Erosion Hazard Report

Flood Mitigation Adaptation for Painkalac Creek Estuary, Aireys Inlet

Surf Coast Shire

16 April 2025

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Project Name	Flood Mitigation Adaptation for Painkalac Creek Estuary, Aireys Inlet
Client	Surf Coast Shire
Client Project Manager	Sharna Whitehand
Water Technology Project Manager	William Hibberd
Water Technology Project Director	Toby Devlin
Authors	William Hibberd
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51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800
ACN 093 377 283
ABN 60 093 377 283

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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.

Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- *Seven circles representing each of the States and Territories in Australia where we do our work*
- *Blue dots between each circle representing the waterways that connect us*
- *The animals that rely on healthy waterways for their home*
- *Black and white dots representing all the different communities that we visit in our work*
- *Hands that are for the people we help on our journey*

CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Purpose and Scope

This erosion hazard report is one of multiple key deliverables of the wider project; Flood Mitigation Adaptation for Painkalac Creek Estuary, Aireys Inlet. The objective of the study is to develop an understanding of climate impacts on the flood risk within the Painkalac Estuary and the erosion hazards on the Aireys Inlet and Fairhaven coastline.

This report objective is to develop an understanding of climate impacts of erosion hazards on the Aireys Inlet and Fairhaven coastline.

1.2 Study Area

The study area, presented in Figure 1-1 spans from Urquhart Bluff to Eastern View. The study area is divided into four Coastal Geomorphic Compartments (CGCs), the boundaries of the CGCs are indicated in blue in Figure 1-1. The CGCs are the subdivision of the coastal zone into spatially discrete areas based on natural divisions of nearshore and backshore morphology and geomorphology. This section of coastline was divided into CGCs as part of the Barwon South West Local Coastal Hazard Assessment (LCHA) (Water Technology 2018).

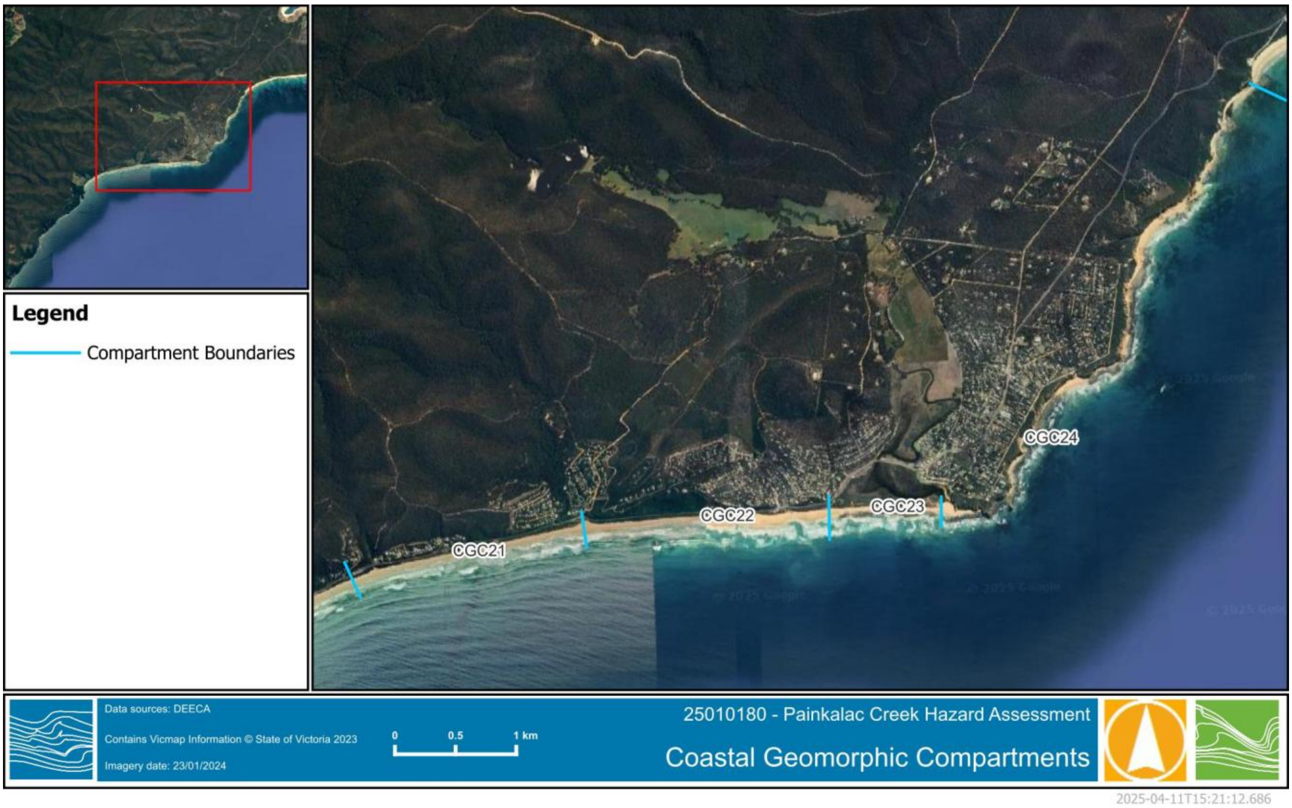

Figure 1-1 Study area Coastal Geomorphic Compartments (CGCs) from Water Technology (2018)

2 COASTAL ENVIRONMENT

2.1 Coastal Geology and Geomorphology

The local geology and geomorphology of the study area has implications for beach and backshore morpho-dynamics and understanding how these change across the study area is important for understanding how coastal hazards may also vary. A detailed description of the geology for the Barwon South West region, including regional geology and local backshore and shore zone characteristics, is provided in Bird (1993) and by Rosengren (2017), prepared as part of the Barwon South West Region Local Coastal Hazard Assessment – Stage 1 Scoping Study (Water Technology 2018).

2.1.1 Regional Geology

The coastal landscape of the Surf Coast is, in part, a reflection of the morphology of the backshore terrain with local variations determined by the geological characteristics, notably lithology and rock structure, and the marine and climatic environment (Rosengren 2017). The NE orientation of the coastline is determined by the extent of the Otways Group, an area of high relief between Moonlight Head and Aireys Inlet, that has developed on uplifted Jurassic to lower Cretaceous volcaniclastic sediments (Figure 2-1). The coastal geology northeast of Eastern View is a sequence of Cainozoic marine and non-marine sedimentary rocks of the Demon's Bluff Group and Torquay Group with a volcanic succession (Older Volcanic) exposed between Aireys Inlet and Anglesea.

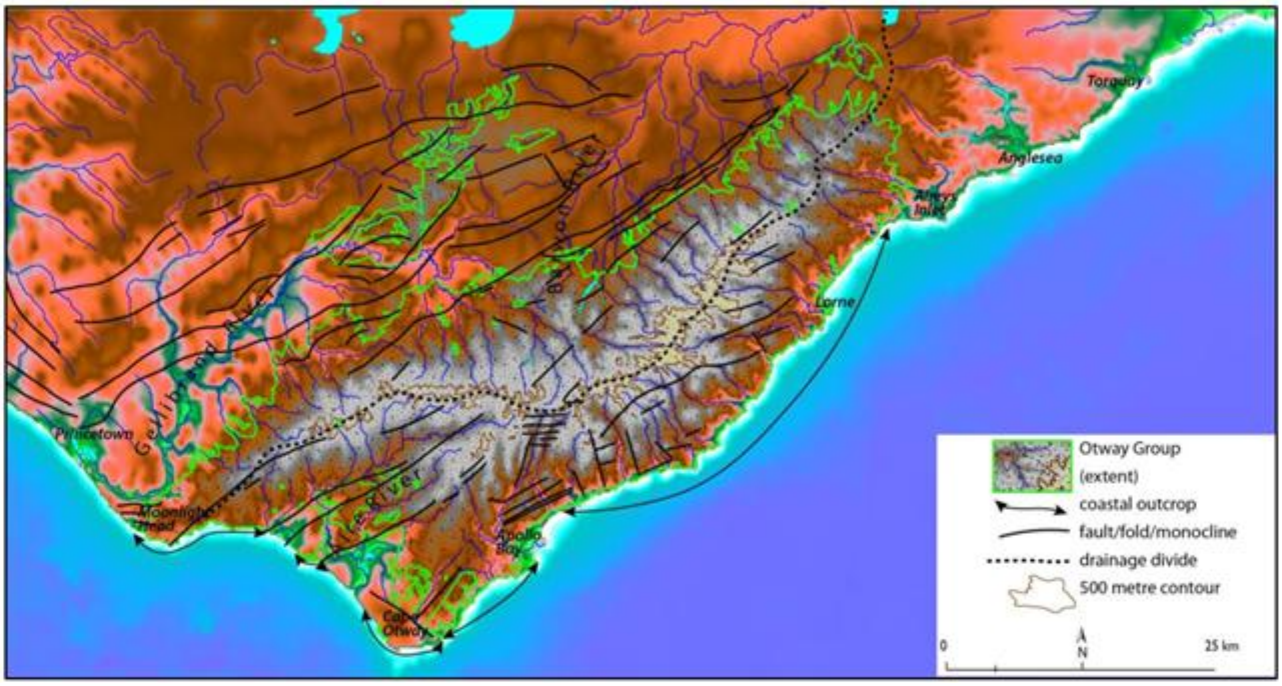

Figure 2-1 Regional Geology (Seamless Geology, 2011)

2.1.2 Local Geology

Between Eastern View and Breamlea, the backshore and shore zone geology consist of outcrop of variably resistant but predominantly soft rock of the three main onshore stratigraphic units of the Torquay Basin – Eastern View Formation, Demons Bluff Group, Torquay Group (Rosengren 2017). These groups are Palaeoscene to Miocene marine carbonates, terrestrial and paralic sandstone, conglomerate and claystone with local occurrence of basalt and pyroclastics, including between Aireys Inlet and Urquhart Bluff. Shore platforms are limited and sand beaches without a rock base are more extensive and wider with sections of single and multiple coastal barriers.

