Cape to Cape Resilience Project

Stage 2 Economic Case Studies

June 2023

FINAL

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NCEconomics

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

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1 Introduction

The Cape to Cape Resilience Project is being undertaken as part of the Inverloch Regional and Strategic Partnership (RaSP), in order to proactively plan for future changes to the coastline. The coastline at and around Inverloch has experienced significant erosion in recent years, with public assets, values and infrastructure now at risk of damage and loss.

The project offers a chance to pilot various strategic components that have been developed as part of the Victoria's Resilient Coast - Adapting for 2100+ initiative, which is a comprehensive state-wide effort focused on planning for long-term resilience and adaptation to coastal hazards. The project has utilized a best practice approach that includes robust coastal hazard assessment, evaluation of risk and vulnerability, strategic planning for adaptation, tailored economic analysis, and active involvement of the community and stakeholders.

During stage 1 of the project, an economic methodology was developed as guidance for undertaking coastal hazard assessments in Victoria, which were then applied to the Cape to Cape region as a pilot. This stage 1 work looked to understand potential costs of coastal hazards for the Cape to Cape communities and inform the development and assessment of adaptation actions.

Continuing from stage 1 of the project, this project looks to build upon the economic assessment work to date, through additional specific case studies. These case studies have been selected by the RaSP team, based on an increased appreciation of exposure and risk, as well as findings from the economic base case assessment.

The three identified economic case studies are:

1. **Tarwin Lower – Venus Bay access and utilities:** Adaptation actions/options for the roads in and out of Tarwin Lower Road/Venus Bay at risk from coastal hazards from now until 2100.

2. **Blue Carbon:** Blue Carbon initiative options for transition of land use on the shore of Anderson Inlet

3. **Stage 2 economic assessment for Cape Paterson-Inverloch Road (Bunurong Road):** Stage 2 assessment of realignment/relocation of **Cape Paterson-Inverloch** Road & interdependent utilities/services. This is to build upon the economics assessment of **Cape Paterson-Inverloch** Road in Stage 1.

These additional economic analyses continue to be a key part of a suite of technical and strategic assessments being used to inform adaptation and resilience planning within the Inverloch region.

2 Tarwin Lower – Venus Bay access and utilities

This case study focuses on the economic effects of road access closures due to temporary and permanent inundation for Venus Bay and Tarwin Lower communities, and outlines where and when there may be opportunities for economically viable adaptation.

2.1 Study area

Venus Bay

Venus Bay is a small town in South Gippsland. Its relative proximity to Melbourne CBD (2.5 hrs), Traralgon (104 kilometres/80 mins), and Leongatha (40 kilometres/35 mins), added to its coastal environment, has made it a tourist alternative accessible for day and overnight visitors from Melbourne and Latrobe Valley.

Although the tourist attractions of Venus Bay are dominated by nature-based activities related to water sports (e.g., surfing, fishing), some other activities such as cultural, artistic and indigenous history experiences have been gaining relevance in recent years, expanding the alternatives offered to tourists. Venus Bay's touristic nature is reflected by the small resident population (904 people [ABS, 2022]) compared to the number of tourists. While there are no current visitation estimates for Venus Bay, estimates based on data from Tourism Research Australia suggest that more than 100,000 people travelled to Venus Bay in 2016 (Nott, 2019; Venus Bay Tourism Precinct Plan, 2019).

These people are typically accommodated within the numerous existing houses that operate as AirBNB and commercial accommodations such as Venus Bay Caravan Park. A web search conducted in February 2023 revealed that over 230 homes are offered as accommodation on the Airbnb service, with the capacity to accommodate more than 1,000 visitors at any one time.

The high percentage of unoccupied houses in Venus Bay in the 2021 census (75.5%) contrasts with the values for South Gippsland (25.7%), Victoria (11.1%) and Australia (10.1%) and positions it as the coastal community with the highest percentage of unoccupied private dwellings in South Gippsland (ABS, 2022). Although occupation patterns have been described as seasonal and concentrated mainly around summer, the census data collected in August will reflect the situation outside of the tourist season.

While Venus Bay is considered to be primarily a coastal holiday location, an increasing number of people have taken up residence in the township, especially non-resident owners moving to their holiday home permanently. Between the 2011 and 2021 censuses, the resident population increased by around 50%, going from 589 to 904 people, who have possibly taken advantage of increasing flexible working arrangements and improved access to and from Melbourne-based services.[1] This population increase is mainly represented by people over 55, whose proportion is double that observed for these age groups in the State. The prevalence of this age group results in an average age of 58 years, much higher than the 48 in South Gippsland and the 38 in Victoria and Australia. With a large majority of homes owned outright (53.2%) and a relatively low proportion of people renting (14.9%), this trend may continue, suggesting the possible transition of Venus Bay as a retirement town.

The tourist nature and the demographic structure of Venus Bay explain to a great extent the predominant commercial sectors in the area. The primary industries of employment in Venus Bay are in Social Assistance, Supermarket and Grocery, Cafes and Restaurants, Pubs, Taverns and Bars, and Gardening Services (ABS, 2022). While nearly half of the workforce works in South Gippsland, a significant section is employed in nearby LGAs, mainly Bass Coast (10%), Melbourne (5%), and Latrobe (4%). Although it is not expected that all workers commute daily to their workplace (30.3% worked at home on the day of the 2021 Census), it is likely that a significant proportion regularly travel for work outside the town.

Venus Bay has a lower average weekly household income than Australia ($922 versus $1,746 [ABS, 2022]), which may be related to an ageing population and the possible lower number of members per household that receives income.

Tarwin Lower

Tarwin Lower is a small farming township with a resident population of 462 people and around 280 dwellings (ABS, 2022). It is located on the south bank of the Tarwin River, 5 km to the East of Venus Bay. Although it offers some tourist attractions such as fishing, boating and water-skiing, it mainly serves as an entry point for tourists accessing Anderson Inlet and Venus Bay (5 km).

Tarwin Lower presents relatively high unoccupied private dwellings (32.2%) compared to State and National levels (Table 3). However, unlike Venus Bay, this proportion has remained relatively stable over the past decade. In the case of Tarwin Lower, unoccupied dwellings have mainly been attributed to the high proportion of residential development on relatively small lots (less than 40ha), predominantly for non-commercial temporary rural lifestyle purposes. Tarwin Lower presents a large majority of homes owned outright (54.2%) and a relatively low proportion of properties rented (11.1%), suggesting a predominantly resident population.

The population has grown by around 100 people in the last decade and it is characterised by the high representation of people over 55 and a relatively low presence of young groups compared to LGA and State levels, especially those between the ages of 20 and 34 (ABS, 2022).

[1] Note that the date of the 2021 Census was also during Melbourne's 6th COVID-19 lockdown, so the population may have been boosted by holiday homeowners choosing to sit out the lockdown in the township rather than their residence in the city.

Tarwin Lower's rural character is reflected by its employment profile, with over 17% of employed people working in beef and sheep-beef cattle farming, followed by dairy cattle farming (4.7%) (ABS, 2022). Most of the workforce is locally concentrated in South Gippsland (63%), with a smaller proportion working in neighbouring LGAs such as the Bass Coast (9%) or Melbourne (2%). Although the median weekly income per household ($1,260) is higher than Venus Bay and similar to South Gippsland, it is still below the State levels (Table 1).

Table 1. Demographics.

	Venus Bay	Tarwin Lower	South Gippsland	Victoria	Australia
People (no.)	904	462	30,577	6,503,491	25,422,788
Median age	58	53	49	38	38
Median weekly household income	$922	$1,262	$1,266	$1,759	$1,746
Median weekly rent	$280	$210	$260	$370	$375

Source: ABS (2022)

Table 2. Participation in the labour force and method of travel to work.

	Venus Bay		Tarwin Lower		South Gippsland		Victoria	Australia
	#	%	#	%	#	%	%	%
In the labour force	335	41.4%	223	56.7%	14,053	55.2%	62.4%	61.1%
Not in the labour force	408	50.4%	148	37.7%	9,705	38.1%	32.2%	33.1%
People who travelled to work by car (driver or passenger)	164	51.7%	115	53.7%	8,426	61.9%	54.5%	57.8%
People who walked to work	5	1.6%	14	6.5%	611	4.5%	2.3%	2.5%
People who worked at home	96	30.3%	58	27.1%	2,530	18.6%	25.7%	21.0%

Source: ABS (2022)
* Respondents had the option to report up to three methods of travel to work on the day of the Census.

Table 3. Dwellings and housing.

	Venus Bay		Tarwin Lower		South Gippsland		Victoria	Australia
	#	%	#	%	#	%	%	%
Occupied private dwellings	423	24.3%	190	66.4%	12,001	74.3%	2,390,232	88.9%
Unoccupied private dwellings	1,313	75.5%	92	32.2%	4,148	25.7%	298,029	11.1%
Owned outright	225	53.2%	103	54.2%	5,680	47.3%	768,730	32.2%
Owned with a mortgage	122	28.8%	65	34.2%	3,984	33.2%	862,658	36.1%
Rented	63	14.9%	21	11.1%	1,828	15.2%	681,419	28.5%

Source: ABS (2022)

Reliance on larger population centres

Venus Bay and Tarwin Lower are only 5 km apart, and there is considerable interaction between the towns for commercial and community activities. Although Venus Bay has some minor commercial activity, Tarwin Lower provides most basic services (e.g., supermarket and community health) to residents and tourists in Venus Bay. Retail and services offered are limited, with most people needing to travel daily to Leongatha, Inverloch, Meeniyan (or further away) for work, school, shopping and medical services (SGSC, 2019). With an increasing aging population, it is anticipated that Venus Bay and Tarwin Lower will experience growth in demand for mobility assistance and medical and social services.

Prolonged duration or increasing frequency of road access cut-offs associated with flooding would affect not only the provision of supplies for essential services in the area (e.g. pharmacies, supermarkets, fuel stations) but also the access to relevant services only available in neighbouring areas. Table 4 shows some relevant services available in Venus Bay, Tarwin Lower, and nearby localities, evidencing the high dependence on larger centres for higher order community and commercial services.

Additionally, a series of environmental factors (i.e., acid sulphate soils, bushfire risk) and the lack of services such as reticulated water, sewer, and gas in Venus Bay and Tarwin Lower may not only extend the impacts of flooding but also add potential risks and increase the area's vulnerability. For example, with the residential areas surrounded by Cape Liptrap Coastal Park and Anderson Inlet, Venus Bay is classified as high risk of bushfire. Any extended closure of the main access due to floods could seriously affect rescue operations where a bushfire occurs during a time of closure.

Table 4. Services present in Venus Bay, Tarwin Lower and nearby localities.

	Venus Bay	Tarwin Lower	Inverloch	Meeniyan	Fish Creek	Leongatha	Wonthaggi	Foster	Korumburra
Distance to Venus Bay/Tarwin Lower (km)	-	-	29.4	31.2	31.8	40.0	41.4	45.1	51.4
Health									
Ambulance[a]	✖	✖	✓	✖	✖	✓	✓	✓	✓
Hospital	✖	✖	✖	✖	✖	✓	✓	✓	✓
General Practitioner[b]	✖	✓	✓	✖	✖	✓	✓	✓	✓
Dentist	✖	✖	✓	✖	✓	✓	✓	✓	✓
Pharmacy	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education									
Childcare / Kindergarten	✖	✖	✓	✓	✖	✓	✓	✓	✓
Primary school	✖	✓	✓	✓	✓	✓	✓	✓	✓
Specialist school	✖	✖	✖	✖	✖	✓	✓	✖	✖
Highschool	✖	✖	✖	✖	✖	✓	✓	✓	✓
Adult Education	✖	✖	✖	✖	✖	✓	✓	✖	✖
Energy									
Fuel station	✓	✓	✓	✓	✓	✓	✓	✓	✓
Electric car charge station	✖	✖	✓	✖	✓	✖	✖	✓	✖
Emergency Services									
Police station	✖	✖	✓	✓	✖	✓	✓	✓	✓
Fire station[c]	✖	✖	✓	✖	✓	✓	✓	✓	✓
Others									
Public transport[d]	✖	✖	✓	✓	✓	✓	✓	✓	✓
Airport	✖	✖	✓	✖	✖	✓	✖	✖	✓

[a] Venus Bay counts with a Community Emergency Response Team (CERT) trained in first response that could manage minor emergencies while an ambulance is dispatched from Foster or Leongatha.

[b] Local services are provided by Tarwin Lower Community Health Centre and Gippsland Southern Health Service. However, the provision may be affected by road closures as most professionals live outside the area. Tarwin Lower Community Health Centre provides a range of health services (e.g., nurse, pathology, private General Practitioner, maternal and child health program). Home and Community Care (HACC) provides basic support to frail older people, people with disability and their carers. Gippsland Southern Health Service provides district nursing, social work, physiotherapy, occupational therapy, dietetics, speech, palliative care, and specialist community nursing. When transport is not available, services are provided to the home.

[c] Venus Bay relies on a volunteer service provided by the Country Fire Authority that can manage minor events.

[d] School bus service to Leongatha is available for local students. Community transport from Venus Bay to Tarwin Lower and Wonthaggi is provided by local organisations.

2.2 Flood impacts

Historical events

The South Gippsland region is susceptible to significant flooding events – both catchment and coastal driven. Historical events are registered for 1934, 1990, March 2011, May 2012 and June 2012, which caused substantial damage to infrastructure and property (VICSES, 2023). Some of the most affected areas in recent events included Venus Bay and Tarwin Lower, mainly due to the inundation of the Inverloch-Tarwin Lower Road (C443), the primary road access connecting these towns to commercial centres north of the Tarwin River (i.e., Inverloch, Leongatha, Koonwarra, Meeniyan). Over the last ten years, four flooding events (July 2012; September 2021, October 2021, August 2022) caused a temporary closure of the route, isolating Venus Bay/Tarwin Lower and forcing residents and service providers to use less optimal substitute routes in terms of distance and time (Victoria Department of Transport, pers comms). Given the location of this road at the mouth of the Tarwin River and potential sea level rise, the frequency and impact of closures due to flooding are expected to increase in the future. The absence of early flood warning reports for the area increases the risk for these communities and limits their adaptive capacity.

Venus Bay and Tarwin Lower's high reliance on larger commercial centres has raised concerns about the need to guarantee connectivity of the road network, accessibility to or - if necessary - evacuation from flooded areas to reduce the economic and social costs that the community faces during flood events. For example, the few currently available alternatives that connect Inverloch to Venus Bay are not reliable (and are also prone to flooding) and fail to offer a cost-effective alternative for residents and tourists. According to traffic count data (Department of Transport and Planning, 2023), the Inverloch-Tarwin Lower Road is estimated to be used more than 760 times daily (Figure 1) by residents and visitors.

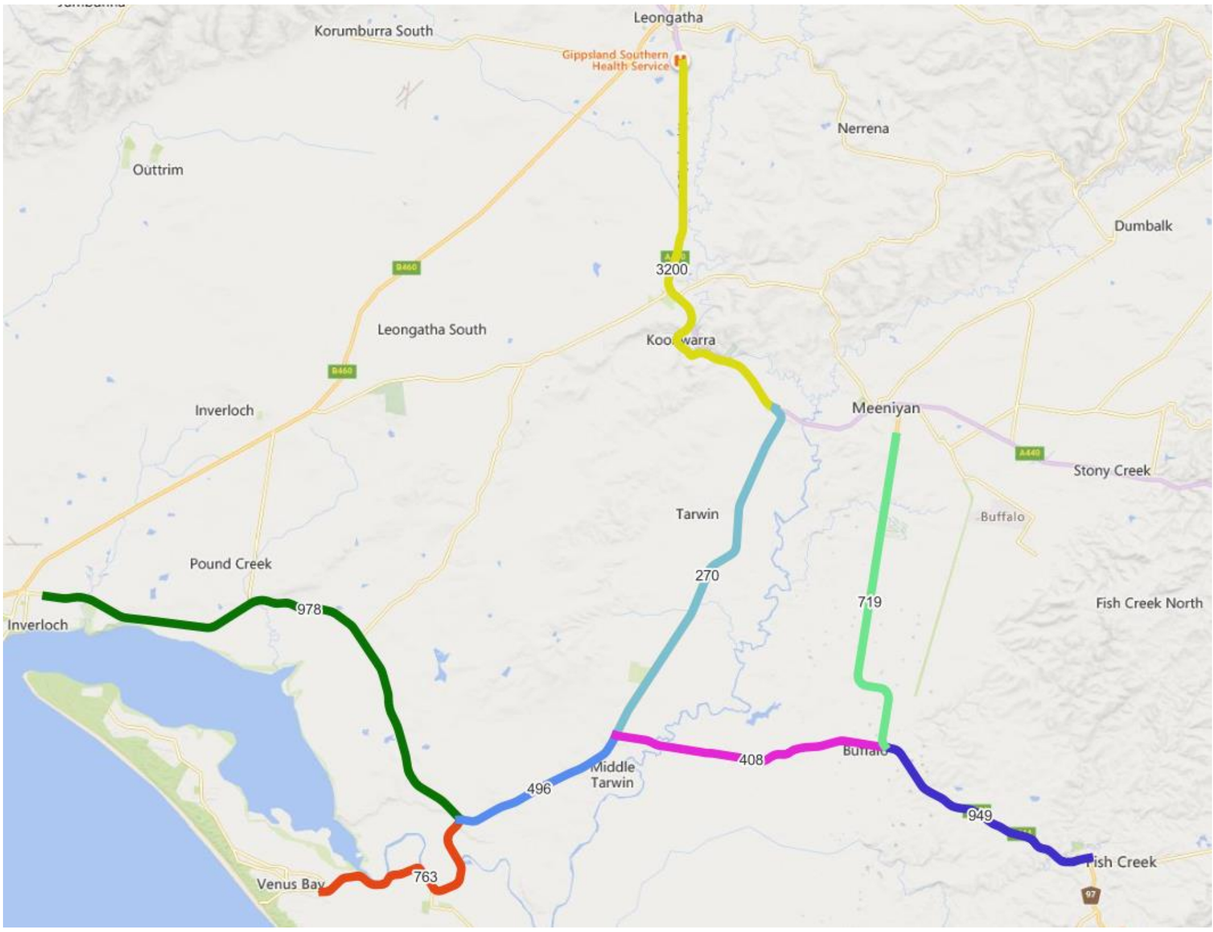

Figure 1. *Traffic flows (Average Annual Daily Traffic [AADT]).*

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Future events

The Inverloch Region Coastal Hazard Assessment (Reports 1 to 7, Water Technology, 2022) provided a range of key technical assessments for the Cape to Cape Resilience Project. This work included modelling, conducted to understand the likely impacts of future storm-tide flooding over a range of time horizons and (sea level rise) SLR scenarios for Venus Bay and Tarwin Lower. These events have been defined under two flood related coastal hazards - permanent inundation (due to sea level rise) or temporary inundation (i.e. storm tide). Permanent inundation refers to a flood scenario whereby rising sea levels will permanently inundate land, while temporary inundation is the result of short-term elevation of sea levels over normal tidal levels, generally experienced during storms or king tides.

