List of Insets

List of Appendices

1. Introduction

This report presents the results of geotechnical services undertaken to support development of the Eurobodalla Shire Council's (Council) Open Coast Coastal Management Plan (CMP). Pells Sullivan Meynink (PSM) was engaged by Rhelm Pty Ltd (Rhelm) to undertake the geotechnical services component of work. Rhelm have been engaged by Council to finalise the Eurobodalla's Open Coast CMP as per the technical brief[1].

The geotechnical services requested relate to the investigation of three beach sites along the Eurobodalla Shire Council coast, namely, Long Beach, Surfside, and Tomakin (the sites). Results of the geotechnical investigation will be used as input for the probabilistic erosion and recession estimates within the Vulnerability Assessment stage of the open coast CMP.

This document presents the results of a desk-study and geotechnical investigation of the sites. A preliminary geotechnical model of each site is provided. Suggestions for further investigations are provided.

2. Scope of Work

The scope of work was set by Council and comprised:

- Stage 1 – Desk study
- Stage 2 – Non-Intrusive Field Investigation:
  - Engineering geological field mapping
  - Geophysical investigations.
- Stage 3 - Compilation of a simplified geotechnical model.

3. Desk Study

3.1 Introduction

A desk study forms the basis for the conceptual model of a site and considers geology, geomorphology, hydrogeology and surface processes. The conceptual models formulated for the sites in this study focus on the following:

- Coastal processes and interactions
- Review of possible subsurface conditions underlying the site based on an assessment of the terrain and landforms, and
- Identification of data gaps.

As part of the desk study, the following data and documents were reviewed:

- Geological maps and associated notes
- Geographical information systems (GIS) data, and
- Available elevation data including LiDAR and bathymetry.

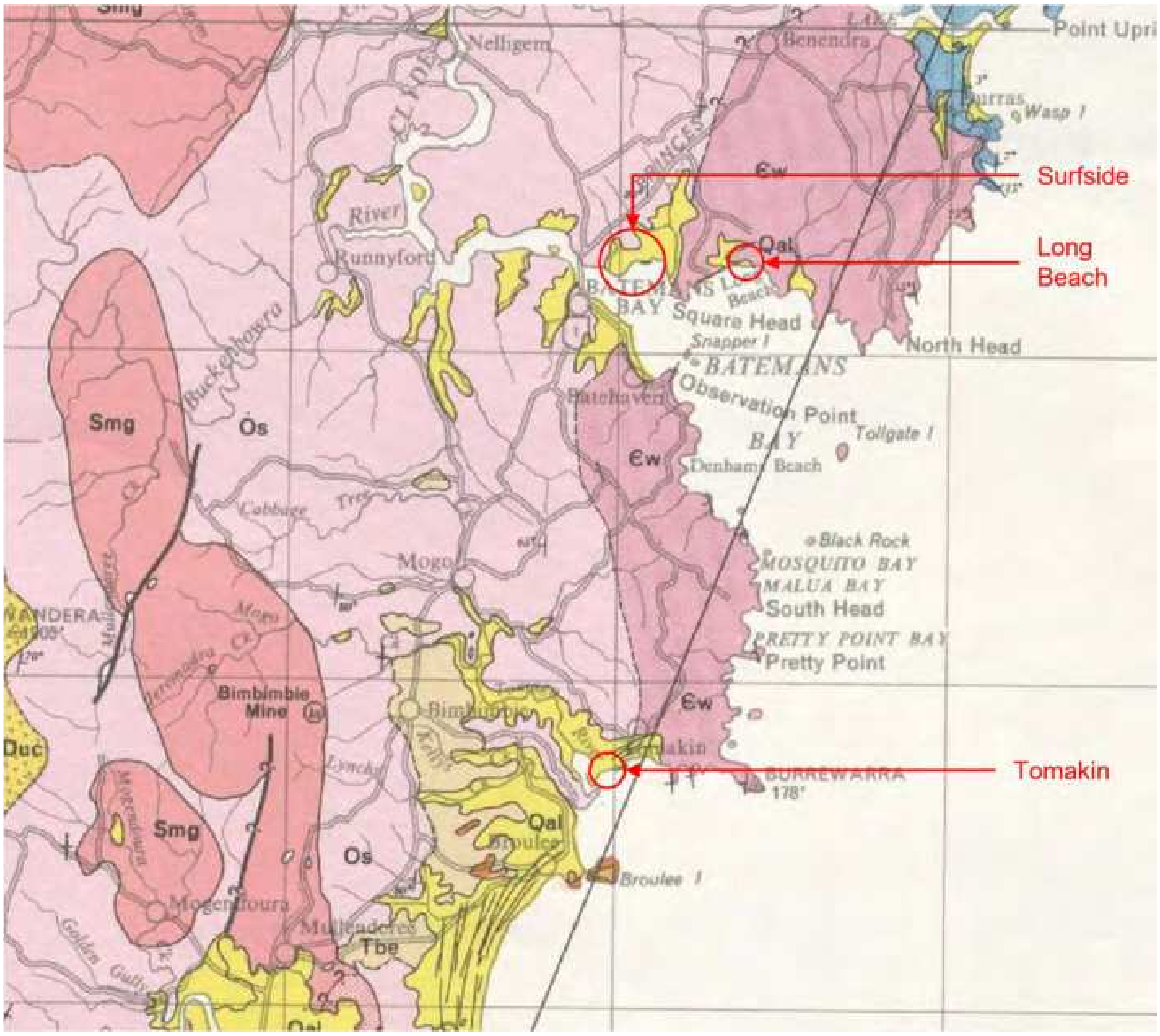
The aim of the resultant conceptual model was to guide the field mapping program, and subsequently be tested and validated against the on-site observations. Figures from the desk study are presented in Appendix A and discussed below.

3.2 Geological Setting

The 1:250,000 Ulludulla Geological Map shows that the basement geology underlying the sites encompasses rocks of the Lachlan Orogen, and described as follows, Inset 1:

- Adaminaby Group, (Os) – siltstone, claystone, sandstone, quartzite, chert
- Wagonga Group, (Ɛw) – chert, conglomerate, agglomerate, slate, sandstone, phyllite.

[1] Eurobodalla Shire Council Technical Brief: Eurobodalla's Open Coast CMP; brief issued July 2020



Inset 1: **Ulludulla 1:250,000 (Rose, 1966). The site locations are approximated by the red circles and associated annotations.**

Both the Adaminaby and Wagonga Groups form part of the Narooma Accretionary Complex. The rocks of the Adaminaby Group have been folded along meridional axes and dips of the bedding rarely exceed 70°. The folding in these rocks has produced a slaty cleavage and bedding has substantially been obscured. Sediments of the Wagonga Group generally dip sub-vertically and strike north-south. The geological maps shows that the basement rocks are overlain by thick Quaternary deposits (Qal).

3.3 Terrain Evaluation

3.3.1 Overview

Development of a conceptual model for the sites is based on a remote sensing assessment of the terrain using GIS methods. Terrain evaluation is a form of engineering geomorphology that uses principles of mapping and classification to sub-divide the landscape into a series of smaller and more detailed hierarchical groups, typically comprising (from largest to smallest):

- Land systems
- Land facets, and
- Land elements.

These groups are assigned physical attributes based on the geomorphological processes that formed them and the underlying bedrock geology. It is a particularly useful technique where there is limited sub-surface geotechnical data.

Terrain evaluation aims to develop a conceptual engineering geological model of a site to understand the spatial distribution and relationship between each identified land facet as well as to infer the extent, thickness and engineering geological characteristics of sub-surface materials.

3.3.2 Terrain Classification

Digital elevation models (DEMs) were generated from LiDAR and bathymetry data obtained from public repositories[2], and were used to undertake the terrain mapping and classification. The mapped terrain classification plans for each respective site are shown in Insets 2 to 4, and all terrain classification figures included in Appendix A.

Three broad land systems are identified across the sites:

- Estuarine – drowned valley system comprising tidal rivers depositing into saline waters
- Marine – shoreline systems comprising sediments deposited by wind, wave, and tidal processes
- Uplands – general geomorphic system at higher elevations than the coastal plain, comprising weathered bedrock overlain by surficial deposits predominantly deposited by mass wasting processes (i.e., gravity).

A total of eight land facets are identified across the sites. Table 1 presents a description of the landforms and their anticipated engineering geological characteristics.

3.4 Publicly Available Data

Publicly available sources were reviewed to identify potential data that may supplement the conceptual models. The most useful public source was WaterNSW through their real-time data website[3]. The WaterNSW database was reviewed for borehole records proximal to each of the sites, particularly with regards to drillers logs if available.

Where boreholes contained drillers logs with notes on the materials encountered during drilling, these were used to inform the conceptual model. It is important to note that drillers logs are not technical logs, are often subjective and are based on the operator's experience. For the purposes of informing the conceptual models, the drillers logs are therefore considered as being anecdotal and assessed as having a low confidence.

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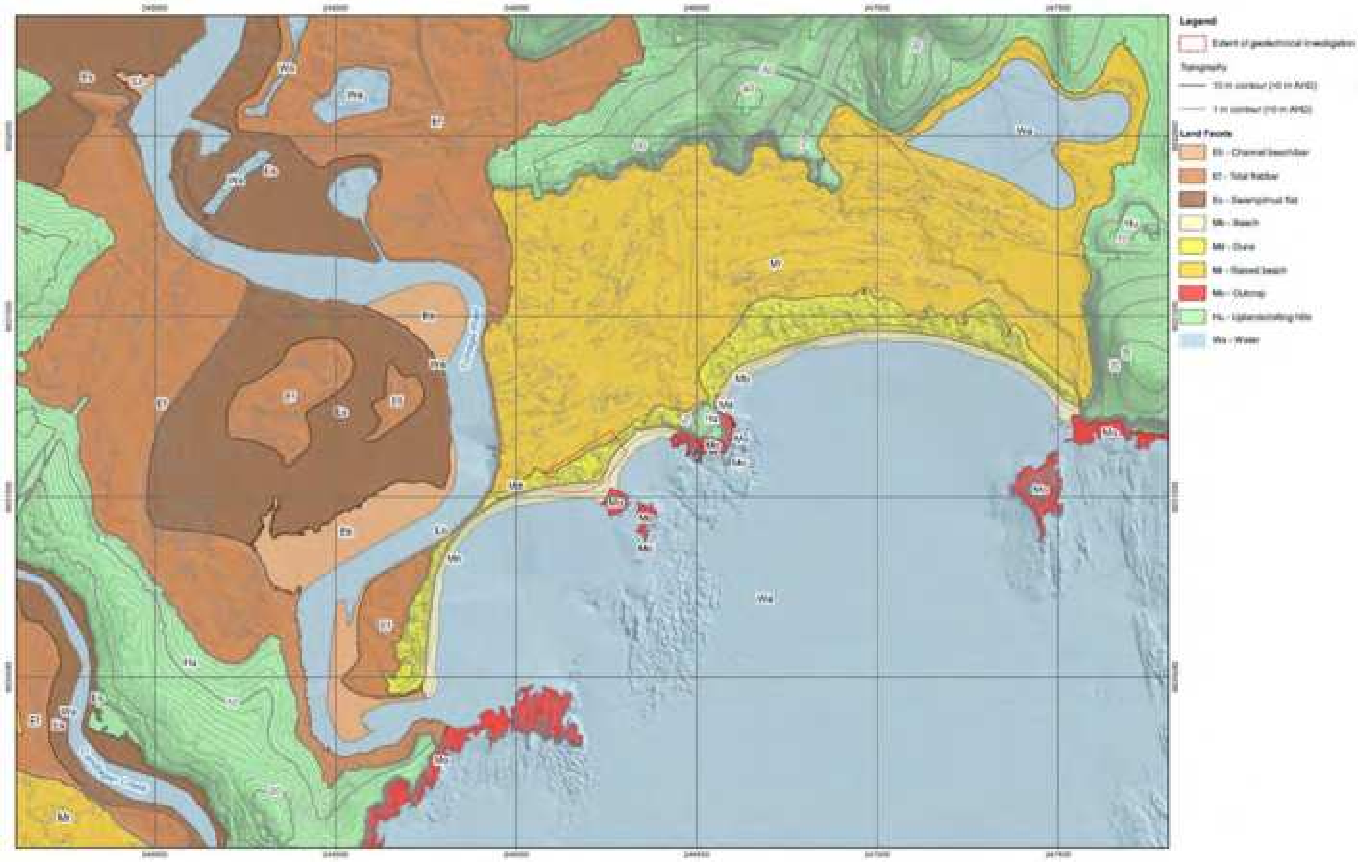
[2] Elvis – Elevation and Depth – Foundation Spatial Data, *https://elevation.fsdf.org.au/*

[3] WaterNSW Real Time Data, *https://realtimedata.waternsw.com.au/*

Inset 2: Terrain classification for Surfside.

Inset 3: Terrain classification for Long Beach.



Inset 4: Terrain classification for Tomakin.

Table 1 – Identified land systems and facets.

Land System	Land Facet	Symbol	Description and Anticipated Characteristics
Estuarine	Channel beach/bar	Eb	Sub-tidal bars and beaches within, and on the flanks of, active channels. Deposits typically several to tens of metres thick comprising sand with minor fines.
	Tidal flat/bar	Ef	Sub- to supratidal low slopes that are vegetated. Deposits typically several to tens of metres thick comprising sands, silts, and clays.
	Swamp/mud flat	Es	Intertidal low slopes that are waterlogged. Deposits typically several to tens of metres thick comprising clays and silts with minor sand.
Marine	Beach	Mb	Swash zone gently sloping towards coast. Typically, several to tens of metres thick comprising well-sorted sand.
	Dune	Md	Supra-tidal and back-of-beach, with rounded, shallow to moderate slopes. Typically, several metres thick comprising aeolian (wind-deposited) sands and minor silts.
	Raised beach	Mr	Perched behind beach/dune, with moderate ascending slope flanking seaward side, flat on top, and moderate descending slopes flanking landward side. Can also be terraced. Typically, several to tens of metres thick comprising well-sorted sand with minor silts and gravels.
	Intertidal outcrop	Mo	Intertidal wave-cut platform, shore platform, or coastal bench. Typically, flat but depends on underlying geology, comprising weathered bedrock and weathered subcrop covered by sand.
Uplands	Rolling hills	Hu	Terrestrial system at higher elevations, comprising concave footslopes, convex upper slopes and rounded ridges. Weathered bedrock overlain by colluvium of varying thickness.

4. Non-Intrusive Geotechnical Investigation

4.1 Introduction

The non-intrusive geotechnical investigation comprised:

- Field mapping – consisting of a site walk-over and engineering geological mapping undertaken between the 16th and 18th June 2021
- Geophysical surveys – undertaken during the week beginning 21st June 2021.

As intrusive investigations were not undertaken as originally planned, the results obtained from the non-intrusive fieldwork are the only data that is used to progress the conceptual models formulated during the desk study to observational engineering geological models.

4.2 Engineering Geological Field Mapping

4.2.1 Overview

Geotechnical ground-based mapping of exposures and geomorphological features was carried out to delineate and describe the various natural and man-made materials found in the study areas. Although this mapping focused on the study areas specifically, the regional area surrounding each site was also considered to understand the larger engineering geological setting. Field mapping sheets are attached in Appendix B.

Observations from the mapping campaign serves to inform the engineering geological models and understand the geotechnical character of the surficial soils and bedrock. Additionally, these observations compliment the non-intrusive geophysical investigations, with the aim of comparing the observed surficial materials with the geophysical profile.

Inset 5 presents an example of an observed outcrop, which was used to inform the likely bedrock profile in this geology. In this instance, the observed variability in the top of bedrock was noted as being a significant geotechnical characteristic that could be inferred to occur at depth below the soil profile.

Inset 5: Example of variability in the bedrock:soil interface (~4 m vertical drop over ~2 m horizontal) identified during the mapping campaign. In this example at Surfside North, the variable rock:soil interface is controlled by bedding structure in the rock.

4.2.2 Observed Geotechnical Units

The materials observed during the mapping campaign can largely be categorised into three geotechnical units:

- Marine/littoral deposits
- Colluvium, and
- Turbiditic bedrock.

A typical description of each geotechnical unit and associated land facets from the terrain classification is presented in Table 2 as observed during the mapping. It is expected there will likely be some variability in the geotechnical character of the units presented, however, without the benefit of the intrusive investigations, it is not possible to provide information on the nature of the geotechnical variability in each unit.

Table 2 – Typical geotechnical units and descriptions as observed in the mapping.

Geotechnical Unit	Associated Land Facets	Typical Material Description
Marine/littoral deposits	Mb – Beach Md – Dune Mr – Raised Beach	Sand, light brown, non-plastic with silt (variable proportions), slightly moist to wet, loose to medium dense, well graded.
Colluvium	Hu – Uplands	Silty gravel, low plasticity, with sand, moist, loose, poorly graded
Turbiditic bedrock	Hu – Uplands Mo – Outcrop	Turbidite (sequence of sandstone, siltstone, claystone, sandstone, chert), fine to medium grained, pale orange, brown, grey, very low to low strength, highly weathered.

4.3 Geophysical Surveys

4.3.1 Overview

Geophysical surveys were undertaken to investigate the possible distribution of material and depth to bedrock based on the observed seismic velocities. It is important to note that any geophysical investigation is an indirect method of testing the sub-surface conditions. Intrusive investigations are routinely used to ground truth and calibrate the results of geophysical investigations, which only measures the geophysical properties of the sub-surface.

4.3.2 Seismic Refraction (SRF) Survey

The seismic survey report is attached in Appendix C with the results summarised as follows:

- Marked seismic velocity contrasts were identified, increasing with depth, and providing a reasonable seismic profile across each SRF traverse
- Significantly higher velocities observed in the profile were attributed to seismic velocities associated with bedrock, although there is uncertainty in this assumption without testing from drilling
- Smaller differences in the seismic velocities in the upper profile were attributed to a possible shallow groundwater table, whereby the seismic velocities of saturated sediments (i.e., below the water table) are typically higher than dry sediments (i.e., above the water table)
- There is a degree of ambiguity in the measured seismic velocities and associated material interpretations for some layers at the Tomakin and Long Beach sites. This includes some ambiguity in the seismic velocities recorded in the vicinity of the buried seawall at Long Beach.

Overall, the results obtained from the SRF are considered reasonable for the purposes of this CMP.