The coastline along the western edge of the study site at Moggs Creek consists of grassy dunes and heathy bluffs cut into the Eastern View Formation, which outcrops in small valleys. East of Moggs Creek, these sediments are overlain in the coastal bluffs by the Demons Bluff Formation, which comprises the Upper Eocene

Anglesea beds, a deltaic deposit of dark grey to black carbonaceous silty clays capped by ferruginous sands and clays of the Lower Oligocene Angnahook beds (Bird 1993). From Fairhaven, the bluff passes inland alongside the Aireys Inlet valley which encompasses the Painkalac Creek and estuary that winds through salt marshes on an alluvial plain behind a single Holocene narrow coastal sand barrier ridge that extends between Grassy Creek and Split Point. The estuary mouth opens to the sea beside cliffs comprised of Point Addis Limestone, a yellow rubbly calcareous rock. The coastline runs around the narrow headland of stratified sandy limestone, overlooking an irregular shore platform cut in the same material.

At Split Point, the Point Addis Limestone in the shore platform gives place to grey basalt, where the limestone is underlain by a dissected Eocene volcano. The cliffs of Split Point are cut in layered limestone with a basalt abrasion notch and a breach of well-rounded basalt and limestone boulders. Beneath Castle Rock there are structural ledges at varying levels, and the cliff face shows fluting where cylindrical soil-filled solution pipes that penetrate far down into the Point Addis Limestone. Caves have been excavated in the cliff base in the cove beneath the lighthouse, and columnar jointing is prominent in the weathered lava. East of the Split Point, the volcanic deposits are overlain in the cliffs by Point Addis Limestone which is capped by clay that descends into large cylindrical solution pipes (Bird 1993). This geology continues until the eastern edge of the study site.

2.1.3 Coastal Geomorphic Compartment

As part of the LCHA Scoping Study (Water Technology 2018), the Barwon South coastline was divided into 9 Coastal Units and 44 Coastal Geomorphic Compartments (CGC), as presented in Figure 2-2. The different Coastal Units are based on changes in the extent of beach and shore platforms, coastal sand barriers, the type of marine cliffs and elevation of the backshore while the different compartments represent a change in either the backshore geomorphic type or shore zone class. The shore zone was defined as the area between the upper subtidal zone and the backshore and includes the intertidal zone and supratidal zone and is the area directly affected by waves. The CGCs, and the assigned shore zone classes and backshore geomorphologic types and their susceptibility to coastal hazards, as per Water Technology (2018), are presented in Table 2-1.

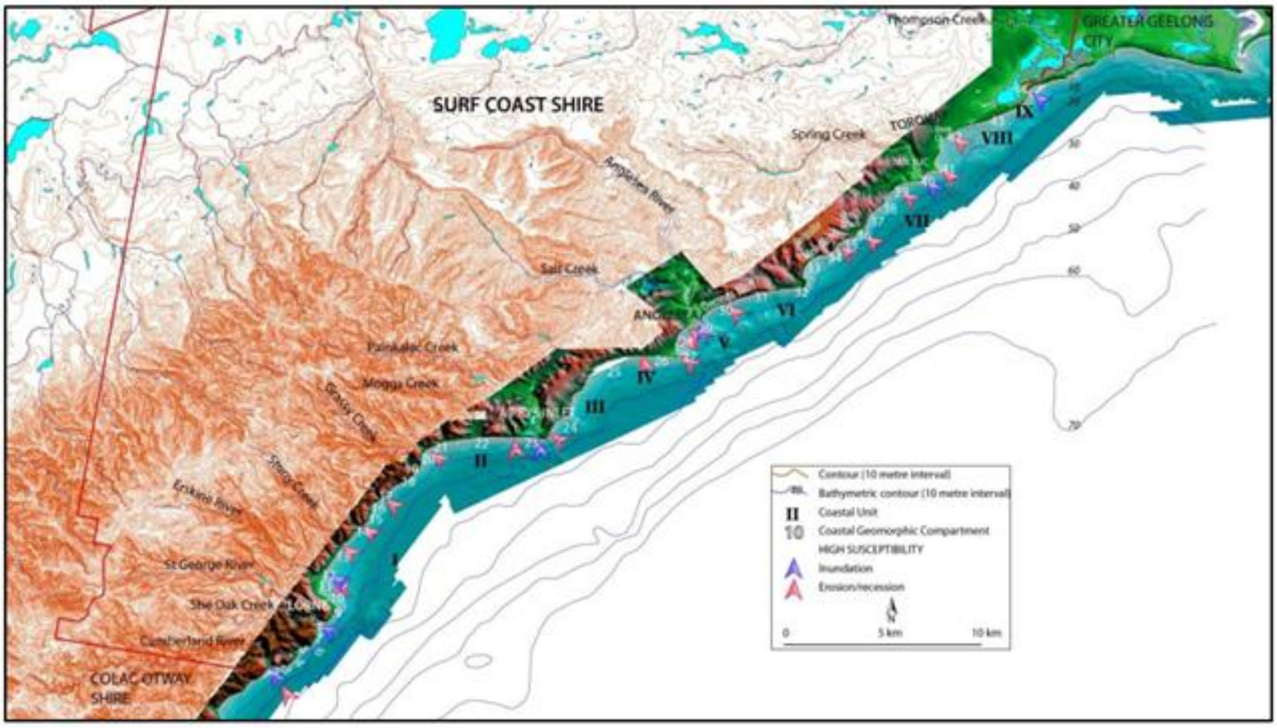

Figure 2-2 Surf Coast Shires 9 Coastal Units and 44 Coastal Geomorphic Compartments.

Table 2-1 Relevant Coastal Geomorphic Compartments (from Water Technology 2018)

Coastal Geomorphic Compartment	Shore Zone	Backshore Geomorphic Type	Coastal Hazard Susceptibility		
			Inundation	Erosion	Risk Rating
Moggs Creek CGC 22	Sand Beach including channel of Moggs Creek	Estuary (Channel only)	**High**	Moderate	Medium
Fairhaven SLSC CGC 22A	Sand Beach	Backshore Bluff (High Bluff), and Engineered (Permeable)	Low	**High**	Medium
Painkalac Creek Entrance, Lagoon and Floodplain CGC 2	Sand Beach (Wide steep beach face)	Estuary (Channel and Lagoon)	**High**	**High**	**High**
Split Point CGC 24	Cliff-Bluff including shore platform	Backshore Bluff (High Bluff)	N/A	**High**	Medium

3 COASTAL EROSION HAZARD ASSESSMENT

3.1 Wave Conditions

Wave conditions, including significant wave height (Hs), wave period (Tp) and wave direction, have been extracted from the 40-year (01/01/1981 to 31/12/2020) University of Melbourne regional hindcast wave model (Liu et al. 2022) approximately 2 km and 10 km offshore of the study site. A single central point (wave model node) 2 km offshore has been considered representative of the wave conditions across the site. An Extreme Value Analysis (EVA) has been conducted for Hs for the 40-year hindcast timeseries to determine the 1% AEP and 10% AEP wave conditions. The extreme wave conditions calculated from the EVA are presented in Table 3-1.

Table 3-1 Significant Wave Height EVA Results

	1% AEP	10% AEP
Significant Wave Height (Hs) (m)	4.36	3.77

Analysis of wave period of the extreme waves at the data extracted 10 km offshore indicates there are two distinct subsets of wave sources, the southwest and southeast, with the wave period varying based on where the wave originates. The southwest waves, which are swell waves propagating into Bass Strait from the Southern Ocean, typically have larger wave periods, between 10 s and 17 s, while the southeast waves, which are wind waves generated locally across Bass Strait, have smaller wave periods of around the 8 s to 10 s (Figure 3-1).

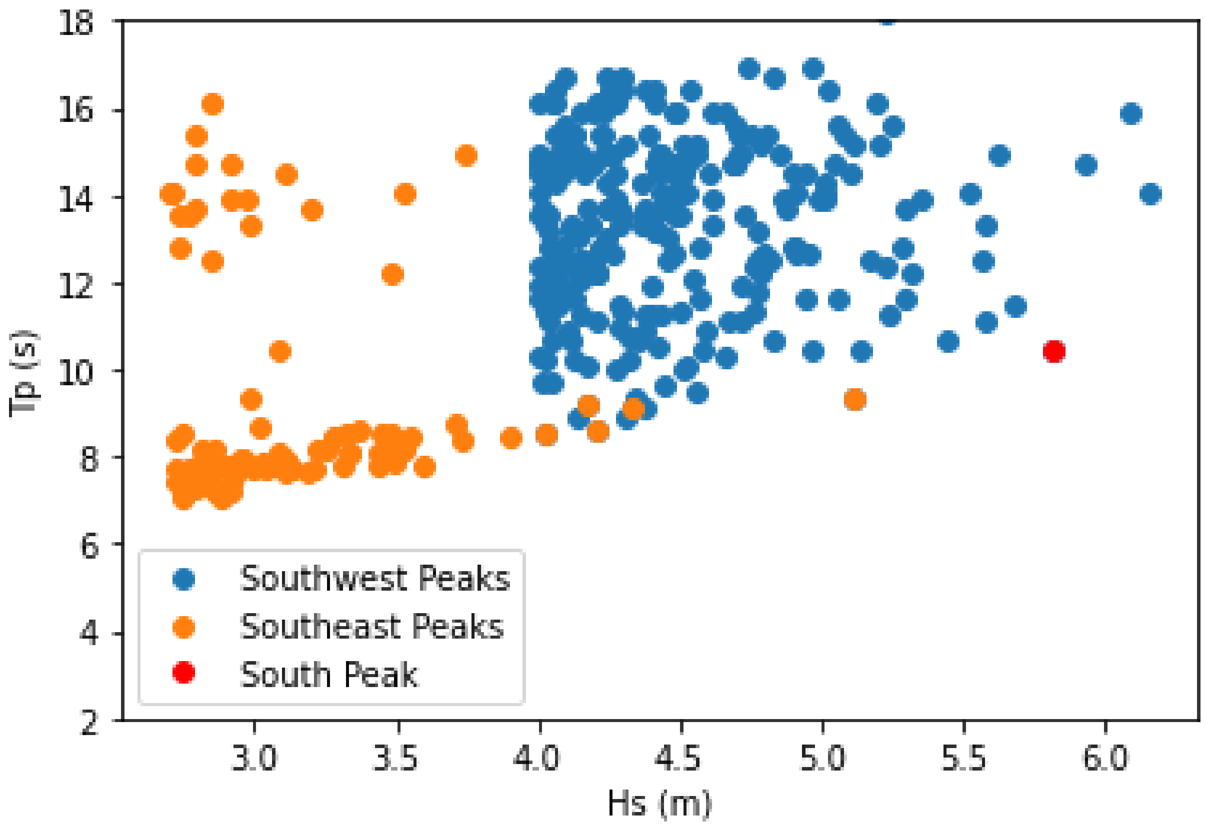

Figure 3-1 Peak Wave Period Analysis of Waves Extracted 10 km offshore in Bass Strait