Flood events have been modelled across five separate SLR scenarios for both permanent and temporary events, as listed below.

1. Present Day (2021) – 0.0 m SLR
2. 2040 – 0.2 m SLR
3. 2070 – 0.5 m SLR
4. 2100 – 0.8 m SLR.
5. 2100 – 1.1 m SLR.

Modelling has also been undertaken for a range of storm event likelihoods and combined catchment flooding probabilities. A key output from the Coastal Hazard Assessment (CHA) has been spatial hazard extents. These extents have been used to assess what assets (roads/utilities) and levels hazard risk based on tailored risk framework for the region.

Venus Bay / Tarwin Lower connection

Exposed lengths of road for the Venus Bay /Tarwin Lower connection have been calculated for permanent inundation, presented in Table 5 below. The exposed length column refers to the length of road exposed to the permanent inundation hazard extent under different planning horizons. It has been calculated by intersecting roads with the hazard for a given year (SLR scenario) and adding all road segments to determine a total exposed length (water over road).

Results in the second column assume that exposure to more frequent tidal action may impact road embankment integrity, potentially eroding and damaging the road and restricting access. Therefore, in sections of road where increasing tidal areas (regular tides action) project water on either side of the road embankments, the road itself is also considered exposed, despite current higher road surface elevations.

Exposed lengths of road are minimal between present day and 2070, before increasing substantially to 457m and 1,320m for the 2100 0.8m and 2100 1.1m SLR scenarios respectively. By 2070, over 1,200m of road could potentially be damaged under the more frequent tidal action assumption, increasing to 2,197 by 2100 (1.1m SLR). However, even when a short distance of road is inundated, that inundation can effectively render a road impassable.

Table 5. Venus Bay / Tarwin Lower connection: permanent inundation exposure for Inverloch-Venus Bay Road.

Planning horizon	Exposed length (m)	Assuming road washed out (eroded)
Present day (2021 (0.0 m SLR))	-	-
2040 (0.2 m SLR)	10	-
2070 (0.5 m SLR)	58	1,262
2100 (0.8 m SLR)	457	1,688
2100 (1.1 m SLR)	1,320	2,197

Figure 2 below provides a high-level map of affected sections of road under the different permanent inundation scenarios, assuming that the road is washed out with tidal action.

Figure 2. *Venus Bay / Tarwin Lower connection: permanent inundation exposed lengths (assuming road is washed out).*

Temporary storm-tide inundation for Venus Bay / Tarwin Lower connection is expected to measure significantly higher exposure levels in comparison and has been presented in Table 6 below across varying Annual Exceedance Probabilities (AEP's). [2] Less frequent but most damaging event, 1% AEP flooding across Venus Bay is likely to impact over 1,400 m of exposed road in the present day and the main access road is expected to be entirely flooded by 2040. By 2070, the most frequent 10% AEP flood events will impact over 2,200 m of road.

Table 6. Venus Bay / Tarwin Lower connection: temporary storm-tide inundation exposure lengths

Planning horizon	Exposed length (m)		
	10% AEP event	5% AEP event	1% AEP event
Present day (2021 (0.0 m SLR))	514	1,070	1,418
2040 (0.2 m SLR)	1,258	1,827	2,142
2070 (0.5 m SLR)	2,212	2,250	2,265
2100 (0.8 m SLR)	2,269	2,272	2,275
2100 (1.1 m SLR)	2,278	2,282	2,290

Tarwin Lower / Inverloch connection

As seen in Table 7 below, Tarwin Lower / Inverloch is expected to experience similar levels of permanent inundation exposure when compared to Venus Bay / Tarwin Lower route, with relatively small levels up until the 2100 0.8 m SLR scenario. Applying the same tidal action assumptions as described above, over 2,200 m of road is likely to be impacted under the 2100 0.8 m SLR scenario.

[2] An AEP, or Annual Exceedance Probability, is a measure of the likelihood of a flood or water flow of a certain magnitude occurring or being exceeded in any given year. Consequently, in any one year, there is a 1-in-100 chance of a 1% AEP flood event occurring.

Table 7. Tarwin Lower / Inverloch connection: permanent inundation exposure lengths.

Planning horizon	Exposed length (m)	Assuming road washed out (eroded)
Present day (2021 (0.0 m SLR))	-	-
2040 (0.2 m SLR)	23	-
2070 (0.5 m SLR)	130	1,266
2100 (0.8 m SLR)	590	2,214
2100 (1.1 m SLR)	1,734	2,244

Figure 3 below provides a high-level map of affected sections of road under the different permanent inundation scenarios, assuming that the road is washed out with tidal action.

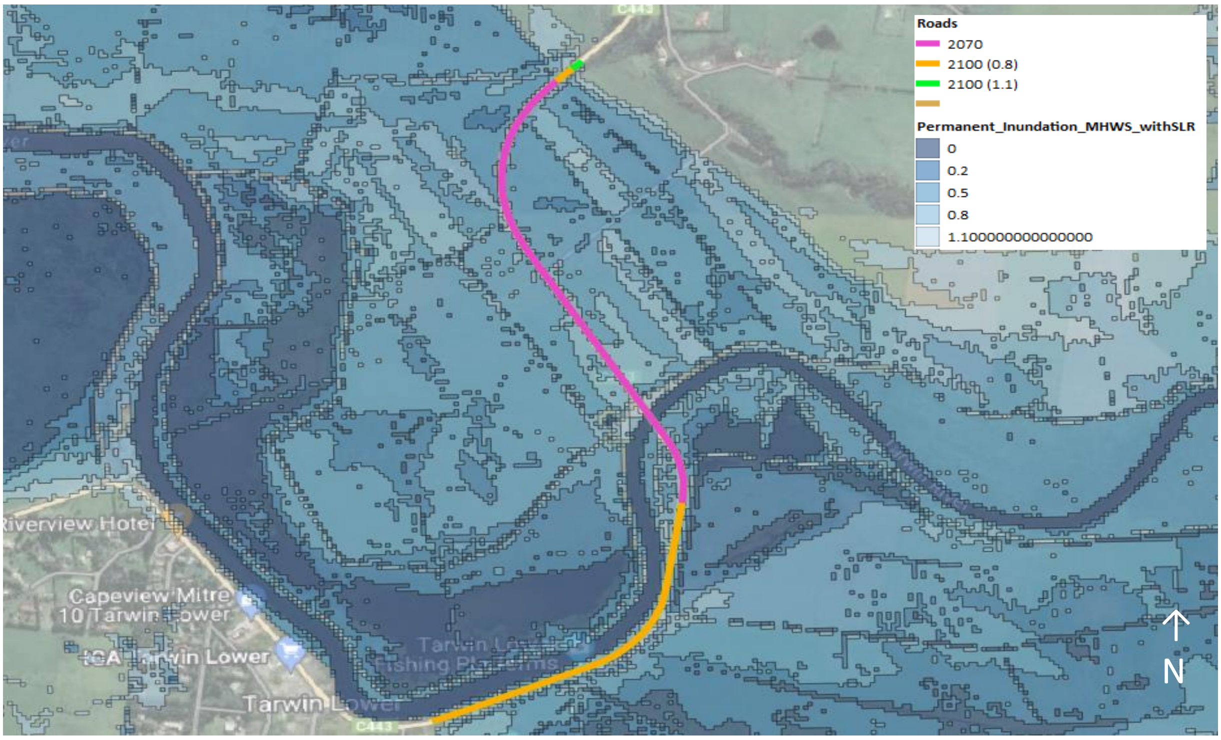


Figure 3. *Tarwin Lower / Inverloch connection: permanent inundation exposed lengths (assuming road is washed out).*

Note: Present day and 2040 not shown in figure as the exposed length under those timeframes is limited (i.e. would not likely provide a significant restriction on access).

Temporary storm-tide inundation results for Tarwin Lower are presented in Table 8 below. For the 10% and 5% AEP scenarios, the main access road into Tarwin Lower will be entirely flooded by 2070. For the 1% AEP scenario, the main access road is expected to be entirely flooded by 2040.

Table 8. Tarwin Lower / Inverloch connection: temporary storm-tide inundation exposure lengths.

Planning horizon	Exposed length (m)		
	10% AEP event	5% AEP event	1% AEP event
Present day (2021 (0.0 m SLR))	2,155	2,154	2,167
2040 (0.2 m SLR)	2,165	2,175	2,182
2070 (0.5 m SLR)	2,182	2,182	2,182
2100 (0.8 m SLR)	2,182	2,182	2,182
2100 (1.1 m SLR)	2,182	2,182	2,182

2.3 Economic impacts of isolation

Approach

There are a range of potential economic impacts associated with isolation of communities. The type and magnitude of impacts is likely to depend on the degree of isolation (i.e. partial vs. complete isolation) and the duration of impacts. Partial isolation represents a scenario with some kind of alternative access option. The hazard type also determines the duration of disruption (i.e. temporary inundation from storm tide vs. permanent inundation from sea level rise), from very short-term/during high tide through to permanent. The sections below cover each of these scenarios.

While the hazard modelling from the CHA provides data on the extent and likelihood of different hazard events, it does not provide an estimate of the precise frequency or duration of access loss. As a result, all impacts have been estimated in per day or per year terms where relevant.

Temporary partial isolation

Temporary partial isolation refers to the case where a community's access is restricted for a relatively short period of time (e.g. hours, days); however, a less preferred access route remains open. This is likely to be the case for the Tarwin Lower community for a range of storm-tide events. As outlined above, the hazard modelling indicates that Inverloch-Venus Bay Rd just north of Tarwin Lower (Tarwin Lower – Inverloch connection) will likely be inundated during storm-tide events. With that route closed, residents would need to use alternative routes to get in and out of Tarwin Lower. This is particularly an issue for those who regularly leave or come to Tarwin Lower for work. As such, the valuation approach is based on the additional cost and time required to utilise the alternative route, and uses the following formula:

> *Economic losses from temporary partial isolation = Number of people who use the car to go to work * Additional distance (km) * Fuel cost ($/km) * Additional time (hr) * Time cost ($/hr) * Trips per day*
>
> Where the additional distance was calculated based on travel to nearby centres such as Inverloch via Walkerville Rd to the south.

Table 9 presents a summary of the input data used for the valuation of temporary partial isolation.

Table 9. Temporary partial isolation valuation inputs

Input name	Low	More likely	High	Comment
Traffic affected (no.)	91	144	137	Based on ABS (2022) number of residents using a car to go to work from Tarwin Lower.
Additional travel distance (km)	50	75	100	Estimated from Google Maps based on distances to various other population centres in the region.
Additional travel time (hrs)	0.5	1	1.5	
Vehicle running costs ($/km)	0.62	0.78	0.94	Average allowable running costs of a vehicle from the Australian Taxation Office
Time cost ($/hr)	28.9	36.2	43.5	Average hourly incomes for Tarwin Lower residents[3]
Trips per car per day	1	1.5	2	Assumption

The economic cost to the 462 permanent residents in Tarwin Lower (Census 2021) will be largely determined by the frequency of trips and the length of a closure. This analysis shows the economic costs range from $5,563 to $13,159 per day of closure.

[3] This approach is the standard approach to assessing delays in transport studies.

As the exact number of days of closures in an average year is unknown this is assessed as a threshold in the cost-benefit analysis (CBA) below.

It is noted that Venus Bay residents may also be impacted by closure of this northern section. However, given the Venus Bay – Tarwin Lower connection is also likely impeded for these same storm events, isolation costs to the Venus Bay community are reflected in the assessment for temporary complete isolation below.

The availability of alternate formal access routes is limited for Venus Bay community. This means flooding, whether temporary or permanent (due to sea level rise), results in complete isolation for the Venus Bay community. Partial isolation is not a possible scenario for consideration and has not been assessed.

Permanent partial isolation

Permanent partial isolation refers to the case outlined above for temporary partial isolation except that it is permanent. This means that road users must travel the less preferred access route all the time (i.e. 365 days per year). Using the same approach and inputs as above, the economic cost to residents in Tarwin Lower will be in the order of $3.3 million per year ($2 million to $4.8 million per year).

Temporary complete isolation

Temporary complete isolation refers to the case where a community's access is restricted for a relatively short period of time (e.g. hours, days) and no alternative access options are available. This is likely to be the case for the Venus Bay community for a range of storm-tide events. As outlined above, the hazard modelling indicates that Inverloch-Venus Bay Rd just east of Venus Bay (Venus Bay – Tarwin Lower connection) will likely be inundated during storm-tide events. With that route closed, cars would be unable to get in or out of Venus Bay.[4] This may result in a range of different economic losses:

- *Tourism / accommodation operators*
    - Cancellation of bookings and foregone revenue (in the short run and for low frequency events).
    - Where short-term consumables are required (e.g. food and beverages) higher stocks will be required to safeguard against periods of isolation with an associated holding cost. In addition, already purchased stock may perish if visitor demand is insufficient.
    - If the disruption becomes more frequent, and visitor numbers permanently decline in response to low reliability of access, the viability of enterprises will be compromised and cashflow problems will be reflected in the value of these businesses.
- *For residents*
    - Access and delay costs could impact employment (e.g. completely unable to travel to/from work, use of longer and more expensive alternatives).
    - Disruption of essential and emergency services (e.g. healthcare and ambulance).
    - Where short-term consumables are required (e.g. food and beverages) higher stocks will be required to safeguard against periods of isolation and this has a holding cost.
    - If the problem becomes more frequent, such impacts will be reflected in property values, where values drop top reflect the likelihood of limited access.
- *For government*
    - Upgrades and higher maintenance costs for road infrastructure.
    - Emergency services typically provided by ambulance would need to be replaced by helicopter. Although local media reports show that air services are used for emergency rescue on a regular basis, it is assumed that in the event of a road closure, their use would become more frequent, and even for lower risk medical incidents.
    - If the problem becomes more frequent, such impacts could result in the need to consider alternative transportation options (e.g. ferry, making alternative road access more reliable, or other major infrastructure investments).

[4] It is acknowledged that it may be possible for cars to get in and out through informal access on private property in some situations; however, this is not considered sufficient to offset the impacts of isolation for the entire community, particularly in the longer term with greater frequency and duration of flood events.

The limited understanding of timing and duration of any road closure means estimating reasonable annual average economic losses resulting from closures is not possible. Instead, the assessment considers three different scenarios of closure duration to understand the potential economic costs. These scenarios are described in Table 10. For each impacted party (tourism / accommodation operator, residents and government), an element of the costs experienced has been estimated, as follows:

- *Tourism / accommodation operator* – it is assumed that operators experience a reduction in income because visitors cannot access accommodation in the towns.
- *Residents* – it is assumed that employed residents are not able to travel to work, and a loss is incurred.
- *Government* – it is assumed that a medical emergency occurs that requires helicopter evacuation because an ambulance cannot gain access to the towns, or it takes too long.[5]

Table 10. Economic cost of road closure events (case study scenarios, impacted party and cost categories)

	Tourism / accommodation operators	Residents	Government
	Foregone income	Foregone wages	Rescue costs
Scenario 1 (High / worst cost): Inundation of road lasting 5 days and medical emergency requiring helicopter rescue	✓	✓	✓
Scenario 2 (Mid cost): Inundation of road for 3 days	✓	✓	×
Scenario 3 (low cost): Inundation of road for 2 days	✓	✓	×

The approach to estimating the **total cost to tourism / accommodation** owners is as follows:

*(Dwellings used as holiday businesses*Mean capacity + Tourism accommodation capacity) * Rental cost * Occupancy at holiday businesses *Days that road inundation occurs*

The approach to estimating the **total cost to the working population** is as follows:

*Number of people who use the car to go to work[6] * Median daily household income * Days that road inundation occurs*

The approach to estimating the **cost to the government associated with an emergency rescue** is as follows:

*(Cost of a helicopter ambulance call-out - Cost of a road ambulance call-out) * Number of call-outs*

Key parameters underpinning the estimated costs are contained in Table 11.