5. Preliminary Engineering Geological Model

5.1 Surfside South

Based on the desk study and field mapping for Surfside South, the expected ground conditions for each land facet existing across the site comprises, Figure 1:

- Beach, dune and raised beach facets:
  - Marine/littoral deposits
  - Approximately 5 to 15 m thick, thinning out towards adjacent intertidal outcrop and rolling hill facets.
- Intertidal outcrop facets:
  - Turbiditic bedrock
  - Becoming sub-crop overlain by thin (<1 m) marine/littoral deposits adjacent to beach, dune, and raised beach facets.
- Rolling hills facets:
  - Colluvium of <1 m thickness

– Underlain by turbiditic bedrock.

The seismic section is reproduced in Figure 2, and indicates that seismic layer 2 (2,200 – 2,800 m/s) is interpreted as possibly being bedrock. Levels of this layer vary approximately between 2.3 m depth in the southeast and deepens to approximately 8 m depth towards the northwest. It is noted that this interpretation is based on typical seismic velocities only and is therefore assessed as having a low confidence.

Groundwater is expected to be close to or otherwise at surface, with several waterlogged areas noted during the field mapping. Seismic velocities of layer 1 (1,500 – 1,500 m/s) are also interpreted as being saturated sand.

5.2 Surfside North

Expected ground conditions for each land facet present at Surfside North comprises, Figure 3:

- Beach, dune and raised beach facets:
  - Marine/littoral deposits
  - At least 4 m thick (possibly up to tens of metres), and thinning out towards intertidal outcrop and rolling hill facets.
- Intertidal outcrop facet:
  - Turbiditic bedrock
  - Becoming subcrop overlain by thin (<1 m) marine/littoral deposits adjacent to beach, dune, and raised beach facets.
- Rolling hills facets:
  - Colluvium of <1 m thickness
  - Underlain by turbiditic bedrock.

The seismic section is reproduced in Figure 4, and indicates that seismic layer 3 (1,950 – 2,200 m/s) is interpreted as possibly being bedrock. Levels of this layer vary approximately between 3.5 m to 6 m depth. This interpretation is based on typical seismic velocities only and is again assessed as having a low confidence.

Groundwater is expected to be shallow, with several waterlogged areas noted during the field mapping. Seismic velocities of layer 2 (1,100 – 1,350 m/s) are also interpreted as being partially saturated to saturated sand.

5.3 Long Beach

Based on the desk study and field mapping undertaken at Long Beach, the expected ground conditions for each land facet within the area of interest comprises, Figure 5:

- Beach, dune and raised beach facets:
  - Marine/littoral deposits
  - Approximately 2 m thick in the centre of the study area (based on mapped intertidal sub-crop)
  - Thickening to several metres towards the west and east.

The location of the seawall structure at Long Beach is fairly evident at surface, being approximately 280 m in extent, as annotated in Figure 5. However, without the sub-surface intrusive investigations the depth of the seawall and its foundation conditions are not known.

The seismic section is reproduced in Figure 6 and indicates that seismic layer 4 (1,900 – 2,300 m/s) is possibly interpreted as bedrock. Levels of this layer vary approximately between 5 m to 11 m depth. Above this, the velocities associated with seismic layer 3 (1,700 – 1,950 m/s) are ambiguous and the possible materials are uncertain. The seismic velocities of this layer may either be indicative of weathered bedrock or a coarse grained soil such as gravel/sandy gravel with boulders. Intrusive investigations would be required to confirm the material type and geotechnical condition.

Groundwater is expected to be shallow, due to the proximity to the shoreline. Seismic velocities of layer 2 (600 – 1,450 m/s) are interpreted as being partially saturated sand.

5.4 Tomakin

Expected ground conditions for each land facet present within the study area at Tomakin comprises, Figure 7:

- Beach, dune and raised beach facets:
  - Marine/littoral deposits
  - At least 6 m thick (possibly up to tens of metres).

The seismic section is reproduced in Figure 8 and indicates that seismic layer 4 (2,000 – 2,100 m/s) is possibly interpreted as bedrock. Levels of this layer vary approximately between 7 m to 10 m depth. The velocities associated with seismic layer 3 (1,550 – 1,650 m/s) are ambiguous and the possible materials are uncertain. The seismic velocities of this layer may either be indicative of weathered bedrock or dense to very dense sand/gravel. Intrusive investigations are required to confirm the material type and geotechnical condition.

Groundwater is expected at moderate depths of approximately 5 to 6 m. The seismic velocities of layer 2 (600 – 950 m/s) are interpreted as being partially saturated sand at depths of 2.5 to 4 m.

6. Discussion and Recommendations

6.1 Qualifications

The work undertaken and presented in this report has provided a preliminary understanding of the geotechnical conditions at each of the four sites. The ground profile is inferred from the terrain classification, field mapping, and the seismic survey results, which includes interpretations of the possible sub-surface geological materials based on the seismic velocities only. Geophysical surveys are an indirect method of testing the sub-surface conditions and are routinely ground-truthed and calibrated by intrusive investigations. Without intrusive investigations, such as drilling and test pitting, the degree of confidence in the interpreted subsurface conditions based on the geophysical results is lower compared to interpretations that would include such intrusive investigation data. Further Investigations

To address the above qualifications and improve the preliminary engineering geological models for the sites, intrusive investigations are suggested. The amount of sub-surface geotechnical investigations can be optimised with the benefit of the work to date and to fit within the environmental and archaeological constraints of undertaking intrusive investigations. In summary the quantum of sub-surface work that could be undertaken in the future includes:

- A total of 5 no. machine-augered holes across the sites:
  - 2 no. at Surfside
  - 2 no. at Long Beach
  - 1 no. at Tomakin.
- Two (2) no. machine excavated test pits at Long Beach only, to assess the foundation conditions of the buried seawall.

Intrusive investigations would allow for the ground truthing of the geophysical results, in particular to associate the seismic velocities directly with material drilled or excavated and sampled from the sub-surface. This would allow for confirmation of the interpreted geological materials with the aim to resolve the uncertainties around ambiguous seismic velocity layers and expected variability in the sub-surface profile.

7. Closure

We trust this report provides the information you require for the CMP. We would be happy to answer any questions that may arise.

Yours Sincerely

M J Eggers

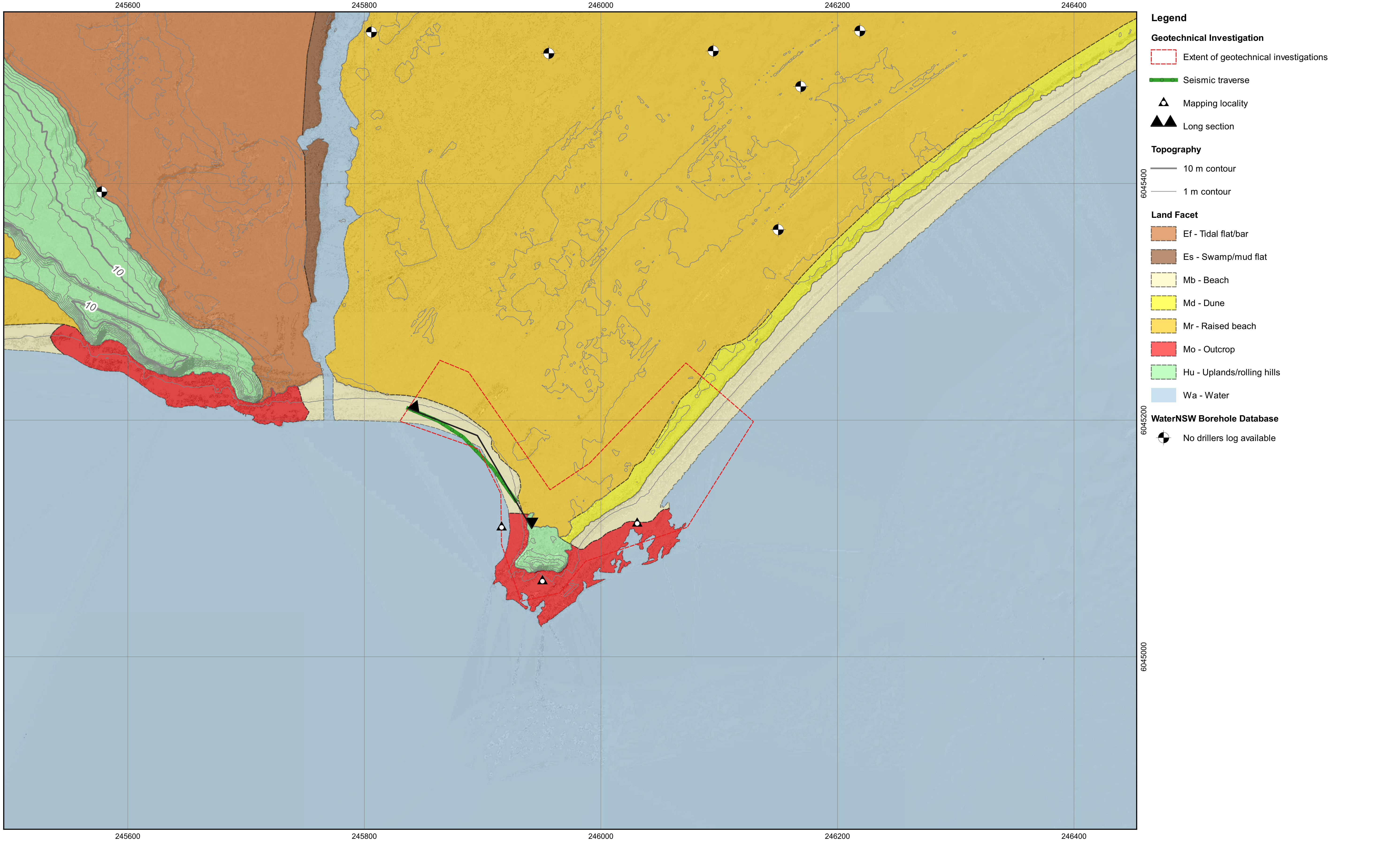
BRENDON JONES
SENIOR ENGINEERING GEOLOGIST

MARK EGGERS
CHIEF ENGINEERING GEOLOGIST

8. References

Rose G., 1966, Ulladulla 1:250 000 Geological Sheet SI/56-13, 1st edition, Geological Survey of New South Wales, Sydney

List of Figures:



C:\Users\Brendon.Jones\Pells Sullivan Meynink\GIS - ArcGIS\PSM4238\02_WorkSpace\01_MXDs_QGZs\Eurobodalla Open Coast CMP BRJ Working.qgz Layout: Surfside_South_Land_Facets_Sections_WaterNSW_3k

NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au
2. WaterNSW borehole database - drillers logs are not technical logs and can be subjective. Assessed as low confidence.

N

Scale 1:3,000

0 25 50 75 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

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Created By: BRJ

Revision: A

Date: 09 Aug 2021

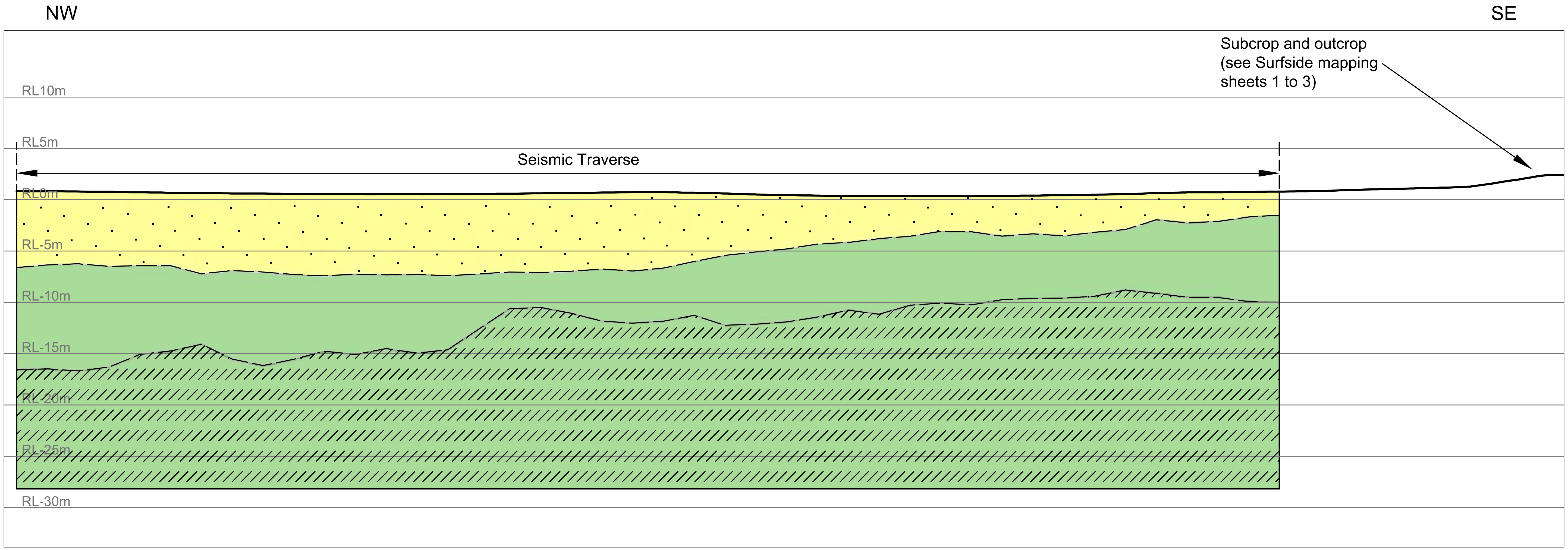
Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

SURFSIDE SOUTH PLAN

PSM4238-005R

Figure 1



Legend	Seismic velocity (m/s)	Possible materials based on interpreted seismic velocities only[1]
(yellow, dotted)	1500 - 1500	Sand, medium dense to dense, saturated
(green)	2200 - 2800	Rock, highly to moderately weathered, moderate to high strength
(green, hatched)	2800 - 3500	Rock, slightly weathered to fresh, high to very high strength

Ground surface

Interpreted seismic refractor boundary

Notes:
1. Geological material interpretations based on seismic velocities only, assessed as low confidence, and require confirmation from drilling.

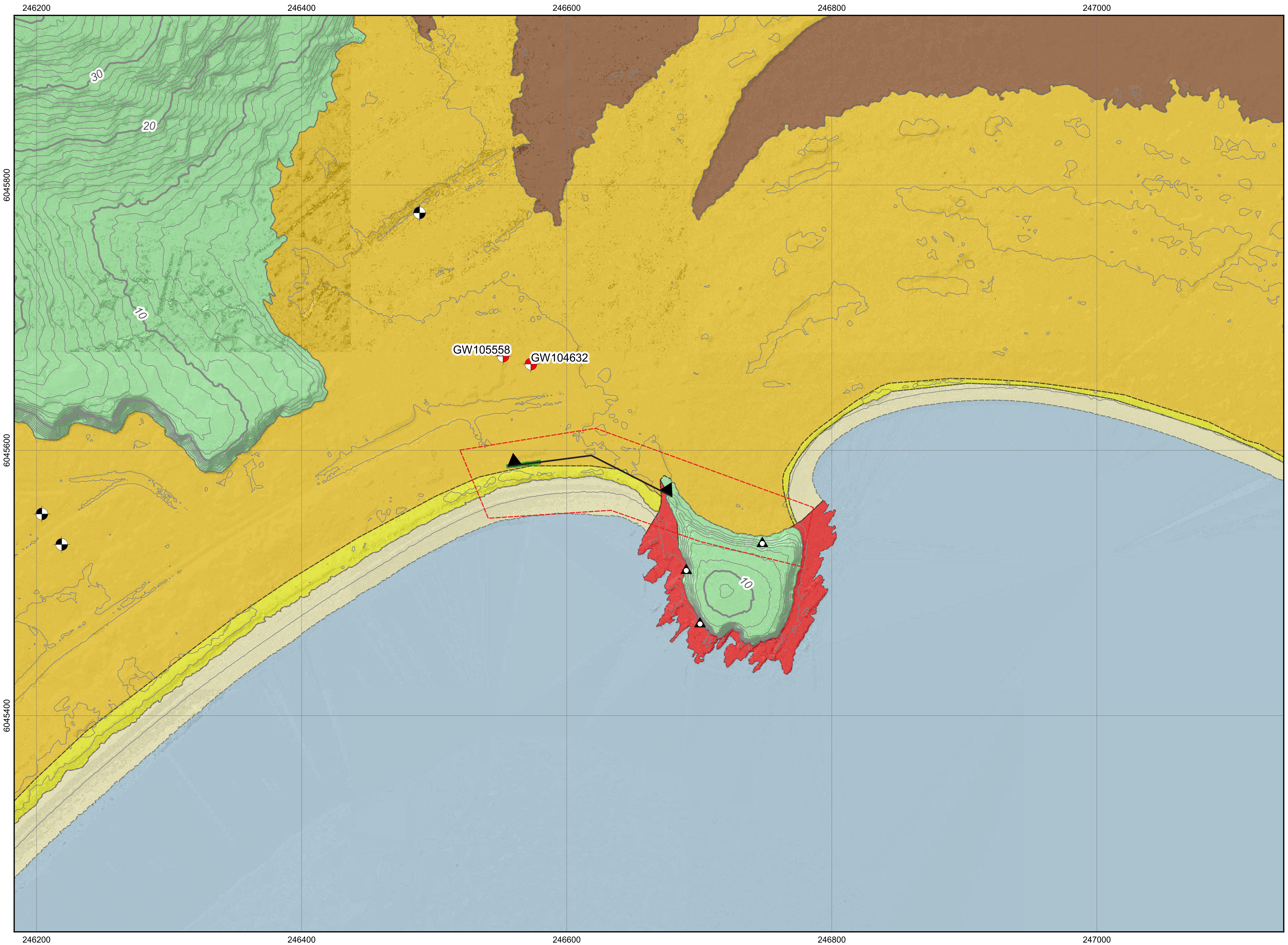
0 5 10 15 20
Scale (m)

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

SURFSIDE SOUTH CROSS-SECTION

PSM4238-005R

Figure 2



Legend

Geotechnical Investigation

- Extent of geotechnical investigations
- Seismic traverse
- Mapping locality
- Long section

Topography

- 10 m contour
- 1 m contour

Land Facet

- Es - Swamp/mud flat
- Mb - Beach
- Md - Dune
- Mr - Raised beach
- Mo - Outcrop
- Hu - Uplands/rolling hills
- Wa - Water

WaterNSW Borehole Database

- Drillers log available
- No drillers log available

NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au
2. WaterNSW borehole database - drillers logs are not technical logs and can be subjective. Assessed as low confidence.