3.2 Water Levels

Water levels for the study area were sourced from the Lorne Tide Gauge, part of the Australian Baseline Sea Level Monitoring Project (ABSLMP). The Lorne Tide Gauge provides a dataset extending from 01/01/1993 to 29/04/20234 (with a gap in 2007). An EVA was conducted on the Lorne Tide Gauge to determine the extreme water level conditions with the results presented in Table 3-2.

Table 3-2 Lorne Tide Gauge EVA Results

	1% AEP	10% AEP
Storm Tide Level (m AHD)	1.76	1.59

3.3 Coastal Erosion Hazards

There are several different coastal erosion hazards that impact the study area, with the degree of exposure varying depending on the backshore/dune geomorphology and geology. The main coastal erosion components experienced across the study site include:

- Storm erosion and recovery,
- Ongoing shoreline change due to imbalance in the net sediment budget (either temporary or long-term) or shoreline rotating to reach an equilibrium with the prevailing wave direction,
- Long term shoreline recession due to sea level rise,
- Coastal cliff erosion/instability; and
- Estuary barrier migration.

3.4 Open Coast Sandy Beach Erosion Hazard

The open coast sections of the study area that consist of a sandy beach and coastal dune in the backshore are impacted by storm erosion, ongoing shoreline erosion and erosion caused by sea level rise.

3.4.1 Storm Erosion

Storm erosion is caused by large storm waves (often in combination with storm tides) that erode the beach. For shorelines that exist in a state of equilibrium (i.e. no net loss of sediment from the beach compartment), this is a cyclical process where storms draw sand offshore into sandbars, that are then slowly worked back onto the beach during calmer conditions (i.e. beach 'recovery').

To determine the storm erosion hazards, the one-dimensional cross-shore sediment transport model SBEACH (part of CEDAS) was used. SBEACH is a numerical model used for predicting beach, berm and dune erosion in response to storm waves and water levels. The magnitude of cross-shore transport is empirically related to wave energy dissipation per unit water volume in the main portion of the surf zone. The model uses an initial beach profile upon which a storm is run.

3.4.1.1 Beach Profiles

A key input into the SBEACH model is the initial elevation profile. A single profile for each of the three CGCs was selected that is considered representative for that compartment. The surface elevation for the initial profile was constructed by merging the VCMP drone survey from 05/02/2024 at Fairhaven with the FutureCoast LiDAR (VCDEM 2017). Profiles extend approximately 200 m inland, far enough to experience no change from coastal influences, and 1000 m offshore.

Sediment grain size data was extracted from the Western Victoria Beach Sediment Samples dataset, collected in 2019/2020 as part of the VCMP. The D50 (median diameter of the sediment grains) of the closest sample for a given profile was selected to represent the grain size in the SBEACH model. The D50 used for CGC21 was 0.269 mm, while CGC22 and CGC23 used a D50 of 0.266 mm. These values were confirmed by recent sand sampling of the mid-beach face at Fairhaven which returned D50s of between 0.26 mm and 0.27 mm.

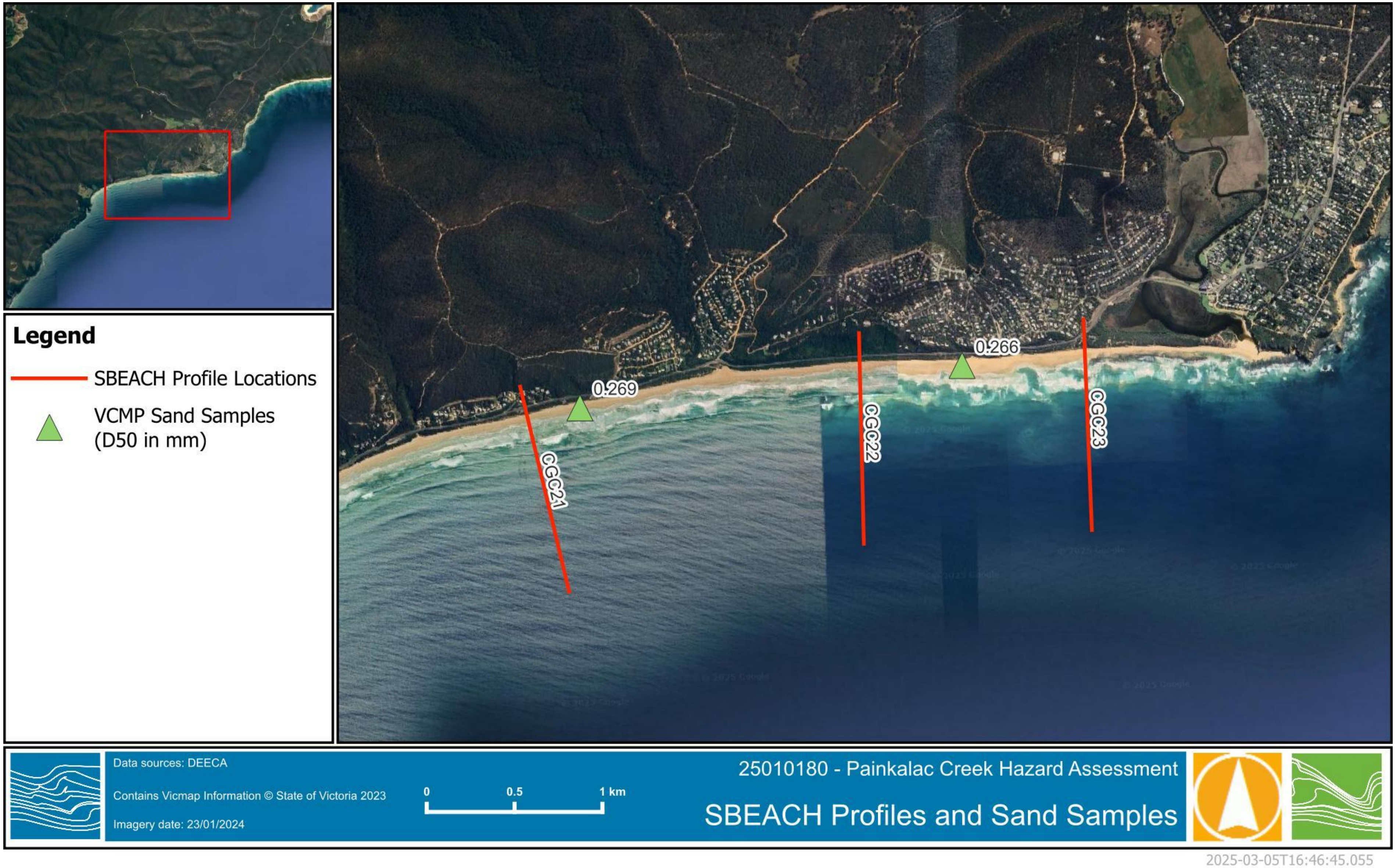

Figure 3-2 SBEACH Profile and Sand Sample Locations

3.4.1.2 Design Storm Conditions

The SBEACH model is forced with extreme offshore water level and wave conditions that have been constructed into a synthetic 'design storm'. For this study, the 1% AEP and 10% AEP storm conditions have been modelled.

To develop a schematisation of a typical storm event for the study site, wave data from the 40-year University of Melbourne regional hindcast wave model was extracted approximately 10 km offshore. The wave data was screened for wave heights that exceeded 3.8 m with event duration being classified as the time spanning from when the waves first rose above this level and last fell below 2.92 m (the 90th percentile). This starting threshold is subjective but was selected as it represents when waves begin to extend beyond the typical background wave conditions. 261 events were identified, with storm duration ranging from 9-hours to over 150 hours with the average event ~40 hours. The 80th percentile duration of 60 hours was selected as a conservative upper bound for storm duration.

The synthetic storm conditions for the 1% AEP and 10% AEP events were constructed using:

- Simulated storms run for 60 hours, with the peak conditions occurring at the middle timestep of the timeseries (t = 30h).
- Significant wave heights applied as a simple triangular timeseries that builds from a base wave height of 2 m up to the applied peak wave condition (EVA results in Table 3-1) before returning to the baseline.
- Peak wave period applied as a constant value for the 60-hour period. The upper value of 17 s was considered appropriate as a conservative estimate.
- Water level as a simple triangular timeseries for storm-surge and adding this to a predicted spring tide from the Lorne tide gauge, with the peak water level aligning to the target total extreme water level (EVA results in Table 3-2).
- Wave direction applied immediately shore-normal (SBEACH does not resolve any changes in wave direction within the model profile).

3.4.1.3 SBEACH Results

Results of the SBEACH modelling of the setback distances for the 1% AEP and 10% AEP events are presented in Table 3-3. These distances have been calculated as the distance between HAT and the most landward spot that experiences erosion.