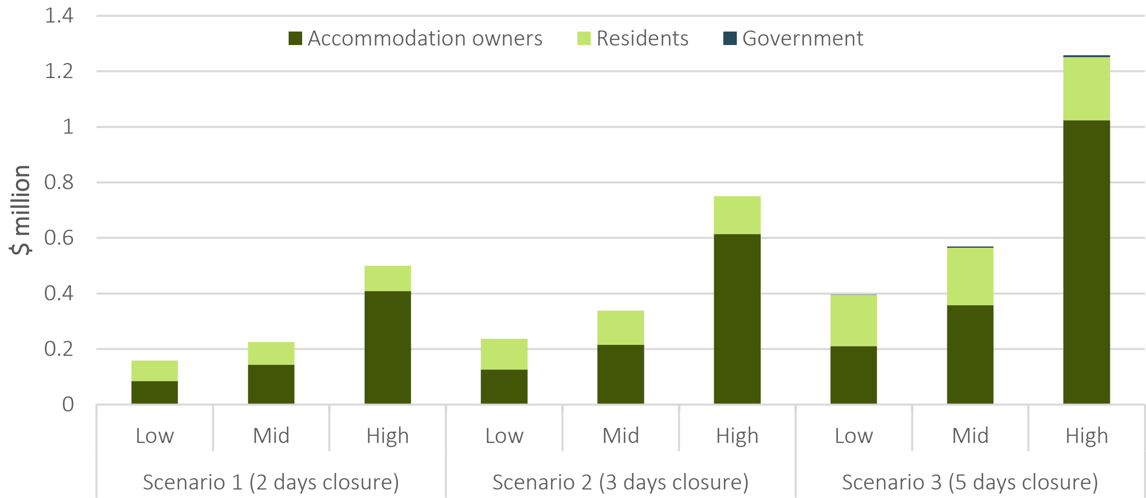
[5] It is acknowledged that it is possible that, in urgent cases, Venus Bay may need helicopter evacuations for medical emergencies due to its location far from ambulance services and therefore this may not necessarily be a completely additional impact from access loss. (https://www.theage.com.au/national/victoria/helicopter-rescue-for-group-of-swimmers-near-cape-schanck-20210113-p56tv3.html).
[6] This assumes that the current population that travel to work by car do not have the option to work remotely.

Table 11. Temporary complete isolation valuation inputs

Input name	Low	More likely	High	Comment
Tourism / accommodation owners				
Dwellings used as a holiday business (no.)	0	660	1,313	Based on unoccupied private dwellings (ABS (2022)).
Mean capacity of dwellings used as accommodation (no. people/dwelling)	2	5	6	Based on the Airbnb advertised in the area.
Capacity tourism accommodation (no. people)	188	235	282	Based on the website of tourist operators
Rental cost ($/night/person)	20	36	128	Based on the website of tourist operators and Airbnb advertised in the area.
Occupancy (%)	-	59%	-	Australian Accommodation Monitor average accommodation occupancy in Gippsland tourism region.
Working population				
People who commute by car (no.)	141	157	173	Based on ABS (2022) number of residents using a car to go to work.
Median daily personal income ($/day)	61	76	91	Estimate based on ABS (2022) median weekly personal income.
Government				
Cost of a helicopter ambulance call out ($)	770	970	1200	Based on reported costs for different rescue services
Cost of a helicopter ambulance call out ($/h)	3200	4000	4800	Based on reported costs for different rescue services
Cost of a road ambulance call out ($)	596	1,261	1,927	Based on ambulance charges in Victoria (Regional and Rural Emergency Road)
Cost of road ambulance ($/h)	3	4.5	6	Based on reported costs for different rescue services

Figure 4 contains indicative values for each of the costs and each of the scenarios. It demonstrates that, in a partial access loss (2 – 5 days), Venus Bay experience significant costs, ranging between $158,000 - $1,250,000, depending on the scenario. The largest proportion of costs in all the scenarios is associated with the income that the owners of tourist accommodation (e.g., dwellings used as holiday businesses and commercial accommodation) would not receive due to the decreases in visitors.

The costs associated with the loss of income earned by employees are much lower than the impact on tourism. However, since a rather conservative approximation was used based on the number of people who reported having use a car to go to work in the day of the Census 2021, this value might be an underestimation. Traffic data shows that over 760 trips take place between Venus Bay and Tarwin Lower, with a high proportion expected to travel further to commercial centres (e.g., Leongatha, Inverloch) for work-related activities.



Source: NCE estimates

Figure 4. *Temporary complete isolation economic losses.*

As the exact number of days of closures in an average year is unknown, this is assessed as a threshold in the cost-benefit analysis below. For the threshold analysis it was assumed that closures would generally only last for one day (using the economic losses per day from Scenario 1 above); and therefore the threshold represents the number of 1-day closures in a given year.

Permanent complete isolation

Permanent and complete isolation refers to the case where a community's access is restricted permanently and no alternative access options are available (i.e. the community effectively becomes an island). This is likely to be the case for the Venus Bay community in the longer term with sea level rise. As hazard modelling indicates, Inverloch-Venus Bay Rd just east of Venus Bay will likely be well within the tidal area. With that route closed, vehicles would be unable to get in or out of Venus Bay.[7]

The economic impacts of this type of isolation are highly uncertain. If the (potentially regular) tidal inundation of the road is not addressed Venus Bay may need to be accessed by boat (e.g. private vessels or a more formal ferry service). Even with boat access the connectivity of the community for employment, services, and tourism will be impacted (e.g. ferry services operate only at certain times and are not impervious to outages either). The value that residents place on this connectivity is likely to be reflected in property values and therefore a potential change in property values has been used to assess the impact of permanent complete isolation.

The current median price in Venus Bay is $700,000 (realestate.com, 2023) and there are 1,736 properties in the locality, reflecting a total property value of $1,215 million. If the permanent loss of access resulted in a 1% decrease in this value that would result in a total economic loss of over $12 million. The exact percentage decrease in values is unknown and has been assessed as a threshold in the cost-benefit analysis below.

While examples to draw from are limited, a few other residential communities in Australia are accessed by ferry service. Table 12 presents a comparison of property values and ferry service costs for a sample of these communities. While property value data was not readily available for many of these, the 31% difference between Coochiemudlo Island (Qld) property values and mainland-based Victoria Point (Qld) property values indicate that it is possible for restricted access to correlate with lower values.[8] It is completely reasonable to expect a material decline in property prices in the region in circumstances where road access is restricted.

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[7] It is acknowledged that it may be possible for cars to get in and out through informal access on private property in some situations; however, this is not considered sufficient to offset the impacts of isolation for the entire community, particularly for permanent inundation.
[8] Note that to robustly determine a causal link between access restrictions and property values a detailed study would need to be undertaken that controls for a range of other property characteristics. This was not undertaken for this case study analysis.

Table 12. Island community property values (3BR) and ferry service costs

Island community	Island population	Comparable mainland community	Island median property values	Mainland median property values	Ferry service cost	Ferry service frequency
Raymond Island, VIC	589	Paynesville, VIC	No data	$500,000	Annual pass: $300/year Can/Van/Ute: $13/trip Pedestrians: Free	Every 20 mins from 7:00am to midnight, with additional services from 6:20am, between 7:00am-9:00am, and 3:30pm-6:00pm on weekdays.
French Island, VIC	141	Crib Point, VIC	No data	$780,000	Adult return trip: $29/trip	One trip each way every hour and a half on weekdays between 7:10am to 7:30pm. On less service a day on weekends. Based on services to Stony Point only, there are additional services to Phillip Island which are less frequent.
Coochiemudlo Island, QLD	850	Victoria Point, QLD	$515,000	$750,000	Adult return: $12/trip Adult 10-trip multi-ticket: $48/10 trips Private vehicles return: $65/trip Commercial vehicles return: $75/trip	Passenger ferry runs every half hour on weekdays: between 5:15am and 10:30pm and on weekends: starting later at 6:30am. Vehicular barge runs every 40 mins between 6:00am and 5:40pm on weekdays, starting later at 7:40am on Saturdays and 8:20am on Sundays.
Noosa North Shore, QLD	253	Tewantin, QLD	No data	$855,000	Passengers: $1/trip Cars: $10/trip	Ferry runs approx. every 10 mins between 5:30am and 10:20pm Sun-Thur, extending to 20 past midnight for Fri-Sat.

Source: Realestate.com, ABS (2022), Various ferry services websites

2.4 Adaptation actions

Action definition

There are a number of adaptation actions available to reduce or avoid the access issues that Tarwin Lower and Venus Bay are likely to experience due to coastal hazards. The broad actions are outlined here.

Armoured levee on existing alignment (raised road and flood levee)

Considering that a significant proportion of the South Gippsland region near Venus Bay and Tarwin Lower is prone to flooding (both coastal and catchment), alternatives such as levees (e.g., permanent earthen embankments, concrete walls, and demountable and temporary structures) to prevent or mitigate the consequences of massive flooding could be considered. Road improvement/s would need to be constructed in a way such that it also protects the side of the road from scour due to water lapping at the edges. It should also be noted that these types of structures will change catchment hydrology and flow paths. This could have risk implications to surrounding catchment areas, both upstream and downstream for tidal inundation and flooding events (including catchment flooding).

Causeway on existing alignment

Significant engineering and structures can be used to elevate infrastructure above certain flood levels, to protect routes and ensure connectivity. Examples include bridges, floating roads, or elevated roads. Since the construction and maintenance of this type of infrastructure are usually more expensive than ground-level road infrastructure, the magnitude of the potential damage should justify the investment. In cases where recurring flood events have significant social and economic consequences, it may demonstrate need for the more definitive, larger-scale measures.

It should also be noted that these types of structures generally allow for water to flow underneath them in a way that would be similar to an unmodified landscape. This may have further hydrological implications (positive or negative) for tidal inundation and flooding events.

Alternate access routes

An alternative to ensure connectivity between Tarwin Lower and the north bank of the Tarwin River may be the provision of alternate access roads. The most cost-effective approach to this type of adaptation would be to leverage existing roads as much as possible to minimise the length of new road required. This may mean sealing currently unsealed or partially sealed roads in conjunction with new sections of road. Additionally, a new bridge is likely to be required along the new road in order to cross the Tarwin River, ideally at a point where the hazard extents are relatively narrow, minimising the length of bridge required (as the cost of bridge construction is orders of magnitude higher than road construction).

Figure 5 presents the potential alignment for an alternate access road used in this analysis.

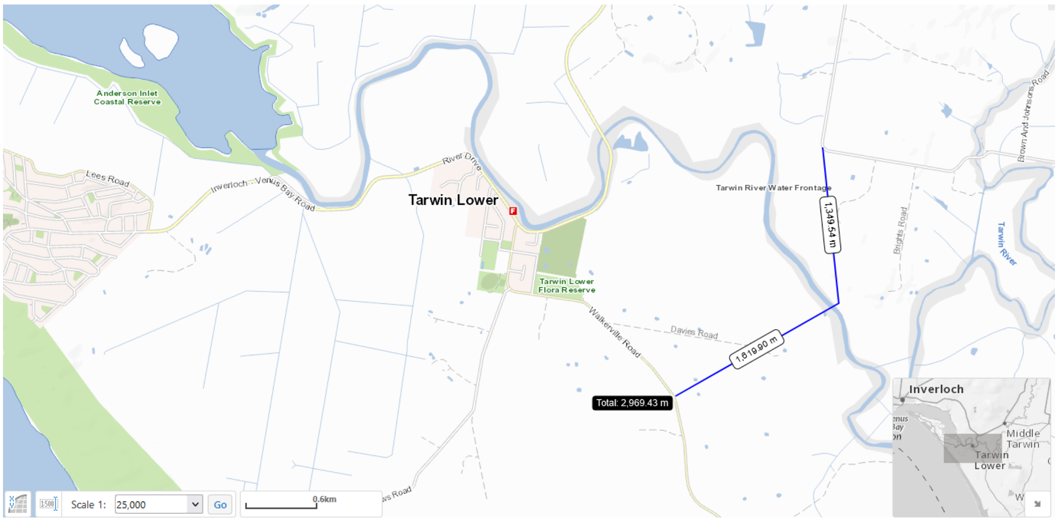

Figure 5. *Tarwin Lower possible alternate access road (utilising existing roads where possible).*
Source: CoastKit, 2023

Location specific options

Table 13 presents a summary of the adaptation actions assessed for Venus Bay and Tarwin Lower, including a description of their likely costs and benefits, while Table 14 presents their present value of costs. To estimate these costs, the length of road requiring protection (e.g. levee, causeway, etc.) was determined using the longest distance of road exposed out of the 1% storm-tide inundation event (the lowest probability temporary inundation event for which data was available) and the permanent inundation extent for a given year.

Table 13. Venus Bay - Tarwin Lower adaptation actions

Action group	Action	Description	Costs*	Benefits
Maintain Venus Bay access only	Venus Bay causeway	A raised causeway between Venus Bay and Tarwin Lower.	Unit cost of $1,880/sqm[9] applied to a length of road that would be sufficient to protect from both storm-tide and tidal inundation impacts for a given planning horizon.	Provides protection against *temporary complete* isolation for Venus Bay only in the present day and 2040, and *permanent complete* isolation in 2070 and beyond.
	Venus Bay levee	An armoured levee between Venus Bay and Tarwin Lower.	Unit cost of $10,000/m[10] applied to a length of road that would be sufficient to protect from both storm-tide and tidal inundation impacts for a given planning horizon.	
Maintain Tarwin Lower access only	Tarwin Lower causeway	A raised causeway between Tarwin Lower and Tarwin Lower Rd (north of township).	Unit cost of $1,880/sqm[9] applied to a length of road that would be sufficient to protect from both storm-tide and tidal inundation impacts for a given planning horizon.	Provides protection against *temporary partial* isolation for Tarwin Lower only in the present day and 2040, and *permanent partial* isolation for Tarwin Lower only in 2070 and beyond.
	Tarwin Lower levee	An armoured levee between Tarwin Lower and Tarwin Lower Rd (north of township).	Unit cost of $10,000/m[10] applied to a length of road that would be sufficient to protect from both storm-tide and tidal inundation impacts for a given planning horizon.	
	Alternative Road	A new road and bridge to the east of Tarwin Lower to link Walkerville Rd to Stewart and Dunlops Rd (Figure 5), providing an alternative access route that is resilient to inundation.	Unit cost of $8 million/km[11] applied to a length of road (as well as $1,880/sqm for a bridge) that would be sufficient to protect from both storm-tide and tidal inundation impacts for a given planning horizon. Since the alternative road is in a different site than the current Tarwin Lower-Inverloch connection, the construction costs are independent of the potential damage suffered by existing roads across time horizons.	
Maintain access to both communities	Venus Bay causeway & Tarwin Lower causeway	Various combinations of the above actions in order to maintain access to both Tarwin Lower and Venus Bay.	Costs are simply the sum of the relevant individual action costs from above.	Benefits are simply the sum of the relevant individual actions benefits from above.
	Venus Bay causeway & Tarwin Lower levee			
	Venus Bay causeway & Alternative Road			
	Venus Bay levee & Tarwin Lower causeway			
	Venus Bay levee & Tarwin Lower levee			
	Venus Bay levee & Alternative Road			

*Note: The cost rates used are indicative values for construction. It should be noted however, that there may be additional costs involved depending on the final location and terrain, possible environmental issues/offsets, and cultural heritage implications. Road realignment costs were based on numbers provided by Department of Transport and include some consideration of these factors.

[9] Source: Rawlinsons (2023)
[10] Source: AECOM (2019)
[11] Source: Victoria Department of Transport – Pers Comm

Table 14. Present value ($ million) of costs by adaptation action and planning horizon

		Present value of cost ($ million)				
Action Group	Action	Present day (0.0m SLR)	2040 (0.2m SLR)	2070 (0.5m SLR)	2100 (0.8m SLR)	2100 (1.1m SLR)
Maintain Venus Bay access only	Venus Bay causeway	19.8	29.9	31.6	31.8	32.0
	Venus Bay levee	15.2	22.9	24.2	24.3	24.5
Maintain Tarwin Lower access only	Tarwin Lower causeway	30.3	30.5	30.5	30.9	31.4
	Tarwin Lower levee	23.2	23.3	23.3	23.7	24.0
	Alternative Road	24.0	24.0	24.0	24.0	24.0
Maintain access to both communities	Venus Bay causeway & Tarwin Lower causeway	50.1	60.4	62.2	62.3	62.5
	Venus Bay causeway & Tarwin Lower levee	43.0	53.3	55.0	55.1	55.3
	Venus Bay causeway & Alternative Road	43.8	53.9	55.7	55.8	56.0
	Venus Bay levee & Tarwin Lower causeway	45.5	53.4	54.7	54.8	55.0
	Venus Bay levee & Tarwin Lower levee	38.4	46.3	47.6	47.7	47.8
	Venus Bay levee & Alternative Road	39.2	46.9	48.2	48.3	48.5

It should also be noted that many of these actions may provide additional benefits through protection from catchment flooding. Furthermore, there may be negative impacts of measures like levees which can slow the egress of water after a flooding event, causing greater duration or depth of flooding in some cases. These aspects were unable to be quantified for inclusion in this case study analysis but are acknowledged as limitations that may require additional technical assessment and modelling.