Scale 1:3,000

N

0 25 50 75 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

Created By: BRJ	Revision: A	
Date: 09 Aug 2021	Paper Size: A3	

Eurobodalla Shire Council
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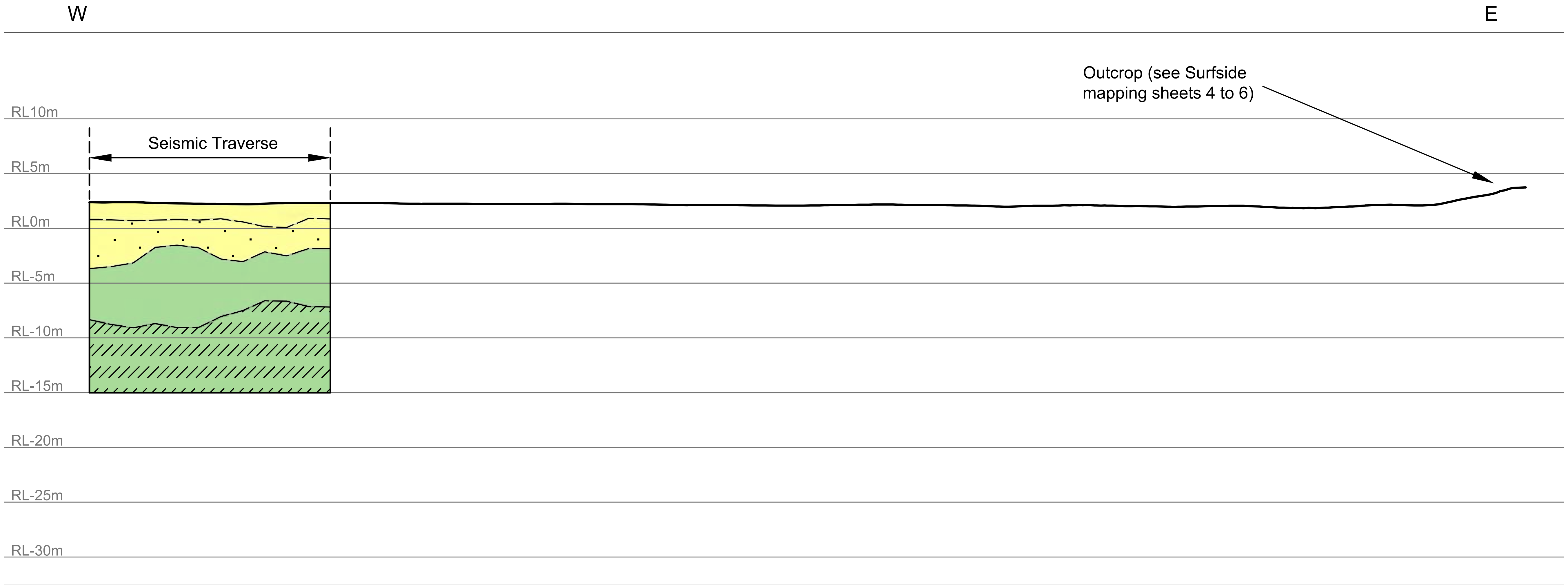
Geotechnical Investigation

SURFSIDE NORTH PLAN

PSM4238-005R Figure 3



Legend	Seismic velocity (m/s)	Possible materials based on interpreted seismic velocities only[1]
	300 - 350	Sand, medium dense to dense, dry
	1100 - 1350	Sand, medium dense to dense, partially saturated to saturated
	1950 - 2200	Rock, extremely to highly weathered, low to moderate strength
	2250 - 2400	Rock, highly to slightly weathered, moderate to high strength

Ground surface

Interpreted seismic refractor boundary

Notes:
1. Geological material interpretations based on seismic velocities only, assessed as low confidence, and require confirmation from drilling.

0 5 10 15 20
Scale (m)

Eurobodalla Shire Council
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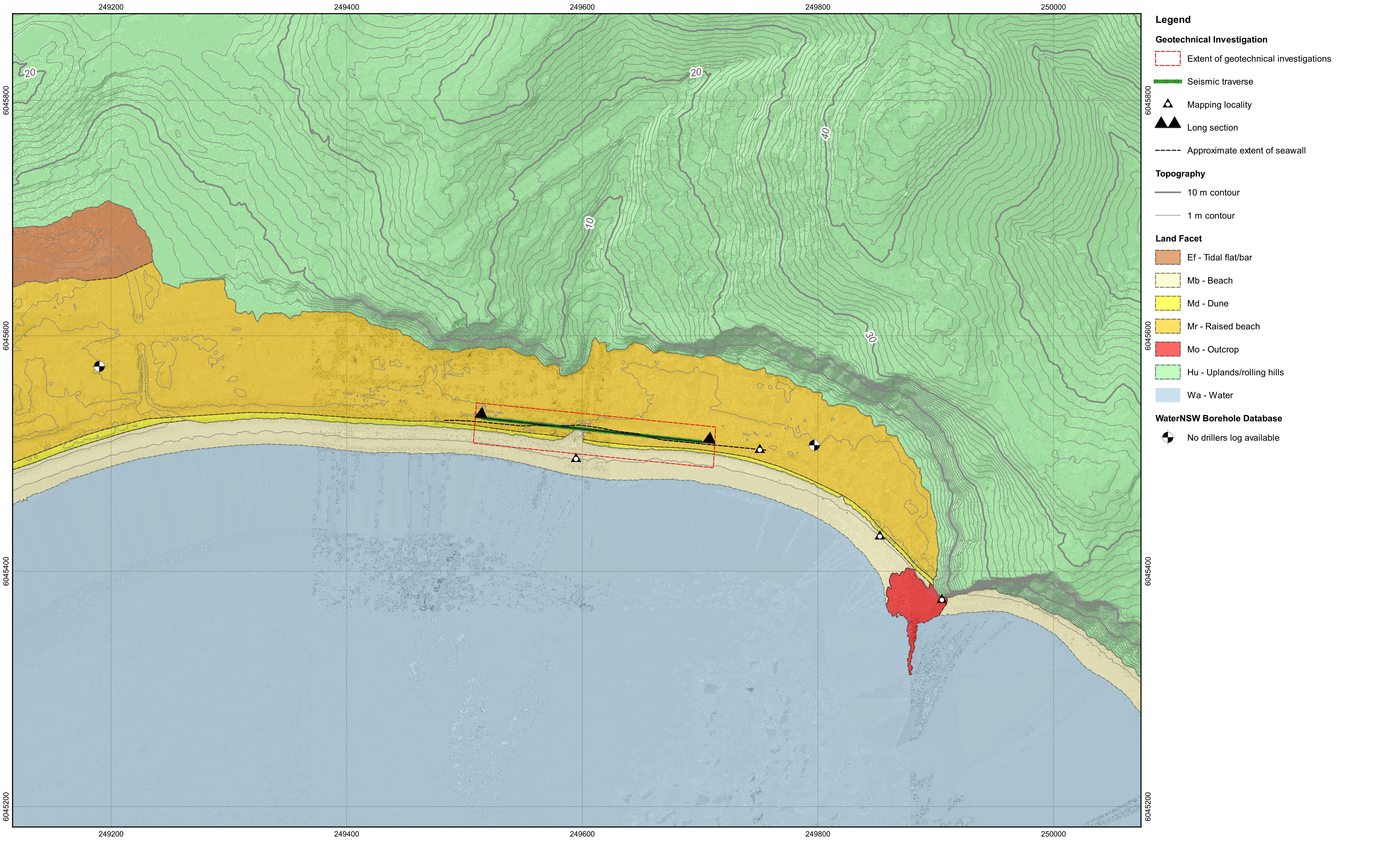
Geotechnical Investigation

SURFSIDE NORTH CROSS-SECTION

PSM4238-005R	Figure 4



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NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au
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N

Scale 1:3,000

0 25 50 75 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

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	Date: 10 Aug 2021	Paper Size: A3

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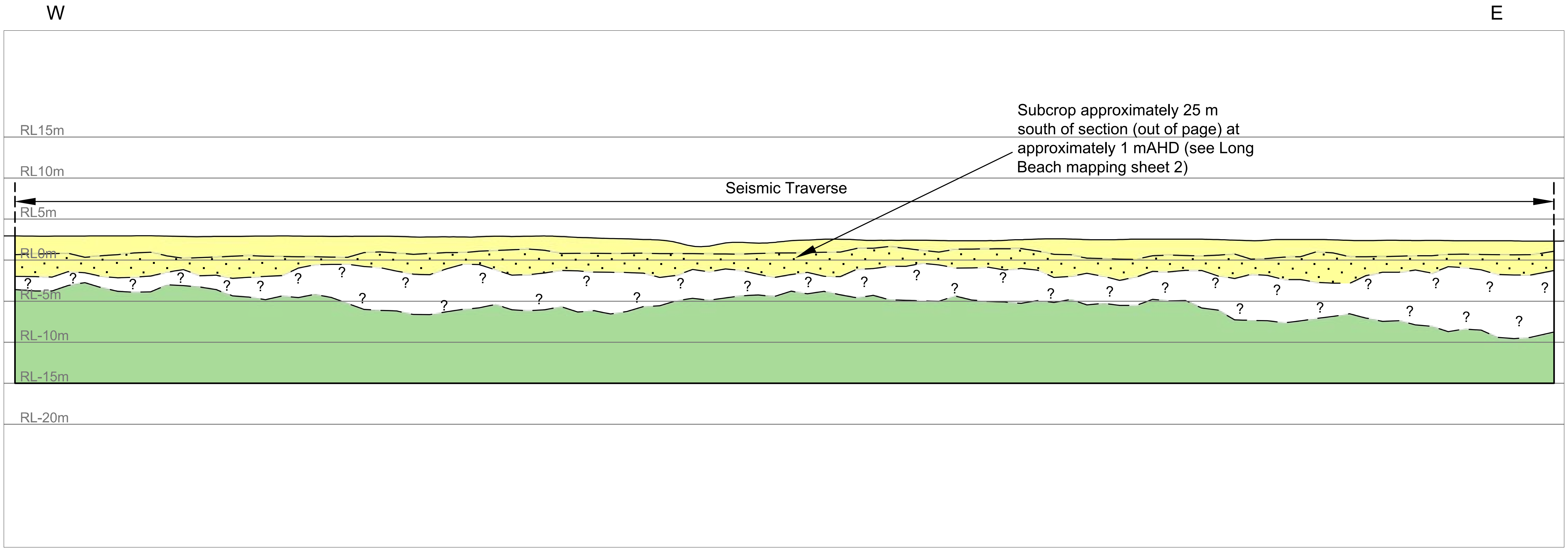
Geotechnical Investigation

LONG BEACH PLAN

PSM4238-005R | Figure 5

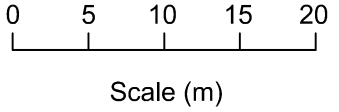


Legend	Seismic velocity (m/s)	Possible materials based on interpreted seismic velocities only[1]
(yellow)	300 - 450	Sand, medium dense to dense, dry
(yellow, dotted)	600 - 1450	Sand, medium dense to dense, partially saturated
?	1700 - 1950	Uncertain (ambiguous seismic velocities)
(green)	1900 - 2300	Rock, moderately to slightly weathered, medium to high strength

——— Ground surface

– – – – Interpreted seismic refractor boundary

Notes:
1. Geological material interpretations based on seismic velocities only, assessed as low confidence, and require confirmation from drilling.



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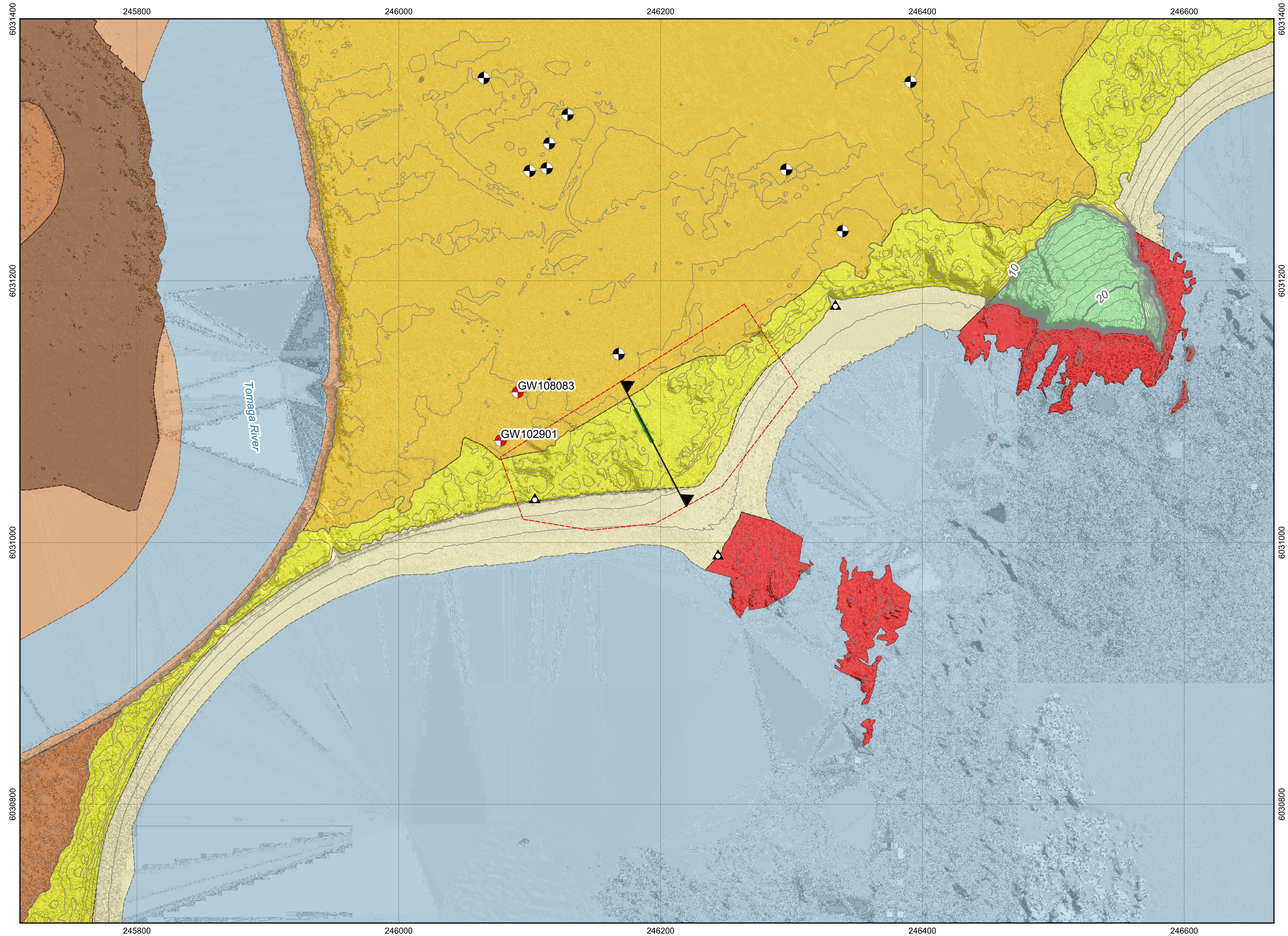
Geotechnical Investigation

LONG BEACH CROSS-SECTION

PSM4238-005R	Figure 6



Legend

Geotechnical Investigation

- Extent of geotechnical investigations
- Seismic traverse
- Mapping locality
- Long section

Topography

- 10 m contour
- 1 m contour

Land Facet

- Eb - Channel beach/bar
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Scale 1:3,000

0 25 50 75 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

Created By: BRJ

Revision: A

Date: 09 Aug 2021

Paper Size: A3

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Geotechnical Investigation

TOMAKIN PLAN

PSM4238-005R

Figure 7

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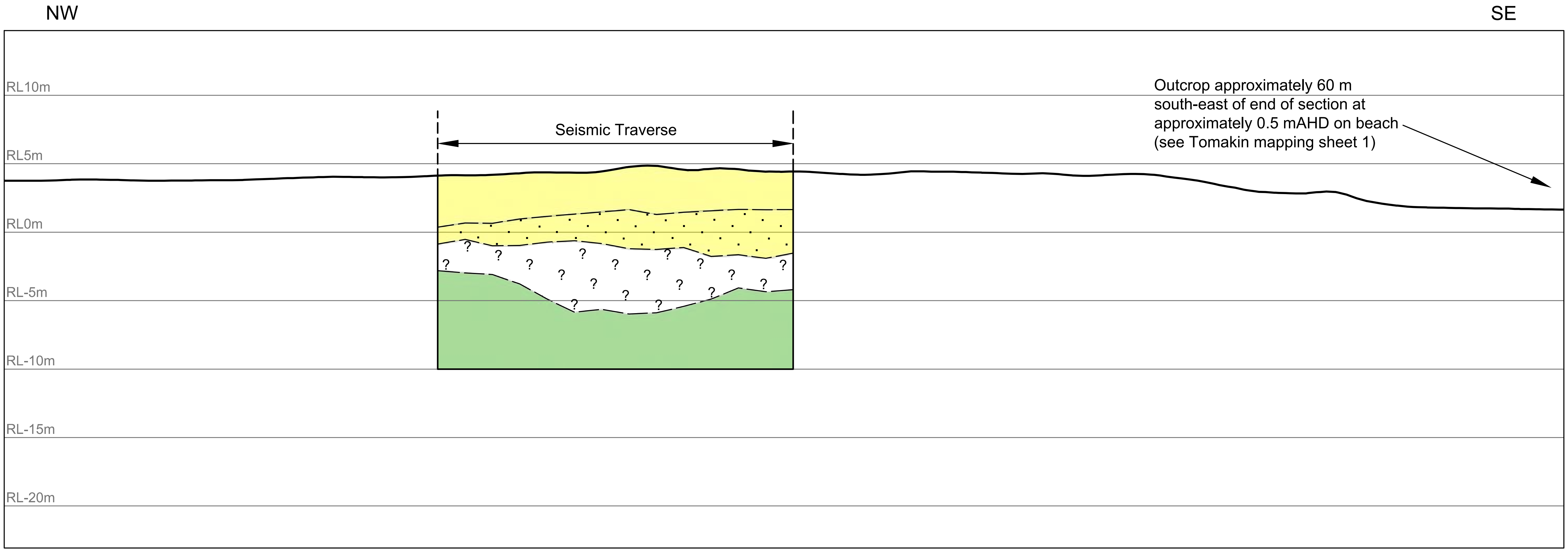

Legend	Seismic velocity (m/s)	Possible materials based on interpreted seismic velocities only[1]
(yellow)	350	Sand, medium dense to dense, dry
(yellow, dotted)	600 - 950	Sand, medium dense to dense, partially saturated
?	1550 - 1650	Uncertain (ambiguous seismic velocities)
(green)	2000 - 2100	Rock, highly to slightly weathered, medium to high strength

——— Ground surface

– – – – Interpreted seismic refractor boundary

Notes:
1. Geological material interpretations based on seismic velocities only, assessed as low confidence, and require confirmation from drilling.