Table 3-3 SBEACH Results

Compartment	1% AEP Erosion Distance (m)	10% AEP ErosionDistance (m)
CGC21	26	23
CGC22	28	26
CGC23	37	32

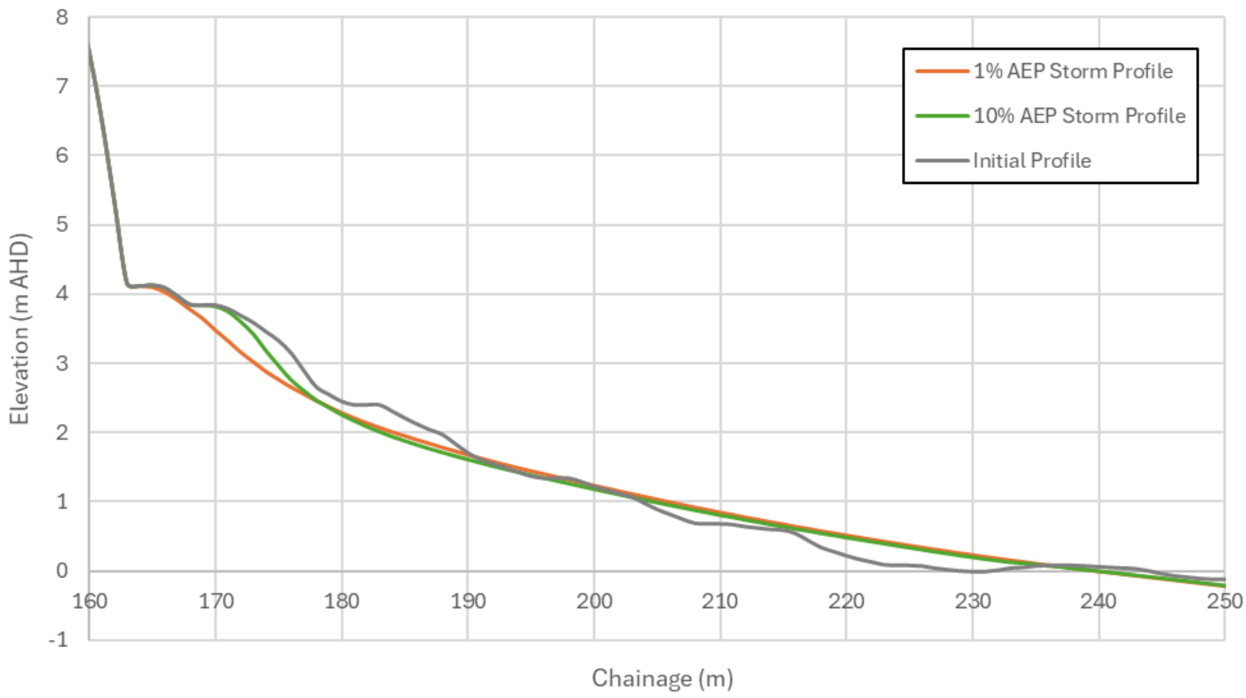

Figure 3-3 Example SBEACH Profile for CGC23 for the 1% and 10% AEP Event.

3.4.2 Ongoing Shoreline Erosion

Ongoing change in the shoreline position occurs in response to an imbalance in the sediment transport processes within a given beach compartment. This can be a steady loss or gain of sand (and respective retreat or accretion of the shoreline) or a beach 'rotation' that causes erosion at one end and accretion at the other on either a permanent or variable basis. Construction of coastal protection structures (such as seawalls) can exacerbate these changes as the shoreline is forced to maintain a certain alignment in these locations and the adjacent shoreline is made to adjust more dramatically in response.

The trend in ongoing shoreline change was assessed using the Digital Earth Australia (DEA) Coastlines dataset (Bishop-Taylor et al. 2021), which uses Landsat satellite imagery to estimate the average position of mean sea level (MSL) for each year from 1988 to 2023. The observed rate of shoreline change using historical aerial imagery was also undertaken for comparison to the DEA Coastlines dataset by digitising the 'shoreline' position – the shoreline that is stable in short-term and is therefore not influenced by seasonal rotation or present-day storm erosion/recovery processes. The stable shoreline for this section of coastline is considered to be the vegetation line. The vegetation line for the open coast areas of the study area were digitised for 2007 and 2024. Early historical imagery from 1970, 1977 and 1989 was also available however these images have errors in the shoreline position estimated up to over 10 meters for some sections of coastline and were therefore omitted from the analysis.

Due to the limited availability of historical aerial imagery years (17 years) compared to the DEA Coastlines dataset (35 years), the DEA Coastlines have been considered more appropriate for evaluating the changing shoreline position for this section of coastline. The values extracted from the DEA Coastlines are consistent with other datasets available in the area, namely the Victorian Coastal Monitoring Program (VCMP) OmniLine (DEECA 2024), which uses the DEA Coastlines dataset and VCMP drone surveys to determine MSL and the rate of change every 30 meters along the Victorian coastline.

The average rate of change from the DEA Coastlines dataset per CGC is summarised in Table 3-4 with spatial data for each CGC presented in Appendix A.

Table 3-4 Shoreline Response to Ongoing Shoreline Change (Setback Distances in m)

Compartment	Rate (m/yr)	Present-day	2040 (0.2 m SLR)	2070 (0.5 m SLR)	2100 (0.8 m SLR)	2100 (1.1 m SLR)
CGC21	0.51	0	8	23	39	
CGC22	0.30	0	5	13	22	
CGC23	0.13	0	2	6	10	

3.4.3 Response to Sea Level Rise

With an increase in mean sea level, there is an increase in the volume of sand required to maintain a stable beach. The result is that without the input of additional sand, the shoreline will retreat as sea levels increase. This process has been described by Bruun (1962), and while not applicable in all coastal areas, is a conservative assumption. The Painkalac Spit and adjacent Fairhaven Beach is likely to experience some level of retreat in response to sea level rise via this process. The formulation of this retreat is known as the 'Bruun Rule' as follows:

$$R = S.L/(H_d + H_f)$$

The selection of a depth of closure (H_f), beyond which no cross-shore transport occurs, has been estimated at -10 m AHD using the Hallermeier inner shoal depth formulation, based on the wave height exceeded 12 hours per year. The 'Bruun Factor' (i.e. retreat per 1 m of sea level rise) determined for the different CGCs (based on the cross-shore profiles used in SBEACH) and the associated final setback distances for each SLR scenario are presented in Table 3-5.

Table 3-5 Shoreline Response to SLR (Setback Distance in m)

Compartment	Bruun Factor	Present-day	2040 (0.2 m SLR)	2070 (0.5 m SLR)	2100 (0.8 m SLR)	2100 (1.1 m SLR)
CGC21	46	0	9	37	51	65
CGC22	34	0	7	27	37	47
CGC23	15	0	3	12	16	20

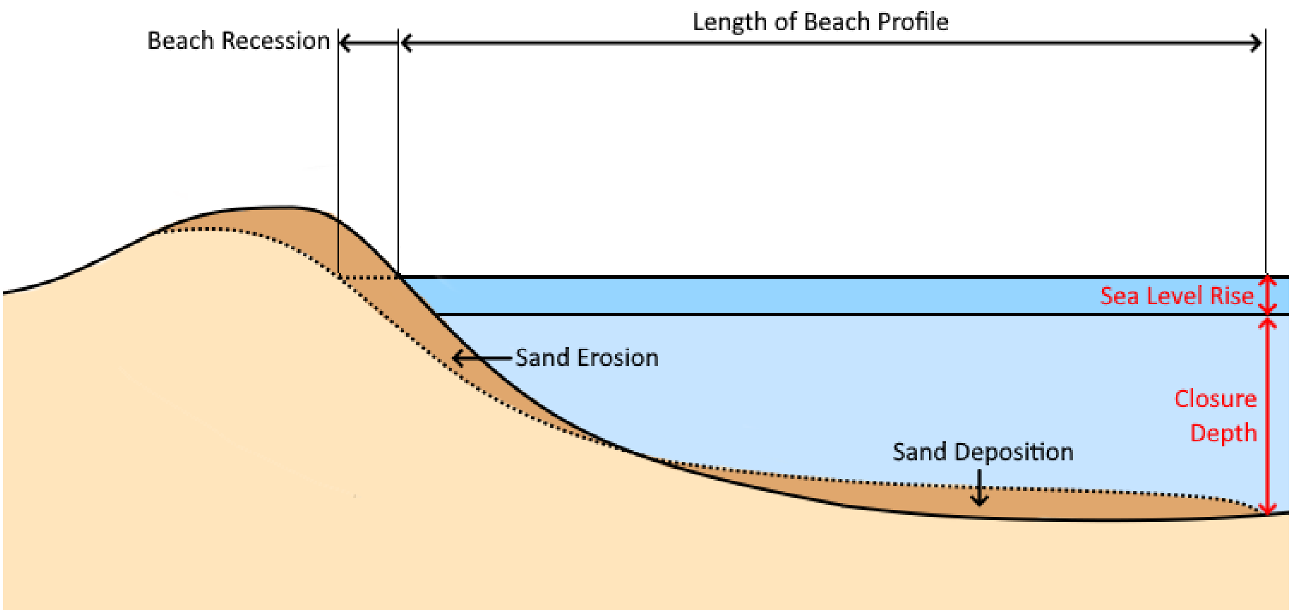

Figure 3-4 Bruun Rule Schematization

4 HAZARD EXPOSURE MAPPING

4.1 Sandy Open Coast Beach Erosion Hazard

Table 4-1 presents a summary of the total erosion setback values for each compartment and planning horizon for the open coast sandy beach sections of the study site. The erosion hazard extents are presented in Figure 4-1 to Figure 4-3.

*Note – the 1% AEP storm erosion distances have been used to assess total erosion hazard. The hazard extent at the compartment boundaries has been smoothed at the interface of each for continuity.