Cost-benefit / threshold analysis

The purpose of the cost-benefit analysis (CBA) is to determine if there is a strong economic case for investment into particular adaptation action/s, and by when (which planning horizon). The CBA uses the economic value of access losses as a reference condition to estimate the effectiveness of possible adaptation actions, and assess the suitability of potential investment.

Collation for CBA

The results of the cost-benefit analysis are an estimation of the ratio of benefits to costs (referred to as benefit-cost ratio or BCR). A BCR result greater than 1 means the benefits outweigh the costs over the long-term and the action is economically viable. A result of <1 means the costs outweigh the benefits and the action is not economically viable. The greater the value, the greater the benefit in comparison to the cost.

The base case results, efficacies[12], and costs of adaptation have been brought together in a typical CBA process involving the discounting of costs and benefits with a discount rate of 7 % (4 % to 10 % range tested in the sensitivity analysis) over a 30-year period.[13]

Capital expenditures were assumed to be incurred in the first years of the analysis with operating and maintenance costs starting from the subsequent year and the benefits (avoided damages) also starting from the same year. This was done for each locality where there was a proposed adaptation action.

The CBA and sensitivity analyses were undertaken using most likely, high and low estimates as input variables into a Monte Carlo simulation. Sensitivity analysis was undertaken for the following variables:

- discount rate,
- base case results (i.e. the value of access impacts avoided),
- adaptation costs.

For scenarios where actions that provide protection against permanent partial access loss only, BCRs are reported. For the rest of the actions assessed, threshold analysis has been applied as there are unknown variables that were not able to be estimated within the scope of this project (i.e. frequency of access loss from temporary inundation, property price impacts of permanent access loss). Threshold analysis looks at a variable of interest (i.e. access, property value) and estimates the minimum value that the variable needs to be in order to make intervention economically worthwhile (i.e., when costs equal benefits (BCR = 1)). A lower threshold (value) represents a higher likelihood of economic viability.

In this analysis, we have looked at two distinct thresholds:

- Frequency of temporary access loss – as number of events per year
- Proportion of property value loss – as a percentage reduction

In the shorter term (present day and 2040), restricted access events are only temporary. Hence the most relevant threshold is the number of events where access is temporarily restricted. However, by 2070, hazard modelling indicates that access roads will effectively be permanently inundated, and costs associated with temporary restrictions are irrelevant. The relevant threshold becomes a permanent decline in property values (reflecting the permanent additional costs and time of accessing the property).

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[12] Efficacy is the estimated effectiveness of the adaptation action in reducing risk. Efficacy ratings were based on expert opinion and experience in coastal management; however, some uncertainty around them was considered in the sensitivity analysis by way of Monte Carlo simulations.

[13] Since the costs and benefits identified in an economic evaluation generally occur over several years (30 years in this analysis), the associated values are converted and expressed in present dollar value to facilitate comparison. This widely used approach, referred to as 'discounting' future values, reflects society's preferences to have access to cash flow now/sooner rather than in the future (i.e. it places more value on a dollar received today than on a dollar received in the future). Infrastructure Australia recommends a constant central rate of 7%, with sensitivity testing at 4%, and 10% to complete an evaluation.

Results
Table 15 presents the results of various actions and action combinations for Tarwin Lower and Venus Bay.

Table 15. Cost-benefit / threshold analysis results

		Frequency of temporary access loss required for BCR=1 (no. events per year)		*Proportion of property value lost required for BCR=1 (% of property value)*		
Option group	Option	Present day (0.0m SLR)	2040 (0.2m SLR)	2070 (0.5m SLR)	2100 (0.8m SLR)	2100 (1.1m SLR)
Maintain Venus Bay access only	Venus Bay causeway	18	27	2.61%	2.62%	2.63%
	Venus Bay levee	14	21	1.99%	2.00%	2.02%
Maintain Tarwin Lower access only	Tarwin Lower causeway	244	246	BCR = 1.49*	BCR = 1.46*	BCR = 1.44*
	Tarwin Lower levee	187	188	BCR = 1.94*	BCR = 1.91*	BCR = 1.89*
	Alternative Road	193	193	BCR = 1.89*	BCR = 1.89*	BCR = 1.89*
Maintain access to both communities	Venus Bay causeway & Tarwin Lower causeway	41	50	1.39%	1.44%	1.49%
	Venus Bay causeway & Tarwin Lower levee	35	44	0.80%	0.84%	0.88%
	Venus Bay causeway & Alternative Road	36	44	0.85%	0.86%	0.88%
	Venus Bay levee & Tarwin Lower causeway	37	44	0.78%	0.82%	0.87%
	Venus Bay levee & Tarwin Lower levee	32	38	0.19%	0.22%	0.26%
	Venus Bay levee & Alternative Road	32	39	0.24%	0.25%	0.26%

**No threshold analysis was necessary in these cases as BCR >1. BCR values are presented.*

The threshold analysis shows limited justification for implementing the adaptation measures in the near term (Present Day– 2040), noting that the Lower Tarwin – Venus Bay Road has been closed due to flooding on four occasions in the last ten years (Victoria Department of Transport – Pers Comm.). For most cases in this analysis, the frequency of events involving temporary loss of access must occur more than thirty times a year to justify the cost.

However, given the permanent loss of access by 2070 for Tarwin Lower and Venus Bay, it is highly likely that implementing adaptation actions will be economically viable after that point. A reduction in median property values in Venus Bay between 0.8% and 2.6% due to isolation would justify the cost of implementing adaptation actions, depending on the scenario. While estimating the reduction in property values is complex, examples from elsewhere show that island community property values could be 31% lower than nearby mainland communities (see example above).

In the case of Tarwin Lower, although a permanent loss of connectivity like Venus Bay is not expected, all the alternatives analysed beyond 2070 show BCRs > 1, which suggests the viability of implementing adaptation options. The armoured levee actions perform the best economically for both sections of road assessed.

It should also be noted that for both the early periods (present day and 2040) and the later periods (2070 and beyond), thresholds are increasing over time (i.e. economic viability becoming harder to achieve). Increasing tidal inundation extents result in greater lengths of roads at risk, which also increases the scale of adaptation actions (ie. structure size/length) required to provide the benefits of maintaining access.

Constructability is another important factor for decision making, not captured directly in the CBA. While economic viability increases significantly between 2040 and 2070, the ability to construct a causeway or levee may be compromised with more regular inundation (e.g. construction is costly and difficult due to the need to undertake works within tidal areas). This means that any adaptation should be proactive and implementation should occur *before* the hazard is too great. Actions staging to increase scale could be considered.

The sensitivity analysis results (Table 16), ranges represent the 10th and 90th percentile estimate for each threshold. The result variability effectively confirm the findings of the central estimates (above). In the nearer term, all simulations resulted in thresholds of over 100 days a year of flooding required to reach economic viability, still an unlikely scenario. In the long term, economic viability looks highly likely, with only a 3.2% avoided loss in property values required to offset the cost of adaptation in the worst case.

In some cases, the threshold estimated shows a negative percentage avoided loss in property value, indicating that the action is economically viable even without the benefit of avoiding permanent complete isolation for Venus Bay (i.e. benefits of avoiding permanent partial isolation for Tarwin Lower are sufficient to offset adaptation costs for both sections of road).

Table 16. Sensitivity analysis results

		Frequency of temporary access loss required for BCR=1 (no. events per year)		*Proportion of property value lost required for BCR=1 (% of property value)*		
Option group	**Option**	**Present day (0.0m SLR)**	**2040 (0.2m SLR)**	**2070 (0.5m SLR)**	**2100 (0.8m SLR)**	**2100 (1.1m SLR)**
Protect Venus Bay access only	Venus Bay causeway	7 - 20	11 - 30	2.18% - 3.15%	2.18% - 3.16%	2.20% - 3.18%
	Venus Bay levee	8 - 20	11 - 30	2.25% - 3.15%	2.26% - 3.17%	2.27% - 3.19%
Protect Tarwin Lower access only	Tarwin Lower causeway	168 - 409	170 - 412	0.89 - 2.15*	0.87 - 2.12*	0.86 - 2.09*
	Tarwin Lower levee	173 - 414	174 - 417	0.87 - 2.1*	0.86 - 2.07*	0.85 - 2.04*
	Alternative Road	142 - 354	142 - 354	1.03 - 2.57*	1.03 - 2.56	1.03 - 2.57*
Protect access to both communities	Venus Bay causeway & Tarwin Lower causeway	18 - 45	21 - 54	-0.27% - 3.02%	-0.22% - 3.07%	-0.17% - 3.13%
	Venus Bay causeway & Tarwin Lower levee	18 - 45	22 - 54	-0.18% - 3.01%	-0.12% - 3.06%	-0.07% - 3.12%
	Venus Bay causeway & Alternative Road	16 - 41	20 - 50	-0.61% - 2.60%	-0.59% - 2.61%	-0.58% - 2.63%
	Venus Bay levee & Tarwin Lower causeway	18 - 45	22 - 54	-0.18% - 3.01%	-0.12% - 3.06%	-0.07% - 3.12%
	Venus Bay levee & Tarwin Lower levee	18 - 45	22 - 55	-0.15% - 3.07%	-0.10% - 3.12%	-0.05% - 3.18%
	Venus Bay levee & Alternative Road	16 - 41	20 - 50	-0.56% - 2.63%	-0.54% - 2.64%	-0.53% - 2.67%

* *No threshold analysis was necessary in these cases as BCR >1. BCR values are presented.*

Utilities

In addition to access issues outlined above, Venus Bay is likely to experience increased risk of impacts to utilities like electricity and water supply.

Cable infrastructure

Electricity lines and telecommunications cables are located in the same area where the road to Venus Bay is at risk of inundation (Table 17 provides the length of infrastructure within the tidal area for each planning horizon). While these assets may have a degree of resilience to temporary inundation, it would be a challenge to maintain them if the location was to become a tidal area. On top of this, it is understood that these utilities can be unreliable even in the present day, which can be an issue for hazard events, both coastal and non-coastal (e.g. bushfires) when communication and warning is of the utmost importance. Assets betterment is needed to provide reliable electricity and communications for Venus Bay.

Table 17. Length of cable infrastructure exposed to tidal inundation

	Present day (0.0m SLR)	2040 (0.2m SLR)	2070 (0.5m SLR)	2100 (0.8m SLR)	2100 (1.1m SLR)
Electricity (m)	727	1,901	5,267	7,662	9,410
Telecommunications (m)	782	2,635	13,242	18,964	23,740

Upgrades and improvement to electricity and telecommunications infrastructure could be integrated with road capital works projects, to enable economies of scope and realise possible efficiencies.

Water supply

Venus Bay is not connected to the water mains network and currently uses bore water as its primary source of supply. It is possible that with sea level rise, the underground water table will become more saline, potentially to the point of becoming unusable without desalination. Desalination or the importation of water (another contingency option) can both be very expensive exercises. Furthermore, trucking in water becomes impossible when flood events occur, and road access is restricted.

It is recommended that the issue of future water supply for Venus Bay is investigated more closely to help plan a pathway for the longer-term water security of the town. This may involve a detailed groundwater assessment and options analysis of a variety of potential adaptations.

3 Blue Carbon Case Study

This case study explores the economic implications of sea level rise (SLR) in the Anderson Inlet region. Rising sea level rise is predicted to change the composition of the area, providing opportunities for land use transitions to provide new ecosystem services.

3.1 Background

Study area

Anderson Inlet is an area of tidal floodplain approximately 2,400 hectares in the Inverloch catchment. It is recognised for its high biodiversity values and for its critical role in flood storage. These areas also hold cultural significance to the Gunai Kurnai, the Bunurong and Boon Wurrung Traditional Owners.

Anderson Inlet and the surrounding floodplain currently supports a range of land uses including: rural and agriculture, conservation, and open space purposes.

Management and care involves a range of partners, including Bass Coast Council, South Gippsland Council, West Gippsland Catchment Management Authority (WGCMA), Traditional Owners representatives as well as local community members.

Figure 6. *Wetland and estuary within Anderson Inlet.*

Recent management for the health and condition of Anderson Inlet has looked to:

- Secure the protection and management of the most critical areas of the floodplain.
- Develop guidelines for planners to ensure the protection of wetlands.
- Take a proactive approach to understanding and managing current and future impacts of coastal hazards, such as inundation.
- Establish a regionally-significant complex of wetland and floodplain ecosystems delivering enhanced fish habitat and water quality outcomes within the local Subcatchment system.
- Revegetate wetlands with indigenous vegetation.
- Strengthen the Screw Creek, Pound Creek and Anderson Inlet Subcatchment Corridor - which is recognised as having high biodiversity value at state and national levels (WGCMA, 2015).

The impacts of rising waters

As a floodplain area, Anderson Inlet and surrounds is already prone to flooding. With climate change and rising sea levels, an expansion of the area that is subject to tidal inundation is expected. As a consequence, some land may gradually transition from current uses (i.e. grazing) to a tidally influenced wetland area over the next 80 years.

The potential extent of this expansion has been estimated, taking into consideration the highest astronomical tide (HAT) and projected sea level rise (SLR) in 2100 compared to current HAT and SLR. Based on this analysis, the extent of the region could increase by 1,956 ha by 2100.

3.2 A transition to other land uses and ecosystem services

A change in the extent of the floodplain area will result in a change in landforms and, with this transition, there will be a change in ecosystem services. Box 1 contains further information about the types of ecosystem service provided by our environment.

Box 1. Definition of ecosystem services

Natural assets provide a range of benefits or 'ecosystem services' that contribute to human wellbeing through both their extent and condition. Ecosystem services are the benefits people obtain from the natural environment, often in conjunction with built assets (MEA, 2005). According to Haines-Young et al. (2018), ecosystem services can be categorised as:

- Provisioning services: products directly obtained from ecosystems (e.g. fish from nursery areas).
- Regulating services: the benefits obtained from the regulation of ecosystem processes such as flood mitigation and carbon sequestration.
- Cultural services: non-material benefits, for instance recreational/tourism, aesthetic, cognitive and spiritual benefits.

The key ecosystem services provided by wetlands within the Anderson Inlet and the surrounding floodplains are likely to be cultural and regulating services, which are summarised in Table 18.

Table 18. Key services provided by ecosystems in Anderson Inlet

Cultural services[14]	Regulating services[15]
Recreation. Environmental assets provide a wide range of experiential services such as bushwalking, bird-watching and fishing. ***Visual aesthetic***. Environmental assets in Anderson Inlet and along the Bluff Estuary Walk are areas of outstanding natural beauty. These are important to local residents as well as to regional and international tourists. ***Spiritual***. Wilderness and natural areas provide a sense of tranquillity for many residents and for tourists. For Traditional Owners, environmental assets further provide cultural identity and broader spiritual values. ***Existence and bequest***. Local residents generate cultural value simply from knowing healthy ecosystems (and its component biodiversity) exist (referred to as 'existence value') and will be available for their children and grandchildren to enjoy (referred to as 'bequest value').	***Disturbance regulation / Flood risk mitigation***. While the broad area within Anderson Inlet is gradually becoming at greater risk of inundation, it provides a significant floodplain area that enables both terrestrial and storm-tide inundation flooding to spread, reducing the frequency and extent of flood risk to built assets. This would not be possible if Anderson Inlet was extensively developed. ***Climate regulation***. Ecosystems regulate the global climate by storing greenhouse gases. For example, as wetland trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues. ***Habitat / refugia***. *Wetland e*cosystems supports biodiversity by providing habitat for animals (e.g. juvenile fish) that underpin the productivity of commercial fisheries. ***Nutrient cycling.*** Wetland ecosystems play an important role in trapping sediment and filtering nutrients, especially in intensive agricultural landscapes.

[14] Includes all non-material ecosystem outputs that have symbolic, cultural or intellectual significance.
[15] Includes all the ways in which ecosystems control the environment of people (e.g. local air quality, water quality, global climate). Habitat/nursery functions that (ecosystems have in the) support of fisheries are also often considered within this category (European EPA, 2011).

3.3 A review of relevant literature and studies

Saltmarsh ecosystems and Spartina

Salt marshes are among the most efficient ecological systems for the storage of organic carbon, acting as carbon sinks that can store up to 2,100 kg of carbon per hectare every year (Carnell et al., 2019). Some species of salt marsh have even been measured as being the highest amongst all coastal wetland and forested terrestrial ecosystems for their ability to store organic carbon (Ouyang & Lee, 2014).

Spartina is an invasive species of cordgrass which thrives in temperate estuaries such as the saltmarsh environment found in the south-eastern part of Anderson Inlet. The species was first introduced to Anderson Inlet in the 1930s and has since grown to dominate the development of the local shallow intertidal Inlet. As an invasive species, control programs are currently in place within the West Gippsland region (including Anderson Inlet) to limit the growth of Spartina, although they do offer ecosystem benefits in the form of carbon sequestration (WGCMA, 2022).

A study published by Kennedy et al. (2018) assessed the impacts of this species on both the geomorphology as well as the carbon sequestration capacity of Spartina in Anderson Inlet. Results estimated that the species promotes accretion of around 18 mm/year of sediment, which has led to the stable formation of approximately 108 ha of supratidal island over the past 100 years (Kennedy et al., 2018). These islands are estimated to contain over 5.5 million tonnes of CO_2 equivalent carbon, a value which is expected to increase with sea level rise.