0 2 4 6 8 10
Scale (m)

Eurobodalla Shire Council
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Geotechnical Investigation

TOMAKIN CROSS-SECTION

PSM4238-005R | Figure 8

Appendix A
Desk-Study Figures

Legend

Geotechnical Investigation

Extent of geotechnical investigations

Topography

10 m contour (>0 m AHD)

NOTES:
1. Imagery dated 1/04/2021

Scale **1:10,000**

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

Created By: BRJ	Revision: A
Date: 29 Jun 2021	Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

AERIAL IMAGE:
SURFSIDE (1:10,000)

PSM4238-005R | Figure A1

NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au
2. Point clouds from LiDAR and bathymetry data merged and interpolated with triangulation network method.

Scale 1:10,000

0 100 200 300 400 m

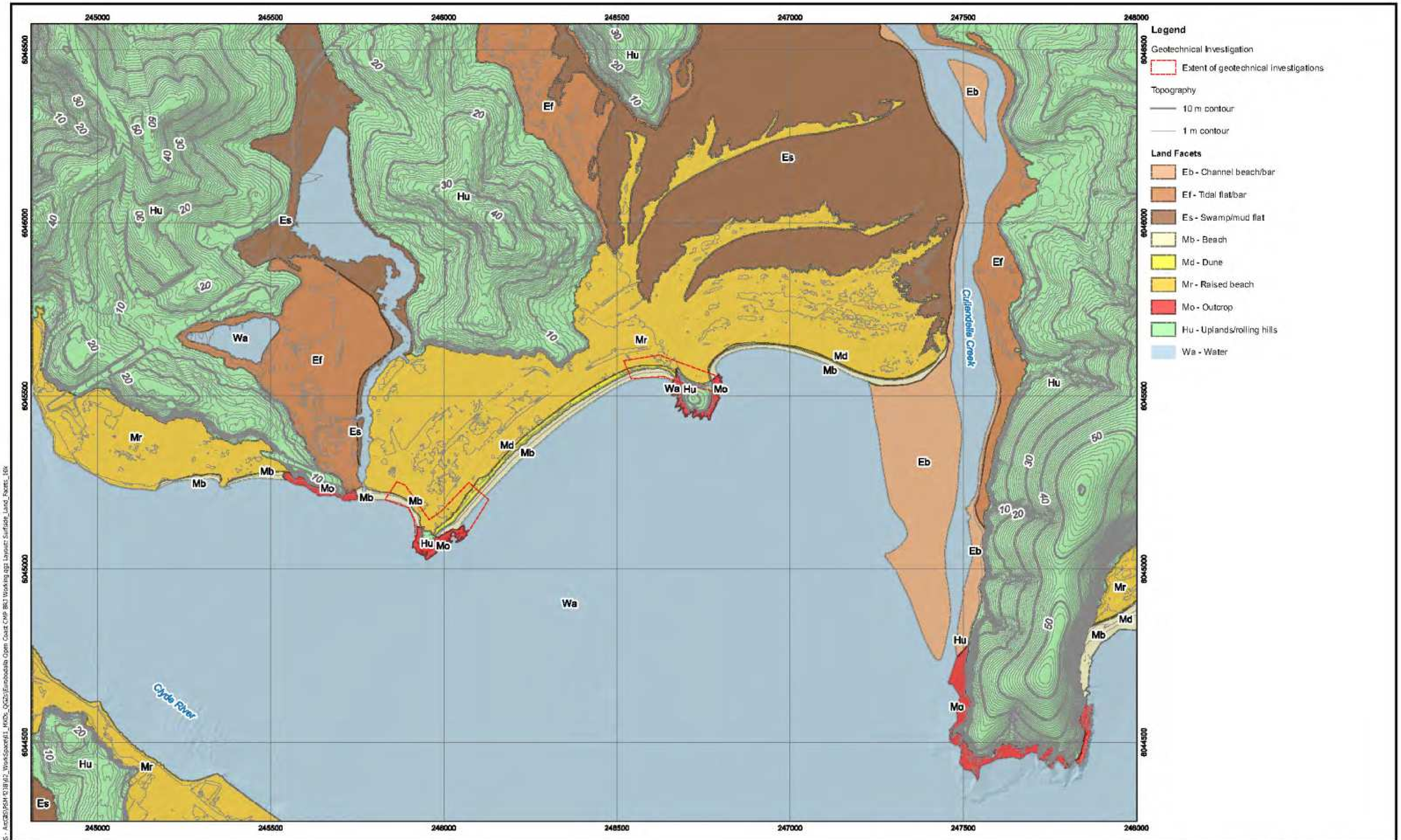
Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

Created By: BRJ	Revision: A
Date: 29 Jun 2021	Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

DIGITAL ELEVATION MODEL:
SURFSIDE (1:10,000)

PSM4238-005R | Figure A2



NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au

Scale 1:10,000

N

0 100 200 300 400 m

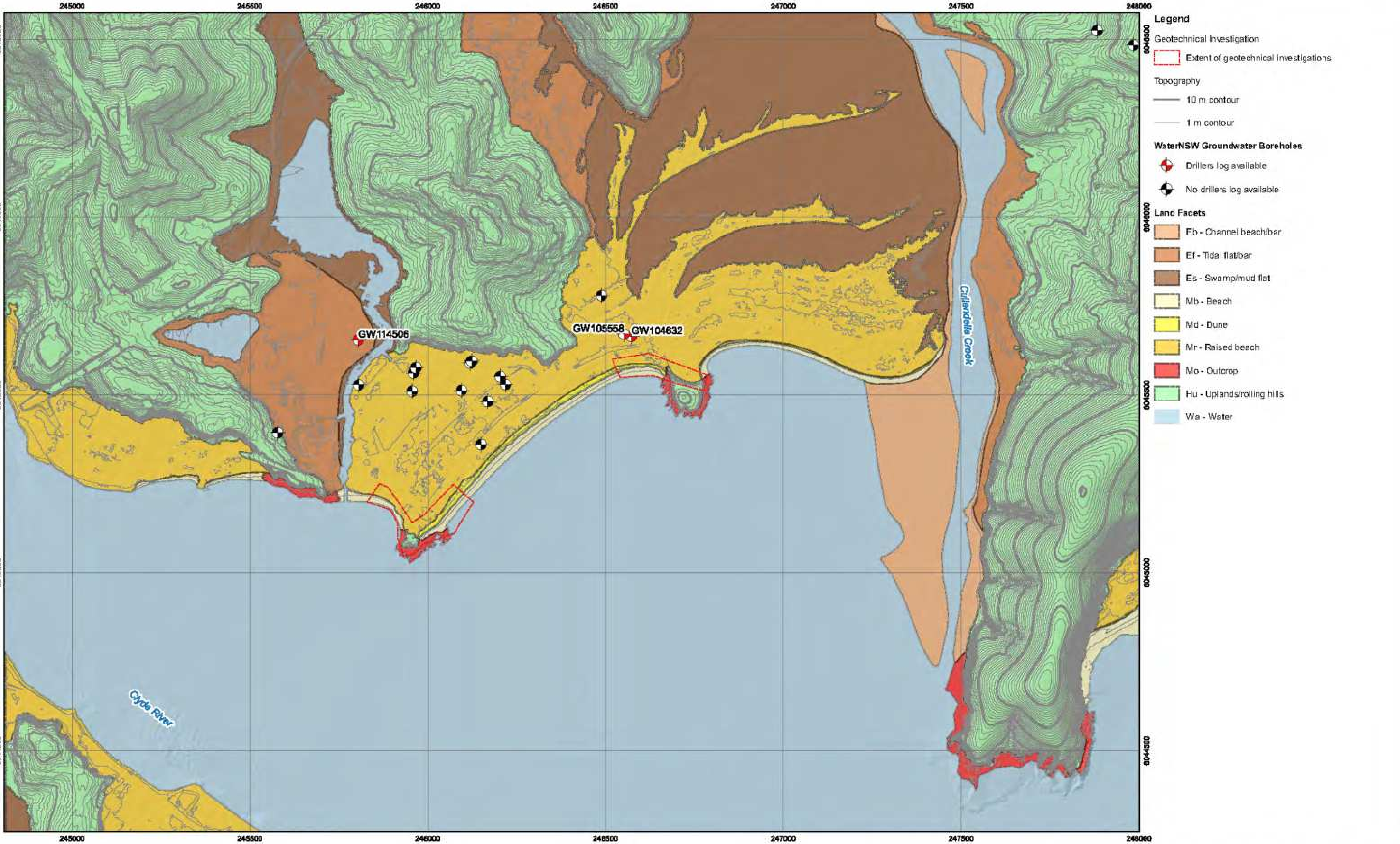
Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

P	S	M	Created By: BRJ	Revision: A
			Date: 28 Jun 2021	Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

TERRAIN CLASSIFICATION:
SURFSIDE (1:10,000)

PSM4238-005R | Figure A3



NOTES:
1. Groundwater bore information obtained from realtimedata.waternsw.com.au

Created By: BRJ	Revision: A		
Date: 08 Jul 2021	Paper Size: A3	PSM4238-005R	Figure A4

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

WaterNSW GROUNDWATER BOREHOLE DATABASE: SURFSIDE

NOTES:
1. Imagery dated 1/04/2021

Scale 1:10,000

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM

Created By: BRJ

Revision: A

Date: 29 Jun 2021

Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

AERIAL IMAGE:
LONG BEACH (1:10,000)

PSM4238-005R

Figure A5

Legend

Geotechnical Investigation

Extent of geotechnical investigations

Topography

10 m contour (>0 m AHD)

Elevation (m AHD)

- -20.00
- 0.00
- 10.00
- 25.00
- 40.00

NOTES:

1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au
2. Point clouds from LiDAR and bathymetry data merged and interpolated with triangulation network method.

Scale **1:10,000**

N

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM

Created By: BRJ	Revision: A
Date: 29 Jun 2021	Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

DIGITAL ELEVATION MODEL:
LONG BEACH (1:10,000)

PSM4238-005R | Figure A6

NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au

Scale 1:10,000

N

0 100 200 300 400 m

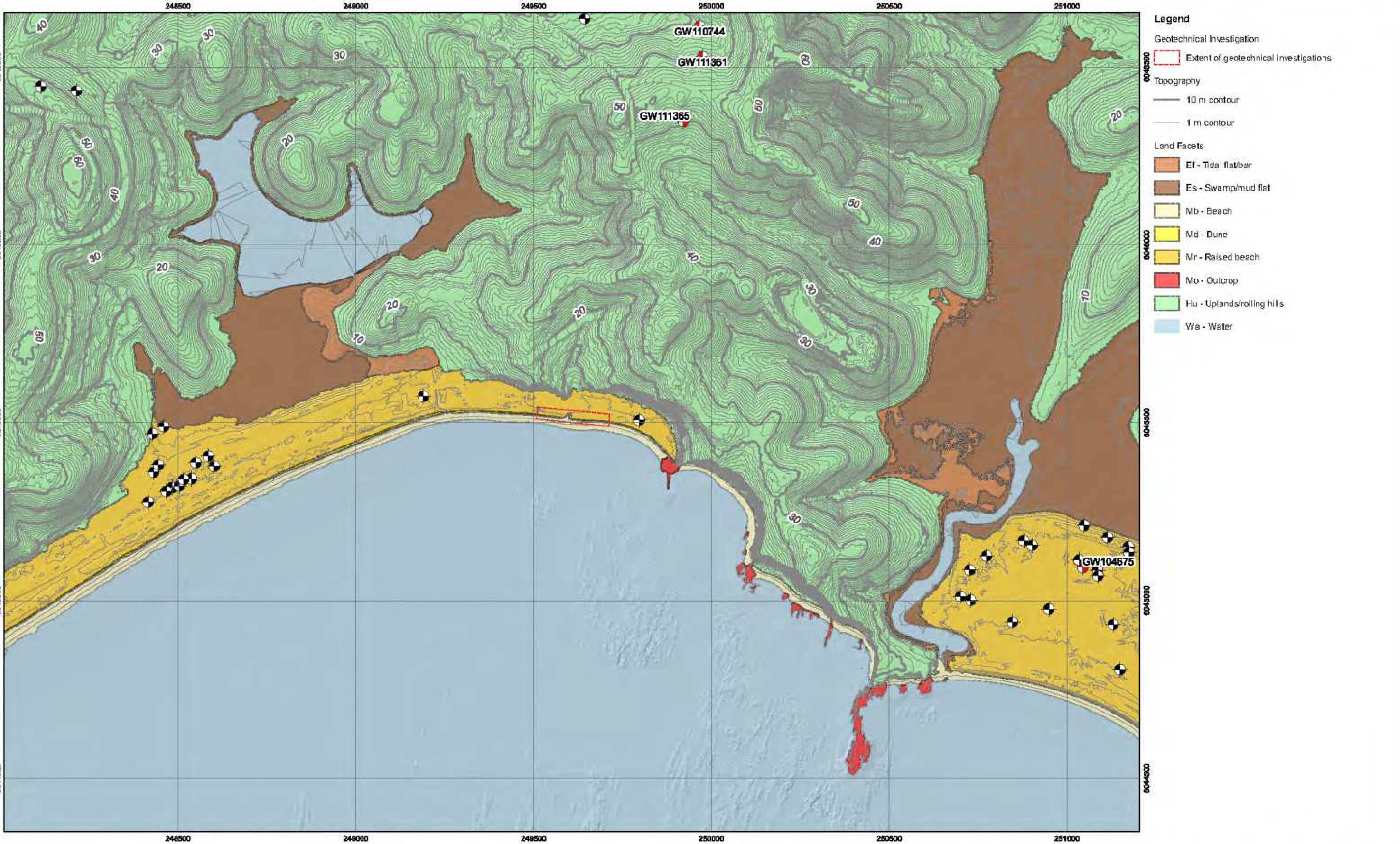
Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM	Created By: BRJ	Revision: A
	Date: 30 Jun 2021	Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

TERRAIN CLASSIFICATION:
LONG BEACH (1:10,000)

PSM4238-005R | Figure A7



NOTES:
1. Groundwater bore information obtained from realtimedata.waternsw.com.au

Scale 1:10,000

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM

Created By: BRJ

Revision: A

Date: 30 Jun 2021

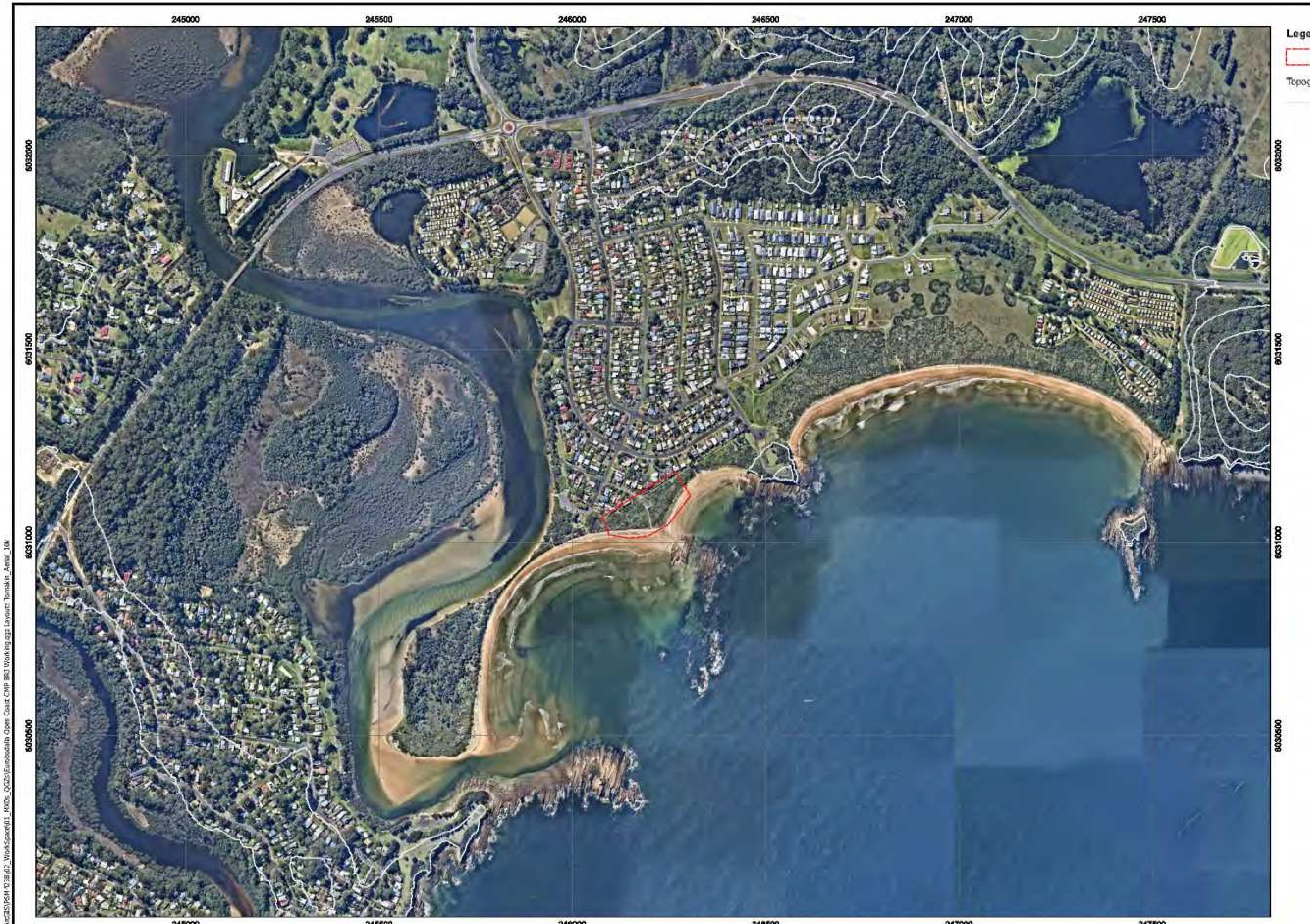
Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

WaterNSW GROUNDWATER
BOREHOLE DATABASE:
LONG BEACH

PSM4238-005R

Figure A8



NOTES:
1. Imagery dated 1/04/2021

Scale 1:10,000

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM

Created By: BRJ

Revision: A

Date: 29 Jun 2021

Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

AERIAL IMAGE:
TOMAKIN (1:10,000)

PSM4238-005R

Figure A9

Legend

Extent of geotechnical investigations

Topography

10 m contour (>0 m AHD)

Elevation (m AHD)

- -20.00
- 0.00
- 10.00
- 25.00
- 40.00

NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au
2. Point clouds from LiDAR and bathymetry data merged and interpolated with triangulation network method.