Table 4-1 Open Coast Erosion Setback Summary

Compartment	Scenario	Storm Erosion (m)	Ongoing Shoreline Erosion (m)	Response to SLR (m)	Total Erosion Extent (m)
CGC21	Present-day	26	0	0	**26**
	2040 (0.2m SLR)		8	9	**43**
	2070 (0.5m SLR)		23	23	**72**
	2100 (0.8m SLR)		39	37	**102**
	2100 (1.1m SLR)			51	**116**
CGC22	Present-day	28	0	0	**28**
	2040 (0.2m SLR)		5	7	**39**
	2070 (0.5m SLR)		13	17	**58**
	2100 (0.8m SLR)		22	27	**78**
	2100 (1.1m SLR)			37	**88**
CGC23	Present-day	37	0	0	**37**
	2040 (0.2m SLR)		2	3	**42**
	2070 (0.5m SLR)		6	7	**50**
	2100 (0.8m SLR)		10	12	**59**
	2100 (1.1m SLR)			16	**63**

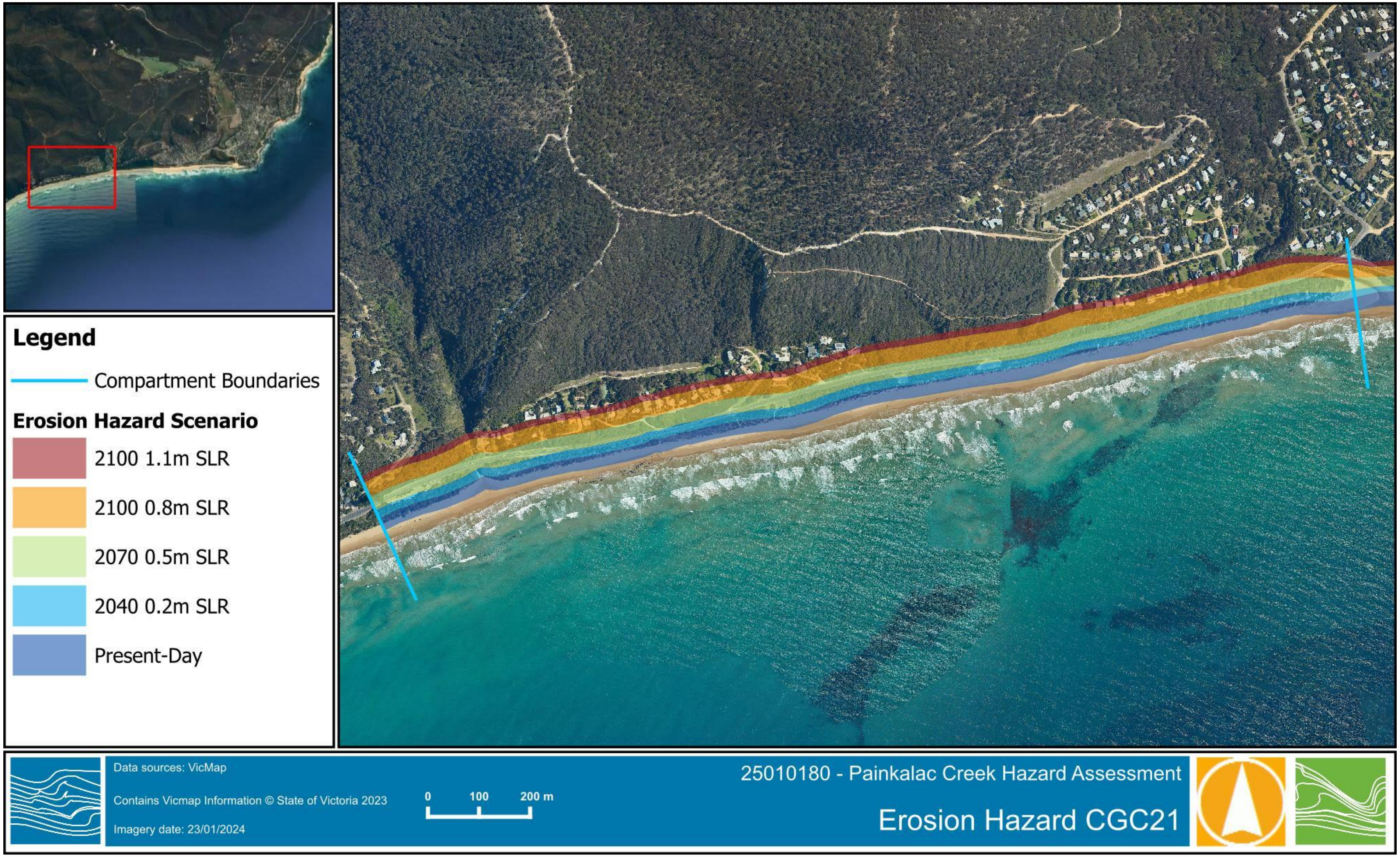

Figure 4-1 Coastal Erosion Hazard Area for CGC21

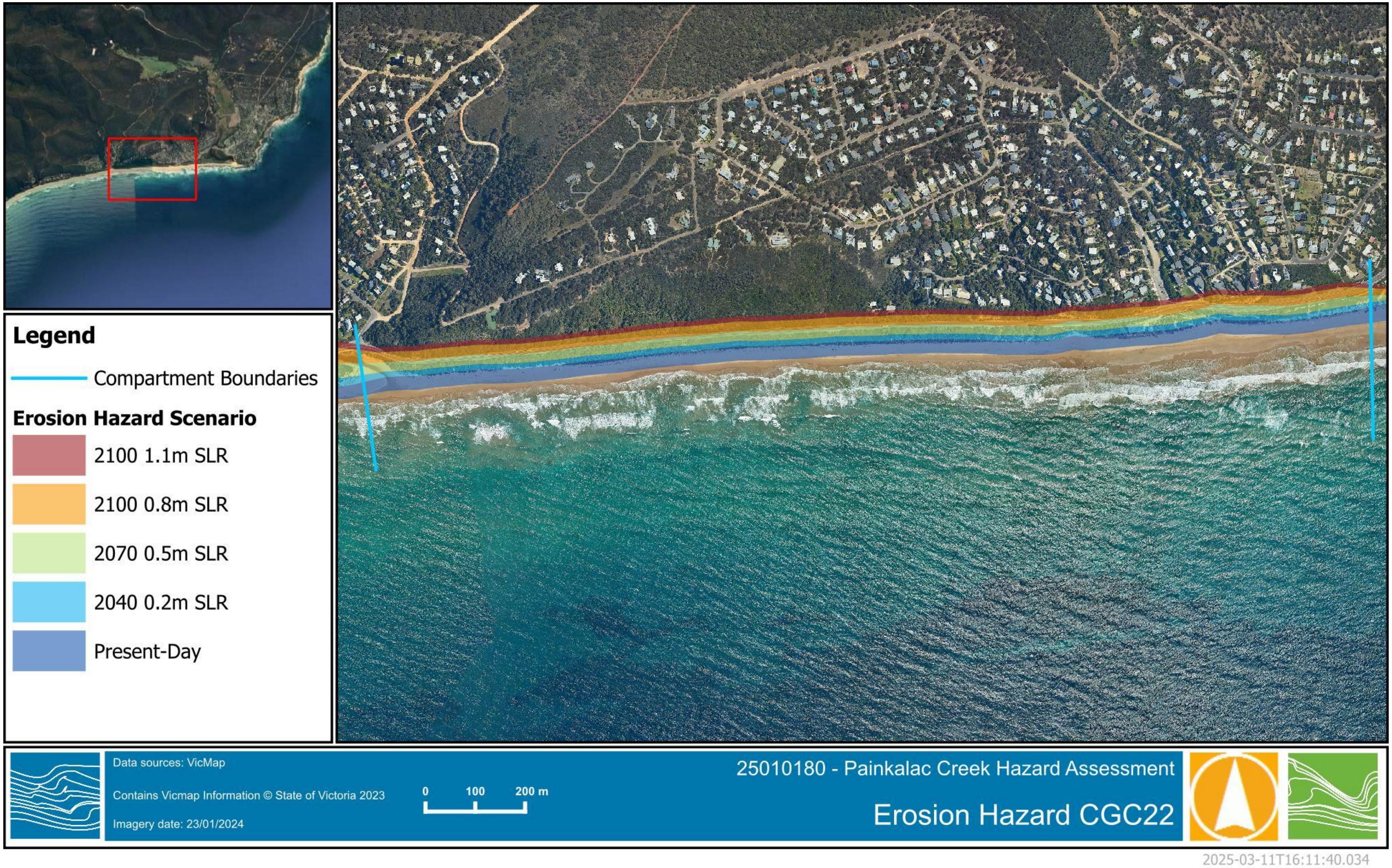

Figure 4-2 Coastal Erosion Hazard Area for CGC22

Figure 4-3 Coastal Erosion Hazard Area for CGC23

4.2 Cliff Erosion Hazard

Coastal cliff erosion hazards are caused by weather of the cliff face and/or scouring of the cliff toe which causes collapse or slipping of the cliff face. Coastal cliff erosion hazards were recently assessed in the Victorian Coastal Cliff Assessment (Tonkin & Taylor, 2023) which provides estimates of areas susceptible to coastal cliff instability/erosion. The section of coastal cliff within the study area, from the eastern side of the Painkalac Creek mouth to Sunnymead Beach, was assessed as part of the study with hazard areas presented based on the different geological units of the cliffs. This section of coastal cliff consists primarily of the Jan Juc Formation (Jan Jun Marl) geological unit and the Demons Bluff Formation. Increases in the hazard extents for future planning horizons were calculated as a function of increased toe erosion through a change in wave energy. The two geologic units of these cliffs were identified as having a medium response to SLR due to the geological units materials having a medium-high susceptibility to SLR and a medium change to wave exposure (Tonkin & Taylor 2023). Setback distances for the Jan Juc Formation and Demons Bluff Formation for the relevant planning horizons are presented in Table 4-2 with the extents presented in Figure 4-4. Additional viewing scales of the hazard extents are presented in Appendix B.