Being an invasive species, Spartina is highly resilient and therefore without the control programs currently in place, would continue to be a dominant species within Anderson Inlet. Although providing carbon sequestration benefits, it has the potential to cause significant habitat change to native tidal marshes, noting that the ability for mangroves (the other dominant species in the area) to outcompete Spartina is presently unknown as sea levels rise. Therefore, it is important to highlight that any efforts to establish additional saltmarsh habitats in the region will have to be considered alongside the exclusion of Spartina.

Sea level rise has however been found to be a driving factor in increasing these saltmarshes' abilities to bury carbon more efficiently below the surface. One article published by Rogers, Kelleway & Saintilan (2019) analysed more than 300 saltmarshes across six continents, finding that in regions where sea level rise had been greater over the last 6,000 years, 2 to 4 times more carbon in the top 20 cm of sediment and 5 to 9 times more carbon in lower 50-100 cm of sediment was found compared to regions where sea level rise had been more stable. Therefore, organic carbon was shown to be buried more efficiently as wetlands grew on coastlines which experienced greater sea level rise.

Mangrove ecosystems

Mangroves can sequester around 4,800 kg of carbon per hectare each year, and provide significant coastal defence benefits by both heavily reducing wave energy and rates of erosion (Carnell et al., 2019). It was estimated in 2019 that $1.86 billion of infrastructure across south-eastern Australia is currently being protected by mangroves, while an additional $702 million is protected by saltmarsh wetlands.

One Victorian study examining the carbon stock benefits of mangrove habitats in Victoria found that in nearby Port Phillip and Westernport, mangroves had an average carbon stock value of 82.9 Mg (i.e. tonnes) of carbon per hectare (Carnell et al., 2015). A trend was also highlighted that carbon stocks were recorded to be higher for areas further inland within the estuaries (or closer to fluvial inputs). Carbon accumulation rates in soil have also been provided under the official guidelines of the Blue Carbon Accounting Model (BlueCAM), stating an annual accumulation stock rate of 0.95 Mg of carbon per hectare per year (BlueCAM, 2021a).

To understand the impact of an increase in these wetland ecosystems in the extent of Anderson Inlet, we have investigated the potential change in ecosystem services, with a focus on the estimated gain in ecosystem services from wetlands relative to the losses from the current dominant land use - agriculture. In effect, this considers how the economic value of ecosystem services from wetlands increases as they gradually replace agricultural land use.

Review and learnings from Western Port case study (Victoria)
Western Port, Victoria, provides a good example of attempts at re-introducing native carbon-sequestrating species into the environment. The area has been acknowledged as a prime example of a mangrove-saltmarsh-seagrass wetland complex and has been classified as an internationally important wetland under the Ramsar Convention (Kellogg Brown & Root, 2010). Over the period between the 1970s and 1980s, seagrass populations within the Western Port area decreased by around 70%, with Melbourne Water (2013) identifying that excessive sediment input into the bay was most likely the leading cause. A combination of sediment heavily reducing the quality of water available for photosynthesis of the seagrass, as well as the physical rising of seagrass habitats with higher sediment and consequential longer exposure to hot weather in low tides were the deduced drivers behind this decline (Melbourne Water, 2013).

The Western Port Seagrass Partnership has attempted to mitigate the loss of the natural species in the area, largely by attempting to stabilise the coastline area with mangroves as well as by planting additional seagrass populations. Erosion has been highlighted as a major risk along the north-eastern coast (in proximity to the Lang Lang River mouth). Some nature based methods, including mangrove planting, have been trialled, aimed at stabilising these eroding cliffs in the area. The remoteness and size of the area (the most at risk, northeast area of the bay stretches over 9 km) means largescale conventional engineering solutions such as seawalls are cost-prohibitive (Melbourne Water, 2013).

Key learnings that can be transferred from attempts undertaken by the Western Port Seagrass Partnership can be applied to the case of Anderson Inlet. Nursery propagated seedlings maintained the highest survival rates of the various revegetation techniques used, with a detailed outline of the method used provided by Melbourne Water (2013). Higher survival was generally observed where mangroves were planted in protected coves along the coastline, where jutting shorelines provided protection from waves. Seedlings planted behind old pipe outlets also saw much higher survival rates. Another key learning was the almost complete failure of trials using the direct seeding method, which saw almost a zero seed survival rate after one year. Much of the labour required to collect propagules and plant seedlings in the initial phases was provided by local volunteers within the community, providing a cost-effective means for the project.

Areas where survival of mangrove seedlings were particularly low were largely characterised by steepness of the shore at the rear of the cove (therefore increasing wave turbulence on the planting zone), as well as areas where there was the presence of a pronounced shelf below the bench in the cove. Planting undertaken in the area in 2013 therefore focussed on three key aspects; the production of large seedlings, the protection of these seedlings using protective measures and the timing of planting in the spring.

An updated report provided by the Western Port Seagrass Partnership in 2019 outlined changes in survival rates of mangrove communities in three key areas (WPSP, 2019). The northern study site (Lang Lang North) saw the worst survival rates of seedlings, although it was noted that areas with lower water salinity saw greater survival rates. Mangroves planted further offshore also saw lower survival rates. Results of the study suggested that the removal of mangroves changes local habitat in ways that limit recruitment into the now mangrove-free habitat.

3.4 Spatial analysis

A spatial analysis assessment was conducted to identify potential blue carbon growth areas for mangrove and saltmarsh vegetation species under different sea level rise scenarios in the Anderson Inlet region. To identify potential areas that could support blue carbon species, the analysis used:

- permanent inundation data from Stage 1 of the Cape to Cape Resilience Project – in particular hazard extents and exposure analysis from the Inverloch Region Coastal Hazard Assessment.
- aquatic vegetation data provided by Seamap Australia (2023).
- agriculture/ land use data (including grazing areas).

Specific vegetation classifications described by Frood and Papas (2016) were applied to understand typical depth and salinity conditions for saltmarsh and mangroves within the region. This determined potential growth areas based on water depth ranges for each species across all SLR scenarios. A detailed methodology has been provided in Attachment 1.

3.5 Quantification of potential benefits and disbenefits

Blue Carbon Accounting Method (BlueCAM) and modelling

Blue carbon refers to carbon captured and stored by coastal and marine ecosystems such as mangroves, seagrasses, and salt marshes. The BlueCAM model is a technical framework developed by the Australian Clean Energy Regulator following the most recent research conducted by the International Panel on Climate Change (BlueCAM, 2021b). It provides a standardized approach for quantifying and reporting blue carbon stocks and sequestration rates, which can be used to inform policy and management decisions.

BlueCAM has been designed to estimate the abatement from carbon and greenhouse gas sources that arise from coastal wetland restoration, including not only the carbon sequestered in soils and biomass but also the avoided emissions from alternative land uses. Box 2 contains further information about the contribution of agricultural land to carbon emissions.

Box 2. Contribution of agricultural land to carbon emissions

As outlined by the IPCC, agricultural land uses result in CO_2 emissions not only from the process of production but also from tillage and other practices which disturb soils, resulting in the decomposition of soil organic matter (IPCC, 2019).

The effect of this soil organic carbon loss from agricultural land use was recently estimated by Lovelock et al. (2022), finding that for agricultural land in temperate climates, average grazing soil organic carbon (SOC) stocks contained 62.2Mg (i.e. tonnes) of carbon per hectare (a relatively high amount when compared to the mangrove carbon stock value of 82.9Mg per hectare outlined by Carnell (2015)). However, when sea level rise inundates agricultural land, the disturbance and release of this CO2 emitting soil is negated.

The BlueCAM model has been applied in this analysis to estimate the net carbon abatement volumes of transitioning vegetation (i.e. saltmarsh and mangroves) under projected sea level rise scenarios within Anderson Inlet. [16] A current day scenario, based on potential changes under the existing tidal range, as well as three incremental SLR scenarios have been used for the analysis, as listed below:

- Present Day (2021) – 0.0 m SLR
- 2040 – 0.2 m SLR
- 2070 – 0.5 m SLR
- 2100 – 0.8 m SLR.

As demonstrated in Attachment 1, modelling applied to this analysis assumed that saltmarsh will vegetate land that lies between 0.0 m and 0.5 m of the intertidal zone (i.e. at a HAT depth of 0.0 m to 0.5 m), while saltmarsh located lower than this in the intertidal zone (i.e. at a HAT depth of 0.3 m or more) will transition into mangroves.

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[16] Note that Anderson Inlet lies with the temperate BlueCAM geographical region designated by the official BlueCAM guidelines (BlueCAM, 2021a). Region specific modelling has been designed to account for variations of climate and the subsequent abatement levels for coastal wetlands.

A major criterium for the land expected to transition in the future is connectivity, meaning that only farmland areas adjacent to existing saltmarsh and mangroves (i.e. have natural connectivity) were included. Figure 7 shows the general transition of vegetation within coastal wetlands (noting that seagrass is not present within Anderson Inlet).

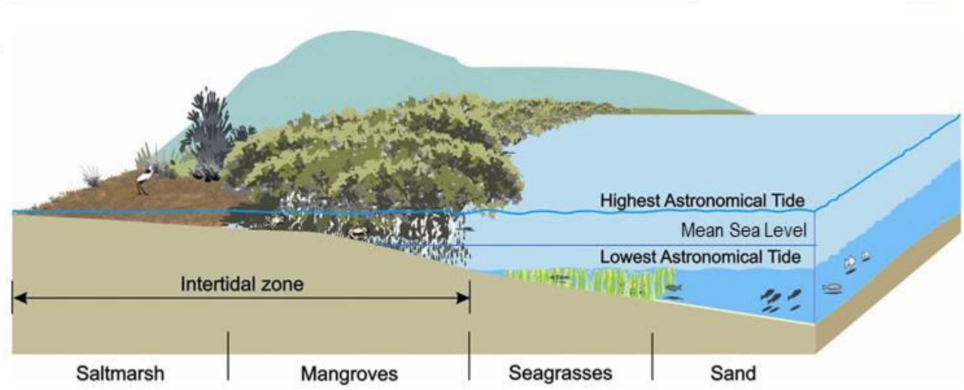

Figure 7. *Vegetation transitions across intertidal zone*.

Source: BlueCAM (2021a)

Following the methodology outlined in Attachment 1, the estimated size of land with the potential for transition from existing agricultural (grazing) land has been calculated across all scenarios and is presented in Figure 8 below.

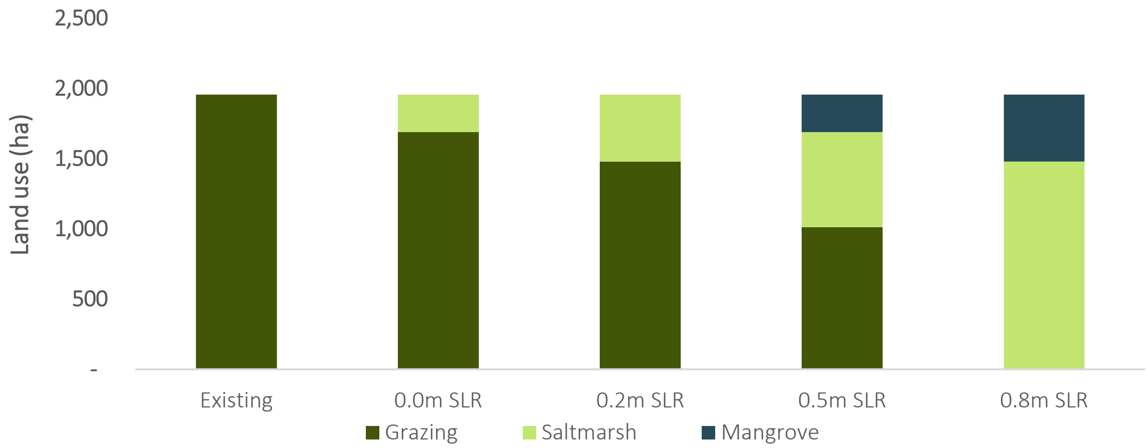

Figure 8. *Size of potential land for transition, over sea level rise scenarios.*

By 2100, it is estimated that approximately 1,480 ha of existing agricultural land surrounding Anderson Inlet will transition to saltmarsh, while an additional 476 ha of agricultural land will transition to mangroves. Note that within the case study area there is already approximately 250 ha of existing saltmarsh/mangrove vegetation. The areas provided in Table 19 represent the potential for additional vegetation (i.e. excluding existing areas).

Table 19. Size of potential land for transition, over sea level rise scenarios.

	0.0m SLR (Present day)	0.2m SLR (2040)	0.5m SLR (2070)	0.8m SLR (2100)
Potential saltmarsh	266.2	475.6	677.9	1,480.2
Potential mangroves	-	-	266.2	475.6

These values were applied to designated reporting periods within the BlueCAM model (i.e. Present Day, 2040, 2070 and 2100), with 25-year incremental permanence periods assumed in order to calculate net abatement volumes (of CO_2 emissions) for each reporting period. Net abatement results are presented in Figure 9.

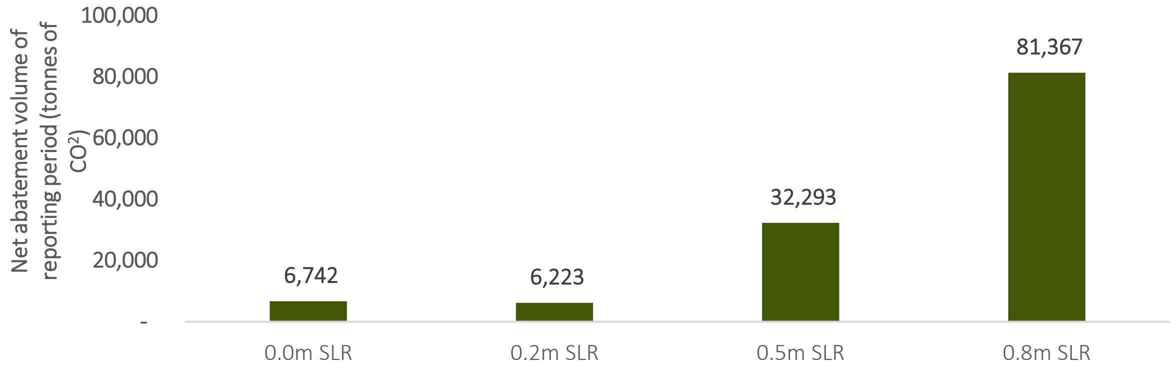

Figure 9. *Net abatement volume for reporting periods (tonnes of CO_2).*

By 2100, with an assumed 0.8m SLR, the transition of agricultural land into coastal mangrove and saltmarsh is expected to abate a net total of almost 100,000 tonnes of CO_2 within the Anderson Inlet area.

Net abatement value of CO_2

Two scenarios were assessed when calculating the net abatement value of CO_2 for future transitions to Anderson Inlet's coastal ecosystems. The first scenario considered the market value of CO_2 abatement under the framework of Australia's emissions reduction fund (ERF), whereby CO_2 abatement credits are purchased on the market in the form of an auction. The latest ERF auction was held in April 2022 and averaged a price per tonne of CO_2 abatement of $17.25 (ERF, 2022). This value is therefore determined by the open market influences of supply and demand, and consequently only reflects the measurable and tradable costs and benefits of CO_2 abatement.

Alternatively, the second scenario incorporated within this analysis applied the social value of carbon abatement, a value provided by the Interagency Working Group (IWG) of the United States Government. The social value of carbon abatement refers to the broader benefits that carbon abatement activities provide to society, beyond the direct financial benefits captured by carbon credit prices. These benefits may include reductions in air pollution, improved public health outcomes, and enhanced resilience to climate change impacts such as extreme weather events. As of 2021, this social cost of carbon abatement value has been calculated as AUD $104.1 per tonne of CO_2 abated (IWGUSG, 2021).

Figure 10 below presents both the market and social carbon abatement values calculated for the Anderson Inlet area, out to 2100 (i.e. a 0.8m SLR scenario). Note that the market value of carbon is captured within the social cost calculated below. Across the 0.0m, 0.2m, 0.5m and 0.8m SLR scenarios, total benefits (i.e. market plus other social values) have been estimated at $0.70, $2.0, $3.34 and $10.35 million respectively. Within this net value, market values were estimated at $0.12, $0.34, $0.56 and $1.72 million for the four respective scenarios.

Monte Carlo sensitivity testing was also conducted around these values to find a probabilistic range for high and low values. [17] As there is a high level of variability and uncertainty around the true net social cost of carbon, low and high modelled ranges by 2100 were estimated at $6.33 million and $26.00 million for P5 and P95 respectively. The P5 and P95 ranges are shown by error bars in Figure 10.

[17] Monte Carlo simulation uses probability distribution for modelling a stochastic or a random variable. Different probability distributions are used for modelling input variables such as normal, lognormal, uniform, and triangular. From probability distribution of input variable, different paths of outcome are generated. Compared to deterministic analysis, the Monte Carlo simulation provides a superior simulation of risk. It gives an idea of not only what outcome to expect but also the probability of occurrence of that outcome. For this project, 10,000 simulations were conducted, assuming a triangular distribution. P5 and P95 ranges refer to the 5th and 95th percentile for the probability distribution.