Scale **1:10,000**

N

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM

Created By: BRJ

Revision: A

Date: 29 Jun 2021

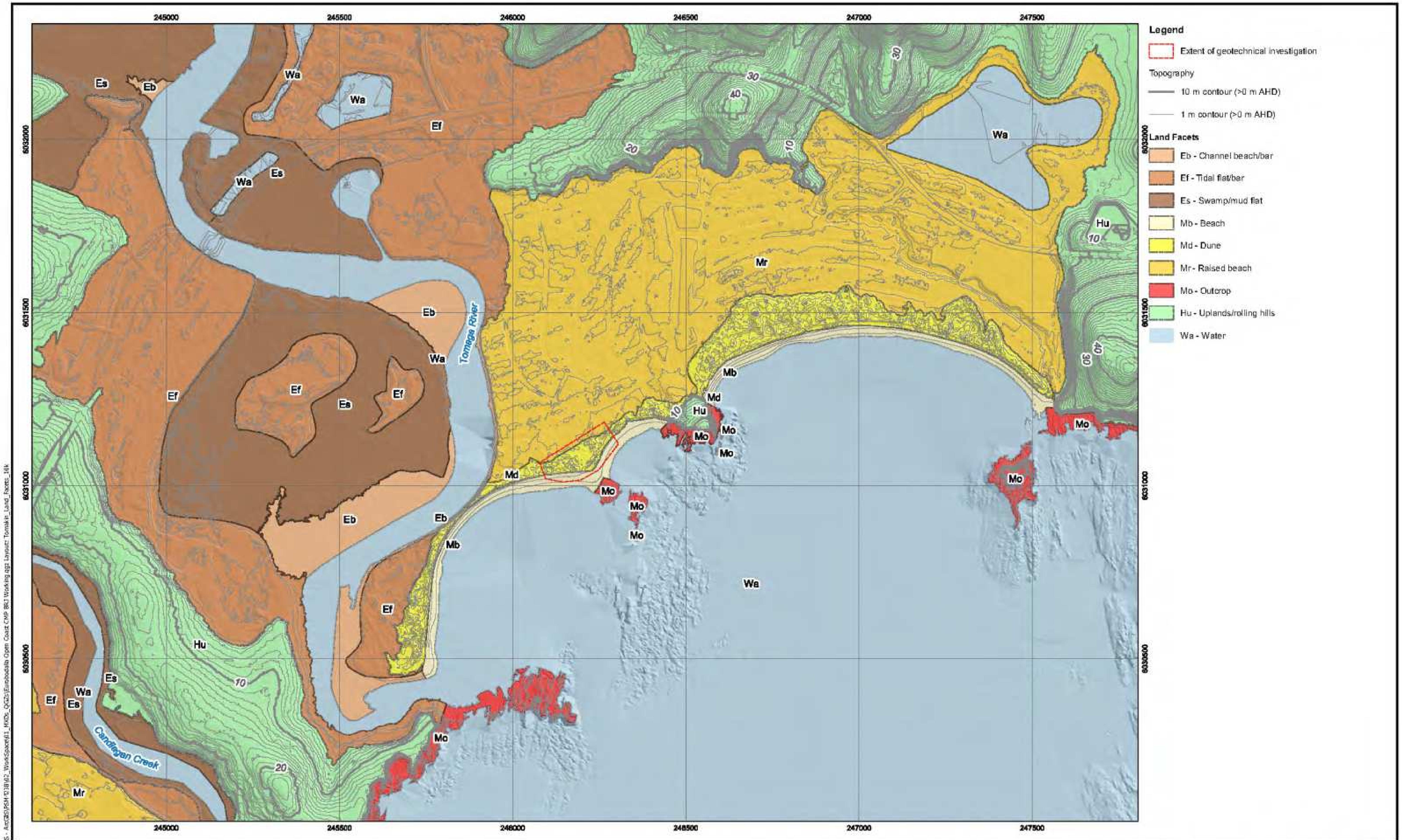
Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

DIGITAL ELEVATION MODEL:
TOMAKIN (1:10,000)

PSM4238-005R

Figure A10



NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au

N

Scale 1:10,000

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

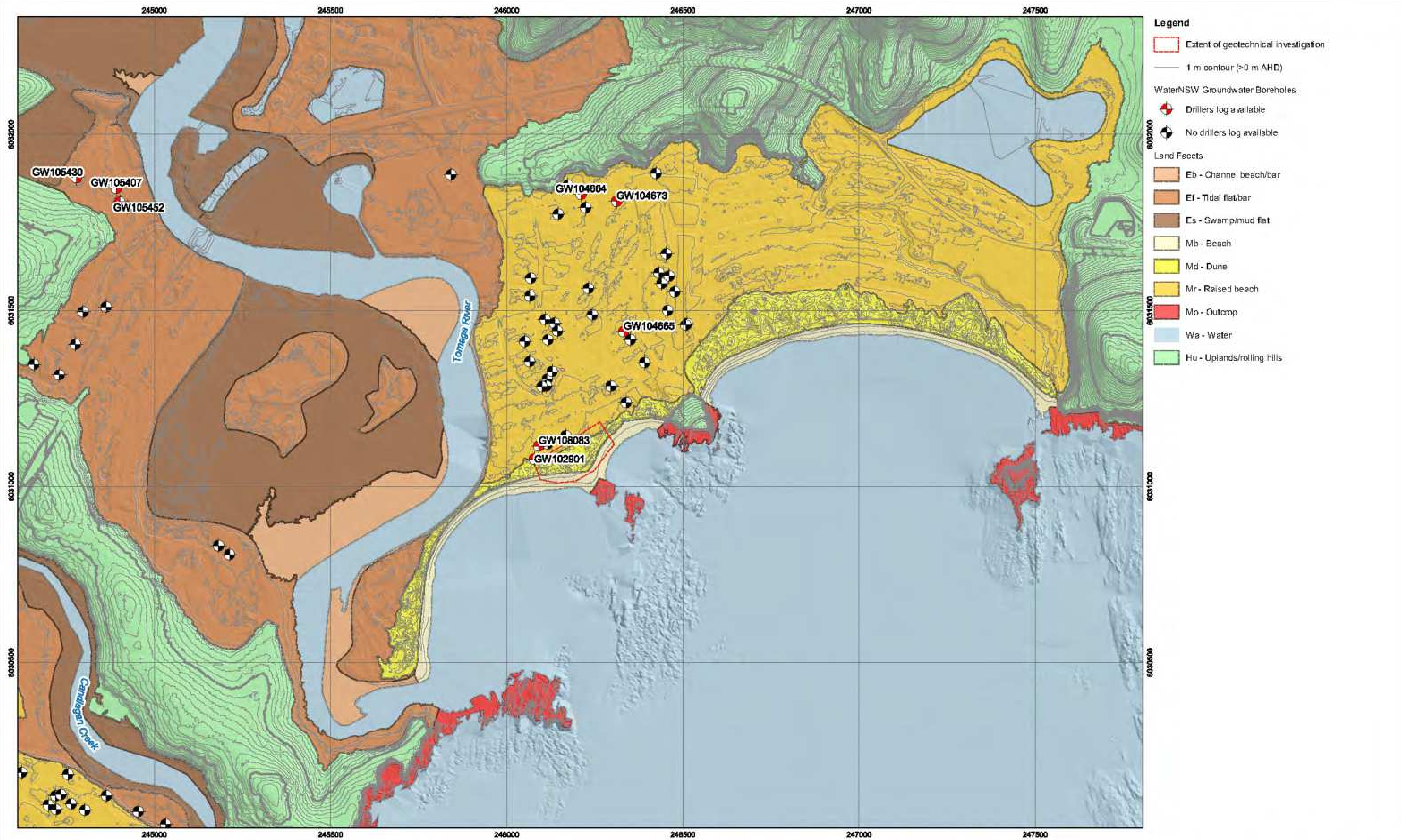
PSM

Created By:	Revision:
BRJ	A
Date: 29 Jun 2021	Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

TERRAIN CLASSIFICATION:
TOMAKIN (1:10,000)

PSM4238-005R | Figure A11



NOTES:
1. Groundwater bore information obtained from realtime.waternsw.com.au

Scale 1:10,000

N

0 100 200 300 400 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM	Created By: BRJ	Revision: A
	Date: 30 Jun 2021	Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

WaterNSW GROUNDWATER BOREHOLE DATABASE: TOMAKIN

PSM4238-005R | Figure A12

Appendix B
Field Mapping Sheets

NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au

Scale 1:3,000

0 25 50 75 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

P S M

Created By: BRJ

Revision: A

Date: 28 Jun 2021

Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

TERRAIN CLASSIFICATION:
SURFSIDE SOUTH (1:3,000)

PSM4238-005R

Figure B1

Eurobodalla CMP
PSM4238

Title Surfside 1
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

PSM

Viewing direction	NW	Comments

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							SAND, light brown, trace silt, non-plastic, wet, very loose, uniform, marine
B	Sandstone	HW	L	Brown	10-30mm		Outcrop flanked by subcrop covered by marine sands
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination
	BP	85	097	Rough	CN		0.1-0.3	CU	
	BP	71	099	Rough	CN		0.1-0.3	CU	
	BP	89	128	Rough	CN		0.1-0.3	CU	
	BP	88	309	Rough	CN		0.1-0.3	CU	
	BP	89	311	Rough	CN		0.1-0.3	CU	
	BP	76	313	Rough	CN		0.1-0.3	CU	
	BP	58	321	Rough	CN		0.1-0.3	CU	

Eurobodalla CMP
PSM4238

Title Surfside 2
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

Viewing direction	SW	Comments

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							SAND, light brown, wet, very loose, uniform, marine
B	Sandstone	HW	L	Brown	10-30cm		Outcrop and subcrop covered by marine sands
C							
D							

DEFECTS Bedding parting (BP) orientation averaged from several readings

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination
	BP	89	288	Rough	CN		0.1-0.3	CU	

Eurobodalla CMP
PSM4238

Title: Surfside 3
Logged by: BRJ | Date / Time: 17/06/2021 | Sheet 1 of 1

PSM

Viewing direction	NW	Comments

Elevation m (RL)

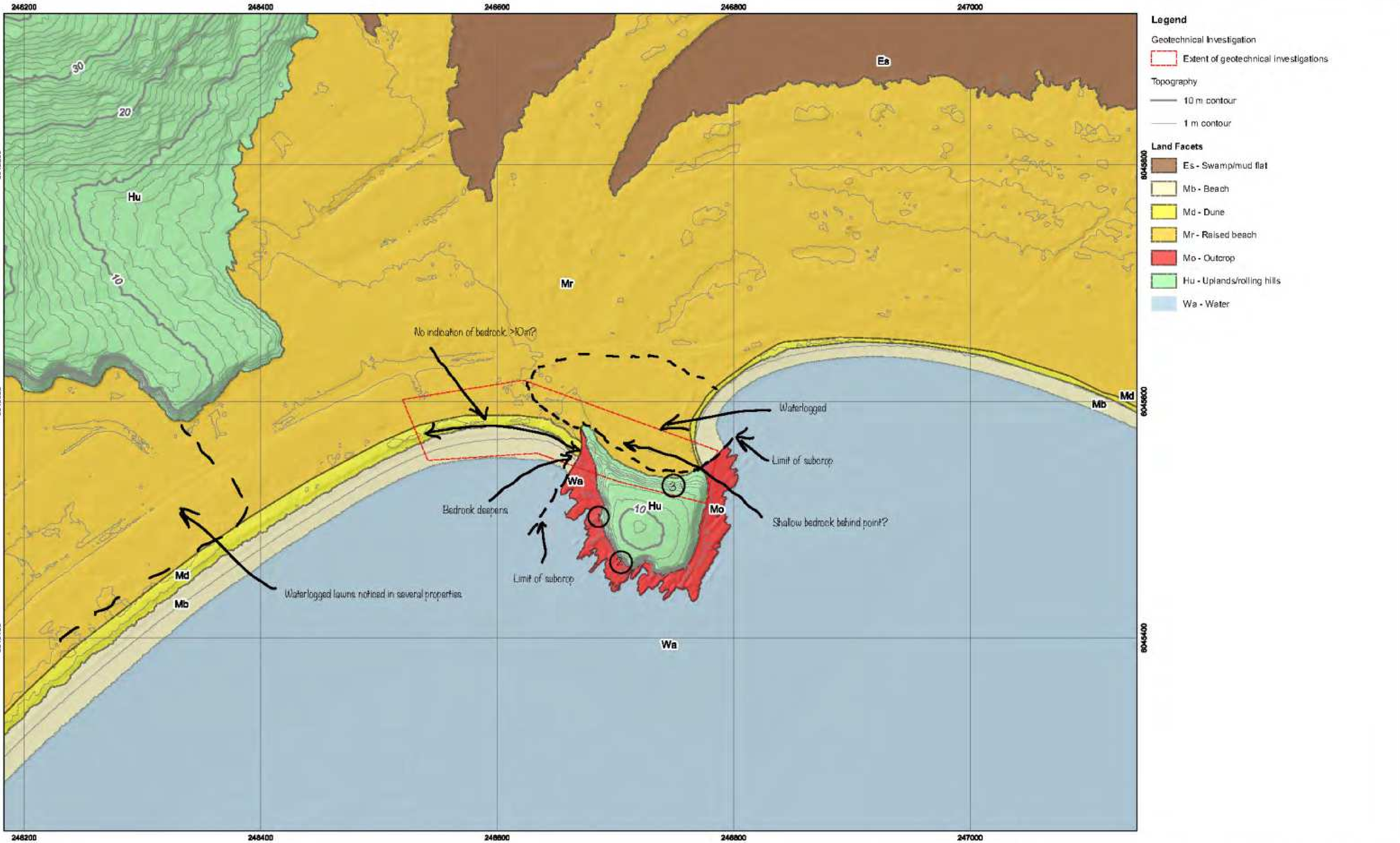
CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							SANDY SILT, low plasticity, dark brown, with clay and gravel, moist, loose poorly graded, colluvium
B							SAND, light brown, trace silt, non-plastic, moist, very loose, marine
C	Sandstone	HW	L	Brown	10-30cm		
D							SAND, light brown, minor gravel, non-plastic, moist, very loose, marine

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination
	BP	85	113	Rough	CA		0.1-0.3	CU	



NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au

Scale 1:3,000

0 25 50 75 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

Created By: BRJ

Revision: A

Date: 28 Jun 2021

Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

TERRAIN CLASSIFICATION:
SURFSIDE NORTH (1:3,000)

PSM4238-005R

Figure B2

Eurobodalla CMP
PSM4238

Title Surfside 4

Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

Viewing direction	SE	Comments

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							SILTY SAND, low plasticity, with clay and gravel, moist, loose, poorly graded colluvium
B	Interbedded Sandstone/ Siltstone	HW/MW	L	Grey	0.1-0.2		Pockets of unit A
C							SILTY GRAVEL, low plasticity, with sand, moist, loose, poorly graded colluvium
D	Interbedded Sandstone/ Siltstone	MW	L	Brown	0.1-0.3		

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination
	BP	47	309						
	BP	54	304	Rough					
	BP	53	315		SA			CU	
	BP	86	119						
	BP	84	120						

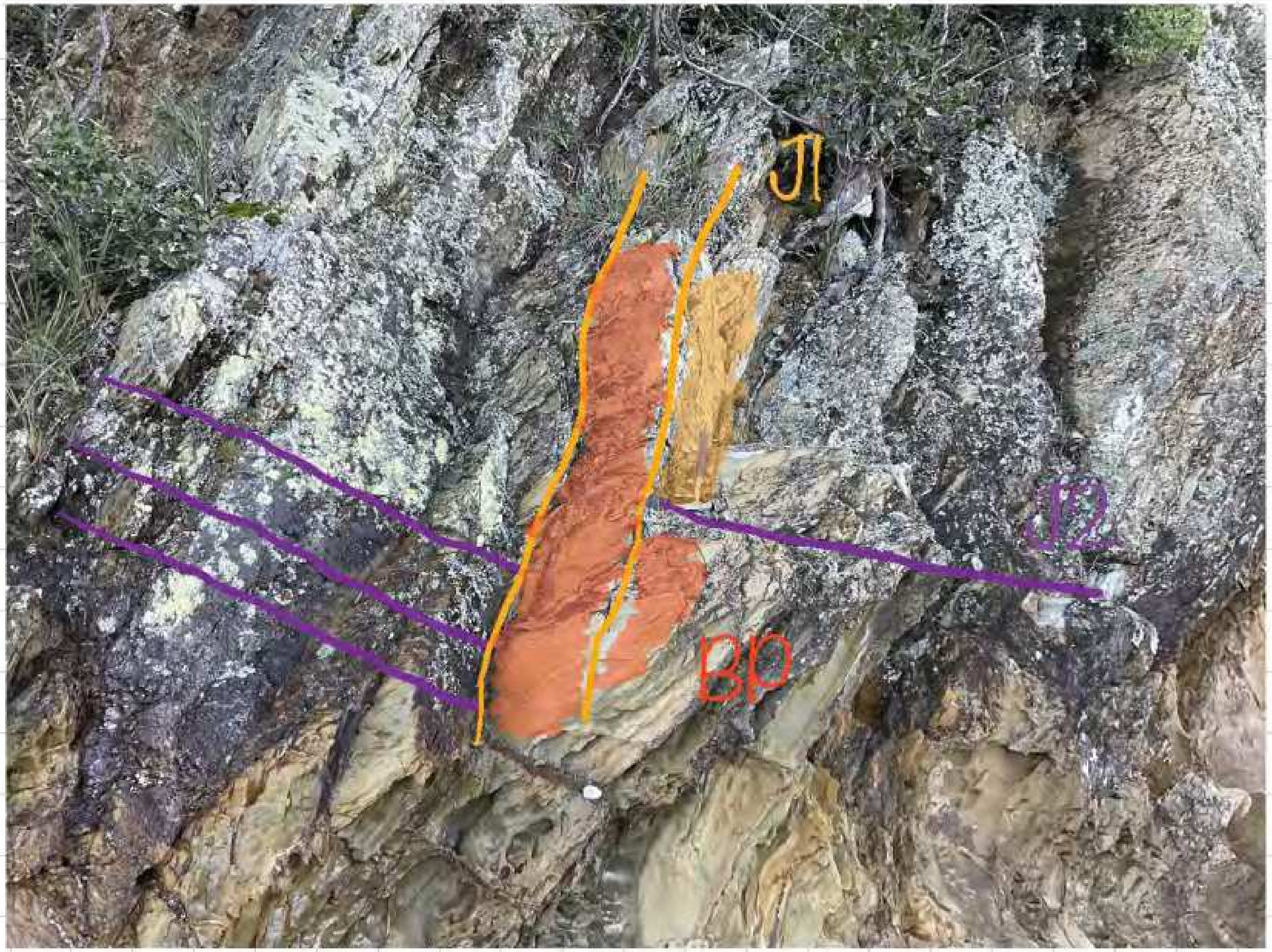
Eurobodalla CMP
PSM4238

Title Surfside 5
Logged by BRJ   Date / Time 17/06/2021   Sheet 1 of 1

PSM

Viewing direction		Comments

Elevation m (RL)



CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A	Interbedded Sandstone/ Siltstone	HW	L	Brown			
B							
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination
	BP	75	283						
	BP	81	296						
	BP	84	295						
	BP	85	293	Rough	CA			CU	
	J1	75	189						
	J1	74	182						
	J1	85	178						
	J2	39	104						

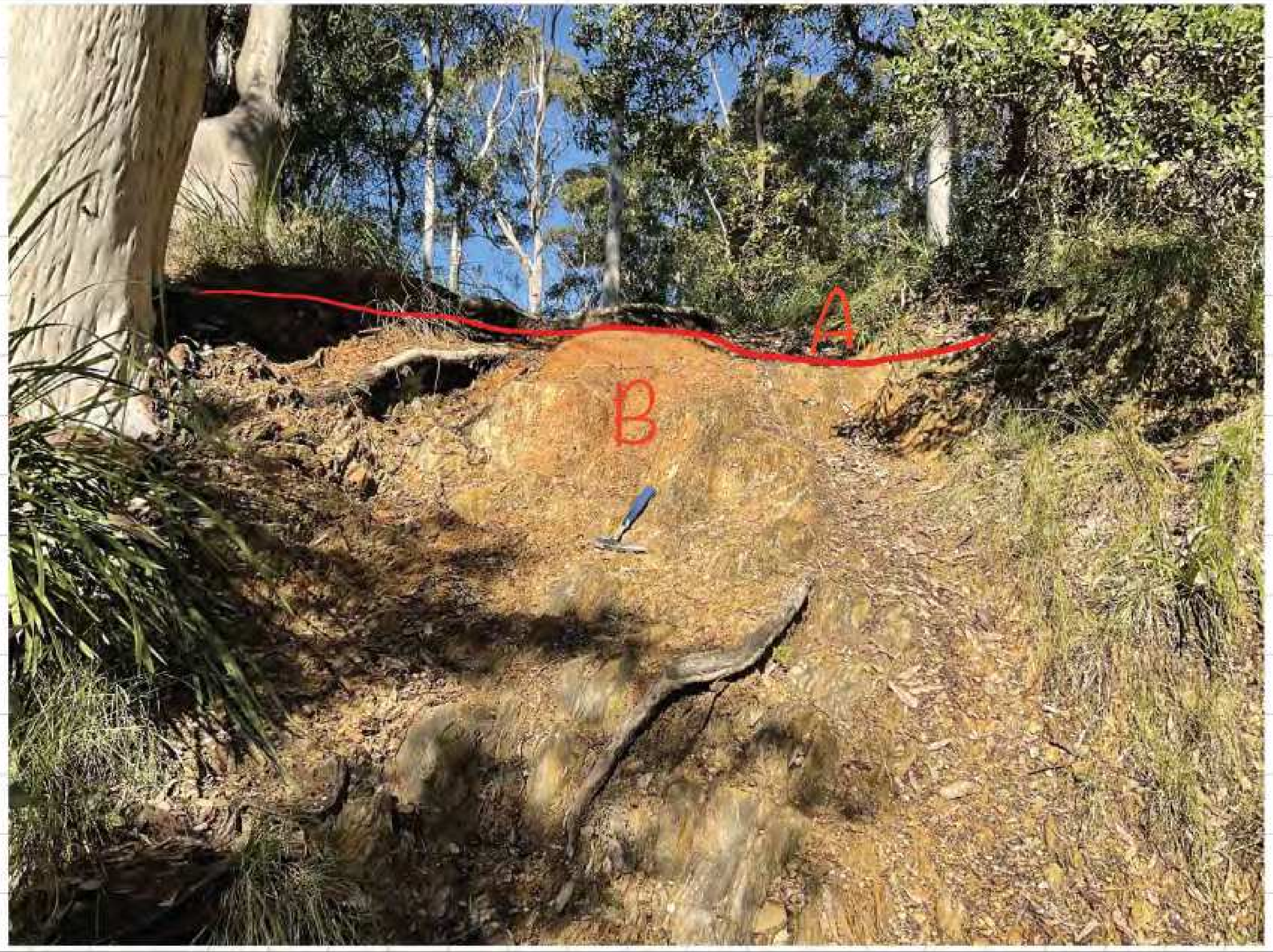
Eurobodalla CMP
PSM4238

Title Surfside 6

Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

Viewing direction		Comments

Elevation m (RL)



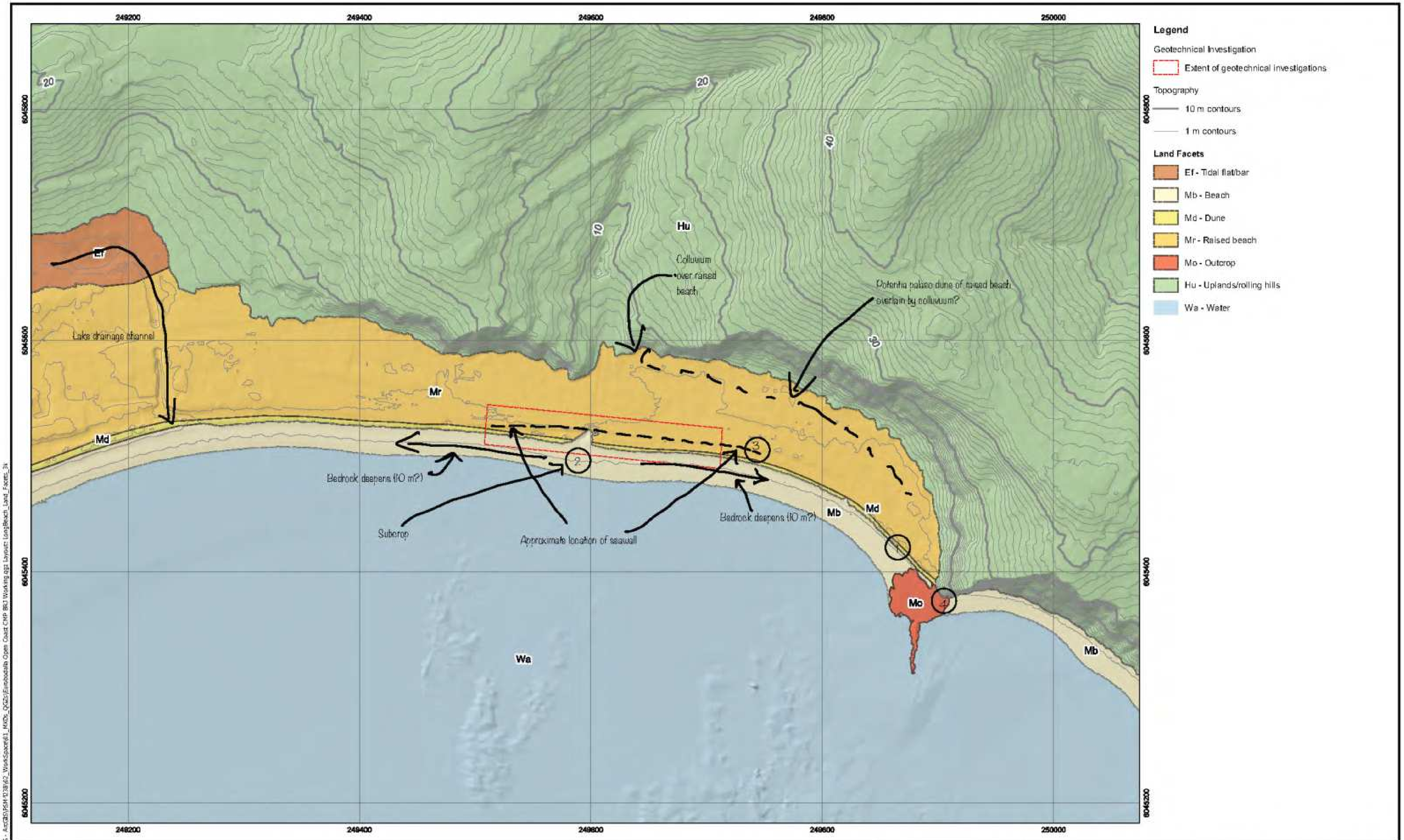
CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							SILTY SAND, low plasticity, with clay and gravel, moist, loose, poorly graded colluvium
B	Siltstone	CW/HW	VL	Pale orange	0.1-0.2		
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination



NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au

Scale 1:3,000

0 25 50 75 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM	Created By: BRJ	Revision: A	
	Date: 30 Jun 2021	Paper Size: A3	

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

TERRAIN CLASSIFICATION:
LONG BEACH (1:3,000)

PSM4238-005R | Figure B3

Eurobodalla CMP
PSM4238

Title Long Beach 1
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

PSM

Viewing direction	NE	Comments	Eastern end of Long Beach

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							SILT, low plasticity, dark brown with minor sand and gravel, moist, very soft, homogenous, colluvium
B							CLAY, medium plasticity, light brown mottled yellow, with gravel, moist, very soft, homogenous, residual
C							SAND, light brown, wet, very loose, uniform, marine (deposited adjacent to terrestrial profile)
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination

Eurobodalla CMP
PSM4238

Title Long Beach 2
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

Viewing direction	W	Comments Mid-Long Beach below intersection of Bay Road and Fauna Avenue

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							SAND, light brown, wet, very loose, uniform, marine
B	Sandstone	HW	L	Brown			Scattered subcrop covered by marine sands
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination

Eurobodalla CMP
PSM4238

Title: Long Beach 3
Logged by: BRJ   Date / Time: 17/06/2021   Sheet 1 of 1

PSM

Viewing direction	W	Comments: Mid-Long Beach.

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							Boulders, dark grey, with sand (matrix), possible sea wall?
B							SAND, light brown and grey, with gravel moist, very loose, poorly graded, possibly marine reworked with uncontrolled fill?
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination

Eurobodalla CMP
PSM4238

Title Longbeach 4
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

PSM

Viewing direction	NE	Comments

Elevation m (RL)

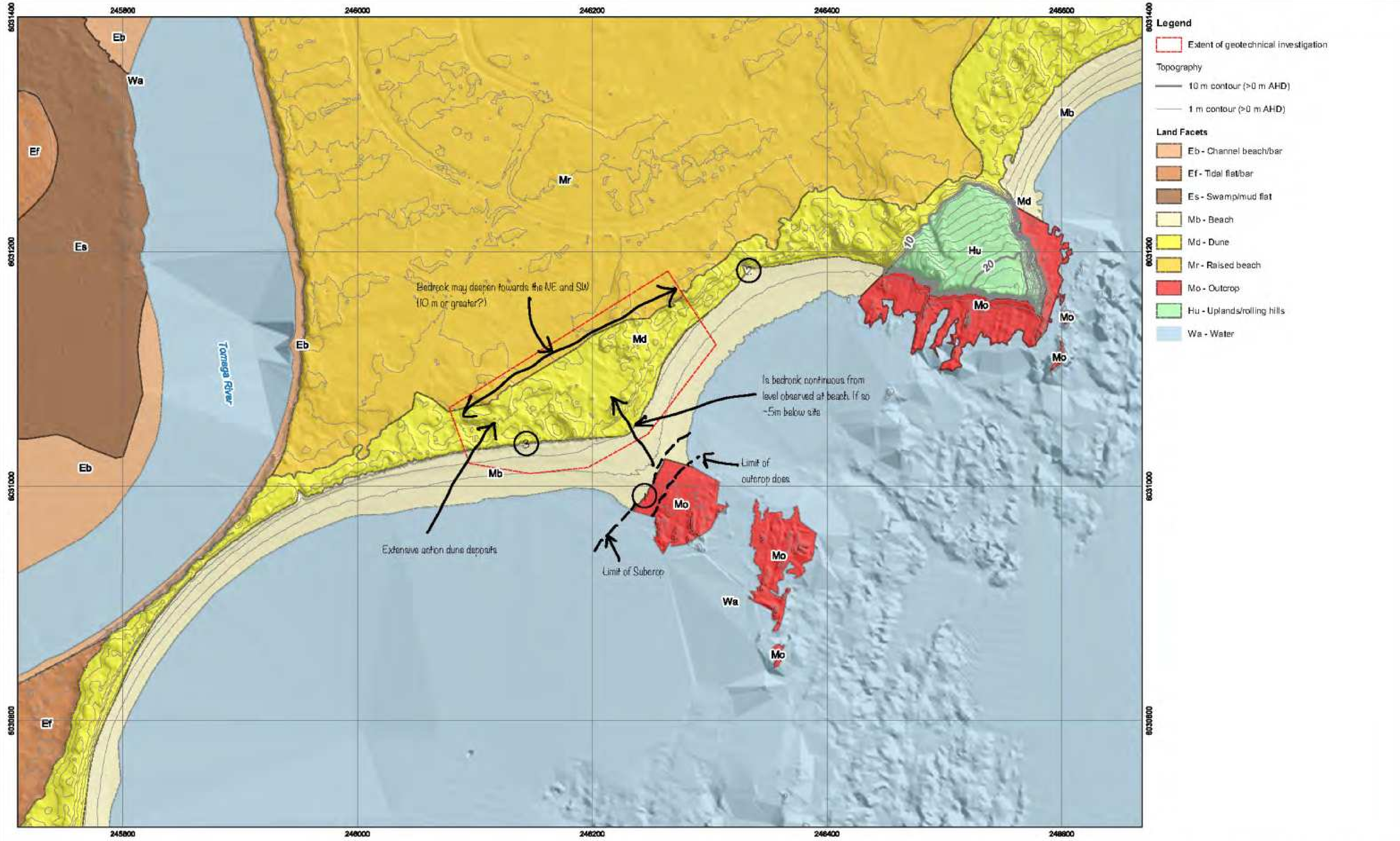
CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A	Interbedded Sandstone/ Siltstone	HW	L	Light Brown			Fine grained sandstone with minor chert. Very oxidised and leached throughout outcrop
B	Basalt	HW	M	Dark Brown			Very oxidised
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	O0Shape	Persistence/ Termination
	BP	73	251						
	BP	81	253						



NOTES:
1. DEM generated from LiDAR and bathymetry data obtained from elevation.fsd.org.au

Scale 1:3,000

N

0 50 100 m

Map Projection:
GDA2020 / MGA zone 56
EPSG:7856

PSM

Created By: BRJ

Revision: A

Date: 29 Jun 2021

Paper Size: A3

Eurobodalla Shire Council
Eurobodalla CMP - Open Coast
Geotechnical Investigation

TERRAIN CLASSIFICATION:
TOMAKIN (1:3,000)

PSM4238-005R

Figure B4

Eurobodalla CMP
PSM4238

Title Tomakin 1
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

Viewing direction	S	Comments

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							Sand, light brown, trace silt, non-plastic, very loose, uniform, marine
B	Sandstone	HW	L	Brown			Subcrop of sandstone covered by marine sands
C	Sandstone	HW	L	Brown			
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination
	BP	75	097						

Eurobodalla CMP
PSM4238

Title Tomakin 2
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

Viewing direction	NW	Comments

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							Silty sand, low plasticity, loose poorly graded, topsoil
B							Sand, light brown, trace silt, non-plastic, loose, marine
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	Shape	Persistence/ Termination

Eurobodalla CMP
PSM4238

Title Tomakin 3
Logged by BRJ Date / Time 17/06/2021 Sheet 1 of 1

PSM

Viewing direction	NE	Comments

Elevation m (RL)

CHAINAGE

MATERIAL/MASS DESCRIPTION

Mapped Unit	Lithology	Weathering	Est. Strength	Colour	Fracture Spacing	Inferred GSI	Soil Description / Other Observations
A							Sand, light brown, non-plastic, with silt, loose, Marine (Aeolian dune)
B							Sand, light brown, non-plastic, loose, well graded, Marine (beach)
C							
D							

DEFECTS

ID	Type	Dip	Dip Dir. (Mag)	Roughness	Infill	Thickness (mm)	Spacing (m)	O0Shape	Persistence/ Termination

Appendix C
Geophysical Survey Report

Report
prepared for

Pells Sullivan Meynink

On behalf of

Eurobodalla Shire Council

SEISMIC REFRACTION SURVEY
Batemans Bay, NSW

June 2021 ETS Report No ET524.01

Report prepared by:
Earth Technology Solutions Pty Ltd
ABN 12 078 325 658

35 O'Keefe Crescent
Eastwood NSW 2122

Ph: 02 9804 1752

TABLE OF CONTENTS

1.0 INTRODUCTION

At the request of Pells Sullivan Meynink (PSM) on behalf of Eurobodalla Shire Council, seismic refraction testing was completed at sites at Surfside, Long Beach and Tomakin, NSW.

The seismic survey was undertaken as part of an investigation for sediment erosion at these sites. The objective of the seismic study was to provide the subsurface seismic velocity distribution to assist the assessment of the bedrock profile and general subsurface conditions at each site.

A single seismic refraction line was completed at each site as close as possible to the indicated preferred positions, given any minor site and access constraints. A site plan is provided in Figure 1 which shows the location of each seismic line on aerial photographs of the sites.