*Note – The western end of the cliff hazards displayed in Figure 4-4 have been interpolated from the original layers from Tokin & Taylor (2023) to extend the length of the cliff.

Table 4-2 Cliff Hazard Scenarios and Distances (from Tonkin &Talyor (2023))

Geologic Unit	Component	Present-day	2040 (0.2 m SLR)	2070 (0.5 m SLR)	2100 (0.8 m SLR)	2100 (1.1 m SLR)
Jan Juc Formation	Toe	0	14.3	38.2	62.2	68.4
	ASCCIE	46	62	86	110	115
Demons Bluff Formation	Toe	0	14.3	38.2	62.2	68.4
	ASCCIE	51	70	97	122	128

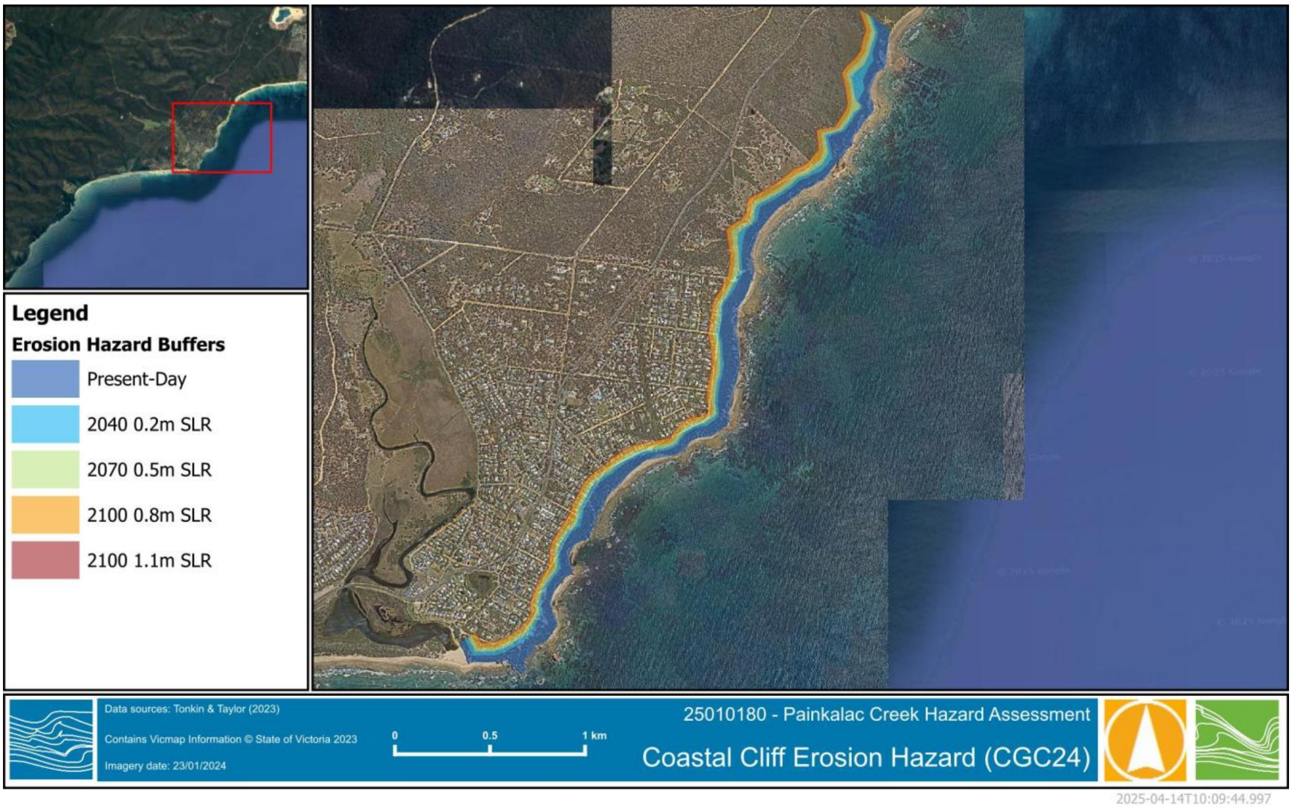

Figure 4-4 Coastal Cliff Erosion Hazard Extent (from Tonkin & Taylor (2023))

4.3 Barrier Migration

It is likely that the seaward edge of the coastal barrier will migrate landward in response to ongoing shoreline change and sea level rise processes. The expected landward position of the barrier vegetation line has been mapped using the present-day vegetation line (2024) and offsetting this line based on the combined setback distances for ongoing shoreline rate and response to SLR for CGC23 (see Table 4-3 and Figure 4-5).

There are generally higher uncertainties associated with barrier migration due to the following:

- Barrier retreat may typically require overwash or windblown sand to progressively transport sand into the lee of the existing barrier/dune system. This may be impacted by artificial entrance management or controls that release water and potentially circulate some sediments back to the nearshore coast.
- River entrance areas are unstable and also exposed to scour from the riverine side. These may alter the width of the barrier and the ability of the barrier to retreat homogenously.
- The combined processes of coastal erosion and riverine scour can result in a breakthrough, with a new entrance (either temporary or permanent) being formed. Such a change would destabilise the system and mean that the adopted approach of extrapolating existing conditions is invalid.

Table 4-3 Combined Ongoing Shoreline Change and SLR Distances for Future Planning Horizons

	2040 (0.2 m SLR)	2070 (0.5 m SLR)	2100 (0.8 m SLR)	2100 (1.1 m SLR)
Barrier Migration (m)	5	14	23	27