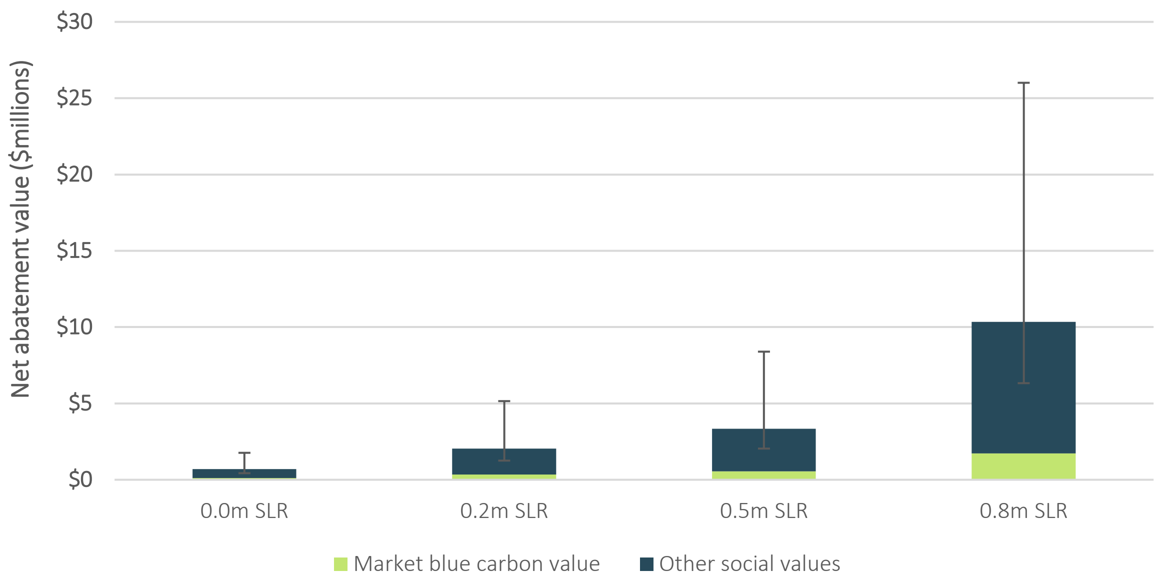

Figure 10. *Net abatement values with P5 and P95 sensitivity ranges.*

Foregone value of agriculture
Although this case study focusses on the abatement value of the potential blue carbon stock provided by inundated land, the value of foregone agricultural production for designated grazing land surrounding Anderson Inlet must also be considered. By allowing the gradual inundation and transition of this land by rising sea waters, the potential benefits of agricultural production are forgone. This typically represents an opportunity cost for the land.

The indictive value of foregone agriculture in 2100 has been estimated using the following approach:

*Forgone value of agriculture = (future area of inundated agricultural land - current area of inundated agricultural land) * capitalised gross margin*[18] *of agricultural production*

Spatial analysis of floodplain extent was used to identify the area of land that is currently being used for agricultural purposes that could be permanently inundated by 2100. The total area of potentially impacted agricultural land is approximately 1,956 ha.

To estimate the foregone value associated with the forgone land uses, the gross margin (GM) per hectare of grazing land for the Gippsland region was obtained. The results are presented in Table 20. The total capitalised value of agricultural land potentially inundated is estimated to be approximately $2.65 million (with a range of $1.771 to $3.565 million). [19]

[18] Gross Margin (GM) is the value of production (revenue) less the cost of production. Gross margins have been discounted across a 25-year period (to align with modelling assumptions of the BlueCAM) to calculate a capitalised value. When placing values on future values, it is common practice to 'discount' these values to the current day to take into consideration the time value of money. By discounting these values, results across all sections of this case study can be considered comparable.

[19] It should be noted at this point that from the perspective of a private landholder, the potential exists to build levies (or upgrade existing levies) along private farm boundaries to avoid the gradual inundation of land. However, for the purpose of this analysis, and the range of depths that are likely to inundate farm boundaries up until 2100, it was considered that the private landholders would probably not invest in building higher levies in the long run. This is because the cost of establishing levies is much greater than the value of the foregone value of low-intensity farming such as grazing. Therefore, a rational farmer would not attempt to protect such low-value agricultural activity and the value of foregone agriculture could actually be zero.

Table 20. Estimated capitalised value of inundated agricultural land.

Land use	Area (ha)	Estimated gross margin ($/ha)	Estimated value ($, rounded)		
			Low (P5)	More Likely	High (P95)
Capitalised value of grazing	1,956	$8,606 ($5,749 - $11,574)	$1,771,000	$2,651,000	$3,565,000
Total	**1,956**		**$1,771,000**	**$2,651,000**	**$3,565,000**

Source: Natural Capital Economics estimates based on – Agriculture Victoria (2022).

Wider ecosystem service benefits

With the inundation and transition of land within Anderson Inlet, there are also a wider range of ecosystem service benefits created outside of capture and storage of carbon.

The value of these ecosystem services for both saltmarsh and mangrove communities were estimated based on a study by Gaylard, Waycott & Lavery (2020). This study (*Review of Coast and Marine Ecosystems in Temperate Australia Demonstrates a Wealth of Ecosystem Services*) provides estimates of the economic value of ecosystem services such as wetlands that are specific to temperate Australia. The values are based on a range of ecosystem service valuation studies that have been undertaken comparable to the temperate climate and environment experienced in Anderson Inlet.

Table 21 contains the estimated unit values ($/ha) of the ecosystem services considered to be most relevant to Anderson Inlet and excludes those that are less relevant or have already been accounted for within the BlueCAM section above (e.g. carbon sequestration). [20]

Table 21. Unit values used to estimate ecosystem services.

Habitat type	Ecosystem services	Estimated capitalised value ($/ha)
Saltmarsh	*Waste treatment/water purification*	$99,308
	Regulation of extreme events (erosion, flood prevention)	$139,119
	Cultural services (tourism, recreation)	$83,558
Mangrove	*Waste treatment/water purification*	$172,853
	Regulation of extreme events (erosion, flood prevention)	$42,941
	Cultural services (tourism, recreation)	$10,769

Source: Gaylard, Waycott & Lavery (2020). Estimates have been updated to reflect AUD 2022 prices.

Using a simple value transfer approach, the annual values contained in Table 21 have been applied to the estimated change in the area of inundation in 2100.

[20] Note that these ecosystem service values have been discounted across a 25-year period (to align with modelling assumptions of the BlueCAM) in order to calculate a capitalised value.

Table 22 contains the aggregate estimated value of ecosystem services. Key points to note include:

- The estimates are a snapshot at a point in time (2100) that have been discounted to current day values over a 25-year period to allow results comparable to the BlueCAM net abatement results.[21]
- Estimated values here represent the average values for each habitat and ecosystem data point provided by Gaylard, Waycott & Lavery (2020). [22]
- Sensitivity testing has provided a wider range of possible ecosystem values, as ecosystem values can range significantly even within the same temperate climate zone from site to size. The impacts of site specificity for data points used means that a high level of uncertainty will always exists in estimates.
- Waste treatment and water purification is estimated to represent the greatest ecosystem service for mangroves and the second greatest ecosystem service for saltmarsh by 2100. Gaylard, Waycott & Lavery (2020) highlights that in the case of waste treatment services, "fine scale local details are required to undertake accurate valuation relevant for particular regions". Location-specific hydrological modelling could potentially be used to estimate likely load reductions, and provide a greater understanding of water quality improvement benefits for Anderson Inlet.
- Regulation of extreme events is estimated to make up a much larger proportion of total ecosystem services values for saltmarsh compared to mangroves. The extent to which this value may be realised in the Anderson Inlet region will be contingent on the frequency and intensity of flood events in 2100, as well as the proximity of key infrastructure and assets in the area and the density of habitat.
- Cultural services in the form of tourism and recreation are estimated to represent a small proportion of the total ecosystem service for mangroves but a larger proportion of value for saltmarsh. The extent to which this value may be realised in the Anderson Inlet will also be contingent on the availability and quality of nearby wildlife habitat and visitation rates in 2100.

Table 22. Estimated capitalised economic value of Anderson Inlet wetland ecosystem services in 2100 ($million).

Habitat type	Ecosystem services	Area (ha)	Estimated value of capitalised ecosystem services ($million) (P5 to P95)
Saltmarsh	*Waste treatment/water purification*	**1,480**	$147.0 ($106.9 - $195.5)
	Regulation of extreme events (erosion, flood prevention)		$205.9 ($49.4 - $266.9)
	Cultural services (tourism, recreation)		$123.7 ($76.0 - $694.2)
Mangrove	*Waste treatment/water purification*	**476**	$82.3 ($64.2 - $104.5)
	Regulation of extreme events (erosion, flood prevention)		$20.4 ($10.7 - $77.6)
	Cultural services (tourism, recreation)		$5.1 ($2.6 - $15.3)
	Estimated median value of selected ecosystem services	1,956	**$584.4** **($309.7 - $1,353.9)**

Source: Gaylard, Waycott & Lavery (2020).

[22] Note that outlier data points have been excluded from analysis where necessary.

Comparison of key results

Table 23 provides a comparison of the key results of this case study for the 2100 (0.8m SLR scenario), including the net abatement blue carbon value, the net value of agriculture foregone due to inundation as well as the net value of wider ecosystem services.

Table 23. Comparison of estimated gross values in 2100.

Ecosystem	Value ($million)		
	Low	More Likely	High
Estimated total value of blue carbon net abatement	$6.3	$10.3	$26.0
Estimated total value of wider ecosystem services	$309.7	$584.4	$1,353.9
Estimated total value of agriculture foregone	$1.7	$2.6	$3.6

Source: NCEconomics estimates.

Based on the 'more likely' estimates, the value gained from blue carbon net abatement could be almost 4 times greater than the value of agriculture foregone. The additional wider ecosystem services provided are estimated to be over half a billion dollars by 2100.

Key points to note include:

- This is a high-level comparison, designed to inform discussion about the relative merits of different climate change adaptation actions. It does not constitute a cost benefit analysis and is based on available region-specific data.
- As highlighted above, there are a number of uncertainties associated with estimating both the wetland ecosystem service values and the agriculture values, which may significantly alter the estimates, and which may warrant further investigation before adaptation actions and options are decided.

While the region may naturally be inundated, there may be some restoration costs required to establish the new vegetation, particularly if the incursion of Spartina grass is to be avoided. Bayraktarov et al. (2014) estimates that the initial cost of restoring wetlands costs in the range of AUD $73,400 to $213,400 per hectare ($2022) for saltmarsh and mangroves, while Waltham et al. (2016) estimates that annual maintenance costs for restored natural coastal wetlands are around AUD $856 per hectare ($2022).

Another additional consideration that could impact the financial viability of purchasing potentially inundated land is the accompanying transaction cost. These transaction costs can include (but are not limited to) legal fees, surveying costs, valuation costs and settlement costs, and depending on the size and location of land can sometimes be substantial. Therefore, consideration should be given to the net abatement value of the land being purchased, as transaction costs for some smaller blocks of land will likely exceed potential blue carbon benefits.

Across the 57 properties assessed within this analysis, 39 properties recorded aggregate saltmarsh/mangrove land areas estimated to be greater than 10 hectares by 2100, while there were 15 properties that were predicted to be less than 5 hectares. A greater return on investment can therefore be achieved by prioritising the purchasing of larger land parcels, especially in the case where transaction costs are fixed regardless of land size. For example, 53% of all net carbon abating land (equivalent to 1,179 ha) by 2100 can be accrued by purchasing the 10 largest properties assessed, while the purchase of the 10 smallest properties would only accrue to 0.45% (47 ha) of net carbon abating land.

Market opportunities

The expansion of Anderson Inlet and associated growth in wetland areas provides significant ecosystem services. While many of the ecosystem services provided within Anderson Inlet are non-market values, there are market-like mechanisms that are emerging that potentially provide commercial opportunities. In addition to tourism, and carbon sequestration, wetlands could be a source of environmental offset revenue from developers wishing to offset adverse environmental impacts (see Box 2 for further detail).

Box 2. Overview of environmental offsets

The traditional role of environmental offsets has been as part of the environmental impact mitigation hierarchy. Progressively, through avoidance, minimisation and rehabilitation of the site, the impact can be lessened, but a residual impact may remain. This residual can be offset through projects or areas that have an equivalent positive impact to 'offset' the residual impact, ultimately resulting in no net loss. This can be either a direct offset (a specific project / area), a financial offset (developer pays into an offset fund), or a mix of the two offset options.

The commercial rationale for an offset is relatively simple. If the cost of the offset is lower than the alternative options available without the offset (e.g. on-site mitigation), the offset provides a superior commercial outcome. If offsets are well designed, this can be achieved without compromising environmental objectives. However, realising those dual benefits requires a robust approach to offset development and use.

Consistent with typical practice, environmental offsets are currently used as a mechanism within a broader dynamic policy environment as a measure to be pursued after options to avoid, mitigate and remediate damage to project sites are already undertaken. The Bushbank Program provides another example of a state-funded program aimed at providing incentives for biodiversity offsetting.

Box 3. BushBank Program

The Victorian "Bushbank" program is a government initiative originally launched in 2002 to encourage landholders to plant trees on their properties. The program provided financial incentives and technical assistance to landowners who agreed to plant trees on their land for a minimum of 15 years. The program is largely focussed on benefits centred around carbon sequestration and habitat creation.

$77 million has been dedicated towards the program thus far, with $30.9 million going towards habitat restoration on private land and $4m committed towards public land. Under the program, landholders are responsible for the initial planting and ongoing maintenance of the trees, while the government provides financial support and technical assistance.

Research conducted by Natural Capital Economics (2019) found that there are opportunities to better harness the benefits of offsets across two areas:

- Reducing developer compliance costs and risks where developers are able to access offsets.
- Enhancing regional economic outcomes where economic activity and economic diversification is enhanced through the provision and management of environmental assets (such as wetlands for blue carbon).

Offsets provide a significant opportunity to reduce environmental compliance costs and risks to developers, while simultaneously ensuring Council's sustainable development objectives are met. However, this would require addressing a number of common issues relating to efficient offset markets.

4 Stage 2 assessment of Cape Paterson-Inverloch Road (Bunurong Road) realignment

This case study takes a deeper dive into the potential realignment or protection of Cape Paterson-Inverloch Road (Bunurong Road) (previously assessed at a high level in Stage 1 of the project). It provides further insight into the decision-making for the future of the road while considering other associated services within the road corridor.

4.1 Background

Context

Cape Paterson-Inverloch Road (also referred to as Bunurong Road/Bunurong Tourist Drive) is located to the South-West of Inverloch, and running directly adjacent to the coastline between Cape Paterson and Inverloch. This route provides direct access from Inverloch to Cape Paterson and its coastal village, as well as other important sites along the coastline including Eagles Nest, Flat Rocks, dinosaur fossil sites and various small beaches in the Yallock-Bulluk Marine and Coastal Park. Cape Paterson-Inverloch Road is approximately 9 km in length and was highlighted in Stage 1 of the Cape to Cape project as having segments significantly at risk of erosion and inundation from future SLR, severely impacting road access if left unmanaged.

Previous traffic study

Road traffic data was collected by the Department of Transport (DoT) in April and May 2022 at several locations on the road, to identify key attributes of traffic along the route.

Site 3 in this study, labelled "Bunurong Road East of RACV" was located along one key segment of road that is expected to be severely impacted by future erosion. Automatic Tube Counts (ATC's) were used to collect data at this location on holidays and non-holidays periods, with the data provided by DoT presented in Figure 11 below.

Figure 11. *Bunurong Road traffic volumes holiday period vs non-holiday.*
Source: DoT (2022)
Note: These traffic volumes reflect recordings taken at location 2 (near Cape Paterson) but are highlighted as being almost identical to the site 3 location.

Key observations from the recorded data were the higher traffic rates over holiday periods compared to non-holiday periods, with weekend holiday traffic around 34% higher than non-holiday period weekends. Other key observations from the road traffic study were the daily use of the road by two buses; a school bus service which provides important services for the local community, as well as a V/Line service running several times a day. Additionally, although only around 10 heavy vehicles per day operated in each direction, the road was identified as having a minor service in supporting local industry, noting that seasonal agricultural peaks were likely not during the survey period.

It was highlighted by DoT (2022) that Bunurong Road does not exhibit typical commuter peaks during non-holiday periods. Therefore it is likely that the roads' primary function is local trips (i.e. school runs, local property access and local recreational trips). The secondary function of the road is likely employments trips and commercial inter-town trips.

Using car specific Bluetooth tracking devices, recorded data also showed duration of time spent within the 9 km stretch of road. Results demonstrated that many people spend several hours at various beach side locations, indicating that Bunurong Road is a destination in itself and does not only serve tourists through trips (DoT, 2022).

Previous work from Stage 1

The initial Cape to Cape Resilience Project Stage 1 explored several actions that could be used to protect Bunurong Road from future erosion, using coastal modelling and economic assessment. Two adaptation actions to protect the road were examined - beach nourishment and the construction of a seawall. Both were assessed at a high-level in the form of a CBA against a base case scenario of relocating a section of the road (as a "retreat" pathway).

This preliminary economic analysis considered up to 5 km of road realignment, to retain access through the eastern end of Bunurong Road as well as some potentially impacted private properties and sites. It assumed that relocation would require:

- the purchase of the land for the new road corridor
- the demolition and rehabilitation of the existing road
- the construction of the new section of road.

Using approximated lengths and possible alignment routes, the total of this was calculated at a cost of approximately $10.2 million, with no additional ongoing costs. This figure was then incorporated into the CBA of actions being considered for the "protect" pathway.