The coordinates of the start and end points of each of the seismic lines, are listed in section 4.0, and are also shown on the interpreted seismic sections.

The fieldwork was carried out from the 22nd to 24th June 2021. The seismic data acquisition was carried out in accordance with the standard engineering seismic practice as described below.

2.0 EQUIPMENT

2.1 Seismograph

Geometrics STRATAVISOR 48 channel engineering seismographs were used. This unit has internal calibration, paper printer and hard and floppy disc drive capability. A sampling interval of 0.064 milliseconds was used and typically a record length of 120 millisecond.

2.2 Geophones

The geophones used for the survey were Geospace GS11D, with a natural resonant frequency of 8Hz. A rigid coupling with the ground was obtained with 75mm tapered spikes on the geophone base. The seismic refraction testing was completed using a linear array of up to 48 geophones, connected via two 24 channel multi-core cables to the seismograph.

2.3 Seismic Source

A triggered 14lb sledge hammer impacting an aluminium strike plate was used as the seismic source. A number of impacts were stacked until sufficient quality seismic data was achieved. Typically between 5 and 15 impacts were required, depending on the position within the spread and the level of background noise.

In general the background noise was relatively low with minimal traffic, and relatively low wave energy. The data acquisition at the Surfside site was impacted by some heavy vehicles on the adjacent Wharf Road, however sufficient breaks in traffic at this site enabled very good quality data to be acquired.

3.0 FIELD PROCEDURES

3.1 Geophone and Source Point Configurations

A 3m geophone spacing was used with a source spacing of 9m for the Surfside profile, whilst at the remaining sites a 2m geophone spacing and 12m shot spacing was considered more appropriate. The end source points were generally external - undertaken 1.5m beyond the end geophone. Typically 3 to 4 offset source points were used for each spread at approximately 13m, 25m, and 45m from the end shots were access permitted.

Generally access for the offset source points was very good. Typically 15 to 20 seismic source positions were used for each full spread resulting in reversed coverage seismic data with source-receiver offsets of over 150m.

3.2 Positioning

The seismic lines were positioned based on the lines indicated on aerial photo plans provided by PSM. Some minor repositioning of some of the seismic lines were required to avoid surface features.

Generally the ground surfaces were relatively flat. Surface elevations along each seismic line were surveyed by the seismic crew and tied in to adjacent State Survey Marks to allow reduction to AHD. Positioning along the lines during the seismic survey was maintained using 100m tapes along the ground surface.

3.3 Records and Documentation

All seismic data were recorded on hard drive and copied to field computer. A complete set of seismic data and field records has been archived.

4.0 SUMMARY OF SEISMIC LINES COMPLETED

A summary of the seismic refraction work completed is provided below.

Line	**Start & End**	**Distance**	**Position: MGA56 & AHD(m)**		
			Easting	**Northing**	**Elevation**
Surside (South)	Start	0m	245837	6045210	1.2
	End	123m	245928	6045132	0.8
Surfside (North)	Start	0m	246579	6045591	2.4
	End	24m	246556	6045588	2.3
Long Beach	Start	0m	249700	6045510	2.3
	End	184m	249516	6045530	2.6
Tomakin	Start	0m	246193	6031078	4.2
	End	26m	246181	6031101	4.1

5.0 INTERPRETATION PROCEDURES

The digital seismic records were examined and the first arrival times were determined using REFRACT2006 software. Generally the data was considered of good to very good quality signal to noise.

The seismic data were interpreted using the interpretation program REFRACT 2006, which is based on the Intercept Time Method and the Reciprocal Method in accordance with accepted engineering seismic practice.

Following manual identification and editing of the travel-times of the first arrival seismic energy. As the seismic source was surface impacts no shot depth corrections were required. Reciprocal time checks were determined automatically and edited manually to reduce any reciprocal time errors. The interpretation continued with segmentation of the T-X graph to identify individual layers. Velocity analysis followed using the computed Minus-Time Graph, derived from the reverse overlapped phantomed data for each layer. Least squares fitted lines were manually selected from each refractor, allowing identification of lateral velocity changes along the profile, and the velocities were computed.

The time depths and layer thicknesses, which were computed automatically, were checked, edited to remove any obvious errors, and any highly irregular layer surfaces manually smoothed.

The final output of the seismic refraction method is an interpreted seismic section, which is a 2 dimensional representation of the earth beneath the survey line. Discrete layers of differing seismic velocity were interpreted with measured lateral velocity variations indicated within each layer.

The surface elevations along each seismic line as measured by the project surveyor were input into REFRACT 2006 to allow reduction of the interpreted seismic sections to AHD.

6.0 RESULTS

The interpreted seismic sections for each of the seismic refraction lines completed are provided in Figures 2 to 5. The seismic lines for Surfside (south) and Long Beach are presented at a natural scale of 1:500 (A3) and at 1:250 (A3) for the shorter lines at Surfside (North) and Tomakin. The distance shown on the x-axis is the distance along the line from the start of each seismic line.

The interpreted seismic sections were also provided to PSM in .DXF format as output by REFDRAW, to enable inclusion of these seismic sections with other geotechnical data if required.

Typically three to four layers of differing seismic velocity were interpreted with interpreted seismic velocities range from 300m/s in the surface layer to 3500m/s at depth.

As with all seismic methods, seismic refraction has some inherent limitations in effectively representing subsurface conditions in all geological environments. Some of these issues are presented in Appendix A – Guide to the Use of Interpreted Seismic Sections. This offers some general information on the seismic refraction method including the precision and accuracy of results and the possible effects of violations of the assumptions on which the method and interpretation procedure is based.

A brief summary of the interpreted seismic velocity ranges for each seismic layer identified, and the key points and limitations of the seismic interpretations are provided for each seismic line. A general geological interpretation for each seismic layer is provided based solely on the seismic velocity range and general site observations. The interpretations should be correlated with any available geological mapping and borehole information where possible.

Surfside South (Figure 2)

The seismic line at Surfside was positioned along the beach at approximately the high tide mark. The work was undertaken at or near low tide.

There is some evidence in the seismic travel-time data of velocity increase with depth within Seismic Layers 2 and 3.

The following geological interpretations have been based on the interpreted seismic velocities obtained in comparison with previous seismic surveys. The results obtained are summarised below in terms of a generally layered earth.

Layer	Seismic Velocity (m/s)	General Geological Interpretation (Based on seismic velocity ranges)
1	1500–1550	Saturated SAND Medium Dense to Dense
2	2200–2800	HW to MW ROCK, Moderate to High strength.
3	2800–3500	SW to Fresh ROCK, High to Very High strength.

The bedrock profile (Seismic Layer 2) is interpreted at a level varying from approximately RL-1.5m (approx 2.3m depth) in the South East of the seismic line and deepens to generally RL -6m (approx 8m depth) towards the North West.

Surfside North (Figure 3) adjacent to Cullendulla Reserve

Seismic Layers 2 and 3 are relatively thin, and the velocities of these layers are based on limited data (hatched areas on the interpreted seismic sections)

The following geological interpretations have been based on the interpreted seismic velocities obtained in comparison with previous seismic surveys with borehole correlations and the results obtained are summarised below in terms of a generally layered earth.

Layer	Seismic Velocity (m/s)	General Geological Interpretation (Based on seismic velocity ranges)
1	300–350	Dry SAND, Medium Dense to Dense
2	1100-1350	Partially saturated to saturated SAND, M Dense to Dense
3	1950–2200	EW to HW ROCK, Low to Moderate strength.
4	2250–2400	HW to SW ROCK, Moderate to High strength.

The bedrock profile (Seismic Layer 3) is interpreted at a level varying from approximately RL-1.5m to RL-3m (approx 3.5m to 6m depth).

Long Beach (Figure 4)

There is some evidence in the seismic travel-time data of velocity increase with depth within Seismic Layer 4.

The following geological interpretations have been based on the interpreted seismic velocities obtained and the results obtained are summarised below in terms of a generally layered earth.

Layer	Seismic Velocity (m/s)	General Geological Interpretation (Based on seismic velocity ranges)
1	300-450	Dry SAND, Medium Dense to Dense
2	600–1450	Partially saturated to saturated SAND M Dense to Dense
3	1700–1950	Highly Fractured EW to MW ROCK, Moderate to High strength, or potentially very Dense SAND /GRAVEL with ROCK boulders.
4	1900–2300	MW to SW ROCK, Moderate to High strength.

The seismic velocities of Layer 3 are not unambiguously indicative of a ROCK profile and could potentially represent very dense saturated SAND/GRAVEL. However given the nature of the highly fractured and weathered rock reefs visible on the adjacent headland and just offshore from that section of the beach, it is considered that this layer represents highly fractured and/or weathered rock.

Seismic Layer 3 is interpreted at a level varying from approximately RL-0.5m to RL-2.5m (approx 3.5m to 5m depth).

Tomakin (Figure 5)

The following geological interpretations have been based on the interpreted seismic velocities obtained in comparison with previous seismic surveys.

Layer	Seismic Velocity (m/s)	General Geological Interpretation (Based on seismic velocity ranges)
1	350	Dry SAND, Medium Dense to Dense
2	600–950	Partially saturated SAND M Dense to Dense
3	1550–1650	Highly Fractured EW to MW ROCK, Moderate to High strength, or potentially Dense to very DENSE SAND /GRAVEL.
4	2000–2100	EW to MW ROCK, Low to Moderate strength.

Again the seismic velocities of Layer 3 are not unambiguously indicative of a ROCK profile and could potentially represent dense saturated SAND or GRAVEL. However given the highly fractured and weathered rock reef visible immediately offshore from this section of the beach, it is considered that this layer represents highly fractured and/or weathered rock or at least a significant concentration of ROCK boulders. This layer varies from approximately 2m to 4m thick.

Seismic Layer 4 is interpreted at a level varying from approximately RL-3m to RL-5.5m (approx 7m to 9.5m depth).

7.0 CONCLUSIONS

Seismic refraction testing was successfully completed along the designated profiles and the seismic data acquired is considered generally of good quality. This seismic study has generally delineated 4 layers of differing seismic velocity within the shallow subsurface with interpreted seismic velocities range from 300m/s in the surface layer to 3500m/s at depths of up to 15m.

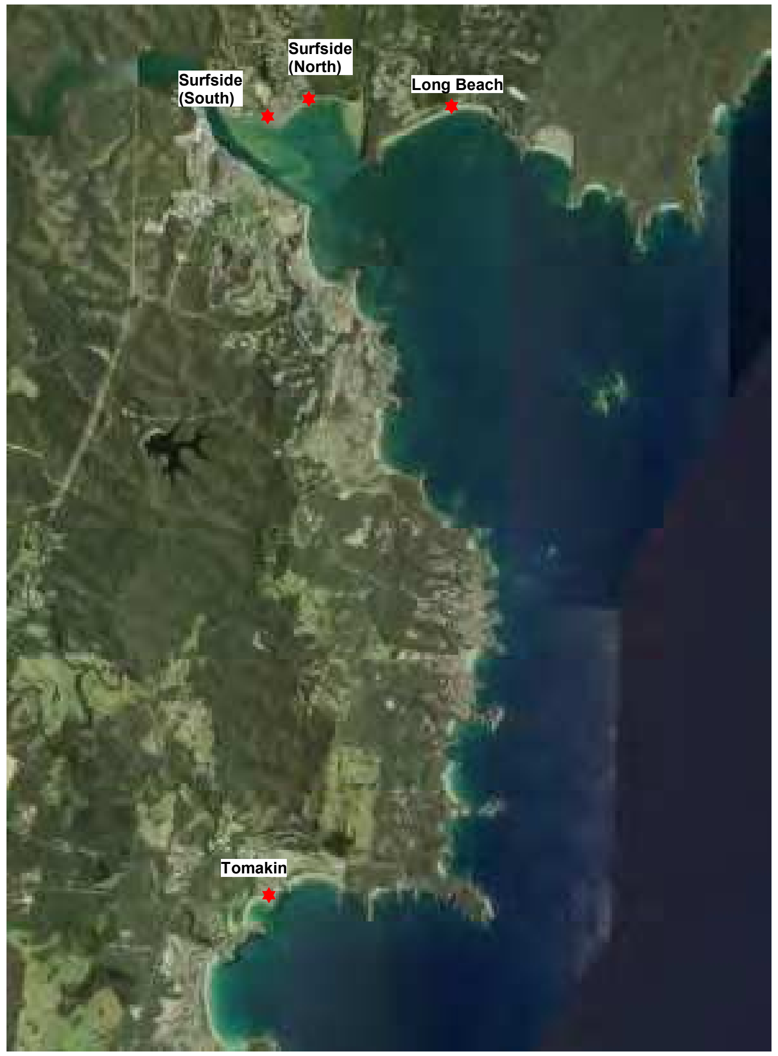
Whilst these seismic velocity ranges are indicative of and consistent with a range of material from dry SAND through to Fresh High strength ROCK and a general interpretation based on the interpreted seismic velocity ranges have are provided. There is some ambiguity of the geological interpretation of Seismic Layer 3 at Long Beach and Tomakin due to the intermediate seismic velocities obtained.

This seismic information should be correlated, where possible, with any boreholes or other geotechnical information, to increase the understanding of the subsurface conditions. Appendix A – Guide to the Use of Interpreted Seismic Sections is provided to offer some general information on the seismic refraction method including the precision and accuracy of results and should be read before using the seismic sections.

Surfside Beach (South)

Surfside Beach (North - adjacent Cullendulla Reserve)

Overall Site Plan



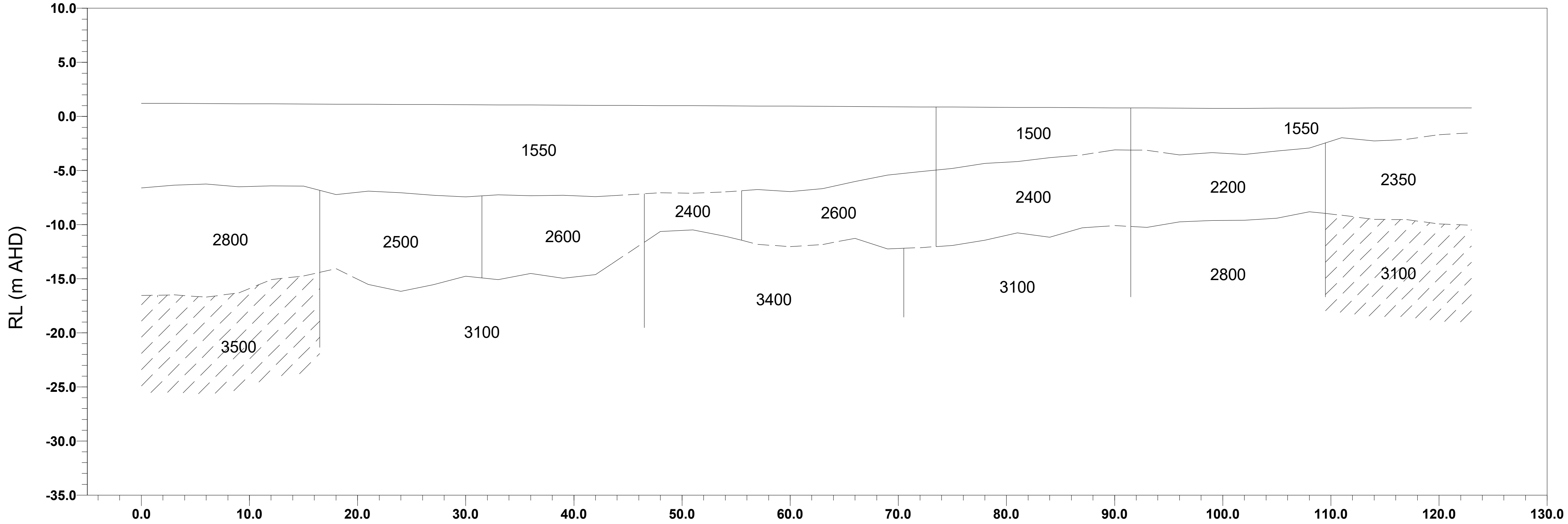
Long Beach

Tomakin

Location of Seismic Lines and coordinates of End Points

Pells Sullivan Meynink / Eurobodalla Shire Council Seismic Refraction Survey Selected Sites, Batemans Bay, NSW Site Plan - Showing Location of Seismic Lines	ETS	Figure 1

INTERPRETED SEISMIC SECTION : SURFSIDE (SOUTH)



SEISMIC LINE DISTANCE (m)

North West
0m (start)
E: 245837mE
N: 6045210mN RL: 1.2m AHD

South East
123m (end)
E: 245928mE
N: 6045132mN RL: 0.8m AHD

Scale H 1:500 (@ A3)
V 1:500

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

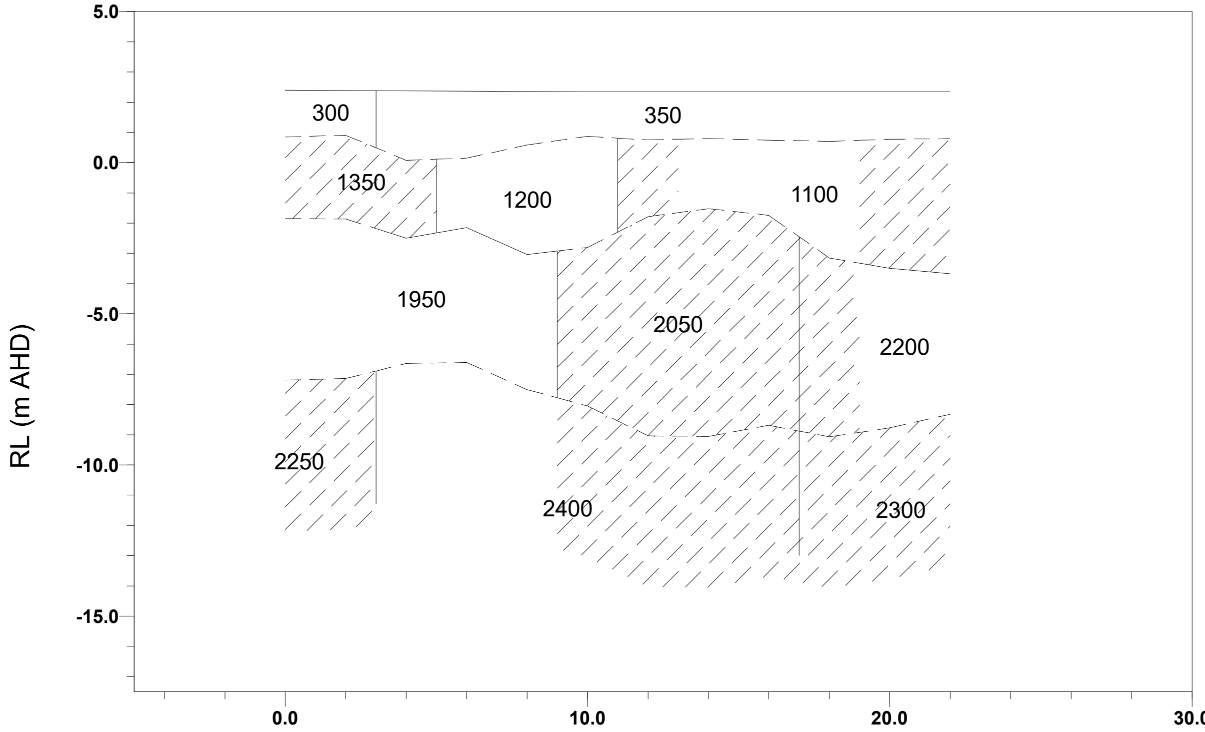
Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658	ETS
AUTHORISED : PF	Pells Sullivan Meynink / Eurobodalla Shire Council SEISMIC REFRACTION SURVEY Interpreted Seismic Section SURFSIDE BEACH (South)
DATE : 29 June 2021	