Figure 4-5 Barrier Migration

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APPENDIX A
COASTAL EROSION SUPPLEMENTARY DATA

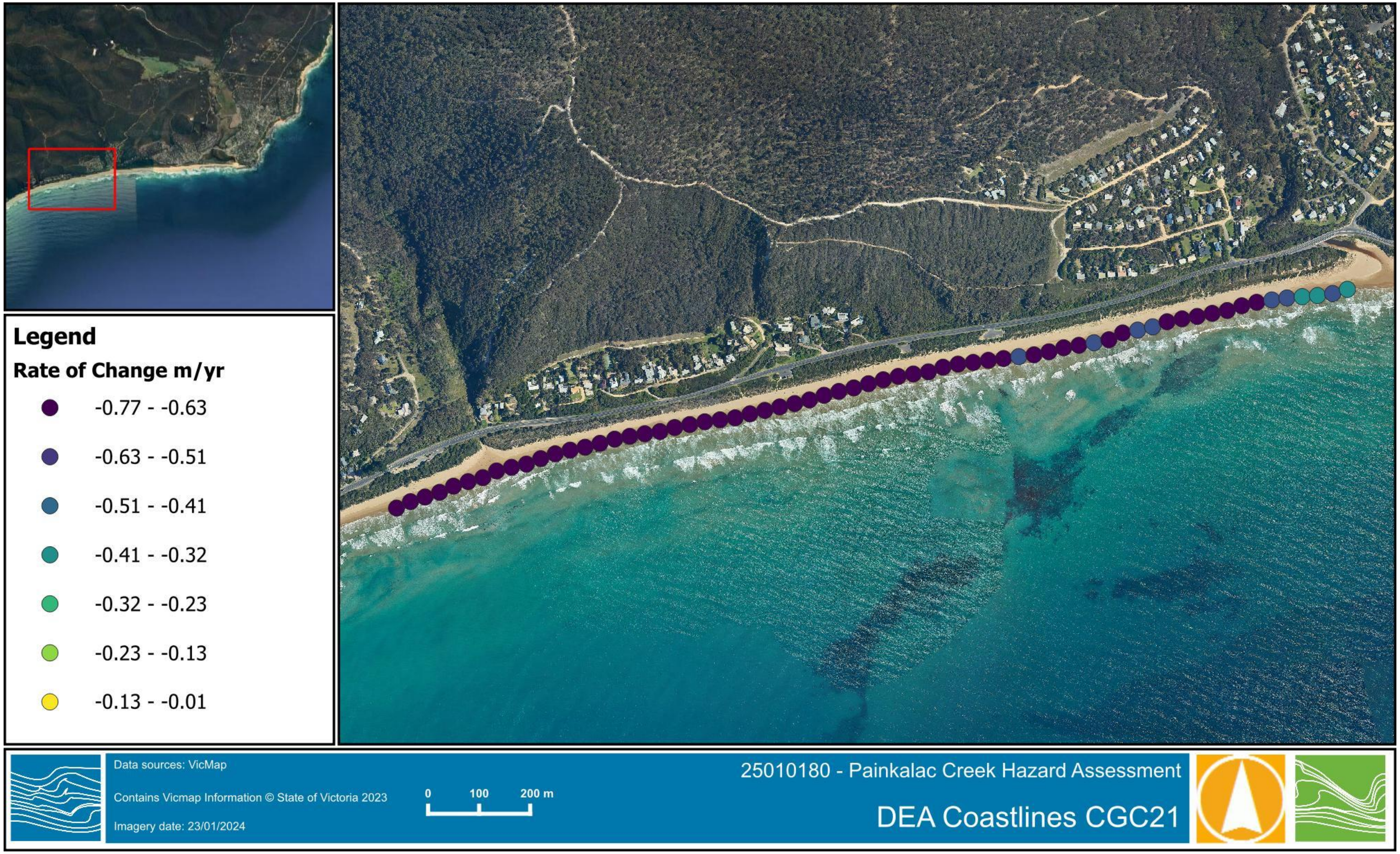

Figure A-1 DEA Coastlines CGC21

Figure A-2 DEA Coastlines CGC22

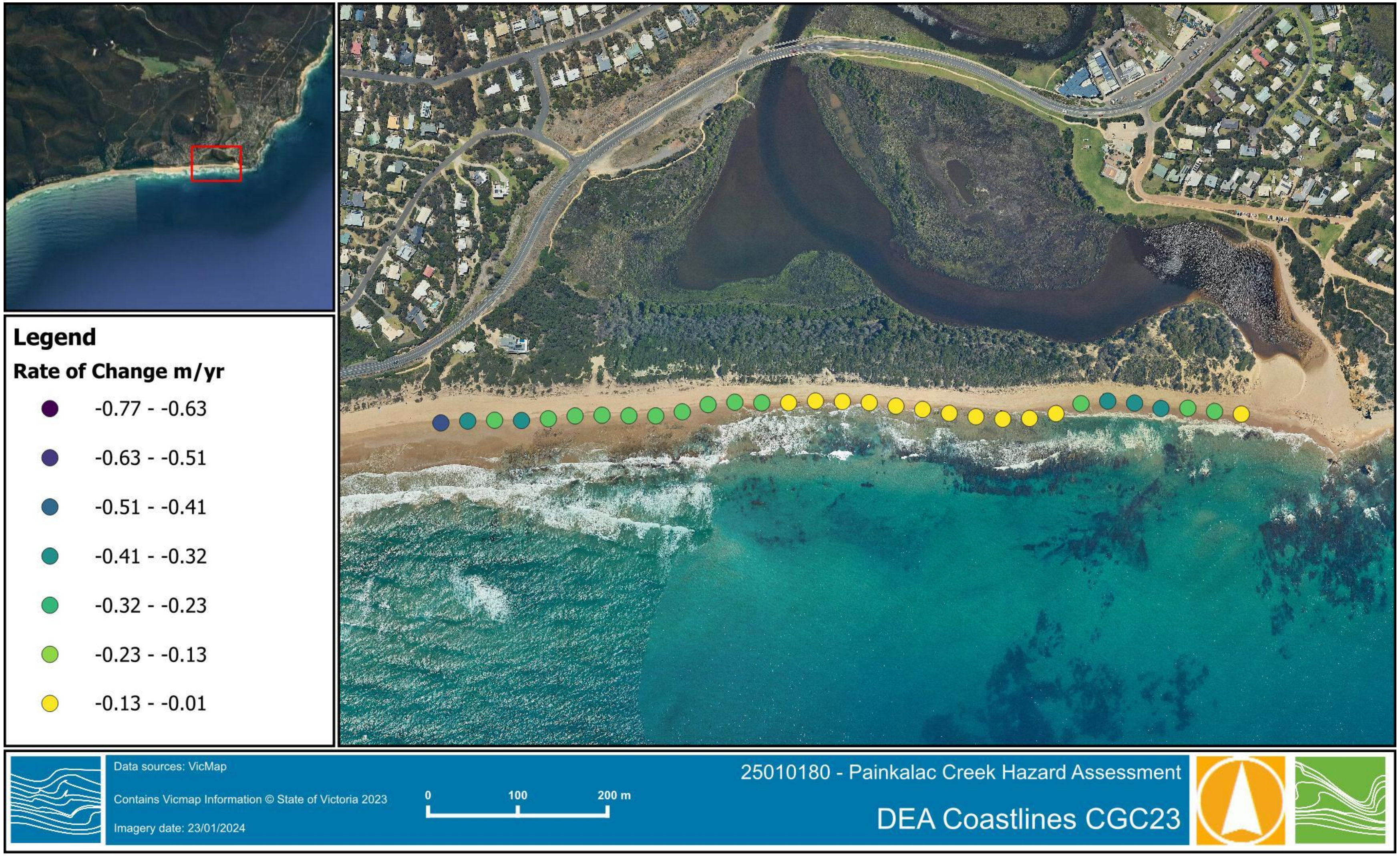

Figure A-3 DEA Coastlines CGC23

APPENDIX B
CLIFF HAZARD EXTENT

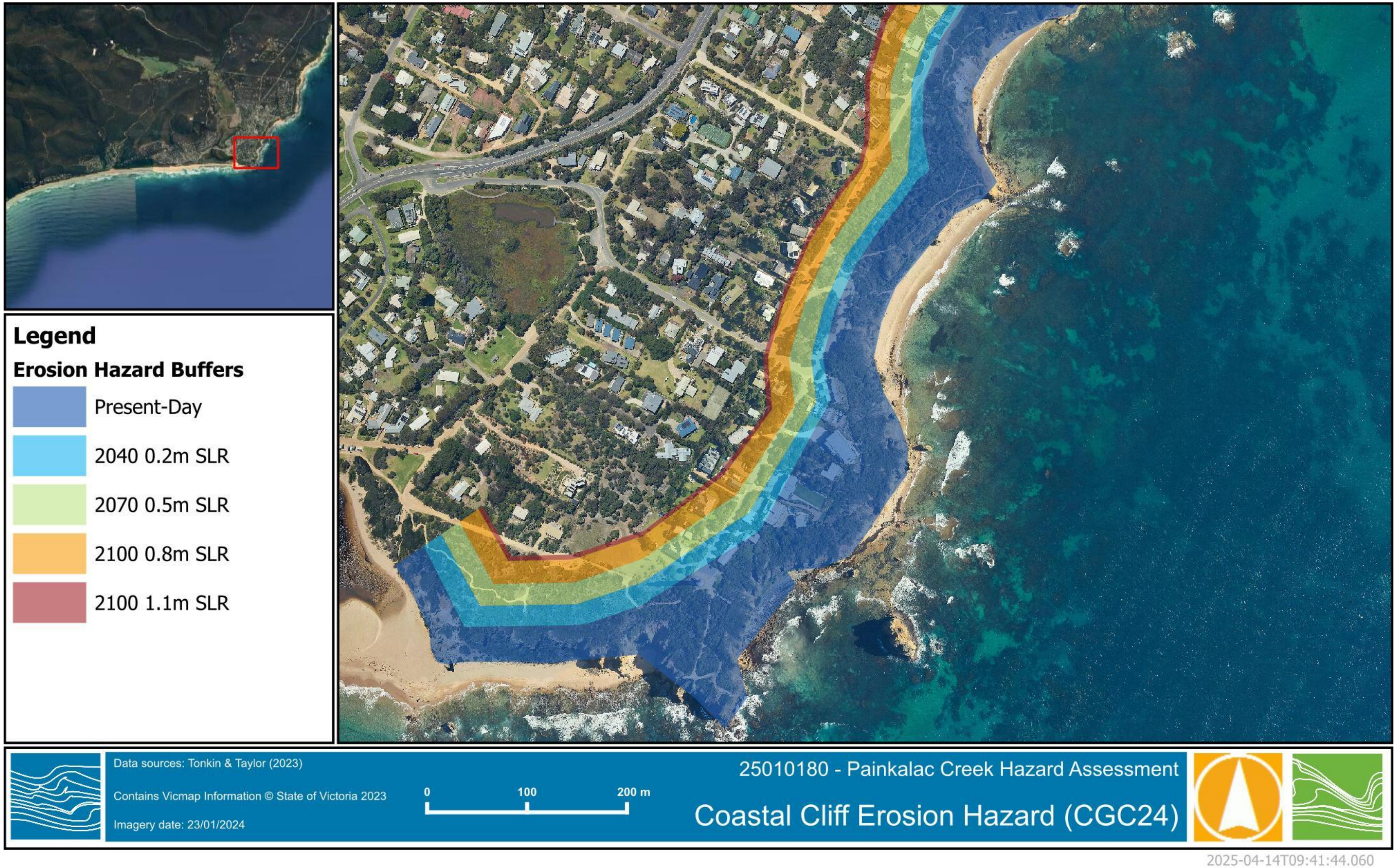

Figure B-1 Coastal Cliff Erosion Hazard Extent – cropped view 1 (southern) (from Tonkin & Taylor (2023))