CBA results demonstrated the more likely scenarios for both actions were not economically viable (Table 24) (with BCR<1), although the seawall was economically viable under some scenarios in sensitivity testing.

Table 24. BCR results of stage 1 Cape to Cape adaptations for Bunurong Road.

Adaptation action	2100		
	Low	More Likely	High
Bunurong Road nourishment	0.24	0.32	0.42
Bunurong Road seawall	0.70	0.88	1.05

It was determined that further investigation was required to inform adaptation planning. This assessment has been undertaken to provide greater definition of road relocation and road protection options, along with a more detailed assessment of the associated costs and benefits. It has also benefitted from more direct consultation with Department of Transport and Planning and South Gippsland Water, to better understand the full scope and likely magnitude of the costs and benefits and challenges associated with the various options.

Wastewater treatment plant and network – South Gippsland Water

South Gippsland Water (SGW) have a wastewater treatment plant (WWTP) located at 320 Cape Paterson-Inverloch Road. Critical services (sewer mains) which connect the plant to the Inverloch township run alongside the existing road corridor, mainly within the road reserve. SGW operations rely upon access and to and from the plant, and along the length of underground network assets.

SGW need to carefully plan the long-term asset management for the plant and its network. The pipeline infrastructure has been identified as being within the erosion zone (similar to the road), and increasingly at risk. Additionally, sections of the network are reaching the end of their design life, requiring renewal or replacement in the near future.

WWTP and network locality shown in purple

Asset resilience, integrity, and accessibility are key to SGW operations. Longevity of any replacement/ upgrades to the network within the current alignments need to consider current and future risks in the absence of hazard mitigation or changes to mitigation (i.e. current protection). Implications of planned retreat of built assets need to be investigated should road and asset retreat (realignment) be the preferred option. This includes necessary forward planning and interim network maintenance.

Decision making and longer-term planning of the road infrastructure is closely linked to those of the water network. SGW and DoT will need to work together to develop a coordinated long term approach to increase the resilience of critical services for the Inverloch community. This integrated context has been considered as part of the economic assessment of adaptation measures for Bunurong Road.

4.2 Base case – Road realignment and dependent services

Road realignment - using existing road reserves

Focussing on the eastern end, and the more immediate hazard risks, a potential Bunurong Road realignment that utilises current road reserves[23] (Figure 12), has been considered. Reserve areas are displayed in yellow. Some existing roads can be used to connect some reserve areas to the network. In the north-east of the study area, the existing Drowleys Road (shown in light pink) could provide some of this connectivity as part of an alternate route.

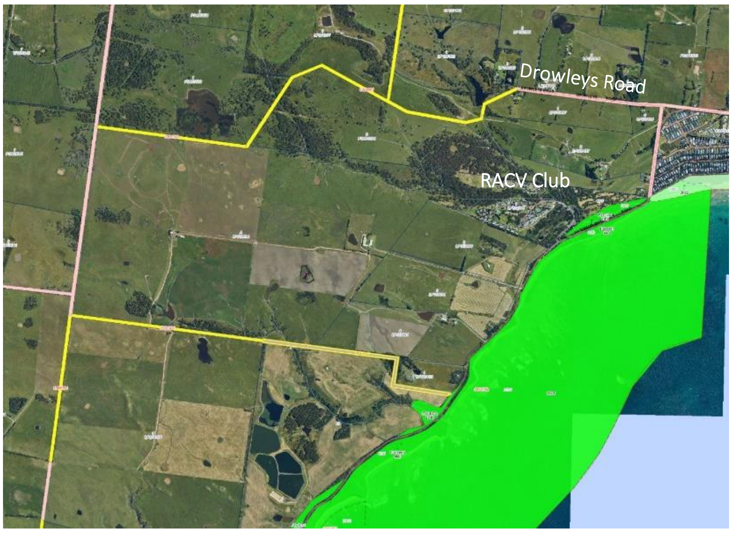

Figure 12. *Potential Bunurong Road realignment (unused road reserves shown in yellow).*

Considering access to local properties within this area, connection of these road reserves could provide access to properties via the use of 3 additional driveways (Figure 13) – noting that multiple properties are accessible from one driveway. This main connecting road is expected to measure 1,804 m while the displayed driveways together would require 2,439 m of road.

Figure 13. *Potential driveway access for private properties with measurements.*

In addition to the realignment of the road, South Gippsland Water (SGW) assets in the erosion zone would need to be relocated to the new road corridor (for easy maintenance access and simplifying/reducing land acquisition). Both the pipeline in the current road corridor, and the plant are in need of renewal in the near future. SGW have advised that the plant can be renewed in place provided they have access to it from the

23 A road reserve refers to public land that is beyond the boundary of a private allotment, generally reserved for future public travel uses.

Inverloch side. However, the pipeline would need to be relocated with the new road alignment, which will require a greater length of pipeline than would otherwise be needed.[24]

It should also be noted that construction of the road on a new alignment is likely to have cultural heritage impacts (e.g. unearthing cultural sites). This has been factored into the cost provided by Department of Transport and Planning.

4.3 Project case – Road protection and renewal of services in place

The project case reflects protection of the existing road and infrastructure assets on its current alignment. This would remove the need for realignment of the main road, provision of new access roads, realignment of the SGW pipeline, and reduce the risk of cultural heritage impacts.

Two protection actions have been considered:

- seawall (1 km in length)
- beach nourishment (87,500m^3 of annual sand nourishment)

It should also be noted that the construction of the seawall or nourishment works would need to take place within the Yallock-Bulluk Marine and Coastal Park boundary, providing an additional complexity for approvals. Furthermore, implementation of a seawall would likely result in loss of beach in front of the hard structure due to scouring (with the structure reflecting wave energy rather than absorbing it like a natural coastline).

While there are other sandy beach areas nearby, and this particular stretch is not a key location for visitation, the RACV club is likely to value having the beach on their doorstep and would likely prefer options that do not result in the loss of the sandy beach.

4.4 Cost-benefit analysis (CBA)

The purpose of the cost-benefit analysis (CBA) is to determine if there is a strong economic case for investment into particular adaptation action/s, and by when (which planning horizon). The CBA uses the costs and benefits of a road realignment as a reference condition to estimate the effectiveness of possible protection measures and assess the suitability of potential investment.

Collation for CBA

The results of the cost-benefit analysis are an estimation of the ratio of benefits to costs (referred to as benefit-cost ratio or BCR). A BCR result greater than 1 means the benefit outweighs the cost over the long-term and the action is economically viable. A result of <1 means the costs outweigh the benefits and the action is not economically viable. The greater the value, the greater the benefit in comparison to the cost.

The base case results, efficacies[25], and costs of adaptation have been brought together in a typical CBA process involving the discounting of costs and benefits with a discount rate of 7 % (4 % to 10 % range tested in the sensitivity analysis) over a 30-year period. Capital expenditures were assumed to be incurred in year 0 with operating and maintenance costs starting from year 1 and the benefits (avoided damages) also starting from year 1. This was done for each locality where there was a proposed adaptation action.

The CBA and sensitivity analyses were undertaken using most likely, high and low estimates as input variables into a Monte Carlo simulation. Sensitivity analysis was undertaken for the following variables:

- discount rate,
- base case results (i.e. the value of access impacts avoided),
- adaptation costs.

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[24] SGW have advised that while it is possible to maintain their pipeline assets through private property, their preference is to have them within road corridors for unrestricted access.

[25] Efficacy is the estimated effectiveness of the adaptation action in reducing risk. Efficacy ratings were based on expert opinion and experience in coastal management; however, uncertainty was considered in the sensitivity analysis by way of Monte Carlo simulations.

Key CBA inputs

Table 25 presents the key inputs used in the CBA of the Bunurong Rd adaptation options.

Table 25. Bunurong Rd CBA inputs.

Input	Unit cost	Size	Cost	Sources
***Base case** - Road realignment and dependent services*				
Removal of Road	$3.65/m^2	16,000 m^2	$58,400	Rawlinsons (2021) and estimated area of road.
Revegetation of old road	$0.32/m^2	16,000m^2	$5,040	Central West LLS (2016) and estimated area of road.
New road construction	$8,000,000/km for 2 lanes	4.1km	$32,800,000	Victoria Department of Transport – Pers Comm. Includes consideration of the location, terrain, likelihood of environmental issues/offsets, and cultural heritage implications. Note that this rate is considerably higher than that of the Stage 1 analysis due to the inclusion of the above considerations.
New access road construction	$750,000/km	2.5km	$1,875,000	Victoria Department of Transport – Pers Comm.
Decommissioning old pipe	$27,780/km	3.5km	$97,230	Disposal of asbestos containing material (CIE, 2017)
New pipe construction	$530,000/km	5.2km	$1,855,000	SGW – Pers. Comm.
***Project case** – Road protection and renewal of services in place*				
Seawall				
Seawall (Rock Armour) upfront cost	$23,150/m	1,000m	$23,150,000	Water Technology (2022). Report 7.
Seawall (Rock Armour) ongoing cost	$463/m/y	1,000m	$463,000/y	Water Technology (2022). Report 7 and estimated as proportion of capital cost for Rock Armour.
Beach nourishment				
Nourishment upfront cost	$82.9/ m^3/y	87,500m^3	$7,250,000/y	Water Technology (2022). Report 7.
Nourishment ongoing cost	$82.9/ m^3/y	87,500m^3	$7,250,000/y	Water Technology (2022). Report 7 and assumption.

Results
Table 26 presents the BCRs for the two engineering adaptation actions assessed against the road realignment base case. Sensitivity analysis was undertaken using high and low estimates as input variables into a Monte Carlo simulation. The results of these CBA simulations for the actions are reported as a range where the low results represent the 10th percentile, and the high results represent the 90th percentile.

Table 26. CBA results (BCRs) and sensitivity analysis

Adaptation action	BCR	Range
Bunurong Road seawall	1.1	0.8 – 1.5
Bunurong Road nourishment	0.3	0.2 – 0.4

Results may also change over time and should be the subject of future hazard mapping updates, particularly if the hazard extents change/are updated in the future.

4.5 Conclusions and recommendations

The construction of a seawall appears to be economically viable when compared to the base case of shifting the road and associated infrastructure, as the analysis shows that the benefits outweigh the costs (BCR > 1). However, economic viability is marginal, with the range indicating that realignment also performs well. On the other hand, the beach nourishment option has a BCR < 1, indicating that the ongoing requirements and associated costs of this option outweigh the anticipated benefits. As a result, the nourishment option is deemed economically inviable and should not be considered as a favourable adaptation choice under the assumptions and cost ranges used in this analysis.

These results slightly differ from those estimated in Stage 1 where neither of the adaptation options were considered economically viable (although the seawall had a high BCR that was > 1). The change in economic viability results from higher costs under the base case (i.e. unit costs for road increased to account for a broader scope of cost items, a more well-defined road alignment, inclusion of cost to provide access roads for impacted properties, inclusion of requirements for relocation and renewal of SGW infrastructure), and higher costs for the adaptation options (albeit to a slightly lesser degree).

It should be noted that this situation calls for good coordination between Department of Transport and Planning and SGW. SGW infrastructure is already at the end of its design life and therefore they are seeking to renew their assets in the very near future. A decision on the preferred pathway would enable SGW to undertake the works they need to maintain their level of service. SGW may be able to delay their investment in the short term; however, there is a limit to this and it would likely result in a decline in their level of service.

In the longer term, there may also be an opportunity for SGW to completely relocate their assets away from the Bunurong Road area (e.g. expansion of plant in Wonthaggi to enable service of a larger areas).

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Attachment 1. Blue carbon spatial analysis methodology

Broad approach

A spatial analysis assessment was conducted to gain insight into potential future areas of blue carbon assets within agricultural parcels of land adjacent to Anderson Inlet, and the opportunity costs of foregoing the current land uses.

Potential blue carbon growth areas are defined as regions or parcels of land that may have the potential to support blue carbon vegetation species under sea level rise. The analysis focused solely on the potential recruitment of mangrove and saltmarsh vegetation species, the primary aquatic vegetation species in the study region. It also used the latest permanent inundation modelled data produced as part of Stage 1 of the Cape to Cape Resilience Project and aquatic vegetation data from Seamap Australia (2023).

The analysis initially focussed on the localities of existing mangrove or saltmarsh communities and their ability to migrate and move with the changing waterline. Mangroves and saltmarshes are aquatic vegetation species, which germinate (and migrate) by disseminating seedlings through the water column. Barriers to water movement can prevent potential migration of seedlings and overall distribution area of the mangroves and saltmarsh communities.

The analysis assumed:

- mangroves and saltmarsh species could only establish in permanently inundated areas directly connected to existing mangrove or saltmarsh communities.
- Inundated areas disconnected from vegetation communities by physical barriers (i.e., roads, levees and other coastal structures/features) or dry land, were viewed as areas unable to support the migration or recruitment of mangroves or saltmarsh communities.

Potential blue carbon growth areas were calculated for planning horizons (sea level rise (SLR) scenarios): 2021 (0.0 m SLR), 2040 (0.2 m SLR), 2070 (0.5 m SLR) and 2100 (0.8 m SLR).

Detailed method

A baseline of existing blue carbon assets (mangroves and saltmarsh communities) was established by mapping and calculating the localities and areas of these communities within the Anderson Inlet study area.

Potential blue carbon growth areas were then calculated by isolating and extracting areas landward of existing blue carbon assets likely to be permanently inundated under 0.0 m, 0.2 m, 0.5 m and 0.8 m SLR.

Figure 14 and Table 27 highlight the layers and method used to calculate the potential growth areas for the different planning horizons: present day (2021), 2040, 2070 and 2100.

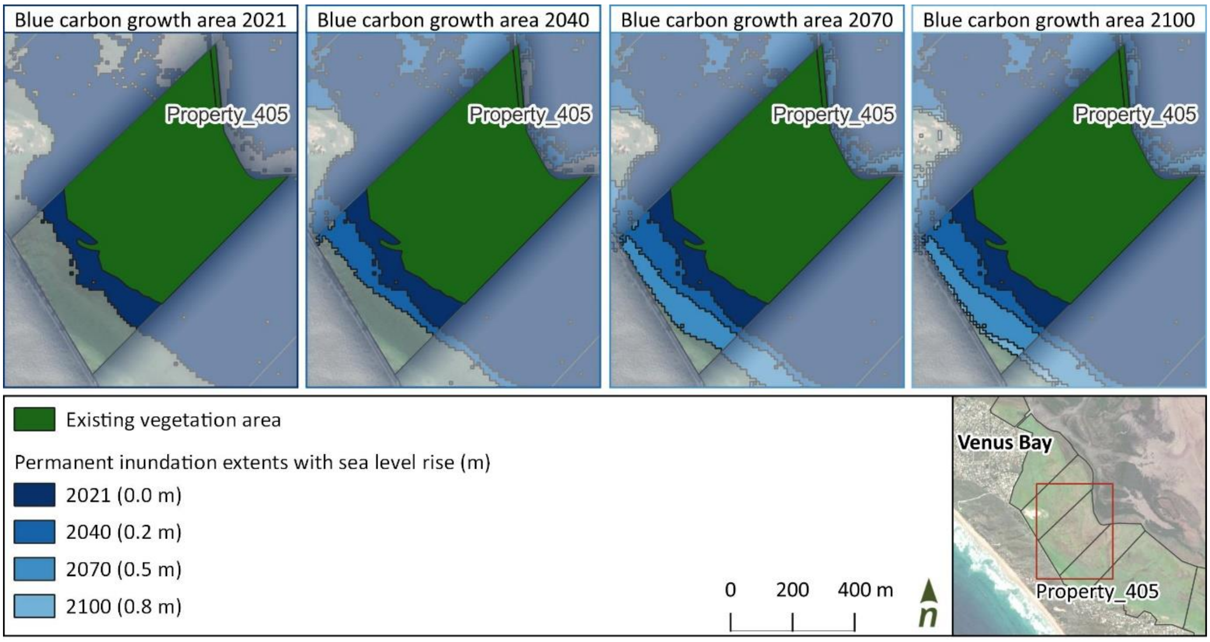

Figure 14. *Example of the permanent inundation extents used to calculate potential blue carbon growth areas on an individual property in Venus Bay.*

Table 27. Calculations used to determine potential blue carbon growth areas for different planning horizons.

Planning horizon	Sea level rise (m)	Potential blue carbon assets areas
2021	0.0	Existing + adjoining permanently inundated areas under 0.0 m SLR
2040	0.2	Existing + adjoining permanently inundated areas under 0.0 m SLR and 0.2 m SLR
2070	0.5	Existing + adjoining permanently inundated areas under 0.0 m SLR, 0.2 m SLR and 0.5 m SLR
2100	0.8	Existing + adjoining permanently inundated areas under 0.0 m SLR, 0.2 m SLR, 0.5 m SLR and 0.8 m SLR

Permanent inundation depths were then used to determine the distribution of mangrove and saltmarsh vegetation communities across each planning horizon (SLR scenario).

The change in sea level between each SLR scenario was used to provide an approximate indication of increasing water depths across the existing land surface. These are reflected as banded water depths, increasing by 0.2 m, then 0.3 m and then 0.3 m. These water depth increases relative to SLR are presented in Table 28 below.