DRAWN BY PF FOR ETS	REPORT ET524/ 1	SCALE H 1:500 @ A3	Figure No. 2

INTERPRETED SEISMIC SECTION : SURFSIDE (NORTH)



East
0m (start)
E: 246579mE
N: 6045591mN RL: 2.4m AHD

West
22m (end)
E: 246556mE
N: 6045588mN RL: 2.3m AHD

Scale H 1:250 (@ A3)
V 1:250

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

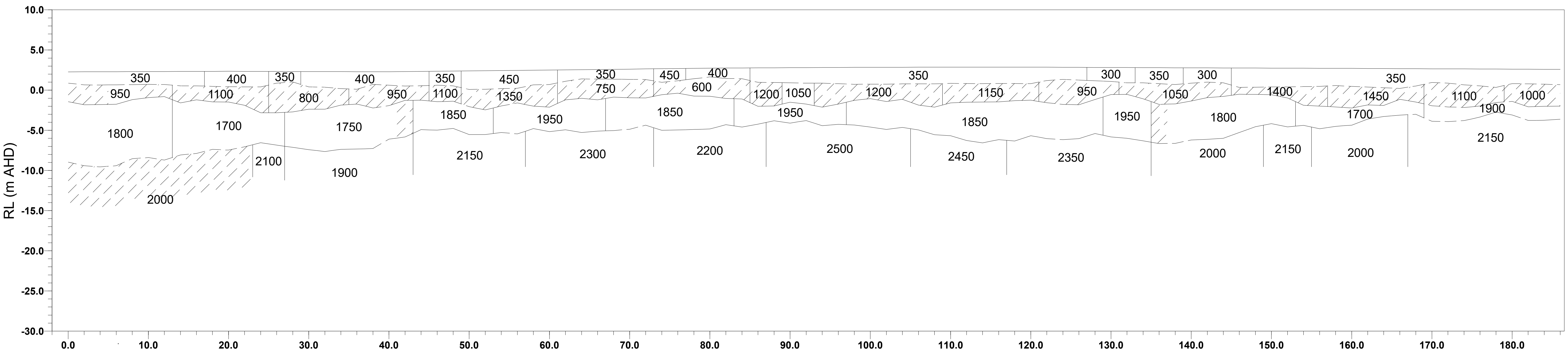
Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658	**ETS**
AUTHORISED : PF	Pells Sullivan Meynink / Eurobodalla Shire Council SEISMIC REFRACTION SURVEY Interpreted Seismic Section Surfside Beach (North) near Cullendulla Reserve
DATE : 29 June 2021	

DRAWN BY PF FOR ETS	REPORT ET524/ 1	SCALE H 1:500 @ A3	Figure No. 3

INTERPRETED SEISMIC SECTION : LONG BEACH



SEISMIC LINE DISTANCE (m)

East
0m (start)
E: 249700mE
N: 6045510mN RL: 2.3m AHD

West
184m (end)
E: 249516mE
N: 6045530mN RL: 2.6m AHD

Scale H 1:500 (@ A3)
V 1:500

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

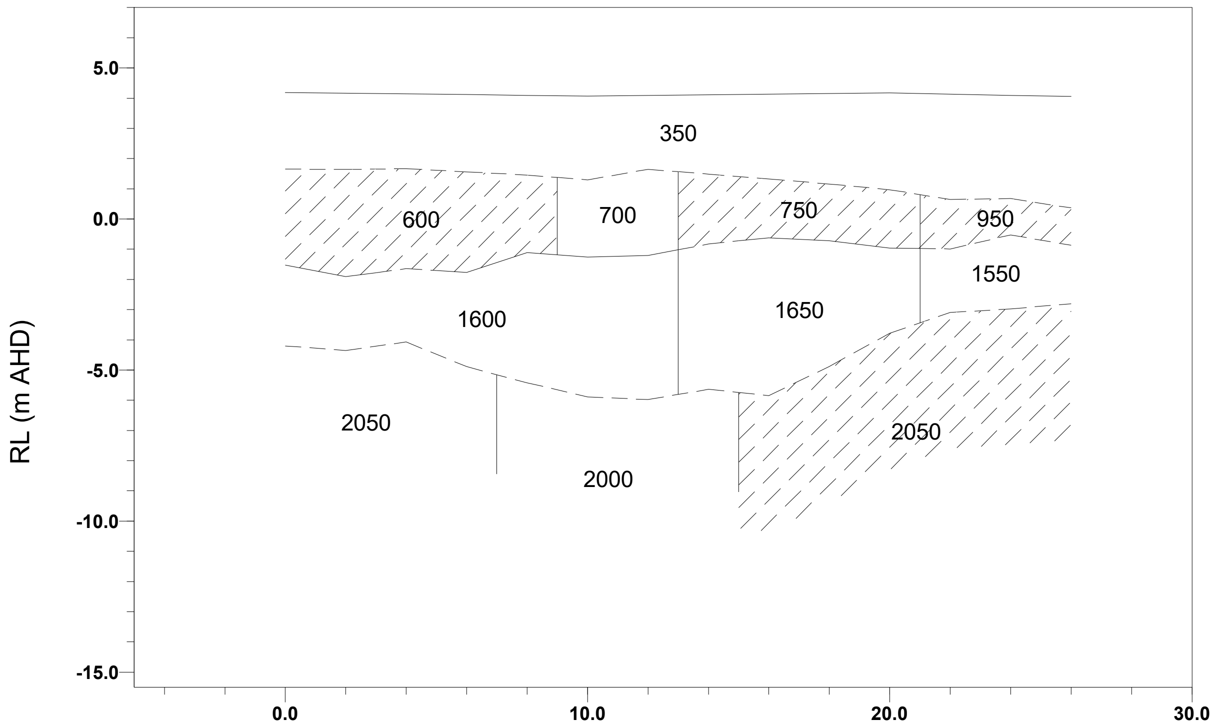
Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658				ETS
AUTHORISED : PF	Pells Sullivan Meynink / Eurobodalla Shire Council SEISMIC REFRACTION SURVEY Interpreted Seismic Section LONG BEACH			
DATE : 29 June 2021				
DRAWN BY PF FOR ETS		REPORT ET524/ 1	SCALE H 1:500 @ A3	Figure No. 4

INTERPRETED SEISMIC SECTION : TOMAKIN



SEISMIC LINE DISTANCE (m)

South
0m (start)
E: 246193mE
N: 6031078mN RL: 4.2m AHD

North
26m (end)
E: 246181mE
N: 6031101N RL: 4.1m AHD

Scale H 1:250 (@ A3)
V 1:250

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658			ETS
AUTHORISED : PF	Pells Sullivan Meynink / Eurobodalla Shire Council SEISMIC REFRACTION SURVEY Interpreted Seismic Section Tomakin		
DATE : 29 June 2021			
DRAWN BY PF FOR ETS	REPORT ET524/ 1	SCALE H 1:500 @ A3	Figure No. 5

APPENDIX A

A1 GUIDE TO THE USE OF INTERPRETED SEISMIC SECTIONS

The results of seismic refraction surveys are presented as vertical sections beneath the line of traverse. These sections show a two-dimensional distribution of seismic velocities, which have been interpreted from first arrival travel time data obtained in the field.

The following general summary is intended to assist in the understanding of the interpreted seismic sections provided.

A1.1 Methods Of Interpretation

First arrival travel times obtained for individual source locations representing the arrival at individual detectors of seismic waves which have travelled through the earth via least-time paths are determined interactively from the digital seismic field records. These times are plotted against distance from the source, as travel-time curves. These times are examined, reviewed and edited as necessary.

Further quantitative seismic interpretation, aimed at providing subsurface depth and velocity information, is carried out using the intercept time or reciprocal methods as appropriate. The interpretation method applied is determined by the field procedure used, the nature of the subsurface at the site, and by the objectives of the seismic study.

The interpretation provides a simplified seismic picture of the subsurface and depends on a number of assumptions about its nature. The major assumptions are:

i) The subsurface essentially consists of a series of discrete uniform layers which may vary laterally in velocity,
ii) The boundaries between these layers are distinct. For the simpler methods of interpretation, these boundaries are also assumed to be planar, but can be highly irregular,
iii) The seismic velocities of successive layers increase with depth,
iv) Each layer is of sufficient thickness to critically refract energy, and to produce a refracted wave arrival at the surface of sufficient energy to be detected as a first arrival.

These assumptions demonstrate requirements of the interpretation procedure for ideal conditions of which all of the requirements are unlikely to be fulfilled in reality. The extent to which each assumption is valid may vary from site to site and within a site. Consequently, at all sites, interpreted seismic sections are a simplification of the actual subsurface velocity distribution. The degree of simplification depends on the interpretative method used, the amount of data available for analysis and the extent to which the basic assumptions are violated at a site.

Some violations of the basic assumptions, such as diffractions from large irregularities, and non-critical refractions, may be observed in the seismic data or may be undetectable. Consequently the interpretation process is partly subjective; other interpretations of the data are possible and may differ considerably from the interpretation presented.

The effects of common violations of the assumptions are discussed in Section A1.3, below. Other effects, which may be relevant to the understanding of the seismic sections, are discussed in Section A1.4.

It should be noted that, at a given site, these effects can occur in virtually any combination and that, as a result, even highly complex subsurface conditions may give rise to relatively simple-looking seismic sections.

A1.2 <u>Precision And Accuracy Of Results</u>

A given seismic velocity does not necessarily uniquely determine the engineering properties of an earth material, even for the one rock type. For example a medium strength rock may have the same seismic velocity as a mixture of extremely low strength rock, and boulders or corestones of very high strength rock.

Moreover a relatively small proportion of extremely low strength material can dramatically lower the composite seismic velocity. For example a material composed of 50% boulders with seismic velocity 4000 m/s, and 50% of material with seismic velocity 800 m/s, then the composite velocity is lowered to 1333 m/s.

Interpreted velocities are usually shown on the seismic sections to the nearest 50 or 100 m/s. Interpreted velocities, as a measure of the actual field velocities, are not regarded as being accurate to better than ± 10%, but can be independently calibrated using drilling or excavation.

Calculated layer thickness' are subject to a similar level of experimental error. This has a cumulative effect on interpreted depths to deeper interfaces. For example, the interpreted depth to the base of the first layer defined is often considered accurate to better than ± 10%, however depths to deeper layers may not be accurate to better than ± 30% (Dampney and Whiteley, 1978).

These experimental errors are inherent in the procedure and must be taken into account in any use which is made of the seismic sections e.g., in estimating the volume of material represented by each layer in a proposed excavation.

A1.3 Effects Of Violation Of Assumptions

A1.3.1 Assumption of Discrete, Uniform Layers.

The most common problems are:

i) continuous increase in velocity with depth.
ii) inhomogeneity below the scale of resolution of the survey.

The first of these occurs in many geological settings, particularly in sediments, or highly weathered sedimentary rocks. It can be allowed for in a number of ways but contributes to the uncertainty in depth calculations based on constant layer velocity. Often the seismic sections show the "average" velocity of the layer.

For the second type of problem, under ideal conditions a refraction study can resolve features as small as 1.5-2 times the geophone spacing. In general, however, the practical limit of resolution is 2-3 times this spacing although the presence of inhomogeneity may be observable from the travel time curves, without more detailed interpretation being possible.

Calculated seismic velocities are averages which represent the bulk properties of the interpreted layers. It is possible for this averaging to conceal major, local variations in velocity on a scale up to at least twice the geophone spacing. The likely nature of these variations depends on the geological setting of the site but clearly boulder conditions and rapid lateral changes in weathering or lithology would be among the difficult sites.

A1.3.2 Assumptions of Distinct Boundaries

Real geological boundaries, especially those related to weathering, are often gradational and/or irregular. The seismic method inevitably disguises gradation and smoothes irregularity. The importance of this varies from site to site, but it is common for interpreted seismic boundaries to appear at an intermediate level somewhere between the limits of gradation. For example, if there is an irregular boundary between fresh and highly weathered rock, the interpreted boundary frequently appears at a level some metres below the highest points at which fresh rock is found.

A1.3.3 Assumption of Increasing Velocity with Depth

This assumption may be violated for a number of different reasons and such violations (termed velocity reversals, or velocity inversions) often cannot be detected from the travel time data alone. It may be possible (in some, but not all cases) to infer them from the geological setting, from borehole information, or from surface-to-borehole seismic. If the inversion layers do not persist laterally their effect may also be observable on the travel-time data.

In general, it is not possible to allow for a velocity inversion in the interpretation unless there is an independent means of estimating both the thickness and the velocity of the layer. If an undetected velocity reversal is present, all calculated depths below the reversal will be in error. In particular, depths to underlying high velocity layers may be significantly over-estimated. Areas where strong layers overlay weaker layers, for example, a basalt flow overlying sediments or weathered rock, or sandstone overlying coal, are sites where these problems sometimes occur.

A1.3.4 Assumption of Detectability

Two main types of violation occur:

i) When a layer is too thin to transmit the seismic wave.
ii) When a layer transmits the wave but is not detected because waves from a deeper, higher velocity layer reach the detector first.

The first type of problem may occur in many geological settings and means that relatively thin, higher velocity layers may occur undetected within lower velocity materials. “Thin” in this context is defined in terms of seismic detectability and can imply thickness of the order of 1-1.5m. The effect cannot be detected from the surface seismic refraction data alone, but may be inferred from borehole information, surface mapping or surface-to-borehole seismic. If such a layer were thick enough to be detected, it would form a velocity reversal (see Section A1.3.3).

The second type of problem (termed a hidden layer or blind zone) may be inferred from the geological setting, borehole data or sometimes from the seismic refraction data. If it is not detected, it also results in erroneous depth calculations in the interpreted section; normally the calculated depth to deeper interfaces is underestimated. In theory, between every pair of layers there could be a hidden layer (or blind zone), whose maximum thickness may be calculated for a range of intermediate velocities.

A1.4 Other Factors

Other common factors may lead to differences between the surface seismic refraction model and reality. While not strictly due to assumptions made in interpretation, they should still be taken into account, if the site conditions dictate, in any further use of the interpreted sections. These factors are:

i) Three-dimensional effects
ii) Effect of water
iii) Anisotropy

A1.4.1 Three-dimensional effects

The interpreted sections are two-dimensional representations and only apply to a narrow zone below the line of traverse typically 5 -10m either side of the seismic line. However, the real subsurface is three-dimensional and as a result significant lateral variations in conditions can occur without being detected, even within a short distance to the side of a traverse. If seismic signals originating from such features are obtained, they may result in the interpreted sections containing features, which are non-existent, displaced from their true position or shown with incorrect velocities. This problem is most common in sites with irregular topography, boulders and highly irregular rock masses.

In some cases three-dimensional effects may be observed by using cross seismic spreads at right angles to the main profile, or additional parallel seismic lines, or from other information.

A1.4.2 Effect of Water

The presence of water can greatly increase the field velocity of materials which have low velocities in the dry condition. The effect is most pronounced in soils or unconsolidated materials and is due to the difference in seismic velocity between air and water (340 m/s and 1470 m/s, respectively). It may however occur to a significant degree in materials with dry velocities as high as 2000-2500m/s. The change is not related to the normal trends of change in material properties with velocity.

Less frequently, it is possible for water saturation to cause a decrease in field velocity, most commonly in low velocity materials where highly expansive clay minerals are present and the material is unconfined. In the marine environment the presence of gas in otherwise water-saturated sediments can lower velocities below that in water.

Velocity changes due to the presence of a water table cannot normally be distinguished from the seismic data alone. The effect may be inferable from the geological setting and the interpreted velocities, but can only be confirmed by drilling.

A1.4.3 Anisotropy

Field velocities may vary with the direction of the seismic line. Usually if the velocity measured in different directions agree to within ± 10% the condition is treated as isotropic. Anisotropy is most common in steeply dipping sediments or metasediments but can occur in other settings. When measured across strike, the velocity is an average for the different materials present. Along strike the higher velocity of the fresher or more competent materials is measured. This effect may be detectable from cross spreads which show a markedly higher or lower velocity than longitudinal traverses. However it may not be detected, depending on the relative orientations of the traverses and the strike of the subsurface materials.

A more subtle form of anisotropy occurs in many sedimentary rocks where the vertical velocity differs from the horizontal velocity. Normally seismic refraction studies provide information on the horizontal velocities which are commonly higher than the vertical velocities. The possible effects of anisotropy are similar to those discussed above in section A1.3

A1.5 References

Dampney, CNG and Whiteley, RJ (1978). Velocity determination and error analysis for the seismic refraction method. Geophysical Prospecting, 28, pp. 1-17.

Dobrin, MG (1976). Introduction to geophysical prospecting. 3rd edition. McGraw-Hill,New York.

Hawkins, LV (1961). The reciprocal method of routine shallow seismic refraction investigations. Geophysics, 26(6), pp. 806-19.

Leung, T.M., Win, M.A., Walker, C.S., & Whiteley, R.J., 1997. A Flexible Algorithm for Seismic Refraction Interpretation Using Program REFRACT, from McCann, D.D., Eddleston, M., Fenning, P.J. & Reeves, G.M (eds), 1997, *Modern Geophysics in Engineering Geology*. Geological Society Engineering Special Publication No. 12, pp 399-407