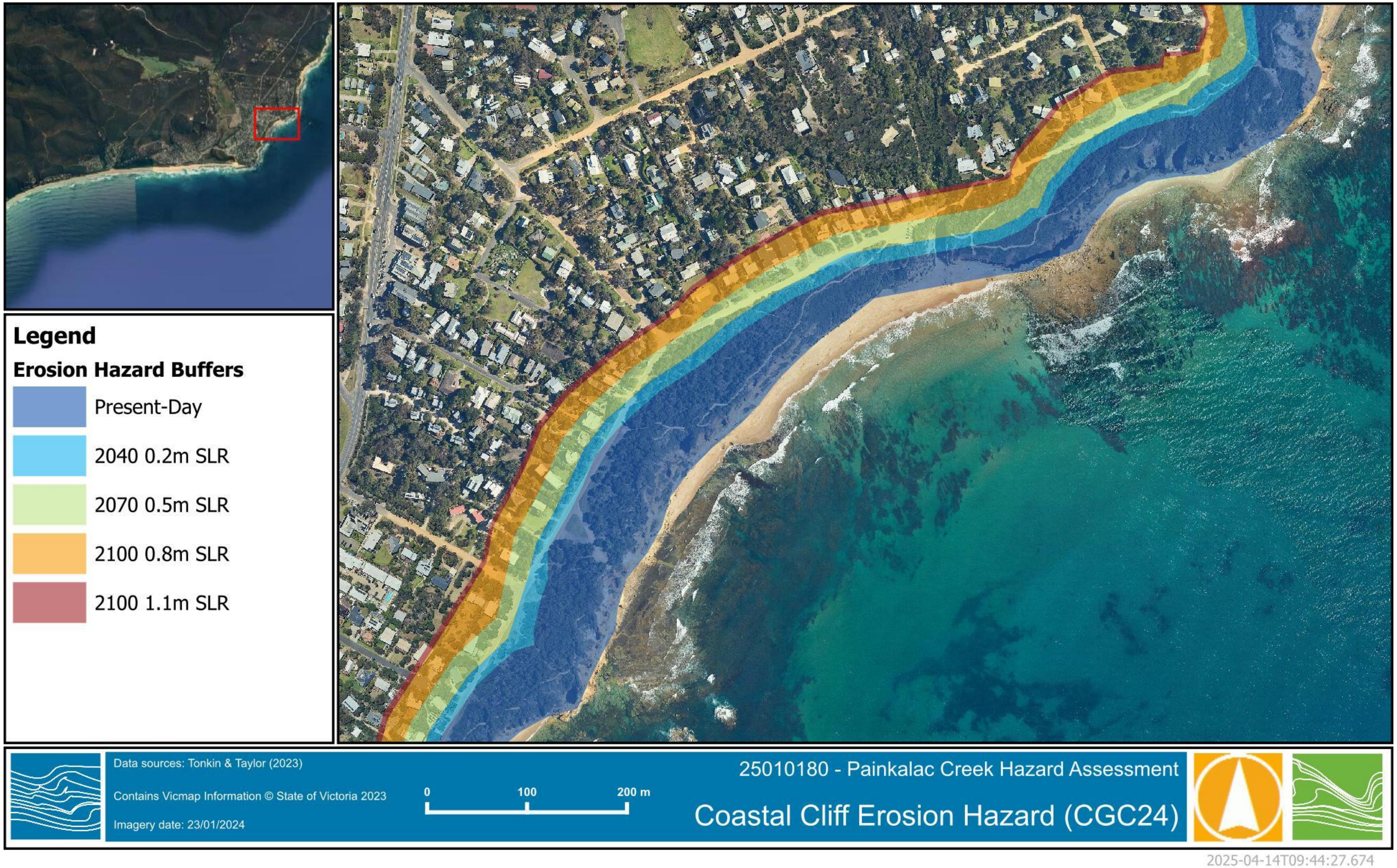

Figure B-2 Coastal Cliff Erosion Hazard Extent – cropped view 2 (southern mid) (from Tonkin & Taylor (2023))

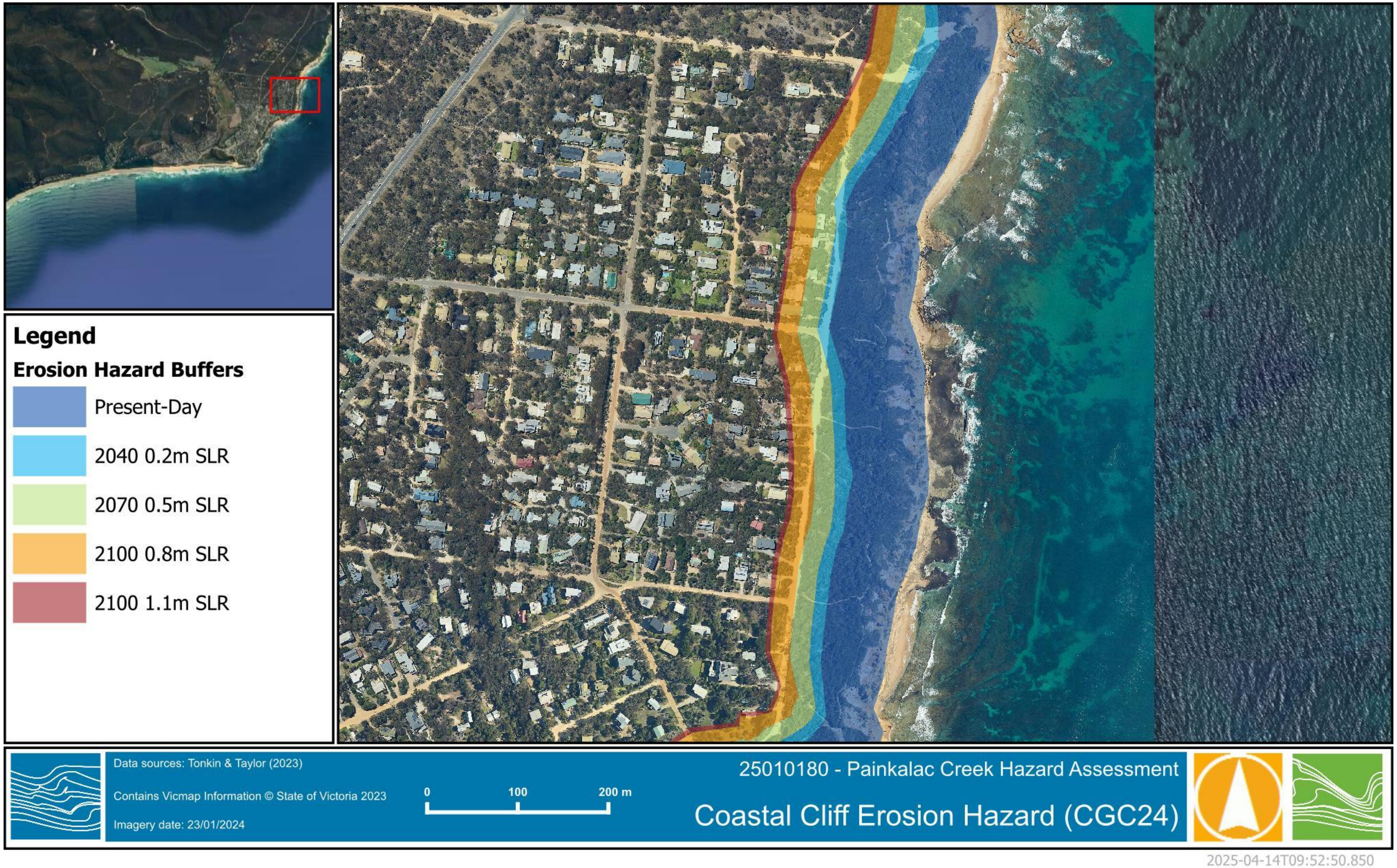

Figure B-3 Coastal Cliff Erosion Hazard Extent – cropped view 3 (northern mid) (from Tonkin & Taylor (2023))

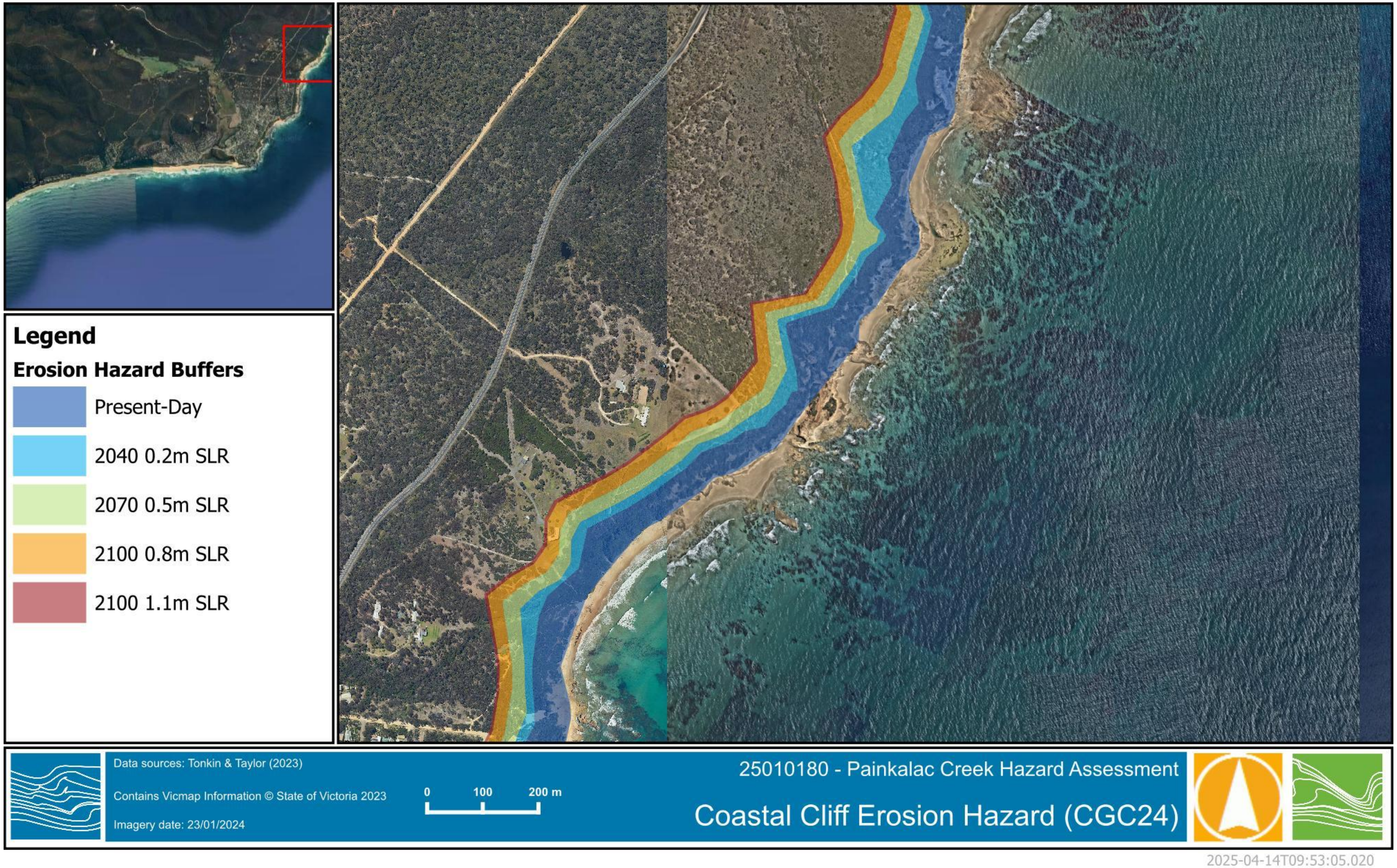

Figure B-4 Coastal Cliff Erosion Hazard Extent – cropped view 4 (northern) (from Tonkin & Taylor (2023))

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800

Sydney

Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150
Telephone (02) 9354 0300

Brisbane

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000

Perth

Level 1, 21 Adelaide Street
Fremantle WA 6160
Telephone (08) 6555 0105

New Zealand

7/3 Empire Street
Cambridge New Zealand 3434
Telephone +64 27 777 0989

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Geelong

51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800

Wimmera

597 Joel South Road
Stawell VIC 3380
Telephone 0438 510 240

Gold Coast

Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227
Telephone (07) 5676 7602

watertech.com.au