Table 28. Water depths of sea level rise scenarios

Planning horizon	Sea level rise (m)	Water depth increase (m)
2021	0.0	
2040	0.2	0.2
2070	0.5	0.3
2100	0.8	0.3

Different vegetation classes have been classified by Frood and Papas (2016), including saltmarsh and mangroves, and highlight typical depths and salinity conditions that can sustain these species. Based on understanding of local environment and prevalent species for the region, it was presumed that saltmarsh species within the study area could only grow in water depths between 0 - 0.3 m and mangroves in water depths between 0.3 - 1 m.

For each planning horizon, the water depth ranges for saltmarsh and mangroves were used to determine what vegetation species could establish within each potential growth area. A summary of the methodological logic is presented in Figure 15.

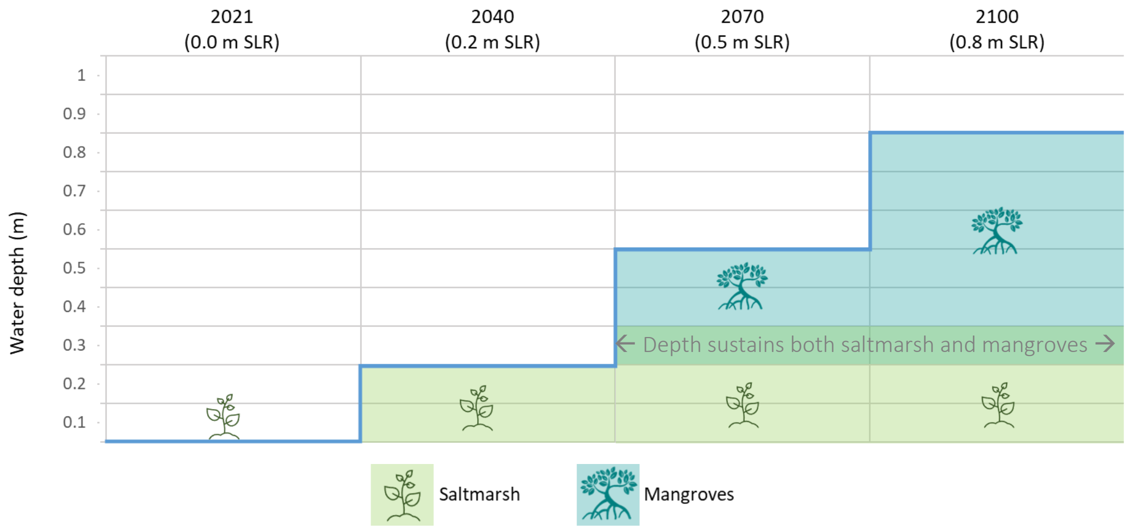

Figure 15. *Chart displaying water depth range for mangrove and saltmarsh communities to establish in the Cape to Cape region, based on data from Frood and Papas (2016).*

Using the each SLR scenario, the change in hazard extents (as increasing inundated areas and increasing water depths) were used to indicate the potential for saltmarsh and mangroves to establish in the new locations at different points in time.

Potential blue carbon growth areas were then overlaid on agricultural properties (grazing modified pastures and cropping land uses) within the South Gippsland Shire region to understand the potential opportunity costs for foregoing land on individual properties.

This was calculated at an individual property (land parcel) scale, and then combined to calculate a cumulative total for each planning horizon, as presented in below.

Table 29. Aggregate potential blue carbon growth areas (including existing areas).

	SLR 0.0 m (Present day)	SLR 0.2 m (2040)	SLR 0.5 m (2070)	SLR 0.8 m (2100)
Potential mangroves	-	-	5,152,621.39	7,246,748.62
Potential saltmarsh	5,152,621.39	7,246,748.62	6,778,706.47	14,801,752.54

A visual summary of how potential mangrove and saltmarsh growth areas were determined for each property is presented in Figure 16 to Figure 20 using property 405 as an example.

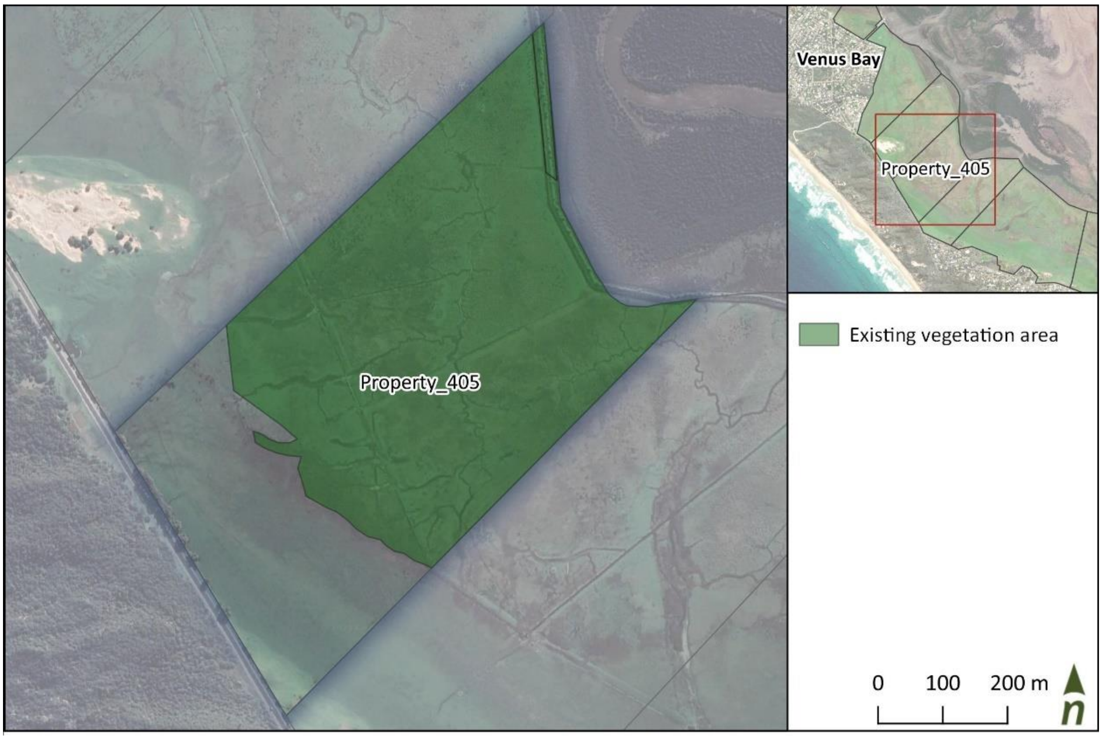

Figure 16. *Example of the existing blue carbon vegetation area on property 405 in Venus Bay, which was used as a baseline to calculate potential mangrove or saltmarsh establishment areas under different planning horizons.*

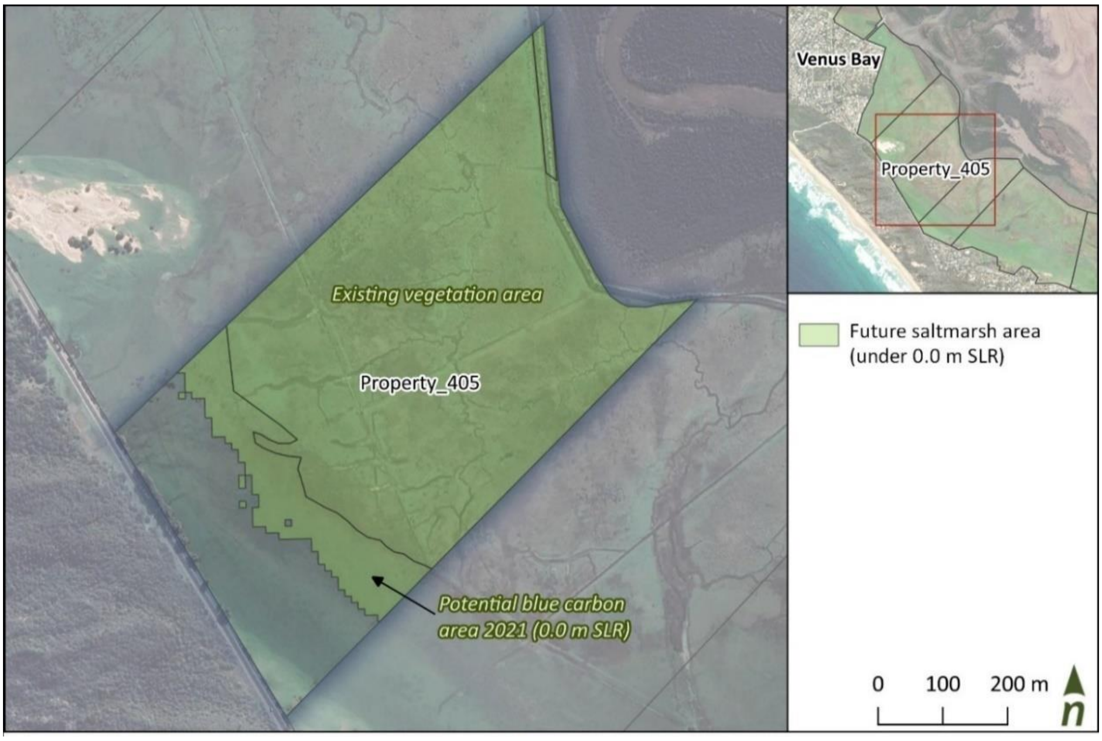

Figure 17. *Potential saltmarsh growth area in 2021.*

Note: No mangrove species can establish in 2021 as the water depths are 0.0 m and not within the range supporting mangrove recruitment.

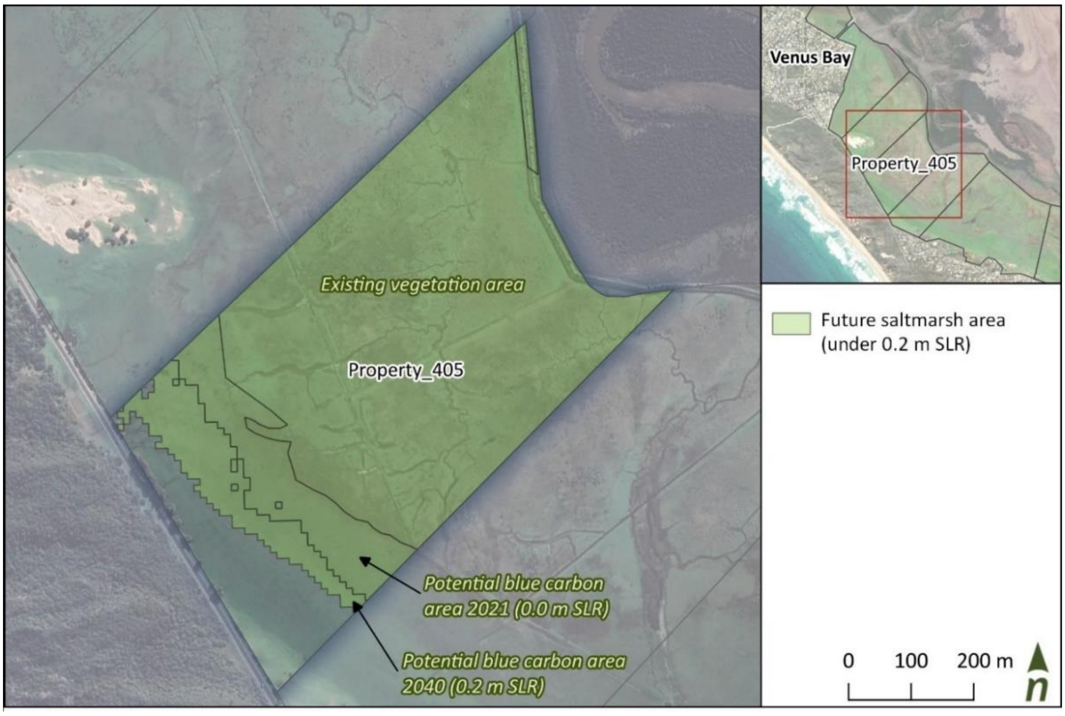

Figure 18. *Potential saltmarsh growth area in 2040.*

Note: No mangrove species can establish in 2040 as the water depths are 0.2 m and not within the range supporting mangrove recruitment.

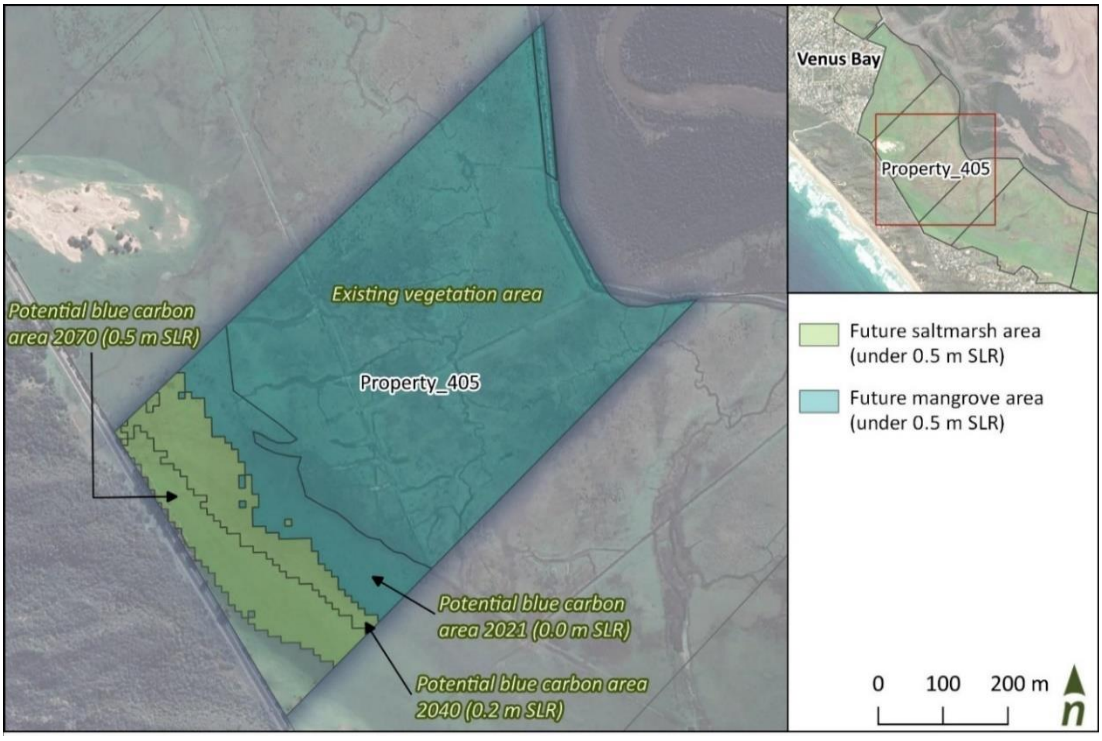

Figure 19. *Potential saltmarsh and mangrove growth areas in 2070.*

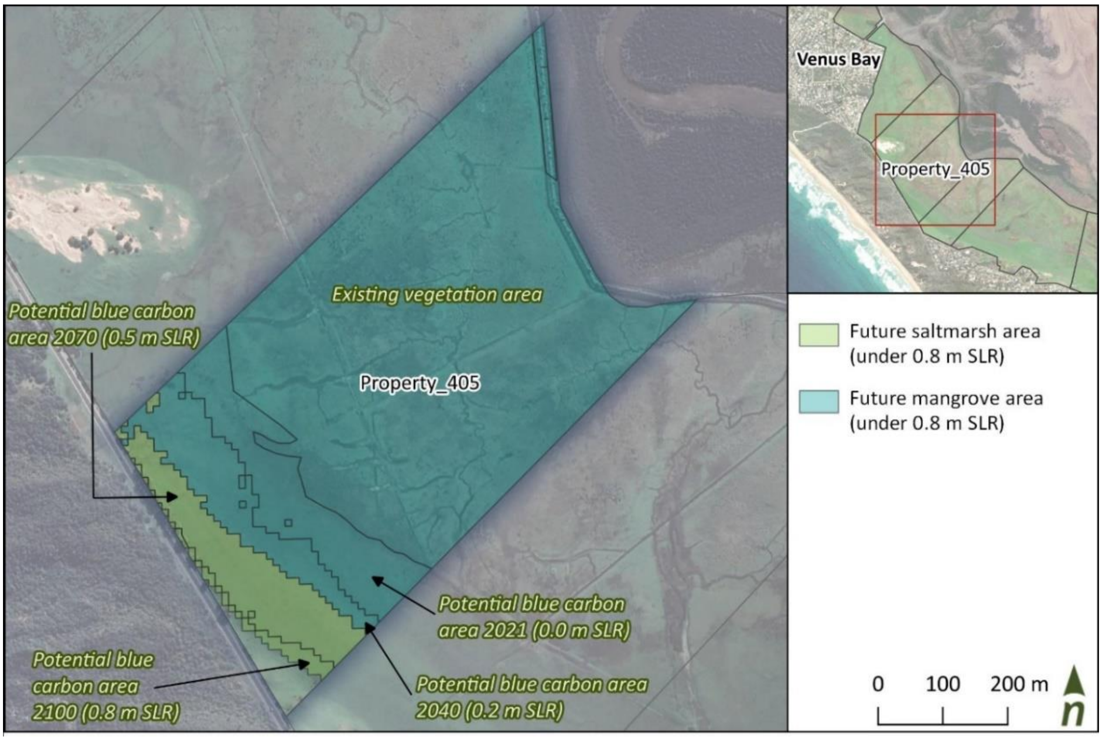

Figure 20. *Potential saltmarsh and mangrove growth areas in 2100.*